



Railway track material Part 1: Steel rails



Infrastructure Standard

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AS 1085.1:2019 **Railway track material Part 1: Steel rails**

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This Australian Standard® AS 1085.1 Railway track material
Part 1: Steel rails was prepared by a Rail Industry Safety and Standards Board (RISSB) Development Group
consisting of representatives from the following organisations:

Transport for NSW,	Arc Infrastructure,	ARTC,
Public Transport Victoria,	Queensland Rail,	Aurizon,
Monash University,	Liberty One Steel	

The Standard was approved by the Development Group and the **Enter Standing Committee** Standing Committee in
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Development of the Standard was undertaken in accordance with RISSB's accredited process. As part of the
approval process, the Standing Committee verified that proper process was followed in developing the Standard.

RISSB wishes to acknowledge the positive contribution of subject matter experts in the development of this Standard.
Their efforts ranged from membership of the Development Group through to individuals providing comment on a draft
of the Standard during the open review.

I commend this Standard to the Australasian rail industry as it represents industry good practice and has been
developed through a rigorous process.

Paul Daly
Chief Executive Officer
Rail Industry Safety and Standards Board

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Industry Safety and Standards Board, PO Box 518 Spring Hill Qld 4004, Australia.

AS 1085.1:2018

Railway track material
Part 1: Steel rails

Document details

First published as: Enter first publication identifier (AS XXXX:yyyy)

ISBN Enter ISBN.

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PO Box 518 Spring Hill Qld 4004, Australia

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Document control

Document identification

Designation / Title
AS 1085.1:2018 Railway track material Part 1: Steel rails

Document history

Publication Version	Effective Date	Reason for and Extent of Change(s)
2018	Select Board approval date	

Approval

Name	Date
Rail Industry Safety and Standards Board	Select Board approval date

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1 Introduction

1.1 Purpose

The purpose of this Standard is to provide purchasers and suppliers, including owners, operators, designers and manufacturers of railway rail with requirements for as-rolled and hardened steel rails, made from continuously cast blooms for railway purposes.

1.2 Scope

This Standard specifies requirements for as-rolled and hardened steel rails made from continuously cast blooms and profiles for asymmetric switch rails and elevated guardrails for railway purposes.

NOTES:

1. Guidelines for purchasers are given in Appendix A.
2. Guidance on the means for demonstrating compliance with this Standard is given in Appendix B.
3. Information on residual stresses in rail is given in Appendix C.

1.3 Compliance

There are two types of control contained within Australian Standards developed by RISSB:

- (a) Requirements.
- (b) Recommendations.

Requirements – it is mandatory to follow all requirements to claim full compliance with the Standard.

Requirements are identified within the text by the term 'shall'.

Recommendations – do not mention or exclude other possibilities but do offer the one that is preferred.

Recommendations are identified within the text by the term 'should'.

Recommendations recognise that there could be limitations to the universal application of the control, i.e. the identified control cannot be applied, or other controls could be appropriate / better.

For compliance purposes, where a recommended control is not applied as written in the standard it could be incumbent on the adopter of the standard to demonstrate their actual method of controlling the risk as part of their WHS or Rail Safety National Law obligations. Similarly, it could also be incumbent on an adopter of the standard to demonstrate their method of controlling the risk to contracting entities, or interfacing organisations where the risk may be shared.

1.4 Referenced documents

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document:

- (a) AS 1003, Engineers' straightedges (metric units)
- (b) AS 1100.201, Technical drawing Mechanical engineering drawing
- (c) AS 1199.0 Sampling procedures for inspection by attributes Introduction to the ISO 2859 attribute sampling system

- (d) AS 1199.1 Sampling procedures for inspection by attributes Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection
- (e) AS 1391, Metallic materials - Tensile testing at ambient temperature
- (f) AS 1816.1, Metallic materials - Brinell hardness test Test method (ISO 6506-1:2005, MOD)
- (g) AS 1817.1, Metallic materials - Vickers hardness test Test methods (ISO 6507-1:1997, MOD)
- (h) AS 1817.2 Metallic materials - Vickers hardness test Verification of testing machines
- (i) AS 1817.3 Metallic materials - Vickers hardness test Calibration of reference blocks
- (j) AS 1929, Non-destructive testing—Glossary of terms
- (k) AS 2205.5.1, Methods for destructive testing of welds in metal Macro metallographic test for cross-section examination
- (l) AS 2706, Numerical values - Rounding and interpretation of limiting values
- (m) AS/NZS 1050 (all parts), Methods for the analysis of iron and steel
- (n) AS/NZS ISO 9001, Quality management systems—Requirements
- (o) AS/NZS ISO 9004, Quality management systems—Guidelines for performance improvements
- (p) HB 18.28, Guidelines for third-party certification and accreditation Guide 28 - General rules for a model third-party certification system for products
- (q) ASTM E1180, Practice for preparing sulfur prints for macrostructural examination
- (r) UIC 860, Technical specification for the supply of rails
- (s) UIC 861-2, Standard sections for points rails adapted to the UIC 54 and 60 kg/m rail sections

1.5 Definitions

For the purpose of this Standard, the definitions given in AS 1929 and those given below apply.

As-rolled rail: Rail that is cooled off the mill, without accelerated cooling, and is not subsequently heat treated.

Head-hardened rail: Rolled rail in which the head has a hardened zone extending inwards from its top and side surfaces.

NOTE: For the purpose of this Standard, head-hardened rail has been treated by accelerated cooling of the head to produce a fine pearlitic structure.

Hardened rail: Rolled rail that has been head-hardened or full section hardened by in-line or off-line processes.

2 Context of use

2.1 Function

Steel rail forms the direct longitudinal support member of the railway permanent way and provides the guiding and running surface for rolling stock. Rail can also be used to conduct current for signalling and traction purposes.

2.2 Action

Steel rail is subjected to:

- (a) loads imposed by the passage of rolling stock and during maintenance;
- (b) the effects of temperature, fastening systems, joints and welding; and
- (c) fatigue, wear, damage and corrosion.

3 Rounding of numbers

3.1 General

For the purpose of assessing compliance with this Standard, the specified limiting values herein shall be interpreted in accordance with the 'rounding method' described in AS 2706, that is, the observed or calculated value shall be rounded to the same number of figures as in the specified or calculated value and then compared with the specified limiting values. For example, for specified limiting values of 2.5, 2.50 and 2.500, the observed or calculated value would be rounded respectively to the nearest 0.1, 0.01 and 0.001.

3.2 Tensile properties

The determined value of tensile strength shall be rounded off to the nearest 10 MPa, and the determined value of yield stress shall be rounded off to the nearest 5 MPa.

4 Designation

The nominal rail size shall be designated by the nominal mass, in kilograms, of a 1 m length of rail. For example, 31 kg rail means a rail section having nominally a mass of 31 kg per metre.

The switch rail profiles are matched with 50 kg and 60 kg rails. They shall be referred to as 50 kg asymmetrical switch rails and 60 kg asymmetrical switch rails, respectively. The elevated guardrail profile is for use with either 50 kg or 60 kg rails. It shall be referred to as '50/60 kg elevated guardrail'. The guardrail specified in this Standard, also known as check rail, is for use in points and crossings.

NOTE: The masses used to refer to asymmetrical switch rails and elevated guardrails refer to the rail profile with which they are commonly used and not the actual mass of the section. This naming convention does not preclude their use with other rail profiles.

5 Track system compatibility

5.1 Profile shape

The dimensions of rails shall conform to the appropriate profile drawing given in Appendix D within the dimensional tolerances given in Table D1. Methods for testing the dimensional tolerances shall be as given in Appendix D.

5.2 Materials

Requirements for materials for track system compatibility shall be deemed to be met when Section 6.1 is satisfied.

6 Service life

6.1 Materials

When tested in accordance with Appendix E, the chemistry shall conform with the limits given in Table E1 for the basic chemical elements and Table E2 for the residual elements.

6.2 Shape stability and wear resistance

Shape stability and wear resistance requirements shall be deemed to be met when the requirements of Sections 6.1 and 7 are satisfied.

6.3 Fatigue

Fatigue requirements shall be deemed to be met when the requirements of Sections 6.1 and 7 are satisfied.

7 Material integrity

7.1 Material properties

7.1.1 As-rolled rail

When tested in accordance with Appendix F Section F1.1 (tensile testing) and Appendix F Section F1.2 (surface hardness test) of Appendix F, the material properties shall conform to the limits given in Table E3 of Appendix E.

7.1.2 Head-hardened rail

Head-hardened rail shall comply with the following performance requirements:

- (a) Tensile testing When tested in accordance with Section F1.1 of Appendix F, the material properties shall conform to the limits given in Table E3 of Appendix E.
- (b) Surface hardness test When determined in accordance with Section F1.2 of Appendix F, surface hardness shall be within the limits given in Table E3 of Appendix E.

- (c) Test for depth of heat treatment (etch test) When determined in accordance with Section F1.3 of Appendix F, the dimensions of the heat-affected zone shown in Figure F1(c) shall be in accordance with Table E5 of Appendix E.
- (d) Hardness gradient test When determined in accordance with Section F1.4 of Appendix F, the hardness results obtained shall vary gradually toward the centre of the rail, with no sharp drop or discontinuity and shall be within the limits given in Table E4 of Appendix E.
- (e) Microstructure test When examined in accordance with Section F1.5 of Appendix F, the microstructure of the entire cross-section shall be substantially pearlitic and shall not exhibit grain boundary cementite.

NOTE: For rails where additional hardening of the rail section has taken place, the above tests may be specified, and additional tests could be necessary to cover further requirements such as the hardness throughout the cross-section.

7.2 Internal soundness

7.2.1 Bloom reduction

The cross-section of the rail shall not exceed one-ninth (0.111) that of the bloom from which the rail is rolled.

7.2.2 Post-rolling operations

Rails shall be ground or machine-cut to length and drilled, if required, in such a way that the temperature of the rail is not high enough to cause any changes in the microstructure of the steel.

7.2.3 Sulfur print test

When tested in accordance with ASTM E1180 (Bauman sulfur print test), the sulfur segregation in the rail shall not exceed the following:

- (a) Segregation, which can take the form of a single line, a double line or a cluster of spots, and which occurs within the web region shown in Figure F2 of Appendix F, shall not extend beyond that boundary into the rail head or foot.
- (b) Outside the web region, as shown in Figure F2 of Appendix F, the sum of the lengths of other streaks shall not exceed:
 - i. 6 mm in the head; and
 - ii. 6 mm in the foot.

7.2.4 Ultrasonic test

When tested in accordance with Section F2.2 of Appendix F, discontinuities shall—

- (a) not extend outside the web region shown in Figure F2 of Appendix F; and
- (b) not exceed 10 mm in vertical height transverse to the direction of rolling.

NOTE: In view of the significant probability of false rejection, rails that register apparent discontinuities may be retested or cut back and retested. No rail should be accepted until the full length delivered has been confirmed to be satisfactory. Rails containing confirmed discontinuities exceeding the limits given should be rejected or cut back to remove the affected portion.

7.2.5 Hydrogen-induced cracks

The rail shall be free of hydrogen-induced cracks.

7.3 External finish

7.3.1 Visual inspection

When inspected visually, the depth of surface imperfections such as seams, rolled-in scale and other marks in the zones indicated (see Figure F5, Appendix F) shall be:

- (a) less than 0.5 mm in zone A (rail head) and zone C (edge of rail foot);
- (b) less than 0.75 mm in zone B (rail web and top of foot); and
- (c) less than 1 mm in zone D (underside of rail foot).

Subject to agreement between the supplier and purchaser, discontinuities deeper than the above may be removed by grinding out smoothly. After any such grinding, the rail dimensions shall be not less than specified in Section 5.1. All grinding shall be conducted in such a way that the temperature of the rail is not high enough to cause any changes in the microstructure and the finished surface is free of sharp edges.

Recurrent or extensive discontinuities in zone A within the limits set in Section are unacceptable.

7.3.2 Eddy current test

When tested in accordance with Section F3 of Appendix F, discontinuities in 50, 60 and 68 kg rail shall not exceed 1.0 mm in depth on the underside of the foot of the rail.

NOTE: The eddy current test for 31 and 41 kg rails may be specified at the option of the purchaser (see Appendix A).

8 Suitability for connection

8.1 Profile consistency and end squareness

Requirements for the suitability of rail profile and end squareness for connection purposes shall be deemed to be met when Section 5.1 is satisfied.

8.2 Suitability for welding and drilling

Requirements for the suitability of rail for welding and drilling for connection purposes shall be deemed to be met when Section 6.1 is satisfied.

8.3 Holes for fishbolts

Where drilling is required, rails shall be drilled for the fishbolts conforming to the centres and dimensions shown on the appropriate profile drawing in Appendix D. In the process of drilling, the rails shall not be split or damaged, and any resulting burrs or projections shall be removed.

9 Suitability for maintenance

9.1 Suitability for welding, drilling and grinding

Requirements for the suitability of rail for welding, drilling and grinding for maintenance purposes shall be deemed to be met when Section 6.1 is satisfied.

9.2 Material properties

Requirements for the material properties of rail for maintenance purposes shall be deemed to be met when Sections 6.1 and 7 are satisfied.

10 Handling

Rails shall not be supplied with burrs or sharp edges, which could be a hazard for those handling the rail.

11 Marking

11.1 General

Rolled-in and stamped brands shall be legible, readily found and shall not compromise the integrity of the rail. These requirements shall be deemed to be met when Sections 11.2 and 11.3 are satisfied.

NOTE: Manufacturers making a statement of compliance with this Australian Standard on a product, packaging, or promotional material related to that product are advised to ensure that such compliance is capable of being verified.

11.2 Rolled-in brands

Rolled-in brands shall be applied as follows:

- (a) They shall be rolled into the web of each rail at a spacing of not greater than 1.8 m.
- (b) The characters shall be a minimum of 20 mm in height.
- (c) The characters shall be raised at least 0.5 mm from the plane surface of the web.
- (d) The brand shall show the following:
 - i. Nominal rail size.
 - ii. Mill brand.
 - iii. Month and year of rolling.
 - iv. If head-hardened rail, the letter 'H', to indicate 'head-hardened'.

NOTES:

1. For 68 kg rail a stamped 'NH' may be used to indicate 'head-hardened' if agreed between the supplier and the purchaser.
2. The month and year of manufacture is to be used for the purpose of identification only and should not be used as a basis for rejection of the steel rails.

11.3 Stamped brands

Stamped brands shall be applied as follows:

- (a) They shall appear at least once on each piece of rail.
- (b) They shall be positioned on the opposite side of the web to the rolled-in brand.
- (c) One of the stamped brands shall appear at least 500 mm from the end of the piece of rail.

- (d) Characters shall be a minimum of 16 mm in height.
- (e) Characters shall be sloped 10° off vertical and shall be so designed that they will not initiate cracking (see Figure 1).

NOTE: Sloping and rounding of marks is intended to reduce the opportunity for initiation of cracking.

- (f) They shall include a unique identification code that indicates the production history of the rail (e.g., heat number, bloom number).
- (g) The action of applying the brand shall not cause metallurgical changes in the rail.

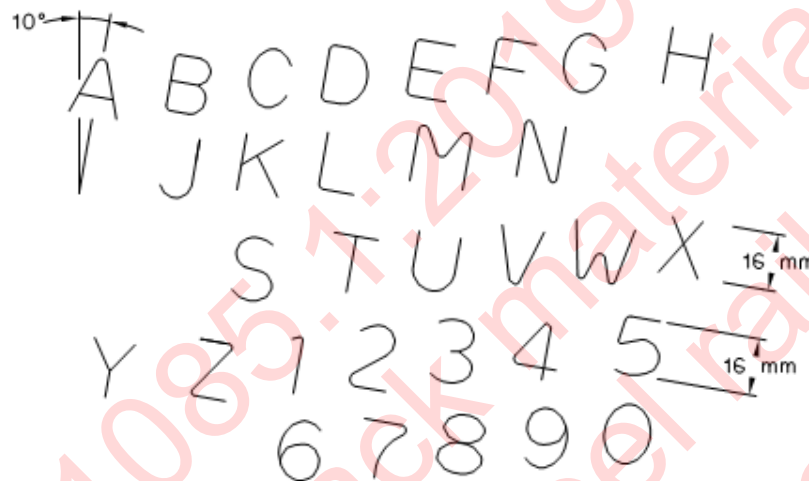


FIGURE 1 LETTERS FOR STAMPED BRANDS

Appendix A Information to be supplied by the purchaser (Informative)

The following information should be supplied by the purchaser (see also Section 4):

- (a) Number and part of this Australian Standard, i.e. AS 1085.1.
- (b) Nominal rail size (e.g., 50 kg) where this applies, or the number of the appropriate drawing.
- (c) Quantity (mass or number of pieces).
NOTE: It should be remembered that the actual mass of the profile can be different to the nominal size.
- (d) Lengths of rails, including the supply of short lengths.
- (e) Whether rails are to be drilled or undrilled.
- (f) Any exceptions to the requirements specified in this Standard, and any special or supplementary requirements.
- (g) Information required to be supplied on production quality, such as a quality plan or appropriate acceptable quality levels (see AS 1199).
- (h) Whether inclusion is required of the following tests for all rails in a continuous manner during production:
 - i. Ultrasonic testing (see Appendix F Section F2.2).
 - ii. Visual surface inspection (see Appendix F Section F3.1).
 - iii. Eddy current testing (see Appendix F Section F3.1).

Appendix B Means of demonstrating compliance with this Standard (Informative)

B.1 Scope

This Appendix sets out the following different means by which compliance with this Standard can be demonstrated by the manufacturer or supplier:

- (a) Evaluation by means of statistical sampling.
- (b) The use of a product certification scheme.
- (c) Assurance using the acceptability of the supplier's quality system.
- (d) Other such means proposed by the manufacturer or supplier and acceptable to the customer.

B.2 Statistical sampling

Statistical sampling is a procedure which enables decisions to be made about the quality of batches of items after inspecting or testing only a portion of those items. This procedure will only be valid if the sampling plan has been determined on a statistical basis and the following requirements are met:

- (a) The sample should be drawn randomly from a population of product of known history. The history should enable verification that the product was made from known materials at essentially the same time, by essentially the same processes and under essentially the same system of control.
- (b) For each different situation, a suitable sampling plan should be defined. A sampling plan for one manufacturer of given capability and product throughput might not be relevant to another manufacturer producing the same items.

In order for statistical sampling to be meaningful to the customer, the manufacturer or supplier shall demonstrate how the above conditions have been satisfied. Sampling and the establishment of a sampling plan should be carried out in accordance with AS 1199.

B.3 Product certification

The purpose of product certification is to provide independent assurance of the claim by the manufacturer that products comply with the stated Standard.

The certification scheme should meet the criteria described in HB 18.28 in that, as well as full type testing from independently sampled production and subsequent verification of conformance, it requires the manufacturer to maintain effective quality planning to control production.

The certification scheme serves to indicate that the products consistently conform to the requirements of the Standard.

B.4 Suppliers quality management system

Where the manufacturer or supplier can demonstrate an audited and registered quality management system complying with the requirements of the appropriate or stipulated Australian or international Standard for a supplier's quality management system or systems, this could provide the necessary confidence that the specified requirements will be met. The quality assurance requirements need to be agreed between the customer and supplier and should include a quality or inspection and test plan to ensure product conformity.

Information on establishing a quality management system is set out in AS/NZS ISO 9001 and AS/NZS ISO 9004.

B.5 Other means of assessment

If the above methods are considered inappropriate, determination of compliance with the requirements of this Standard may be assessed from the results of testing coupled with the manufacturer's guarantee of product conformance.

Irrespective of acceptable quality levels (AQLs) or test frequencies, the responsibility remains with the manufacturer or supplier to supply products that conform to the full requirements of the Standard.

Appendix C Residual stresses (Informative)

C.1 General

Residual stresses in rails are internal stresses that exist independently of externally applied force or thermal gradient and are induced during the manufacturing process by such operations as cooling after hot rolling, roller straightening and heat treatment during head-hardening. Residual stresses can be either tensile or compressive, and the stress gradient can vary non-linearly across the section in a complex manner. The form and distribution of residual stresses at any cross-section within an individual rail length are such that they are in internal equilibrium.

Residual stresses in rails can be modified from the as-manufactured condition by installation processes such as welding, and by in-service conditions such as normal operating loads.

Residual stresses in rails, and in particular in rails that have been roller straightened during manufacture, can contribute to unacceptable rail performance in terms of either unstable crack growth in the rail web, or fatigue crack initiation from surface imperfections introduced during rail manufacture, transport, handling or installation procedures, or introduced during operational service. Test procedures such as the web saw cut method, strain-gauging or the crack arrest test may be used to obtain quantitative information about the magnitude of residual stresses or their effect on the behaviour of the rail section. Data obtained using such procedures should be considered as indicative only, as rails that are currently in use and have provided satisfactory service performance can fail the proposed acceptance criteria.

Further testing is required to confirm the validity of methods that may be used to determine the magnitude of residual stresses in rails, and any acceptance criteria that relate to rail performance.

In respect of unstable web cracking behaviour examined by means of the web saw cut test, it should also be noted that an additional factor that can influence the probability of this occurring is the presence or otherwise of a suitable initiation site. Typical initiation sites might include a flame-cut end of a rail length.

C.2 Influence of residual stresses on rail performance

Failures will not occur solely as a result of residual stresses but can occur in situations where the combination of residual stresses with discontinuities, railway loadings and thermally induced stresses becomes critical. In other words, high levels of residual stress or any unacceptable distribution of residual stresses within the rail section can increase the probability of fatigue or other cracking modes to initiate at an existing discontinuity.

Failure modes to which residual stresses can contribute are:

- (a) unstable longitudinal cracking of the rail web; and
- (b) fatigue crack initiation in the presence of a suitable discontinuity and most probably from a surface or near surface discontinuity.

References 1, 2, 3, 5, 6, 11 and 17 provide further information on these failure modes.

C.3 Influence of the manufacturing process on residual stresses

Rails are straightened during manufacture to meet the requirements outlined in Section 5.1. For most rail manufacturing, straightening is carried out using a roller straightening process, which can subject the rail section to repeated bending in the vertical and lateral directions. A typical

distribution of longitudinal stresses in roller straightened rail is shown by the example given in Figure C1.

This distribution can be present throughout a majority of the rail length, other than near the ends. Longitudinal stresses in a rail length processed by roller straightening decrease to zero towards the end of individual bars, due to the following factors:

- (a) The arrangement of rollers in typical roller straightening machines is such that the ends of individual bars (over a distance that is determined by the spacing between the individual rollers of the roller straightening machine and the height of the rail section) are not subjected to the same straightening conditions as apply to the remainder of the length of the rail (Appendix C Section 4.6 Ref. 1).
- (b) Longitudinal stresses cannot exist at the free end of a rail length (Appendix C Appendix C Section 4.6 Ref. 14).

Other rail manufacturing processes (e.g. Appendix C Section 4.6 Ref. 16) can give other residual stress distributions to that shown in Figure C1.

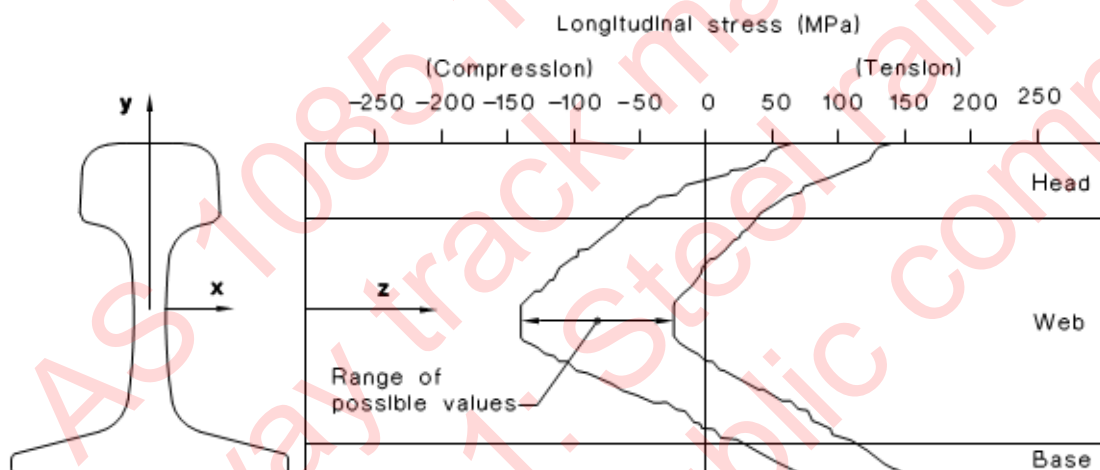


FIGURE C1 TYPICAL DISTRIBUTION OF LONGITUDINAL RESIDUAL STRESSES IN ROLLER-STRAIGHTENED RAIL

C.4 Measurement and calculation of residual stresses

C.4.1 General

Measurement procedures, which may be used to determine the level of residual stresses in rail, or the propensity for unstable web cracking in the presence of the residual stress distribution, are as follows:

- (a) Web saw cut method.
- (b) Strain gauge method.
- (c) Crack arrest method.

All of the above methods are destructive. Other, non-destructive methods may be used to provide information on residual stresses in rails. Such techniques can require specialized equipment or additional calibration measurements or both, and hence are not as yet considered either sufficiently accurate or suitable for routine measurement of residual stresses in rails.

References 1 and 15 provide information on residual stresses in rails measured using one such method.

NOTES:

1. Values of longitudinal residual stress derived using the strain gauge procedure might not correlate with corresponding data obtained using the web saw cut test.
2. Reference 10 provides detailed information on mechanical methods of stress determination, which may be used for the determination of residual stresses.
3. The contribution of residual stresses to fatigue crack initiation and growth from localized surface defects has been examined previously (Appendix C Section 4.6 Ref. 11) and forms the basis of the surface finish requirements described in Section 7.3.1 of this Standard.

C.4.2 Web saw cut method

C.4.2.1 Purpose

The purpose of this test is to determine if a sample piece of rail contains a residual stress distribution that has the potential to initiate or promote unstable crack growth in the web of the rail.

C.4.2.2 Procedure

The web saw cut test involves cutting a length of rail longitudinally along the web, at the neutral axis of the section, to relieve all or part of the residual stress distribution. Changes to the dimensions of the rail section, which arise as a result of the web saw cut, may be used to determine the magnitude of the initial residual stress distribution in the rail web, or the magnitude of the stress intensity value corresponding to the web opening behaviour.

Figure C2 illustrates the general concept of the web saw cut test.

References 7 and 12 provide further details on two such methods. A similar test has been developed and used to examine the probability of unstable crack growth behaviour in railway wheels as a result of changes to the residual stress distribution due to overheating (Appendix C Section 4.6 Ref. 8).

It should be noted that in the method described, the test sample may be prepared such that the saw cut is carried out in a region representative of the roller-straightened portion of the rail length. The action of removing such a test sample from a roller-straightened length of rail modifies the residual stress distribution from that shown in Figure C1.

Longitudinal stresses decrease to zero at the free end of the sample, and there is a corresponding increase in the level of vertical residual stresses (Appendix C Section 4.6 Ref. 14). The distribution of residual stresses near the end of such a sample is illustrated in Figure C3. The figure indicates that the redistribution of residual stresses occurs over a distance approximately 1.2 times the height of the rail section, and a region of high vertical residual stresses exists at the end of the sample.

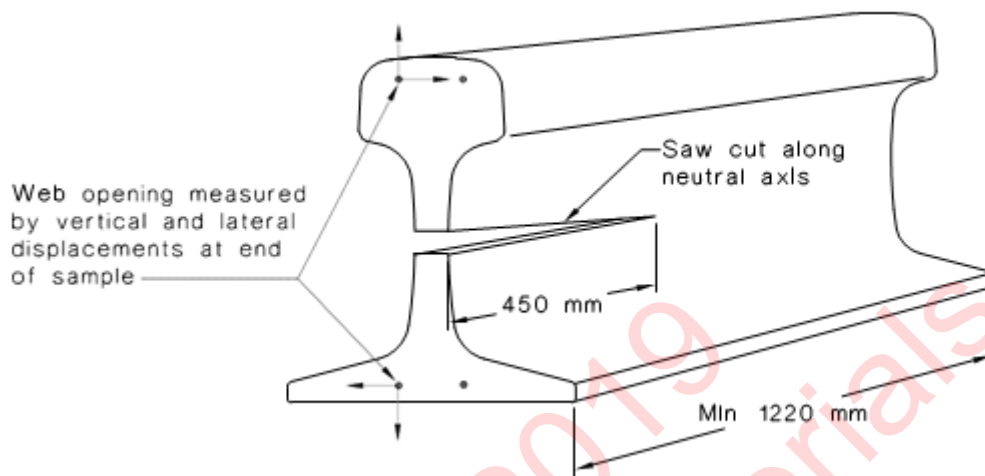


FIGURE C2 GENERAL ARRANGEMENT FOR WEB SAW CUT TEST FOR THE DETERMINATION OF RESIDUAL STRESSES IN THE RAIL WEB

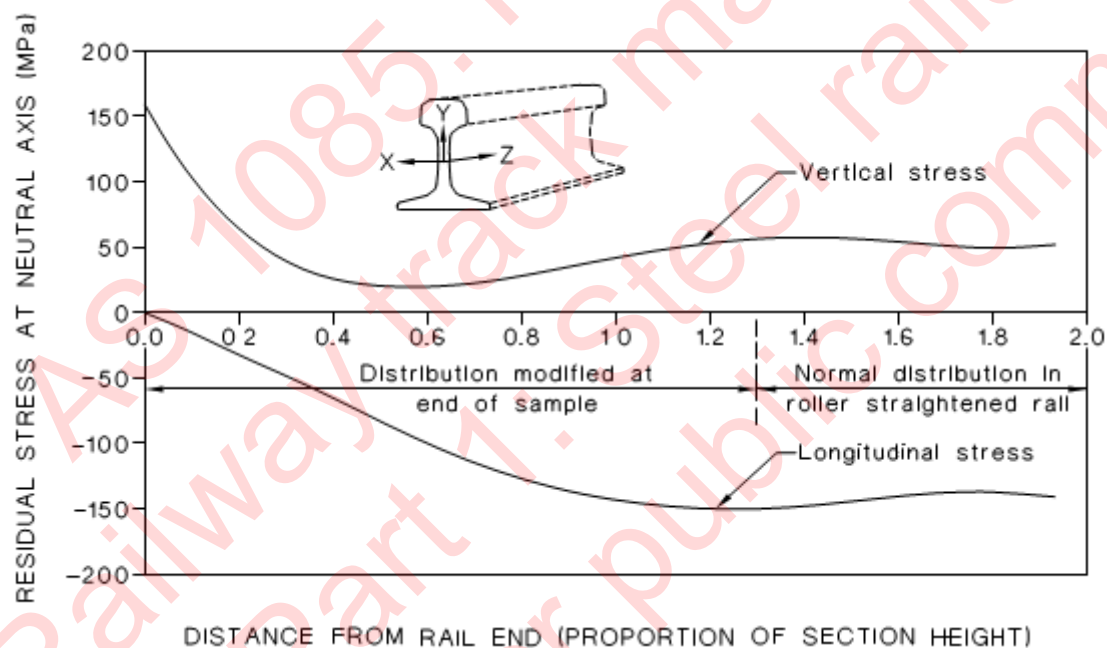


FIGURE C3 DISTRIBUTION OF LONGITUDINAL AND VERTICAL RESIDUAL STRESSES NEAR END OF SAMPLE REMOVED FROM ROLLER STRAIGHTENED RAIL
(based on strain gauge measurements along the neutral axis at the web surface)

C.4.2.3 Acceptance criteria based on the web saw cut test

Acceptance criteria that have been proposed for the web saw cut test may be based on either:

- the value of the web opening measurement as determined from the vertical and lateral displacements measured at the end of the sample, which should not exceed a nominated value; or
- the value of the stress intensity value derived from the web opening measurements, which should not exceed the plane strain fracture toughness for the rail material present in the web (Appendix C Section 4.6 Refs 1, 7 and 12). Such a criterion requires that the fracture toughness of the rail material

also be measured. Appendix C Section 4.6 Ref 7 provides further information regarding the location of samples in the rail web for the determination of fracture toughness.

There are several aspects of the procedure involved in the derivation of a stress intensity factor for the web saw cut test in which uncertainty exists; these are as follows:

- i. The strain conditions in the rail web might not represent plane strain criteria (Appendix C Section 4.6 Ref. 13); the value of fracture toughness that is applicable could be slightly higher than the plane strain fracture toughness; use of the plane strain fracture toughness as an acceptance criteria, therefore, represents a lower bound.
- ii. A complex residual stress distribution in the web of a rail, for example resulting from straightening in both vertical and lateral planes, might result in some combination of Mode I (in-plane opening) and Mode III (out-of-plane shear) behaviour, in which case the propensity for unstable web cracking might not be adequately described by the Mode I stress intensity factor.
- iii. The procedure used for derivation of the stress intensity value should make use of the relevant section properties for the rail section being tested.

It should also be noted that information obtained from the web saw cut test might indicate that rails already in use by rail systems, and which have shown satisfactory in-service performance, could fail the test based on the above criteria.

In view of the above issues, it is not possible at this point in time to confirm the validity of the acceptance criteria that have been proposed for the web saw cut test.

C.4.3 Strain gauge procedure

C.4.3.1 Purpose

The purpose of this test is to determine the magnitude of residual stresses at selected locations on the surface of a sample of rail.

Residual stresses at various locations may be determined using techniques that involve the following:

- (a) Attachment of electrical resistance strain gauges to the surface of the rail in accordance with the procedures recommended by the strain gauge manufacturer.
- (b) Measurement of the initial gauge resistance.
- (c) Relieving the surrounding residual stress field by progressive sectioning and isolation of the gauged location.
- (d) Measurement of the final gauge resistance.
- (e) Determination of the change in strain resulting from sectioning.
- (f) Determination of the residual stress by reversing the sign of the strain change (to account for the stress relief effect) and multiplying by the modulus of elasticity for rail steel (2.07×10^5 MPa).

C.4.3.2 Strain gauge types

For the measurement of longitudinal stresses, single-element strain gauges positioned longitudinally on the rail surface may be used. Such gauges should be of the encapsulated type, with a gauge length of between 2 mm and 5 mm, and with a gauge factor accuracy of less than ± 1 percent.

Other gauge orientations may be used for the determination of residual stresses in other directions. In addition, multi-element strain-gauge rosettes may be used for the determination of residual stresses in more than one direction, or for the determination of principal stresses and their orientation. In the latter case, reference should be made to standard engineering procedures for data reduction.

C.4.3.3 Procedure

The procedure should be as follows:

- (a) The initial and final strain measurements should be carried out with the rail at the same temperature, to avoid any additional component due to thermal effects. In addition, attachment of electrical leads to the strain gauge terminals should be consistent for all measurements.
- (b) Preparation of the rail surface prior to attachment of the strain gauges should be in accordance with the recommendation of the strain-gauge manufacturer and, in any case, consistent with accepted engineering practice, noting that procedures for residual stress measurement might be more rigorous than those for measurement of strains resulting from applied loading. In particular, the surface preparation technique should not in itself modify the residual stresses in the rail.
- (c) Sectioning of the rail to isolate the strain-gauged location should be carried out in a manner that minimizes heat input to the gauged locations and avoids the possibility of damaging the gauges.

C.4.3.4 Strain gauge locations

For the determination of residual stresses that might be present in the rail as a result of the manufacturing processes, specifically roller straightening, measurement of longitudinal residual stresses is recommended at the centre of the rail base, on either side of the web at the neutral axis, and at the centre top of the rail head. The strain gauges should be positioned at these locations, at the centre of a 1 m length of rail, which is in turn a minimum of 2 m away from the end of a standard length of rail (typically 25 m). The gauged location is therefore 2.5 m from the end of the original rail length.

Figure C4 illustrates the general arrangement of the strain gauge procedure for determination of residual stresses at the rail surface.

Isolation of the strain-gauged locations for the measurement of residual stresses should be carried out by cutting vertically through the rail section at ± 10 mm about the line of the gauges, so as to remove a vertical slice 20 mm in length. Alternative sectioning techniques such as trepanning or hole drilling may be used for the relief of residual stresses. It should be noted that the latter techniques can differ from that illustrated in Figure C4, to the extent to which they relieve the residual stresses, and hence could give rise to different residual stress values.

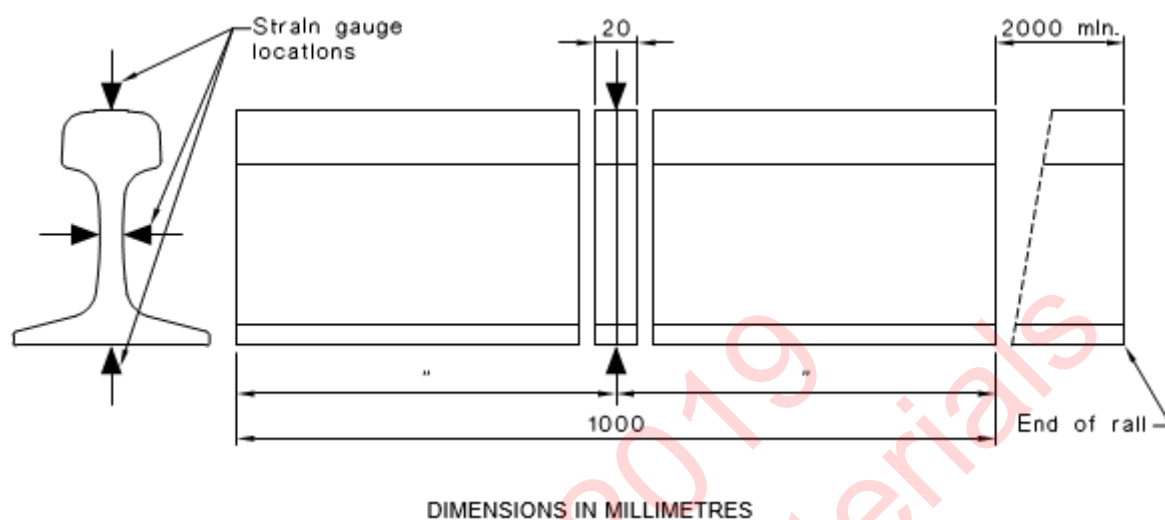


FIGURE C4 GENERAL ARRANGEMENT OF STRAIN GAUGE METHODS FOR THE MEASUREMENT OF RESIDUAL STRESSES AT THE RAIL SURFACE

C.4.3.5 Acceptance criteria based on the strain gauge procedure

The strain gauge procedure provides information on the magnitude of residual stresses in the immediate vicinity of the gauged locations. Such data are applicable to the analysis of fatigue crack initiation and growth processes from near or near-surface defects.

In general, such processes might occur under the influence of additional stresses developed through service loading. In the absence of quantitative information regarding the magnitude of the latter stresses, it is not possible to provide acceptance levels for residual stresses obtained by means of the strain gauge procedure.

Acceptance levels that have been proposed include a fixed value (e.g., 250 MPa) or 0.6 times the proof stress of the rail material.

NOTE: Other strain gauge techniques (Appendix C Section 4.6 Ref. 9) may be used for the determination of surface residual stresses in rails. Care should be taken in the interpretation of such results, as the accuracy of strain gauge techniques for the measurement of residual stresses is influenced by factors such as the distribution of residual stresses in the immediate vicinity of the gauge location, and the procedures used for the relief of the surrounding residual stress field.

C.4.4 Crack arrest test

The purpose of this test is to determine if a sample piece of rail contains a residual stress distribution that has the potential to initiate or promote unstable crack growth in the web of the rail.

C.4.5 Procedure

The crack arrest test involves machining a notch in the web at the end of a rail length, insertion of a wedge in the notch and positioning the rail length such that the wedge can be loaded by means of a drop weight impact load. The web cracking behaviour is characterized by interpretation of the length and direction of any crack that propagates from the end of the notch under the action of the impact load.

Appendix C Section 4.6 References 1, 3, 4 and 18 provide further detail on the test method, including notch dimensions, loading conditions and typical results.

Figure C5 illustrates the general concept of the crack arrest test.

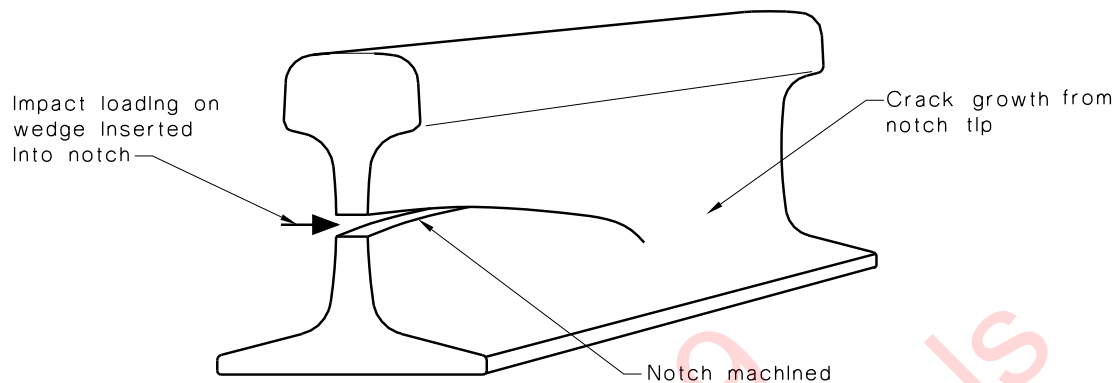


FIGURE C5 GENERAL ARRANGEMENT OF CRACK ARREST TEST

C.4.6 References

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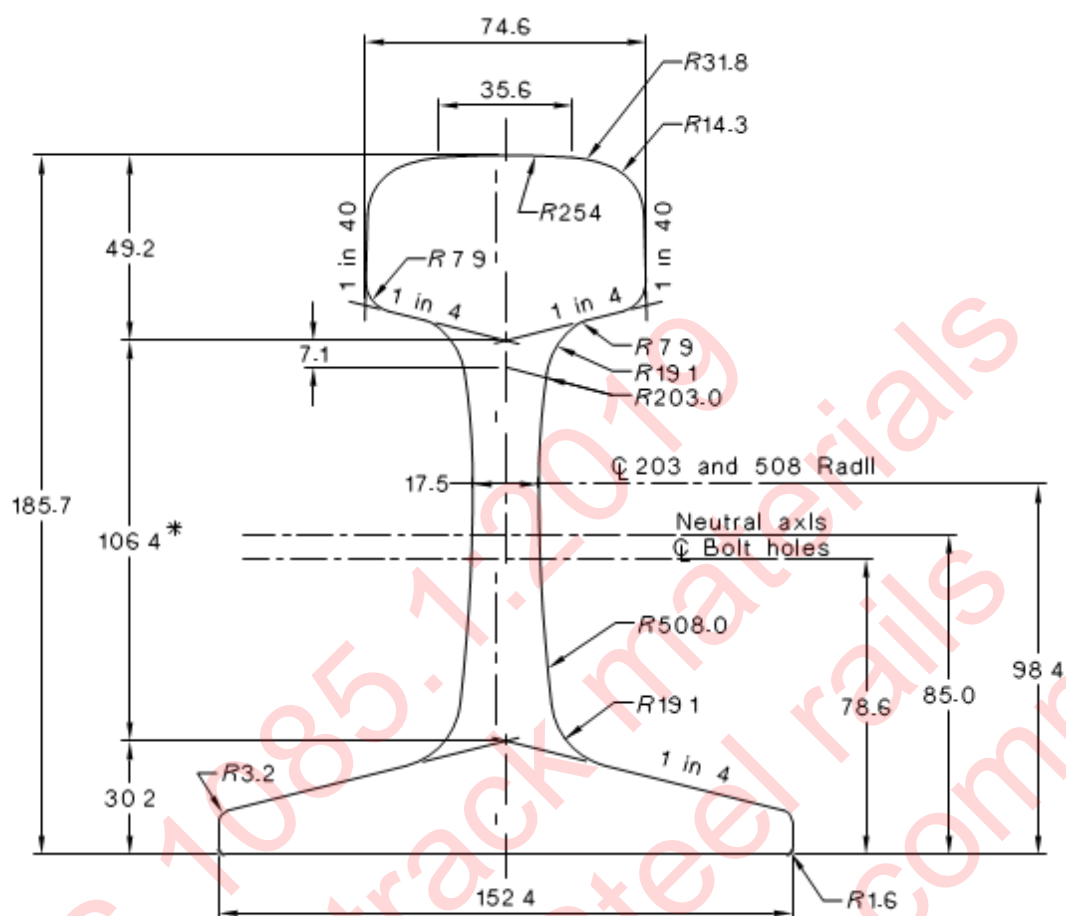
Appendix D Track system compatibility (Normative)

D.1 Nominal rail profiles

This paragraph provides the following profile and drilling details:

- (a) Profile details for 68 kg, 60 kg, 50 kg, 41 kg and 31 kg rolled steel (see Figures D1 to D5).
- (b) Drilling details for 31 kg, 41 kg, 50 kg, 60 kg and 68 kg rolled steel (see Figures D6 and D7).
- (c) Profile details for 50 kg and 60 kg rolled steel asymmetrical switch (see Figures D8 and D9).
- (d) Profile details for 50 kg and 60 kg rolled steel elevated guardrails (see Figure D10).

The mass values given in this Appendix are rounded to three significant figures and are based on the rail steel density of 7850 kg/m³.



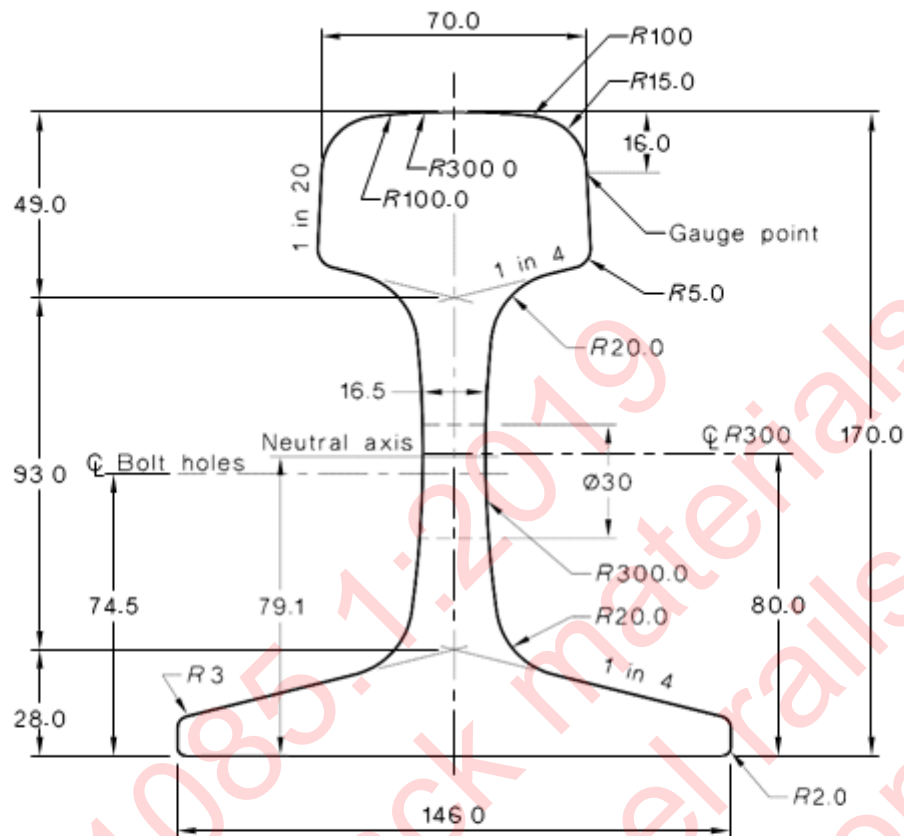
Head area	$3.125 \times 10^3 \text{ mm}^2$	Second moment of area (I_{x-x})	$39.4 \times 10^6 \text{ mm}^4$
Web area	$2.335 \times 10^3 \text{ mm}^2$	Second moment of area (I_{y-y})	$6.02 \times 10^6 \text{ mm}^4$
Foot area	$3.142 \times 10^3 \text{ mm}^2$	Section modulus head	$391.7 \times 10^3 \text{ mm}^3$
Total area	$8.602 \times 10^3 \text{ mm}^2$	Section modulus foot	$463.8 \times 10^3 \text{ mm}^3$
		Calculated mass	67.5 kg/m

NOTE: The * alongside the dimension 106.4 indicates that the values 49.2, 106.4 and 30.2 do not add up to 185.7. The reason for this is that the dimensions are rounded values.

NOT TO SCALE

DIMENSIONS IN MILLIMETRES, SOME OMITTED FOR CLARITY

FIGURE D1 68 kg RAIL 1

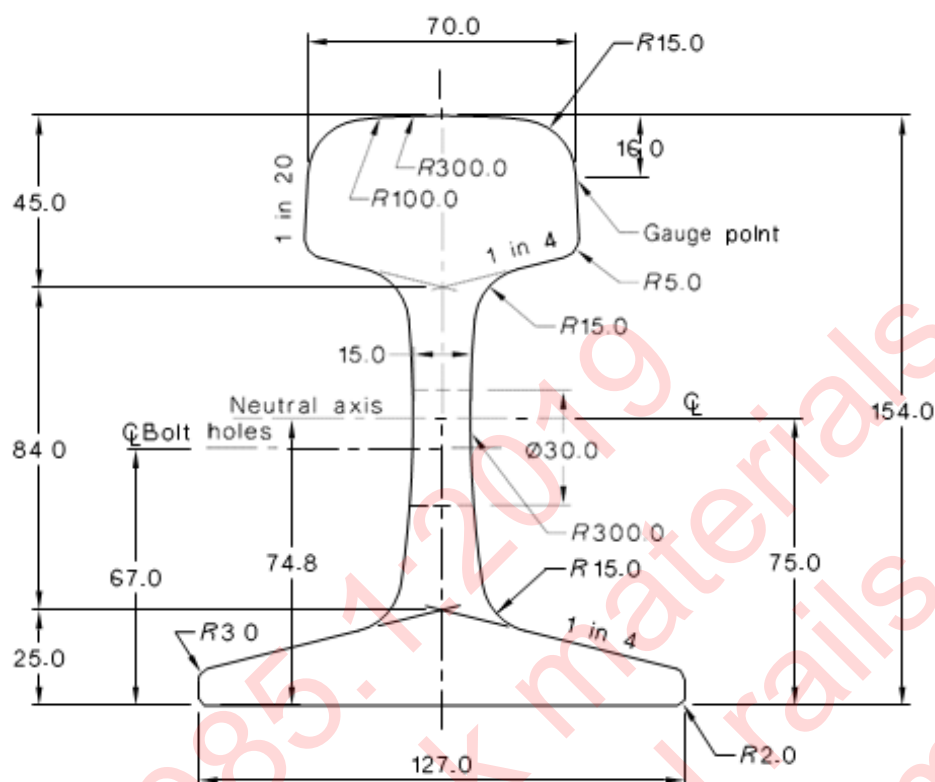


Head area	$3.018 \times 10^3 \text{ mm}^2$	Second moment of area (I_{x-x})	$29.4 \times 10^6 \text{ mm}^4$
Web area	$1.958 \times 10^3 \text{ mm}^2$	Second moment of area (I_{y-y})	$4.91 \times 10^6 \text{ mm}^4$
Foot area	$2.752 \times 10^3 \text{ mm}^2$	Section modulus head	$323.2 \times 10^3 \text{ mm}^3$
Total area	$7.728 \times 10^3 \text{ mm}^2$	Section modulus foot	$371.4 \times 10^3 \text{ mm}^3$
		Calculated mass	60.7 kg/m

NOT TO SCALE

DIMENSIONS IN MILLIMETRES, SOME OMITTED FOR CLARITY

FIGURE D2 60 kg RAIL 1

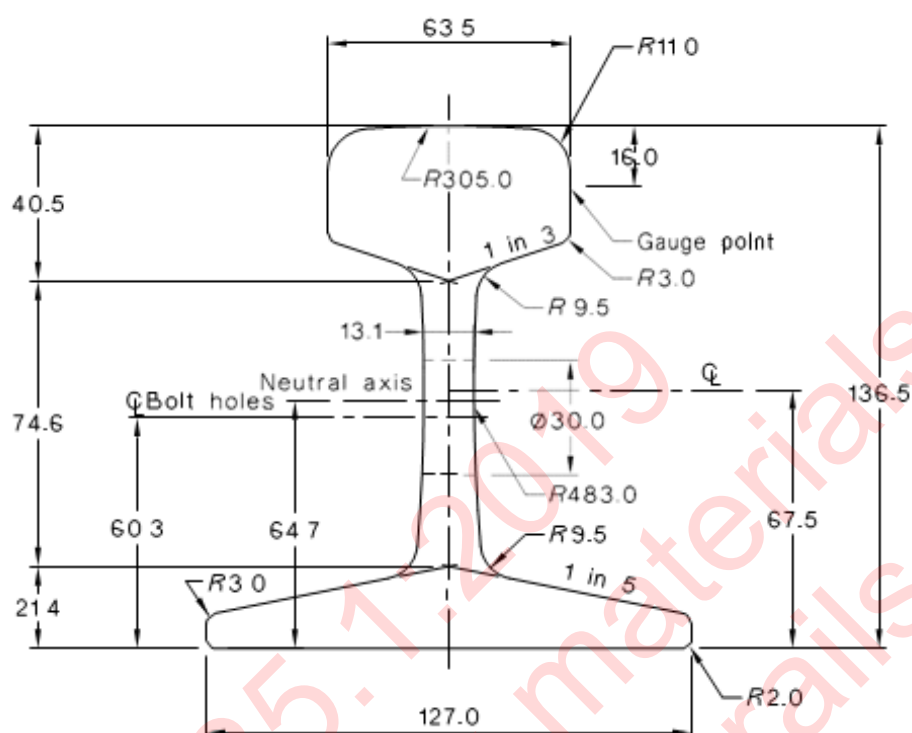


Head area	$2.729 \times 10^3 \text{ mm}^2$	Second moment of area (I_{x-x})	$20.2 \times 10^6 \text{ mm}^4$
Web area	$1.565 \times 10^3 \text{ mm}^2$	Second moment of area (I_{y-y})	$3.27 \times 10^6 \text{ mm}^4$
Foot area	$2.164 \times 10^3 \text{ mm}^2$	Section modulus head	$254.1 \times 10^3 \text{ mm}^3$
Total area	$6.457 \times 10^3 \text{ mm}^2$	Section modulus foot	$269.3 \times 10^3 \text{ mm}^3$
		Calculated mass	50.7 kg/m

NOT TO SCALE

DIMENSIONS IN MILLIMETRES, SOME OMITTED FOR CLARITY

FIGURE D3 50 kg RAIL 1

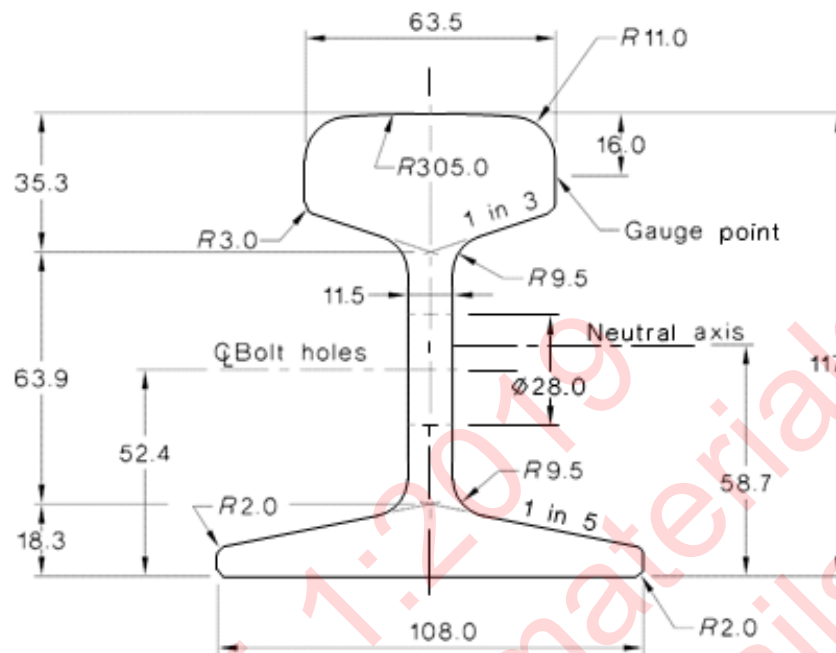


Head area	$2.162 \times 10^3 \text{ mm}^2$	Second moment of area (I_{x-x})	$13.27 \times 10^6 \text{ mm}^4$
Web area	$1.122 \times 10^3 \text{ mm}^2$	Second moment of area (I_{y-y})	$2.67 \times 10^6 \text{ mm}^4$
Foot area	$1.908 \times 10^3 \text{ mm}^2$	Section modulus head	$184.4 \times 10^3 \text{ mm}^3$
Total area	$5.192 \times 10^3 \text{ mm}^2$	Section modulus foot	$204.5 \times 10^3 \text{ mm}^3$
		Calculated mass	40.8 kg/m

NOT TO SCALE

DIMENSIONS IN MILLIMETRES, SOME OMITTED FOR CLARITY

FIGURE D4 41 kg RAIL 1



Head area	$1832 \times 10^3 \text{ mm}^2$	Second moment of area (I_{x-x})	$7.68 \times 10^6 \text{ mm}^4$
Web area	$0.786 \times 10^3 \text{ mm}^2$	Second moment of area (I_{y-y})	$160 \times 10^6 \text{ mm}^4$
Foot area	$1.391 \times 10^3 \text{ mm}^2$	Section modulus head	$130.4 \times 10^3 \text{ mm}^3$
Total area	$4.009 \times 10^3 \text{ mm}^2$	Section modulus foot	$130.4 \times 10^3 \text{ mm}^3$
		Calculated mass	31.5 kg/m

NOT TO SCALE

DIMENSIONS IN MILLIMETRES, SOME OMITTED FOR CLARITY

FIGURE D5 31 kg RAIL 1

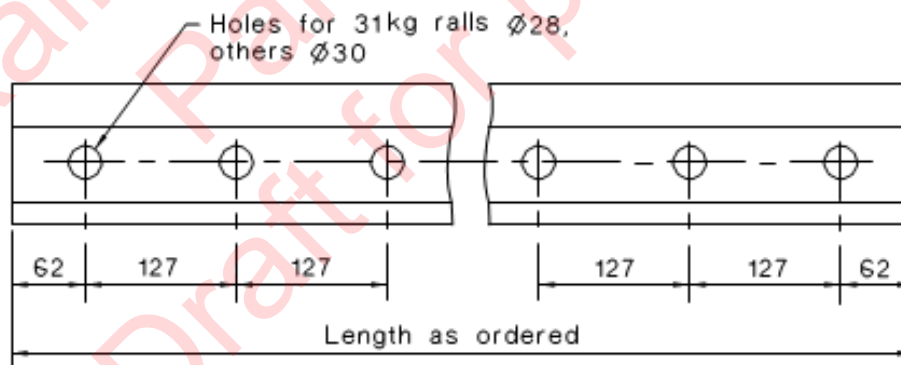


FIGURE D6 DRILLING DETAILS FOR 31 kg AND 41 kg RAILS

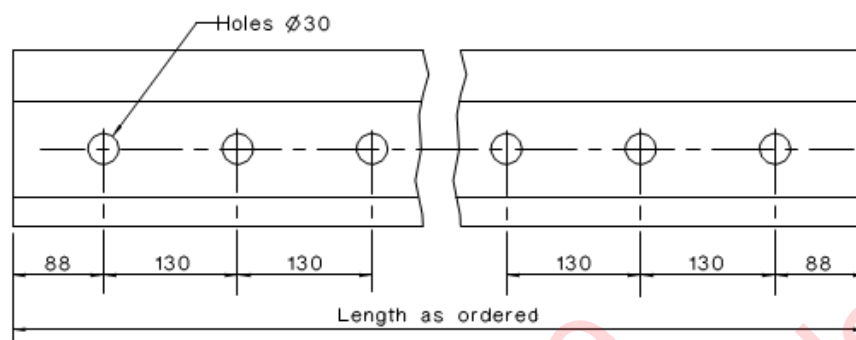
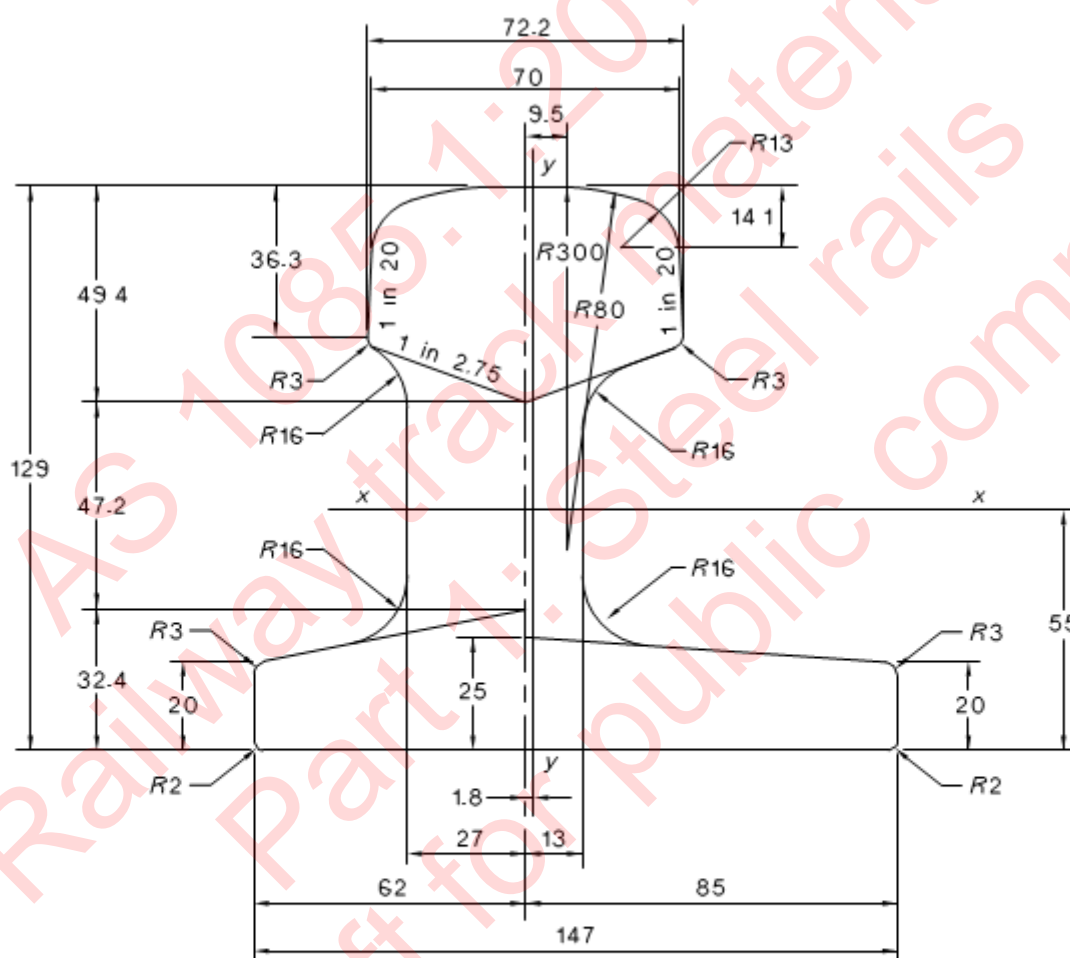


FIGURE D7 DRILLING DETAILS FOR 50 kg, 60 kg AND 68 kg RAILS

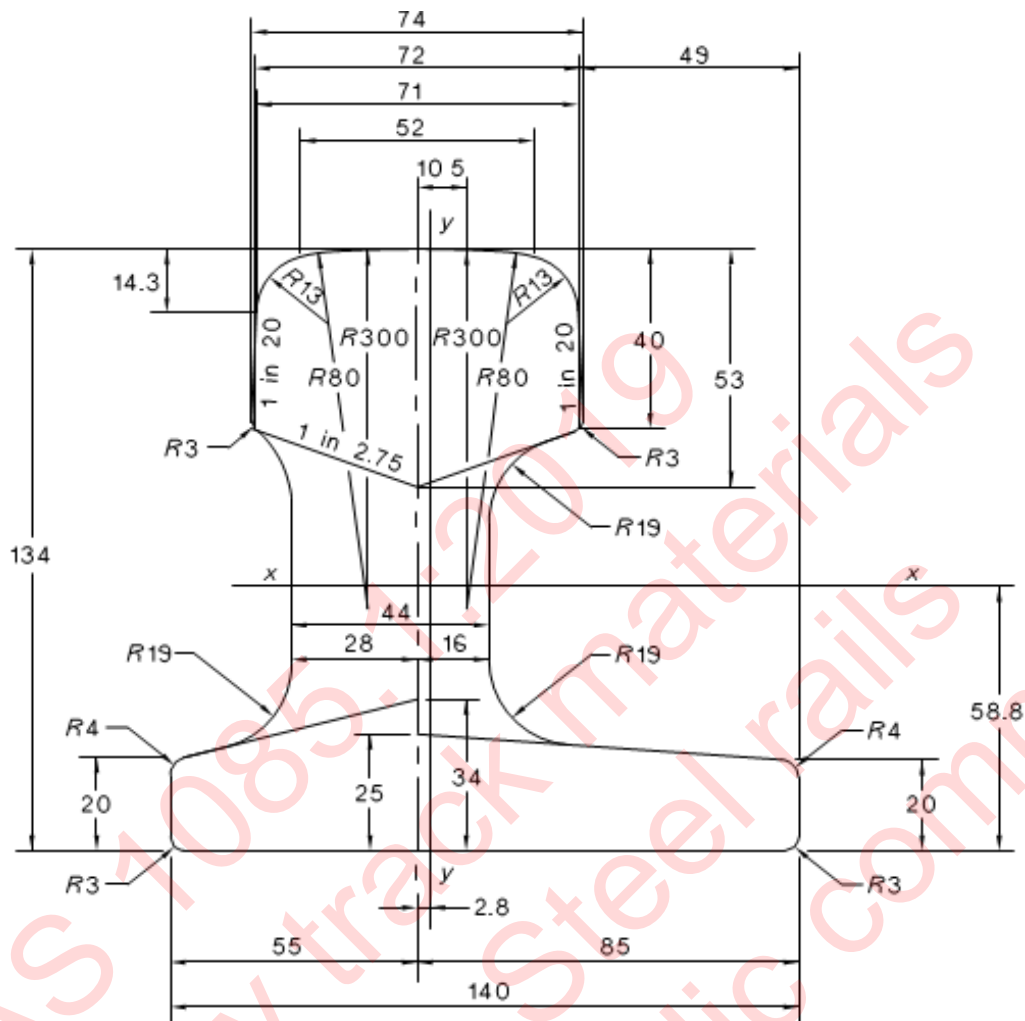


Head area	$2.90 \times 10^3 \text{ mm}^2$
Web area	$2.35 \times 10^3 \text{ mm}^2$
Foot area	$3.53 \times 10^3 \text{ mm}^2$
Total area	$8.78 \times 10^3 \text{ mm}^2$

Second moment of area (I_{x-x})	$15.40 \times 10^6 \text{ mm}^4$
Second moment of area (I_{y-y})	$7.68 \times 10^6 \text{ mm}^4$
Section modulus head	$207.5 \times 10^3 \text{ mm}^3$
Section modulus foot	$281.0 \times 10^3 \text{ mm}^3$
Calculated mass	68.9 kg/m

DIMENSIONS IN MILLIMETRES

FIGURE D8 50 kg ASYMMETRICAL SWITCH RAIL



Head area	$3.24 \times 10^3 \text{ mm}^2$
Web area	$2.68 \times 10^3 \text{ mm}^2$
Foot area	$3.38 \times 10^3 \text{ mm}^2$
Total area	$9.30 \times 10^3 \text{ mm}^2$

Second moment of area (I_{x-x})	$17.28 \times 10^6 \text{ mm}^4$
Second moment of area (I_{y-y})	$7.44 \times 10^6 \text{ mm}^4$
Section modulus head	$229.9 \times 10^3 \text{ mm}^3$
Section modulus foot	$293.8 \times 10^3 \text{ mm}^3$
Calculated mass	73.0 kg/m

DIMENSIONS IN MILLIMETRES

FIGURE D9 60 kg ASYMMETRICAL SWITCH RAIL

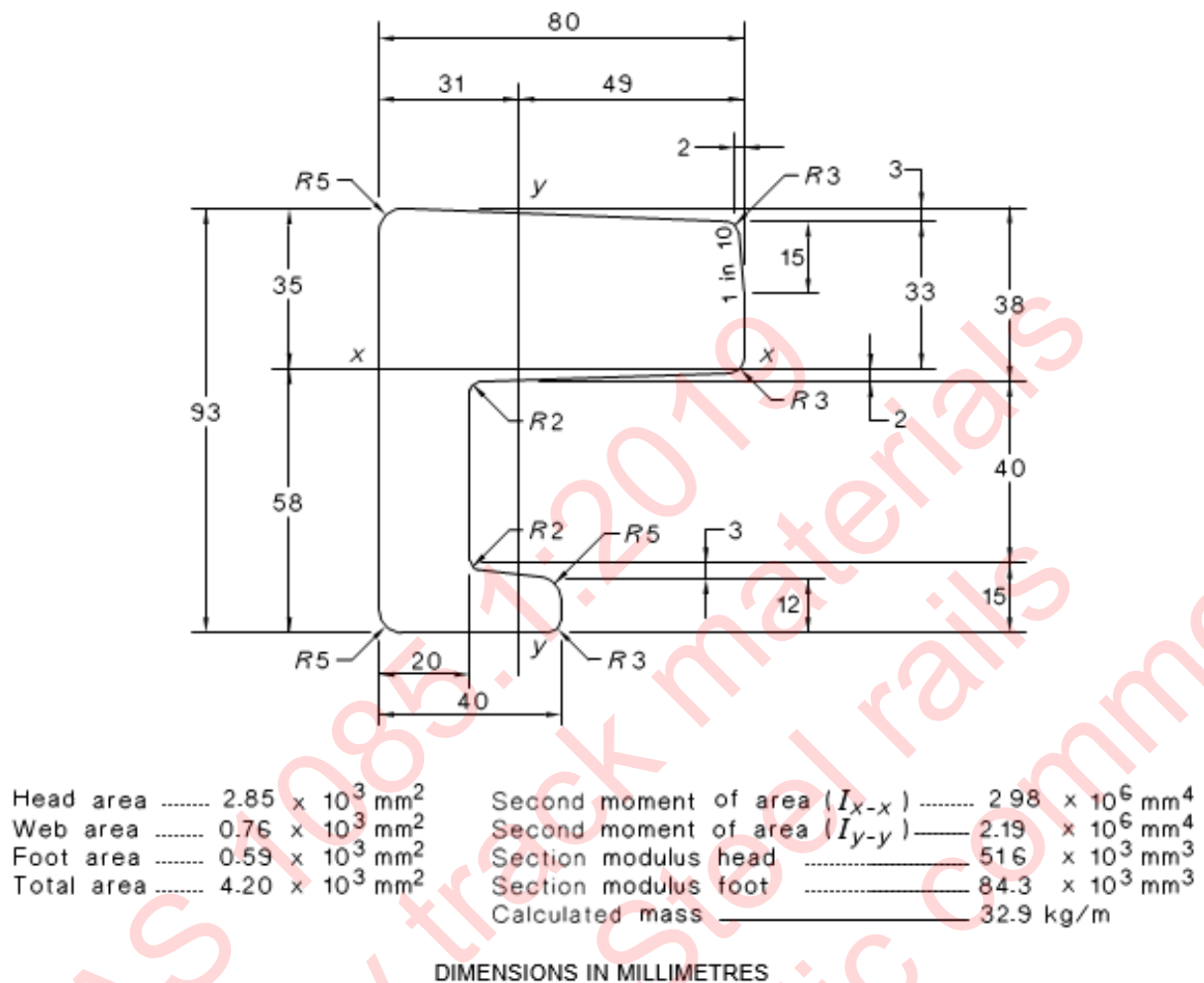


FIGURE D10 50/60 kg ELEVATED GUARDRAIL FOR 50 kg AND 60 kg RAILS

D.2 Measurement of dimensions

Dimensions of the rail shall be measured as follows:

- End straightness: End straightness shall be measured by a procedure that is not less accurate than that of placing a 1 m straightedge of Grade A in accordance with AS 1003 at various positions along the end 1.5 m of the rail. The maximum deviation measured as a chordal ordinate of the rail from the straightedge both upwards and sideways shall be measured in millimetres.
NOTE: A Grade A 1 m straight edge has a flatness tolerance of 12 μm .
- Overall straightness: The rail shall be placed head up on a horizontal plane support, with supports at not more than 5 m centres. The maximum ordinate of the upswEEP above the level of the horizontal supports shall be measured in millimetres.

Where rail lengths are less than 27 m, the maximum allowable upswEEP shall be reduced proportionally.

Rail that is in doubt, contains visible bends, waves or kinks, or is in dispute shall be checked by measuring the maximum deviation from a 1 m straightedge placed on the rail.

- (c) Fishing template standoff: The template shall be shaped to the profile for the designated rail section and shall include the upper fishing surface, the web and the lower fishing surface. With the template in sliding contact with the lower fishing surface, check for standoff from the contour of the web and clearance at the upper fishing surface.
- (d) Eccentricity: Rail eccentricity shall be checked by use of the gauge shown in Figure D11. When using the gauge shown in Figure D11, the gauge point shall not touch the head of the rail and a slip of dimension $2e$ shall not pass between the gauge point and the head of the rail, on either side of the rail (see Figure D12).
- (e) Twist: Rail twist shall be measured as shown in Figure D12.

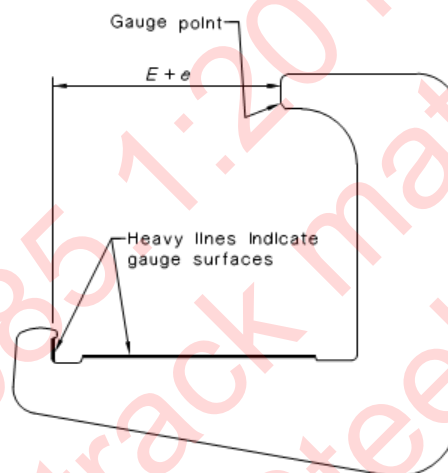


FIGURE D11 ECCENTRICITY GAUGE

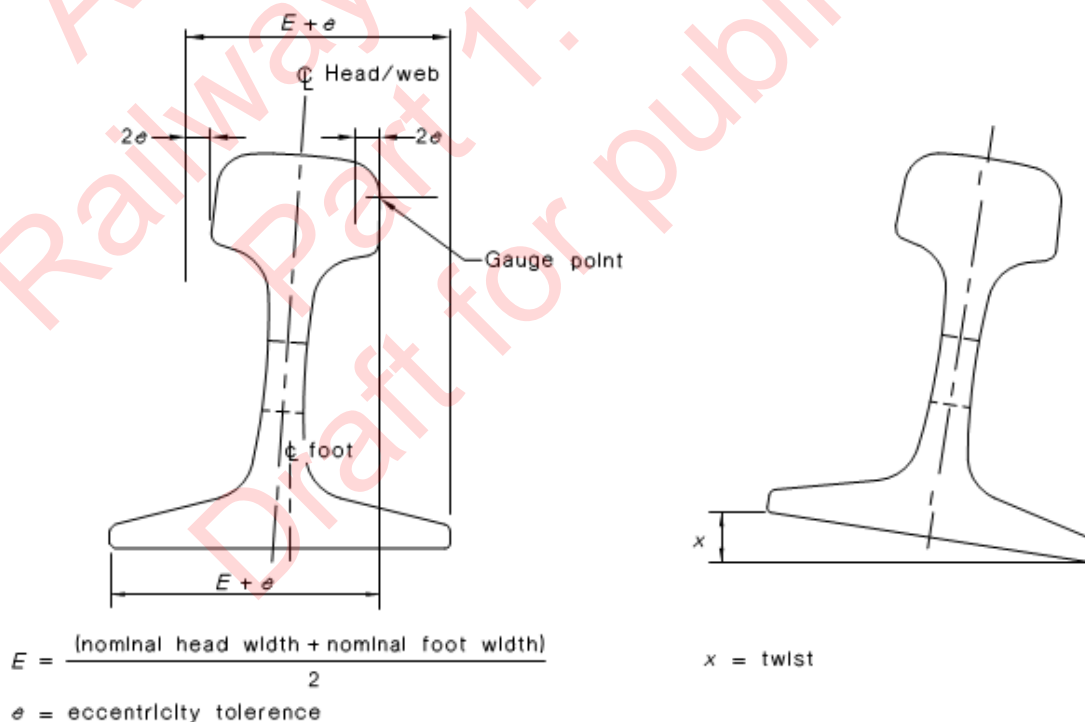


FIGURE D12 MEASUREMENT OF ECCENTRICITY AND TWIST

Table D1
Dimensional Tolerances (Note 1)

Characteristic	Tolerance mm
Overall height of rail	+1.0 -0.5
Width of head	+1.0 -0.5
Width of foot	±1.0
Thickness of web	+1.0 -0.5
Foot base: flat to maximum concavity (no convexity)	0.5
Fishing surfaces (see Note 2):	
(a) Maximum standoff of fishing template from web	2
(b) Maximum clearance of template at upper fishing surface	0.2
Eccentricity 'e' of rail section as checked by means of an eccentricity gauge (see Note 2)	±1.5
Overall length measured with a steel tape and adjusted to a rail temperature of 20°C—	
Undrilled rails	+150, -0
Drilled rails	±8
End squareness—	
Horizontal	0.7
Vertical	0.7
End straightness (see Note 2)—maximum deviation:	
Head: sideways	0.5
upwards	0.5
downwards	0
Foot: sideways	1.0
Overall straightness (see Note 2):	
(a) maximum upsweep over 27 m chord	20
(b) over 1 m chord	0.5
Twist (see Note 2)—	
(a) at either end of the rail with the rail lying naturally	2
(b) at any point along the rail	2
(c) a maximum rate of change	1 in 1000
Bolt holes:	
Diameter	±1
Location (measured in accordance with the maximum material principle, see AS 1100.201)—	
(a) from end of rail to centre of any hole measured at level of bolt	±1
(b) from base of rail to centre of hole measured perpendicularly	±1

NOTES:

1. Tolerances for guardrail and switch rail to be in accordance with UIC 861-2.
2. Appropriate methods for measurement are given in Paragraph D2.
3. Rails shall not contain bends, waves or kinks.

Appendix E Material properties (Normative)

E.1 Chemical composition

E.1.1 Chemical composition other than oxygen and hydrogen

Chemical composition other than oxygen and hydrogen shall be determined as follows:

- (a) Take a sample of liquid steel representing the final product in accordance with AS/NZS 1050.1. Where it is impractical to test a sample taken from the liquid steel or a sample has been contaminated, analysis of test samples from solid metal taken in accordance with AS/NZS 1050.1 may be reported as cast analysis.
- (b) Test the sample by procedures that are not less accurate than the methods given in the appropriate parts of AS/NZS 1050.

NOTES:

1. The chemical composition of 50 kg and 60 kg asymmetrical switch rail and elevated guardrail are not specified by this Standard. The use of the 50 kg/60 kg chemical composition given in this Appendix, or the chemistry specified in UIC 861-2 is appropriate.
2. Levels for chromium, molybdenum, niobium and vanadium may be increased subject to agreement between the supplier and the purchaser.
3. Methods available for the removal of hydrogen include diffusion and vacuum degassing.

E.1.2 Oxygen

The total oxygen content shall be determined from a sample taken from the head of the rail and tested in accordance with AS/NZS 1050.

NOTE: Total oxygen content includes oxygen present in the form of oxides and is an important indicator of rail cleanliness. Steel cleanliness refers to the presence of non-metallic inclusions, e.g., oxides, sulfides, nitrides.

E.1.3 Hydrogen

The requirement for hydrogen content given in Table E2 shall be demonstrated by chemical testing or process control under an appropriate quality system.

E.2 Mechanical properties

The procedures for determining the mechanical properties are given in Appendix F for the limits given in Tables E3, E4 and E5.

Table E1

Chemical Composition

Nominal rail size	Carbon %	Manganese %	Silicon %	Phosphorus %	Sulfur %	Aluminium %	Nitrogen %
31 kg, 41 kg	0.53 to 0.69	0.60 to 0.95	0.15 to 0.58	0.025 max.	0.025 max.	0.005 max.	0.010 max.
50 kg, 60 kg, 68 kg	0.65 to 0.82	0.70 to 1.25					

Table E2
Maximum for other elements

Residual metals									
Cr	Mo	Ni	Cu	Sn	Ti	Nb	V	Cu + 10Sn	Cr + Mo + Ni + Cu + V
0.15	0.02	0.10	0.15	0.04	0.025	0.01	0.03	0.45	0.30
Total oxygen and hydrogen									
O					H				
35 ppm (solid)					2.5 ppm (finished rail)				

Table E3
Mechanical Properties

Nominal rail size		0.2% proof stress MPa, min.	Tensile strength MPa, min.	Elongation %, min.	Surface hardness HB, min.
All rail	31 kg, 41 kg	—	700	8	—
	50 kg, 60 kg, 68 kg	420	880	8	260
Head-hardened rail	50 kg, 60 kg, 68 kg	780	1130	9	340

Table E4
Hardness in the heat affected zone for head hardened rails

Location	Hardness HV30
Position C	430 max.
Along traverse 1	430 max. at any point, 360 min. at 10 mm from the rail surface
Along traverse 2	430 max. at any point, 340 min. at 10 mm from the rail surface

Table E5
Dimensions of heat affected zone for head hardened rails

Nominal rail size	Dimensions (see Figure F1)			
	<i>a</i>		<i>b</i>	
	Min.	Max.	Min.	Max.
50 kg	15	23	20	35
60 kg, 68 kg	15	23	25	40

Appendix F Material integrity (Normative)

F.1 Material properties

F.1.1 Tensile testing

Tensile testing shall be carried out in accordance with AS 1391 on a proportional test piece of circular section having a diameter of 10 mm and a gauge length of 50 mm, with other dimensions and tolerances as given in AS 1391. Tensile test pieces shall be machined from the head of the rail at the position given in Table F1 and Figures F1(a) and F1(b) for the particular rail size and type.

Table F1
Position of tensile test sample by rail size

Nominal rail size	As-rolled rail	Head-hardened rail
31 kg	A	N.A.
41 kg	A	N.A.
50 kg	A	B
60 kg	A	B
68 kg	B	B

F.1.2 Surface hardness test

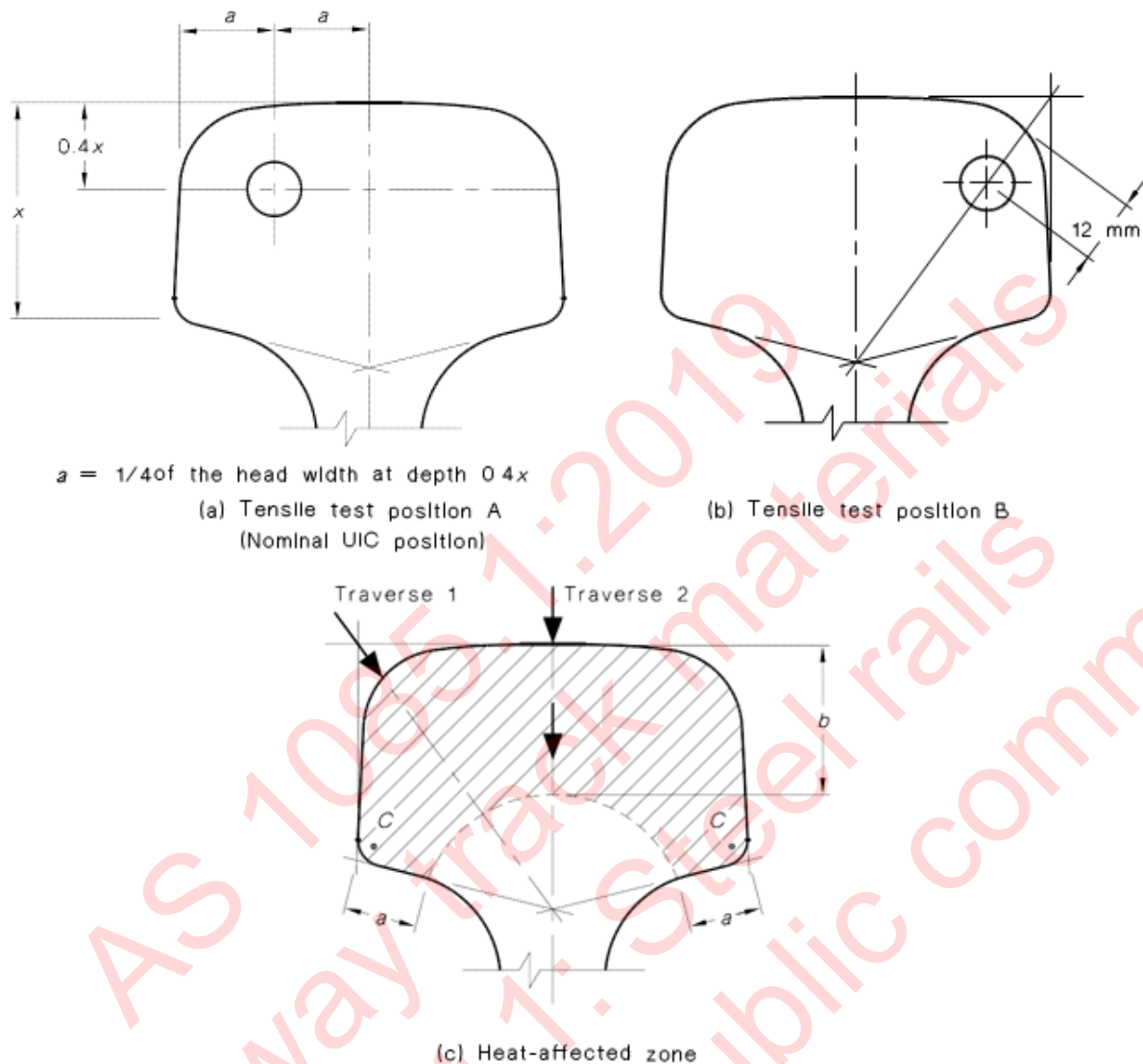
After removal of surface decarburization up to a limit of 0.5 mm depth, a Brinell hardness test shall be made on the running surface of the head in a position not more than 20 mm from the centre-line of the rail head. The test should be made with a 10 mm ball with a force of 29.4 kN, in accordance with AS 1816.

F.1.3 Test for depth of heat treatment (etch test)

The depth of the heat treatment shall be determined by etching a section of rail. Etching shall be carried out generally in accordance with the requirements of AS 2205.5.1. The shape of the heat-treated zone shall approximate that shown in Figure F1(c) and the dimensions a and b shall be recorded.

F.1.4 Hardness gradient test

Check the hardness gradient along traverses 1 and 2, as shown in Figure F1(c) and the hardness at position C as shown in Figure F1(c), at approximately 2 mm from the surface of the rail. Position C and traverse 1 shall be selected such that random testing of both sides of the rail head is achieved. The hardness traverse, with readings taken at a spacing not greater than 2 mm, shall cover the first 12 mm from the beginning of the traverse at the surface of the rail and shall be performed using the Vickers Diamond Pyramid with a 294 N force in accordance with AS 1817.



$a = 1/4$ of the head width at depth $0.4x$

(a) Tensile test position A
(Nominal UIC position)

(b) Tensile test position B

(c) Heat-affected zone

NOTE: The hatched area indicates the heat-affected zone within which the hardened zone will be.

FIGURE F1 RAIL HEAD

F.1.5 Microstructure test

A sample shall be taken from the tensile testing position in the rail head (see Figures F1(a) and F1(b)). The sample shall be prepared and examined under a metallurgical microscope at magnifications up to 500X to determine the microstructure of the steel.

F.2 Internal soundness

F.2.1 Sulfur print test

Figure F2 shows the regions of head, web and foot referenced by Section 7.2.3 for the sulfur print test.

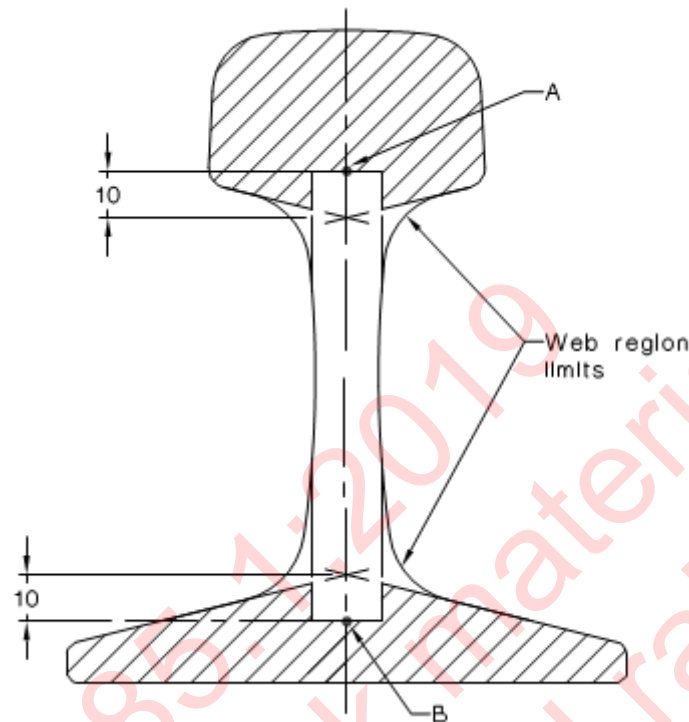


FIGURE F2 RAIL HEAD, WEB AND FOOT REGIONS

F.2.2 Ultrasonic test for rolled steel rails

F.2.2.1 General

Ultrasonic testing of unused rails in the head, web and section of foot (see Figure F3) to determine the presence of discontinuities shall be performed using a technique that ensures that the minimum cross-sectional area that the inspection covers is as follows:

- (a) 95 percent or more of the head and web except for 68 kg rail which is 90 percent.
- (b) The region shown in Figure F3 for the foot.

NOTE: These areas are based on projecting the nominal crystal diameter at the probe.

The location and aiming of the probes shall be chosen by the tester to detect the discontinuities most common to the method of manufacture.

F.2.2.2 Apparatus

The equipment used shall have sensitivity levels capable of detecting the artificial discontinuities of the size shown in Figure F4.

The equipment shall be tested at intervals appropriate to maintain the required accuracy using a calibration piece with artificial discontinuities in the head, web and foot as shown in Figure F4. The calibration piece shall be of the same nominal rail size as the rails being tested. Other methods of calibration may be used provided that they ensure the same or better level of accuracy.

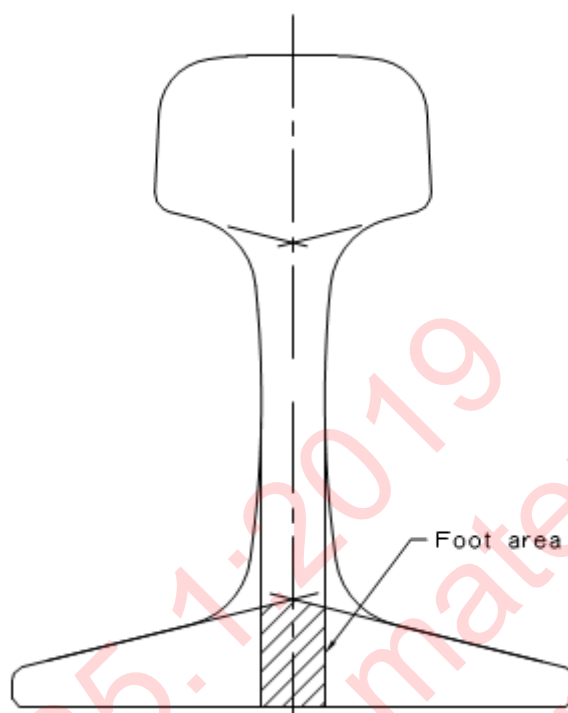
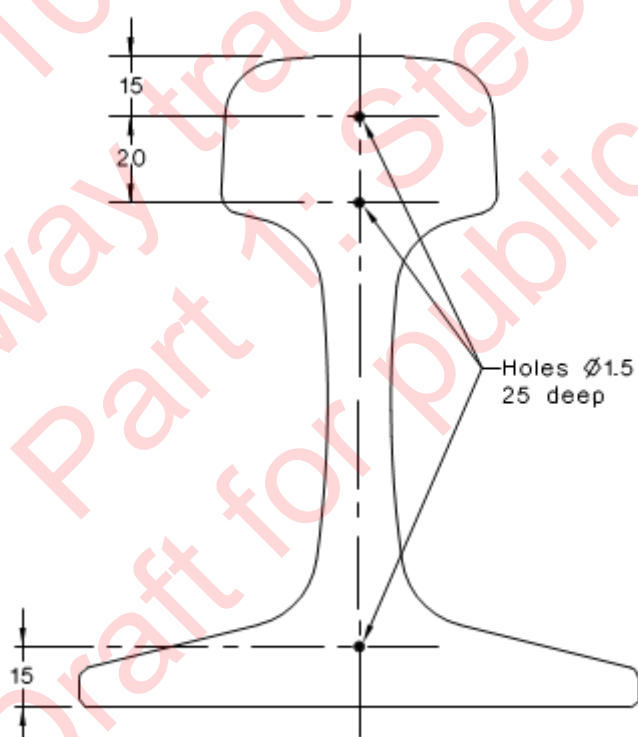


FIGURE F3 AREA OF FOOT TO BE ULTRASONICALLY TESTED



DIMENSIONS IN MILLIMETRES

FIGURE F4 REFERENCE BLOCK—RAIL HEAD AND FOOT

F.3 External finish

F.3.1 Visual inspection

Figure F5 shows the limits of the surface zones for visual inspection.

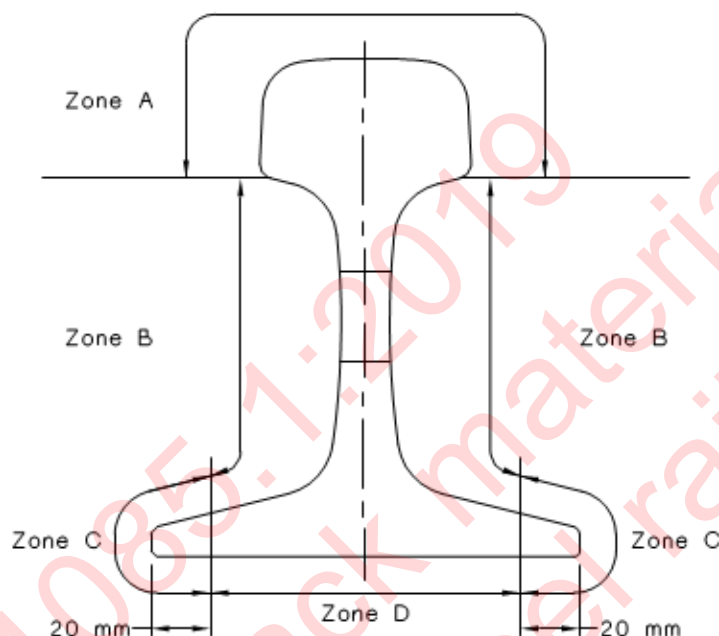


FIGURE F5 ZONES FOR SURFACE DEFECTS

F.3.2 Eddy current test for rolled steel rails

F.3.2.1 General

Eddy current testing of base sections of 50 kg, 60 kg and 68 kg rails shall be performed using a technique that ensures that a band at least 60 mm wide at the centre of the foot of the rail is sound.

NOTE: It is intended that this method be primarily applicable to unused rail. More complex methods are necessary for eddy current testing for in-service defects.

F.3.2.2 Apparatus

The equipment used shall have sensitivity levels capable of detecting the artificial surface opening discontinuities of the size shown in Figure F6.

The equipment shall be tested at intervals appropriate to maintain the required accuracy using a calibration piece with artificial discontinuities as shown in Figure F6. The calibration piece shall be taken from the same nominal rail size as the rails being tested.

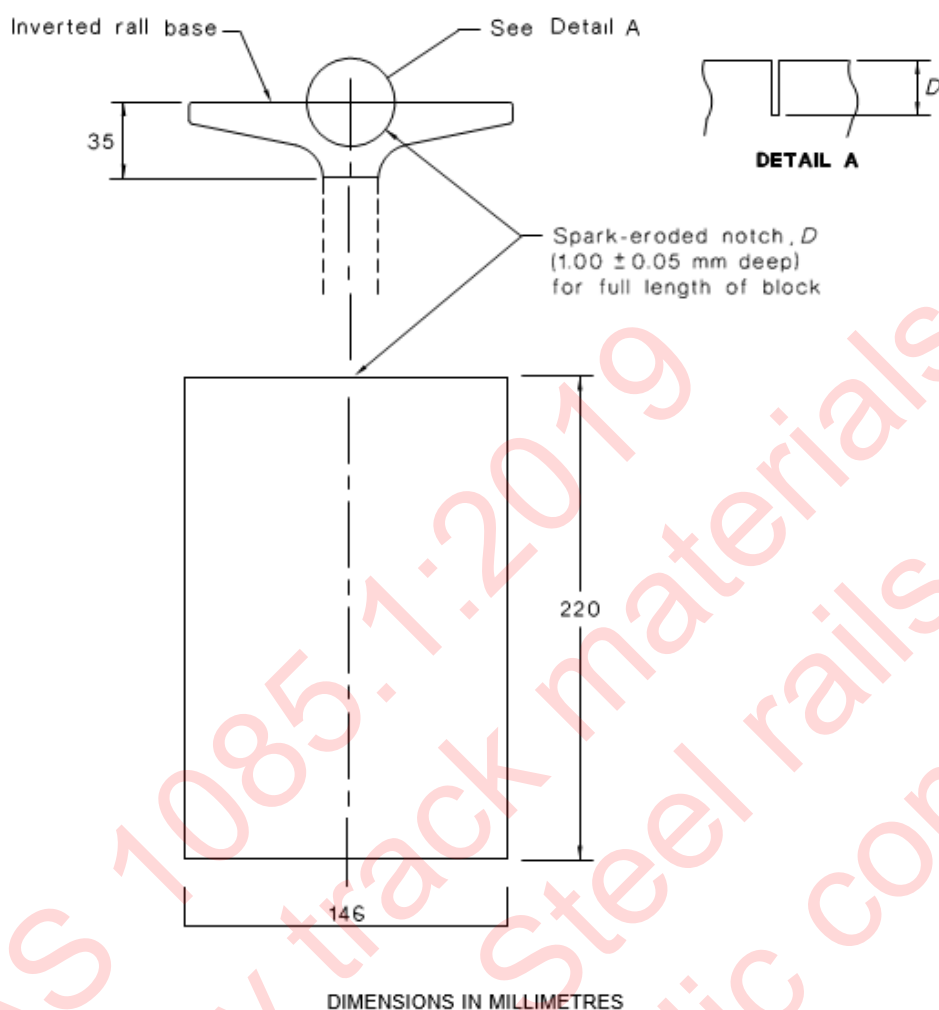


FIGURE F6 EDDY CURRENT TEST-CALIBRATION BLOCK

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ISBN: Enter ISBN.

AS 1085-1:2019
Railway track materials
Part 1: Steel rails
Draft for public comment