AS 1085.20—2006

Australian Standard™

Railway track material

Part 20: Welding of steel rail

STANDARDS
Australia

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Australasian Railway Association
Australian Chamber of Commerce and Industry
Australian Industry Group
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Australian Standard™

Railway track material

Part 20: Welding of steel rail

Originated as AS 1085.15—1995.
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PREFACE

This Standard was prepared by the Standards Australia Committee CE-002, Railway Track Materials, to supersede AS 1085.15—1995, *Railway permanent way material*, Part 15: *Aluminothermic rail welding*.

The objective of this Standard is to provide welders and specifiers with specifications for and means of qualification of welding procedures for use with rail steel in railway track.

As this is a new Standard, it is expected that existing welding procedures will be accepted as qualified to this Standard (see Appendix A).

This Standard is not intended to cover welding of worn rails using flash butt or aluminothermic welds. However, the principles and procedures may be adapted for the welding of worn rails.

It is not intended to cover existing welds.

Changes to the 1995 edition include the following:

(a) Introduction of performance requirements for aluminothermic rail welding rather than control of consumables.

(b) Qualification procedure for the personnel.

(c) Flash butt welding included.

(d) Metal arc welding included.

(e) Describes the procedure for qualifying and requalifying a welding process.

(f) Includes test methods harmonized with proposed European test methods.

(g) Fatigue performance now assessed using a series of tests known as a staircase.

The terms 'normative' and 'informative' have been used in this Standard to define the application of the appendix to which they apply. A 'normative' appendix is an integral part of a Standard, whereas an 'informative' appendix is only for information and guidance.

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Part 20: Welding of steel rail

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard specifies performance requirements for welds in steel rail in accordance with AS 1085.1 or rails that are shown to be metallurgically equivalent, for use in railway track. The following processes are covered:

(a) Joining of rails by flash butt welding.

(b) Joining of rails by aluminothermic fusion welding.

(c) Repair of the railhead by arc welding.

This Standard covers the joining of rails and the repair of the railhead by welding using the processes described. Other welding is outside the scope of this Standard and should be covered by documentation other than this Standard.

The Standard does not provide strength properties of welds for use in design nor cover the welding of austenitic manganese steels.

NOTES:

1 Commentary on the background to the Standard is given in Appendix A.

2 Guidance on information to be supplied when ordering or supplying is given in Appendix B.

3 Guidance on the means for demonstrating compliance with this Standard is given in Appendix C.

4 Rail steel is considered to be very difficult to weld for structural purposes. It is not recommended that welded rail be used in applications other than railway track.

5 Rail produced to specifications other than AS 1085.1 may require a separate qualification process. Appropriate testing may need to be determined.

1.2 PURPOSE AND CONTEXT OF USE

1.2.1 Function

Rail welds join lengths of rail or restore some part of the rail in railway track. They connect the rails together maintaining the qualities of the rail across the join. Rail welds may also be used to repair damage to the rail surface.

1.2.2 Action

Rail welds are subject to—

(a) loads imposed by the passage of rolling stock and during maintenance;

(b) loads generated by thermal effects on the rail and by ballast movement; and

(c) fatigue, wear, corrosion and other damage.

1.3 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

AS
1003 Engineers' straightedges (metric units)

1085 Railway permanent way material
1085.1 Steel rails

1101 Graphic symbols for general engineering
1101.3 Part 3: Welding and non-destructive examination

1199 Sampling procedures for inspection by attributes
1199.0 Part 0: Introduction to the ISO 2859 attribute sampling system
1199.1 Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection

1816 Metallic materials—Brinell hardness test—Test method (ISO 6506-1:1999, MOD)

1817 Metallic materials—Vickers hardness test
1817.1 Part 1: Test methods

2193 Calibration and classification of force-measuring systems

2205 Methods for destructive testing of welds in metal
2205.5.1 Method 5.1: Metallographic tests—Macro test—Cross-section examination
2205.6.1 Method 6.1: Hardness tests—Weld joint hardness test

2207 Non-destructive testing—Ultrasonic testing of fusion welded joints in carbon and low alloy steel

2812 Welding, brazing and cutting of metals—Glossary of terms

AS/NZS
2576 Welding consumables for build-up and wear resistance

ISO 9001 Quality management systems—Requirements

ISO 9004 Quality management systems—Guidelines for performance improvements

HB
18 Guidelines for third-party certification and accreditation
18.28 Guide 28—General rules for a model third-party certification scheme for products

WTIA Welding Technology Institute of Australia
Technical Note 7—Safety in welding

1.4 BASIC REQUIREMENTS

Welds shall—

(a) be qualified by testing;

(b) be made with an appropriate level of skill;

(c) be made in accordance with the job document that references the required welding procedure; and

(d) comply with the requirements of this Standard, including testing, for one of—

  (i) flash butt welding as given in Section 2;

  (ii) aluminothermic welding as given in Section 3; or

(iii) arc welding repairs as given in Section 4.

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

1.5 QUALIFICATION OF THE WELDING PROCESS

1.5.1 Qualification

The welding process, as described in the welding procedure, shall be qualified by testing in accordance with the appropriate Section of this Standard.

Records shall be kept of the results of all qualification tests carried out together with the relevant welding procedure. All these records shall be kept and made available to those authorized to examine them.

Separate qualification is required for each rail profile and for each rail material grade.

1.5.2 Requalification

Requalification of the welding procedure shall be required, and a new welding procedure produced when any one of the following changes occur:

(a) *All welding*—welds on rails that are subject to change in the profile or material grade.

(b) *Specific welding methods*—in accordance with the testing procedures set out in the appropriate section of this Standard.

1.6 QUALIFICATION OF WELDING PERSONNEL

Welds shall be made by personnel who are qualified according to the requirements of Appendix D.

1.7 DOCUMENTATION

1.7.1 Job document

The whole of the work to be carried out, including safety precautions, shall be described in the job document. The job document shall make reference to the welding procedure to be used. It shall be readily accessible, held as a record, and available for examination.

NOTES:

1 Rail welding requires considerations other than the production of the weld itself. Some of these will depend on the situation of the weld and the needs of the organizations involved. For example, access to a part of a railway track may require permission from the owner and any user of that track. The job document should set out how such permission is to be secured and any operating procedures for safety.

2 Safe working procedures that are suitable for the activities to be carried out should be established and included in the job document (see WTIA Technical Note 7).

1.7.2 Welding procedure

The welding process, that is, the weld preparation, the welding consumables (if relevant) and the welding parameters shall be documented in a welding procedure. The welding procedure shall be available at the welding site and shall also be referenced in the job document.

1.8 TESTING

Test methods for use in this Standard are given in the following Appendices:

(a) Visual inspection alignment and size ranges for imperfections ..... Appendix E.

(b) Ultrasonic test ..... Appendix F.

(c) Weld metal hardness ..... Appendix G.

(d) Hardness traverse ..... Appendix G.

(e) Macroscopic test ..... Appendix H.

(f) Microscopic test ..... Appendix I.

(g) Chemical analysis ..... Appendix J.

(h) Slow bend test ..... Appendix K.

(i) Fatigue test ..... Appendix L.

1.9 DEFINITIONS

For the purpose of this Standard, the definitions given in AS 1101.3 and AS 2812 and those below apply. Where the definitions in this Standard differ from those in AS 1101.3 or AS 2812, those given below apply.

1.9.1 Aluminothermic welding

A welding process in which an aluminothermic reaction takes place within a crucible and the resultant molten metal flows into a weld joint contained by a mould. The by-product, aluminium oxide slag, is contained in a side receptacle.

1.9.2 Bond line

Vertical centre-line of a flash butt weld.

1.9.3 Closing portion

Granular refractory material that glazes when subjected to the heat of the aluminothermic reaction to seal the thimble to the crucible.

1.9.4 Closure

A short length of rail to replace a piece of rail in tracks, also called a plug.

NOTE: A minimum length of a closure or plug should be specified by the track owner.

1.9.5 Cold shut

Prematurely chilled pieces of metal forming unfused discontinuities within the weld metal.

1.9.6 Consumables

Material consumed in the performance of a weld.

1.9.7 Crucibles

Conical-shaped refractory for containing the portion during ignition, reaction and pour.

NOTE: Crucibles may be designed for single use or multiple uses.

1.9.8 Flashing

Flat fin of weld metal located on the rail surface adjacent to the weld collar caused by gaps between the mould and the rail.

1.9.9 Fusion zone

Area of weld metal revealed by etching cut sections.

NOTE: This represents the area of molten metal consisting of a mixture of parent metal and weld metal (where applicable) that has solidified to form the weld metal as revealed in the etched cross-section during testing.

1.9.10 Heat-affected zone

Section of the parent rail outside the fusion zone that has mechanical properties altered by the welding process.

1.9.11 Heat-affected zone, visible

Section of the parent rail either side of the fusion zone within which microstructure has been altered by the heat of the welding process.

NOTE: It can be made visible by macro etching and is not to be confused with heat-affected zones identified by hardness variation.

1.9.12 Heat-softened zone

Part of the heat-affected zone characterized by hardness below that of the parent rail.

1.9.13 Hot tear

Fracture in the weld caused by tension on the weld during solidification of the molten metal.

1.9.14 Igniter

Device, usually a special 'ignition tape', used to ignite the portion and initiate the aluminothermic reaction.

1.9.15 Inclusions

Slag or other foreign non-metallic matter entrapped during welding.

1.9.16 Job document

Document that describes the specific program of work and refers to the welding procedure to be used.

1.9.17 Junction weld

Weld joining together two different rail profiles, (e.g., 50 kg and 60 kg rail). *See* also 'Step weld' (Clause 1.9.25).

1.9.18 Luting material

Refractory material used to seal the mould components around the rail.

1.9.19 Mould unit

Preformed refractory receptacles that are placed around the rail at the gap to be welded and which receive the molten metal from the crucible.

1.9.20 Porosity

Cavities formed by entrapped gas during the solidification of molten metal.

1.9.21 Portion

A prepared package containing the correct quantity of aluminothermic powder for the type of weld to be made.

1.9.22 Pouring mode

Path by which molten metal enters the mould cavity, e.g., side pour or centre pour.

1.9.23 Short head

Insufficient weld metal head. *See* also 'Weld metal head' (Clause 1.9.31).

1.9.24 Shrinkage crack

Crack in the weld metal occurring during solidification. It can be on the surface or in the body of the weld.

1.9.25 Step weld

Weld joining together rails of the same profile but of different heights due to wear. *See* also 'Junction weld' (Clause 1.9.27).

1.9.26 Thimble

Refractory insert sealing the bottom of the crucible. It contains a fusible insert to hold the molten metal until the aluminothermic reaction is complete and then automatically taps the metal into the mould.

1.9.27 Upset

The stage during flash butt welding, after completion of pre-heat, when the two rail ends are forged together.

1.9.28 Welding procedure

The written detailed methods and practices involved in the making and testing of a rail weld.

1.9.29 Welding process

A particular method of welding involving the application of certain metallurgical, electrical, physical, chemical, or mechanical principles.

1.9.30 Weld gap

The distance between the ends of the rail prior to welding.

1.9.31 Weld metal head

Weld metal remaining above the top of the rail profile after solidification.

1.9.32 Weld reinforcement

Weld metal external to parent rail profile.

1.10 NOTATION

Unless stated otherwise, the notation used in this Standard shall have the following meanings.

A = a value used in calculating the variation of fatigue results

= $\Sigma (i\, n_i)$

AB = distance identified as the width of the heat-softened zone by a hardness traverse jKeping St ipgidrs ipSuieKd-rogi

B = a value used in calculating the variation of fatigue results

= $\Sigma (i^2\, n_i)$

D_1, D_2 = collar depth at location A

d = constant stress increment of the staircase, in megapascals, taken as 20 MPa

d_1, d_2 = collar depth at location B

E = eccentricity on the railhead

HBW = Brinell hardness number with the test carried out using tungsten carbide ball

HV = Vickers hardness number

I = second moment of area of the rail section, in millimetres to the fourth power

i = number assigned to indicate the test stress level (coded stress level) ($i = 0$ for S_0)

L = test span, in millimetres

m = mean fatigue strength, in megapascals

N = total number of less frequent events

$= \Sigma (n_i)$

n_i = number of less frequent events at the i-th moment level above S_0

P = test load, in newtons

R_f = riser cross-section, in feet

R_N = riser cross-section, in neutral axis

S_0 = lowest stress range at which tests with the less frequent result were conducted, in megapascals

s = standard deviation

W = weld collar width

x_f = minimum width of fusion zone

x_{vhaz} = width of visible heat-affected zone, measured at the running surface

y_{foot} = distance of the extreme fibre in the foot from the neutral axis, in millimetres

σ = outer fibre stress, in megapascals

SECTION 2 FLASH BUTT WELDING

2.1 GENERAL

This Section covers the joining of lengths of rail by flash butt welding. Both permanent installations and portable equipment for use in the field or on the track are covered.

2.2 DESCRIPTION OF THE PROCESS

Flash butt welding is a resistance welding process that produces a weld at the mating surfaces of a butt joint by a flashing action and by the application of pressure after heating is substantially completed. The flashing action, caused by very high current densities at small contact points between the work-pieces, forcibly expels the material from the joint as the work-pieces are slowly moved together. The weld is completed by a rapid upsetting of the work-pieces.

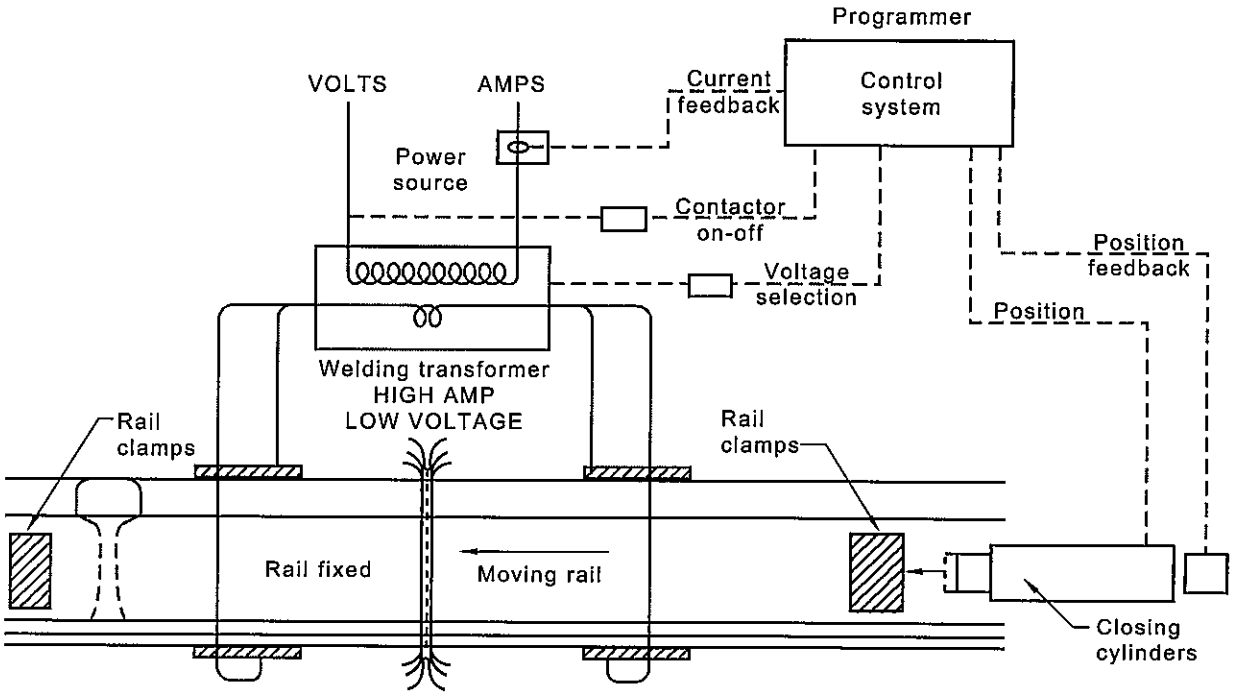


FIGURE 2.1 TYPICAL FLASH BUTT WELDING SET-UP

2.3 QUALIFYING THE WELDING PROCEDURE

A flash butt welding procedure shall be qualified in accordance with Appendix M.

Requalification of a flash butt welding procedure shall be carried out when—

(a) any change in any of the welding parameters (cycle time, duration of flashing, voltage, amps, and similar) exceeds 10%; or

(b) the preheating is changed.

2.4 JOB DOCUMENT

All flash butt welds shall have a job document prepared, which shall include the following:

(a) Description of the work.

(b) A reference to the qualified welding procedure to be used.

(c) An arrangement for the protection of the equipment and the welded rail from adverse weather conditions during the process of welding and subsequent cooling.

(d) Safety procedures (OH&S) and safe working.

(e) Any preparatory tasks needed prior to welding (e.g., permission for access).

2.5 WELDING PROCEDURE

The welding procedure shall include the following:

(a) *Name of the procedure.*

(b) *Welding personnel qualification* Welding shall be performed by personnel qualified to the requirements of Appendix D.

(c) *Rail type* Rail type shall be described (for example, 60 kg head-hardened).

NOTE: Where the welding procedure is for a part worn rail, it should define the degree of wear for which it is applicable.

(d) *Diagrams of the process.*

(e) *List of equipment.*

(f) *Weather conditions* Limits on weather conditions where welding is to be carried out in the open.

(g) *Proximity of boltholes and other welds* The welding procedure shall define the proximity of boltholes and the minimum distance to other flash butt or aluminothermic welds.

(h) *Preparation of the surfaces to be welded* The defined minimum surface finish requirement of the rails to be welded.

(i) *Preparation for electrical contact.*

(j) *Alignment of rails* Rails shall be aligned prior to welding, taking into account cooling and the specified tolerance of the finished weld. Alignment is required both vertically and horizontally.

(k) *Preheating* (if applicable).

(l) *Welding parameters* Welding parameters shall include identification of critical parameters of flash butt welding equipment.

(m) *Post-weld heat treatment* (if applicable).

(n) *Controlled cooling* (if applicable).

NOTE: Cooling of the weld may need to be controlled to achieve the mechanical and microstructural properties.

(o) *Pressing of weld for alignment.*

(p) *Dressing and grinding of welds* After welding, excess metal shall be removed and the running surface finished by grinding. 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.

NOTE: Shearing or grinding may be required on other surfaces such as the underside of the foot or the outer edges of the foot.

(q) *Inspection and testing* Post-weld inspection and testing shall be carried out as given in Clause 2.7.

(r) *Marking and records* Marking and records shall be in accordance with Clause 2.8.

NOTES:

1 The ends of the welded string may be drilled with consideration given to the number and position of holes. Generally, holes are not allowed closer to the end than the position of the second hole in the 6 hole fishplate for that rail.

2 Monitoring of the machine parameters (such as flashing time, current, hydraulic pressure, upset slippage and similar) may assist in control of the quality of the welds.

3 It is recommended that a finished weld be selected from normal production on a regular basis and tested in accordance with Appendix M, to ensure the welds continue to comply with this Standard.

(s) *Qualification to AS 1085.20* Statement that the procedure has been qualified to this Australian Standard.

2.6 MAINTENANCE OF EQUIPMENT

The equipment shall be maintained and calibrated in accordance with a written procedure.

2.7 INSPECTION AND TESTING OF FINISHED WELDS

Inspection and testing of finished welds shall be carried out to ensure the weld satisfies the criteria given in Table 2.1 for weld collar tolerances, surface finish, surface alignment (AT1, AT2 and AT3, as specified) and ultrasonic testing.

TABLE 2.1

INSPECTION OF FINISHED FLASH BUTT WELDS

Test	Test method (Appendix)	Description	Pass criteria		
Visual inspection	E	Visual inspection of all surfaces	No cracks, tears, gouges, shear drag, electrical contact burns, grinding burns		
Surface alignment tolerances		**Tolerance grade***	**Vertical**	**Horizontal**	**Maximum slope angle on top of rail**
	E	AT1	−0.0 mm, +0.3 mm	0.5 mm	7 milliradians†
		AT2	0.5 mm	0.5 mm	Limit to be specified by the user
		AT3	Limit to be specified by the user	Limit to be specified by the user	Limit to be specified by the user
Weld collar tolerances— Deviations from rail profile	E	At rail web and upper side of rail foot	−0 mm, +2 mm		
		Underside of rail foot	−0.0 mm, +1.0 mm		
Ultrasonic test	F	Internal imperfections	Reject level 1		

* The grade is specified for the application. Selection of tolerance level will affect the loads experienced at the weld and thus the expected life of the joint for given track conditions and level of traffic.

† This can be measured using commercially available instruments, i.e., dip weld gauge.

2.8 MARKING AND RECORDS

2.8.1 Marking

Unique markings shall be incorporated onto the rail web of each weld with UV-stabilized paint or indelible ink letters not less than 10 mm high.

2.8.2 Records

A record of the procedure shall be kept, which shall include manufacturer's identification, weld number, date, rail string classification type and post-welding treatments applicable to the weld, the rail number, welding parameters, (e.g., primary welding current, upset force, welding cycle time), inspection and testing.

SECTION 3 ALUMINOTHERMIC WELDING

3.1 GENERAL

This Section covers the joining of lengths of rail by aluminothermic welding. Aluminothermic welding is usually carried out on the track.

3.2 DESCRIPTION OF THE PROCESS

Aluminothermic welding is a process in which an aluminothermic reaction takes place within a crucible (from a chemical reaction between iron oxide and aluminium) and the resultant molten metal flows into a weld joint contained by a mould and the rail ends. The joint is formed by the fusion of the weld metal and the rail.

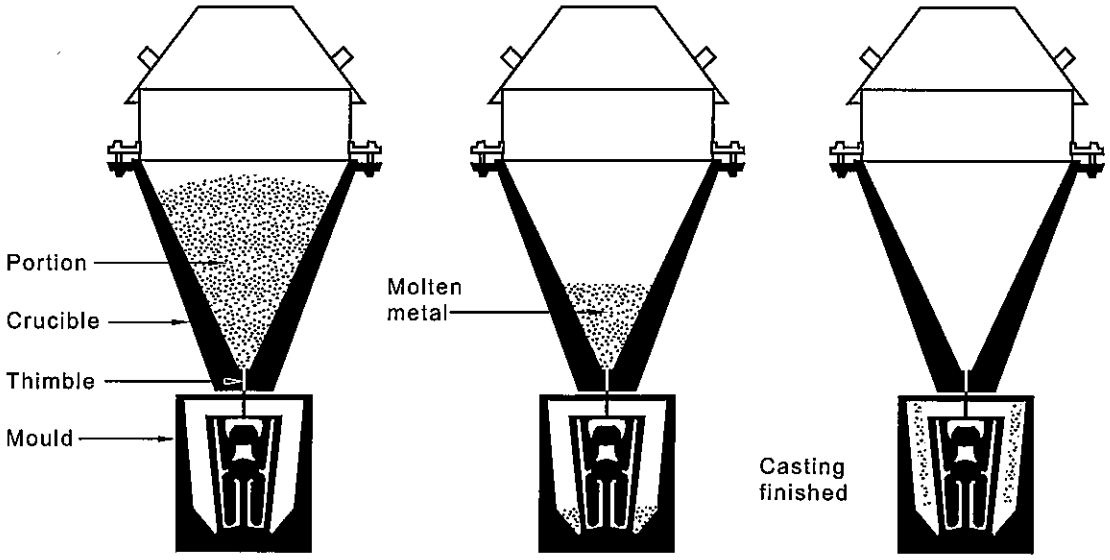


FIGURE 3.1 TYPICAL ALUMINOTHERMIC WELDING PROCESS

3.3 QUALIFYING THE WELDING PROCEDURE

An aluminothermic welding process shall be qualified in accordance with Appendix N.

Requalification of aluminothermic welding shall be carried out when a change in the welding parameters exceeds the range set out in Paragraph N4, Appendix N.

3.4 JOB DOCUMENT

All aluminothermic welds shall have a job document prepared, which shall include the following:

(a) Description of the work.

(b) Selection of the welding process including consideration of the following:

  (i) Type and size of rail.

  (ii) Weld of same profile or junction or step weld.

  (iii) Size of gap.

(iv) Speed of process (quick or slow, that is, short or long pre-heat).

(v) Control of fume (for enclosed spaces).

(vi) Consideration of the impact of the weld on rail adjustment in the area.

(c) A reference to the qualified welding procedure to be used.

(d) An arrangement for the protection of the equipment and the welded rail from adverse weather conditions during the process of welding and subsequent cooling.

(e) Safety procedures (OH&S).

(f) Storage and transport of materials.

(g) Any preparatory tasks needed prior to welding (e.g., permission for access).

(h) Time or temperature at which traffic can be allowed to pass.

(i) Maximum time before inspection and testing is carried out.

3.5 WELDING PROCEDURE

The welding procedure shall include the following:

(a) *Name of the procedure.*

(b) *Welding personnel qualification* Welding shall be performed by personnel qualified to the requirements of Appendix D.

(c) *Rail type.*

(d) *Manufacturer's instructions* The procedure shall include relevant information provided by the manufacturer of the consumables, including diagrams.

(e) *List of equipment.*

(f) *Weather conditions* Limits on weather conditions where welding is to be carried out in the open.

NOTE: Welding should not be performed—

(a) where fire restrictions are in place;

(b) in extreme temperatures;

(c) during high winds; and

(d) heavy rain.

(g) *Proximity of boltholes and other welds* The welding procedure shall define the proximity of boltholes, the distance to other flash butt or aluminothermic welds and, for closure welds, the minimum time between adjacent welds in the same rail.

(h) *Preparation of rails to be welded* Preparation shall include a procedure for the cutting of the rail and a tolerance on the squareness and surface finish of the cut ends.

(i) *Track lifting* Procedure for track lifting and removal of plastic components (e.g., rail pads).

(j) *Alignment of rails* Rails shall be aligned prior to welding, taking into account cooling and the specified tolerance of the finished weld. Alignment is required both vertically and horizontally.

(k) *Preheating.*

(l) *Welding parameters* Welding parameters shall include identification of critical parameters of aluminothermic welding equipment.

(m) *Post-weld heat treatment* (if applicable).

(n) *Mould removal* Process timings from end of reaction to start of mould removal.

(o) *Dressing and grinding of welds* After welding, excess metal shall be removed and the running surface finished by grinding. 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.

(p) *Inspection and testing* Post-weld inspection and testing shall be carried out as given in Clause 3.7.

(q) *Marking and records* Marking and records shall in accordance with Clause 3.8.

(r) *Qualification of AS 1085.20* Statement that the procedure has been qualified to this Australian Standard.

3.6 MAINTENANCE OF EQUIPMENT

The equipment shall be maintained and calibrated in accordance with a written procedure.

3.7 INSPECTION AND TESTING OF FINISHED WELDS

Inspection and testing of finished welds shall be carried out to ensure the weld satisfies the requirements given in Table 3.1 for surface finish, surface alignment (AT1, AT2 and AT3, as specified) and ultrasonic testing.

TABLE 3.1

TEST LIMITS FOR FINISHED ALUMINOTHERMIC WELDING

Test	Test method (Appendix)	Description	Pass criteria		
Surface finish tolerances	E	Visual inspection of all surfaces	Satisfactory external appearance and shape; no gouges, cracks, tears, porosity, weld protrusion, shear drag or evidence of a short head		
Surface alignment tolerances		**Tolerance grade ***	**Vertical**	**Horizontal**	**Maximum slope angle on top of rail**
	E	AT1	−0.0 mm, +0.3 mm	0.5 mm	7 milliradians†
		AT2	0.5 mm	0.5 mm	Limit to be specified by the user
		AT3	Limit to be specified by the user	Limit to be specified by the user	Limit to be specified by the user
Ultrasonic test	F	Internal imperfections	Reject level 3		

* The grade is specified for the application. Selection of tolerance level will affect the loads experienced at the weld and thus the expected life of the joint for given track conditions and level of traffic.

† This can be measured using commercially available instruments, i.e., dip weld gauge.

3.8 MARKING AND RECORDS

3.8.1 Marking

Unique markings shall be incorporated onto the rail web of each weld with UV-stabilized paint or indelible ink letters not less than 10 mm high.

3.8.2 Records

A record of the procedure (weld return) shall be kept, which shall include the weld number, date, location, welding information (e.g., pre heat time, weld gap, tapping time, time to first train), identification of the welder, inspection and testing, consumable manufacturer, process type and batch number.

SECTION 4 ARC WELDING

4.1 GENERAL

This Section covers the weld repair of the head of rails to remove defects or repair head wear such as wheel burns. It is not intended to cover the joining of rails by arc welding.

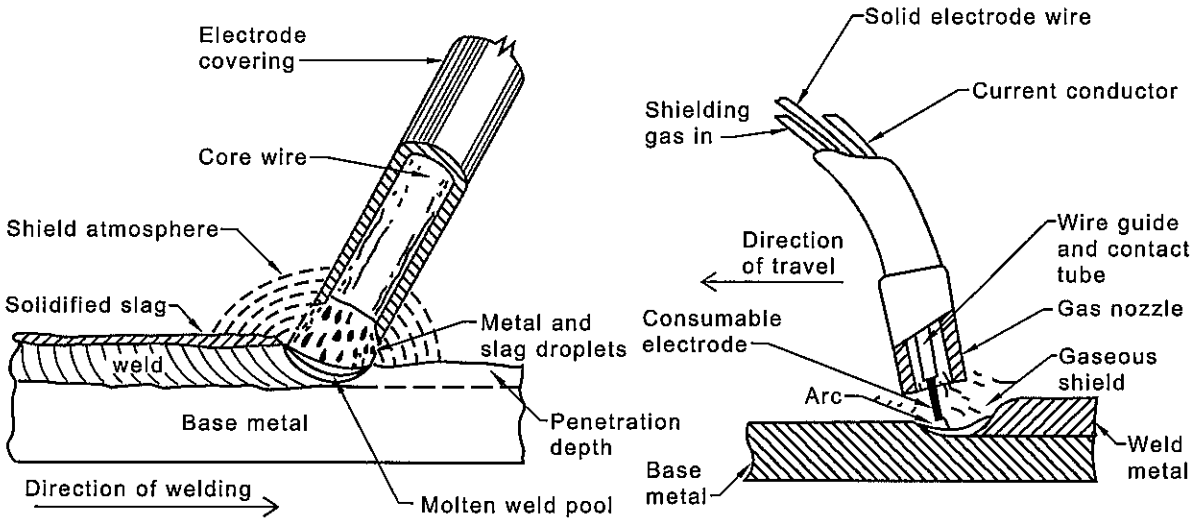
4.2 DESCRIPTIONS OF WELDING METHODS

4.2.1 Manual metal arc welding (MMAW)

Manual metal arc welding is a process of arc welding with a covered electrode manually applied by the welder, without automatic or semi-automatic replacement of the electrode. Shielding is provided only by decomposition of the electrode covering.

4.2.2 Flux-cored arc welding (FCAW)

Flux-cored arc welding is a process that uses a consumable continuous flux cored electrode, which provides the filler metal. Shielding is provided by the flux contained within the electrode. Additional shielding may be obtained from an externally supplied gas or gas mixture.



(a) Manual metal arc welding (b) Gas metal arc welding

FIGURE 4.1 TYPICAL ARC WELDING PROCESSES

4.2.3 Gas metal arc welding (GMAW)

Gas metal arc welding is a process that uses a consumable continuous solid electrode, which provides the filler metal. Shielding is obtained entirely from an externally supplied gas or gas mixture.

4.3 QUALIFYING THE WELDING PROCEDURE

An arc welding process shall be qualified in accordance with Appendix O.

Requalification of an arc welding procedure shall be carried out when a change in the welding parameters exceeds the range set out in Paragraph O4 of Appendix O.

4.4 JOB DOCUMENT

All arc welds shall have a job document prepared, which shall include the following:

(a) Description of the work to include the portion of the rail to be repaired.

(b) A reference to the qualified welding procedure to be used.

(c) An arrangement for the protection of the equipment and the welded rail from adverse weather conditions during the process of welding and subsequent cooling.

(d) Safety procedures (OH&S).

(e) Any preparatory tasks needed prior to welding (e.g., permission for access).

(f) Maximum time before inspection and testing is carried out.

4.5 WELDING PROCEDURE

The welding procedure shall include the following:

(a) *Name of the procedure.*

(b) *Welding personnel qualification* Welding shall be performed by personnel qualified to the requirements of Appendix D.

(c) *Rail type.*

(d) *Manufacturer's instructions* The procedure shall include relevant information provided by the manufacturer of the consumables, including diagrams.

(e) *List of equipment.*

(f) *Weather conditions* Limits on weather conditions where welding is to be carried out in the open.

NOTE: Welding should not be performed—

(a) where fire restrictions are in place;

(b) in extreme temperatures;

(c) during high winds; and

(d) heavy rain.

(g) *Preliminary non-destructive testing* Prior to carrying out any work, testing shall be carried out to check for the presence of cracking or other defects in the rail.

(h) *Grinding* Defects shall be removed by grinding.

NOTE: It is recommended that the maximum build-up be less than 10 mm. If cracking extends beyond 10 mm in depth, then the rail should be replaced rather than repaired.

(i) *Non-destructive testing* Magnetic particle/dye penetrant tests shall be performed to check extent of cracking before and after grinding.

All cracks shall be removed before welding commences.

(j) *Plastic components* A procedure shall be used to remove from the track plastic components that are likely to be affected by the welding (e.g., rail pads).

(k) *Preheating* The preheating temperature shall be 350°C minimum and for head-hardened rails shall be in the range 350°C to a maximum of 450°C. The soaking time shall be sufficient to maintain the rail temperature in the range of 350°C to 450°C during welding. The repair area plus 100 mm to 150 mm on either side of the repair area shall be preheated.

(l) *Welding parameters* Procedures shall define the welding parameters, e.g., amps, volts, travel speed, electrical stickout, and similar, including identification of critical parameters.

(m) *Welding techniques* Weld beads shall be made primarily in the longitudinal direction or in a pattern similar to that shown in Figure 4.2. Arc strike shall not be permitted outside the preheated weld area.

(n) *Interpass temperature* The procedure shall define the minimum rail temperature to maintain throughout the welding of the rail.

(o) *Post-weld heat treatment* (if applicable).

(p) *Dressing and grinding of welds* After welding, excess metal shall be removed and the running surface finished by grinding. 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.

(q) *Inspection and testing* Post-weld inspection and testing shall be carried out as given in Clause 4.7.

(r) *Marking and records* Marking and records shall be in accordance with Clause 4.8.

(s) *Qualification of AS 1085.20* Statement that the procedure has been qualified to this Australian Standard.

4.6 MAINTENANCE OF EQUIPMENT

The equipment shall be maintained and calibrated in accordance with a written procedure.

4.7 INSPECTION AND TESTING OF FINISHED WELD

Inspection and testing of finished welds shall be carried out to ensure the weld satisfies the criteria given in Table 4.1 for surface finish, surface alignment (AT1, AT2 and AT3, as specified).

Finished welds shall be ultrasonically tested.

TABLE 4.1

INSPECTION OF FINISHED ARC WELDS

Test	Test method (Appendix)	Description	Pass criteria		
Visual inspection	E	Visual inspection of all surfaces	No regions of underfill, cracking, inclusions, lack of fusion, gas porosity, slag inclusions, grinding burns and electrical contact burns		
Surface alignment tolerances		**Tolerance grade ***	**Vertical**	**Horizontal**	**Maximum slope angle on top of rail**
	E	AT1	−0.0 mm, +0.3 mm	0.5 mm	7 milliradians†
		AT2	0.5 mm	0.5 mm	Limit to be specified by the user
		AT3	Limit to be specified by the user	Limit to be specified by the user	Limit to be specified by the user
Ultrasonic	F	Internal imperfections	Reject level 4		

* The grade is specified for the application. Selection of tolerance level will affect the loads experienced at the weld and thus the expected life of the joint for given track conditions and level of traffic.

† This can be measured using commercially available instruments, i.e., dip weld gauge.

4.8 MARKING AND RECORDS

4.8.1 Marking

Unique markings shall be incorporated onto the rail web of each weld with UV stabilized paint or indelible ink letters not less than 10 mm high.

4.8.2 Records

A record of the procedure (weld return) shall be kept, which shall include the weld number, date, location, welding information, identification of the welder, inspection and testing, consumable manufacturer and process type.

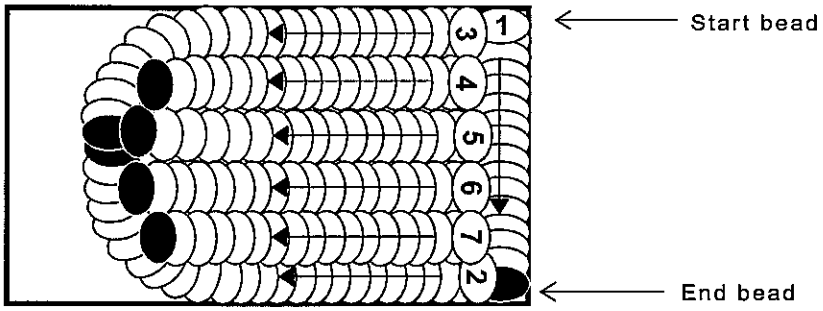


FIGURE 4.2 TYPICAL PATTERN OF WELD REPAIR OF RAIL END

APPENDIX A

COMMENTARY ON THE STANDARD

(Informative)

A1 GENERAL

The aim of this Standard is to ensure that rail welds perform as follows:

(a) The properties and durability of finished weld and the heat-affected zone match as close as possible those of the parent rail.

(b) Welds do not introduce weaknesses into the rail that reduce the properties of the rail below acceptable limits (that is, the finished weld and the heat-affected zone to have the required properties).

(c) Provide a continuous running surface on the rail.

(d) Welds do not introduce bulges, dips or angles into the running surface.

The Standard is intended to be used by owners and maintainers of railway track to give confidence that welds carried out are of a given quality. The provision of tests and pass criteria will assist in setting up new processes and in training staff.

A2 INFORMATION ON METHODS NOT COVERED BY THIS STANDARD

This Standard is not intended to preclude the use of any welding processes, new materials, or consumables, which do not comply with the specific requirements of this Standard or are not mentioned in it.

Qualification should be on a similar basis and to an equivalent level of confidence as given for the methods covered in this Standard.

A2.1 Changes from AS 1085.15—1995

The focus of AS 1085.15—1995 (the previous edition of this Standard) was on the manufacture of consumables for aluminothermic welding. This Edition (2006) covers other types of welding and introduces a process for qualification that depends on achieving performance represented by specific test criteria. Many of the tests are similar to those given in AS 1085.15—1995.

The requirements for flash butt and electric arc welding are new material.

Changes to the 1995 edition are as follows:

(a) New requirements introduced for flash butt welding.

(b) New requirements introduced for welding repairs of the railhead (arc welding).

(c) The procedure for performing the weld is to be defined in a welding procedure.

(d) A job document is required to be prepared and to describe all aspects of the work to be done (information is provided on the items to be included).

(e) Each welding method has to be qualified for use with particular rails through a series of tests of welds. Type testing of consumables for aluminothermic welding has been replaced by qualification testing.

(f) Test limits are set for the acceptance of finished welds.

(g) Information is provided on the qualification of welders.

(h) All aspects of quality control of production of consumables for aluminothermic welding have been deleted (including batch testing).

(i) A staircase test has been introduced for assessing fatigue performance.

(j) The minimum elastic response limit has been removed from the slow bend test.

(k) Where appropriate, methods of testing have been aligned with European methods.

A3 ALUMINOTHERMIC WELDING—DESIGNATION OF WELD TYPES

The following designations should be used to identify particular aluminothermic weld types:

(a) *SGW* Standard gap weld with an initial rail gap up to and including 40 mm. It may be supplied with or without reinforcement under rail foot, e.g., crane rail.

(b) *WGW* Wide gap weld with an initial rail gap greater than 40 mm.

(c) *SJW* Standard junction weld used to weld dissimilar rail sections using an initial rail gap of up to and including 40 mm.

(d) *LPH* Long preheat process requiring a preheat temperature of 900°C to 1000°C at the rail ends prior to welding.

(e) *SPH* Short preheat process requiring a preheat temperature of 600°C to 700°C at the rail ends prior to welding.

A4 ALUMINOTHERMIC WELDING—QUALITY CONTROL OF PRODUCTION OF CONSUMABLES

The production of consumables for aluminothermic welding may be monitored using tests appropriate for the purpose. The tests to be carried out, the sampling methods and frequency of testing and retesting should be specified, as appropriate for the situation and as agreed by the purchaser and supplier (e.g., by setting acceptable quality levels).

NOTE: For guidance on demonstrating compliance, see Appendix C.

As guidance, the previous edition of this Standard identified the following tests for proof testing:

(a) Visual inspection.

(b) Weld metal hardness test (see Appendix G).

(c) Chemical analysis (see Appendix J).

(d) Slow bend test (see Appendix K).

Other tests, such as ultrasonic testing, may be used.

APPENDIX B

INFORMATION TO BE SUPPLIED WHEN SPECIFYING WELDING FOR STEEL RAIL

(Informative)

B1 FLASH BUTT WELDING

The following information should be supplied when ordering or specifying:

(a) The rail profiles and grades to be welded.

(b) Alignment tolerance grade.

(c) Any additional requirements for shearing or grinding of the finished weld.

(d) Any requirements for drilling of ends of welded strings.

(e) Any special requirements for marking or provision of records.

B2 ALUMINOTHERMIC WELDING

The following information should be supplied when ordering or specifying:

(a) The rail profiles and grades to be welded.

(b) Any additional requirements for shearing or grinding of the finished weld.

(c) Which of the three width levels of visible heat-affected zone is required (see Table N3, Appendix N).

(d) Which of the three width levels of heat-softened zone is required (see Table N3, Appendix N).

(e) Where different to Table N3, Appendix N, the fatigue requirement in terms of the mean and of the standard deviation of the fatigue strength.

(f) Whether the fatigue test for web of welded section is required.

B3 ELECTRIC ARC WELDING

The following information should be supplied when ordering or specifying:

(a) The rail profiles and grades to be welded.

(b) Type of welding to be used.

APPENDIX C

MEANS FOR DEMONSTRATING COMPLIANCE WITH THIS STANDARD

(Informative)

C1 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.

C2 STATISTICAL SAMPLING

Statistical sampling is a procedure that 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 needs to be drawn randomly from a population of product of known history. The history needs to 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 needs to be defined. A sampling plan for one manufacturer of given capability and product throughput may 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 needs to demonstrate how the above conditions have been satisfied. Sampling and the establishment of a sampling plan should be carried out in accordance with AS 1199.1, guidance to which is given in AS 1199.0.

C3 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.

C4 SUPPLIER'S 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 may 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.

C5 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 D

QUALIFICATION OF PERSONNEL

(Normative)

D1 GENERAL

Welding shall be performed, supervised and inspected by suitably qualified personnel. Such qualification shall include appropriate experience in welding of steel rails.

Evidence of the qualification of welding personnel shall be available on site. Records shall include the particulars of any tests passed during qualification.

D2 WELDERS

Welders shall be qualified to perform the welding procedures on which they will be employed. Qualification shall be based upon the following:

(a) *For flash butt welding* Welders shall be given training in the welding procedures and shall make the required test welds as specified in Paragraph D3.

(b) *For aluminothermic welding* Welders shall be given training in the welding procedures and shall make the required tests welds as specified in Paragraph D3.

(c) *For metal arc welding* Qualifications obtained by welders under appropriate Standards laying down welder qualification tests are acceptable as evidence of their ability. Such evidence should refer to welding carried out in positions as close as practicable to the actual positions to be used on the job as specified in Paragraph D3.

A welder already qualified shall be required to requalify as follows:

(i) *For flash butt welding* Every 2 years or where less than 500 welds are performed within a 12 month period.

(ii) *For aluminothermic welding* Every 2 years or where less than 50 welds are performed within a 12 month period.

(iii) *For metal arc welding* Every 2 years or where less than 20 welds are performed within a 12 month period.

D3 QUALIFICATION TESTING OF WELDERS

A welder not already qualified or needing requalification should be required to demonstrate an ability to comply with the appropriate requirements of this Standard by performing the specified weld under observation to confirm compliance with the welding procedure and by testing of the weld as follows:

(a) *For flash butt welding*.....Appendices E and F.

(b) *For aluminothermic welding*.....Appendices E and F.

(c) *For metal arc welding* ..... Appendices E, F, and Paragraphs G1 and G4, Appendix G.

NOTE: Where welds do not comply with this Standard, further training, followed by repeated testing, should be carried out until the tests are passed.

APPENDIX E

VISUAL INSPECTION AND ALIGNMENT

(Normative)

E1 VISUAL INSPECTION

Following completion of the weld and final grinding, the entire weld shall be inspected including the ground weld surface, the heat-affected zone on either side of the weld and the as-cast weld surface (where applicable).

Identify, record and report evidence (including size and position) of the following:

(a) Cracks.

(b) Tears.

(c) Gouges.

(d) Gas porosity.

(e) Shrinkage porosity.

(f) Slag or sand inclusions.

(g) Underfill.

(h) Weld shape and contour.

(i) Fins.

(j) Electrode burns.

(k) Grinding burns.

(l) Hammer marks.

Measure the slope angle of any dips on the top of the head using a gauge designed for the purpose.

E2 JOINT GEOMETRY TEST

E2.1 Surface alignment

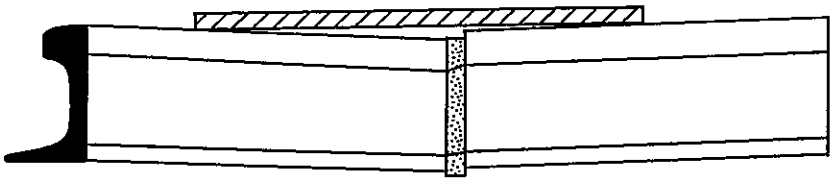
Weld straightness shall be measured by a procedure that is not less accurate than that of placing a 1 m hardened straightedge of Grade B in accordance with AS 1003 across the weld (see Figures E1 to E5).

Measure the maximum deviation of the rail from the straightedge both upwards and sideways in millimetres and report as a gap.

NOTE: A 1 m Grade B straightedge has a flatness tolerance of 20 μm (see AS 1003).

Alternatively, a modified straightedge, having lugs on each end as shown in Figure E6, may be used.

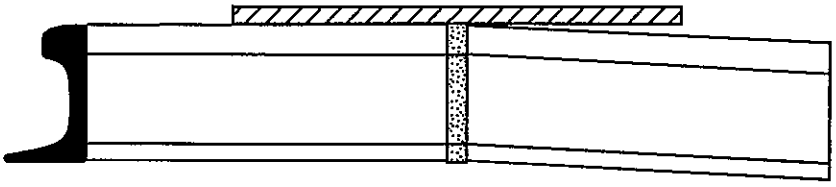
For aluminothermic welding, the lateral measurement shall be made on the gauge side of the rail.



The recorded value for the dip is the measured gap

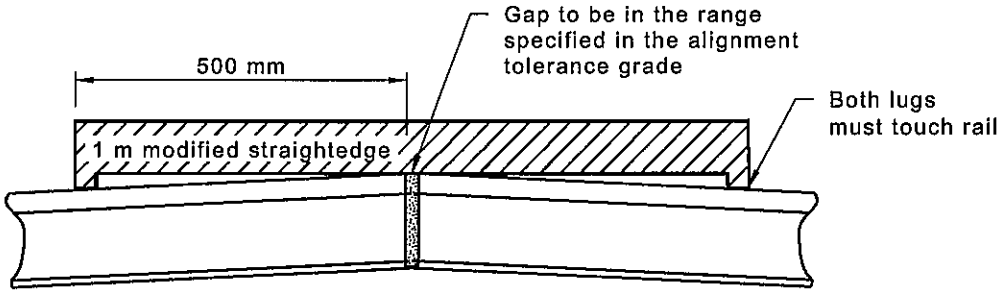
NOTE: For surface alignment tolerance grade AT1 this will be 0 mm.

FIGURE E1 JOINT GEOMETRY—SURFACE ALIGNMENT METHOD—VERTICAL (DIP)



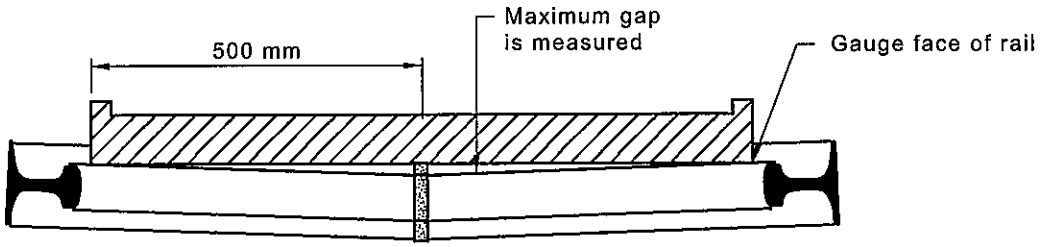
The recorded value for the peak is half the measured gap

FIGURE E2 JOINT GEOMETRY—SURFACE ALIGNMENT METHOD—VERTICAL (PEAK)



Alternative method using modified straightedge. Both lugs must touch the rail, and the gap is to be in the range for the specified alignment tolerance grade (see Tables 2.1, 3.1 and 4.1)

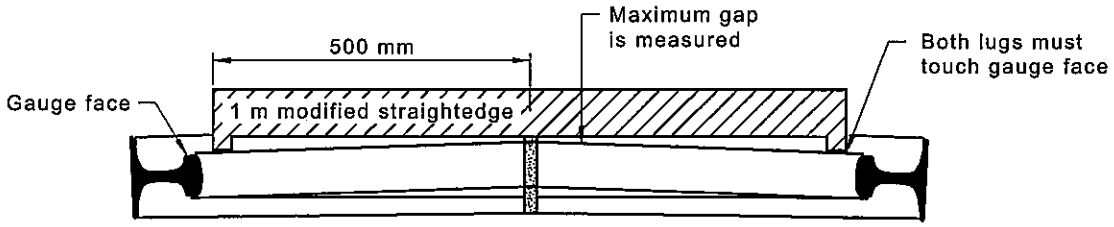
FIGURE E3 JOINT GEOMETRY—SURFACE ALIGNMENT METHOD—VERTICAL (PEAK)—ALTERNATIVE



The recorded value is the measured gap

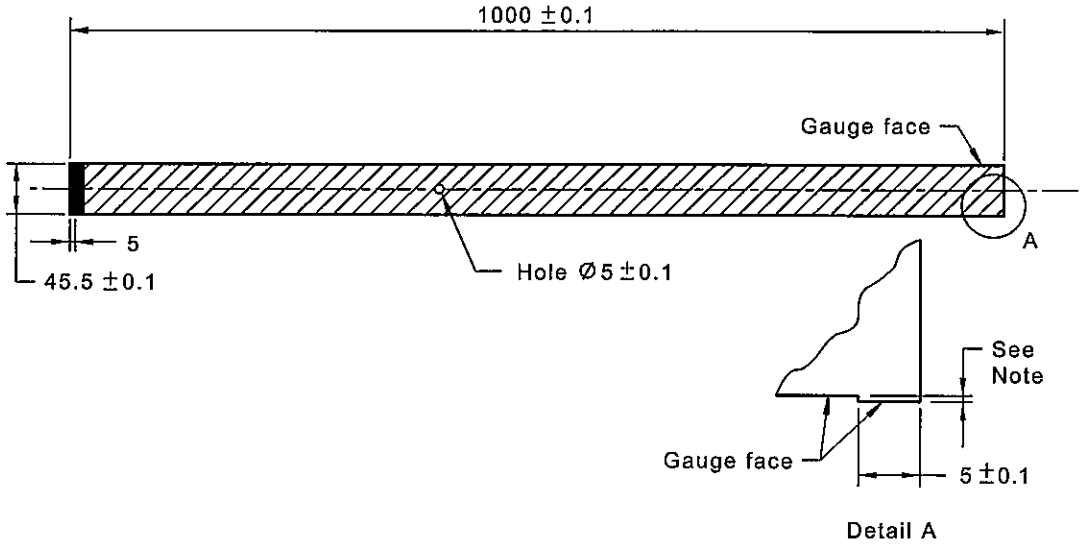
NOTE: For curved track the gap is not covered in the Standard.

FIGURE E4 JOINT GEOMETRY—SURFACE ALIGNMENT METHOD—LATERAL (FOR STRAIGHT TRACK)



Alternative method using modified straightedge. Both lugs must touch the rail face and the gap must be between 0 mm and 0.5 mm

FIGURE E5 JOINT GEOMETRY—SURFACE ALIGNMENT METHOD—LATERAL (FOR STRAIGHT TRACK)—ALTERNATIVE



NOTE: A separate modified straightedge is required for each surface alignment tolerance grade (see Tables 2.1, 3.1 and 4.1). The size of the lug is 0.3 mm, 0.5 mm, or as defined by the user.

DIMENSION IN MILLIMETRES

FIGURE E6 MODIFIED STRAIGHTEDGE

E2.2 Surface slope

After grinding is completed, the top and sides of the railhead shall be checked to ensure it is smooth with no steps. The maximum slope of the top of the rail shall be checked for a distance of 500 mm either side of the weld. Individual measurements shall be taken over a distance not greater than 50 mm. The maximum slope on both sides shall be recorded in milliradians.

NOTES:

1 This test is a requirement for welds made to Tolerance Grade AT1 in Tables 2.2, 3.1 and 4.1.

2 This test may be performed using commercially available instruments, e.g., a dip weld gauge (P2 gauge) or an electronic straightedge.

E3 WELD COLLAR TEST

The outstand of metal at the collar shall be tested using a gauge designed for the purpose. The rail web, upper side of the rail foot and the underside of the rail foot shall be inspected.

NOTE: The weld collar test is for flash butt weld only.

E4 SIZE OF IMPERFECTIONS

The maximum dimension of any pores, slag inclusions, sand inclusions or metal beads shall be measured as follows and the number for the head, web and foot recorded:

(a) Group in size bands:

(i) 1 ..... (>0 mm to 1 mm).

(ii) 2 ..... (>1 mm to 2 mm).

(iii) 3 ..... (>2 mm to 3 mm).

(b) Where multiple imperfections are revealed, they shall be counted and measured as a single imperfection if they are less than 1 mm apart. Areas containing micro-porosity or inter-dendritic shrinkage are not counted as single imperfections and therefore reported separately.

NOTE: For qualification, the number of welds to be examined is specified in Appendix N as the sum of those in which imperfections are detected using ultrasonic testing, slow bend test and fatigue test.

APPENDIX F

ULTRASONIC TESTING

(Normative)

F1 SCOPE

This Appendix specifies the method for ultrasonic testing of welds for the qualification of a welding procedure and for the routine (field) ultrasonic testing of new flash butt, aluminothermic and arc welds.

F2 TESTING FOR QUALIFICATION

F2.1 General

The head, web and foot of the rail containing the weld (see Figure F1) shall be examined ultrasonically in accordance with Paragraph F4. The positions of any apparent imperfections found by ultrasonic testing shall be reported. The size of each imperfection shall be reported in accordance with Paragraph F4.

F2.2 Test required for each weld process

The tests that are required for the weld process are set out in Table F1.

TABLE F1

TEST REQUIRED FOR EACH WELD PROCESS

Test methods	Flash butt	Aluminothermic	Arc welding
F4.2	Yes	Yes	Yes
F4.3	Yes	Yes	Yes
F4.4	Yes	Yes	Yes
F4.5	Yes	Yes	No
F4.6	Optional	Optional	No

F2.3 Report

The following shall be reported:

(a) Date of testing and name of testing facility.

(b) Identification of the samples.

(c) Size and position of any imperfections found.

(d) Reference to the test method, (i.e., AS 1085.20, Appendix F).

F3 ROUTINE TESTING OF FINISHED WELDS

F3.1 General

The head, web and foot of the rail containing the weld (see Figure F1) shall be examined ultrasonically in accordance with Paragraph F3.2. For electric arc weld repairs, the head only may be tested. The size and positions of any apparent imperfections found by ultrasonic testing, including any lack of fusion, cracks, cold shut, porosity, inclusion or shrinkage shall be recorded and reported.

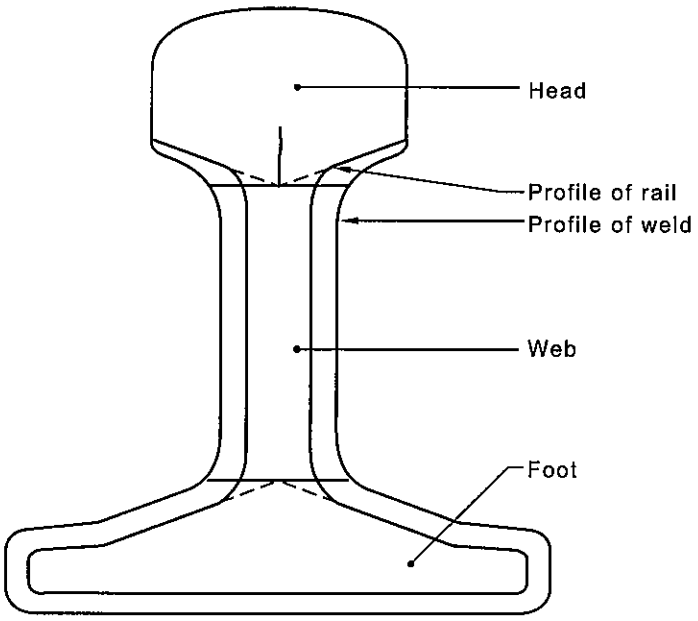


FIGURE F1 HEAD, WEB AND FOOT OF THE RAIL

F3.2 Details for routine testing of finished welds

After completion and grinding of the weld, ultrasonic testing shall be carried out in accordance with AS 2207. Required tests are set out in Table F1.

Testing is normally carried out from the top of the rail. Probes are directed at a number of different angles in order to test for defects, in particular positions and orientations.

Care should be taken when changing from one height rail to another, as it will be necessary to recalibrate the instrument. Recalibration avoids the possibility of indications appearing on the screen, which, due to their positions, may be wrongly identified as imperfections.

F3.3 Measurement of size

If required, the maximum dimension of any pores, slag inclusions, sand inclusions or metal beads that are revealed may be measured and recorded in accordance with Paragraph E4 of Appendix E.

F3.4 Report

The following shall be reported:

(a) Date of testing and name of testing facility.

(b) Identification of the welds tested.

(c) Whether internal imperfections have been found and their type.

(d) If required, position and size of any imperfections found.

(e) Statement that the weld complies or fails to comply with the appropriate reject level requirements for each of the tests.

(f) Reject level used.

(g) Reference to the test method (i.e., AS 1085.20, Appendix F).

F4 TEST METHOD

F4.1 General

This Paragraph sets out the test methods for ultrasonic testing of total rail and cut samples, (see Table F2).

The test methods use a reject level based on the extent of probe movement whenever there is a signal exceeding the criteria set up during calibration. The reject levels are as follows:

(a) *Reject level 1* Used for the qualification and routine (field) testing of flash butt welds.

(b) *Reject level 2* Used for the qualification of aluminothermic welds.

(c) *Reject level 3* Used for the routine (field) testing of aluminothermic welds.

(d) *Reject level 4* Used for the qualification and routine (field) testing of arc welds.

F4.2 Horizontal imperfections (0° probe)

To ensure that the rail adjacent to the weld is free from horizontal defects, which could interfere with further testing, the weld surrounds shall be tested as follows:

(a) *Probe* One twin-crystal 0° longitudinal wave of frequency 2 MHz or 4 MHz.

(b) *Probe position* The running surface of the rail.

(c) *Extent of test zone* On each side of the weld for a distance of 2 × the rail height.

(d) *Time base* 200 mm.

(e) *Scanning sensitivity* Grass set to 10% to 20% full screen height.

(f) *Sizing method* AS 2207, last significant echo technique.

(g) *Reject levels 1 to 4* Any defect showing greater than 15 mm probe movement.

NOTE: If the rail fails this test, then the weld cannot be adequately tested and such a weld should be rejected.

F4.3 Head zone test (70° probe)

The weld shall be tested as follows:

(a) *Probe* One single-crystal 70° transverse wave of frequency 2 MHz. For testing arc-welded head repairs, a twin crystal 70° transverse wave probe of 4 MHz frequency shall be used.

(b) *Probe position* The running surface of the rail.

(c) *Time base* 100 mm.

(d) *Scanning sensitivity* Grass set to 10% to 20% full screen height.

(e) *Sizing method* AS 2207, last significant echo technique.

(f) *Reject level 1* Maximum 5 mm longitudinal movement.

(g) *Reject level 2* Maximum 15 mm longitudinal movement.

(h) *Reject level 3* Half head width or 40 mm longitudinal movement.

(i) *Reject level 4* Maximum 20 mm of probe movement in any direction.

F4.4 Head zone test (0° probe)

The weld shall be tested as follows:

(a) *Probe* One twin-crystal 0° longitudinal wave of frequency 2 MHz or 4 MHz.

(b) *Probe position* The running surface of the rail.

(c) *Time base* 200 mm.

(d) *Scanning sensitivity* Grass set to 10% to 20% full screen height.

(e) *Sizing method* AS 2207, last significant echo technique.

(f) *Reject level 1* N/A.

(g) *Reject level 2* Maximum 20 mm of probe movement in any direction.

(h) *Reject level 3* Maximum 15 mm of probe movement.

(i) *Reject level 4* Maximum 20 mm of probe movement in any direction.

F4.5 Web test (38° probe)

The weld shall be tested as follows:

(a) *Probe* One single-crystal 38° transverse wave of frequency 2 MHz.

(b) *Probe position* The running surface of the rail.

(c) *Time base* 250 mm.

(d) *Scanning sensitivity* Grass set to 10% to 20% full screen height.

(e) *Sizing method* AS 2207, last significant echo technique.

(f) *Reject level 1* Maximum 5 mm longitudinal movement.

(g) *Reject level 2* Maximum 5 mm longitudinal movement.

(h) *Reject level 3* Maximum 25 mm longitudinal movement.

F4.6 Foot test (70° probe)

The weld shall be tested as follows:

(a) *Probe* One twin-crystal 70° transverse wave of frequency 4 MHz.

(b) *Probe position* Upper surface of foot.

(c) *Time base* 100 mm.

(d) *Scanning sensitivity* Grass set to 10% to 20% full screen height.

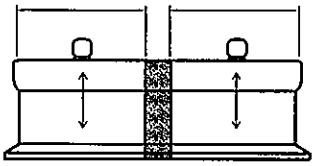
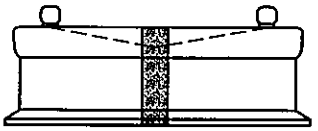
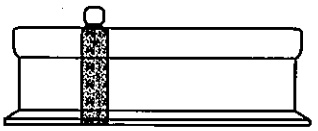
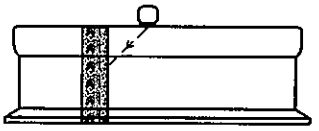
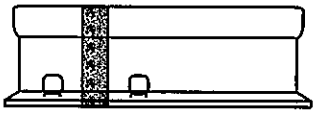
(e) *Sizing method* AS 2207, last significant echo technique.

(f) *Reject level 1* Maximum 5 mm of movement.

(g) *Reject level 2* Maximum 5 mm of movement.

(h) *Reject level 3* Maximum 15 mm of movement in the horizontal direction.

TABLE F2
POSITIONING OF CRYSTALS

Summary of tests			
Test paragraph		Description	Illustration
F4.2	Plain rail	One 0° twin-crystal probe	
F4.3	Test of head for non-planar imperfections	One 70° single-crystal probe from both sides	
F4.4	Test of head for non-planar imperfections	One 0° twin-crystal probe	
F4.5	Test of web for planar imperfections	One 38° single-crystal probe	
F4.6	Test of foot	One 70° single-crystal probe from both sides	

APPENDIX G
HARDNESS TESTS
(Normative)

G1 SCOPE

This Appendix sets out the method for hardness testing of welds.

G2 WELD METAL HARDNESS FOR ALUMINOTHERMIC WELDING

G2.1 General

Brinell hardness tests shall be carried out in accordance with AS 1816, using a 10 mm diameter tungsten carbide ball at 3000 kg load.

Impressions shall be made on a flat surface that is tangential to the rail crown at the point of intersection with the rail vertical axis in accordance with Figure G1 with a spacing (Y) of 15 mm.

Three hardness values shall be determined for each weld.

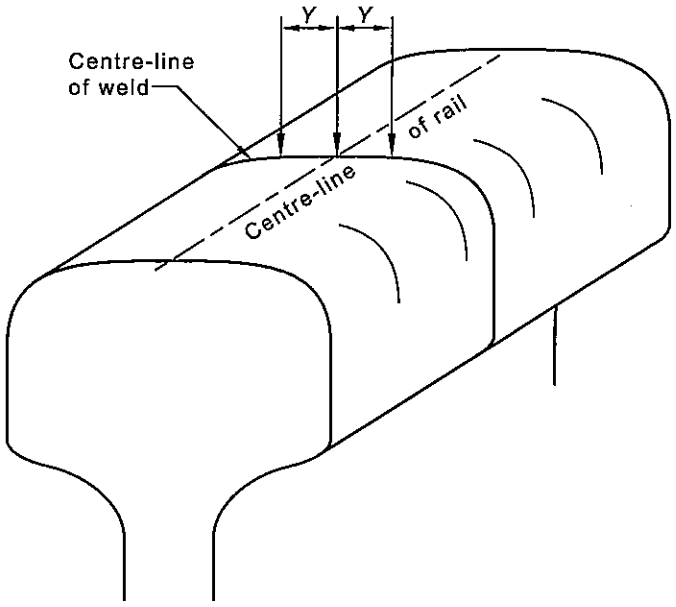


FIGURE G1 LOCATION OF EXTERNAL HARDNESS TESTS

G2.2 Report

The following shall be reported:

(a) Date of testing and name of testing facility.

(b) Identification of the samples.

(c) All test values and the average Brinell hardness (BH).

(d) Reference to this test method (i.e., AS 1085.20, Paragraph G2, Appendix G).

G3 HARDNESS TRAVERSE FOR FLASH BUTT AND ALUMINOTHERMIC WELDS

G3.1 Principle

The purpose of the test is to provide an indication of the width of the softened zone, the minimum hardness in the heat-affected zone and any off-centre softening.

G3.2 Procedure

The procedure shall be as follows:

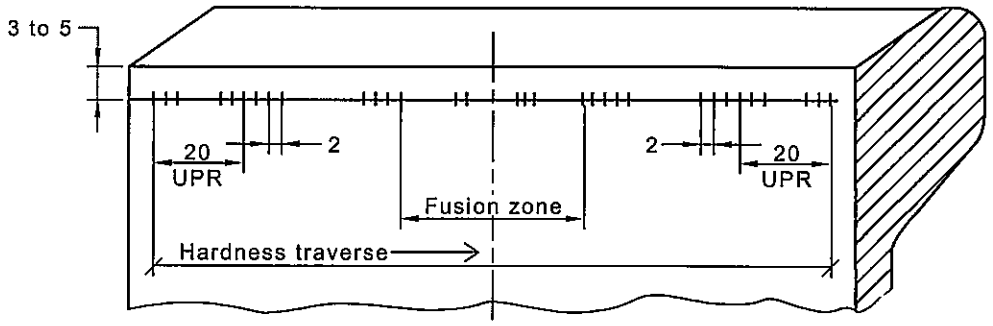
(a) Section the weld longitudinally along the centre-line of the welded rail so as to include all the heat-affected zone on both sides of the weld for at least 20 mm (see Figure G2).

(b) Perform a hardness traverse using the Vickers hardness test method in accordance with AS 2205.6.1.

(c) Run each traverse across the entire weld region including the parent rails, heat-affected zones and fusion zone, continuing until 20 mm of parent rail hardness has been encountered. Measure spacing of 2 mm, as illustrated in Figure G2.

(d) Measure the hardness distribution of the heat-softened zone using the Vickers hardness test in accordance with AS 1817.1 using a load of 30 kg.

(e) Make impressions on a line between 3 mm and 5 mm below the rail running surface on the longitudinal axis of the rail.



UPR = Unaffected parent rail

NOTE: For flash butt welds, the fusion zone appears as a single line.

DIMENSIONS IN MILLIMETRES

FIGURE G2 LONGITUDINAL HARDNESS TEST LOCATION

(f) Record the hardness measurements on a graph (see the typical graphs shown in Figures G3 and G4).

(g) Take a minimum of 10 hardness measurements, at intervals of 2 mm, in the unaffected parent rail on both sides of the weld.

(h) Calculate the mean hardness of the parent rail and draw a line equal to the mean hardness on the hardness graph as shown (Line 1 in Figure G4).

(i) Mark the measurement hardness line (Line 2 in Figure G4) at a distance of X hardness points below the mean hardness line.

(j) The value of X varies with the rail grade as follows:

(i) $X = 10$ HV for as-rolled rail.

(ii) $X = 25$ HV for head-hardened rail.

(k) Determine the heat-softened zone width as the distance between points A and B (as shown in Figure G4).

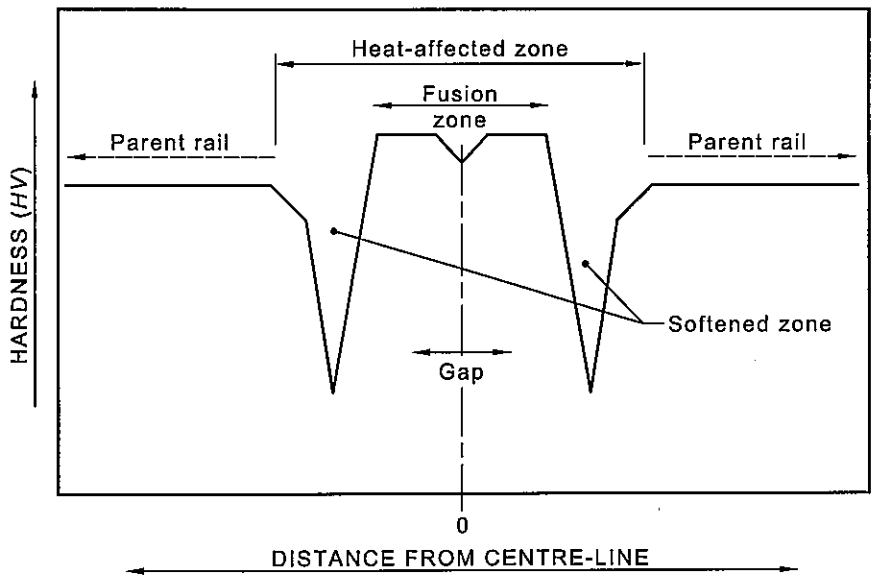


FIGURE G3 SCHEMATIC OF VARIATION OF HARDNESS FOR LONGITUDINAL TRAVERSE

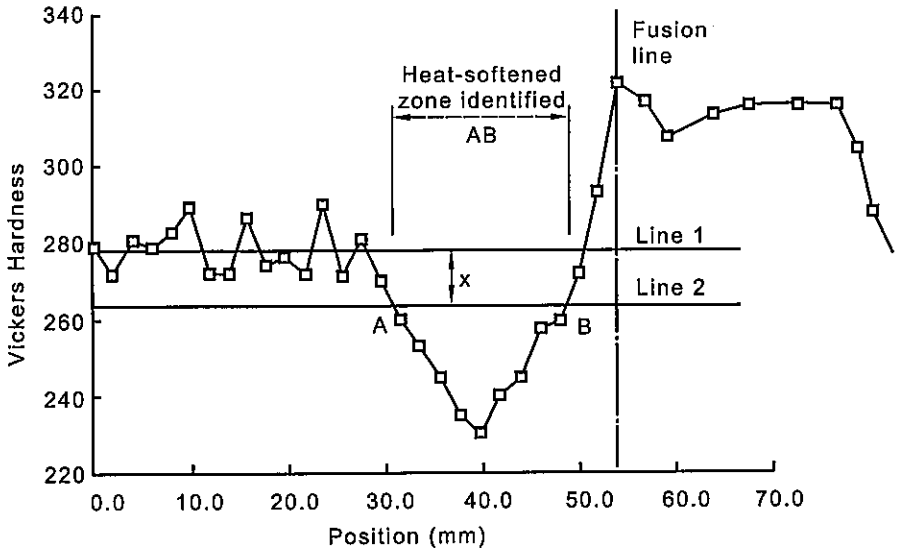


FIGURE G4 TYPICAL HARDNESS PROFILE

G3.3 Parent rail hardness variation

In some cases, the unaffected parent rail may have a large standard deviation of hardness about the mean, which may cause individual points within the unaffected rail to be below the measurement hardness line (Line 2). For the purposes of heat-softened zone width measurement, individual points lying below the measurement hardness line may be ignored where the following apply:

(a) No more than one hardness point of those used to define the parent rail mean hardness lies below Line 2.

(b) The hardness point lying below Line 2 is more than 4 mm from Point A of Figure G4.

G3.4 Report

The following shall be reported:

(a) Date of testing and name of testing facility.

(b) Identification of the samples.

(c) Hardness results and graph.

(d) The width of the heat-softened zone.

(e) Reference to this test method, (i.e., AS 1085.20, Paragraph G3, Appendix G).

G4 HARDNESS TRAVERSE FOR ARC WELDS

G4.1 Principle

Vickers hardness tests are carried out in accordance with AS 1817.1 using a 30 kg load. Impressions are made on a section across the rail and weld in three vertical traverses down from the top of the weld. The maximum hardness value is determined for each weld.

G4.2 Procedure

The procedure shall be as follows:

(a) Section the weld transversely across the rail and weld (see Figure G5).

(b) Establish the unaffected parent rail hardness by testing well down the head.

(c) Perform the hardness traverses using the Vickers Hardness test method, in accordance with AS 2205.6.1.

(d) Run each traverse vertically down from the top of the weld until three consecutive measurements indicate the traverse has reached the unaffected parent rail (see Figure G5). Measure spacings at 2 mm.

(e) Perform three traverses at the following positions (see Figure G5):

  (i) Down from the centre of the top surface of the rail.

  (ii) On each side of the railhead, down from points 10 mm in from the outside edges of the railhead.

(f) Record the hardness values at each measurement.

(g) Determine the extent of the heat-affected zone and the weld metal, as shown in Figure G6.

NOTE: Where doubt occurs as to the start of the unaffected parent metal, a similar approach may be used as given in Paragraph F2.

G4.3 Report

The following shall be reported:

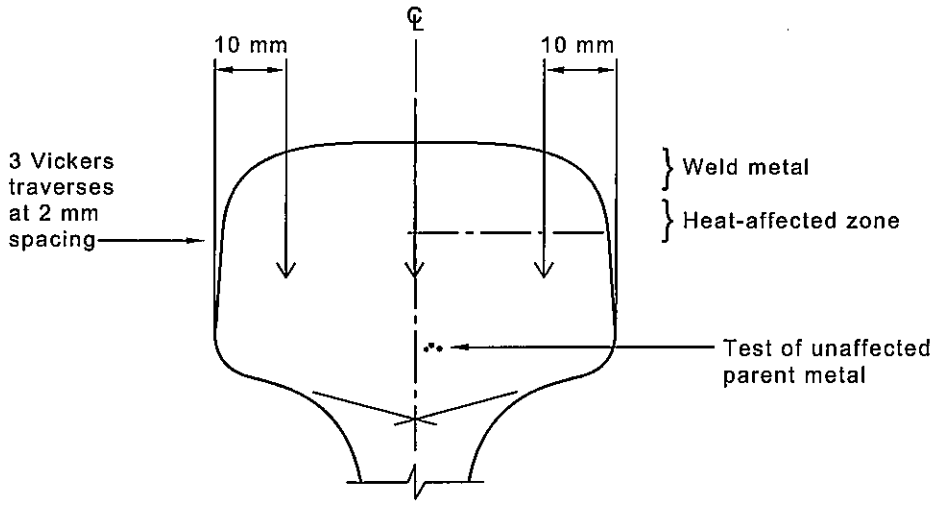
(a) Date of testing and name of testing facility.

(b) Identification of the sample.

(c) Hardness results, graph and maximum hardness (HV) of the heat-affected zone.

(d) Range of hardness (HV) in the weld metal.

(e) Reference to this test method, (i.e., AS 1085.20, Paragraph G4, Appendix G).



Vickers traverses at 2 mm spacings until 3 values indicate unaffected parent metal

FIGURE G5 HARDNESS TRAVERSE DOWN FROM TOP

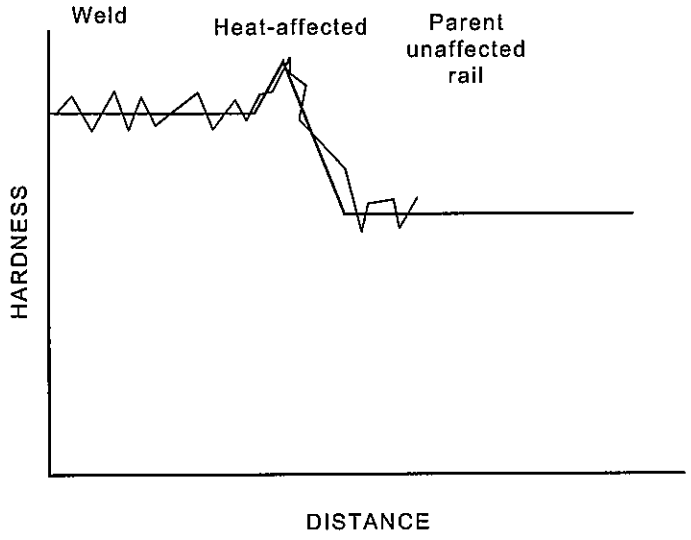


FIGURE G6 TYPICAL HARDNESS PROFILE

APPENDIX H
MACROSCOPIC TESTS
(Normative)

H1 SCOPE

This Appendix sets out the method for macroscopically testing welds.

H2 FUSION ZONE—SHAPE AND DIMENSION

H2.1 Procedure

The procedure shall be as follows:

(a) Section the weld longitudinally along the centre-line of the welded rail so as to include all the heat-affected zone on both sides of the weld for at least 20 mm (see Figure H1).

(b) Perform a macroscopic test (by etching) in accordance with AS 2205.5.1.

H2.2 Records

The following shall be recorded:

(a) The symmetry of the shape of the fusion zone.

(b) For flash butt welding, the symmetry and straightness of the bond line.

(c) The dimension x_f.

NOTES:

1 Measurement of x may be made using datum lines marked on each rail prior to welding.

2 For flash butt welding, the fusion zone is regarded as a line (bond line) and x is not measured.

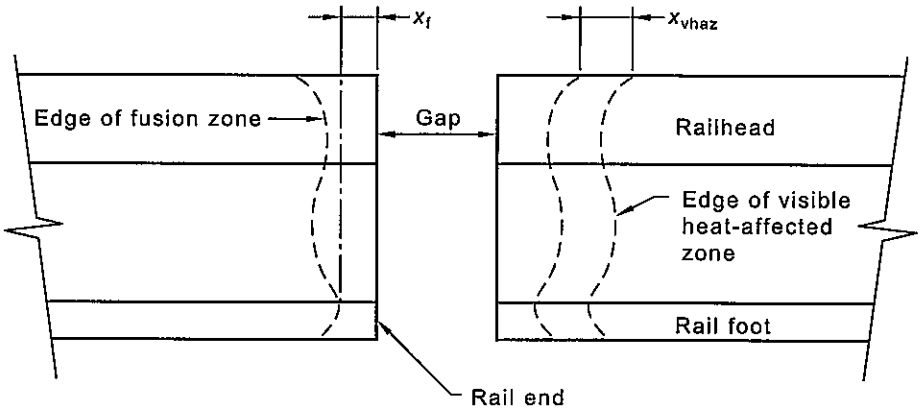


FIGURE H1 SHAPE OF FUSION ZONE

H2.3 Report

The following shall be reported:

(a) Date of testing and name of testing facility.

(b) Identification of the samples.

(c) Any lack of symmetry of the fusion zone.

(d) The minimum width of the fusion zone (x_f).

(e) Lack of fusion.

(f) Presence of slag inclusions, porosity.

(g) Reference to this test method (i.e., AS 1085.20, Paragraph H2, Appendix H).

H3 VISIBLE HEAT-AFFECTED ZONE—RUNNING SURFACE

H3.1 Procedure

The procedure shall be as follows:

(a) Prepare the running surface of the rail for a macroscopic test and perform the test (including etching) in accordance with AS 2205.5.1.

(b) Measure the width of the visible heat-affected zone (see Figure H1) on the rail running surface centre-line.

H3.2 Report

The following shall be reported:

(a) Date of testing and name of testing facility.

(b) Identification of the samples.

(c) Width of the visible heat-affected zone (x_{vhaz}).

(d) Reference to this test method, (i.e., AS 1085.20, Paragraph H3, Appendix H).

APPENDIX I

MICROSCOPIC TESTS

(Normative)

I1 SCOPE

This Appendix sets out the method for microscopically testing welds.

I2 PROCEDURE

The procedure shall be as follows:

(a) Section the rail and take two samples as shown in Figure I1.

(b) Prepare and etch the samples in 2% Nital (i.e., nitrtic acid in ethanol) or similar.

(c) Examine using a metallurgical microscope at × 100 magnification, to determine the microstructure of the fusion zone and the heat-affected zone of the parent rail.

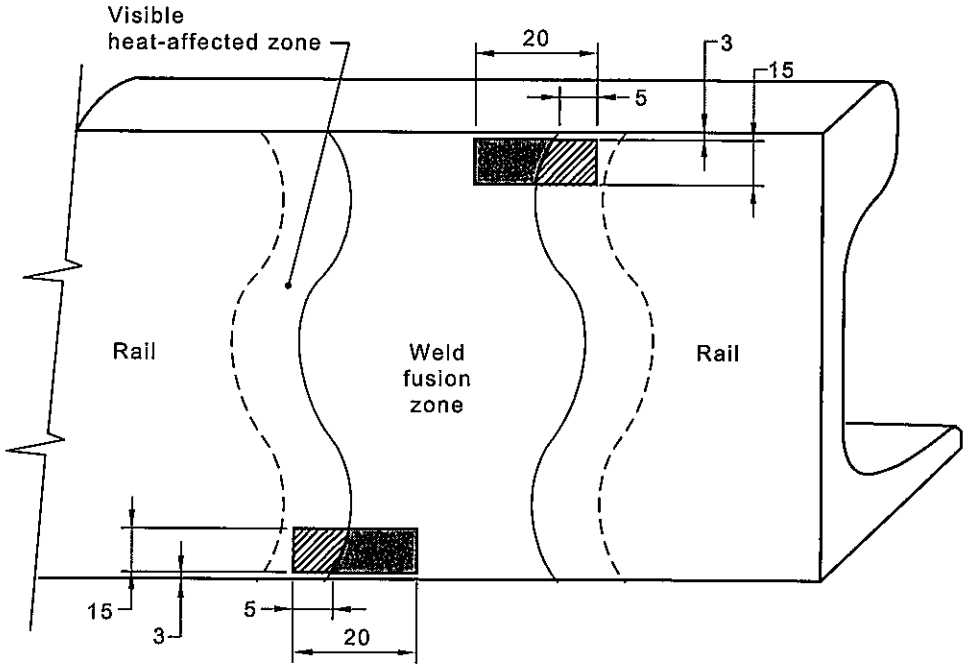


FIGURE I1 SCHEME FOR TAKING SAMPLES FOR MICROSCOPIC EXAMINATION

I3 REPORT

The following shall be reported:

(a) Date of testing and name of testing facility.

(b) Identification of the samples.

(c) The presence and position of martensite and bainite.

(d) Reference to this test method, (i.e., AS 1085.20, Appendix I).

APPENDIX J
CHEMICAL ANALYSIS
(Normative)

J1 SCOPE

This Appendix sets out the method for determining elements by chemical analysis.

J2 PROCEDURE

Conduct a chemical analysis for aluminothermic welds on a sample from the fusion zone within the railhead, at least 5 mm from the transverse centre-line of the weld or on a riser from the weld (see Figure J1).

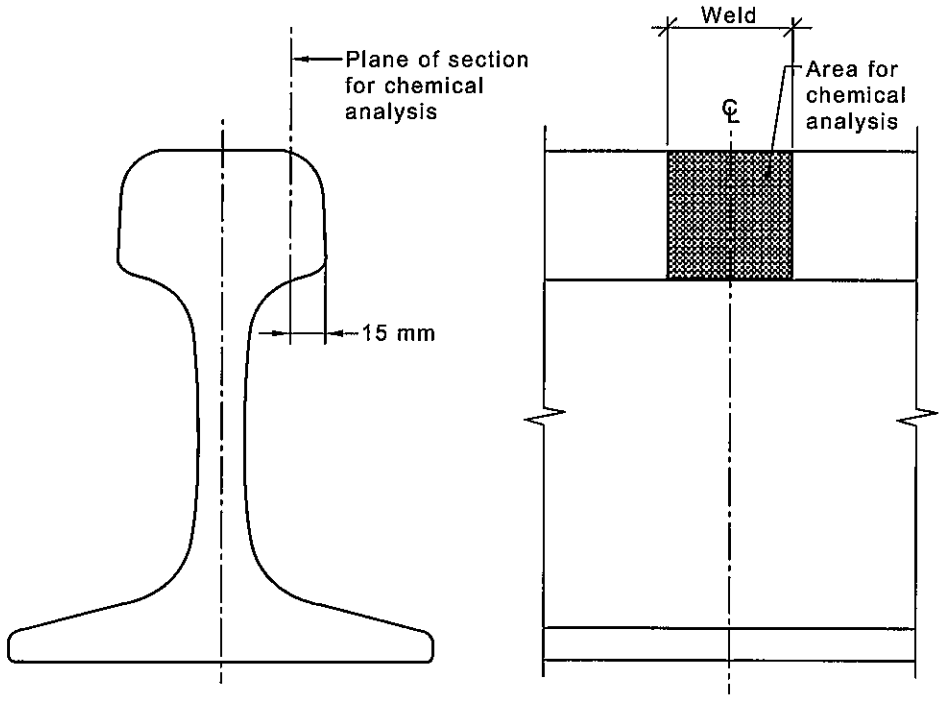


FIGURE J1 POSITION FOR CHEMICAL ANALYSIS OF WELD MATERIAL

J3 REPORT

The following shall be reported:

(a) Date of testing and name of testing facility.

(b) Identification of the samples.

(c) The proportions of the elements detected.

(d) Reference to this test method, (i.e., AS 1085.20, Appendix J).

APPENDIX K

SLOW BEND TEST

(Normative)

K1 SCOPE

This Appendix sets out the method for conducting the static slow bend test for welded rail sections.

K2 PRINCIPLE

The welded rail section is subjected to static loading under three point bending conditions so that the foot is placed in longitudinal tension. The load is increased in a controlled manner until the welded rail section fails. The break load and deflection at fracture are recorded.

K3 APPARATUS

The following apparatus is required:

(a) *Testing stand*—structurally rigid stand to be used as a support for the test weld.

(b) *Testing device*—preferably a hydraulic testing machine, to be used for applying the load at the weld centre-line.

The testing machine shall comply with the accuracy requirements for Grade A or Grade B testing machines given in AS 2193.

(c) *Measuring device*—accurate to 1.0 mm, suitable for indicating deflection measurements on the welded rail section.

K4 PROCEDURE

The procedure shall be as follows:

(a) Mount the test specimen in the test stand centrally over the specified span width (see Figure K1).

(b) Restrain the test specimen by means of clamps or other fixing devices.

(c) Apply increasing load, without shock, at a maximum loading rate of 5 kN/s to the weld centre-line through a thrust piece until failure occurs.

(d) Continuously record the load and deflection of the rail at mid-span throughout the test until failure.

(e) Carry out visual inspection.

(f) Calculate the maximum stress in the foot as follows:

$$\sigma = PLy_{foot}/4I \quad \ldots K1$$

where

σ = outer fibre stress, in megapascals

P = test load, in newtons

L = test span, in millimetres

y_{foot} = distance of the extreme fibre in the foot from the neutral axis, in millimetres

I = second moment of area of the rail section, in millimetres to the fourth power

(g) For junction welds, calculate the maximum stress in the foot of the smaller of the two rails being joined.

K5 ASSESSMENT OF FRACTURE FACES

If required, the maximum dimension of any pores, slag inclusions, sand inclusions or metal beads that are revealed may be measured and recorded in accordance with Paragraph E4 of Appendix E.

K6 REPORT

The following shall be reported:

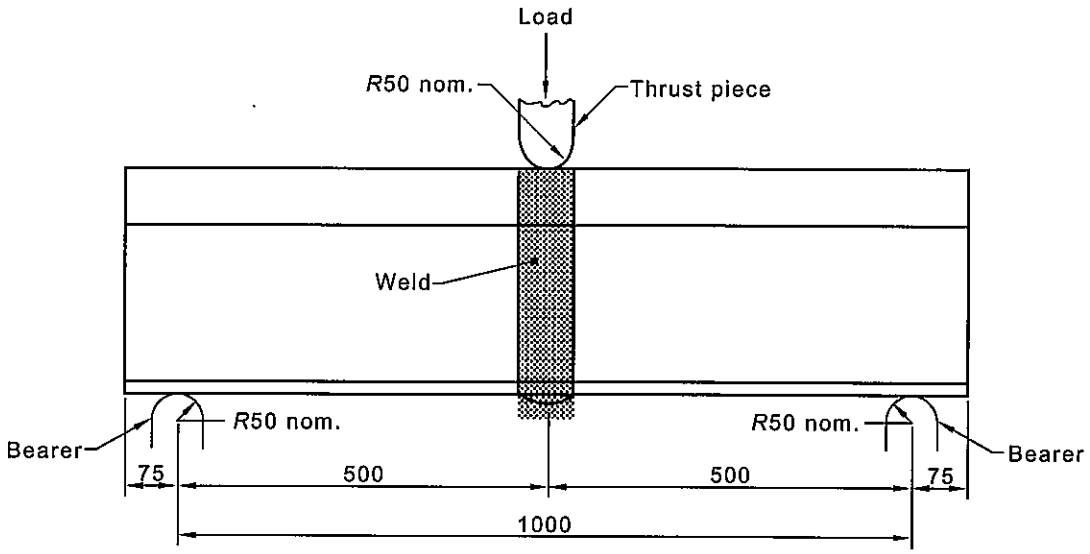
(a) Date of testing and name of testing facility.

(b) Identification of the samples.

(c) Load, maximum stress in the foot and mid-span deflection at failure.

(d) If required, type, size and position of any visible imperfections of the fracture face.

(e) Reference to this test method, (i.e., AS 1085.20, Appendix K).



DIMENSIONS IN MILLIMETRES

NOTE: R = radius.

FIGURE K1 TYPICAL TESTING ASSEMBLY FOR SLOW BEND TEST

APPENDIX L

FATIGUE TEST

(Normative)

L1 SCOPE

This Appendix specifies the method of testing welded rail to determine the fatigue strength.

L2 STAIRCASE FATIGUE TEST

L2.1 Principle

The 'staircase' method establishes the fatigue strength of a weld at an endurance of 5 000 000 cycles. The fatigue strength is measured in terms of the nominal outer fibre stress range in the foot of the weld, that is, the stress range that would exist in the parent rail at the weld location in the absence of the weld. The relationship of the applied load to the nominal outer fibre stress is established using a separate, strain-gauged test piece made of plain rail of the profile under consideration.

L2.2 Apparatus

Tests shall be conducted in four-point bending with the rail foot in tension. The inner span shall be not less than the sum of twice the rail height plus the weld collar width; the outer span shall exceed the inner span by at least twice the rail height (see Figure L1).

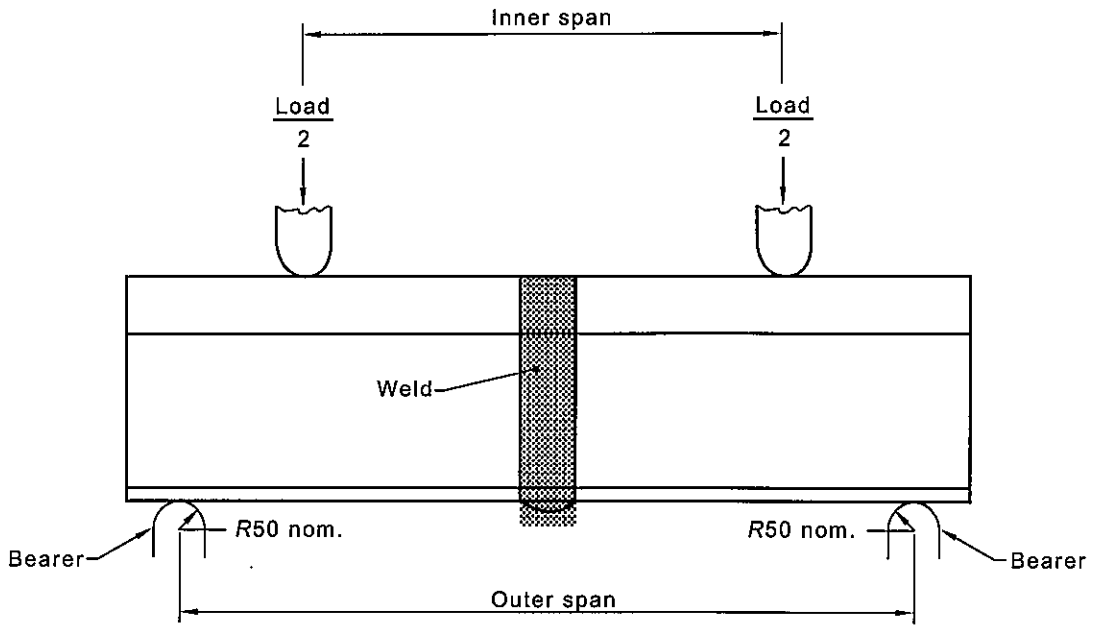
The inner and outer spans shall be measured and recorded.

The distances from the centre-line of the actuator to the loading points shall be measured and recorded. Corresponding dimensions on either side of the actuator centre-line shall not differ by more than 3 mm.

The radius of curvature of the loading points shall be in the range 40–60 mm. The loading point contact surfaces shall be free to translate or rotate so that friction between the loading points and the specimen is minimized.

The testing machine shall comply with the accuracy requirements for Grade A or Grade B testing machines given in AS 2193.

NOTE: A 1000 kN actuator is likely to be suitable for most applications.



NOTE: R = radius.

FIGURE L1 TYPICAL TESTING ASSEMBLY FOR STAIRCASE FATIGUE TEST

L2.3 Determination of stress to load relationship

L2.3.1 *Test pieces*

The test pieces shall be sections of new rail of the profile under consideration with a length exceeding that of the outer span of the test rig by at least 50 mm. For junction welds (of different rail sizes), the rail profile used to establish the load versus stress relationship shall be the smaller of the two profiles.

L2.3.2 *Procedure*

The relationship between the nominal outer fibre stress in the test piece and the applied load shall be established as follows:

(a) Attach strain gauges to the foot of the rail.

(b) Load the test piece to a significant proportion of the elastic capacity of the rail section.

(c) Derive a relationship for stress as a function of applied force on the basis of a linear relationship.

L2.4 Test pieces for fatigue strength determination

Test pieces shall be produced by joining two rail sections using the weld to be tested. The weld shall be positioned at the centre of the test piece to within ±10 mm. The test piece length shall not exceed the outer test span by more than 100 mm.

L2.5 Fatigue strength procedure

The procedure shall be as follows:

(a) Position a test piece in the test rig so that the centre-line of the weld is aligned with the centre-line of the actuator to within 3 mm.

(b) Estimate the maximum force corresponding to the mean fatigue strength of the weld at 5 000 000 cycles when the ratio of the minimum to the maximum cycle load is 0.1.

NOTE: Where no other information exists, a reasonable assumption would be that the mean fatigue strength at 5 000 000 cycles corresponds to a nominal cyclic outer fibre bending stress range of about 260 MPa.

(c) Cyclically load the weld by applying the force estimated above. The cycling frequency shall not exceed 10 Hz. The indicated maximum load and load range shall be maintained to within 2% of the nominal value required. Continue cycling until either the test piece breaks or 5 000 000 cycles have been applied. If the test piece breaks, the test result shall be recorded as a 'failure'. If it survives, it shall be recorded as a 'run-out'. The cyclic force range shall also be recorded.

(d) Where the test results in a run-out, repeat the test on another test piece using a cyclic force range corresponding to a nominal outer fibre stress in the foot 20 MPa above that in the first test. Where the test result is a failure, repeat the test on another test piece with a cyclic force range corresponding to 20 MPa below that in the first test.

(e) Continue testing until either one of the following occurs:

(i) Results are available for at least 3 stress range levels with results of both types, that is, both a failure and run-out obtained at an intermediate test level. Ten results shall be obtained.

(ii) At least 6 consecutive results are obtained, which alternate between failure and run-out at two neighbouring stress levels.

L2.6 Data analysis

Determine the mean value (m) and standard deviation (s) of the fatigue strength using the following equations, by determining first whether failures or run-outs are the less frequent events:

$$m = S_0 + d([A/N] \pm 0.5) \quad \ldots \text{L(1)}$$

$$s = 1.62d(0.029 + (BN - A^2)/N^2), \text{ but} \geq 5.3 \text{ MPa} \quad \ldots \text{L(2)}$$

(In cases where the calculated value of the standard deviation is less than 5.3 MPa, the standard deviation is small and will be deemed acceptable.)

where

$[(A/N) + 0.5]$ is used if the less frequent event is a run-out; and

$[(A/N) - 0.5]$ is used if the less frequent event is a failure

m = mean fatigue strength, in megapascals

S_0 = Lowest stress range at which tests with the less frequent result were conducted, in megapascals

d = Constant stress increment of the staircase, in megapascals, taken as 20 MPa

A = a value used in calculating the variation of fatigue results

$= \Sigma (i\, n_i)$

N = total number of less frequent events

$= \Sigma (n_i)$

i = coded stress level ($i = 0$ for S_0)

n_i = number of less frequent events at the i-th moment level above S_0

B = a value used in calculating the variation of fatigue results

$= \Sigma (i^2\, n_i)$

s = Standard deviation

Example calculation

This example shows the analysis of data from a fatigue strength determination using the staircase method. Results are given in the Table L1 and the calculations below.

The lowest stress range at which a failure occurs (S) is 220 MPa. As failure is the less frequent event, the form of Equation L2 to be used is as follows:

$$m = S + d([A/N] - 0.5)$$
$$= 220 + 20([4/4] - 0.5)$$
$$= 230 \text{ MPa}$$

The standard deviation (Equation L3) is as follows:

$$s = 1.62d(0.029 + (BN - A)/N)$$
$$= 1.62 \quad 20(0.029 + (24 - 16)/16)$$
$$= 17.1 \text{ MPa}$$

TABLE L1

TYPICAL TEST RESULTS

Test load (S)	Test number											Calculations				
	1	2	3	4	5	6	7	8	9	10	11	Lowest load with failure	i	n	in	i^2n
260			x										2	1	2	4
240		0		x				x					1	2	2	2
220	0				x		0		0			S	0	1	0	0
200						0										
d = 20 MPa												$N = \Sigma(n)$		4		
Failures (x): 4—less frequent event												$A = \Sigma(in)$			4	
Run-outs (0): 5												$B = \Sigma(i^2n)$				6

L2.7 Assessment of fracture faces

If required, the maximum dimension of any pores, slag inclusions, sand inclusions or metal beads that are revealed may be measured and recorded in accordance with Paragraph E4 of Appendix E.

L2.8 Report

The following shall be reported:

(a) Date of testing and name of testing facility.

(b) Identification of the samples.

(c) Mean fatigue strength.

(d) Standard deviation of the fatigue strength.

(e) If required, type, size and position of any imperfections found.

(f) Reference to this test method, (i.e., AS 1085.20, Paragraph L1, Appendix L).

L3 FATIGUE TEST FOR WEB OF WELDED SECTION (OPTIONAL)

L3.1 Principle

This optional method is provided for use if required. The weld rail section is subjected to fatigue-loading conditions so that the web is placed in vertical bending to specified minimum and maximum values. Sufficient vertical load is applied at a location on the edge of the railhead to produce the maximum load eccentricity obtained under the service conditions for which the welds are intended.

L3.2 Testing conditions

The purchaser and supplier shall establish the following by agreement:

(a) Maximum vertical test load that will produce the maximum vertical bending stress at the web.

(b) Support spacing.

(c) Value of eccentricity (E) that defines the point of application (generally, in the range 0.25–0.30 times the railhead width).

In general, the test load will be equal to the maximum dynamic wheel load obtained under service conditions.

L3.3 Apparatus

A testing device is required, preferably a servo-hydraulic testing machine, which is capable of—

(a) supporting the specimen centrally over the specified span width, as shown in Figure L2;

(b) applying a minimum vertical load equal to 0.0 kN, or as near to this value as possible, but not greater than 10 kN;

(c) applying the maximum vertical test load at the eccentricity (E) on the railhead of the specimen; and

(d) applying the required minimum and maximum vertical loads in a cyclic manner for a duration of 5×10^6 cycles, (unless otherwise agreed between the purchaser and the supplier).

The testing machine shall comply with the accuracy requirements for Grade A or Grade B testing machines given in AS 2193.

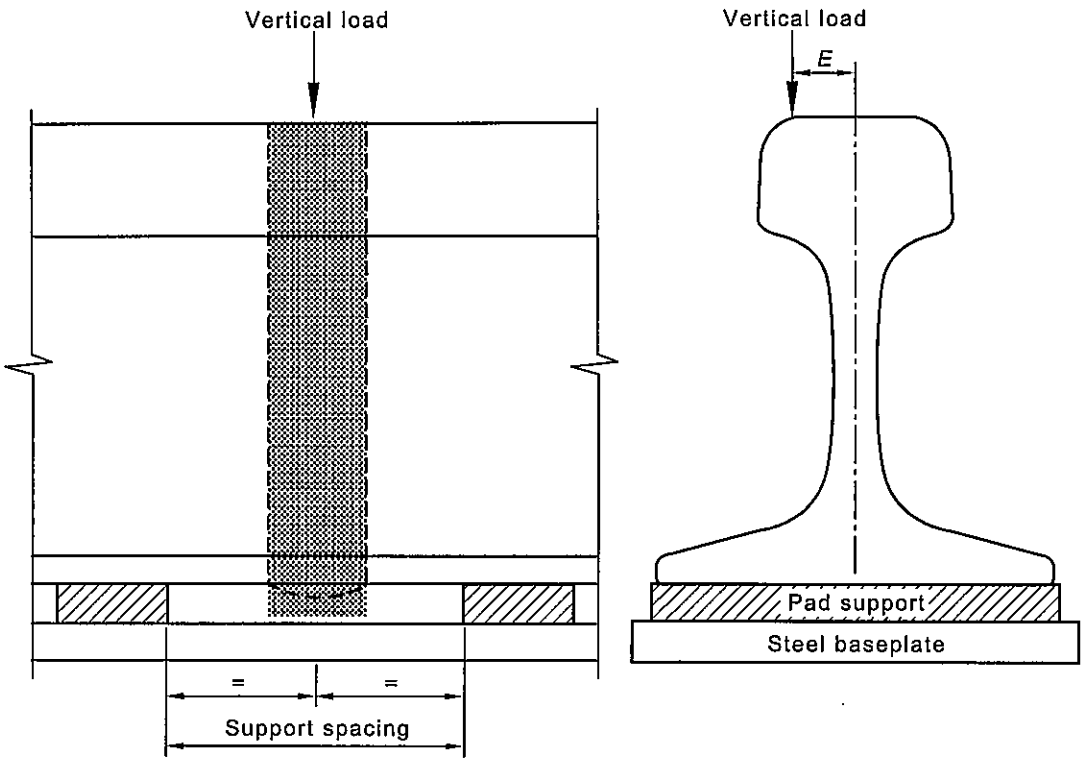


FIGURE L2 TYPICAL ASSEMBLY FOR THE FATIGUE TESTING OF WEB OF WELDED RAIL

L3.4 Procedure

The procedure for fatigue testing the web of a welded rail section shall be as follows:

(a) Mount the test specimen in the testing device so that it is located over the specified support span width (see Figure L2(a)) or continuously supported (see Figure L2(b)).

(b) Restrain the test specimen by means of clamps or other fixing devices on the rail foot of the specimen.

(c) Apply to the test specimen 5×10^6 cycles of loading between the minimum vertical load and the maximum vertical loading through a hardened steel ball or other means to simulate point load (if necessary, a small indentation may be machined into the railhead to locate and adequately restrain the load applicator) to the edge of the railhead. The cyclic loading shall be applied at a loading frequency between 5 Hz and 10 Hz.

NOTE: A higher loading frequency may be used, provided it can be demonstrated that the requirements regarding the control of the minimum and maximum vertical loads are satisfied.

L3.5 Report

The following shall be reported:

(a) Date of testing and name of testing facility.

(b) Identification of the samples.

(c) Minimum and maximum vertical applied test loads.

(d) Number of test cycles and loading frequency.

(e) Any fatigue cracks that occur.

(f) If required, position and size of any imperfections found.

(g) Reference to this test method, e.g., AS 1085.20, Paragraph L2, Appendix L.

APPENDIX M

QUALIFICATION OF A FLASH BUTT WELDING PROCEDURE

(Normative)

M1 SCOPE

This Appendix defines the qualification of a flash butt welding procedure.

M2 GENERAL REQUIREMENTS

Qualification of a flash butt welding procedure shall be undertaken using welds produced in accordance to the documented welding procedure.

M3 TESTING FOR QUALIFICATION AND REQUALIFICATION

M3.1 General

Qualification of the welding process, as described on the welding procedure, shall be in accordance with the tests set out in this Clause. Failure of any test will cause non-compliance for rail profiles being tested.

Separate qualification is required for each rail profile and each rail material grade.

Tests for qualification are set out in Table M1.

NOTE: For qualification, the number of welds examined for visual imperfections is specified as the sum of those in which imperfections are detected using ultrasonic testing and slow bend test.

TABLE M1

FLASH BUTT WELDING—NUMBER OF TESTS REQUIRED FOR QUALIFICATION

Test	Test method (Appendix)	Number of samples tested
Surface examination—Visual (as cast and ground)	E	All
Ultrasonic inspection	F	All
Hardness test Weld heat-affected zone and bond line Width of heat-softened zone	G	2
Macroscopic test Visible heat-affected zone (x_{vhaz})	H	2
Microscopic test Bond line, decarburization Heat-affected zone	I	 1 1
Slow bend test	K	3

M3.2 Qualification for junction and step welds

This Standard does not cover junction or step welds made by flash butt welding.

M3.3 Preparation and allocation of test welds

The number of test welds required for the tests referred to in Table M1 shall be produced in accordance with the welding procedure and allocated randomly.

The number of each test shall be in accordance with the appropriate parts of Table M1.

Where tests fail to meet the required test criteria as a result of an imperfection or imperfections in the rail, retesting shall be made on a one-to-one basis.

M3.4 Qualification of flash butt welding procedure

A flash butt welding procedure for a particular rail profile and material grade shall be qualified by passing the tests given in Table M2.

TABLE M2

TEST REQUIREMENTS FOR QUALIFICATION OF FLASH BUTT WELDING

Test	Test method (Appendix)	Description	Pass criteria	
Visual inspection	E	Visual inspection of all surfaces	No cracks, tears, gouges, shear drag, electrical contact burns, grinding burns	
		Surface finish tolerances: Top of railhead Side of railhead	0.15 mm 0.3 mm	
Surface alignment tolerances		**Tolerance grade ***	**Vertical**	**Horizontal**
	E	AT1	−0.0 mm, +0.3 mm	0.5 mm
		AT2	0.5 mm	0.5 mm
		AT4	Limit to be specified by the user	Limit to be specified by the user
Weld collar tolerances—Deviations from rail profile	E	At rail web and upper side of rail foot	−0, +2 mm	
		Underside of rail foot	−0, +0.5 mm	
Ultrasonic test	F	Internal imperfections	Reject level 1	
Hardness traverse		**Rail type**	**Deviation from parent material (excluding the bond line) in Vickers hardness**	
	G (Paragraph G3)	As-rolled rail	40 to a maximum of 380 HV	
		Head-hardened rail— air quenched non-air quenched	−20, +60 to a maximum of 430 HV 40 to a maximum of 430 HV	
		Width of heat-softened zone (Dimension *AB*)	On either side of the weld, less than or equal to one of the following widths: * 20 mm 30 mm 40 mm	
Macrostructure	H	Weld heat-affected zone and bond line	Perpendicular to rail foot 5°	
		Heat-affected zone (x_{vhaz})	30 to 50 mm	
Microstructure	I	In weld heat-affected zone and bond line	No martensite present. Be substantially pearlitic and free of grain boundary cementite	
		Width of decarburization at the bond line	Maximum 1.0 mm	
Slow bend test		**Rail type**	**Stress in the foot**	
	K	As-rolled rail at failure	900 MPa (min.)	
		Head-hardened rail at failure	900 MPa (min.)	
		Condition of fracture face	No cracks, lack of fusion or entrapped slag	

* The grade is specified for the application. Selection of tolerance level will affect the loads experienced at the weld and thus the expected life of the joint for given track conditions and level of traffic.

NOTE: Railway owners should determine the limits for internal imperfections.

APPENDIX N

QUALIFICATION OF AN ALUMINOTHERMIC WELDING PROCEDURE

(Normative)

N1 SCOPE

This Appendix defines the qualification of an aluminothermic welding process.

N2 GENERAL REQUIREMENTS

Qualification of the welding process shall be undertaken using welds produced in accordance to the documented welding procedure.

The following general requirements apply:

(a) All elements and consumables for a single weld shall be clearly identified. They may be packaged together in kit form except for igniters, which shall be separate.

(b) The aluminothermic welding portion shall be ready for use (that is, pre-mixed and packed in such a way as to prevent segregation during transport).

(c) The mould shall be prefabricated, for the rail profiles to be welded.

(d) The crucible shall be tapped automatically (automatic tapping) and shall have a device to limit spattering.

(e) When used, preheating tools shall be able to operate at ambient temperatures down to 0°C without the need for special precautions.

(f) The process shall be capable of being carried out on track where the maximum rail inclination to the vertical is 1 in 6.

(g) The range of gap shall be limited to ±2 mm, unless stated otherwise on the welding procedure.

N3 TESTING FOR QUALIFICATION

N3.1 General

Qualification of the welding process, as described in the welding procedure, shall be in accordance with the tests set out in this Paragraph. Failure of any test will cause non-compliance for the group of rail profiles being tested.

Rail profiles shall be grouped as given in Table N1. Separate qualification is required for each rail profile group and each rail material grade.

NOTE: The testing of welds using the testing regimes given, allows for reduced costs in extending the qualification of a particular weld procedure to other rail sizes and types, (i.e., head-hardened, see AS 1085.1).

Tests for qualification are set out in Paragraphs N3.2 to N3.5 and Table N2. The process of testing is given in Paragraph N3.6.

TABLE N1

RAIL PROFILE GROUPS

Group	Rail profile (AS 1085.1) kg
0	68
1	60
2	53
3	50, 47
4	41, 31

N3.2 Qualification for group 1 rails (60 kg)

Qualification of a weld for group 1 rails (60 kg rail, see Table N1) shall be by passing the tests given for testing regime 1 as given in Table N2. The weld to be qualified shall be as described on the welding procedure.

N3.3 Qualification for rails in other groups

To extend qualification from tests done using testing regime 1 to another rail profile (group of profiles, see Table N1), further testing shall be carried out in accordance with testing regime 2 given in Table N2.

N3.4 Qualification for other types of rail

To extend qualification from tests done using testing regime 1 to another type of rail (e.g., head-hardened within the same group, see Table N1) further testing shall be carried out in accordance with testing regime 3 given in Table N2.

N3.5 Qualification for junction and step welds

For junction welds and step welds where the difference in height between the rails to be joined is less than or equal to 16 mm, qualification for the group associated with the larger rail profile to be welded is sufficient. Otherwise, qualification shall be as for a new weld.

TABLE N2

ALUMINOTHERMIC WELDING—NUMBER OF TESTS REQUIRED FOR QUALIFICATION

Test	Test method (Appendix)	Testing regime		
		1 (Initial qualification)	2 (Extension to other groups)	3 (Extension to other types)
Surface examination—Visual (as cast and ground)	E	All	All	All
Ultrasonic inspection	F	All	All	All
Hardness test—Running surface	G (Paragraph G2)	6	6	6
Hardness test—Width of heat-softened zone	G (Paragraph G3)	2	2	2
Macroscopic test—				
visible heat-affected zone	H (Paragraph H2)	2	2	2
fusion zone shape and dimensions	H (Paragraph H3)	2	2	Nil
Microscopic test—				
fusion zone	I	1	Nil	1
heat-affected zone		1	Nil	1
Chemical analysis	J	3	Nil	3
Slow bend test	K	6	2	2
Fatigue test	L	1 (see Note)	Nil	Nil

NOTE: Indicates the number of welds required for one staircase.

N3.6 Preparation and allocation of test welds

The number of test welds required for the tests referred to in Table N2 shall be produced in accordance with the welding procedure.

The welds required for fusion zone shape and dimensions shall be produced to give 3 welds at the minimum and 2 welds at the maximum of the initial range of welding gap (that is, 3 welds at nominal gap −2 mm and 2 welds at nominal gap +2 mm).

Welding gap shall be measured after weld alignment (peaking) at the running surface, web mid-point and foot tips. The maximum gap is the maximum distance measured at any of the points and the minimum gap is the minimum of any of these points.

All laboratory welds should be subjected to the ultrasonic test procedure given in Paragraph F2 of Appendix F. If any welds show a response, they shall be included in the fatigue test.

Any test welds allocated to the fatigue test, as a result of ultrasonic testing, shall not be tested at the lowest load and, therefore, shall not be introduced into the test sequence until this has been established. If the cause of the ultrasonic response is not apparent following fatigue testing and inspection, further investigation shall be made to try to establish the cause. Otherwise, welds shall be allocated to the tests randomly.

The number of each test shall be in accordance with the appropriate parts of Tables N2 and N3.

Where tests fail to meet the required test criteria as a result of an imperfection or imperfections in the rail, retests shall be made on a one-to-one basis.

N3.7 Qualification of aluminothermic welding process

N3.7.1 *General*

An aluminothermic welding process for a particular rail profile group and material grade shall be qualified by passing the tests given in Table N3.

TABLE N3

TEST REQUIREMENTS FOR QUALIFICATION OF ALUMINOTHERMIC WELDING

Test	Test method (Appendix)	Description	Pass criteria
Visual inspection—Surface examination	E	As-cast weld surface	See Paragraph N3.7.1, Appendix N
		Ground weld surface	See Paragraph N3.7.2, Appendix N
Ultrasonic test	F	Internal imperfections	Reject level 2*
Weld hardness (HBW)	G (Paragraph G2)	Weld centre-line	As-rolled rail: 280 20 mm
		Weld centre-line	Head-hardened rail: 360 20 mm
Hardness traverse	G (Paragraph G3)	Max fusion zone hardness	430 HV
		Shape of the hardness graph	A nominally symmetrical shape about the centre of the weld
		Width of heat-softened zone (Dimension *AB*, see Paragraph G3.2(k))	On either side of the weld, less than or equal to one of the following widths (see Note): 20 mm 30 mm 40 mm
Macroscopic tests (etched)	H	General	Lack of fusion; presence of slag inclusions, porosity
Fusion zone	H (Paragraph H2)	Shape	A nominally symmetrical shape about the longitudinal and transverse axes
		Width of fusion zone (x_f)	Min. 3 mm
Visible heat-affected zone—Running surface	H (Paragraph H3)	Visible heat-affected zone—Running surface (x_{vhaz}) (See Paragraph H3.2(d))	Less than or equal to one of the following widths (see Note): 20 mm 30 mm 40 mm
Microscopic tests	I	In fusion zone	No bainite or martensite
		In heat-affected zone	No bainite or martensite
Chemical analysis	J	Composition	See Paragraph N3.7.3, Appendix N
Slow bend test	K	Stress in the foot at failure	750 MPa (min.)
		Fracture face imperfections	(See Note)
Fatigue	L	Fatigue strength	Mean: 210 MPa (min.) Standard deviation: 20 MPa (max.)
		Fracture face imperfections	(See Note)
	L (Paragraph L2)	Optional fatigue test for web	No failure at 3 000 000 cycles

NOTE: Railway owners should determine the limits for internal imperfections, width of heat-softened zone, fracture face imperfections and width of fusion zone (as appropriate).

N3.7.2 *As-cast weld surface*

Following stripping and final grinding, the as-cast weld collar surface shall be visually examined for fusion zone soundness. Any imperfections shall conform to the following:

(a) There shall be no cracks with surface length of 2 mm, or greater.

(b) There shall be no pores with a dimension greater than 3 mm, nor shall there be more than three pores in the size range 2 mm to 3 mm per test piece excluding the flashing.

(c) Slag or sand inclusions shall conform to all the limits given in Table N4. Any imperfections shall remain within the collar, i.e., not intrude into the rail cross-section, and shall not touch the edge of the weld collar to rail intersection.

TABLE N4

MAXIMUM DIMENSIONS OF SLAG OR SAND INCLUSIONS

Surface dimension (max.) mm	Depth (max.) mm
10	3
15	2
20	1

N3.7.3 *Ground weld surface*

The finished ground surface of the head (including the weld collar surface on either side of the railhead) shall comply with the following:

(a) There shall be no cracks.

(b) In an area of 2 mm diameter, associated with the lower edge of the railhead and weld collar (see Figure E2), there shall be no more than two welds out of the number required for the tests defined in the appropriate testing regime shall contain a maximum of one pore, slag or sand inclusion with a maximum dimension of 1 mm to 2 mm.

(c) With the exception of the above, there shall be no pores or other volume imperfections greater than 1.0 mm.

N3.7.4 *Chemical analysis of weld metal*

The maximum and minimum concentration of each element shall be specified in the welding procedure. When tested in accordance with Appendix J, the results shall fit within the ranges set out in Table N5. The working range shall be within the permitted range.

TABLE N5

LIMITS FOR CHEMICAL ANALYSIS OF THE WELD METAL

Element	Rail grade	Permitted range (limits to all products) %		Working range (limits for a particular product—within the permitted range) %
		Min.	Max.	
Carbon	As-rolled, head-hardened	0.50 0.60	0.75 0.85	— —
Silicon	All	0.00	1.20	0.25
Manganese	As-rolled, head-hardened	0.50 0.60	1.40 1.60	0.20 0.20
Phosphorus	All	0.00	0.035	—
Sulfur	All	0.00	0.030	—
Chromium	As-rolled, head-hardened	0.00 0.00	0.20 0.40	—
Molybdenum	All	0.00	0.10	—
Nickel	All	0.00	0.10	—
Aluminium	All	0.02	0.60	0.20
Copper	All	0.00	0.12	—
Tin	All	0.00	0.02	—
Antimony	All	0.00	0.02	—
Titanium	All	0.00	0.05	—
Niobium	All	0.00	0.01	—
Vanadium	As-rolled, head-hardened	0.00 0.00	0.10 0.40	— —

N4 TESTING FOR REQUALIFICATION

N4.1 General

Approval for changes to an already qualified procedure shall be made following the limited testing set out in Table N6. The degree of the change shall be the variation from the values given in the original qualification.

Table N6 identifies the tests to be performed when changes fall within the limited testing range of variation. Changes greater than the numeric values set in the limited testing range of Table N6 shall require full qualification as given in Paragraph N3.

For any process modification that requires an ultrasonic test or slow bend test (Appendix F or K), the results of the evaluation shall be the same as or better than the appropriate part of the original evaluation.

A single process variation or change may involve any combination of the parameters specified in Table N6. Parameters may be changed repeatedly in new variants or changes using the 'limited testing' ranges given in Table N6, provided the value is not outside the range when compared to the original qualification.

A process shall be tested as it will be used, that is, independently tested changes cannot be combined without further testing.

N4.2 Parameters

The parameters for determining a change to the process listed in Table N3 are defined as follows (see Figure N1):

(a) *Mould* Collar and riser, where the dimensions of W, D, d and cross-sectional areas of risers are to be nominal dimensions taken from the drawing of the model (pattern) used to produce the moulds (a similar drawing is required for the changed process):

(i) Weld collar width (W).

(ii) Collar depth (D_1 and D_2).

(iii) Collar depth (d_1 and d_2).

(iv) Riser cross-section—in foot (R_f).

(v) Riser cross-section—in neutral axis (R_N).

(vi) Riser configuration—position.

(vii) Riser configuration—numbers.

(viii) Any changes in the chemical nature of the main component of the refractory.

(b) *Crucible system*:

(i) Any changes in the chemical nature of the main component of the refractory.

(ii) Any changes in the initial internal crucible geometry outside the supplier's drawing.

(c) *Tapping system*:

(i) The refractory of the tapping system body.

(ii) Any changes in the geometry of the tapping system body outside the supplier's drawing.

(iii) All changes to the releasing mechanism.

(d) *Preheating system*:

(i) Any changes outside the defined critical parameters and equipment used in the preheating chain will require testing.

(ii) Any change of preheating fuels (oxidizing or reducing) will require testing.

(iii) Any change in working pressure or preheating times outside the ranges originally specified will require testing.

(e) *Portion* Changes in the weight outside of the production tolerances given by the supplier and changes in the ranges of elements specified.

(f) *Welding gap* Change of the range of gap outside the ±2 mm. Testing shall cover each end of the new range of gap not covered by the original testing.

NOTE: For measurement of the gap, see Paragraph N2.4.

TABLE N6

TESTING REQUIRED FOR LIMITED CHANGES

Process variants	Range outside which limited testing is required	Limited testing following changes (test methods as defined in Table N1)					
		Appendices					Other tests
		G, (Paragraph G2)	K	E, F (see Note)	H	J	
		Centre-line hardness	Slow bend test	Total imper-fections	Visible HAZ and fusion zone width	Chemical analysis	
Weld collar depth (d_1 or d_2)	2 mm			4	4		1 App L (Paragraph L2) fatigue (one staircase)
Weld collar depth (D_1 or D_2)	2 mm			4	4		
Weld collar width (W)	3 mm			4	4		
Riser cross-section—Foot (R_f)	10%			4	4		
Riser cross-section—Neut. axis (R_N)	10%			4	4		
Riser config—Position	5 mm			4	4		
Riser config—Numbers	All			4	4		
Crucible system	All		6			3	
Tapping system	All		6		4	3	
Preheating system	All	6	6	4	4		2 Paragraph G3 HSZ hardness
Portion	All	6	6	4	4	3	1 Appendix I Microstructure 2 Paragraph G3 HSZ hardness
Welding gap	All	6	6	4	4		2 Paragraph G3 HSZ hardness

NOTE: The total number of imperfections found should include any found as a result of inspection of the fracture faces following the slow bend test or the fatigue test.

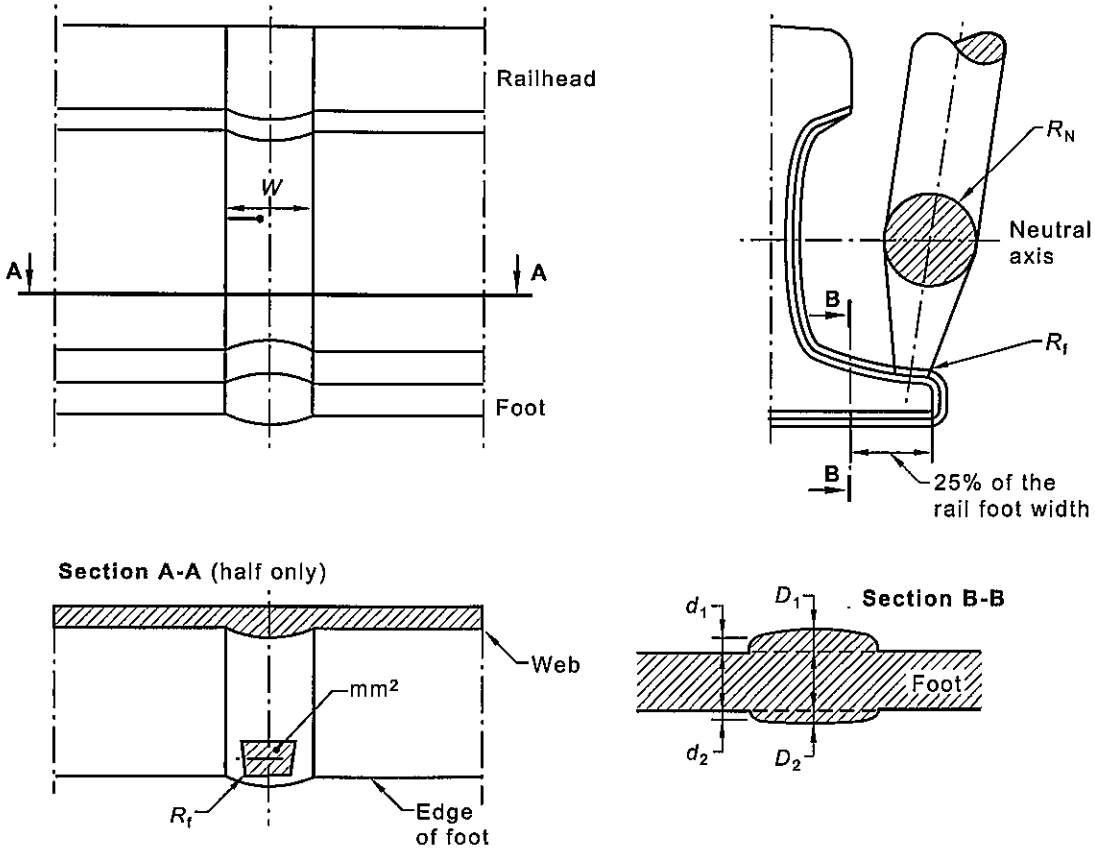


FIGURE N1 PROCESS DETAILS

APPENDIX O

QUALIFICATION OF AN ARC WELDING PROCEDURE

(Normative)

O1 SCOPE

This Appendix defines the qualification of an arc welding procedure for the repair of a railhead.

O2 GENERAL REQUIREMENTS

Qualification of the welding process shall be undertaken using welds produced in accordance to the documented welding procedure.

O3 QUALIFICATION OF WELDING PROCESS

O3.1 Prequalified consumables

Prequalified welding consumables shall be those given in Table O1, as specified in AS/NZS 2576.

TABLE O1

PREQUALIFIED WELDING CONSUMABLES

Manual metal arc welding	Flux cord arc welding	Gas metal arc welding
1130-A1	1130-B7	1130-B5, B6
1430-A1	1430-B7	1430-B5, B6

O3.2 Qualification tests

Qualification of the welding process, as described in the welding procedure, using the prequalified welding consumables defined in Table O1, shall be in accordance with the tests set out in this Paragraph.

A series of 3 test welds shall be performed and tested as set out in Table O2. The welds shall be performed on lengths of new rail with 10 mm removed to simulate a ground out wheel burn.

O3.3 Qualification of an arc welding procedure

An arc welding procedure for the repair of a railhead, for a particular rail size and material grade, shall be qualified by passing all the tests given in Table O2.

TABLE O2
QUALIFICATION OF METAL ARC WELDING

Test	Number of samples	Test method (Appendix)	Description	Pass criteria
Visual inspection—Surface examination	All 3	E	Ground weld surface	See Clause 4.6
Ultrasonic test	All 3	F	Internal imperfections of weld area and heat-affected zone only	Reject level 4
Hardness traverse—Vertical	2	G (Paragraph G3)	Max. heat-affected zone hardness	Max. 430 HV
			Weld metal hardness	330 to 420 HV
Macroscopic tests	2 (Same as for hardness traverse)	AS 2205.5.1	Cracking, lack of fusion, gas porosity and slag inclusions	None
Microscopic tests	1	I	Fusion zone	No martensite
	1		Heat-affected zone	No martensite

O4 REQUALIFICATION

Requalification shall be carried out for metal arc welding when the following occurs:

(a) Change in the consumable type.

(b) Change in amps of more than 15%.

(c) Change in voltage of more than 15%.

(d) Change in welding current from a.c. to d.c., and vice versa or a change in d.c. polarity.

(e) A change in metal transfer across the arc.

(f) Decrease of more than 20°C in the minimum specified preheat and interrun temperature.

(g) Change in electrode stick out of more than 20%.

(h) Change in preheating.

(i) Change in soaking time.

NOTES

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