BS EN 14730-1:2006 +A1:2010

Railway applications — Track — Aluminothermic welding of rails —

Part 1: Approval of welding processes

ICS 25.160.10; 45.080

British Standards

National foreword

This British Standard is the official English language version of EN 14730-1:2006+A1:2010. It supersedes BS EN 14730-1:2006, which is withdrawn.

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

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to CEN text carry the number of the CEN amendment. For example, text altered by CEN amendment 1 is indicated by [A1⟩ ⟨A1].

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

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

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

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 August 2006

ISBN 978 0 580 63892 3

Amendments/corrigenda issued since publication

Amd. No.	Date	Comments
	30 September 2010	Implementation of amendment A1:2010

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 14730-1:2006+A1

July 2010

ICS 25.160.10; 93.100

Supersedes EN 14730-1:2006

English Version

Railway applications - Track - Aluminothermic welding of rails - Part 1: Approval of welding processes

Applications ferroviaires - Voie - Soudage des rails par aluminothermie - Partie 1 : Approbation des procédés de soudage

Bahnanwendungen - Oberbau - Aluminothermisches Schweißen von Schienen - Teil 1: Zulassung der Schweißverfahren

This European Standard was approved by CEN on 12 June 2006 and includes Amendment 1 approved by CEN on 15 May 2010.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: Avenue Marnix 17, B-1000 Brussels

Ref. No. EN 14730-1:2006+A1:2010: E

Contents

Page

Foreword 4
Introduction 5
1 Scope 6
2 Normative references 6
3 Terms and definitions 6
4 Information to be supplied by the railway authority 7
5 Approval procedure 8
5.1 General 8
5.2 Process identification 8
5.3 General requirements 8
5.4 Initial compliance testing 9
5.5 Extension of initial compliance testing 10
5.6 Documents to be submitted with the request for approval 11
5.6.1 The process manual 11
5.6.2 Drawing with the required measurements 11
5.6.3 Chemical analysis ranges and tolerances 12
5.7 Preparation and allocation of test welds 12
6 Re-approval following process changes 13
7 Laboratory tests 16
7.1 Visual surface examination 16
7.1.1 As cast weld surface 16
7.1.2 Ground weld surface 16
7.1.3 Visible heat affected zone 17
7.2 Running surface hardness test 17
7.3 Slow bend test 18
7.4 Internal examination 18
7.4.1 Weld soundness 18
7.4.2 Fusion zone – shape and dimension 21
7.4.3 Microscopic examination 22
7.4.4 Heat softened zone width 22
7.5 Fatigue test 22
7.6 Chemical analysis 23
Annex A (informative) Steps in approval 25
Annex B (informative) Suggested sequence of laboratory tests 26
Annex C (normative) Ultrasonic testing procedure for aluminothermic welds in rail 27
C.1 A test of the head zone of the weld (non-planar defects) 27
C.2 A test of the head zone of the weld (planar defects) 27
C.3 A test of the head and web zone of the weld (planar defects) 27
C.4 A test of the middle zone of the foot of the weld 27
C.5 A test of the ankle zone of the foot of the weld 28
C.6 A test of the toe zone of the foot of the weld 28
C.7 [A1) Calibration (A1] 29
Annex D (normative) Procedure for FRY etching 31
Annex E (normative) Procedure for measurement of surface hardness 32

Annex F (normative) **Procedure for slow bend test** 33

Annex G (normative) **Procedure for recording test weld fracture face defects** 34

Annex H (normative) **Ultrasonic inspection procedure on aluminothermic welds to be sectioned** 36
H.1 Principle 36
H.2 Apparatus 36
H.3 Preparation of samples 36
H.4 Calibration 36
H.5 Testing 37
H.6 Reporting 37

Annex I (normative) **Procedure for microscopic examination of the visible heat affected zone and fusion zone of welds** 38

Annex J (normative) **Procedure for measurement of the heat softened zone width** 39
J.1 Measurement of hardness 39
J.2 Evaluation of hardness data 40
J.2.1 General 40
J.2.2 Mean hardness of parent rail 40
J.2.3 Measurement hardness line 40
J.2.4 Heat softened zone width measurement 41
J.2.5 Parent rail hardness variation 41

Annex K (normative) **Fatigue test methods for aluminothermic welds** 42
K.1 Scope 42
K.2 Test equipment 42
K.3 Calibration procedure 43
K.3.1 General 43
K.3.2 Test piece 43
K.3.3 Test piece preparation 43
K.3.4 Instrumentation 44
K.3.5 Procedure 44
K.4 Fatigue test method 47
K.4.1 General 47
K.4.2 Staircase testing method 47
K.4.3 Example of the data analysis of a fatigue strength determination by the staircase method 49
K.4.4 Past-the-post testing method 50

Annex L (informative) **A–deviations** 51

Foreword

This document (EN 14730-1:2006+A1:2010) has been prepared by Technical Committee CEN/TC 256 “Railway applications”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 2011, and conflicting national standards shall be withdrawn at the latest by January 2011.

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

This document includes Amendment 1 approved by CEN on 15 May 2010.

This document supersedes EN 14730-1:2006.

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

[A1) This document has been prepared under a mandate given to CEN/CENELEC/ETSI by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive 93/38/EEC. (A1]

The European Standard EN 14730 *Railway applications — Track — Aluminothermic welding of rails* is composed of two parts.

— *Part 1: Approval of welding processes*;

— *Part 2: Qualification of aluminothermic welders, approval of contractors and acceptance of welds*.

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

Introduction

This standard defines the approval procedure for aluminothermic welding processes for rail welding through laboratory tests of welds produced in a workshop. This laboratory approval will provide the railway authority with sufficient information for tests in the track if required.

1 Scope

This standard defines the laboratory tests and requirements for approval of an aluminothermic welding process using welds produced in workshop conditions.

It applies to the joining of new, Vignole rails as described in EN 13674-1 of the same profile and steel grade.

Compliance with the requirements of this standard does not of itself ensure the suitability of a welding process for specific conditions of track and traffic.

The standard does not cover welds made between different rail sections, differently worn rails and different rail grades.

In addition to the definitive requirements this standard also requires the items detailed in Clause 4 to be documented. For compliance with this standard, it is important that both the definitive requirements and the documented items be satisfied.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 473, *Non destructive testing — Qualification and certification of NDT personnel — General principles*

EN 13674-1, *Railway applications — Track — Rail — Part 1: Vignole railway rails 46 kg/m and above*

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

EN ISO 6507-1, *Metallic materials — Vickers hardness test — Part 1: Test method (ISO 6507-1:2005)*

EN ISO 7500-1:2004, *Metallic materials — Verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Verification and calibration of the force-measuring system (ISO 7500-1:2004)*

3 Terms and definitions

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

3.1
fusion zone
area of the weld which has been in a liquid state and which is revealed by etching sections cut through the weld

3.2
visible heat-affected zone
HAZ
areas on either side of the fusion zone within which rail steel microstructure has been visibly modified by the heat of the welding process as revealed by FRY macro-etching

3.3
heat softened zone
part of the HAZ characterised by a lower hardness

3.4
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

3.5
surface defect
any defect visible on the weld surface after normal finishing operations

3.6
internal defect
any defect that is revealed by sectioning or on a fracture face following bend or fatigue testing that has not already been identified as a surface defect

3.7
stress range
stress range for the fatigue test is the maximum stress minus minimum stress

3.8
railway authority
either the railway regulator or the owner of a railway infrastructure or the custodian with a delegated responsibility for a railway infrastructure

3.9
process supplier
company which provides an approved aluminothermic welding process in accordance with this standard and which is approved by the railway authority to supply consumables and tools for the execution of aluminothermic welds

4 Information to be supplied by the railway authority

The following information shall be fully documented by the railway authority. For compliance with the standard both the definitive requirements specified throughout the standard and the following documented items shall be satisfied.

a) Any limitations on the type of pre-heating.

b) Maximum permissible numbers and/or dimensions of slag or sand inclusions on the as-cast weld surface.

c) Any limitation on the weld collar geometry affected by riser removal (other than that on the ground rail head).

d) The maximum size and number of pores to be permitted on the ground surfaces if the railway authority's requirements are more severe than those in 7.1.2.

e) Any additional non-destructive testing requirements.

f) Which of the width levels of visible heat affected zone is required (7.1.3).

g) Which of the two formulae for minimum fracture load shall apply for R320Cr rail grade (7.3).

h) Any limit on the depth of the weld collar's edge (less than 2 mm) that may remain unfused to the rail surface.

i) Which of the width levels of heat-softened zone is required (7.4.4).

j) The fatigue requirement in terms of the mean and of the standard deviation of the fatigue strength for the staircase method of testing or the minimum value of upper stress in the rail foot for past the post testing (7.5.2).

k) Which of the two hardness ranges for R260 rail grade specified in 7.2, Table 5 is required.

5 Approval procedure

5.1 General

An outline of the steps required for compliance to this standard is given in informative Annex A.

5.2 Process identification

The approval shall involve a single process identified by:

a) The process name.

b) A drawing of the pouring system.

c) The characteristic geometry of the weld collar and riser configuration as given in 5.6.2 and Figure 1.

d) The process manual in accordance with 5.6.1.

5.3 General requirements

The following general requirements shall be met.

a) The process shall be capable of being carried out on track where the maximum can be 180 mm. It shall be capable of being carried out in track, at or near trackside or in a workshop.

b) The aluminothermic welding portion shall be packed to avoid the risk of moisture contamination in proscribed storage conditions. The portion shall be identified by markings on the package.

c) The mould shall be pre-fabricated for the rail profiles to be welded and be identified by markings on the package.

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

e) Pre-heating shall comply with any limitations of the railway authority as specified in Clause 4 a). The pre-heating tools shall operate at temperatures down to 0 °C without the need for special precautions.

f) The process shall not damage the rail.

5.4 Initial compliance testing

a) For the purposes of approval the standard rail profiles (see EN 13674-1) shall be grouped as follows:

Table 1 — Rail profile groups

Group	Rail profiles
1	60E1, 60E2
2	54E1, 54E2, 54E3, 55E1, 56E1
3	46E1, 46E2, 46E3, 46E4, 49E1, 49E2, 49E3, 50E1, 50E2, 50E3, 50E4, 50E5, 50E6, 52E1
4	49E4

b) Initial compliance with this standard shall be achieved by undertaking the tests specified in category 1 of Table 2 using either grade R220 or grade R260 rail of one profile in either group 1 or 2 of Table 1. Compliance with all the criteria specified and with the railway authority's documented requirements specified in Clause 4 shall be demonstrated. A test sequence is outlined in informative Annex B. A test specimen can be used for several different tests.

Table 2 — Testing scheme

Test	Section Reference	Number of Tests					
		Category 1[a]	Category 2[b]	Category 3[c]			
				R200/R220/ R260/R260 Mn	R320Cr	R350HT	R350LH T
A Hardness Test	7.2	6	Nil	6	6	____6_____	
B Surface Examination - Visual	7.1.1 7.1.2	All	All	All	All	_____All_____	
C Visible Heat Affected Zone	7.1.3	2	2	2	2	______2_____	
D Slow Bend Test	7.3	6	2	2	6	_____6______	
E Ultrasonic Inspection - Annex H	7.4.1.1	5	2	Nil	Nil	Nil	Nil
F Fatigue Test	7.5	n*	Nil	Nil	n*	Nil	n*
G Fusion Zone -Weld Soundness	7.4.1 7.3 7.5.3	5 (6) (n*)	2 (2) Nil	Nil (2) Nil	Nil (2) (n*)	Nil ______2_____ Nil	Nil n*
H Fusion Zone - Shape and Dimensions	7.4.2	5	2	Nil	Nil	Nil	Nil
I Chemical Analysis	7.6	3	Nil	3	3	______3______	
J Heat Softened Zone - Hardness Distribution	7.4.4	2	2	2	2	______2_______	
K Structure - Fusion Zone - Heat Affected Zone	7.4.3.3 7.4.3.2	1 1	Nil Nil	1 1	1 1	______1_______ ______1_______	
L Ultrasonic Inspection - Annex C	5.7 d)	All	All	All	All	All	All

NOTE 1 n* indicates the number of welds required for one staircase or past the post evaluation. Typically 10 test pieces will be required for a staircase and 3 for a past the post evaluation.

NOTE 2 ____X____ indicates that tests in one rail grade cover the other indicated grade

NOTE 3 ( ) indicates weld soundness evaluation of the fracture face of the slow bend test or fatigue specimens

[a] Category 1 Initial tests to be conducted using R220 or R260 grade rail and one profile from either of rail profile groups 1 or 2 (Table 1).

[b] Category 2 Tests to be carried out on one profile from each of the remaining rail profile groups in order to extend approval to that group.

[c] Category 3 Tests required extending approval to other rail grades. Tests on one rail profile cover all profile groups approved in categories 1 and 2.

5.5 Extension of initial compliance testing

Initial compliance can be extended as follows:

The relevant railway authority requirements defined in Clause 4 a) to k) shall be met for each of the items below:

a) To other groups of rail profiles of Table 1 [subclause 5.4 a)] by the tests in category 2 of Table 2 [subclause 5.4 b)] to be conducted on one profile from each of the appropriate groups. Failure of any test shall cause non-compliance for the group of rail profiles being tested.

b) To other rail grades by the tests in category 3 of Table 2 [subclause 5.4 b)]. Failure of any test shall cause non-compliance for that rail grade. Tests on one rail profile cover all profiles in categories 1 and 2.

c) To process changes as prescribed by the limits and tests of Clause 6. Failure of the relevant tests of Table 3 shall cause non-compliance of the process change.

5.6 Documents to be submitted with the request for approval

When applying for approval, the following documents shall be submitted:

5.6.1 The process manual

The process supplier shall produce a manual identifying all the consumable materials and equipment used, as well as the operating method to be followed for all steps of welding. The approval procedure for laboratory tests will not include means of alignment or finishing operations. The manual shall specify the critical parameters of the welding process and their safe bounds, and shall include the following:

a) number of people required carrying out the operations;

b) diagram of equipment;

c) portion for each rail grade and profile;

d) rail end preparation requirements;

e) nominal gap shall have a tolerance of ± 2 mm for a gap up to 30 mm and ± 3 mm for gaps above 30 mm and up to 50 mm and ± 5 mm for gaps above 50 mm;

f) preheating details;

g) range of ignition to tap times for the portion;

h) critical process timings;

i) time (or temperature) before trains can pass;

j) safety information.

5.6.2 Drawing with the required measurements

A drawing, as illustrated in Figure 1, which provides the measurements listed below:

a) weld collar width (W1). The development of the weld collar shall be fully dimensioned around the weld;

b) maximum depth of collar at section B-B (D1 and D2);

c) minimum depth of collar at section B-B (d1 and d2);

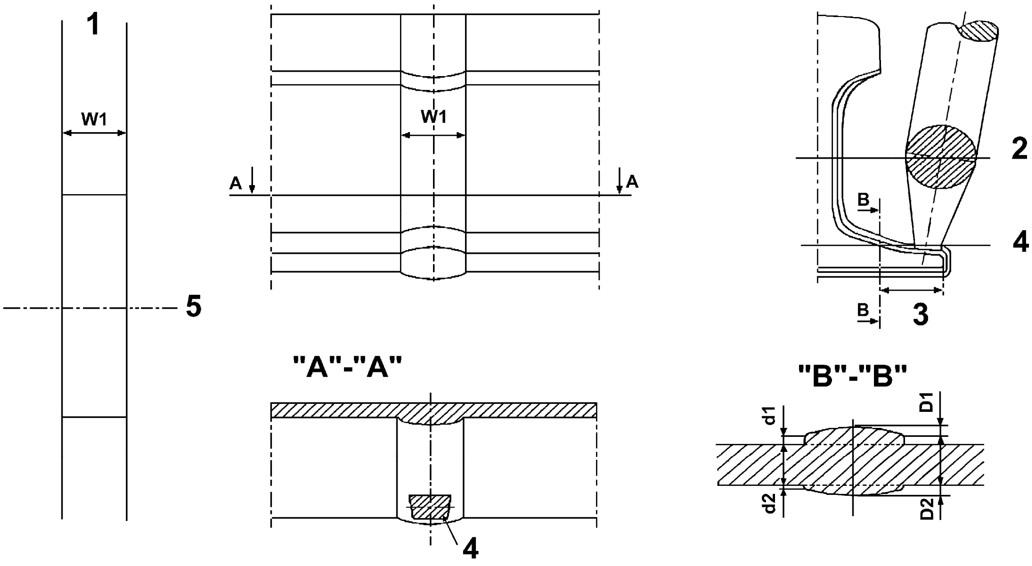
d) riser cross section at foot;

e) riser cross section at neutral axis;

f) number of risers;

g) position of risers.

The dimensions W, D and d and cross sectional areas of the risers shall be the nominal dimensions taken from the drawing of the pattern used to produce the moulds.



Key

1 Figure showing the width of the weld collar around the weld
2 Riser cross section on the neutral axis mm²
3 25 % of the foot width
4 Riser cross section at the foot mm²
5 Longitudinal axis under the rail foot

Figure 1 — Dimensions taken from mould pattern

5.6.3 Chemical analysis ranges and tolerances

The chemical analysis ranges and tolerances according to 7.6.1.

5.7 Preparation and allocation of test welds

a) Welds required for the tests shall be produced in accordance with the process manual (5.6.1) under the supervision of the approving authority recognised by the railway authority. Rails to be used for the production of test welds shall be new rails. Fifty percent of test welds shall be made with minimum gap and fifty percent at maximum gap.

b) Welding gap shall be measured after weld alignment (peaking) on both sides of the rail head (or on the running surface), web mid point and both foot tips. The maximum gap is the maximum at any of the above points and minimum the minimum of any of the above points.

c) The weld gap for all welds made for Table 2 tests shall be within the specified range. In the case of the welds required for test H in category 1 of Table 2, three welds shall be produced at the minimum gap and two at the maximum, and for category 2 of Table 2, one weld at the maximum gap and one weld at the minimum gap. Measurements shall be made to an accuracy of ± 0,5 mm.

d) All welds shall be tested ultrasonically using the procedure given in Annex C and the results recorded.

e) With the exception of the welds made for test H, as many as possible of the welds that show an ultrasonic response shall be allocated to test as follows:

— Response from web or foot – slow bend test (test D);

— Response from head – weld soundness test (test G)

Otherwise welds shall be allocated to tests randomly.

f) The number of each test shall be in accordance with the appropriate parts of Tables 2 and 3. The process supplier shall determine the order of testing.

g) Where tests fail to meet the required test criteria as a result of a defect (or defects) in the rail, re-tests shall be made on a one-to-one basis.

6 Re-approval following process changes

6.1 Changes to the following criteria require approval.

6.1.1 Any geometric parameters given in 5.6.2:

a) weld collar width (W);

b) collar depth (D);

c) collar depth (d);

d) riser cross-section – in foot;

e) riser cross-section – in neutral axis;

f) riser configuration – position;

g) riser configuration – numbers.

A revised drawing shall be submitted.

6.1.2 Crucible system

— Any changes in the chemical nature of the main component of the refractory;

— Internal crucible geometry changes outside the range covered by the tolerances shown on the suppliers drawing.

6.1.3 Tapping system

— Any changes in the chemical nature of the main component of the refractory of the tapping system body;

— Any changes in the geometry of the tapping system body outside the suppliers drawing;

— All changes to the releasing mechanism.

6.1.4 Pre-heating system

— Any change in the equipment or critical parameters;

— Any change of pre-heating fuels (oxidising or reducing);

— Any change in working pressure or pre-heating times outside the ranges originally specified.

6.1.5 Portion

— Changes in the weight outside of the production tolerances given by the supplier and changes in the ranges of elements specified by the supplier.

6.1.6 Welding gap

Initial approval involves testing a welding process at either end of the ranges specified in 5.6.1 e).

If the maximum gap proposed exceeds the maximum covered by the initial approval, testing is required at the new maximum gap. If the minimum gap proposed is less than the minimum covered by the initial approval, testing is required with new minimum gap.

Measurement of the gap shall be made as defined in 5.7 b).

6.2 Changes to the portion shall be tested in accordance with Table 2 categories 1 and 3, but shall exclude the fatigue test requirement.

6.3 Where the proposed change lies within the range or ranges given in Table 3, the tests shall be undertaken as detailed in Table 3. The change shall be approved if the acceptance criteria for each of the required tests are met. In house laboratory facilities shall be approved by the railway authority.

6.4 Changes which fall outside the limits of the range or ranges given in Table 3 shall only be approved if they meet the requirements for demonstrating initial compliance as given in Table 2.

6.5 In all instances the magnitude of a change shall be judged in relation to that value used in the original approval as defined in 5.4.

In the case of the combination of multiple changes, the number of tests to be undertaken will be the largest number required in each column of Table 3 for these particular changes. e.g. combining changes to the pre-heating system and welding gap shall require 6 of test A (not 12), 1 of test C, etc.

6.6 Re-approval following the process changes detailed in Table 3 shall be made in one profile of groups 1 or 2 of Table 1 and rail grades R260 and shall cover all profiles and grades of the existing approval.

Table 3 — Process changes

Test	In house [a]	External [b]										Total number of welds required
	Range or modification	Range or modification	Number of tests (Test as defined in Table 2)									
			A Centreline hardness	C Visible HAZ	D Slow bend test	F Fatigue test	G Weld soundness	H Fusion width	I Chemical analysis	J HAZ hardness	K Structure	
6.1.1 a) Weld collar width W	± 3mm	± 10mm	-	-	-	-	4	4	-	-	-	4
6.1.1 b) Collar depth (D)	± 2mm	± 6mm	-	-	-	-	4	4	-	-	-	4
6.1.1 c) Collar depth (d)	± 2mm	± 4mm	-	-	-	n [c]	4	4	-	-	-	4 + n [c]
6.1.1 d) Riser X-section – Foot	± 10%	± 30%	-	-	-	-	4	4	-	-	-	4
6.1.1 e) Riser X-section – Neut. axis	± 10%	± 40%	-	-	-	-	4	4	-	-	-	4
6.1.1 f) Riser config. – Position	± 5mm	± 10mm	-	-	6	-	4	4	-	-	-	10
6.1.1 g) Riser config. – Numbers	-	All	-	-	6	-	4	4	-	-	-	10
6.1.2 Crucible system	-	All	-	-	6	-	-	-	3	-	-	9
6.1.3 Tapping system	-	All	-	-	6	-	-	4	3	-	-	10
6.1.4 Pre-heating system	-	All	6	1	6	-	4	4	-	2	-	10
6.1.6 Welding gap	-	All	6	1	6	-	4	4	-	2	-	10

[a] In house – Conducted by the process supplier

[b] External – Conducted by a test house approved by the railway authority

[c] n: One staircase or past the post evaluation. Typically 10 test pieces will be required for a staircase and 3 for a past the post evaluation.

7 Laboratory tests

7.1 Visual surface examination

7.1.1 As cast weld surface

Following stripping and final grinding the as-cast weld collar surface shall be visually examined for soundness. For the process to be accepted:

— there shall be no cracks with length of 2 mm, or greater. Joints between weld collars and rail and flashing and rail are not cracks;

— 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 flashing;

— slag or sand inclusions shall not exceed the limits set in Table 4. No defect shall intrude into the rail cross section nor touch the edge of the weld collar/rail intersection.

Table 4 — Maximum dimensions of slag or sand defects

Dimensions in millimetres

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

The number and dimensions of slag or sand inclusions shall not exceed the values specified in the information supplied by the railway authority [Clause 4 b)]:

— the condition of the surface left by riser removal (other than that on the ground rail head) shall conform with the requirements specified in the information supplied by the railway authority [(Clause 4 c)].

7.1.2 Ground weld surface

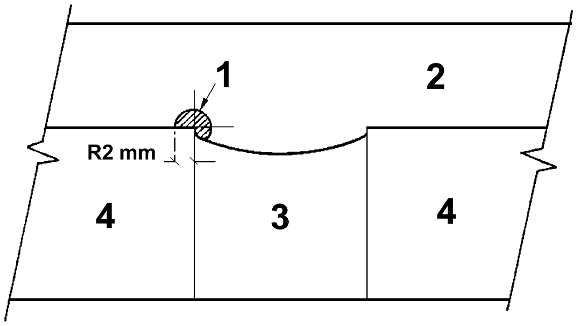
The head and the ground weld collar surface on either side of the rail head shall comply with the following:

— There shall be no cracks. Joints between weld collars and rail and flashing and rail are not cracks;

— There shall be no defects (pores, slag, sand inclusions, metal beads) with a dimension greater than 1 mm or limit fixed by the railway authority if the limit is less than 1 mm [Clause 4 d)];

— A defect with a maximum dimension of 2 mm shall be accepted in the hatched zone 1 of Figure 2 for no more than 10 % of the test welds or one weld if fewer than 10 welds;

— Any additional non-destructive testing requirements specified in the information supplied by the railway authority [Clause 4, e)].



Key

1 Zone with a 2 mm radius
2 Rail head
3 Weld collar
4 Rail web

Figure 2 — Ground collar surface

7.1.3 Visible heat affected zone

Following FRY etching in accordance with Annex D the visible heat affected zones on each side of the weld shall be measured on the rail running surface centre line. Their widths shall not exceed 20 mm, 30 mm or 40 mm as specified in the information supplied by the railway authority [Clause 4 f)]. The visible heat affected zone shall be nominally symmetrical about the longitudinal axis of the rail and transverse axis of the weld.

7.2 Running surface hardness test

Measurements shall be made in accordance with Annex E.

The average of the three hardness measurements made on each weld shall fall within the range given in Table 5 for the appropriate parent rail grade.

Table 5 — Ranges for running surface hardness tests

Rail grade	Hardness range HBW	
	Rail running surface on the unaffected parent rail	Weld centre-line
R200	200 to 240	230 ± 20
R220	220 to 260	250 ± 20
R260	260 to 300	280 ± 20
R260	260 to 300	300 ± 20
R260Mn	260 to 300	280 ± 20
R320Cr	320 to 360	330 ± 20
R350HT	350 to 390	350 ± 20
R350LHT	350 to 390	350 ± 20
NOTE 0,5 mm should be ground from the running surface before a hardness impression is made.		

NOTE The centre-line hardness of the welds for the chromium alloyed and for the heat-treated grades is established below the hardness values of the rail running surface to ensure a fully pearlitic structure. The hardness profile along the rail crown centre-line of welds varies with the level of alloying element additions, with higher alloyed welds showing a relatively higher hardness at the weld edges. Therefore to achieve the correct average hardness a lower centre-line hardness is required.

7.3 Slow bend test

Details of the slow bend test procedure are given in Annex F.

The minimum fracture load (kN), rounded to the nearest 5 kN is defined by the equation $F = 0{,}0032 \cdot S$ (equivalent to a minimum tensile bending strength of 800 MPa), where S (mm^3) is the section modulus for the base of the rail, given in EN 13674-1.

An alternative $F = 0{,}003 \cdot S$ may be used for R320Cr rail grade when specified by the railway authority. The formula given shall be specified.

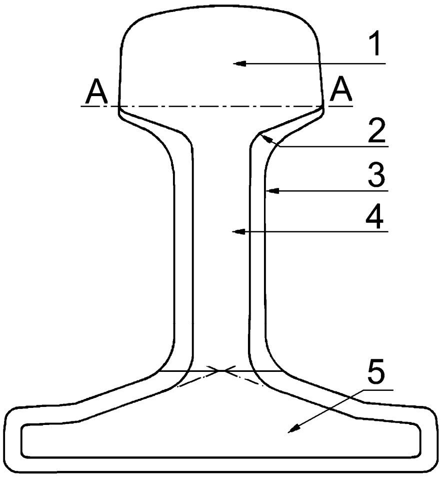
The fracture face shall be subject to the soundness examination in accordance with 7.4.1.5 and a record made in accordance with Annex G.

If the origin of any ultrasonic response is not revealed by slow bend testing, no further investigation is required.

7.4 Internal examination

7.4.1 Weld soundness

7.4.1.1 The head, web and foot of the rail containing the weld, (see Figure 3), shall be examined ultrasonically in accordance with Annex H. The positions of any apparent defects found by ultrasonic testing shall be recorded so that they may be revealed by sectioning.



Key

1 Head
2 Profile of rail
3 Profile of weld
4 Web
5 Foot

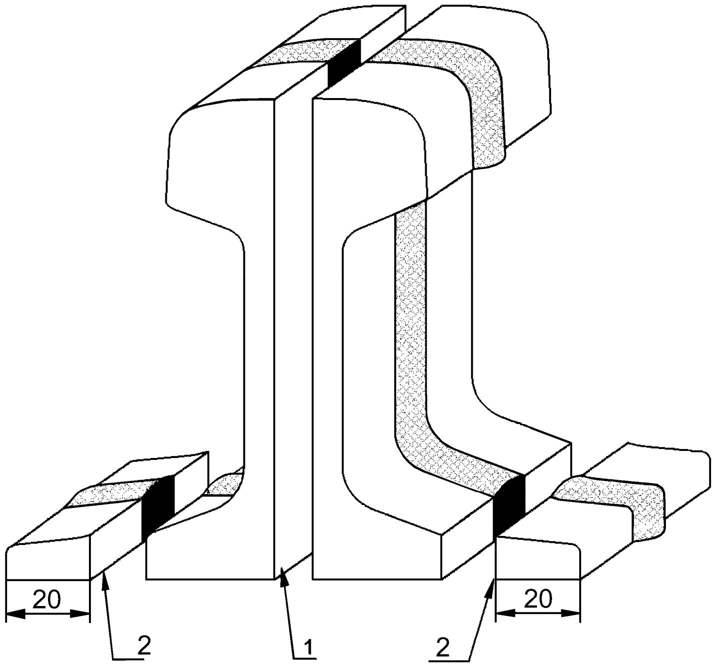
Figure 3 — Head, web and foot of the rail

7.4.1.2 The rails containing the welds shall then be sectioned to give:

— longitudinal vertical section on the symmetry plane (cut 1 in Figure 4);

— longitudinal vertical sections in the rail foot (cuts 2 in Figure 4);

— cuts as appropriate at least 5 mm from any apparent defects located by the ultrasonic testing method specified in Annex H. For each defect, the size shall be determined by progressively grinding and measuring until the maximum dimension is found.



Key

1 Longitudinal vertical section on centre line

2 Longitudinal vertical section of foot tip

Figure 4 — Sectioning of welds

7.4.1.3 Visual examination of the cut sections (polished to 220 grit) shall show no evidence of lack of fusion between the rail and fusion face.

The weld collar's edge is permitted to be unfused to the rail surface for a maximum of 2 mm from the edge of the collar unless a lesser figure is specified in the information supplied by the railway authority [Clause 4, h)].

7.4.1.4 The maximum dimension of any pores, slag inclusions, sand inclusions or metal beads shall be recorded. If multiple defects are revealed, they shall be counted and measured as a single defect if they are less than 1 mm apart. The maximum dimension of each defect shall be grouped in 1 mm size bands for the head, web and foot and summed for the number of sectioned welds examined in each test category of test G in Table 2 and Table 3. The size bands shall be as follows:

— Greater than 0 mm to 1 mm;

— Greater than 1 mm to 2 mm;

— Greater than 2 mm to 3 mm, etc.

Per population of test welds in test G in Tables 2 and 3:

— no more than one defect with maximum dimension greater than 2 mm in the region of the head above the line A-A on Figure 3 shall be permitted.

NOTE 1 The information on weld soundness collected by the requirements of this subclause is used for reference in the appropriate tests of Clause 6 required for process changes.

NOTE 2 Areas containing micro-porosity or inter-dendritic shrinkage are not counted as single defects and therefore are not taken into consideration.

7.4.1.5 Fracture faces revealed by the slow bend test specified in 7.3 and each of the fatigue test pieces specified in 7.5.3 shall be examined visually and a record made, in accordance with Annex G, of the maximum dimensions of any pores, slag inclusions, sand inclusions or metal beads. A summary of these defects will be made for each group of test specimens as per 7.4.1.4.

Per population of test welds in test G in Tables 2 and 3:

— no more than one volumetric defect with maximum dimension greater than 2 mm in the region of the head above the line A-A on Figure 3 shall be permitted.

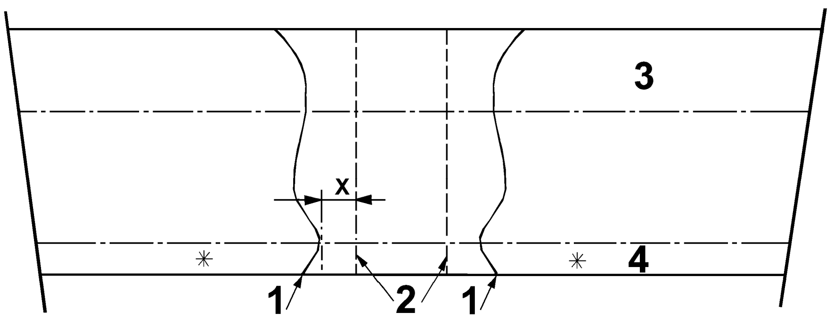
7.4.1.6 The above mentioned records shall be available to any railway authority.

7.4.2 Fusion zone – shape and dimension

7.4.2.1 Following FRY etching in accordance with Annex D, measurement of the fusion zone shall be made on the cuts illustrated in Figure 4.

7.4.2.2 The minimum distance X (Figure 5) between the parent rail end before welding and the fusion line shall be equal to or greater than 3 mm.

Measurement of X shall be made using datum marks to locate the original position of the rail ends.



Key

* Datum marks on foot tip
1 Fusion line
2 Rail ends before welding
3 Rail head
4 Rail foot

Figure 5 — Shape of fusion zone on the etched longitudinal vertical section

7.4.2.3 The fusion zone shall exhibit a nominally symmetrical shape about the welding gap.

7.4.3 Microscopic examination

7.4.3.1 General

Samples for microscopic examination shall be taken and prepared in accordance with Annex I.

7.4.3.2 Visible heat affected zone

The visible heat affected zone shall not contain any bainite or martensite examined at ×100 magnification. The structure shall be recorded.

7.4.3.3 Fusion zone

The structure of the fusion zone shall conform with that defined by the supplier, which shall not include martensite or bainite examined at ×100 magnification. In special cases the railway authority may permit a fully bainitic structure. The structure shall be recorded.

7.4.4 Heat softened zone width

The procedure for measuring the width of the heat softened zone is given in Annex J.

The heat softened zone on either side of the weld shall have one of the following widths which shall comply with the information supplied by the railway authority [Clause 4, i)].

Table 6 — Ranges of heat softened zone

Less than or equal to	Heat treated rail	Non-heat treated rail
20 mm	✓	✓
30 mm	✓	✓
40 mm	✓	✓
50 mm	✓	-
60 mm	✓	-

7.5 Fatigue test

7.5.1 Fatigue strength shall be evaluated by the staircase or past the post procedure in accordance with Annex K.

7.5.2 The fatigue strength in terms of the mean fatigue strength and standard deviation for the staircase method or the minimum value of upper stress in the rail foot for the past the post method shall comply with the information supplied by the railway authority [Clause 4 j)].

7.5.3 All test pieces remaining unbroken after fatigue testing shall be broken by slow bending in order to examine the fracture faces.

For staircase testing the fracture faces of those welds broken during fatigue testing shall be examined visually. If fatigue has initiated at a lack of fusion defect, the process shall be rejected.

The fracture faces of all welds, however broken, shall be examined for soundness in accordance with 7.4.1.5.

7.6 Chemical analysis

7.6.1 The supplier shall define the mean values for the concentration of each element of Table 7. Actual values shall not vary by more than the working range and this range shall fit within the permitted range.

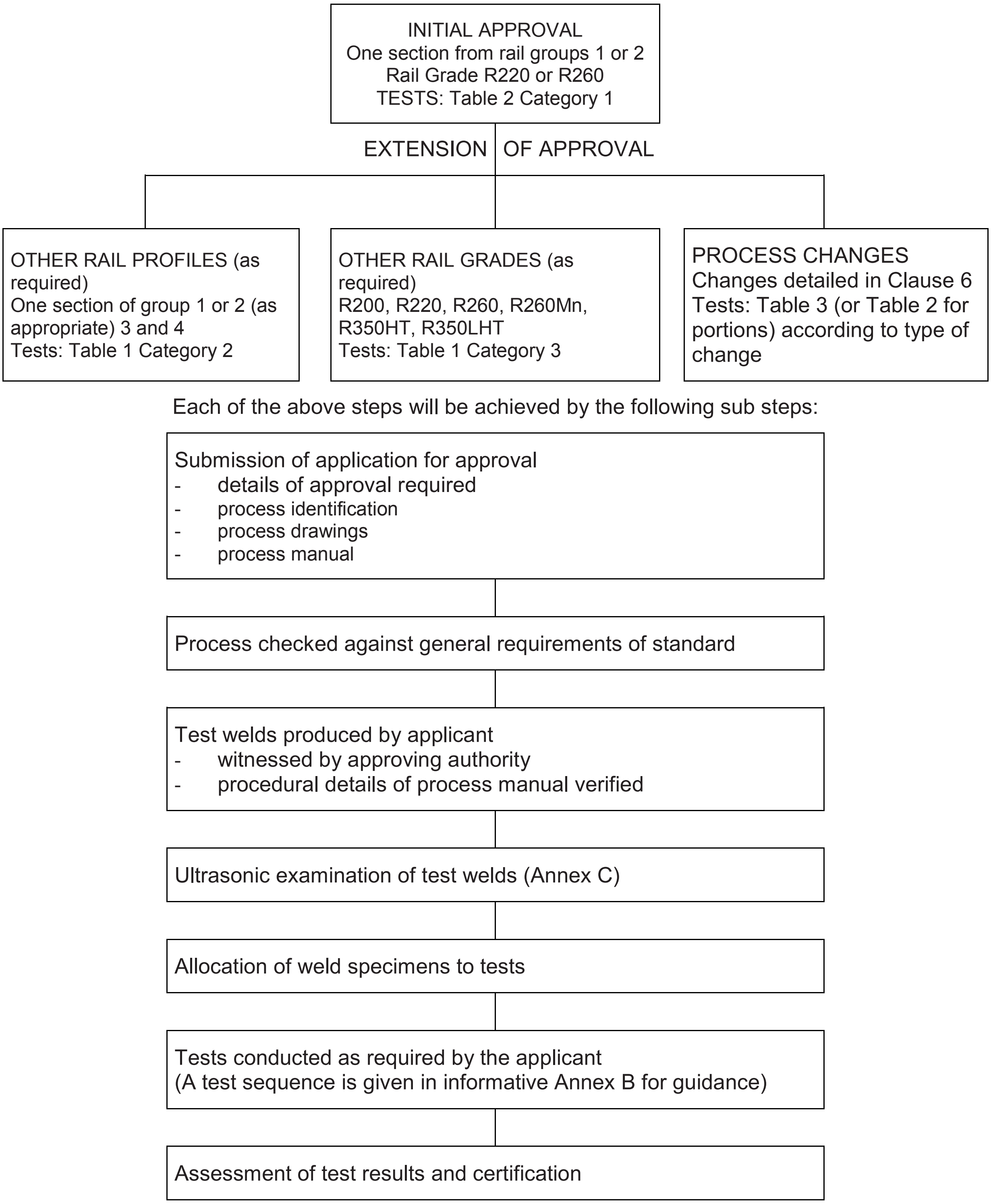
7.6.2 Chemical analysis is to be conducted on the rail weld running surface in the fusion zone at least 5 mm from the weld transverse axis and at least 5 mm from the limit of the fusion zone. Results of analysis shall fall within the ranges specified by the process supplier.

Table 7 — Chemical composition

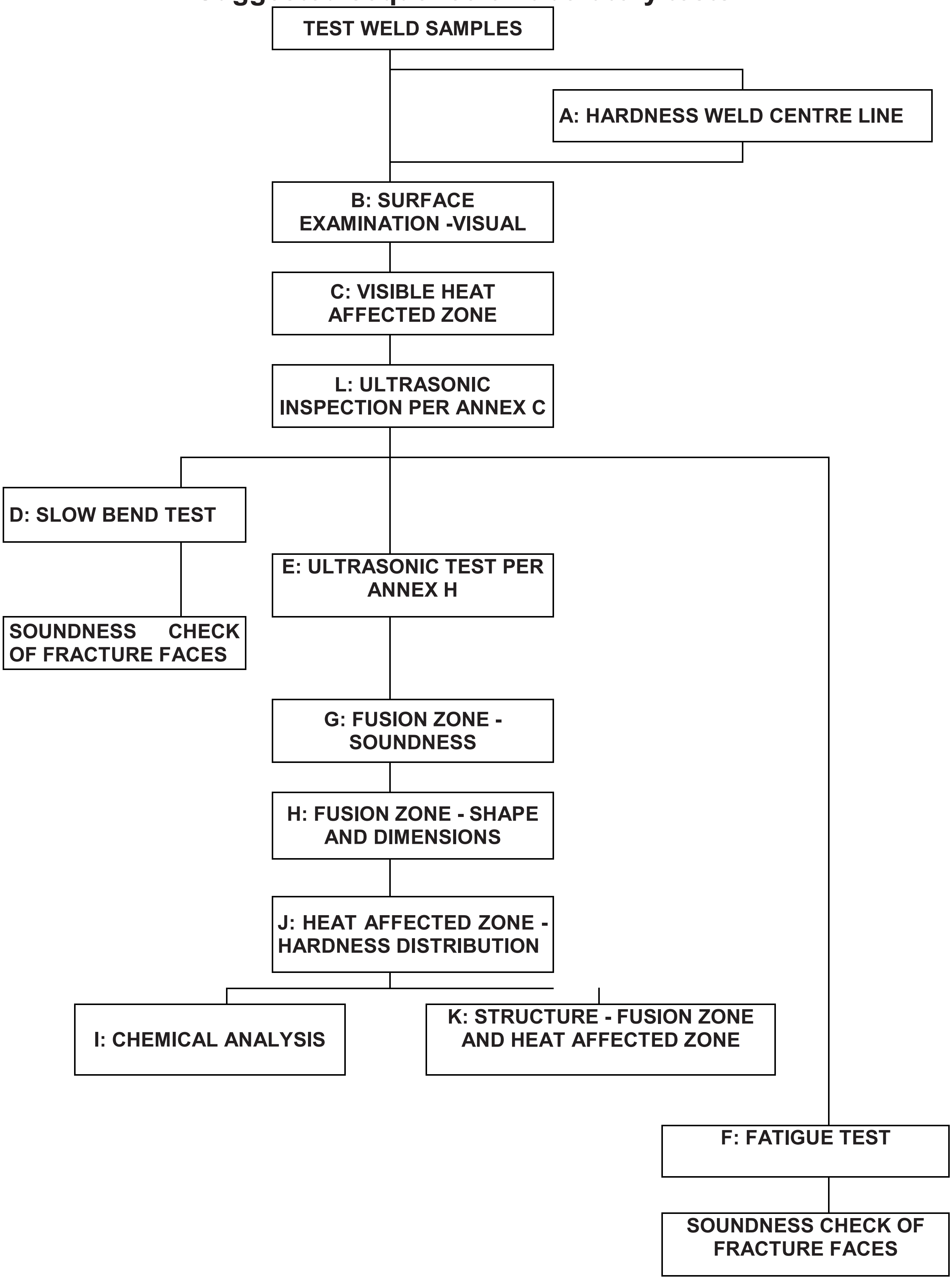
Element	Permitted range %		Working range	Rail grade EN 13674-1
	Minimum	Maximum		
Carbon	0,30 0,35 0,40 0,50	0,55 0,70 0,75 0,85	± 0,12 ± 0,12 ± 0,12 ± 0,12	R200 R220 R260, R260Mn R320Cr, R350HT, R350LHT
Silicon	0,00	1,20	±0,25	All
Manganese	0,40 0,45 0,50 0,50	1,00 1,20 1,40 1,60	± 0,20 ± 0,20 ± 0,20 ± 0,20	R200 R220 R260, R320Cr, R350HT, R350LHT R260Mn
Phosphorous	0,00	0,035	—	All
Sulphur	0,00	0,035	—	All
Chromium	0,00 0,00	0,20 0,80	— ± 0,20	R200, R220, R260, R260Mn R320Cr, R350HT, R350LHT
Molybdenum	0,00	0,10	—	All
Nickel	0,00	0,10	—	All
Aluminium	0,02	0,60	± 0,20	All
Copper	0,00	0,20	—	All
Tin	0,00	0,02	—	All
Antimony	0,00	0,02	—	All
Titanium	0,00	0,05	—	All
Niobium	0,00	0,01	—	All
Vanadium	0,00 0,00 0,00	0,25 0,45 0,65	— — —	R200, R220, R260, R260Mn R320Cr R350HT, R350LHT

Annex A
(informative)

Steps in approval



Annex B
(informative)
Suggested sequence of laboratory tests



Annex C
(normative)

Ultrasonic testing procedure for aluminothermic welds in rail

C.1 A test of the head zone of the weld (non-planar defects)

Probes – one double-crystal 70° transverse wave; frequency 2 MHz.

Probe position for the test – the running surface of the rail.

!A1) Calibration sensitivity: adjust the gain level of the flaw detector until the signal from the hole B1 is at 50 % of full screen height.

Action level – any defect signals ≥ 50 % of full screen height. (A1!

C.2 A test of the head zone of the weld (planar defects)

Probes – two single-crystal 70° transverse wave; frequency 2 MHz.

Additional apparatus – mechanical rig to assist the positioning of the probes.

Probe position for the test – the sides of the rail head.

!A1) Calibration sensitivity: adjust the gain level of the flaw detector until the signal from the hole R1 is at 50 % of full screen height.

Action level – any defect signals ≥ 50 % of full screen height. (A1!

C.3 A test of the head and web zone of the weld (planar defects)

Probes – two single-crystal 45° transverse wave; frequency 2 MHz.

Additional apparatus – mechanical rig to assist the positioning of the probes.

Probe position for the test – the running surface of the rail.

!A1) Calibration sensitivity: adjust the gain level of the flaw detector until the signal from the hole R2 is at 50 % of full screen height.

Action level – any defect signals ≥ 50 % of full screen height. (A1!

C.4 A test of the middle zone of the foot of the weld

Probe – one single-crystal 45° transverse wave; frequency 2 MHz or 4 MHz.

Probe position for the test – the running surface of the rail.

[A1⟩ Calibration sensitivity: adjust the gain level of the flaw detector until the signal from the hole R3 is at 50 % of full screen height.

Action level – any defect signals ≥ 50 % of full screen height. ⟨A1]

C.5 A test of the ankle zone of the foot of the weld

Probe – one single crystal 70° transverse wave; frequency 2 MHz or 4 MHz.

Probe position for the test – the upper surface of the ankle, on the rail adjacent to the weld.

[A1⟩ Calibration sensitivity: adjust the gain level of the flaw detector until the minimum signal from the hole B3 or B’3 is at 50 % of full screen height.

Action level – any defect signals ≥ 50 % of full screen height. ⟨A1]

C.6 A test of the toe zone of the foot of the weld

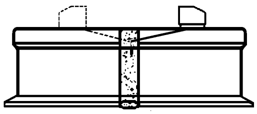
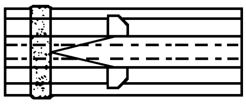
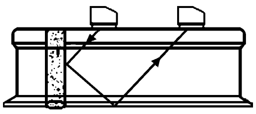
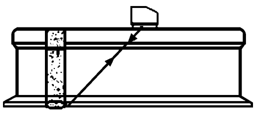
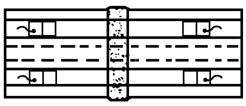
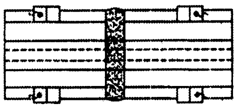
Probe – one single-crystal 70° transverse wave; frequency 2 MHz or 4 MHz.

Probe position for the test – the upper surface of the toe, on the rail adjacent to the weld.

[A1⟩ Calibration sensitivity: adjust the gain level of the flaw detector until the minimum signal from the holes B4 or B’4 is at 50 % of full screen height.

Action level – any defect signals ≥ 50 % of full screen height. ⟨A1]

Table C.1 — Positioning of probes

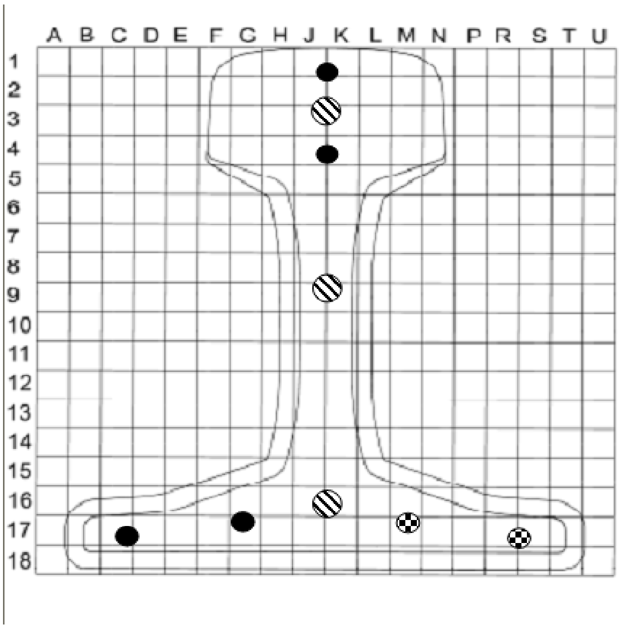
Summary of test			
1	Test of head for non-planar defects		One 70° double crystal probe from both sides
2	Test of head for planar defects		Two 70° single crystal probes (TX & RX)
3	Test of web for planar defects		Two 45° single crystal probes in tandem with a positioning rig
4	Test of middle of foot		One 45° single crystal probe from both sides
5	Test of ankles		One 70° single crystal probe
6	Test of toes		One 70° single crystal probe
	Total number of probes required:	6 or 7	

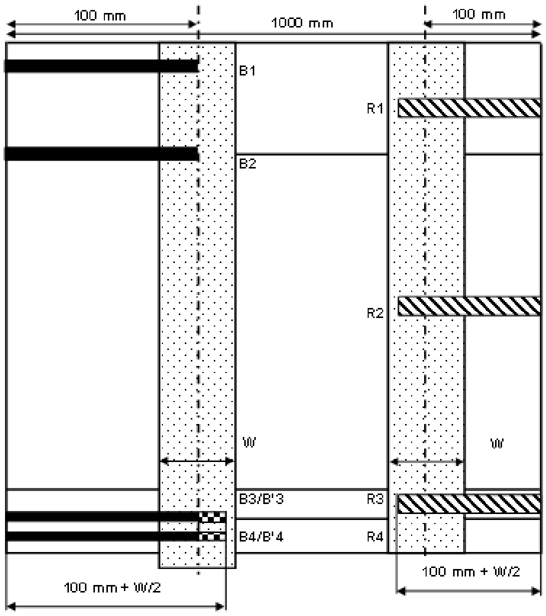
C.7 A1 Calibration

Timebase - Using the calibration block, see Figure C.1, for each test (C.1 to C.6) calibrate the timebase according to the reference hole used for the calibration sensitivity. The timebase shall be wide enough to do the examination of the whole concerned zone.

Sensitivity - Using the calibration block, the calibration sensitivity is defined for each test (C.1 to C.6).

The positioning of the probes is given in Table C.1.





Key

(dotted)	weld (right weld shall have weld collar ground flush under the foot)
(dash-dot line)	weld centre line
(solid)	Φ 5 mm flat bottomed hole (in depth of 100 mm)
(checkered)	Φ 5 mm flat bottomed hole (in depth of 100 mm +W/2 mm)
(hatched)	Φ 10 mm flat bottomed hole (in depth of 100 mm +W/2 mm)
W	nominal gap

Figure C.1 — Positioning of the holes (front view and side view) A1

Annex D
(normative)

Procedure for FRY etching

Many of the macrostructure characteristics are measured following FRY etching which is conducted using the following method.

The etching agent should have the following chemical composition (for 10 l):

— 1,875 kg cupric chloride ($CuCl_2.2H_20$);

— 5 l hydrochloric acid (HCl 1,18 g/ml – 35 %);

— 4,2 l distilled water.

Macro-etching at room temperature shall be for sufficient time (minimum 30 min) to clearly show the boundary lines. Sample polished to minimum 220 grit paper.

Annex E
(normative)

Procedure for measurement of surface hardness

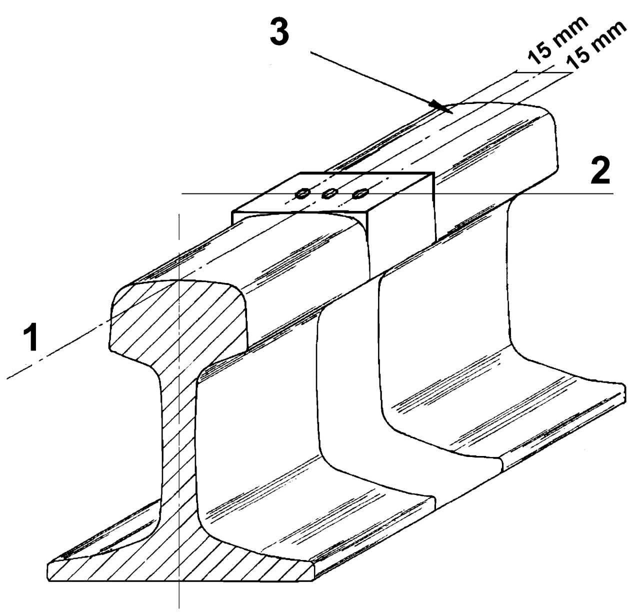
Brinell hardness tests shall be carried out in accordance with EN ISO 6506-1 using:

— 10 mm diameter tungsten carbide ball;

— Test load 3000 kg;

— load application time of 15 s.

The top of the test weld shall be ground to produce a flat surface which is tangential to the rail crown at the point of intersection with the rail vertical axis in accordance with Figure E.1.



Key

1 Rail crown centre line
2 Weld transverse centre line
3 Rail running surface

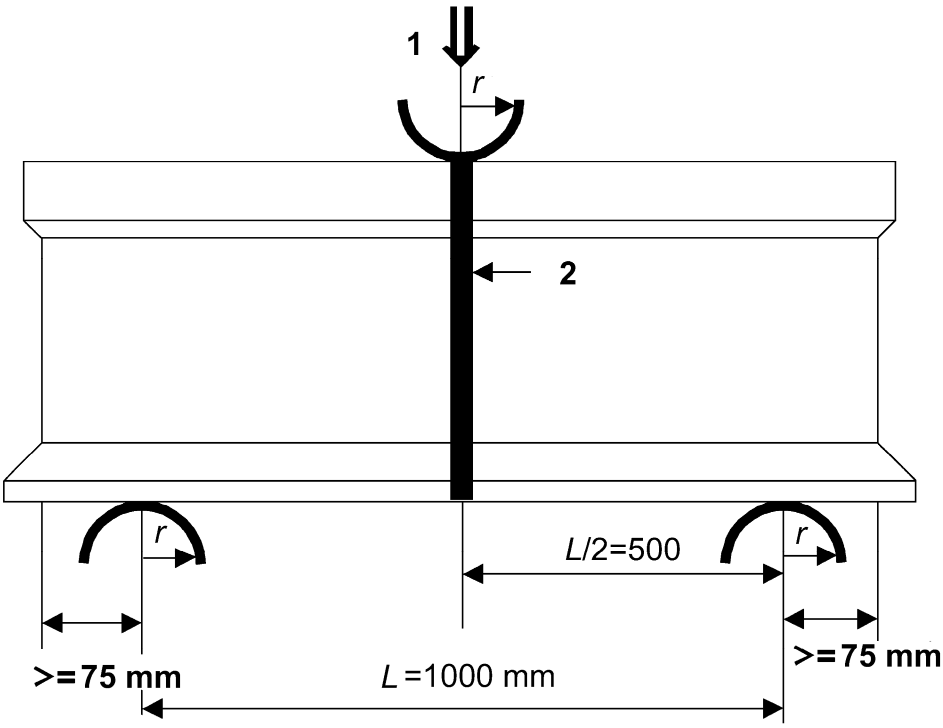
Figure E.1 — Location of surface hardness tests

Three hardness values shall be determined for each weld as shown in Figure E.1.

Annex F
(normative)

Procedure for slow bend test

The key dimensions for the slow bend test apparatus are given in Figure F.1.



Key

1 Load

2 Weld

25 mm ≤ r ≤ 70 mm

Minimum sample length = 1150 mm

Loading rate ≤ 60 kN/s.

Figure F.1 — Slow bend test schematic

The load shall be applied to the running surface of the weld by a single fulcrum. The test shall continue until fracture.

Forces shall be measured using a load cell verified to EN ISO 7500-1:2004, grade 2.0.

Annex G
(normative)

Procedure for recording test weld fracture face defects

A record of any defects found on the fracture face of each weld shall be made on a rail profile grid (Figure G.1). The record shall include the following details:

- type of defect;
- surface dimensions;
- shape;
- location;
- depth of pores;
- whether surface breaking.

The record will show the test weld identification and whether the weld was used for slow bend or fatigue testing.

A weld fracture face containing no defects shall have the rail profile grid clearly worded “No visible defects”.

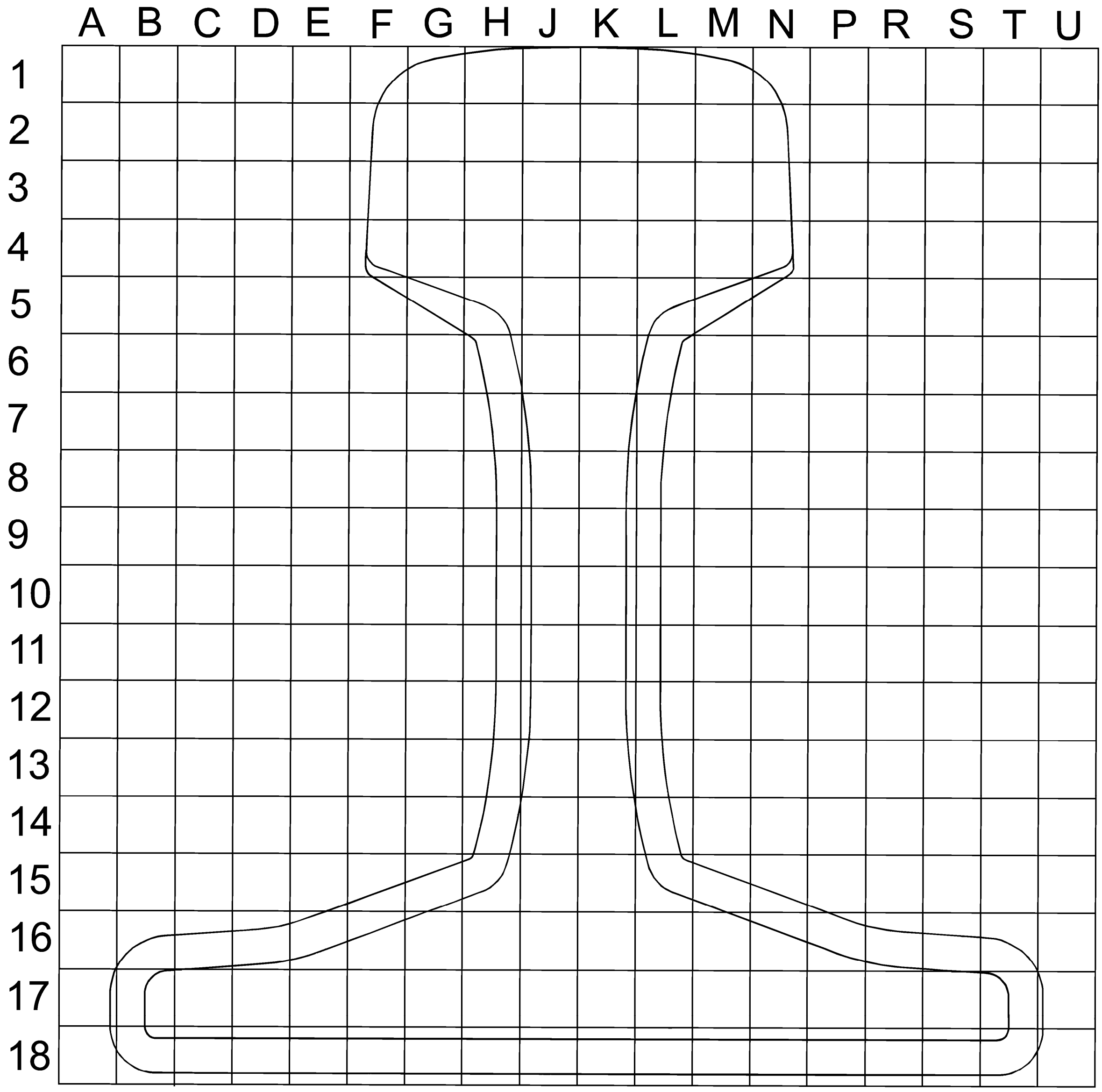


Figure G.1 — Rail profile grid

Annex H
(normative)

Ultrasonic inspection procedure on aluminothermic welds to be sectioned

H.1 Principle

This procedure concerns the use of an ultrasonic method for examination of aluminothermic welds in rail specimens to be sectioned. The method is able to detect transverse-vertical 'lack-of-fusion' defects, large gas pores and 'hot tears' caused by rail movement. This procedure shall establish the location of defects relative to the rail cross-section and shall provide an estimation of their transverse extent. If more accurate sizing is required, other ultrasonic procedures shall be applied. Personnel using this procedure shall be qualified to EN 473.

H.2 Apparatus

Ultrasonic flaw detector approved by the railway authority.

Double crystal, 0° compression wave probe, of 20 mm diameter and frequency 4 MHz to 5 MHz.

Metric universal calibration block for general purpose checking.

H.3 Preparation of samples

A section of rail containing the aluminothermic weld shall be prepared by making two transverse cuts, one on each side of the weld at equidistant spacing from the edge of the weld collar. The cuts shall be perpendicular to the longitudinal axis of the weld, parallel to each other and to the weld collar. The length between the cut faces shall be between 180 mm and 200 mm in the case of standard-width welds and between 210 mm and 230 mm in the case of wide-gap welds.

H.4 Calibration

Timebase – using the metric calibration block calibrate the timebase of the flaw detector

For aluminothermic welds with normal gaps up to 30 mm, the timebase shall be calibrated to 10 mm per scale division (i.e. 400 mm full screen width).

For aluminothermic welds with normal gaps above 30 mm, the timebase shall be calibrated to 20 mm per scale division (i.e. 400 mm full screen width).

Sensitivity – place the probe on one of the surfaces of the cut sample and obtain a signal from the opposite face. Adjust the gain level until the signal is at 100 % of screen height. The sensitivity level shall be reset for each face of each sample tested.

H.5 Testing

Place the probe on one of the transverse-cut faces and obtain the full screen height signal from the opposite parallel face. Scan the whole area of the rail section and note the presence of any signals and any zones where the signal from the opposite face falls below 50 % of full screen height.

If a signal or a decrease in backwall signal is detected, determine the limits of the defective zone by probe movement and mark these limits on the face being scanned.

If signals are detected, use the timebase to determine their depth below the scanned surface. In each case note the depth and note the amplitude of the signal.

Repeat the scan from the other transverse-cut face.

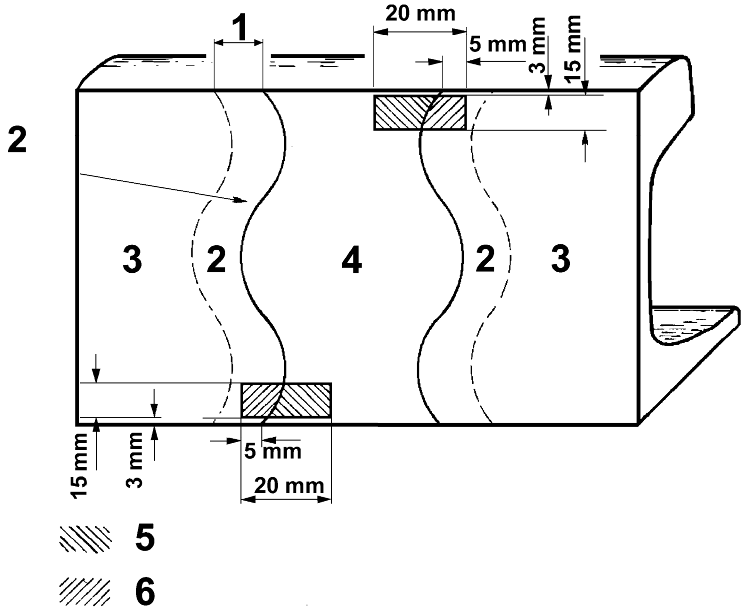
H.6 Reporting

The extent and depth of any defect found shall be marked on the sample and reported for further investigation.

Annex I
(normative)

Procedure for microscopic examination of the visible heat affected zone and fusion zone of welds

Samples for microscopic examination shall be taken in accordance with Figure I.1. The samples shall be prepared and etched in 4 % Nital.



Key

1 Width of the visible heat affected zone to be measured at the weld longitudinal centre line of the running surface

2 Visible heat affected zone

3 Unaffected parent rail

4 Weld fusion zone

5 Area of fusion zone to be examined microscopically

6 Area of visible heat affected zone to be examined microscopically

Figure I.1 — Scheme for taking samples for microscopic examination

Annex J
(normative)

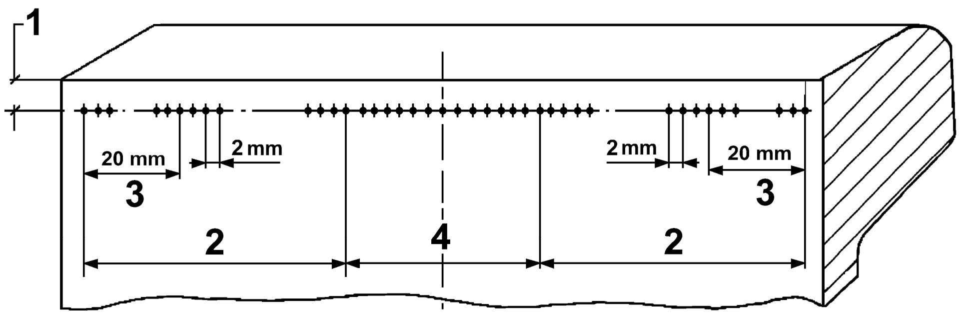
Procedure for measurement of the heat softened zone width

J.1 Measurement of hardness

The hardness distribution of the heat softened zone shall be measured using the Vickers hardness test in accordance with EN ISO 6507-1 and a load of 30 kg.

Impressions shall be on a line between 3 mm and 5 mm below the rail running surface on the longitudinal axis of the rail.

The hardness traverse shall extend across and to both sides of the weld continuing until 20 mm of unaffected parent rail hardness has been encountered. Measurement shall be made at points 2 mm apart as shown in Figure J.1.



Key

1 Depth between 3 mm and 5 mm

2 Parent rail

3 Unaffected parent rail

4 Fusion zone

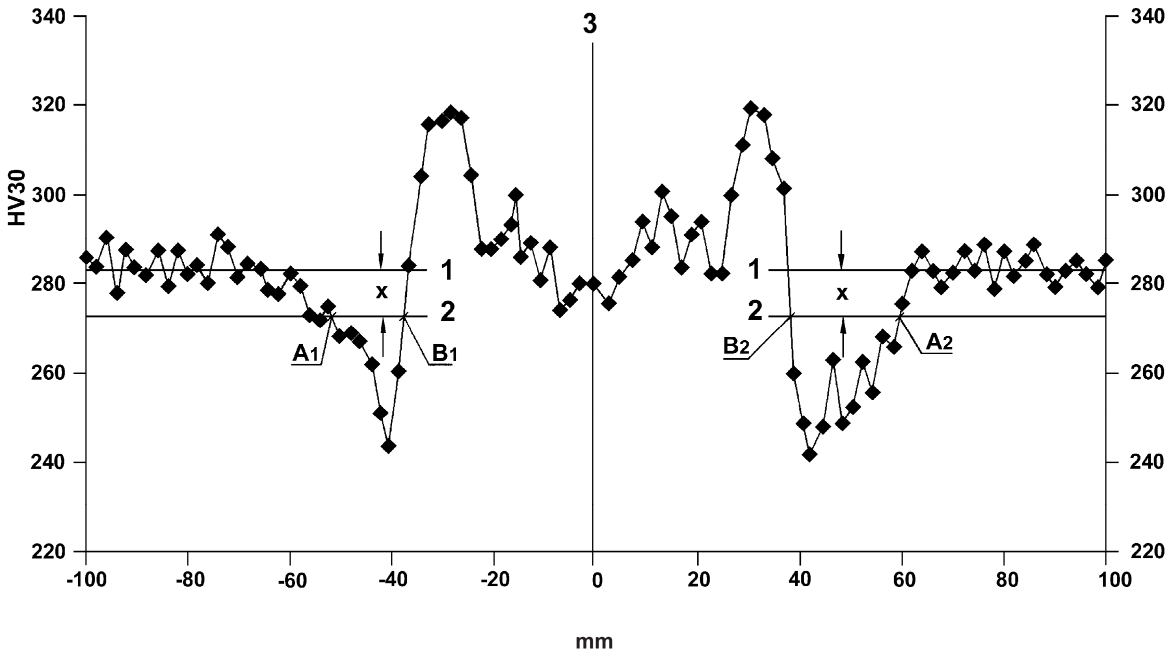
Figure J.1 — Longitudinal hardness measurement

Hardness measurements obtained shall be recorded numerically and graphically.

J.2 Evaluation of hardness data

J.2.1 General

Hardness measurements shall be graphically shown as in Figure J.2.



Key

1 Line 1
2 Line 2
3 Weld centre line

Note Figure not to scale

Figure J.2 — Typical hardness profile

J.2.2 Mean hardness of parent rail

The mean hardness of the parent rail on either side of the weld is calculated from a minimum of ten hardness measurements taken at intervals of 2 mm in the unaffected parent rail. A line equal to the mean hardness is marked on the hardness graphs for each side of the weld as shown (Line 1).

J.2.3 Measurement hardness line

The measurement hardness line (Line 2) is marked parallel to the mean hardness line, and at a distance of X hardness points below the mean hardness line. The value of X varies with the rail grade:

— X=10 for: Grade R200, Grade R220, Grade R260, Grade R260Mn, Grade R320Cr;

— X=25 for: Grade R350HT, Grade R350 LHT.

J.2.4 Heat softened zone width measurement

The heat softened zone width is defined as the distance between points A and B in Figure J.2 above.

J.2.5 Parent rail hardness variation

In some cases the unaffected parent rail may have a large standard deviation of hardness about the mean. This 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 can be ignored if a) and b) 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 J.2.

Annex K
(normative)

Fatigue test methods for aluminothermic welds

K.1 Scope

This annex describes the staircase test method (see K.4.2) to establish the fatigue strength distribution of a weld at an endurance of 5 million 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 past-the-post method (see K.4.4) is also described for testing three welds, none of which shall break at a defined cyclic stress level.

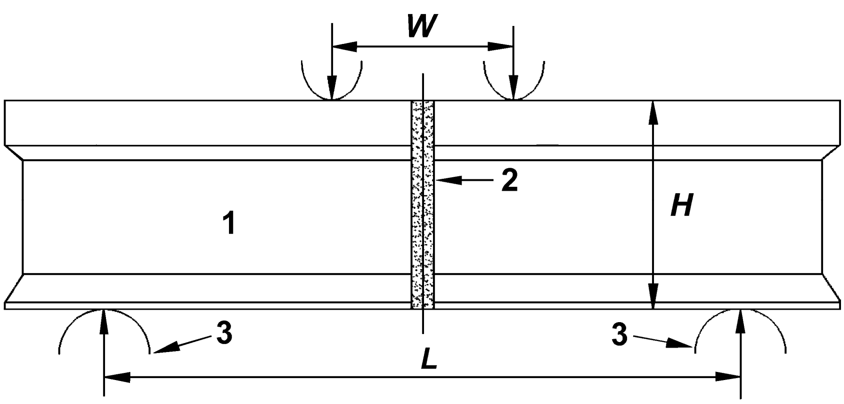
The relationship of the applied load to the nominal outer fibre stress is established using a length of plain rail, strain-gauged and load-cycled at the frequency of the test.

K.2 Test equipment

K.2.1 Tests shall be conducted in four point bending with the rail foot in tension.

The inner span (*W*) shall be minimum 150 mm plus weld collar width under the foot. The outer span (*L*) shall exceed the inner span by at least twice the rail height and shall be symmetrical about the inner span.

$L \geq W + 2 \cdot H$



Key

1 Rail
2 Weld
3 Bearer

Figure K.1 — Fatigue test arrangement

K.2.2 The inner and outer spans shall be measured and recorded.

K.2.3 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 should not differ by more than 3 mm.

K.2.4 The radius of curvature of the loading points shall not be less than 40 mm. The loading point contact surfaces shall be free to translate or rotate so that friction between the loading points and the specimen is minimised.

NOTE High contact stresses may result in cracks developing at the loading points. The use of arrangements that minimize contact stresses at the loading points is therefore advised. Contact stresses may be further reduced by increasing the outer span and so reducing the force required to achieve a given applied bending moment.

K.2.5 The applied force should be measured using a fatigue rated load cell verified to EN ISO 7500-1:2004, Grade 1.0.

NOTE Depending on the outer span, a 500 kN or 1000 kN actuator is likely to be suitable for most applications.

K.3 Calibration procedure

K.3.1 General

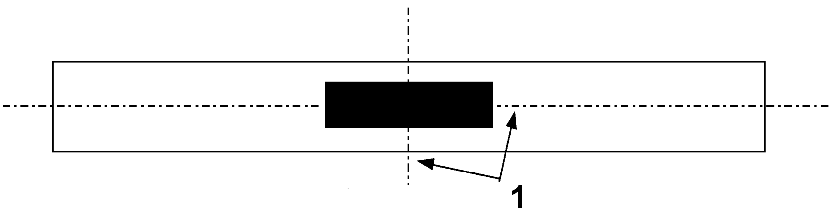
This clause describes the determination of the relationship between the nominal outer fibre stress and the applied load.

K.3.2 Test piece

The test piece shall be a section of new rail of the profile under consideration with a length exceeding that of the outer span of the test rig by no more than 100 mm.

K.3.3 Test piece preparation

Attach a strain gauge to the foot of the rail as shown in Figure K.2. Use a gauge of nominally 350 Ω resistance and a gauge length of 6 mm. The gauge factor shall be known to an accuracy of 1 %. Attach three similar gauges to an independent block of the same steel.



Key

1 Centre lines of gauge and rail to coincide

Figure K.2 — Location of gauge

NOTE For more detailed instructions on the fitment and use of strain gauges, it is recommended to refer to specialist manuals.

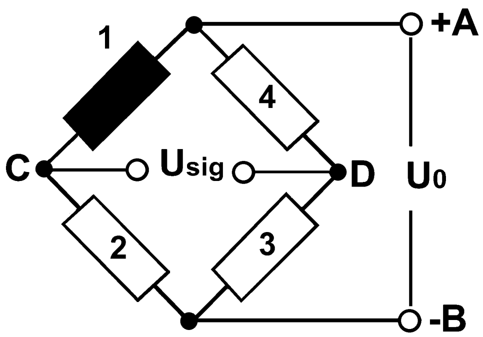
K.3.4 Instrumentation

A digital voltmeter, with peak reading circuits accurate to 1 part in 1000 at the test frequency, shall be used.

K.3.5 Procedure

K.3.5.1 Mount the rail in the test rig with the strain gauge positioned directly beneath the actuator. The rail shall be mounted so that the application of compressive loads by the actuator places the foot of the rail in tension. Position the independent block adjacent to the test piece. Wire the gauges to form a Wheatstone bridge circuit as shown schematically in Figure K.3. Apply a constant voltage of approximately 9 V d.c. between points A and B with A positive with respect to B.

Allow the system to stabilise for one hour before taking measurements. Measure and record the value of this voltage as U_0.



Key

1 Strain gauge on the test piece

2, 3, 4 Unstrained gauges on the independent block

Figure K.3 — Circuit diagram (schematic)

NOTE The wires connecting the active gauge to the remainder of the bridge should be of equal length and twisted together.

K.3.5.2 Let the nominal outer fibre stress = σ. For the range of values of σ_j given in Table K.1, calculate U_{sig} using the formula:

[A1) $U_{sig} = (\sigma_j \cdot gf \cdot U_0) / (4 \cdot E)$ (K.1) (A1]

where:

U_{sig} = the voltage increase between C and D when σ is increased from 0 to σ_j

gf = the gauge factor of the strain gauge on the rail

U_0 = the voltage applied to the bridge

E = Young's modulus, to be taken as 210 GPa

K.3.5.3 Apply a cyclic force to the rail with a sinusoidal waveform and a frequency equal to that to be used for fatigue testing. For k = 1 to 8 (see Table K.1) vary the applied minimum and maximum force until the maximum and minimum values of U_{sig} associated with the paired values of σ_j are achieved. Record the associated forces indicated by the load cell. Repeat three times, going through the full range of stresses on each occasion.

Table K.1 — Values of σ_j (MPa) for which U_{sig} is to be determined

k	σ_j (MPa)	σ_j (MPa)
1	15	150
2	17	170
3	19	190
4	21	210
5	23	230
6	25	250
7	27	270
8	29	290

K.3.5.4 Ignoring the first group of tests, tabulate the results as shown in Table K.2.

K.3.5.5 Using the data given in Table K.2, create dynamic calibration curves showing the maximum cyclic stress, and the stress range as a function of forces measured by the load cell, at the test frequency to be used.

Table K.2 — Calibration results

k	σ_j (MPa)	$U_{sig.}$ (v)	Associated force (kN)	Average force $F_{k\,min}$ (kN)	σ_j (MPa)	U_{sig} (v)	Average force (kN)	Average force $F_{k\,max}$ (kN)	ΔF_k (kN)
1	15				150				
							a		
2	17				170				
3	19				190				
4	21				210				
5	23				230				
6	25				250				
7	27				270				
8	29				290				

a $\Delta F_k = F_{k\,max} - F_{k\,min}$

K.4 Fatigue test method

K.4.1 General

The railway authority has the option according to Clause 4 j) and 7.5.1 to select either a staircase (see K.4.2) or a past-the-post test (see K.4.4).

K.4.2 Staircase testing method

K.4.2.1 Test pieces

Ten test-pieces are required. 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.

K.4.2.2 Procedure

K.4.2.2.1 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.

K.4.2.2.2 Determine the maximum stress associated with the mean fatigue strength at 5 million cycles required by the railway authority.

EXAMPLE If the mean fatigue strength is to be not less than a stress range of 230 MPa when the ratio of the minimum to maximum applied stress (*R*) is 0,1, then the maximum stress will be 230/(1 - *R*) = 256 MPa.

From the calibration curves created in K.3.5.5, determine the maximum force and the force range corresponding to these values of maximum stress and stress range.

K.4.2.2.3 Cyclically load the weld using a sinusoidal waveform so that the maximum value of force, and the range derived in K.4.2.2.2 are achieved. The indicated maximum load and load range shall both be maintained to within 2 % of the nominal value required. Continue cycling until either the test piece breaks or 5 million cycles have been applied.

K.4.2.2.4 If the test piece breaks, the test result shall be recorded as a 'failure'. If it does not fail it shall be recorded as a 'run-out'. The cyclic force range and nominal outer fibre stress range shall also be recorded.

K.4.2.2.5 Where the test results in a run-out, repeat the test on another test piece but increase the cyclic force range by an amount corresponding to an increase in the nominal outer fibre stress range in the foot of 10 MPa. Where the test result is a failure, repeat the test on another test piece with the maximum foot stress range reduced by 10 MPa. In both cases the minimum load applied shall be 10 % of the maximum.

K.4.2.2.6 Continue as above until ten test pieces have been tested.

K.4.2.3 Data analysis

K.4.2.3.1 Results are all failures or all run-outs

No data analysis is required.

K.4.2.3.2 Both failures and run-outs obtained

Estimate the mean value and standard deviation of the fatigue strength as follows.

Determine first of all whether failures or run-outs are the less frequent events. Then calculate the mean fatigue strength σ_m using the formula:

$$\sigma_m = \sigma_0 + d \cdot \left(\frac{A}{N} \pm 0{,}5 \right) \quad \text{(K.2)}$$

where:

σ_0 is the lowest stress range at which tests with the less frequent result were conducted (MPa)

d = 10 MPa

A = $\Sigma\, i \cdot n_i$ where i ranges from 0 to z

$N = \Sigma\, n_i$ where i ranges from 0 to z = total number of less frequent events

where:

n_i = number of less frequent events at the i-th stress level above σ_0

i = coded stress level (i = 0 for σ_0)

z = number of stress levels above σ_0 at which testing has been undertaken

In the formula use (A/N) + 0,5 if the less frequent event is a run-out and (A/N) - 0,5 if the less frequent event is a failure.

Calculate the standard deviation using the formula:

$$s = 1{,}62 \cdot d \cdot \left(\frac{B \cdot N - A^2}{N^2} + 0{,}029 \right) \quad \text{(K.3)}$$

where:

$B = \Sigma\, i^2 n_i$

K.4.2.3.3 Information to be reported

For each test series the following shall be reported:

— The inner and outer spans of the test rig (K.2.2);

— The distances from the centre line of the actuator to the loading points (K.2.3);

— Dynamic calibration results (K.3.5.4);

— The mean and standard deviation of the fatigue strength at 5 million cycles if calculated according to the procedure given in K.4.2.3.2.

For each test, report:

— The maximum force range applied;

— The nominal outer fibre stress range applied;

— Whether the test resulted in a failure or a run-out;

— In the case of failure, the crack initiation location.

K.4.2.4 Acceptance criteria

K.4.2.4.1 All results are failures

The process is not acceptable.

K.4.2.4.2 All results are run-outs

The process is acceptable.

K.4.2.4.3 Both run-outs and failures occur

The mean fatigue strength shall exceed the value specified by the railway authority and the standard deviation shall be less than the value specified by the railway authority

If the calculated value of $s \leq 5{,}3$ MPa, the standard deviation is small and shall be deemed acceptable. However the value given by Equation K.3 will be spurious.

K.4.3 Example of the data analysis of a fatigue strength determination by the staircase method

Table K.3 — experimental results

σ	1	2	3	4	5	6	7	8	9	10	i	n_i	in_i	i^2n_i
230			x								2	1	2	4
220		0		x				x		0	1	2	2	2
210	0				x		0		0		0	1	0	0
200						0								
											N	4		
											A		4	
											B			6

Number of Failures (x): 4 less frequent event

Number of Run outs (0): 6

The lowest stress range at which a failure occurs (σ_0) is 210 MPa. As failure is the less frequent event, the form of the Equation K.2 which shall be used is:

$$\sigma_m = \sigma_0 + d \cdot \left(\frac{A}{N} \pm 0{,}5 \right) = 210 + 10 \cdot \left(\frac{4}{4} - 0{,}5 \right) \text{ MPa} = 215 \text{ MPa}$$

The standard deviation according to Equation K.3 is:

$$s = 1{,}62 \cdot d \cdot \left(\frac{B \cdot N - A^2}{N^2} + 0{,}029 \right) = 1{,}62 \cdot 10 \cdot \left(\frac{6 \cdot 4 - 4^2}{4^2} + 0{,}029 \right) \text{ MPa} = 8{,}6 \text{ MPa}$$

K.4.4 Past-the-post testing method

K.4.4.1 Test pieces

Three test-pieces are required. 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.

K.4.4.2 Procedure

K.4.4.2.1 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.

K.4.4.2.2 The maximum applied stress is specified by the railway authority. The minimum stress applied shall be 10 % of the maximum stress. No failures are acceptable at an endurance of less than 5 million cycles.

From the calibration curves created in K.3.5.5, determine the maximum force and the force range corresponding to these values of maximum stress and stress range.

K.4.4.2.3 Cyclically load the weld using a sinusoidal waveform so that the maximum and minimum stress values are achieved. The indicated values shall both be maintained to within 2 % of the nominal value required. Continue cycling until either the test piece breaks or 5 Mc 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'.

K.4.4.3 Information to be reported

For each test series the following shall be reported:

— The inner and outer spans of the test rig (K.2.2);

— The distances from the centre line of the actuator to the loading points (K.2.3);

— Dynamic calibration results (K.3.5.4);

— The outer fibre stresses applied (K.4.4.2.2).

For each test, report:

— Whether the test resulted in a failure or a run-out;

— In the case of failures, the crack initiation location.

K.4.4.4 Acceptance criterion

If any test-piece breaks at less than 5 million cycles, the process shall be rejected.

Annex L
(informative)

A–deviations

A-deviation: National deviation due to regulations, the alteration of which is for the time being outside the competence of the CEN/ CENELEC member.

This European Standard does not fall under any Directive of the EU.

In the relevant CEN/ CENELEC country this A-deviation is valid instead of the provisions of the European Standard until it has been removed.

Switzerland:

Application guide for railway regulation dated 2002-12-01, article 31, page number 9N, 6, clause 5:

The minimum bending (base 1000 mm, tensile strength at the rail foot) is 10 mm during the static bending test at fracture, not taken into account profile size and steel grade.

BSI - British Standards Institution

BSI is the independent national body responsible for preparing British Standards. It presents the UK view on standards in Europe and at the international level. It is incorporated by Royal Charter.

Revisions

British Standards are updated by amendment or revision. Users of British Standards should make sure that they possess the latest amendments or editions.

It is the constant aim of BSI to improve the quality of our products and services. We would be grateful if anyone finding an inaccuracy or ambiguity while using this British Standard would inform the Secretary of the technical committee responsible, the identity of which can be found on the inside front cover. Tel: +44 (0)20 8996 9000. Fax: +44 (0)20 8996 7400.

BSI offers members an individual updating service called PLUS which ensures that subscribers automatically receive the latest editions of standards.

Buying standards

Orders for all BSI, international and foreign standards publications should be addressed to Customer Services. Tel: +44 (0)20 8996 9001. Fax: +44 (0)20 8996 7001 Email: orders@bsigroup.com You may also buy directly using a debit/credit card from the BSI Shop on the Website http://www.bsigroup.com/shop

In response to orders for international standards, it is BSI policy to supply the BSI implementation of those that have been published as British Standards, unless otherwise requested.

Information on standards

BSI provides a wide range of information on national, European and international standards through its Library and its Technical Help to Exporters Service. Various BSI electronic information services are also available which give details on all its products and services. Contact Information Centre. Tel: +44 (0)20 8996 7111 Fax: +44 (0)20 8996 7048 Email: info@bsigroup.com

Subscribing members of BSI are kept up to date with standards developments and receive substantial discounts on the purchase price of standards. For details of these and other benefits contact Membership Administration. Tel: +44 (0)20 8996 7002 Fax: +44 (0)20 8996 7001 Email: membership@bsigroup.com

Information regarding online access to British Standards via British Standards Online can be found at http://www.bsigroup.com/BSOL

Further information about BSI is available on the BSI website at http://www.bsigroup.com

Copyright

Details and advice can be obtained from the Copyright and Licensing Manager. Tel: +44 (0)20 8996 7070 Email: copyright@bsigroup.com

BSI Group Headquarters 389 Chiswick High Road, London, W4 4AL, UK
Tel +44 (0)20 8996 9001
Fax +44 (0)20 8996 7001
www.bsigroup.com/standards