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Railway applications — Infrastructure — Aluminothermic welding of grooved rails

bsi.

National foreword

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CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

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European foreword

This document (EN 16771:2016) 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of an identical text or by endorsement, at the latest by May 2017, and conflicting national standards shall be withdrawn at the latest by May 2017.

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Introduction

This standard defines the approval procedure for aluminothermic welding processes for grooved 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, grooved rails as described in EN 14811 of the same profile and steel grade. Welding of construction profiles and machined profiles are not covered in this standard.

Compliance with the requirements of this standard does not in 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, worn rails or 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 documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

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

EN ISO 9712, *Non-destructive testing - Qualification and certification of NDT personnel (ISO 9712)*

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 the 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 (Heat Affected Zone) 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 testing that has not already been identified as a surface defect

3.7
railway authority
railway regulator, or owner of a railway infrastructure, or custodian with a delegated responsibility for a railway infrastructure

3.8
process supplier
company which provides an approved aluminothermic welding process in accordance with this standard

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) which of the width levels of heat-softened zone is required (7.4.4);

b) limitations on the pre-heat to comply with the railway authority regulations.

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 and the casting system;

c) the characteristic geometry of the weld collar and riser configuration as given in 5.4.2 and Figure 1;

d) the process manual in accordance with 5.4.1.

5.3 General requirements

The following requirements shall be met:

a) the process shall be capable of being carried out on track and at or near trackside or in a workshop;

b) the aluminothermic welding portion shall be packed to avoid the risk of moisture contamination in prescribed 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, b).

5.4 Documents to be submitted with the request for approval

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

5.4.1 The process manual.

The 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 to carry 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 ≤ 30 mm gap and ± 3 mm for > 30 mm to 50 mm gaps and ± 5 mm for > 50 mm gaps;

f) preheating details;

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

h) critical process timings;

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

j) safety information.

5.4.2 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*);

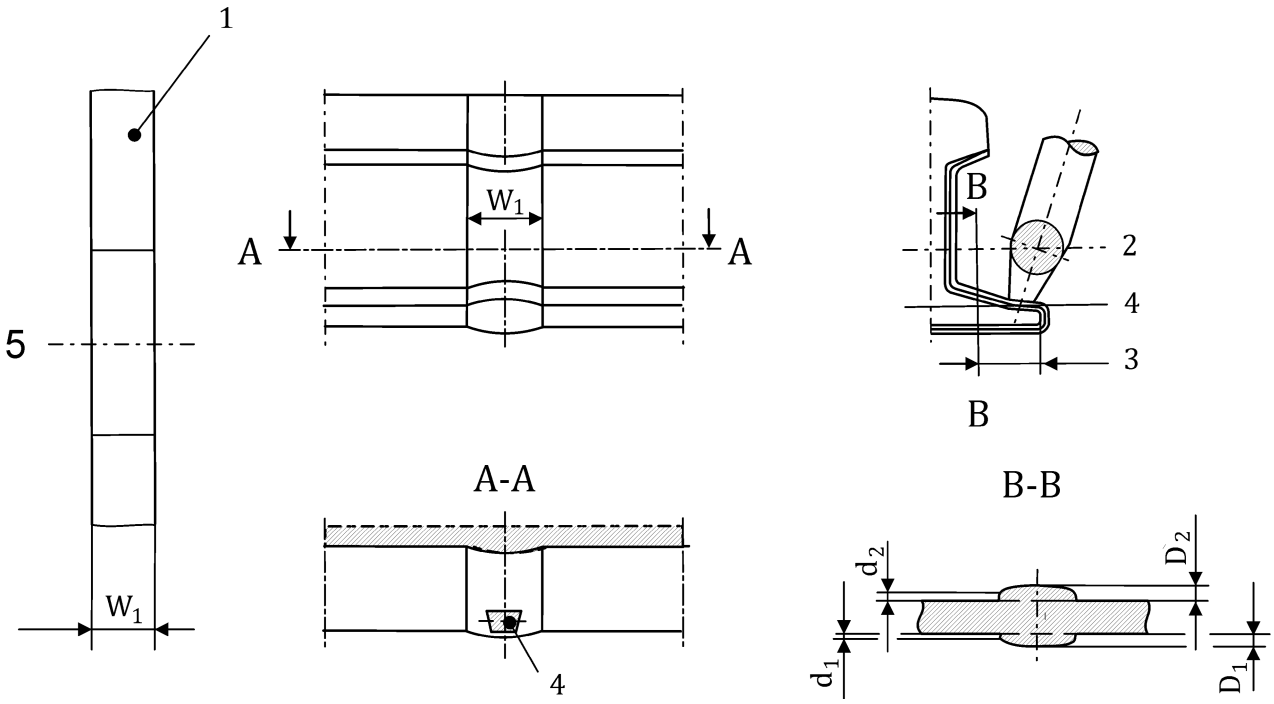
d) riser cross section at foot;

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

5.4.3 Chemical analysis ranges and tolerances.

The chemical analysis ranges and tolerances shall be in accordance with 7.5.1.

5.5 Initial compliance testing

a) For the purposes of approval the standard, rail profiles (see EN 14811) shall be grouped as follows.

Table 1 — Rail profile groups 1

New names	Former names
57R1	Ph 37
59R1	Ri 59-R10, Ri 59
59R2	Ri 59-R13, Ri 59N
60R1	Ri 60-R10, Ri 60
60R2	Ri 60-R13, Ri 60 N
60R3	Ri 210/95+80
62R1	NP4aM
62R2	NP4aS
63R1	Ri 210/95+80a
67R1	Ph 37a
68G1	70 G

Table 2 — Rail profile groups 2

New names	Former names
46G1	60 G
51R1	Ri 52-R13, Ri 52
52R1	Ri Ir
53R1	Ri 53-R13, Ri 53
55G1	35 GP
55G2	41 GP
56R1	Ri lc

b) Initial compliance with the present standard shall be achieved by undertaking the tests specified in category 1 of Table 3 using not heat treated rail, by using either R200 or R220G1 or R260 grade. Results are valid for the three grades of all rail profiles in either group 1 or group 2. 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 3 — Testing scheme

Test	Section reference	Number of tests	
		Category 1[a]	Category 2[b]
A Hardness test	7.2	6	5
B Surface examination – Visual	7.1.1 7.1.2	6	5
C Slow Bend Test	7.3	6	3
D Ultrasonic inspection – Annex G	7.4.1.1	2	Nil
E Weld soundness	7.4.1 7.3	2 (2)	Nil
F Fusion Zone – Shape and Dimensions	7.4.2	2	Nil
G Chemical analysis	7.5	3	3
H Heat softened zone – Hardness distribution	7.4.4	2	2
I Structure – Fusion Zone – Heat affected zone	7.4.3.3 7.4.3.2	2 2	1 1
NOTE () indicates weld soundness evaluation of the fracture face of the slow bend test specimens.			
[a] Category 1 Initial tests to be conducted using not heat treated grade on one rail profile from group 1 or 2 (Table 1 or 2). [b] Category 2 Tests required extending approval for heat treated grades. Tests on one rail profile cover all profile groups approved in categories 1 and 2.			

5.6 Extension of initial compliance testing

Initial compliance can be extended as follows:

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

a) to other group of rail profiles listed in Table 1 or 2 [5.5, a)], by doing the tests given in Table 3 category 1 [5.5, b)] on one profile of the appropriate group. Failure of any test shall cause non-compliance for the group of rail profiles being tested;

b) to other rail grade by doing the tests given in Table 3 category 2 [5.5, b)]. Failure of any test shall cause non-compliance for that rail grade. Tests on one rail profile cover all profiles in group 1 or 2.

5.7 Preparation and allocation of test welds

a) Welds required for the tests shall be produced in accordance with the process manual (5.4.1) under the supervision of the approving 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 50 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 3 tests shall be within the specified range. In the case of the welds required for test H in category 1 of Table 3, one weld shall be produced at the minimum gap and one at the maximum.

d) The number of each test shall be in accordance with the appropriate parts of Tables 3 and 4. The process supplier shall determine the order of testing.

e) 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 require approval:

6.1.1 Any geometric parameters given in 5.4.2:

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.

6.1.3 Pre-heating system:

— Any change in the equipment or parameters;

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

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

6.1.4 Welding gap:

Initial approval involves testing a welding process at either end of the ranges specified in 5.4.1, 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 Where the proposed change lies within the range or ranges given in Table 4, the tests shall be undertaken as detailed in Table 4. 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 approving authority.

6.3 Changes which fall outside the limits of the range or ranges given in Table 4 shall only be approved if they meet the requirements for demonstrating initial compliance as given in Table 3.

6.4 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 4 for these particular changes. e.g. combining changes to the pre-heating system and welding gap shall require 6 of test *A* (not 12), 6 of test *C* (not 12), etc.

6.5 Re-approval following the process changes detailed in Table 4 shall be made in one profile of group 1 of Table 1 or group 2 of Table 2 and rail grade R200, R220G1 or R260 and shall cover all profiles and grades of the existing approval.

6.6 Failure of the relevant tests of Table 4 shall cause non-compliance of the process change.

Table 4 — 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	C	E	F	G	H	I	
			Centreline hardness	Slow bend test	Weld soundness	Fusion width	Chemical analysis	HAZ hardness	Structure	
6.1.1 a) Weld collar width (*W*)	±3 mm	±10 mm	-	-	4	4	-	-	-	4
6.1.1 b) Collar depth (*D*)	±2 mm	±6 mm	-	-	4	4	-	-	-	4
6.1.1 c) Collar depth (*d*)	±2 mm	±4 mm	-	-	4	4	-	-	-	4
6.1.1 d) Riser cross-section – Foot	±10 %	±30 %	-	-	4	4	-	-	-	4
6.1.1 e) Riser cross-section – Neutral Axis	±10 %	±40 %	-	-	4	4	-	-	-	4
6.1.1 f) Riser config. – Position	±5 mm	±10 mm	-	6	4	4	-	-	-	10
6.1.1 g) Riser config. – Numbers	-	All	-	6	4	4	-	-	-	10
6.1.2 Crucible system	-	All	-	6	-	-	3	-	-	6
6.1.3 Pre-heating system	-	All	6	6	4	4	-	2	-	10
6.1.4 Welding gap	-	All	6	6	4	4	-	2	-	10
[a] In-house – Conducted by the process supplier										
[b] External – Conducted by a laboratory approved by the railway authority										

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;

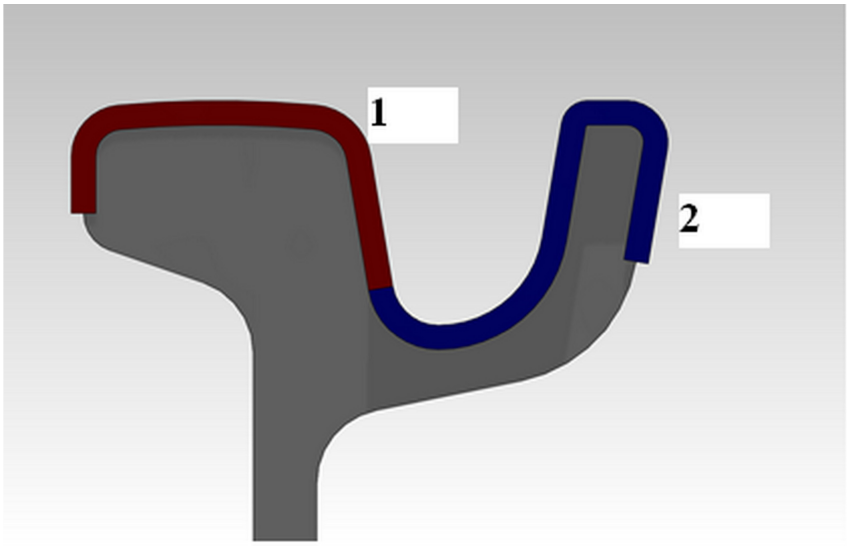
— slag or sand inclusions shall not exceed the limits set in Table 5. No defect shall intrude into the rail cross section nor touch the edge of the weld collar/rail intersection.

Table 5 — Maximum dimensions of slag or sand defects

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

7.1.2 Ground weld surface

Two zones with different inspection criteria are defined in accordance with the figure below.



Key

1 Ground zone

2 Not ground zone

Figure 2 — Definition of ground weld surface

For ground zone:

For isolated and non-linear defect, on the external and internal part of the head of the rail:

— All defects less than 4 mm with a maximum of 4 defects are allowed.

For isolated and non-linear defect, on the running head of the rail:

— All defects less than 4 mm with a maximum of 5 defects are allowed.

For linear and multiple defects, on the external and internal part of the head of the rail:

— All defects less than 3 mm with a maximum of 2 defects are allowed.

If the distance between two defects is less than 10 mm, the defect is considered as a linear and single defect.

For not ground zone:

For isolated and non-linear defect:

— All defects less than 6 mm with a maximum of 3 defects are allowed.

For linear and multiple defects:

— All defects less than 3 mm with a maximum of 2 defects are allowed.

If the distance between two defects is less than 10 mm, the defect is considered as a linear and single defect.

7.2 Running surface hardness test

Measurements shall be made in accordance with Annex D.

The average of the three hardness measurements made on each weld shall fall within the range given in Table 6 for the appropriate parent rail grade.

Table 6 — Ranges for running surface hardness tests

Rail grade	Hardness range HBW	
	Rail running surface on the unaffected parent rail	Weld centre-zone
R200	200 to 240	230 ± 20
R220G1	220 to 260	250 ± 20
R260	260 to 300	280 ± 20
R260GHT	260 to 300	280 ± 20
R290GHT	290 to 330	300 ± 20
R340GHT	340 to 390	350 ± 20
NOTE 0,5 mm should be ground from the running surface before a hardness impression is made.		

7.3 Slow bend test

Details of the slow bend test procedure are given in Annex E. The Force F is applied directly on the top of the rail by using a transition device. Details are given in the Annex E.

The minimum fracture load (kN), equivalent to a minimum tensile bending strength of 600 MPa, rounded to the nearest 5 kN, is defined by Formula (1):

$$F = 0{,}0024 \times (I_{xx}/h) \quad (1)$$

where

I_{xx} is the moment of inertia in mm^4 following the neutral axis XX;

h is the distance in mm between the foot of the rail and the neutral axis XX.

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 F.

7.4 Internal examination

7.4.1 Weld soundness

7.4.1.1 Welds for ultrasonic inspection (test D in Table 3) shall be sectioned so that the head, web and foot of the rail containing the weld (see Figure 4) can be examined ultrasonically in accordance with Annex G. The positions of any apparent defects found by ultrasonic testing shall be recorded so that they may be revealed by sectioning. Cuts as appropriate shall be made at least 5 mm from any apparent defects located by the ultrasonic testing method specified in Annex G. For each defect, the size shall be determined by progressively grinding and measuring until the maximum dimension is found.

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 a distance of 20 mm from each foot tip, see Figure 4).

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.

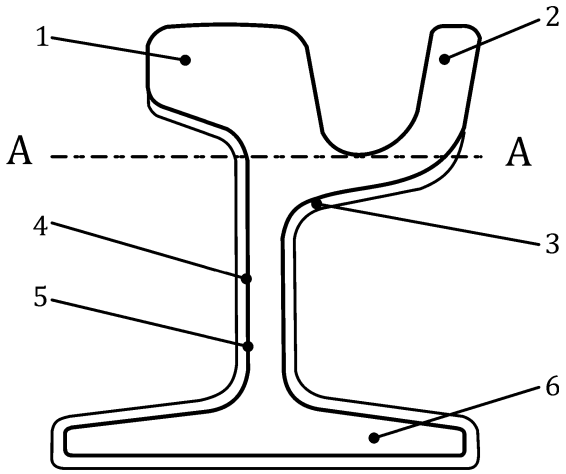
7.4.1.4 The maximum dimension of any pores, slag inclusions, sand inclusions or metal beads shall be recorded. If multiple defects are revealed, they shall be counted and measured as a single defect if they are less than 1 mm apart.

No more than one defect with maximum dimension greater than 5 mm in the region of the head above the line A-A on Figure 3 shall be permitted. In case of multiple defects, the total area shall not exceed 2 % of the total rail cross section.

NOTE 1 The information on weld soundness collected by the requirements of this subclause is used for reference in the appropriate tests of chapter 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.

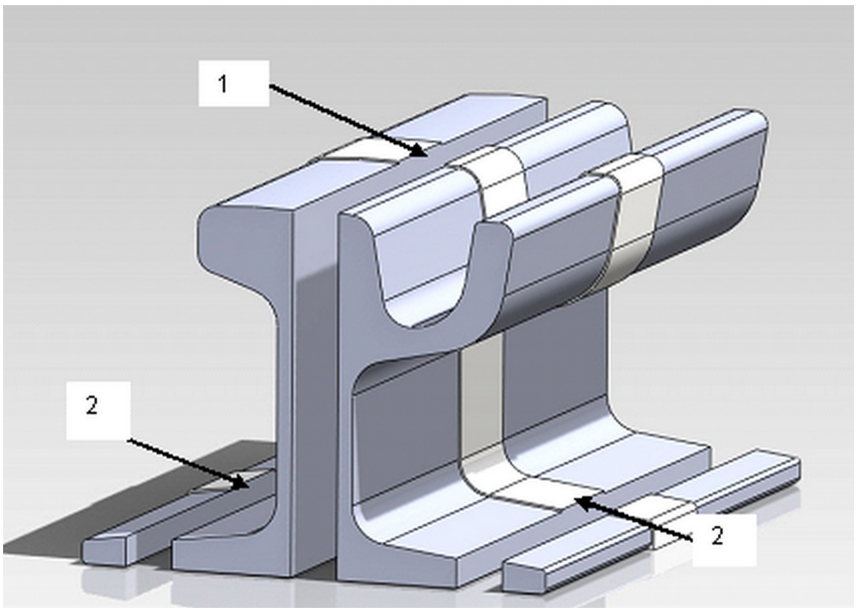
NOTE 3 For multiple defects, if the distance is more than 1 mm between two defects, they are considered as two separate defects. If the distance is less than 1 mm, it is considered as a single defect which total area is divided by the total rail area.



Key

A limit of the rail head area
1 head
2 lip
3 profile of the weld
4 profile of rail
5 web
6 foot

Figure 3 — Head, web and foot of the rail



Key

1 longitudinal vertical section on centre line
2 longitudinal vertical section of foot tip

Figure 4 — Sectioning of welds

7.4.1.5 Fracture faces revealed by the slow bend test specified in 7.3 shall be examined visually and a record made, in accordance with Annex F, of the maximum dimensions of any pores, slag inclusions,

sand inclusions or metal beads. A summary of these defects shall be made for each group of test specimens as per 7.4.1.4.

No more than one defect with maximum dimension greater than 5 mm in the region of the head above the line A-A on Figure 3 shall be permitted. In case of multiple defects, the total area shall not exceed 2 % of the total rail cross section.

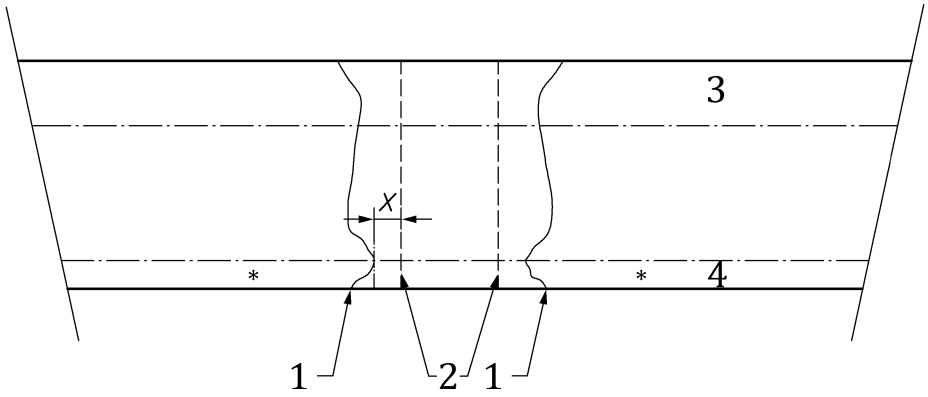
7.4.1.6 The above mentioned records shall be available to any customer.

7.4.2 Fusion zone – Shape and dimension

7.4.2.1 Following FRY etching in accordance with Annex C, measurement of the fusion zone shall be made on the cuts illustrated in Figure 5.

The minimum distance X (Figure 5) between the parent rail ends 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
1 fusion line
2 rail ends before welding
3 rail head
4 rail foot
X distance parent rail to fusion line

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

7.4.2.2 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 H.

7.4.3.2 Visible heat affected zone

The visible heat affected zone shall not contain any bainite or martensite at x100 magnification

7.4.3.3 Fusion zone

The structure of the fusion zone shall conform with that defined by the process supplier, which shall not include martensite or bainite at × 100 magnification. 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 I.

The heat softened zone on either side of the weld shall have one of the following widths indicated in Table 7.

Table 7 — 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 Chemical analysis

7.5.1 The process supplier shall define the mean values for the concentration of each element of Table 8. Actual values shall not vary by more than the working range and this range shall fit within the permitted range.

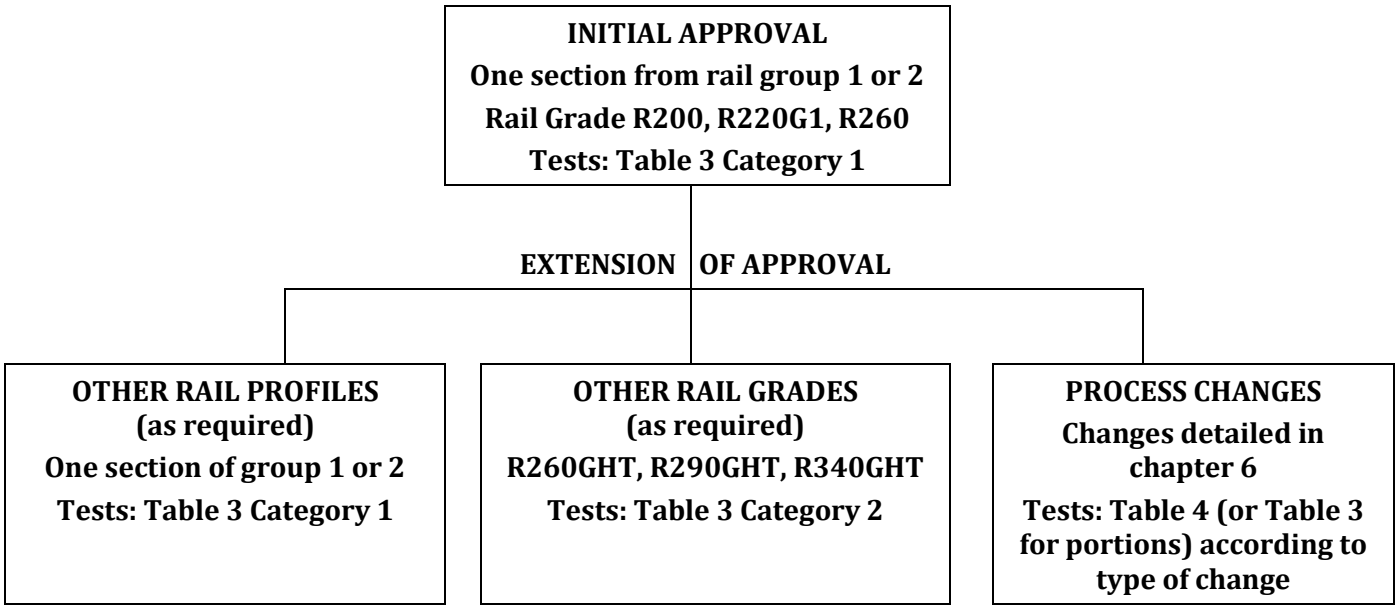
7.5.2 Chemical analysis is to be conducted on the rail weld running surface in the fusion zone at least 5 mm from the weld transverse axis and at least 5 mm from the limit of the fusion zone. Results of analysis shall fall within the ranges specified by the process supplier.

Table 8 — Chemical composition

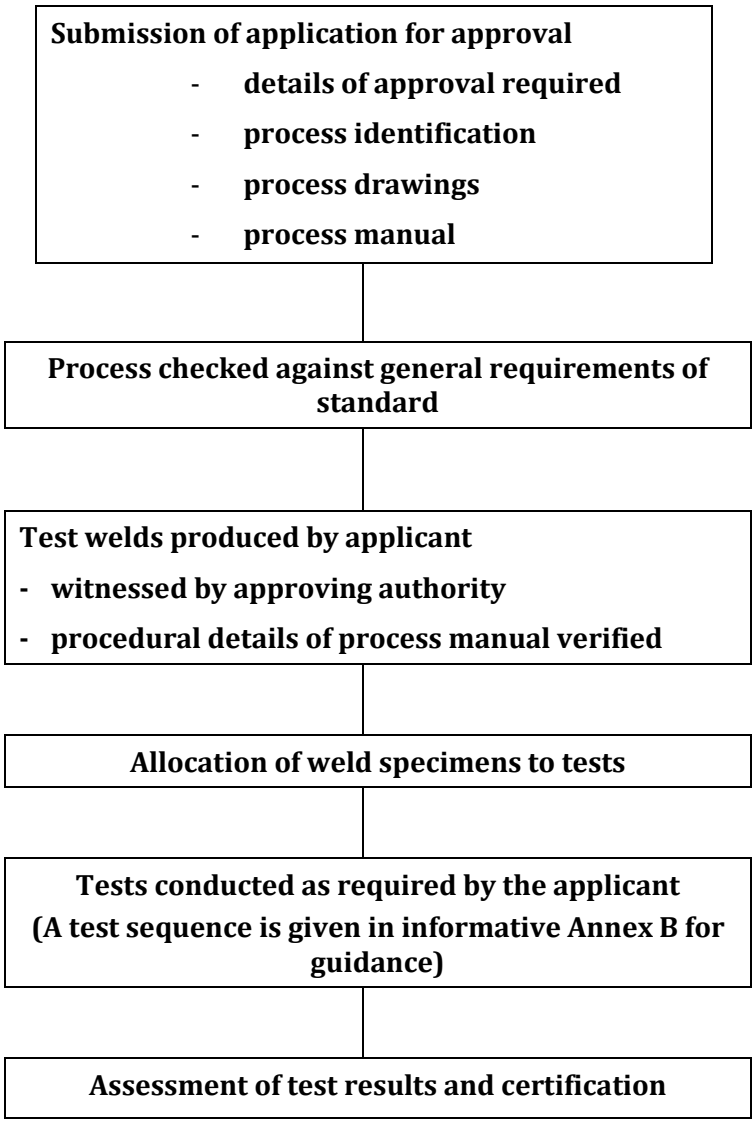
Element	Permitted range %		Working range	Rail grade
	Minimum	Maximum		EN 14811
Carbon	0,30	0,55	±0,12	R200
	0,35	0,70	±0,12	R220G1
	0,40	0,75	±0,12	R260, R260GHT
	0,50	1,00	±0,12	R290GHT, R340GHT
Silicon	0,00	1,60	±0,25	All
Manganese	0,40	1,00	±0,20	R200
	0,45	1,20	±0,20	R220G1
	0,50	1,40	±0,20	R260, R260GHT
	0,50	1,60	±0,20	R290GHT, R340GHT
Phosphorous	0,00	0,035	-	All
Sulphur	0,00	0,035	-	All
Chromium	0,00	0,20	-	R200, R220G1, R260, R260GHT
	0,00	0,80	±0,20	R290GHT, R340GHT
Molybdenum	0,00	0,40	-	All
Nickel	0,00	0,20	-	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	0,02	-	All
Vanadium	0,00	0,25	-	R200, R220G1, R260, R260GHT
	0,00	0,45	-	R290GHT, R340GHT

Annex A
(informative)

Steps in approval

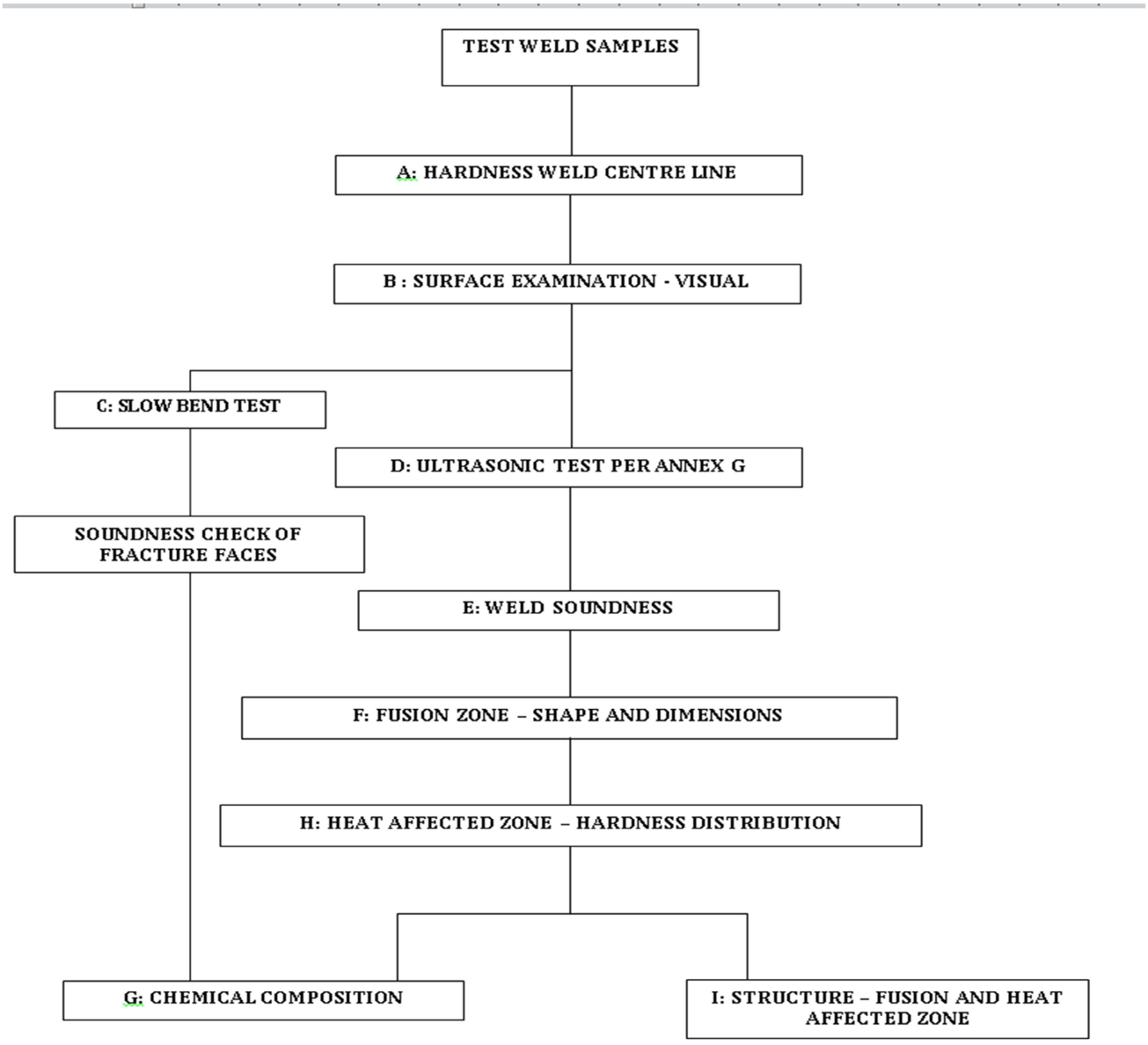


Each of the above steps will be achieved by the following sub-steps:



Annex B
(informative)

Suggested sequence of laboratory tests



Annex C
(informative)

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 ($CuCl_2$. $2H_2O$);

— 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 with minimum 220 grit paper.

Annex D
(normative)

Procedure for measurement of surface hardness

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

— 5 mm or 10 mm diameter tungsten carbide ball;

— test load 750 kg (5 mm diameter ball) or 3000 kg (10 mm diameter ball);

— 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 D.1.

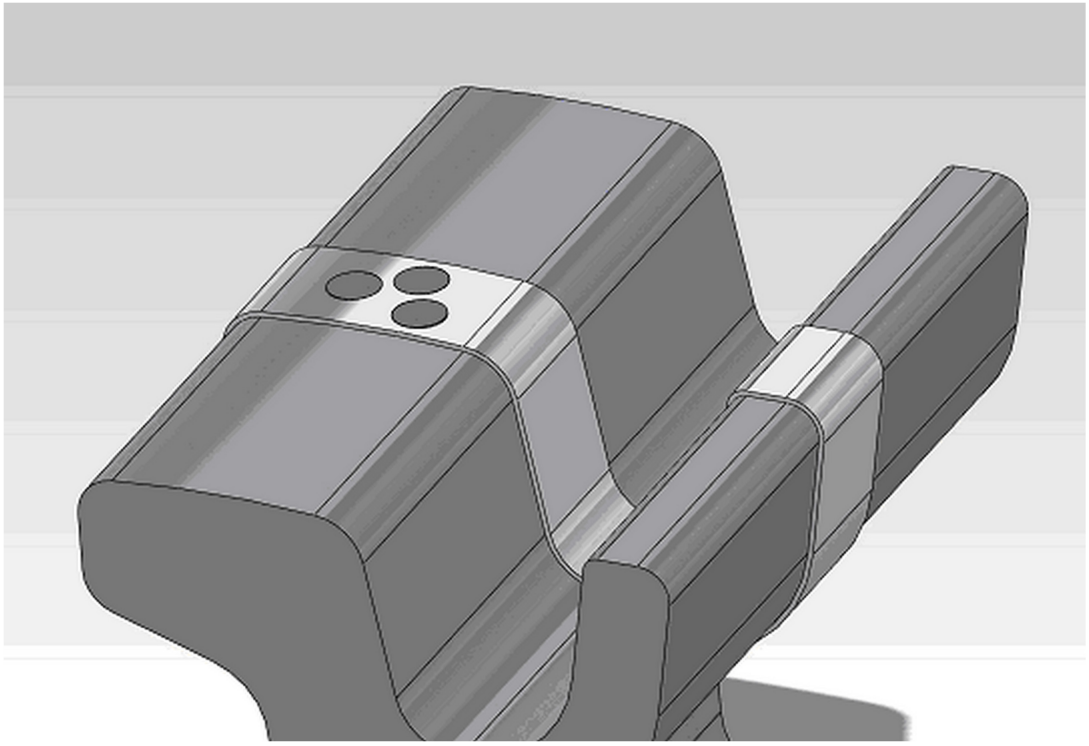


Figure D.1 — Location of surface hardness tests

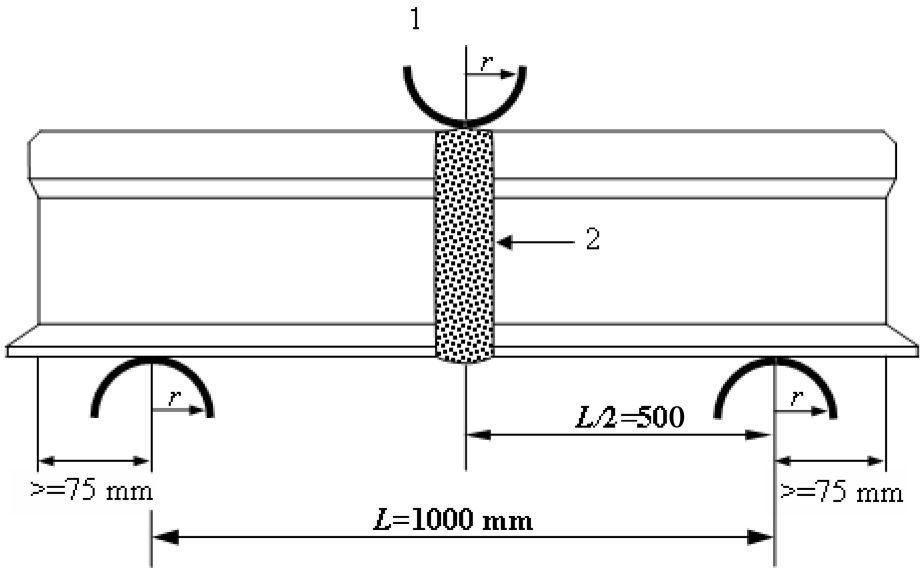
Three hardness values shall be determined for each weld as shown in Figure D.1.

Annex E
(normative)

Procedure for slow bend test

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

Dimensions in millimetres



Key
1 load
2 weld

25 mm ≤ *r* ≤ 70 mm

Minimum sample length = 1150 mm

Loading rate ≤ 60 kN/s

Figure E.1 — Slow bend test schematic

The load shall be applied to the running surface of the weld by a single fulcrum directly on the head of the rail or by using a transition device of which details are given below for information. The test shall continue until fracture.

Dimensions in millimetres

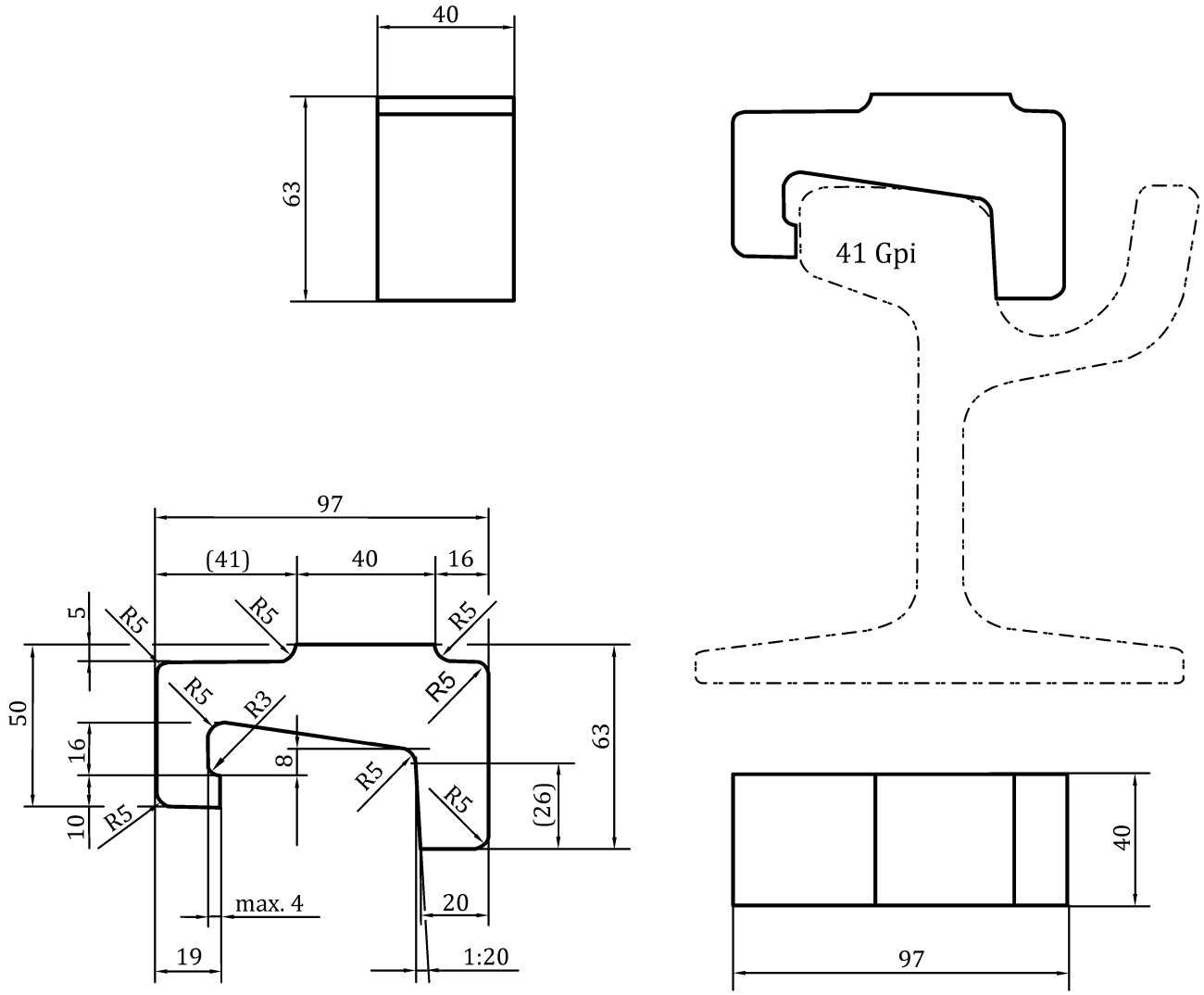


Figure E.2 — Transition piece for slow bend test

The transition piece material shall be manufactured in a material as hard as the material used for applying the force (as an example: 1.6580 – 30CrNiMo8).

Annex F
(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 F.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 testing.

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

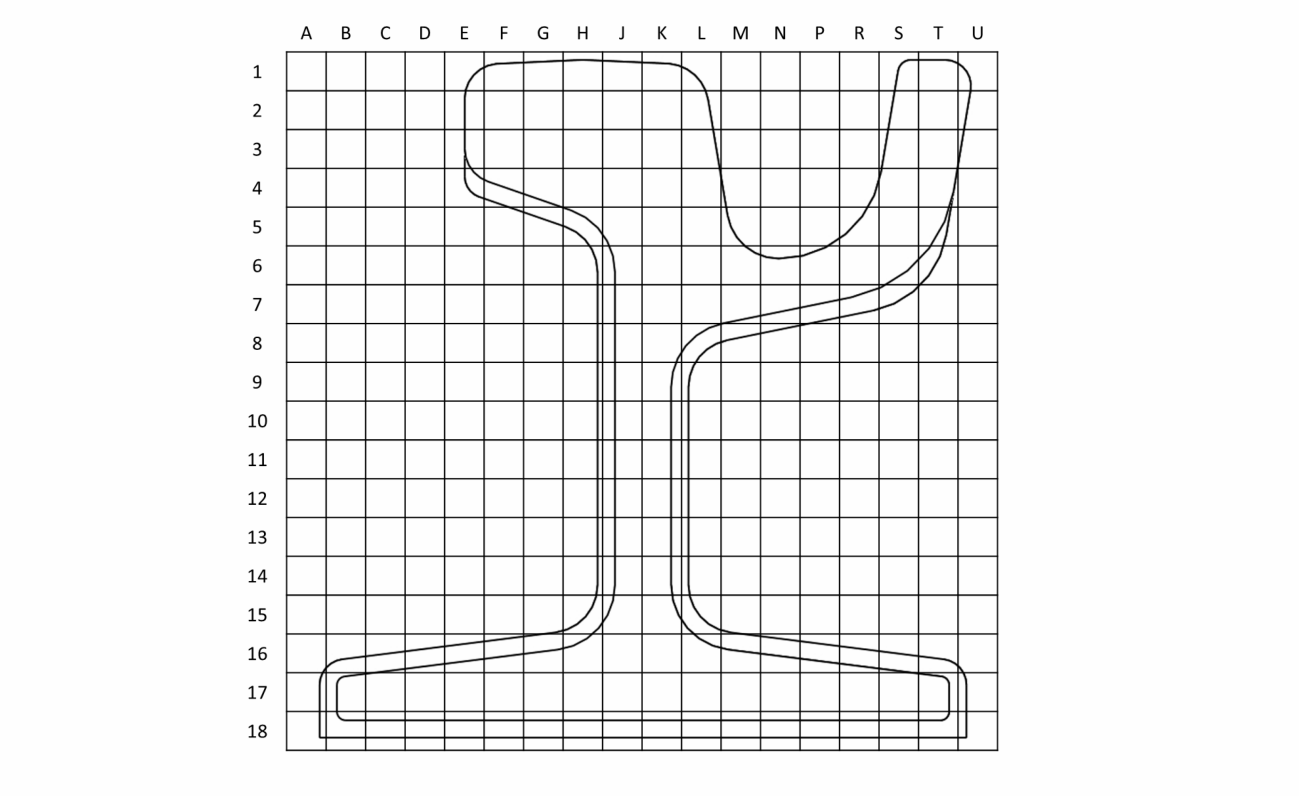


Figure F.1 — Rail profile grid

Annex G
(normative)

Ultrasonic inspection procedure on aluminothermic welds to be sectioned

G.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 ISO 9712.

G.2 Apparatus

Ultrasonic flaw detector approved by relevant approving 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.

G.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.

G.4 Calibration

Timebase – using the metric adjustment 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 full screen height. The sensitivity level shall be reset for each face of each sample tested.

G.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.

G.6 Reporting

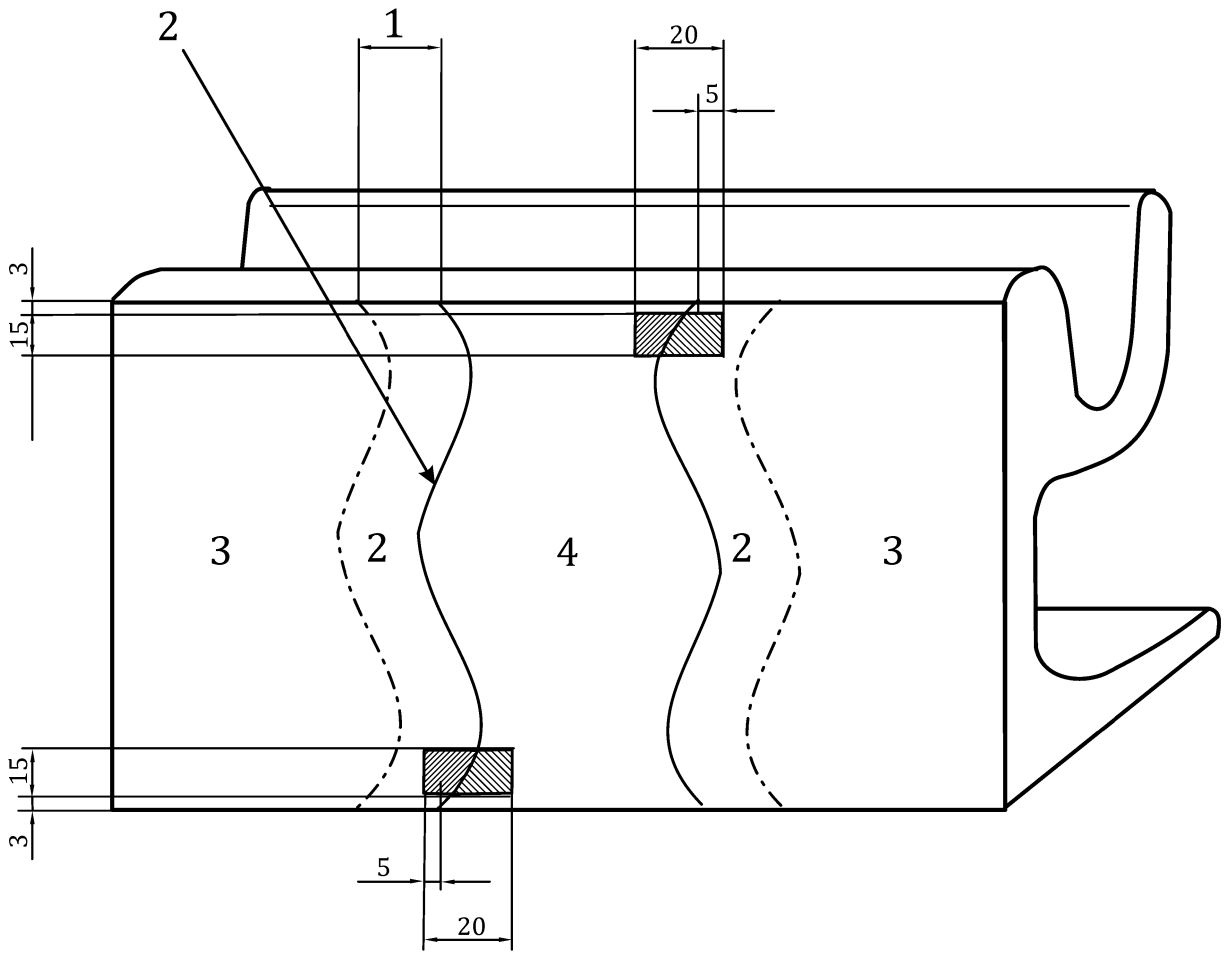
The extent and depth of any defect found shall be marked on the sample and reported for further investigation.

Annex H
(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 H.1. The samples shall be prepared and etched in 4 % Nital.

Dimensions in millimetres



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

area of fusion zone to be examined microscopically

area of visible heat affected zone to be examined microscopically

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

Annex I
(normative)

Procedure for measurement of the heat softened zone width

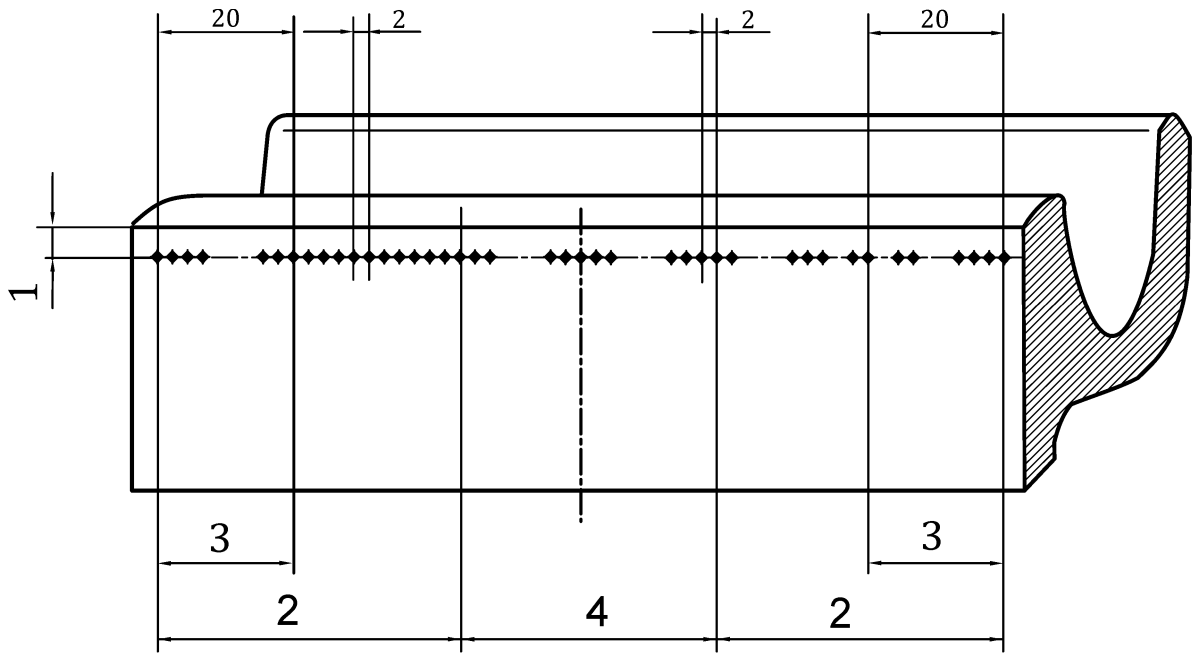
I.1 Measurement of hardness

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. Alternatively, impressions may be taken on the running surface of the rail on the longitudinal axis after 3 mm has been machined off the head.

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 I.1.

Dimensions in millimetres



Key

1 depth between 3 mm and 5 mm
2 parent rail
3 unaffected parent rail
4 fusion zone

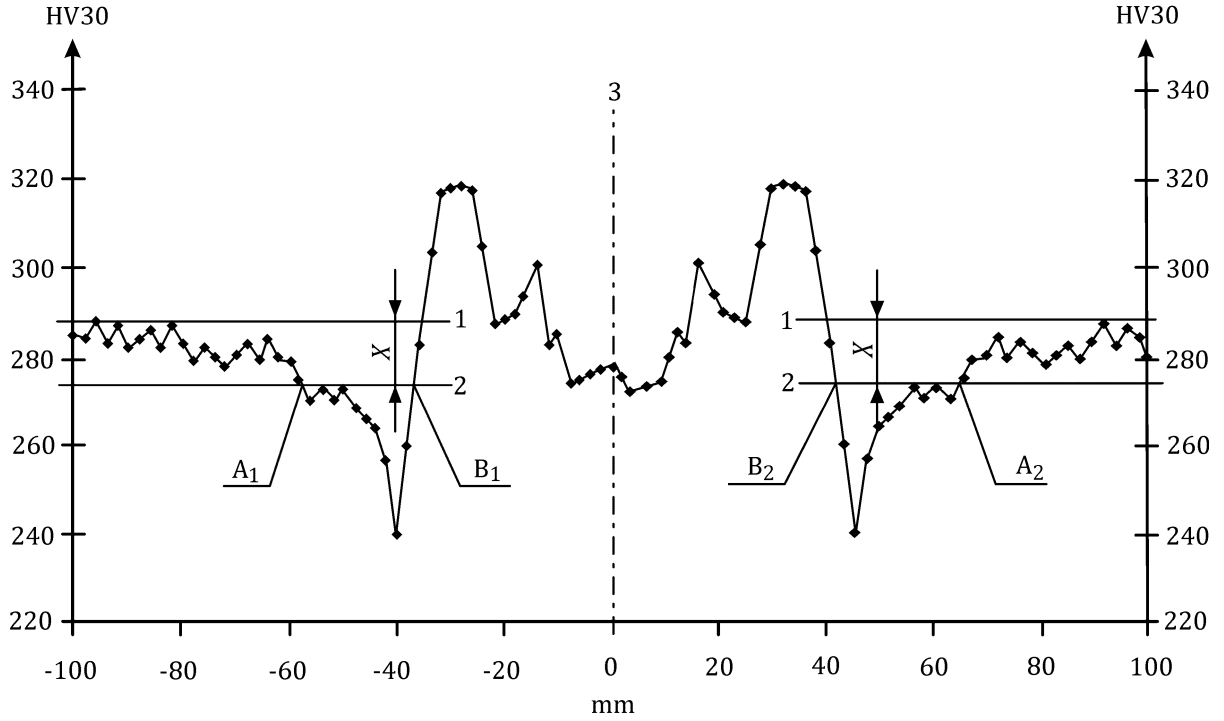
Figure I.1 — Longitudinal hardness measurement

Hardness measurements obtained shall be recorded numerically and graphically.

I.2 Evaluation of hardness data

I.2.1 General

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



Key

1	line 1
2	line 2
3	weld centre line
$\overline{A_1B_1}$, $\overline{A_2B_2}$	width of the visual heat softened zone (left, right)

NOTE Figure not to scale.

Figure I.2 — Typical hardness profile

I.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 10 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).

I.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 HV for: Grade R200, R220G1, R260;

— X = 25 HV for: Grade R260GHT, R290GHT, R340GHT.

I.2.4 Heat softened zone width measurement

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

I.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 I.2.

Bibliography

[1] EN ISO 7500-1, *Metallic materials - Calibration and verification of static uniaxial testing machines - Part 1: Tension/compression testing machines - Calibration and verification of the force-measuring system (ISO 7500-1)*

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