BS EN 14587-3:2012

BSI Standards Publication

Railway applications — Track — Flash butt welding of rails

Part 3: Welding in association with crossing construction

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National foreword

This British Standard is the UK implementation of EN 14587-3:2012.

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

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

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

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This European Standard was approved by CEN on 6 July 2012.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Foreword

This document (EN 14587-3:2012) 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of an identical text or by endorsement, at the latest by March 2013, and conflicting national standards shall be withdrawn at the latest by March 2013.

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 has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

This document is one of a series of three parts of the EN 14587 "*Railway applications – Track – Flash butt welding of rails*". The list of parts is as follows:

— *Part 1: New R220, R260, R260Mn and R350HT grade rails in a fixed plant*

— *Part 2: New R220, R260, R260Mn and R350HT grade rails by mobile welding machines at sites other than a fixed plant*

— *Part 3: Welding in association with crossing construction* (the present standard)

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

Introduction

This part of EN 14587 has four main topics:

- requirements of a welding process;
- procedure approval for a fixed plant;
- approval of other rail profiles or grades;
- weld production following approval.

This European Standard satisfies the needs of the railway authority. The manufacturer should achieve the specified requirements of this European Standard.

1 Scope

This European Standard specifies requirements for the approval of a welding process in a fixed plant, together with the requirements for subsequent welding production.

This European Standard applies to new Vignole rails welded by flash butt welding to crossing components in a fixed plant, and intended for use on railway infrastructures.

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 571-1, *Non-destructive testing — Penetrant testing — Part 1: General principles*

EN 1371-1, *Founding — Liquid penetrant testing — Part 1: Sand, gravity die and low pressure die castings*

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

EN 13674-2, *Railway applications — Track — Rail — Part 2: Switch and crossing rails used in conjunction with Vignole railway rails 46 kg/m and above*

EN 13674-4, *Railway applications — Track — Rail — Part 4: Vignole railway rails from 27 kg/m to, but excluding 46 kg/m*

EN 14587-1:2007, *Railway applications — Track — Flash butt welding of rails — Part 1: New R220, R260, R260Mn and 350HT grade rails in a fixed plant*

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

EN ISO 11666, *Non-destructive testing of welds — Ultrasonic testing — Acceptance levels (ISO 11666)*

EN ISO 17638, *Non-destructive testing of welds — Magnetic particle testing (ISO 17638)*

EN ISO 17640, *Non-destructive testing of welds — Ultrasonic testing — Techniques, testing levels, and assessment (ISO 17640)*

EN ISO 23279, *Non-destructive testing of welds — Ultrasonic testing — Characterization of indications in welds (ISO 23279)*

3 Terms and definitions

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

3.1
manufacturer
company that joins rails to rails, rails to crossings and rails to crossing components by flash butt welding in a fixed plant

3.2
purchaser
buyer of the flashbutt welded crossings working in accordance with the requirements of the railway authority

3.3
railway infrastructure
permanent way of national or private railways

3.4
fixed plant
stationary machine for flash butt welding of rails to rails, rails to crossings and rails to crossing components

3.5
die burn
damage caused by localised overheating on the electrode contact surfaces

3.6
upset
metal extruded around the rail profile as a result of forging

3.7
specimen
portion detached from a welded component or a welded joint and prepared as required for testing

3.8
profile finishing
operation by which the rail or relevant part of the component at the weld is returned to original profile, by removal of upset material

Note 1 to entry: This operation can be achieved by grinding, milling, planing or any other suitable means.

3.9
finished condition
welded and profile finished

3.10
flat spot
feature having a localised smooth texture when viewed in a vertical transverse section (see Annex A)

Note 1 to entry: When viewed longitudinally in macro this may appear as a lens-shaped feature.

3.11
bright spot
localised bright area occurring at the stainless insert/rail interface indicative of a possible martensitic area (see Annex A)

3.12
lack of bond
area within the weld where there is no metal to metal contact (excluding flat spots and bright spots)

Note 1 to entry: This may appear as a linear discontinuity at the interfaces when examined in the finished condition or after sectioning.

3.13
welded zone
areas of 50 mm on either side of the weld centreline

3.14
throat flare
wing entry flare (front) machining or setting of wings to give an entry flare into the throat

3.15
foundry method
system to produce casting compliant with the requirements of EN 15689

3.16
workpiece
crossing component, insert rail or rail leg-end extension

3.17
railway authority (RA)
either the railway regulator or the owner of the railway infrastructure or the custodian with a delegated responsibility for a railway infrastructure

3.18
as welded condition
rails that have been welded and trimmed only

4 Information to be supplied for approval of procedure

4.1 By the purchaser

The following information shall be supplied by the purchaser, agreed upon by the manufacturer, and shall be fully documented:

a) the rail profile and crossing geometrical details;

b) the rail and crossing grades/materials;

c) the profile class of the rail leg-end extension as specified in EN 13674-1, EN 13674-2 or EN 13674-4;

d) alignment class/classes of the flash butt welds (see Table 1);

e) the type of fatigue tests (if applicable) for approval;

f) tolerances at rail ends on the delivered crossing;

g) minimum length of rail leg-end extension;

h) rail profile, number and frequency of production bend tests (see 13.7);

i) requirements of any track trials.

4.2 By the manufacturer

The following information shall be supplied by the manufacturer, agreed upon by the purchaser, and shall be fully documented:

a) a qualified weld procedure;

b) traceability system of the welds;

c) type and identification number of machine being used.

5 Approval of the manufacturer

5.1 General

The manufacturer shall meet the approval requirements as defined in 5.2 to 5.7. The purchaser reserves the right to audit the manufacturer at any time.

5.2 Welding procedure

The manufacturer shall use welding procedures and flash butt welding machines that are approved by the RA.

5.3 Operators

The manufacturer shall maintain a system that ensures the competence of their welding operators by appropriate training and assessment.

5.4 Supervision

The manufacturer shall maintain a management and supervision system of flash butt welding that complies with the requirements of the purchaser.

5.5 Weld Inspection

The manufacturer shall maintain a system of weld inspection according to the purchaser requirements. Instances of non-conformity found during these inspections shall be recorded in the traceability system.

5.6 Equipment

Equipment shall comply with the operating manual. Inspection and calibration equipment shall comply with those requirements as agreed between the manufacturer and the purchaser.

5.7 Quality assurance

The manufacturer shall operate an independently approved and audited quality assurance system, e.g. conforming to the requirements of EN ISO 9001 or other approval accepted by the purchaser.

6 Requirements for the welding process

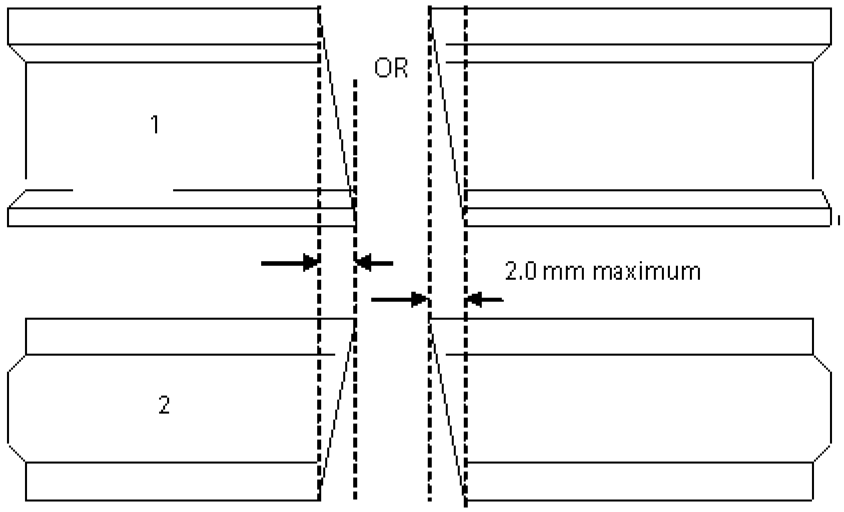
6.1 General

All welding shall be carried out on a flash butt welding machine using an automatic, programmed welding sequence using RA approved procedures.

6.2 Workpiece preparation

The crossing/insert/rail faces to be welded shall always be sawn, disc cut or machined prior to welding and shall conform to the tolerances given in Figure 1. Areas of electrical contact on the workpieces and the machine shall be clean and free of any deleterious materials that could affect current flow. The workpieces shall not be damaged by the cleaning operation.

The total mismatch of the two workpieces shall not exceed 2 mm and shall be corrected by grinding or machining prior to welding.



Key

1 elevation

2 plan

Figure 1 — Tolerances for rail end squareness

6.3 Clamping force

Workpieces shall be secured in the flash butt welding machine by clamps of such a surface shape or contour, that when a clamping force is exerted on the workpieces, it shall not damage the workpiece. The clamping force shall be sufficient such that slippage does not occur.

6.4 Initial burn-off

The workpieces should undergo initial flashing to ensure full rail end contact during the subsequent preheating cycles.

6.5 Preheating

The fronts of the heating area shall progress such that at completion of preheating an even heat band is present in both workpieces. On completion of welding there shall be no evidence of localised melting on the ends of the workpieces.

6.6 Final flashing

Once initiated, final flashing shall be continuous.

6.7 Upsetting

Upsetting shall immediately follow flashing. Sufficient forging pressure shall be applied to ensure that voids are closed and oxides are expelled such that they are kept to a minimum at the weld interface. The weld interface shall extend into the upset.

The time between completion of upsetting and unclamping shall be sufficient to ensure required weld integrity. During this time, sufficient longitudinal force shall remain present to prevent damage to the weld.

6.8 Post-weld treatment

6.8.1 Before unclamping

Post-weld heating could be required for certain rail grades and alloyed steels.

6.8.2 After removal from machine

A post-weld controlled cooling could be required.

Additional post-weld heat treatment may be required after removal from the welding machine for certain steel grades.

6.9 Welding parameters

The welding machine and/or management system equipment shall be capable of recording the following:

a) welding current;

b) upset force or pressure;

c) displacement;

d) welding time;

e) programme identification and setting details;

f) weld identification;

g) post-weld heat treatment (if applicable).

The welding programmes and any post-weld heat treatment shall be determined during procedural trials and once approval has been granted they shall not be changed without prior purchaser approval.

The welding parameters shall be monitored, checked against approval limits and recorded. These records shall be referenced to the appropriate welds.

The post-weld heat treatment parameters shall be monitored, checked against approval limits and recorded. These records shall be referenced to the appropriate welds.

6.10 Removal of upset and correction of weld alignment

The upset material shall be removed by the method carried out during the approval process and once agreed shall not be changed without prior purchaser approval. In exceptions where upset material cannot be removed, finish and dimensions shall be agreed between the purchaser and the manufacturer.

Removal of the upset shall not cause any mechanical or thermal damage to the crossing or rail.

Any surface where upset has been removed shall be free from visible cracking.

The correction of the weld alignment shall be carried out by pressing.

7 Profile finishing of the weld

The surface finishing shall be carried out in the longitudinal direction using machining/grinding.

The roughness limit within the welded zone shall be:

a) 6,3 µm Ra on the underside of the welded rail foot and wheel contact area;

b) 12,5 µm Ra in all other finished areas.

The profile finishing shall not cause any thermal or mechanical damage. The rail profile in the wheel contact area shall be maintained during profile finishing. The remainder of the welded surfaces shall be smoothly blended to the profile of the surrounding material, so as to avoid a localised stress concentration.

Where this is not possible, the finished profile shall be agreed between the manufacturer and the purchaser.

Profile finishing of the rail-head shall be contained in the shortest possible length, but shall in any case not exceed 900 mm.

8 Weld geometry and dimensions

8.1 General

The alignment of the welded joint after pressing and profile finishing shall be measured, vertically and horizontally within a 1 m span.

The horizontal alignment of the rail head shall apply to running edges only. Any deviation of alignment shall be in accordance with Table 1, at ambient temperature.

Table 1 — Tolerances for alignment and flatness of flash-butt welds at ambient temperature

	Class 1	**Class 2**	**Class 3**	**Class 4**	**Maximum grinding length**
Horizontal	0/+0,3	0/+0,5	+/-0,4		900 mm
Vertical	0/+0,3	-0,1/+0,2	-0,3/0	+0,1/+0,3	900 mm
Flatness	≤ 0,1	≤ 0,2			

NOTE 1 For horizontal alignment, positive tolerances will widen gauge.

NOTE 2 The purchaser may select different classes for vertical and horizontal alignment and flatness from the above. The vertical and horizontal alignment can be mixed between classes. Horizontal and vertical alignment should be checked by use of a 1 m straightedge. Flatness should be checked by use of a 1 m straightedge in the grinding zone to be in accordance with EN 14587-1 and EN 14587-2.

NOTE 3 Horizontal tolerances do not apply to crossings with built-in curvatures or where the weld is within the throat flare area. Where crossings are manufactured with built-in curves, an agreement concerning the tolerances is necessary between the manufacturer and the purchaser.

NOTE 4 Maximum grinding length is not necessarily symmetrical about the weld but no more than 450 m either side of the weld.

8.2 Alignment and flatness across the weld

Alignment and flatness across the weld shall be measured as follows:

a) The vertical alignment across the running surface shall be measured along the longitudinal centre line of the rail with the weld centrally between and referenced to datum points on the rail 500 mm either side of the weld.

b) The horizontal alignment of the weld across the rail head shall be measured on the running edge at a point 14 mm below the running surface and referenced to datum points on the rail 500 mm either side of the weld.

c) The running surface flatness at the level of the weld shall be measured by means of a 200 mm straightedge positioned on the ground area. The maximum gap between the straightedge and the profiled running table of the rail shall be in one of the classes in Table 1.

d) The means of measuring the weld alignment as described above shall be by the use of a 1 m straightedge and feeler shims calibrated in accordance with the requirements of the manufacturer's quality system. Any alternative measurement system used shall first be agreed upon with the purchaser.

8.3 Foot dimensions

a) A difference of up to 4 mm in the nominal foot width dimension is permitted in the weld zone, owing to upset removal and manufacturing tolerances. Further reductions in the foot width may be necessary owing to the angle of the crossing. In this instance, the manufacturer shall supply the information to the purchaser.

b) At 14 mm from the foot tip, a tolerance of 15 % maximum thickness reduction from the minimum rail foot thickness may be permitted subject to agreement between the manufacture and the purchaser.

9 Weld identification

Weld identification shall permit traceability to production records.

10 Procedure approval

10.1 General

Flash butt welding machines used in this work shall be individually approved by the RA; type approval is not permitted. Approval is granted for welding procedures specified to selected materials. Approval for rail profiles within the same grade can be considered in groups (see Table 2). At least one profile in a group shall undergo testing in accordance with 10.4; the remaining rail profiles within that group shall undergo a minimum of five bend tests in accordance with 10.4.7.

Table 2 — Rail groups

Cross sectional area (cm²)	**Examples**
40 < 46	33E1(42,6)
46 < 52	39E1(50,6)
52 < 58	43E1 (55,8)
58 < 64	49E1(62,9)
64 < 71	52E1 (66,4)
71 < 78	60E2 (76,5)
78 < 85	49E1 A3 (80,5)
85 < 92	60E1 A4 (88,9)
92 ≤ 99	60E1 T2 (94,6)

60E1 and 60E2 may be considered as the same profile.

The approval tests for rail grade/material combinations and extensions of these approvals are given in 10.4 and Clause 11. The grades and materials shall be specified using the respective European Standard or by their mechanical and chemical characteristics in the absence of a European Standard. Procedure approval shall be carried out by testing weld samples produced in accordance with this standard; the samples shall be representative of those carried out in production. Procedure approval testing shall be carried out on the rail/crossing profile and material grade specified by the purchaser. The intermediate buffer material used for the approval tests shall be the same as that used in production. All test results and weld fracture faces shall be made available for inspection.

10.2 Test weld specimen preparation

Materials shall be cast, rolled, forged, heat treated, machined and inspected by the same method used for production pieces. The foundry method used to produce cast manganese specimens shall be that used for the normal production of cast crossings.

The prepared specimens shall be flash butt welded by the same programme(s) and sequence used in production.

Welds shall be finished and inspected in accordance with normal production methods.

When employing non-austenitic materials, specimens for the bend tests shall be in the as-welded condition.

10.3 Number of specimens

For welds with austenitic components, nine welds in the finished condition (see 3.9) shall be manufactured. For welds without austenitic components, four welds shall be prepared in the finished condition and five in the as-welded condition.

Depending on the type of fatigue test specified by the purchaser, ten additional welds in the finished condition (see 3.9) for the staircase test method, or three additional welds in the finished condition (see 3.9) for the past-the-post test method shall be manufactured to meet the test program.

10.4 Approval tests

10.4.1 General

To achieve compliance with this standard, either fatigue testing or micro-examination shall be carried out as specified by the approving RA. Fatigue testing shall be in accordance with 10.4.8; micro-examination shall be in accordance with 10.4.10.

10.4.2 Weld geometry and dimensions

All the welds submitted in the finished condition shall conform to 8.3.

10.4.3 Visual inspection

The specimens shall be inspected for tears, cavities, cracks, damage and geometrical non-conformities. The contact positions of the electrodes on the specimens shall be inspected for thermal damage.

10.4.4 Surface finish

The surface finish of the specimen shall be checked against and conform with Clause 7.

10.4.5 Liquid penetrant testing and magnetic particle testing

On completion of visual inspection, the welded zone to be tested by non-destructive testing is limited to 20 mm either side of the weld(s) including the whole of the insert.

The following tests are required on welds in the finished condition:

— welds with austenitic component(s): liquid penetrant testing shall be carried out in accordance with EN 571-1, acceptance shall be in accordance with EN 1371-1: severity level SP1. No linear indications shall be permitted.

— welds without austenitic component(s): magnetic particle testing shall be carried out in accordance with EN ISO 17638. No cracks or lack of bond shall be permitted.

Liquid penetrant testing may be carried out on welds without austenitic component(s) in place of magnetic particle testing. In these cases, the acceptance level shall be agreed upon with the purchaser.

The area of the electrode contacts shall be visually checked. The inspected area shall be free of cracks. If any evidence of surface cracking is revealed, liquid penetrant testing shall be applied. In the case of any cracks being confirmed, the welding process shall be deemed unsuitable.

10.4.6 Internal soundness

Welds without austenitic components shall be tested by ultrasonic methods. The methods and acceptance criteria are described in Annex G.

10.4.7 Bend testing

10.4.7.1 General

The five specimens having met the requirements of 10.4.2 to 10.4.6 shall be subject to bend testing in accordance with Annex B.

Each bend test shall be continued until the specimen reaches fracture or the maximum deflection capability of the machine is achieved. Photographs shall be taken of the fracture faces (one per sample) of all broken test welds.

10.4.7.2 Acceptance criteria for bend tests

a) For welds with austenitic component(s):

   1) Bend test requirements are specified in Table B.1.

   2) Deflection values shall be recorded during the approval bend tests.

   3) The deflection requirements of the approval bend test shall be agreed between the purchaser and the supplier. These requirements shall recognise the material composition and the insert thickness.

b) For welds with non austenitic component(s):

   1) Bend test requirements and deflection values are specified in Table B.2 and actual values shall be recorded.

   2) The specimens shall be in the as-welded and wire-brushed condition, they shall meet the requirements 10.4.3, 10.4.5 and 10.4.6 and shall be subject to bend testing in accordance with Annex B.

If full section fracture occurs about the weld line, the fracture surfaces shall be inspected. The details of any weld imperfection shall be recorded in accordance with Annex C. Lack of bond shall not be permitted. If fracture occurs remote from the weld, the fracture surfaces shall be checked for the presence of die burn, which if detected shall cause the process to fail approval. If fracture occurs within the non-austenitic rail for reasons other than die burn then another test weld specimen shall be substituted for testing.

10.4.8 Fatigue testing

If fatigue testing is required by the approving RA, it shall be carried out in accordance with 4.1 e) and Annex D of this European Standard.

Depending on the type of fatigue test specified by the RA, ten welds in the finished condition (see 3.9) shall be taken for the staircase test method, or three welds in the finished condition (see 3.9) shall be taken for the past-the-post test method.

10.4.9 Macro-examination

Four welds in the finished condition shall be sectioned for macro-examination in accordance with Annex E, E.1 when welding austenitic component(s) and shall conform to the following requirements:

a) There shall be no evidence of lack of bond, inclusions, cracks or shrinkage. Indications that cannot be positively identified by macro examination shall be examined by micro examination at x 100 magnification. If any cracks are found, the process is rejected.

b) In the longitudinal vertical section of the centre line, four flat spots are accepted at each weld line provided that they meet the following requirements:

— a maximum vertical dimension of 10 mm and a maximum thickness of 1 mm.

c) There shall be no indication of embrittlement due to welding, cooling or finishing.

For welds without austenitic component(s), the requirements of Annex D of EN 14587-1:2007 shall apply.

10.4.10 Micro-examination

10.4.10.1 Welds with austenitic component(s)

Following the completion of the macro examination, a micro examination shall be mandatory when no fatigue test has been undertaken. When required, the micro examination shall be in accordance with Annex E, E.2 and shall be applied to two welds. There shall be no evidence of embrittlement, e.g. acicular carbide, continuous networks of inter-granular carbides at x 100 magnification (this list is not exhaustive). Isolated martensite is permitted.

10.4.10.2 Welds without austenitic component(s)

For welds without austenitic component(s), the requirements of Annex D of EN 14587-1:2007 shall apply. In addition, for quenched and tempered steels and bainitic steels, no martensite shall be present with hardness greater than 500 HV.

10.4.11 Hardness testing

10.4.11.1 General

The remaining two of the four full rail depth longitudinal vertical sections taken for macro- and micro-examination shall be subjected to hardness testing which shall be carried out in accordance with Annex F.

10.4.11.2 Grades R220, R260 and R260Mn

For the grades R220, R260 and R260Mn, the minimum and maximum hardness values obtained in the rail steel shall conform to the following requirements:

a) minimum hardness in the rail steel shall not be less than P - 30 HV_{30}

b) maximum hardness in the rail steel shall not exceed P + 60 HV_{30}

where

P is the average hardness in the rail steel of the parent rail as specified in EN 13674-1.

An isolated hardness value falling outside of the stated minimum and maximum values above shall be permitted when such a hardness value falls between the two adjacent values that conform to the requirements.

10.4.11.3 Grades with hardness values higher than R260Mn

Each hardness > P + 60 HV_{30} in the rail steel shall be investigated to determine the reason for this hardness level. In the case of martensite being present, further investigation shall be undertaken with the agreement of the RA.

An isolated hardness value falling outside of the stated minimum and maximum values above shall be permitted when such a hardness value falls between the two adjacent values that conform to the requirements.

10.4.11.4 Stainless steel and manganese steel

Where the recorded hardness exceeds by 50 HV_{30} the hardness value specified in the specification of the material, the test shall be considered as "non-valid". The test shall then be re-conducted. If elevated hardness values are still present, the sample shall be fully investigated to ensure that the requirements of 10.4.10 are fully met.

10.5 Test result report

A report which contains the results shall be produced. Photographs of the fracture faces (one per sample) of all broken test welds as well as macro and micro examination, and the rail profile grid shown in Annex C shall be included.

The test report shall include, as a minimum, the following:

- identification of the welding machine: type and serial number;
- identification of all materials welded in accordance with appropriate specification;
- the welding programme identification;
- the identification reference of the weld record;
- the record of any post-weld heat treatment applied;
- the method of upset removal;
- results of all tests employed during approval.

10.6 Validity of approval

Re-approval of welding procedures is required when:

- steel grades or steel production methods are changed,
- changes are made to welding parameters within an approved programme excepting pre-flashing distance,
- changes are made to any post-weld heat treatment.

11 Approval of other rail profiles or grades

11.1 General

Following the initial process approval with a particular rail profile and grade, other rail profiles within that particular group (see Table 2) and the other rail grades, as contained in EN 13674-1, EN 13674-2 or EN 13674-4, shall be approved as and when required.

Similarly, the other rail grades permitted by this standard shall be qualified for approval as and when required.

11.2 Sample preparation

For each rail profile or grade, the sample preparation shall be in accordance with 10.3.

11.3 Approval tests

All of the welds shall be subjected to approval testing and shall fulfil the requirements of 10.4, with the exception of the fatigue test (10.4.7), which is not mandatory.

11.4 Test result report

A report in accordance with 10.5 shall be produced.

12 Track trials

12.1 General

Following successful laboratory approval, track trials may be required by the RA to verify the performance of the weld(s) in track. The exact requirements of any track trials shall be specified by the RA.

12.2 Track trial test result report

Following track trials, a report shall be prepared by the manufacturer and RA detailing as a minimum the following:

— track category;

— speed;

— tonnage;

— geometry;

— support system;

— number of welds;

— duration of trial;

— type and frequency of inspection;

— test results.

13 Weld production following procedure approval

13.1 Weld production

Following procedure approval, weld production may commence on those rail profiles and grades approved. Weld production shall be carried out in accordance with the requirements of this European Standard.

13.2 Weld parameter monitoring

Automatic monitoring and recording of the weld parameters shall be required for all welds.

The welding programme and parameters shall be as those for which approval was granted.

The records shall be analysed in accordance with the requirements of this European Standard and shall be retained for not less than five years.

13.3 Visual inspections

All welds shall be visually inspected for compliance with this European Standard.

13.4 Weld geometry and dimensions

All welds shall be checked for alignment and shall conform to the requirements of this European Standard as specified in Clause 8.

13.5 Liquid penetrant testing and magnetic particle testing

All welds shall be checked and shall conform to the requirements of this European Standard as specified in 10.4.5.

13.6 Internal soundness

Welds without austenitic components shall be checked and shall conform to the requirements of this European Standard as specified in 10.4.6.

13.7 Bend Testing

13.7.1 General

Test welds shall be produced or selected while the plant is in production, regardless of production output, and shall be subjected to bend testing at a rate of at least one per week, in accordance with 4.1 h) and 10.4.7. All test welds shall be supplied in accordance with 10.2. These tests shall reflect the welding programmes and cooling conditions. All test welds shall be at 50 ºC temperature or less when tested. If enhanced cooling is applied other than as part of normal production, the cooling method shall be recorded on the test data sheet.

13.7.2 Additional test requirements

In addition to the routine requirements for bend tests, the following occurrences will require a mandatory bend test to be carried out:

a) immediately following rectification of a welding machine malfunction;

b) immediately following machine overhaul or work other than normal maintenance;

c) immediately following any change in the welding parameters;

d) immediately commencing production when the welding machine has not been used for more than one week.

13.7.3 Bend test procedure

The bend test procedure shall be carried out in accordance with 10.4.7 and Annex B. The load shall be applied until the minimum production test load and deflection limit (where required) are reached, after which the test can be terminated.

The requirements for minimum bend test load and deflection for weld production tests shall be in accordance with Table B.1 or Table B.2.

The following information shall be recorded at least:

— rail profile;

— the grade of constitute elements with the manufacturing number;

— the value of the applied load;

— the value of the deflection under load (if required);

— the date of welding;

— the reason for test.

Upon completion of the bend test, should the weld have fully fractured, the fracture surfaces shall be examined and weld features as described in this standard shall be recorded. Such defects shall be investigated in accordance with 10.4.7.

13.7.4 Interpretation of results

Upon completion of the test, the results shall be interpreted as follows.

a) If the weld has met the minimum load and deflection (where required), the weld shall be deemed to have met the required standard. In this case, production may commence or continue.

b) If the weld fails to meet the specified minimum production test load and deflection (where required), and the joint has fractured outside the welding zone owing to causes not relating to the welding process, e.g. a casting defect, the test shall be repeated.

c) If the weld fails to meet the specified minimum production test load and deflection (where required), then the weld shall be deemed to have failed and a retest shall be carried out in accordance with 13.7.5. If the weld has fractured, the fracture surfaces shall be examined and if die burns or the incidence of flat spots greater than that found and recorded in accordance with 10.4.7, or any other deleterious effect is found to be present, the cause shall be investigated before retesting.

13.7.5 Retesting

In the event of the bend test failing to meet the specified requirements, the procedure for retesting shall be as follows.

— If failure has occurred two more welds shall be tested in accordance with 13.7.3. If both of these welds meet the specified requirements production may continue.

— Failure of either of these welds shall result in all production welds subsequent to the previous satisfactory test being considered as suspect and subject to investigation. Welds shall be tested until two consecutive production welds are deemed to be satisfactory by meeting the specified requirements.

13.7.6 Documentation

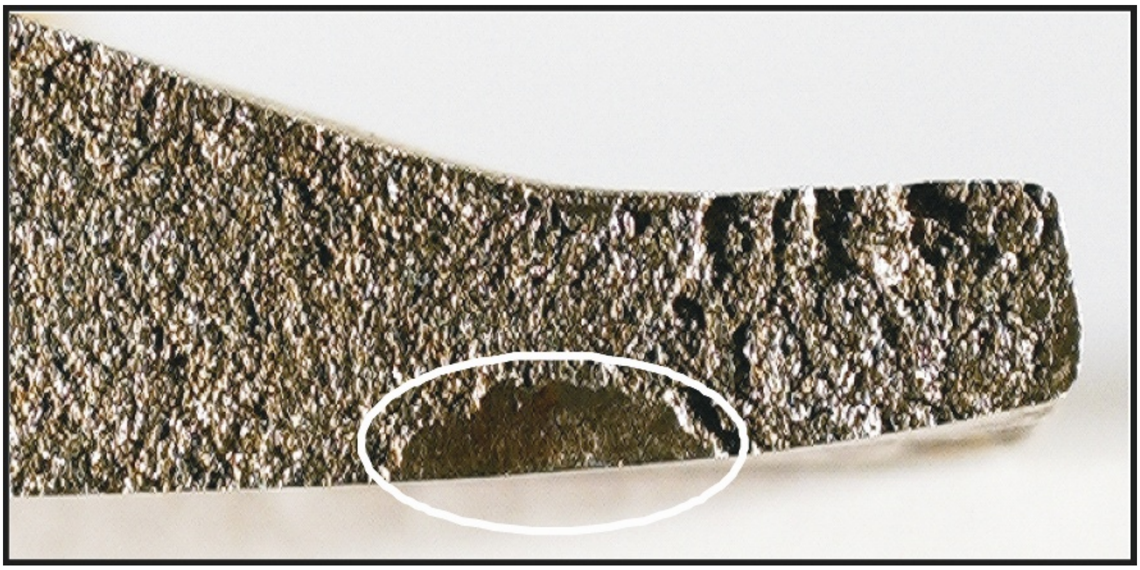
The records made in 13.7.3 shall be retained for a period of not less than five years and be made available to the purchaser as and when requested.

Annex A
(informative)

Example of Flat spot and Bright spot

NOTE The encircled area shows an example of a Flat spot.

Figure A.1 — Example of a Flat spot



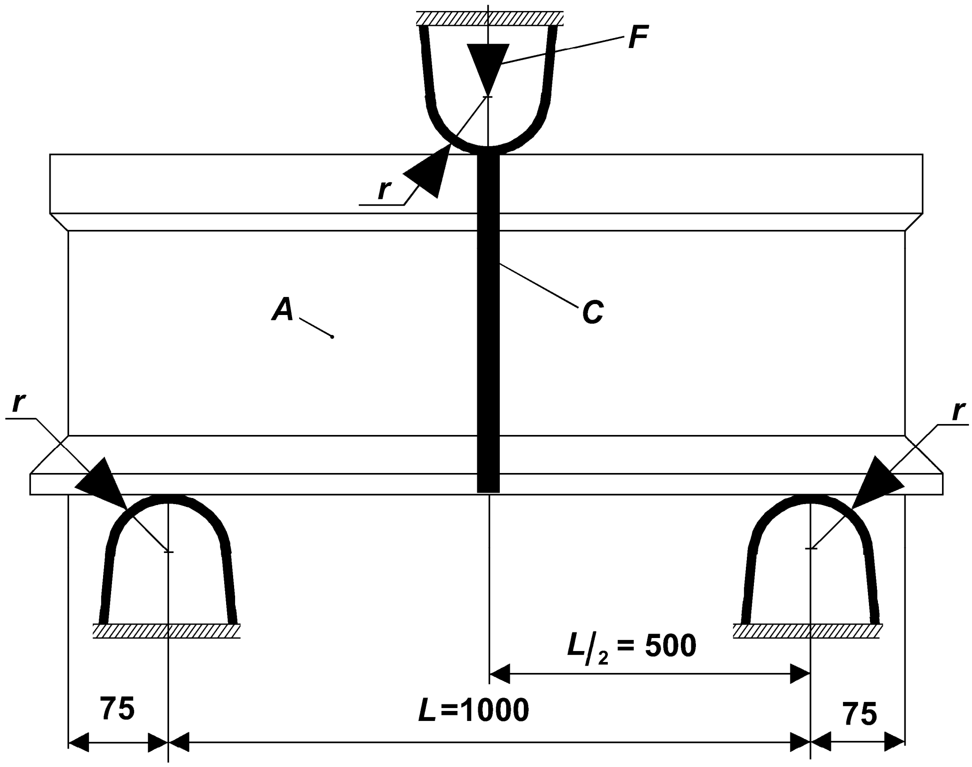
NOTE The encircled area shows an example of a Bright spot

Figure A.2 — Example of a Bright spot

Annex B
(normative)

Bend test requirements

Dimensions in millimetres



Key

F force (at the centreline of the insert or of the single weld)
A rail
C weld

NOTE 1 *r*: 25 mm to 70 mm.

NOTE 2 loading speed (1 mm/s maximum).

NOTE 3 deflection capability of the bend test rig is be 60 mm minimum.

NOTE 4 length *L*: (1000 ± 5) mm; the 75 mm overhang dimension is a minimum value.

Figure B.1 — Bend test arrangement

Table B.1 — Minimum Bend Test Requirements when welding with austenitic components

Rail Profile	Force kN
60E1	850
60E2	
56E1	750
54E1	
54E2	
54E3	
54E4	
52E1	
50E2	700
50E3	
50E5	
50E6	
49E1	
49E5	

Table B.2 — Minimum Bend Test Requirements when welding with non-austenitic components

Rail Profile	Minimum bend test deflection in mm when under load		Minimum bend test force in kN
	Materials ≤ 320HB	Materials > 320HB	All Materials
60E1	20	16	1350
60E2			
56E1			
55E1			
54E1	25	18	950
54E2			
54E3			
54E4			
52E1			
50E6			
50E3			
49E1	30	20	800
49E5			
46E1			
46E2			

Annex C
(normative)

Test weld fracture faces – Recording of defects

All weld fracture faces from the approval tests referred to in 10.4.7 and 10.4.8, and all weld fracture faces from production tests referred to in 13.7.3, shall be inspected and the details of any weld defects recorded.

A separate record shall be made for each weld fracture face on the rail profile grid shown in Figure C.1.

The record shall show the following details relative to each defect:

a) size: x and y dimensions;

b) shape;

c) location;

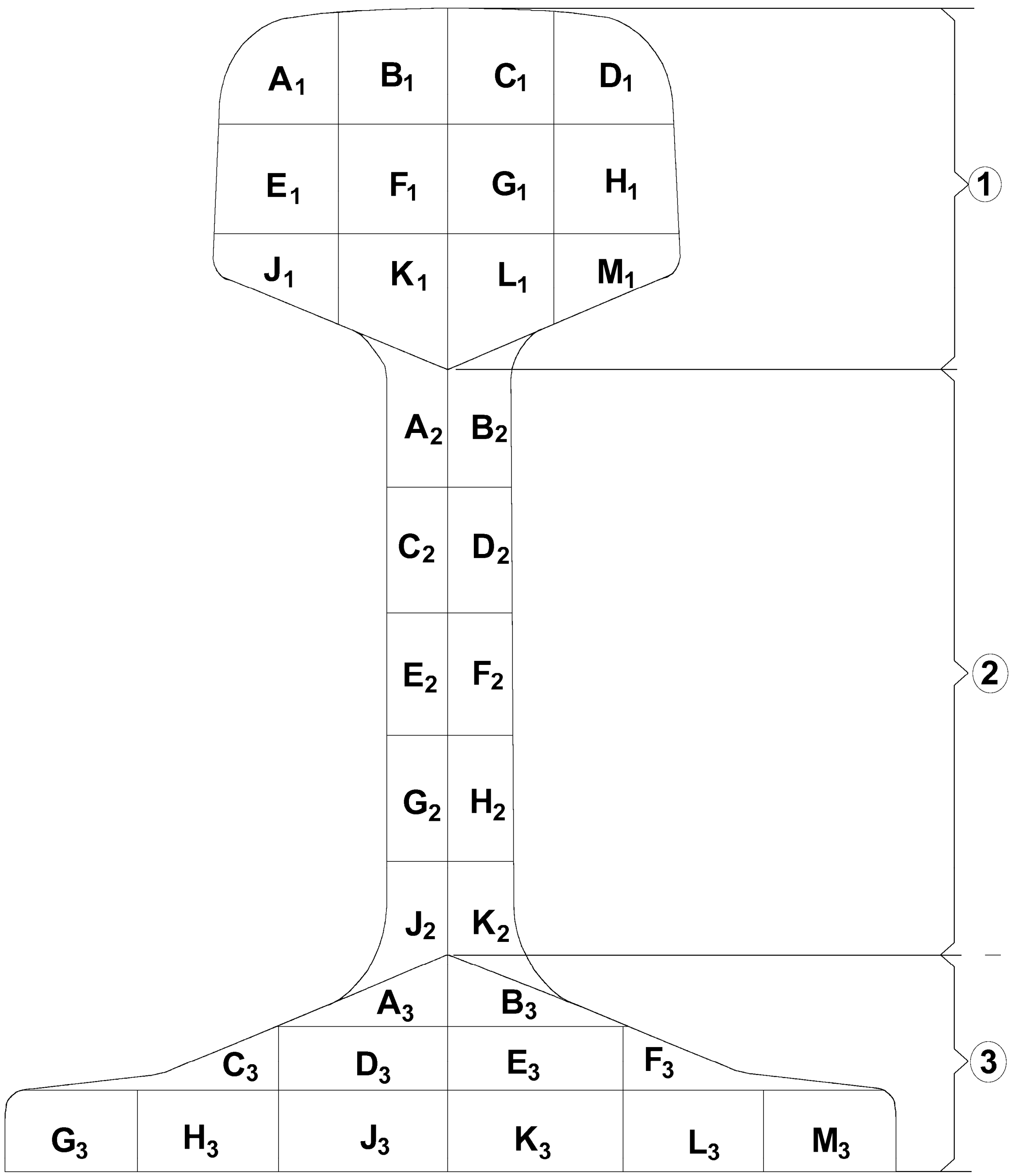
d) orientation;

e) origin of fracture;

f) type of defect.

Test weld identification and the relevant bend test or fatigue test information shall be endorsed and appended to the rail profile grid.

A weld fracture face containing no imperfections shall be similarly recorded with an entry being made on the rail profile grid to show clearly the wording "No visible imperfections".



Key

1 head
2 web
3 foot

Figure C.1 — Rail profile grid

Annex D
(normative)

Fatigue test method for flash butt welds

D.1 Scope

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

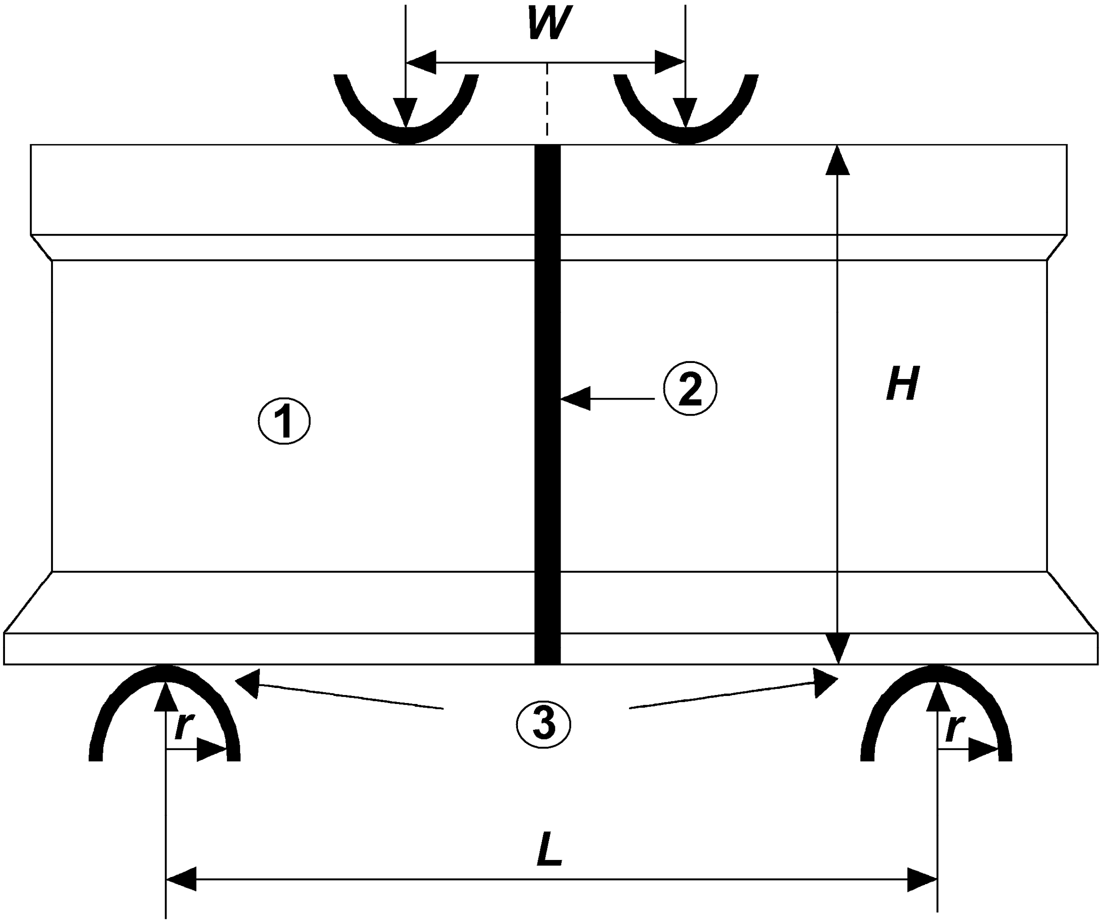
The relationship of the applied load to the nominal outer fibre stress is established using a length of plain rail, strain-gauged and load-cycled at the frequency of the test.

D.2 Test equipment

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

The inner span (W) shall be a minimum 150 mm. The outer span (L) shall exceed the inner span by at least twice the rail height and shall be symmetrical about the inner span.

$L \geq W + 2H$



Key

1 rail or casting
2 weld(s)
3 bearers

Figure D.1 — Fatigue test arrangement

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

D.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.

D.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 such 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 minimise 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.

D.2.5 The applied force shall be measured using a calibrated load cell.

NOTE Depending on the outer span, a 500 kN or 1 000 kN actuator is likely to be suitable for most applications.

D.3 Calibration procedure

D.3.1 General

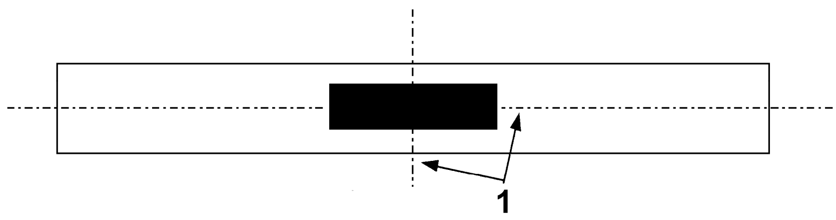
This clause describes the determination of the relationship between the nominal outer fibre stress and the applied load.

D.3.2 Test piece

The test piece shall be of the profile(s) under consideration. It shall be unused with a length exceeding that of the outer span of the test rig by no more than 100 mm.

D.3.3 Test piece preparation

Attach a strain gauge to the foot of the rail as shown in Figure D.2. Use a gauge of nominally 120 Ω or 350 Ω resistance and a gauge length of 5 mm or 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 if the gauges do not have a self-temperature-compensation for common steel.



Key

1 centre lines of gauge and rail to coincide

Figure D.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.

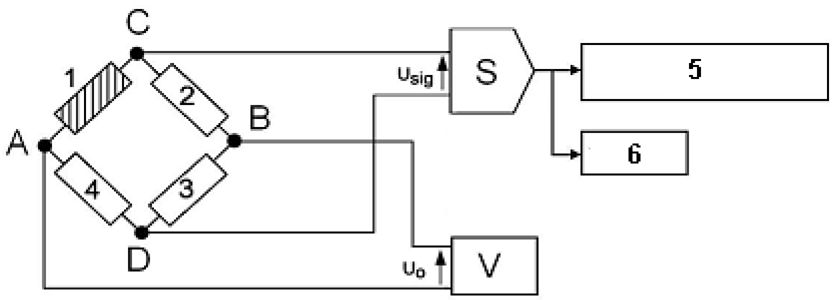
D.3.4 Instrumentation

A digital voltmeter or digital strain-meter, with peak reading circuits accurate to 1 part in 1 000 at the test frequency, shall be used.

D.3.5 Procedure

D.3.5.1 Mount the rail in the test rig with the strain gauge positioned directly beneath the actuator. The rail should be mounted so that the application of compressive loads by the actuator places the foot of the rail in tension. If the gauges do not have a self-temperature-compensation for common steel, position the independent block adjacent to the test piece. Wire the gauges to form a Wheatstone bridge circuit as shown schematically in Figure D.3 if the laboratory uses a digital voltmeter or a digital strain-meter for full bridges and wire the strain gauge 1 if the laboratory uses a digital strain-meter for quarter bridges. Apply a constant voltage of approximately between 5 V DC and 10 V DC between points A and B (for full bridge) or C (for quarter bridge) 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
5	signal processing system converting volts to MPa
6	voltmeter
S	signal amplifier (in volts)
V	input voltage

Figure D.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.

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

$$U_{sig} = \frac{\sigma_i \cdot gf \cdot U_0}{4 \cdot E} \tag{D.1}$$

where

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

gf is the gauge factor of the strain gauge on the rail;

U_0 is the voltage applied to the bridge;

E is the Young's modulus, to be taken as 210 GPa.

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

k	σ_i (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

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

D.3.5.5 Using the data given in Table D.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 D.2 — Calibration results

k	σ_i MPa	U_{sig} V	**Associated force** kN	**Average force** $F_{k\ min}$ kN	σ_i MPa	U_{sig} V	**Associated force** kN	**Average force** $F_{k\ max}$ kN	ΔF_k kN [a]
1	15				150				
2	17				170				
3	19				190				
4	21				210				
5	23				230				
6	25				250				
7	27				270				
8	29				290				

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

D.4 Fatigue test method

D.4.1 General

The purchaser has the option according to 4.1 e) to select either a staircase (see D.4.2) or a past-the-post test (see D.4.4). Table D.3 defines the requirements for both types of test.

Table D.3 — Fatigue Test Requirements for the profile 60E1/60E2/56E1

	Staircase test method (D.4.2) Minimum requirements		**Past-the-post test method (D.4.4)**
Rail profile with austenitic component	Main fatigue strength (MPa) / No. of cycles	Standard deviation (MPa)	Specified stress (MPa) / No. of cycles
60E1/60E2	150 / 5000000	< 15	130 / 5000000
56E1	150 / 5000000	< 15	130 / 5000000
Rail profile without austenitic component	Mean fatigue strength (MPa) / No. of cycles	Standard deviation (MPa)	Specified stress (MPa) / No. of cycles
60E1/60E2	245 / 5000000	< 27	190 / 5000000

D.4.2 Staircase testing method

D.4.2.1 Test pieces

Ten test pieces are required. The test piece shall be positioned at the centre of the weld to within ± 10 mm. The test piece length shall not exceed the outer test span by more than 100 mm.

D.4.2.2 Procedure

D.4.2.2.1 Position a test piece in the test rig so that the centre line of the weld(s) is aligned with the centre line of the actuator to within 3 mm.

D.4.2.2.2 Determine the maximum stress associated with the mean fatigue strength at five million cycles.

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 D.3.5.5, determine the maximum force and the force range corresponding to these values of maximum stress and stress range.

D.4.2.2.3 Cyclically load the weld using a sinusoidal waveform so that the maximum value of force, and the range derived in D.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 five million cycles have been applied.

D.4.2.2.4 If the test piece breaks, the test result shall be recorded as a 'failure'. If it survives, it shall be recorded as a 'run-out'. The cyclic force range and nominal outer fibre stress range shall also be recorded.

D.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 force applied shall be 10 % of the maximum.

D.4.2.2.6 Where any failure is due to die-burn, the result shall be disregarded and an additional test piece made and tested.

D.4.2.2.7 Continue as above until ten test pieces have been tested.

D.4.2.3 Data analysis

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

No data analysis is required.

D.4.2.3.2 Both failures and run-outs obtained

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

First determine whether failures or run-outs are the less frequent events. Then calculate the mean fatigue strength σ_m using the formula:

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

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;

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

where

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

i is the coded stress level (i = 0 for σ_0);

z is the 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 following formula:

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

where

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

D.4.2.3.3 Information to be reported

For each test series the following shall be reported:

a) the inner and outer spans of the test rig (D.2.2);

b) the distances from the centre line of the actuator to the loading points (D.2.3);

c) dynamic calibration results (D.3.5.4);

d) the mean and standard deviation of the fatigue strength at five million cycles if calculated according to the procedure given in D.4.2.3.2.

For each test report:

e) the maximum force range applied;

f) the nominal outer fibre stress range applied;

g) whether the test resulted in a failure or a run-out;

h) in the case of failure, the crack initiation location.

D.4.2.4 Acceptance criteria

D.4.2.4.1 All results are failures

The process is not acceptable.

D.4.2.4.2 All results are run-outs

The process is acceptable.

D.4.2.4.3 Both run-outs and failures occur

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

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 Formula (D.3) will be spurious.

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

Table D.4 — Experimental results

σ	1	2	3	4	5	6	7	8	9	10	i	n_i	$i \cdot n_i$	$i^2 \cdot n_i$
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 – anticipated

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 Formula (D.2) which shall be used is:

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

The standard deviation according to Formula (D.3) is:

$$s = 1{,}62 \cdot d \cdot \left(\frac{B \cdot N - A^2}{N^2} + 0{,}029 \right) = 1{,}62 \cdot 10 \cdot \left(\frac{6 \cdot 4 - 4^2}{4^2} + 0{,}029 \right) \text{MPa} = 8{,}6 \text{ MPa} \quad \text{(D.5)}$$

D.4.4 Past-the-post testing method

D.4.4.1 Test pieces

Three test pieces are required. The test piece shall be positioned at the centre of the weld to within ± 10 mm. The test piece length shall not exceed the outer test span by more than 100 mm.

D.4.4.2 Procedure

D.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.

D.4.4.2.2 The specified stress is shown in Table D.3. The minimum stress applied shall be 10 % of the maximum stress. No failures are acceptable at an endurance of less than five million cycles .

EXAMPLE If the specified stress range is 180 MPa when the ratio of the minimum to maximum applied stress (*R*) is 0,1, then the maximum stress will be 180/(1 - *R*) = 200 MPa.

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

D.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'.

D.4.4.3 Information to be reported

For each test series the following shall be reported:

a) the inner and outer spans of the test rig (D.2.2);

b) the distances from the centre line of the actuator to the loading points (D.2.3);

c) dynamic calibration results (D.3.5.4);

d) the outer fibre stresses applied (D.4.2.3.2).

For each test, report:

e) whether the test resulted in a failure or a run-out;

f) in the case of failures, the crack initiation location.

D.4.4.4 Acceptance criterion

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

Annex E
(normative)

Macro-examination and micro-examination

E.1 Macro examination

A longitudinal vertical section shall be taken centrally down the vertical axis of the full rail and extend 60 mm each side of the fusion line when welding with non-austenitic component(s). When welding with austenitic component(s), the specimen length shall be the stainless insert plus 60 mm minimum into the rolled rail and 30 mm minimum into the austenitic rail.

Similar sections shall be taken from both sides of the foot, 20 mm inboard of the foot tips. The sections shall be polished to a suitable finish using a minimum 220 grit paper. One full depth rail sample and the associated rail foot samples from each of the two welds shall be etched to show the weld boundary lines. In case of dispute, the FRY etching method shall be used.

The etching agent shall have the following chemical composition per 10 ℓ:

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

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

— 4,2 ℓ distilled water.

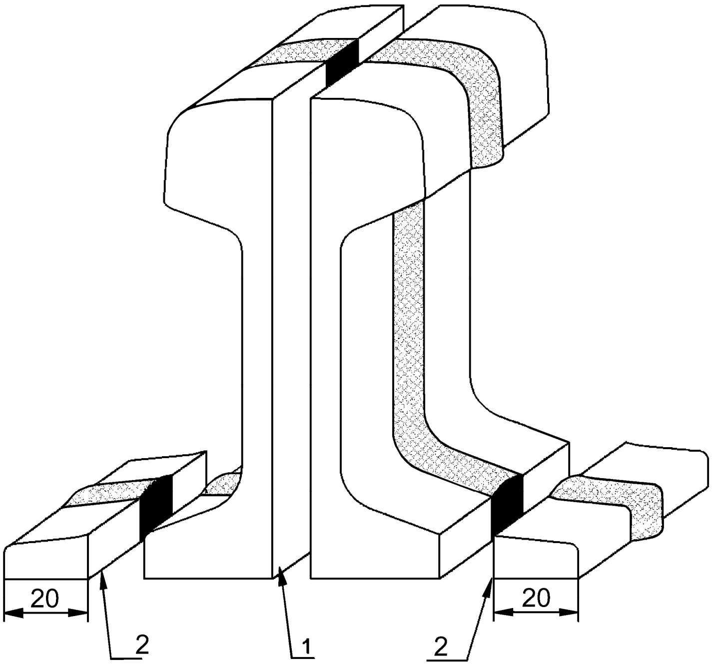
Etching at room temperature shall be for sufficient time, 30 min minimum, in order to show the boundary lines clearly when examined.

E.2 Micro examination

For austenitic components microscopic examination shall be carried out on samples from the cut sections taken from the head (one sample 20 mm x 20 mm) and foot tips (two samples 10 mm high x 20 mm) of two of the four welds (see sketch below). The samples shall be examined in a polished and etched condition.

For non–austenitic components, micro examination is necessary when failure has occurred during the bend tests or macro examination. The samples shall be examined in a polished and etched condition.

Dimensions in millimetres



Key

1 longitudinal vertical section on centre line

2 longitudinal vertical section of foot tip

Figure E.1 — Sectioning of welds

Annex F
(normative)

Hardness testing

Two welds in the finished condition shall be sectioned for hardness testing. A longitudinal vertical section shall be taken centrally down the vertical axis of the full rail and extend 60 mm each side of the fusion line when welding with non-austenitic component(s). When welding with austenitic component(s), the specimen length shall be the stainless insert plus 60 mm minimum into the rolled rail and 30 mm minimum into the austenitic rail.

The variation in hardness across the heat affected zone of each of the two welds shall be measured using the Vickers hardness test in accordance with EN ISO 6507-1 and the following parameters:

a) HV 30;

b) impressions to be on a line between 3 mm and 5 mm below the running surface on the vertical longitudinal axis of the rail. Spacing shall be at 2 mm centres;

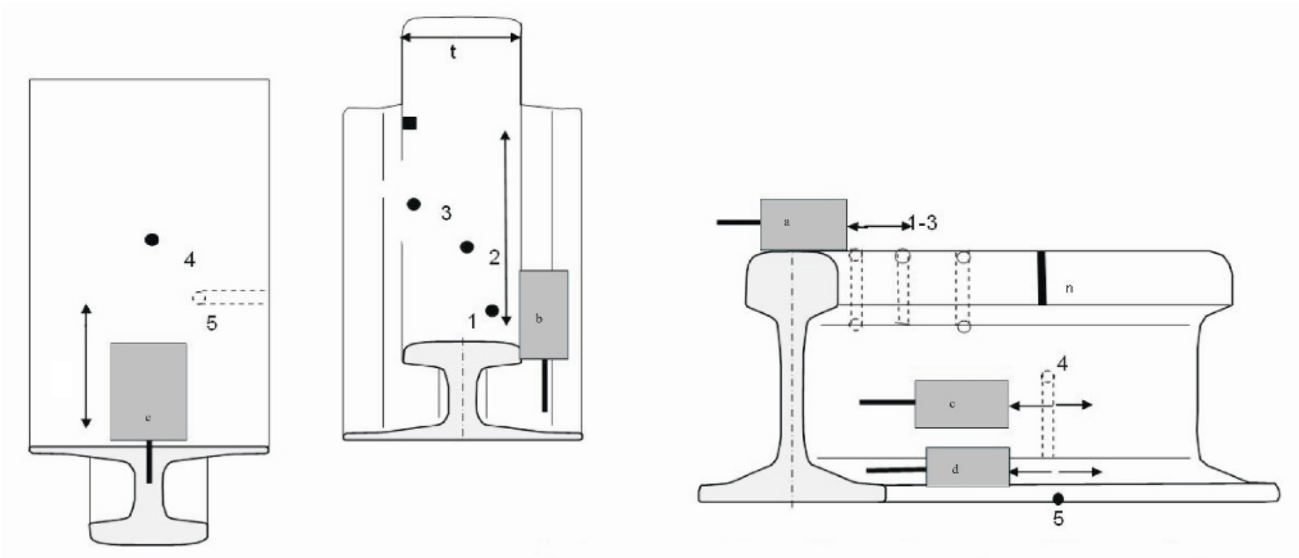
c) the hardness traverse shall extend from the weld to points on each side of the weld at least 20 mm into unaffected parent rail.

The measurements obtained shall be recorded in graphical and numerical form.

Annex G
(normative)

Ultrasonic testing non-austenitic materials

G.1 Reference line (DAC) generation – Reference block



Key

1, 2, 3	¼, ½, ¾ head-width thickness, 3 mm drilling, depth: min. 35 mm DAC generation
4	2 mm drilling, depth: min. 60 mm, check
5	2 mm drilling, depth: min. 35 mm, check
n	notch, with: 3 mm depth: 1,5 mm length: head height
b	probe position reference line generation
a, b, c, d, e	probe positions production tests from both directions to welds (b, c, d on both sides of rail)

NOTE Probe: MWB 70-2.

Figure G.1 — Reference line (DAC) generation – Reference block

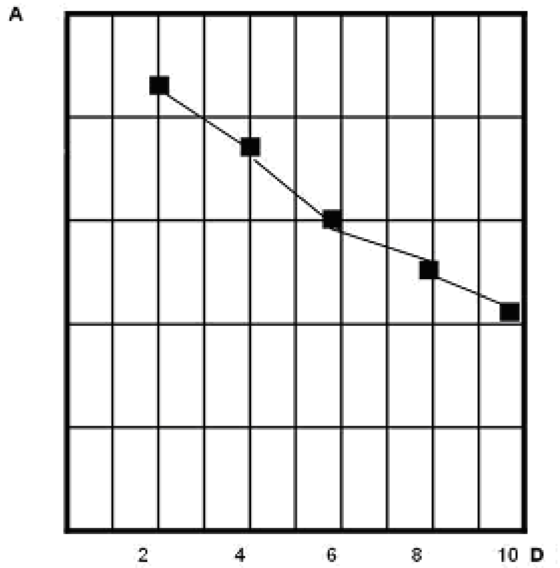
G.2 Reference line (DAC) generation and acceptance criteria

The acceptance criteria are as follows:

— Registration limit: ≥ 50% reference line.

— Acceptance level: cracks, lack of fusion and all defects with indications ≥ reference are not acceptable.

— All other ultrasonic testing requirements shall conform to EN ISO 11666, EN ISO 17640 and EN ISO 23279.



Key

A amplitude corresponding to the echo height of drillings and notches, measured in % screen height

D distance

■ points connected = reference line

Figure G.2 — Reference line (DAC) generation and acceptance criteria

The following criteria to be taken into account are as follows:

— The largest echo from holes 1, 2, 3 shall be set to 80% of full screen height (FSH);

— Distance scale:

  — ¼ thickness echo to 2 scale parts

  — ½ thickness echo to 4 scale parts

  — ¾ thickness echo to 6 scale parts

  — notch echo to 8 scale parts

  — ¾ thickness echo, indirect, to 10 scale parts.

Bibliography

[1] EN 15689, *Railway applications — Track – Switches and crossings — Crossing components made of cast austenitic manganese steel*

[2] EN ISO 9001, *Quality management systems — Requirements (ISO 9001)*

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BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK