INTERNATIONAL STANDARD

ISO 23300-1

First edition
2021-08

Railway infrastructure — Rail welding —

Part 1: General requirements and test methods for rail welding

Reference number
ISO 23300-1:2021(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

Foreword iv
Introduction v
1 Scope 1
2 Normative references 1
3 Terms and definitions 1
4 Rail welding processes 3
5 General process of rail welding 3
6 Approval/homologation of welding processes 4
6.1 General 4
6.2 Non-destructive testing (NDT) 4
6.3 Slow-bending test 4
6.4 Past-the-post fatigue test 5
6.5 Macro examination 5
6.6 Micro examination 5
6.7 Hardness test 5
6.8 Drop-hammer test (optional) 5
6.9 Recording of defects 5
6.10 Test result reports 5
7 Acceptance in factory/track 6
7.1 General 6
7.2 Weld inspection 6
7.3 Straightness inspection 6
7.4 Documentation 8
8 Requirement on contractor/welder/inspector 8
8.1 Contractor 8
8.2 Welder, operator and inspector 8
8.3 Audit 9
Annex A (normative) **Slow-bending test method for rail foot in tension** 10
Annex B (normative) **Slow-bending test method for rail head in tension** 13
Annex C (normative) **Three-point bending fatigue test** 16
Annex D (normative) **Four-point bending fatigue test** 18
Annex E (normative) **Macro examination** 20
Annex F (normative) **Micro examination** 21
Annex G (normative) **Hardness test** 24
Annex H (normative) **Drop-hammer test** 26
Annex I (normative) **Recording of defects on fracture faces** 28
Annex J (normative) **Ultrasonic testing** 30
Annex K (normative) **Magnetic particle testing** 36
Annex L (normative) **Dye penetrant testing** 38
Annex M (informative) **Examples of acceptance criteria for straightness** 40
Bibliography 43

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 269, *Railway applications*, Subcommittee SC 1, *Infrastructure*.

A list of all parts in the ISO 23300 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Rail welding is an essential technology in the railway track domain for reducing noise and vibration on rail joints, improving ride comfort and reducing maintenance costs.

Since environments (e.g. geography, deployable resources and energy affairs) differ by region and railway line, rail welding processes have been developed to meet the requirements and conditions of each environment. As a result, various rail welding processes exist, e.g. flash butt welding (FBW), gas pressure welding (GPW), aluminothermic welding (ATW) and enclosed arc welding (EAW).

For this reason, a general rail welding standard on an international level covering conventional rail welding processes was deemed necessary. This document contributes to the development of railways by ensuring the quality of welded joints in terms of enhancing the reliability of train operation, improving the welding work efficiency and facilitating the introduction of new procedures.

This document covers the general requirements for rail welding and is used in conjunction with the subsequent parts of the ISO 23300 series, which cover the specific requirements for each welding process (such as FBW, GPW, ATW and EAW).

Railway infrastructure — Rail welding —

Part 1:
General requirements and test methods for rail welding

1 Scope

This document specifies requirements concerning the approval and/or homologation of welding processes, contractors, welders, inspectors and acceptance of welded joints in the factory and/or track.

This document is applicable to the following rail welding processes:

a) flash butt welding (FBW);

b) gas pressure welding (GPW);

c) aluminothermic welding (ATW);

d) enclosed arc welding (EAW).

In this document, 43 kg/m to 75 kg/m new flat-bottomed rails of the same profiles and same steel grades are used as the subject of welding.

This document does not specify requirements or test methods specific to each welding process. These are to be prescribed in the subsequent parts of the ISO 23300 series.

Concerning butt welding, this document is restricted to connecting rail ends.

This document does not cover the welding for construction of crossings, railway switches, signal bond installation or restoration of rails.

This document does not cover any safety regulations for welding operations.

In this document, the qualifications of individuals and organizations that are approved by the railway authority for rail welding are not specified.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO 6508-1, *Metallic materials — Rockwell hardness test — Part 1: Test method*

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*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
railway authority
either the railway regulator or the owner of a railway infrastructure or the custodian with a delegated responsibility for a railway infrastructure

3.2
process supplier
company which provides a rail welding process which is approved by the *railway authority* (3.1) to supply machines, consumables and tools for the making of *welded joints* (3.13)

3.3
training centre
organization or centre responsible for training *welders* (3.5) and which is approved by the *railway authority* (3.1), and, in the case of aluminothermic welding, by the *process supplier* (3.2)

3.4
contractor
company approved by the *railway authority* (3.1) to provide staff and machinery in order to execute the *production* (3.8) of *welded joints* (3.13)

3.5
welder
person who is trained and competent to undertake the appropriate welding process

3.6
operator
person who is trained and competent to undertake the appropriate welding machine operation

3.7
inspector
person who is trained, qualified, approved and competent to carry out inspection of *welded joints* (3.13) by observation and judgement, accompanied as appropriate by measurement and testing techniques

3.8
production
butt welding work to connect rails for rail transport operation, whether performed in-factory or on-site

3.9
fixed plant
stationary production line for solid phased welding of rails

3.10
profile finishing
operation by which the rail head or relevant part of the rail head at the *welded joint* (3.13) is returned to rail profile

Note 1 to entry: Operation can be carried out by grinding, milling, planing or any other suitable means.

3.11
post-weld heat treatment
application of heating and cooling control to a *welded joint* (3.13) after welding

3.12
heat-affected zone
HAZ
part of the unmelted base metal where the metal structure, metallurgical properties, mechanical properties are transformed due to heat input during the welding process such as welding, *post-weld heat treatment* (3.11) and flame cutting

3.13
welded joint
rail joints bonded by welding, which includes the weld metal and the *heat-affected zone* (3.12)

3.14
finished condition
welded, trimmed, dressed and *profile finished* (3.10)

3.15
non-destructive testing
NDT
application of technical methods to examine materials or components in ways that do not impair their future usefulness and serviceability, in order to detect, locate and evaluate defects, to assess integrity, properties, composition and geometrical characteristics

3.16
acceptance in factory/track
acceptance inspection conducted from the viewpoint of quality control targeting *welded joints* (3.13) which will be used in track

4 Rail welding processes

The following processes are currently applied for butt welding connecting rail ends:

a) FBW: Hot pressure welding process using electric current and axial force to produce a welded joint (there are two types: fixed plant and mobile).

b) GPW: Hot pressure welding process using gas flame and axial force to produce a welded joint.

c) ATW: Cast fusion welding process using aluminothermic reaction to generate liquid steel.

d) EAW: Electric arc welding process performed by surrounding rails with copper or ceramic block.

5 General process of rail welding

The rail welding process generally consists of the following stages:

a) Preparatory stage: Including provision of information from the railway authority or delegated company and arrangement of conditions.

b) Working stage: Including rail end preparation, alignment, step treatment, welding work and post-weld heat treatment.

c) Finishing stage: Including profile finishing and welded joint identification.

d) Verification/acceptance stage: Including the tests/inspections classified in Clauses 6 and 7.

NOTE Further details on each stage of each applied process will be prescribed in the subsequent parts of the ISO 23300 series.

6 Approval/homologation of welding processes

6.1 General

Initial approval/homologation tests shall be carried out for every application of each rail welding process. Approval/homologation tests are used to confirm the reliability of the welding process and do not reflect quality control in production. Approval/homologation tests shall be carried out for a particular rail profile and grade, using a specific welding machine or specific type of welding consumable material.

NOTE The series and sequence of tests for each welding process, together with the number of specimens for each test item, are specified in the subsequent parts of the ISO 23300 series.

The specification requirements of each approval/homologation test shall be provided to the contractor from the railway authority before conducting the test.

6.2 Non-destructive testing (NDT)

In this document, NDT methods include:

a) visual testing (VT);

b) ultrasonic testing (UT);

c) magnetic particle testing (MT);

d) dye penetrant testing (PT).

After the VT, further appropriate NDT methods shall be applied in accordance with the relevant annexes of this document and the subsequent parts of the ISO 23300 series, and shall be used to inspect the welded joint in finished condition.

The NDT methods for sectioned and full-size samples are dependent upon the welding process being used.

NOTE The NDT methods for sectioned and full-size samples are described in the subsequent parts of the ISO 23300 series.

6.3 Slow-bending test

The slow-bending test for a welded joint is a practical and efficient test method that can simply evaluate the performance of the welded joint on whether the load and the deflection satisfy the specified value. However, the original purpose of the test is to force failure of the welded joint and to observe the existence or non-existence of weld defects on the fracture face.

In this test, two loading modes are applied as appropriate:

a) one with the rail head upwards in which tensile stress is applied to the rail foot;

b) one with the rail head downwards in which tensile stress is applied to the rail head.

Each slow-bending test shall also be continued until the load or deflection reaches the specified value or fracture occurs.

For applying the slow-bending test in which tensile stress is applied to the rail foot, the requirements and the test method given in Annex A shall be followed.

For applying the slow-bending test in which tensile stress is applied to the rail head, the requirements and the test method given in Annex B shall be followed.

6.4 Past-the-post fatigue test

The straightness of the welded joint in finished condition shall not affect the execution of a past-the-post fatigue test.

The test sample shall be subject to NDT, which shall include VT and UT, MT or PT as appropriate. Only those samples that have been qualified by NDT can be used for the fatigue test.

The test shall be conducted in three-point or four-point bending with the rail foot in tension. Each test type is sufficient for approval.

The requirements for the three-point bending test and the test method given in Annex C shall be followed.

The requirements for the four-point bending test and the test method given in Annex D shall be followed.

6.5 Macro examination

Macro examination shall be performed to investigate the presence or absence of defects in the relevant sections, or on a fracture face following bend, fatigue or drop-hammer testing that is not identified as a surface breaking defect in the welded joint and to confirm that the appropriate heat input has been achieved. The macro structures depend on each welding process.

The macro examination described in Annex E shall be followed.

6.6 Micro examination

Micro examination shall be performed to investigate the presence or absence of an abnormal metallographic structure in the welded joint. The micro structures depend on each welding process.

The micro examination described in Annex F shall be followed.

6.7 Hardness test

A hardness test shall be performed to evaluate wear resistance and to confirm accordance with specification. The hardness values depend on each welding process.

The hardness test described in Annex G shall be followed.

6.8 Drop-hammer test (optional)

A railway authority may demand a drop-hammer test to assess the welded joint's performance.

If applied, the drop-hammer test described in Annex H shall be followed.

6.9 Recording of defects

The details of weld defects shall be recorded.

The recording of defects described in Annex I shall be followed.

6.10 Test result reports

Test result reports shall contain, as a minimum, items in accordance with the relevant annexes and shall reference this document.

7 Acceptance in factory/track

7.1 General

Documentation and records relating to traceability shall be made available upon request by the railway authority.

7.2 Weld inspection

Prior to any inspection, the welded joint shall be completed and the traceability shall be identified. The welded joint shall be in the finished condition.

Joints welded in a fixed plant shall be inspected in the plant. Based on the inspection, the welded joint shall be deemed as accepted or rejected.

Joints welded on-site shall be inspected on the railway track. Based on the inspection, the welded joint shall be deemed as accepted or rejected. This is applicable to FBW using a mobile machine, GPW, ATW and EAW.

The equipment used for inspection shall be calibrated and shall meet the requirements of the relevant equipment supplier and the railway authority.

The inspector shall be competent and shall meet the requirements of the railway authority.

A weld inspection report containing the result and details of the weld inspection shall be completed. When the inspection results do not conform to this document or the subsequent parts of the ISO 23300 series, the welded joint shall be treated as unqualified products.

Items to be inspected for the acceptance of welded joints shall include:

a) straightness (see 7.3);

b) NDT (VT shall be applied to find the surface breaking defect about the welded joint. Other inspection items are optional, and shall be defined by the railway authority. If applicable, Annexes J, K and L shall be followed).

7.3 Straightness inspection

The straightness of the welded joint in finished condition shall be measured, vertically and horizontally over a 1 m span. The error of 1 m straight edge shall not exceed 0,05 mm.

The straightness shall be measured while the welded joint is at ambient temperature. In some specific cases (i.e. immediately following profiling, insufficient cooling times for site-made welded joints), any measurement of alignment can be made while the welded joint is hot. The effect of temperature on the welded joint shall be taken into consideration.

Straightness across the welded joint shall be measured as follows (see Figure 1):

a) The vertical straightness of the running surface shall be measured along the longitudinal surface of the rail. Measurement points are shown in Figures 1 a) and b). For negative tolerance, see Figure 1 a). For positive tolerance, see Figure 1 b).

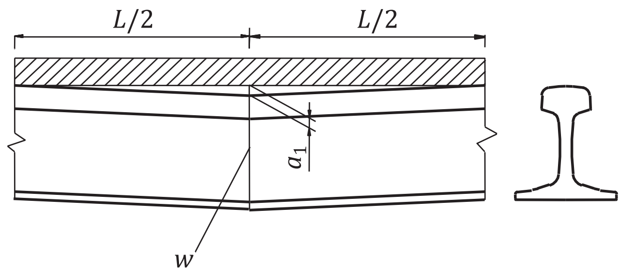
b) The horizontal straightness of the welded joint at the running edge shall be measured on one or both faces at a gauge measuring point below the running surface. Measurement points are shown in Figures 1 c) and d). For negative tolerance which widens the gauge, see Figure 1 c). For positive tolerance which tightens the gauge, see Figure 1 d).

c) The necessity of measurement on the field side shall be confirmed by the railway authority with the contractor.

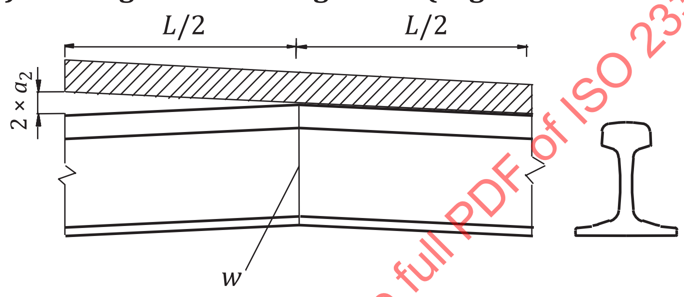
d) The means of measuring the straightness of the welded joint as described shall be the choice of the contractor, but in the case of acceptance inspection a calibrated straight edge shall be used.

Acceptance criteria for straightness shall be specified by the railway authority.

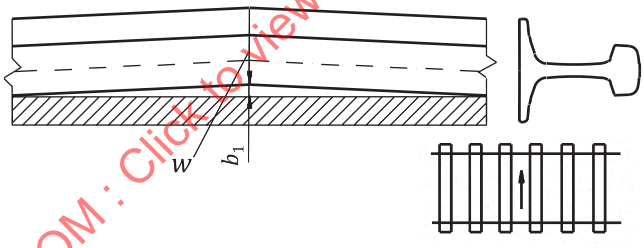
Examples of acceptance criteria for straightness are given in Annex M.



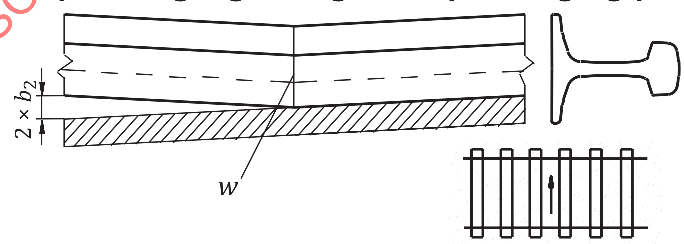
a) running surface straightness (negative tolerance)



b) running surface straightness (positive tolerance)



c) running edge straightness (widens gauge)



d) running edge straightness (tightens gauge)

Key

w weld centre

L measurement span, L = 1 m

a_1 vertical straightness tolerance on the running surface (a_1 is negative tolerance)

a_2 vertical straightness tolerance on the running surface (a_2 is positive tolerance)

b_1 horizontal straightness tolerance (tolerance widens gauge)

b_2 horizontal straightness tolerance (tolerance tightens gauge)

Figure 1 — Schematic of straightness measurement

7.4 Documentation

Documentation shall contain traceability of the welded joint and inspection reports in accordance with the relevant annexes and shall reference this document.

8 Requirement on contractor/welder/inspector

8.1 Contractor

The welding contractor shall maintain a management system of rail welding that complies with the requirements of the railway authority.

The welding contractor shall maintain a system that ensures the competence of employed welders, welding operators and inspectors through appropriate training, assessment and authorization, and which shall include:

a) welder/operator training and competences;

b) weld records;

c) number of welded joints produced in a given period;

d) number of welded joints rejected;

e) notified number of welded joints failed in service.

The welding contractor shall maintain a system of weld inspection according to the relevant railway authority requirements. Nonconformities found during these inspections shall be recorded in the traceability system.

Welding equipment and welding consumable materials shall be approved by the relevant railway authority. Equipment shall comply with the manual of the welding process.

Inspection and calibration equipment shall comply with those requirements as agreed between the contractor and the relevant railway authority.

8.2 Welder, operator and inspector

The welder, operator and inspector shall be trained at an approved training centre.

Training shall include both practical and theoretical elements.

All training shall conclude with a practical and theoretical examination to confirm the trainee's ability to carry out the welding of rails in accordance with the requirements of the relevant welding process.

The qualification to work in track shall be provided by the railway authority.

The knowledge acquired by the trainee should contain, but is not limited to:

a) basic safety;

b) rails;

c) operating equipment;

d) specific information to the welding process (FBW, GPW, ATW, EAW);

e) abnormalities, causes and effects;

f) grinding and finishing;

g) NDT of welded joints;

h) record of installation and inspection.

8.3 Audit

The railway authority reserves the right to audit the welding contractor, welder/operator/inspector or training centre at any time. Audits may be carried out by technical organizations recognized by the railway authority which include the ATW process supplier.

Annex A
(normative)

Slow-bending test method for rail foot in tension

A.1 General

For the requirements and test method for the slow-bending test in which tensile stress is applied to the rail foot, see A.2 to A.4.

A.2 Bending test arrangement

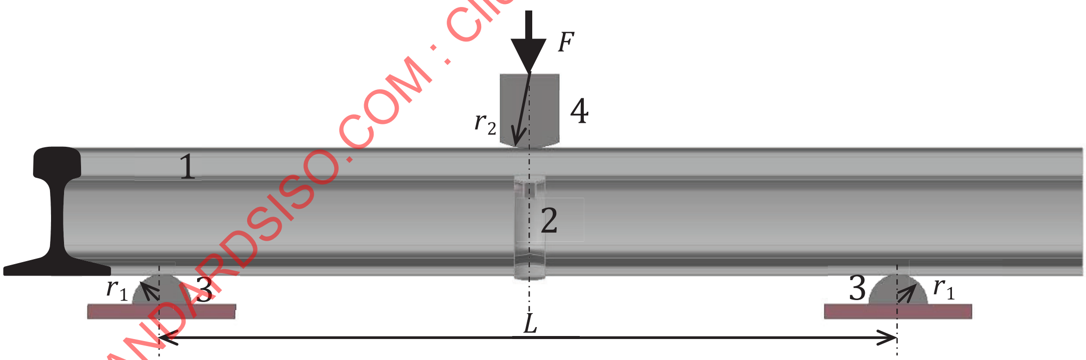
All test welded joints shall be in the finished condition. Test welded joints shall either be selected from the production line or be made using appropriate test pieces.

The straightness of the welded joint in finished condition shall not affect the execution of the slow-bending test.

All test welded joints shall be at ambient temperature when tested. The test welded joints shall be placed on the two supports of the bending testing machine, with the weld centre of the rail head located at the span centre to bear the concentrated load.

The radius of curvature of the three load points shall not be less than 30 mm.

Figure A.1 shows the relative positions of the test welded joint on the bending testing machine. The length of the test welded joints should be 200 mm to 600 mm longer than the span (L) with the weld itself at the centre.



Key

F force

L span

r_1 radius of curvature of the lower load point (3)

r_2 radius of curvature of the upper load point (4)

1 rail head

2 centre of welded joint

3 lower load point

4 upper load point

Figure A.1 — Bending test arrangement for rail foot in tension

A.3 Bending testing machine and load

The loading capacity of bending testing machine shall not be less than 2 000 kN. The bending testing machine shall be calibrated at least once every two years in accordance with ISO 7500-1.

The specified value of the test load shall be determined based on the required minimum tensile bending strength according to the rail grade and type. The minimum specified value of the load for evaluating the welded joint shall be calculated using Formula (A.1):

$$F = (4M \times \sigma)/L \quad \text{(A.1)}$$

where

F is the specified load applied on the rail (expressed as N);

σ is the minimum tensile bending strength (expressed as MPa);

L is the span of the test rig (expressed as mm);

M is the section modulus base (expressed as mm^3).

The minimum tensile bending strength shall be prescribed by the railway authority. Table A.1 shows examples of the minimum tensile bending strength for slow-bending test requirements applied in China, Europe and Japan.

The loading rates depend on each welding process. Each bending test shall be continued until the specified values (F) are reached. In cases where fracture face observation is necessary, the bending test can be continued or the drop-hammer test (see Annex H) can be used. To ensure that fracture occurs in the welding zone, the test welded joints may be notched at the centre of the welded joint.

A.4 Test results, interpretation and test report

The load and deflection shall be recorded when the specified value is reached or the test weld fractures. If any test piece fractures before achieving the specified load (F), the welding process shall be rejected.

Any defects/imperfections found on the fracture face of each test welded joint shall be recorded on a rail profile grid. The record shall include the following details:

a) reference to this document, i.e. ISO 23300-1:2021;

b) identification number of the welded joint;

c) the date of testing;

d) type of defect/imperfection;

e) dimensions;

f) shape;

g) location;

h) depth of pores.

A weld fracture face containing no defects/imperfections shall have the rail profile grid clearly worded "No visible defects/imperfections".

Table A.1 — Example of minimum tensile bending strength requirements for rail foot in tension

No.	Railways	Welding process	Rail grade[a]	Minimum tensile bending strength (MPa)	Remarks
1	China railway	FBW	HR280, HT340	915	Welded joint is in finished condition. (The post-weld heat treatment is normalizing.)
		GPW	HR280, HT340	915	
		ATW	HR280, HT340	800	Welded joint is in finished condition.
2	European railways	FBW	HR220	978	Welded joint is in as welded condition or finished condition. NOTE: The values of the minimum tensile bending strength for FBW of European railways have been calculated and averaged from the test force specified in EN 14587-1:2018, Table A.1, and EN 14587-2:2009, Table A.1. The values of the minimum tensile bending strength for ATW of European railways have been referenced from EN 14730-1:2017, 7.3.
			HR260A, HR260B, HT350A	1 065	
		ATW	HR 200	700	
			HR320, HT370C, HT400	750	
			HR220, HR260A, HR260B, HT350A, HT350B	800	
3	Japan railways	FBW	HR235	865	Welded joint is in finished condition.
			HT320, HT330	865	
		GPW	HR235	865	
			HT320, HT330	865	
		ATW	HR235	680	
			HT320, HT330	680	
		EAW	HR235	865	
			HT320, HT330	865	

[a] Rail grades are referenced from ISO 5003:2016.

Annex B
(normative)

Slow-bending test method for rail head in tension

B.1 General

For the requirements and test method for the slow-bending test in which tensile stress is applied to the rail head, see B.2 to B.4.

B.2 Bending test arrangement

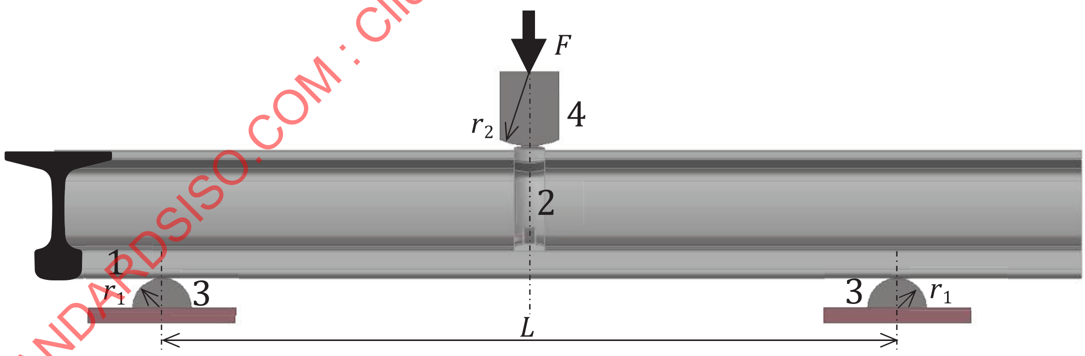
All test welded joints shall be in the finished condition. Test welded joints shall either be selected from the production line or be made using appropriate test pieces.

The straightness of the welded joint in finished condition shall not affect the execution of the slow-bending test.

All test welded joints shall be at ambient temperature when tested. The test welded joints shall be placed on the two supports of the bending testing machine, with the weld centre of the rail foot located at the span centre to bear the concentrated load.

The radius of curvature of the three load points shall not be less than 30 mm.

Figure B.1 shows the relative positions of the test welded joint on the bending testing machine. The length of the test welded joints should be 200 mm to 600 mm longer than the span (L), with the weld itself at the centre.



Key

F force

L span

r_1 radius of curvature of the lower load point (3)

r_2 radius of curvature of the upper load point (4)

1 rail head

2 centre of welded joint

3 lower load point

4 upper load point

Figure B.1 — Bending test arrangement for rail head in tension

B.3 Bending testing machine and load

The loading capacity of bending testing machine shall not be less than 2 000 kN. The bending testing machine shall be calibrated at least once every two years in accordance with ISO 7500-1.

The specified value of the test load shall be determined based on the required minimum tensile bending strength according to the rail grade and type. The minimum specified value of the load for evaluating the welded joint shall be calculated using Formula (B.1):

$$F = (4M \times \sigma)/L \tag{B.1}$$

where

F is the specified load applied on the rail (expressed as N);

σ is the minimum tensile bending strength (expressed as MPa);

L is the span of the test rig (expressed as mm);

M is the section modulus head (expressed as mm^3).

The minimum tensile bending strength shall be prescribed by the railway authority. Table B.1 shows examples of the minimum tensile bending strength for slow-bending test requirements applied in China, Europe and Japan.

Table B.1 — Examples of minimum tensile bending strength requirements for rail head in tension

No.	Railways	Welding process	Rail grade[a]	Minimum tensile bending strength (MPa)	Remarks
1	China railway	FBW	HR280, HT340	950	Welded joint is in finished condition. (The post-weld heat treatment is normalizing.)
		GPW	HR280, HT340	950	
		ATW	HR280, HT340	800	Welded joint is in finished condition.
2	European railways	FBW	NA	NA	
		ATW	NA	NA	
3	Japan railways	FBW	HR235	955	Welded joint is in finished condition.
			HT320, HT330	955	
		GPW	HR235	955	
			HT320, HT330	955	
		ATW	HR235	840	
			HT320, HT330	840	
		EAW	HR235	880	
			HT320, HT330	880	

[a] Rail grades are referenced from ISO 5003:2016.

The loading rates depend on each welding process. Each bending test shall be continued until the specified values (F) are reached. In cases where fracture face observation is necessary, the bending test can be continued or the drop-hammer test (see Annex H) can be used. To ensure that fracture occurs in the welding zone, the test welded joints may be notched at the centre of the welded joint.

B.4 Test results, interpretation and test report

The load and deflection shall be recorded when the specified value is reached or the test weld fractures. If any test piece fractures before achieving the specified load (F), the welding process shall be rejected.

Any defects/imperfections found on the fracture face of each test welded joint shall be recorded on a rail profile grid. The record shall include the following details:

a) reference to this document, i.e. ISO 23300-1:2021;

b) identification number of the welded joint;

c) the date of testing;

d) type of defect/imperfection;

e) dimensions;

f) shape;

g) location;

h) depth of pores.

A weld fracture face containing no defects/imperfections shall have the rail profile grid clearly worded "No visible defects/imperfections".

Annex C
(normative)

Three-point bending fatigue test

C.1 General

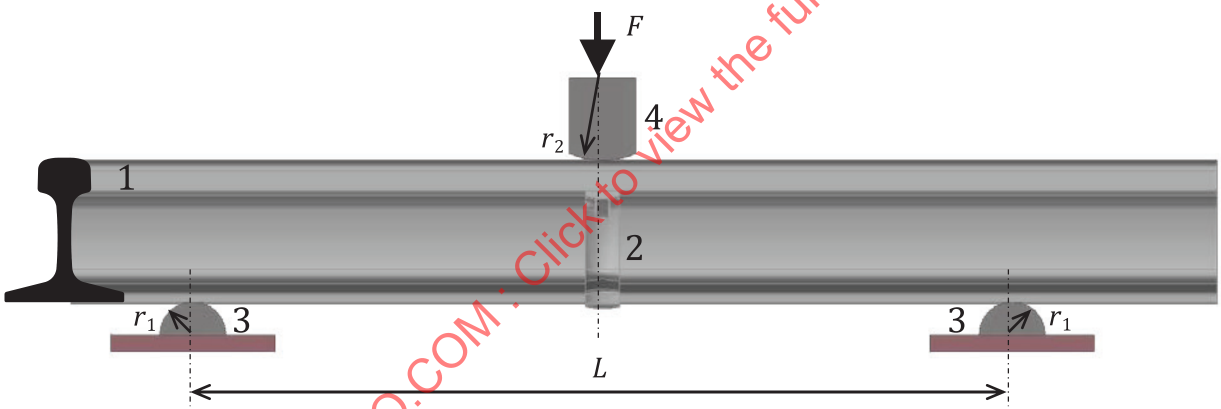
For applying the three-point bending fatigue test method, the requirements and test method are provided in C.2 to C.4.

C.2 Fatigue test arrangement

The test shall be performed at ambient temperature. The test sample is placed on the two supports of the fatigue testing machine, with the weld centre of the rail head located at the span centre to bear the concentrated load.

The radius of curvature of the three load points shall not be less than 30 mm.

Figure C.1 shows the relative positions of test samples on a fatigue testing machine.



Key

F	force
L	span (1,0 m ≤ L ≤ 1,6 m)
r_1	radius of curvature of the lower load point (3)
r_2	radius of curvature of the upper load point (4)
1	rail head
2	centre of welded joint
3	lower load point
4	upper load point

Figure C.1 — Fatigue test arrangement

C.3 Fatigue testing machine and load cycles

The loading capacity of fatigue testing machine shall not be less than 500 kN. The fatigue testing machine shall be calibrated annually. The error of maximum load and load range shall not exceed 2 %. When testing under certain loads, the error of indicating values shall not exceed ±1 %.

A pulse bending fatigue test shall be carried out. The load shall be determined according to the rail type, with the maximum load recorded as F_{max} and the minimum load recorded as F_{min}. The load cycles shall be counted when the required load is reached.

The span may be changed according to the test equipment, which shall be in the range of 1 m to 1,6 m. The maximum load for different spans shall be calculated using Formula (C.1):

$$F_{max} = (4M \times \sigma_{max})/L \qquad \text{(C.1)}$$

where

F_{max} is the maximum load applied on the rail (expressed as N);

σ_{max} is the maximum fatigue stress (expressed as MPa);

L is the span of the test rig (expressed as mm);

M is the section modulus base (expressed as mm^3).

Continue cycling until either the test piece breaks or two million cycles have been applied.

C.4 Test results, interpretation and test report

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

If the test welded joint has fractured, the fracture origin shall be identified.

For each test, the following shall be reported:

a) reference to this document, i.e. ISO 23300-1:2021;

b) identification number of the welded joint;

c) the date of testing;

d) the spans of the test rig;

e) the outer fibre stresses applied;

f) whether the test result is failure or pass;

g) in the case of failure, the crack initiation location;

h) in the case of failure, the cause of fracture.

Annex D
(normative)

Four-point bending fatigue test

D.1 General

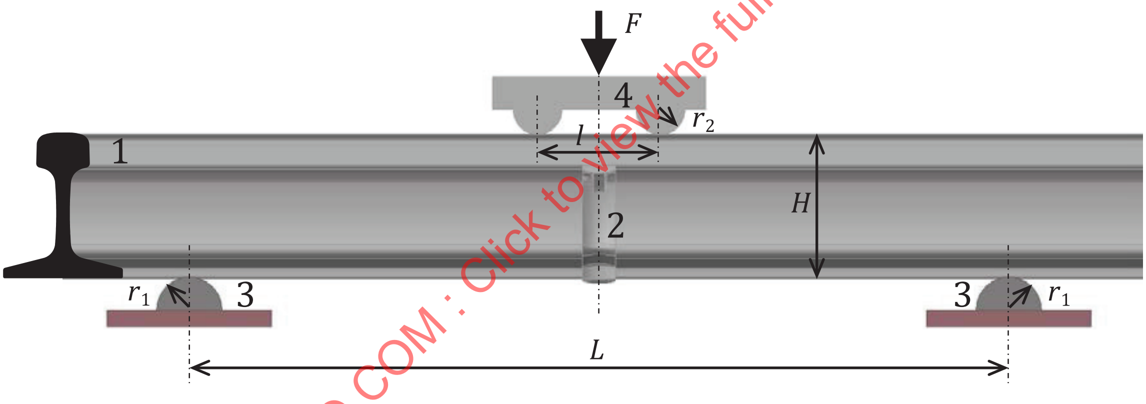
For applying the four-point bending fatigue test method, the requirements and test method are provided in D.2 to D.4.

D.2 Fatigue test arrangement

The span (L) shall exceed the loading width (l) by at least twice the rail height (H) and shall be symmetrical about the loading width, see Formula (D.1):

$$L \geq l + 2 \times H \tag{D.1}$$

The arrangement is shown in Figure D.1.



Key

F force
H rail height
l loading width
L span (1,0 m ≤ L ≤ 1,6 m)
r_1 radius of curvature of the lower load point (3)
r_2 radius of curvature of the upper load point (4)
1 rail head
2 centre of welded joint
3 lower load point
4 upper load point

Figure D.1 — Fatigue test arrangement

The span and the loading width shall be measured and recorded. The distances from the centre line of the actuator to the loading points shall be measured and recorded. Corresponding dimensions on either side of the actuator centre line should not differ by more than 5 mm. The radius of curvature of four load points shall not be less than 30 mm. The loading point contact surfaces shall be free to rotate so that friction between the loading points and the specimen is minimized.

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

Position a test piece in the test rig so that the centre line of the welded joint is aligned with the centre line of the actuator to within 3 mm.

D.3 Fatigue testing machine and load cycles

The applied force shall be measured using a fatigue rated load cell verified to ISO 7500-1, Grade 1.0.

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

Cyclically load the welded joint 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 a minimum of two million cycles have been applied.

D.4 Test results, interpretation and test report

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

If the test welded joint has fractured, the fracture origin shall be identified.

For each test, the following shall be reported:

a) reference to this document, i.e. ISO 23300-1:2021;

b) identification number of the welded joint;

c) the date of testing;

d) the span and the loading width of the test rig;

e) the distances from the centre line of the actuator to the loading points;

f) the outer fibre stresses applied;

g) whether the test result is failure or pass;

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

i) in the case of failure, the cause of fracture.

Annex E
(normative)

Macro examination

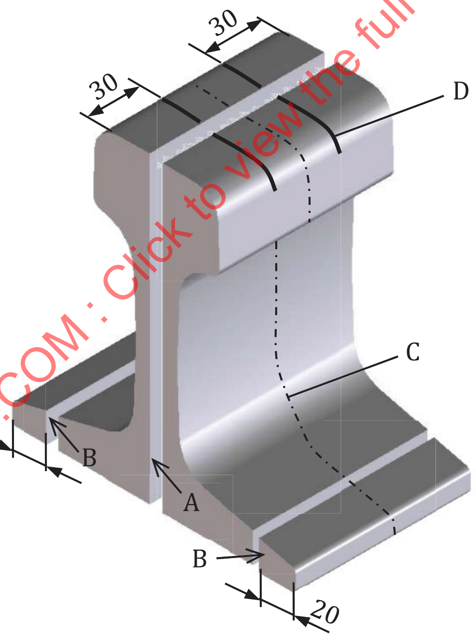
A longitudinal vertical section shall be taken centrally down the vertical axis of the full rail and extend at least 30 mm on each side of the boundary of the heat-affected zone (HAZ) observed on the running surface.

Corresponding sections shall be taken from at least one side of the foot, 20 mm inboard from the foot tips as shown in Figure E.1.

The sections shall be polished to a suitable finished condition. One full depth rail sample and the associated rail foot samples from a test sample shall be etched to show the weld boundary lines. The samples shall be etched in 5 % to 10 % Nital.

The visible fusion zone and HAZ on each section shall be of a nominally symmetrical shape about the weld centre. The width of weld metal and the HAZ shall be evaluated according to the subsequent parts of the ISO 23300 series or specified by the railway authority.

Dimensions in millimetres



Key

A longitudinal vertical section on the centre line of the welded rail

B longitudinal vertical section of the foot tips

C weld centre

D boundary of HAZ

Figure E.1 — Weld sectioning diagram

Annex F
(normative)

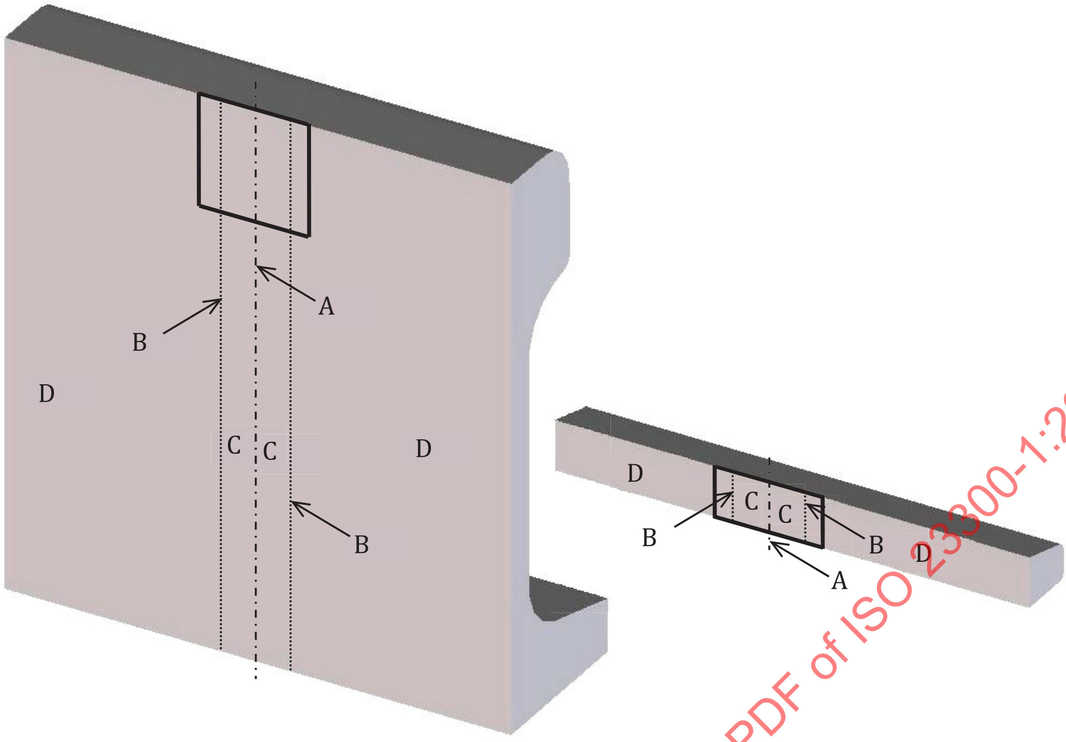
Micro examination

Microscopic examination shall be carried out on samples that have been cut from the rail head and foot areas (if required by the railway authority) of the test samples which can be taken for macro and micro examination from same welded joint.

As shown in Figures F.1 and F.2, the microstructure in at least the following areas shall be examined for each welding process:

— FBW and GPW:
  — weld centre;
  — HAZ;
  — unaffected parent rail;
— ATW and EAW:
  — weld metal (include boundary of the fusion);
  — HAZ;
  — unaffected parent rail.

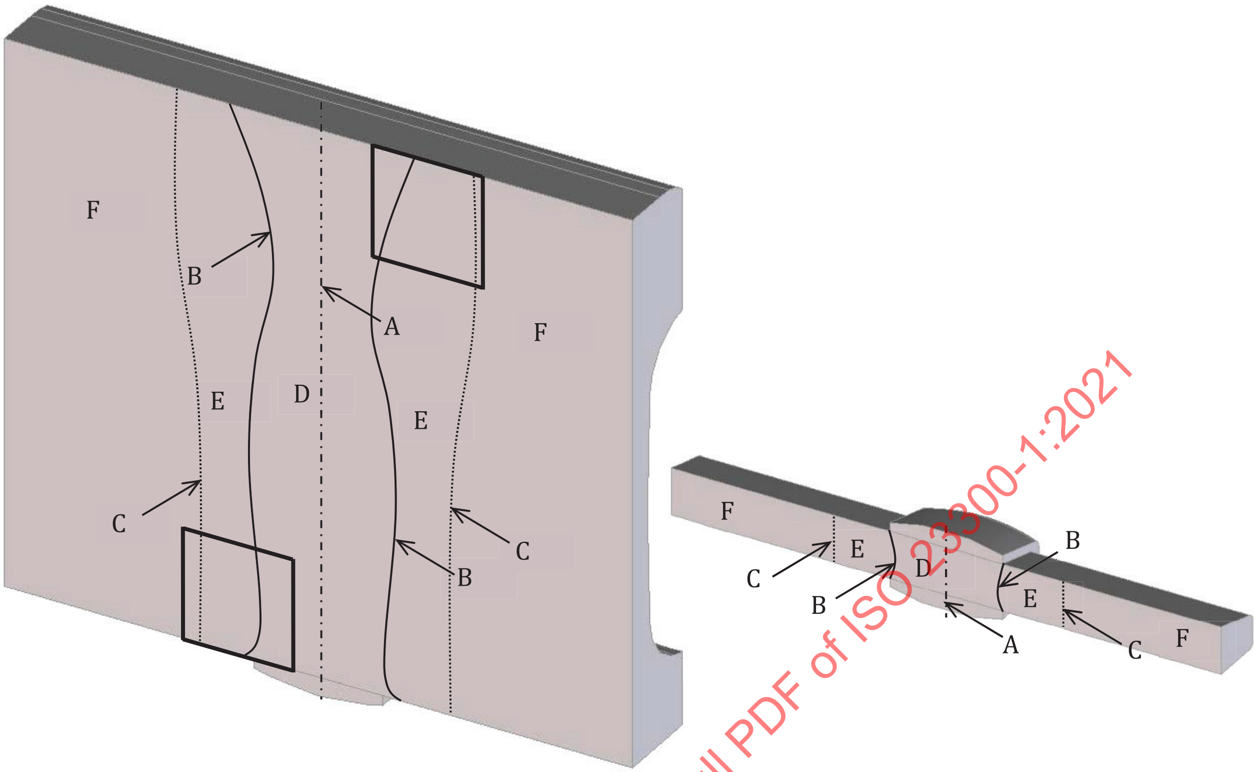
The samples shall be etched in 2 % to 4 % Nital.



Key

A	weld centre (weld line)
B	boundary of the HAZ visible on the etched samples
C	visible HAZ
D	unaffected parent rail
▭	example area to be examined microscopically

Figure F.1 — Example of the microscopic examination areas for FBW and GPW



Key

A	weld centre
B	fusion line
C	boundary of the HAZ visible on the etched samples
D	weld metal
E	visible HAZ
F	unaffected parent rail
▭	example area to be examined microscopically

Figure F.2 — Example of the microscopic examination areas for ATW and EAW

Annex G
(normative)

Hardness test

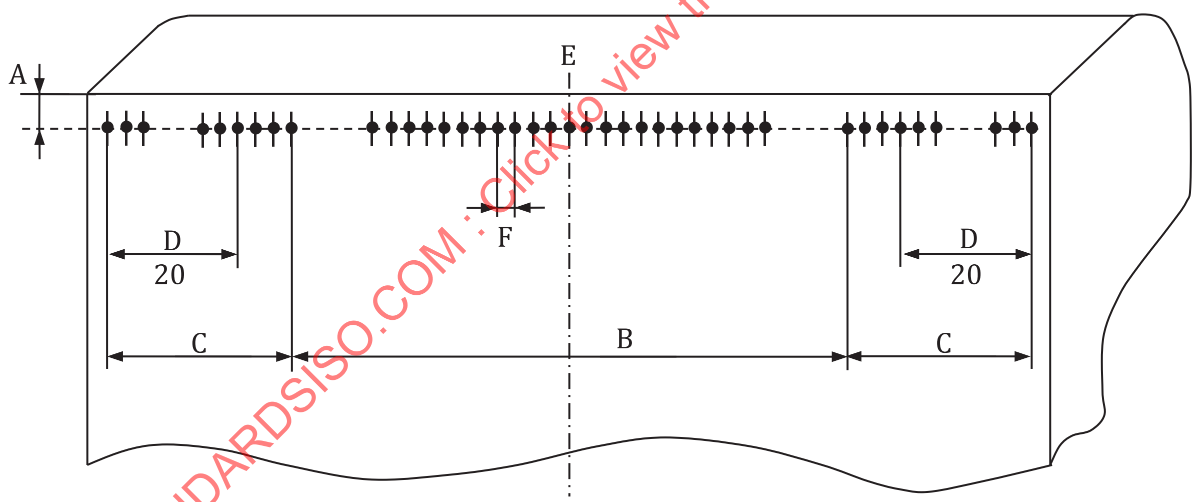
G.1 Measurement of hardness

The hardness distribution including the heat softened zone shall be measured using the Vickers hardness test in accordance with ISO 6507-1 and a load between 10kg to 30 kg, or using the Rockwell hardness test in accordance with ISO 6508-1 and a C scale. Impressions shall be on a line between 3 mm and 5 mm below the rail running surface on the centrally longitudinal section of the test sample for macro examination. The hardness traverse shall extend across and to both sides of the welded joint, continuing until 20 mm of unaffected parent rail hardness has been encountered. Measurements shall be made at points 2 mm apart, as shown in Figures G.1 and G.2.

The hardness measurements obtained shall be recorded numerically and graphically.

Surface hardness test methods for ATW and EAW are to be specified in the subsequent parts of ISO 23300 series.

Dimensions in millimetres



Key

A depth between 3 mm and 5 mm

B parent rail in the visible HAZ

C parent rail beyond the visible HAZ

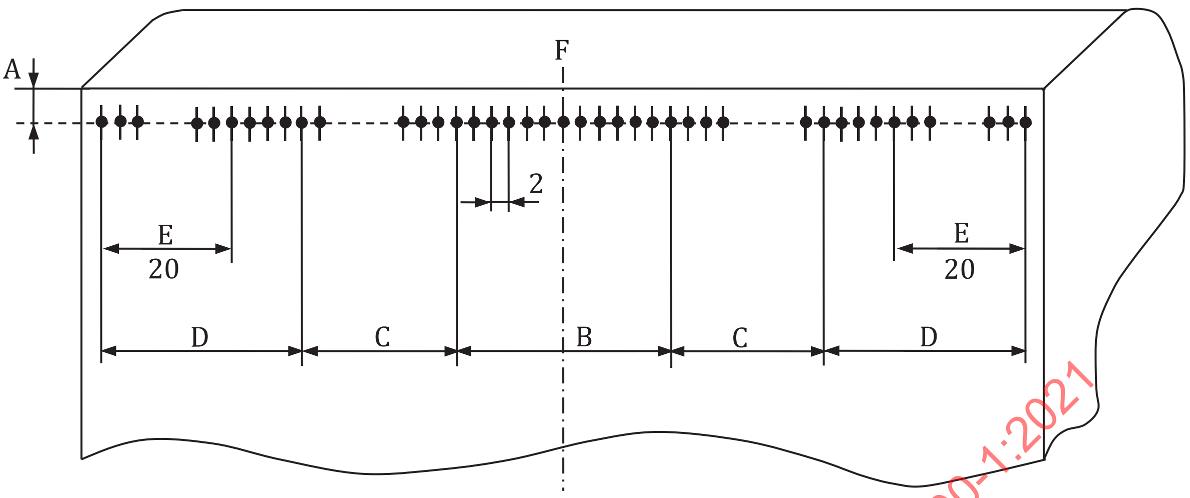
D unaffected parent rail

E weld centre line

F spacing between the test points, spacing shall be at 2 mm centres for the Vickers hardness test and 5mm centres for the Rockwell hardness test

Figure G.1 — Longitudinal hardness measurement for FBW and GPW

Dimensions in millimetres



Key

A depth between 3 mm and 5 mm

B weld metal

C parent rail in the visible HAZ

D parent rail beyond the visible HAZ

E unaffected parent rail

F weld centre line

Figure G.2 — Longitudinal hardness measurement for ATW and EAW

G.2 Evaluation of hardness data

The measured hardness data on each welded joint shall be evaluated according to the subsequent parts of the ISO 23300 series.

Annex H
(normative)

Drop-hammer test

H.1 General

The drop-hammer test can be used to determine whether the welded joint by FBW or GPW contains defects, and also to optimize the welding parameters.

H.2 Drop-hammer test arrangement

The test sample shall be at least 1,3 m long, with the welded joint located at the centre of the test sample and both ends machine cut.

The test sample shall be placed flat with the rail head upward on the two fixed supports of the testing machine, with a 1 m span and the welded joint located in the centre.

The temperature of the test sample shall be 10 °C to 50 °C during the test.

H.3 Drop-hammer test machine

A rigid foundation shall be used to support the drop-hammer testing machine. The mass of the anvil shall be a minimum of 10 000 kg.

The radius of the hammer head bottom shall be 100 mm to 300 mm. The support structure shall prevent the test sample from rolling over.

The standard mass of the hammer shall be 1 000 kg ± 5 kg. The rack of the drop-hammer testing machine shall be stable. The guide rail shall not incline and shall be lubricated frequently to reduce the friction between the guide rails and the dropping hammer.

Safety facilities such as the cage surrounding the test machine shall be closed and locked during the test.

The drop height, which can vary for different rail profiles and the number of test samples, are determined by the relevant railway authority. As a reference, in the case of a Chinese standard 60 kg/m rail welded joint, the drop height is 5,2 m.

H.4 Test results, interpretation and test report

The test welded joint may be considered qualified if there is no fracture after one drop. If the test welded joint breaks, the fracture face shall be inspected and recorded. Further analysis can be required to optimize the welding parameters and check the operation of the welding machines.

For each test, the following shall be reported:

a) reference to this document, i.e. ISO 23300-1:2021;

b) identification number of the welded joint;

c) the date of testing;

d) the spans of the test rig;

e) whether the test result is failure or pass;

f) in the case of failure, the crack initiation location;

g) in the case of failure, the cause of fracture.

Annex I
(normative)

Recording of defects on fracture faces

All weld fracture faces from the approval tests referred to in 6.3 and 6.4 shall be inspected and the details of any weld defects/imperfections recorded.

A separate record shall be made for each weld fracture face on a rail profile grid shown in Figure I.1. The record shall show the following details relative to each defect/imperfection:

a) size: height and width dimensions;

b) shape;

c) location;

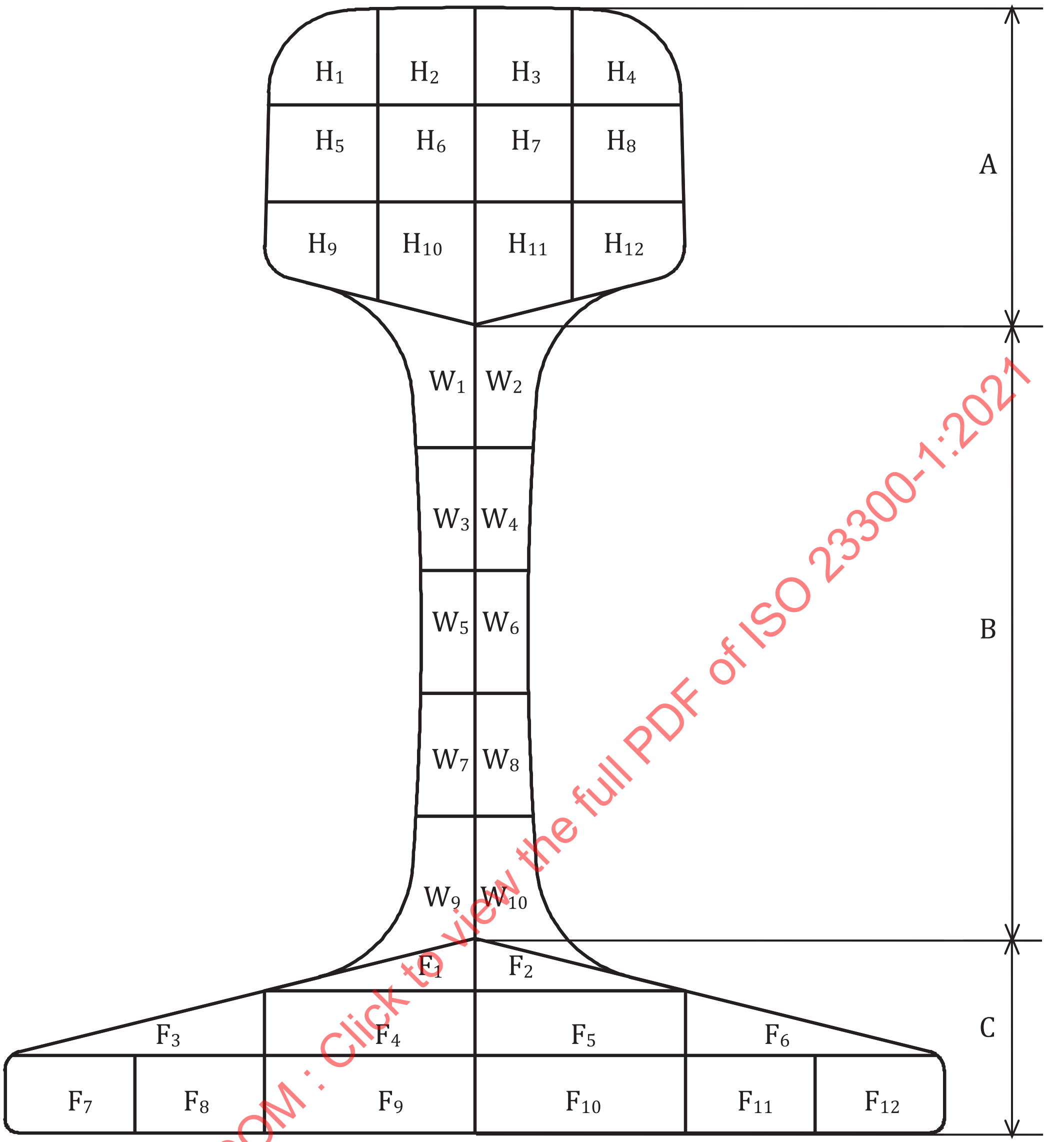
d) orientation;

e) origin of fracture;

f) type of defect/imperfection.

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

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



Key

A head

B web

C foot

Figure I.1 — Rail profile grid

Annex J
(normative)

Ultrasonic testing

J.1 General

This annex introduces the basic conditions for UT and describes the personnel, equipment used, single-probe technique and double-probe technique (tandem technique) utilized on various welded joints and the basic parameters that shall be recorded during testing.

Acceptance criteria for welded joints in track and the optional scanning techniques in Table J.1 are determined by the relevant railway authority.

Table J.1 — Typical scanning techniques of UT for welded joint

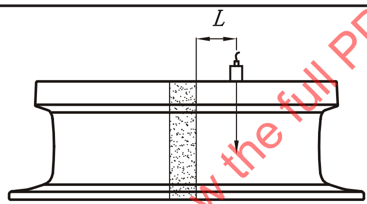
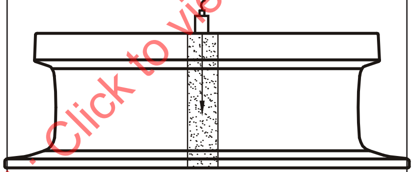
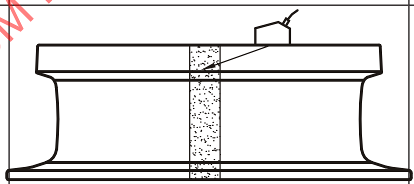
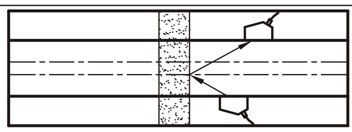
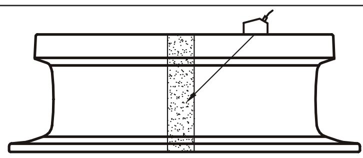
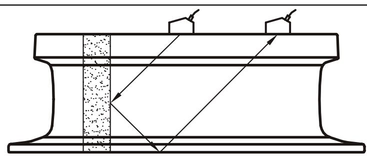
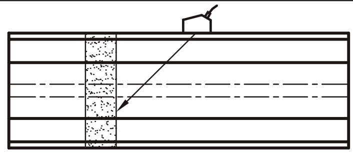
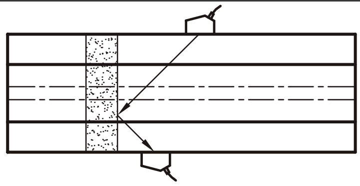
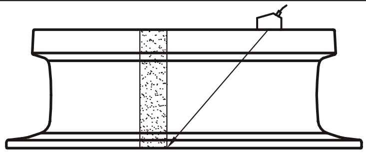
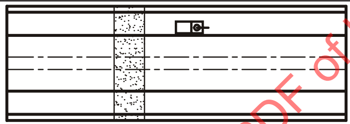
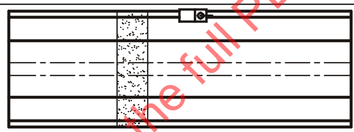
No.	Purpose	Illustration	Probe and scanning surface
1	Horizontal defects in parent metal adjacent to the welded joint		One normal-beam probe at the running surface
2	Horizontal defects in the weld metal		One normal-beam probe at the running surface
3	The non-planar defects inside head		One 70° angle-beam probe at the running surface
4	The planar defects inside head		Two 45° angle-beam probes at the sides of the rail head
5	The non-planar defects inside web		One 45° angle-beam probe at the running surface
6	The planar defects inside web		Two 45° angle-beam probes at the running surface (tandem technique)
NOTE $L \geqq 2h \times \tan\beta$, where h is the height of rail, β is the refraction angle of the probe.			

Table J.1 *(continued)*

No.	Purpose	Illustration	Probe and scanning surface
7	The non-planar defects inside foot		One 45° angle-beam probe at the foot tip
8	The planar defects inside foot		Two 45° angle-beam probes at the foot tips
9	Testing of middle of foot		One 45° angle-beam probe at the running surface
10	Testing of ankles		One 70° angle-beam probe at the upper surface of the ankles
11	Testing of toes		One 70° angle-beam probe at the upper surface of the toe
NOTE $L \geqq 2h \times \tan\beta$, where h is the height of rail, β is the refraction angle of the probe.			

J.2 Test personnel

Inspectors shall be approved by the relevant railway authority or by any accredited certified centre.

J.3 Test equipment

Only test equipment approved by the relevant railway authority shall be used for the detection of volumetric and planar defects.

The frequency of the ultrasonic probes shall not be less than 2 MHz.

Suitable reference blocks which are used to set sensitivity and range of the UT shall be available.

The type and size of prefabricated reflectors in the reference block shall be specified by the railway authority. Some examples are given in J.5 for reference.

A declaration of conformity by the manufacturer shall be available for the instrument, the probes and the reference blocks.

J.4 Scanning techniques

UT shall be carried out on the welded joints in finished condition.

The scanning shall be performed from both sides of the welded joint.

J.5 Reference blocks

A typical reference block example for each scanning technique is given as follows:

a) A typical reference block for the double-probe technique is given in Figure J.1.

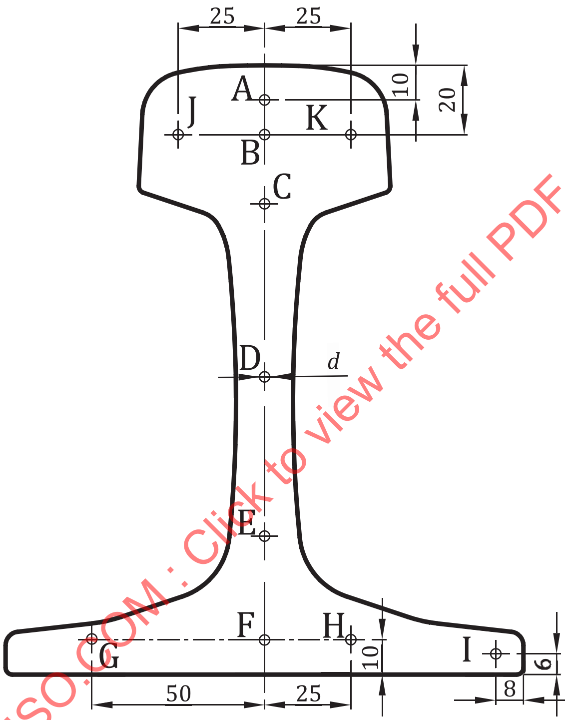
b) A typical reference block for the normal-beam probe technique is given in Figure J.2.

c) A typical reference block for the 45°/70° angle-beam probe technique is given in Figure J.3.

d) A typical reference block for the 70° angle-beam probe technique at foot toe/ankle is given in Figure J.4.

e) A typical reference block for the double-probe technique at head/base area and for the 45° angle-beam probe technique at all areas is given in Figure J.5.

Dimensions in millimetres



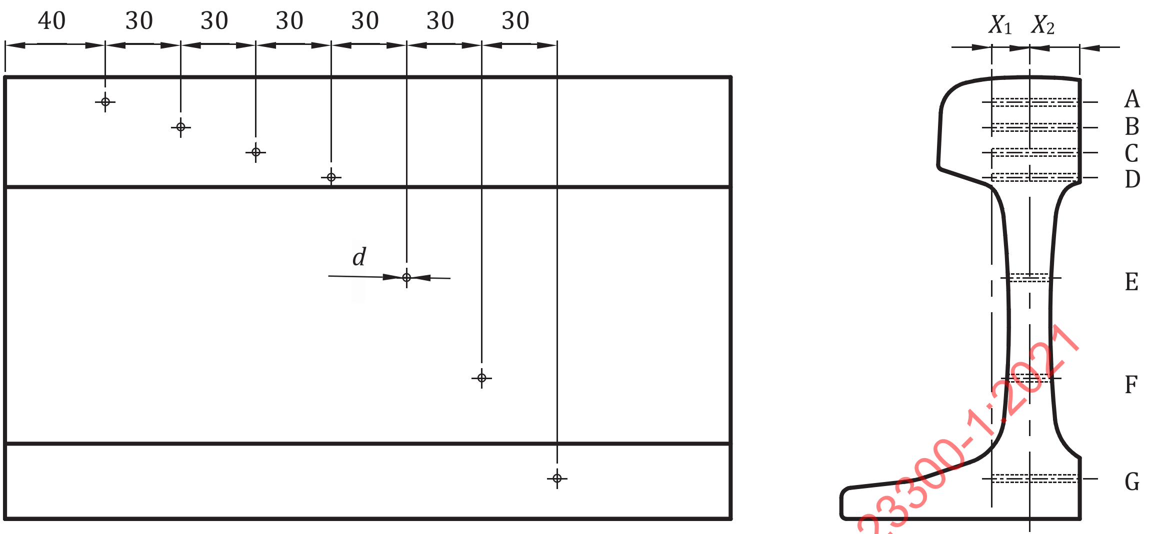
Key

A to K flat-bottomed holes

d diameter of flat-bottomed hole

Figure J.1 — Typical reference block for double-probe technique

Dimensions in millimetres



Key

A to G side-drilled holes

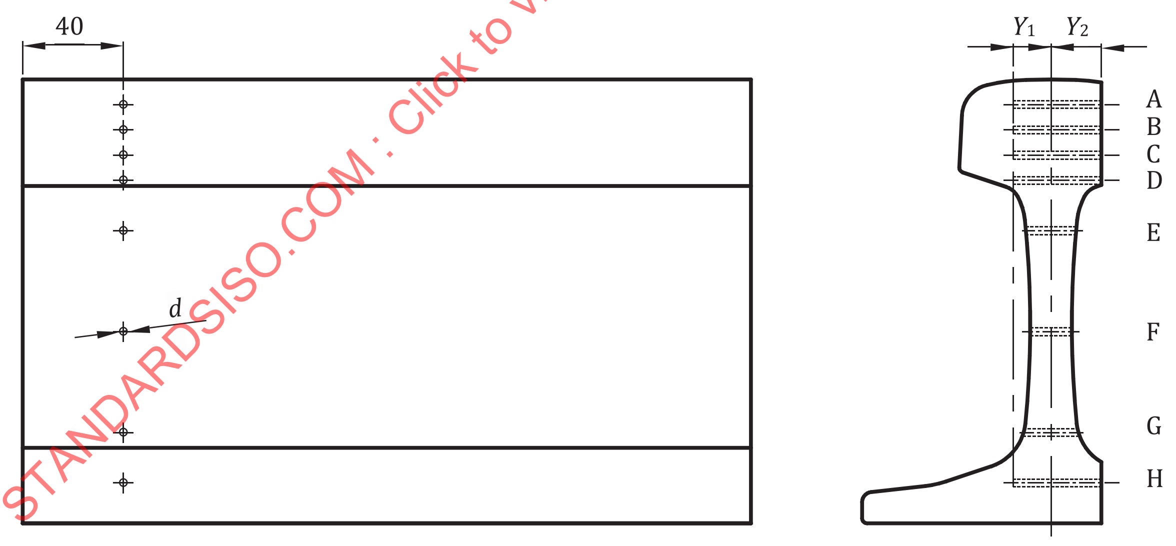
d diameter of side-drilled hole

X_1 ≧ 15 mm

X_2 ≧ 20 mm

Figure J.2 — Typical reference block for normal-beam probe technique

Dimensions in millimetres



Key

A to H side-drilled holes

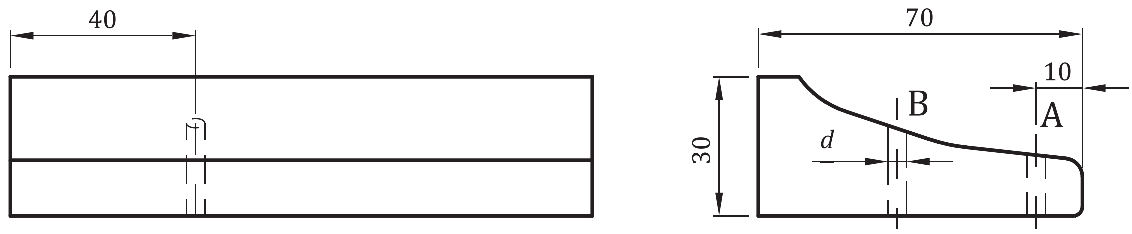
d diameter of side-drilled hole

Y_1 ≧ 15 mm

Y_2 ≧ 20 mm

Figure J.3 — Typical reference block for angle-beam probe technique

Dimensions in millimetres



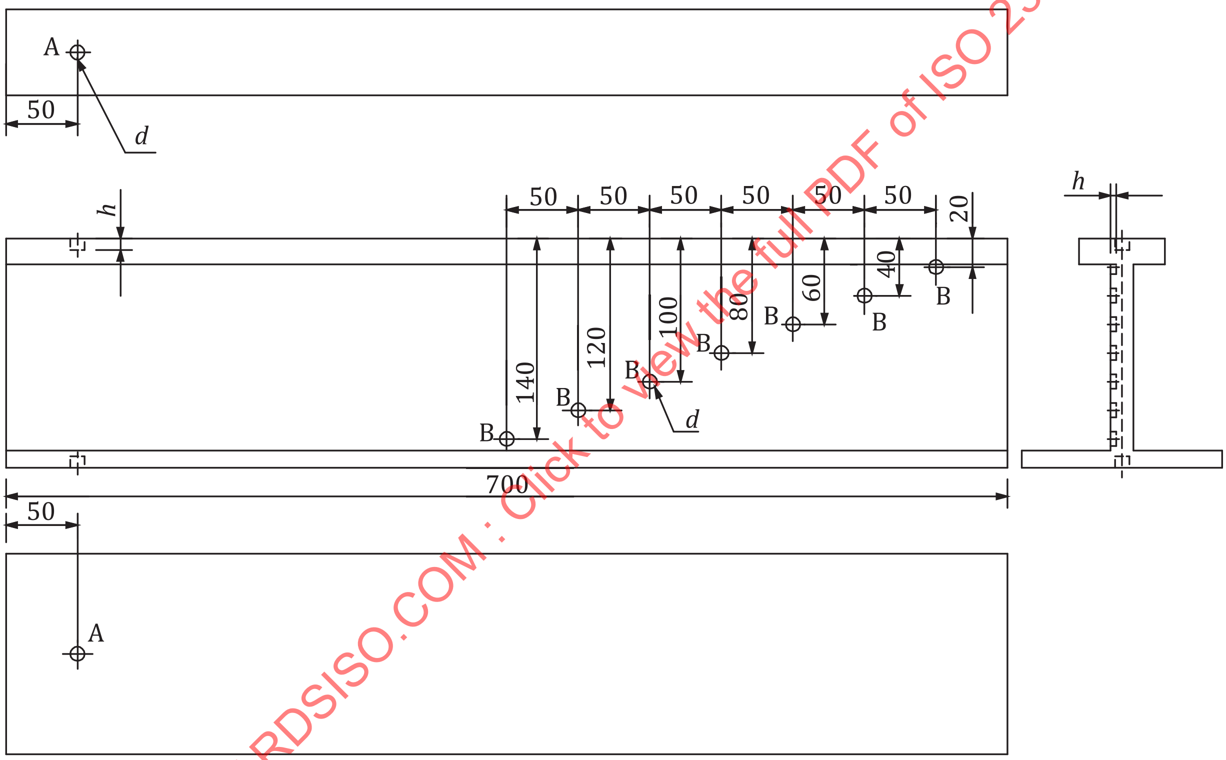
Key

A, B vertical-drilled holes

d diameter of vertical-drilled hole

Figure J.4 — Typical reference block for angle-beam probe technique on foot toe and ankle

Dimensions in millimetres



Key

A flat-bottomed hole applied for double-probe technique

B flat-bottomed hole applied for single-probe technique

d diameter of flat-bottomed hole

h depth of flat-bottomed hole

Figure J.5 — Typical reference block for double-probe and single-probe technique