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Resistance welding — Procedure for seam welding of uncoated and coated low carbon steels

Soudage par résistance — Mode opératoire pour le soudage à la molette des aciers à bas carbone revêtus et non revêtus

Reference number
ISO 16433:2006(E)

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Contents

Page

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 16433 was prepared by the International Institute of Welding, recognized as an international standardizing body in the field of welding in accordance with Council Resolution.

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Introduction

Requests for official interpretations of provisions in this standard should be made in writing and sent to the ISO Central Secretariat who will forward them to the IIW Secretariat for an official response.

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Resistance welding — Procedure for seam welding of uncoated and coated low carbon steels

1 Scope

This International Standard specifies requirements for resistance seam welding in the fabrication of assemblies of uncoated and metallic coated low carbon steel comprising two sheets of metal, where the maximum single sheet thickness of components to be welded is within the range 0,4 mm to 3 mm for the following materials:

— uncoated steels;

— hot-dip zinc or iron-zinc alloy (galvannealed) coated steel;

— electrolytic zinc, zinc-iron, or zinc-nickel coated steel;

— aluminium coated steel;

— zinc-aluminium coated steel.

Organic-coated or primer-coated steels are not covered by this International Standard. Guidelines for the design of appropriate seam welding equipment and welding conditions are given in Annexes A and B. These are for guidance only and may need to be adapted to suit the specified service conditions of the fabrication, prevailing production conditions, type of welding equipment, mechanical and electrical characteristics of the welding machine, electrode configuration, and material. These requirements shall be taken from the relevant welding procedure specification for the application or procedure, where these exist.

2 Normative references

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

ISO 669, *Resistance welding — Resistance welding equipment — Mechanical and electrical requirements*

ISO 5182:1991, *Welding — Materials for resistance welding electrodes and ancillary equipment*

ISO 10447, *Welding — Peel and chisel testing of resistance spot, projection and seam welds*

ISO 14270, *Specimen dimensions and procedure for mechanized peel testing resistance spot, seam and embossed projection welds*

ISO 14327, *Resistance welding — Procedures for determining the weldability lobe for resistance spot, projection and seam welding*

ISO 14329, *Resistance welding — Destructive tests of welds — Failure types and geometric measurements for resistance spot, seam and projection welds*

ISO 15609-5, *Specification and qualification of welding procedures for metallic materials — Welding procedure specification — Part 5: Resistance welding*

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ISO 15614-12, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 12: Spot, seam and projection welding*

ISO 17654, *Destructive tests on welds in metallic materials — Resistant welding — Pressure test on resistance seam welds*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 669 and ISO 14329 and the following apply.

3.1
continuous-current seam welding
use of a continuous-current waveform to make a weld

NOTE A continuous weld nugget is formed along the weld seam.

3.2
interrupted-current seam welding
use of a current program comprising two or more pulses of current (commonly known as “on-time”) separated by a pre-set cool time (commonly known as “off-time”)

NOTE A weld nugget is produced during each pulse.

3.3
tread width
width of the electrode face which is in contact with the work piece

NOTE Sometimes this is called electrode face width.

4 Materials

4.1 Form

The steel shall be flat rolled, in coils or cut to length, and shall be free of all harmful imperfections.

4.2 Steel grades

A partial list of steel grades to which this International Standard is applicable is given in Annex C.

4.3 Surface conditions

Prior to welding, all surfaces of components to be seam welded shall be free of contaminants such as grease, scale, corrosion products, paint, dirt or excessive pitting. This condition shall be maintained until the welding process is completed. Uncoated hot-rolled steel shall be in the pickled condition.

Certain surface treatments, such as the application of paint primers, rust preventions, and oils may be applied before welding, provided that the coating is uniform in thickness and it has been demonstrated that consistent welds, conforming to this International Standard, can be obtained. Excessive use of surface pre-treatments may adversely affect electrode life and should therefore be avoided.

Coated steels can be supplied with a chromate or phosphate passivation treatment. Phosphated mild steel may be used in certain applications. These materials can be resistance seam welded, although the welding parameters outlined in Annex B may require appropriate adjustment. Generally, only thin phosphate pre-treatment of steel is acceptable prior to seam welding.

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5 Component design and manufacture

5.1 Component design

Components shall be designed and manufactured to provide adequate flange widths, free from potentially harmful physical deformations and internal stresses, and which can accommodate the weld seam. The flange width should also provide proper access for the electrodes and any necessary tooling. Account shall be taken of the degree of mechanization for guiding the components along the weld path/track during the welding process. The procedure shall include provision for reviewing the design as a result of tests, whether compliance with this International Standard is achievable or not.

The design of the assembly to be seam welded shall take into account the process requirements specified in Clause 6, and the process variation appropriate to the application. The shape of both components shall be such that there is proper contact over the entire weld path.

The weld size (seam width) and the distance (edge distance) from the centre of the weld to the nearest edge of the components shall comply with the process requirements given in Clause 6.

NOTE Reducing the edge distance below the recommended values can affect weld quality and reduce the operating tolerances. In this case, the nominal weld size may need to be specified below the value given in 9.2.1, and allowance for a lower weld strength made in the design.

The pitch between two parallel seam welds, i.e., the centre-to-centre distance of the seam welds, shall not be less than 16 × sheet thickness (t) and preferably larger. When seam welding sheets up to, and including, t = 1,5 mm, the inter-weld pitch shall therefore approximate to 3 W_e (W_e = tread width). To stabilize any shunting effects, this pitch shall be maintained within $t \pm 10$ % over the entire length of the joint.

In cases where smaller weld pitches are necessary, the weld current in subsequent seam welds should be increased to compensate for the shunting effect.

5.2 Component manufacture

The components to be welded shall be free from distortions, burrs, wrinkles, internal stresses and other defects, which would in any way interfere with proper physical and electrical contact at the electrode or component interfaces during the welding process.

6 Process requirements

6.1 Seam welding with wide wheels

If "W_e" is the electrode-wheel tread width (see Figure 1), the centre of the electrode-wheel tread shall not be placed less than 1,25 W_e from the nearest edge of the component.

6.2 Seam welding with thin wheels

The centre of the electrode-wheel tread shall be placed such that the distance between the centre of the weld and the nearest edge of the component shall be not less than $5\sqrt{t}$, where t = sheet thickness, in mm.

The electrode force shall always be applied normal to the component surface with both wheels running on parallel axes.

NOTE Toe-in may be applied as necessary.

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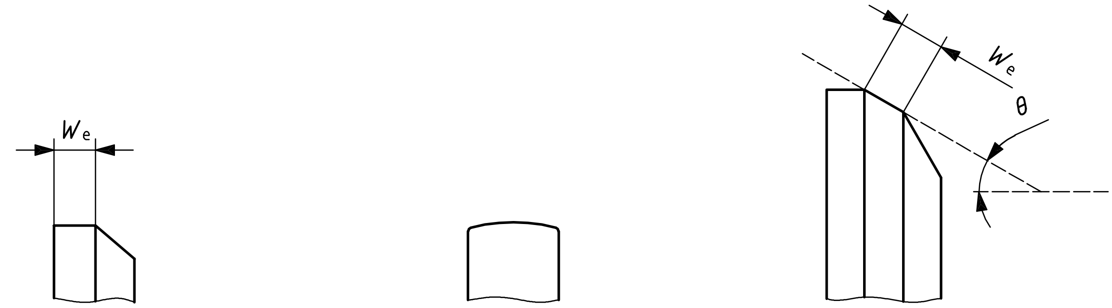

a) **Centre-tread electrode**

b) **Offset-tread electrode**

c) **Single side bevel**

d) **Radius**

e) **Angled offset tread**

Figure 1 — Typical electrode shapes

6.3 Mash seam welding

Depending upon the application and the thickness required at the joint, the selected width of the overlap shall be between t and $3t$ of the sheet being welded, and this shall be maintained over the entire length of the joint to within ± 10 % or ± 0,05 mm, whichever is the greater. Large overlaps may result in a partial mash.

6.4 Wire seam welding

The contour of the wire and the electrodes shall be that specified by the machine supplier for the application.

6.5 Wire electrode seam welding

Depending upon the application, the edge distance, or overlap, shall comply with the specification issued by the machine supplier.

6.6 Foil seam welding

The edge condition and the foil used shall be that specified by the machine supplier for the application.

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7 Welding equipment

7.1 Welding machine

When specifying the process details for an application, the type of machine (e.g., portable, manual/mechanized, pedestal, automated), its power source (e.g., dc, ac standard, or elevated frequency) and cooling requirements shall be stated and a specific machine/controls/ancillary equipment/tooling to be used for this application shall be identified. It is recommended that, if possible, the secondary current be prevented from passing through the bearings supporting the electrode wheels and transmitting the electrode force in the specified machine.

Machine/controls serial or plant numbers, electrode/tooling drawing, as well as settings and services requirements should be recorded in the Welding Procedure Specification (WPS) (see ISO 15609-5).

7.2 Electrodes (wheels, mandrels, pads, backing bars)

Seam welding electrodes may be driven using different systems. The most popular systems are described in ISO 669.

7.2.1 Electrode materials

Electrode wheels, mandrels, and backing bars shall be made of suitable copper alloys with high thermal and electrical conductivity, and be provided with an adequate cooling system, and shall comply with, and be used in accordance with, the relevant requirements of ISO 5182.

7.2.2 Electrode dimensions

The welding electrodes shall be of sufficient cross-sectional area and strength to carry the welding current and support the electrode force without overheating, deformation, or excessive deflection under the specified production conditions.

7.2.2.1 Seam welding with wide wheels

Typical wheel-tread geometries are of the form shown in Figure 1. Where two wheels are used, the tread width, W_e, of both, or of the small tread width side shall approximate to the following formula:

$$W_e = 5\sqrt{t} \quad (1)$$

where

W_e is the tread width, expressed in millimetres (mm);

t is the thickness of the sheet in contact with the wheel, expressed in millimetres (mm).

If one wheel is used in association with a mandrel, pad or backing bar, the tread width of the wheel shall also approximate to formula (1).

The thickness of the wheel shall not be less than twice the tread width, i.e., > 2 W_e [see Figure 1a)].

In general, the tread of the electrode wheels shall be normal to the electrode force transmitted to the components during welding but, where access is restricted, inclined electrode wheels (see Figure 2) may be employed, provided the specified weld strength can be demonstrated. Unless precluded by the shape of the component, both the drive shafts should have the same inclination to the surface of the weld and the combined convergence shall not exceed 30° (see Figure 2), if electrode wear as a consequence of wheel misalignment is to be minimized. The welded assembly shall conform to the relevant drawings and, unless otherwise specified, a sheet separation gap shall be tolerated, provided the test requirements of 9.2 are met.

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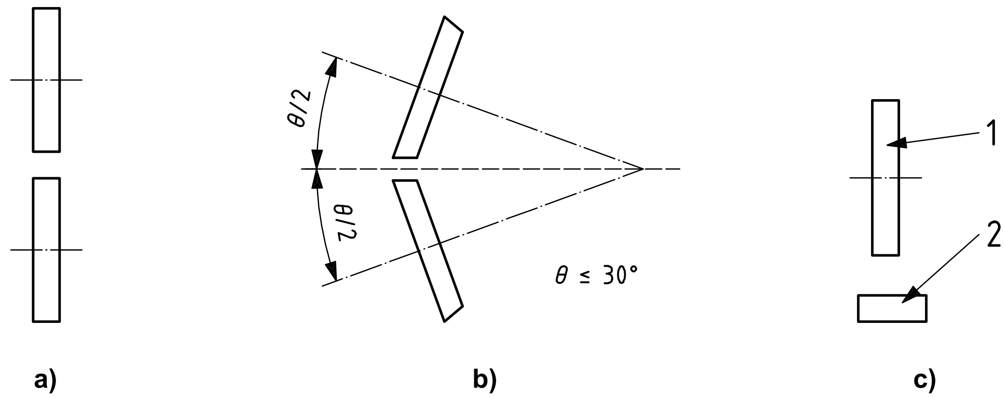

Key

1 Wheel

2 Backing electrode/Mandrel

Figure 2 — Electrode-wheel configuration

Where an offset tread is necessitated by the shape of the components to be welded, the offset of the tread width should not reduce the bevel width below 0,3 W_e [see Figure 1b)].

The angle of the bevels shall be 30°, as shown in Figure 1, unless the geometry of the component demands an angle greater than 30° to give access for welding. These requirements do not apply to a pad or mandrel electrode where these are used.

Where continuous dressing is not provided, the tread width of an electrode wheel shall not be allowed to grow wider than 1,4 W_e during service. When this limit is reached, the wheel shall be replaced or redressed so as to restore it to its initial contour and surface condition.

Increased tread widths should only be permitted if the weld quality continues to comply with the specified requirements of this International Standard.

Where pad- or mandrel-type electrodes are used as backing, the surface in contact with the component shall be kept clean, free from ruts, grooves, loose debris, or other contaminants that would be detrimental to the operation. The shape and contour of the surface in contact with the component shall be maintained to match that of the component.

When welding two sheets of dissimilar thickness, the weld size, electrode tread width, and the machine settings shall be specified to suit the thinner sheet.

If the weld width specified is smaller or larger than that given by formula (1), then the electrode tread width should be specified to conform.

7.2.2.2 Seam welding with thin wheels

The wheel tread geometry shall be of the form and dimensions shown in Figure 3.

When using domed or radius electrode wheels, the formula for determining the electrode tread width cannot be applied directly and the electrode-wheel dimensions will depend on accessibility and flange width. In this case, welding conditions should be chosen to produce a seam weld width which will meet the minimum requirements outlined in the appropriate welding procedure specification for the application or application standard, as defined by the requirements in Clause 9.

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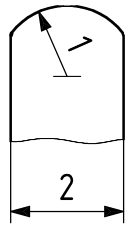

Key

1 R: 4 mm to 6 mm

2 8 mm to 10 mm

Figure 3 — Electrode dimensions for thin-wheel welding

7.2.2.3 Mash seam welding

The geometry of the electrodes shall be of the form shown in Figure 4. Where two wheels are used, their tread width shall be identical. Where a pad or mandrel is used as a backing, their width shall not be less than that of the tread width of the associated electrode wheel.

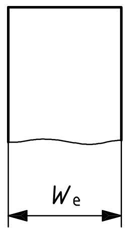

Figure 4 — Electrode shape for mash seam welding

The tread width, W_e of both wheels (or one wheel where a mandrel is used) shall not be less than eight times the sheet thickness ($8t$) or four times the overlap, whichever is the greater.

The electrode wheel and mandrel surfaces shall be kept clean and free from ruts, grooves, loose debris, or other contaminants that would be detrimental to the operation. The shape and contour of the surface in contact with the component shall be maintained to match that of the component.

7.3 Electrode-wheel cooling

Where the machine design allows it, internal cooling of the electrode body, shaft and bearing assembly shall be employed.

External floodwater cooling directed at the weld area or the electrode assembly may be employed to benefit electrode life, minimize electrode pickup or component distortion, unless precluded by other practical considerations.

To obtain the best cooling effect, the electrode cooling water supply should be independent of transformer or other cooling circuits. Separate cooling circuits should be used for the top and bottom electrodes.

8 Weldability assessment

The weldability of a particular production material can be assessed by determining a weldability lobe using procedures defined in ISO 14327. This procedure shall also be used for verifying the suitability of a particular machine, electrode/tooling, and settings for producing a specific component assembly. The weldability lobe depicts the welding range defined in terms of welding current and welding speed at a constant electrode force, or weld current and electrode force at a fixed welding speed. In addition to determining the range of available welding conditions, in some instances it may be used for determining the consistency of weld quality, or the electrode life obtainable. These factors may need to be taken into account when specifying appropriate welding conditions for an application.

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Based on the weldability lobe, a procedure shall be established for each machine using the sheet thickness and material, or combination thereof, to be used for the particular component to be welded. The record of the procedures should be based on the requirements of ISO 15609-5 and ISO 15614-12.

Guidelines for the welding equipment and welding conditions are given in Annexes A and B.

9 Weld assessment — Type tests

Weld assessments shall be used to

a) verify weld procedures prior to commencement of production WPQR approval test (see ISO 15614-12), and

b) maintain the specified conditions and quality standards during production (routine tests).

The number of type tests needed, and the occasion and frequency of all routine tests performed, shall be sufficient to provide reliable statistical data for each application.

Assessment of the welding procedure shall be based on the following type tests:

a) peel test, manual or mechanized;

b) pressure test (sometimes called leak test), where applicable (see 9.1.4);

c) visual and metallurgical examination.

9.1 Test pieces

9.1.1 General

A procedure shall be established in accordance with ISO 15609-5 for the welding equipment, the sheet thickness, material, or combinations thereof, used for the component being welded. The procedure shall be qualified in accordance with ISO 15614-12.

Where practicable, actual components shall be used for testing. Where it is not practicable to use actual components for some tests, test pieces produced from the same material as used for the actual components shall be used in the weld tests, ensuring that the actual production conditions, such as thermal or inductive losses, are taken into consideration in the tests.

9.1.2 Manual peel test piece

The manual peel test piece shall contain a weld length of 75 mm, or as near to this as the component design allows, and sufficient metal to enable the specimen to be clamped in a vice. Where specimens are obtained from assemblies selected from production, the specimen shall be cut from an actual component at a specified position on the component. Where such an assessment is possible, the specimen should be cut from that part of the weld most likely to fail for whatever reason (e.g., stress concentration, curvature, accessibility, etc).

9.1.3 Mechanised peel test piece

The test specimen shall be prepared and tested in accordance with the procedures specified in ISO 14270.

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9.1.4 Pressure test

Pressure testing for weld procedure approval shall be performed using actual production components. If this is impractical, the pressure test may be performed on a representative test specimen (e.g., pillow test). Where a pressure or leak test is specified as part of the production quality-control procedure, all assemblies, or a proportion, shall be so tested.

If a pillow test is used, the test specimen shall be prepared and tested in accordance with the procedures specified in ISO 17654.

9.1.5 Metallurgical examination

For verifying the size and quality of welds produced, metallographic sections shall be prepared in the longitudinal direction of the weld seam and, if necessary, in the transverse direction.

9.2 Test requirements

9.2.1 Weld dimensions

The width of the weld produced by thick-wheel seam welding shall approximate to the wheel tread width and shall not be less than 80 % of this value, unless permitted by the requirements in the welding procedure specification for the application (see 7.2.2.1).

The width of the weld produced by thin-wheel seam welding shall comply with the specification issued by the machine supplier, provided the weld complies with the relevant requirements of this International Standard.

NOTE 1 Typical weld seam widths produced by thin-wheel seam welding are shown in Annex B; see Tables B.3, B.4, B.5 and B.6.

The width of the weld produced by mash seam welding shall satisfy the requirements of the application standard or the welding procedure specification for the application in question.

NOTE 2 Typical indentation levels produced by thick and thin-wheel seam welding and typical weld thickness values produced by mash seam welding are also shown in Annex B.

9.2.2 Manual peel test

Weld quality shall be assessed by the mode of fracture and weld seam width. The mean seam width shall be the average width measured along the entire length of the weld.

9.2.3 Mechanised peel test

To meet the mechanised peel test requirements, welds shall conform to the requirements specified for visual examination in 9.2.5.

9.2.4 Pressure test

The requirements of the pressure test shall be those of the relevant welding procedure specification for the application.

9.2.5 Visual and metallurgical examination

Test pieces shall be examined visually for appearance, weld position, and indentation. Excessive pitting, craters, weld splashes, or inadequate mashing (in the case of mash seam welds) shall not be acceptable.

NOTE Surface discolorations may be unavoidable.

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Metallurgical examination, if specified, shall show that the required penetration, i.e., weld size, has been achieved, and that sheet separation is not excessive. The type and location of any weld defect or abnormality detected shall be recorded.

The weld should be correctly located within the body of the joint. Small isolated cracks in the weld nugget should be permitted, provided they do not influence product performance. Where maximum hardness for the weld nugget is specified, this should be tested and the value recorded.

9.3 Acceptance requirements

The acceptance requirements shall be those specified in this International Standard or in the relevant welding procedure specification for the application.

The welded assembly shall conform to the relevant drawings and, unless otherwise specified, a sheet separation gap shall be tolerated, provided the test requirements of 9.2 are met.

10 Weld assessment — routine tests

10.1 General

A system of routine testing shall be established to ensure consistent weld quality in the production of seam welds.

The following routine tests shall be performed:

a) visual examination;

b) manual peel test or chisel test, and/or pressure test (see ISO 10447 and ISO 17654);

c) cup test for mash seam welds, if specified (see ISO 15614-12);

d) radiographic examination, if specified (see ISO 15614-12).

10.2 Batch testing

A pressure test shall be performed on every component produced in which seam welds form part of a vessel or container for fluids. Some seam welds specified to be watertight cannot be tested in this way (e.g., ducts, culverts, etc.) and a suitable penetration technique may be applicable.

Seam welds produced to provide a mechanical joint without needing to retain fluids should be tested in compliance with the relevant welding procedure specification for the application.

10.3 Test pieces and test procedures

The requirements for routine test pieces and test procedures shall be as specified in 9.1.

10.4 Number of tests

The occasion and frequency of all routine tests performed shall be sufficient to provide reliable statistical data for each application (see Clause 11).

10.5 Test requirements

Routine test requirements shall be as specified in 9.2, where applicable.

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11 Routine production weld quality-control requirements

Tests shall be performed on each of the following occasions:

a) at random times during the production period;

b) immediately before and after new or reconditioned electrodes are fitted to the machine;

c) whenever any of the machine services have been altered or any of the machine settings are changed; and

d) immediately following a change in component or material supply source.

Production shall not start unless a satisfactory test weld has been obtained at the beginning of each work period specified above.

In the event of the test piece failing at the end of a shift or work period, 1 % or 5 pieces, whichever is lower, shall be randomly selected from assemblies produced since the previous successful test on the machine/station in question and shall be tested in accordance with Clause 9. In the event of any of the selected components failing, the whole production over that period shall be deemed not to conform to this International Standard.

So as not to impede visual inspection, no surface grinding, painting, or other operation interfering with the examination of the weld area shall be carried out on any assembly until after the weld has been examined.

To meet the requirements for visual examination, the surface of the components in the weld area shall conform to the requirements specified in 9.2.5.

11.1 Weld size — nugget width

The weld width produced on flanges not less than the recommended width should approximate $5\sqrt{t}$ and shall not fall below $3{,}5\sqrt{t}$, where t is the sheet thickness in mm, unless otherwise specified in the relevant welding procedure specification for the application.

In cases where a narrower flange width is specified than can satisfy the prescribed relationship between weld width and edge distance, i.e., < 1,25 W_e, a smaller weld width may be specified and reference should be made to the relevant welding procedure specification for the application.

In such cases allowance shall be made in the design calculations for the lower strength obtained with smaller welds.

NOTE The available tolerances in welding conditions and machine operation may be considerably restricted at these small weld widths.

11.2 Weld dimensions

When seam welding two sheets of equal thickness, electrode indentation on each sheet shall not exceed 20 % of a single thickness (t).

Except for mash seam welds, penetration of the weld nugget into each sheet shall be between 20 % and 80 % of the sheet thickness. Sheet separation shall not exceed 10 % of a single sheet thickness (t).

When seam welding two sheets of dissimilar thickness, electrode indentation into the thinner sheet may exceed 20 %. Similarly, a larger indentation is acceptable on the reverse side of a non-marking (face) weld. Penetration of the weld nugget in these cases will be asymmetrical and dependent upon the ratio of the sheet thicknesses being welded.

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11.3 Weld failure mode

To comply with this International Standard, all welds made on test coupons, test specimens, and components where the single sheet thickness < 1,5 mm shall pull a plug on peel or chisel testing.

Interface, or partial plug failures are acceptable, provided other important specified criteria, e.g., pressure tightness, have been satisfied.

11.4 Weld appearance – surface condition

The component surface in the weld area shall be free from surface cracks. In the case of coated steels, severe “brassing” of the surface in the weld area should be avoided.

Surface expulsions, sometimes referred to as weld splash (whiskers), shall not be acceptable.

11.5 Distortion

A weld shall be considered unacceptable where the component has been deformed to make it unfit for its purpose. The amount of acceptable deformation, particularly in the critical area, shall be defined before production proceeds.

In critical cases, the provision of acceptance gauges/fixtures is recommended.

12 Reclamation of non-conformant assemblies

This International Standard does not permit reclamation of non-conformant assemblies by re-welding of the same components using seam welding.

NOTE Reclamation using other welding methods may be used. Such repair procedures are not recommended or covered by this International Standard.

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Annex A
(informative)

Welding equipment

Resistance seam welding equipment should follow the guidelines given in ISO 669.

The machine should be equipped with an automatic control gear which, on the initial actuation of a foot-operated or hand-operated auxiliary switch, takes the control of the machine out of the hands of the operator and performs at least the following cycle of operations in the sequence given:

a) brings the electrodes into contact with the components and applies welding force to the work piece;

b) causes the welding current to flow after the pre-set welding force (the force between the electrodes) has been attained;

c) maintains the pre-set heat and cool sequence while the force is maintained.

At the end of the weld, release of the foot-operated or hand-operated auxiliary switch causes the automatic control to stop the flow of current before the force is automatically released. The electrode wheel or wheels may be rotated continuously or may be started or stopped by the action of a pressure switch.

The welding force, on (heat) time and off (cool) time should be variable over a range sufficient to ensure that optimum welding conditions can be obtained. The machine should be provided with methods of indicating the current setting, pressure and time.

An automatic electrode-wheel-trimming device may be incorporated into the machine when welding coated steels, where electrode-wheel contamination is a particular problem. Effective tooling should be specified and any locating and clamping devices should not interfere with the welding or cause shunting of current through the fixtures themselves.

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Annex B
(informative)

Typical seam welding conditions

Tables B.1 to B.6 give guidance on seam welding conditions for the uncoated and coated steels in the most commonly used thicknesses covered by this International Standard. These may require modification, depending on the mechanical properties and electrical characteristics of the welding equipment (see ISO 669).

These welding conditions are applicable for truncated cone electrodes of Class A2/2 material (see ISO 5182:1991) and may require modification for other electrode shapes and materials.

When welding sheets of dissimilar thickness, welding conditions should be based on the thinnest sheet or the second thinnest sheet when welding three sheets.

In the case of high-strength steels, up to 20 % higher electrode force may be necessary. Welding currents may be reduced up to 20 %, depending on the type of high-strength steel being welded.

The welding conditions presented in Tables B.1 to B.5 correspond to the necessary welding parameters for producing watertight joints at welding speeds of 2 m/min. Satisfactory welding can be effected at much higher speeds, particularly if thin-wheel seam welding or wire electrode seam welding is carried out using either continuous or interrupted current waveforms. Typical examples are illustrated for hot-dip zinc and iron-zinc alloy coated steels are shown in Figures B.1 and B.2.

Table B.1 — Typical wide-wheel seam welding conditions for two uncoated low carbon steel sheets of combined thickness 0,8 mm to 6,0 mm

Single sheet thickness mm		Electrode tread width W_e	Welding conditions							
			Speed v	Force	On time t_{on}		Off time t_{off}		Current	Number of welds per cm S
Over	Up to and including	mm	m/min	kN	Cycles at 50 Hz	s	Cycles at 50 Hz	s	kA	
0,4[a]	0,6	4	2,2	2,5	2	0,04	1	0,02	9	5,0
0,6	0,8	4,5	2,0	3,5	2	0,04	1	0,02	11	4,5
0,8	1,0	5	1,8	4,0	2	0,04	2	0,04	12	4
1,0	1,2	5,5	1,7	4,8	3	0,06	2	0,04	14	3,5
1,2	1,5	6	1,6	5,2	3	0,06	3	0,06	17	3
1,5	2,0	7	1,5	6,5	4	0,08	3	0,06	20	3
2,0	2,5	8	1,4	7,5	5	0,10	4	0,08	22	2,5
2,5	3,0	8,5	1,2	9,0	5	0,10	5	0,10	24	2,5

NOTE 1 If higher or lower welding speeds than those specified above are required , the appropriate $t_{on} + t_{off}$ can be calculated from the formula:

$$t_{on} + t_{off} = 30/Sv$$

by insertion of the required speed, v, in m/min, and the number of welds per cm, specified above ($t_{on} + t_{off}$ is in cycles). For higher welding speeds, t_{on} and t_{off} should be set at equal values, unless $t_{on} + t_{off}$ is less than 2 cycles, where continuous current should be employed. For lower welding speeds, t_{on} should be as specified in this table. Current should be adjusted to obtain the specified weld size.

NOTE 2 It is recommended that the indentation caused by the electrode wheel after the weld has been made should be not greater than 10 % of the thickness of the steel with which the wheel is in contact.

[a] This range includes the thickness 0,4 mm as the lower limit.

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Table B.2 — Typical wide-wheel seam welding conditions for two electrolytic zinc coated steel sheets of combined thickness 0,8 mm to 4,0 mm

Single sheet thickness mm		**Electrode tread width** W_e	**Welding conditions**							
			Speed v	Force	On time t_{on}		Off time t_{off}		Current	Number of welds per cm S
Over	Up to and including	mm	m/min	kN	Cycles at 50 Hz	s	Cycles at 50 Hz	s	kA	
0,4[a]	0,6	4,0	2	2,5	2	0,04	2	0,04	12	4
0,6	0,8	4,5	2	2,8	2	0,04	2	0,04	14	4
0,8	1,0	5,0	2	3,3	2	0,04	2	0,04	17	4
1,0	1,2	5,5	2	3,8	2	0,04	2	0,04	18	4
1,2	1,5	6,0	2	4,5	2	0,04	2	0,04	22	4
1,5	2,0	7,0	2	5,5	2	0,04	2	0,04	26	4

NOTE It is recommended that the indentation caused by the electrode wheel after the weld has been made should be not greater than 10 % of the thickness of the steel with which the wheel is in contact.

[a] This range includes the thickness 0,4 mm as the lower limit.

Table B.3 — Typical thin-wheel seam welding conditions for two hot-dip zinc-coated steel sheets of combined thickness 0,8 mm to 4,0 mm

Single sheet thickness mm		**Welding conditions**								
		Speed v	Force	On time t_{on}		Off time t_{off}		Current	Number of welds per cm S	Typical weld width
Over	Up to and including	m/min	kN	Cycles at 50 Hz	s	Cycles at 50 Hz	s	kA		mm
0,4[a]	0,6	2	2,5	2	0,04	2	0,04	10	4	2,0
0,6	0,8	2	3,2	2	0,04	2	0,04	12	4	2,2
0,8	1,0	2	3,6	2	0,04	1	0,02	13	4	2,5
1,0	1,2	2	4,2	2	0,04	1	0,02	14	4	2,7
1,2	1,5	2	5,5	2	0,04	1	0,02	15,5	4	3,0
1,5	2,0	2	6,0	2	0,04	1	0,02	17	4	3,5

NOTE It is recommended that the indentation caused by the electrode wheel after the weld has been made should be not greater than 20 % of the thickness of the steel with which the wheel is in contact.

[a] This range includes the thickness 0,4 mm as the lower limit.

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Table B.4 — Typical thin-wheel seam welding conditions for two hot-dip iron-zinc coated steel sheets of combined thickness 0,8 mm to 4,0 mm

Single sheet thickness mm		Welding conditions								
		Speed v	Force	On time t_{on}		Off time t_{off}		Current	Number of welds per cm S	Typical weld width
Over	Up to and including	m/min	kN	Cycles at 50 Hz	s	Cycles at 50 Hz	s	kA		mm
0,4[a]	0,6	2	2,6	2	0,04	2	0,04	10	4	2,0
0,6	0,8	2	3,2	2	0,04	2	0,04	11	4	2,2
0,8	1,0	2	3,6	2	0,04	2	0,02	12	4	2,5
1,0	1,2	2	4,2	2	0,04	2	0,02	13	4	2,7
1,2	1,5	2	4,7	2	0,04	2	0,02	13,5	4	3,0
1,5	2,0	2	5,5	2	0,04	2	0,02	15	4	3,5

NOTE It is recommended that the indentation caused by the electrode wheel after the weld has been made should be not greater than 20 % of the thickness of the steel with which the wheel is in contact.

[a] This range includes the thickness 0,4 mm as the lower limit.

Table B.5 — Typical thin-wheel seam welding conditions for two electrolytic zinc-coated steel sheets of combined thickness 0,8 mm to 4,0 mm

Single sheet thickness mm		Welding conditions								
		Speed v	Force	On time t_{on}		Off time t_{off}		Current	Number of welds per cm S	Typical weld width
Over	Up to and including	m/min	kN	Cycles at 50 Hz	s	Cycles at 50 Hz	s	kA		mm
0,4[a]	0,6	2	2,6	2	0,04	2	0,04	10	4	2,0
0,6	0,8	2	3,2	2	0,04	2	0,04	11	4	2,2
0,8	1,0	2	3,7	2	0,04	2	0,04	11,5	4	2,5
1,0	1,2	2	4,3	2	0,04	2	0,04	12	4	2,7
1,2	1,5	2	4,8	2	0,04	2	0,04	13	4	3,0
1,5	2,0	2	5,5	2	0,04	2	0,04	14,5	4	3,5

NOTE It is recommended that the indentation caused by the electrode wheel after the weld has been made should be not greater than 20 % of the thickness of the steel with which the wheel is in contact.

[a] This range includes the thickness 0,4 mm as the lower limit.

Table B.6 — Typical mash seam welding conditions for two uncoated steel sheets of combined thickness 0,8 mm to 4,0 mm using a continuous 50 Hz current supply

Single sheet thickness mm		Welding conditions			
Over	Up to and including	Initial Overlap mm	Speed v m/min	Force kN	Current kA
0,4[a]	0,6	0,9	4,0	3,0	12,0
0,6	0,8	1,2	3,2	4,0	13,0
0,8	1,0	1,5	2,6	5,0	14,0
1,0	1,2	1,8	2,2	6,5	15,0
1,2	1,5	2,0	1,6	9,0	17,5
1,5	2,0	2,5	1,2	11,5	20,0

NOTE It is recommended that the indentation caused by the electrode wheel after the weld has been made should be not greater than 150 % of the thickness of the steel with which the wheel is in contact.

[a] This range includes the thickness 0,4 mm as the lower limit.

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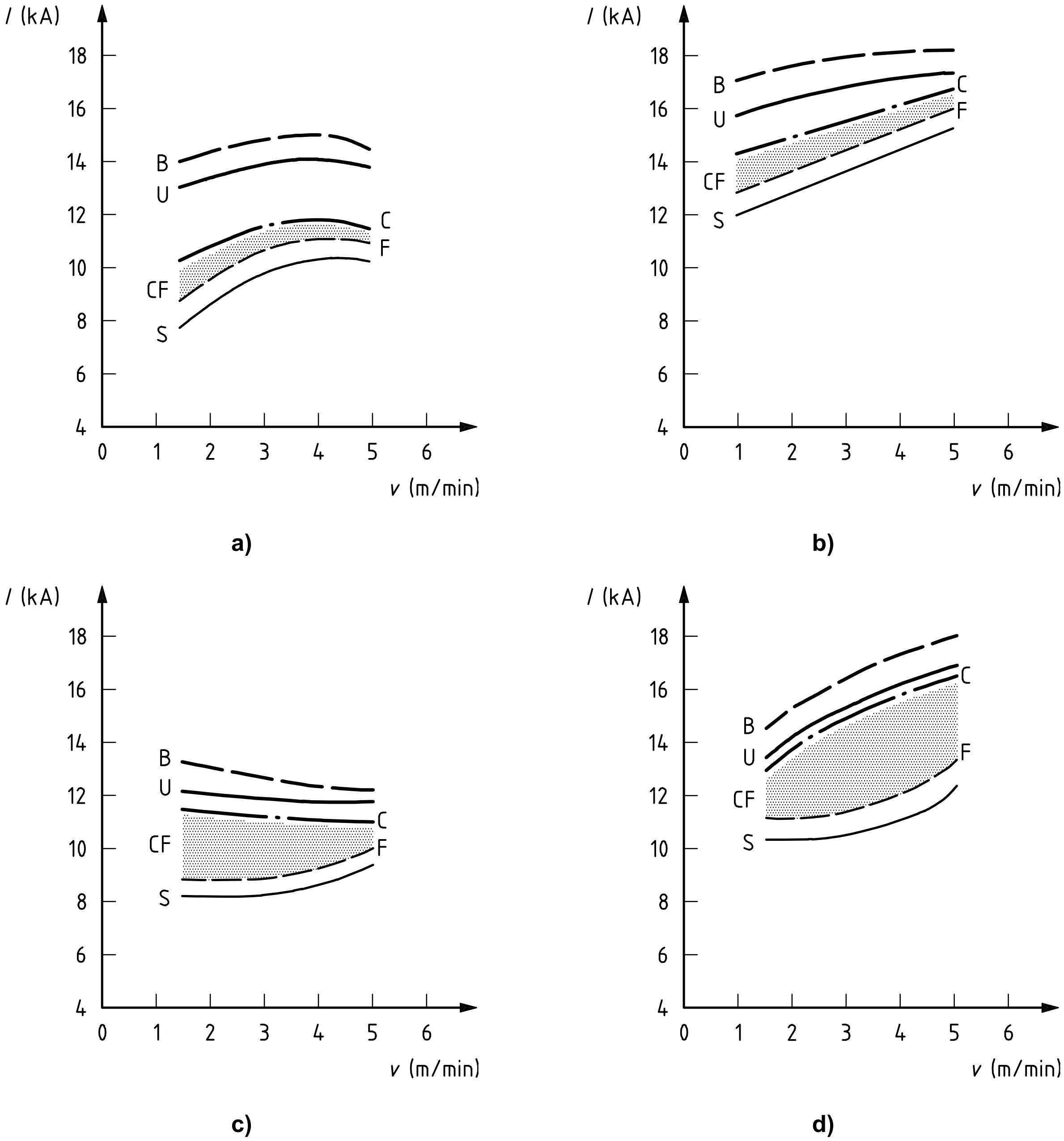

Key

B burning limit

C start of cracking

CF crack-free zone

F fully welded seam

S stuck weld limit

U upper limit

I welding current

v welding speed

Figure B.1 — Effect of welding speed on weldability range in thin-wheel seam welding (Electrode force: 2,4 kN)

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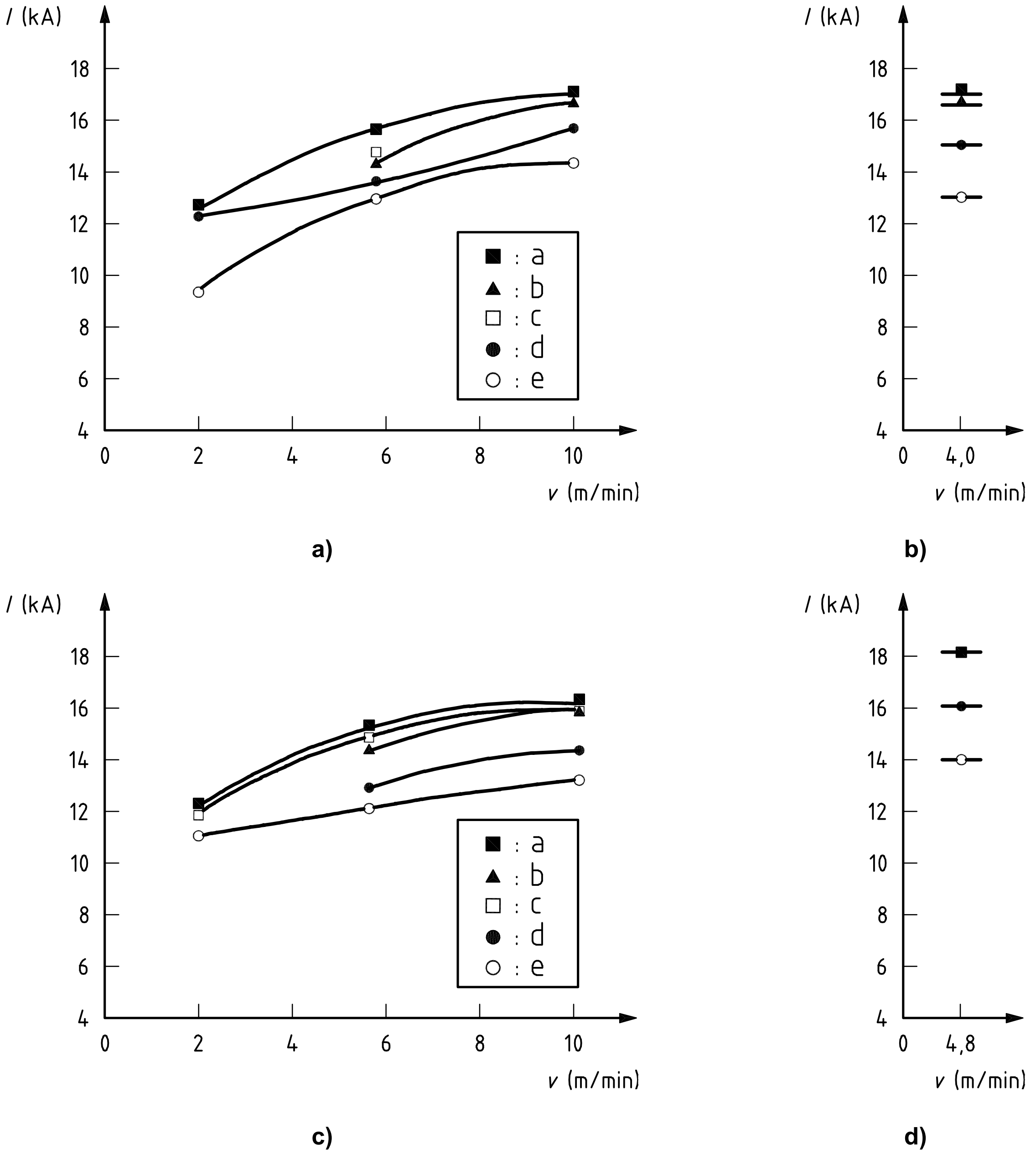

Key

a splash

b cracking

c brassing

d continuous weld

e stuck weld

I welding current

v welding speed

Figure B.2 — Effect of welding speed on weldability range in wire electrode seam welding (Electrode force: 4,0 kN)

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Annex C
(Informative)

Partial list of steel types applicable to the standard

C.1 Uncoated steel

Sheet and strip material should comply with the general requirements and chemical composition specified in ISO 3574. Hot rolled steel should be in the pickled condition for best results and should comply with the requirements of ISO 3573 and ISO 4950-1 and ISO 4950-2.

C.2 Hot-dip zinc or iron-zinc alloy coated steel

Several types of zinc coatings are available with various steel substrates and surface treatments. They should comply with the requirements for hot-dip zinc coated and iron-zinc coated (galvannealed) steel coil and cut lengths, in forming and structural grades specified in ISO 3575 and ISO 4998. Coating types and coating mass should comply with these standards; the lower-mass zinc coatings and the zinc alloy coatings being the most readily weldable.

C.3 Electrolytic zinc coated steel

Electrolytic zinc coated steel should be produced by electrolytic deposition of pure zinc onto low carbon steel. The maximum coating thickness should be 15 µm nominal (≡ coating mass 107 g/m^2) on each surface and should comply with ISO 5002 for the more readily weldable grades.

C.4 Electrolytic zinc-nickel or zinc-iron coated steel

Such coatings deposited electrolytically should be limited to a maximum coating thickness of 7 µm (≡ coating mass 51 g/m^2) on each surface.

C.5 Aluminium coated steel

Aluminium coated steel produced by the hot-dip process, the coating containing 5 % to 11 % silicon, should comply with ISO 5000. Aluminium coated steels may also be produced by a roll bonding technique. Coating mass up to 150 g/m^2 nominal including both surfaces is considered the most readily weldable.

C.6 Zinc – (50-55) % aluminium coated steel

Zinc – (50-55) % aluminium coated steel produced by the hot-dip process, with a maximum coating mass of 185 g/m^2, including both surfaces for the more readily weldable grades, should comply with ISO 9364. Heavier coating thicknesses can be welded, provided that suitable welding conditions are used.

C.7 Zinc – 5 % aluminium coated steel

Zinc – 5 % aluminium coated steel should be produced by the hot-dip process. The maximum coating mass should be 180 g/m^2 including both surfaces for the more readily weldable grades.

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Bibliography

[1] ISO 3573, *Hot-rolled carbon steel sheet of commercial and drawing qualities*

[2] ISO 3574, *Cold-reduced carbon steel sheet of commercial and drawing qualities*

[3] ISO 3575, *Continuous hot-dip zinc-coated carbon steel sheet of commercial and drawing qualities*

[4] ISO 4950-1, *High yield strength flat steel products — Part 1: General requirements*

[5] ISO 4950-2, *High yield strength flat steel products — Part 2: Products supplied in the normalized or controlled rolled condition*

[6] ISO 4998, *Continuous hot-dip zinc-coated carbon steel sheet of structural quality*

[7] ISO 5000, *Continuous hot-dip aluminium-silicon-coated cold-reduced carbon steel sheet of commercial and drawing qualities*

[8] ISO 5002, *Hot-rolled and cold-reduced electrolytic zinc-coated carbon steel sheet of commercial and drawing qualities*

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