
Resistance welding — Weldability —
Part 1:
General requirements for the
evaluation of weldability for
resistance spot, seam and projection
welding of metallic materials

Soudage par résistance — Soudabilité —

Partie 1: Exigences générales pour l'évaluation de la soudabilité pour le soudage par résistance par points, à la molette et par bossages des matériaux métalliques



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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 44, *Welding and allied processes*, Subcommittee SC 6, *Resistance welding and allied mechanical joining*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 121, *Welding and allied processes*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 18278-1:2015) and the first edition of ISO 14327:2004, which have been technically revised.

The main changes are as follows:

- the concept of weldability lobe was added to this document.

A list of all parts in the ISO 18278 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.

Resistance welding — Weldability —

Part 1:

General requirements for the evaluation of weldability for resistance spot, seam and projection welding of metallic materials

1 Scope

This document specifies procedures for assessing the generic weldability for resistance spot, seam and projection welding of uncoated and coated metals.

The purpose of the tests described in this document are to

- a) compare the metallurgical weldability of different metals,
- b) assess the weldability of differing component designs, e.g. dimensional configuration, stack-up, projection geometry, etc.,
- c) investigate the effect of changes in welding parameters such as welding current, weld time, electrode force or complex welding schedules including pulse welding, current stepping etc. on weldability, and/or
- d) compare the performance of resistance welding equipment.

Precise details of the test procedure to be used depend on which aspect of items a) to d) will be evaluated relative to the welding result obtained.

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

ISO 693, *Dimensions of seam welding wheel blanks*

ISO 5182, *Resistance welding — Materials for electrodes and ancillary equipment*

ISO 5821, *Resistance welding — Spot welding electrode caps*

ISO 8167, *Resistance welding — Embossed projection welding — Projections for resistance welding*

ISO 14270, *Resistance welding — Destructive testing of welds — Specimen dimensions and procedure for mechanized peel testing resistance spot, seam and embossed projection welds*

ISO 14271, *Resistance welding — Vickers hardness testing (low-force and microhardness) of resistance spot, projection, and seam welds*

ISO 14272, *Resistance welding — Destructive testing of welds — Specimen dimensions and procedure for cross tension testing of resistance spot and embossed projection welds*

ISO 14273, *Resistance welding — Destructive testing of welds — Specimen dimensions and procedure for tensile shear testing resistance spot and embossed projection welds*

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

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

ISO 16432, *Resistance welding — Procedure for projection welding of uncoated and coated low carbon steels using embossed projection(s)*

ISO 17657-2, *Resistance welding — Welding current measurement for resistance welding — Part 2: Welding current meter with current sensing coil*

ISO 17677-1, *Resistance welding — Vocabulary — Part 1: Spot, projection and seam welding*

ISO/TR 581, *Weldability — Metallic materials — General principles*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 17677-1, ISO 669, ISO/TR 581 and the following 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 <https://www.electropedia.org/>

3.1

weldability

<resistance welding> capacity of the component to be welded under the imposed fabrication conditions into a specific suitability designed structure and to perform satisfactorily in the intended service

3.2

welding current range

welding current domain allowing the production of spot welds without expulsion and of a diameter equal to or more than a pre-determined value under constant machine settings

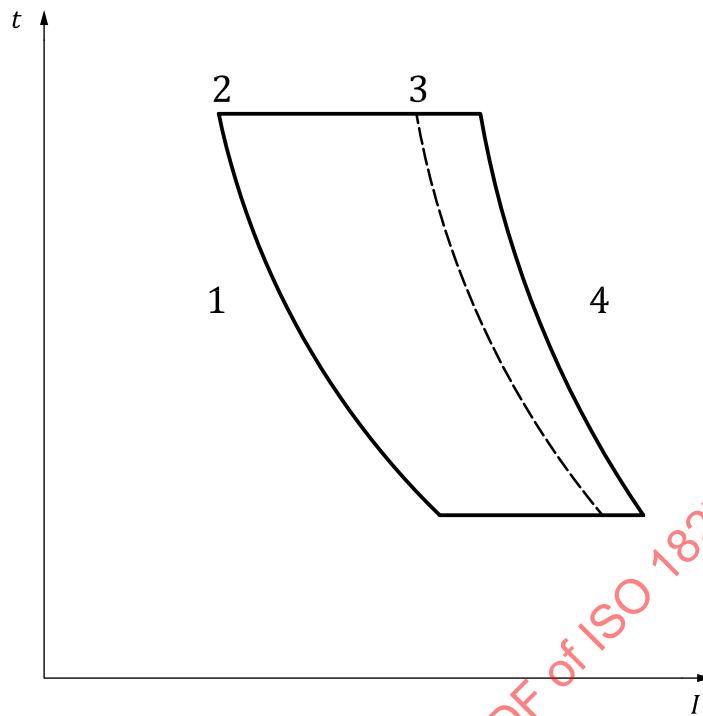
3.3

weldability lobe

welding current domain allowing the production of spot welds without splash and of a diameter equal to or more than a pre-determined value, using varied values of either welding time or electrode force

Note 1 to entry: In the case of resistance seam welding, welding speed (m/min) is used instead of weld time.

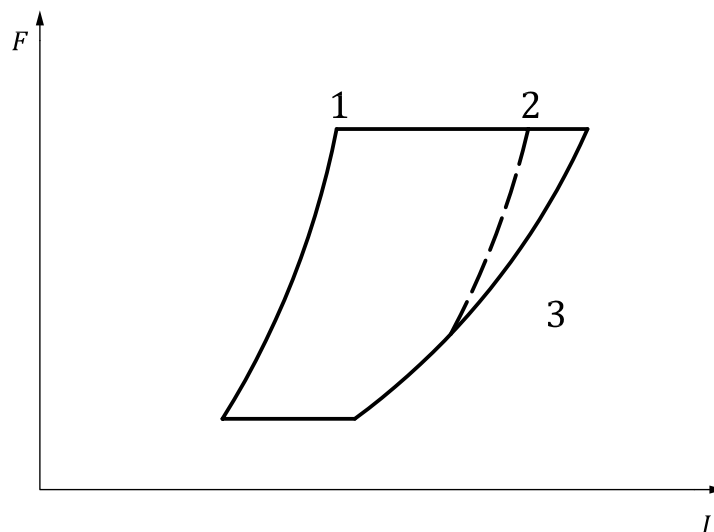
Note 2 to entry: To meet the above requirements, the weldability lobes can be a two-dimensional plot (see [Figure 1](#)) or a three-dimensional plot indicating the inter relationship between weld time (welding speed in the case of seam welding), welding current and electrode force:



Key

- t weld time
- I welding current
- 1 $< 3,5\sqrt{t}$
- 2 $3,5\sqrt{t}$
- 3 $5\sqrt{t}$
- 4 expulsion

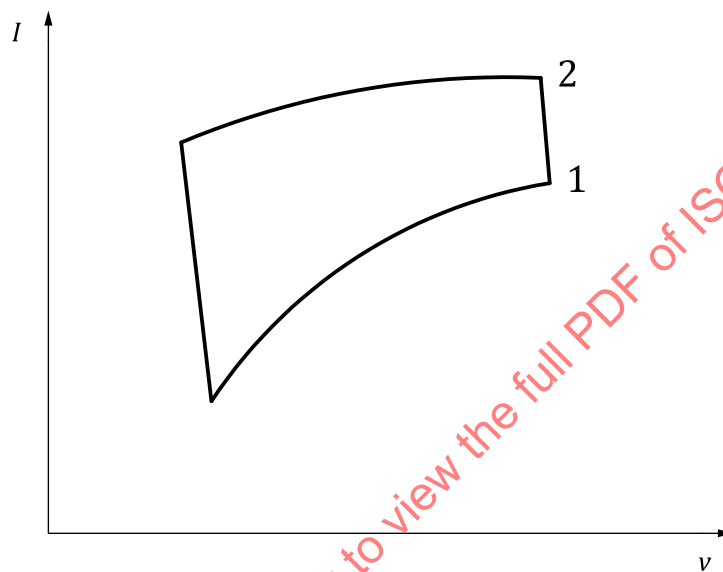
a) Spot welding — constant force



Key

- F electrode force
- I welding current
- 1 $3,5\sqrt{t}$
- 2 $5\sqrt{t}$
- 3 expulsion

b) Spot welding — constant weld time



Key

- I welding current (kA)
- v welding speed (m/min)
- 1 lower limit
- 2 upper limit

c) Seam welding — constant weld force — typical for zinc coated steels

Figure 1 — Typical weldability lobes

4 Weldability

4.1 Weldability of a component

4.1.1 General

Weldability of a component is governed by three factors: material, design, and production (see [Figure 2](#)).

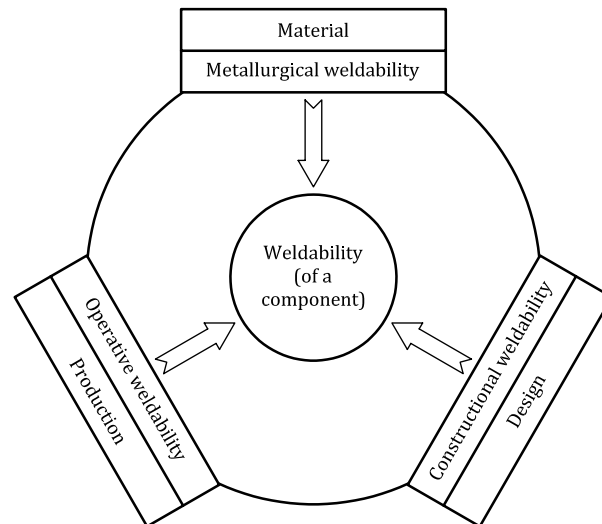


Figure 2 — Weldability

4.1.2 Metallurgical weldability

The less the factors governed by the material have to be taken into account when determining the welding procedure for a given construction, the better the metallurgical weldability of a material group.

The ease by which a material can be welded determines its metallurgical weldability.

4.1.3 Operative weldability

Operative weldability exists for a welding procedure if the welds envisaged for a particular construction can be made properly under the chosen conditions of production.

The less the factors governed by the welding procedure have to be taken into account in designing a construction for a specific material, the better is the operative weldability of a procedure intended for a specific structure or component.

4.1.4 Constructional weldability

Constructional weldability exists in a construction if the material concerned and the component remain capable of functioning under the envisaged operating conditions by virtue of their design.

The less the factors governed by the design have to be taken into account when selecting the material for a specific welding procedure, the greater the constructional weldability of a specific structure or component.

4.2 Criteria for the evaluation of weldability

Weldability in resistance welding requires the ability to make a weld in the first place, the ability to continue making welds, and the ability of the weld to withstand the imposed service stresses.

Criteria for the evaluation of the weldability in resistance welding are typically as follows:

- weldability lobe and welding current range which quantify ability to make a weld (see NOTE);
- electrode wear and life which quantify the ability to continue making welds (see NOTE);
- strength of joints under different load directions;
- material hardness modifications;

- presence, number, and size of the surface or inner cracks, pores, shrink holes, and other defects;
- fracture behaviour under different load directions;
- resistance to service stresses such as corrosion, humidity, low, elevated, or fluctuating temperatures etc.

NOTE Results of weldability lobe, welding current range and electrode life investigations do not only reflect material characteristics, but are also highly related to the characteristics of the welding equipment employed.

A final evaluation of weldability in each case can only be estimated by considering the prioritized criteria laid down by the end user.

5 Preparation of welding equipment

5.1 Welding machine

The electrical and mechanical characteristics of the welding machine used for the tests shall meet the requirements specified in ISO 669.

In a.c.-welding machines and single-phase d.c.-welding machines, wherever possible, a transformer tap setting should be selected which allows the secondary welding current to be achieved using a conduction angle greater than 120°. The water supply to the transformer and/or rectifier and welding controller cooling circuits should be independent of cooling water to the electrodes. If this is not possible, the water should flow from the electrode to the welding controller/transformer circuits and not vice versa.

The mass and static friction properties of the welding head can be determined in accordance with [Annex A](#). It is recommended to record the test results to evaluate the mechanical characteristics of the welding machine.

NOTE If low electrode force values are used, then the welding process can be adversely influenced by the follow-up behaviour of the electrode head assembly. If electrode force levels near the top end of the available range are used, then contact errors and electrode approach are more important.

5.2 Welding electrodes

5.2.1 General

The welding electrodes shall conform to alloys as specified in ISO 5182 unless otherwise agreed between contracting parties. Electrodes should be of sufficient cross-sectional area and strength to carry the welding current and electrode force without overheating, deformation, or excessive deflection.

5.2.2 Spot welding

In the case of spot welding, the electrode dimensions shall conform to the requirements of ISO 5821. Alternative electrode shapes and dimensions may be used by agreement between contracting parties.

5.2.3 Seam welding

In the case of wide wheel seam welding, the electrode dimensions shall conform to the requirements of ISO 693. Alternative electrode wheel width and face profile may be used by agreement between contracting parties.

5.2.4 Projection welding

In the case of embossed projection welding, the electrode dimensions shall conform to the requirements of ISO 16432. Alternative electrode shapes and dimensions may be used by agreement between contracting parties.

5.3 Measurement of parameters

5.3.1 Welding current

The welding current shall be measured with a current measuring system of high accuracy class in accordance with ISO 17657-2. The welding current value shall be measured over the total weld time.

The shape of the welding current waveform shall be measured using a suitable device to determine the regularity of welding current peak values and conformity of the actual welding cycle with the programmed welding cycle.

5.3.2 Electrode force

The electrode force shall be expressed in kilonewtons with an accuracy of $\pm 3\%$ and measured without current flow.

6 Test procedures

6.1 General

Tests which are considered necessary by the user for assessing the weldability shall be specified.

Acceptance criteria for each test will depend on the requirements of the product being welded and shall be specified before commencing the test programme.

The evaluation of weldability requires the following steps:

- ensure the welding equipment is within specifications;
- analyse and determine material properties;
- carry out the test procedure according to pWPS (ISO 15614-12, ISO 15609-5);
- document and evaluate the test results.

6.2 Basic test procedures

6.2.1 Essential variables

The weldability lobe, welding current range and electrode life are influenced by the following:

- a) the electrical and mechanical characteristics of the welding equipment, including cooling conditions;
- b) the welding parameters, including welding rate for electrode life;
- c) the electrical, mechanical and physical properties of the material being welded;
- d) the welding configuration used;
- e) the electrode material and design of the welding electrode;
- f) the test specimen or component being welded.

6.2.2 Welding current range test

For the determination of the ability to make a weld, a welding current range shall be determined according to the procedures agreed upon between the contracting parties. In producing a welding current range, electrode wear can occur due to heavy expulsion, surface expulsion, mushrooming, or

alloying. This can have an adverse effect on the reproducibility and validity of the results, particularly when welding coated steels or aluminium and aluminium alloys. To control this, the testing procedure shall specify the following:

- electrode alignment and conditioning procedure;
- the number of welds and their order for the determination of the welding range limits;
- the welding parameters to be used for the test (except the welding current), including electrode shape, size and material, welding force and sequence, as well as holding time;
- the shape, size of the workpieces to be welded, and their preparation if needed (i.e. projection shape and size in the case of projection welding in accordance with ISO 8167);
- starting current level for the test;
- the number of welds to be done for each current setting;
- welding current increments (increasing or decreasing) in each phase of the test;
- the criteria to determine if a current setting is in the welding current range (for example, if all the welds done at this current level should meet the no-expulsion requirement or only the majority or other such requirements by the WPS). The lower limit is the current setting which results in a predetermined weld diameter for spot welds, and size and overlap for seam welds. The upper limit of the welding current range is the maximum current setting without expulsion;
- number of welds to be produced (and at which place in the procedure), if any, for metallographic examination or mechanical testing.

NOTE Other criteria can be specified for upper limit upon agreement of contracting parties, for example, maximum weld size, maximum indentation depth, surface splashing (especially for seam welding) or the onset of surface cracking in the weld or electrode-to-workpiece sticking.

In addition, testing procedures should consider scatter analysis of the welding current range results, for example, through specifying a number of test replicates for standard deviation calculation, or through regression analysis of the points used to perform an individual test.

6.2.3 Electrode life test

The ability to continue making acceptable welds shall be determined by electrode life tests according to the procedures agreed to between the contracting parties.

The electrode life testing procedure shall specify the following:

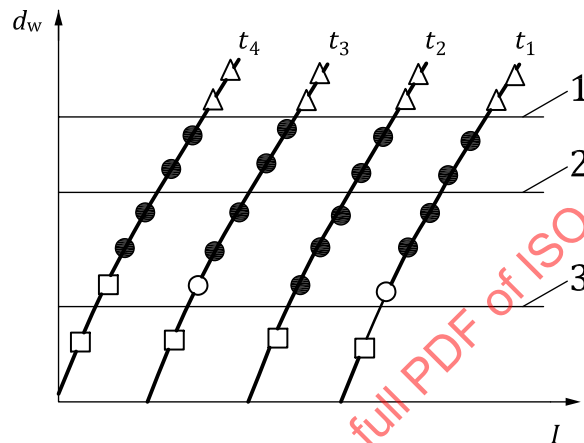
- the welding parameters to be used for the test, including electrode shape, size and material, welding force and sequence, hold time, welding rate, and cooling conditions;
- the procedure to determine the testing welding current, for example, just below the expulsion limit;
- the procedures to increase or decrease current during the test, for example, in case of expulsion or current stepping;
- the shape and size of the work pieces to be welded and their preparation if needed (i.e. projection shape and size in the case of projection welding);
- the arrangement of the welds on testing sheets, including weld spacing and distance from edges;
- the criteria to end the test (e.g. testing shall continue until the weld diameter or weld strength becomes below a certain value decided by a WPS or between the contractive parties).

Testing procedures should consider scatter analysis of the electrode life test results, for example, through specifying a number of test replicates for standard deviation calculation, or through regression analysis of the points used to perform an individual test.

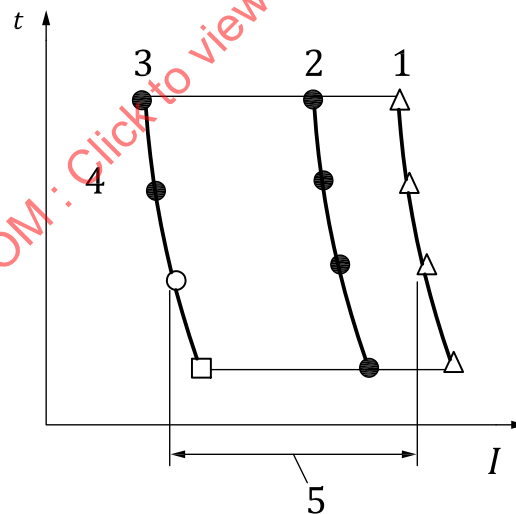
In other cases (seam welding, projection welding, multi-sheet spot welding), criteria for the end of electrode life have to be defined between the contracting parties. Alternative procedures shall be specified or developed for the evaluation of electrodes for seam welding. Generally, special variants of the seam welding process are used to weld coated steels which eliminate the problems associated with electrode contamination, for example, in narrow wheel welding and wire seam welding.

6.2.4 Weldability lobe test

The weldability lobe is constructed from a series of welding current ranges (see 6.2.2) for which either the welding time, the electrode force or both are increased sequentially, at pre-determined intervals depending on the purpose of the test and the application being welded (see Figure 3).



a) Welding current range diagram by constant electrode force and weld time $t_1 < t_2 < t_3 < t_4$



b) Weld time — welding current weldability lobe by constant electrode force**Key**

X	welding current, I
Y	weld diameter, d_w and time, t
1	expulsion limit
2	$5\sqrt{t}$
3	min. weld diameter
4	fusion defect
5	welding current range
t_1 to t_4	weld time
□	interface failure
○	partial plug with interface failure
●	plug failure
△	expulsion

Figure 3 — Examples of diagrams to display the weldability lobe at varying welding time and constant electrode force (for spot welding)

When welding aluminium, aluminium alloys or material with extremely poor electrode life (e.g. some coated steels), the electrodes should be replaced at the end of each welding current range.

In the case of resistance seam welding, the maximum welding speed occurs when there is no current range left between weld formation and weld splash.

6.3 Evaluation of weld properties

6.3.1 General

The relevant tests to be used according to 6.3.2 to 6.3.7 shall be specified, if necessary.

The failure mode and imperfections observed in a test depend on the material being welded and on the type of test, for example:

- rephosphorized steels, some high-strength and ultra-high-strength steels can promote interface failures, partial plug fractures, and partial thickness fractures or mixed combinations of those modes depending on the welding parameters and the applied testing conditions;
- in the case of aluminium and aluminium alloys, porosity and internal cracks can occur;
- with nickel alloys, hot cracking can occur;
- for the same type of material, increasing the thickness favours interfacial failures;
- for zinc-coated materials, liquid metal embrittlement can occur (surface cracks within electrode indentation).

6.3.2 Shop floor tests

Shop floor tests are used to determine the failure mode and the weld diameter by chisel or peel tests according to ISO 10447, or torsion test according to ISO 17653 can be used. The results obtained from such tests give information on the ability to control weld quality on the shop floor.

6.3.3 Tensile shear testing

The tensile shear testing shall be carried out according to ISO 14273.

The purpose of this test is to determine the failure mode and the maximum shear force that the test specimen can sustain.

6.3.4 Mechanized peel testing

The mechanized peel testing shall be carried out according to ISO 14270.

The purpose of this test is to determine the failure mode and the maximum peel force that the test specimen can sustain.

6.3.5 Cross-tension testing

The cross-tension testing shall be carried out according to ISO 14272.

The purpose of this test is to determine the failure mode and the maximum tensile force that the test specimen can sustain.

6.3.6 Macro-sections and hardness test

The shape and dimension of the weld nugget, together with hardness values, shall be determined on etched macro-sections according to ISO 14271 and ISO 17677-1.

6.3.7 Further weld properties

Further weld properties can be determined by using the following tests:

- fatigue testing according to either ISO 14324 or ISO 18592;
- impact shear test according to ISO 14323;
- pressure testing of seam welds according to ISO 17654.

The influence of hold time should be determined if brittle fractures in test specimen are observed in the weld zone.

7 Test report

7.1 General

The results of the assessment shall be given in tabular form as stipulated in ISO 15609-5 and ISO 15614-12.

7.2 Welding current range test

The test report for welding current range shall contain at least the following information:

- a) a reference to this document, i.e. ISO 18278-1:2022;
- b) date of testing;
- c) criteria to determine the minimum welding current;
- d) criteria to determine the maximum welding current;
- e) minimum current value;
- f) maximum current value;
- g) weld diameter, current, and failure mode as determined;

- h) occurrence of expulsion or not, for each weld;
- i) welding process;
- j) welding conditions and equipment;
- k) electrode material, geometry and condition;
- l) workpiece material and its condition;
- m) other information by agreement.

7.3 Electrode life test

The test report for electrode life shall contain at least the following information:

- a) a reference to this document, i.e. ISO 18278-1:2022;
- b) date of testing;
- c) criteria for evaluation of the weld quality;
- d) electrode life (described in number);
- e) scatter range of weld quality level and the average value;
- f) weld diameter, current, and failure mode as determined;
- g) welding process;
- h) welding conditions and equipment;
- i) electrode material, geometry and condition;
- j) work piece material and its condition;
- k) any additional remarks and any deviations from this document.

7.4 Weldability lobe test

The test report for weldability lobe shall contain at least the following information:

- a) a reference to this document, i.e. ISO 18278-1:2022;
- b) date of testing;
- c) welding process;
- d) workpiece material and its condition;
- e) electrode material, geometry and condition;
- f) electrode force and/or welding time steps used in test;
- g) other welding conditions and equipment, if applicable;
- h) criteria to determine the minimum welding current;
- i) criteria to determine the maximum welding current;
- j) minimum current value for each welding time and/or electrode force step;
- k) maximum current value for each welding time and/or electrode force step;