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Resistance welding — Weldability —

Part 2: Alternative procedures for the assessment of sheet steels for spot welding

Soudage par résistance — Soudabilité —

Partie 2: Méthodes alternatives d'évaluation des tôles d'acier pour le soudage par points

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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 18278-2 was prepared by the European Committee for Standardization (CEN) in collaboration with Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 10, *Unification of requirements in the field of metal welding,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

Throughout the text of this document, read "...this European Standard..." to mean "...this International Standard...".

ISO 18278 consists of the following parts, under the general title *Resistance welding — Weldability*:

— *Part 1: Assessment of weldability for resistance spot, seam and projection welding of metallic materials*

— *Part 2: Alternative procedures for the assessment of sheet steels for spot welding*

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Foreword

This document (EN ISO 18278-2:2004) has been prepared by Technical Committee CEN/TC 121 “Welding”, the secretariat of which is held by DIN, in collaboration with Technical Committee ISO/TC 44 “Welding and allied processes”.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by May 2005, and conflicting national standards shall be withdrawn at the latest by May 2005.

This standard consists of the following parts:

— Part 1: Assessment of weldability for resistance spot, seam and projection welding of metallic materials;

— Part 2: Alternative procedures for the assessment of sheet steels for spot welding.

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

Introduction

This document describes alternative procedures for assessing the weldability of sheet steels by determining the welding range and electrode life for resistance spot welding.

It supplements generic standards for the assessment of the weldability lobe (EN ISO 14327) and electrode life at constant machine settings (EN ISO 8166). These procedures can be used to evaluate the following:

a) the effect of electrode material, shape, dimensions and electrode cooling when welding a particular material;

b) the effect of material type and thickness being welded;

c) the effect of welding conditions;

d) the effect of welding equipment type.

1 Scope

This document specifies a laboratory test procedure for the determination of the acceptable welding current range and the assessment of electrode life using a multi-spot test with specific conditions.

This document is applicable for the assessment of the weldability of uncoated and coated sheet steels of thicknesses up to 3 mm.

The test procedure specified in this document and the results obtained, apply only for the introduction of a new type or batch of material.

Procedures for determining the generic weldability lobe at a constant weld time or electrode force are given in EN ISO 14327.

The electrode life at constant machine settings is given in EN ISO 8166.

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.

EN 22768-1, *General tolerances — Part 1: Tolerances for linear and angular dimensions without individual tolerance indications (ISO 2768-1:1989).*

EN 22768-2, *General tolerances — Part 2: Geometrical tolerances for features without individual tolerance indications (ISO 2768-2:1989).*

EN 25821, *Resistance spot welding electrode caps (ISO 5821:1979).*

EN ISO 5183-1, *Resistance welding equipment — Electrode adaptors, male taper 1:10 — Part 1: Conical fixing, taper 1:10 (ISO 5183-1:1998).*

EN ISO 6520-2, *Welding and allied processes — Classification of geometric imperfections in metallic materials — Part 2: Welding with pressure (ISO 6520-2:2001).*

EN ISO 8166, *Resistance welding — Procedure for the evaluation of the life of spot welding electrodes using constant machines settings (ISO 8166:2003).*

EN ISO 14272, *Specimen dimensions and procedure for cross tension testing resistance spot and embossed projection welds (ISO 14272:2000).*

EN ISO 14327, *Resistance welding — Procedures for determining the weldability lobe for resistance spot, projection and seam welding (ISO 14327:2004).*

EN ISO 14329:2003, *Resistance welding — Destructive tests of welds — Failure types and geometric measurements for resistance spot, seam and projection welds (ISO 14329:2003).*

EN ISO 18278-1:2004, *Resistance welding — Weldability — Part 1: Assessment of weldability for resistance spot, seam and projection welding of metallic materials (ISO 18278-1:2004).*

ISO 669:2000, *Resistance welding — Resistance welding equipment — Mechanical and electrical requirements.*

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

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

ISO/DIS 14373, *Resistance welding — Procedure for spot welding of uncoated and coated low carbon steels.*

ISO/DIS 17657-1, *Resistance welding — Welding current measurement for resistance welding — Part 1: Guideline for measurement.*

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

ISO/DIS 17657-3, *Resistance welding — Welding current measurement for resistance welding — Part 3: Current sensing coil.*

ISO/DIS 17657-4, *Resistance welding — Welding current measurement for resistance welding — Part 4: Calibration system.*

ISO/DIS 17657-5, *Resistance welding — Welding current measurement for resistance welding — Part 5: Verification of welding current measuring system.*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 669:2000, EN ISO 14329:2003 and EN ISO 18278-1:2004 and the following apply.

3.1
acceptable welding current range
range of R.M.S. values of welding current between lower and upper limits which allows an acceptable weld diameter

3.2
R.M.S. value
R.M.S. value of an alternating voltage is the square root of the mean value of the square of the voltage values during a complete cycle

4 Purpose

This procedure allows the determination of the lower and upper limits of the welding current under specific welding configuration in order to assess the life of the electrode for a given welding current chosen within the acceptable welding current range, without any redressing of the electrode tips.

NOTE If automatic redressing or current stepping procedures are used, it is necessary to use a modified test and procedure.

5 Welding equipment

5.1 General

Welding equipment shall be capable of delivering the required welding conditions to carry out the tests as defined below.

5.2 Electrodes

The electrodes shall be of type A 2/3 material as defined in ISO 5182 unless otherwise specified.

The electrode configuration for these tests shall conform to:

— cap electrodes to be used;

— EN 25821 - G 16 $\times$ 20 - (d_1 = 16 mm - l_1 = 20 mm) for sheets with a thickness < 1,3 mm;

— EN 25821 - G 20 × 22 - (d_1 = 20 mm - l_1 = 22 mm) for sheets with a thickness ≥ 1,3 mm.

The geometry shall be checked prior to commencing the test to ensure that tolerances are within ± 0,1 mm of the range permitted for grade F of EN 22768-1 or EN 22768-2.

A typical gauge for checking electrode geometry is described in Annex A.

The adapter used shall have a cooling bore complying with:

— EN ISO 5183-1 - B 16 x 71 - A 2/3, or

— EN ISO 5183-1 - B 16 x 88 - A 2/3.

5.3 Welding current

Unless otherwise specified, welding current should be single phase AC, its R.M.S. value shall be set and recorded.

The equipment shall be set so that R.M.S. welding current is not less than 70 % of R.M.S. value at full conduction angle.

5.4 Mechanical system

The electrode force applied by the electrode head assembly shall be chosen to minimize the impact effect of the electrode meeting the sheet. For example, an electrode approach rate of 0,15 m/s is recommended. The electrode approach rate measurements shall conform to ISO 669:2000, Annex A.

5.5 Parameter measurement

5.5.1 Welding current

In order to ensure optimum reproducibility and allow comparison of the results obtained from the various tests previously carried out, the welding current shall be measured with a current measuring system which is regularly calibrated in accordance with procedures outlined in ISO/DIS 17657-1 to ISO/DIS 17657-5. The R.M.S. current value shall be measured over the entire effective welding time as defined in ISO/DIS 17657-1.

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

5.5.2 Welding force

The welding force shall expressed in kN with an accuracy of ± 3 % measured during the setup.

5.5.3 Electrode approach rate

The electrode approach rate on the sheet shall be measured with an accuracy better than 0,02 m/s.

5.5.4 Detection of splash

Occurrence of splashed spot welds shall be determined/confirmed from visible examination or from the electrode displacement curve or the welding force, welding voltage or welding current signal. A splashed spot weld is characterized by a very sharp deviation in the trace of an electrode displacement or welding force signal.

5.5.5 Electrode flow rate cooling water

The electrode cooling water flow rate shall be measured as specified in EN ISO 8166.

5.5.6 Weld diameter measurement

After the destructive test, the maximum and minimum dimensions of the weld diameter shall be measured with a calliper gauge, according to ISO 10447 and EN ISO 14329. The weld diameter value shall be rounded to 1/10 mm.

6 Range of qualification

The range of qualification given in Table 1 shall apply unless otherwise specified.

Table 1 — Range of qualification

Thickness of the test specimen	Sheet thicknesses
0,8 mm	< 1,3 mm
2,0 mm	≥ 1,3 mm

7 Test specimen characteristics

7.1 Materials

Material conditions and properties shall be as defined the specific conditions or on the test order form.

7.2 Assemblies

Assemblies for testing shall be as defined on the test order form.

Configuration shall be representative of the component to be welded.

8 Preliminary adjustments

8.1 Electrode position check under electrode force used for the test

Only the adapters (see EN ISO 5183-1) shall be aligned. To do this, specific caps shall be used (see Figure B.1). Both axial and angular alignments shall be checked, this can be done using the carbon imprint method where a sheet of paper is sandwiched between two carbon papers inserted between the two caps then applying the electrode force.

The tolerance for linear alignment shall be ± 0,5 mm. Angular misalignment shall not exceed 5 rad.

Examples of carbon imprints obtained on the paper sheet after application of pressure are shown in Figure B.2.

8.2 Electrode conditioning

Before each test, the electrodes shall be conditioned using the following parameters:

— for welding sheet thicknesses < 1,3 mm conditions A apply;

— for welding sheet thicknesses ≥ 1,3 mm conditions B apply.

Table 2 — Electrode conditioning

Conditions	A	B
Electrodes type	G16 x 20	G20 x 22
Thickness of sheets	0,8 mm	2,0 mm
Material	DC 04	DC 04
Coating	none	none
Squeeze force	(2,30 ± 0,11) kN	(4,50 ± 0,22) kN
Weld force	(2,30 ± 0,11) kN	(4,50 ± 0,22) kN
Hold force	(2,30 ± 0,11) kN	(4,50 ± 0,22) kN
Squeeze	Adjust to the value corresponding to the stabilized force	—
Weld time	Single pulse welding 0,2 s (10 cycles)	Multi pulse welding 4 pulses with 0,12 s (6 cycles) with current and 0,04 (2 cycles) without current
Hold time	0,2 s (10 cycles)	0,3 s (15 cycles)
Weld current	(7 ± 0,5) kA	(11 ± 0,5) kA
Number of weld spots	300 pieces	300 pieces
Welding rate	30 welds/min	15 welds/min
Min. water flow rate at electrode cooling inlet	4 l/min	6 l/min
Min. water temperature electrode cooling inlet	17 °C	17 °C
Max. water temperature electrode cooling inlet [a]	25 °C	25 °C

[a] Since water temperature can significantly influence electrode life, the actual water temperature should be measured, and kept constant in any series of tests.

9 Determination of the acceptable welding current range

9.1 Test specimens

Cross tension test specimens shall be used for all sheet thicknesses. The dimensions of these shall be 38 mm × 125 mm (see Figure C.1) or 50 mm × 150 mm according to complying with EN ISO 14272.

The exact positioning of the test specimen on the welding equipment shall be obtained with a template (see Figure C.2). Other tests may be specified.

9.2 Welding parameters

Welding parameters appropriate to the product shall be specified in the instructions or in the test order form.

9.3 Acceptance criteria

The minimum dimensions of the weld diameter measured at the faying interface shall be specified in the instructions or in the test order form.

9.4 Procedure

After a preliminary search aimed to define the current needed initiate adhesion (stuck weld), the R.M.S. value of the welding current is increased progressively at 400 A steps. Three cross tension test specimens shall be prepared for each setting. Each test specimen shall be submitted to a tensile-load according to EN ISO 14272.

If the weld diameters of all three welds conform to the requirements of 8.2, the welding current is considered to be within the acceptable welding current range and the test is repeated for higher welding currents, using the same current steps, until the splashing condition is reached in these tests.

I_1 is the first suitable current, I_2 is the splashing current.

The lower limit of the acceptable welding current range, I_{min}, is determined with greater accuracy by decreasing I_1 in 100 A steps until unacceptable welds are produced.

The upper limit of the acceptable welding current range, I_{max}, is also determined more accurately by decreasing I_2 with 100 A steps until no splashing occurs.

10 Estimation of electrode lifetime *N*

10.1 Essentials of the test

The welding current shall be set just below the splashing limit and the other parameters shall be set as defined in 8.2. The test requires the making spot welds on sheets of the material being assessed, using new electrodes conditioned as described in 8.2. Test strips for mechanical characterization of the results shall be made every 200 (or 100 or 50) welds, and segregated as soon as the diameter of one weld falls below the minimum limit, the test is completed.

Tests using current stepping programmes may be specified and the details of which shall be recorded. If $400 \leq N \leq 600$, the test shall be repeated with control strips taken every 100 spot welds.

If $N < 400$ the test shall be repeated with control strips taken every 50 spot welds.

The test is stopped at the operator's initiative who shall record the reason for stopping in the test report (e.g. unattainable current requirement, number of spots per increment too small, unacceptable visual appearance according to EN ISO 6520-2).

10.2 Adjustment of machine settings

After conditioning the electrodes according to the procedures outlined in 8.2, the upper limit shall be sought according to the procedures outlined in clause 8, a single spot being carried out for each welding current level.

10.3 Procedure

Spot welds should be produced on the sheets and, every 200 spot welds (or 100 or 50), 10 spot welds shall be produced on a separate test strip, with the following additional settings according to Table 3:

Table 3 — Additional settings for spot weld production

Conditions	A	B
Thickness of sheets	0,8 mm	2,0 mm
Welding rate	30 spots/min	15 spots/min
Min. weld pitch on sheet	12 mm ± 1 mm	16 mm ± 2 mm
Test weld pitch	30 mm	30 mm
Precision of positioning weld on the test strips	± 1 mm	± 1 mm
Min. water flow rate at electrode cooling inlet	4 l/min	6 l/min
Min. water temperature electrode cooling inlet	17 °C	17 °C
Max. water temperature electrode cooling inlet [a]	25 °C	25 °C

[a] Since water temperature can significantly influence electrode life, the actual water temperature should be measured, and kept constant in any series of tests.

NOTE The dimension of the test specimens should be in accordance to Figure D.1.

10.4 Test criteria, interpretation of results

The test strip may be tested in a single operation or in two operations if necessary (in which case the strip is cut into two halves, this may be unavoidable in the case of thick sheets).

Figure D.2 gives an example of a device for simultaneously separating ten or five spot welds.

The results obtained take into account the diameters of the eight central spot welds in the case of a full strip, or the three central spot welds in the case of half a strip.

For certain applications, additional tests according to EN ISO 14271 may be specified. These supplementary results can be useful in the interpretation of results of the multi-weld tests.

11 Specific conditions for steel sheet customer qualification

11.1 Purpose

For the qualification of a new grade steel or a new coating, the customer can ask the producer to characterize the weldability of its product.

The general conditions of the method shall be applied together with the following specific conditions.

11.2 Material

Tests are carried out on sheets having a thickness which is considered representative of the end application.

— 0,8 mm ± 0,04 mm for sheets with thickness $t < 1{,}3$ mm representing the thinner sheets;

— 2 mm ± 0,1 mm for sheets with thickness $t \geq 1{,}3$ mm representing medium thickness sheets.

Other thicknesses may be specified.

11.3 Assemblies

This document is only relevant for homogeneous assemblies carried out on two sheets made of the same sheet steel product and of the same thickness.

In the case of single face coated sheets, the three coating positions shall be studied:

— external coating;

— internal coating;

— alternating coating.

11.4 Welding parameters

Welding parameters for different material specifications are specified in Table 4. The X value depending on the number of coated faces at the faying interface, is given in Table 5.

Table 4 — Welding parameters for steel sheets

Sheet thickness [a] (mm)	Electrode diameter (mm)	Electrode force (kN)		Weld time cycles [d]				Hold time cycles [d]	
				Number of pulses	Weld time [b]		Hold time	Uncoated sheet	Coated sheet
		R_m < 380 MPa	R_m ≥ 380 MPa		R_m < 380 MPa	R_m ≥ 380 MPa			
0,5	6	1,70	2,10	1	5 + X	6 + X	—	c	c
0,6	6	1,90	2,30	1	6 + X	7 + X	—	c	c
0,7	6	2,10	2,60	1	7 + X	8 + X	—	c	c
0,8	6	2,30	3,00	1	8 + X	9 + X	—	c	c
0,9	6	2,50	3,50	1	9 + X	10 + X	—	c	c
1,0	6	2,70	3,50	1	10 + X	11 + X	—	c	c
1,2	6	3,00	4,00	1	12 + X	14 + X	—	c	c
1,5	8	4,00	4,50	3	6 + X	7 + X	2	15	20
1,8	8	4,50	5,00	3	7 + X	8 + X	2	15	20
2,0	8	4,50	5,00	4	6 + X	7 + X	2	15	20
2,5	8	5,00	6,00	5	6 + X	7 + X	2	20	25
3,0	8	5,50	6,50	5	7 + X	8 + X	2	25	30

[a] When welding sheets of unequal thickness, the thinner sheet determines the weld parameters.
For mid-range thicknesses, use lower thickness parameters from x,x to x,x4 and greater thickness parameters from x,x5 to x,x9.
EXAMPLE: From 0,8 mm to 0,84 mm use parameters for 0,8 mm ; from 0,85 mm to 0,9 mm use parameters for 0,9 mm.
From 1,2 mm to 1,34 mm use parameters for 1,2 mm ; from 1,35 mm to 1,5 mm use parameters for 1,5 mm.

[b] For coated sheets, add X cycles to weld time.

[c] Hold time equals weld time.

[d] 1 cycle equals 0,02 s.

Table 5 — X value (for Table 4) depending on coating thickness and number of coated faces at the faying interface

Number of coated faces at the faying interface	1	2
thickness ≤ 10 µm	X = 1	X = 2
thickness > 10 µm	X = 2	X = 4

For other materials, the welding parameters shall be selected in accordance with ISO/DIS 14373.

11.5 Acceptance criteria

11.5.1 Type of fracture

The type of fracture defined in EN ISO 14329 shall be specified.

11.5.2 Measure criteria

The weld obtained shall have the following dimensions, measured at the plane of the joint:

Range of thickness	< 1,3 mm	≥ 1,3 mm
Sheet thickness	0,8 mm	2,0 mm
Circular weld: ∅	≥ 4 mm	≥ 6 mm
Non-circular weld:		
Average of the larger and smaller dimension	> 4 mm	> 6 mm
With smaller dimension	> 3 mm	> 5 mm

12 Test report

12.1 General

All welding currents recorded in the test report shall be corrected according to the relevant references (see 5.5.1).

In addition to the information required in 11.2 and 11.3, the test report shall include all information that facilitate interpretation, especially anomalies such as sticking of the electrodes to the sheet, etc.

12.2 Available welding current range

For each test carried out, the following information shall be recorded on a graph:

— welding current;

— diameter of the welds obtained during each test;

— splashing (if any).

The mean tensile load value for every set of test specimens shall be recorded in the table.

In addition, the report shall include all test data as specified in EN ISO 8166 and a record of the current used to produce a weld spot at the minimum current I.

An example of a typical data sheet is given in Annex E.

12.3 Electrode lifetime

The following information shall be presented on a graph:

— change in weld diameter as a function of the number of spot welds produced;

— change in weld current as a function of the number of spot welds produced;

— electrode sticking (if any).

Electrode lifetime value N obtained without the use of a current stepping procedure shall be recorded with $N + n$ value with the reason why the test was stopped.

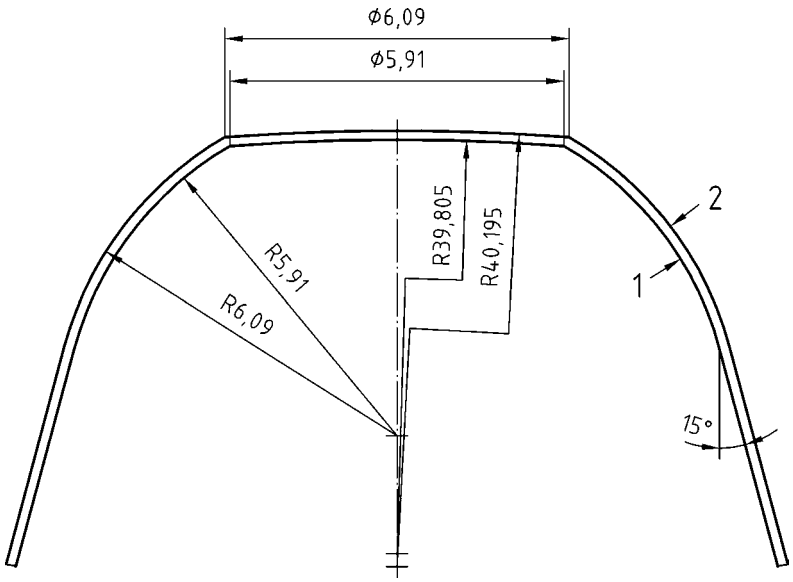
In addition, the report shall include all test data as specified in EN ISO 14327.

An example of a typical data sheet is given in Annex F.

Annex A
(normative)

Profile tolerances and control gauges for electrodes

Dimensions in millimetres

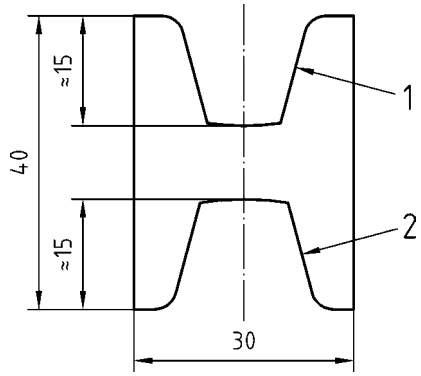


Key

1 Profile A
2 Profile B

Figure A.1 — Control gauge for electrodes used on sheet of 0,8 mm (G 16×20)

Dimensions in millimetres

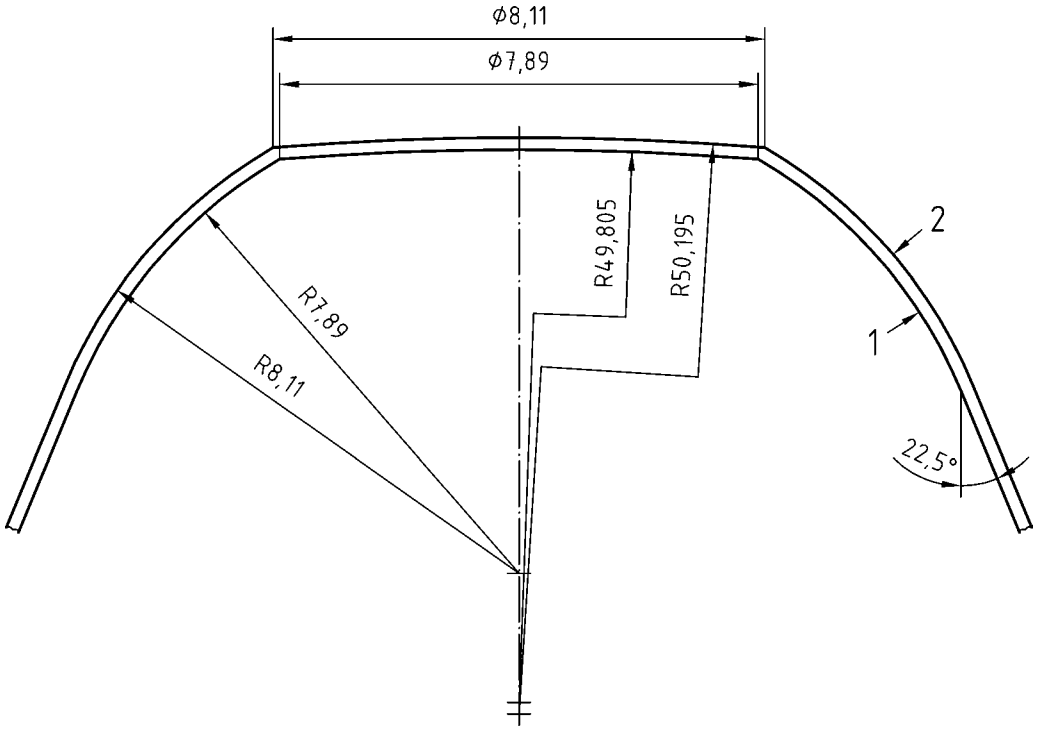


Key

1 Profile A
2 Profile B

Figure A.2 — Profile tolerances for electrodes used on sheet of 0,8 mm (G 16×20)

Dimensions in millimetres

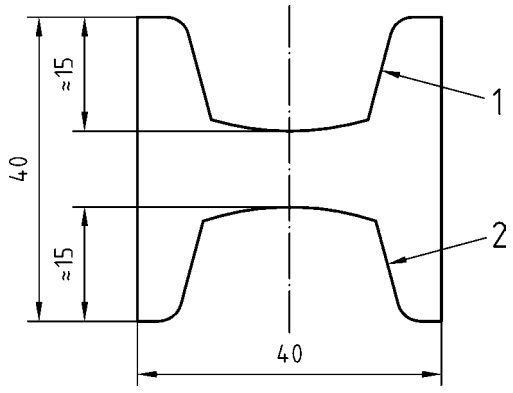


Key

1 Profile C
2 Profile D

Figure A.3 — Control gauge for electrodes used on sheet of 2,0 mm (G 20×22)

Dimensions in millimetres



Key

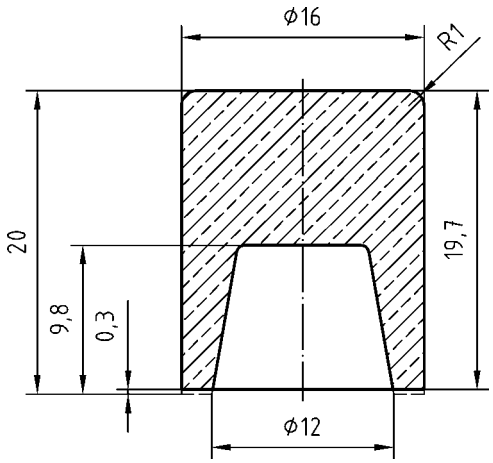
1 Profile C
2 Profile D

Figure A.4 — Profile tolerances for electrodes used on sheet of 2,0 mm (G 20×22)

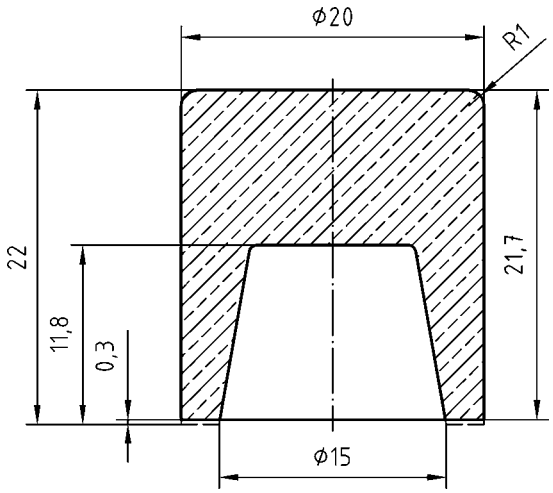
Annex B
(normative)

Electrode position check

Dimensions in millimetres

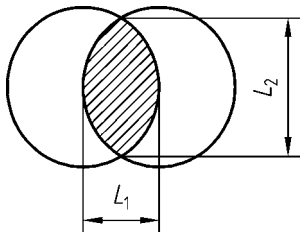


a) For test on sheet of 0,8 mm
Taper according to EN 25821

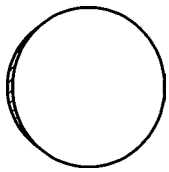


b) For test on sheet of 2 mm
Taper according to EN 25821

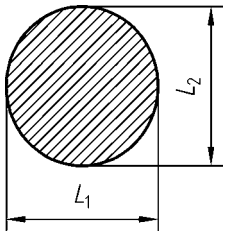
Figure B.1 — Electrode caps specific to the electrode position check



Unacceptable

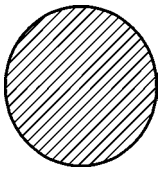


Unacceptable



Acceptable

a) Alignment L_2-L_1 ≤ 1 mm



Acceptable

b) Parallelism

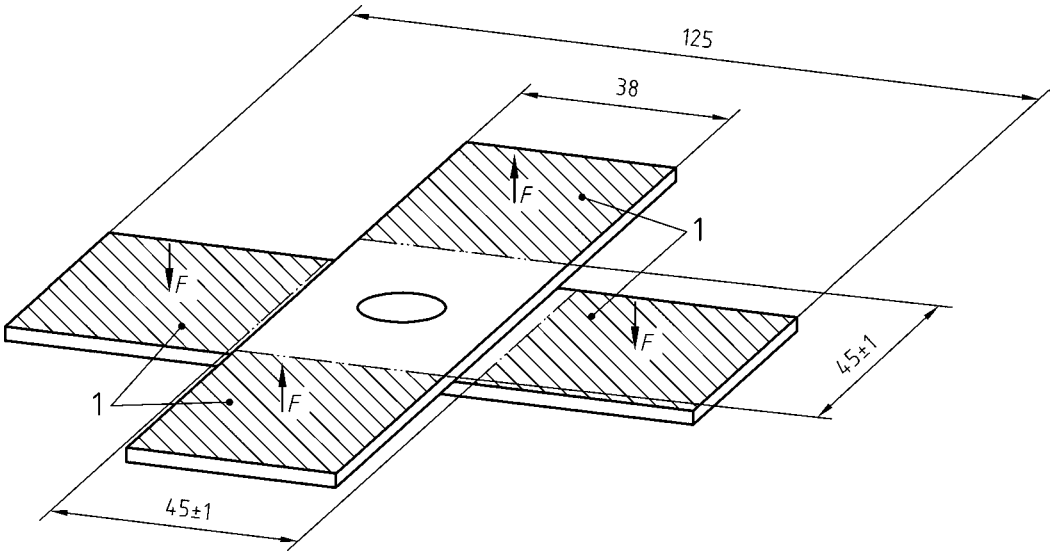
Carbon imprint on the paper

Figure B.2 — Acceptance criteria for the electrode position

Annex C
(normative)

Determination of available welding current range

Dimensions in millimetres



Key

1 For clamping

Figure C.1 — Cross tension test specimen

Dimensions in millimetres

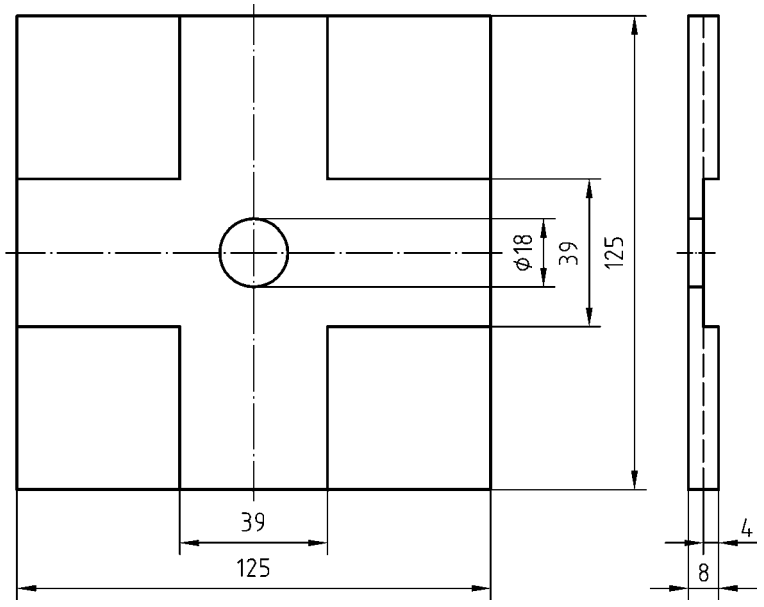
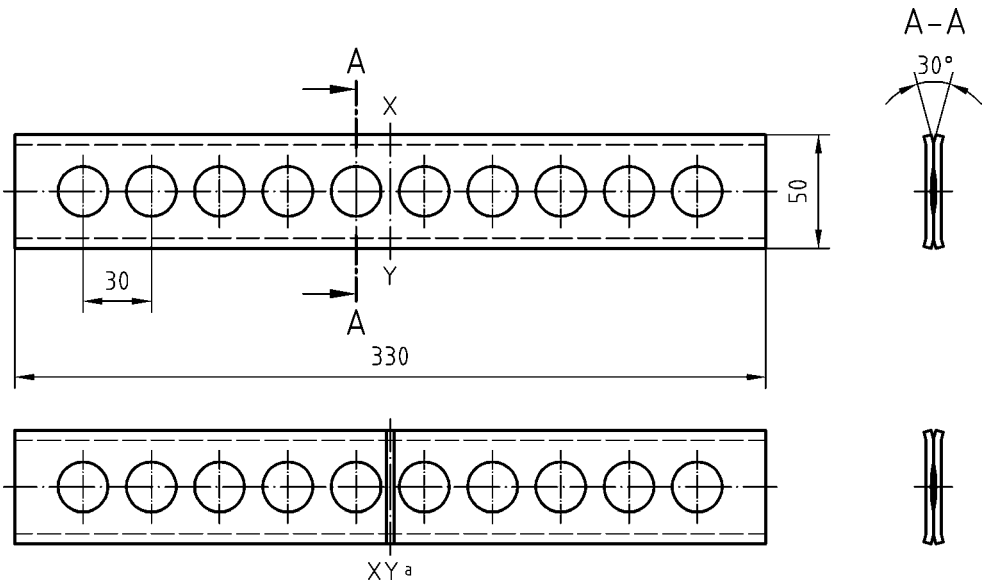


Figure C.2 — Positioning template for test specimens - Insulation material

Annex D
(informative)

Test specimens for mechanical characterisation

Dimensions in millimetres



Key

a Cut centre

Figure D.1 — Test strip

Dimensions in millimetres

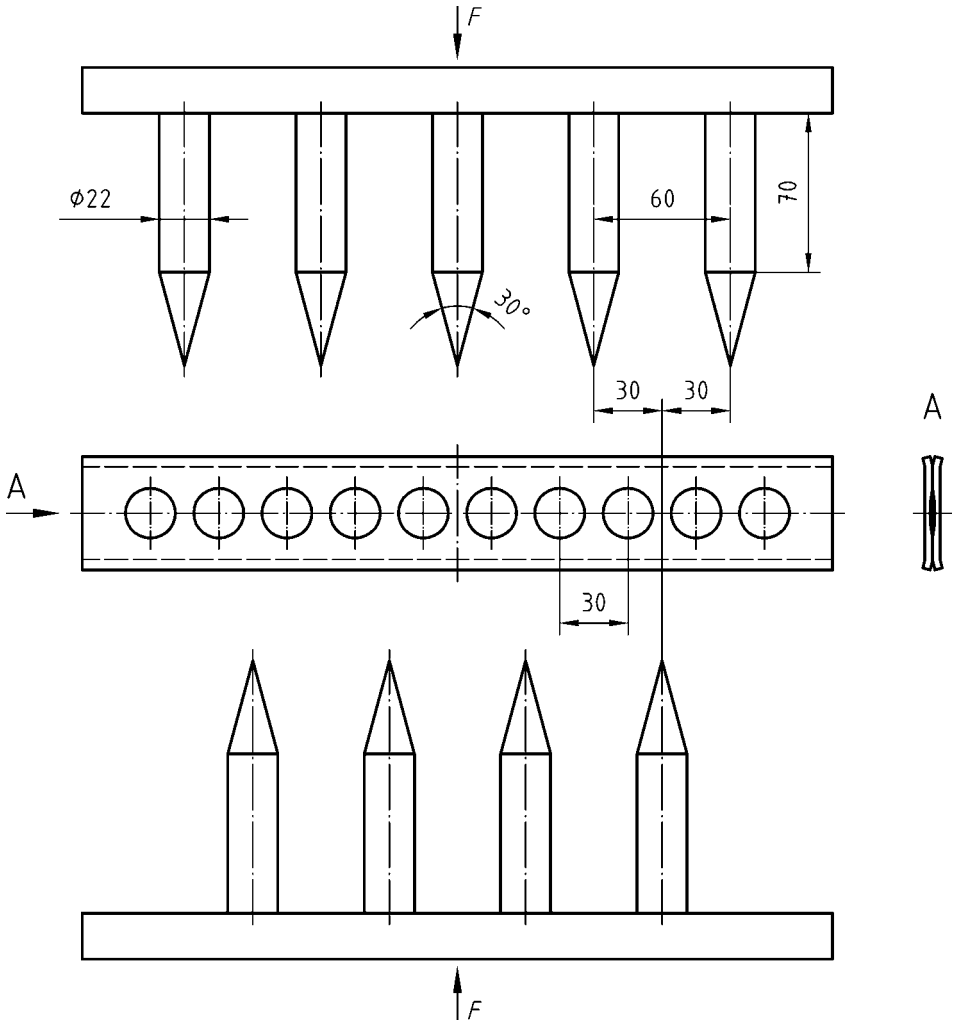


Figure D.2 — Device for simultaneous separation of 5 or 10 weld spots

Annex E
(informative)

Test sheet - Available welding current range

Available welding current range

Date :

Configuration

Coating :

: yes

Sheet : Thickness :
mm

Supplier :

Coating : (type, thickness, 1 or 2 faces)

Electrodes : ∅ : mm

Force : kN

Welding time :
periods

Holding time :
periods

Average ∅ of weld (mm)

1 mm

1000 A

Current in A

Average ∅ of weld mm	Failure force kN

+ Unacceptable spots
~ Acceptable spots

★Splashed spots
() Possible sticking electrode / sheet

Weldability
range : A
A

Tests carried out by :
Firm :

Name :
Service :
Tel. :
Visa :

Annex F
(informative)

Test sheet - Lifetime of electrodes

Lifetime of electrodes

Date :

Configuration

Coating :

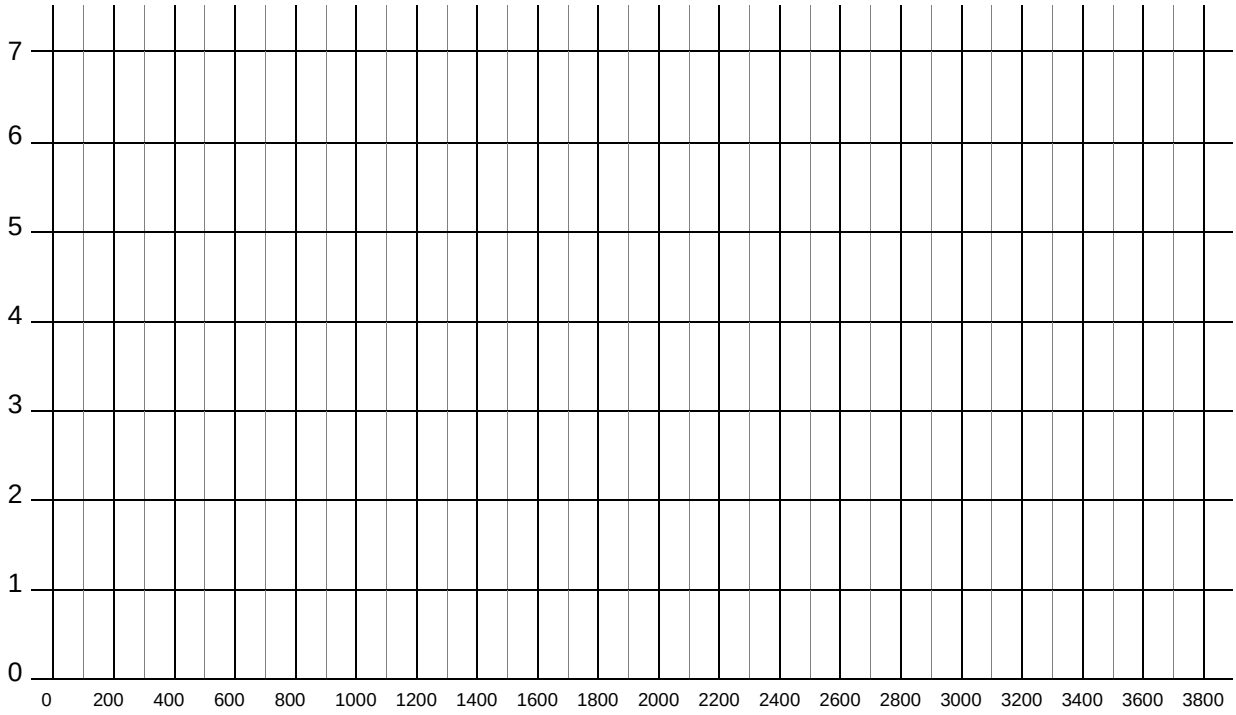
: yes

Sheet : Thickness :
mm
Supplier :
Coating : (type, thickness, 1 or 2 faces)

Electrodes : ∅ :
Force : kN
Welding time :
periods
Holding time :
periods
Welding current : I_E A

- - - Welding current (A)

Average ∅ of weld (mm)



___ Number of spots

Number of spots with constant current : N = spots
Number of spots with I_{En} : $N + n$ = spots

Possible sticking sheet/electrode
yes no
Indicate the sticking ranges on the graph (• • •)

Tests carried out by :
Firm :
Name :
Service :
Tel. :
Visa :

Bibliography

EN ISO 14271, *Vickers hardness testing of resistance spot, projection and seam welds (low load and microhardness) (ISO 14271:2000).*

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