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Resistance welding — Weldability —

Part 2: Evaluation procedures for weldability in spot welding

Soudage par résistance — Soudabilité —

Partie 2: Méthodes d'évaluation de la soudabilité par points

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ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

Contents

Page

Foreword

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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).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 44, *Welding and allied processes*, Subcommittee SC 6, *Resistance welding and allied mechanical joining*.

Requests for official interpretations of any aspect of this document should be directed to the Secretariat of ISO/TC 44/SC 6 via your national standards body. A complete listing of these bodies can be found at www.iso.org.

This second edition cancels and replaces the first edition (ISO 18278-2:2004), which has been technically revised.

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

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

— *Part 2: Evaluation procedures for weldability in spot welding*

Introduction

This document describes procedures for evaluating the resistance spot welding weldability by determining the welding current range and electrode life.

These procedures can be used to evaluate the following:

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

b) the effect of material types and thicknesses and coatings being welded;

c) the effect of welding conditions;

d) the effect of welding equipment.

Resistance welding — Weldability —

Part 2:
Evaluation procedures for weldability in spot welding

1 Scope

This part of ISO 18278 provides specific test procedures for the determination of the acceptable welding current range and the electrode life.

It is applicable for the evaluation of the weldability of assemblies of uncoated and coated sheets of individual thicknesses from 0,4 mm to 6,0 mm.

2 Normative references

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

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

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

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

ISO 10447, *Resistance welding — Testing of welds — Peel and chisel testing of resistance spot and projection welds*

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

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

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

ISO 17653, *Resistance welding — Destructive tests on welds in metallic materials — Torsion test of resistance spot welds*

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

ISO 18278-1, *Resistance welding — Weldability — Part 1: General requirements for the evaluation of weldability for resistance spot, seam and projection welding of metallic materials*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 669, ISO 14373, ISO 17677-1 and ISO 18278-1 apply.

4 Welding equipment

4.1 General

Methods to characterize resistance welding equipment can be found in ISO 669.

The mass and friction of the movable electrode assembly can be determined in accordance with ISO 18278-1.

4.2 Electrodes

The electrodes shall be of type A 2/2 material as defined in ISO 5182. Their geometry shall be defined according ISO 5821.

4.3 Welding current

The type of welding current used (AC or DC) shall be specified before testing. Constant current control settings shall be used.

When using AC resistance welding equipment, it shall be set so that welding current is not less than 30 % of R.M.S. value at full conduction angle.

4.4 Mechanical settings

The mechanical settings shall be chosen to limit the impact of the electrode meeting the sheet.

NOTE To limit the impact of the electrode an electrode approach speed of 0,15 m/s is recommended and/or the peak force should be less than 150 % of the nominal electrode force.

The machine squeeze time should be of sufficient duration to overcome electrode bounce effects and machine inertia so as to allow the electrode force to build up to the required value before the welding current is initiated.

4.5 Measurement of parameters

4.5.1 Welding current and electrode force

Measurement of welding current and electrode force requirements shall be in accordance with ISO 18278-1.

4.5.2 Electrode cooling water flow rate

Since water cooling significantly influences electrode life, the inlet water temperature should be maintained at 20 °C and shall not exceed 30 °C. A separate water supply should be used for each electrode, and the water flow rate for each electrode shall be a minimum of 4 l/min. The water cooling tube should be arranged to ensure that the water directly cools the electrode.

Dimensions of the water cooling holes and pipes shall comply with the relevant requirements of the appropriate ISO Standard for various electrode types. The distance between the back and working face of the electrode should not exceed the values given in ISO 5821 which specifies electrode dimensions.

Any deviations shall be recorded.

All machine and water cooling details shall be recorded in the format presented in Clause 8.

4.6 Measurement of results

4.6.1 Weld diameter

After the destructive testing, the weld diameter shall be measured, see ISO 17677-1.

4.6.2 Detection of expulsion

Occurrence of expulsion shall be determined visually, by the electrode displacement curve, by the welding voltage signal or by the electrode force signal. For steel sheets, an expulsion is characterized by a very sharp deviation in the trace of an electrode displacement or welding voltage signal.

5 Preliminary adjustments

5.1 Electrode alignment

Electrode alignment shall be checked. This may be accomplished by the methods suggested in Annex A.

Eccentricity (see ISO 669) should be less than 0,5 mm. This may be checked using the carbon imprint method where a sheet of paper is sandwiched between two carbon papers inserted between the two caps after which the electrode force is applied. Examples of carbon imprints obtained on the paper sheet after application of pressure are shown in Figure A.1.

Angular deflection (see ISO 669) should not exceed 5°. A method using a tube is described in Figure A.2.

5.2 Electrode conditioning

Electrodes shall not be conditioned.

6 Determination of the welding current range

6.1 Test specimens

Test specimens shall be single spot specimens, and their geometry shall be defined for a given welding current range test. Recommended geometries are those defined in ISO standards, especially cross-tension specimens (ISO 14272), tensile-shear specimens (ISO 14273), torsion specimens (ISO 17653), mechanized peel specimens (ISO 14270).

In the case of chisel/peel test (ISO 10447), the specimen shall have a minimum size of 40 mm × 40 mm with at least 35 mm overlap.

NOTE It is easier to accurately measure weld diameters after cross-tension, peel and chisel tests.

6.2 Welding parameters

Appropriate welding parameters shall be specified in the instructions or in the test order form. Proposed sets of welding parameters for steel assemblies are given in Annex B.

6.3 Test procedure

Starting with a level sufficiently low to be under any welding or even bonding condition, the welding current is increased in 200 A steps, and never decreased. Three test specimens shall be prepared and welded for each current setting, two will be used for destructive testing and the third will be kept in reserve, for example for metallographic analysis.

When splashing occurs, the test shall be continued until the welding current reaches 10 % above the current after splashing first occurred.

Destructive testing and measurement of the weld diameter shall be performed according to 4.6.1 and the information supplied in 6.1.

In case of instrumented mechanical testing of the welds, it shall be performed at least 10 hours after welding.

6.4 Current range criteria

The minimum weld diameter shall be specified in the instructions.

NOTE This minimum weld diameter can be equal to $3{,}5\sqrt{t}$, t being the thickness of the thinnest sheet of the assembly.

The upper end of the welding current range I_{max} is defined as the maximum current setting for which at least two out of three spot welds show no splash, and all current settings below satisfy the same condition.

The lower end of the welding current range I_{min} is defined as the minimum current setting for which both spot weld specimens which are destructively tested will have a diameter equal or greater than the defined minimum, and all current settings above until I_{max} satisfy the same condition.

6.5 Three sheet and multiple stack-ups

In such cases, each interface shall be considered individually. Therefore, the shape and number of test specimens shall be adapted to test each interface separately (i.e. in the case of instrumented testing, two specimens per interface and one in reserve for metallographic analysis).

The minimum weld diameters shall be defined for each interface of the stack-up, and the lower end of the welding current range is defined when every interface reaches its own minimum weld diameter condition.

The upper end of the welding current range is defined when every interface matches the no-splashing condition.

7 Estimation of electrode life

7.1 Test specimens

Two types of specimens are to be welded during this test:

a) welding sheets (e.g. dimensions 300 mm × 400 mm) used to wear the electrodes through continuous spot welding;

b) test strips for test welds. The size of these strips can be chosen depending on the means used for destructive testing, however, the overlap shall be at least 40 mm × 300 mm. Annex C gives examples of a test strip and a device for simultaneously separating 10 spot welds.

NOTE Single or double spot coupons can be specified by the contracting parties instead of test strips but the results may change.

7.2 Welding parameters

The welding current shall be set at I_{max} as determined during a welding current range test on the same stack-up, the other parameters being defined in the instructions or in the test order form. New electrodes shall be installed before for this test.

NOTE Proposed sets of welding parameters for steel stack-ups are given in Annex B.

7.3 Procedure

The test sequence is as follows.

a) First test strip: 10 welds.

   If splashing occurs on three consecutive welds, the testing current shall be reduced by 100 A. If splashing still occurs on the three next welds then the test shall be restarted at I_{max} minus 200 A.

b) 40 welds continuously on welding sheets.

c) 10 welds on subsequent test strips.

d) 40 welds continuously on welding sheets.

e) Repeat c) and d) until 400 welds.

f) 10 welds on a test strip.

g) 90 welds continuously on welding sheets.

h) Repeat f) and g) until ending conditions are reached.

The testing procedure shall be performed in a continuous mode, ideally in the same day.

For b), d) and g) a welding rate of 30 spots per minute is recommended for thin sheet material, see Table B.1 for details in the case of steel sheets.

The test settings are given in Table 1.

Table 1 — Settings for spot weld production

Weld pitch	30 mm
Edge distance	15 mm
Precision of weld positioning on the test strips	±5 mm

After welding, each test strip shall be tested destructively, and the weld diameters of the eight central spots shall be measured. The test shall be continued until at least four spots out of eight show a no-weld condition (weld diameter equal to zero). Other ending conditions may be defined.

The test shall be performed without tip dressing and current stepping control.

7.4 Test criteria, interpretation of results

Electrode life is defined as the last weld number of a test strip before reaching more than two welds out of eight below a minimum weld diameter defined by the contracting parties.

The electrode wear can be evaluated by

— the overall reduction in length of the electrodes, which can also be followed in-line by using displacement sensors,

— tip profile and diameter through carbon imprints or by using optical devices,

— the change of mass in the electrode.

NOTE This minimum weld diameter can be equal to $3{,}5\sqrt{t}$, t being the thickness of the thinnest sheet of the assembly.

8 Test report

8.1 General

The test report shall include data about stack up being welded (e.g. sheet thicknesses, materials, coatings) and welding parameters (e.g. machine type, machine reference, current type (AC or DC), electrode type, electrode force, welding cycle, inlet cooling water temperature and flow rate). See ISO 15609-5 for further details.

The test report shall also include all information that facilitates interpretation, especially anomalies such as sticking of the electrodes to the sheet, etc.

8.2 Welding current range

The test report shall include the minimum and maximum welding currents, defining the welding current range.

In addition, for each individual spot weld, the following information shall be recorded:

— welding current;

— diameter of the weld and failure type obtained as defined in ISO 17677-1;

— maximum load in case of instrumented mechanical testing;

— splashing and electrode sticking (if any);

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

8.3 Electrode life

The test report shall include the electrode life obtained and the welding current used for the test.

In addition, the following information shall be recorded:

— individual weld diameter as a function of the number of spot welds on test strips;

— splashing and electrode sticking (if any);

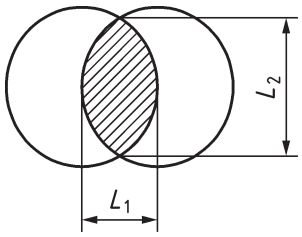
— change in weld current during the test (if applied).

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

Annex A
(informative)

Electrode alignment

There are many methods to check the position of electrodes. Annex A shows two possibilities (see Figure A.1 and Figure A.2).



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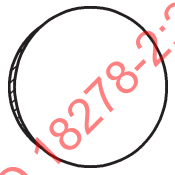

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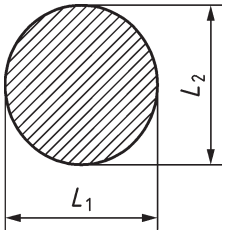
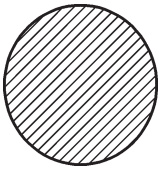


Acceptable



Acceptable

a) Alignment $L_2 - L_1 \leq 1$ mm

b) Parallelism

Key

Carbon imprint on paper

The use of type C0 electrode caps (see ISO 5821) is recommended.

Figure A.1 — Acceptance criteria for the electrode alignment

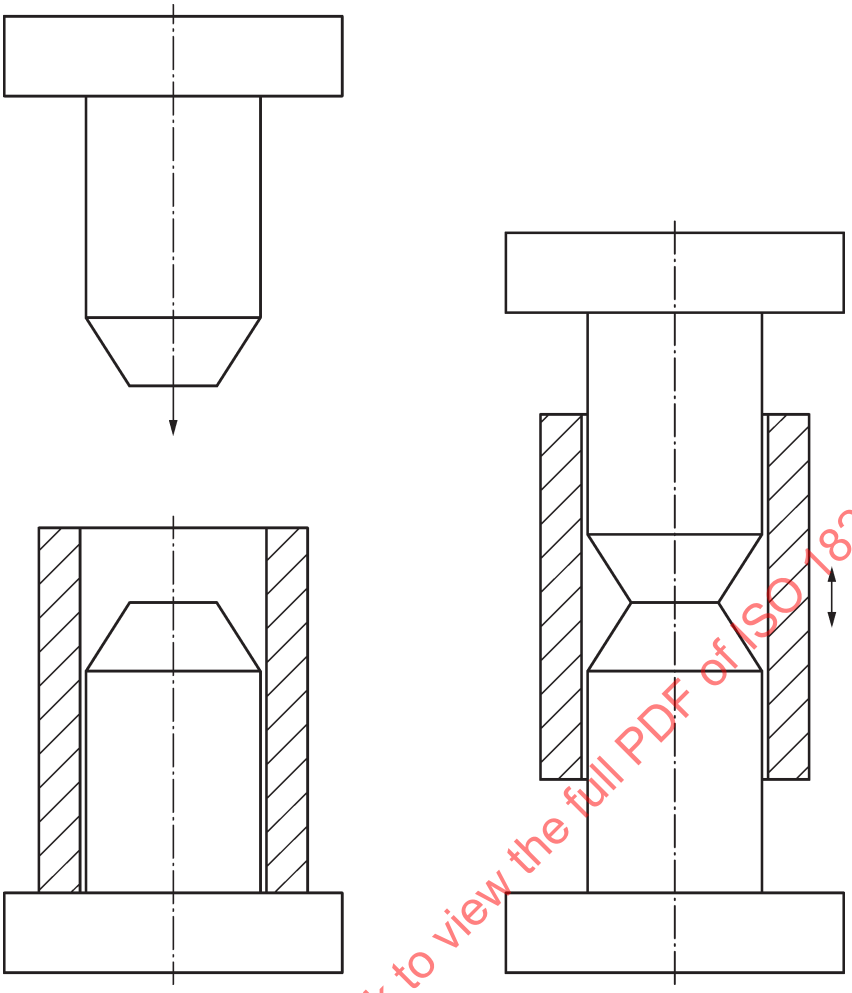


Figure A.2 — Tube method

Annex B
(informative)

Specific conditions for steel sheet customer qualification

B.1 Purpose

For the qualification of a new grade of steel or a new coating, the customer can ask the producer to characterize the weldability of its product. The general conditions of the method can be applied together with the following specific conditions.

B.2 Single-side coatings

In the case of single-side coated sheets, the coating position in the stack up should be reported (external coating; internal coating; alternating coating).

B.3 Welding parameters

Welding parameters for different steel sheet configurations are specified in Table B.1. Table B.2 gives maximum electrode diameter, electrode force, welding time and hold time which can be used for high strength steels (UTS ≥ 650 MPa) if nominal parameters from Table B.1 give unsatisfactory results..

B.4 Minimum weld diameter

The minimum weld diameter is used to evaluate the lower end of the welding range and the end of electrode life. It can be defined as

$$x * \sqrt{t}$$

where

t is the thinner sheet thickness;

x is a coefficient to be defined (usually between 3 and 4,5).

Table B.1 — Welding parameters for steel sheets

Sheet thickness[a] mm	**Electrode type acc.** ISO 5821 mm	**Electrode force**[c] kN		**Weld time** ms				**Hold time** ms	**Welding rate for electrode life test** welds per min
				Number of impulses	**Individual weld time**[b,c]		**Cool time**		
		UTS < 380 MPa	UTS ≥ 380 MPa		UTS < 380 MPa	UTS ≥ 380 MPa			
0,50 to 0,54	F1 – 16 – 20 – 50 – 6	1,70	2,10	1	100 + X	120 + X	—	**120**	30
0,55 to 0,64	F1 – 16 – 20 – 50 – 6	1,90	2,30	1	120 + X	140 + X	—	**120**	30
0,65 to 0,74	F1 – 16 – 20 – 50 – 6	2,10	2,60	1	140 + X	160 + X	—	**140**	30
0,75 to 0,84	F1 – 16 – 20 – 50 – 6	2,30	3,00	1	160 + X	180 + X	—	**140**	30
0,85 to 0,94	F1 – 16 – 20 – 50 – 6	2,50	3,50	1	180 + X	200 + X	—	**160**	30
0,95 to 1,09	F1 – 16 – 20 – 50 – 6	2,70	3,50	1	200 + X	220 + X	—	**180**	30
1,10 to 1,34	F1 – 16 – 20 – 50 – 6	3,00	4,00	1	240 + X	280 + X	—	**200**	30
1,35 to 1,64	F1 – 16 – 20 – 50 – 6	4,00	4,50	1	300 + X	340 + X	—	**260**	30
1,65 to 1,89	F1 – 20 – 22 – 50 – 8	4,50	5,00	3	140 + X	160 + X	40	**320**	20
1,90 to 2,24	F1 – 20 – 22 – 50 – 8	4,50	5,00	4	120 + X	140 + X	40	**360**	20
2,25 to 2,74	F1 – 20 – 22 – 50 – 8	5,00	6,00	5	120 + X	140 + X	40	**460**	20
2,75 to 3,00	F1 – 20 – 22 – 50 – 8	5,50	6,50	5	140 + X	160 + X	40	**520**	20

NOTE The table is compiled using 50 Hz.

[a] When welding two sheets of unequal thickness, the thinner sheet determines the welding parameters. When welding a three sheets stack-up, the thinner of the two thicker sheets determines the welding parameters.

[b] Add X = 40 ms to the individual weld time when at least one coating is present at one faying interface of the assembly.

[c] When sheets with differing UTS are welded together, choose the highest UTS of the assembly to set weld time and electrode force.

Table B.2 — Optional maximum welding parameters for advanced high strength steel sheets (UTS ≥ 650 MPa)

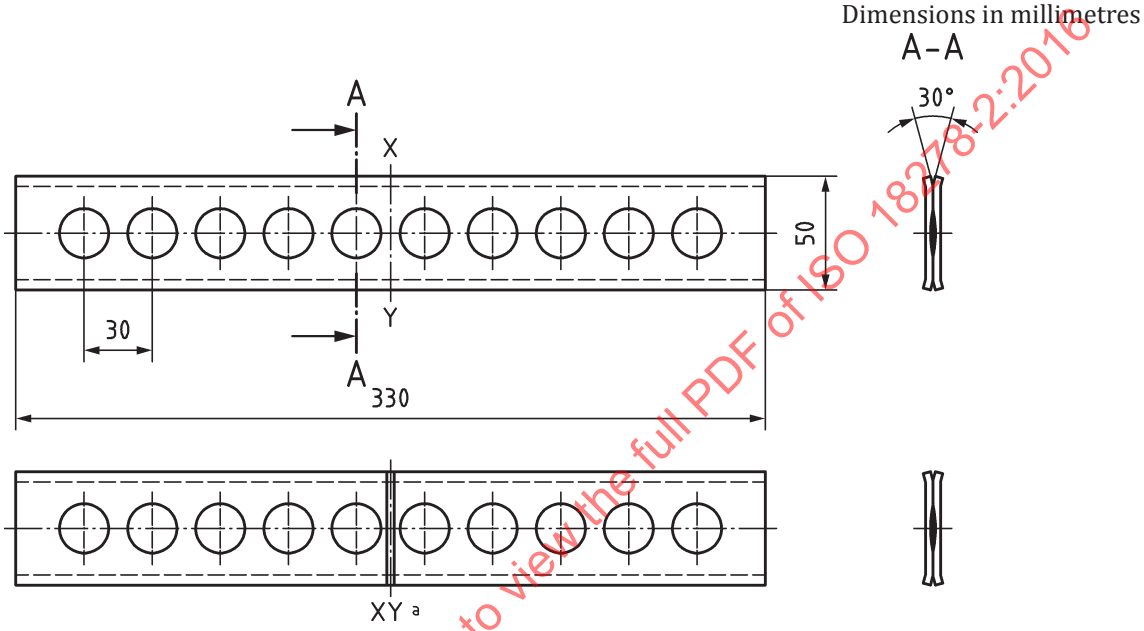
Sheet thickness mm	**Maximum electrode face diameter** mm	**Maximum electrode force** kN	**Maximum weld time** ms	**Maximum hold time** ms
0,50 to 0,54	6	2,10	240	240
0,55 to 0,64	6	2,30	240	240
0,65 to 0,74	6	2,60	320	320
0,75 to 0,84	6	3,00	320	320
0,85 to 0,94	6	3,80	320	320
0,95 to 1,09	6	4,00	400	400
1,10 to 1,34	6	4,50	500	500
1,35 to 1,64	8	5,50	800	500
1,65 to 1,89	8	6,00	900	500
1,90 to 2,24	8	6,50	1100	500
2,25 to 2,74	10	7,00	1200	600
2,75 to 3,00	10	7,50	1400	700
These parameters are the maximum values that may be used in case of unsatisfactory results obtained for standard parameters given in Table B1.				

Annex C
(informative)

Test specimens for mechanical characterization

See Figures C.1 and C.2.

Dimensions in millimetres



Key

a Cut centre.

Figure C.1 — Example of test strip

Dimensions in millimetres

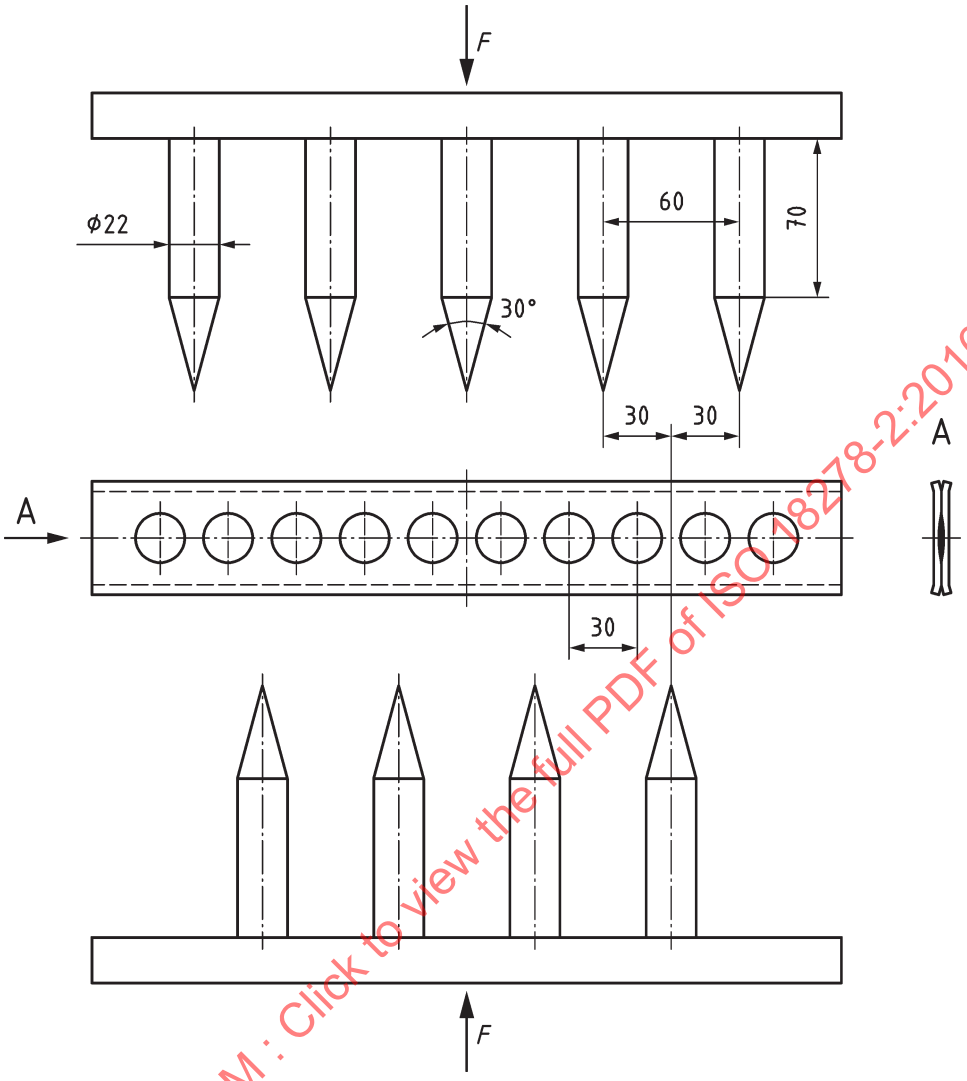


Figure C.2 — Example of device for simultaneous separation of 5 or 10 weld spots