INTERNATIONAL STANDARD

ISO 14327

First edition
2004-04-01

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

Soudage par résistance — Modes opératoires pour la détermination du domaine de soudabilité pour le soudage par résistance par points, par bossages et à la molette

Reference number
ISO 14327:2004(E)

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Published in Switzerland

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 14327 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...".

Contents

Foreword

This document (EN ISO 14327:2004) 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of an identical text or by endorsement, at the latest by October 2004, and conflicting national standards shall be withdrawn at the latest by October 2004.

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 European Standard enables the weldability lobe to be determined for resistance spot, projection and seam welding. This standard does not invalidate procedures for the determination of the weldability lobe or their approval documents in current use which complied with the national or International Standards or regulations existing at that time, provided the intent of the technical requirement is satisfied and the specified application, its performance and equipment with which it is performed remain unchanged.

When this standard is referenced for contractual purposes, all questions relating to the specification and implementation of welding procedures should be agreed between the contacting parties at the time of enquiry or at the contract stage.

It has been assumed in this standard that the execution of its provisions is entrusted to appropriately trained, skilled and experienced personnel.

For the quality of welded structures the relevant part of EN ISO 14554 should be applicable. The specification of procedures should follow guidelines as in EN ISO 15609-5.

1 Scope

This European Standard specifies procedures for determining the weldability lobe for producing quality welds. The tests are used in particular to determine the weldability lobe for coated/uncoated steels, stainless steels and aluminium and its alloys but may also be used for other metallic materials.

The aim of this procedure is to allow determination of the range of welding parameters which give rise to an acceptable weld quality as defined within precise limits. The procedure can be used to determine:

a) The influence of electrode material, electrode shape and dimensions on the available welding range for a particular material and welding machine.

b) The influence of material type and thickness on the available welding range when using a particular combination of welding electrodes and welding machine.

c) The influence of welding machine type, or electrode cooling on the available welding range for a particular material using a particular electrode shape.

d) The available welding range in a production situation.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

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 15609-5:2004, *Specification and qualification of welding procedures for metallic materials — Welding procedure specification — Part 5: Resistance welding (ISO 15609-5:2004).*

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

ISO 693, *Dimensions of seam welding wheel blanks.*

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

EN 25184, *Straight resistance spot welding electrodes (ISO 5184:1979).*

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

ISO 5830, *Resistance spot welding — Male electrode caps.*

EN 28167, *Projections for resistance welding (ISO 8167:1989).*

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

3 Terms and definitions

For the purposes of this European Standard, the terms and definitions given in ISO 669:2000 and EN ISO 14329:2003, and the following apply.

NOTE Further definitions are given in ISO/DIS 17657-1 (see Bibliography)

weldability lobe
welding current domain allowing the production without splash of spot welds of a diameter equal or more than a pre-determined value under either constant welding time or constant electrode force

4 Weldability lobe limits

The weldability lobe will define the available welding conditions in terms of:

a) Weld current and time at a constant electrode force. Or:

b) Weld current and electrode force at a constant weld time.

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

To meet these requirements, the weldability lobes can be a two dimensional plot as indicated in a) and b) above 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.

For the purpose of this standard, the lower and upper limits of the weldability lobe should be as follows:

1) Lower limit – This equates to the welding conditions which result in a weld diameter equal to 3,5 $\sqrt{t}$ where t equal sheet thickness in mm. In the case of two dissimilar thicknesses, "t" refers to the thinner sheet.

NOTE 1 A limit other than 3,5 $\sqrt{t}$ may be acceptable by agreement between contracting parties provided the strength of the weld or welded assembly satisfy the necessary design requirements.

NOTE 2 Guidelines for measuring weld diameter for both plug and interface failure are given in EN ISO 14329. The weld diameter should be measured from a broken specimen, e. g. peel test.

NOTE 3 In 3 or 4 thickness welding the minimum of the diameter specified will depend on the position of the thinner sheets from design process requirements.

2) Upper limit – This corresponds to the welding conditions which give rise to interfacial splash in the case of spot and projection welding. In seam welding the limit corresponds to surface splash or surface cracking in the weld or heat-affected zone areas.

NOTE 4 Alternative criteria may be specified, such as the minimum value of the shear force that the weld can withstand based on recommendations made in ISO or product standards in the case of coated/uncoated steels. Minimum surface indentation or the amount of weld nugget penetration can be specified by agreement.

In the case of resistance seam welding, other intermediate limits may be chosen based on alternative weld sizes or the onset of surface cracking. The use of such limits depend on the application being welded and should be by agreement between contracting parties.

Typical weldability lobes are shown in Figure 1.

5 Test equipment

5.1 Welding electrodes

5.1.1 General

The welding electrodes shall conform to alloys 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.

5.1.2 Spot welding

In the case of spot welding, the electrode dimensions shall conform to the requirements of ISO 5184, ISO 5821 and ISO 5830 where applicable. Alternative electrode shapes and dimensions may be used by agreement between contracting parties. Pre-conditioned electrodes should be used for each individual weldability lobe determined. Electrodes shall be pre-conditioned as summarised below. Where appropriate, dimensions of the water cooling holes and pipes shall comply with the relevant requirements of the appropriate ISO standard.

NOTE It is recommended that the water flow should be a minimum of 4 l/min per electrode although, higher flow rates are recommended when welding coated steels. The water cooling feed tube should be arranged to impinge the water onto the back face of the electrode. The distance between the back and the working face of the electrode should not exceed the values given in the appropriate ISO standard. Separate water supplies should be used for top and bottom electrodes and should be independent of other cooling circuits. It is recommended that the inlet water temperature should not exceed 20 °C (293 K) and the outlet temperature should not exceed 30 °C (303 K) (except when water cooling temperature is the parameter being studied). Higher inlet/outlet water temperatures can be used by agreement between contracting parties.

Both top and bottom electrodes shall be properly aligned prior to commencement of the test. The electrode face of the top and bottom electrodes should be parallel to each other and have an electrode diameter that is within the specified tolerances of the diameter called for any given sheet thickness or that agreed between the contracting parties. Alignment of electrodes should be checked using carbon imprints.

When welding uncoated/coated steels and stainless steels, the welding electrodes should be pre-conditioned for 50 welds prior to determining the weldability lobe. Pre-conditioning should be carried out at a nominal weld time of approximately e. g. 8 cycles at 50 Hz on uncoated sheets in the same material and with the same thickness. For pre-conditioning a welding current equal to that which gives a stuck weld condition or a weld of diameter equal to $3\sqrt{t}$ should be used. When welding aluminium and aluminium alloys, pre-conditioning of electrodes should not be carried out.

5.1.3 Seam welding

In the case of wide wheel seam welding, the electrode face dimensions shall conform with the requirements of ISO 693 and follow similar criteria as used for spot welding, i.e. tread width equal $5\sqrt{t}$. However, for thin wheel seam welding, alternative electrode dimensions, i. e. electrode thickness and face dimensions, may be used by agreement between contracting parties. The welding wheels should be pre-conditioned by producing 10 rotations of weld wheel at a welding current which gives a stuck weld condition.

5.1.4 Projection welding

Similar criteria may be used for the lobe limits when projection welding. In this case, projection dimensions shall conform to the requirements of ISO 8167.

5.2 Welding machine

The need to specify machine details depends on:

a) Whether the lobe is being determined to assess the weldability of a metallic material or to determine the available welding range for a particular electrode type, shape design and/or material.

b) Whether the weldability lobe is to determine production conditions using a particular machine.

Both the static and dynamic mechanical characteristics should be determined in accordance with the requirements of ISO 669. Machine characteristics shall be specified in accordance with the requirements of ISO 669.

NOTE 1 If electrode force values are used which are near the lower end of the available force range of the machine, 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 important. Similar considerations apply at extremely high values of electrode force.

NOTE 2 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 100 % of the nominal value before the welding current is initiated.

6 Welding procedure

6.1 Spot or projection welding

6.1.1 General

In producing a weldability lobe, see Figure 1, electrode wear/contamination can occur due to heavy splash, mushrooming or alloying. This can have an adverse affect on the reproducibility and validity of the results, particularly when welding coated steels or aluminium and aluminium alloys. To overcome this, the following welding sequence shall be used.

6.1.2 Weldability lobe at constant electrode force

The weldability lobe is constructed from a series of a weld growth curves at constant force (see Figure 1a)) and shall be produced at a predetermined value of electrode force, and the specified limits are determined by varying weld current and weld time. 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°.

At the minimum weld time, e. g. 5 cycles when welding uncoated/coated steels, the welding current is increased progressively in order to determine the stuck weld condition or $3,5\sqrt{t}$ limit, a nominal weld diameter (e.g. weld diameter equal to $5\sqrt{t}$) and the splash limit. The minimum welding time may be lower than 5 cycles depending on the material being welded, e. g. 3 cycles in the case of aluminium alloys. The weld time is increased sequentially, at intervals depending on the purpose of the test and the application being welded, determining the stuck weld condition, nominal weld diameter condition and the splash limits at each weld time.

When welding aluminium, aluminium alloys or material with extremely poor electrode live, e. g. zinc coated and zinc aluminium alloys steels, the electrodes should be replaced at the end of each weld growth curve.

The procedure to determine the weldability lobe and the weldability range at constant electrode force has the following steps:

a) Start with welding data from standards e. g. ISO/DIS 14373, WPS, recommendation or pre-tests e.g. depending of the planned work, see annex A in EN ISO 15609-5:2004.

b) Check and optimize data.

c) Develop the growth diagram with weld growth curve by tests. Figure 2a) with the principle description of the diagram and one weld growth curve is referred to one selected weld time t_1. The tests shall be repeated by varied weld times t_1 to t_4, see Figure 2b). The characterisation of the failure type gives information of the quality of the welding process and the weld.

d) Develop with the data of the cross-points for fusion defects, minimal weld diameter, $5\sqrt{t}$ weld diameter, the diameter of the splash limit and the failure types the weldability lobe at constant electrode force, see Figure 2c).

e) Choose the welding current range (WCR) for your work (wide range: good presumption for a controlled process), use annex B and annex C in EN ISO 15609-5:2004.

6.1.3 Weldability lobe at constant time

The weldability lobe is constructed from a series of growth curves at constant time (see Figure 1b)) and shall be produced at a predetermined weld time, for example 10 cycles, and the specified lobe limits are determined by varying weld current and electrode force.

Using the value of electrode force generally recommended for the sheet thickness being welded, the weld current is increased progressively to determine the stuck weld condition or $3,5\sqrt{t}$ limit, the nominal weld diameter condition and the splash limit. This procedure is then repeated at values of electrode force determined by production, equipment constraints and the surface requirements of the end application.

When welding aluminium or aluminium alloys, the electrodes should be replaced at the end of each weld growth curve.

The procedure to determine the weldability lobe and the weldability range at constant weld time has the following steps:

a) Start with welding data from standards e. g. ISO/DIS 14373, WPS, recommendation or pre-tests e.g. depending of the planned work, see annex A in EN ISO 15609-5:2004.

b) Check and optimize data.

c) Develop weld growth diagram by tests. Figure 2d) with the principle of the diagram and one weld growth curve is referred at constant time and one selected electrode force F_1. The tests shall be repeated by varied electrode forces F_1 to F_4, see Figure 2e). The characterisation of the failure type gives information of the quality of the welding process and the weld.

d) Develop with the data of the cross-points for fusion defects, minimal weld diameter, $5\sqrt{t}$ weld diameter, the diameter of the splash limit and the failure types the weldability lobe at weld time, see Figure 2f).

e) Choose the welding current range (WCR) for your work (wide range: good presumption for a controlled process), use annex B and annex C in EN ISO 15609-5:2004.

6.2 Seam welding

In the case of seam welding, the weldability lobe defines the available welding conditions in terms of the available welding current range plotted against welding speed. A typical example is shown in Figure 1c). In this case, the following shall be kept constant:

— electrode force;

— current programme.

To determine the various limits, the predetermined values of electrode force and welding speed are first set, and the welding current is increased progressively in regular steps between the stuck and splash/cracking conditions. This procedure shall be repeated at other selected welding speeds appropriate to the application being welded. The maximum welding speed occurs when there is no current range between weld formation and weld splash.

7 Statistical evaluation of test results

The weldability lobe shall be constructed from a minimum 4 weld growth curves (see Figure 2) made at 4 specified weld times or electrode force levels. A statistical estimate of the weld growth curve should then be obtained by a regression analysis based on the pooled results of the five individual growth curves. However, any lateral shift between individual growth curves can result in a mean slope which will not follow the true gradient indicated by the individual growth curves. Consequently, each growth curve should be analysed separately and a regression analysis, based on the slope of the line values should then be carried out rather than on individual points. Stuck and splash welds shall not be included in this regression analysis. However, these points should be included in all plotted weld growth curves.

8 Report of test results

The test report shall contain at least the following and be based on the format given in EN ISO 15609-5:

a) welding procedure number;

b) related specification and/or drawing number;

c) material to be welded: specification number or composition; type and thickness of material; type and thickness of coating, if applicable;

d) metallurgical condition of material;

e) welding equipment;

f) top electrode particulars:

- type and initial tip size;
- permissible increase of tip diameter before replacement;
- water inlet / water outlet temperature and water flow;

g) bottom electrode particulars:

- type and initial tip size;
- permissible increase of tip diameter before replacement;
- water inlet / water outlet temperature and water flow;

h) method of cleaning material, if applicable;

i) set-up of joints;

j) sequence of welding;

k) particulars of welding conditions or machine settings:

- transformer tap setting;
- heat control setting (percentage heat);
- electrode force;
- pressure gauge setting;

— squeeze time;

— weld time;

— hold time;

— off time;

— throat depth;

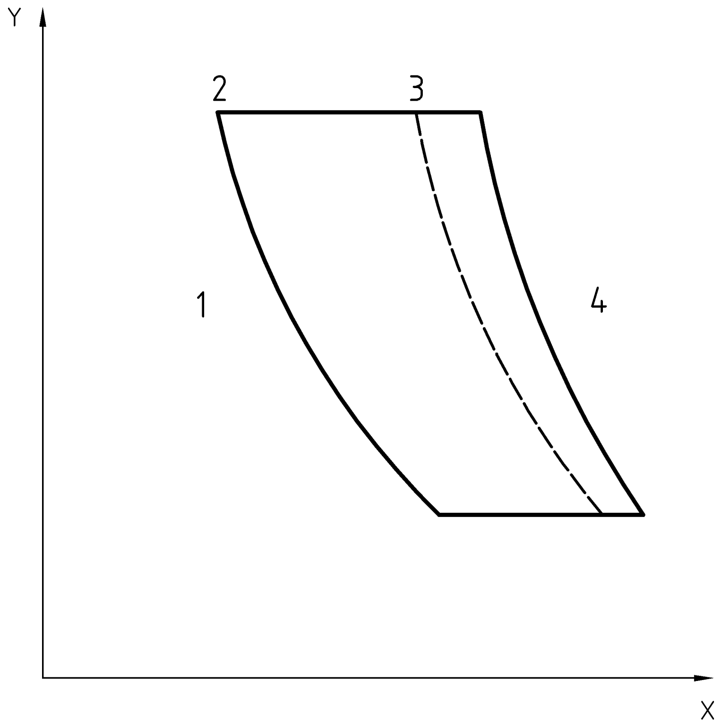
— distance between electrodes;

— distance between arms;

— type of current;

— type of current polarity;

l) routine for making test welds.



Key

Y Weld time

X Weld current

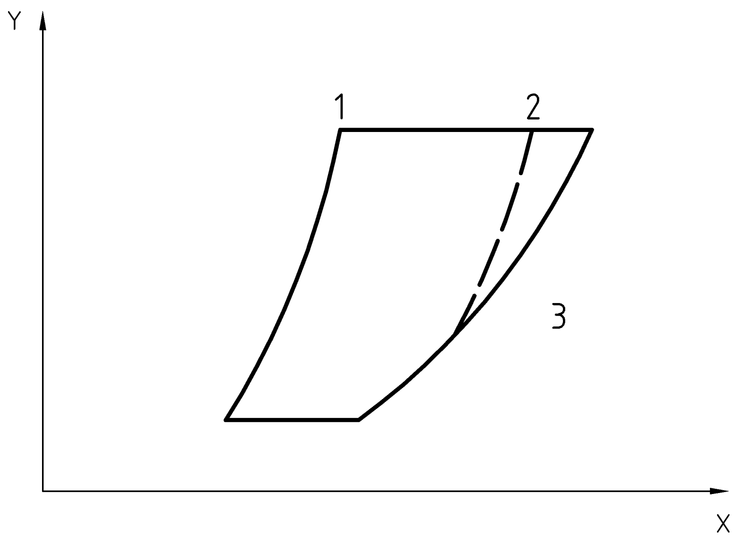
1 Smaller than 3,5√ *t* (fusion defect, stuck weld)

2 3,5√ *t*

3 5√ *t*

4 Splash

a) Spot welding — Constant force



Key

Y Electrode force

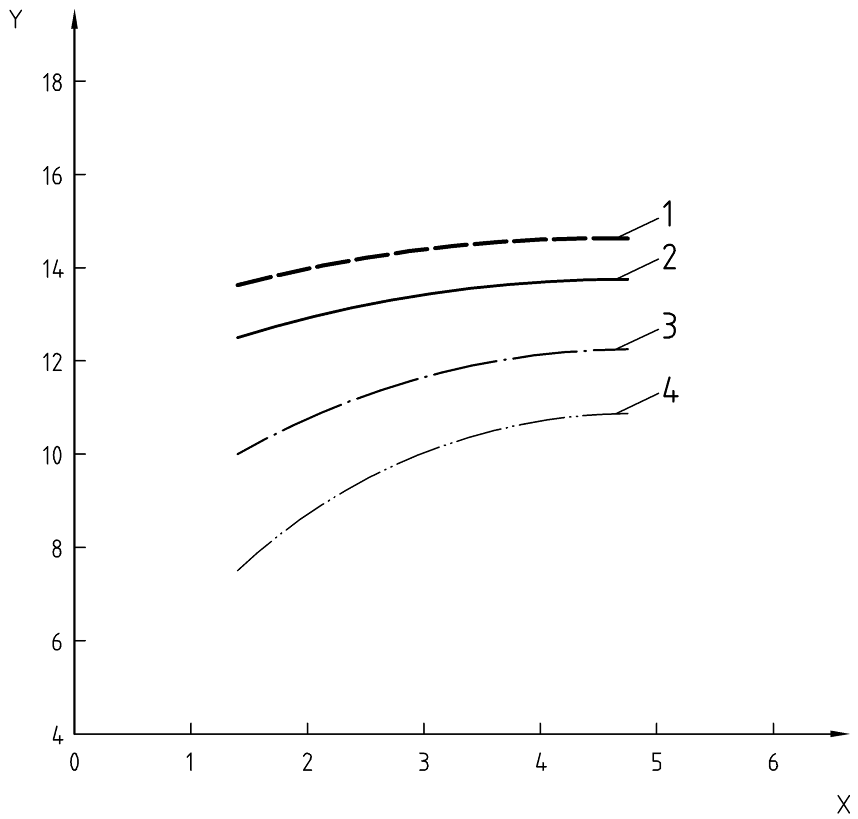
X Weld current

1 3,5√ *t*

2 5√ *t*

3 Splash

b) Spot welding — Constant weld time



Key

Y Weld current (kA)

X Welding speed (m/min)

1 Burning limit

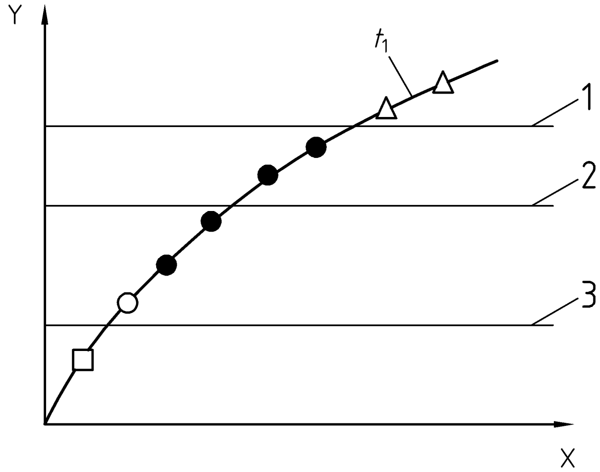
2 Upper limit

3 Start of cracking

4 Stuck weld limit

c) Seam welding —— constant weld force — Typical for zinc coated Steels

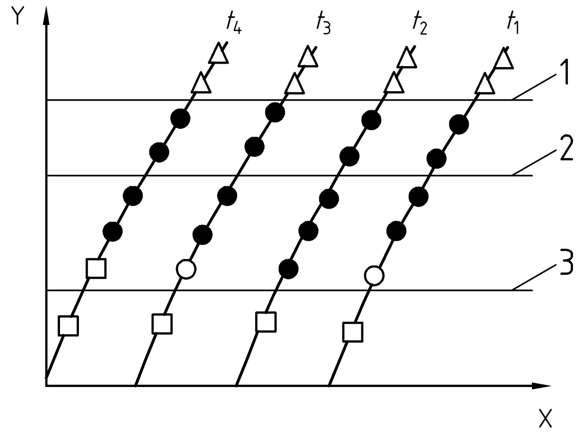
Figure 1 — Typical weldability lobes



Key

Y	Weld diameter	t_1	Weld time
X	Weld current	□	Interface failure
1	Splash limit	O	Partial plug failure
2	$5\sqrt{t}$	●	Plug failure
3	Min. weld diameter	Δ	Splash

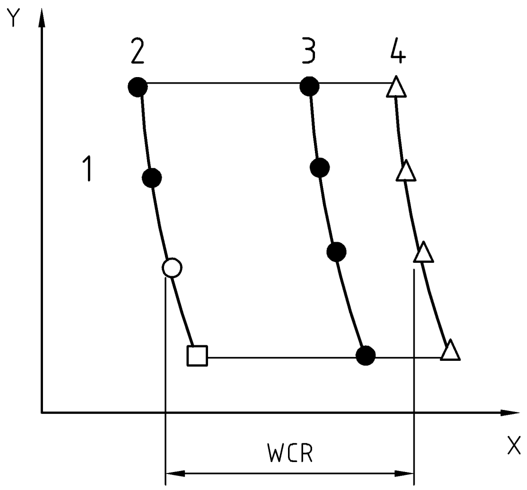
a) Weld growth diagram by constant electrode force, weld time t_1 and varied weld current



Key

Y	Weld diameter	t_1 to t_4	Weld time
X	Weld current	□	Interface failure
1	Splash limit	O	Partial plug failure
2	$5\sqrt{t}$	●	Plug failure
3	Min. weld diameter	Δ	Splash

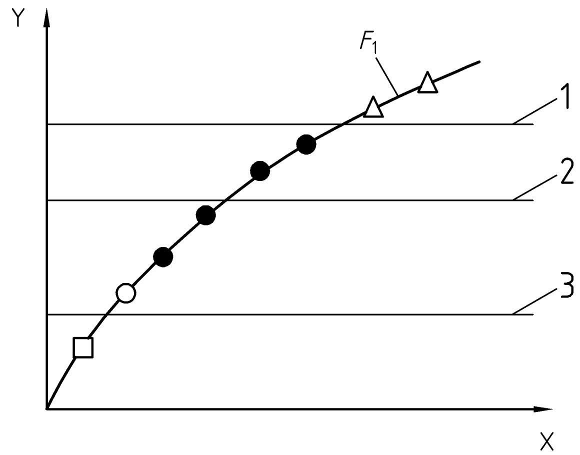
b) Weld growth diagram by constant electrode force, weld time $t_1 < t_2 < t_3 < t_4$ and varied weld current



Key

Y	Weld time	WCR	Welding current range
X	Weld current	□	Interface failure
1	Fusion defect	O	Partial plug failure
2	Min. weld diameter	●	Plug failure
3	5√ *t*	Δ	Splash
4	Splash limit		

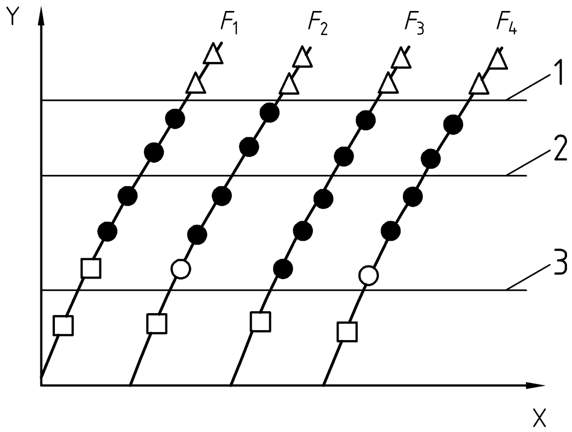
c) Weld time— weld current — weldability lobe by constant electrode force with an example for welding current range



Key

Y	Weld diameter	F_1	Electrode force
X	Weld current	□	Interface failure
1	Splash limit	O	Partial plug failure
2	5√ *t*	●	Plug failure
3	Min. weld diameter	Δ	Splash

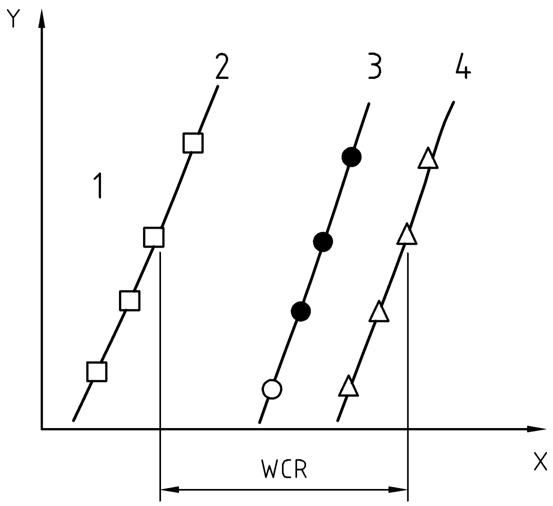
d) Weld growth diagram by constant weld time, electrode force F_1 and varied weld current



Key

Y	Weld diameter	F_1 to F_4	Electrode force
X	Weld current	□	Interface failure
1	Splash limit	O	Partial plug failure
2	$5\sqrt{t}$	●	Plug failure
3	Min. weld diameter	Δ	Splash

e) Weld growth diagram by constant weld time, electrode force $F_1 < F_2 < F_3 < F_4$ and varied weld current



Key

Y	Electrode force	WCR	Welding current range
X	Weld current	□	Interface failure
1	Fusion defect	O	Partial plug failure
2	Min. weld diameter	●	Plug failure
3	$5\sqrt{t}$	Δ	Splash
4	Splash limit		

f) Electrode force — weld current — weldability lobe by constant weld time with an example for welding current range

Figure 2 — Diagrams for determine the weldability lobe

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

ICS 25.160.10

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