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Resistance welding — Procedure for the evaluation of the life of spot welding electrodes using constant machine settings

Soudage par résistance — Mode opératoire pour l'évaluation de la durée de vie des électrodes utilisées en soudage par points avec des réglages de machines constants

Reference number
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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 8166 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 8166:2003) has been prepared by Technical Committee CEN/TC 121 "Welding", the secretariat of which is held by DS, 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of an identical text or by endorsement, at the latest by December 2003, and conflicting national standards shall be withdrawn at the latest by December 2003.

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

Introduction

This European Standard enables the electrode life of spot welding electrodes to be determined. This standard does not invalidate procedures for electrode life testing or their qualification 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 shall be defined in the design specification 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 standard EN ISO 14554 should be applicable. The specification of procedures should follow guidelines as in standard prEN ISO 15609-5.

The specified procedure allows the determination of the life of spot welding electrodes i.e. the number of acceptable spot welds which can be made between the need for re-dressing of the electrodes. The test procedure can be used to evaluate the following:

a) the influence of electrode material or electrode shape and dimensions on the electrode life when welding a particular material;

b) the affect of material being welded on the electrode life obtained using a fixed electrode shape and dimensions;

c) the influence of welding conditions on electrode life when using a particular combination of electrode material and shape for the welding of any material type;

d) the influence of welding machine type, electrode cooling on electrode life.

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

For convenience, a generic test procedure is described in this document which allows assessment of the effect of the material being welded on the electrode life obtained when using precisely defined welding conditions/electrode configurations. These can be modified depending on the particular parameters being investigated.

Recommendations are also given concerning the important parameters which need to be kept constant so as to allow the appropriate comparisons to be made as indicated in a), c) and d) above.

1 Scope

This European Standard specifies a procedure to be used for the evaluation of the life of spot welding electrodes when welding uncoated and coated steels, stainless steels, aluminium and aluminium alloys using constant machine settings which are not changed during the test. The procedure can also be used to establish the electrode life when spot welding other metallic materials.

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 14273, *Specimen dimensions and procedure for shear testing resistance spot, seam and embossed projection welds (ISO 14273:2000).*

prEN ISO 14329:1999, *Welding — Destructive testing of welds — Failure types and geometric measurements for resistance spot, seam and projection welds (ISO/DIS 14329:1999).*

prEN ISO 15609-5, *Specification and approval of welding procedures for metallic materials — Welding procedure specification — Part 5: Resistance welding (ISO/DIS 15609-5:2000).*

EN ISO 17653, *Destructive tests on welds in metallic materials — Torsion of resistance spot welds (ISO 17653:2003).*

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

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

ISO 5184, *Straight resistance spot welding electrodes.*

ISO 5821, *Resistance spot welding electrode caps.*

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

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

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

3 Terms and definitions

For the purposes of this European Standard, the terms and definitions given in ISO 669:2000 and prEN ISO 14329:1999 apply.

4 Criteria for the end point of the electrode life test

For the purpose of this procedure for all materials, the electrode life is the number of welds which can be made giving the required weld quality before re-machining of the electrode face is necessary.

The electrode shall be considered to have reached its life when the welds being produced have a weld diameter, as indicated in a peel test, of less than 3,5 $\sqrt{t}$ (where t is the sheet thickness in mm) for three welds in a test sample of five consecutive welds. Peel testing shall be carried out according to ISO 10447. All electrode life tests will be repeated three times to give an indication of the amount of scatter. Both the average value and the range of electrode life shall be quoted. Ring or stuck welds are not acceptable. It should be noted that ring welds occur sooner when welding coated steels.

Alternative criteria for determining the end of electrode life shall be used as defined in the design specification. These depend on the requirements of the product. Typical examples which can be used when testing uncoated or coated steels include:

a) agreed reduction in tensile shear force of the weld e.g., 30 %. (Shear Testing will be carried out in accordance with EN ISO 14273);

b) agreed criteria using a torsion testing procedure according to EN ISO 17653;

c) agreed criteria based on micro-sections;

d) limits based on aesthetic requirements, e.g. surface indentation or surface marking;

e) agreed criteria based on electrode sticking.

When testing aluminium or aluminium alloys, the following criteria for the end of the electrode life can be used as defined in the design specification. These depend on the requirements of the end product and include:

f) an agreed 30 % reduction in tensile shear force of the weld;

g) agreed criteria using a torsion testing procedure;

h) agreed criteria based on weld nugget porosity or cracking;

i) criteria based on surface cracking;

j) limits based on aesthetic requirements, e.g. surface indentation or surface marking;

k) agreed criteria based on electrode sticking.

5 Machine details

5.1 General

The electrode life is very dependent on the type of spot welding machine or gun used. It is necessary therefore to specify various aspects of machine or gun design. Both electrical and mechanical characteristics of the welding machine and gun shall be specified according to ISO 669.

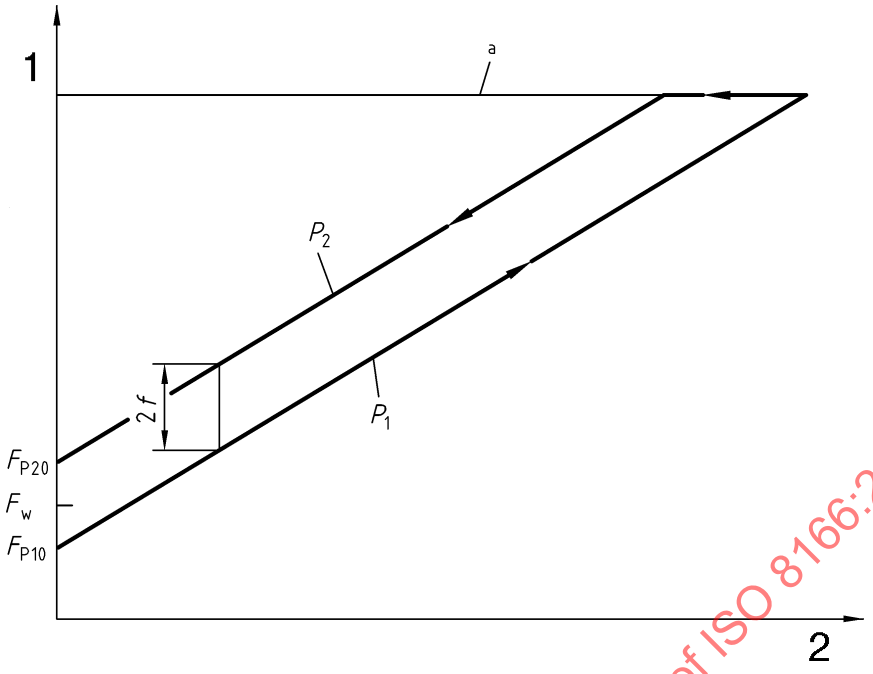
5.2 Machine type

The spot welding machines or guns shall be a conventional 50 Hz or 60 Hz AC type with electrical and mechanical properties specified in ISO 669. If phase shift control is used for the adjustment of the welding current, then the required welding current shall be attained with a phase setting giving not less than 70 % of the full sinusoidal waveform. The phase angle should be measured and recorded whenever possible.

Machines based on DC, or other generated waveform type can be used as defined in the design specification. Special machines may be necessary for spot welding aluminium and aluminium alloys depending on the required weld quality. For best results when welding aluminium and aluminium alloys, machines fitted with a low inertia electrode head assembly with a rapid follow-up action should be used.

5.3 Mechanical characteristics

The mass and static friction properties of the upper movable electrode head assembly shall be determined and recorded. Mass (M) and static friction (f) of the upper movable parts shall be determined from the hysteresis curve of electrode force vs air pressure in the upper cylinder (see Figure 1).



Key

1 Electrode force F
2 Air pressure in cylinder P

a Nominal electrode force

f Force included by static friction
f_0 Force included by static friction at zero air pressure
F_{P10} Electrode force at zero air pressure in case of increasing air pressure
F_{P20} Electrode force at zero air pressure in case of decreasing air pressure
F_W Weight of upper movable head
g Constant of gravitation
M Mass of upper movable head

$$F_W + f = F_{P20}$$

$$F_W - f = F_{P10}$$

$$F_{P20} - F_{P10} = 2f$$

$$F_{P10} + F_{P20} = 2F_W$$

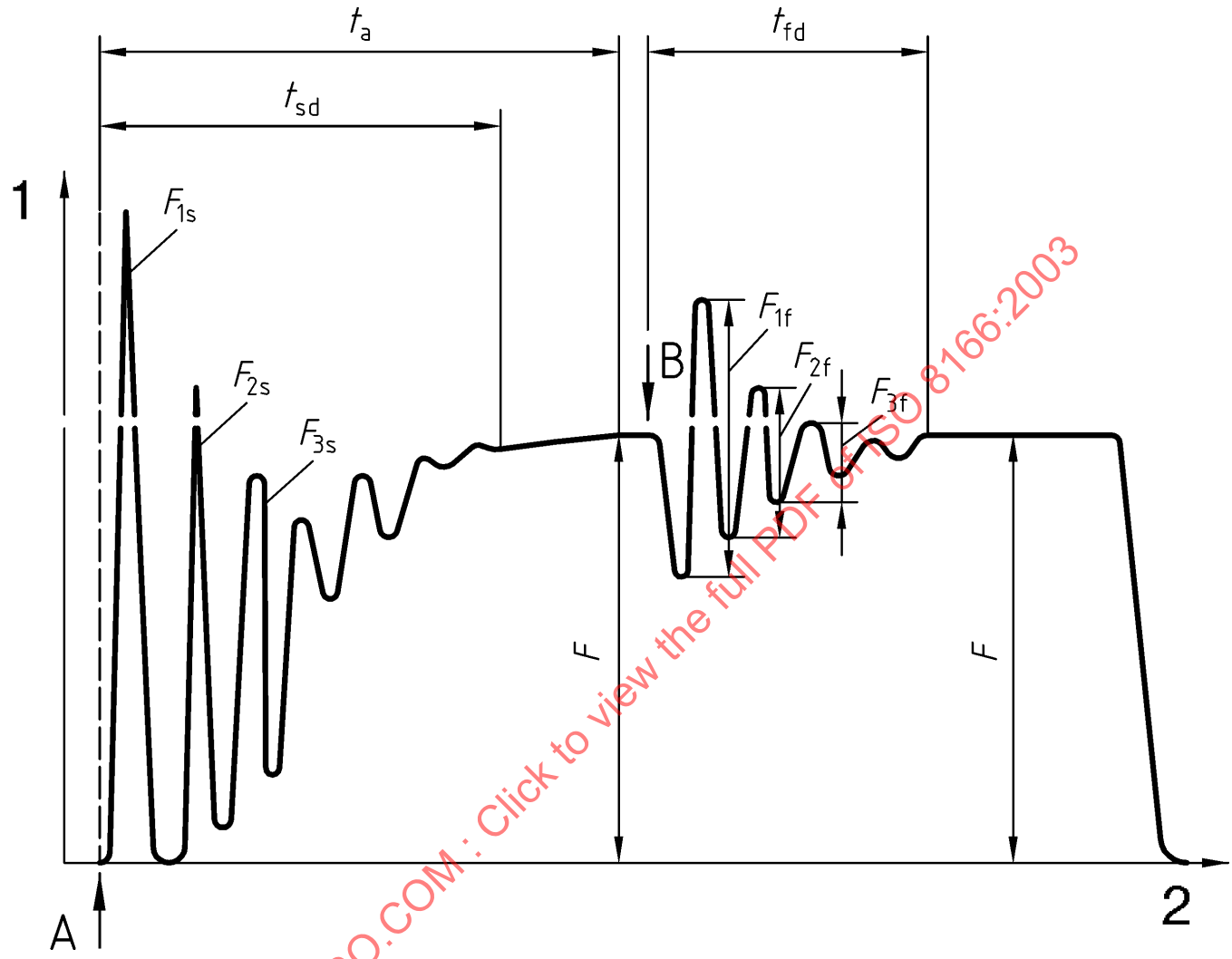
$$M = \frac{F_W}{g}$$

$$F_W = \frac{F_{P10} + F_{P20}}{2}$$

$$f_0 = \frac{F_{P20} - F_{P10}}{2}$$

Figure 1 — Mass M and static friction f of the upper movable electrode head assembly determined by hysteresis curve for electrode force vs cylinder air pressure

The impact characteristics of the electrode head assembly shall be determined as specified in ISO 669 from a force-time curve (see Figure 2) determined using an accelerometer or a load cell fitted to the electrode head assembly.



Key

1 Electrode force F
2 Time t

A Moment of electrode contact
B Start of electrode follow up
t_a Force rise time
t_{fd} Decay time during follow up
t_{sd} Decay time after electrode contact
F Electrode force
F_{1s} to F_{3s} Force oscillations during follow up
F_{1f} to F_{3f} Force oscillations after electrode contact

Figure 2 — Dynamic behaviour of a spot welding machine (schematic)

Any deviation from these requirements, arising because of machine design or instrumentation shall be defined in the design specification prior to carrying out the test.

5.4 Electrical characteristics

The electrical characteristics of the machine should follow guidelines specified in ISO 669.

5.5 Water cooling of electrodes

Where appropriate, dimensions of the water cooling holes and pipes shall comply with the relevant requirements of the appropriate ISO Standard for various electrode types. Unless the effects of water cooling are being investigated, the water flow rate should be a minimum of 4 l/min per electrode for uncoated steel and 6 l/min per electrode for coated steels. The water cooling tube should be arranged to ensure that the water impinges onto the back working face of the electrode. The distance between the back and working face of the electrode should not exceed the values given in the appropriate ISO Standard specifying electrode dimensions. The inlet water temperature should not exceed 20 °C (293 K) whilst the outlet water temperature should not exceed 30 °C (303 K). Since water temperature can significantly influence electrode life, the actual water temperature should be measured, and in any series of tests, kept constant. Separate water should be used for the top and bottom electrodes. The water supply to the electrodes should be independent of transformer and thyristor water cooling circuits. If this is not possible, the water should flow from the electrode to the thyristor/transformer circuits and not vice versa.

Deviations from the above procedures are permitted only if part of an investigation. Any deviation shall be defined in the design specification and shall be recorded.

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

6 Electrode details

Depending on the objective of the test procedure, the choice of electrode material, electrode shape and dimensions shall be defined in the design specification but should conform to the requirements of the appropriate ISO Standards.

Unless otherwise specified, straight welding electrodes shall be used of dimensions and tolerances specified in ISO 5184 except that the electrode tip shall be a standard truncated cone (included angle 120°), the choice of tip diameter being governed by sheet thickness according to the relationship.

$$d = 5\sqrt{t}$$

where

d = diameter of electrode tip;

t = sheet thickness in mm.

Both top and bottom electrodes shall be properly aligned prior to commencement of the test. In addition, the electrode face of the top electrode shall be parallel to that of the bottom electrode. Alignment of electrodes should be checked using carbon imprints.

The following shall be followed:

a) electrode material shall conform to ISO 5182:1991 Class A2/1 or A2/2 by agreement. The method of electrode manufacture shall be specified, i.e. forged or cold drawn. Whenever possible, the electrodes should be taken from the same batch in order to maintain consistency.

b) an alternative domed type cap electrode may be defined in the design specification and shall conform to dimensions stipulated in ISO 5821 or ISO 5830 depending on whether a female or male cap is to be used.

c) if the effect of electrode shape or dimensions are the subject of investigation, then all other parameters i.e. electrode configuration, welding conditions and electrode cooling should be defined in the design specification.

d) different electrode shape, dimensions and electrode materials are generally used when welding aluminium alloys, stainless steel and alloy steels.

Whether an electrode is pre-conditioned prior to an electrode life test shall be defined in the design specification. In general, electrodes are not preconditioned prior to electrode life testing. Electrodes should not be dressed during the life test.

If electrode preconditioning is specified then, when welding uncoated or coated steels, electrodes should be pre-conditioned for 50 welds prior to determining the electrode life. Pre-conditioning should be carried out at a nominal weld time (approximately 8 cycles) using a welding current equal to that which gives a stuck weld condition, or a weld of diameter equal to $3\sqrt{t}$.

When welding aluminium or aluminium alloys, no pre-conditioning of electrodes should be carried out.

7 Test procedure

7.1 General

Except for the case when the material being welded is the subject of investigation, tests should be carried out using the following:

a) cold reduced steel – extra deep drawing quality, sheet thickness 0,8 mm;

b) hot dip zinc coated steel – coating thickness 7 μm - 12 μm per side. Sheet thickness shall be 0,8 mm or 2,0 mm;

c) high strength steel, sheet thickness 0,8 mm.

Other sheet and coating thicknesses or coating types can be used as defined in the design specification.

If the test is being carried out aluminium or aluminium alloys, then the following base materials shall be used, unless otherwise defined in the design specification:

d) series 5000 alloy – sheet thickness 1,5 mm;

e) series 6000 alloy – sheet thickness 1,5 mm.

If other non-ferrous materials are being welded, then the electrode life test shall be carried out using the material appropriate to the product being manufactured.

Welding shall be carried out at one of the following rates:

1) 50 welds/min – typical of welding using pedestal type machines;

2) 30 welds/min – typical of robotic spot welding;

3) 10 welds/min – typical of multi-spot welder operations.

Edge distances of 10 mm min. and a weld pitch of 30 mm min. shall be used. The dimensions of the test sheets shall be such as to accommodate a total of at least 192 welds/panel, e.g. at least 12 rows of 16 welds.

7.2 Dimensions

The dimensions of the test sheets shall be at least 470 mm long by at least 350 mm wide.

Welds shall be made according to the following sequence:

The first row of welds is started at one corner of the panel and welds produced at the required interval across the panel. On completion of the first row, the movement of the panel is reversed and the second row of welds now completed. This procedure is continued until the panel has reached a temperature at 60 °C. Then the panel is rotated

horizontally through 180° and the procedure repeated. Spot welding is stopped when 192 welds have been produced on the panel.

Eight test welds shall be made every 192 welds. These test welds shall be made on a separate sheet 30 mm × 250 mm using the same materials, edge distances and weld pitch as for the main electrode life test piece in the case of test pieces to be used for peel testing or producing micro-sections. If a shear or torsion test is to be carried out, then test specimen dimensions shall conform with EN ISO 14273 or EN ISO 17653. These test welds are to be included in the total number making up the electrode life. The test piece will be positioned between the electrodes with the longer dimension transverse to the throat of the machine. Five of the welds will be tested with three welds being kept in reserve in case any re-examination of weld quality is necessary.

In the case of aluminium alloys or coated steels the number of test welds should be specified on a significant lower number.

Measurement of weld properties will be made using the 5 test welds.

Alternative test sheet/test piece/test specimen dimensions may be used as defined in the design specification. In this case, weld spacing, edge distances and welding rate may also be changed within limits as defined in the design specification.

7.3 Selection of welding conditions

With the given uncoated or coated steel sheet material, electrode design and electrode material, a suitable electrode force and weld time shall be selected from the guidelines given in ISO/DIS 14373 depending upon production requirements. In the case of aluminium and aluminium alloys, the welding conditions will depend on the type of machine used and shall be defined in the design specification.

In all cases, the starting weld diameter shall approximate to the initial electrode tip diameter which in the case of truncated cone electrodes is equal to $5\sqrt{t}$.

In the case of domed electrodes, the electrode dimensions and welding conditions should be chosen to give an initial weld diameter between $5\sqrt{t}$ and $5{,}5\sqrt{t}$.

For both materials, a weld growth curve, i.e. weld diameter vs weld current, will be determined using the selected weld time and electrode force, in order to determine the welding current requirements to give:

a) a weld size equal to $3{,}5\sqrt{t} < d_0 < 3{,}9\sqrt{t}$;

b) a weld size equal to $5\sqrt{t} < d_0 < 5{,}5\sqrt{t}$;

c) the splash condition.

The weld growth curve will be produced from a maximum of 10 welds using a similar electrode, configuration and material as to be assessed in the life test. The electrode life test shall be carried out using a value of weld current setting which is kept constant throughout the tests. Two current values will be used. The first series of tests will be made using a start test condition 1, see below. A second test series will be carried out using a start condition selected from start conditions 2 - 4, (see below) as defined in the design specification.

— Start current 1 – Current value to give a weld size of $5\sqrt{t} < d_0 < 5{,}5\sqrt{t}$ in diameter.

— Start current 2 – Current value equal to 10 % lower than the minimum value to give splash or expulsion.

— Start current 3 – Current value equal to 200 A lower than the minimum value to give splash or expulsion.

— Start current 4 – Current value equal to 10 % above that required to cause splash or expulsion to simulate hot welding condition.

Other values of starting current can only be used as defined in the design specification or, if other criteria are used to define weld quality based on strength/aesthetic requirements or, if the effects of weld current are the subject of investigations. The welding currents shall be defined in terms of an RMS value.

8 Report of test results

The results obtained can either be presented in tabular form or graphically, see Figure 3. The test report shall contain at least the following and based on the format given in prEN ISO 15609-5.

Details of the following shall be recorded for all tests if not otherwise stated:

a) location of test;

b) type of welding machine used:

   1) maximum rated capacity;

   2) maximum electrode force;

   3) maximum short circuit current;

   4) secondary voltage;

   5) mass of moving head;

   6) static friction of moving head;

   7) maximum impact force[1)];

   8) force coefficient[1)];

   9) impact velocity of upper electrode;

   10) machine, manufacturer, control type.

c) electrode details:

   1) type of material;

   2) shape;

   3) dimensions.

d) electrode cooling:

   1) water flow rate;

   2) water temperature – inlet;

   3) water temperature – outlet;

   4) water tube/back face distance.

e) details of sheet steel being welded:

1) Specialised instrumentation is required for measuring these parameters. These measurements can be omitted when defined in the design specification.

1) type;

2) coating;

3) thickness.

f) welding conditions:

1) electrode force;

2) weld time;

3) squeeze time;

4) hold time;

5) welding current;

6) welding controller mode.

g) weld current programme:

1) single/pulsation;

2) up slope details.

h) electrode life criteria:

1) purpose/requirement of test.

i) start weld properties:

1) start weld size, initial weld strength.