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(Reaffirmed 1998)

Indian Standard

CODE OF PRACTICE FOR RESISTANCE SPOT WELDING FOR LIGHT ASSEMBLIES IN MILD STEEL

(Third Reprint JUNE 1983)

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INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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(Reprinted OCTOBER 1966)

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Indian Standard

CODE OF PRACTICE FOR RESISTANCE SPOT WELDING FOR LIGHT ASSEMBLIES IN MILD STEEL

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 21 May 1957, on approval by the Building Division Council of the draft finalized on 13 December 1956, by the Structural Steel Sectional Committee.

0.2 This code is meant to serve as a guide to the industries using the resistance welding process in the fabrication of light mild steel assemblies. Since sheet and strip steel will now be available from local production in India, increased use of the resistance welding process would naturally follow. This code will, therefore, help to ensure that development of spot welding in India takes place along proper lines.

0.3 For a particular weld design to be efficient, safe and satisfactory, the designer should be conversant with the possibilities and limitations of the welding processes which are available for use. It is only in recent years that sufficient information and data regarding resistance welding processes have become available to give designers the necessary confidence to use resistance spot welding in assemblies where strength and safety are of importance. It is possible now to indicate procedures and suggest formulæ for the design of such assemblies.

0.4 The decision of the Government of India to introduce uniform weights and measures throughout the country based on metric system has been taken into consideration in the formulation of this code. In order to assist the users in the changeover to the new system, values in the metric system of weights and measures have been given in the code with equivalents in the ft-lb system. It is proposed to eliminate the values in ft-lb units in future revisions of this code and it is emphasized that the users of this code should familiarize themselves with the use of the metric units.

0.4.1 Conversion from ft-lb units to metric units has been done according to IS: 787-1956 Guide for Inter-Conversion of Values From One System of Units to Another.

0.5 In the formulation of this standard, the Sectional Committee has derived assistance from Messrs Ramseyer & Miller Inc, Consultants to the Iron & Steel Industry, New York. This assistance was made available to the Indian Standards Institution by the Technical Co-operation Mission to India of the Government of United States of America under their technical assistance programme.

0.6 Taking into consideration the views of the producers, consumers, technologists, etc, the Sectional Committee, responsible for the preparation of this code felt that it should be related to the trade practices followed in the country in this field. Furthermore, due weightage had to be given to the need for international co-ordination between standards prevailing in different countries of the world. These considerations have led the Sectional Committee to derive assistance from the following standards:

AWS: CL. 1-50 RECOMMENDED PRACTICES FOR RESISTANCE WELDING. American Welding Society.

DOC: CX (WEE) 1182 January 1957. DRAFT REVISION OF B.S. 1140: 1946 SPOT WELDING FOR LIGHT ASSEMBLIES IN MILD STEEL. British Standards Institution.

WELDING MEMORANDUM NO. 4C MEMORANDUM ON THE RESISTANCE WELDING PROCESSES. Ministry of Supply, London, 1946.

T.21A TECHNIQUE FOR SPOT WELDING LOW CARBON STEEL [FROM 0·022 in (24 SWG) TO $\frac{1}{8}$ in]. British Welding Research Association. London, 1953.

0.7 This Indian Standard is one of a series of Indian Standard Specifications and Codes of Practice being prepared by the Welding Subcommittee of the Structural Steel Sectional Committee in the field of welding. Other standards in the series cover the following subjects:

a) Glossary of terms relating to welding and cutting of metals
b) Scheme of symbols for welding
c) Specification for covered electrodes for metal arc welding of mild steel
d) Classification and coding of covered electrodes for metal arc welding of mild steel and low alloy high-tensile steels
e) Code of practice for use of metal arc welding for general construction in mild steel
f) Code of practice for training and testing of metal arc welders
g) Code of practice for safety and health requirements in electric and gas welding and cutting operations
h) Code of practice for use of welding in tubular construction
j) Code of practice for use of welding in pipe-lines
k) Code of practice for inspection of welds

m) Procedure code for manual metal arc welding of structural steel

n) Code of practice for use of welding in bridges and structures subject to dynamic loading

0.8 This code requires reference to the following Indian Standards:

IS: 812-1957 GLOSSARY OF TERMS RELATING TO WELDING AND CUTTING OF METALS

*IS: 1079-1958 SPECIFICATION FOR LIGHT GAUGE STRUCTURAL QUALITY HOT ROLLED CARBON STEEL SHEET AND STRIP

0.8.1 Wherever a reference to any standard mentioned under **0.8** appears in this code, it shall be taken as a reference to the latest version of that standard.

0.9 For the purpose of deciding whether a particular requirement of this code is complied with, the final value, observed or calculated, shall be rounded off in accordance with †IS: 2-1949 Rules for Rounding Off Numerical Values. The number of places retained in the rounded off value, should be the same as those of the specified value in the code.

0.10 This code is intended chiefly to cover the technical provisions relating to use of spot welding for light assemblies in mild steel, and it does not include all the necessary provisions of a contract.

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1. SCOPE

1.1 This code lays down the procedure for resistance welding of the single impulse spot and stitch type used in the fabrication of assemblies from mild steel sheet, strip and plate. It also covers the procedure for the design of spot welds and prescribes suitable tests for ascertaining the quality of the weld.

2. TERMINOLOGY

2.1 For the purpose of this code, the definitions given in IS: 812-1957 shall apply.

3. MATERIALS

3.1 Parent Metal

3.1.1 Steel sheets, strips and plates to be resistance welded in accordance with this code shall have a chemical composition with the following

*Since revised.

†Since revised.

limits for carbon, manganese, sulphur and phosphorus:

a) *For sheets up to and including* 1·2 *mm* (*or* 0·048 *in*):

	Percent, Max
Carbon	0·10
Manganese	0·50
Sulphur	0·040
Phosphorus	0·040

b) *For sheets over* 1·2 *mm* (*or* 0·048 *in*):

	Percent, Max
Carbon	0·15
Manganese	0·50
Sulphur	0·050
Phosphorus	0·050

3.1.1.1 Residual elements, such as chromium, nickel, copper and molybdenum may, if present in excessive quantities, result in hard or brittle welds. Specimens of such materials shall be subjected to tests specified in Appendix A and shall satisfy the requirements before the material is used in the fabrication.

3.1.2 The shear strength of the metal after welding shall not vary by more than ± 10 percent of the shear strength of the unwelded metal.

3.1.3 The 'welding quality' strip specified in *IS: 1079-1958 satisfies the requirements specified under **3.1.1**.

4. WELDING PLANT

4.1 Welding machines used for spot welding may be of the following types:

i) Power operated type	a) Stationary b) Mobile
ii) Manual or pedal operated type	a) Stationary b) Mobile

4.1.1 The different types of welding machines should conform to the appropriate requirements laid down in Appendix B. Machines of the mobile type are used when the assembly is bulky and inconvenient for operation on the stationary type.

5. ELECTRODES

5.1 The electrodes used for spot welding should conform to the requirements specified in Appendix C.

*Since revised.

6. WELDING PROCEDURE

6.1 Preparation of Parent Metal — All metal surfaces to be spot welded shall be free from scale, rust, paint, grease, dirt or excessive *pitting*. However, certain surface treatments, such as paint primer treatment, rust prevention treatment, oiling or plating may be applied before welding, provided that the coating is uniform in thickness and that consistent welds conforming to the requirements specified under 7 and in Appendix A can be obtained.

6.1.1 The surface of the components shall be so prepared that minimum practicable force is required to bring them into intimate contact.

6.2 Machine Setting — The factors governing the production of spot welds and the means of controlling them on the welding machine are given in Table I.

TABLE I FACTORS WHICH INFLUENCE THE CHARACTERISTICS OF A SPOT WELD

Sl No.	Factors Which Influence the Weld	Means of Control
i)	Current	Tap switch
ii)	Time	Weld timer
iii)	Pressure	Adjustable air or spring pressure
iv)	Area of contact	Size of electrode tip
v)	Surface condition of components	Method of treatment — pickling or shotblasting

6.2.1 The first three factors in Table I relate to the welding machine itself and the quality of weld among other things depends upon the correct setting of these variables. In every case, setting of the machine is to be done by actual trial with the material to be welded, taking into consideration the manufacturer's recommendation. Recommended design data for machine settings for spot welding of mild steel in metric units are given in Table II and in foot-pound units in Table IIA.

6.2.1.1 The pressures indicated in Table II (or IIA) for different electrode tip diameters are calculated on the basis of a recommended minimum pressure of 700 kg/cm^2 (or 10 000 lb/in^2) up to and including 8 mm (or $\frac{5}{16}$ in) electrode tip diameter and 1 000 kg/cm^2 (or 15 000 lb/in^2) in the case of 9 mm (or $\frac{11}{32}$ in) electrode tip diameter.

6.2.1.2 The minimum weld diameter obtained when the correct current setting is adopted is given in Table II (or IIA). If the weld diameter is specified, the total pressure required shall be based on the minimum pressure intensity of 700 kg/cm^2 (or 10 000 lb/in^2) up to and including 8 mm (or $\frac{5}{16}$ in) electrode tip diameter and 1 000 kg/cm^2 (or

15 000 lb/in^2) in the case of 9 mm (or $\frac{11}{32}$ in) electrode tip diameter, over the total area equivalent to the specified weld size.

6.3 Material Indentation — The indentation caused by any tip of the electrode after the weld has been made shall be not greater than 10 percent of the thickness of the sheet with which the tip is in contact.

7. ROUTINE TESTS

7.1 To ensure consistent spot welds, the following tests shall be carried out in accordance with the procedure laid down in Appendix A:

a) Slug test
b) Shear test
c) Visual examination
d) Microscopic examination

7.1.1 Slug tests shall be carried out whenever assemblies are made by spot welding except that they are optional in cases where shear tests are carried out.

7.1.2 Shear tests shall be carried out where spot welds are designed for strength or where joints are highly stressed. Shear tests may be conducted instead of, or in addition to, the slug tests as agreed to between the purchaser and the fabricator.

7.1.3 Visual examination shall be carried out whenever assemblies are made using spot welds.

7.1.4 Microscopic examination shall be carried out if so required by the purchaser.

8. DESIGN

8.1 General

8.1.1 Design of spot-welded assemblies shall take into consideration the possibilities of the failure of the joint by:

a) failure of the weld by shear,
b) failure of the weld by tearing out of the plate (plug failure), and
c) tearing of the plate itself.

8.1.2 *Shear and Plug Failure* — It may be assumed that strength per unit area of each weld remains reasonably constant whether the welds are arranged singly or in groups or whether they fail purely in shear or by tearing out of the plate (plug failure). The design of spot welded assemblies against shear and plug failure shall be based on the shear strength of welds.

For the parent metal under consideration in this code ultimate shear stress of the welds has been specified at a minimum of 31·5 kg/mm² (or 20·0 tons/in²).

8.1.3 In spot welded assemblies, although the welds themselves have very little ability to deform under load due to their cast structures, the welded joints have certain amount of ability to yield under stress. When the weld size is sufficient to carry the direct stresses, considerable bending of the plates takes place before the weld can fail. This ability of the joint to yield is assumed as sufficient to distribute the load to all the spot welds in the assembly.

8.1.4 Failure by the tearing of the plate is avoided by maintaining sufficient edge distances for the welds. The recommended minimum edge distance of 1·5 times the diameter of the weld (*see* **8.5**) normally ensures that welds shear rather than the plates tear along the plate edges.

8.2 Size of Weld — The size of a spot weld shall be based on the thickness of thinner of the two sheets in the assembly. The size of the weld should be according to the minimum weld diameter indicated in Table II (or IIA) unless there are special reasons for adopting a larger diameter. The weld diameter should approximate to the initial tip diameter of the electrode.

8.3 Permissible Stress — The permissible shear stress in a spot weld shall be taken as 800 kg/cm² (or 5·00 tons/in²).

8.4 Minimum Pitch of Welds — The distance between centres of spot welds shall be not less than 3 times the diameter of the spot weld.

8.4.1 In assemblies designed for strength, the maximum straight line pitch should be not greater than 12 times the thickness of the thinnest plate in the assembly in the case of single rows of spot welds or 18 times the thickness of the thinnest plate in the assembly in the case of staggered rows.

8.5 Minimum Edge Distance — The minimum edge distance of spot welds shall be not less than 1·5 times the diameter of the weld and shall preferably be as shown in Table II (or Table IIA).

8.6 Design Data — Table II (or IIA) gives data calculated on the basis of the rules specified under **8.2**, **8.3**, **8.4** and **8.5**.

8.7 A typical design of a spot welded joint is given in Appendix D for guidance.

TABLE II DESIGN DATA FOR SPOT WELDING TWO EQUAL THICKNESSES OF LOW CARBON MILD STEEL SHEETS (IN METRIC UNITS)

(*Clauses* 6.2.1, 8.2, 8.5 *and* 8.6)

Sheet Thickness (mm)	Electrode Tip Dia (mm)	Electrode Load (kg)	Welding Current in Amperes, Weld Time in Cycles (50 c/s)						Maximum Permissible Load per Spot at 800 kg/cm² Shear (kg)	Weld Dia (mm)	Minimum Edge Distance (mm)	Minimum Weld *Pitch (mm)
			Normal Recommended Condition		Limiting Condition for Most Efficient Use of Energy		Limiting Condition for Low Currents and Long Times					
			Current	Time	Current	Time	Current	Time				
0·6	4·0	90	5 000	5	5 000	10	5 000	20	104	4·0	6·0	12·0
0·8	5·0	140	8 000	5	6 500	10	5 000	25	160	5·0	7·5	15·0
1·0	5·0	140	8 000	10	6 500	15	5 500	30	160	5·0	7·5	15·0
1·2	6·0	200	9 000	10	7 500	20	6 500	40	224	6·0	9·0	18·0
1·2	7·0	270	10 500	15	9 000	25	8 500	40	304	7·0	10·5	21·0
1·6	7·0	270	9 500	15	8 000	20	7 500	50	304	7·0	10·5	21·0
2·0	8·0	350	12 500	20	10 500	30	9 000	50	400	8·0	12·0	24·0
2·5	8·0	350	13 000	20	11 000	40	9 500	80	400	8·0	12·5	25·0
3·2	9·0	640	15 500	20	13 000	40	9 500	100	512	9·0	14·0	28·0

*At closer pitches, increased current or time is required to offset the effects of current loss through previous welds.

TABLE IIA DESIGN DATA FOR SPOT WELDING TWO EQUAL THICKNESSES OF LOW CARBON MILD STEEL SHEETS (IN INCH UNITS)

(*Clauses* 6.2.1, 8.2, 8.5 *and* 8.6)

Sheet Thickness		Electrode Tip Dia (in)	Electrode Load (lb)	Welding Current in Amperes, Weld Time in Cycles (50 c/s)						Maximum Permissible Load per Spot at 5 tons/in² Shear (lb)	Weld Dia (in)	Minimum Edge Distance (in)	Minimum Weld *Pitch (in)
				Normal Recommended Condition		Limiting Condition for Most Efficient Use of Energy		Limiting Condition for Low Currents and Long Time					
in	SWG			Current	Time	Current	Time	Current	Time				
0·022	24	5/32	190	5 000	5	5 000	10	5 000	20	198	0·15	0·25	0·45
0·028	22	3/16	275	8 000	5	6 500	10	5 000	25	286	0·18	0·30	0·55
0·036	20	3/16	275	8 000	10	6 500	15	5 500	30	286	0·18	0·30	0·55
0·048	18	7/32	375	9 000	10	7 500	20	6 500	40	426	0·22	0·35	0·65
0·048	18	1/4	500	10 500	15	9 000	25	8 500	40	550	0·25	0·40	0·75
0·064	16	1/4	500	9 500	15	8 000	20	7 500	50	550	0·25	0·40	0·75
0·080	14	5/16	770	12 000	20	10 500	30	9 000	50	845	0·31	0·45	1·00
0·104	12	5/16	770	13 000	20	11 000	40	9 500	80	1 020	0·34	0·50	1·25
0·125	—	11/32	1 400	15 500	20	13 000	40	9 500	100	1 205	0·37	0·55	1·50

*At closer pitches, increased current or time is required to offset the effects of current loss through previous welds.

APPENDIX A

(*Clauses* 3.1.1.1, 6.1 *and* 7.1)

METHOD OF CARRYING OUT ROUTINE TESTS FOR SPOT WELDS

A-1. GENERAL

A-1.1 This appendix lays down the procedure for preparation of test specimens and carrying out slug test, shear test, visual examination and microscopic examination of spot welds.

A-2. PREPARATION OF TEST SPECIMENS

A-2.1 Test pieces shall be made:

a) at the commencement of the daily work period and as soon as practicable at the beginning of each shift,

b) whenever the diameter of one of the electrode tips has increased to the maximum specified under **C-3.4**,

c) whenever new electrode tips are fitted to the machine, and

d) whenever any of the machine settings are varied.

A-2.1.1 In case foot operated machines without an interlock are used, one percent of the total output shall be selected at random in addition to the samples selected in accordance with **A-2.1**.

A-2.2 As far as possible the test pieces should consist of welded components. If this is not practicable the test pieces should be made as follows:

a) Test pieces shall be prepared out of pieces of the same material and dimensions as the work piece and welded under the same conditions at the minimum spot spacing specified;

b) When the workpiece is of large dimensions, one of the following procedures may be adopted:

A jig which is a model of the workpiece shall be prepared using the same material as the workpiece; to this a test piece of the same material may be attached so that it is welded with the maximum amount of material in the throat of the machine, at the minimum spot spacing and under the same machine settings;

OR

A test piece of the same material as the workpiece shall be welded to the workpiece itself under the worst condition

of material in the throat with minimum spot spacing and the same machine settings;

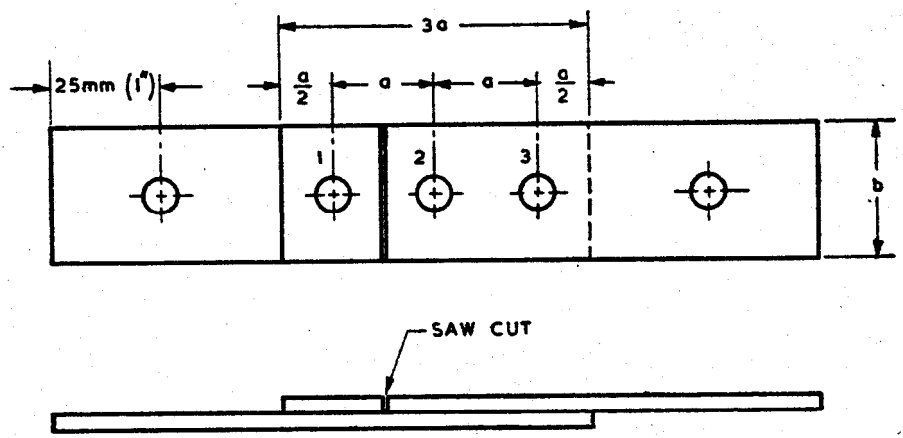
OR

A test piece shall be made using two pieces of the same material as the workpiece while the workpiece is held in the throat of the machine in a position which gives the worst condition during welding and welds shall be made at the minimum spacing and under the same machine settings.

A-2.2.1 The test pieces shall comply with the following requirements:

a) No test piece shall be made with less than three spot welds,
b) When a series of welds are being made, a minimum of six spot welds shall be made on the test piece,
c) The order of making the welds shall be clearly marked on the test piece,
d) The test pieces shall always be made with the same number and of sheets of the same thickness, plates or strips as on the workpiece, and
e) The test pieces shall be taken simultaneously from all the machines that are in use.

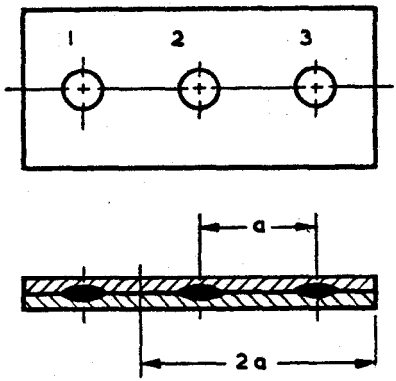
A-2.3 The test specimens for shear test shall conform to the requirements specified in Fig. 1.



a = pitch of production welds
b = { 32 mm for strip up to and including 18 SWG
    { 6 × weld dia for strip over 18 SWG

FIG. 1 TEST PIECE FOR SHEAR TEST

A-2.4 The test specimens for microscopic examination shall conform to the requirements specified in Fig. 2.



a = pitch of production welds

FIG. 2 TEST PIECE FOR MICROSCOPIC EXAMINATION

A-3. PROCEDURE

A-3.1 Slug Test — The test piece shall be prized apart or one part peeled off from the other (*see* Fig. 3) so that slugs of metal tend to be pulled out from one or the other of the sheets.

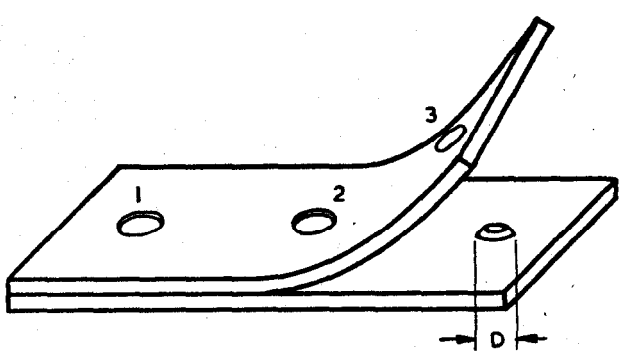


FIG. 3 TEST PIECE FOR SLUG TEST

A-3.1.1 The third or the last weld made on the test piece shall pull out a slug of a mean diameter equal to the diameter specified on the drawing or equal to the initial electrode tip diameter as obtained from the formula under C-3.2.

The mean diameter shall be the average of two diameters measured at right angles, one of which is the apparent minimum. The diameters shall be measured at the original interface. The edges of the slugs shall be bright and free from evidence of hot cracking.

NOTE — When slug tests are made on spots on thin sheets, the slug obtained may appear sound, but only the outer ring may be welded. Care should, therefore, be taken to ensure that the weld is sound.

A-3.2 Shear Test — All welds in the test piece, except the last two, shall be drilled out or cut away. The test piece shall then be tested to destruction on a tensile testing machine. The effect of eccentricity in the pulls on the two sheets may be disregarded.

A-3.2.1 The ultimate strength per spot shall be taken as one-half the maximum load required to break the joint in the test piece. The ultimate shear stress so calculated on each weld shall be not less than 31·5 kg/mm^2 (or 20·0 tons/in^2).

A-3.3 Visual Examination — The test piece shall be visually examined for alignment, spacing and pitch of the weld.

A-3.4 Microscopic Examination — The third weld on the test piece shall be sectioned across its diameter and the cut-section shall be polished, etched and then examined under a microscope with a magnification of not less than × 10.

A-3.4.1 The microscopic examination of the spot weld cross-section shall show that the desired quality of weld is being maintained and that no harmful defects are present.

APPENDIX B

(*Clause* 4.1.1)

REQUIREMENTS OF WELDING PLANT

B-1. POWER OPERATED MACHINE

B-1.1 The power operated machine should be equipped with an automatic control gear which, on the initial actuation of a foot- or hand-operated auxiliary switch, takes the control of the machine out of

the hands of the operator and performs the following cycle of operations in the sequence given below:

a) Brings the electrodes into contact with the components and applies welding pressure to the workpiece;

b) Causes the welding current to flow after the pre-set welding pressure (the pressure between the electrodes) has been attained;

c) Maintains the flow of the pre-set value of current for pre-set time, these remaining within the limits which do not affect the weld strength (as determined in accordance with the methods prescribed under **7** and in Appendix A) and the welding pressure being maintained throughout;

d) Cuts off the welding current at the end of the pre-set time;

e) Maintains the welding pressure for a minimum of 0·05 seconds (the forging time) after the current ceases to flow; and

f) Releases the pressure at the end of this time and returns the welding machine to a condition where it is ready to recommence the same cycle of operations. The welding pressure should be capable of being varied over a range which shall be indicated on the machine.

B-1.1.1 The time of flow of current and value of current should be capable of being varied over a range which should be indicated on the machine. When required, the forging time should be capable of being varied over a range, which should be indicated on the machine.

B-1.2 A variable forging time should be supplied whenever the pieces to be welded are equal to two thicknesses of 2 mm (or 14 SWG) or thicker.

B-1.3 Timers sensitive to temperature variation should not be used.

B-2. MANUAL OR PEDAL OPERATED MACHINE (NOT POWER OPERATED)

B-2.1 The foot operated machine should be equipped with control devices so that after the foot pedal has been depressed to a given position, thus applying the welding pressure (the pressure between the electrodes), the following sequence of operations is carried out automatically and unaffected by any action of the operator:

a) Causes the welding current to flow when a pre-set welding pressure has been reached,

b) Maintains the flow of a pre-set value of current for a pre-set time, these remaining within the limits which do not affect the weld strength (as determined in accordance with the methods prescribed under **7** and in Appendix A) and the welding pressure being maintained throughout,

c) Causes a visible signal to be given whilst the welding current is flowing,

d) Cuts off the welding current at the end of the pre-set time,

e) Causes the welding pressure to be maintained for a minimum of 0·05 second (the forging time). Where no interlock is provided the forging time shall be controlled by the operator (*see* **A-2.1.1**),

NOTE — The forging time required increases as the material thickness increases, e.g. approximately one-tenth of a second is sufficient when welding 1·6 mm (or 16 SWG) thick material whereas at least one second is needed to weld a 3·2 mm (or $\frac{1}{8}$ in) thick material.

f) Allows the welding pressure to be released at the end of this time, and allows the machine to be returned to a condition where it is ready to recommence the cycle of operations.

B-2.2 Means for adjusting the welding pressure should be provided on all machines.

B-2.3 The time of flow of current and value of current should be capable of adjustment over a range which would be indicated on the machine.

B-2.4 When required, the forging time should be capable of adjustment over a range, which should be indicated on the machine.

B-2.5 Timers sensitive to temperature variation should not be used.

APPENDIX C

(*Clause* 5.1)

ELECTRODES

C-1. MATERIAL

C-1.1 The electrodes used for spot welding should comply with the following requirements:

a) The electrical conductivity should be not less than 80 percent of that for standard annealed copper. The volume resistivity of standard annealed copper at 20°C may be taken as $\frac{1}{58}$=0·017 241 ohm square millimetre per metre $\left(\frac{\text{ohm mm}^2}{\text{m}}\right)$,

b) The thermal conductivity at 20°C should not be less than 0·73 cal/cm²/cm/deg C/s, and

c) The hardness should be not less than 110 Vickars Pyramid Hardness (VPH) and the electrode shall not soften up to temperature of 250°C. For heavy duty cycle and continuous operation, the electrode material should have a minimum of 150 VPH (when made from hard-drawn rod) and have a softening temperature not lower than 500°C. Forged and cast electrodes having a minimum hardness of 130 and 110 VPH respectively may also be used.

C-2. SHANK SIZE AND SHAPE

C-2.1 The shank diameter of the electrode should be so chosen that there is no softening due to overheating. It is recommended that the shank diameter should be at least thrice the tip diameter and preferably not less than 13·0 mm (or 0·50 in). The electrode taper should be such as to enable ease of removal and ensure good electrical contact. A taper with 5° included angle has been found to be convenient for most purposes; No. 2 Morse taper is also used in many cases where the pressure is not too high. The length of the tapered portion shall be not less than $1{\cdot}25D$ in the case when the thrust is in line with the shank and not less than $2D$ in the case of electrodes with eccentric loading; D being the diameter of the electrode at the large end of the taper of the shank.

C-3. TIP SIZE

C-3.1 The size of the spot in the weld depends on the size of the tip. Table II (or IIA) contains recommendations regarding tip size for different thicknesses of sheets. Unless otherwise specified in the design or drawing, the values given in Table II (or IIA) should be used.

C-3.2 The formula from which the tip sizes given in Table II (or IIA) have been calculated is given below:

$$d = 5{\cdot}04\ \sqrt{e}$$

where

d = tip diameter in mm, and
e = thickness of the component in mm

OR

$$D_1 = \sqrt{t}$$

where

D_1 = tip diameter in inches, and
t = thickness of component in inches.

C-3.3 Where welding is done with two sheets of different thicknesses, the tip diameter of the electrode shall be based on the thickness of sheet with which it is to be in contact.

C-3.4 The diameter of at least one of the tips shall not be allowed to increase by more than 20 percent of the initial electrode tip diameter.

C-3.5 The supervisor or operator shall from time to time check the size of the tip by means of a gauge; when its size has increased to the maximum permissible limit (*see* **C-3.4**), the electrode shall be replaced or redressed to its initial size by a competent person.

C-4. INCLUDED ANGLE

C-4.1 The included angle of the truncated cone which is twice the complement of the rake angle has a bearing on the life of the electrode. For tip diameters up to and including 2·5 mm (or $\frac{5}{16}$ in) an included angle of 120° is recommended. For tip diameters greater than 2·5 mm (or $\frac{5}{16}$ in) an included angle of 140° is recommended.

C-5. COOLING

C-5.1 In order to avoid softening of the electrode it shall be water-cooled. The water hole diameter should be not greater than $\frac{2}{3}D$ but preferably $\frac{1}{2}D$, D being the diameter of the electrode at the large end of the taper of the shank. The maximum distance between the end of the water cooling hole and the tip of the electrode shall be not more than 13·0 mm (or 0·50 in). The distance between the tip of water inlet tube and the blind end of the water hole shall not exceed 13·0 mm (or 0·50 in). The arrangement should be such as to allow a minimum quantity of 7 litres (or 1·5 gal) of water to pass per minute through each circuit of each machine.

APPENDIX D

(*Clause* 8.7)

TYPICAL DESIGN OF A SPOT-WELDED JOINT

D-1. TYPICAL DESIGN OF A SPOT-WELDED JOINT IN METRIC UNITS

D-1.1 It is required to spot weld together two plates, each 2·5 mm thick to obtain the full strength from the joint (*see* Fig. 4).

D-1.2 Diameter of Weld — From Table II the weld diameter is taken as 8·0 mm for a plate thickness of 2·5 mm.

D-1.3 Number of Welds Required per cm Width of Joint — Safe load per weld at 800 kg/cm² on the area corresponding to 8·0 mm diameter is 400 kg (*see* Table II).

Safe load in tension of 1 cm width of plate at 1 250 kg/cm² on the area $1 \times 0{\cdot}25$ cm² is 315 kg.

To develop full strength of plate, number of welds required per cm width $= \frac{315}{400} = 0{\cdot}79$.

D-1.4 Spacing of Welds and Edge Distance — (*see* Table II and **8.4**)

minimum pitch $= 3 \times 8{\cdot}0$ mm
$= 24$ mm

Two rows of welds at a pitch of 25 mm give a little over 0·79 welds per cm and are satisfactory.

Minimum distance between rows $= 25 \text{ mm} \times \sin 60°$
$= 0{\cdot}87 \times 25$ mm
$= 21{\cdot}8$ mm, say 22 mm.

D-1.5 Minimum edge distance $= 1{\cdot}5 \times 8{\cdot}0$ mm $= 12$ mm (*see* **8.5**). But as per Table II minimum edge distance will have to be 12·5 mm.

D-1.6 The finished arrangement of a portion of the joint, based on this design, is shown in Fig. 4.

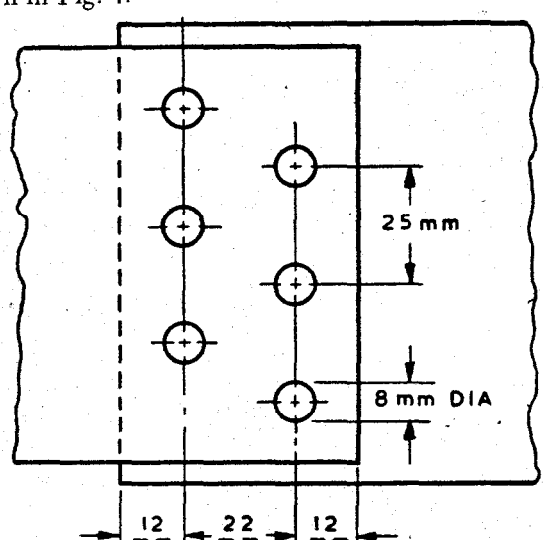


FIG. 4 TYPICAL ARRANGEMENT OF JOINT

(*Continued from page* 2)

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