

Arc welding power sources equipment and accessories

Part 4. Specification for welding cables

ICS 25.160.30

Committees responsible for this British Standard

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British Cable Makers' Confederation
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Health and Safety Executive
Institution of Electrical Engineers
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Foreword

This Part of BS 638 has been prepared by Technical Committee WEE/6. It supersedes BS 638 : Part 4 : 1979, which is withdrawn.

This Part is divided into three sections:

- a general section;
- a section implementing the European Harmonization Document HD 22.6 S2;
- a section on cables of national interest in the United Kingdom and not included in HD 22.6 S2.

NOTE. Annex A is a guide to use (and implements Amendment No. 3 of HD 516.S1).

The other Parts of BS 638 are as follows.

Part 5: *Specification for accessories*

Part 7: *Specification for safety requirements for installation and use*

Part 8: *Specification for electrode holders and hand held torches and guns for MIG, MAG and TIG welding*

Part 9: *Specification for power sources for manual arc welding with limited duty*

Part 10: *Specification for safety requirements for arc welding equipment: welding power sources*

The preliminary drafting of this Part of BS 638 was undertaken by the BCMC to whom due acknowledgement is made.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Section 1. General

1.1 Scope

This Part of BS 638 specifies requirements for single core flexible cables carrying the welding current in arc welding circuits.

Section 2 specifies requirements for arc welding cables rated for connection between the industrial arc welding power source and the electrode holder and the workpiece in manual metal-arc welding. These cables are rated at 100 V a.c. r.m.s. and 150 V d.c. This section implements HD 22.6 S2 : 1995 and also includes CENELEC recognized national types.

Section 3 specifies requirements for additional arc welding cables widely used in the United Kingdom. These cables are rated at 100 V a.c. r.m.s. and 150 V d.c. but undergo a higher voltage test and are therefore capable of being used at voltages up to but not exceeding 450 V a.c. r.m.s. or 675 V d.c., provided they are suitably enclosed to protect the covering from damage.

Annex A gives guidance on the selection of the size and type of cables covered by this standard. This annex implements Amendment No. 3 : 1993 to HD 516.S1.

NOTE 1. Recommendations for the protection of personnel from welding hazards and safety precautions concerning arc welding power sources are given in BS 638 : Part 7 and BS 638 : Part 10, to which reference should be made.

NOTE 2. In section 2 and annex A the wording of the harmonized documents has been amended in order to clarify the meaning.

1.2 References

1.2.1 Normative references

This Part of BS 638 incorporates, by dated or undated reference, provisions from other publications. These normative references are made at the appropriate places in the text and the cited publications are listed on the inside back cover. For dated references, only the edition cited applies; any subsequent amendments to or revisions of the cited publication apply to this Part of BS 638 only when incorporated in the reference by amendment or revision. For undated references, the latest edition of the cited publication applies, together with any amendments.

1.2.2 Informative references

This Part of BS 638 refers to other publications that provide information or guidance. Editions of these publications current at the time of issue of this standard are listed on the inside back cover, but reference should be made to the latest editions.

1.3 Definitions

For the purposes of this Part of BS 638, the definitions given in BS 499 : Part 1 and BS 4727 : Part 2 : Group 08 apply, together with the following.

1.3.1 cable

A length of single-stranded covered insulated conductor.

1.3.2 conductor

The conducting portion of a cable consisting of a group of wires assembled together and in contact with each other.

1.3.3 arc welding power source

Equipment for supplying current and voltage with the characteristics required for arc welding and allied processes.

NOTE 1. An arc welding power source may also supply services to other equipment and auxiliaries e.g. auxiliary power, cooling liquid, consumable arc welding electrode and gas to shield the arc and the welding area.

1.3.4 manual metal-arc welding (MMA welding)

Metal-arc welding with straight, covered electrodes of a suitable length and applied by the operator without automatic or semi-automatic means of replacement. No protection in the form of a gas or mixture of gases from a separate source is applied to the arc or molten pool during welding.

1.3.5 automatic welding

Welding in which all the welding parameters are automatically controlled. Manual adjustments may be made between welding operations but not during welding.

1.3.6 semi-automatic welding

Welding in which some of the welding parameters are automatically controlled, but manual guidance is necessary.

1.3.7 duty cycle

The ratio, for a given time interval, of the on-load duration to the total time.

NOTE. This ratio, lying between 0 and 1, may be expressed as a percentage.

1.3.8 single cycle operation

A single on-load period, not exceeding a specified time, followed by a period in which the cable temperature returns to ambient.

NOTE. In this Part of BS 638, the maximum, single on-load period is 5 min and the equipment usage is expressed as a percentage of 5 min.

1.3.9 repeat cycle operation

A periodically switched constant load with an on-load period followed by an off-load period. This cycle is repeated.

1.3.10 type tests

Tests made before supplying cable conforming to this Part of BS 638 on a commercial basis in order to demonstrate satisfactory performance characteristics to meet the intended application.

NOTE. These tests need not be repeated unless changes are made in the cable materials or design which might affect the performance characteristics.

1.3.11 sample tests

Tests made on samples of completed cable, or components taken from a completed cable to verify that the finished products meet the design specifications.

Section 2. Arc welding cables rated at 100 V a.c. r.m.s.

2.1 Code designations

2.1.1 Harmonized types

Designations for harmonized arc welding cables rated at 100 V a.c. r.m.s. are as follows:

- for cables with normal flexibility, HO1N2-D;
- for cables with extra high flexibility, HO1N2-E.

2.1.2 CENELEC recognized national types

Designations for national arc welding cables rated at 100 V a.c. r.m.s. are as follows:

- for cables with RS5 covering and normal flexibility, AO1B-D.
- for cables with RS5 covering and extra high flexibility, AO1B-E.
- for cables with EM5 covering and aluminium conductors, AO1N2-A.
- for cables with RS5 covering and aluminium conductors, AO1B-A.

2.2 Rated voltage

The rated voltage shall not exceed 100 V a.c. r.m.s. between conductors or between conductor and earth.

NOTE. The corresponding d.c. voltage rating for these cables is 150 V.

2.3 Conductors

2.3.1 General

Conductors shall conform to either of the following.

- a) For cables HO1N2-D, HO1N2-E, AO1B-D and AO1B-E. The conductors shall be circular, plain or tinned, annealed copper. They shall conform to BS 6360, and shall be of multiple strand formation as given in table 1 or table 2.
- b) For cables AO1N2-A and AO1B-A. The conductors shall be composed of hard drawn aluminium, or aluminium alloy, wire of multiple strand formation, the wire being plain or metal coated, as given in table 3.

NOTE. The attention of purchasers and users is drawn to the following limitations of aluminium conductors and of most aluminium alloy conductors compared with copper conductors:

- 1) terminations should be suitable for use with the conductors;
- 2) the service life is reduced if the cable is subjected to repeated flexing;
- 3) the conductors are more liable to atmospheric corrosion;
- 4) the cable size is larger for similar electrical properties, which may cause difficulties in mating with other items of equipment manufactured in accordance with this Part of BS 638.

The maximum conductor resistance shall be as given in tables 1 to 3, as applicable.

2.3.2 Diameter of wires

The diameter of the wires in the conductor shall be not greater than that given in tables 1 to 3, as applicable.

NOTE. The conceptual construction number and the nominal diameter of the wires in the conductor given in table 3 are for information only. These formations were assumed in calculating the maximum specified conductor resistances.

2.3.3 Separator

A separator consisting of a suitable material shall be applied around the conductor.

NOTE. Embrittlement or discoloration of this separator after vulcanization of the covering may be disregarded.

2.4 Covering

The covering shall be applied by extrusion around the conductor and consist of two layers.

For coverings in one layer, the covering shall be of rubber compound type EM5 or RS5¹⁾ conforming to BS 7655 : Section 2.4.

NOTE 1. The RS5¹⁾ covering should be grey.

For coverings in two layers, the covering shall comprise an outer layer of rubber compound type EM5 and an inner layer which shall be either of rubber compound type EM5 or rubber compound type EI7 conforming to HD 22.1.S2.

NOTE 2. The ratio of thicknesses of the two layers is not specified.

Full testing shall be carried out on both layers, except where the resulting sample from the inner layer is less than 0.8 mm thick. In this case full testing shall be carried out on the outer layer and only the hot set test shall be carried out on the inner layer.

The thickness of covering shall be as given in tables 1 to 3, as applicable.

2.5 Overall diameter

The overall diameter of the cable shall be as given in tables 1 to 3, as applicable.

2.6 Marking

2.6.1 General

The outer covering shall be marked, by printing, indenting or embossing, with the following:

- a) the appropriate code designation (in accordance with 2.1); and
- b) the cross-sectional area (in mm²) of the conductor.

¹⁾ CENELEC recognized national type.

Conductor		Total radial thickness of covering	Mean overall diameter		Max. conductor resistance per 1000 m at 20 °C	
Nominal cross-sectional area mm ²	Maximum diameter of wires mm		Lower limit mm	Upper limit mm	Tinned wires Ω	Plain wires Ω
10	0.21	2.0	7.7	9.7	1.95	1.91
16	0.21	2.0	8.8	11.0	1.24	1.21
25	0.21	2.0	10.1	12.7	0.795	0.780
35	0.21	2.0	11.4	14.2	0.565	0.554
50	0.21	2.2	13.2	16.5	0.393	0.386
70	0.21	2.4	15.3	19.2	0.277	0.272
95	0.21	2.6	17.1	21.4	0.210	0.206
120	0.51	2.8	19.2	24.0	0.164	0.161
150	0.51	3.0	21.1	26.4	0.132	0.129
185	0.51	3.2	23.1	28.9	0.108	0.106

NOTE. This table applies to both harmonized and CENELEC recognized national types.

Conductor		Total radial thickness of covering	Mean overall diameter		Max. conductor resistance per 1000 m at 20 °C	
Nominal cross-sectional area mm ²	Maximum diameter of wires mm		Lower limit mm	Upper limit mm	Tinned wires Ω	Plain wires Ω
10	0.16	1.2	6.2	7.8	1.95	1.91
16	0.16	1.2	7.3	9.1	1.24	1.21
25	0.16	1.2	8.6	10.8	0.795	0.780
35	0.16	1.2	9.8	12.3	0.565	0.554
50	0.16	1.5	11.9	14.8	0.393	0.386
70	0.16	1.5	13.6	17.0	0.277	0.272
95	0.16	1.8	15.6	19.5	0.210	0.206
120	0.21	1.8	17.2	21.6	0.164	0.161
150	0.21	1.8	18.8	23.5	0.132	0.129
185	0.21	1.8	20.4	25.5	0.108	0.106

NOTE. This table applies to both harmonized and CENELEC recognized national types.

Conductor			Total radial thickness of covering	Mean overall diameter		Max. conductor resistance per 1000 m at 20 °C
Nominal cross-sectional area mm ²	Conceptual construction number ¹⁾ and nominal diameter of wires No./mm	Maximum diameter of wires mm		Lower limit mm	Upper limit mm	
25	154/0.45	0.46	2.0	10.0	13.0	1.25
35	217/0.45	0.46	2.0	11.0	14.5	0.886
50	312/0.45	0.46	2.2	13.0	17.0	0.616
70	437/0.45	0.46	2.4	15.0	19.0	0.440
95	589/0.45	0.46	2.6	17.0	21.5	0.326
120	756/0.45	0.46	2.8	19.0	24.5	0.254
150	925/0.45	0.46	3.0	21.0	26.5	0.208
240	1525/0.45	0.46	3.4	26.0	33.0	0.126

NOTE 1. This table applies to CENELEC recognized national types.
¹⁾ Provided for information only (see 2.3.2).

The marking shall be such that the gap between the end of one complete inscription and the beginning of the next does not exceed 550 mm.

NOTE. For the UK market, cables may be additionally marked by printing, indenting or embossing with:

- 1) the number of the standard and section, i.e. BS 638-4 S2;
- 2) the type of conductor (Cu for copper or Al for aluminium).

2.6.2 Indication of origin

All cables shall be provided with an indication of origin consisting of an identification thread or threads or the continuous marking of the manufacturer's name or trademark.

If coloured threads are used, the colours shall conform to those registered in PD 2379 where applicable. The colours shall be easy to recognize or easily made recognizable, if necessary, by cleaning with a solvent, for example petrol.

The manufacturer's name or trademark shall be marked, if used, either by printing on a separate tape or by printing, indenting or embossing on the covering. The marking shall be regarded as continuous if the gap between the end of one complete inscription and the beginning of the next does not exceed:

- a) 550 mm if the marking is on the covering;
- b) 275 mm in all other cases.

2.7 Voltage test

When tested in accordance with **B.1**, there shall be no voltage breakdown.

2.8 Test under fire conditions

Cables with a type EM5 covering shall conform to BS 4066 : Part 1.

2.9 Static flexibility test

2.9.1 Cables with copper conductors shall be tested in accordance with annex C.

NOTE. The test does not apply to cables with aluminium or aluminium alloy conductors.

The calculated mean value of l' shall be not greater than the maximum value given in table 4.

2.9.2 If the mean value of l' is greater than the value given in table 4, the sample shall be pre-conditioned by the method described in **C.3**. After this pre-conditioning, the sample shall be re-tested in accordance with **C.2** and, for acceptance, shall conform to **2.9.1**.

Table 4. Values of maximum distance in static flexibility test

Nominal cross-sectional area mm ²	Maximum distance l'	
	Class D conductors (normal flexibility) cm	Class E conductors (extra high flexibility) cm
10	65	45
16	65	45
25	65	45
35	75	50
50	75	50
70	80	55
95	90	60
120	110	75
150	130	90
185	150	95

2.10 Test of the resistance to hot particles

The covering of the cables shall not ignite nor be completely penetrated when tested in accordance with annex D using a test voltage of 1000 V a.c. r.m.s. In addition the heated rod shall not have penetrated into the covering so that it contacts the conductor of the cable. If the gases emitted from the covering during the test are flammable, the burning shall not continue for longer than 15 s after the heated rod is removed.

Following this test the cable shall be tested in accordance with **B.1**. There shall be no voltage breakdown.

2.11 Schedule of tests

Tests shall be carried out in accordance with the schedule given in table 5.

²⁾ Marking 'BS 638-4. S2' (BS 638 : Part 4 : Section 2) on or in relation to a product represents a manufacturer's declaration of conformity, i.e. a claim by or on behalf of the manufacturer that the product meets the requirements of the standard. The accuracy of the claim is solely the claimant's responsibility. Such a declaration is not to be confused with third party certification of conformity, which may also be desirable.

Test	Requirements (clause number)	Test method	Test category	
			EM5	RS5
<i>Tests on components:</i>				
conductor construction	2.3	Visual examination	T, S	T, S
conductor resistance	2.3.1	BS 6360	T, S	T, S
separator covering	2.3.3	Visual examination	T, S	T, S
a) material	2.4	BS 7655 : section 2.4 : 1993	T	T
b) thickness	2.4	BS 6469 : section 1.1 : 1992	T, S	T, S
c) overall diameter	2.5	BS 6469 : section 1.1 : 1992	T, S	T, S
<i>Tests on completed cables:</i>				
cable marking	2.6	Visual examination	T, S	T, S
voltage test	2.7	Annex B	T, S	T, S
Under fire conditions: vertical burning (single cable)	2.8	BS 4066 : Part 1 : 1980	T	—
static flexibility (copper conductors only)	2.9	Annex C	T	T
resistance to hot particles	2.10	Annex D	T	T
T = type tests S = sample tests				

Section 3. Arc welding cables rated for use up to 450 V a.c. r.m.s.

3.1 Rated voltage

This cable is recognized for welding duty at voltages to earth not exceeding 100 V a.c. r.m.s. value. This limitation does not however apply to the voltage produced by a superimposed high frequency supply or other similar low power device used for starting or stabilizing an arc. When required the cable may be used at voltages above 100 V a.c. r.m.s. but not exceeding 450 V a.c. r.m.s. and, in these cases, it shall be adequately protected from damage to the covering.

NOTE. the corresponding d.c. voltage ratings for these cables is 150 V and 675 V.

3.2 Conductors

3.2.1 General

The conductors shall be circular, plain or tinned, annealed copper. Flexible conductors shall comply with BS 6360, and shall be of multiple strand formation as given in table 6.

Alternatively, the conductors shall be composed of hard drawn aluminium, or aluminium alloy, wire of multiple strand formation, the wire being plain or metal coated, as given in table 7.

NOTE. The attention of purchasers and users is drawn to the following limitations of aluminium conductors and of most aluminium alloy conductors compared with copper conductors:

- 1) terminations should be suitable for use with the conductors;
- 2) the service life is reduced if the cable is subjected to repeated flexing;
- 3) the conductors are more liable to atmospheric corrosion;
- 4) the cable size is larger for similar electrical properties, which may cause difficulties in mating with other items of equipment manufactured in accordance with BS 638.

The maximum conductor resistance shall be as given in tables 6 and 7, as applicable.

3.2.2 Diameter of wires

The diameter of the wires in the conductor shall be not greater than that given in tables 6 and 7, as applicable.

NOTE. The conceptual construction number and nominal diameter of the wires in the conductor, given in table 7, are for information only. These formations were assumed in calculating the maximum specified conductor resistances.

3.2.3 Separator

A separator consisting of a suitable material shall be applied around the conductor.

NOTE. Embrittlement or discoloration of this separator after vulcanization of the covering may be disregarded.

3.3 Covering

The cables shall have a covering consisting of an outer layer of EM5 sheathing compound conforming to BS 7655 : Section 2.4 or RS3 sheathing compound conforming to BS 7655 : Section 2.3. They shall have an inner layer of GP4 insulating compound conforming to BS 7655 : Section 1.2.

NOTE 1. When these cables are used at voltages above 100 V a.c. r.m.s. but not exceeding 450 V a.c. r.m.s. they should be suitably enclosed to protect them from damage to the covering.

NOTE 2. The outer layer should be orange or black.

The thickness of covering shall be as given in tables 6 and 7, as applicable.

The mean total radial thickness of covering shall be not less than the value in table 6 or table 7, as applicable, and the smallest measured value shall not fall below the tabulated value by more than $15\% + 0.1$ mm, i.e. the smallest measured value (in mm) shall be not less than:

$$t_v - \left(\frac{t_v \times 15}{100} + 0.1 \right)$$

where

t_v is the tabulated value (in mm).

In composite coverings the outer layer shall be 60 % to 80 % of the total thickness.

3.4 Overall diameter

The overall diameter of the cable shall be as given in table 6 or table 7, as applicable.

3.5 Marking

3.5.1 The outer covering of all types shall be marked, by printing, indenting or embossing, with:

- a) the number of the standard and section, i.e. BS 638-4.S3³⁾;
- b) the numerical value of the nominal area of the conductor in square millimetres; and
- c) the type of conductor (Cu for copper or Al for aluminium).

The marking shall be such that the gap between the end of one complete inscription and the beginning of the next does not exceed 550 mm.

³⁾ Marking 'BS 638-4.S3' (BS 638 : Part 4 : Section 3) on or in relation to a product represents a manufacturer's declaration of conformity, i.e. a claim by or on behalf of the manufacturer that the product meets the requirements of the standard. The accuracy of the claim is solely the claimant's responsibility. Such a declaration is not to be confused with third party certification of conformity, which may also be desirable.

3.5.2 Indication of origin

All cables shall be provided with an indication of origin consisting of an identification thread or threads or the continuous marking of the manufacturer's name or trademark.

If coloured threads are used, the colours shall conform to those registered in PD 2379 where applicable. The colours shall be easy to recognize or easily made recognizable, if necessary, by cleaning with a solvent, for example petrol.

The marking of the manufacturer's name or trademark, if used, shall be either by printing on a separate tape or by printing, indenting or embossing on the covering. The marking shall be regarded as continuous if the gap between the end of one complete inscription and the beginning of the next does not exceed:

- a) 550 mm if the marking is on the covering;
- b) 275 mm in all other cases.

3.6 Voltage test

When tested in accordance with B.2.1 or B.2.2 there shall be no voltage breakdown.

3.7 Test under fire conditions

Cables shall conform to BS 4066 : Part 1.

3.8 Static flexibility test

3.8.1 Cables with copper class D conductors shall be tested in accordance with annex C.

NOTE. The test does not apply to cables with aluminium or aluminium alloy conductors.

The calculated mean value of l' shall be not greater than the maximum value given in table 4.

3.8.2 If the calculated mean value of l' is greater than the value given in table 4, the sample shall be pre-conditioned by the method described in C.3. After this pre-conditioning, the sample shall be re-tested in accordance with C.2 and, for acceptance, shall conform to 3.8.1.

3.9 Test of the resistance to hot particles

The covering of the cables shall not ignite nor be completely penetrated when tested in accordance with annex D using a test voltage of 3000 V a.c. r.m.s. In addition, the heated rod shall not have penetrated into the covering so that it contacts the conductor of the cable. If the gases emitted from the covering during the test are flammable, the burning shall not continue for longer than 15 s after the heated rod is removed.

Following this test, the cable shall be tested in accordance with B.1. There shall be no voltage breakdown.

3.10 Schedule of tests

Tests shall be carried out in accordance with the schedule given in table 8.

Table 6. Constructional details of cables with flexible copper conductors

Conductor		Total radial thickness of covering mm	Mean overall diameter		Max. conductor resistance per 1000 m at 20 °C	
Nominal cross-sectional area mm ²	Maximum diameter of wires mm		Lower limit mm	Upper limit mm	Tinned wires Ω	Plain wires Ω
10	0.21	2.0	7.8	10.0	1.95	1.91
16	0.21	2.0	9.0	11.5	1.24	1.21
25	0.21	2.0	10.0	13.0	0.795	0.780
35	0.21	2.0	11.5	14.5	0.565	0.554
50	0.21	2.2	13.0	17.0	0.393	0.386
70	0.21	2.4	15.0	19.0	0.277	0.272
95	0.21	2.6	17.5	21.5	0.21	0.206
120	0.51	2.8	19.5	24.0	0.164	0.161
150	0.51	3.0	21.5	26.0	0.132	0.129
185	0.51	3.2	23.0	29.0	0.108	0.106

Conductor			Total radial thickness of covering	Overall diameter		Max. conductor resistance per 1000 m at 20 °C
Nominal cross-sectional area	Conceptual construction number ¹⁾ and nominal diameter of wires	Maximum diameter of wires		Lower limit	Upper limit	
mm ²	No./mm	mm	mm	mm	mm	Ω
25	154/0.45	0.46	2.0	10.0	13.0	1.25
35	217/0.45	0.46	2.0	11.0	14.5	0.886
50	312/0.45	0.46	2.2	13.0	17.0	0.616
70	437/0.45	0.46	2.4	15.0	19.0	0.440
95	589/0.45	0.46	2.6	17.0	21.5	0.326
120	756/0.45	0.46	2.8	19.0	24.5	0.254
150	925/0.45	0.46	3.0	21.0	26.5	0.208
240	1525/0.45	0.46	3.4	26.0	33.0	0.126

¹⁾ Provided for information only (see note to 3.2.2).

Test	Requirements (clause number)	Test method	Test category
<i>Tests on components:</i>			
Conductor construction	3.2	Visual examination	T, S
Separator	3.2.3	Visual examination	T, S
<i>Covering:</i>			
a) material	3.3	BS 7655 : Sections 1.2, 2.3 and 2.4 : 1993	T
b) thickness	3.3	BS 6469 : section 1.1 : 1992	T, S
c) overall diameter	3.4	BS 6469 : section 1.1 : 1992	T, S
<i>Tests on completed cables</i>			
Conductor resistance	3.2.1	BS 6360 : 1991	T, S
Cable marking	3.5	Visual examination	T, S
Voltage test	3.6	Annex B	T, S
Under fire conditions: vertical burning (single cable)	3.7	BS 4066 : Part 1 : 1980	T
Static flexibility(copper conductors only)	3.8	Annex C	T
Resistance to hot particles	3.9	Annex D	T

T = type test
S = sample test

Annexes

Annex A (informative)

Guide to use

A.1 General

The cables specified in this standard are suitable for general use in dry, humid or moist conditions, indoors or outdoors, including industrial and agricultural locations, construction sites and shipyards.

The information in A.2 to A.4 is given to assist the user in selecting the most suitable size and type of welding cable.

A.2 Selecting the cable size

A.2.1 General

The cable size is usually chosen on the basis of the current rating at the duty cycle required.

A.2.2 Duty cycle

Welding equipment conforming to BS 638 is rated for repeat cycle operation based on a 10 min period, and the cable should be selected according to this rating (see tables A.1 and A.2). Where the duty cycle of the power source or particular application is not known it can be assumed that for manual welding the duty cycle will be between 35 % to 60 %. Duty cycles of 85 % to 100 % may be achieved in automatic welding.

When authorized by the equipment manufacturer or competent person a repeat cycle based on a 5 min period or 5 min single cycle may be used. Ratings for copper cables and aluminium cables based on these periods are given in tables A.3, A.4, A.5 and A.6.

For percentage duty cycles not stated in the tables, the next higher percentage duty cycle rating should be used or reference should be made to the cable manufacturer.

A.2.3 Temperature

The current ratings given in the tables are for cables in free air at an ambient temperature of 25 °C and a conductor temperature of 85 °C.

Where the ambient temperature differs from 25 °C, the current should be derated by multiplying it by the appropriate factor shown in table A.7.

NOTE 1. Where cables operate with a conductor temperature of 85 °C, the outer covering may reach 80 °C. Cables operating at this temperature may cause damage to other types of cable coverings and may cause burn injuries if touched. Suitable precautions should be taken to segregate such cables to prevent these hazards.

To allow the operator to handle the cable during use, with suitable gloves, a maximum conductor temperature of 60 °C is advisable.

For arc welding cables in free air at an ambient temperature of 25 °C and a conductor temperature of 60 °C, the ratings in tables A.1, A.3, A.5 and A.6 shall be derated by a factor of 0.76. If the ambient temperature differs from 25 °C, the 60 °C adjusted rating should be further corrected by multiplying it by the appropriate factor shown in table A.8.

A.2.4 Voltage drop

Where long cable runs are involved, it may be necessary to choose the cable size on the basis of the voltage drop. Tables A.9 and A.10 give voltage drop values for both copper and aluminium conductors and three typical conductor temperatures. The values given are for 10 m of cable carrying 100 A. For longer cable lengths and higher currents, the values should be increased pro rata. Excessive voltage drop may result in reduction in the selected welding current and/or deterioration of welding conditions.

The values in tables A.9 and A.10 apply to direct current only. With alternating current the values will be higher, the amount depending on the spacing between the welding and return cables. To minimize the effects of alternating current on voltage drop, the two cables forming the welding circuit should be kept as close together as possible and not coiled.

NOTE. Where cables of an adequate current capacity are not available two or more cables may be used in parallel. These cables should be of the same type, cross-sectional area and length to ensure adequate current sharing. The total nominal area of the cable should be at least equivalent to the values given in the appropriate table.

A.3 Conductor flexibility

Flexible and extra high flexible copper cables are suitable for connections direct to electrode holders for MMA welding. Flexible copper cables are also used for connection to appropriate types of equipment for semi-automatic and automatic welding and, in addition, to connect the work piece to the power source.

Aluminium cables, when used, are subject to fracturing of conductors when repeatedly flexed; they may be difficult to join; they are subject to corrosion; and they are generally less flexible than the equivalent related copper cables. However, they are lighter than copper cables.

A.4 Choice of covering material

A.4.1 Wear resistance

Covering materials specified in this standard have good mechanical properties and will give a satisfactory life under flexing. The actual life obtained from the cable is usually determined by mechanical damage and severe abrasion. Where the cables are used for hand welding and are dragged over rough surfaces or sharp edges, the cable life may be only a few months, but where there is some protection against severe wear and mechanical damage, e.g. where the cable forms part of a welding machine, then the cable may last for many years. Outer coverings of type EM5 or RS3 are generally more durable than those of type RS5 under severe mechanical conditions.

A.4.2 Resistance to oil and greases

Outer coverings of type EM5 or RS3 are resistant to oils, greases, acids, alkalis, and to a wide range of aggressive substances. These covering materials should be chosen when the cables are used in places such as workshops, where they may come into contact with oil, grease etc.

It should be noted that these materials may deteriorate if immersed in oil or other aggressive substances. The amount of deterioration will depend on the type of substance, temperature, and the length of time for which the materials are immersed.

Covering materials consisting of RS5 should not be used where extensive contact is expected with oils, greases and other aggressive substances.

A.4.3 Reduced flame propagation

Outer coverings of type EM5 or RS3 have reduced flame propagation. Covering materials based on RS5 have no reduced flame propagation properties.

A.4.4 Heat resistance

The covering materials in this standard are suitable for a normal working life at a maximum working temperature of 85 °C. Higher operating temperatures will shorten the life of the cable.

The specified covering materials are resistant to weld spatter.

A.4.5 Low temperature flexibility

Most materials become less flexible as the temperature is reduced. It is generally considered that the cables specified in this standard can be used down to the temperatures given in table A.11.

A wide range of materials has been, and is being, used for welding cable coverings. The materials specified in this standard are crosslinked elastomeric compounds which are considered to have the best thermal properties for flexible cable coverings for welding. PVC is not recommended for use as a welding cable covering as it can become stiff and brittle at temperatures around 0 °C and, as with other thermoplastic coverings, it can also be easily damaged by contact with hot metal or hot particles.

Table A.1 Current rating for repeat cycle operation based on a 10 min period (copper conductors)

Current rating at various duty cycles							
Nominal cross-sectional area mm ²	100 %	85 %	80 %	60 %	35 %	20 %	8 %
	A	A	A	A	A	A	A
10	100	100	100	101	106	118	158
16	135	136	136	139	150	174	243
25	180	182	183	190	213	254	366
35	225	229	231	243	279	338	497
50	285	293	296	316	371	457	681
70	355	367	373	403	482	602	908
95	430	448	456	498	606	765	1164
120	500	524	534	587	721	917	1404
150	580	610	622	689	853	1090	1676
185	665	702	717	797	995	1277	1971

Table A.2 Current rating for repeat cycle operation based on 10 min period (aluminium conductors)

Nominal cross-sectional area mm ²	100 %	85 %	80 %	60 %	35 %	20 %	8 %
	A	A	A	A	A	A	A
25	140	141	141	144	155	179	250
35	175	177	177	183	203	239	341
50	225	228	230	240	272	326	474
70	275	282	284	302	351	430	637
95	335	345	350	376	446	553	830
120	390	404	410	444	534	669	1011
150	455	474	482	525	637	803	1220
240	600	632	645	714	886	1134	1744

Current rating at various duty cycles							
Nominal cross-sectional area mm ²	100 %	85 %	80 %	60 %	35 %	20 %	8 %
	A	A	A	A	A	A	A
10	100	101	102	106	119	143	206
16	135	138	140	148	173	212	314
25	180	186	189	204	244	305	460
35	225	235	239	260	317	400	608
50	285	299	305	336	415	529	811
70	355	375	383	426	531	682	1053
95	430	456	467	523	658	850	1319
120	500	532	545	613	776	1006	1565
150	580	619	634	716	911	1184	1845
185	665	711	729	826	1054	1374	2145

Nominal cross-sectional area mm ²	100 %	85 %	80 %	60 %	35 %	20 %	8 %
	A	A	A	A	A	A	A
25	140	143	145	153	178	218	323
35	175	180	183	196	233	289	433
50	225	234	237	257	310	389	589
70	275	288	293	322	395	502	767
95	335	353	360	399	495	633	975
120	390	412	421	469	587	755	1166
150	455	482	493	552	694	896	1388
240	600	640	656	742	944	1228	1915

Current rating at various duty cycles				
Nominal cross-sectional area mm ²	100 %	85 %	60 %	35 %
	A	A	A	A
10	100	103	108	122
16	135	145	175	230
25	180	195	230	300
35	225	245	290	375
50	285	305	365	480
70	355	385	460	600
95	430	470	560	730
120	500	540	650	850
150	580	630	750	980
185	665	720	860	1120

Current rating at a maximum duty cycle of				
Nominal cross-sectional area mm ²	100 %	85 %	65 %	35 %
	A	A	A	A
25	140	150	180	240
35	175	190	225	295
50	225	245	290	380
70	275	300	355	465
95	335	365	430	570
120	390	425	500	660
150	455	495	590	770
240	600	650	775	1015

Table A.7 Derating factors for a conductor temperature of 85 °C (free air, ambient temperature 25 °C)	
Ambient temperature °C	Factor
30	0.96
35	0.91
40	0.87
45	0.82

Table A.8 Derating factors for a conductor temperature of 60 °C (free air, ambient temperature 25 °C)	
Ambient temperature °C	Factor
30	0.92
35	0.84
40	0.75
45	0.65

Table A.9 Voltage drop in copper conductors at normal and elevated temperatures (for guidance only)			
Nominal cross-sectional area of copper conductor mm ²	D.C. ¹⁾ voltage drop/100 A/10 m of cable at		
	20 °C	60 °C	85 °C
	V	V	V
10	1.950	2.260	2.450
16	1.240	1.430	1.560
25	0.795	0.920	0.998
35	0.565	0.654	0.709
50	0.393	0.455	0.493
70	0.277	0.321	0.348
95	0.210	0.243	0.264
120	0.164	0.190	0.206
150	0.132	0.153	0.166
185	0.108	0.125	0.136

¹⁾ The corresponding values when using a.c. may be much higher, depending on the configuration of the cables.

Table A.10 Voltage drop in aluminium or aluminium alloy conductors at normal and elevated temperatures (for guidance only)			
Nominal cross-sectional area of aluminium conductor mm ²	D.C. ¹⁾ voltage drop/100 A/10 m of cable at		
	20 °C	60 °C	85 °C
	V	V	V
25	1.248	1.45	1.58
35	0.886	1.03	1.12
50	0.616	0.715	0.778
70	0.440	0.511	0.555
95	0.326	0.379	0.411
120	0.254	0.295	0.321
150	0.208	0.242	0.263
240	0.126	0.146	0.159

¹⁾ The corresponding values when using a.c. may be much higher, depending on the configuration of the cables.

Table A.11 Minimum handling temperature for covering materials	
Covering materials (see 2.4 and 3.4)	Temperature °C
EM5	-20
RS5	-40
GP4/RS3	-20
GP4/EM5	-20

Annex B (normative)

Voltage test

B.1 Test for arc welding cables rated at 100 V a.c. r.m.s.

Immerse a sample of cable in water, at $20\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$, for not less than 1 h. Apply the test voltage between the conductor and the water in which the cable is immersed, which shall be earthed, for 15 min. The alternating voltage shall have a frequency in the range of 40 Hz to 60 Hz. Its wave form shall approximate to a sine curve and both half cycles shall be reasonably alike. The r.m.s. value of the applied voltage shall be 1000 V. Increase the voltage gradually and maintain at the full value for 15 min without breakdown.

B.2 Test for arc welding cables rated at 450 V a.c. r.m.s.

B.2.1 Immerse a sample of cable in water, at $20\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$, for not less than 12 h. Apply the test voltage between the conductor and the water in which the cable is immersed, which shall be earthed, for 15 min. The alternating voltage shall have a frequency in the range of 40 Hz to 60 Hz. Its wave form shall approximate to a sine curve and both half cycles shall be reasonably alike. The r.m.s. value of the applied voltage shall be 3000 V. Increase the voltage gradually and maintain at the full value for 5 min without breakdown.

B.2.2 Spark test the cable in accordance with BS 5099 with a test value of 6000 V r.m.s.. The total radial thickness of covering shall be in accordance with tables 6 and 7.

Annex C (normative)

Static flexibility test

C.1 Apparatus

A sample with a length of $3\text{ m} \pm 0.05\text{ m}$ shall be tested using test apparatus, similar to that shown in figure C.1. Two clamps, A and B, shall be located at a height of at least 1.5 m above ground level. Clamp A shall be fixed and clamp B shall move horizontally at the level of clamp A.

C.2 Procedure

Clamp the ends of the sample vertically so that they remain vertical during the test, one end in clamp A, the other in the movable clamp B which shall be at a distance $l = 0.20\text{ m}$ from clamp A.

NOTE. The cable should take approximately the shape indicated by figure C.1 (dotted lines).

Move the movable clamp B away from the fixed clamp A until the loop formed by the cable takes the shape, indicated in figure C.1 by the heavy outline, of the U enclosed wholly between two plumb lines through the clamps and set up tangentially to the external generatrix of the cable. Measure the new distance l' . The cable shall then be turned in the clamps by 180° and the test repeated.

Calculate the mean value of l' .

C.3 Pre-conditioning of non-conforming samples

Wind the sample four times on and off a reel with a diameter approximately 20 times the outer diameter of the cable. Each time the sample shall be turned through 90° .

After this pre-conditioning, the sample shall be subjected to the test described in C.2.

Annex D (normative)

Test of the resistance to hot particles

D.1 Apparatus

D.1.1 *Test device*, as shown in figure D.1, to enable a heated rod, in a horizontal position, to be applied with a given force to a contact point on the outer cover of the cable.

D.1.2 *Rod*, made of 18/8 chrome-nickel steel with a diameter of $2.5\text{ mm} \pm 0.05\text{ mm}$ and a length of $100\text{ mm} \pm 0.5\text{ mm}$.

D.1.3 *Burner*, consisting of a tube which is at least 35 mm long and has a bore $0.5\text{ mm} \pm 0.1\text{ mm}$ and an outer diameter not exceeding 0.9 mm.

NOTE. A hypodermic needle, the tapered end of which is cut off, may be used for the test.

D.2 Procedure

Using the appropriate a.c. r.m.s. voltage, pass an electric current of approximately 25 A through the rod until a steady thermal state at a temperature of $300^{+5}_0\text{ }^{\circ}\text{C}$ is reached.

Measure this temperature by a contact thermometer or thermocouple and maintain the temperature during the whole test period.

Apply the rod to the outer cover of the cable with a force of $1.2^{+0}_{-0.2}\text{ N}$.

Attempt to ignite the gases emitted in the region of the contact point with a burner and flame 100 s after the rod has been applied to the cable, and at 10 s intervals until the end of the test.

The burner shall be supplied with butane or propane gas having a purity of at least 95 %. There shall be no air admitted to the burner tube.

With the axis of the burner in the vertical position, adjust the gas supply so that without artificial air supply, the length of the flame is $12\text{ mm} \pm 1\text{ mm}$.

Continue for 2 min.

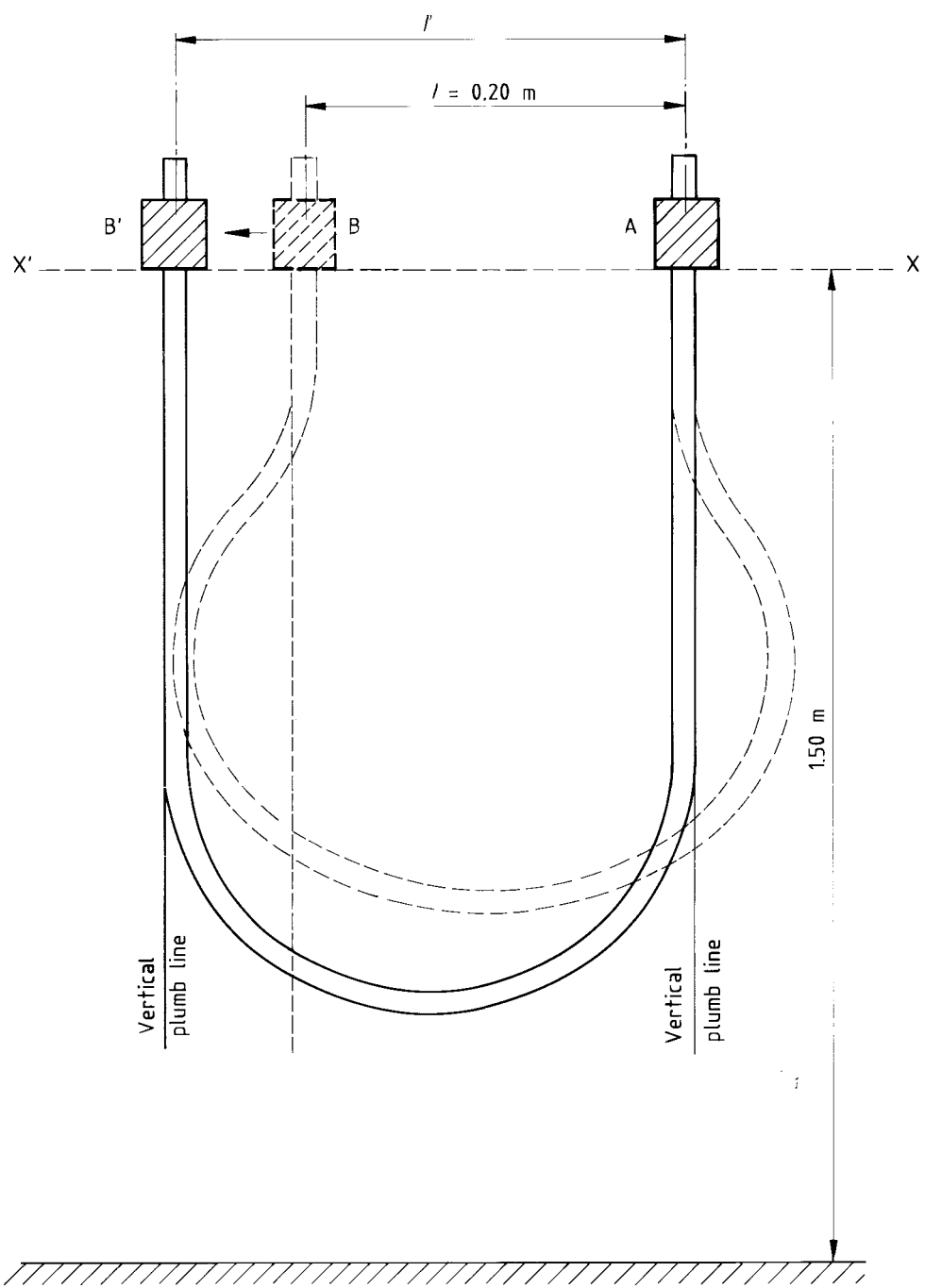
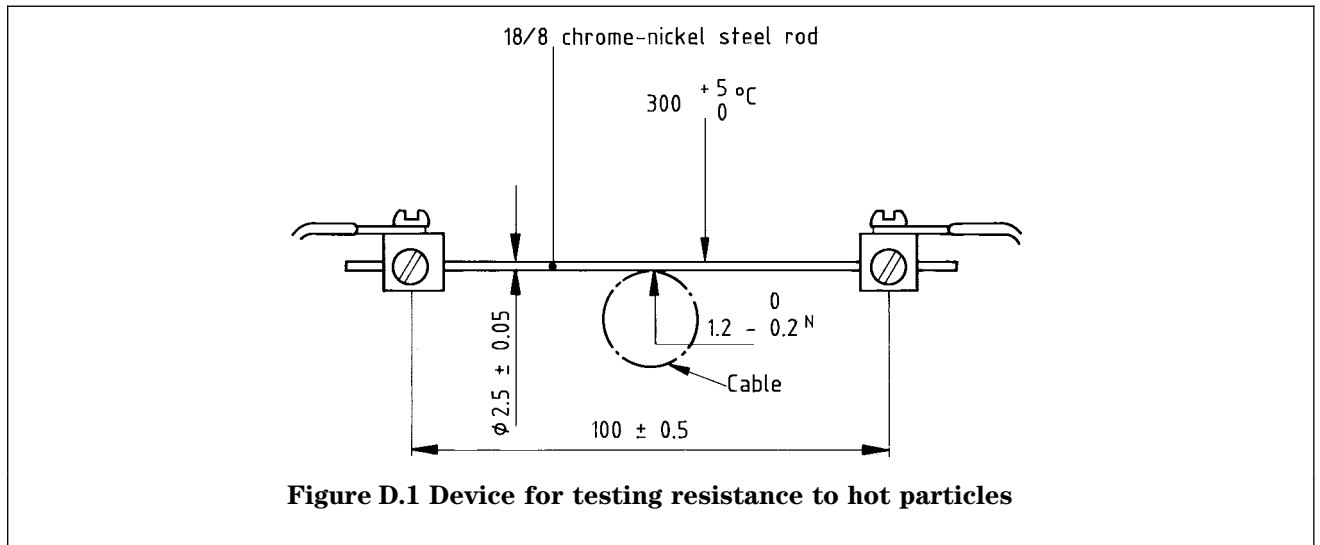


Figure C.1 Static flexibility test apparatus



List of references

Normative references

BSI publications

BRITISH STANDARDS INSTITUTION, London

BS 499	<i>Welding terms and symbols</i>
BS 499 : Part 1 : 1991	<i>Glossary for welding, brazing and thermal cutting</i>
BS 4066	<i>Tests on electric cables under fire conditions</i>
BS 4066 : Part 1 : 1980	<i>Method of test on a single vertical insulated wire or cable</i>
BS 4727	<i>Glossary of electrotechnical power, telecommunication, electronics, lighting and colour terms</i>
BS 4727 : Part 2	<i>Terms particular to power engineering</i>
BS 4727 : Part 2 : 1986 : Group 08	<i>Electric cables</i>
BS 5099 : 1992	<i>Specification for spark testing of electric cables</i>
BS 6360 : 1991	<i>Specification for conductors in insulated cables and cords</i>
BS 6469	<i>Insulating and sheathing materials of electric cables</i>
BS 6469 : Part 1 : Section 1.1 : 1992	<i>Measurement of thickness and overall dimensions. Tests for determining the mechanical properties</i>
BS 7655	<i>Specification for insulating and sheathing materials for cables</i>
BS 7655 : Part 1 : Section 1.2 : 1993	<i>General 90 °C application</i>
BS 7655 : Part 2 : Section 2.3 : 1993	<i>General application</i>
BS 7655 : Part 2 : Section 2.4 : 1993	<i>Welding cable covering</i>
PD 2379 : 1994	<i>Register of colours of manufacturer's identification threads for electric cable and cords</i>

Informative references

BSI publications

BRITISH STANDARDS INSTITUTION, London

BS 638	<i>Arc welding power sources, equipment and accessories</i>
BS 638 : Part 5 : 1988	<i>Specification for accessories</i>
BS 638 : Part 7 : 1984	<i>Specification for safety requirements for installation and use</i>
BS 638 : Part 8 : 1984	<i>Specification for electrode holders and hand-held torches and guns for MIG, MAG and TIG welding</i>
BS 638 : Part 9 : 1990	<i>Specification for power sources for manual arc welding with limited duty</i>
BS 638 : Part 10 : 1990	<i>Specification for safety requirements for arc welding equipment: welding power sources</i>

CENELEC publications

EUROPEAN COMMITTEE FOR ELECTROTECHNICAL STANDARDIZATION (CENELEC), Brussels (All publications are available from Customer Services, BSI.)

HD 22.6 S2 : 1995	<i>Rubber insulated cables of rated voltages up to and including 450/750 V — Part 6: Arc welding cables</i>
HD 22.1 S2 : 1992	<i>Rubber insulated cables of rated voltages up to and including 450/750 V — Part 1: General requirements</i>
HD 516 S1 : 1990	<i>Guide to use of low voltage harmonized cables</i>

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