
British Standard Specification for Electrode wires and fluxes for the submerged arc welding of carbon steel and medium-tensile steel

Fils-électrodes et flux pour soudage à l'arc sous flux en poudre des aciers au carbone
et des aciers à résistance moyenne à la traction — Spécifications

Schweißdrähte und Schweißpulver für das Unterpulverschweißen von unlegiertem
Stahl und von Stahl mit mittlerer Zugfestigkeit

Foreword

This British Standard, prepared under the direction of the Welding Standards Committee, supersedes BS 4165 : 1971 which is withdrawn. It is the second revision since the standard was published in 1967. This present revision extends the scope of the standard to cover the welding of steels such as those introduced in BS 4360 and includes weld impact values appropriate to these steels.

The results of Charpy V-notch impact tests are known to be affected by many factors. Amongst these are the composition of the welding wire and the type of welding flux, the effect of dilution from the parent material, the heat input of the weld which in turn is affected by the welding current, arc voltage and travel speed, and the disposition of the weld runs in a multi-run weld. For this reason it is usual to carry out tests to assess the mechanical properties on all-weld metal test pieces deposited under defined parameters and thus unaffected by the parent metal used in the preparation of the tests.

The submerged arc process can be used to make butt welds by a two-run technique, one run from each side of the joint, with either square or partially bevelled edges with a generous root face. Such are the penetrating properties with this process that a sound weld can be obtained without resort to back gouging. The weld metal deposited in this manner is heavily diluted with parent plate and is likely to provide significantly different properties to that deposited by a multi-run technique which results in low dilution and provides essentially all-weld metal results. To cater for these differences in technique this standard specifies initial weld tests for both multi-run and two-run deposition. These tests are carried out using specified wire sizes and conditions with an appropriate grade of BS 4360 plate. Testing of these welded joints comprises tensile, bend and Charpy V-notch tests and chemical analysis.

It is important to appreciate that, whilst the tests using the two-run technique give results which approximate to those obtained in practice when welds are carried out under the same conditions with equivalent plate material, the test results obtained from the all-weld metal test pieces with the multi-run technique may not relate to a production type joint. Nevertheless, the tests specified are suitable for grading the results obtained from various wire/flux

combinations and enable the fabricator to select a combination which may be appropriate to his production requirements, having regard to the fact that Charpy results from the approval tests may not be representative of those obtained from production joints.

In view of the factors which affect the results obtained from a production situation, it will be advisable for the fabricator to carry out a welding procedure test and reference should be made to BS 4870 : Part 1.

On completion of testing, the wire/flux combination is assigned the appropriate grading code which takes the form of a prefix number related to the impact test temperature, followed by the letters M and/or T to indicate multi-run, two-run or both and finally a three figure number related to tensile properties of the weld metal. For example, a wire/flux combination giving weld metal in a two-run test with an average impact value better than 35 J at -40°C , a tensile strength in the range 400 N/mm² to 600 N/mm² and yield stress above 300 N/mm², would have the grading 4T300.

Manufacturers usually supply a range of wires and fluxes. This standard includes a table of the commonly used wire analyses and a descriptive table of the various types of welding flux. Fluxes are based on various combinations of compounds and the ratio of basic to acidic components in a flux is known as the Basicity Index.

Generally high basicity fluxes tend to give the best impact properties, other factors being equal. This is a complex subject and in all cases where weld metal toughness is important, the user is advised to consult the consumable supplier since the notch toughness of weld metal is a function not only of the flux chemistry but also of the weld metal chemistry and the weld micro-structure.

Although combinations of wires and fluxes supplied by individual companies may have the same grading, the individual wires and fluxes from different companies are not necessarily interchangeable.

It has been assumed in the drafting of this British Standard that the execution of its provisions is entrusted to appropriately qualified and experienced people.

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

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Specification

1 Scope

This British Standard specifies requirements for solid electrode wires and for fluxes for the submerged arc welding of carbon steel and medium-tensile steel having a tensile strength of not more than 700 N/mm², and sulphur and phosphorus contents of not greater than 0.06 % each. The standard specifies general requirements for all wires and fluxes.

Additionally, clause 12 specifies the initial test requirements for wires and fluxes for use with the multi-run technique while clause 13 specifies the initial test requirements for wires and fluxes for use with the two-run technique.

NOTE. The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this standard the definitions given in BS 499 : Part 1 apply together with the following.

2.1 multi-run technique. A technique in which a complete weld is deposited in two or more runs from one or each side of a joint. The consecutive runs on each side of a joint may be deposited from separate wires fed concurrently.

2.2 two-run technique. A technique in which a complete weld is deposited in a single run from each side of a joint, using one or more wires feeding one molten pool.

3 Size of wire

The size of a wire shall refer to the nominal diameter of the wire and shall be expressed in millimetres.

The nominal diameters of wires shall be:

mm
1.6
2.0
2.5
3.0
3.2
4.0
5.0
6.0
6.3

4 Tolerance on diameter of wire

The tolerance on wire diameter shall be $\pm 3\%$ of the specified nominal diameter or ± 0.1 mm, whichever is the smaller.

5 Condition of wire

5.1 Finish

The wire shall have a smooth finish, free from surface imperfections, corrosion products, grease or other substances which would adversely affect the quality of the weld or the operation of the welding equipment.

5.2 Coating

If the wire has a copper or nickel coating it shall be a uniform, well-bonded, smooth coating applied over a thoroughly clean surface. The copper content of a copper coated wire, expressed as a percentage of the wire plus the coating, shall not exceed 0.4 % by mass. For nickel coated wires the total nickel content of the wire plus coating shall not be increased by more than 0.2 % by mass.

5.3 Tensile strength

The tensile strength of the wire shall not exceed 930 N/mm² for carbon steel and shall not exceed 1080 N/mm² for medium-tensile steel.

NOTE. Wires having higher values of tensile strength may be supplied by agreement between the purchaser and manufacturer.

6 Composition of wire

The chemical composition of the wire shall correspond with one of those given in table 1.

NOTE. The composition of certain other ferritic steel submerged arc wires are included in appendix A. It is not intended that these wires be subjected to the tests or grading specified in this standard.

Table 1. Wire composition (% by mass)

Type	Designation	C		Mn		Si		S	P	Ni*		Cr	Mo		Cu*	Al	Sn
		min.	max.	min.	max.	min.	max.	max.	max.	min.	max.	max.	min.	max.	max.	max.	max.
C-Mn	S1	0.04	0.12	0.40	0.65		0.10	0.03	0.03		0.15	0.15		0.15	0.15	0.04	0.03
	S1 Si	0.04	0.12	0.40	0.65	0.05	0.20	0.03	0.03		0.15	0.15		0.15	0.15	0.04	0.03
	S2	0.06	0.15	0.80	1.20		0.10	0.03	0.03		0.15	0.15		0.15	0.15	0.04	0.03
	S2 Si	0.06	0.15	0.80	1.20	0.10	0.35	0.03	0.03		0.15	0.15		0.15	0.15	0.04	0.03
	S3	0.06	0.15	1.30	1.80		0.25	0.03	0.03		0.15	0.15		0.15	0.15	0.04	0.03
	S3 Si	0.06	0.15	1.30	1.80	0.15	0.40	0.03	0.03		0.15	0.15		0.15	0.15	0.04	0.03
	S4	0.07	0.16	1.80	2.20		0.25	0.03	0.03		0.15	0.15		0.15	0.15	0.04	0.03
	S4 Si	0.07	0.16	1.80	2.20	0.10	0.35	0.03	0.03		0.15	0.15		0.15	0.15	0.04	0.03
Mn-Ni	S2-1Ni	0.05	0.12	0.80	1.20	0.05	0.30	0.02	0.02	0.75	1.25	0.15		0.15	0.15	0.04	0.03
	S2-1½Ni	0.05	0.12	0.80	1.20	0.05	0.30	0.02	0.02	1.25	1.75	0.15		0.15	0.15	0.04	0.03
	S2-2Ni	0.05	0.12	0.80	1.20	0.05	0.30	0.02	0.02	1.75	2.25	0.15		0.15	0.15	0.04	0.03
	S2-2½Ni	0.05	0.12	0.80	1.20	0.05	0.30	0.02	0.02	2.25	2.75	0.15		0.15	0.15	0.04	0.03
	S2-3Ni	0.05	0.12	0.80	1.20	0.05	0.30	0.02	0.02	2.75	3.25	0.15		0.15	0.15	0.04	0.03
	S3-1Ni	0.05	0.12	1.30	1.70	0.05	0.30	0.02	0.02	0.75	1.25	0.15		0.15	0.15	0.04	0.03
	S3-1½Ni	0.05	0.12	1.30	1.70	0.05	0.30	0.02	0.02	1.25	1.75	0.15		0.15	0.15	0.04	0.03
NiMo	S2-1NiMo	0.07	0.15	0.80	1.20	0.05	0.30	0.02	0.02	0.75	1.25	0.15	0.10	0.50	0.15	0.04	0.03
	S3-1NiMo	0.07	0.15	1.30	1.80	0.05	0.30	0.02	0.02	0.75	1.25	0.15	0.45	0.65	0.15	0.04	0.03
	S3-1½NiMo	0.07	0.15	1.30	1.80	0.05	0.30	0.02	0.02	1.25	1.75	0.15	0.45	0.65	0.15	0.04	0.03
	S4-1NiMo	0.10	0.17	1.80	2.20	0.05	0.30	0.02	0.02	0.75	1.10	0.15	0.45	0.65	0.15	0.04	0.03
Mn-Mo	S1 Mo	0.07	0.15	0.40	0.65	0.05	0.30	0.025	0.025		0.15	0.15	0.45	0.65	0.15	0.04	0.03
	S2 Mo	0.07	0.15	0.80	1.20	0.05	0.30	0.025	0.025		0.15	0.15	0.45	0.65	0.15	0.04	0.03
	S3 Mo	0.07	0.15	1.30	1.70	0.05	0.30	0.025	0.025		0.15	0.15	0.45	0.65	0.15	0.04	0.03
	S4 Mo	0.07	0.15	1.70	2.20	0.05	0.30	0.025	0.025		0.15	0.15	0.45	0.65	0.15	0.04	0.03
* Excluding coating if any.																	

7 Coils

Wire shall be supplied in coils or pay-off packs having dimensions and masses as given in table 2.

8 Coiling conditions

The wire shall be wound evenly in one continuous length and shall be free from kinks, waves, sharp bends or twists, so that it is free to unwind without restriction.

The starting end of the wire on each coil shall be clearly indicated.

9 Flux

The flux shall be free flowing and when used in conjunction with an appropriate wire and in accordance with the manufacturer's recommendations, shall have such characteristics as to produce welds having acceptable contour, appearance and penetration.

Appendix B provides guidance on flux types and characteristics.

10 Testing and grading

The wires and fluxes shall be capable of complying in all respects with the appropriate requirements and tests in this standard. In particular wire and flux combinations which are suitable for multi-run, two-run techniques or both shall

be tested initially in accordance with the tests in clauses 12 and 13, as appropriate. Wire-flux combinations suitable for use on either a.c. or d.c. shall be tested on a.c. In all cases the type of current used in the tests shall be reported.

On satisfactory completion of these tests the flux and wire combinations shall be graded as complying with this standard using the grades listed under clauses 12 and 13.

The grade number is made up of three parts: a prefix number related to impact testing temperature, the letters M or T indicating multi- or two-run techniques and a three figure suffix related to minimum yield stress in N/mm², e.g.:

Grade 2	M	350
Test temperature of 0 °C	Multi-run	Minimum yield stress of 350 N/mm ² (tensile strength 460 N/mm ² to 650 N/mm ²)

Where both M and T gradings are approved for a particular wire/flux combination the grade numbers shall be given separately, e.g.:

3M450/1T450

11 Initial tests

These comprise the initial tests to which each type of wire and flux shall be subjected. Although it is not expected that every batch of wire and flux will be subjected to the initial tests the manufacturer shall ensure that every batch is capable of passing the whole of the test requirements.

NOTE. The purchaser may require that some or all of the tests are carried out on batches supplied to him (see clause 14).

Table 2. Dimensions of coils and pay-off packs of wire

Outer diameter (max.)	Inner diameter of bound coil with no former	Inner diameter of bound former	Width (max.)	Depth (max.)	Mass of wire (max.)
mm	mm	mm	mm	mm	kg
<i>Coils</i>					
300	200 ⁺⁵ / ₀	200 ⁺¹ / ₀	90	—	13
420	300 ⁺⁵ / ₀	300 ⁺¹ / ₀	80	—	25
420	300 ⁺⁵ / ₀	300 ⁺¹ / ₀	100	—	30
420	300 ⁺⁵ / ₀	300 ⁺¹ / ₀	115	—	30
760	610 ± 10	610 ± 10	100	—	70
760	610 ± 10	610 ± 10	100	—	100
760	610 ± 10	610 ± 10	150	—	100
<i>Pay-off packs</i>					
600	—	—	—	900	400

12 Initial test requirements for multi-run technique

12.1 All-weld tensile test

Two all-weld tensile test specimens, one using 3.2 mm or less diameter wire and one using the largest size of wire submitted for approval, shall be prepared and tested in accordance with appendix D. The tensile strength, yield stress and elongation shall comply with the appropriate grade requirements.

12.2 All-weld impact test

Six Charpy V-notch impact test specimens, three using 3.2 mm or less diameter wire and three using the largest size of wire submitted for approval, shall be prepared and tested in accordance with appendix D. The test results shall comply with the appropriate grade requirements.

If the average of the three impact values from either set of specimens fails to comply with the requirements by an amount not exceeding 15 % of the required value, the test shall be repeated on a further set of three specimens taken from the original test piece and the results added to those previously obtained to form a new average which shall comply with the requirements.

When the average of the three impact values from either set of specimens is more than 15 % below the required value, the requirements of clause 15 shall apply.

12.3 Chemical composition*

The percentage contents of carbon, manganese, silicon, sulphur, phosphorus, nickel†, molybdenum† and copper in

the deposited weld metal from the all-weld test piece shall be reported. The sulphur and phosphorus contents shall comply with the appropriate grade requirements.

12.4 Transverse tensile test

Two transverse tensile test specimens, one using 3.2 mm or less diameter wire and one using the largest size of wire submitted for approval, shall be prepared and tested in accordance with appendix E.

The tensile strength of each test specimen shall comply with the appropriate grade requirements.

12.5 Transverse bend test

Four transverse bend test specimens, two using 3.2 mm or less diameter wire and two using the largest size of wire submitted for approval, shall be prepared and tested in accordance with appendix E. One specimen of each pair shall be tested with the face of the weld in tension and the other specimen with the root of the weld in tension.

Specimens shall satisfy the test if, on completion of the test no crack or defect at the outer surface of the test specimen is greater than 3 mm measured across the test specimen or 1.6 mm measured along the length of the test specimen. Premature failure at the corners of the test specimen shall not be considered cause for rejection.

12.6 Requirements for M300 grades

The test results for M300 grades shall comply with table 3 as appropriate.

Table 3. M300 grade requirements								
Grade	All-weld tensile test			All-weld impact test		All-weld test piece composition		Transverse tensile strength (min.)
	Tensile strength	Yield stress (min.)	Elongation (min.)	Minimum impact value (average of three values)	Testing temperature	Sulphur (max.)	Phosphorus (max.)	
	N/mm ²	N/mm ²	%	J	°C	%	%	N/mm ²
1M300	400 to 600	300	22	35	20 approx.	0.05	0.05	400
2M300	400 to 600	300	22	35	0 ± 1	0.05	0.05	400
3M300	400 to 600	300	22	35	-20 ± 1	0.05	0.05	400
4M300	400 to 600	300	22	35	-40 ± 1	0.05	0.05	400
5M300	400 to 600	300	22	35	-50 ± 1	0.05	0.05	400
6M300	400 to 600	300	22	35	-60 ± 1	0.05	0.05	400

* See BS Handbook No. 19.

† Where appropriate.

12.7 Requirements for M350 grades

The test results for M350 grades shall comply with table 4 as appropriate.

Table 4. M350 grade requirements								
Grade	All-weld tensile test			All-weld impact test		All-weld test piece composition		Transverse tensile strength (min.)
	Tensile strength	Yield stress (min.)	Elongation (min.)	Minimum impact value (average of three values)	Testing temperature	Sulphur (max.)	Phosphorus (max.)	
	N/mm ²	N/mm ²	%	J	°C	%	%	N/mm ²
1M350	460* to 650	350	22	40	20 approx.	0.05	0.05	500
2M350	460* to 650	350	22	40	0 ± 1	0.05	0.05	500
3M350	460* to 650	350	22	40	-20 ± 1	0.05	0.05	500
4M350	460* to 650	350	22	40	-40 ± 1	0.05	0.05	500
5M350	460* to 650	350	22	40	-50 ± 1	0.05	0.05	500
6M350	460* to 650	350	22	40	-60 ± 1	0.05	0.05	500

* The lower limit of the range of tensile strength has been reduced from the minimum value specified for the transverse tensile test since with the type of weld preparation used for the all-weld test pieces, dilution from the parent metal is less.

12.8 Requirements for M450 grades

The test results for M450 grades shall comply with table 5 as appropriate.

Table 5. M450 grade requirements								
Grade	All-weld tensile test			All-weld impact test		All-weld test piece composition		Transverse tensile strength (min.)
	Tensile strength	Yield stress (min.)	Elongation (min.)	Minimum impact value (average of three values)	Testing temperature	Sulphur (max.)	Phosphorus (max.)	
	N/mm ²	N/mm ²	%	J	°C	%	%	N/mm ²
1M450	520* to 700	450	19	45	20 approx.	0.04	0.04	550
2M450	520* to 700	450	19	45	0 ± 1	0.04	0.04	550
3M450	520* to 700	450	19	45	-20 ± 1	0.04	0.04	550
4M450	520* to 700	450	19	45	-40 ± 1	0.04	0.04	550
5M450	520* to 700	450	19	45	-50 ± 1	0.04	0.04	550
6M450	520* to 700	450	19	45	-60 ± 1	0.04	0.04	550

* The lower limit of the range of tensile strength has been reduced from the minimum value specified for the transverse tensile test since with the type of weld preparation used for the all-weld test pieces, dilution from the parent metal is less.

13 Initial test requirements for two-run technique

13.1 Longitudinal weld tensile test*

Two tensile test specimens, one using 3.2 mm or less diameter wire and one using the largest size of wire submitted for approval, shall be prepared and tested in accordance with appendix F. The tensile strength, yield stress and elongation shall comply with the appropriate grade requirements.

13.2 Impact test

Six Charpy V-notch impact test specimens, consisting wholly of deposited metal in the region of the notch, three using 3.2 mm or less diameter wire and three using the largest size of wire submitted for approval, shall be prepared and tested in accordance with appendix F. The test results shall comply with the appropriate grade requirements.

If the average of the three impact values from either set of specimens fails to comply with the requirements by an amount not exceeding 15 % of the required value, the test shall be repeated on a further set of three specimens taken from the original test piece and the results added to those previously obtained to form a new average which shall comply with the requirements.

When the average of the three impact values from either set of specimens is more than 15 % below the required value, the requirements of clause 15 shall apply.

13.3 Transverse tensile test

Two transverse tensile test specimens, one using 3.2 mm or less diameter wire and one using the largest size of wire

submitted for approval, shall be prepared and tested in accordance with appendix F.

The tensile strength of each test specimen shall comply with the appropriate grade requirements.

13.4 Transverse bend test

Four transverse bend test specimens, two using 3.2 mm or less diameter wire and two using the largest size of wire submitted for approval, shall be prepared and tested in accordance with appendix F. One specimen from each test piece shall be tested with the first side welded in tension and one specimen with the second side welded in tension. Specimens shall satisfy the test if, on completion of the test, no crack or defect at the outer surface of the test specimen is greater than 3 mm measured across the test specimen or 1.6 mm measured along the length of the test specimen. Premature failure at the corners of the test specimen shall not be considered cause for rejection.

13.5 Chemical composition†

An all-weld test piece of the form shown in figure 1 shall be prepared for the purpose of obtaining the chemical composition of the deposited weld metal. The percentage contents of carbon, manganese, silicon, sulphur and phosphorus shall be reported. The sulphur and phosphorus contents shall comply with the appropriate grade requirements.

13.6 Requirements for T300 grades

The test results for T300 grades shall comply with table 6 as appropriate.

Table 6. T300 grade requirements								
Grade	Longitudinal weld tensile test			Impact test		Transverse tensile strength (min.)	All-weld test piece composition	
	Tensile strength	Yield stress (min.)	Elongation (min.)	Minimum impact value (average of three values)	Testing temperature		Sulphur (max.)	Phosphorus (max.)
	N/mm ²	N/mm ²	%	J	°C	N/mm ²	%	%
1T300	400 to 600	300	22	35	20 approx.	400	0.05	0.05
2T300	400 to 600	300	22	35	0 ± 1	400	0.05	0.05
3T300	400 to 600	300	22	35	-20 ± 1	400	0.05	0.05
4T300	400 to 600	300	22	35	-40 ± 1	400	0.05	0.05

* This test is not required if the particular wire/flux combination is also submitted and approved for use with the multi-run technique. The results obtained from this test should not be compared with the results from an all-weld tensile test prepared by the multi-run technique.

† This test is not required if the particular wire/flux combination is also submitted for approval for use with the multi-run technique. See BS Handbook No. 19.