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British Standard Specification for
**Covered carbon and carbon manganese steel
electrodes for manual metal-arc welding**

Electrodes enrobées en acier au carbone et au carbone manganèse pour soudage manuel à l'arc —
Spécifications

Umhüllte Stabelektroden aus Kohlenstoff- und Kohlenstoff-Mangan-Stählen
zum Metalllichtbogenhandschweißen

British Standards Institution

BS 639 : 1986

Foreword

This British Standard has been prepared under the direction of the Welding Standards Committee and supersedes BS 639 : 1976 which is withdrawn.

During the periodic review of the standard, when the opportunity was taken to consult all the contributing organizations, a majority was in favour of retaining the basic format and classification system of BS 639 but of subjecting the content to appropriate technical update, clarification and extension. Questions of principle were reconsidered during the preparation of this revision and the eventual consensus to make no fundamental changes was set against the background of the international activities regarding the classification of electrodes. The 1976 edition of BS 639 implemented ISO 2560 which the United Kingdom had supported and it was felt that any change from this standpoint should be deferred until the outcome of further international work in hand is known. Within this consideration, note was also taken of the extensive use of the American Welding Society (AWS) classification system but it was decided not to propose a metricated version of this system since the information it provides is in general less complete and does not give sufficient differentiation between electrodes of identical classification but of significantly different impact strength. The United Kingdom will continue to participate in the relevant international standards work in an endeavour to achieve a classification system that is adopted worldwide. The situation internationally, as it then is, will be reviewed at the time of any proposed changes to BS 639.

Low alloy steel electrodes and chromium and chromium nickel steel electrodes are covered in BS 2493 and BS 2926 and therefore the title of this standard has been modified to reflect that only carbon and carbon manganese steel electrodes are covered in BS 639.

Ordering electrodes complying with this standard gives an assurance of electrode quality and the classification has significance to the fabricator as a first step in selecting electrodes that may be suitable for a particular production joint. It should be noted that the impact and tensile strength of all-weld test specimens used to classify the electrodes will vary from those obtained in production joints because of differences in welding procedure such as electrode size, width of weave, welding position and material composition. The user is therefore advised to carry out welding procedure tests if notch toughness criteria have to be satisfied and these tests should be representative of the appropriate production joints as specified in BS 4870 : Part 1. Furthermore if a fabrication is to be heat treated after welding a similar post-weld heat

treatment should be applied to the welding procedure test pieces because heat treatment can affect both the tensile and impact strength.

This standard provides a classification system for electrodes using the criteria specified in the standard. Different manufacturers may have a number of electrodes with identical or very similar classifications and the user's choice may depend upon other factors such as ease of use, deslagging or welder appeal (weldability). Electrodes bearing identical codings may be expected to have generally similar characteristics and properties, even if made by different manufacturers, but some differences may exist between such electrodes. The selection of electrodes should be made on the basis of the particular application and the user should consult the electrode manufacturer or other appropriate authoritative sources for guidance.

If the classifications of this standard are used for purchasing it should be made clear that they represent minimum requirements since electrodes with higher toughness properties than the minimum required may also be appropriate for use on a production joint. Furthermore the manufacturer's brand name or identification number should also be quoted.

Electrode manufacturers have to comply with two different criteria for impact strength, a minimum average of 28 J for ISO 2560 and a minimum average of 47 J to meet the requirements of the unified rules of the classification societies. These different requirements are the origin of the two digits for impact strength in BS 639. In this revision the two digits for impact strength have been retained but the tables showing the requirements have been simplified and in table 3 has been extended to lower temperatures. The method of weld metal deposition has been modified to ensure greater uniformity of results. The method for the determination of diffusible hydrogen content has also been modified and is now published separately as BS 6693 : Part 2.

Since this standard has been updated from a technical aspect it is possible that the classification of some electrodes will differ from BS 639 : 1976 but this does not necessarily signify any change in the electrode itself. In cases where clarification is needed the electrode manufacturer should be consulted.

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 covered carbon and carbon manganese steel electrodes for manual metal-arc welding depositing weld metal having a tensile strength of not more than 650 N/mm².

NOTE 1. As this standard is primarily concerned with the mechanical properties of weld metal no limits are placed on chemical composition of weld metals (but see clause 2(e)). If weld metal with tensile strength higher than 650 N/mm² is required, reference should be made to BS 2493 or BS 2926.

NOTE 2. The titles of the publications referred to in this standard are listed on the inside back cover.

2 Information to be supplied by the purchaser

When ordering electrodes that comply with the requirements of this standard, purchasers shall state:

- the number and date of this British Standard, i.e. BS 639 : 1986;
- the electrode classification (see clause 3), at least the strength, toughness and covering (STC) code and/or the manufacturer's trade designation;

NOTE. The continuity of a trade designation is not an assurance that the electrode classification is unchanged.

- whether a test certificate for the initial tests or for the most recent periodic check tests is required (see 7.1 and clause 9);
- whether mechanical test certificates are required for each batch of electrodes supplied (see clause 8);
- whether chemical analysis certificates are required and whether any elements have to be controlled to specific limits (see clause 8).

3 Classification

3.1 General

The classification of an electrode shall be indicated by the following coding, in the order stated.

- Strength, toughness and covering code (STC code)**
 - the letter E for a covered electrode for manual metal-arc welding;
 - two digits indicating the strength (tensile, yield and elongation properties of the weld metal) (see table 1);

- a digit indicating the temperature for a minimum average impact value of 28 J (see table 2);

- a digit indicating the temperature for a minimum average impact value of 47 J (see table 3);

- a letter or letters indicating the type of covering (see 3.3).

(b) Additional coding

The following additional coding shall be determined, and shall be used in parentheses in the manufacturer's literature following the STC coding.

- when appropriate, three digits, indicating the nominal electrode efficiency (see 3.4);

- a digit indicating the recommended welding positions for the electrode (see 3.5);

- a digit indicating the power supply requirement (see 3.6);

- when appropriate, a letter H indicating a hydrogen controlled electrode (see 3.7).

NOTE 1. Two examples, illustrating how electrode codings are established from initial test results, are given in appendix A.

NOTE 2. It is recommended that a space should be left between the different parts of both the STC and additional coding as shown in appendix A.

3.2 Weld metal properties (see also note 1 to clause 1)

That part of the classification which relates to mechanical properties from all-weld tests shall be allocated appropriately from tables 1, 2 and 3 depending on the particular combination of results obtained from the relevant tests as specified in clause 7.

3.3 Covering

The type of covering shall be indicated by the appropriate letter or letters as follows:

| | |
|--------------|------------------------|
| E - - - - B | basic |
| E - - - - BB | basic, high efficiency |
| E - - - - C | cellulosic |
| E - - - - R | rutile |
| E - - - - RR | rutile, heavy coated |
| E - - - - S | other types |

Electrodes with coverings containing iron powder or other materials which would not affect the characteristics of the particular type of covering shall be classified by the letter or letters for that type of covering and not by the letter S.

NOTE. The characteristics of each of the types of covering are described in appendix B.

Table 1. Designation for tensile properties

| Electrode designation digit | Tensile strength | Minimum yield stress | Minimum elongation | | |
|-----------------------------|------------------------------|--------------------------|---------------------------------|----------------------------|------------------------------------|
| | | | When digit of table 2 is 0 or 1 | When digit of table 2 is 2 | When digit of table 2 is 3, 4 or 5 |
| E 43 - - - | N/mm ² 430-550 | N/mm ² 330 | % 20 | % 22 | % 24 |
| E 51 - - - | 510-650 | 360 | 18 | 18 | 20 |

| Digit | Temperature for minimum average impact value of 28 J using 4 mm diameter electrodes only (see 7.3.1 and foreword) |
|-----------|---|
| | °C |
| E -- 0 -- | Not specified |
| E -- 1 -- | +20 |
| E -- 2 -- | 0 |
| E -- 3 -- | -20 |
| E -- 4 -- | -30 |
| E -- 5 -- | -40 |

| Digit | Temperature for minimum average impact value of 47 J using 4 mm diameter and largest diameter electrodes submitted for classification (see 7.3.2 and foreword) |
|------------|--|
| | °C |
| E --- 0 -- | Not specified |
| E --- 1 -- | +20 |
| E --- 2 -- | 0 |
| E --- 3 -- | -20 |
| E --- 4 -- | -30 |
| E --- 5 -- | -40 |
| E --- 6 -- | -50 |
| E --- 7 -- | -60 |
| E --- 8 -- | -70 |

3.4 Efficiency

The nominal electrode efficiency, which is the ratio of the mass of weld metal to the mass of nominal diameter core wire consumed for a given electrode, shall be determined on the largest diameter electrode covered by the classification in accordance with the method given in appendix C.

The value obtained by that method shall be rounded off to the nearest multiple of 10, with values ending in 5 being rounded up.

The rounded efficiency figure shall be included in the classification only if it is equal to or greater than 110.

3.5 Welding position

The welding position or positions (see BS 499 : Part 1 for definitions) in which the electrode can be used, as

recommended by the manufacturer, shall be indicated by the appropriate digit as follows:

- 1 all positions
- 2 all positions except vertical/down
- 3 flat and, for fillet welds, horizontal/vertical
- 4 flat
- 5 flat, vertical/down and, for fillet welds, horizontal/vertical
- 9 any position or combination of positions not classified above.

3.6 Welding current and voltage conditions

The welding current and open circuit voltage conditions at which the electrode can be operated, as recommended by the manufacturer, shall be indicated by the appropriate digit as given in table 4.

NOTE. The open circuit voltages given in table 4 apply to electrodes of at least 2.5 mm diameter; higher voltages may be necessary for smaller sizes.

| Digit | Direct current | Alternating current |
|-------|---|-----------------------------------|
| | Recommended electrode polarity | Minimum open circuit voltage |
| 0 | Polarity as recommended by manufacturer | V Not suitable for use on a.c. |
| 1 | + or - | 50 |
| 2 | - | 50 |
| 3 | + | 50 |
| 4 | + or - | 70 |
| 5 | - | 70 |
| 6 | + | 70 |
| 7 | + or - | 80 |
| 8 | - | 80 |
| 9 | + | 80 |

3.7 Hydrogen controlled electrodes

The letter H shall be included in the classification for those electrodes which will deposit not more than 15 mL of diffusible hydrogen per 100 g of deposited weld metal when determined in accordance with the method given in BS 6693 : Part 2.

NOTE 1. Other methods of collection and measurement of the diffusible hydrogen may be used for batch testing provided they possess equal reproducibility with, and are calibrated against the method given in BS 6693 : Part 2.

The manufacturer shall provide information on the recommended drying conditions for achieving hydrogen levels determined in accordance with the method given in

BS 6693 : Part 2 within the following ranges, as appropriate.

| | |
|---------------------|--|
| Not exceeding 15 mL | } per 100 g of deposited weld metal. |
| Not exceeding 10 mL | |
| Not exceeding 5 mL | |

NOTE 2. In practice, the appropriate hydrogen level will depend on the particular application and, to ensure that this is achieved, the relevant drying conditions recommended by the electrode manufacturer should be followed.

NOTE 3. The diffusible hydrogen evolved by the method given in BS 6693 : Part 2 will in general be higher than the hydrogen evolved in the method given in BS 6693 : Part 1. Users wishing to comply with BS 5135 should consult the manufacturer for appropriate information on hydrogen levels determined by the method given in BS 6693 : Part 1.

4 Dimensions and tolerances

4.1 Size

The size of an electrode shall be the specified nominal diameter of the core wire and shall be selected from the following range:

1.6, 2, 2.5, 3.2, 4, 5, 6, 6.3 and 8 mm.

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

4.2 Length

The length of an electrode shall be within ± 2 mm of the nominal value given in table 5.

| Diameter | Nominal length |
|-----------|--|
| mm | mm |
| 1.6 | 200 250 |
| 2 | 200 250 300 350 |
| 2.5 | 250 300 350 |
| 3.2, 4, 5 | 350 450 |
| 6 to 8 | 350 450 500 600 700 900 |

5 Covering

The covering shall be free from defects, such as coating cracks and eccentricity of the core wire, which will adversely affect the operation of the electrode when used under the correct conditions.

The gripped end of each electrode shall be free from covering for a minimum distance of 15 mm and a maximum distance of 40 mm.

6 Electrode identification

The STC code (see clause 3) shall be marked on the covering of each electrode, except on electrodes of 1.6 mm and 2 mm diameter where it is not practicable, as near as possible to the gripped end.

When electrodes are used in accordance with the manufacturer's recommendations, the marking shall survive subsequent baking and contact incidental to normal handling, transport and storage and shall remain legible on electrodes and stub ends.

7 Initial tests

7.1 General

The initial tests to which electrodes are subjected are specified in this clause and although it is not expected that every batch of electrodes will be subjected to the initial tests, the manufacturer shall ensure that every batch is capable of passing the initial tests.

NOTE. The purchaser may require that some or all of the tests are carried out on batches supplied to him (see clause 8).

When electrodes of a nominal size are manufactured in a range of lengths, the electrodes used for the tests shall be the longest that are normally manufactured.

An electrode suitable for use on either a.c. or d.c. shall be tested on a.c.

If a test certificate giving the results of the initial tests carried out on the type of electrode supplied is requested by the purchaser at the time of order (see clause 2(c)), it shall be made available by the manufacturer.

7.2 Weld metal tensile test

Two weld metal tensile test specimens, one using 4 mm electrodes and one using the largest size electrode submitted for classification, shall be prepared and tested in accordance with the method described in appendix D.

The tensile properties from both test specimens shall comply with one of the sets of values given in table 1. If the requirements are not met, retests shall be carried out as specified in 10.1.

7.3 Weld metal impact tests

7.3.1 *Temperature for a minimum average impact value of 28 J* (see table 2). Six Charpy V-notch test specimens shall be prepared using 4 mm electrodes and tested in accordance with the method described in appendix D.

The average of the six impact values shall be at least 35 J at the appropriate testing temperature as given in table 2. If the average of the six impact values is greater than 16 J but less than 35 J, twelve additional specimens, taken from a new test piece, shall be prepared and tested in accordance with the method described in appendix D and the results added to those previously obtained to form a new average that shall be at least 28 J.

If the average of the original six impact values does not exceed 16 J, retests shall be carried out as specified in 10.2.

NOTE. Table 2 is based on the requirements of ISO 2560 which assumes that 18 impact test specimens may be necessary to establish a statistically significant average. Advantage has been taken of the anticipated distribution of individual values to indicate initial levels above or below which it is considered unnecessary to test a complete set of 18 specimens in order to establish compliance or non-compliance.

7.3.2 Temperature for a minimum average impact value of 47 J (see table 3). Six Charpy V-notch test specimens, shall be prepared, three using 4 mm electrodes and three using the largest size electrode submitted for classification and tested in accordance with the method described in appendix D.

The average of the three impact values from each set of specimens shall be at least 47 J at the appropriate testing temperature as given in table 3.

If the average of the three impact values from either or both sets of specimens is below 47 J but not less than 40 J, three additional specimens for each set concerned, taken from the same test piece, shall be prepared and tested in accordance with the method described in appendix D and the results added to those previously obtained to form a new average that shall be at least 47 J.

If the average of the three impact values from either or both sets of specimens is below 40 J, if the average of six is below 47 J or if any single value is below 20 J, retests shall be carried out as specified in 10.3.

7.4 Transverse bend test

Two bend tests, one with the face and the other with the root in tension, shall be carried out for each welding position for which the electrode is classified by the manufacturer, except that, when the electrode is classified for welding in the flat position only, four tests shall be carried out.

The method of preparation of the test pieces and test specimens and the method of carrying out the tests shall be as described in appendix E.

On completion of the test, no crack or defect at the outer surface of the test specimen shall be greater than 3 mm measured in any direction. If this requirement is not met, retests shall be carried out as specified in 10.1.

8 Quality control*

The manufacturer shall have a quality control system to ensure that all electrodes supplied satisfy the requirements of this standard. The system shall be documented and provide for the ready detection of discrepancies and for timely and positive corrective action. The system shall provide records such that the identification number of each batch of electrodes shall provide references to the manufacturer's own documented records.

Tests and inspections shall be performed during manufacture so that continuous quality control of production is maintained and any departure from the accepted quality will be detected before despatch. From each batch of electrodes a sufficient quantity of finished electrodes shall be taken to allow execution of the quality control tests defined in the manufacturer's system.

At the time of placing the order, the purchaser shall indicate whether he requires additional tests to be made or certificates to be provided for each batch of electrodes supplied. If so, the tests and batch definition shall be agreed between the purchaser and the manufacturer (see clause 2 (d) and (e)).

9 Periodic check tests

Periodic check tests shall consist of the tests specified in 7.2 and 7.3.2. Periodic check tests shall be repeated at intervals of not more than twelve months to provide evidence that the electrodes currently produced continue to represent the classification achieved in the initial tests.

If requested by the purchaser at the time of order (see clause 2(c)), the manufacturer shall produce the results of the most recent periodic check tests on electrodes representative of the electrodes supplied.

10 Retests

10.1 Retests as specified in 7.2 or 7.4

When any test specimen fails to satisfy the test requirements of 7.2 or 7.4, twice the number of specimens specified for the initial or periodic check tests shall be prepared from new test pieces made using the same number of layers with electrodes from the same batch and submitted to the test in which failure occurred. Provided that the tests of the additional specimens are satisfactory, the electrodes shall be accepted as having passed the test.

* Further guidance on general principles may be obtained from BS 4891.

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10.2 Retests required as specified in 7.3.1

When retests are required as specified in 7.3.1, two new test pieces shall be made using the same number of layers with electrodes from the same batch. Six Charpy V-notch test specimens shall be prepared from each new test piece. Provided that the average of the six impact values from each test piece is at least 35 J at the appropriate testing temperature, the electrodes shall be accepted as having passed that test.

10.3 Retests required as specified in 7.3.2

When retests are required as specified in 7.3.2, two new test pieces shall be made with 4 mm electrodes and two new test pieces shall be made with the largest size electrode submitted for classification, using the same number of layers with electrodes from the same batch. Three Charpy V-notch test specimens shall be prepared from each new test piece. Provided that the average of the six impact values from the test pieces made with 4 mm electrodes and the average of the six impact values from the test pieces made with the largest size electrode submitted for classification are each at least 47 J at the appropriate testing temperature, with no single value below 20 J, the electrodes shall be accepted as having passed that test.

11 Packing, storage and marking**11.1 Packing and storage**

Electrodes shall be suitably packed to guard against damage during transportation.

NOTE 1. When stored, the electrodes should be kept in their original bundles or packages in a dry storeroom.

If the composition of the covering is such that special protection during storage or special treatment before use is necessary, details of such protection or treatment shall be furnished by the manufacturer.

NOTE 2. If there is any doubt about the actual conditions during storage or the condition of the electrodes after storage, the manufacturer's advice should be sought before the electrodes are used.

11.2 Marking

Each bundle or package of electrodes shall be clearly marked with the following information.

- (a) the number and date of this British Standard, i.e. BS 639 : 1986*;
- (b) classification (see clause 3);
- (c) name of manufacturer;
- (d) trade designation of electrodes;
- (e) size and quantity of electrodes;
- (f) batch number (see clause 8);
- (g) recommended current range, polarity and power supply;
- (h) recommendations for special storage conditions if required (see 11.1).
- (i) any other significant information on electrode characteristics or limitations on use;
- (j) health warning (see appendix F): the general warning sign (given below) accompanied by the following:



**WARNING. PROTECT YOURSELF AND OTHERS.
READ AND UNDERSTAND THIS LABEL.
TAKE PRECAUTIONS WHEN WELDING. ASK FOR YOUR
EMPLOYER'S SAFETY PRACTICES WHICH SHOULD BE
BASED ON MANUFACTURER'S HAZARD DATA.
FUMES AND GASES CAN BE DANGEROUS TO YOUR
HEALTH. ARC RAYS CAN INJURE EYES AND BURN
SKIN. ELECTRIC SHOCK CAN KILL.
KEEP YOUR HEAD OUT OF THE FUMES.
USE ENOUGH VENTILATION, EXHAUST AT THE ARC,
OR BOTH, TO KEEP FUMES AND GASES FROM YOUR
BREATHING ZONE AND THE GENERAL AREA.
WEAR CORRECT EYE, EAR AND BODY PROTECTION.
DO NOT TOUCH LIVE ELECTRICAL PARTS.
DO NOT REMOVE THIS LABEL.**

* Marking BS 639 : 1986 on or in relation to a product is a claim by the manufacturer that the product has been manufactured to the requirement of the standard. The accuracy of such a claim is therefore solely the manufacturer's responsibility. Enquiries as to the availability of third party certification should be addressed to the appropriate certification body.

Appendices

Appendix A. Examples of electrode classification

The following examples illustrate the way in which the coding is expressed and the use of the complete classification or only the compulsory part.

Example (a). Covered electrodes for manual metal-arc welding having a rutile covering (R) but not designated as a high efficiency electrode.

The electrode may be used for welding in all positions and it welds satisfactorily on alternating current with a minimum open circuit voltage of 50 V and on direct current with positive polarity. The electrode is not designed to give hydrogen controlled weld metal.

The electrode deposits weld metal with the properties given in table 6 when tested in accordance with this standard and when the manufacturer submits 8 mm diameter electrodes as the maximum size to be classified. The table of results shows that the manufacturer carried out sets of impact tests at 0 °C, at -20 °C and at -30 °C in order to determine the appropriate classification.

| Table 6. Test results for example (a) | | | | |
|---------------------------------------|--|---------------------------------|--|---|
| Property | Test plates for 4 mm electrode | Test plates for 8 mm electrode | Classification E 43 — — — equivalent | Result |
| Tensile strength (N/mm ²) | 475 | 470 | 430 to 550 | Satisfactory |
| Yield stress (N/mm ²) | 345 | 340 | 330 min. | Satisfactory |
| Impact value at -30 °C (J) | 42 20 } average 47 27 } 49 31 } 36 | Not required (see 7.3.1) | Temperature for impact value of 28 J average but no one value less than 16 J | This result is greater than both 35 J and 28 J and the results are satisfactory for classification of first digit at -30 °C (see 7.3.1 and table 2) |
| Impact value at 0 °C (J) | 70 } average 75 } 65 } 70 | 60 } average 66 } 63 } 63 | Temperature for impact value of 47 J average but no one value less than 20 J | Satisfactory results for classification of second digit at 0 °C (see 7.3.2 and table 3) |
| Impact value at -20 °C | 60 } average 65 } 67 } 64 | 42 } average 38 } 31 } 37 | Temperature for impact value of 47 J average but no one value less than 20 J | The average for the 8 mm electrode has failed as it is less than 47 J (see 7.3.2) |
| Elongation % | 26 | 25 | 24 min.* | Satisfactory |

* Elongation determined from table 1 after establishment of first impact digit.

The classification for the electrode is therefore:

STC code E 43 4 2 R

Strength (430 N/mm² to 550 N/mm²) _____

Temperature for minimum average impact strength of 28 J (-30 °C) _____

Temperature for minimum average impact strength of 47 J (0 °C) _____

Covering (Rutile) _____

Additional code [1 3]

Welding position _____

Welding current and voltage conditions _____

Complete classification

The complete classification is therefore E 43 4 2 R [1 3]

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Example (b). An electrode for manual metal-arc welding having a basic covering, with a nominal efficiency of 158 % and depositing weld metal containing 8 mL of diffusible hydrogen per 100 g of deposited weld metal.

The electrode may be used for welding in the flat or horizontal/vertical positions direct current only.

The electrode deposits weld metal with the properties given in table 7 when tested in accordance with this standard and when the manufacturer submits 6 mm electrodes as the maximum size to be classified. The table of results shows that the manufacturer carried out sets of impact tests at -30°C and at -40°C .

| Table 7. Test results for example (b) | | | | |
|---|---|---|--|--|
| Property | Test plates for 4 mm electrode | Test plates for 6 mm electrode | Classification E 51 — — — equivalent | Result |
| Tensile strength (N/mm ²) | 565 | 560 | 510 to 650 | Satisfactory |
| Yield stress (N/mm ²) | 400 | 395 | 360 min. | Satisfactory |
| Impact value at -40°C (J) | 46 20 } aver- 40 31 } age 43 42 } 37 | Not required (see 7.3.1) | Temperature for impact value of 28 J average but no one value less than 16 J | This result is greater than both 35 J and 28 J and the results are satisfactory for classification of first digit at -40°C (see 7.3.1 and table 2) |
| Impact value at -30°C (J) | 120 } aver- 110 } age 106 } 112 | 60 } aver- 68 } age 70 } 66 | Temperature for impact value of 47 J average but no one value less than 20 J | Satisfactory results for classification of second digit at -30°C (see 7.3.2 and table 3) |
| Impact value at -40°C (J) | Results from previous test give average 37* (see above). No need to repeat test | 4 mm electrode failed so no need to test 6 mm electrode | Temperature for impact value of 47 J average but no one value less than 20 J | Failed requirements of 7.3.2 |
| Elongation % | 24 | 23 | 20 min.† | Satisfactory |
| <p>* Only three values are in fact required but whichever three values out of the six are taken the average is less than the required minimum of 47 J.</p> <p>† Elongation determined from table 1 after establishment of first impact digit.</p> | | | | |

The classification of the electrode is therefore:

STC code E 51 5 4 BB

Strength (510 N/mm² to 650 N/mm²) _____

Temperature for minimum average impact strength of 28 J (-40 °C) _____

Temperature for minimum average impact strength of 47 J (-30 °C) _____

Covering (basic, high efficiency) _____

Additional code [160 3 0 H]

Efficiency _____

Welding positions _____

Welding current and voltage conditions _____

Hydrogen controlled _____

Complete classification

The complete classification is therefore **E 51 5 4 BB [160 3 0 H]**

Appendix B. Characteristics of electrode coverings

NOTE. The hydrogen level of consumables used will affect selection of welding procedures and reference should be made to the appropriate clauses of BS 5135.

The characteristics of the coverings indicated by the letters given in 3.3 are as follows.

B (Basic). Electrodes with basic coverings have a gas shield produced by the decomposition, in the arc, of calcium carbonate. The resultant calcium oxide combines with calcium fluoride to produce a chemically basic slag with a low melting point. This leads to clean weld metal resistant to solidification cracking, and tolerant of high sulphur levels in steel. The absence of organic materials and hydrated minerals, as contributors to the gas shield, makes the electrodes suitable for high temperature baking to give a low hydrogen level in the weld metal. Baked electrodes reduce the risk of cold cracking, which would otherwise be a problem in thick sections or highly restrained joints, particularly when welding steels of high carbon equivalent. Basic covered electrodes have a relatively small gas shield and should be used with a short arc technique.

BB (Basic, high efficiency). Electrodes with basic high efficiency coverings are similar to basic covered electrodes, but additional metallic components in the covering raise the efficiency to levels of 130 % or more. They are suitable for welding in the flat and horizontal/vertical positions but the high efficiency coverings render them unsuitable for welding in the vertical and overhead positions.

C (Cellulosic). Electrodes with cellulosic coverings have a voluminous gas shield produced by the decomposition, in the arc, of cellulose and other organic substances. The electrodes give good penetration, fast welding speeds, and the ability to weld vertically down. Hydrogen levels are high.

R* (Rutile). Electrodes with rutile coverings have a gas shield produced by the decomposition, in the arc, of organic materials and/or hydrated minerals. They derive their name from the large proportion of rutile (titanium dioxide) present in the coverings. The electrodes are comparatively easy to use but the hydrogen level in the weld metal limits their useful application in the welding of thick joints.

RR* (Rutile, heavy coated). Electrodes with heavy rutile coverings are generally unsuitable for welding in the vertical and overhead positions. Additional metallic components may be added to the coverings to raise the efficiency level to 130 % or more.

S (Other types). Electrodes with other types of coverings may range from rarely used types, such as oxide or acid fluxes, to newly developed flux systems. No general guidance on special covering electrode characteristics is possible, so potential users should seek the manufacturer's advice.

Appendix C. Method for the determination of nominal electrode efficiency

C.1 The test plate shall be of carbon steel (up to 0.25 % C) and shall have the following approximate dimensions:

| | |
|----------------|--------|
| width | 75 mm |
| minimum length | 300 mm |
| thickness | 12 mm |

The surface of the plate on which the deposit is to be made shall be cleaned, if necessary, by light grinding or other suitable means so that it is free from scale, rust, paint and oil.

The mass m_1 of the plate after cleaning and before welding shall be determined to an accuracy of ± 1 g.

C.2 A sufficient number of electrodes to give weld metal of mass at least 20 % of m_1 , shall be selected so that their core wire is the same nominal diameter (see clause 4) and all of the same nominal length (correct to ± 0.5 mm). The mass m_3 of core wire can be obtained by weighing core wires having the same nominal diameter and length as the electrodes or by stripping the covering from similar electrodes and weighing to an accuracy of ± 1 g.

If this is not possible, the mass m_3 (in g) may be calculated from the equation:

$$m_3 = \frac{\pi d^2 n \rho L}{4000}$$

where

d is the nominal diameter of electrode core wire (in mm);

n is the number of electrodes used;

ρ is 7.85 g/cm³ for steel;

L is the length of electrode (± 0.5 mm);

Hence $m_3 = 0.0062 n d^2 L$.

C.3 The electrodes shall then be deposited on the test plate in the flat position using the welding current as near as possible to the maximum value of the range indicated by the electrode manufacturer on the electrode packet for the flat position; the deposition shall be such that a sound deposit is obtained throughout its length. The current setting shall be kept constant during the whole test.

Electrodes suitable for welding on d.c. only, or those for which the manufacturer specifies that d.c. is preferable, shall be tested on d.c. with the polarity recommended by the manufacturer. For electrodes suitable for welding on either d.c. or a.c., a.c. shall be used.

NOTE 1. It is recommended that the required length of stub end be marked on the electrode before starting to weld.

Each electrode shall be deposited without interruption until a stub length of approximately 50 mm remains.

When one bead has been deposited, all slag and spatter shall be removed from the bead and the plate before depositing another bead. The interpass temperature shall not exceed 100 °C.

NOTE 2. Quenching in water between runs is permissible.

* The limit between coverings of medium (R) and heavy (RR) thickness corresponds to a ratio of 1 : 1.5 between the outer diameter of the covering and the core wire diameter.

On completion of welding, all slag and spatter shall be removed from the beads and plate, and the plate and weld cooled to ambient temperature before weighing. This mass m_2 shall be recorded to an accuracy of ± 1 g.

C.4 All covering shall be removed from the stub ends before weighing and their mass m_4 recorded to an accuracy of ± 1 g.

C.5 The nominal electrode efficiency R_N (expressed as a percentage) shall be calculated from the equation:

$$R_N = \frac{m_2 - m_1}{m_3 - m_4} \times 100$$

where

m_1 is the mass of the test plate before welding (± 1 g);

m_2 is the combined mass of the test plate and of the weld metal deposited onto it (± 1 g);

m_3 is the mass of the core wire of the number of whole electrodes used (± 1 g);

m_4 is the mass of the core wire in the stub ends remaining after welding (± 1 g).

Appendix D. Weld metal tests

D.1 Preparation of test pieces

D.1.1 General

This procedure includes tolerances for preparation parameters, providing conditions for comparison of test results of the same weld metal grades of different origin. Electrodes may range in size from 4 mm to 8 mm and may be with or without iron powder in the covering.

D.1.2 Preparation of the test assembly

The assembly shall be prepared as shown in figure 1 in the form of a butt joint with a single V-groove on a backing strip.

The backing strip shall be tack welded to the test assembly.

The plate and backing strip material shall be a steel of grade 43 of BS 4360 or any equivalent.

D.1.3 Welding procedure

D.1.3.1 The assembly shall be welded in the flat position with the weld axis and the plates horizontal. The assembly shall be preset or restrained during welding to prevent warpage in excess of 5° . A test assembly that has warped more than 5° shall be discarded. Welded test assemblies shall not be straightened.

D.1.3.2 The test assembly shall be tack welded and preheated to $110 \pm 14^\circ\text{C}$. Welding shall be continued with an interpass temperature of not less than 110°C , nor more than 180°C as measured by temperature indicating crayons or surface thermometer at the location indicated in figure 1. The welding procedure shall be as given in table 8. The preheat and interpass temperature shall be maintained during welding.

D.1.3.3 Electrodes with the required core wire diameter shall be used. Each pass shall be welded with a welding current of 90 % of the maximum current which is advised by the manufacturer for welding in the flat position with the electrode completely consumed (stub end no more than 50 mm).

The electrode shall be welded with the type of current indicated in the classification.

The welding current shall be a.c. if the electrode can be used either with a.c. or d.c.

The welding current shall be d.c., electrode positive polarity, if the electrode can be used either with d.c. negative or positive polarity.

D.1.3.4 The butt weld geometry shall be as shown in figure 2. Each layer shall be made up of two passes. The welding speed shall be adapted to obtain the number of layers given in table 8.

D.1.3.5 Each electrode shall be consumed completely (up to a stub end of not more than 50 mm). The direction of deposition of each layer shall alternate from each end of the plate.

D.1.3.6 When the assembly has been welded it shall be allowed to cool in still air. The portion including the weld shall then be removed by cutting away the excess plate at the places indicated in figure 1. These cuts may be made using a thermal cutting machine, provided care is taken to ensure that the lines of cut for the tensile specimen are at least 25 mm from the toes of the weld.

D.2 Tensile test specimen

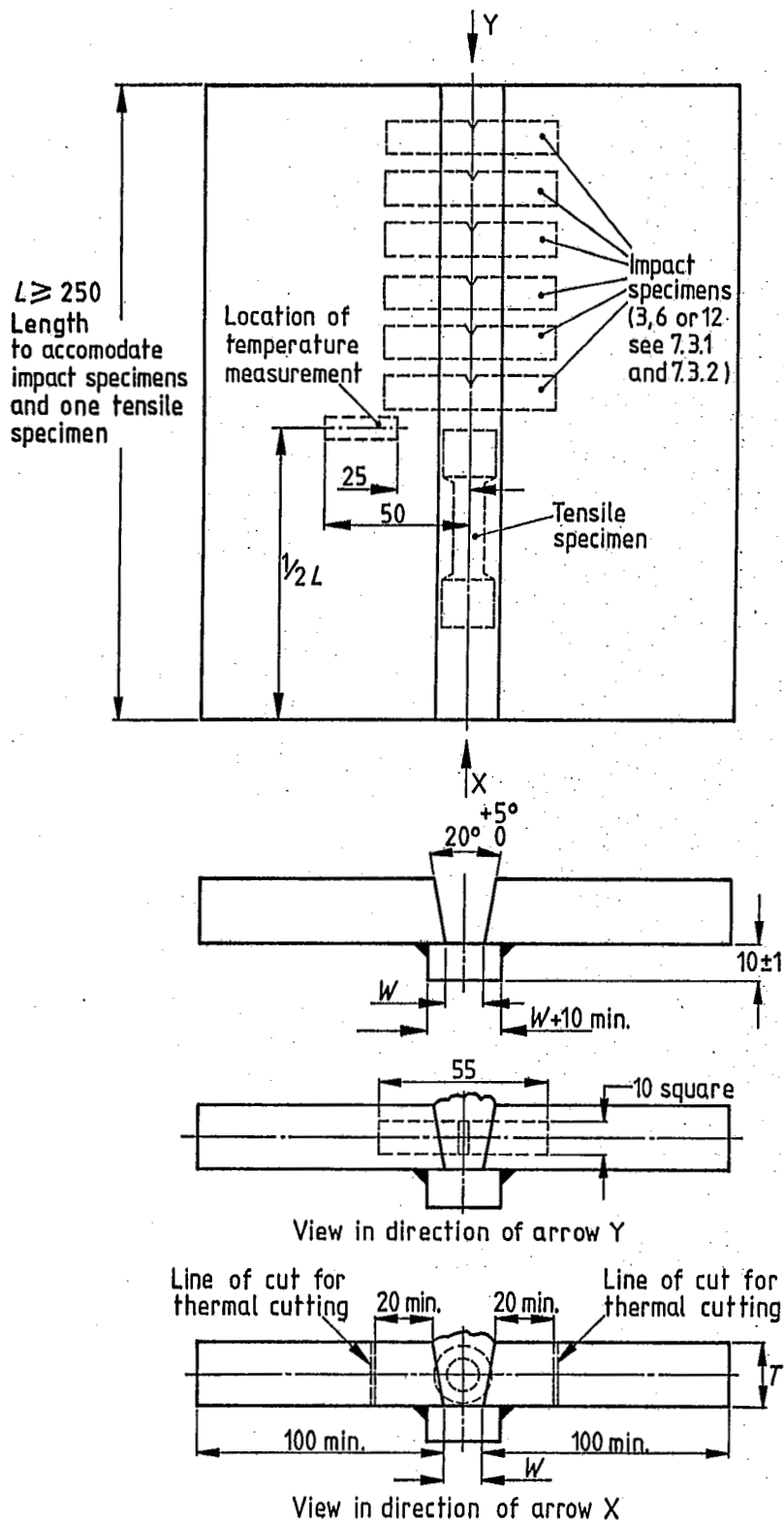
The tensile test specimen shall be machined from the test piece to the dimensions given in figure 3, care being taken that the longitudinal axis of the test specimen coincides with the centre line of the weld and the mid-thickness of the plate as indicated in figures 1 and 2. The specimen shall then be subjected to a temperature of 250°C for a period of not less than 6 h and not more than 16 h for hydrogen removal, prior to testing.

The specimen shall then be tested in tension in accordance with BS 18 : Part 2. Up to the yield point, the stress shall be applied at a rate not exceeding $12 (\text{N}/\text{mm}^2)/\text{s}$.

D.3 Impact test specimens

The Charpy V-notch impact test specimens shall be machined from the test piece to the dimensions given in BS 131 : Part 2. The test specimens shall be cut with their longitudinal axes transverse to the weld axis and each specimen shall be taken at the mid-thickness of the plate. The specimens shall be etched to ensure that each notch is positioned in the centre of the weld as shown in figure 2 and the notch shall be cut in that face of each test specimen that is perpendicular to the surface of the plate.

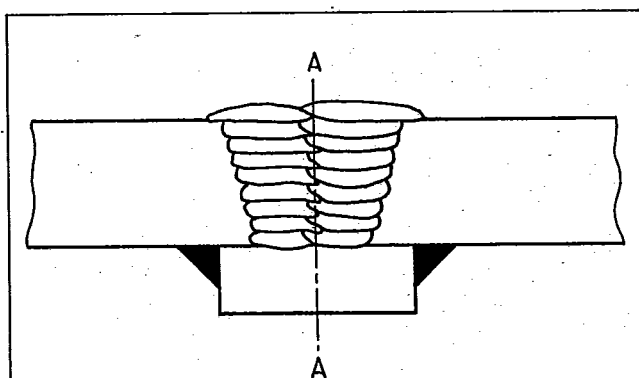
The specimens shall then be tested in accordance with BS 131 : Part 2.



All dimensions are in millimetres.

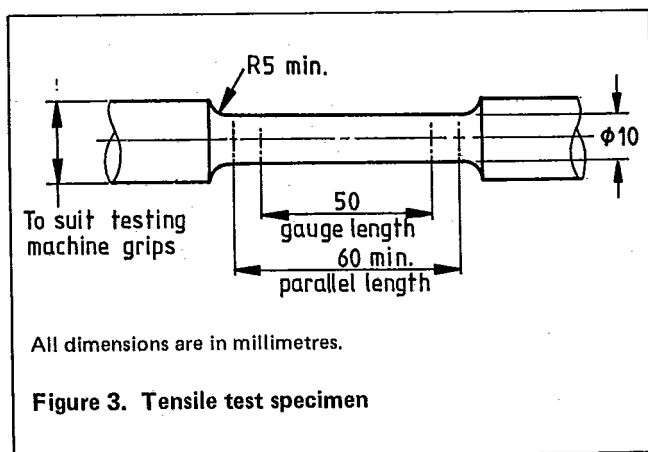
Figure 1. Preparation of weld metal test pieces

| Electrode size | Split weave layer no. | Passes per layer | Number of layers | Width <i>W</i> of weld gap | Plate thickness <i>T</i> |
|----------------|-----------------------|------------------|------------------|----------------------------|--------------------------|
| mm | | | | mm | mm |
| 4 | 1 to top | 2 | 7 to 9 | 16 ± 1 | 20 ± 1 |
| 5 | 1 to top | 2 | 6 to 8 | 20 ± 1 | 20 ± 1 |
| 6 or above | 1 to top | 2 | 8 to 11 | 24 ± 1 | 25 ± 1 |



NOTE. The test specimens to be located on the centreline A-A.

Figure 2. Weld geometry



All dimensions are in millimetres.

Figure 3. Tensile test specimen

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Appendix E. Transverse bend tests

E.1 Preparation of test pieces

The parent metal for plates used in preparing test pieces shall be carbon or carbon manganese steel of comparable strength to the weld metal and complying with BS 4360.

The temperature of the parent metal used for making the test pieces shall be between 10 °C and 30 °C immediately before depositing the first run of weld metal. The test specimens shall not be subjected to any mechanical or thermal treatment other than that specified in this appendix.

Test pieces shall be made as shown in figure 4 by welding together two plates of suitable length to allow the cutting out of test specimens of the specified size. The plates shall be 20 mm thick and not less than 100 mm wide.

The plate edges shall be prepared to form a single-V joint, the details of which shall be as follows:

| | |
|----------------|------------|
| included angle | 60° to 70° |
| root face | 3 mm max. |
| gap | 3 mm max. |

NOTE 1. Plates may be preset to allow for slight distortion due to welding.

The welding procedure followed in making the test pieces shall be as set out in table 9, according to the position of welding. When the electrode is classified for welding in the flat position only, test pieces shall be welded by both the procedures given in the table. In all cases sealing runs shall be made with 4 mm electrodes in the welding position applicable to each test piece.

NOTE 2. To facilitate deposition of the sealing runs, a groove to a depth of 3 mm may be cut if considered necessary (see figure 5).

The welding current used shall be within the appropriate range recommended by the manufacturer.

The test piece for the vertical position shall be welded using the upward method unless the electrode manufacturer specifically recommends that only the downward method shall be used. If both methods are recommended, test pieces welded by each method shall be made.

After welding, the test pieces shall be cut, by sawing or machining, to form one face-bend and one root-bend test specimen, as indicated in figure 4. The specimens shall then be subjected to a temperature of 250 °C for a period of not less than 6 h and not more than 16 h for hydrogen removal prior to testing.

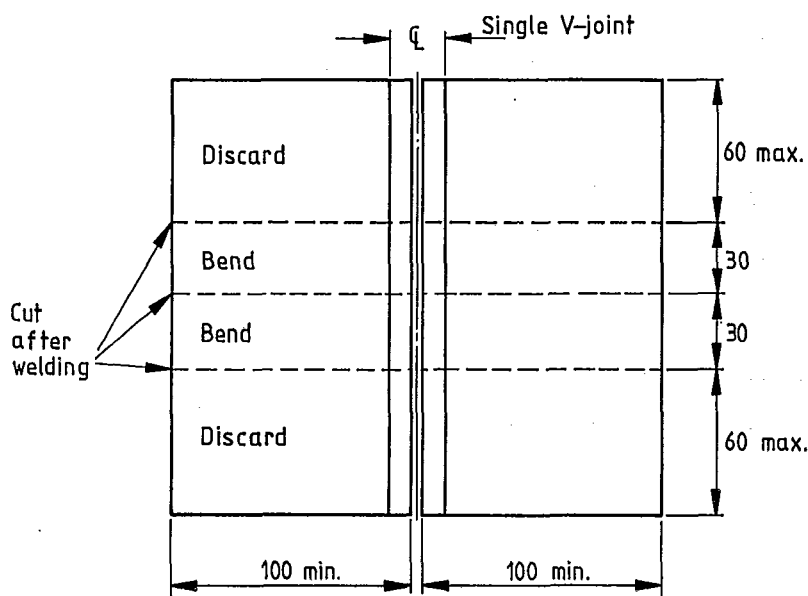
E.2 Transverse bend test

Each bend test specimen shall be 30 mm wide. The upper and lower surfaces of the weld shall be filed, ground or machined level with the respective original surfaces of the plates.

NOTE. Where the surfaces of the plates are not level with each other, the metal may be cut away to bring them approximately level, provided that the thickness of the plate is not reduced by more than a total of 1 mm. Tool marks should be avoided as they lead to localization of stress and may cause premature failure. For this reason, the direction of machining of the surfaces should be along the specimens and transverse to the weld.

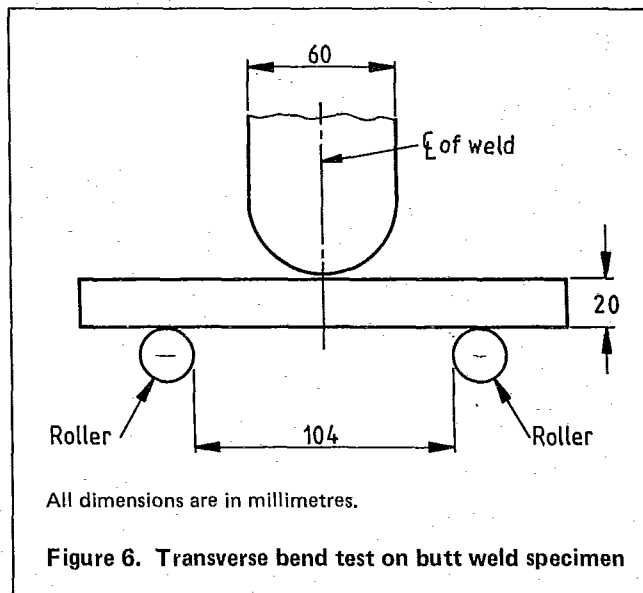
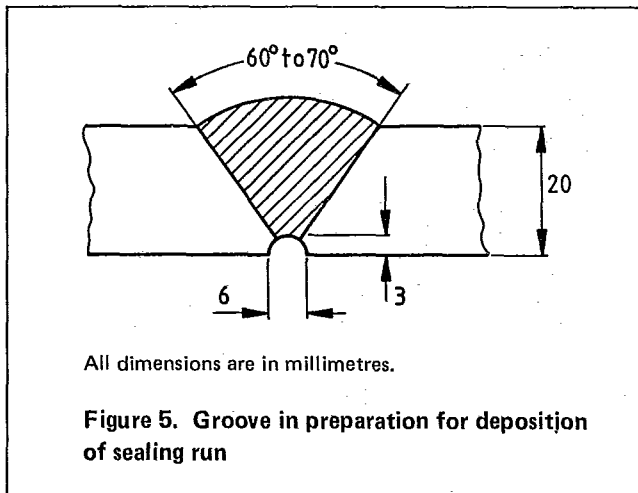
The sharp corners of test specimens shall be rounded to a radius not exceeding 10 % of the specimen thickness.

The test specimen shall be bent through an angle of 180° over a former having a diameter equal to three times the thickness of the specimen, as shown in figure 6. One test specimen shall be tested with the face of the weld in tension and one with the root of the weld in tension.



All dimensions are in millimetres.

Figure 4. Method of making transverse bend test piece and cutting of specimens



| Table 9. Welding procedures for preparation of bend test pieces | |
|--|--|
| Welding position for test pieces (as defined in BS 499 : Part 1). All angles $\pm 5^\circ$ | Welding procedure |
| Flat weld slope 0° weld rotation 0° | (a) First run with 4 mm electrode. Subsequent runs (except last two layers) with 5 mm or 4 mm electrodes according to normal practice with the electrodes. Runs of last two layers with largest size of electrode submitted for approval. When required (for welding in the flat position only): (b) First run with 4 mm electrode. Second run with 5 mm, 6 mm or 6.3 mm electrode. Subsequent runs with largest size of electrode submitted for approval. |
| Horizontal/vertical weld slope 0° weld rotation 90° | First run with 4 mm or 5 mm electrode. Subsequent runs with 5 mm electrodes. |
| Vertical weld slope 90° | First run with 3.2 mm electrode. Subsequent runs with one of the following: |
| Overhead weld slope 0° weld rotation 180° | (a) 4 mm electrodes; (b) if recommended by manufacturer for this position, with 5 mm electrodes; (c) when the nominal electrode efficiency exceeds 110 %, with 3.2 mm electrodes. |

Appendix F. Safety references

The following publications about health and safety are available.

The Facts About Fume. The Welding Institute, Abington 1976.

Welding Fume. The Welding Institute, Abington 1981.

Health and Safety Executive Guidance Note EH15 'Threshold Limit Values'.

Department of Employment Guidance Note MS15 'Welding'.

American Standard ANSI Z 49.1 'Safety in Cutting and Welding'. American Welding Society 1973.

Health Hazards of Welding, Dr H T Doig, British Safety Council.

Welding Manufacturers' Association, Publication No. 237 'The Arc Welder at Work'.

BS 679 Filters for use during welding and similar industrial operations.

Publications referred to

- BS 18 Methods for tensile testing of metals
Part 2 Steel (general)
- BS 131 Methods for notched bar tests
Part 2 The Charpy V-notch impact test on metals
- BS 499 Welding terms and symbols
Part 1 Glossary for welding, brazing and thermal cutting
- BS 679 Filters for use during welding and similar industrial operations
- BS 2493 Specification for low alloy steel electrodes for manual metal-arc welding
- BS 2926 Specification for chromium and chromium nickel steel electrodes for manual metal-arc welding
- BS 4360 Specification for weldable structural steels
- BS 4870* Approval testing of welding procedures
Part 1 Fusion welding of steels
- BS 4891 A guide to quality assurance
- BS 5135 Specification for process of arc welding of carbon and carbon manganese steels
- BS 6693 Diffusible hydrogen
Part 1 Method for determination of hydrogen in manual metal-arc weld metal using 3 day collection
Part 2 Method for determination of hydrogen in manual metal-arc weld metal
- ISO 2560* Covered electrodes for manual arc welding of mild steel and low alloy steel — Code of symbols for identification

* Referred to in the foreword only.

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The following BSI references relate to the work on this standard: Committee reference WEE/39 Draft for comment 83/70003 DC

Committees responsible for this British Standard

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