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Methods of testing

Fusion welds in copper and copper alloys

Co-operating organizations

The Welding Industry Standards Committee, under whose supervision this British Standard was prepared, consists of representatives from the following Government Departments and scientific and industrial organizations:

Aluminium Federation
Associated Offices Technical Committee*
Association of Consulting Engineers
Board of Trade*
British Acetylene Association
British Constructional Steelwork Association
British Electrical and Allied Manufacturers' Association
British Iron and Steel Federation
British Railways Board
British Welding Research Association*
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Lloyd's Register of Shipping
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Ministry of Defence, Navy Department
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Ministry of Technology, National Engineering Laboratory
Shipbuilding Employers' Federation
Society of British Aerospace Companies Limited

The Government department and scientific and industrial organizations marked with an asterisk in the above list, together with the following were directly represented on the committee entrusted with the preparation of this British Standard:

British Chemical Plant Manufacturers Association
British Non-ferrous Metals Research Association
Copper Cylinder and Boiler Manufacturers
Copper Development Association
Council of British Manufacturers of Petroleum Equipment

This British Standard, having been approved by the Welding Industry Standards Committee and endorsed by the Chairman of the Engineering Divisional Council, was published under the authority of the General Council on 17 August 1967

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Foreword

This standard makes reference to the following British Standards:

BS 499, *Welding terms and symbols — Part 1: Glossary for welding, brazing and thermal cutting.*

BS 871, *Specification for abrasive papers and cloths.*

BS 2600, *Radiographic examination of fusion welded butt joints in steel — Part 1: Methods for steel 2 mm up to and including 50 mm thick.*

BS 3971, *Specification for image quality indicators for industrial radiography (including guidance on their use).*

BS EN 895, *Destructive tests on welds in metallic materials. Transverse tensile test.*

BS EN 910, *Destructive tests on welds in metallic materials. Bend test.*

BS EN 1320, *Destructive tests on welds in metallic materials. Fracture tests.*

BS EN 1321, *Destructive tests on welds in metallic materials. Macroscopic and microscopic examination of welds.*

The wide use of welding in industry has resulted in an increasing need for standards relating to welded construction in various branches of engineering. These standards generally include requirements for certain welding tests to be conducted and there is seldom any technical reason for divergence in the procedures followed for such tests, there being both practical and economic advantages to be gained in their standardization.

The main purpose of this standard is to recommend test procedures, non-destructive and destructive, and test specimens that should be quoted or incorporated in engineering application standards that deal with welded constructions of copper or copper alloy. Where differences exist between application standards, the methods of test given in this standard are to be preferred and it is hoped that in time the alternatives will be dropped.

A general indication is given of the purpose served by each of the different standard tests, but the standard does not purport to lay down when any particular test should or should not be used; again it does not state the number of specimens to be tested, the repeat tests to be allowed in the event of failure or acceptance requirements. Such requirements, if not covered by the application standard should be agreed between the contracting parties.

Tests for fusion welds in copper and copper alloys should be selected on their own merits, there being no value in making comparisons with other materials and experience in testing other materials is not necessarily valid. It should also be appreciated that variations in welding procedure and the preparation of test specimens can give rise to variations in test results.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

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

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 5 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 General

1.1 Scope

This British Standard deals with methods for the testing of fusion welds in copper and copper alloys up to 40 mm thick and in all forms of material including pipes and castings.

Requirements for test plates, number of test specimens, mechanical test requirements and acceptance levels are not included. These are covered in the appropriate application standard.

1.2 Definitions

For the purposes of this British Standard, the definitions given in BS 499-1[1)] apply.

1.3 Recommended non-destructive tests

The recommended non-destructive tests are:

1) Visual examination aided by dye or fluorescent penetrant methods.

2) Radiography.

NOTE Although no British Standard exists for the method, ultrasonic examination is sometimes applicable to copper and copper alloy welds. Under optimum conditions it can detect coarse porosity and planar defects (such as lack of fusion) which are not always revealed by radiography, but interpretation can be complicated by the effect of the metallurgical structure.

1.4 Recommended destructive tests

The recommended destructive tests are:

Butt welds

1) Transverse tensile test.

2) Examination of cross-sections (macro-examination).

3) Side bend test.

4) Transverse and longitudinal bend tests (under certain circumstances).

5) Nick-break test (under certain circumstances).

Fillet welds

1) Examination of cross-sections (macro-examination).

2) Fracture test (under certain circumstances).

2 Non-destructive tests

2.1 Visual examination

2.1.1 Object. The object of visual examination is to check the contour and soundness of the surface of the weld zone. The use of penetrant methods is an aid to detecting flaws that would not be apparent under normal vision. Penetrant methods may also be used to check that defects have been completely removed before re-welding.

This is the primary method of weld examination and should always precede any other non-destructive or destructive testing.

2.1.2 Preparation. The weld shall be examined in the as-welded condition except that the surface to be examined shall be clean and free from any residues from the welding process.

2.1.3 Examination. The surface of the weld zone shall be examined visually with or without the use of a magnifier.

As a further aid to visual examination, one of the following types of penetrant methods may be used:

1) A coloured dye which indicates flaws after treating the weld with developer.

2) A fluorescent penetrant which reveals its presence under a beam of ultraviolet radiation; treatment with a developer may or may not be used. This is less suitable than 1) for site inspection and requires particularly careful interpretation.

2.1.4 Reporting of results. The appearance and contour of the weld zone shall be described in the report, together with the nature and location of all flaws found. The use of any aid to examination shall be indicated in the report.

2.2 Radiographic examination

2.2.1 Object. The object of radiographic examination is to detect flaws which are not apparent during visual examination. It is useful for detecting porosity, cavities, tungsten or flux inclusions and severe lack of penetration. It cannot always be relied upon to detect cracks, oxide films and inclusions, lack of fusion and less severe lack of penetration.

2.2.2 Preparation. The surfaces of welded joints which are to be radiographically examined need not be chipped or ground to a smooth surface so long as the contours of the welds do not interfere with the interpretation of the radiograph.

[1)] BS 499, *"Welding terms and symbols"*, Part 1, *"Glossary for Welding, brazing and thermal cutting"*.

Welded joints of the "backing strip" type may be radiographed without removing the backing strip provided that the image of the latter is not significantly detrimental to the interpretation of the radiographs.

2.2.3 Identification of radiographs. Numerals shall be marked on the work alongside the welded joints so that each radiograph may be identified with the portion of joint represented.

Where radiographs are required of the entire length of a welded joint, sufficient overlap shall be provided to ensure that the radiographs cover the whole of the welded joint, and each radiograph shall exhibit a number near each end.

Lead numerals shall be placed on the opposite side of the weld to the appropriate stamped numerals to provide ready identification of the radiograph with the portion of welded joint represented.

The width of the weld shall be indicated by suitable lead pointers placed on each side of, and clear of, the toes of the weld. Alternatively, lead wires of small diameter, placed each side of the weld and clear of, but not more than 3 mm from, the outside edges of the weld, may be employed.

Lead characters shall be placed alongside the weld to provide the following information on the individual radiographs:

1) The region of the welded joint covered by the radiograph.

2) The location of the welded joint on the work.

3) The particular job to which the radiographs apply. This identification could be provided by lead characters which indicate information such as the works' serial number, the order number or similar references.

2.2.4 Radiographic technique

2.2.4.1 *Type of film*. The film shall be one of the following non-screen types:

B	medium- or high-speed	See BS 2600-1[a]
C	fine-grain	
D	ultra-fine-grain	

[a] BS 2600, "*Radiographic examination of fusion welded butt joints in steel", Part 1, "Methods for steel 2 mm up to and including 50 mm thick*".

2.2.4.2 *Intensifying screens*. Lead screens shall be used and shall be 0.10 mm thick for the front and 0.15 mm thick for the back screen.

2.2.4.3 *Cassettes*. Where flexible cassettes are used adequate precautions shall be taken to ensure good film to screen contact.

2.2.4.4 *Interception of unwanted and scattered radiation*. The cassette shall be shielded from all radiation other than that part of the primary beam passing through the region under examination. If masking is used for this purpose it shall be so arranged as not to obscure any of the radiographic detail.

2.2.4.5 *Image quality indicators*. A wire-type image quality indicator complying with BS 3971[2)] shall be placed at one end of every radiograph on the surface facing the source of radiation. It shall be positioned across the weld with the finest wire in the outermost position. A lead marker shall be placed alongside the I.Q.I. indicating the wire having a thickness equal to or immediately below a value of 2 % of the thickness of the material under examination. The sensitivity of the radiographic technique shall be better than 2 % of the thickness penetrated.

2.2.4.6 *Density of radiographs*. The photographic density of the radiographs shall be within the range 1.5 to 2.5.

2.2.4.7 *Tube voltage (X-rays) and source (Gamma rays)*. Where possible X-ray radiography should be used in preference to gamma-ray radiography.

1) The maximum X-ray tube voltage to be used shall be obtained from Figure 1.

2) The gamma-ray sources tabulated below are suitable for penetrating the thicknesses of material given in Table 1.

Table 1 — Recommended thicknesses for gamma-ray sources

Source	Approximate thickness range
	mm
Iridium 192	6 – 75
Caesium 137	20–90
Cobalt 60	50–190

NOTE For certain less dense alloys the thickness values given in Figure 1 and Table 1 may be increased slightly.

[2)] BS 3971, "*Specification for image quality indicators for industrial radiography (including guidance on their use)*".

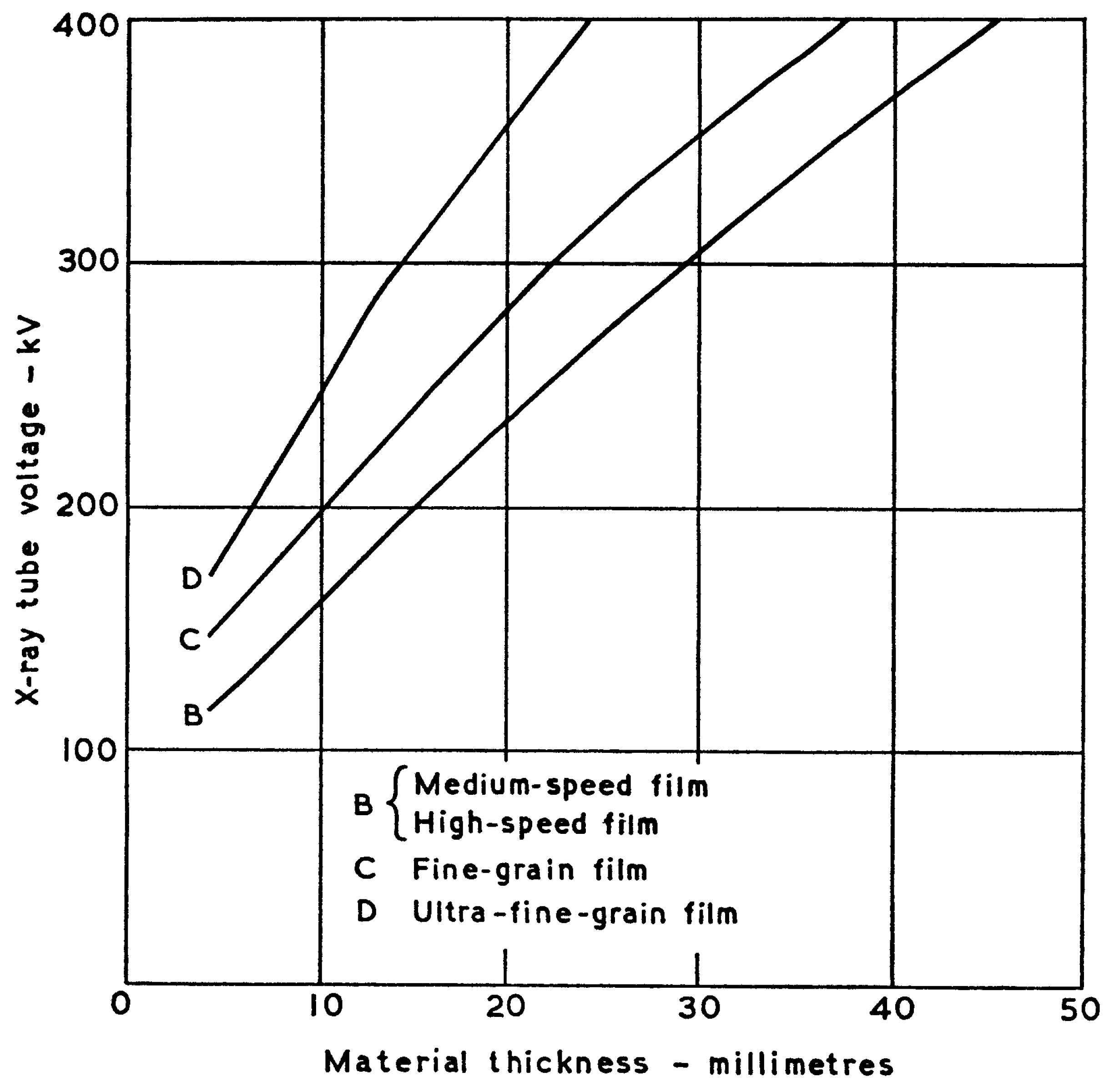

Figure 1 — Maximum X-ray tube voltage

3 Destructive tests

3.1 Separation of test specimens

Machining shall be used to separate test specimens from the test piece. Any angular misalignment of welded test plates shall be corrected cold before machining. To avoid localization of stress and premature failure, tool marks shall be minimized and shall preferably run parallel to the length of the specimens.

3.2 Transverse tensile test

Transverse tensile tests shall be carried out in accordance with BS EN 895.

Figure 2 — *Figure deleted.*

Figure 3 — *Figure deleted.*

3.3 Macroscopic examination

Macroscopic examination shall be carried out in accordance with BS EN 1321.

Figure 4 — *Figure deleted.*

3.4 Side bend test (for material of thickness 10 mm and over)

Side bend tests shall be carried out in accordance with BS EN 910.

Figure 5 — *Figure deleted.*

Figure 6 — *Figure deleted.*

3.5 Transverse and longitudinal bend tests

Transverse and longitudinal bend tests shall be carried out in accordance with BS EN 910.

Figure 7 — *Figure deleted.*

Figure 8 — *Figure deleted.*

3.6 Fracture test

Fracture tests shall be carried out in accordance with BS EN 1320.

Figure 9 — *Figure deleted.*

3.7 Fillet weld fracture test (for material of thickness 3 mm and over)

3.7.1 Object. The object of the fracture test on fillet welds is to reveal the depth of root penetration and the presence of root flaws, or, if a saw cut is made along the weld face, to break the joint through the weld to permit examination of the fracture surfaces. The test is of limited usefulness for welds in copper and copper alloys, however, because of the high ductility of these materials.

3.7.2 Preparation of test specimen. The test specimen shall be prepared according to one of the forms shown in Figure 10. To ensure fracture in the weld a central saw cut 1.5 mm deep may be made along the length of the weld face.

3.7.3 Testing. The specimen shall be fractured by bending or by blows applied in the direction indicated in Figure 10.

3.7.4 Reporting of results. The following shall be reported as results of the test:

1) Thickness of parent metal.

2) Throat thickness and leg length of weld.

3) Location of fracture.

4) Appearance of joint after testing, e.g. type and location of any flaws present.

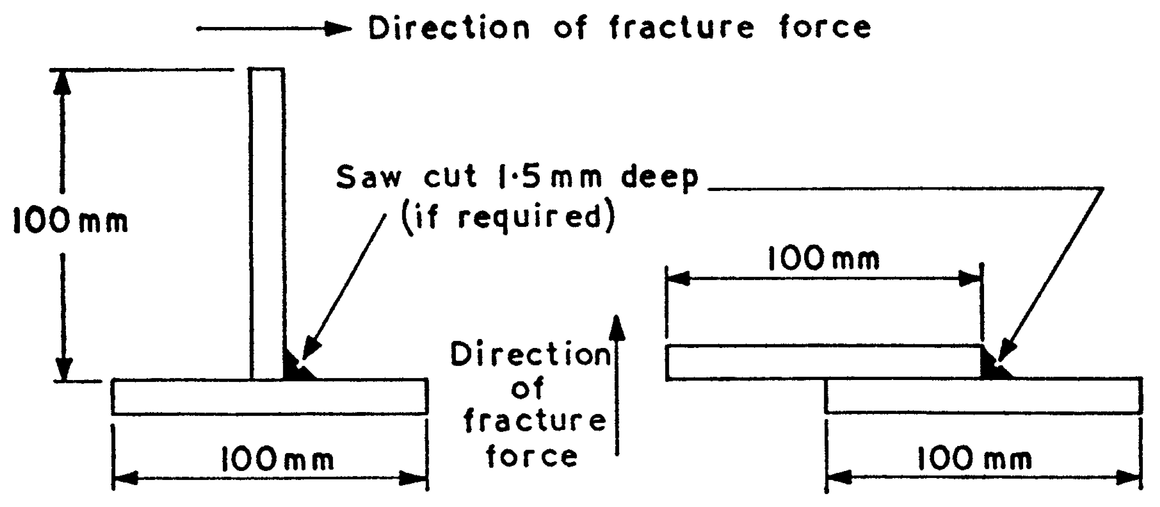

Figure 10 — Alternative forms of fillet weld fracture test specimen

Appendix A Suggested method of preparing etched specimens

A.1 Preparation of surfaces for etching

The initial preparation of a cut surface may be by milling or turning. Alternatively, the surface should be filed with a coarse file until all deep marks are removed. It should then be filed at right angles to the original coarse file marks with a smooth file. The application of chalk to the teeth of the fine file will reduce the risk of surface scoring by metallic particles trapped in the teeth of the file.

The machined or smooth-filed surface is then abraded on successively finer grades of waterproof silicon carbide paper[3]. A suitable sequence of grit sizes is P100, P240, P400 and P600. If the specimen is of suitable size to be conveniently handled, the most satisfactory procedure is to lay the appropriate sheet of abrasive paper, face up, on a flat surface such as plate glass, resin impregnated paper laminate, etc. The abrasive paper is then lubricated either with water, industrial alcohol, or white spirit, and the specimen carefully rubbed on it, with the application of moderate pressure, until all traces of the surface scratching from the previous treatment are removed. The specimen is then washed to remove all traces of abrasive, and the procedure repeated with the next finer grade of abrasive paper, the direction of abrading in each case being at right angles to the marks made by the previous paper.

In cases where the specimen size is such that the above procedure is inconvenient, the abrading may be carried out by employing rotating abrasive disks in a suitable hand tool. This operation will of necessity be carried out dry, and successively finer grit sizes should be used, as in the wet method. Care should be taken to avoid exerting undue pressure on the surface, since this will cause metal to flow over, and obscure any fine porosity which may be present.

A fine-machined surface, produced by sharp tools, with adequate lubrication, is suitable for macro-etching without any further preparation, and the abrading of a filed surface need only be taken as far as P400 grade for a satisfactory etch to be obtained. Such machined surfaces are not, however, in the most suitable condition for the detection of fine porosity, for which purpose it is recommended that abrading down to P600 grade paper should be employed.

A.2 Etching for macro-examination

A suitable etching reagent is a cold 10 % aqueous solution of nitric acid. On large specimens, application is by swabbing, whereas for small specimens, complete immersion is the most convenient method. Etching times vary, depending on the composition of the parent metal and filler metal, but are generally within the range 3–10 minutes. Etching times, when using the complete immersion technique, can be considerably shortened by warming the acid gently. Precautions should be taken to avoid inhalation of the toxic brown fumes, consisting of oxides of nitrogen, which are evolved during the etching.

When the structure has been adequately revealed, the acid is washed off in running water, and the specimen dried as quickly as possible, to avoid staining.

If difficulty is experienced in obtaining sufficient contrast using the nitric acid etch alone, it can be improved by swabbing the specimen, after etching in nitric acid and washing, with a cotton wool pad soaked in a 5 % aqueous ferric chloride solution. Washing and drying is then carried out as before.

[3] See BS 871, "*Specification for abrasive papers and cloths*".

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