British Standard

BRITISH STANDARD

BS 709:1983

Incorporating Amendment Nos. 1, 2 and 3

Methods of

Destructive testing fusion welded joints weld metal in steel

ICS 25.160.40

Committees responsible for this British Standard

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Aluminium Federation
Associated Offices Technical Committee
British Compressed Gases Association
British Constructional Steelwork Association
British Railways Board
British Steel Industry
Electricity Supply Industry in England and Wales
Health and Safety Executive
Institution of Structural Engineers
Ministry of Defence
Water-tube Boilermakers' Association
Welding Manufacturers' Association

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Contents

Foreword

This revision of BS 709:1971 has been prepared under the direction of the Welding Standards Committee. It retains the general pattern of the 1971 edition but has been modified to take into account developments in the international field. This edition introduces an intercrystalline corrosion test, a fracture toughness test and a test of hardness gradient across a weld. BS 709:1971 is withdrawn.

The standard covers only routine approval tests normally required by application standards. Tests for the susceptibility to lamellar tearing, re-heat cracking and fatigue are therefore not included.

Standards relating to welded constructions in various branches of engineering generally include requirements for certain welding tests to be conducted, primarily for the approval of welding procedures and operators. There is seldom any technical reason for divergence from standard procedures to be followed for such welding tests and there are both practical and economic advantages to be gained in standardization. The main purpose of this standard is to describe test procedures and to specify requirements for test specimens that should be quoted, or incorporated, in engineering application standards that deal with welded constructions. Where differences still exist between application standards, the methods of test given in this standard are to be preferred.

A general indication is given of the purpose served by each of the different 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 or the repeat tests to be allowed in the event of failure. Such requirements are matters to be dealt with in the particular application standard, where this exists, or to be agreed between the manufacturer and purchaser.

It should be realized that variations in the welding procedure or the quality of test specimen preparation can give rise to variations in the 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 10, an inside back cover 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 Scope

This British Standard describes routine destructive methods of testing fusion welded joints and weld metal in steel (including pipes[1)] where appropriate) but does not include non-destructive examination. It also specifies the shape and dimensions of standard test pieces and specimens for the tests described.

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 British Standard, the definitions given in BS 499-1[2)] apply together with the following definitions given in BS 499-1:1965.

2.1
test piece

components welded together in accordance with a specified welding procedure, or a portion of a welded joint detached from a structure for test

2.2
test specimen

a portion detached from a test piece and prepared as required for testing

3 Separation of test specimen

The method employed for the separation of test specimens shall be such as to cause minimum deformation and minimum heating of that part of the test specimen to be used for measurement. Particular attention shall be paid to this when measurement of proof stress, permanent set stress or yield stress is to be made. Machining is usually the best method, but when a specimen is sheared or thermally cut an adequate allowance shall be left for machining if necessary.

Each test specimen shall be marked so that it is possible to identify the exact position in the fabrication or test assembly from which it was taken.

4 Heat treatment

Test specimens shall be heat treated only if specified or allowed by the application standard relating to the welded joint to be tested. Where possible, they shall be treated together with the welded part. Where this is not possible, the specimens shall be heat treated separately, the treatment and the rate of cooling being similar to that given to the welded part.

A hydrogen release treatment shall be applied for the purpose of testing only in those situations where it is permitted under the conditions specified in the application standard, e.g. BS 639, or the particular weld procedure.

Details of any heat treatment applied to the test pieces shall be reported.

5 Tensile tests

5.1 Transverse tensile test

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

Table 1 — *Table deleted*

Figure 1 — *Figure deleted*

Figure 2 — *Figure deleted*

Figure 3 — *Figure deleted*

Figure 4 — *Figure deleted*

Figure 5 — *Figure deleted*

[1)] In this standard the word "pipe" alone or in combination is used to mean "pipe" or "tube" or "structural hollow section" (circular or rectangular), although these terms are often used for different categories of product by different industries.

[2)] Under revision.

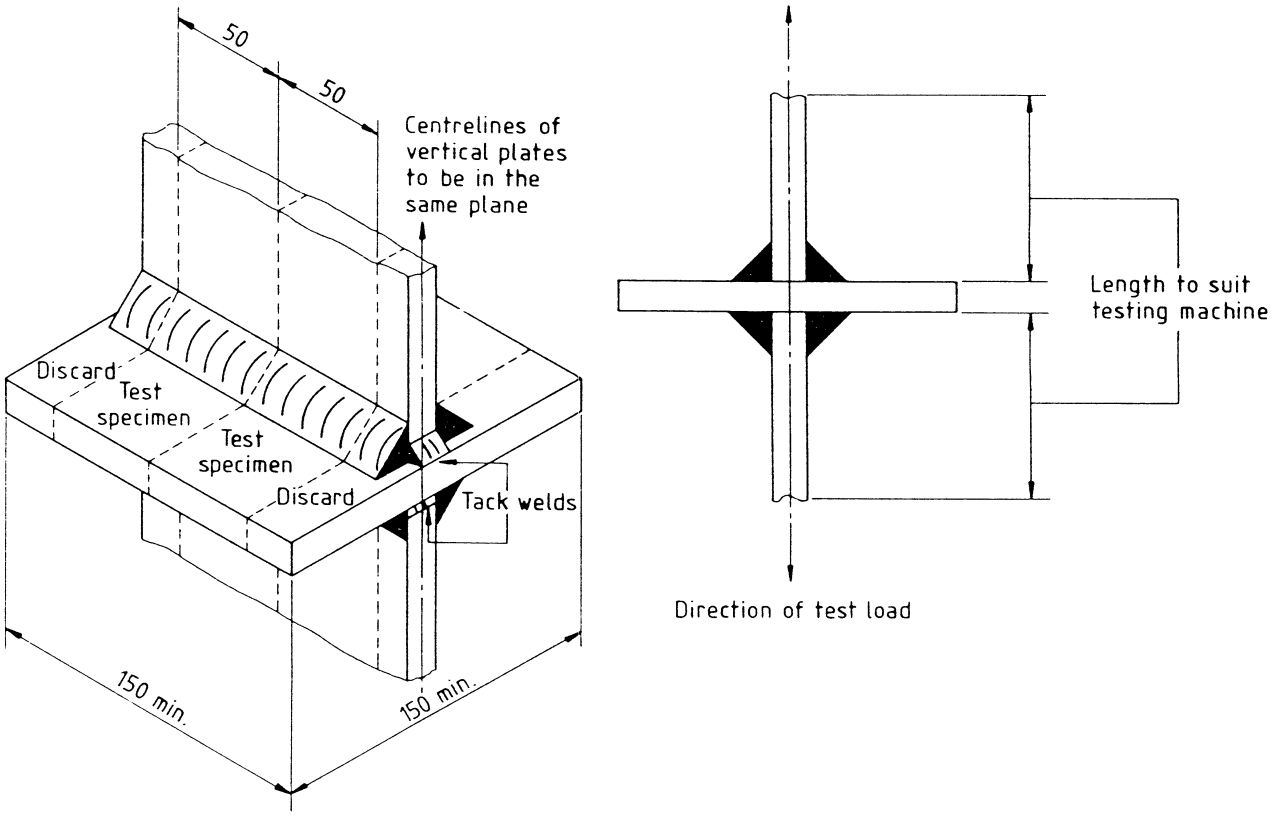


Figure 6 — Cruciform test piece, specimens and method of testing

5.2 Cruciform test

5.2.1 *Principle.* The cruciform test determines the relative tensile strength under static loading of fillet welded joints between plates.

NOTE This test should preferably be supplemented by the use of macro-examination of cross sections of the joint (see clause **9**).

5.2.2 *Preparation of test piece and test specimens.* The test piece shall be made from plate of full thickness. The test piece and test specimens shall be of the shape and dimensions shown in Figure 6. The plate thickness, fillet leg length, welding procedure and penetration shall be as specified in the appropriate application standard.

If macro-examination is to be carried out, the inner edges of the outer discards shall be prepared in accordance with clause **9**.

5.2.3 *Procedure.* Test the specimens in tension with the load applied in the direction indicated in Figure 6.

5.2.4 *Test report.* The following shall be reported as results of the test:

a) thickness of parent metal;

b) throat thickness and leg length of weld;

c) location of the fracture, whether in the weld, in the heat-affected zone or in the parent metal (if the fracture is in the parent metal, its approximate distance from the weld junction shall be stated);

d) the type and location of any weld flaws present on the fracture surfaces;

e) description of the appearance of surfaces subjected to macro-examination and the type and location of any weld flaws present.

5.3 All-weld tensile test

All-weld tensile tests shall be carried out in accordance with BS EN 876.

Figure 7 — *Figure deleted*

Figure 8 — *Figure deleted*

Table 2 — *Table deleted*

6 Bend tests

Bend tests shall be carried out in accordance with BS EN 910:1996.

Figure 9 — *Figure deleted*

Figure 10 — *Figure deleted*

Figure 11 — *Figure deleted*

Figure 12 — *Figure deleted*

Figure 13 — *Figure deleted*

Figure 14 — *Figure deleted*

Figure 15 — *Figure deleted*

Figure 16 — *Figure deleted*

7 Fracture test (for material of thickness 2 mm and over)

Fracture tests shall be in accordance with BS EN 1320.

Figure 17 — *Figure deleted*

8 Fillet weld fracture test

8.1 Principle. The joint is broken through the weld to permit examination of the fracture surfaces for welding defects.

8.2 Preparation of test piece and test specimens. The form of the test piece shall be one of those shown in Figure 18. The thickness of the plates used shall be greater than the throat thickness of the fillet weld under test.

The test piece shall be cut to give three test specimens of approximately equal length.

NOTE To ensure fracture in the weld, a central saw cut 2 mm deep may be made along the length of the weld surface.

8.3 Procedure. Fracture the specimens either by bending or by blows applied in the direction indicated in Figure 18.

8.4 Test report. The following shall be reported as results of the test:

a) thickness of parent metal;

b) throat thickness and leg length of weld;

c) location of fracture;

d) appearance of joint after testing, e.g. type and location of any defects present.

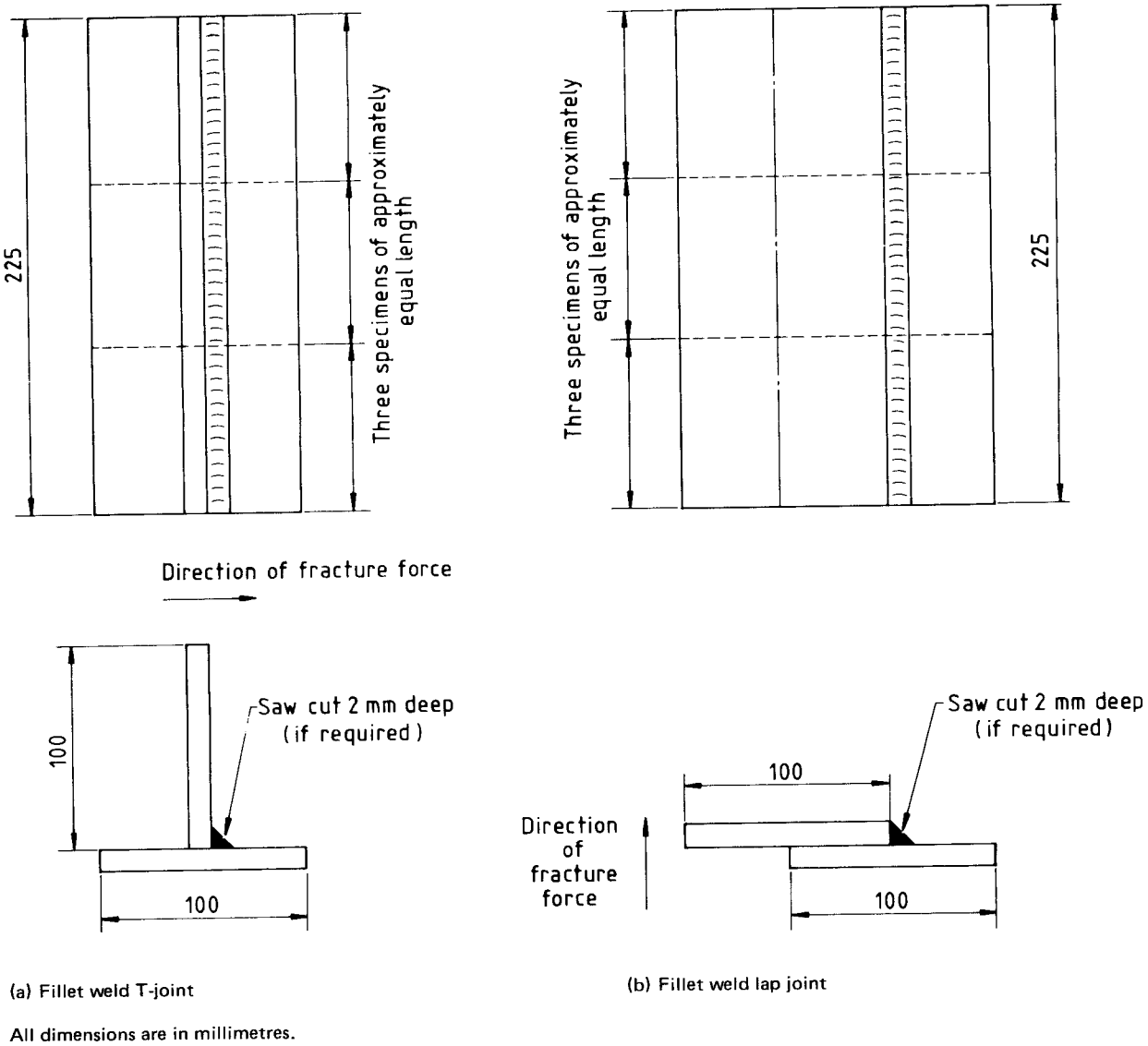


Figure 18 — Alternative forms of fillet weld test piece and specimens

9 Macroscopic examination

Macroscopic examination shall be in accordance with BS EN 1321.

Figure 19 — *Figure deleted*

10 Test for hardness across welded joint

Test for hardness across the welded joint shall be carried out in accordance with BS EN 1043-1:1996.

Table 3 — *Table deleted*

Figure 20 — *Figure deleted*

11 Charpy V-notch impact test

Impact tests shall be in accordance with BS EN 875.

Figure 21 — *Figure deleted*

Table 4 — *Table deleted*

12 Intercrystalline corrosion test (for austenitic stainless steel plate or pipe welds)

12.1 Principle. The susceptibility to intergranular attack at a welded joint is checked under standard conditions (see BS 5903).

NOTE This accelerated laboratory test is no guarantee of the performance in service of particular joints but may be used to compare various procedures and consumables.

12.2 Preparation of test specimen. If the material does not exceed 13 mm, the test specimen shall be the full thickness of the material at the welded joint. If the material exceeds 13 mm, two specimens shall be cut to include the inner and outer surfaces.

The excess weld metal and penetration bead shall be left intact except for those applications where the weld represented is dressed.

12.3 Procedure. Completely immerse the test specimen and approximately 50 g of copper turnings or filings, such that the test specimen is in contact with the copper, for a period of 24 h in a boiling solution of sufficient volume to provide a minimum of 8 mL of solution per square centimetre of test specimen surface area, having the following composition:

100 g copper sulphate ($CuSO_4 \cdot 5H_2O$)

184 g (100 mL) sulphuric acid (relative density 1.84)

made up to 1 L with distilled water (or water complying with BS 3978).

After the completion of the boiling period, cold bend the specimen through 90° around a former of diameter 2 t, where t is the thickness of the test specimen, with the weld surface under investigation in tension at the crown of the bend.

12.4 Test report. The following shall be reported as results of the test:

a) width and thickness of specimen;

b) any heat treatment applied after welding;

c) period of immersion;

d) angle of bend;

e) appearance of specimen after bending, e.g. any cracking on outer convex surface.

13 Fracture toughness test (K_{Ic}/CTOD test)

13.1 Principle. The resistance of a material to fracture is determined in order to evaluate its defect tolerance under service conditions.

In order to have the necessary confidence in test results, a minimum of three specimens is tested under the specified conditions. The acceptibility of this minimum depends on the particular fracture regime in which the material fails. In a complex piece, such as a weldment, such groups of tests are conducted at various areas within the weldment.

13.2 Preparation of test specimens. The number, location and orientation of the test specimens shall be as specified in any appropriate application standard. The specimen thickness shall be the full thickness of the plate.

NOTE 1 The plane strain fracture toughness, K_{Ic}, is a material property independent of specimen geometry and size, although minimum size requirements are necessary to ensure failure under plane strain. It is therefore necessary to test specimens of full plate thickness. CTOD data is relevant where plastic deformation prevails outside the limitations of LEFM and the resultant value of this parameter is specimen thickness dependent. It is therefore necessary to test specimens of full plate thickness.

The dimensions of the test pieces and detailed methods of preparation shall be in accordance with BS 5447:1977 (K_{Ic} tests) or BS 5762:1979 (CTOD testing).

NOTE 2 The fracture initiating crack is grown by fatigue from a notch machined prior to testing. For specimens with through thickness notches into multipass weldments in the as-welded condition, unacceptable fatigue crack growth may be experienced unless special fatigue cracking techniques are employed. One suitable technique to avoid this potential problem is local compression. Reference may be made to the *Welding Journal,* December 1976, pp. 1052-1057.

13.3 Procedure. Test the prepared specimen in three point bending, as shown schematically in Figure 22, at the temperature specified in the appropriate application standard and in accordance with the appropriate test standard.

Fit a clip gauge across the notch during testing to indicate the extent of crack opening prior to the onset of unstable fracture.

13.4 Test report. Test results shall be reported in accordance with the appropriate test standard, i.e. BS 5447 or BS 5762, and shall include the location and orientation of the initiating crack.

NOTE Using the information obtained from the test together with the material properties and the proposed service loading, the defect tolerances of the material can be evaluated for the particular test temperature (see PD 6493).

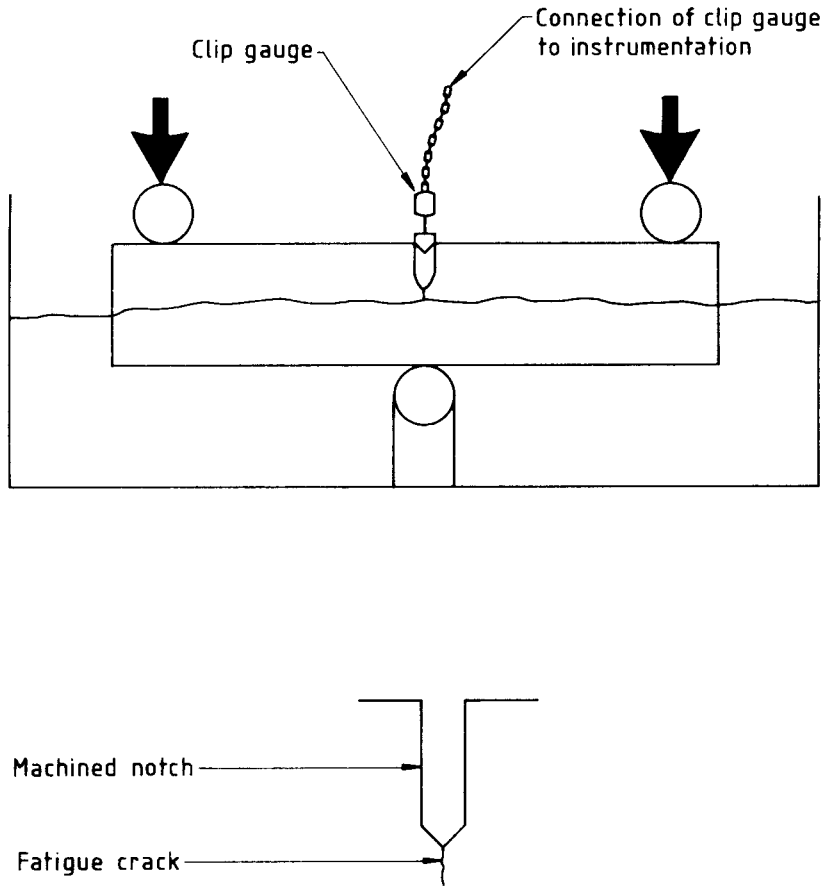


Figure 22 — K_{1c}/CTOD test configuration

Appendix A Suggested methods of preparing etched specimens

A.1 General. The methods of preparing etched specimens given in this appendix are suggested for convenience and are not requirements of this standard.

A.2 Preparation of surface for etching. After preliminary preparation, the smooth surface should be polished with successively finer grades of waterproof silicon carbide paper (see BS 871), e.g. P280, P320, P400, P500, the direction of polishing being at right angles to the marks made by the previous paper in each case, polishing being continued until the scratches of the previous paper have been removed before proceeding to the next finer grade.

A.3 Etching for macro-examination. In general for steel a P400 grade finish will be smooth enough for a satisfactory etch to be obtained for macro-examination. Suitable etching solutions are as follows.

a) For ferritic steels:

10 mL to 15 mL nitric acid (70 % *m*/*m*) (16N)

85 mL to 90 mL alcohol (industrial spirit[3])

NOTE Great care should be exercised in the preparation of this solution as the mixing of concentrated nitric acid and alcohol can be extremely dangerous. The acid should be added slowly to the alcohol and the mixture should be constantly stirred. The solution should be stored in a stoppered container to avoid concentration by evaporation.

b) For austenitic steels:

40 mL hydrochloric acid (36 % *m*/*m*) (11N)

30 mL nitric acid (70 % *m*/*m*) (16N)

30 mL water

During etching the reagent should be continuously moved over the specimen surface and this may be achieved by swabbing if desired. When the etching process is completed the specimens should be washed thoroughly with swabbing usually in water and then carefully dried, for example by the application of acetone in a fine jet followed by evaporation in a stream of hot air.

A.4 Etching for micro-examination. Where some critical examination is required (e.g. for micro-cracking) the specimen should be finished by fine polishing using diamond pastes.

Suitable etching solutions are as follows.

a) For ferritic steels:

1 mL to 5 mL nitric acid (70 % *m*/*m*) (16N)

100 mL alcohol

b) For austenitic steels:

1 g picric acid

5 mL hydrochloric acid (36 % *m*/*m*) (11N)

100 mL alcohol

Alternatively, the following reagent may be used for electrolytic polishing/etching of austenitics after wet pre-grinding up to grade P600 silicon carbide paper:

10 g oxalic acid

100 mL water

The etching process, whether chemical or electrolytic, is applied for the length of time found by experience to be suitable for the particular steel. The specimen should then be thoroughly washed in water followed by alcohol and dried in a stream of hot air.

[3] It should be noted that the use of industrial methylated spirits is governed by The Methylated Spirits Regulations, 1952 (S.I. 1952, No. 2230).

Appendix B
Vickers hardness test report for welded joints

The following is a specimen test report.

Testing by row of indentations

Parent metal: _____

Welding process: _____

Form of joint: _____

Thickness of material: _____

Filler metal: _____

Post-weld heat treatment: _____

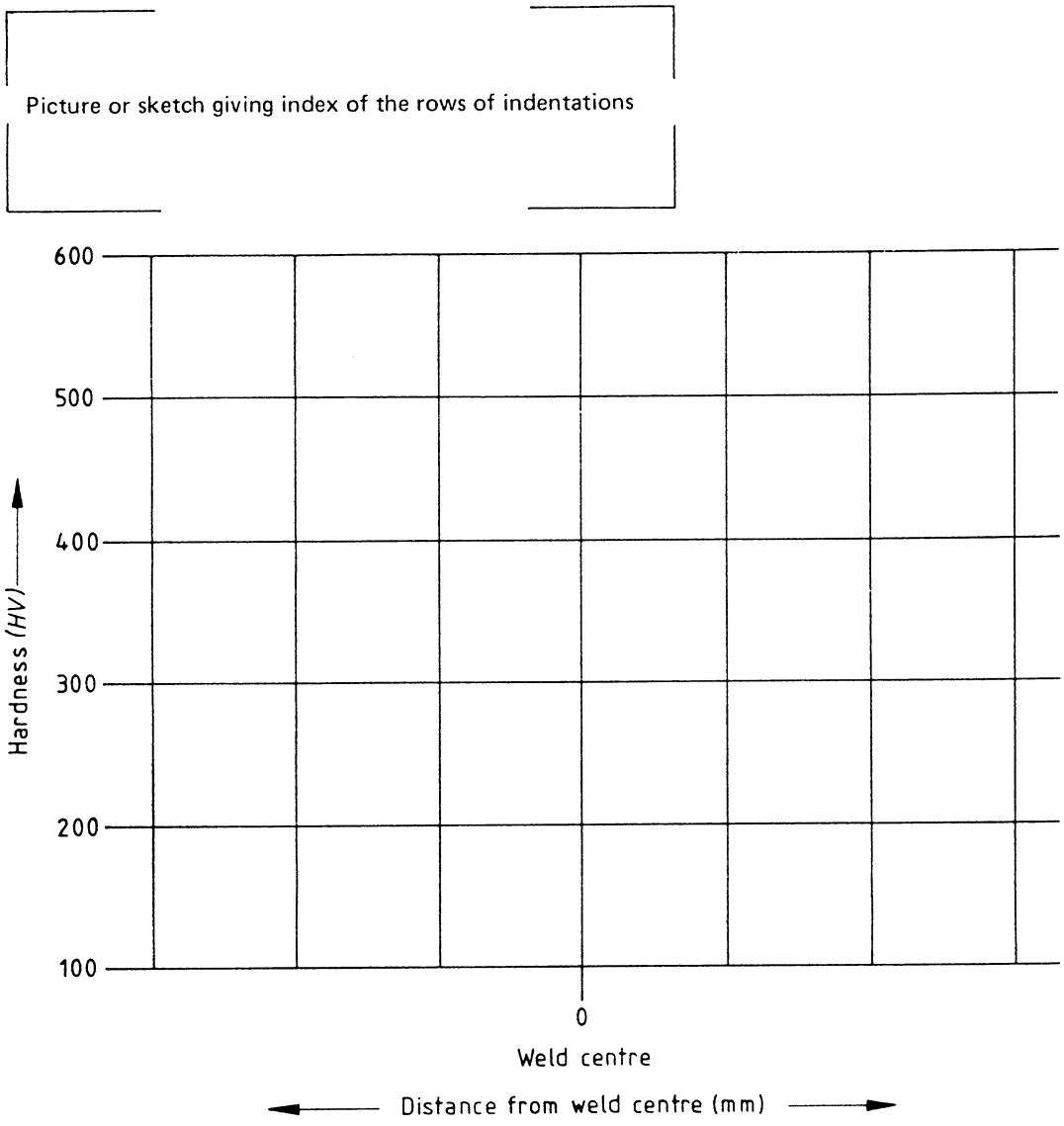
Test load: _____

Index of the row of indentations: _____

Interval *A* between indentations in the heat affected zone: _____

Remarks: _____

(continued on inside back cover)



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Publications referred to

BS 427, *Method for Vickers hardness test.*

BS 427-1, *Testing of metals.*

BS 499, *Welding terms and symbols.*

BS 499-1, *Welding, brazing and thermal cutting glossary.*

BS 639, *Covered electrodes for the manual metal-arc welding of carbon and carbon manganese steels.*

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

BS 3978, *Water for laboratory use.*

BS 5447, *Methods of test for plane strain fracture toughness (K_{1c}) of metallic materials.*

BS 5762, *Methods for crack opening displacement (COD) testing.*

BS 5903, *Method for determination of resistance to intergranular corrosion of austenitic stainless steels: copper sulphate-sulphuric acid method (Moneypenny Strauss test).*

BS EN 875, *Destructive tests on welds in metallic materials — Impact tests — Test specimen location, notch orientation and examination.*

BS EN 876, *Destructive tests on welds in metallic materials — Longitudinal tensile test on weld metal in fusion welded joints.*

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

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

BS EN 1043, *Destructive tests on welds in metallic materials — Hardness tests.*

BS EN 1043-1, *Hardness test on arc welded joints.*

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

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

PD 6493, *Guidance on some methods for the derivation of acceptance levels for defects in fusion welded joints.*

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