British Standard

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BRITISH STANDARD

BS 1723-3:
1988

Brazing —

Part 3: Methods for non-destructive and destructive testing

UDC 621.791.36

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Welding Standards Committee (WEE/-) to Technical Committee WEE/19, upon which the following bodies were represented:

BNF Metals Technology Centre
British Association for Brazing and Soldering
British Non-Ferrous Metals Federation
Electricity Supply Industry in England and Wales
Heating and Ventilating Contractors' Association
Institute of Refrigeration
Joint Industry Board for Plumbing Mechanical Engineering Services in England and Wales
Plumbing Trades Union
Society of British Aerospace Companies Limited
Welding Institute
Coopted member

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Contents

Foreword

This Part of BS 1723 has been prepared under the direction of the Welding Standards Committee. It was originally published as one standard but this revision has been divided into four Parts as follows:

— *Part 1: Specification for brazing;*

— *Part 2: Guide to brazing;*

— *Part 3: Methods for non-destructive and destructive testing;*

— *Part 4: Method for specifying brazing procedure and operator approval testing.*

Standards relating to welded constructions in various branches of engineering generally include requirements for certain tests to be carried out. This Part of BS 1723 will, for the first time, extend the applicability of destructive and non-destructive tests to joints produced by the brazing process.

BS 1723-2 categorizes joints in brazed constructions into four types, based upon life limiting processes and cost of failure. The application of testing methods for these categories and their limitations are tabulated in Appendix A.

Purchasers of examination services in accordance with the methods described in this Part of BS 1723 are advised to specify in their purchasing contract that the supplier operates a quality system in compliance with BS 5750 to assure themselves that examinations claimed to comply with this Part of BS 1723 consistently achieve the required level of performance.

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.

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 to iv, pages 1 to 52, 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.

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Section 1. General

1.1 Scope

This Part of BS 1723 describes both non-destructive and destructive methods of testing brazed joints. Methods of test for brazing filler metals are also given. When appropriate it also specifies the shape and dimensions of test pieces for the tests described.

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

1.2 Definitions

1.2.1 General

For the purposes of this Part of BS 1723, the definitions given in BS 18, BS 131, BS 240, BS 427, BS 499-1, BS 709, BS 891, BS 1610, BS 1639, BS 1723-1, BS 2600, BS 2910, BS 3451, BS 3500, BS 3636, BS 3683, BS 4331, BS 5466, BS 6072, BS 6443 and BSI Handbook 22 apply together with the following.

1.2.2 Definitions specific to testing of brazed joints

1.2.2.1
defect

any material or process imperfection. A defect may or may not be cause for rejection of a brazed joint

NOTE 1 As well as irregularities in the brazed joint, a defect can cover items such as deviations from the intended relative positions of the component parts and from the designed shape of the brazed construction.

NOTE 2 This term may require a different definition when used in connection with product liability.

1.2.2.2
test

a critical trial (often involving stress) or the examination of one or more properties or characteristics of a material, product or set of observations

1.2.2.3
test sample

an assembly brazed in accordance with an approved brazing procedure. It may be one of the following

a) a brazed construction, either taken from production or made specifically for test purposes;

b) a brazed joint detached from a brazed construction;

c) a simulation that will adequately replicate the brazed joint in the production assembly, e.g. for approval testing.

1.2.2.4
test piece

a portion detached from a test sample and prepared for testing

NOTE This term is synonymous with the term "test specimen".

1.2.2.5
proof load

a specified load applied to proof test a brazed construction

NOTE The loading method and magnitude of the load should be defined by a competent person.

1.2.3 Definitions specific to brazing filler metals

1.2.3.1
differential thermal analysis (DTA)

a technique in which the temperature difference between a substance and a reference material is measured as a function of temperature whilst the substance and the reference material are subjected to a controlled temperature programme

1.2.3.2
sample

the actual material being investigated

1.2.3.3
reference material

a known substance, usually inactive thermally over the temperature range of interest

1.2.3.4
specimens

the sample and the reference material

1.2.3.5
specimen holder assembly

the complete assembly in which the specimens are housed

1.3 General principles

Defects are observed when brazed joints are examined non-destructively and in some cases by destructive tests. They may reduce the quality and performance characteristics of the joint or the brazed construction.

This Part of BS 1723 does not give guidance regarding the cause of the defect or its effect upon the classification of the joint quality (for convenience Appendix A reproduces the classification given in BS 1723-2), or the effects of single or multiple defects upon the performance characteristics of the brazed construction. This will depend upon the life-limiting processes to which the joint is subjected and the life requirements and performance agreed for the brazed construction by the contracting parties. However, guidance is given regarding the types of defect that are observed when non-destructive and destructive tests are applied. These are defined diagrammatically in Appendix B.

NOTE The importance of tolerance to typical defects and cause for rejection should be agreed between the contracting parties. The method of defect interpretation and the method of presentation of observations should be agreed at the time of placing the contract.

The use of any method should always be considered in relation to testing as a whole. The benefits of using any particular method can only be obtained by consideration of results in conjunction with results obtained by using other test methods. The most appropriate method or methods of testing should be selected.

1.4 Items to be agreed and documented

1.4.1 General

The following items shall be agreed between the contracting parties, either at the enquiry stage or at the time of placing the contract, and documented as necessary for verification purposes:

a) type of test;

b) frequency of testing;

c) acceptance/rejection criteria;

d) methods of communication between the contracting parties and the method of progressing concessionable items;

e) retest procedures after repair;

f) method of reporting test piece history (see Appendix C) and test results (see Appendix E);

g) operator and operator qualifications (see Appendix D);

h) separation and preparation of the test piece (see **1.5**);

i) sampling procedures (see **1.6**).

1.4.2 Items specific to tests

1.4.2.1 *General.* The following items listed in **1.4.2.2** to **1.4.2.17** to be agreed between the contracting parties, which are specified in the clauses referred to, shall be documented. Both the definitive requirements specified in any specific test and the following documented items shall be satisfied before a claim that the specific test method has been carried out in accordance with this Part of BS 1723 can be made and verified.

1.4.2.2 ***Visual and aided visual examination*** (clause **2.2**)

a) The methods to be used to clean the surface (see **2.2.3.2**).

1.4.2.3 ***Proof testing*** (clause **2.3**)

a) Other methods of applying the specified load [see **2.3.4.1** f)].

b) The extent of measurements to be made and methods to be used (see **2.3.4.3**).

1.4.2.4 ***Pressure and vacuum testing for leaks*** (clause **2.4**)

a) The method of preparation of the test piece [see **2.4.3** b)].

b) The method of testing the test piece and temperature of test (see **2.4.4.2**).

1.4.2.5 ***Penetrant flaw detection*** (clause **2.5**)

a) Examination test procedure if not in accordance with BS 6443 [see **2.5.4.1** b)].

b) Frequency of control checks on standard pieces (see **2.5.4.2.2**).

1.4.2.6 ***Ultrasonic examination*** (clause **2.6**)

a) Modification of the test piece surface (see **2.6.3.2**).

b) The frequency of examination of the reference standard and the standard defects (see **2.6.4.6.2**).

1.4.2.7 ***Radiographic examination*** (clause **2.7**)

a) Method of identification when permanent marking is not possible (see **2.7.4.1**).

1.4.2.8 ***Thermographic testing*** (clause **2.8**)

a) Criteria of acceptance when there is no application standard (see **2.8.1**).

1.4.2.9 ***Stress rupture testing*** (clause **3.4**)

a) The configuration of the test piece and its method of manufacture (see **3.4.3**).

b) The applied load and temperature of testing (see **3.4.4**).

1.4.2.10 ***Impact testing*** (clause **3.5**)

a) The design of the test piece [see **3.5.3** c)].

b) The test piece dimensions (see **3.5.3**).

c) The method of loading and magnitude of the load (see **3.5.4**).

d) The temperature of test (see **3.5.4**).

1.4.2.11 ***Bend testing*** (clause **3.6**)

a) The details of the test piece [see **3.6.3** b)].

b) Other test piece or test procedure [see **3.6.4** b)].

1.4.2.12 ***Hardness testing*** (clause **3.7**)

a) The positions of the section to be tested (see **3.7.3**).

1.4.2.13 ***Metallographic examination*** (clause **3.8**)

a) The method of processing the data (see **3.8.4**).

1.4.2.14 ***Corrosion testing*** (clause **3.9**)

a) The test piece design (see **3.9.3**).

b) The environmental conditions of the test (see **3.9.4**).

c) The intervals for taking the test pieces from the corrosive environment and the methods of testing (see **3.9.4**).

d) The total exposure time, temperature of testing, corrosive environment, number of samples and any other factors (see **3.9.4**).

1.4.2.15 ***Chemical composition*** (clause **4.3**)

a) The method of determination of chemical composition [see **4.3.2** c)].

1.4.2.16 ***Flow characteristics and wettability test*** (clause **6.2**)

a) The method of surface preparation and the variables to be investigated (see **6.2.3**).

b) Appropriate method of heating to brazing temperature and methods of destructive and non-destructive testing to be applied (see **6.2.4.7**).

1.4.2.17 ***The joint filling and metallurgical characteristics of high temperature brazing filler metals*** (clause **6.3**)

a) The methods of examination of the completed test piece (see **6.3.4**).

1.5 Separation and preparation of the test piece (see 1.4.1)

The test sample from which the test piece is prepared shall be manufactured by the brazing procedure, approved or not approved (see BS 1723-4), or the method of brazing that shall be agreed between the contracting parties at the time of placing the contract. This shall be by the techniques and practice given in BS 1723-1 and BS 1723-2. When test procedures are being used to investigate brazing variables such as joint clearance, parent metal/filler metal reactions, surface preparation, brazing cycle, etc., as well as the comparative basic mechanical and metallurgical properties of the filler metal, the variables not being the subject of the test shall be controlled within agreed tolerances. The variation in the parameters under investigation shall be the subject of agreement between the contracting parties at the time of placing the contract. After the test sample has been manufactured, it shall be prepared for destructive or non-destructive testing. The method of separation of the test pieces shall be such as to cause minimum distortion, damage and heating of the brazed joint and parent material, so that the properties of the test piece and other test pieces are not modified. Some filler metals used in brazing are susceptible to cracking when the brazed joint is separated by machining or sawing, and the method of separation shall be such that the test pieces are not affected. Surface modification such as grinding is permissible in cases when the surface condition interferes with the test procedures or the interpretation of non-destructive test results. The surface of the brazed joint shall be free from any flux residues or any other process debris. The surface shall be cleaned by methods agreed by the contracting parties, which may include washing with hot or cold water or pickling. Debris and overspill that may affect the results of the non-destructive or destructive examination or test shall be removed as necessary by a mechanical method (e.g. scratch brushing).

Test pieces shall be marked by a permanent method of identification so that their position in relation to the test sample is unequivocal and the results can be related to the test sample.

A data sheet similar to that in Appendix C shall be used to record details of the test piece preparation.

1.6 Sampling procedures

Sampling procedures used by the supplier shall be either:

a) in accordance with the application standard; or

b) subject to agreement between the contracting parties (see **1.4.1**).

NOTE 1 See BS 5750-2 and BS 2635.

NOTE 2 Suppliers should apply the necessary conditions for sampling (accurate recording of data, randomness, formation of clear decision rules), as incorrect sampling may indicate a false level of product quality.

NOTE 3 The test samples and the conduct of the test should generally be economic, both in the cost of preparation and in the method of testing. However, when tests are used to determine data for properties such as corrosion or stress rupture, the test procedures, interpretation and examination of the results will in themselves be expensive.

Section 2. Non-destructive testing of brazed joints

2.1 General

This Section describes non-destructive test procedures and test piece types necessary to perform the tests on brazed joints.

The non-destructive test methods described are as follows:

a) visual and aided visual (see clause **2.2**);

b) proof (see clause **2.3**);

c) pressure/vacuum (see clause **2.4**);

d) penetrant (see clause **2.5**);

e) ultrasonics (see clause **2.6**);

f) radiographic (see clause **2.7**);

g) thermographic (see clause **2.8**).

The brazed joints to which these tests are applied can either be test samples manufactured to obtain brazed joint design data, or manufactured as part of the approval testing of a brazing procedure, or parts of a brazed construction. The type of test piece described for each test can be quoted or incorporated in engineering applications standards that deal with brazed constructions.

This section does not recommend the number of test pieces to be tested or the repeat tests allowed. Neither does it specify methods of sampling brazed joints except to give guidance regarding the precautions necessary, nor does it comment on the acceptance criteria applicable to any of the tests. No attempt is made to define which test or tests, if any, should be applied in any situation. This is a matter for agreement between the contracting parties at the time of placing the order (see **1.4.1**).

The methods of evaluation are not associated with any particular type of brazed structure but lay down the general principles of the types of testing described. It is emphasized that a satisfactory examination method can only be developed and used after taking into account all the relevant factors regarding the equipment to be used and the characteristics of the test piece being examined.

2.2 Visual and aided visual examination of brazed joints

2.2.1 General

Brazed joints should be visually inspected (either 100 % or sample inspected) as this is the most elementary method of non-destructive testing. The operator should be aware of the types of defects that may be expected in the brazed joint, and the acceptance/rejection criteria should be agreed (see **1.4.1**). Visual inspection is frequently followed or supplemented by some other method(s) of non-destructive testing.

If the opposite ends of the joint from the pre-placed filler metal can be examined, a witness gives confidence that the filler metal has flowed through the capillary joint gap. Visual examination will not reveal internal defects, such as trapped flux, porosity, lack of fill and internal cracks.

2.2.2 Principle

The principle of visual examination (unaided and aided) which is basic to all manufacturing processes, is to check the appearance, soundness, contour and dimensions of the brazed joint and the adjacent parent material.

The test is effective for detecting the presence of external voids, surface porosity, surface cracks, gross erosion and the general aesthetic appearance of the brazed joint region.

2.2.3 Preparation of the test piece

2.2.3.1 The surface of the brazed joint and adjacent parent material shall be examined in the brazed condition except that the surface shall be clean, i.e. free from any flux residues or any other process deposit.

2.2.3.2 The methods used to clean the surface shall be agreed between the contracting parties [see **1.4.2.2** a)].

2.2.4 Procedure

2.2.4.1 *Aid to visual inspection.* Aids to visual inspection shall be used to assess any imperfections in the brazed joint. The joint shall be illuminated with a suitable light source the light direction of which shall be varied. The colour of the light shall be such that there is good contrast between any imperfections and the background of the brazed joint itself and glare and dazzling of the operator avoided. After visual examination with the unaided eye, the joint shall be examined if required (see **1.4.1**) at a magnification of up to × 5 using a low power magnifier or hand lens. A mirror or some similar device shall be used to examine brazed joints that are not directly visible.

2.2.4.2 *Measurement.* When the dimensions of a brazed joint or brazed construction are required (see **1.4.1**), devices such as those listed below shall be used:

a) straight edge;

b) rule;

c) protractor;

d) calipers (internal, external, vernier);

e) height or depth gauge;

f) any templates or go/no go gauges designed and manufactured for specific applications that will reduce the time spent on non-destructive examination.

2.2.5 Test results and information to be reported

The appearance of the surface(s) of the brazed joint(s) shall be reported.

NOTE 1 To aid classification of any defects, a diagram or photograph of types of defects that may occur and are cause for rejection or for further investigation should be available to the operator.

The visual observations and measurements made during the test shall be recorded.

The test results and information to be reported shall include the following:

a) reference (e.g. contract number, part number, location on brazed structure, as applicable);

b) date of test;

c) method of illumination and magnification;

d) visual defects observed;

e) measurements;

f) results of go/no go examination;

g) name of laboratory and identity of operator.

NOTE 2 Appendix E is a suggested format for reporting test details and results.

2.3 Proof testing of brazed joints

2.3.1 General

Proof testing is a method of inspection that subjects the brazed construction to loads higher than those which the construction will have to support during its subsequent life, but which will not cause permanent deformation. The magnitude of the loads should be specified by a competent person such as a design authority. In some cases representative samples of a manufacturer's production may be tested by this method, or for critical applications, all such brazed constructions may be tested by this method. For checking workmanship and for the quality control of manufacturing processes, the test piece shall generally be the brazed construction.

NOTE 1 The frequency of testing, the test method, and the magnitude of the test load should be agreed between the contracting parties at the time of placing the contract.

NOTE 2 The applied load can be static or dynamic and the temperature of testing can be ambient or other agreed testing temperature.

NOTE 3 If the brazed construction withstands the test then the test is non-destructive. If the brazed construction fails to withstand the test, the test is destructive.

It is normal practice for the test results to be evaluated by a competent person who is aware of the design requirements and the appropriate codes, if applicable. For critical applications an independent party should also evaluate the test results and confirm the interpretation.

NOTE 4 The independent party could be an inspecting authority associated with the insurance aspects of the brazed construction.

2.3.2 Principle

The principle of the test is to confirm the design calculations, to check the quality of materials used to manufacture the brazed construction, and the ability of the brazed construction to withstand the life-limiting processes to which it will be subjected.

NOTE The proof test should be the last procedure after final heat treatment, cleaning and any other finishing process likely to influence the result of the test.

2.3.3 Preparation of the test piece

For testing design calculations and performance requirements, the test piece shall be the brazed joint or a similar configuration to the brazed joint in the brazed construction.

It shall, if necessary, be modified so that it can be accommodated in the test rig. The modification shall in no way influence the result of the test.

2.3.4 Procedure

2.3.4.1 The test shall be conducted by methods most suitable for the shape of the test piece. For items manufactured to comply with an application standard, the requirements of the application standard shall be satisfied.

The specified load shall be applied by one of the following:

a) tensile or compressive loading;

b) hydrostatic methods;

c) pneumatic testing;

d) spin testing;

e) thermal shock;

f) other methods agreed between the contracting parties [see **1.4.2.3** a)].

NOTE For tensile loading, the proof testing load is typically 20 % greater than the maximum load applied during the service life of the brazed construction.

WARNING. Procedures for conducting pressure tests on vessels subjected to internal or external pressure are described in BS 5500 and BS 3636 which specifies methods of calculating test pressures and the safety precautions which are essential to observe.

2.3.4.2 Measurement of the dimensions and changes in dimensions of the test piece shall be taken during the conduct of the test. Strain gauges shall be mechanical, optical or electronic, and the standard of accuracy of these shall be as specified in BS 18.

2.3.4.3 The extent of the measurements to be made and the methods to be used shall be agreed between the contracting parties [see **1.4.2.3** b)].

2.3.4.4 The test piece shall be visually examined during the test and, in the case of hydrostatic testing, the operator shall look for leakage at the brazed joint and in the construction generally.

2.3.5 Test results and information to be reported

The observations made during the test shall be recorded.Any unexpected occurrence such as leakage shall be made the subject of a special note.

The text results and information to be reported shall include the following:

a) reference (e.g. contract number, part number, location on brazed structure, as applicable);

b) date of test;

c) method of testing;

d) authority and designation of person witnessing the test;

e) designation of competent person specifying test conditions;

f) test conditions (temperature, load, etc.);

g) name of laboratory and identity of operator.

NOTE Appendix E is a suggested format for reporting test details and results.

2.4 Pressure and vacuum testing for leaks in brazed joints

2.4.1 General

When pressure testing, the pressure within the test piece is made greater than the external pressure by filling with a liquid or a gas. When liquid pressure testing, the component is examined for leakage of the liquid which may be coloured. When testing using a gas a leak is detected by observing bubble formation from the component, the joint being immersed or a suitable liquid brushed or dabbed on to the surface of the joint and the adjacent parent material.

Testing for leak tightness using the vacuum method is more sensitive than pressure testing. The comparative sensitivities of available testing methods are given in the table "Comparison of proving methods" (pages 16 and 17) and Appendix O of BS 3636:1963.

2.4.2 Principle

The principle of pressure and vacuum testing of brazed joints is to prove that the requirement of the application standard for leak or pressure tightness of a brazed joint and its associated construction has been achieved. BS 3636 describes the procedures for pressure and vacuum leak testing.

NOTE When a brazed joint is being tested by pressure and vacuum methods, the leakage rate, rate of pressure change or any other criteria should be agreed between the contracting parties at the time of placing the contract.

2.4.3 Preparation of the test piece

Before testing the test piece shall be prepared either:

a) as required by the application standard; or

b) as agreed between the contracting parties [see **1.4.2.4** a)].

In the case of vacuum testing all volatile compounds shall be removed before test evacuation. Where required by the application standard the test piece shall be prepared by baking at an appropriate temperature. Care shall be taken to prevent moisture contacting the test region as this may mask small leaks. The test piece shall have a leak tight connection between it and the testing equipment. The test equipment shall be designed so that it can either evacuate or pressurize the test piece.

2.4.4 Procedure

2.4.4.1 The details of the pressure or vacuum test procedures shall be as described as in BS 3636.

2.4.4.2 The test piece shall be tested appropriately as agreed by the contracting parties. The temperature of testing shall be agreed between the contracting parties [see **1.4.2.4** b)].

NOTE Tests may be done at stages during manufacture as well as at the final acceptance stage.

WARNING. All pneumatic test procedures should be supervised by a competent person familiar with the methods being used and with any inherent risk. It is essential that particular note is taken of the safety precautions detailed in Appendix P of BS 3636:1963 and BS 5500.

2.4.5 Test results and information to be reported

The test results and information to be reported shall include the following:

a) type of test, including any modifications to the procedures specified in BS 3636;

b) reference (e.g. contract number, part number, location on brazed structure, as applicable);

c) test site and date of test;

d) detail specific to the particular test;

e) conditions of test, including site temperature and any other interacting factors;

f) operators' actual recorded observations;

g) detailed calculations;

h) result of test;

i) name of laboratory, identity of operator and operator qualifications.

NOTE 1 The test results should be processed and interpreted as specified in BS 3636 and BS 5500.

NOTE 2 Appendix E is a suggested format for reporting test details and results.

2.5 Penetrant flaw detection applied to brazed joints

2.5.1 General

BS 6443 describes the basic techniques used for the application of penetrant flaw detection.

The effectiveness of the penetrant flaw method is dependent upon each stage in the procedure being carried out correctly by competent persons. Any departure from the correct procedure can seriously affect the validity of a penetrant test and the interpretation of results. It is very important to distinguish between relevant indications from flaws and spurious indications from other causes.

NOTE 1 The manufacturers of materials for use in penetrant flaw detection provide comprehensive technical services, and it is recommended that these services are used when selecting a process for a particular inspection.

This technique can only detect surface defects and so it is often inappropriate for the testing of brazed joints. Because small irregularities in the fillet or joint surface may give misleading indications, the interpretation is sometimes difficult. However, it is frequently specified, and incomplete filling can be detected by this method.

Very few defects are revealed that cannot be found by adequate visual inspection. However, penetrants delineate a discontinuity to a much greater extent. Thus, the method can be used in production and will improve the general reliability.

NOTE 2 Since the penetrant components are difficult or impossible to remove completely, particularly from interconnected porosity or cracks, this inspection technique should only be used if complete removal of penetrant can be achieved or re-brazing is not practicable.

In the case of category 1 brazed joints as given in BS 1723-2 (see also Appendix A), the penetrant test shall be considered in relation to the results obtained when more sophisticated methods of non-destructive examination are applied.

2.5.2 Principle

The principle of the test is to locate surface discontinuities such as laps, folds, porosity and lack of wetting that are open to the surface of the brazed joint. (Defects in brazed joints are shown in Appendix B.)

2.5.3 Preparation of the test piece

The test piece shall be prepared as specified in **1.5**. If mechanical methods are used, care has to be taken to ensure that any surface defects in the brazed joint region are not modified in such a way that they cannot be detected by penetrant flaw detection.

NOTE It is of particular importance when conducting this test that all flux or any other masking agent is removed from the surface of the brazed sample.

2.5.4 Procedure

2.5.4.1 *General.* The test shall be carried out in accordance with either:

a) BS 6443 and **2.5.4.2**; or

b) methods agreed between the contracting parties [see **1.4.2.5** a)].

2.5.4.2 *Items not covered in BS 6443*

2.5.4.2.1 As well as the method described in BS 6443 the items described in **2.5.4.2.2** and **2.5.4.2.3** shall be part of the procedure.

2.5.4.2.2 Control checks on standard test pieces, preferably representative of the work being inspected, shall be carried out at a frequency agreed between the contracting parties [see**1.4.2.5** b)].

2.5.4.2.3 When ultraviolet examination is used, the following items shall be checked as follows.

a) Control checks on degreasing materials and plant shall be carried out at intervals specified by the manufacturers of the equipment and degreasant.

b) The efficiency of the ultraviolet lamps shall be checked at suitable intervals using an ultraviolet monitor which complies with BS 4489.

c) The ultraviolet lamps shall be installed in a situation where the electrical line voltage is constant within 10 %.

d) The ultraviolet lamps shall be inspected for cracked or broken filters, or any unfiltered light. Lamps shall not be used if any cracks are detected.

e) The lamps and associated equipment shall be maintained in a clean condition.

WARNING. Particular attention should be paid to the safety requirements specified in BS 6443.

NOTE For guidance on the safe use of ultraviolet radiation see "Protection against ultraviolet radiation at the workplace" National Radiological Protection Board[1)].

[1)] Available from HMSO, P.O. Box 276, London SW8 5DT.

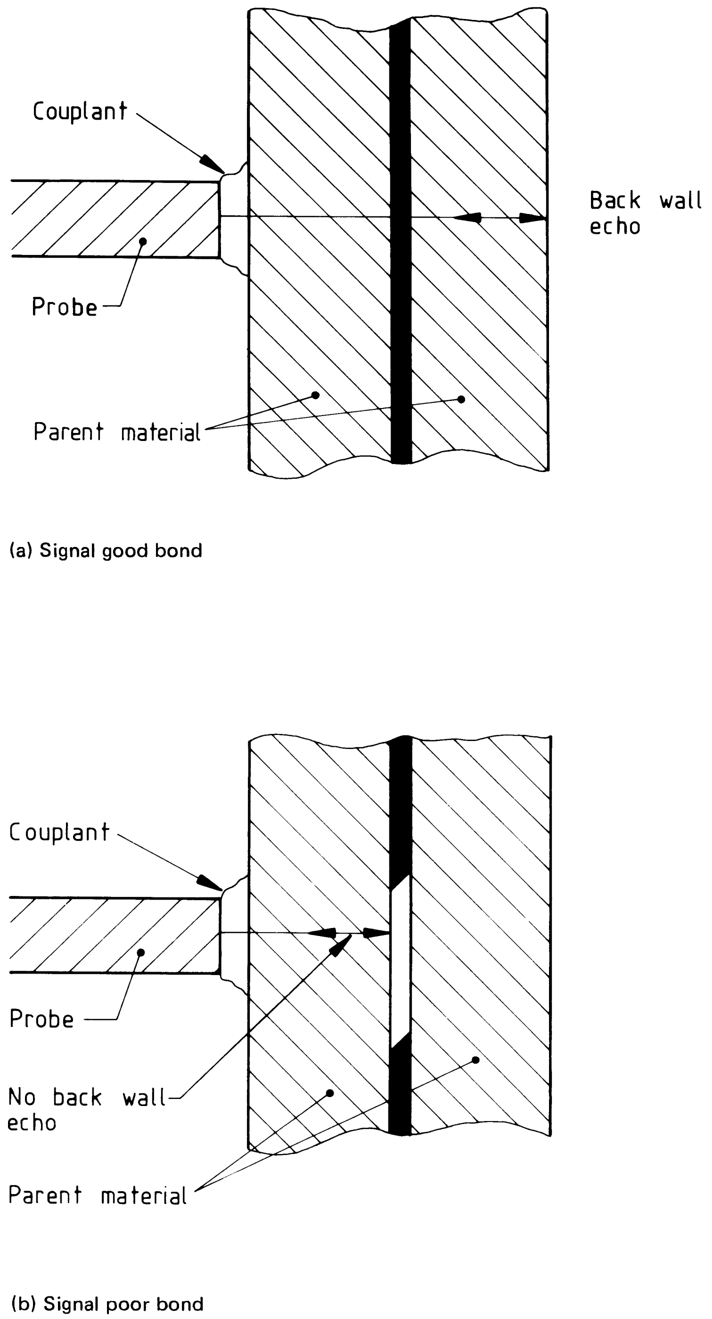


Figure 1 — Direct echo technique

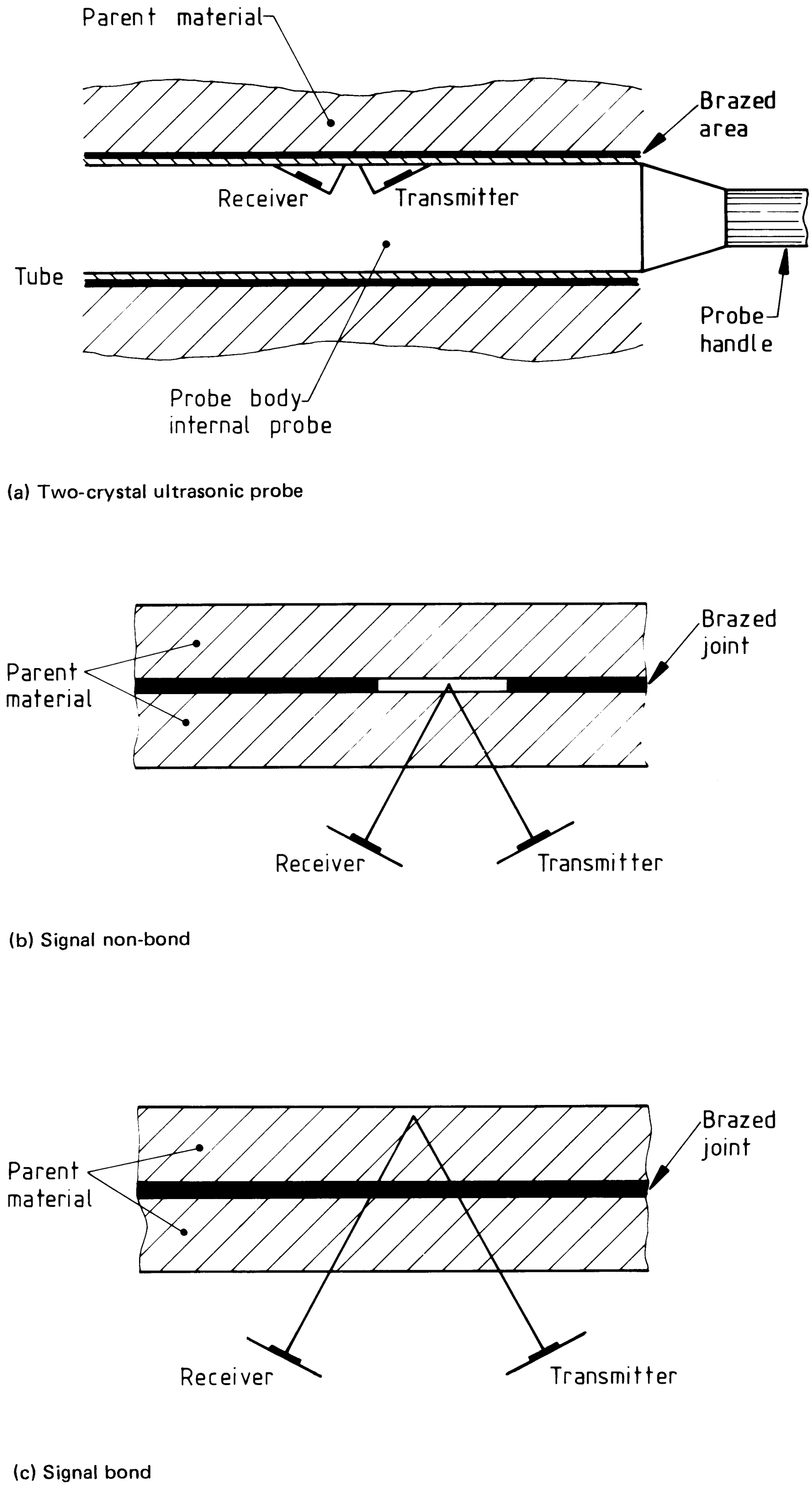


Figure 2 — Indirect echo technique

2.5.5 Test results and information to be reported

The test results and information to be reported shall include the following:

a) type of test, including any modifications to the procedures specified in BS 6443;

b) reference (e.g. contract number, part number, location on brazed structure, as applicable);

c) test site and date of test;

d) detail specific to the particular test;

e) conditions of test, including site temperature and any other interacting factors;

f) operators' actual recorded observations;

g) detailed calculations;

h) result of test;

i) name of laboratory, identity of operator and operator qualifications.

NOTE Appendix E is a suggested format for reporting test details and results.

2.6 Ultrasonic examination of brazed joints

2.6.1 General

The majority of brazed joints are designed with the component parts in a lap configuration. The distance between the component parts of the joint is usually up to 0.3 mm in size. Ultrasonic examination is particularly suitable for the examination of this type of joint configuration, where the sound waves are reflected from surfaces and can detect discontinuities. (See Figure 1 and Figure 2 and Appendix B.)

The great majority of brazed joint designs are of the lap type (see BS 1723-2) and so the direct echo technique shown in Figure 1 is most frequently used. If this is not possible because of the configuration of the test piece, more than one angle probe is used as an alternative (see Figure 2).

Because of the capillary nature of the brazed joint, most observed defects will be contained within the joint region. Any other defects are caused by stresses, causing failure within the parent materials, or were already present before brazing. The data obtained by recording methods should be presented as part of the report of results, as should also the results of the standard sample record. The effects of single and multiple defects upon the total bond area of the joint, and the effects upon properties such as total leak barrier (if this is a critical aspect of the specification) are normally calculated and recorded.

2.6.2 Principle

The principle of the test is to pass signals of ultrasound through the brazed joint and the adjacent component parts of the assembly. The signals are produced from a transducer which is coupled to one of the surfaces of the test piece and reflected pulse signals are received. Defects within the brazed joint or parent material will themselves give reflections or will reduce the strength of the signal from the far surface of the parent material.

2.6.3 Preparation of the test piece

2.6.3.1 The surface condition of the test piece shall be such that a satisfactory coupling between the probe and the surface can be maintained. The surface roughness of all surfaces from which scanning is carried out shall not exceed 6.3 µm R_a.

2.6.3.2 By agreement between the contracting parties the surface being examined shall be modified as necessary by grinding or any other agreed method so that there are no confusing surface signals [see **1.4.2.6** a)].

2.6.4 Procedure

2.6.4.1 *Equipment.* The type of equipment used shall be that described in BS 4331 and BS 3923-1.

2.6.4.2 *Coupling.* The coupling between the probe and the surface of the test piece shall be maintained either by immersing the brazed joint in a liquid or by applying a paste or similar medium suitable for the purpose. This shall be compatible with the material under test, and shall not affect the eventual performance of the brazed construction if residues are not completely removed at completion of the test.

2.6.4.3 *Test frequency.* The equipment (BS 4331 and BS 3923-1) shall be capable of working at a test frequency applicable to the test piece being evaluated.

NOTE The frequency is normally in the range 1 MHz to 6 MHz.

2.6.4.4 *Attenuator and amplifier.* The details of equipment and procedures shall be as specified in BS 4331 and BS 3923-1.

2.6.4.5 *Probe.* Where necessary the probe shall be shaped so that it fits snugly to the contour of the test piece being examined. When a probe is used with a flaw detector from another manufacturer, the need for inductive matching shall be considered. Any internal noise from the probe shall not interfere with interpretation of results at the working sensitivity.

2.6.4.6 *Sensitivity of test*

2.6.4.6.1 The equipment shall be set up initially using either a test block with 3 mm side drilled through hole, or other suitable test block (see BS 2704). This shall be done before starting the test.

2.6.4.6.2 The equipment shall be used to examine a reference sample containing known defects similar to the brazed test piece or brazed construction being tested, at a frequency to be agreed between the contracting parties (see **1.4.1**). The sizes and position of the standard defects shall be agreed between the contracting parties [see **1.4.2.6** b)].

2.6.4.7 *Examination of parent material.* Whether or not the parent materials have been ultrasonically tested prior to the brazing operation, examination shall be carried out after brazing to establish the quality of the parent material and to detect any flaws through which the ultrasonic beam might pass during the examination of the brazed joint.

2.6.4.8 *Information to be supplied to the operator.* The operator shall be supplied with a testing procedure that incorporates the following information:

a) the reference number of the test piece;

b) if located in a complex structure, the location reference of the part to be tested;

c) the joint preparation, including a sketch (drawing) of the joint design;

d) guidance on location and type of possible defects;

e) retest procedure;

f) the method of reporting results.

2.6.4.9 *Examination of the joint.* The operator shall manipulate the probe so that all regions of the test piece are systematically examined, ensuring that there is a 20 % overlap between the traverses.

2.6.4.10 *Test temperature.* If the test is conducted at a temperature other than ambient, the test calibration shall also be carried out at this temperature.

2.6.5 Test results and information to be reported

The test results and information to be reported shall include the following:

a) date of test;

b) reference (e.g. contract number, part number, location on brazed structure, as applicable);

c) surface preparation;

d) name of laboratory, operator identity and qualification;

e) instrument and probe detail;

f) scanning method (automatic, manual);

g) sensitivity, standard test sample identity and result;

h) any other information that may affect test results (couplant temperature, environment, etc.);

i) results obtained (defect size, position, type).

NOTE Appendix E is a suggested format for reporting test details and results.

2.7 Radiographic examination of brazed joints

2.7.1 General

Radiography is a method of non-destructive testing which uses penetrating radiation for the detection of defects in brazed joints. The intensity of the penetration is modified by its passage through the material and by defects in the material. In film methods the rays will affect a photographic emulsion, and the presence of a defect or unbonded region will be distinguished on the developed photographic film. In the case of the examination of brazed joints by this technique, the sensitivity of the method is influenced by the composition of the brazing filler metal. When nickel based filler metals are used to join together stainless steel components, the X-ray absorption coefficient of nickel is only slightly higher than that of iron and so, for all practical purposes, the use of X-ray methods for the examination of small capillary joints presents considerable difficulty. However, if filler metals exhibiting differential absorption from the parent material are used, then X-ray techniques are feasible for the examination of brazed joints.

Non-film methods of radiography are being rapidly developed but should be used with caution as adequate and reproducible sensitivity may be difficult to achieve.

The configuration of the brazed test piece or brazed construction is also an important consideration. Expert advice should be sought before the technique is specified.

Visual guidance should be provided to the operator regarding the typical defects likely to be observed on the radiograph. This shall indicate the method of assessing defects such as single and multiple porosity. The visual guidance shall be in a similar form to that presented in Appendix B. If total area of porosity is an important consideration, this shall be evaluated by the use of a graticule device or some automatic method of assessing the area of porosity in relation to the total area of the brazed joint.

2.7.2 Principle

The principle of the test is to examine the brazed joint with the aim of locating defects, to determine their size and position and to produce a two dimensional record of this information.

2.7.3 Preparation of the test piece

The test piece shall be prepared as specified in **1.5**. Additionally in order to obtain maximum data from the examination of the test piece, the surface of the part of the sample to be examined shall be smooth and free from irregularities such as overflow of brazing filler metal or surface irregularities of any type. If necessary, any surface defects shall be removed by grinding so that they merge smoothly into the parent material. A variation of 10 % in thickness will not seriously reduce the defect detection sensitivity.

2.7.4 Procedure

2.7.4.1 *Radiography*. The radiography shall be performed according to one of the techniques described in BS 2600-1 or BS 2910, suitably modified as necessary. Each test piece being radiographed shall be marked by the use of symbols which shall identify the following:

a) the test piece;

b) the location of the brazed joint;

c) the area of the brazed joint in relation to the test piece.

The symbols shall be positioned so that their images appear on the radiograph. A written record detailing the identification of the radiograph shall be made. If at all possible, permanent marking of the test piece shall be made to provide reference points for the accurate interpretation of the radiograph in relation to the actual sample. If permanent marking is not possible, other agreed suitable methods of identification shall be used [see **1.4.2.7** a)].

NOTE In practical radiography, technique charts should be constructed. These charts are used as a guide by the operator to set up the parameters of a particular source of radiation. They consist of a series of curves in which the exposure necessary to produce a given film density is plotted against the thickness of the specimen. A chart is prepared for a specific material, the source to film distance, and a particular film/screen combination. The three variables remaining are tube voltage or source of radiation, thickness and exposure. A set of charts should be readily available to the operator.

2.7.4.2 *Viewing*. The radiograph shall be examined by diffused light in a darkened room and the illuminated area shall be masked to the minimum required for viewing the radiographic image. The edges of the radiograph shall always be masked. The brightness of the illuminated radiograph shall be not less than 30 cd/m^2 and, whenever possible, approximately 300 cd/m^2 which can be checked by a photographic exposure meter.

NOTE Before viewing, sufficient time should be allowed for the operator's eyes to become adapted to the lighting conditions in the viewing room before radiographs are examined. A low power magnifying lens should be used when necessary by the operator.

2.7.5 Test results and information to be reported

A record of the process conditions used to produce the radiograph shall be kept.

The test results and information to be reported shall include the following:

a) date of examination;

b) reference (e.g. contract number, part number, location on brazed structure, as applicable);

c) orientation and method of permanent or other marking of the test piece;

d) process conditions: X-ray tube voltage (in kV), or gamma-ray source, exposure in mA min, source to film distance (SFD), object to film distance (OFD), film type and intensifying screens;

e) type of image quality indicator (IQI);

f) all observed defects (a sketch or note shall be made of size and position in relation to the brazed joint);

g) name of laboratory, operator identity and qualification.

NOTE For ease of presentation a standard report form should be supplied to the operator so that a systematic method of recording is established. Appendix E is a suggested format.

2.7.6 Protection

Exposure of any part of the human body to X-rays or gamma-rays can be injurious. It is essential that whenever X-ray equipment or radioactive sources are in use, adequate precautions are taken to protect the radiographer and others in the vicinity.

NOTE It should be noted that the use of X-ray equipment and gamma-radiography in factories, on sites and in certain other premises and works coming within the scope of the Factories Act 1974 is currently controlled by the Ionising Radiations Regulations (SI. 1985 No. 1333, ISBN 0 11 057 333 1).
In addition there may be local regulations and requirements which need to be taken into consideration.

These Ionising Radiation Regulations require the use of enclosures or other barriers where radiation levels are maintained and notices provided advising of the hazard. Similarly warning signals are required to be provided to indicate that the source of ionizing radiations is about to be exposed. Different and distinct signals are required during the actual exposure. Warning notices with adequately sized legends should be posted explaining the meaning of the signals.
Some radiographic equipment recommendations are specified in BS 5650.
Advice on radiation safety may be obtained from the National Radiological Protection Board, Harwell, Didcot, Oxon OX11 0RQ, or other consultants in radiation safety.

2.8 Thermographic testing of brazed joints

2.8.1 General

The thermographic testing of brazed joints involves the examination of the distribution of heat through or in a brazed joint. This method will only detect unbonded areas but is a comparatively new technique that has proved successful for the testing of some brazed joints. It has been applied for the examination of brazed constructions of the honeycomb assembly type, when the brazed joint is difficult to examine by other non-destructive testing methods. The testing method involves the examination of the test piece when cooling from a specified temperature, or the examination after cooling of the test piece to a uniform temperature and then examining it as it is allowed to return to ambient temperature. The examination can either be by visual or photographic means and involves the use of a temperature indicating device, which may be wax, a zinc cadmium sulphide phosphor, oxide formation of the surface, a freezing material, or the application of more complex methods of temperature differentiation, such as infra-red analysis and electronic methods of scanning.

The difficulties of applying the technique are as follows:

a) controlling uniformity of the heating cycle with sufficient accuracy to give a signal capable of analysis;

b) the variability of surface emissivity can produce a confusing contrast;

c) convective cooling effects can give spurious results.

The advantages of the method are as follows:

1) it can be applied in many cases when one side only of the brazed construction is accessible;

2) the test is rapid for multi-joint assemblies;

3) the interpretation time involved is comparable with other non-destructive test methods;

4) the safety requirements are not as demanding as they are in radiographic examination.

The visual observation, photograph or video graph should be examined and compared with either the application standard, or criteria of acceptance or rejection agreed between the contracting parties where there is no application standard [see **1.4.2.8** a)].

2.8.2 Preparation of the test piece

The surface of the test piece that is to be examined shall be prepared by the removal of stop-off, flux, paint, grease, non-uniform oxide film or surface dirt of any type so that the surface properties do not affect the observations from which the results are interpreted. The object of this preparation is to produce uniform emissivity so far as this is possible.

If surface coatings such as wax, phosphors or frost-producing sprays are applied to the surface, the thickness of the coatings shall be such that the sensitivity of the test is not reduced.

NOTE The method of application and the thickness of the applied coating can only be determined for the particular method and the coating type being applied.

2.8.3 Procedure

2.8.3.1 *Photographic method.* The test piece shall be photographed immediately upon removal from the brazing furnace or heat source.

2.8.3.2 *Coating method.* The test piece which has been previously coated with wax, zinc cadmium sulphide phosphor, or frosted, shall be heated by a suitable method that raises the temperature to 55 ± 5 °C. In the case of the phosphor method, the test piece shall be thermally cycled between 5 °C and 55 °C and illuminated with an ultraviolet light source[2]. The method of heating shall be by means of induction, hot liquid, an air blower of the high power type or other suitable heat source. When heating cannot be used, the test piece shall be examined by cooling to below ambient temperature.

2.8.3.3 *Inspection.* The surface(s) of the test piece shall be visually inspected or photographs taken of the surface at the predetermined inspection temperature or during the temperature cycle. In the case of phosphor coating, a series of photographs shall be taken, and in the case of infra-red thermography, a suitable infra-red camera, preferably connected to a video monitor, shall be used. The observed variation in the heat pattern shall be recorded either manually or automatically depending on the monitoring equipment being used.

[2] W. J. McGonnagle, Non-destructive Testing. McGraw Hill.

2.8.4 Test results and information to be reported

The test results and information to be reported shall include the following:

a) date of test;

b) reference (e.g contract number, part number, location on brazed structure, as applicable);

c) surface preparation and condition;

d) test method;

e) instrument used;

f) scanning method;

g) results obtained, including photographs or video graph;

h) name of laboratory, operator identification and operator qualification;

i) any other relevant information relating to the test.

NOTE Appendix E is a suggested format for reporting test details and results.

Section 3. Destructive testing of brazed joints

3.1 General

This section describes destructive test procedures and test pieces necessary to perform tests on brazed joints.

The destructive test methods described are as follows:

a) tensile and shear (see clause **3.2**);

b) peel (see clause **3.3**);

c) stress rupture (see clause **3.4**);

d) impact (see clause **3.5**);

e) bend (see clause **3.6**);

f) hardness (see clause **3.7**);

g) metallographic (see clause **3.8**);

h) corrosion (see clause **3.9**).

The type of test piece described for each test can be quoted or incorporated in engineering applications standards that deal with brazed constructions.

The results of the tests are used:

1) to determine basic data regarding filler metal performance;

2) to arrive at optimum brazing designs and brazing procedures;

3) to relate production results to results achieved in development.

This Part of BS 1723 does not recommend the number of samples to be tested or the repeat tests allowed. Neither does it specify methods of sampling brazed joints, except to give guidance regarding the precautions necessary, nor does it comment on the acceptance criteria applicable to any of the tests. No attempt is made to define which test or tests, if any, should be applied in any situation. This is a matter for agreement between the contracting parties at the time of placing the order (see **1.4.1**).

The methods of destructive examination are not associated with any particular type of test piece but lay down the general principles of the types of testing described. It is emphasized that a satisfactory examination method can only be developed and used after taking into account all the relevant factors regarding the equipment to be used and the characteristics of the test piece being examined.

The use of the methods of test described enables results from different organizations to have greater validity when compared, and their use provides designers with basic data on the performance of brazing filler metals and brazed constructions. However, it is essential to appreciate that the results achieved, as with all mechanical tests, are not fundamental, and that the values obtained depend upon the conditions of the test, the condition of the brazing filler metal, the design of the joint and the quality achieved by the brazing process. The brazing process produces joints that are not homogeneous as they are made up of parent materials and a filler metal. Many factors (such as the joint gap, brazing cycle, diffusion of the filler into the parent materials, etc.) will all affect the mechanical properties of the joint, and so, to repeat in production the mechanical properties achieved in test samples or test pieces when applied to brazed constructions, expert knowledge is required.

The results obtained from any test method should always be considered in relation to testing as a whole, and in the case of brazed joints it is essential that the results from non-destructive testing, giving data about the quality of the bond and the bond region, are related to the values obtained by destructive testing.

3.2 Tensile and shear testing of brazed joints

3.2.1 General

Many designs of test specimen have been used to produce tensile and tensile shear data for brazed joints, both in Europe and the USA. The great majority of brazed joints are designed to fail in shear, and it is not possible to convert the results obtained from butt brazed joints into shear strengths. Test samples detached from brazed constructions may be difficult to manufacture into standard shear test specimens, and multi-jointed assemblies produce similar problems where the presence of one defective joint may not reduce the overall tensile strength but can cause failure in service. The tensile/shear specimen should essentially be simple in design and economic to manufacture and test.

The test results should be evaluated taking into consideration the requirements of BS 18 and the requirements of each specific test. In all cases and particularly if there is a wide scatter in the results, the effects of non-bonded areas and other defects observed by non-destructive testing and the visual examination of the fracture surfaces shall be considered.

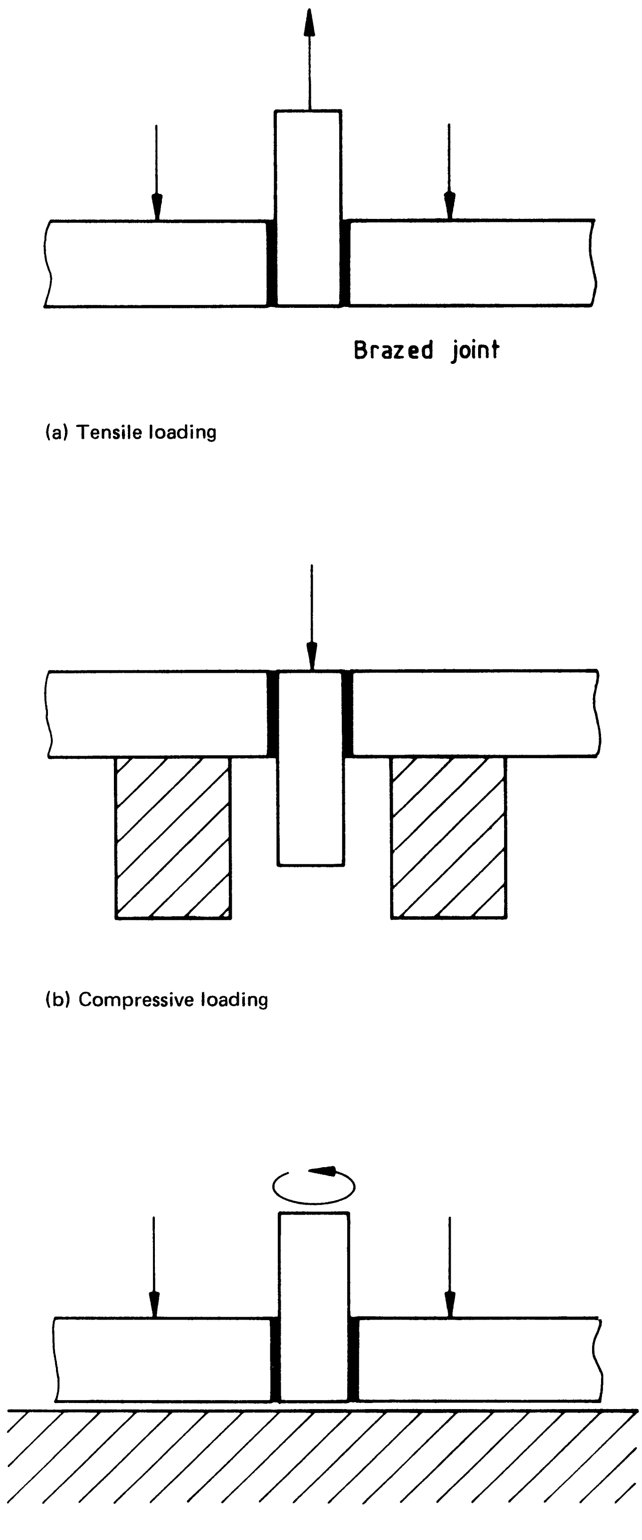
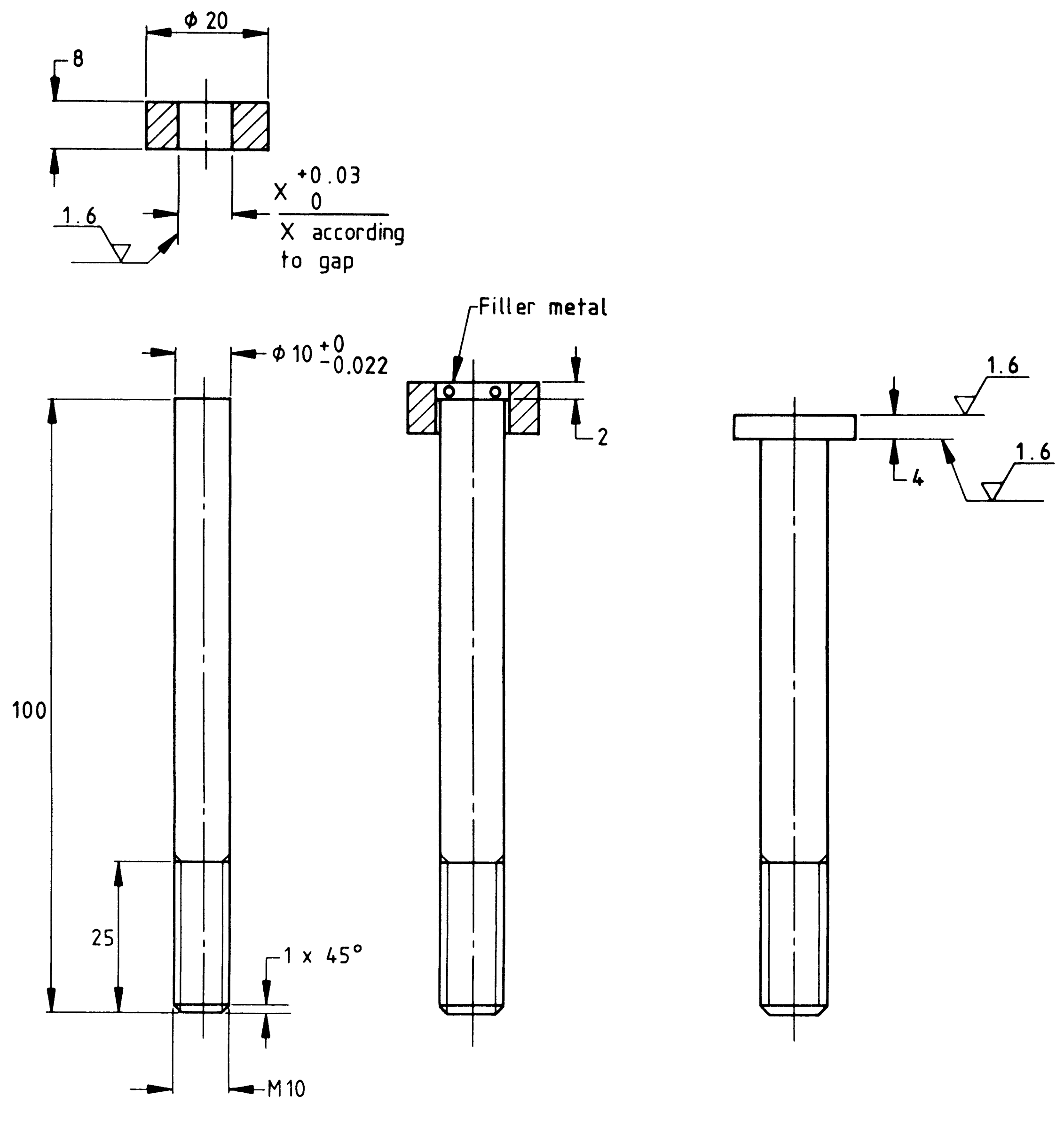


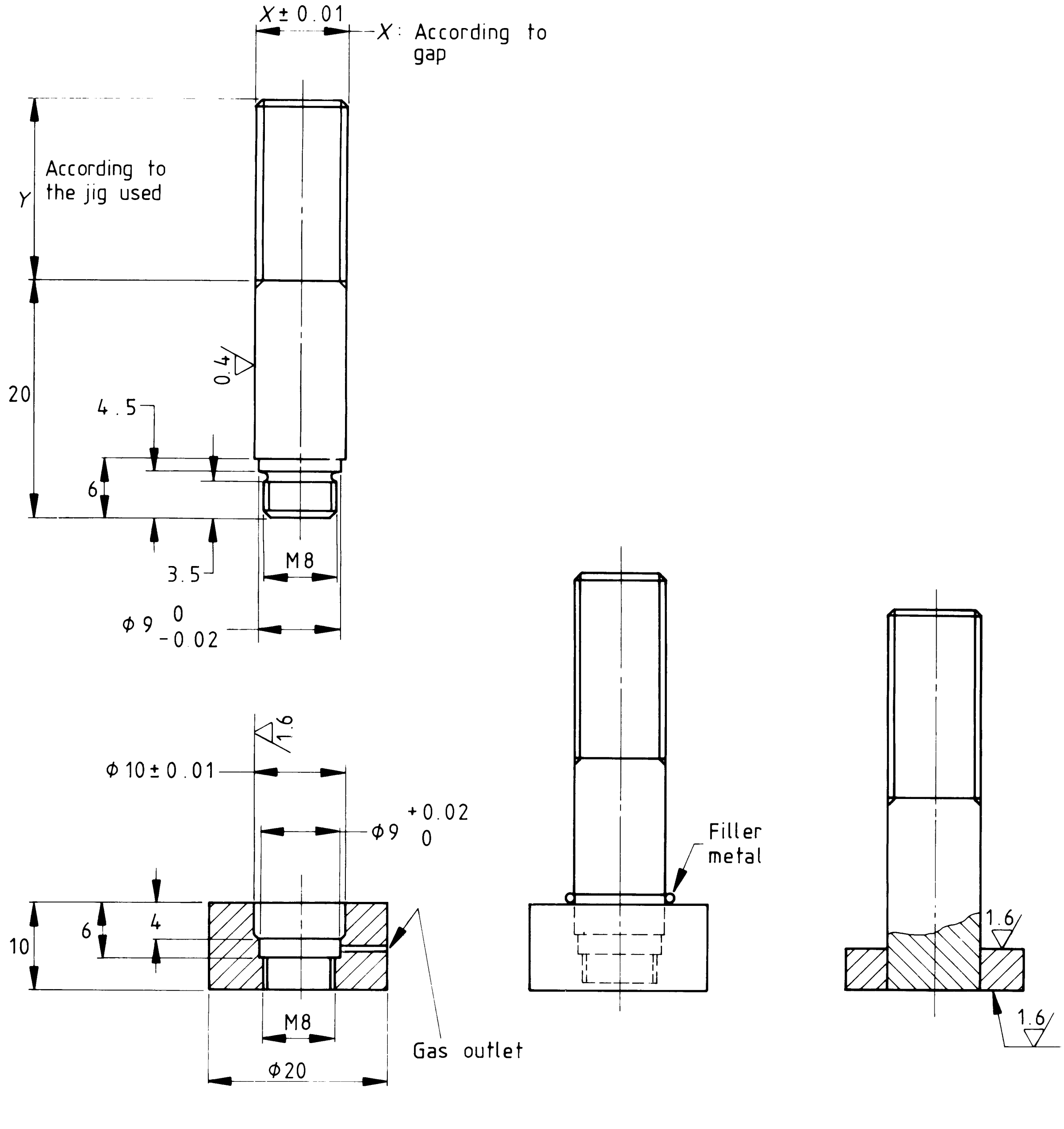
Figure 3 — Principles of shear testing brazed joints



(a) Test piece details (b) Test piece before brazing (c) Test piece before machining

All dimensions are in millimetres.

Figure 4 — Type I shear test piece dimensions



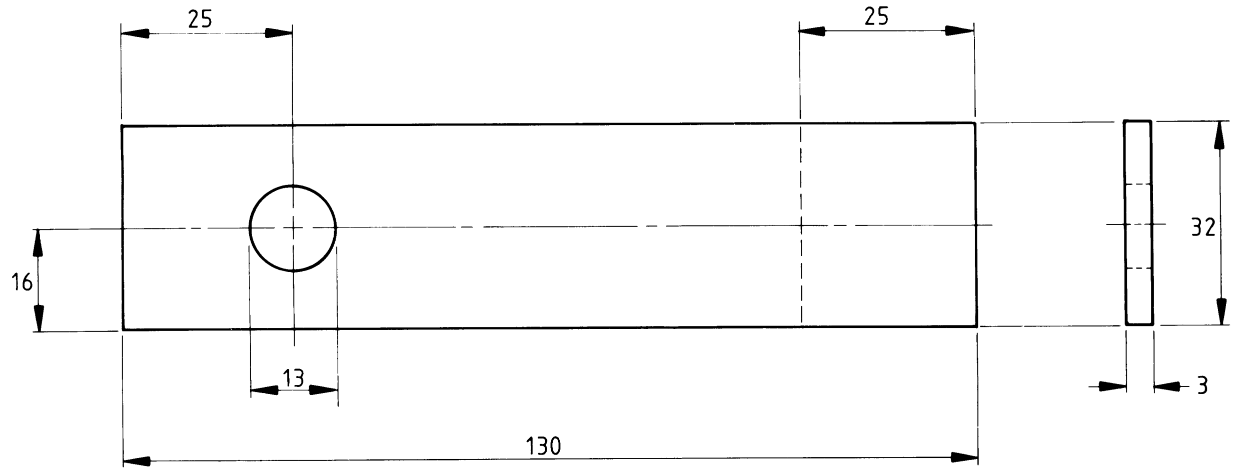
(a) Test piece details

(b) Test piece before brazing

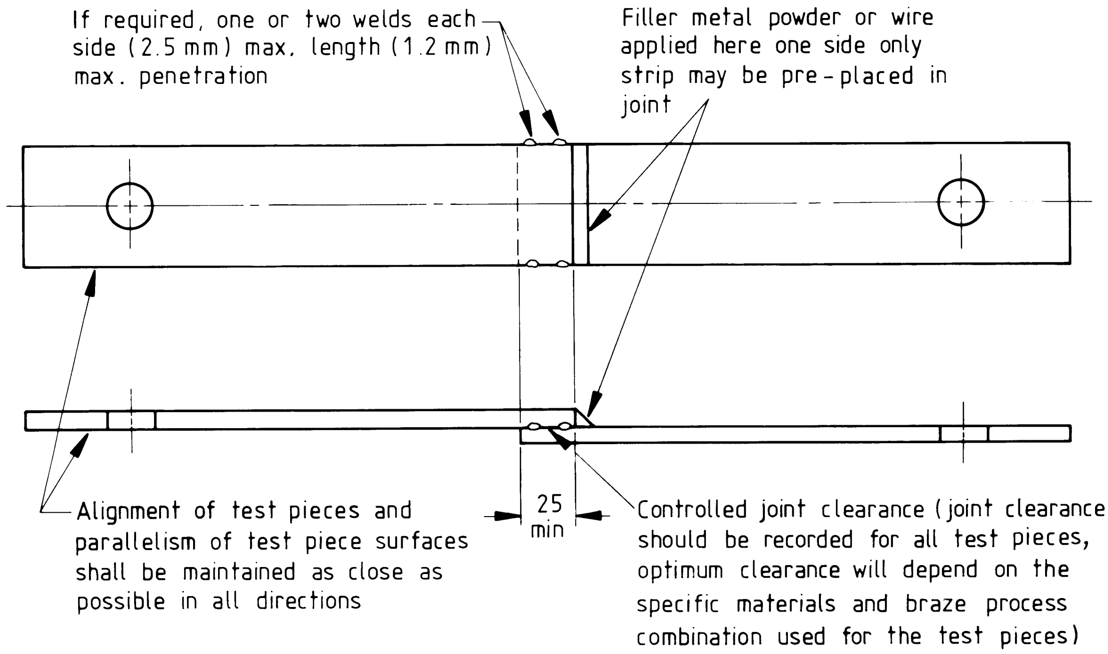
(c) Test piece after brazing and machining

All dimensions are in millimetres.

Figure 5 — Type II shear test piece dimensions



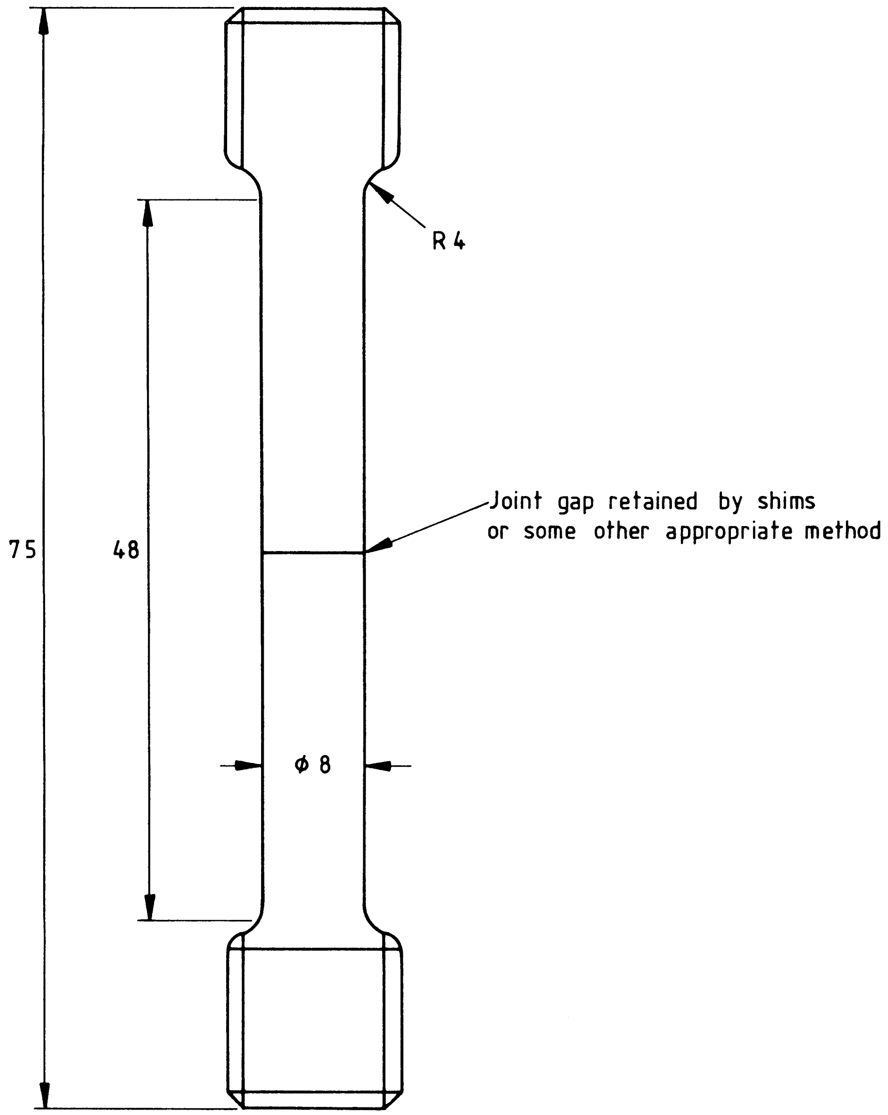
(a) Single-lap shear test blank



(b) Assembly of single-lap shear test piece and application of filler metal

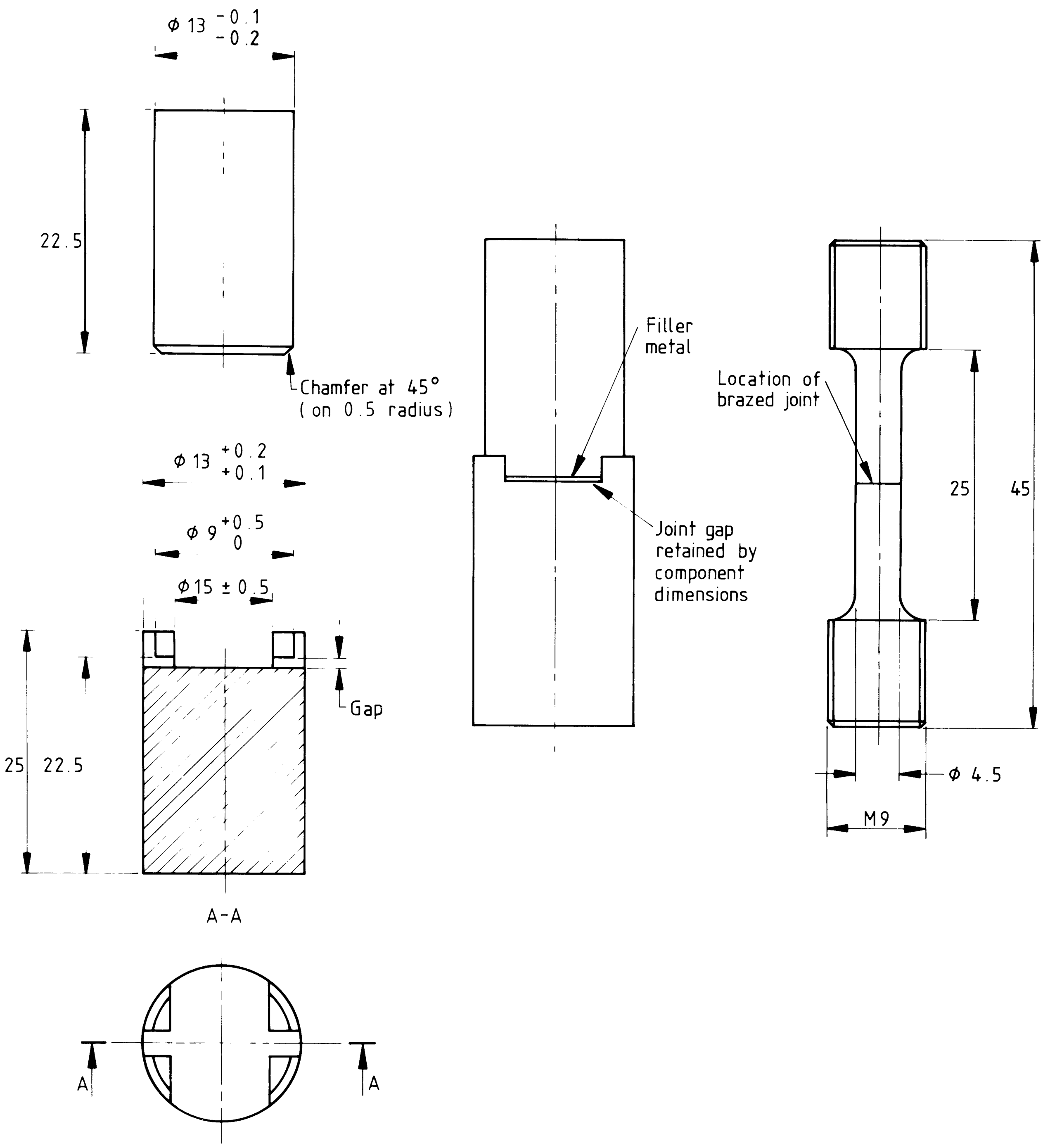
All dimensions are in millimetres.

Figure 6 — Single-lap shear test piece



All dimensions are in millimetres.

Figure 7 — Simple tensile test piece



(a) Test piece details

(b) Test piece before brazing

(c) Test piece after brazing and machining

All dimensions are in millimetres.

Figure 8 — Tensile test piece dimensions

3.2.2 Principle

The principle of the test is to subject the test piece to mechanical loading in tension and/or shear, to fracture and to assess its mechanical properties when subjected to these methods of loading.

3.2.3 Preparation of the test piece

3.2.3.1 *Tensile shear*. The test piece shall be made so that it can be tested in tensile, compressive or torsional shear (see Figure 3). The design of the test pieces shall be as detailed in Figure 4, Figure 5 and Figure 6.

Figure 4 is the type specified in ISO 5187:1985.

Figure 5 is the type specified in ISO 5187:1985.

Figure 6 is the type specified in the American Welding Society specification ANSI/AWS C3.2:1982[3].

3.2.3.2 *Tensile butt*. The test piece shall be made so that it can be tested by tensile loading of the brazed joint. The design of the test pieces shall be as detailed in Figure 7 and Figure 8.

Figure 7 is the type specified in DIN 8525-3:1986.

Figure 8 is the type specified in ISO 5187:1985.

3.2.4 Procedure

The tests shall be conducted according to the relevant requirements for each particular test piece as follows.

a) For a type I shear test piece as shown in Figure 4, test as described in ISO 5187:1985.

b) For a type II shear test piece as shown in Figure 5, test as described in ISO 5187:1985.

c) For a single-lap shear test piece as shown in Figure 6, test as described in ANSI/AWS C3.2:1982.

d) For a simple test piece as shown in Figure 7 and Figure 8, test as described in DIN 8525-3:1986 and ISO 5187:1985.

The requirements of BS 18 and BS 1610 shall also be applied, as relevant.

3.2.5 Test results and information to be reported

The data from the test procedure shall be processed in accordance with BS 18 and also the requirements specified for each particular test piece.

The test results and information to be reported shall include the following:

a) test piece and method of preparation;

b) reference (e.g. contract number, part number, location on brazed structure, as applicable);

c) date of test;

d) brazing filler metal;

e) parent materials;

f) brazing process details;

g) test piece type;

h) number of test pieces;

i) testing method;

j) type of test machine;

k) temperature of test;

l) numerical results;

m) position of fracture;

n) appearance of fracture surface (defects if failure is in the brazed joint);

o) name of laboratory, operator identification and operator qualifications.

NOTE Appendix E is a suggested format for reporting test details and results.

3.3 Peel testing of brazed joints

3.3.1 General

Peel testing is a simple test used as a method of on-line quality control. Because of the nature of the test, it is not usually possible to achieve a numerical result for the load required to peel the component parts of the joint.

NOTE In some cases, because of the basic strength of the bond between the parent materials and the filler metal, the failure may occur through the parent material.

3.3.2 Principle

The principle of the test is to peel apart the components of the brazed joint and to determine the quality by visual examination.

3.3.3 Preparation of the test piece

The test piece (see Figure 9) shall be the test sample and shall be used without further preparation, or shall be detached from a brazed construction. In batch and continuous processes it shall be brazed concurrently with the brazed constructions.

3.3.4 Procedure

One member of the brazed test piece shall be held in a vice or by some similar method, and the other member shall be peeled away to enable the separated faces to be visually examined (see Figure 9).

The separated faces of the joint shall be visually examined as specified in **2.2**. The objective of the examination shall be to determine the general quality of the bond, the presence of unbonded areas, voids and flux inclusions in the joint.

[3] Available from BSI, Linford Wood, Milton Keynes MK14 6LE.

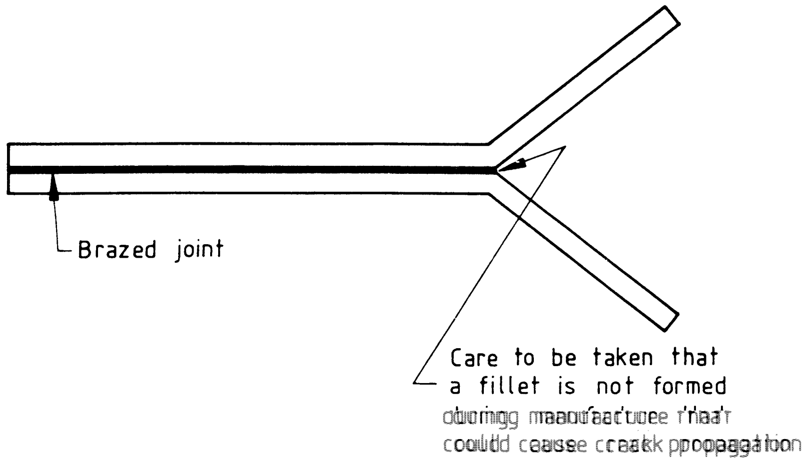


Figure 9 — Peel test piece

3.3.5 Test results and information to be reported

The test results and information to be reported shall include the following:

a) test piece and method of preparation;

b) reference (e.g. contract number, part number, location on brazed structure, as applicable);

c) date of test;

d) filler metal;

e) parent materials;

f) brazing process details;

g) number of specimens;

h) method of peeling;

i) position of fracture;

j) appearance of fracture surface including percentage bond;

k) name of laboratory, operator identification and operator qualification.

NOTE Appendix E is a suggested format for reporting test details and results.

The results of the visual examination shall be assessed and compared with the maximum permissible size, number and distribution of defects, which shall depend upon the service conditions or the quality specification agreed between the contracting parties at the time of placing the contract (see **1.4.1**).

3.4 Stress rupture testing of brazed joints

3.4.1 General

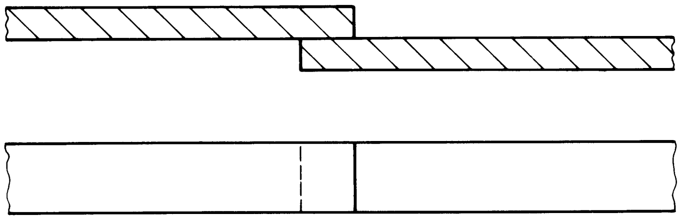
Stress rupture tests are the simplest form of creep test. It should be appreciated that grain boundaries have considerable influence on the creep process and so the previous thermal history of the brazed joint will have a significant effect on the stress rupture properties of the parent materials.

The test results should be processed and evaluated as described in BS 3500 taking particular notice of the fracture site. If failure occurs in the parent materials, the performance characteristics of the brazed joint are superior to those of the parent materials.

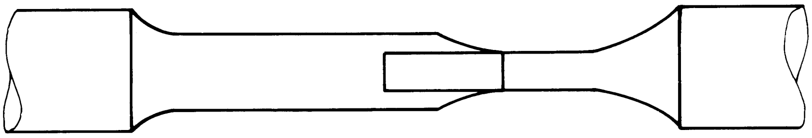
An important limiting factor of the test is the inability in some cases to carry out life tests on component parts to be used for critical applications. It is essential that care is taken when extrapolating the results of short term tests (up to 10 000 h) to components for use in such applications as power stations or when other factors can greatly influence the behaviour of the brazed joint, for example in the gas turbine, when service tests are made before actual application.

3.4.2 Principle

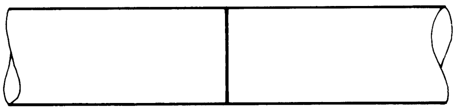
The principle of the test is to subject a test piece to a constant tensile load whilst the temperature is maintained at a uniform value until rupture occurs. The test time to failure is the important aspect of the test.



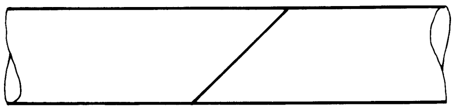
(a) Lap joint in sheet material



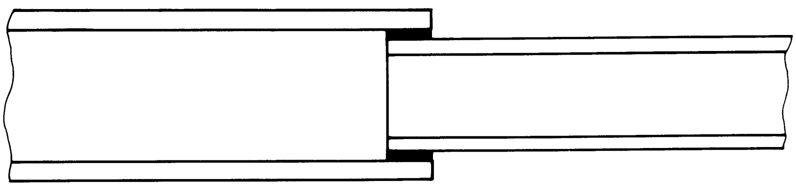
(b) Lap joint in solid round material



(c) Butt brazed joint in round material



(d) Scarf joint in round material



(e) Lap joint in tubular material

Figure 10 — Stress rupture test pieces

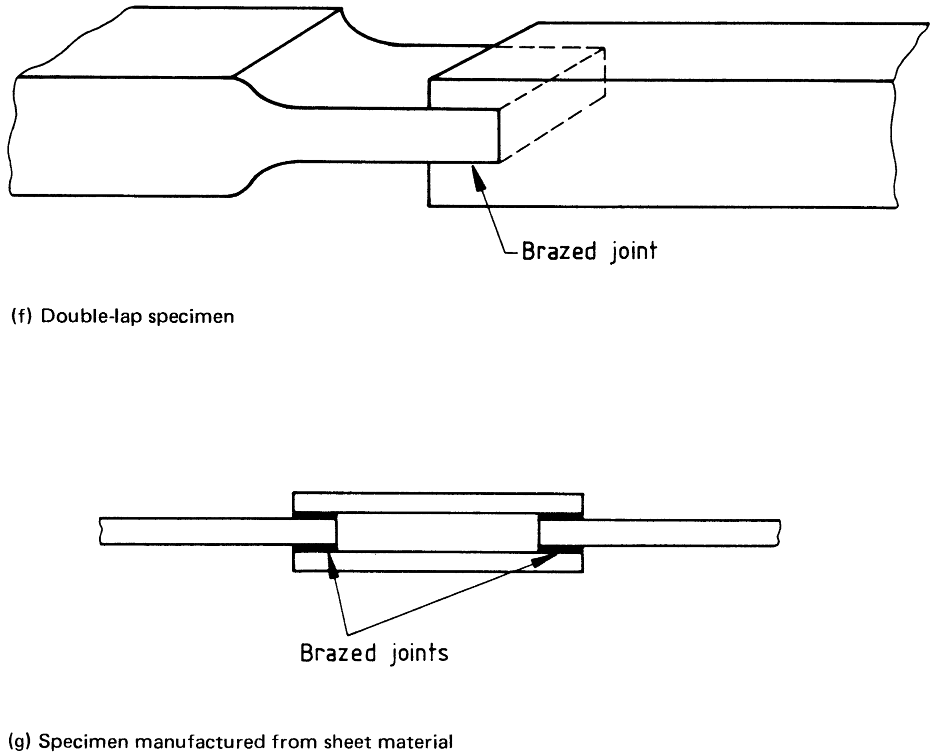


Figure 10 — Stress rupture test pieces *(concluded)*

3.4.3 Preparation of the test piece

The test piece shall be prepared as specified in **1.5** and as described in BS 3500. The configuration of the test piece and its method of manufacture shall be agreed between the contracting parties [see **1.4.2.9** a)]. Typical test pieces are shown in Figure 10.

3.4.4 Procedure

The test shall be conducted as described in BS 3500. The applied load and temperature of testing shall be agreed between the contracting parties [see **1.4.2.9** b)].

3.4.5 Test results and information to be reported

The test results shall be prepared as described in BS 3500.

The test results and information to be reported shall include the following:

a) test piece and method of preparation;

b) reference (e.g. contract number, part number, location on brazed structure, as applicable);

c) brazing filler metal;

d) parent materials;

e) brazing process details;

f) number of test pieces;

g) details of test procedure;

h) date of start of test;

i) dates at which test was interrupted;

j) time (hours to failure or at which test was discontinued);

k) time to achieve test temperature;

l) any deviations from standard test procedure;

m) atmosphere in which test was conducted;

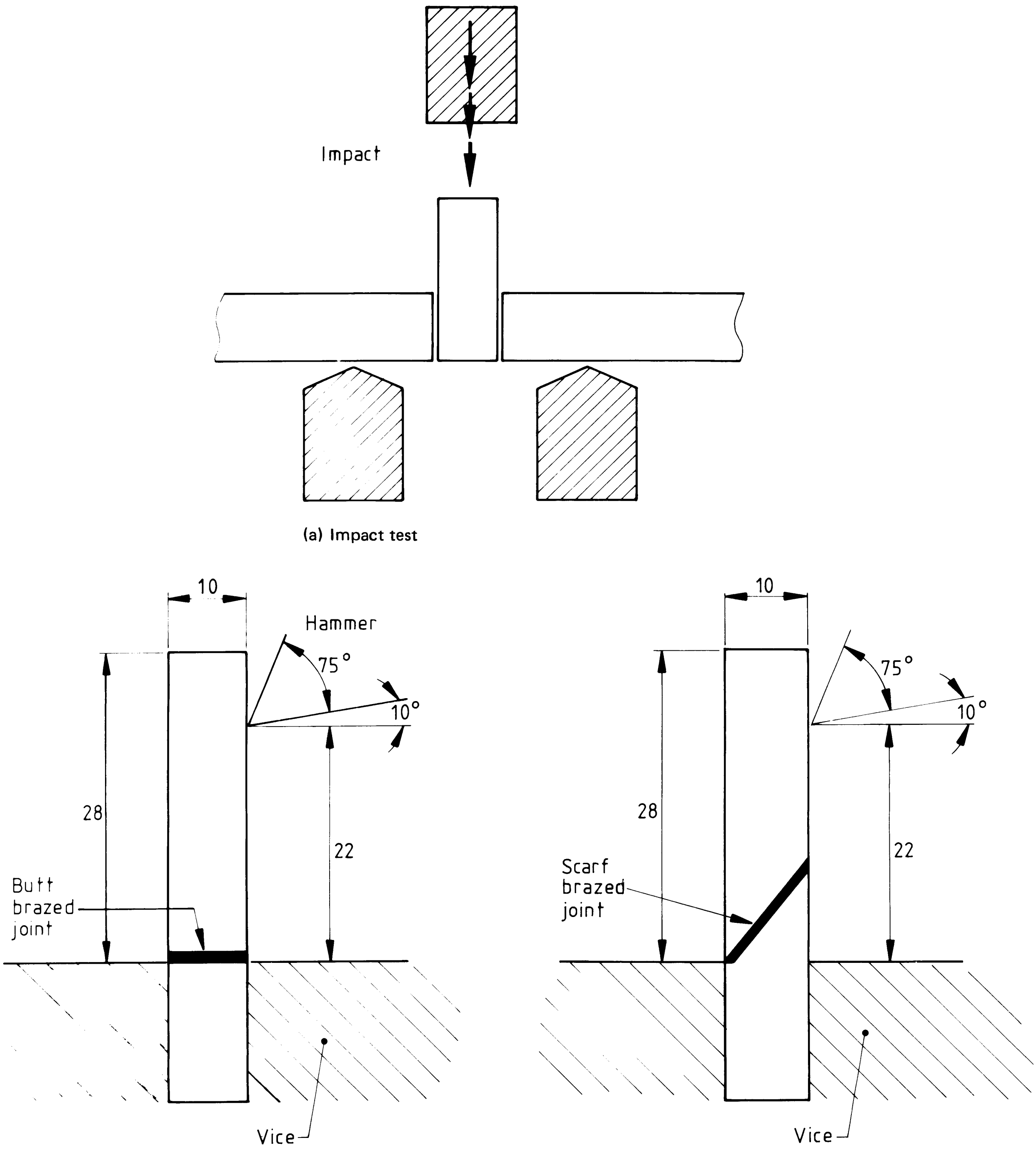
n) position of fracture;

o) type of fracture;

p) appearance of fracture surface;

q) name of laboratory, operator identification and operator qualification.

NOTE Appendix E is a suggested format for reporting test details and results.



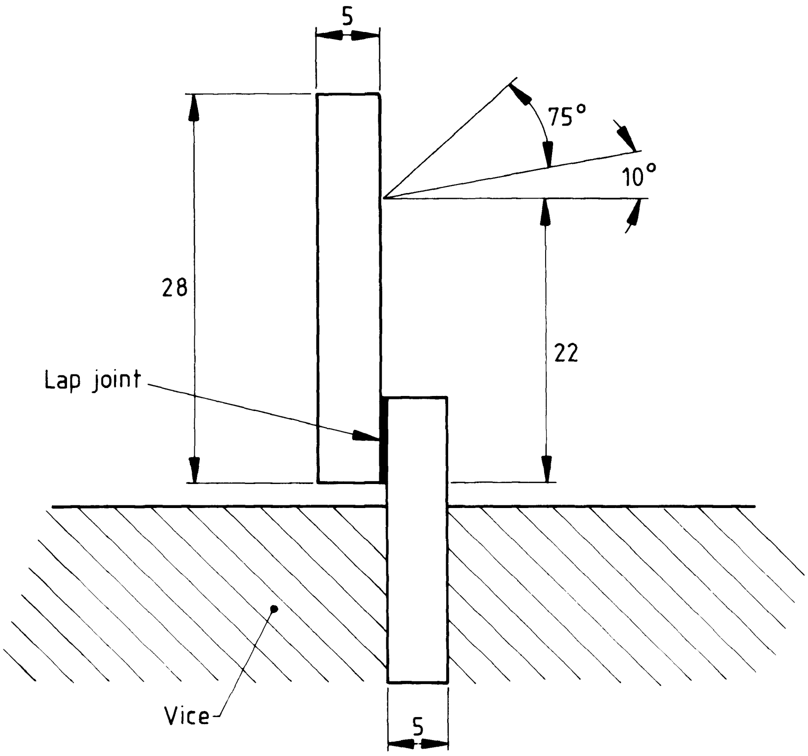
(a) Impact test

(b) Izod test pieces butt brazed joint

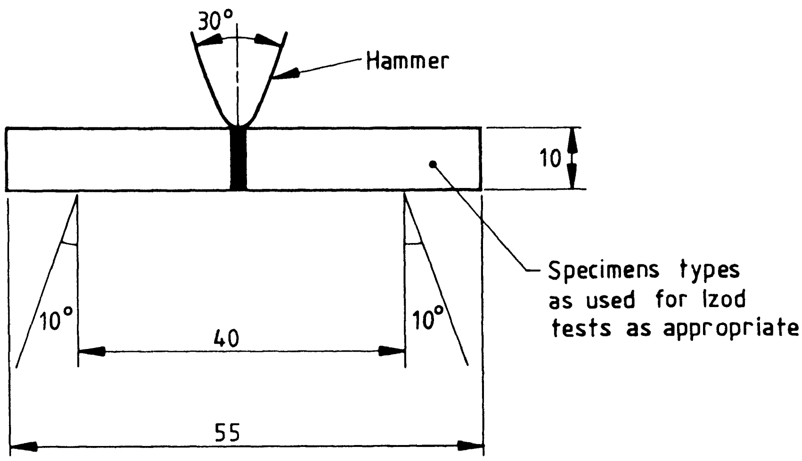
(c) Izod test pieces scarf brazeu joint

Linear dimensions are in millimetres.

Figure 11 — Impact testing



(d) Izod test piece (lap joint)



(e) Charpy test piece

Linear dimensions are in millimetres.

Figure 11 — Impact testing *(concluded)*

3.5 Impact testing of brazed joints

3.5.1 General

Impact strength (toughness) is the resistance of a material, in this case a test piece, to failure under specified conditions of high rates of application of uniform loading. Rate of strain is difficult to control precisely under test conditions, and so the compromise of using a fixed energy of loading is accepted. Either a specified weight falling from a predetermined height or a pendulum hammer swinging from a predetermined angle is used to apply the load.

The dimensions of the overlap and the brazed joint gap will be either constant or vary in a controlled manner, depending upon the variables being investigated.

3.5.2 Principle

The principle of the test is to subject the test piece to impact loading approximating to the severity of loading likely to be encountered in certain life-limiting situations. This test will give guidance regarding the toughness characteristics of the brazed joint.

3.5.3 Preparation of the test piece

The test piece shall be prepared as specified in clause **1.5** and BS 131-1 to BS 131-3. The design of the test piece shall be one of the following:

a) as shown in Figure 11; or

b) a modified Izod or Charpy impact test piece; or

c) another design agreed between the contracting parties [see **1.4.2.10** a)].

The test piece dimensions shall be either as shown in Figure 11(b), Figure 11(c), Figure 11(d) and Figure 11(e), or shall be of dimensions appropriate to the brazed construction which shall be agreed between the contracting parties at the time of placing the contract [see **1.4.2.10** b)].

If the test piece is machined, the machine marks shall be longitudinal.

3.5.4 Procedure

The method of loading and the magnitude of the load shall be agreed between the contracting parties [see **1.4.2.10** c)].

When the Izod or Charpy notch impact test pieces are used the test shall be conducted as specified in BS 131-1, BS 131-2 or BS 131-3.

The temperature of test shall be agreed between the contracting parties [see **1.4.2.10** d)].

NOTE The test is normally conducted at ambient temperature. There are experimental problems associated with testing at higher or lower temperatures, although tests at temperatures other than ambient are more easily done using the Charpy method of testing.

3.5.5 Test results and information to be reported

The test results and information to be reported shall include the following:

a) test pieces and method of preparation;

b) reference (e.g. contract number, part number, location on brazed structure, as applicable);

c) filler metal;

d) parent materials;

e) brazing process details;

f) number of test pieces;

g) details of test procedure;

h) date of test;

i) method of loading;

j) test temperature (Charpy test);

k) magnitude of absorbed energy;

l) failure position;

m) type of failure;

n) name of laboratory, operator identification and operator qualifications.

NOTE Appendix E is a suggested format for reporting test details and results.

3.6 Bend testing of brazed joints

3.6.1 General

Bend tests are not often applied to brazed joints but, when used, can give some indication of the ability of a brazed joint to be deformed as part of the general manufacturing process or its ability to be flexed during its life as an engineering component or construction.

The acceptance or rejection of the test piece which contains minor cracking rather than exhibits total failure depends upon the life-limiting processes to which the brazed construction is subjected.

3.6.2 Principle

The principle of the test is to deform the brazed joint by bending to determine the ductility and resistance to cracking of the brazed joint, the heat affected zone, the parent materials and the brazed construction.

3.6.3 Preparation of the test piece

The test piece shall be prepared as specified in **1.5** and BS 1639. The configuration of the test piece shall be either:

a) as detailed in Figure 10(a), Figure 10(c) or Figure 10(d); or

b) a test piece to be agreed between contracting parties [see **1.4.2.11** a)].

NOTE In the case of tubular test samples it is common practice to take a longitudinal section to produce the test piece.

3.6.4 Procedure

The test piece shall be deformed by bending either in a free mode as shown in Figure 12 or by a controlled bend test around a suitable predetermined radius as shown in Figure 13.

NOTE 1 The controlled bend test is most suitable for the materials incorporating brazed joints.

Bend testing is also a method of applying a proof load and shall be carried out as demonstrated in Figure 14. Loads up to the limiting proof strain shall be applied to the test piece.

NOTE 2 The loading of the test piece may also be increased until failure occurs, or the test piece deforms until it passes through the support blocks.

The methods of testing shall be either:

a) as described in BS 709, BS 1639, BS 3451 or BS 4206; or

b) another test piece or test procedure to be agreed by the contracting parties [see **1.4.2.11** b)].

NOTE 3 The test procedures can be used for both lap and butt brazed test pieces.

WARNING. In some cases when brittle materials or brittle brazed joints are being tested, the fractured materials may be ejected from the test machine in a dangerous manner. It is essential suitably to protect the operator and other persons in the vicinity of the test machine.

3.6.5 Test results and information to be reported

The test results shall be reported as described in BS 709, BS 1639, BS 3451 or BS 4206, as appropriate.

The test results and information to be reported shall include the following:

a) test piece and method of preparation;

b) reference (e.g. contract number, part number, location on brazed structure, as applicable);

c) date of test;

d) brazing filler metal;

e) parent materials;

f) brazing process details;

g) test piece type;

h) number of test pieces;

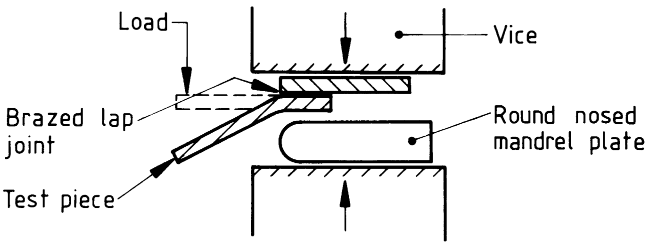
i) testing method;

j) radius of former;

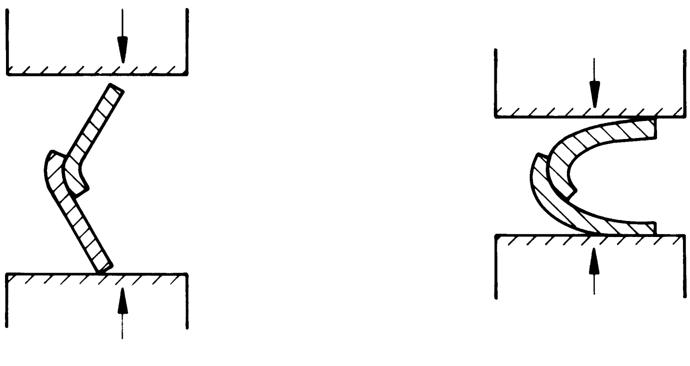
k) position and appearance of fracture;

l) name of laboratory, operator identification and operator qualification.

NOTE Appendix E is a suggested format for reporting test details and results.



(a) Arrangement to give test piece preliminary bend



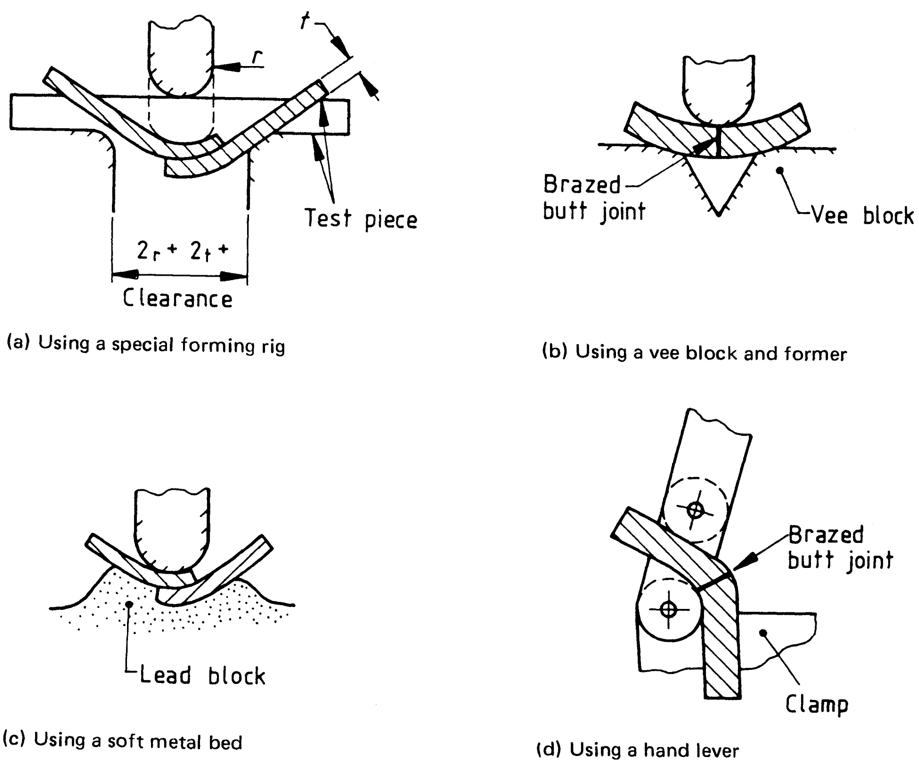
(b) Intermediate stage

(c) Final stage

NOTE 1 These test procedures can be used for both lap and butt configurations.

NOTE 2 See warning in **3.6.4**.

Figure 12 — Free bend test



(a) Using a special forming rig

(b) Using a vee block and former

(c) Using a soft metal bed

(d) Using a hand lever

NOTE These test procedures can be used for both lap and butt configurations.

Figure 13 — Supported bend tests for lap and butt joints

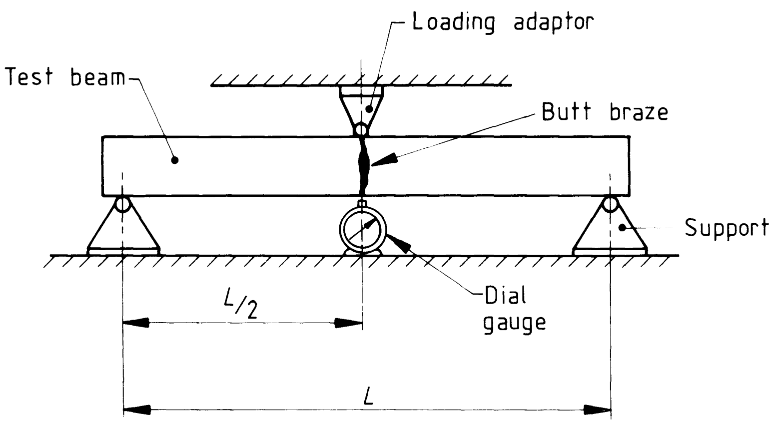


Figure 14 — Simple bend or flexing test

3.7 Hardness testing of brazed joints

3.7.1 General

Different methods of measurement of hardness give different results which do not necessarily correlate. By use of tables, the results from one type of test can be approximately converted into those of others.

When applied to brazed joints, a hardness test is useful as a production method for checking the metallurgical condition of the parent materials and, in the case of heat treatable parent materials, will give guidance regarding the efficiency of the heat treatment process. It is frequently used in research and development to investigate the diffusional characteristics of the filler metal, particularly when investigating the behaviour of nickel based filler metals.

3.7.2 Principle

The principle of the test is to make an indentation in the surface of the test piece, the size of which, in conjunction with the applied load, gives the hardness of the surface layer.

Micro-hardness tests are normally recommended when it is required to measure the hardness of the filler metal within the brazed joint and the hardness of adjacent parent material.

3.7.3 Preparation of the test piece

The surface preparation shall be appropriate to the type of test being applied and shall not influence the results of the test. The smaller the size of the impression, the better the surface preparation needs to be. For micro-hardness tests, the surface shall be prepared as described in **3.8.3**.

To measure hardness in the brazed joint filler metal and adjacent regions, the test sample shall be sectioned. The position of the sections shall be agreed between the contracting parties at the time of placing the contract [see **1.4.2.12** a)].

NOTE Care should be taken when sectioning and preparing the sections to ensure that the surface to be examined is not modified by the method of preparation.

3.7.4 Procedure

3.7.4.1 *Macro-hardness test.* The most common methods of macro-hardness testing are:

a) Vickers diamond pyramid;

b) Brinell;

c) Rockwell.

The test shall be performed as described in BS 240, BS 427 or BS 891. The operator shall be made aware of the possible hardness variations that may occur over the surface of the test piece. The test piece shall be suitably supported during the test so that it does not move when the load is applied by the indentor.

3.7.4.2 *Micro-hardness test.* Micro-hardness methods used shall be either:

a) the diamond pyramid test; or

b) the Knoop diamond hardness test.

The loads applied are in grammes. The dimensions of the indentation shall be measured. The accuracy of measurement shall be better than 1 μm.

3.7.5 Test results and information to be reported

The test results and information to be reported shall include the following:

a) test piece and method of preparation;

b) reference (e.g. contract number, part number, location on brazed structure, as applicable);

c) date of test;

d) testing method;

e) brazing filler metal;

f) parent materials;

g) brazing process details;

h) number of test pieces;

i) method of sectioning;

j) surface preparation;

k) numerical results;

l) name of laboratory, operator identification and operator qualification;

m) summary of results.

NOTE Appendix E is a suggested format for reporting test details and results.

3.8 Metallographic examination of brazed joints

3.8.1 General

The quality of brazed joints, and fundamental information about parent material/filler metal reactions, diffusional characteristics and other aspects can be investigated by macro- and micro-examination of the brazed joint. This technique only gives information about the sectioned surfaces that are the subject of examination. It is also useful for investigating the cause of failures, production quality and to confirm the data produced by non-destructive testing methods.

The operator can, if necessary, be supplied with sketches or photographs of the type of defect that may be present.

3.8.2 Principle

The principle of the test is to examine the macro- and micro-structures of the brazed joint and to investigate its quality.

3.8.3 Preparation of the test piece

The test piece shall be prepared as specified in **1.5**, particular care being taken when sectioning to ensure that the structure is not modified. The sections and their relative positions shall be unequivocally recorded and marked.

The section shall be ground and polished by normal metallurgical methods to achieve the surface finish required for macro- or micro-examination. For more sophisticated methods, such as micro-probe analysis, scanning electron microscopy and similar methods, the sections shall be prepared by methods specific to the method of examination being used. The sections prepared for macro- and micro-examination shall be flat, free from scratches, pits and stains, so that they can be examined with or without etching.

3.8.4 Procedure

The procedure shall be one of the following.

a) *Macroscopic examination.* The section shall be examined at a low magnification, up to × 25. The joint shall be examined for lack of flow, discontinuities, flux entrapment, porosity, cracks and any other defects.

b) *Microscopic examination.* The sections shall be examined by means of a metallurgical microscope at suitable magnifications. The joint shall be examined for detail not revealed by macro-examination, the structure of the brazed joint, erosion, parent metal/filler metal reactions, grain boundary phenomena and any other metallurgical requirement.

c) *Sophisticated techniques.* These techniques shall be used for detailed examination of filler metal composition as brazed, and after heat treatment, diffusion of filler metal into parent materials, and any other data relevant to the investigation of the quality of the brazed joint.

The data from the tests shall be processed according to the agreement between the contracting parties [see **1.4.2.13** a)].

3.8.5 Test results and information to be reported

The test results and information to be reported shall include the following:

a) test piece and method of preparation;

b) reference (e.g. contract number, part number, location on brazed structure, as applicable);

c) date of test;

d) brazing filler metal;

e) parent materials;

f) brazing process details;

g) test method;

h) number of tests;

i) temperature of test;

j) numerical results where applicable;

k) photographs shall be taken if a permanent record is required;

l) any observations that are required by the contractual agreement, e.g. structure of the brazed joint (see **1.4.1**);

m) name of laboratory, operator identification and operator qualification.

NOTE Appendix E is a suggested format for reporting test details and results.

3.9 Corrosion testing of brazed joints

3.9.1 General

Corrosion is the deterioration of a metal by chemical or electrochemical reaction with its environment. Generally the brazed joint consists of dissimilar materials: the parent material(s) and the filler metal. The filler metal may have very different properties from the parent materials and so there is frequently the danger of corrosive attack on the filler metal and/or parent material. The face of a brazed joint exposed to corrosive media is invariably small, compared with the area of the parent materials, and severe preferential galvanic attack may cause catastrophic failure. Corrosion is complex and corrosion rates are affected by such factors as temperature, rate of flow of the corrosive media, concentration, etc. and so interrelated unwanted reactions can occur, producing effects such as interfacial corrosion. Tests may be accelerated. Control test pieces should be stored in a non-corrosive environment.

NOTE 1 The results of accelerated corrosion tests should only be used as guidance.

NOTE 2 If corrosion tests are to be applied, it is important to ensure that conditions are realistic. *Corrosion tests improperly carried out can give misleading information.*

Brazed joints can be attacked in several ways, e.g. general corrosion, selective metal removal, galvanic corrosion, high temperature corrosion and hot gas attack (causing oxidation and sulphidation).

3.9.2 Principle

The principle of the test is to subject test samples to the corrosive life-limiting processes to which they may be subjected during the possible future service of the filler metal or the brazed construction. Tests are accelerated, for example, by testing at an elevated temperature.

NOTE This may be a simple test or, for category 1 brazed joints (see BS 1723-2), the test procedure may be complex, with stress also being applied.

3.9.3 Preparation of the test piece

The test piece shall be designed and manufactured so as to replicate the possible corrosion situation that may arise during the application of the brazed joint in general usage. Typical test pieces are shown in Figure 15, Figure 16 and Figure 17. The test piece design shall be agreed between the contracting parties [see **1.4.2.14** a)]. For specific applications, a brazed construction or a suitable replica sample shall be manufactured. Sufficient test pieces shall be prepared so that they can be withdrawn from the test situation at intervals of time. Control test pieces shall also be manufactured concurrently.

3.9.4 Procedure

Test pieces shall be examined by appropriate destructive or non-destructive tests before and after the corrosion test.

The test shall be conducted so that the test pieces are subjected to the corrosive environment in which they operate. The environment shall have a concentration of corrosive components, rate of flow and test temperature as agreed between the contracting parties [see **1.4.2.14** b)], e.g. by conducting the test in a spray cabinet (see BS 5466). The test shall be designed so that, if stress or thermal cycling are factors, these shall also be applied in a similar way to their application during the life of the brazed construction. Test pieces shall be taken from the corrosive environment at intervals and shall be tested by methods to be agreed between the contracting parties [see **1.4.2.14** c)]. The total exposure time, temperature of testing, corrosive environment, number of test pieces and any other factors shall be agreed between the contracting parties [see **1.4.2.14** d)].

3.9.5 Test results and information to be reported

The test results and information to be reported shall include the following:

a) test pieces and method of preparation;

b) reference (e.g. contract number, part number, location on brazed structure, as applicable);

c) test method (test medium, duration temperature);

d) brazing filler metal;

e) parent materials;

f) brazing process details;

g) date of start of test;

h) date at which test pieces were withdrawn;

i) applied stress or thermal cycle;

j) visual appearance (photograph if necessary);

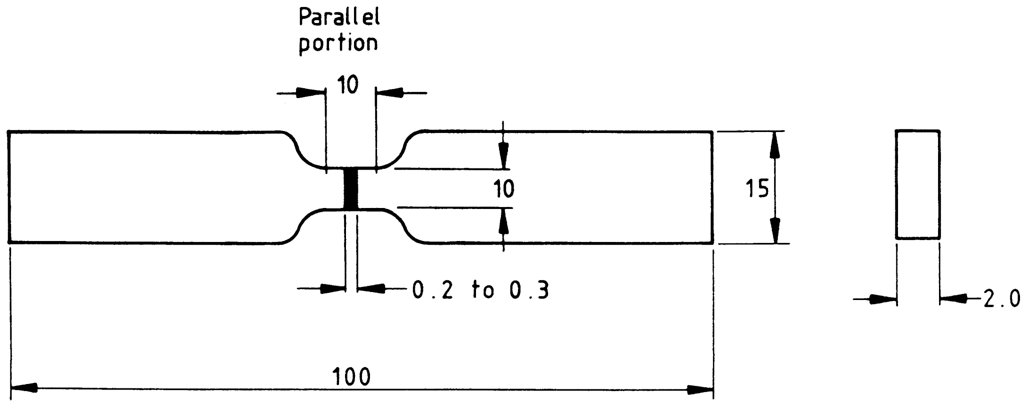
k) mass change;

l) results of non-destructive tests (before, during and after corrosion testing);

m) results of destructive tests (before, during and after corrosion testing);

n) name of laboratory, operator identification and operator qualification.

NOTE Appendix E is a suggested format for reporting test details and results.

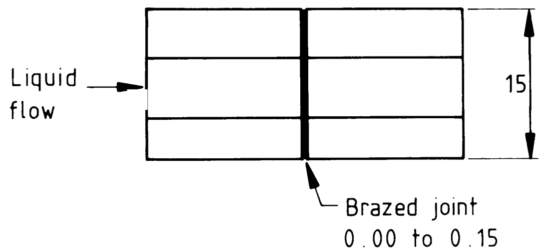


NOTE 1 The parallel portion of the test piece and its edges are machine finished.

NOTE 2 The test piece is to be uniform in thickness of brazing filler metal over the whole surfaces of the joint and should be free from deformation as far as is practicable.

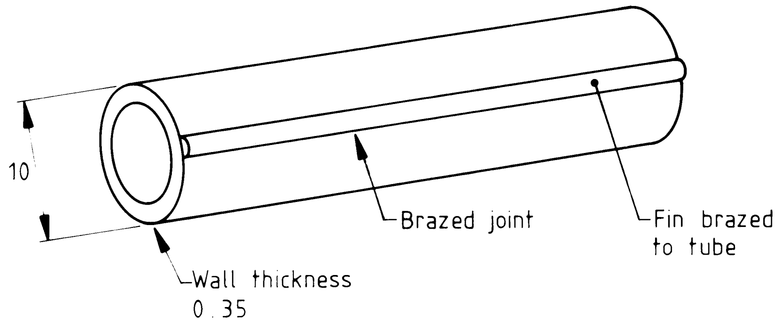
All dimensions are in millimetres.

Figure 15 — Test piece for gaseous and wet corrosion testing



All dimensions are in millimetres.

Figure 16 — Test piece for liquid or liquid metal corrosion testing



All dimensions are in millimetres.

Figure 17 — Test piece for gaseous corrosion testing

Section 4. Testing of brazing filler metals

4.1 General

Brazing filler metals are added during brazing or pre-placed when the component parts of a sample or brazed construction are assembled. They are molten at the brazing temperature, flow between the faying surfaces and complete the joint. The composition of the filler metal should:

a) comply with BS 1845; or

b) be in accordance with the relevant application standard; or

c) be selected by the contracting parties in the absence of an application standard.

For certain critical applications, or when there is a dispute between the supplier of the filler metal and the user, it may be necessary to test the characteristics of the filler metal. Several test procedures are available, which, if any of the tests are used, shall be the subject of agreement between the contracting parties (see **1.4.1**).

The brazing filler metal test methods described are as follows:

1) chemical composition (see **4.3**);

2) carbon and spatter test (see **4.4**).

4.2 Preparation of the test sample

Samples for testing by any method given in this section shall be representative of the manufacturer's production batch or the material under investigation. The sampling procedures used shall be in accordance with the procedures recommended in BS 2635 and BS 3338. In the case of powder sampling, care shall be taken that different particle sizes have not segregated. Similarly, wire or rod shall be selected as representative of the bulk. Where appropriate, the solid sample shall be degreased to remove any surface contamination, unless surface contamination is being investigated. All material shall be uniquely identified and replica samples shall be kept as archives in case of a dispute over results.

When any sample fails to satisfy the test requirements, two further samples shall be prepared, using material from the same batch and submitted to the test(s) in which failure occurred. Provided that the tests of both of the additional samples are satisfactory, the consumables shall be deemed to have passed the test.

4.3 Chemical composition of brazing filler metal

4.3.1 General

Brazing filler metals are normally classified by their composition. They may comply with national standards such as BS 1845, or commercial specifications.

Alternatively, a filler metal with specific mechanical or corrosion requirements may be used.

4.3.2 Procedure

The method of chemical analysis of the filler metal shall comply with:

a) the appropriate British Standards (BS 1748 and BS 6337); or

b) the latest annual book of ASTM Standards Part 12 "Method for Chemical Analysis of Metals"[4]; or

c) any other recognized method agreed between the contracting parties [see **1.4.2.15** a)].

4.3.3 Test results and information to be reported

The test results and information to be reported shall include the following:

a) date of examination;

b) reference (e.g. contract number, part number, location on brazed structure, as applicable);

c) filler metal type;

d) method of testing;

e) elements tested and results;

f) laboratory conducting the test;

g) identity of operator and operator qualification.

NOTE Appendix E is a suggested format for reporting test details and results.

4.4 Carbon and spatter test for brazing filler metals

4.4.1 General

When the brazing filler metal is to be used for joining electronic components, it is important that no spatter or surface carbon is produced during brazing. The surface "carbon" consists of a mixture of carbon and other insoluble impurities such as silica and alumina. They form surface contamination which can possibly fall off on to the cathode, causing bridging or vacuum leaks. The freedom of the brazing filler metal from this deleterious characteristic is important when it is used for fluxless brazing.

[4] Available from BSI, Linford Wood, Milton Keynes MK14 6LE.

The filler metal should have melted at the test temperature. The nickel or molybdenum screen is examined to assess the amount of splashing or spatter. The metal bead is examined for colour, and the surface examined for the presence of discrete black specks. Any discoloration more than a light smokey appearance is cause for retest or rejection.

4.4.2 Preparation of the test sample

Approximately 1 g of filler metal shall be placed in an alumina crucible which has been fired at 1 100 °C in air and stored in a dry dust free environment. A "U" shaped nickel screen shall be placed over the top of the crucible. For high temperature applications a molybdenum screen shall be used.

NOTE There should be a colour contrast between the screen and the filler metal.

The distance between the filler metal and the bridge shall be less than 9.5 mm (see Figure 18) above the metal bead.

4.4.3 Procedure

The sample shall be heated to the brazing temperature in a suitable atmosphere (see Table 1).

4.4.4 Test results and information to be reported

The test results and information to be reported shall include the following:

a) date of test;

b) reference (e.g. contract number, part number, location on brazed structure, as applicable);

c) brazing filler metal;

d) test temperature;

e) atmosphere;

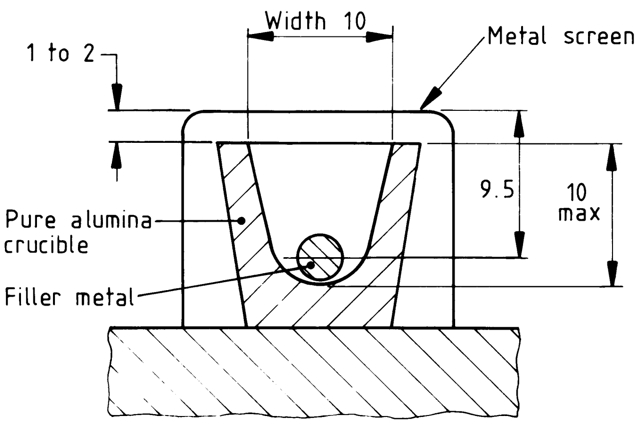
f) method of heating and heating cycle;

g) appearance of underside of the screen when examined using a × 5 magnification lens;

h) the appearance of the brazing filler metal bead;

i) name of laboratory and identity of operator.

NOTE Appendix E is a suggested format for reporting test details and results.



All dimensions are in millimetres.

Figure 18 — Check for the absence of splashing

Section 5. Brazing filler metal melting characteristics

5.1 General

Most brazing filler metals melt over a range of temperature and the flow point of a filler metal *on heating* is of considerable importance. Melting at a higher temperature than specified can result in lack of flow when automatic brazing systems are used, and unwanted metallurgical changes may occur in the parent materials if brazing temperatures used are higher than those specified in the manufacturing procedures.

The brazing filler metal melting characteristics test methods described are as follows:

a) differential thermal analysis (see clause **5.4**).

b) crucible balling test (flow point) (see clause **5.5**).

5.2 Preparation of the test samples

Samples for testing by any method given in this section shall be representative of the manufacturer's production batch or the material under investigation. The sampling procedures used shall be in accordance with the procedures recommended in BS 2635 and BS 3338. In the case of powder sampling, care shall be taken that different particle sizes have not segregated. Similarly, wire or rod shall be selected as representative of the bulk. Where appropriate, the solid sample shall be degreased to remove any surface contamination, unless surface contamination is being investigated. All material shall be uniquely identified and replica samples shall be kept as archives in case of a dispute over results.

5.3 Procedure

Because of the variation in the properties of brazing filler metals when heated, the conditions of the tests shall be as given in Table 1.

Table 1 — Brazing conditions

Filler metal type (see BS 1845)	**Test conditions**
Aluminium (4004, 4104) Silver (AG7) Copper Nickel and cobalt Palladium bearing Gold bearing	Vacuum or controlled atmosphere
Copper-phosphorus	In air without flux
Silver, copper-zinc Aluminium, except 4004, 4104	Appropriate solid liquid or gaseous flux in air

5.4 Differential thermal analysis (DTA)

5.4.1 General

Because of the uncertainty of the experimental procedures, duplicate tests are usually carried out and the results averaged. The solidus/liquidus temperatures of the filler metal being tested can only be determined to an accuracy of 10 °C. This accuracy will be influenced by the accuracy of the thermocouple and the associated instrumentation. The acceptable tolerance band should be agreed by the contracting parties (see **1.4.1**).

NOTE The efficient application of this test depends to a great extent on the skill of the operator, the care in setting up the test and the accuracy of the experimental procedures. Reference should be made to publications produced by Stanton Redcroft, Copper Mill Lane, London, SW17 0BN and the proceedings of the International Confederation for Thermal Analysis.

5.4.2 Principle

The principle of the test is to determine the solidus and liquidus of the filler metal being investigated and to check the reliability and accuracy of the test procedure by heating a reference material at the same time, in close proximity to the filler metal being tested.

5.4.3 Preparation of the test specimen containers

The specimen containers shall be manufactured from dried fused alumina, or some other inert material.

NOTE The specimen mass is typically up to 500 mg, depending upon availability and cost of the materials being tested.

5.4.4 Procedure

The filler metal and reference material shall be placed in the containers in the specimen holder assembly as shown in Figure 19. It is essential that there is good thermal contact between the specimens and their containers, otherwise there is a possibility of spurious temperature readings because of the presence of trapped pockets of air. The temperature measuring thermocouples shall be positioned so that they make and maintain contact with the separate containers holding the specimens during the test cycle. The thermocouples monitoring the specimens shall be joined in opposition so that the resultant signal represents the *difference* in temperature between the specimen temperatures. The *actual* temperature of the sample shall also be monitored.

The atmosphere used shall be compatible with the filler metal being tested and with the reference material (see Table 1). If a gaseous atmosphere is used, it is essential that a dry gas is used, except in cases where an atmosphere containing moisture is part of the test procedure. The rate of rise of temperature shall be 10 °C/min to 20 °C/min. When a temperature difference exists between the sample and the reference as a result of a physical change (melting) of the sample of filler metal, a signal occurs, which shall be graphically recorded.

5.4.5 Test results and information to be reported

The melting range of the sample shall be noted.

The test results and information to be reported shall include the following:

a) date of test;

b) reference (e.g. contract number, part number, location on brazed structure, as applicable);

c) form of filler metal;

d) reference material;

e) sample size;

f) container material;

g) atmosphere or flux used;

h) heating rate;

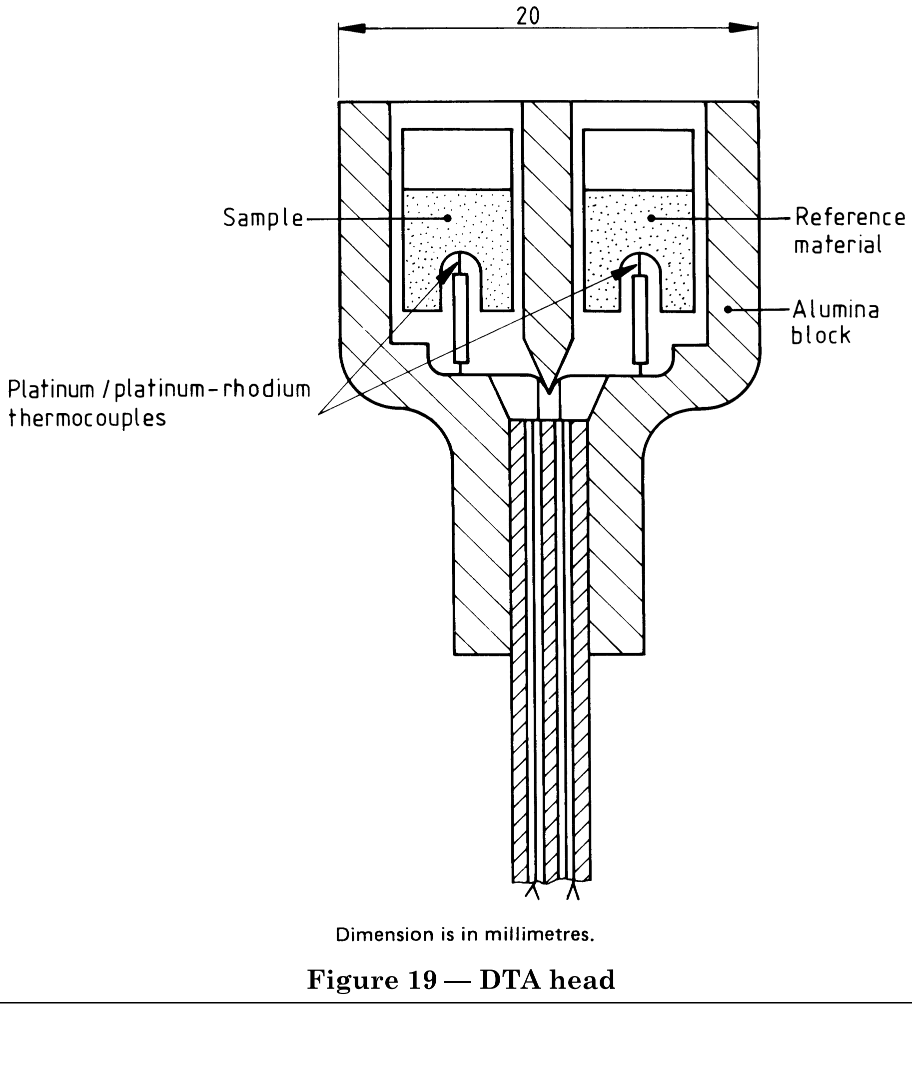
i) solidus/liquidus temperatures;

j) appearance of melted bead;

k) name of laboratory and identity of operator.

NOTE 1 Replicas of the actual temperature records should be part of the report.

NOTE 2 Appendix E is a suggested format for reporting test details and results.



Dimension is in millimetres.

Figure 19 — DTA head

5.5 Crucile balling test (flow point)

5.5.1 General

Most fluid filler metals melt to form a ball shape. When less fluid filler metals with wide melting ranges are melted, the shape may only have assumed an "egg" or "sausage" shape, which is an acceptable result for this type of filler metal.

When visually examined the sample should not be more discoloured than a light smokey appearance. Discoloration in excess of this indicates an unsatisfactory atmosphere or inadequate fluxing.

5.5.2 Principle

The principle of the test is to determine the melting characteristics of the brazing filler metal, by determination of the flow point, assessed by the temperature at which its shape is modified on heating.

5.5.3 Preparation of the test sample

A sample of a solid filler metal, i.e. rod, wire or sheet, shall be cleaned as appropriate to the type of filler metal being tested. This sample shall be separated from the bulk using clean dry tools. If there is doubt about the homogeneity of the bulk material several samples shall be taken throughout the material and tested separately.

5.5.4 Procedure

The sample shall be placed in a clean dense polycrystalline 99.5 % alumina crucible or boat, or in a clean fused silica crucible or boat which has been pre-cleaned by air firing at 1 100 °C and stored in a dry, dust free location until required for the test.

The test sample assembly shall be placed into a furnace which may be a fused silica combustion tube furnace, muffle, or a controlled atmosphere furnace (see Table 1). Whichever system is used, there shall be provision for a shielded thermocouple to be positioned in close proximity to the filler metal being tested. The test shall be conducted in an atmosphere compatible with the filler metal being tested.

NOTE Vacuum atmospheres are not suitable for testing most silver bearing filler metals and other filler metals that contain components that will volatilize during the test, altering the melting temperature.

Typically the atmospheres shall be air, hydrogen (– 40 °C dew point) 99.995 % purity argon or a vacuum atmosphere of better than 10^{-4} mbar[5)] with a low atmosphere leakage into the furnace chamber. The sample shall be raised to the test temperature, which shall be 20 °C higher that the normal liquidus, quoted flow point or brazing temperature of the filler metal being tested and shall be held at this temperature for 5 min to 10 min. The heating rate shall be in the range 2 min to 4 min for each 100 °C. The samples shall then be cooled to ambient temperature and examined. If the sample has not melted, further tests shall be carried out, increasing the temperature for each test by steps of 10 °C to 20 °C as appropriate to the filler metal being tested.

After removal of any flux the sample shall be examined to check the shape and also for any surface discoloration, using a × 5 magnification lens.

5.5.5 Test results and information to be reported

The test results and information to be reported shall include the following:

a) date of test;

b) reference (e.g. contract number, part number, location on brazed construction, as applicable);

c) brazing filler metal and flux if used (powder, wire, etc.);

d) furnace type;

e) heating method;

f) atmosphere;

g) thermocouple composition and position;

h) heating rate;

i) test temperature and time at temperature;

j) appearance of sample at conclusion of test;

k) name of laboratory and identity of operator.

NOTE Appendix E is a suggested format for reporting test details and results.

5) 1 mbar = 100 N/mm^2 = 100 Pa.

Section 6. Initial determination of flow characteristics and wettability of brazing filler metals

6.1 General

Flow characteristics and wettability are not only a function of the properties of the filler metal, they are also greatly modified by the following factors:

a) parent material;

b) surface condition of the parent material;

c) flux and atmosphere;

d) method of heating and brazing cycle;

e) joint clearance.

Because of these factors it is necessary to decide whether the tests are to be used to evaluate the characteristics of the filler metal, or to set the limits of variables that may influence the procedures for manufacturing a brazed construction and the tests in this section can assist in this respect.

The flow and joint filling characteristics and wettability test methods described are as follows:

1) flow characterizing and wettability test (see clause **6.2**);

2) joint filling and metallurgical characteristics (see clause **6.3**).

6.2 Flow characteristics and wettability test

6.2.1 General

The test results are analysed and a comparison made of the flow characteristics of the filler metal when melted with the variable applied to the test pieces being studied. Test pieces are compared and the area and directionality of flow of the filler metal measured and noted.

6.2.2 Principle

The principle of the test is to determine the flow characteristics of brazing filler metals when applied to various parent materials and to assess the effects of brazing variables on these flow characteristics. The tests described are generally used for sorting and give limited numerical data.

6.2.3 Preparation of the test piece

The types of test piece used for this test are shown in Figure 20. The surface of the test piece shall be prepared according to the variables being investigated. The filler metal shall be either pre-placed during preparation of the test piece or applied during the test as illustrated. The methods of surface preparation and the variables being investigated shall be the subject of agreement between the contracting parties [see **1.4.2.16** a)].

6.2.4 Procedure

6.2.4.1 *General.* The conduct of the test shall be appropriate to the filler metal type being tested. The atmosphere or flux used shall be as specified in Table 1.

6.2.4.2 *Coupon test piece* [see Figure 20(a)]. A controlled mass of filler metal shall be placed in the centre of the coupon of the parent material which is part of the test. This shall be heated to a specified temperature, which can be varied if temperature is a variable being investigated.

6.2.4.3 *Modified "T" test piece* [see Figure 20(b)]. The filler metal shall be either pre-placed or, alternatively, the operator shall feed the filler metal into the joint (using good brazing practice) using a flux as appropriate.

6.2.4.4 *Honeycomb test piece* [see Figure 20(c)]. The filler metal shall be pre-placed. It is usually integral with the surface of parent material, or pre-placed in quantities and in a position as appropriate to the configuration being investigated. The sample is generally heated to brazing temperature in a furnace.

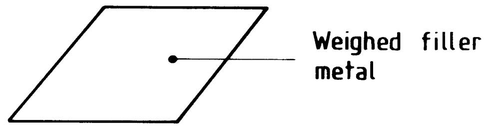
6.2.4.5 *Hairpin test piece* [see Figure 20(d)]. The filler metal is pre-placed adjacent to the hairpin of metal as shown in Figure 20(d). The sample is generally heated to brazing temperature in a furnace.

6.2.4.6 *The ISO 5179 test piece* [see Figure 20(e)]. This sample shall be tested as described in ISO 5179:1983.

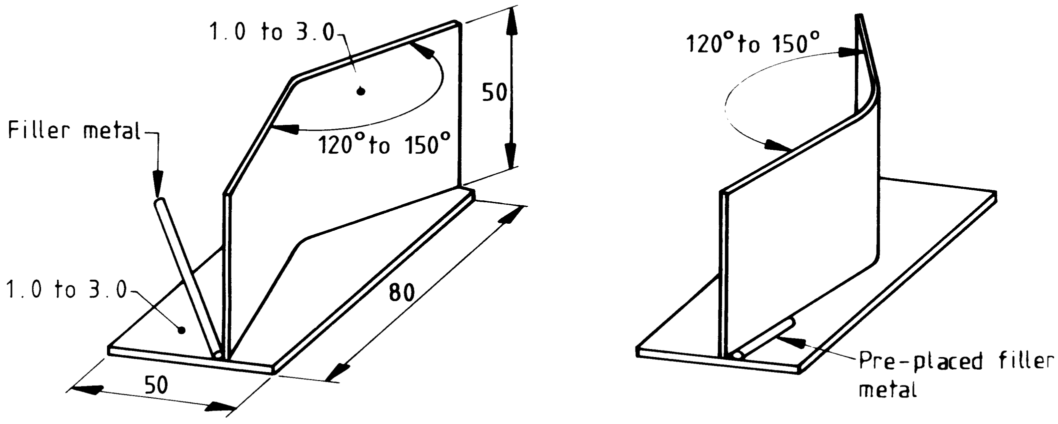
6.2.4.7 *Method of heating.* The test piece shall be heated to the brazing temperature by a method agreed by the contracting parties or, for basic investigations, by a method most appropriate to the particular category of filler metal [see **1.4.2.16** b)]. The melting temperature and range shall be considered when the heating method is selected.

Care shall be taken in the conduct of the test that only the variables being investigated influence the test result. All other factors shall be carefully "standardized".

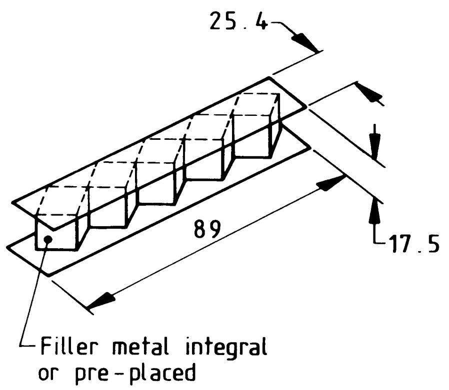
6.2.4.8 *Examination.* The test piece shall be visually examined and the extent of the filler metal flow measured. Relevant observed phenomena shall be the subject of a report. The methods of non-destructive and destructive examination shall be appropriate to the particular test piece and shall be the subject of agreement between the contracting parties (see **1.4.2.16**).



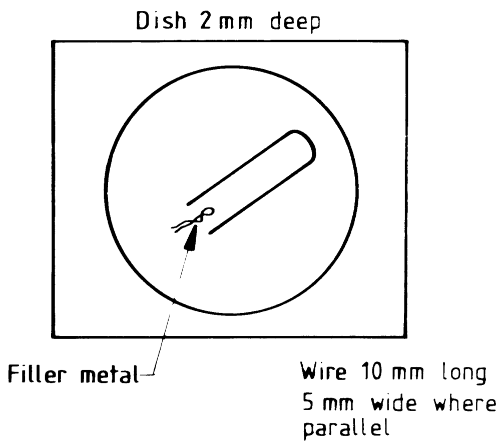
(a) Wettability test furnace brazing processes (coupon test)



(b) Torch brazing



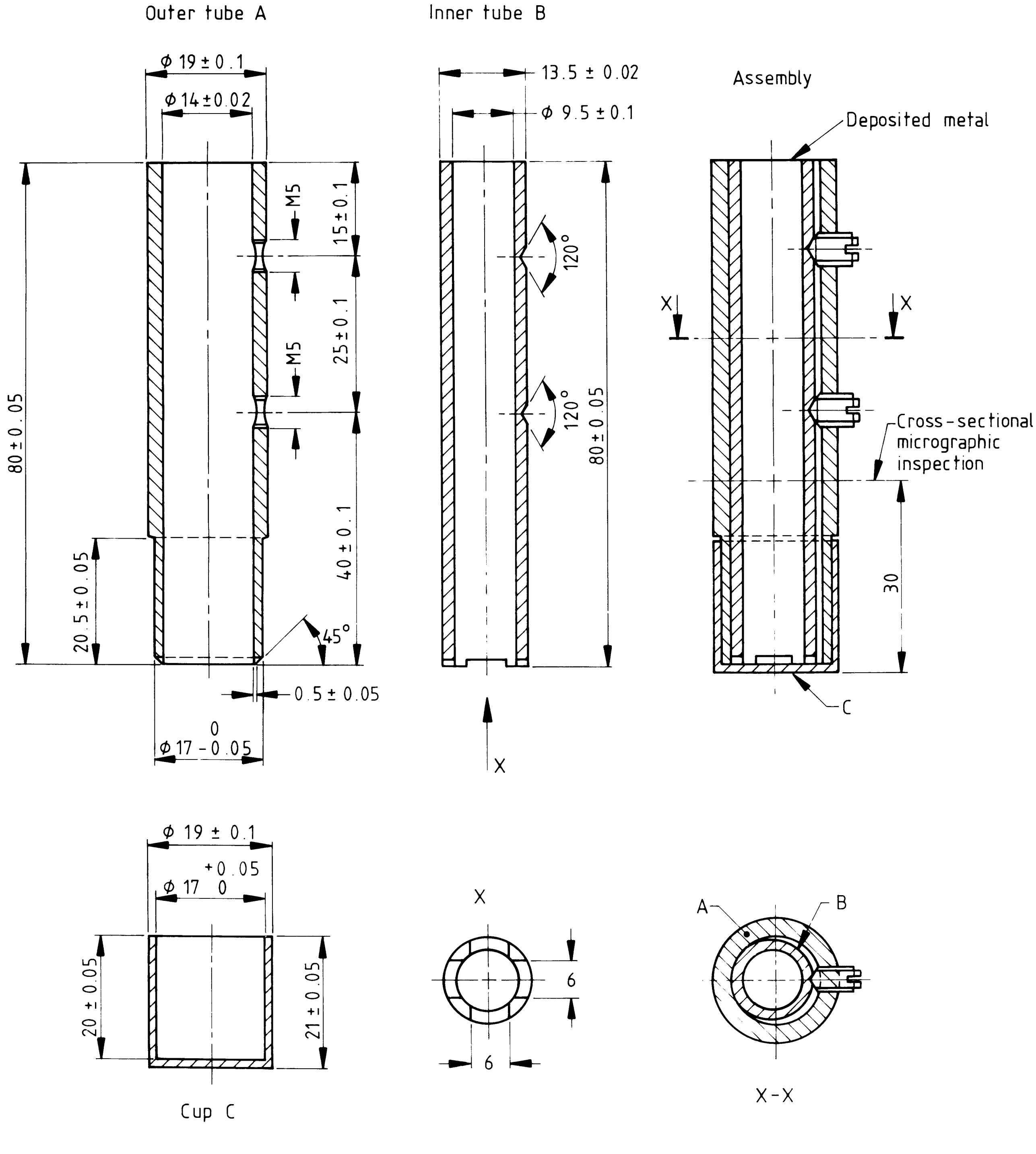
(c) Honeycomb structure



(d) Furnace brazing

Linear dimensions are in millimetres.

Figure 20 — Types of test piece for flow characteristics and wettability test



NOTE 1 Cup C forms the base for the piece.

NOTE 2 The lower end of tube B is provided with four identical centred recess $1^{+0.05}_{0}$ mm high in the shape of an orthogonal cross of 6 ± 0.05 mm width.

NOTE 3 Filler metal preplaced at the base of tube B (also flux if required) in cup C.

(e) ISO 5179 test sample

linear dimensions are in millimetres

Figure 20 — Types of test piece for flow characteristics and wettability test *(concluded)*

6.2.5 Test results and information to be reported

The test results and information to be reported shall include the following:

a) date of test;

b) reference (e.g. contract number, part number, location on brazed construction, as applicable);

c) parent materials;

d) method of surface preparation, including measured surface roughness;

e) brazing filler metal;

f) flux, atmosphere;

g) method of heating;

h) heating cycle, time to reach temperature and at temperature cooling rate;

i) name of laboratory, identity of operator;

j) results.

NOTE Appendix E is a suggested format for reporting test details and results.

6.3 Joint filling and metallurgical characteristics of high temperature brazing filler metals

6.3.1 General

Filler metals are increasingly used for applications which require an exact knowledge of the dependence of brazed joint quality on the manufacturing variables. The major variables are brazing time, temperature, joint clearance and post-brazing heat treatment.

6.3.2 Principle

The principle of the test is to investigate the ability of a filler metal in association with appropriate fluxes or atmospheres to:

a) flow into capillary gaps;

b) react with parent materials.

The test is also used to assess the effects of the following:

1) the brazing cycle;

2) the brazing temperature and time at temperature;

3) post-brazing heat treatment.

6.3.3 Preparation of the test piece

The test piece shall be manufactured and assembled as shown in Figure 21. The surface condition of the faying surfaces shall be the same as would be used in the brazed construction being investigated except where surface finish is the subject of the test. Before assembly, the component parts of the assembly shall be prepared by a method appropriate to the particular parent materials under test, such as mechanical abrasion, surface blasting or plating. Brazing filler metal shall be placed in the "V" groove at the bottom of the test piece, which shall be stood on an alumina plate or a plate of some other material that does not react with the brazing filler metal or the parent materials being tested.

NOTE ISO 5179 test specimen [see Figure 20(e)] is expensive and difficult to apply and is generally used for research and development applications only. The wedge gap specimen (see Figure 21) is much cheaper to prepare and apply.

6.3.4 Procedure

The test procedure will depend upon the type of investigation. The factors other than those being investigated shall not be varied. For example, if time at brazing temperature is being studied, then the brazing temperature and other interacting variables shall not be modified during the test. The test shall be conducted in vacuum, a suitable controlled atmosphere or using a flux compatible with the filler metal and parent materials being investigated.

The test piece shall be visually examined to estimate the flow of filler metal along the wedge. It shall then be prepared for examination by techniques agreed between the contracting parties [see **1.4.2.17** a)], which may include non-destructive testing, metallography and methods for investigating diffusional characteristics of the filler metal into the parent materials.

6.3.5 Test results and information to be reported

The test results and information to be reported shall include the following:

a) date of test;

b) reference (e.g. contract number, part number, location on brazed construction, as applicable);

c) filler metal;

d) parent materials;

e) brazing conditions;

f) variables being investigated;

g) results of examination;

h) name of laboratory and identity of operator.

NOTE Appendix E is a suggested format for reporting test details and results.

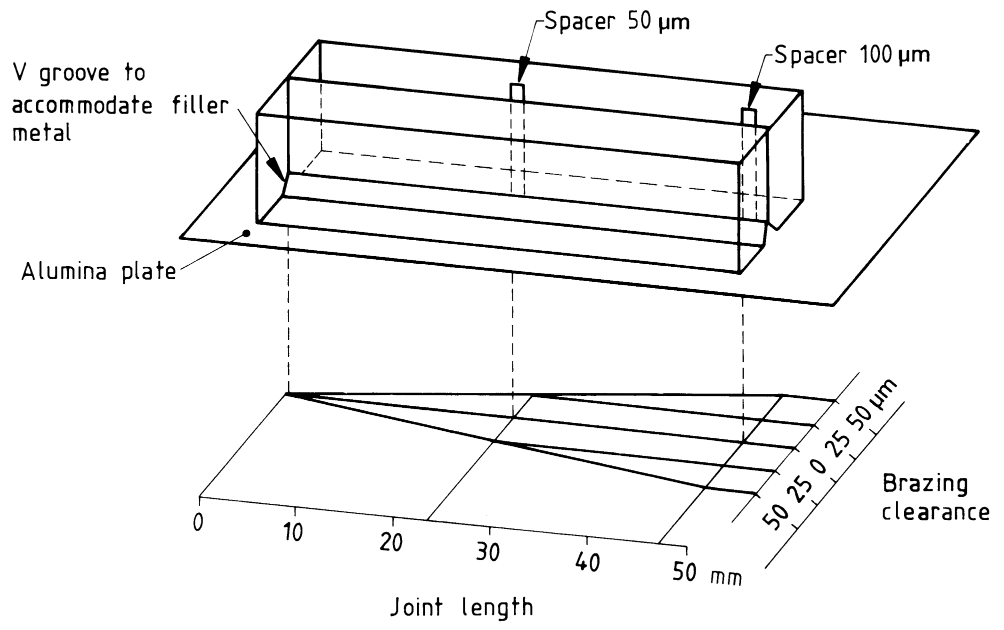


Figure 21 — Wedge gap test piece

Appendix A Brazing categories

Brazing quality categories are given in Table 2.

Table 2 — Brazing quality category

Category	Procedure approval test	Post-braze inspection[a]	
		Visual	Other than visual
1	Required	100 % required	100 % non-destructive testing required. Destructive tests by agreement
2	Required	100 % required	Non-destructive testing required, but not up to 100 % of joints. Destructive tests by agreement
3	Required only by agreement	100 % required	Only required by agreement, on a spot check basis
4	Not required	Required on a spot check basis	Not required
[a] The details should be agreed between the contracting parties [see **1.4.1** a)].			

The following non-destructive and destructive tests can be used to evaluate brazed joints.

a) *Non-destructive tests:* visual and aided visual, proof, pressure/vacuum, penetrant, ultrasonic, radiographic, thermographic.

b) *Destructive tests:* tensile and shear, peel, stress rupture, impact, bend, hardness, metallographic, corrosion.

Appendix B Defects in brazed joints

Figure 22 to Figure 28 illustrate defects in brazed joints.

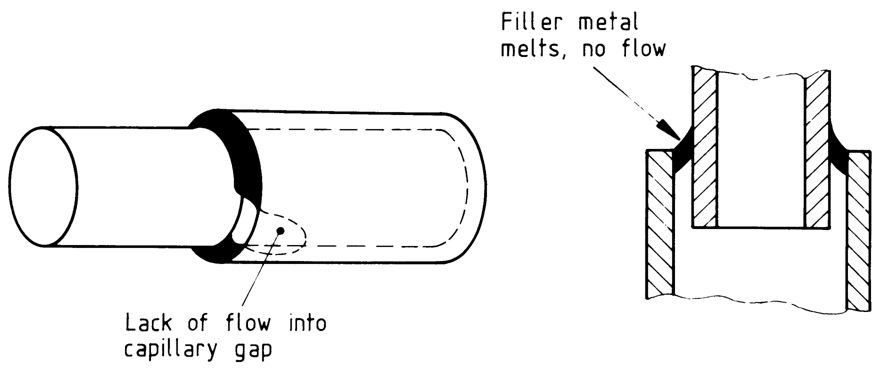


Figure 22 — Incomplete flow at fillet and in capillary

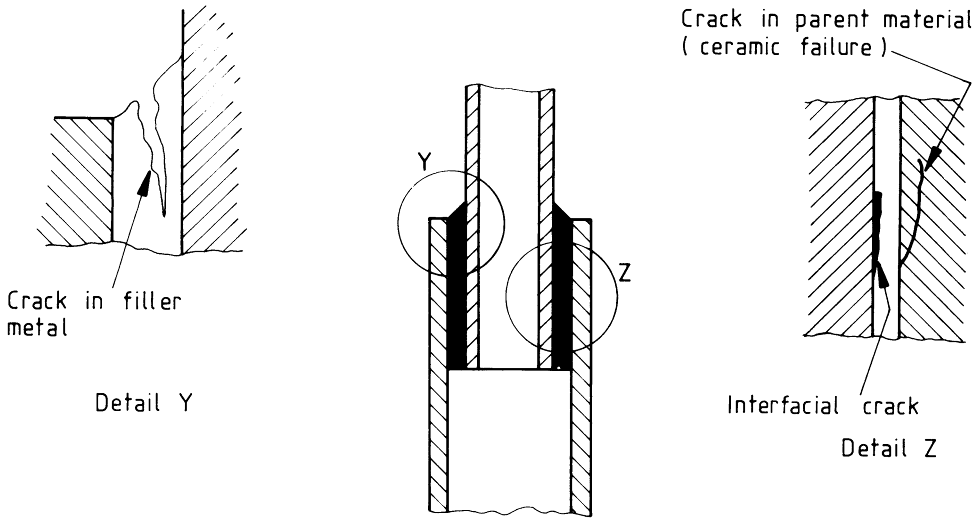


Figure 23 — Longitudinal cracks

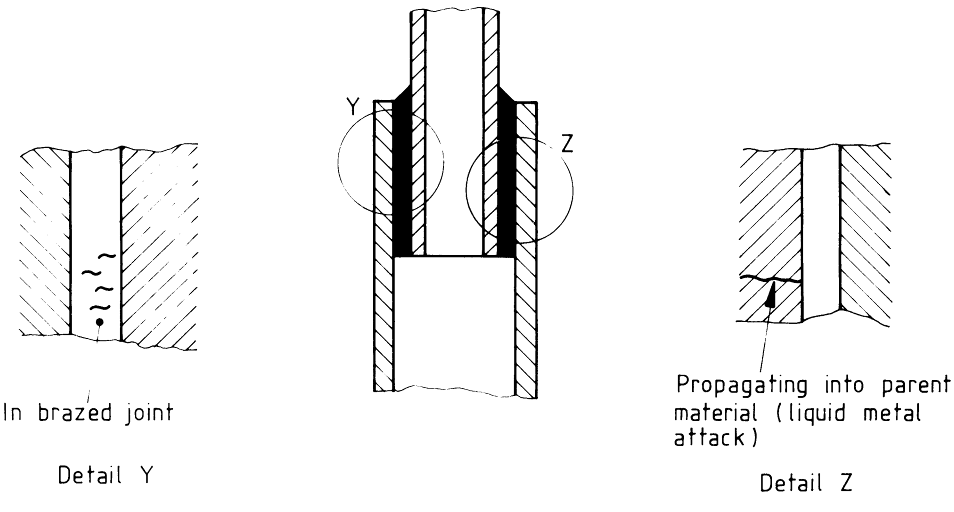


Figure 24 — Transverse cracks

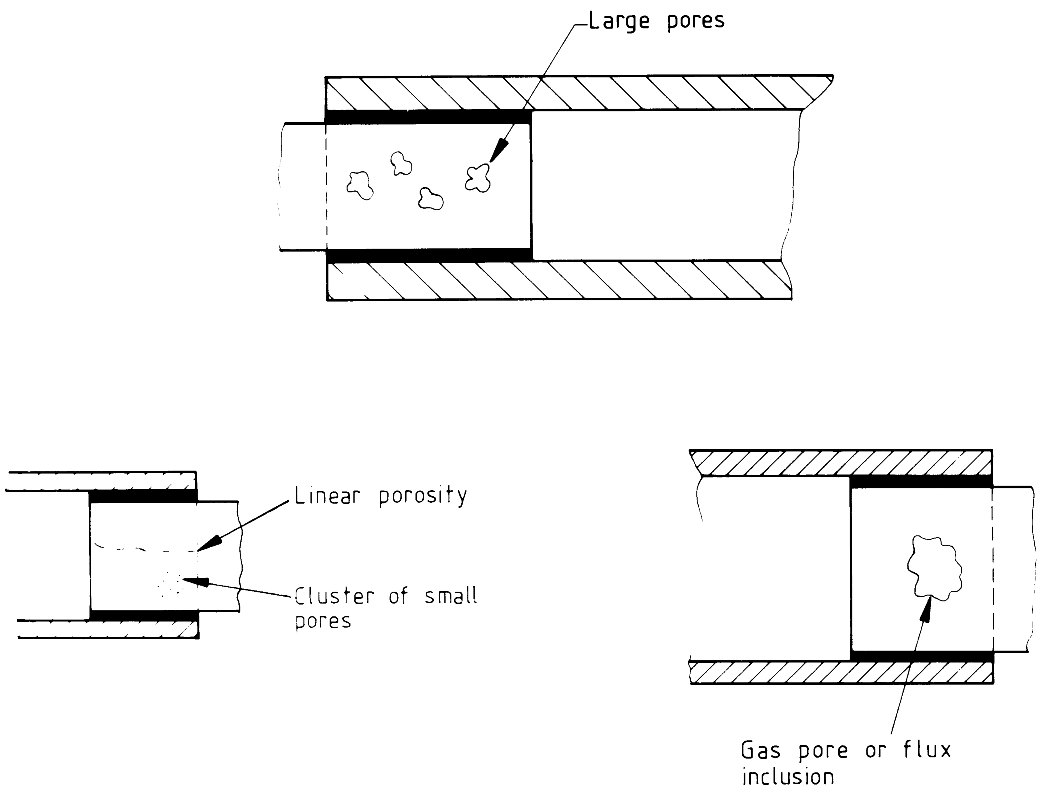


Figure 25 — Porosity and inclusions

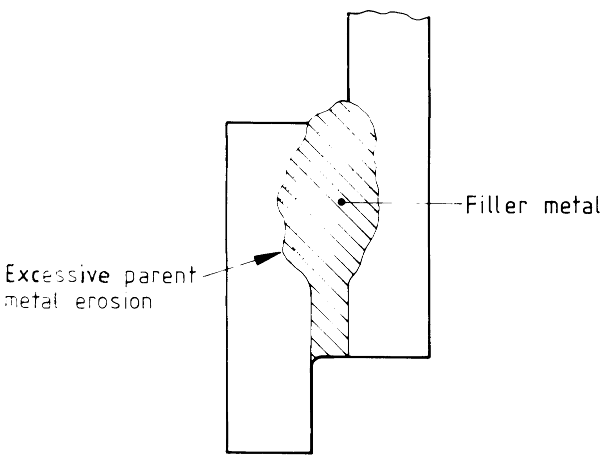


Figure 26 — Erosion

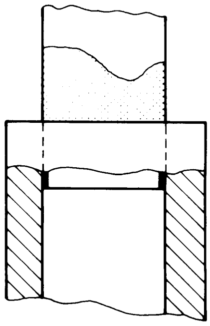


Figure 27 — Excessive filler metal flow

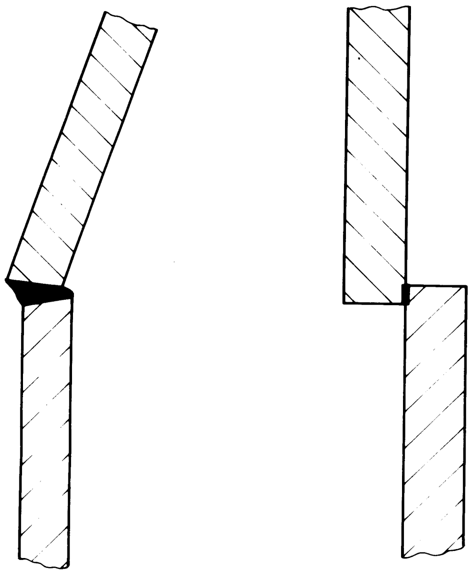


Figure 28 — Incorrect component assembly

Appendix C Example of data sheet for test piece preparation

Data sheet: brazing and mechanical testing of brazed joints

Date of test	Type of test
Parent materials	Filler metal
Manufacture and preparation	Operator
Joint clearance	
Brazing	Date
Brazing method	Atmosphere/flux
Brazing schedule	
Remarks	
Post-brazing heat treatment	Operator

Appendix D Recommendations for operators

The operator should be able to conduct the tests described in this Part of BS 1723, which may include the processes of measuring, examining, destructive and non-destructive tests, gauging and comparing the item being tested with the specified requirements. In many of the non-destructive tests, the effectiveness of the procedures and the interpretation of the attributes[6)] or variables[7)] depends to a great extent upon the skill of the operator. If required, the operator should demonstrate to the satisfaction of the contracting parties that he is capable of meeting the requirements of any particular technique adopted. It is not expected that any one operator will be competent to undertake all of the test procedures described. For specific tests, such as ultrasonic or radiographic examination and the operation of specialized equipment, he/she should have attended a recognized course or received appropriate training, e.g. meeting the Central Certification Board requirements, and the qualification should form part of the report on any of the tests.

The operator should have no physical disability that prevents him/her from carrying out the requirements of the tests. For visual examination, examination of radiographic films, magnetic particle flaw detection and dye penetrant testing, the operator should be able to read the Jaegar J2 chart at 0.5 m, or some similar acceptable test should be applied. This ability should be checked annually and a suitable record kept.

The operator should, as required, also:

a) be capable of making adequate judgements relating to test results, for example comparison of a test sample with supplied standard defects;

b) be able to keep adequate records;

c) do necessary numerical calculations;

d) operate simple photographic equipment;

e) follow specific procedures accurately;

f) prepare reports;

g) operate within the safety requirements;

h) maintain equipment associated with the test procedures.

Appendix E Example of non-destructive and destructive testing data sheet for reporting test results

Data sheet: brazing and mechanical testing of brazed joints

Parent materials (type and form)	Filler metal
Manufacture and preparation	Operator
Joint design	
Brazing	Date
Brazing method	Atmosphere/flux
Brazing schedule	
Remarks	
Post-brazing heat treatment	Brazing operator
Non-destructive testing	
Date of test	Type of test
Results of test	Test operator

[6)] An attribute means a characteristic that is appraised of whether it meets or does not meet a given requirement.

[7)] A variable means a characteristic that is appraised in terms of values on a continuous scale.

Destructive testing

Date of test

Type of test

Test piece (drawing) and number of tests

Test temperature

Results of test

Test operator

Additional information

Publications referred to

BS 18, *Methods for tensile testing of metals (including aerospace metals).*
BS 131, *Methods for notched bar tests.*
BS 131-1, *The Izod impact test of metals.*
BS 131-2, *The Charpy V-notch impact test on metals.*
BS 131-3, *The Charpy U-notch impact test on metals.*
BS 240, *Method for Brinell hardness test and for verification of Brinell hardness testing machines.*
BS 427, *Method for Vickers hardness test.*
BS 499, *Welding terms and symbols.*
BS 499-1, *Glossary for welding, brazing and thermal cutting.*
BS 709, *Methods of destructive testing fusion welded joints and weld metals in steel.*
BS 891, *Method for Rockwell hardness test.*
BS 1610, *Materials testing machines and force verification equipment.*
BS 1639, *Methods for bend testing of metals.*
BS 1723, *Brazing.*
BS 1723-1, *Specification for brazing.*
BS 1723-2, *Guide to brazing.*
BS 1723-4, *Method for specifying brazing procedure and operator approved testing.*
BS 1748, *Methods for the analysis of copper alloys.*
BS 1845, *Specification for filler metals for brazing.*
BS 2600, *Radiographic examination of fusion welded butt joints in steel.*
BS 2600-1, *Methods for steel 2 mm up to and including 50 mm thick.*
BS 2635, *Drafting specifications based on limiting the number of defectives permitted in small samples.*
BS 2704, *Specification for calibration blocks for use in ultrasonic flaw detection.*
BS 2910, *Methods for radiographic examination of fusion welded circumferential butt joints in steel pipes.*
BS 3338, *Methods for the sampling and analysis of tin and tin alloys.*
BS 3451, *Methods of testing fusion welds in aluminium and aluminium alloys.*
BS 3500, *Methods for creep and rupture testing of metals.*
BS 3636, *Methods for proving the gas tightness of vacuum or pressurised plant.*
BS 3683, *Glossary of terms used in non-destructive testing.*
BS 3923, *Methods for ultrasonic examination of welds.*
BS 3923-1, *Methods for manual examination of fusion welds in ferritic steel.*
BS 4206, *Methods of testing fusion welds in copper and copper alloys.*
BS 4331, *Methods for assessing the performance characteristics of ultrasonic flaw detection equipment.*
BS 4489, *Method for measurement of UV-A radiation (black light) used in non-destructive testing.*
BS 4778, *Quality vocabulary.*
BS 5165, *Guide to the selection of low-power magnifiers used for visual inspection.*
BS 5466, *Methods for corrosion testing of metallic coatings.*
BS 5500, *Specification for unfired fusion welded pressure vessels.*
BS 5650, *Specification for apparatus for gamma radiography.*
BS 5750, *Quality systems.*
BS 5750-2, *Specification for production and installation.*
BS 6072, *Method for magnetic particle flaw detection.*
BS 6443, *Method for penetrant flaw detection.*
BSI Handbook 22, *Quality Assurance.*
ISO 5179, *Investigation of brazeability using a varying gap test piece.*
ISO 5187, *Welding and allied processes — Assemblies made with soft solders and brazing filler metals — Mechanical test methods.*

DIN 8525, *Testing of brazed joints.*
DIN 8525-3, *Tensile testing of high temperature close joints.*
ANSI/AWS C3.2.82, *Standard methods for evaluating brazed joints in steel.*
Protection against Ultraviolet Radiation at the Workplace. National Radiological Protection Board.
W. J. McGonnagle, Non-destructive Testing. McGraw Hill.

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