

Brazing —

Part 2: Guide to brazing

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Committees responsible for this British Standard

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- 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
- Joint Industry Board for Plumbing Mechanical Engineering Services in England and Wales
- Ministry of Defence
- Plumbing Trades Union
- Society of British Aerospace Companies Limited
- Welding Institute
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Foreword

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

- *Part 1: Specification for brazing;*
- *Part 2: Guide to brazing;*
- *Part 3: Destructive testing and non-destructive evaluation (in preparation);*
- *Part 4: Procedure and operator approval (in preparation).*

This format has allowed the aspects covered in this guide to be widened and methods of testing together with procedure and operator approval are included for the first time. This is the first revision for which metric units have been used throughout.

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 26, an inside back cover and a back cover.

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

1 Scope

This Part of BS 1723 gives guidance on the practice to be applied to the brazing process.

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

2 Definitions

For the purposes of this Part of BS 1723 the definitions given in BS 499-1 and in BS 1723-1 apply. Where a definition given in BS 1723-1 differs from that given in BS 499-1, the definition in BS 1723-1 applies.

3 Principles

3.1 General

The brazing process has been defined¹⁾ as a joining process in which a filler metal is used which has a melting point of above 450 °C, but below that of the parent material, and which is distributed in the joint by capillary attraction.

3.2 Design

For an assembly to be joined satisfactorily by brazing, the designer has to be aware of the advantages and constraints associated with the process. The main requirement is that the finished brazed assembly should be fit for its intended purpose. To this end the designer should take into account physical properties such as strength, ductility, leak tightness, electrical and thermal conductivity, distortion, appearance, etc., and possible hygienic criteria such as freedom from crevices and avoidance of toxic alloying elements, e.g. cadmium-bearing filler metals. Likewise it is necessary to consider life-limiting processes to which the assembly will be subjected. These include high temperature/corrosive environments and mechanical and thermal stressing. From the separate and cumulative effects of these, and in consultation with the brazing engineer, the design appraisal can be made.

The design should incorporate a gap between the component parts of the joint into which molten brazing filler metal will be drawn or distributed by capillary attraction. The optimum nominal size of this capillary gap will depend upon the composition of the parent materials and filler metal being used. Alloy suppliers will provide data for specific brazing filler metals and appropriate fluxes.

The capillary joint can be achieved either by machining the component parts of the joint to size or by such methods as knurling, expansion of one component, etc.

The preferred joint configuration is with the components overlapping. Whenever possible, for furnace and mechanized brazing, the designer should incorporate a loading groove of a suitable size within the joint in which filler metal is pre-placed.

The designer should be fully aware of inspection requirements, and provision should be made in the design so that inspection at intermediate and final stages of manufacture is possible. The selected inspection method should be compatible with the economics of the manufacturing route.

3.3 Brazing filler metal

The brazing filler metal should be selected bearing in mind the design requirements and the parent materials involved. If in doubt about compatibility with the environment and with the parent materials, advice should be sought from suppliers and other recognized sources of information.

The most commonly used filler metals are listed in BS 1845; other filler metals are listed in suppliers' catalogues.

3.4 Component preparation

The component parts of a joint should be clean and properly fitting. When required by the brazing method, oxide, grease and oil should be removed by chemical and mechanical methods. This may involve degreasing, pickling, scratch brushing and other similar processes. The surface of the component within the brazed joint should not be ground or polished. A roughened surface will assist filler metal flow particularly in the direction of the "lay" of machining. To improve the fit-up it may be necessary to modify the surface by methods such as knurling. To improve wettability of materials such as the nickel alloys containing titanium and aluminium, and ceramics, it may be necessary to plate the surfaces with a suitable material.

To prevent the flow of filler metal outside the joint area, it may be necessary to apply a "stopping off" agent. Care should be taken that this does not penetrate into the capillary joint gap and inhibit flow.

It should be noted that the degree of cleanliness required depends upon the ultimate quality required of the component and also the brazing process to be used. The degree of preparation is most severe for high temperature flux-free controlled atmosphere brazing.

¹⁾ BS 499-1.

3.5 Jigs and fixtures

The designer should endeavour to make the components self-jigging. If jigs are used, they should not impose stresses on the component during the brazing operation. Jigs are frequently expensive to manufacture and may distort at high temperatures and when thermally stressed. They impose a thermal load, and so their mass may be important when the brazing cycle is determined. The effects of the jig may have a considerable influence on process selection.

3.6 Flux

Fluxes assist brazing filler metal flow. They may form an active or a protective covering at the joint region. In the broadest sense, a suitable gaseous atmosphere or a vacuum can be regarded as a substitute for a flux. Fluxes are not intended for primary removal of oxide layers and grease, etc., and their use does not obviate the need for systematic cleaning of components prior to assembly.

The flux should have a lower melting temperature than the brazing filler metal, and be active or protective up to and above the brazing temperature; it should be so fluid that it is swept through the joint by the brazing filler metal and is not entrapped. The manufacturer of the brazing filler metal will recommend an appropriate flux for each application. This will have been tested and found compatible with the brazing operation. In general, fluxes are not used when brazing in controlled atmospheres at temperatures above 900 °C.

Flux residues are generally removed from components after brazing by chemical or mechanical methods. The residues should be disposed of in a suitable manner. It may not be acceptable to drain these into the public disposal system.

3.7 Inspection

Inspection will be used at all stages. The degree of quality control and inspection required will greatly affect the economics of the process, so methods should be agreed between the customer and the manufacturer at the design stage.

Acceptance criteria should be agreed, and any deviation from these should either be a matter of rejection or concessionary action. It is important however, that this is undertaken by persons with wide experience in the brazing field and not only by the inspection department.

3.8 Testing procedures

Tests on brazed joints may be any of three types:

- a) visual examination;
- b) non-destructive physical tests on completed work;
- c) destructive tests on completed joints.

The purchaser, or his representative, should specify which of these tests are to be carried out. The sampling procedure and number of tests should be the subject of agreement between the purchaser, or his representative, and the contractor.

The purchaser may require the contractor to provide evidence that the brazing operators are suitable for the work upon which they will be employed. For this purpose, details of any approval(s) obtained by the operators under any appropriate standard laying down approval tests may be submitted as evidence of their proficiency, the names of all operators so qualified, together with particulars of any tests passed by each, being recorded and made available to the purchaser's inspector as and when required²⁾.

3.9 Defects

Defects occur in brazed joints as in all manufacturing processes. They may be caused by failure to comply with the details of an approved brazing process or because the effects of several interreacting variables are not fully appreciated or understood. The types of defect that may occur and can be observed by destructive and non-destructive methods of examination³⁾ are illustrated in Appendix A. No attempt is made to indicate whether these defect types are cause for rejection. This is part of the agreement between the contracting parties.

3.10 Health and safety⁴⁾

In addition to the obvious hazards due to the heat required to carry out the brazing process, toxic fumes can be produced from the heated filler metals and fluxes and by flames. These fumes may contain cadmium and zinc from low melting temperature brazing filler metals or plated components, fluorides from fluxes, and carbon monoxide and oxides of nitrogen from flames. Of these, the most important are fumes of cadmium or cadmium oxide which are highly toxic, and filler metals containing more than 0.025 % of cadmium should only be used in conjunction with a purpose designed local exhaust ventilation system. Even with cadmium-free alloys, good ventilation of the brazing shop is still required.

²⁾ Further information will be given in BS 1723-4 which is in preparation.

³⁾ Further information will be given in BS 1723-3 which is in preparation.

⁴⁾ See Appendix B.

Operators should be aware of the hazards of fume emission and those of handling fluxes which can be corrosive and irritating to the skin. Suppliers should always be consulted regarding detailed precautions relating to brazing filler metals and fluxes.

4 Categories of brazed joints

Brazed joints are used for a multitude of applications and the demands made upon the joint range from the trivial to ensuring the integrity of an important structure. The most significant property of a joint may be its strength at room temperature or at elevated temperature, its corrosion resistance or its ability to act as a seal. Because of this wide range of applications, it is very difficult to draw up a system of joint categories based on joint properties such as strength or soundness; for example, if a seal is required, even on an important structure, it may well be possible for the actual braze area to be as low as 50 % of the nominal whereas, if strength is required for a less important structure, this might be totally inadequate.

Therefore, the following categories have been based not on the level of properties themselves but the consequences of failure and on the ways in which attainment of the required properties is demonstrated and their maintenance assured. Decisions as to which are the important properties and what level is required should be based on preliminary discussions between the purchaser and the supplier and, if necessary, other interested parties.

Category 1. This category is intended to cover those joints which will be used in the most important applications, where failure of the joint will lead to significant financial loss and, potentially, injury or loss of life.

Category 2. This category is intended to cover those joints which will be used in important applications, where failure of the joint will lead to significant financial loss but not, in general, injury or loss of life.

Category 3. This category is intended to cover those joints whose failure would be inconvenient rather than important and not generally liable to lead to any loss of life.

Category 4. This category covers joints where the service requirements are minimal.

A summary of testing applied to different brazing categories is given in Table 1.

It will not always be easy to decide into which category a particular joint falls, but it is important to do this as accurately as possible. The risks involved in choosing too low a category for a given joint are obvious, but too high a category will impose an economic penalty because of the extra testing and inspection that are involved.

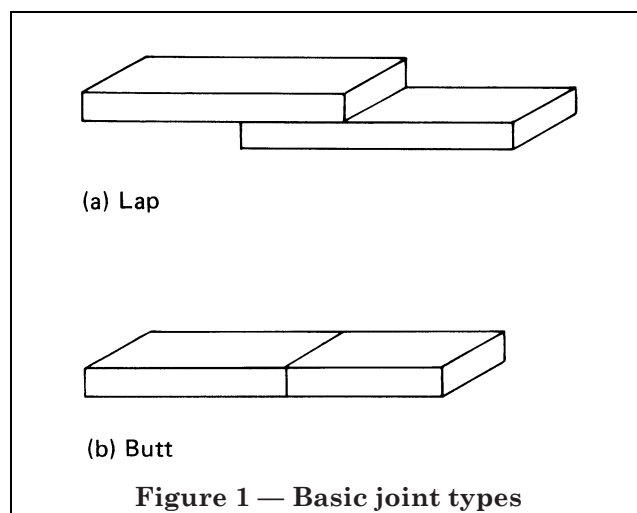
5 Joint design

5.1 Principle

The brazing process depends upon capillary flow of a molten brazing filler metal between parts separated by a narrow gap. The filler metal melts at a lower temperature than the parts being joined and therefore it will be of a different composition. This composition difference has to be taken into account when considering the properties of the joint at service temperature, in corrosive media during service, and under fatigue loading. In addition, it has to be recognized that the parent material of the components to be joined can be affected by the brazing cycle.

5.2 Types of joint

There are basically two types of joint as shown in Figure 1. Lap joints are generally used because they are easier to fabricate, offer increased strength and can tolerate reduced joint soundness. Butt joints are used where adequate strength is readily obtained, e.g. where a parent material is weaker than the brazed joint, or where the thickness of a lap joint is undesirable.



It should be noted that the useful overlap for a lap joint in shear is approximately four times the thickness of the thinner component; beyond this limit there is little to be gained in joint strength.

Table 1 — Brazing quality category

Category	Procedure approval test	Post-braze inspection ^a	
		Visual	Other than visual
1	Required	100 % required	100 % non-destructive testing (NDT) required. Destructive tests by agreement
2	Required	100 % required	NDT 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 interested parties. Test methods are described in BS 1723-3 (in preparation).

5.3 Brazing gap

5.3.1 General. Since each group of brazing filler metals has a preferred brazing gap range, the provision of the appropriate joint clearance is of fundamental importance in achieving efficient capillary penetration. The ideal brazing gap will vary according to the brazing filler metal type but may be modified by a number of other joint parameters.

These include:

- the parent material(s);
- length and geometry of the joint;
- surface finish of the faying surfaces;
- the use of a flux or protective atmosphere;
- careful control of brazing temperature.

Typical brazing gaps are shown in Table 2.

5.3.2 Brazing filler metal. Those types with the shortest melting range, often containing significant additions of temperature depressant elements (Si, B, P, Zn and Cd) exhibit enhanced fluidity and excellent capillary penetration. This also applies to most eutectic compositions and many pure metals. For these filler metals, therefore, joint gaps at the minimum of the range shown in the table will be most suitable. Conversely, those filler metals having wide melting ranges will generally have better gap filling characteristics and will be most suitable for brazing when gaps are at the upper end of the stated range.

5.3.3 Parent material(s). For those parent materials which are not readily soluble in the brazing filler metal, or do not undergo mutual interaction to form alloy layers, gaps may, in general, be tighter than with those combinations where significant alloying occurs. Extensive inter-alloying will impair the fluidity of the brazing filler metal and necessitate the use of wider brazing gaps to ensure complete penetration of the joint by the brazing filler metal.

5.3.4 Dissimilar parent materials. Where dissimilar parent materials, of different coefficients of thermal expansion, are to be joined, care has to be exercised in designing the joint in order to obtain the correct brazing gap. In extreme cases, joint gaps may close completely or open excessively at brazing temperature resulting in non-penetration or non-retention of the brazing filler metal, respectively.

If practicable, the material with the higher expansion should be the outer member of the assembly so that the joint is placed under compression on cooling. This becomes essential as the size of the brazed assembly increases, as the brazing temperature becomes higher and as the thermal expansion differential widens. With large components, the brazing gap may exceed recommended brazing tolerances at brazing temperatures.

5.3.5 Surface finish. Coarse surface finishes may generate irregularities in the joint gap and result in erratic filler metal flow, with reduced joint strength and soundness. Surface roughness should not, in general, exceed R_a 1.6 μm (CLA 63 μin) if the finish is directional.

5.3.6 Atmospheres or fluxes. Processes using a protective atmosphere or a vacuum will tolerate tighter joint gaps, with a given brazing filler metal, than an equivalent process where a flux is used. Unless joint clearances are adequate, flux and gas pockets will be by-passed and become entrapped in the finished joint.

5.4 Stress distribution

Figure 2 illustrates design modifications which endeavour to remove high stress concentrations from joint edges and distribute the stress more evenly in the parent materials.

Table 2 — Typical brazing gaps

Filler metal (see clause 6)	BS 1845:1984 reference	Gap at brazing temperature	Comments
		mm	
Group AL: aluminium	Table 1	0.05 to 0.25	Mineral fluxes
Group AG: silver	Table 2	0.05 to 0.150	Mineral fluxes
		0.025 to 0.125	Protective atmosphere
Group CP: copper-phosphorus	Table 3	0.025 to 0.125	No flux in air or protective atmosphere
		0.05 to 0.150	Mineral fluxes
Group CU: copper	Table 4	– 0.05 ^a to 0.100	Protective atmosphere
Group CZ: copper-zinc	Table 5	0.05 to 0.150	Mineral fluxes
Group HTN: nickel and cobalt	Table 6	0.00 to 0.125	Protective atmosphere
Group PD: palladium bearing	Table 7	0.05 to 0.150	Mineral fluxes
		0.025 to 0.125	Protective atmosphere
Group AU: gold bearing	Table 8	0.025 to 0.125	Protective atmosphere

^a “Positive interference” fit.

5.5 Pre-placement of filler metal

The brazing filler metal can be in the form of wire, shim, strip, foil, powder, paste and sheet or it may be sprayed, coated, plated or vacuum deposited.

For hand torch brazing application, the brazing filler metal may be hand fed. However, in automatic brazing operations, the brazing filler metal is either pre-placed or automatically fed. Examples of filler metal placement are shown in Figure 3.

5.6 Assembly

It is essential, when designing joints, to ensure that the component parts will retain the required relationship during the brazing process. There are several effective methods of achieving this (see Figure 4).

6 Materials

6.1 Parent materials

6.1.1 General. The wide range of materials in current use precludes the listing of every grade which is amenable to joining by the brazing process. General categories are listed here for guidance purposes but other less common materials may well be applicable. In the event that an unlisted material is specified, advice should be sought from the brazing filler metal manufacturer and appropriate sources of technical information (see Appendix C).

a) *Aluminium and its alloys.* Pure aluminium, aluminium-zinc (< 6 %), aluminium-manganese (< 2 %), aluminium-silicon (< 2 %), aluminium-magnesium (< 2 %).

b) *Coated materials.* Materials with electrodeposited or other coatings.

c) *Cobalt and its alloys.* Pure cobalt, hard facing alloys, corrosion-resistant alloys.

d) *Copper and its alloys.* Pure copper and associated grades, tin-bronzes, phosphor-bronzes, gunmetals, brasses, nickel-silver, aluminium-bronzes, beryllium-copper, chromium-copper, cupro-nickel.

e) *Ferrous metals.* Cast iron, malleable iron, mild steel, carbon and low alloy steels, alloy steels, high speed and tool steels, stainless, heat and corrosion-resistant steels.

f) *Magnesium.* Magnesium and some of its alloys.

g) *Nickel and its alloys.* Pure nickel, nickel-copper, nickel-iron, nickel-chromium-iron, nickel-chromium.

h) *Precious metals.* Gold, platinum, palladium.

i) *Refractory metals and alloys.* Titanium, zirconium, tantalum, beryllium, niobium and their alloys.

j) *Tungsten and molybdenum.* Pure tungsten, pure molybdenum, cemented carbides, silver-tungsten, copper-tungsten, heavy metals.

k) *Other materials.* Ceramics, cermets, graphite, tungsten carbide, glass, diamonds and sapphire.