Brazing Materials

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A large number of pure metals and alloys are used as filler material in brazing ; to make a choice of the best brazing material for a given application is, therefore, not easy. Broadly the selection will depend on the nature of the parent metals to be joined, the maximum working temperature of the final product and the brazing method proposed. Inside this broad choice, however, there may be many subsidiary factors such as economic considerations, limitations imposed by the fit of the joints or the degree of skill possessed by the available operators.

The temperature at which a brazing material can be used to make a joint must be lower than the temperature at which the base material becomes molten. The melting temperature of the alloy is therefore of prime importance. However, only pure metals and eutectics have single melting points and reference has, therefore, to be made in many cases to a melting range of which the lower point or 'solidus' is the temperature at which the brazing material starts to melt and the upper point or 'liquidus' is the temperature at which the alloy becomes entirely liquid.

Properties and applications of the most common types of brazing materials are discussed below.

Copper

Copper is mainly used for the flux-free brazing of mild steel in reducing atmosphere furnaces. In certain circumstances, the process may be applied to alloy steels, to high nickel-copper alloys of the monel types and to some grades of cast iron. Copper brazing of heat resisting alloys used in gas turbine construction is also practised to a small extent.

The grade of copper employed is not critical but ductile material substantially free from arsenic is desirable ; if it is deoxidised with phosphorus, the amount of that element left in the copper should be as small as possible.

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Copper-Zinc Alloys

Alpha-beta brasses containing 40 to 50% zinc are widely used as brazing materials and have as their main advantage appreciably lower melting points than that of copper. In addition, they have conveniently small plastic ranges and comparatively low first cost.

60/40 composition has a melting range of 897°C to 900°C and 50/50 composition one of 865° to 872°C. The 50/50 type of brass is used as a molten bath in dip brazing, as spelter granules or as hot rolled strips while the 60/40 type is employed in the cold drawn forms of rod, wire etc. Because of the convenience of cold working to the desired form, 60/40 brass is most widely used. Some additions like silicon, manganese, nickel etc. are made in these alloys for improvement of certain properties. A small addition of silicon particularly is found very useful because it provides deoxidation during the manufacture of the alloy, reduces the loss of zinc by volatilization and oxidation when the alloy is molten in use, and is thought also to improve capillary flow, possibly by the deoxidizing effect on the parent metal surface.

Copper-Phosphorus

Alloys of copper and phosphorus containing up to about 8% of the alloy constituent are used to a considerable extent for brazing copper and copper based alloys. Phosphorus has a marked effect on melting point, the eutectic composition of 8.25% by weight of phosphorus having a melting point of 707°C. Eutectic alloy is, however, less often used than alloys containing about 6½% to 8% of phosphorus because of the brittleness which is somewhat reduced by lowering the phosphorus content. Due to the lack of ductility of these alloys in the useful range of composition, there are limitations of forms in which these are available ; these alloys are, therefore ; used mainly for torch brazing operations.

An important property enjoyed by this type of brazing alloy is that it can be used on copper without a flux in the usual sense. When the alloy is melted, the surface can be seen to be covered with a thin mobile scum which is a fusible slag resulting from oxidation of some of the alloying phosphorus.

The best field for application of this family of brazing material is on copper of comparatively light section which will be fully annealed in the brazing operation ; application of high stresses to the completed joint causes the whole structure to distort and prevent stress concentration at the joint itself which is comparatively brittle.

With the addition of suitable flux, copper-phosphorus alloys can also be used on copper based alloys provided shock or vibration loads are not prominent in the function of the final assembly. Brazing aloys of this type with or without flux should on no account be used on ferrous metals, nickel or alloys containing appreciable amounts of nickel.

Caution should also be observed in their use on apparatus where the copper-phosphorus joint is exposed to unburnt coal gas at higher than normal temperatures. There is evidence that in these instances the brazing alloy is attacked and it disintegrates into a powder with consequent failure of the joint.

Silver-Copper-Phosphorus

The addition of silver to copper-phosphorus alloys results in a great improvement as regards ductility and reduction of melting point. An alloy of 15% silver with 80% copper and 5% phosphorus has been in large scale use for many years.

Apart from the lower melting point and improved flowing properties as compared with binary copper-phosphorus alloys, the greater ductility of this alloy permits its fabrication into wire, strip and foil, thus widening its field of application. When used on copper, no flux is required but flux is necessary on copper alloys. It should be mentioned again that this material is not intended for use on ferrous metals or those of high nickel content due to the possibility of formation of brittle phosphides in the joint.

Another popular alloy in this group has only 2% of silver and a phosphorus content increased to about 6.5%. Somewhere mid-way in properties between copper-phosphorus and the 15% silver alloy, the 2% silver alloy is sufficiently ductile to be fabricated into rod and rolled to fairly small sections of strip but lacks the working properties which could permit ready fabrication into fine wires or foil. This brazing alloy is primarily intended for hand torch work on copper without a flux but it performs satisfactorily on copper based alloys with a suitable addition to flux (not to be used on iron or nickel alloys).

Alloys in this group are used on the largest scale mainly on copper where it is desired to avoid using a flux, to reduce brazing temperatures below those necessary for copper-zinc or copper-phosphorus alloys, and to obtain more ductile and sounder joint than can be expected of the latter material. Applications include copper pipe installations, small copper tanks, water heaters, electric induction motor rotors and electrical connections of all types.

Silver-Copper-Zinc

Because the proportions of the constituent metals in this ternary system can be varied widely without sacrificing the valuable properties possessed by these alloys, this group covers a large number of useful alloys. Additions of 10% of silver to zinc copper alloys are useful in reducing the melting points of the resultant alloys, the maximum effect being obtained with an alloy consisting of 60% silver, 25% zinc and 15% copper which has a single melting point of 682°C.

The useful alloys in this ternary system are characterized not only by their comparatively low melting point but also by their high ductility in the cast condition. This property is important for fabricating the alloy into strip, foil and wire forms which are convenient and economical in application ; and since the alloy is present in the final joint in the cast form, ductility is imparted to the joint.

Ternary silver alloys are capable of successful use on all the parent metals which can be brazed except aluminium and zinc based materials and they can be applied by all the different heating methods employed for brazing. However, the advent of the lower melting quaternary alloys containing cadmium has displaced silver-copper-zinc alloys from many of the diverse applications for which they were previously employed.

Silver-Copper-Zinc-Cadmium

Brazing alloys in this group are used for a wider range of applications than in others. Such quaternary alloys have largely displaced the ternary alloys because of their ability to provide lower working temperatures, better flowing properties and strong and highly ductile joints. The addition of cadmium in a ternary alloy results in the depression of the melting point down to about 600°C.

For industrial brazing applications, an engineer looks for low melting, quick flowing brazing alloys which permit joints to be made between relatively accurate components in the shortest possible time. These requirements are best met by quaternary alloys having silver contents in the range of 40/50% or more. With the rising cost of silver which is easily the most expensive constituent, attention has been focussed in the recent years on alloys containing 42/45% of silver rather than those containing 50%. As the silver content falls below 42%, the solidus temperature remains slightly above 600°C but the liquidus temperature rises steadily. The lower the silver content falls the more illusory become the economies sought by economising in silver.

Quarternary silver brazing alloys with wide melting ranges suffer from a phenomenon called "Liquation". This means that as the solidus temperature is passed during heating, some portion of the alloy flows and begins to penetrate the joint. The unmelted residue no longer in intimate contact with the lower melting constituent cannot melt at the temperature observed as its liquidus in laboratory determination. Consequently the expected liquidus temperature may be considerably exceeded if heating is continued long enough to ensure that all the material is melted. Alternatively heating may be discontinued when the joint is considered to have been filled and an unmelted "skull" of residual material may be left at the point where the joint was fed.

Silver-Copper-Zinc-Cadmium-Nickel

Really an off-shoot from the important nickel-free quaternary group, nickel bearing high silver alloys in this system are distinguished by a certain sluggishness in use but noted ability to provide strong ductile joint with cemented tungsten carbide. In many cases, the nickel bearing alloy appears to wet carbide more readily than the normal ternary or quaternary silver brazing materials. Apart from a limited use on stainless and other alloy steels, nickel bearing silver brazing alloys in this group are used widely for brazing tungsten carbide cutting tool tips to their shanks and the attachment of rock drill tips to the steel drills.

Aluminium Silicon

Alloys of this type are used for the brazing of aluminium and certain types of aluminium alloys. The most widely used alloy in this group is 10/13% silicon alloy.

Other Miscellaneous Brazing Materials—There are many other brazing materials of very limited uses such as silver, gold, silver-copper, 15% manganese copper, 15% manganese silver, chromium nickel manganese brazing alloys, copper-gold alloys, silver-zinc alloys, silver-copper-tin, silver-copper-zinc-nickel and silver-copper-manganese alloys.

Details of the composition and conformity to IS specification of some of the most commonly used brazing material belonging to the main groups are given in a tabular form (Table I).

Possible combinations of similar and dissimilar parent metals that can be brazed are shown in the Table II along with brazing materials that may be used.

Average values of joint strength for design purposes using some of the brazing materials are shown in Table III.

Forms of Brazing Materials

It is evident that any brazing material will be capable of more versatile use if it can be made available in a variety of forms. Table IV gives an indication regarding the principal forms in which various brazing materials can be readily produced.

Fluxes

In most cases of brazing, a flux has to be used to remove inevitable oxides. It is not proposed to consider here to what extent an active flux may promote wetting by galvanic roughening of solid metal surfaces. We will regard fluxes primarily as oxide removers. A flux should be molten and active at a temperature of about 50°C below the temperature at which the brazing material starts to melt ; in addition, the flux should be stable up to the maximum temperature required during the brazing operation.

There are three main types of fluxes which take care of the great majority of brazing operations; these are :

(1) Borax based fluxes for general use at temperatures higher than 750°C except where refractory oxides are encountered. This type of fluxes is commonly used with copper-zinc brazing alloys.

(2) Fluoride type fluxes for general use at temperature below about 750°C and particularly where refractory oxides are involved. Generally used with all silver brazing alloys.

(3) Alkali Halide type fluxes for use in all processes involving brazing of aluminium.

TABLE I

Some of the Common Brazing Materials with their Composition, Melting Range and Conformity to IS : 2927—1964

Brazing Materials	*Classification*	*Silver* %	*Zinc* %	*Cadmium* %	*Nickel* %	*Phosphorus* %	*Copper* %	*Silicon* %	*Aluminium* %	*Other Elements*	*Melting Range*
Copper	BA Cu 1	—	—	—	—	0.075 max	99.90 min*	—	0 03 max	Lead 0.02 max Other Impurities 0.10 max	1085°C
Copper-Zinc	BA CuZn 4	—	Remainder	—	—	—	57-63	0.20 0 50	0 03 max	Tin 0 50 max Iron 0 15 max Antimony 0 05 max Lead 0 03 max Bismuth 0 05 max Arsenic 0 05 max Other Impurities (Total) 0.30 max	875°-895°C
Copper-Phosphorus	BA Cu P2	—	—	—	—	7.00 8.25	Remainder	—		Total Impurities 0.15 max	705°-800°C
Silver-Copper-Phosphorus	a) BA Cu P3	1.80-2.20	—	—	—	6 00-7.00	Remainder	—	—	,, ,, 0 15 max	640°-695°C
	b) BA Cu P5	14.00-15.00	—	—	—	4.30-5 00	Remainder	—	—	,, ,, 0 15 max	625°-780°C
Silver-Copper-Zinc	a) BA Cu Ag 6	60-62	9.0-11.0	—	—	—	27.5-29.5	—	—	,, ,, 0 15 max	690°-735°C
	b) BA Cu Ag 16	42-44	18.5-20.5	--	—	—	36-38	—	—	,, ,, 0 15 max	700°-775°C
Silver-Copper-Zinc-Cadmium	a) BA-Cu Ag 16A	42-44	18-22	20-22	—	—	15-17	—	—	,, ,, 0 15 max	608°-617°C
	b) BA-Cu Ag 11	49-51	14.5-18.5	17-19	—		14.5-16 5	—	—	,, ,, 0 15 max	627°-635°C
Silver-Copper-Zinc-Cadmium-Nickel	BA-Cu Ag 12	49-51	13.5-17.5	15-17	2.5-3.5	—	14.5-16 5	—	—	,, ,, 0 15 max	632°-688°C
Aluminium-Silicon	BA-A1 Si3	—	0.20 max	—	0.20 max	—	0.10 max	10-13	Remainder	Iron 0 60 max Magnesium 0.25 max Manganese 0.50 max Other Impurities (each) 0 05 max Other Impurities (Total) 0.15 max	565°-595°C

* If Silver is present, Copper 99.0% min.

TABLE II

Possible Combinations of Similar and Dissimilar Parent Metals with Brazing Alloys

Parent Metals	*Copper*	*Copper base alloys*	*Mild, carbon and low alloy steels*	*Stainless and heat resisting steel*	*Malleable and wrought iron*	*Cemented carbides*	*Nickel base alloys*	*Aluminium*
Copper	2 3 4 5 6	3 4 5 6 2*	2 4 6	2 4 6	2 4 6	—	4 6 2*	—
Copper base Alloys	3 4 5 6 2*	3 4 5 6 2*	4 6 2*	4 6 2*	4 6 2*	—	4 6 2*	—
Mild, Carbon and Low alloy steels	2 4 6	4 6 2*	1 2 4 6	1 2 4 6	1 2 4 6	1 2 4 6	4 6 1* 2*	—
Stainless and Heat-Resisting steels	2 4 6	4 6 2*	1 2 4 6	1 2 4 6	1 2 4 6	1 2 4 6	4 6 1* 2*	—
Malleable and Wrought Iron	2 4 6	4 6 2*	1 2 4 6	1 2 4 6	1 2 4 6	1 2 4 6	4 6 1* 2*	—
Cemented Carbides	—	—	1 2 4 6	1 2 4 6	1 2 4 6	1 2 4 6	4 6 1* 2*	—
Nickel Base Alloys	4 6 2*	4 6 2*	4 6 1* 2*	4 6 1* 2*	4 6 1* 2*	4 6 1* 2*	4 6 1* 2*	—
Aluminium	—	—	—	—	—	—	—	7

KEY : 1 Copper, 2 Copper-zinc (-Silicon), 3 Copper-Phosphorus, 4 Silver Copper Zinc, 5 Silver Copper Phosphorus, 6 Silver Copper Zinc Cadmium (-Nickel), 7 Aluminium-Silicon. Numbers without asterisks indicate that the brazing material may generally be used. Numbers with asterisks indicate that the use of the brazing material may depend upon special circumstances.

TABLE III

Average Values of Joint Strength for Design Purposes

Joint combination	*Design values for ultimate strength assuming average soundness of joint kg/mm² of joint area*	
	Shear	*Tensile*
Copper in mild steel	16 to 22 depending on fit.	17 to 35
High silver quaternary silver brazing alloy in mild and low alloy steel	17 to 31	27 to 41
High silver quaternary silver brazing alloy in non-ferrous metals	Usually exceeds that of metals joined.	
Brazing brasses in mild and low alloy steels	12.5 to 25	22 to 39
Brazing brasses in non-ferrous metals	Comparable with that of metals joined.	
Aluminium brazing alloys in aluminium	Usually exceeds that of metal joined.	

TABLE IV

Brazing Material	*Forms*							
	Rods	*Strips*	*Wires*	*Foils*	*Powder*	*Clad metals*	*Electro-deposit*	*Com-pound gauze*
Copper	x	x	x	x	x	—	x	—
Copper-Zinc (60/40)	x	x	x	x	—	—	—	—
Copper-Phosphorus	x	—	—	—	—	—	—	—
Silver-Copper-Phosphorus								
(less than 5% P)	x	x	x	x	x	—	—	—
(more than 5% P)	x	x	—	—	—	—	—	—
Silver-Copper-Zinc	x	x	x	x	—	—	—	—
Silver-Copper-Zinc-Cadmium with or without Nickel	x	x	x	x	x	x	—	x
Aluminium-Silicon (10-13% Silicon)	x	—	—	—	—	—	—	—

Note : At the moment, only rods, wires and foils are readily available in our country. X appearing in a column against a brazing alloy, indicates that the alloy can be made in that particular form.