

## COPPER AND COPPER BASE ALLOYS - PART II

### Aluminium Bronze

Aluminium bronze alloys consist of two basic types, those, which can be heat-treated, and those, which cannot be affected by heat treatment. Aluminium bronzes are defined as copper base alloys containing (5 - 15) percent aluminum, up to 10 percent iron, with or without manganese or nickel and with less than 0.5 percent silicon.

Solid solubility of aluminium in copper exists up to about 74 percent at the solidus, with solubility increasing to 94 percent at 565°C. Aluminium bronzes have an extremely narrow freezing range.

### Gas Absorption

The great danger is from hydrogen evolved from the dissociation of water vapour. There is a progressive reduction in both liquid and solid solubility of hydrogen with an increase in aluminium content. At about 8 percent aluminium the solubility is about one - half of that for copper. Sulphur dioxide is absorbed by aluminium bronze to form oxide and aluminium sulphide which compounds, remains in the metal or in the slag. Much of the gas unsoundness experienced during the cooling occur as a result of reacting with oxides.

### Fluxing Treatment

Few elements have a stronger affinity for oxygen than aluminium and so it is not practical to apply deoxidization. Fluxes capable of a solvent action are employed and these are based on fluorides. The charcoal is not allowed to remain for long periods on the molten surface. If it does, the iron, which is a constituent of aluminium bronze, may pick carbon to form hard spots in the castings. Lithium can be usefully applied to aluminium bronzes for combining with both oxygen and hydrogen. Phosphorus is not recommended as a deoxidant and it may lead to the separation of phosphides. Although it reduces the solubility of hydrogen there is a risk that residual phosphorus as phosphides will lower the ductility and resistance to impact and in addition give rise to hot shots. Silicon if employed for removal of oxygen may act similarly on the mechanical properties.

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Manganese and boron are useful additions, despite their inability to reduce aluminium oxide, they increase the fluidity of the melt, thereby assisting the oxide to separate out and float to the surface.

### Degassing of Aluminium Bronze

To avoid risk of gas porosity in large castings, a very low level of dissolved gas must be stipulated. Either nitrogen or carbon dioxide can be used for degassing. But there is a possibility of interaction between nitrogen and aluminium at high temperatures. The use of carbon dioxide does not carry this risk and plunging a carbon dioxide generating briquette provides a useful alternative. Pouring temperatures for aluminium bronze castings lie within a range 1150°C - 1250°C. If the foundry prefers to make its own alloy, it is advisable to start with purchased hardener containing approximately 70 percent aluminium and 30 percent ferrous. Nickel when needed should be added in the form of 50 - 50 nickel copper shots. Manganese is usually added in the form of copper manganese master alloy of 30 percent manganese content.

### Manganese - Aluminium - Bronzes

These alloys contain manganese and aluminium as major alloying elements with smaller additions of iron, nickel and in some cases tin. While the alloy is essentially an aluminium bronze containing (7.0 - 8.5) percent aluminium, the addition (11.0 - 14.0) percent manganese places it in a category removed from the conventional alloys both in composition and mechanical properties. These alloys have an excellent combination of strength and ductility as well as good founding and welding characteristics.

The alloy solidifies over the range of (940° - 980°C). Manganese - aluminium - bronzes was originally developed for marine propellers. Other applications

include cylinders, cylinder heads, pump housings and valve castings.

### **High Strength Yellow Brasses (Manganese Bronze)**

Manganese bronzes are essentially copper - zinc alloys with varying amounts of alloying elements such as manganese, iron and aluminium. As these alloys contain about 55 percent copper and 35 percent zinc, they are not bronzes but brasses. They are among the strongest copper base alloys, and have excellent corrosion resistant properties. They are relatively easy to cast but have high shrinkage characteristics. Careful consideration should be given for gating and risering.

The high strength yellow brasses may be divided into two groups.

#### **a. Medium Tensile Strength**

Alloys containing zinc (35 - 40) percent. Total aluminium, manganese, ferrous not over 4 percent and the balance copper.

#### **b. High Tensile Strength**

Zinc (20 - 30) percent. Total aluminium, manganese, ferrous (10 - 15) percent and the balance copper.

However, small quantities of phosphor copper may be added with the objective of increasing the fluidity and the separation of aluminium oxide from the melt.

#### **Melting Practice**

Although the manganese bronzes are not as susceptible to gas pickup while melting as the other copper alloys, it is recommended that they may be melted under slightly oxidizing atmosphere. No deoxidation is required for the manganese bronze. Zinc vaporizes at (910° - 915° C) and forms zinc oxide in the atmosphere. An efficient flux cover suppresses this vaporization associated with alloys containing appreciable zinc content and having melting points above 915°C. There is also the problem of restricting the formation of the oxide of aluminium and assisting in the removal of the same. This dual function is provided by the fluxes containing fluoride salts.

Manganese bronzes should be melted rapidly and brought to the temperature where zinc begins to flare. In low tensile manganese bronze this will be around 1010°C while for high tensile alloys it will be closer to 1066°C. Superheating should be avoided as this is accompanied with high zinc losses which change the composition of the alloy and alter its physical properties. The ideal pouring temperature for these alloys is just below the point where zinc is flaring. Due to the aluminium oxide skin on these alloys, pouring should be done with little turbulence. The metal should be poured to the mould cavity slowly and quietly.

#### **Hard Spots**

Alloys of high tensile brass are liable to defects known as hard spots. These occur mostly on cope surfaces and revealed during machine operations. Hard spots damage cutting tools, cause drag marks and appears as blemishes on polished and plated surfaces. That is mainly iron - silicon compounds. Boron also may be a constituent. Fluxes and refractories are sources of silicon and boron silicon may also come from sand adhering to scrap returned from the foundry.

Iron is an essential constituent of these alloys, about 1.0 percent of it being necessary to exert the requisite grain refinement. When silicon is present it reduces the solubility of the iron in the molten alloy. The residual silicon content of 0.04 percent is sufficient to initiate this action. Once hard spots have formed no means are known for their affective removal. The manganese bronzes loose strength rapidly at elevated temperatures and are not recommended for use where operating temperatures are above 204°C.

#### **Leaded Red Brass and Leaded Semi Red Brasses**

The leaded red brasses are defined as copper base alloys containing (2-8) percent zinc and less than 6 percent tin and over 0.5 percent lead. Leaded semi red brasses contain (8-17) percent zinc, less than 6 percent tin and over 0.5 percent lead.

Zinc is soluble in copper in all proportions and the copper zinc alloys are therefore all solid solutions. This group of alloys typified by the well known 85 - 5-5-5. It has been in use for many years. One

of the most important roles played by the lead is that of imparting free machining qualities to the alloys. Lead also tends to give a physical impregnation at higher percentages. Normally, lead content of (6 - 6.75) percent helps to reduce leaks. Unlike the yellow brasses, leaded red and leaded semi red brasses possess a rather a wide range of solidification.

### **Melting Practice**

In general best results are obtained when these alloys are melted under slightly oxidizing atmosphere. Fluxes are not particularly necessary, especially when good clean materials are used. For metals melted in crucibles glass used with or without borax, makes a good cover. The borax content can control the consistency of the flux.

Brass alloys suffer little from porosity defects due to dissolved hydrogen. This is because of the pressure of the zinc vapour. It is a common practice to introduce a small percentage of phosphorus for deoxidizing purposes, adding only enough to ensure complete deoxidization of the metal and leaving a trace of phosphorus in the final alloy. Phosphorus usually is introduced as 15 percent phosphor copper. It is customary to add about 28 grams of 15 percent phosphor copper per 45 kilogram of metal to perform this function.

This is equivalent to approximately 0.01 percent of phosphorus. As phosphorus is increased, the metal becomes more fluid and excess phosphorus may increase the fluidity to such an extent that the metal will penetrate the mould walls and cores. High phosphorus also has a tendency to make dirt castings. A pouring temperature within the range of (1066° - 1232°C) is generally satisfactory for the majority of castings. Metal should not be heated to more than (48° - 66°C) higher than the desired temperature. The casting from 85 - 5- 5- 5 are commonly used for the hydrostatic pressure applications.

### **Leaded Yellow Brass**

The leaded yellow brass has been defined as copper base alloys which contain over 17 percent zinc, less than 6 percent tin, under 2 percent total aluminium, manganese, nickel, iron or silicon and more than 0.5 percent lead. The yellow and leaded

yellow brasses are used primarily where it is characteristic yellow colour is desired or where a low cost alloy can be used.

### **Melting Practice**

Eventhough the yellow brasses are not so susceptible to gas pick up it is recommended that melting be carried out under a slight oxidizing atmosphere. Due to the high zinc content of the yellow brasses fluxes are useful as a protective covering during melting due to the large amount of zinc present in the yellow brasses. Little or no deoxidization is required. However, to improve the fluidity of these alloys aluminium or phosphorus is added. Phosphorus is used where the sections are thin and castings are required to be pressure tight. Aluminium is used when there is no pressure requirement and a smooth appearance is required. The suggested amount of aluminium is 85 grams per 45 kilogram. But quantities below or in excess may effect the surface of the casting adversely. The amount of phosphorus to be used is 280 grams per 4 kilogram of 15 percent phosphor copper, excessive amounts may cause metal penetration to the mould and core surfaces.

As copper decrease and zinc increases the strength is raised an ductility lowered. Castings of these alloys become more difficult as zinc increases. Lead promotes machinability. These alloys are used in the plumbing industry and for ornamental purposes, small gears, machine parts and similar castings. In general corrosion resistance of these alloys is not as good as that of red and semi red brass, but in contact with gasoline and fuel oils their resistance is much greater.

### **Melting Furnaces for Copper Base Alloys**

The function of the melting furnace is to supply molten metal satisfactorily in quality and at suitable temperature, at the lowest possible cost. In a copper base alloy melting foundry wide rage of alloys are produced and it is impossible to use one type of furnace to handle in all situations. The size and type of the furnace depends upon the volume of production, size of the casting to be made and the characteristic of the alloy. Regardless of type, the capacity of the furnace employed should have a direct relationship to the size of the casting to be made, or more specifically the number of moulds

to be poured from the furnace heat.

### Induction Furnaces

The induction furnace has become almost universally accepted and is one of the best means of melting brass and bronze. The types of furnaces available are core or channel type, and core less or crucible furnace.

### Channel Type Furnaces

In large foundries which has a regular production this type of furnace perhaps is the most widely used in industrialized countries. Its low cost, simplicity of operation and ability to turn good metal at high production rate are best suited for continuous and long production operations. These furnaces are available from several kilograms capacity to 10 - 15 tons of operation per melt.

### Coreless Induction Furnaces

These furnaces are well suited for batch melting when different alloys are to be run on intermittent schedules. These furnaces are designed with line frequency, medium frequency and high frequency operations. The operation is with a primary coil backed with a magnetic flux created by a secondary coil. When the electrical power is applied to the coil, heat is generated in the metal charge. The electromagnetic pressure produces a strong stirring action in the melt, this producing a complete homogeneous molten metal.

### Fuel Fired Furnaces

The furnaces using fuel oil, gas coke or coal is of three general types.

- \* Crucible pit furnace
- \* Crucible tilting furnace
- \* Crucible open flame furnace

Crucible melting is the oldest and simplest method of melting of copper alloys. The metal is held in a crucible and heated by conduction through the wall by hot gases from the combustion of fuel oil or gas. The crucibles are usually made of cast iron,

graphite or silicon carbide bonded with carbon. Cast iron crucibles are more oftenly used for holding purposes providing sufficient heat to hold the molten metal at constant temperature, but these may also be used in melting operation. It has good thermal conductivity and mechanical strength, which enables to withstand more rigidly than refractory type crucibles. Cast iron crucibles should also be regularly repositioned to change the relationship to the burners thereby minimizing the effect of hot spots.

In building crucible pit furnaces it is advisable to consider to the following location.

The location is a very important factor which requires broad consideration. The place should be free of moisture and it should not get wet during a rain. Ventilation and air circulation is extremely necessary to provide oxidizing atmospheres for the metal. Further, operators must have free access to handle molten metal and to transport it to the moulds.

### Refractories and Castables

The refractories should be of good quality with a medium alumina content so that it can withstand the heat generated by the burner. It is good to use fire clay and silica sand to lay the bricks allowing to dry intermittently while constructing the furnace. Water should be sparingly used to mix the castables as it takes longer time to dry the mixture.

### Crucible

Selection of a crucible should be given a good consideration as it is costly and also it may tend to crack during a heat or while transporting. The installation of the crucible is a very important item and it has to be placed on a graphite base of equal diameter to the base of the crucible, and its height may be equal or little higher than the base. The gap between the refractory and the top outer wall of the crucible (collar) should be within (25-50) millimeters. In between the top and the bottom of the crucible the lining has to be closely packed. The crucible has to be placed on a cylindrical block made from a similar material as the crucible and equal to the base of the crucible. The height may be equal to the same diameter of the block.

### **Burner and Oil Tank**

Several types of burners are available in the market. However a burner with a good air fuel mixing property is necessary. A good combustion with all kinds of liquid fuel is needed. Kerosene, heavy oil or even recycled oil may be used depending on the requirements of the foundry. Long durability is also another area for consideration. A burner which could be used in a place with high humidity or dust is required. The motor has to be sealed and double framed. The length and breadth of the flame should be adjustable by controlling speed of air and oil. The important factors of the crucible furnace melting are the position of the burner and direction of the flame and also slightly oxidizing atmosphere. Therefore, the burner has to be mounted at a specific distance from the base and the height of the crucible recommended by the manufactures. The height of the oil tank is also important factor for efficient operation of the burner. Average height of the oil tank for gravity feed should be about 3 meters from the base of the burner. The air and oil piping should be tightly fitted to avoid leakage, which may give rise to accidents.

### **Crucible Tilting Furnace**

These furnaces are constructed into a cylindrical body, which in turn is mounted into a steel structure. The furnace structure is mounted on to the horizontal axis, so that it can be tilted, and the molten metal can be poured. The significant factor is that the tilting axis passes through the center of the furnace and as a result the pouring lip moves up and down. The entire structure is grouted to the floor keeping allowance for tilting purposes. The cylindrical body should be well lined with firebricks. The crucible and the burner are rigidly fitted inside the brick lined body to the standard specifications. The capacity of these furnaces range from 150 - 50 kilograms of brass melting. The tilting operation may be done manually, electrically or hydraulically. Even though these furnaces can be operated conveniently, they have an important disadvantage. The metal is subject to agitation during the transfer operation from the furnace to ladle. This agitation mixes air with the metal, and creates strong likelihood of the inclusion of copper oxide in the metal and an increase in the gas content.

### **Crucible Open Flame Furnace**

This is similar to the crucible pit furnace, but the flame created by an external oil fired burner is directed to the metal, which is stacked in the crucible. After melting operation is completed the crucible itself is lifted out and placed on stand, and is transferred to moulds for pouring.

### **Bright Dips and Pickling Solutions for Copper and Bronze Products**

The copper and copper alloy castings oxidise very rapidly when exposed to atmosphere. The cleaning is not an easy task in castings, which has finer details specially in art castings. Therefore immersing in a dilute chemical solution will give good results. To brighten copper castings immerse in the following solution.

Water	- 10 gallons
Sulphuric acid	- 1 gallon
Potassium dichromate	- 10 gallons

The sulphuric acid is poured slowly into water, stirring the mixture in the meantime, then dissolve the dichromate in the solution. However, after cleaning in the above solution, the articles should be dipped in running water and subsequently dipped in a 1 % sodium carbonate solution to neutralise the acid. If the desire is to prevent from tarnishing a thin spray with clear lacquer is recommended.

In case of brass products the solution is made of,

Sulphuric acid	- 3 gallons
Nitric acid	- gallon

Increasing the nitric acid to 2 gallons will give better results on some brass alloys, in which case only a momentary immersion is necessary. The items are rinsed in cold running water and are necessary to remove the last trace of acid, otherwise stains will occur. To prevent tarnishing a thin layer of clear lacquer may be sprayed.