- A BRONZ1 WHITE PAPER -

Lead-free brass alloy

NEXTBRASS®

Registered in ASTM, UNS No.C49355, C89720

1. Introduction

For nearly three decades, Joetsu Bronz1 Corporation has been manufacturing and merchandising copper alloy ingot and continuous castings. In response to the needs of lead-free copper alloy in recent years, we are the first manufacturer who have started manufacturing continuous casting of lead-free bronze in Japan. This alloy has been registered in ASTM B584 as a copper alloy C89844, and has become the forerunner of present bismuth copper alloys family. (Shown in TABLE1)

TABLE 1
PLUMBING COPPER ALLOYS – NOMINAL CHEMICAL COMPOSITION (wt%)

Copper Alloys	Copper	Tin	Lead	Zinc	Silicon	Bismuth	Phosphorus	Selenium
CAST / LEADED COPPER ALLOY								
C84400	81.0	3.0	7.0	9.0	–	–	–	–
C83600	85.0	5.0	5.0	5.0	–	–	–	–
WROUGHT / LEADED COPPER ALLOY								
C35600	61.5	–	2.5	36.0	–	–	–	–
CAST / BISMUTH COPPER ALLOY								
C89520	86.0	5.5	–	5.0	–	1.9	–	0.95
C89844	85.0	4.0	–	8.0	–	3.0	–	–
C89836	89.0	5.5	–	3.0	–	2.5	–	–
WROUGHT / BISMUTH COPPER ALLOY								
C49300	60.0	1.5	–	36.0	–	1.2	–	–
NEXTBRASS C49355	66.0	1.0	–	31.0	1.5	0.7	–	–
CAST / SILICON COPPER ALLOY								
C87850	76.0	–	–	20.9	3.0	–	0.12	–
WROUGHT / SILICON COPPER ALLOY								
C69300	75.0	–	–	21.9	3.0	–	0.10	–

Copper alloys like bronze and brass have been used for plumbing components such as fittings and valves with the excellent chemical characteristics. Typically, better machinability is required for production of these products and thus, we have kept on adding lead as a content of alloy to obtain such better machinability as required.

However, lead content tends to be restricted in recent years so that lead has been recognized as harmful element which affects the human body and gets worse environmental health by lead-leachate from water contact surface of plumbing components containing lead element into drinking water and or by the vaporization during melting and casting process. In the USA, new lead content regulation will be enforced on January 1 2014.

Now lead-free copper alloy is mainly classified into bismuth copper alloys family and silicon copper alloys family. We focused on followings for a new alloy development on the ground of material supplier,

1) Both of scraps can be used for cost reduction. 2) Both each other characteristics are held.

Upon our continuous study and experiment for five years, we have finally succeeded in the development of a new lead-free copper alloy that fused with bismuth copper alloy and silicon copper alloy. This alloy is registered into ASTM. (UNS No.C49355, C89720)

2. Features and related background in bismuth copper alloys family, silicon copper alloys family and NEXTBRASS

In order to compare and consider with each alloy, we need to start understanding the features and related background of each alloy. We would like to introduce basic knowledge and information for you to understand these alloys as follows.

2.1 Influence to the health

[Lead]

Lead is contained in copper alloys used for water pipes and plumbing components. Lead leaches into a drinking water as lead ion from plumbing components. As the consequence of the intake of drinking water with lead ion for a long term, lead poisoning may be caused.

[Bismuth/ Silicon/ Tin]

On the other hand, bismuth, silicon and tin are not restricted elements. No information warning the risk of drinking water including these elements is published.

2.2 Basic physical properties of each element and effectiveness of additives to copper alloy

Bismuth itself is very fragile compared with lead which has a big ductility.

Neither bismuth nor lead is in solid solution in an alloy and thus, they remain in a liquid state even below the each melting point when the alloy solidifies. And they exist in granular on the matrix of an alloy as single element respectively. Because these work as a chip-breaker when machining, chip will be smaller and as a consequence, an improvement of machinability will be expected. However, the addition amount can be considered as the factor for deterioration of hot workability and thus, it is not preferable to add too much. In addition, it might be a factor for deterioration of not only hot workability but also mechanical properties.

Furthermore, each cubic volume increases when solidifies, these have effect to bury micro porosity which is in a place where the supply of molten metal is difficult. These can also make pressure resistance improved.

Silicon itself is very fragile. Silicon in copper alloys works as deoxidizing agent at the time of the melting. This can improve fluidity of molten metal and castability.

In addition, a part of it forms a solid solution in the matrix, and can make mechanical strength increased. Then, a part of it works together with zinc and makes hard phase functioned as a chip breaker, but which can provide machinability less than that of bismuth and lead. Tin in copper alloys contributes to an improvement of erosion corrosion resistance and dezincification resistance Especially, tin is well-effective for the improvement of erosion corrosion resistance.

2.3 Features of bismuth copper alloys family and silicon copper alloys family

Mechanical properties, corrosion resistance, machinability and hot workability are very important factors when considering the merit and demerit of lead free copper alloy for plumbing components. So each property will be briefly introduced as follows.

① Dezincification resistance and erosion corrosion resistance

Both bismuth copper alloy and silicon copper alloy don't have β-phase because of matrix constitution. So these alloys don't cause dezincification but erosion corrosion easily occurs in silicon copper alloy. (Shown in TABLE2)

TABLE 2
Corrosion Resistance

Copper Alloys		Corrosion Resistance		
		Dezincification Resistance	Erosion Corrosion Resistance	
		Maximum corrosion depth(μm)	Maximum corrosion depth(mm)	Corrosion weight loss(g)
PLUMBING COPPER ALLOY	C83600	10 or less	0.05	0.25
	C35600	1200	0.65	0.65
CAST / BISMUTH COPPER ALLOY	C89844	10 or less	0.05	0.30
WROUGHT / BISMUTH COPPER ALLOY	NEXTBRASS C49355	77	0.15	0.58
CAST / SILICON COPPER ALLOY	C87850	10 or less	1.00	0.85
WROUGHT / SILICON COPPER ALLOY	C69300			
	Test method	ISO6509-1981	Original Test	Original Test

About dezincification phenomenon

The brass, which contents zinc at 30 ~ 40 wt%, is composed of α-phase consisted of more copper and β-phase consisted of more zinc. Dezincification preferentially happens in β-phase prior to α-phase and copper in red sponge condition is residual.

About erosion corrosion

It is the phenomenon of decreasing wall thickness in plumbing components. That occurs upon interaction with "erosion" caused by mechanical factor and "corrosion" caused by chemical factor from high pressure overheated water and steam through the plumbing. The typical case of this phenomenon can be found in bending portions of plumbing such as elbows and tees.

②Hot workability

Bronze including C89844 cannot be material for hot working. Against it, brass can be used for hot working originally. Silicon copper alloy can be used as the material for hot working, since its composition is close to brass. Brass containing a small amount of bismuth instead of lead can be also used for hot working. However, the addition of large amounts of bismuth tends to inhibit the hot workability.

TABLE 3
Machinability index

Copper Alloys		Machinability Index
PLUMBING COPPER ALLOY	C83600	100
	C35600	130
CAST / BISMUTH COPPER ALLOY	C89844	90
WROUGHT / BISMUTH COPPER ALLOY	NEXTBRASS C49355	90
CAST / SILICON COPPER ALLOY	C87850	102
WROUGHT / SILICON COPPER ALLOY	C69300	

Original Test

③ Machinability

In bismuth copper alloy, the granular bismuth is in to disperse without form a solid solution and is served as a chip breaker. This causes good machinability. On the other hand, in silicon copper alloy, the hard intermetallic compound which exists dispersedly is served as a chip breaker, and causes good machinability. However, since the intermetallic compound of silicon copper alloy is harder than bismuth and lead, it is expected that the life of cutting tools becomes short. (Shown in TABLE3)

④ Mechanical Properties

Silicon copper alloys family is superior to bismuth copper alloys family like C89844 in the strength at room temperature. (Shown in TABLE4)

TABLE 4
ROOM TEMPERATURE – MECHANICAL PROPERTIES

Copper Alloys		Ultimate Tensile Strength (MPa)	Elongation (%)
PLUMBING COPPER ALLOY	C83600	310	34
	C35600	360	36
CAST / BISMUTH COPPER ALLOY	C89844	290	33
WROUGHT / BISMUTH COPPER ALLOY	NEXTBRASS C49355	490	23
CAST / SILICON COPPER ALLOY	C87850	490	27
WROUGHT / SILICON COPPER ALLOY	C69300		

The result is a representative value. Specimens were collected from the test piece was cast

2.4 Features of New alloy "NEXTBRASS"

"NEXT BRASS" C49355 (for hot working)
Dezincification resistance. . . . . excellent
Erosion corrosion resistance. . . . . excellent
Hot workability. . . . . excellent
Machinability. . . . . almost equivalent to bismuth copper alloy
Mechanical properties. . . . . almost equivalent or superior to bismuth copper alloy
Recyclability. . . . . scrap of both bismuth copper alloy and silicon copper alloy can be used

3. Technical point regarding new alloy component design

We, Joetsu Bronz1 Corporation, specialized in supplying ingot, rods and bars, have continuously researched and developed new alloy for a long time upon our concept and idea, that we can produce at lower cost by using various scrap and also that we can satisfy overall properties based upon silicon copper alloy, of which feature can be found in the mechanical strength. Through our research and development for a long time, we, Joetsu Bronz1 Corporation, have finally and successfully developed new alloy. The points to design contents of new alloy are shown below.

① Silicon copper alloy has excellent mechanical properties, dezincification resistance and hot workability, but erosion corrosion resistance is inferior. Minimum content of tin to improve erosion corrosion resistance shall be 0.5wt%.

② Adding large amount of tin to improve erosion corrosion resistance causes mechanical properties(especially elongation for ductility) lowered and hot workability also lowered too since the best temperature range of hot working becomes narrow. We have improved them by controlling content of zinc equivalent to 40 – 43wt%, which enables us to obtain the best mechanical property and hot workability.

③ In addition, the mechanical properties will be the best by less than 20% of area ratio of κ -phase within the range of composition adjusted as indicated above.

④ By reducing the amount of silicon to adjust zinc equivalent, hard phase area working as a chip breaker is reduced and that causes less machinability. Adding bismuth will recover machinability.

⑤ We have finally succeeded in the development of new alloy based on silicon copper alloy which complements each disadvantages of current bismuth copper alloy and silicon copper alloy, and makes it possible to use copper alloy's scraps including bismuth and or silicon.

4. Conclusion

According to our research and examination as explained so far, we, Joetsu Bronz1 Corporation, switched our research and development of lead-free products to the copper silicon alloy from the traditional bismuth copper alloy. Then we have finally succeeded in development of new alloy "NEXTBRASS" (UNS No.C49355, C89720) which can overcome the disadvantages in silicon copper alloy.

This alloy is economically practical, can satisfy the regulation to restrict lead, and has fundamental properties equivalent to traditional alloy.

We believe that this new alloy is the best alternative to the traditional ones in the worldwide market.