ALLOY DATA SHEET

EnviroBrass® (SeBiLOY®)

Non-Leaded* Red Brass and Yellow Brass Casting Alloys

INTRODUCTION

Federal regulations limit the amount of lead permitted in public drinking water supplies. These regulations, in turn, established a need for reduced-lead or non-leaded plumbing alloys and EnviroBrass fills this need.

- The U.S. Environmental Protection Agency's *Lead and Copper Rule* applies to public water utilities and establishes a framework to monitor and control water chemistry in order to reduce the corrosivity of water. Utilities are required to chemically treat water that is sufficiently aggressive to leach excessive copper or lead from the water supply system. The EPA rule established a lead "action level" of 15 parts per billion (ppb), as measured at the household tap in at least 90% of households, at which appropriate water-treatment steps must be applied.
- The 1996 amendments to the Safe Drinking Water Act (SDWA) required the EPA to establish a performance standard to limit the leaching of lead from endpoint devices intended to dispense water for human consumption. The EPA selected Section 9 of ANSI/NSF Standard 61: *Drinking Water System Components–Health Effects* as this performance standard. Endpoint devices covered by the new lead limits include kitchen, bar, and lavatory faucets; drinking fountains; water coolers; residential refrigerator ice makers and water dispensers; and supply stops and endpoint control valves.

Non-leaded red brasses (EnviroBrass C89510 and C89520) and yellow brass (C89550) cast, machine, polish and perform like the leaded brass equivalents.

* Trace amounts up to 0.25%.

Faucets to be certified under NSF Standard 61 must pass a test in which representative products are filled with a pH 8 test water. Samples of the water are withdrawn and analyzed for lead at specified intervals over a 19-day period. Statistical tests are applied to the data to ensure with 90% confidence that 75% of the products examined leach no more than 11 ppb of lead into the water. The 11 ppb limit under NSF Standard 61 is lower than the 15 ppb of the *Lead and Copper Rule* because EPA assumes that as much as 4 ppb of lead could be picked up from other sources. A California Proposition 65 consent judgment has established an even lower limit of 5 ppb lead in California, as determined by the same NSF Standard 61 test protocol.

Why Has Lead Been Traditionally Used in Plumbing Fixtures?

Lead is added to plumbing brasses to improve machinability and ensure pressure tightness. Traditionally, cast red and yellow brasses contain a fine dispersion of lead particles in the microstructure. Without the machinability enhancement made possible by lead, brass plumbing products could be much more expensive due to very high machining costs.

Sand-cast faucets and other plumbing components have traditionally been made from leaded red, semi-red and yellow brasses. The most common plumbing brass, C84400 (also known as 81 Metal or 81-3-7-9) contains nominally 7% lead. The most popular red brass, C83600 (85 Metal, 85-5-5-5), contains nominally 5% lead. Permanent mold and pressure die castings of plumbing components are also commonly made of the leaded yellow brass alloy C85800, which contains nominally 1.5% lead. In contrast to the red brasses, which are moderate-strength, single-phase alpha alloys, alloy C85800 is stronger at both room temperature and at elevated temperatures approaching the solidus, because of the presence of the beta phase in the alpha matrix. These improved mechanical properties are an advantage not only during casting and machining, but also in service. Alloy C85800 has a pleasant light yellow color and can be buffed to a high polish.

Unfortunately, not all products made from leaded brasses can qualify under existing standards. Excessive lead leaching of cast products is usually due to the segregation of lead to internal (i.e., cored) surfaces, where its concentration is far higher than in the casting as a whole. It is difficult for faucets and other devices with large internal surface areas to meet the certification requirements of NSF Standard 61.

EnviroBrass (SeBiLOY)

The idea of using a combination of bismuth and selenium as a substitute for lead was originally conceived by the ASARCO Technical Center, Salt Lake City, Utah. This was pursued by several

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years of research by an industry consortium which included the Copper Development Association Inc. (CDA), the American Foundrymen's Society (AFS), the Brass and Bronze Ingot Manufacturers (BBIM), the Materials Technology Laboratory of CANMET, other foundries and water product producers. The research shows that a combination of bismuth and selenium provides the same beneficial effect on machinability as does lead. In addition, pressure tightness and other casting characteristics of bismuth/selenium brasses were found to be virtually identical to those in conventional leaded alloys.

Optimized red brasses developed by the industry consortium are designated EnviroBrass (SeBiLOY) I and EnviroBrass (SeBiLOY) II. They have been granted UNS numbers C89510 and C89520, respectively, and can be used by all foundries without restriction. EnviroBrass (SeBiLOY) I contains nominally 1% Bi and 0.5% Se; EnviroBrass (SeBiLOY) II contains 2% Bi and 1% Se (see **Table I**).

The name SeBiLOY, which reflects the addition of selenium and bismuth in these alloys is a foundry oriented name. However, in view of the increasing awareness of health and the environment, adoption of the name EnviroBrass should achieve a high degree of acceptance by the specifiers and purchasers of faucets, valves, water meters and other plumbing devices. SeBiLOY will continue to be used and will sometimes appear alone or in parenthesis following the term EnviroBrass.

However, EnviroBrass will be favored in this and subsequent publications. A high-zinc yellow brass, designated EnviroBrass III, was also developed and designated as UNS number 89550.

EnviroBrass III contains up to 1.2% Bi and 0.1% Se, plus 0.5% Al for improved fluidity (see **Table I**). It is suitable for both permanent mold and pressure die castings.

Non-Leaded

No lead is intentionally added to EnviroBrasses. The stated lead content, 0.25% max. for EnviroBrass I, EnviroBrass II, and 0.1% max. for EnviroBrass III, takes into account lead that may be present in recycled materials from which casting alloys are commonly made. Even at maximum permissible levels, however, the lead content of EnviroBrass alloys are sufficiently low enough to pass the stringent lead-leach requirements of NSF Standard 61 for most plumbing devices. If a lower lead content is required, this can be specified when ordering metal from an ingot supplier.

The maximum phosphorous levels noted are usually associated with red brass alloys. Higher levels up to about 0.1% P have been shown to have benefits which include higher ultimate tensile strength and tensile elongation.

Why Bismuth and Selenium?

Bismuth acts very much like lead in many respects. It is lead's neighbor on the Periodic Table of the Elements, and its melting point is 56 C (101 F) lower than that of lead, making its behavior during casting and solidification similar to that of lead. Like lead, bismuth is nearly insoluble in copper and copper alloys. Furthermore, it causes machining chips to break up into small, easily removed particles, similar to lead.

Unlike lead, bismuth is not known to be toxic to humans, except in cases of consumption of immense doses. In fact, its most common use for many years has been as the major ingredient in popular stomach medications.

Selenium enhances the effect of bismuth in red brasses; therefore, it reduces the amount of bismuth needed to achieve the desired improvement in properties. From a health standpoint, selenium, like copper, is one of the essential nutrient elements. Animals, including humans, require a minimum intake of selenium (as well as copper).

Mechanical Properties

The mechanical properties of bismuth/selenium-containing EnviroBrass alloys are functionally equivalent to standard plumbing brasses. Specifically, EnviroBrass I and EnviroBrass II display mechanical properties, including hardness, that are similar to the leaded red brasses although with somewhat

Table I: Compositions of EnviroBrass I, EnviroBrass II and EnviroBrass III Alloys*

Elements	Range or maximum, %		
	EnviroBrass I (C89510)	**EnviroBrass II (C89520)**	**EnviroBrass III (C89550)**
Copper	86.0 - 88.0	85.0 - 87.0	58.0 - 64.0
Tin	4.0 - 6.0	5.0 - 6.0	1.2
Lead	0.25	0.25	0.1
Zinc	4.0 - 6.0	4.0 - 6.0	32.0 - 38.0
Bismuth	0.5 - 1.5**	1.6 - 2.2***	0.6 - 1.2
Selenium	0.35 - 0.75**	0.8 - 1.1***	0.01 - 0.1
Nickel (incl. Cobalt)	1.0	1.0	1.0
Iron	0.2	0.2	0.5
Antimony	0.25	0.25	0.05
Sulfur	0.08	0.08	0.05
Phosphorus	0.05	0.05	0.01
Aluminum	0.005	0.005	0.1 - 0.6
Silicon	0.005	0.005	0.25

* Cu + sum of named elements, 99.5% min. ** Experience favors Bi:Se ≥ 2:1. *** Bi:Se ≥ 2:1

Table II: Typical and Minimum Mechanical Properties of EnviroBrass Alloys				
Alloy	UTS, ksi (MPa)	0.5% YS ksi (MPa)	% Elongation	Hardness, (500 kg) BHN
C83600 (Typical)*	37 (255)	17 (117)	30	60
C84400 (Typical)*	35 (241)	14 (47)	28	55
EnviroBrass I (Typical)*	30 (209)	20 (136)	12	71
EnviroBrass I (Minimum)*	27 (185)	17 (119)	8	66
EnviroBrass II (Typical)*	31 (215)	21 (145)	10	73
EnviroBrass II (Minimum)*	21 (176)	18 (121)	6	68
C85800 (Typical)**	48 (332)	28 (192)	9	60
EnviroBrass III (Typical)**	48 (332)	29 (200)	8	63
EnviroBrass III (Minimum)**	35 (240)	21 (140)	5	60

* Sand Cast **Permanent Mold Cast

lower tensile ductility. In addition, EnviroBrass III is similar in mechanical properties to leaded yellow brass. Ductility of EnviroBrass III is marginally lower than leaded yellow brass. Its strength increases and ductility decreases with increasing zinc and bismuth contents. That means plumbing goods currently made in leaded brasses should not have to be radically redesigned when cast in the EnviroBrass alloys. Mechanical properties listed in **Table II** were derived from standard test bars cast according to ASTM B 208. Properties of traditional leaded casting brasses are included for comparison.

Machinability on a Par with Standard Casting Brasses

All plumbing castings are machined, and machining operations increase manufacturing cost. Traditional leaded plumbing alloys are so highly machinable that cutting fluids are not always needed.

Using Alloy C36000, which as a standard has a machinability rating of 100 based on spindle load requirements for several machining operations (see **Table III**). EnviroBrass II has been assigned a machinability rating of 85. For simple drilling operations, the nominally 2% Bi/1% Se EnviroBrass II alloy actually machines just as fast as free-cutting red brass. EnviroBrass I is marginally more difficult to machine with a machinability rating of 75. EnviroBrass III, with 1.1% Bi, achieves a maximum machinability rating (in drilling) of 97, but the rating decreases as bismuth content decreases. At 0.7% Bi, the machinability rating of EnviroBrass III falls to 75.

Plumbing products cast in EnviroBrass II, can be machined at speeds and feeds very much like those used for leaded red or semi-red brasses. Some adjustment of practice may be required depending on part design and experience. In addition, permanent mold plumbing products in EnviroBrass III can be machined with essentially the same practice as leaded yellow brass but with improved health benefits. The EnviroBrass alloys do not produce any significant lead-bearing airborne particulates when machined dry.

Some machine shops may experience slightly higher tool wear with EnviroBrass I and EnviroBrass II when compared with either C83600 or C84400. Similarly, slightly higher tool wear results may be observed when comparing the machinability of EnviroBrass III with C85800.

The reasons are not yet fully understood. It seems to vary with the type of tooling and machining operation. Measurements show that machined surface quality and finish of EnviroBrass alloys are equal to or better than those produced in traditional leaded brasses.

The EnviroBrass alloys readily accept a high-luster finish by polishing and buffing. The color of EnviroBrass I and EnviroBrass II is nearly identical to that of standard red brass casting alloys. The color of EnviroBrass III is also nearly identical to cast yellow brass, which is a pleasant light yellow. Platability is fully equivalent to C83600, C84400 or C85800. The substitution of bismuth and selenium for lead does not alter the corrosion resistance of brass.

Excellent Casting Properties

The EnviroBrass alloys are not exotic laboratory curiosities. They have been thoroughly tested in commercial foundries and found to have casting properties similar to those associated with leaded red and yellow brasses. Their casting characteristics are summarized in **Table IV**.

EnviroBrass I and EnviroBrass II:

- These are long-freezing alloys, as are conventional red brasses C83600 and C84400, although they have slightly wider freezing ranges. The liquidus temperature for the 2% Bi/1% Se alloy is nearly the same as those of the red brasses. Pouring temperature is, therefore, similar to those of leaded alloys, although foundry experience indicates that about 150 F (83 C) of added superheat is often beneficial. The liquidus temperature for 1% Bi/0.5% Se alloy is about 30 F (17 C) higher, and a correspondingly higher pouring temperature should be observed.
- Like leaded red brasses, EnviroBrass I and EnviroBrass II, also develop a pipe between 3.1% and 3.5% of the casting's volume.

Table III: Machinability Rating of EnviroBrass Alloys	
Alloy	**Machinability Rating (multiple operations)**
C36000 (Free-Cutting Brass)	100
C83600	84
C84400	90
EnviroBrass I (C89510)	**75**
EnviroBrass II (C89520)	**85**
C85800	80
EnviroBrass III* (with 0.7% Bi) (C89550)	**75**
EnviroBrass III* (with 1.1% Bi) (C89550)	**97**

* Permanent Mold Cast

- Contraction ranges from 1.9% to 3.7%.
- Porosity is minimal, about 0.4%.
- Fluidity is identical to that of C84400 at a superheat of 135 F (75 C), but it is somewhat lower than that of red brasses at high superheats.
- The tendency toward hot tearing at abrupt section changes is dramatically reduced compared with leaded red brasses.

EnviroBrass III:

- It has a short-freezing range of 60 F (33 C), similar to that in leaded yellow brass.
- The piping tendency is high.
- The contraction range should be similar to that of leaded yellow brass (not measured).
- The tendency for porosity formation is lower than leaded yellow brass.
- The drossing tendency increases with bismuth content.
- The fluidity is slightly lower than leaded yellow brass in similar casting conditions.
- Compositions with bismuth lower than 1.2% did not show any hot tearing tendency in permanent mold casting. This is an advantage relative to conventional leaded yellow brass (C85800) which is prone to hot tearing within its nominal composition range.
- However, EnviroBrass III exhibits severe hot tearing when superheat exceeds 234 F (130 C).
- Boron is used to grain refine low-tin alloys and zirconium serves the same function in high-tin alloys.
- Grain refinement improves both fluidity and hot tearing resistance.

Health and Environmental Benefits

The EnviroBrass alloys, C89510, C89520 and C89550, were developed to provide the plumbing industry with alloys that will perform as well or better than existing materials while meeting the strict requirements of current federal water quality regulations. The EnviroBrass alloys do all of that very well, but they also offer the following significant environmental, health and safety benefits to the foundryman and plumbing manufacturers:

- The negligible lead content of the EnviroBrass alloys dramatically decreases lead levels in foundry sands and baghouse dust. Foundry worker exposure to airborne lead is sharply lower, and sand reclamation and disposal costs can be lower.
- Airborne lead levels in machine shops are reduced when EnviroBrass alloys are used in place of conventional leaded alloys. This is especially the case when machining is performed dry. Worker lead exposures are reduced accordingly.
- In all cases, special air purification equipment and worker inhalation safeguards may no longer be needed, and a healthier work environmental may be reflected in lower insurance costs.

In Short...

EnviroBrass alloys I (C89510), II (C89520) and III (C89550) offer the foundry industry modern, environmentally friendly alloys that are able to meet the stringent requirements of current water purity regulations. The alloys have good strength, excellent casting characteristics and high machinability. Their extremely low lead content offers the possibility of reduced costs in the foundry as well as the machine shop.

Looking Ahead...

There is neither a royalty nor licensing fee associated with any of the EnviroBrass alloys. EnviroBrass II (C89520) is covered under ASTM specifications B 30 and B 584. At the time of publication of this Alloy Data Sheet, ASTM action on EnviroBrass I and III were in progress. Products, such as plumbing fixtures and faucets, made from EnviroBrass castings, will be marketed to consumers as “made of EnviroBrass.”

For further information regarding EnviroBrass I, C89510, EnviroBrass II, C89520; EnviroBrass III, C89550; and other copper-base casting alloys, contact:

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Table IV: Casting Characteristics of EnviroBrass Alloys

Alloy	Liquidus F (C)	Freezing Range, F (C)	Fluidity, cm at 56 C (100 F) superheat*	Relative Hot Tearing Resistance (lower is better)**	Drossing	Soldering	Brazing	Effect of Section Size on Mechanical Properties
C83600	1850 (1010)	280 (156)	24	15-21	Low	Excellent	Good	Large
C84400	1840 (1004)	291 (161)	30	23-24	Medium	Excellent	Good	Large
EnviroBrass I C89510	**1871 (1021)**	**371 (206)**	**24**	**14**	**Low**	**Excellent**	**Good**	**Small**
EnviroBrass II C89520	**1842 (1005)**	**353 (196)**	**25**	**8**	**Low**	**Excellent**	**Good**	**Small**
C85800	1650 (899)	50 (28)	Medium	Medium	Medium	Good	Good	Medium
EnviroBrass III C89550	**1638 (892)**	**50 (32)**	**Medium**	**Good**	**Medium**	**Good**	**Good**	**Medium**

* Ragone Test, see S. Floreen & D.V. Ragone, “The Fluidity of Some Aluminum Alloys,” AFS Trans. 65, 1957, 391-393.
** Couture & Edwards Test, see A. Couture and J.O. Edwards, “The Hot Tearing of Copper Alloys,” AFS Trans., 74, 1966, 709-721. The two values given represent pouring temperatures of approximately 1170 C (2140 F) and 1225 C (2240 F), respectively.