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.

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 Samples of the water are withdrawn and analyzed for lead at specified intervals over a 19-day period.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
years of research by an industry
correspondence 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.

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>
<thead>
<tr>
<th>Elements</th>
<th>Range or maximum, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>86.0 - 88.0</td>
</tr>
<tr>
<td>Tin</td>
<td>4.0 - 6.0</td>
</tr>
<tr>
<td>Lead</td>
<td>0.25</td>
</tr>
<tr>
<td>Zinc</td>
<td>4.0 - 6.0</td>
</tr>
<tr>
<td>Bismuth</td>
<td>0.5 - 1.5**</td>
</tr>
<tr>
<td>Selenium</td>
<td>0.35 - 0.75**</td>
</tr>
<tr>
<td>Nickel (incl. Cobalt)</td>
<td>1.0</td>
</tr>
<tr>
<td>Iron</td>
<td>0.2</td>
</tr>
<tr>
<td>Antimony</td>
<td>0.25</td>
</tr>
<tr>
<td>Sulfur</td>
<td>0.08</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.05</td>
</tr>
<tr>
<td>Aluminum</td>
<td>0.005</td>
</tr>
<tr>
<td>Silicon</td>
<td>0.005</td>
</tr>
</tbody>
</table>

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

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 materi-
als from which casting alloys are
commonly made. Even at maximum
permmissible 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 machin-
ing 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

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

<table>
<thead>
<tr>
<th>Elements</th>
<th>EnviroBrass I (C89510)</th>
<th>EnviroBrass II (C89520)</th>
<th>EnviroBrass III (C89550)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>86.0 - 88.0</td>
<td>85.0 - 87.0</td>
<td>58.0 - 64.0</td>
</tr>
<tr>
<td>Tin</td>
<td>4.0 - 6.0</td>
<td>5.0 - 6.0</td>
<td>1.2</td>
</tr>
<tr>
<td>Lead</td>
<td>0.25</td>
<td>0.25</td>
<td>0.1</td>
</tr>
<tr>
<td>Zinc</td>
<td>4.0 - 6.0</td>
<td>4.0 - 6.0</td>
<td>32.0 - 38.0</td>
</tr>
<tr>
<td>Bismuth</td>
<td>0.5 - 1.5**</td>
<td>1.6 - 2.2**</td>
<td>0.6 - 1.2</td>
</tr>
<tr>
<td>Selenium</td>
<td>0.35 - 0.75**</td>
<td>0.8 - 1.1***</td>
<td>0.01 - 0.1</td>
</tr>
<tr>
<td>Nickel (incl. Cobalt)</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Iron</td>
<td>0.2</td>
<td>0.2</td>
<td>0.5</td>
</tr>
<tr>
<td>Antimony</td>
<td>0.25</td>
<td>0.25</td>
<td>0.05</td>
</tr>
<tr>
<td>Sulfur</td>
<td>0.08</td>
<td>0.08</td>
<td>0.05</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.05</td>
<td>0.05</td>
<td>0.01</td>
</tr>
<tr>
<td>Aluminum</td>
<td>0.005</td>
<td>0.005</td>
<td>0.1 - 0.6</td>
</tr>
<tr>
<td>Silicon</td>
<td>0.005</td>
<td>0.005</td>
<td>0.25</td>
</tr>
</tbody>
</table>
Properties of traditional leaded casting bars cast according to ASTM B 208. For several machining operations (see Table III), based on spindle load requirements standard has a machinability rating of 100. Cutting fluids are not always needed. Plumbing alloys are so highly machinable that cutting fluids are not always needed. 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 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 brasses, EnviroBrass I and EnviroBrass II, also develop a pipe between 3.1% and 3.5% of the casting’s volume.

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Machinability Rating (multiple operations)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C36000 (Free-Cutting Brass)</td>
<td>100</td>
</tr>
<tr>
<td>C83600</td>
<td>84</td>
</tr>
<tr>
<td>C84400</td>
<td>90</td>
</tr>
<tr>
<td>EnviroBrass I (C89510)</td>
<td>75</td>
</tr>
<tr>
<td>EnviroBrass II (C89520)</td>
<td>85</td>
</tr>
<tr>
<td>C85800</td>
<td>80</td>
</tr>
<tr>
<td>EnviroBrass III* (with 0.7% Bi) (C89550)</td>
<td>75</td>
</tr>
<tr>
<td>EnviroBrass III* (with 1.1% Bi) (C89550)</td>
<td>97</td>
</tr>
</tbody>
</table>

* Permanent Mold Cast
Boron is used to grain refine low-tin brasses. The fluidity is slightly lower than leaded yellow brass. The drossing tendency increases with bismuth content. 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 environment may be reflected in lower insurance costs.

**In Short...**

EnviroBrass alloys I (C89510), II (C89520) and III (C89550) offer the significantly 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:

**Copper Development Association Inc.**
260 Madison Avenue
New York, NY 10016
Tel: 212/251-7200 • Fax: 212/251-7234
Internet: www.copper.org

This publication, based on available data, has been prepared for the information and use of professionals in the castings industry. CDA assumes no responsibility or liability in connection with this publication and makes no warranties of any kind with respect to the information contained herein.

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**Table IV: Casting Characteristics of EnviroBrass Alloys**

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Liquidus F (°C)</th>
<th>Freezing Range, F (°C)</th>
<th>Fluidity, cm at 56 C (100 F) superheat*</th>
<th>Relative Hot Tearing Resistance (lower is better)**</th>
<th>Drossing</th>
<th>Soldering</th>
<th>Brazeing</th>
<th>Effect of Section Size on Mechanical Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>C83600</td>
<td>1850 (1010)</td>
<td>280 (156)</td>
<td>24</td>
<td>Low</td>
<td>Excellent</td>
<td>Good</td>
<td>Large</td>
<td></td>
</tr>
<tr>
<td>C84400</td>
<td>1840 (1004)</td>
<td>291 (161)</td>
<td>30</td>
<td>23-24</td>
<td>Medium</td>
<td>Excellent</td>
<td>Good</td>
<td></td>
</tr>
</tbody>
</table>
| **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                                         |
| C89550       | 1650 (899)     | 50 (28)                | Medium                                   | Medium                                           | Medium   | Medium    | Medium    |                                |
| **EnviroBrass III**
| C89550       | 1638 (892)     | 50 (32)                | Medium                                   | Good                                             | Medium   | Good      | Medium    |                                |


** 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.