MANUFACTURING CHANGES IN COPPER ALLOYS & THEIR PERFORMANCE IN THE FIELD:

A DIVE INTO BRASS, BRONZE, AND DEZINCIFICATION

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Compliance with the updated lead free laws for domestic water led manufacturers to change their copper alloy compositions and machining processes. As a result of these changes, new brass and bronze alloys were introduced to the commercial plumbing market in 2008. Unfortunately, some of these manufacturing changes have resulted in poor field performance when installing valves. The goal of this white paper is to present the changes in the manufacturing of copper alloys and to address dezincification susceptibility as a result of the updated lead free laws.

CHANGES IN MANUFACTURING TO THE COMMERCIAL PLUMBING INDUSTRY

The 2011 revision of the Safe Drinking Water Act reduced the maximum allowable lead content that comes in contact with potable water. The United States Environmental Protection Agency states "Section 1417 of the Safe Drinking Water Act (SDWA) establishes the definition of 'lead free' as a weighted average of 0.25% lead calculated across the wetted surfaces of a pipe, a pipe fitting, plumbing fitting, or fixture and 0.2% lead for solder and flux."[1] This lead free standard revision required full field acceptance by January 2014. Therefore, manufacturers decreased the lead content in their potable water application products. The new lead free industry standards caused manufacturers to make adjustments in their tooling, manufacturing processes, and alloy compositions for brass and bronze products. When developing these new copper alloys to meet the new standard, manufacturers need to prioritize dezincification resistance. In order to maintain a malleable alloy, lead was replaced by other metallic or crystalline elements such as bismuth, silicon, or by increasing two elements to create a binary alloy. The resulting changes in alloy composition affected soldering practices and valve performance in the field.

FIELD PERFORMANCE OF BISMUTH, SILICON, AND BINARY ALLOYS

Bismuth is a metallic element with similar properties to tin and lead. This metal has a similar malleability to lead, making it easy to machine, which is a benefit to the manufacturer. While bismuth maintains better machinability, it is a brittle material and may lead to complications in the field if used in an application where lead is present. For example, when a bismuth based alloy is soldered at higher temperatures in the field, it results in the alloy cracking in the field over time. Over the past decade, manufacturers of bismuth based alloys have adjusted their formula to prevent cracking.

Silicon is a crystalline element with similar properties to carbon and germanium. When silicon is added to zinc and copper alloys, it dissolves into the alloy. As a result, this increases the hardness of the alloy and leads to increased tool wear during the machining process. Silicon has a lower conductivity than bismuth or binary alloys, which leads to a slower heat transfer when soldering or brazing a silicon copper alloy. Installers need to take extra care and attention during installation to guarantee proper heating and soldering procedure to ensure high-quality solder joints.[2] Manufacturers often recommend the application of a special tinning flux to the alloy, allowing for an easier soldering process while installing fittings and valves made from silicon based alloys.

Binary alloys offset the removal of lead with the addition of two metallic elements. The most commonly added metallic elements by manufacturers are zinc and copper. The addition of these metallic components, with corrosion inhibitors, allows valves to solder at the same temperature as before the low lead laws of 2011, eliminating the need to make adjustments to traditional soldering practices.

The addition of zinc can be harmful to a copper alloy in an open loop system due to dezincification susceptibility. However, advancements in manufacturing resulted in brass having the same dezincification resistance as bronze after undergoing a heat treating process. While both brass and bronze are copper based alloys, there are key differences between the two in material composition.

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BRONZE ALLOY ELEMENTS

Bronze is an alloy comprised primarily of copper and tin. Other metals are often added to bronze alloys, such as aluminum, bismuth, manganese, nickel, and zinc. Non-metals also make up the composition of a bronze alloy such as phosphorus or silicon. Bronze alloys typically contain less than 15% zinc in their alloy composition and the principal alloy is neither zinc nor nickel.[3]

BRASS ALLOY ELEMENTS

Brass is an alloy consisting of predominantly copper and zinc[4] and is comprised of two molecular phases, referred to as alpha and beta. The higher zinc content led manufacturers to develop new technologies in manipulating the molecular phases of the brass alloy to help combat dezincification. The process of heating and slowly cooling the brass alloy results in a predominately dezincification resistant alpha phase.

Terminology for identifying a brass valves can be a bit confusing as silicon bronze material technically falls under the subgroup as a high-strength brass.[5] Therefore many engineers may have a "bronze" lead free valve written into their specification when the alloy material is actually a brass alloy. Traditionally, only brass valves are perceived as being susceptible to dezincification. However, bronze valves are also susceptible to dezincification when they are installed in harsh water conditions, such as in bodies of water off the Colorado River, water with a pH above 7, as well as water with a high concentration of chloride.

WHAT IS DEZINCIFICATION?

Dezincification is a process in which zinc is selectively removed from an alloy, leaving behind a porous, copper-rich structure that has little mechanical strength. Manufacturers must design and produce items preventing dezincification susceptibility to their products. A method of fortification of the alloy compound would be a heat treating process. These products are tested to the ISO 6509 standard to ensure they meet proper levels of dezincification resistance.

DEZINCIFICATION TESTING

ISO 6509 is the international testing standard to determine dezincification depth of copper alloys with zinc when exposed to fresh, saline or drinking water. This method of testing is intended for copper alloys with a mass fraction of more than 15% zinc. The results of testing against ISO 6509 reveal the depths to which zinc was removed from an alloy, displaying its susceptibility to dezincification.

CONCLUSION

Lead free laws have changed the way manufacturers create and machine their copper alloys. The adoption of the 2011 Safe Drinking Water Act introduced new copper alloys comprised with the addition of binary elements, bismuth or silicon. With the changes in available brass and bronze alloys, it is important for engineers to review their specifications in detail to ensure the copper alloys in their specification, whether bronze or brass, are not only dezincification resistant but are also not a concern for failure during installation.

References: 1. "Use of Lead Free Pipes, Fittings, Fixtures, Solder and Flux for Drinking Water." EPA, Environmental Protection Agency, 27 Jan. 2020, www.epa.gov/sdwa/use-lead-free-pipes-fittings-fixtures-solder-and-flux-drinking-water. 2. "Recommended Practice for Soldering of No-Lead Copper Alloys." Official Site of Copper Development Association, Inc. (USA), Copper Development Association Inc. , 2014, www.copper.org/. 3. "Copper Casting Alloys Handbook." The Copper Development Association,Copper Development Association Inc., 1994, https://www.copper.org/publications/pub_list/pdf/7014.pdf" 4. The Copper Advantage: A Guide to Working with Copper and Copper Alloys." The Copper Development Association, Copper Development Association Inc., 2010, www.copper.org/publications/pub_list/pdf/a1360.pdf. 5. "The Copper Advantage: A Guide to Working with Copper and Copper Alloys." The Copper Development Association, Copper Development Association Inc., 2010, www.copper.org/publications/pub_list/pdf/a1360.pdf.