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SOLDERING OF NIBCO® LEAD-FREE DEZINCIFICATION RESISTANT COPPER SILICON ALLOYS

NIBCO® "Lead-Free"[1] (LF) Copper Silicon Alloy plumbing valves and fittings are made out of dezincification resistant (DZR) forged C69300 alloy and cast C87850 and C87600 alloys. These alloys are categorized by NIBCO as Performance Bronze™ due to their excellent mechanical properties and superior corrosion resistance.

C69300, C87850 and C87600 alloys are rated "Excellent" in Solder Suitability[2] and can be effectively brazed. This white paper provides answers to some of the general questions about these alloys with specific discussion of soldering.

How LF DZR bronze alloys differ from standard leaded copper alloys?

It is important to recognize that there are some subtle differences between soldering LF DZR alloys and the traditional leaded copper-based alloys. These differences primarily relate to three factors:

1. Corrosion resistance of the LF DZR bronze alloys.
2. The absence of lead in the LF DZR bronze alloys.
3. The heat transfer differences between the LF DZR bronze alloys and leaded copper alloys.

How do these LF DZR bonze differences impact solder performance?

<u>Corrosion resistance of the LF DZR bronze alloys.</u>

Corrosion resistance as applied to brass is primarily related to dezincification and stress corrosion cracking. During dezincification, zinc is selectively removed from the brass in aggressive water service, leaving a porous and weak structure. Stress corrosion cracking occurs when there is a combination of corrosive attack and internal or external stress on a brass part, leading to fracture.

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[1] Lead Free refers to the wetted surface of pipe, fittings and fixtures in potable water systems that have a weighted average lead content ≤ 0.25% per the Safe Drinking Water Act (Sec. 1417) amended 1-4-2011 and other equivalent state regulations.

[2] "Properties of Wrought and Cast Copper Alloys"; Copper Development Association. 2009. Web. 3 Sep. 2009.

NIBCO INC.
WORLD HEADQUARTERS
1516 MIDDLEBURY ST.
ELKHART, IN 46516-4740
USA
PHONE: 574.295.3000
FAX: 574.295.3307
WEB: www.nibco.com

Copper alloys more than 15 % zinc and no elements added as inhibitors are prone to dezincification and stress corrosion cracking. The standardized tests that are used to determine corrosion-resistance are:

- Dezincification Resistance – BS EN ISO 6506: 1995 Corrosion of Metals and Alloys; Determination of dezincification resistance of brass, and
- Stress Corrosion Cracking – ISO 6957:1988 (E) Copper Alloys – Ammonia test for stress corrosion cracking

The NIBCO LF DZR alloys (C87600, C87850 and C69300) have all passed both of these tests. (See NIBCO Resource: Corrosion Testing Results)

<u>The effect on soldering "no lead" LF DZR alloys</u>

The fact that LF DZR alloys contain only a trace amount of lead also has a bearing on solder performance. Traditionally, lead has been added to improve machining. Lead is a relatively soft metal that does not appreciably combine with copper-based alloys. The lead disperses throughout the alloy in discrete pockets which upon machining break into chips and lubricate the cutting tool. A film of surface lead is present along the machined face that aids solder coverage. Since the LF DZR alloys are lead-free, they have no beneficial film of lead covering the solder cup surface.

<u>Differences in thermal conductivity for NIBCO LF DZR alloys and leaded copper alloys</u>

Thermal conductivity, the capacity of a metal to pass heat throughout itself, varies for different alloys, including LF DZR bronze, and standard leaded copper alloys. For comparison, the following thermal conductivity values are given for some common plumbing alloys:

Thermal Conductivity Comparison[3]

- Copper Tube (C 12200) = 196 Btu · ft/(hr·ft2°F) at 68°F
- Leaded Semi-Red Brass (C 84400) = 41.80 Btu · ft/(hr·ft2°F) at 68°F
- Lead-Free Dezincification Bronze (C 87850 & C 69300) = 21.80 Btu · ft/(hr·ft2°F) at 68°F
- Silicon Brass (C 87600) = 16.40 Btu · ft/(hr·ft2°F) at 68°

Simply stated, the higher the thermal conductivity value, the greater the transfer of heat away from the heat affected area during soldering.

During soldering, a flame is focused on a specific area of a joint for a given length of time. The time of exposure of the flame at each point along the joint combined with the thermal conductivity of the joinery piece dictates how evenly the heat will be distributed throughout the joint. A sound joint requires even heat distribution to allow for timely melting, adequate flow and rapid freezing of the solder within the joint.

[3] "Properties of Wrought and Cast Copper Alloys"; Copper Development Association. 2009. Web. 3 Sep. 2009.

What are the important factors to remember when soldering?

Preparation for Soldering

Good joint preparation is a must in order to ensure a sound solder joint is achieved. Such preparation includes thorough cleaning of mating pieces and use of proper fluxing practice.

Care must be taken not to overheat the joint during soldering. LF DZR alloys will turn a distinctive brown color when overheated. Such overheating can burn the flux out of the solder cup gap, leaving the joinery pieces unprotected to surface oxidation. This surface oxidation acts to restrict flow of solder into the joint and sets up a barrier to solder adhesion.

Selection of an appropriate flux

Water-Soluble Flux and Water-Flushable Flux is used in potable water plumbing systems throughout the USA. Water-flushable fluxes must meet the requirements of the American Society for Testing and Materials (ASTM) Standard B 813. As the name implies, any residual water-flushable flux left within a system after soldering is removed by system flushing. Water-soluble fluxes fall within the broad category of water-flushable flux but a more easily removed from a system, dissolving readily into the water.

The common primary active flux ingredients are zinc chloride and ammonium chloride.

- Zinc Chloride – The melting temperature of zinc chloride is higher than that of most commercial solders. As such, zinc chloride, used alone, may remain as an un-melted salt within the joint, potentially corroding and weakening the solder connection. Therefore, zinc chloride is commonly mixed with inorganic chlorides (i.e., ammonium chloride) to lower the melting point of the flux.
- Ammonium Chloride – Ammonium chloride in a water solution is also used in solder flux. Heating this solvent to the point of evaporation vaporizes the ammonium chloride as a white fume without melting, making the flux less effective.
- Zinc and ammonium chlorides are typically used together to create the foundation of a good flux. However, proprietary ingredients are also used in conjunction with these constituents to enhance flux effectiveness.
- Tinning fluxes contain tin and traces of elements such as copper and bismuth which “tin” the surfaces of the joint improving solder coverage and adhesion.

In summary, a flux must be capable of maintaining oxide-free joinery surfaces throughout the soldering process and aid in solder flow, solidification and adhesion within the joint. In order to be sure of the suitability of a particular flux, contact the flux manufacturer for further information.

How is the quality of a solder joint judged?

The quality of a solder joint is the responsibility of the installation professional. Solder, flux, tube and fitting combinations should be tested for compatibility by “pealing” a few test joints to view solder coverage, prior to installation.

There is no standardized method for judging the quality of a solder joint. Still, solder joints are routinely cut and the pealed back, revealing solder coverage, as part of a qualitative assessment of joint quality. Less than 100 % solder coverage is not uncommon for both leaded and lead-free copper alloys. In fact, even copper to copper joints do not necessarily have 100 % coverage. In general, solder coverage of approximately 70% or better is often cited as the benchmark of a good solder joint.

Solder coverage at or near 100 % is arguably more critical for copper to copper joints than for joinery that combines copper tube to DZR bronze or brass. This argument is made because of the greater overall sensitivity of copper to erosion-corrosion attack.

Copper is sensitive to attack from corrosive agents, including residual flux left along waterway surfaces and water-borne contaminants. DZR copper alloys by design resist corrosive attack from both of these sources. In addition, copper, a relatively soft metal when compared to bronze or brass, is also sensitive to erosion damage associated with excessive water flow and/or localized turbulence. DZR copper alloys are appreciably harder than copper and exhibit erosion in copper plumbing systems. Therefore, in copper-to-copper joints, any voids in solder coverage that produce water channeling and turbulence are more likely to result in erosion-corrosion failure than are joints including brass or bronze.

It should be noted that larger diameter components, including copper and leaded copper alloys, are more difficult to solder than are smaller components due to inherent difficulty in providing uniform heat to the joint.

Additional questions

For answers to additional questions regarding this or any other technical issue involving NIBCO® products, please call toll-free:

NIBCO Technical Services at 1-888-446-4226

About the Authors:

Ben Lawrence, a degreed metallurgical engineer for NIBCO INC., has nearly 30 years of experience in metals manufacturing, application and testing. He has contributed to NIBCO over the past 20 years in various positions, including corporate metallurgist and R & D manager. He is a member of AFS and has participated in CDA and ASTM standards development. Due to his extensive knowledge and experience, he is regularly consulted by plant and field engineers, as well as having played a role in furthering the development of “lead-free” alloys. Mr. Lawrence holds a bachelor’s degree in metallurgical engineering from Western Michigan University in Kalamazoo, Michigan.

Keith Yoder brings more than 15 years of experience in manufacturing and engineering to his current role as product engineer for NIBCO INC. During his tenure, Mr. Yoder spent 10 years as a tool and die maker and five years in the company’s R & D lab. Mr. Yoder holds a degree in mechanical engineering from Purdue University in West Lafayette, Indiana.