Vacuum Brazing of Beryllium Copper Components

for the National Ignition Facility

Federal Manufacturing & Technologies

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Abstract

A process for vacuum brazing beryllium copper anode assemblies was required for the Plasma Electrode Pockels Cell System, or PEPC, a component for the National Ignition Facility (NIF). Initial problems with the joint design and wettability of the beryllium copper drove some minor design changes. Brazing was facilitated by plating the joint surface of the beryllium copper rod with silver 0.0006" thick. Individual air

sampling during processing and swipe tests of the furnace interior after brazing revealed no traceable levels of beryllium.

Summary

Plasma Electrode Pockels Cell System, or PEPC, a component for the National Ignition Facility (NIF), required a vacuum brazing process for the beryllium copper anode assemblies. Before development work could commence, an exposure assessment for vacuum brazing beryllium copper was required. Process controls were agreed upon, and the job hazard analysis was updated.

Process development was hindered by the selective wetting of the filler metal (CuSil) to the plain copper contact plate. For reasons unexplained in the scope of this work, the filler would not wet to the beryllium copper. Cleaning of the beryllium copper surfaces did not improve wetting. Beryllium readily reacts with both atmospheric nitrogen and oxygen, creating a surface that prevents wetting of braze filler metals. Wetting was improved by plating the beryllium copper with a 0.0006" thick layer of silver. The resulting braze joint showed a continuous and adherent layer of filler material throughout the gap.

As predicted using vapor pressure calculations, personal air monitors, and swipe tests of the furnace interior, no detectable levels of beryllium were found.

Discussion

Scope and Purpose

The purpose of this work was to develop a process for vacuum brazing a beryllium copper rod to a plain copper contact plate, also referred to as a "flag."

Activity

Equipment

All brazing was performed using the welding department's vacuum furnace. This furnace has a gas bleed system that maintains a partial pressure of argon inside the chamber during heating. This allows alloys with a high vapor pressure, such as copper and beryllium, to be brazed without vaporizing the base alloy and consequently depositing that alloy inside the furnace. In the case of beryllium, the deposited material poses a health hazard.

Filler

The braze filler used in this procedure has an AWS designation of BAg8. It is composed of 72% silver and 28% copper. Tradenames for this alloy include CuSil (Wesgo) and Silvaloy 72 (Behlman-Melcor). It is eutectic in composition and has a single melting point of 1435 F. This alloy is recommended for vacuum brazing of copper-based alloys, including 2% beryllium copper. It is available in paste and wire form. This process used a 0.031-inch diameter wire.

Vapor Pressure of Beryllium

Table 1 summarizes the vapor pressures of beryllium and copper and compares with the pressures and temperatures used in brazing these alloys. The table shows that a 200-millitorr argon pressure is well above the vapor pressures for copper and beryllium within the brazing temperature range. Therefore, by maintaining the argon pressure above the vapor pressures of the beryllium copper components, vaporization is prevented.

Table 1. Vapor Pressure Data

Vapor Pressure (Torr)	Be Temp (° F)	Cu Temp (° F)	
1	2835	1617	
0.1	2511	1417	Gas bleed maintained about this pressure (0.2 torr)
0.01	2241	1257	
0.001	2007	1132	
0.0001	1827	1027	Normal vacuum brazing performed below this pressure
0.00001	1665	937	
0.000001	1530	852	Vacuum brazing performed around this temp (1550° F)
0.0000001	1404	787	
0.00000001	1304	722	

Sources: *References 1 and 2*

Development

Two test runs were conducted using plain copper test pieces with a small piece of the filler wire placed on them. Cycles were run at 1535° F for 10 minutes. The filler exhibited excellent wetting to the copper, even though the copper was tarnished.

Initial Failures

Development continued using actual parts. The initial procedure was to braze by fixturing the parts with the beryllium copper rod supported vertically by the copper contact plate (see Figure 1). A braze ring was placed around the rod adjacent to the copper component. After brazing, the assembly could be inspected by examining the opposite end of the joint for filler.

Figure 1. Original Tooling Configuration

This configuration failed for two reasons. First, the filler was selectively wetting to the copper contact plate. Three things contributed to this:

- The copper flag, with its large surface area and better thermal conductivity, most likely reached the flow temperature before the rod.
- The thermal conductivity of copper is roughly twice that of beryllium copper (391 W/m*K for copper, compared to 118 W/m*K for C17000, Reference 3).
- The joint design did not provide an effective location to place filler.

Second and most significantly, the filler was showing no indication of wetting to the beryllium copper rod. Even after thorough cleaning of the joining surfaces, no evidence of wetting became apparent. Trial runs with a braze pre-form on a beryllium copper rod showed no wetting up to 1650°F.

Variations in time, temperature, and cleaning practice led to the same result. No explanation for this lack of wetting was found in the scope of this project.

New Joint Design

After failures with the original configuration, it was decided that the joint would have to be modified to accommodate the filler material in a way that molten filler would be contained and prevented from selectively wetting to the copper surface. By removing 0.050" from the end of the rod and fixturing the assembly with the contact plate inverted, a cavity was created that provided more volume for filler wire (see Figure 2).

Figure 2. New Tooling/Joint Configuration

Test runs using this configuration resulted in failure to wet any filler to the beryllium copper. Variations in time, temperature, and cleaning practice yielded failure. However, the joint was successful in containing the liquid filler and was ultimately the configuration used in production runs.

Active Filler

TiCuSi paste was experimented with. This is an active filler since the titanium reacts with any oxygen on the joining surfaces, reducing the surface to bare metal. This method was marginally successful.

Parts were brazed using manufacturer's recommendations for time and temperature. The paste was first applied like a glue to the joining surfaces. After sliding the rod into the flag, most filler was pushed out of the joint. However, enough braze remained to join the parts. Metallographic samples of the joint showed wetting, but the filler was distributed unevenly, and it appeared that the joint lacked sufficient filler to completely fill the cavity.

The next method of application utilized the new joint design. Paste was applied like glue to the joining surfaces. In addition, paste was placed inside the cavity created by the new tooling configuration. Like the

first method, some wetting occurred, but it was discontinuous. Despite the abundance of filler material, none of it appeared to flow into the gap.

The poor braze joint combined with the relatively poor conductivity of the TiCuSi filler ($29 \times 10^6 / \text{Ohm} \cdot \text{m}$ for TiCuSi, compared to $49 \times 10^6 / \text{Ohm} \cdot \text{m}$ for the CuSi, Reference 4) eventually led developers to abandon this avenue.

Copper Plating

Copper plating is commonly used to provide a wettable surface (Reference 5). This is used in a variety of copper-based alloys that contain strong oxide films, such as chromium copper and titanium copper. At least 0.0005" plating thickness is recommended.

Initial runs were made using a copper "flash." This is a 0.0001" layer of copper used to provide a conductive surface to which additional plating may be applied. Brazing runs resulted in the flash completely dissolving either into the filler or the beryllium copper with no wetting to the plated surface.

Samples plated with 0.0005" copper and brazed in the new joint design essentially succeeded in creating an effective joint. The braze wet to both joining surfaces and created a continuous layer.

Silver Plating

Silver plating is another way to provide a wettable surface on beryllium alloys (Reference 5). Beryllium forms both a tenacious oxide and a nitride. Recommended practice for both beryllium and beryllium copper is to braze with a freshly machined surface.

Beryllium copper rods were sent for plating at a local plating shop. Following a copper flash, silver plating was applied 0.0006" thick to the joint portion of the rod. Brazing was done using the new joint configuration at 1500° F for 10 minutes. The resulting joint contained a continuous, homogeneous layer with no distinct layers of plating or braze filler.

The silver plate method provided a more attractive joint than the copper and was ultimately used in production runs.

Beryllium Sampling

Individual air sample monitors and swipes of the furnace were analyzed after the first production run to determine the level of exposure to the operator.

Air samples were analyzed for both beryllium and copper. No detectable levels of beryllium were found. However, some copper was detected in some samples. Normally, the copper level would be a good indication of the level of beryllium exposure. In this instance, the operator used a wire brush to clean the inner diameter of the plain copper contact plates. This explained the copper particles in the air sample, and no concern was raised over beryllium exposure.

Swipe samples were taken inside the vacuum furnace before and after brazing in three locations: at eleven o'clock inside the hot zone, at eleven o'clock on the furnace wall, and on the furnace wall inside the door. All samples showed no detectable levels of beryllium.

Accomplishments

A clean and effective process for vacuum brazing beryllium copper anode assemblies for the National Ignition Facility (NIF) was developed as a result of this work. Several lessons were learned. The brazing of beryllium copper materials may be facilitated by plating joint surfaces with copper or silver 0.0005" thick. Vacuum brazing may be performed on beryllium copper components without contamination to the furnace by maintaining a 200-millitorr or greater partial pressure of argon during the brazing cycle.

References

¹*The Characterization of High-Temperature Vapors*, ed. John L. Margrave, John Wiley & Sons, Inc., New York, 1967.

²*Vapor Pressure Data for the Solid and Liquid Elements*, ed. Richard E. Honig & Dean A. Kramer, RCA Review 30, 1969, pp. 285-305.

³*Metals Handbook*, 9th Edition, Vol. 2, ASM International, Metals Park, OH, pp.276, 302.

⁴<http://www.wesgometals.com/physdata.html>

⁵M. Schwartz, *Brazing*, American Society for Metals, Metals Park, OH, 1990, pp.345-347.

Appendix A

Photograph Showing the Tendency of the Filler Material
to Avoid Wetting to the Beryllium Copper Rod

Appendix B

Photographs of the New Joint Design After Brazing With TiCuSi1

Appendix C

Photographs of the Joint Brazed Using the New Joint Configuration With 0.0005" Copper Plating

Appendix D

Photographs of the Joint After Brazing Using New Joint Configuration With 0.0006" Silver Plating