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On Fabrication and Brazing of 120-keV, 65-A, 0.5-Sec Accelerator Grid Assemblies

L. A. Biagi and J. A. Paterson

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Lawrence Berkeley Laboratory University of California/Berkeley

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ON FABRICATION AND BRAZING OF 120-keV, 65-A, 0.5-SEC ACCELERATOR GRID ASSEMBLIES*

L. A. Biagi and J. A. Paterson

Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

The development of high-intensity neutral-beam sources at the Lawrence Berkeley Laboratory has created a technology for fabricating molybdenum grid assemblies of high tolerances. Grid rail shapes were rolled in the case of the source (beam forming) and gradient grids but were machined in the instance of the suppressor and exit grids, as described in another paper being given at this conference.[1]

The design of the grid structures requires brazing of two opposing grid rail holders and rails into alternating mirror-image comb structures (Fig. 1). These two "combs" are then nested to form the required grid assembly (Figs. 2-5). This technique is typical of all grid assemblies.

Treatment of Materials

Once the necessary parts were fabricated, the following process was established for cleaning prior to brazing. All components were thoroughly washed in a detergent solution such as biodegradable "Sparkleen".[2] Thorough rinsing in running hot tap water was followed by rinsing in distilled water, which in turn was followed by rinsing in ethyl alcohol. During the washing phase and throughout the entire assembly process, all handling was done with plastic surgical-type disposable gloves which were changed after each stage of the washing operation.

H_2 Firing Components

After washing, all components were fired in dry H_2 at a temperature of 1100°C for a period of 10 (+2, -0) minutes. Because of the variation in the geometry of the various components, the heating and cooling cycle was controlled to prevent thermal shock. The time for temperature rise from 900°C to 1100°C was kept to a minimum not to exceed 40 minutes in order to avoid recrystallization problems. During firing, components were placed on racks that avoid "shadowing" by overlapping and provide maximum accessibility of the hydrogen gas during the heat cycle.

Brazing Fixtures

Because of the need to maintain the high tolerances of component parts relative to one another during the brazing cycle, brazing fixures were constructed of .375" (.95 cm) thick molybdenum plates ground flat and parallel within .001" (.025 mm). All fixtures were designed with molybdenum dowel pins set in the ground plate to establish the proper relative position of each rail holder. Extension pieces were added to the main fixture plate to support the cooling tube headers and to properly locate them and the cooling tubes relative to the rail holders (Figs. 2-5). The grid rails were self fixtured when placed in the slots machined in the rail holders. In the case of the gradient grid and exit grid assembly, additional clamps were added to keep the shaped grid rails from rotating in their slots (Figs. 4, 5). The suppressor grid assembly also required backup clamps to position the retainers that were placed over the slots and grid rails (Fig. 5).

Cooling tubes were constructed of OFHC and 304 stainless steel. Molybdenum tubes were used initially, but these proved to be very difficult to form and cut without developing cracks. Sleeve couplings were designed to allow for expansion of the copper cooling tubes which typically grow approximately 0.25" (6.35mm) in length during the braze cycle. During the cool down period below 900°C, the braze filler is set and the annealed condition of the copper tube allows it to stretch the required amount without stressing the rail holders. No problems in braze or tube integrity were encountered. One problem did develop however. The copper tube was clamped to the rail holder at three places with a shouldered clamp. This allowed the tube to slip while still putting enough pressure on it to produce a proper braze to the rail holder. Combination of expansion of the cooling tube not being clamped along its entire length and capillary action of the braze filler caused the copper tube to bulge away from the rail holder in the regions where it was was not clamped. This will be rectified on subsequent brazes by employing a clamp along the entire length of the cooling tube.

Mild diffusion bonding was another problem that had to be overcome. The high degree of cleanliness of mating parts which are screwed together under relatively light pressure can produce diffusion bonds in the high temperature dry H_2 atmosphere. To avoid this problem a "stop-off" mixture of 15 gm -325 mesh boron nitride powder to 34 ml glycerin was used to paint screw threads and interfacing surfaces held together all critical parts, i.e., rail holders, cooling tube clamps, stiffeners and fixture components.

The glycerin binder is burned off during the braze cycle, leaving the fine boron nitride powder in place. Great care was exercised when removing screws that had been coated with the separating mixture to avoid seizing of the threads. A drop of ethyl alcohol on the screw threads along with on oscillating motion while backing off the screws worked very well.

Braze Filler and Cycle

Initial brazes were done in vacuo with Ni (26.2%) - Au (73.8%) eutectic.[3] It was determined that although this filler wet and flowed well, brittle intermetallic compounds were formed. Subsequent test brazes were made with OFHC as a filler metal. Tests were conducted both in vacuo and in dry H_2 atmosphere. Results showed excellent wetting, flow and sound joints. However, the combination of clean parts plus extreme wetting and flow in the H_2 atmosphere caused severe "blushing" of the filler material into regions where braze filler could not be tolerated. Specifically, this was in the slots adjacent to the grid rails that required brazing. A suggestion was made that perhaps a wide-temperature range brazing filler alloy might be useful.[4] Based on this suggestion, an alloy of Pd (25%), Cu (21%) and Ag (54%)[3]

*Work done under the auspices of the United States Department of Energy.

was selected. This alloy has a solidus temperature of 900°C and a liquidus temperature of 950°C. The braze temperature was set from 925° to 930°C, and held for three to five minutes. This combination provided good wetting with controlled flow and resulted in very adequate thermal, electrical, and mechanical bonds which were free of "blushing".

Acknowledgements

The authors wish to thank all of those who were instrumental in helping to make this development a success. In particular, we would like to thank Arthur Hollister for his diligence and expertise in machining and assembling the brazing fixtures, Charles Matuk and Gary Koehler for their design contributions, and Arndt Fortlage and Mike Higgins of Pyromet Industries for their cooperation and assistance in hydrogen firing and brazing of components.

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1. J. A. Paterson et al., "The Design and Fabrication of an Ion Accelerator for TFTR-Type Neutral Beam Systems," paper presented at this conference.

2. Reg. Trademark of Fisher Scientific Co., Springfield, N.J. 07081.

3. Western Gold and Platinum Co., Division of GTE Sylvania, Belmont, CA 94002.

4. Private Communication with John Mark of RCA, Lancaster, Pa.

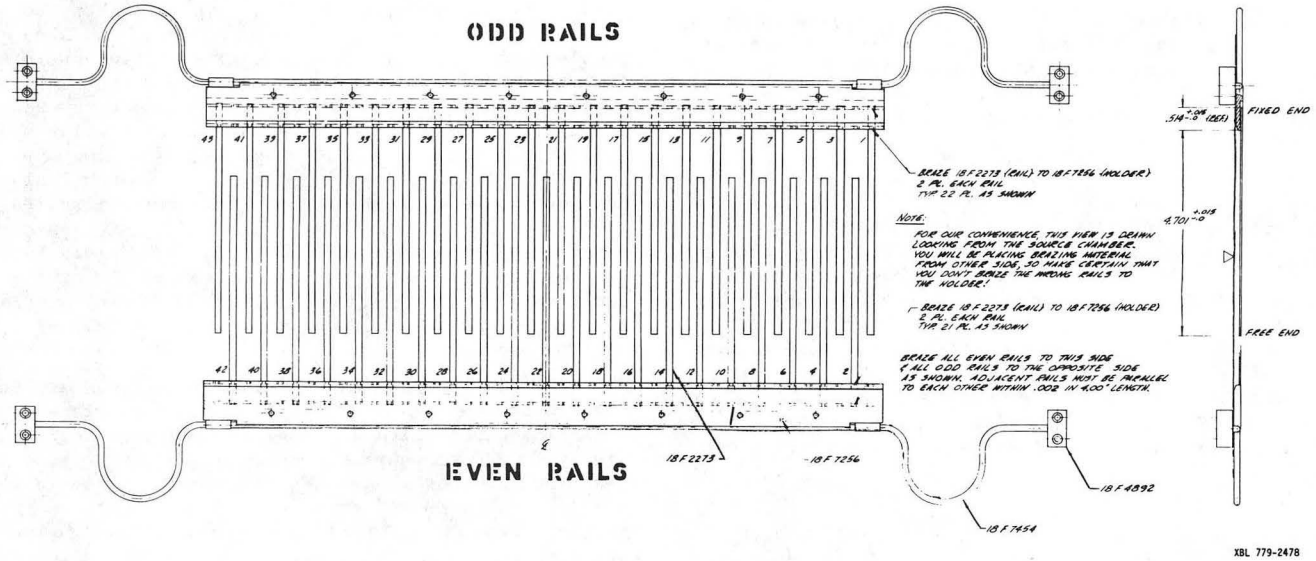

Fig. 1. Exploded view showing grid "comb" structure.

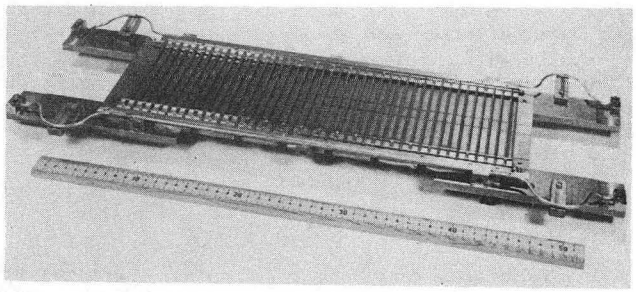

Fig. 2. Source grid brazing fixture assembly.

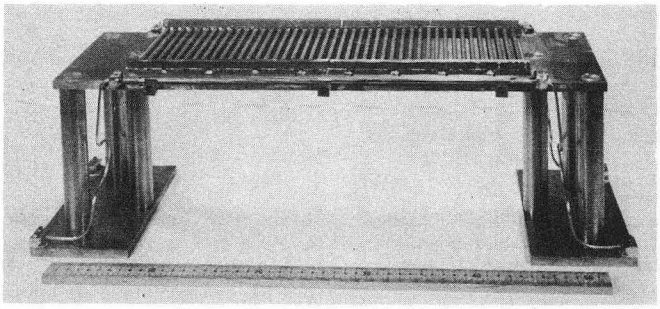

Fig. 4. Suppressor grid brazing fixture assembly.

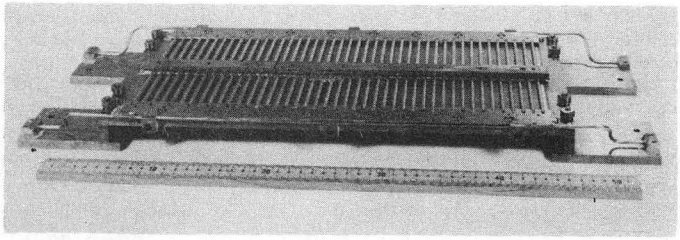

Fig. 3. Gradient grid brazing fixture assembly.

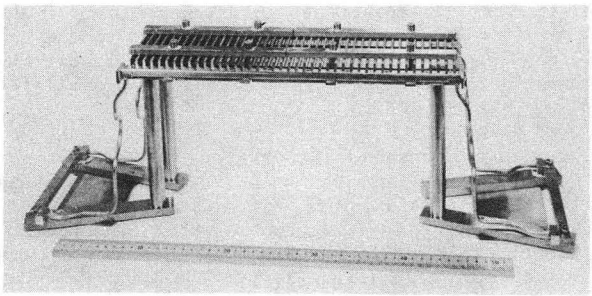

Fig. 5. Exit grid brazing fixture assembly.

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