Title

CERAMIC TO METAL BRAZED RECTANGULAR INSULATOR FOR NEUTRAL BEAM ACCELERATORS

Authors

Paterson, J.A.
Koehler, G.W.
Yee, D.P.

Publication Date

1981-10-01

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

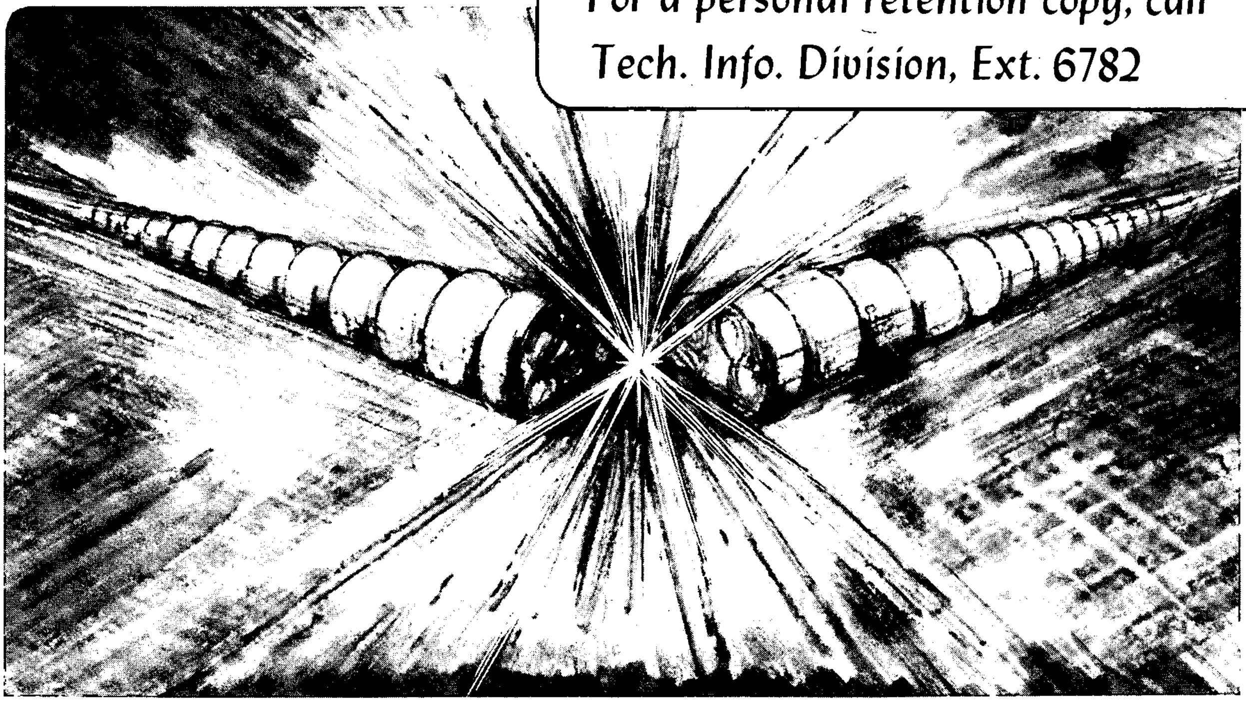
Accelerator & Fusion
Research Division

Presented at the Ninth Symposium on Engineering Problems of Fusion Research, Chicago, IL, October 26-29, 1981

CERAMIC TO METAL BRAZED RECTANGULAR INSULATOR FOR NEUTRAL BEAM ACCELERATORS

J.A. Paterson, G.W. Koehler, and D.P. Yee

October 1981



Prepared for the U.S. Department of Energy under Contract W-7405-ENG-48

DISCLAIMER

LBL-13513

CERAMIC TO METAL BRAZED RECTANGULAR INSULATOR FOR NEUTRAL BEAM ACCELERATORS

J. A. Paterson, G. W. Koehler and D. P. Yee

Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720

Abstract

The details of the manufacturing processes used to fabricate a vacuum tight Alumina to Titanium brazed rectangular insulator structure are presented. The specifics of component cleaning procedures are given and the brazing cycle chosen is described. General precautions and techniques that should be used for similar applications are discussed. The insulator assembly is a weldment of modular brazed sections and is to be the supporting structure for the water cooled molybdenum grids of an Advanced Positive Ion Source.

Introduction

The present generation of tokamak and mirror fusion experiments use neutral beam injection for plasma heating. The ion accelerators of these injection systems use precision assemblies of accelerating electrodes separated by rectangular insulating sections. These insulating sections also form the vacuum wall and the basic mounting structure for supporting the water cooled molybdenum grids described previously.[1] The desirability of having bakeable structures, the original requirement of hard seals for TFTR and the necessity of rectangular geometry resulted in the intensive effort to develop large ceramic to metal brazements.[2] This effort has resulted in the successful fabrication of the vacuum tight, full size accelerator brazement described in this paper. This brazement will be used for further component development work on the long pulse Advanced Positive Ion Source.

Braze Design

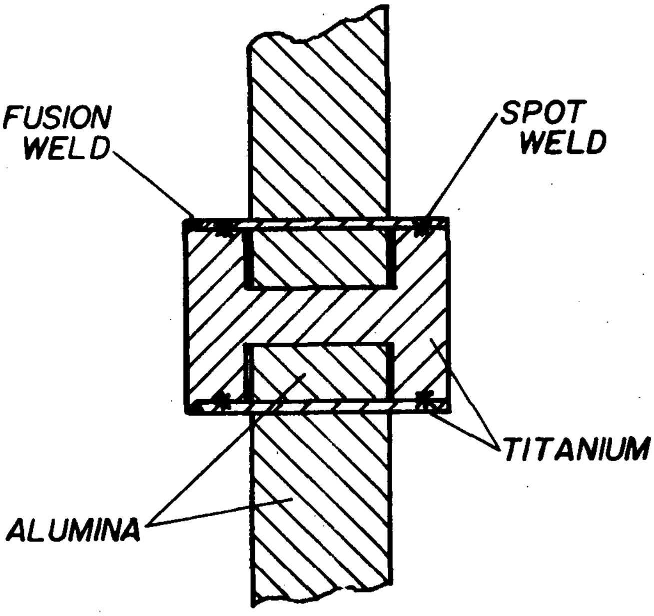
Material

The materials chosen for the assembly were 0.9 mm thick Titanium and 94% Alumina ceramic. The Titanium has an expansion match very near that of the 94% Alumina (10.0 x 10 for Titanium versus 7.7 x 10 C for 94% Alumina) and since any residual stresses left in the brazement would be compressive in nature against the Alumina, a metal having a low yield strength is desireable. Commercially pure Titanium, having a yield strength of 1723 M Pa was chosen while still meeting the other requirements: non-magnetic, vacuum compatible, good welding and mechanical properties, and readily obtainable at reasonable cost.

The braze alloy was selected by two limiting factors: the inability to commercially metallize (sintered moly-manganese) the Alumina due to its large 30 x 60 cm physical size, and the determination not to use an "active" metal Titanium Hydride braze due to its inconsistent performance in past brazing operations where similar materials were used and Helium leak tight braze joints were an absolute requirement. The braze alloy selected was a laminate of Titanium between 2 copper-silver alloy strips; 4.5% Ti, 26.7% Cu, 68.8% Ag. (Trade name: "Ticusil", Western Gold and Platinum Co. Belmont, Calif.) A .10 mm thickness was chosen since the ceramics were ground flat to 50% of this thickness, i.e., .05 mm. The alloy has a Liquidus of 850^{o}C, Solidus of 830^{o}C, and it readily wets ceramics, graphite, and most metals.

Braze Detail

The design approach to building the insulator assembly was based on a modular concept where the entire assembly would consist of three smaller modules, or subsections. Each sub-section could be assembled and brazed, Helium leak tested, and installed by conventional welding techniques into the structural assembly when completed. A typical braze joint section is shown in Fig. 1, where a brazed module is placed in and welded to a structural flange. The thin Alumina section shown is a backing ring necessary to balance the compressive stresses across the brazed joint, and must be accomodated by the structural member. An actual module is shown in Fig. 2, it being one of three modules which comprise the Alumina section of the assembly. It was thought that this modular approach would minimize the risk of brazing so many sections at once, as one subassembly could be brazed at a time, and a revision of the brazing process could be implemented if necessary



XBL 791-7822

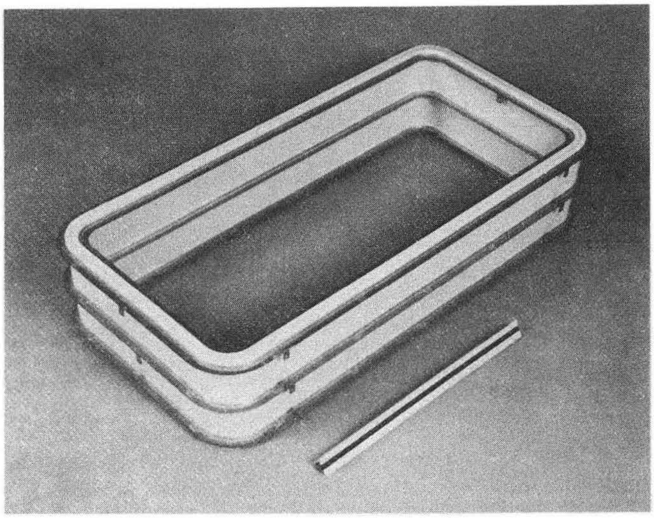
Fig. 1. Titanium-Alumina Joint Section

This work was supported by the Director, Office of Energy Research, Office of Fusion Energy, Development and Technology Division, of the U.S. Department of Energy under Contract No. W-7405-ENG-48.

for the second and third modules. This was not necessary and all joints including the backing rings were vacuum tight.

Test Brazes

Two test brazes were performed duplicating the proposed temperature cycle, materials, joint geometry, and the joint loading pressure; both were Helium leak tight. One sample was subsequently sectioned and elemental distribution was observed across the joint interface using a scanning electron microscope. The analysis showed that the predominant Cu-Ag phase to be evenly distributed between the Titanium and the Alumina substrates while forming ductile layers at the center of the joint. Destructive tests showed excellent adhesion of the Alumina to the substrate, with failures initiated in the bulk Alumina body, leaving material on the Titanium substrate; no test values were recorded.



CBB 8012-14555

Fig. 2. Brazed Modular Subsection

Braze Procedure

Cleaning, Preparation

In any vacuum brazing operation, absolute cleanliness of all materials in an important preliminary step. The procedures for preparing these materials are documented here:

Alumina:

1. Dye check, clean with Acetone.
2. Ultrasonic rinse, Ethyl Alcohol.
3. Fire in air, 1000° C 1 hr. at temperature.

Braze Alloy:

1. Lightly sand with 400 grit Aluminum Oxide paper to remove surface oxides.
2. Ultrasonic rinse Ethyl Alcohol.
3. Spray rinse, using Ethyl Alcohol and dry Nitrogen.

Titanium:

1. Vapor degrease, perchlorethylene.
2. Rinse, hot de-ionized water.
3. Etch as per the following at 60° C in polypropylene container: 10% HNo_3, 10% HF, 80% H_2O, distilled.
4. Etch for 30 sec-1 min. maximum; violent surface attack occurs immediately, coupled with rapid stock removal. Use adequate protective clothing and ventilation.
5. Using stainless steel tongs, immediate flowing water rinse followed by immediate rinse in boiling distilled water, 10-15 min.
6. Repeat, using an alternate container.
7. Final spray rinse, Ethyl Alcohol and dry Nitrogen.
8. Handle only with plastic gloves at this point; surface oxides start forming on Titanium almost immediately after etching, so brazing should take place as soon as possible after the etching process.

Assembly

At assembly, the pre-cleaned braze foil was spot welded into place onto the Titanium substrate before the Alumina was placed to ensure precise positioning of the foil segments. Past experience had shown that optimum abutment of the segments was necessary. Helium leaks had been coincident at poorly aligned segments in prior brazes. The foil segments were cut with a sacrificial tab at each end, whose only function was a location for spot welding and positioning in an area outside of the mating surfaces where wetting was to take place. When installing the Alumina onto the Titanium-foil substrate, longitudinal alignment was aided by the use of spot welded clips along the edge of the Titanium substrate. These had threaded holes to accomodate alignment screws, and, when bearing against the Alumina, made the parts self-fixturing. These clips were removed after the brazing was completed. The aligned assembly was loaded with a 13.3 N loading weight to insure intimate contact between the mated surfaces. Care was taken to thermally isolate this mass from the braze interface using ceramic standoffs. This also permits the pumping of gases from the interior of the assembly.

Braze Cycle

The asembly was then placed onto Alumina standoffs which were positioned around the hearth plate of the vacuum oven. In order to purge the oven of any organic contaminants, it was pre-fired at 1000° C for 1 hour at temperature prior to installation of the assembled parts. The heat cycle is as follows:

1. Maximum heating rate not to exceed 3° C/min. to 760° C. Minimum vacuum to be 5 x 10^{-5} torr.
2. Temperature hold at 760° C 30 min.
3. Rapid heat to 875° C (the brazing temperature) time to reach temperature not to exceed 10 min. The 875° temperature was chosen through the experience of several trial brazes. Although 25° C above the Liquidus, it was found that better wetting occurs at this temperature than at

actual Liquidus temperature. This may in part be due to the irregular geometry of the assembly, in that some areas may not have seen equal temperatures within the vacuum oven. The assembly was brought to the average temperature reading of 8 thermocouples placed about the assembly. Other large brazed assemblies have been fabricated at LBL since this work was done, using the same temperatures and the resultant wetting has been the same.[3]

4. Maintain 875° C for 15 min; thereafter, cooling time from 875° C to 800° C not to exceed 10 minutes.

5. Cool from 800° C at 3° C/min. to 550° C. Temperature hold at 550° C for 1 hour minimum. (This is the stress relief temperature of Titanium).

6. Cool from 550° C to room temperature at 3° C/minute.

Results

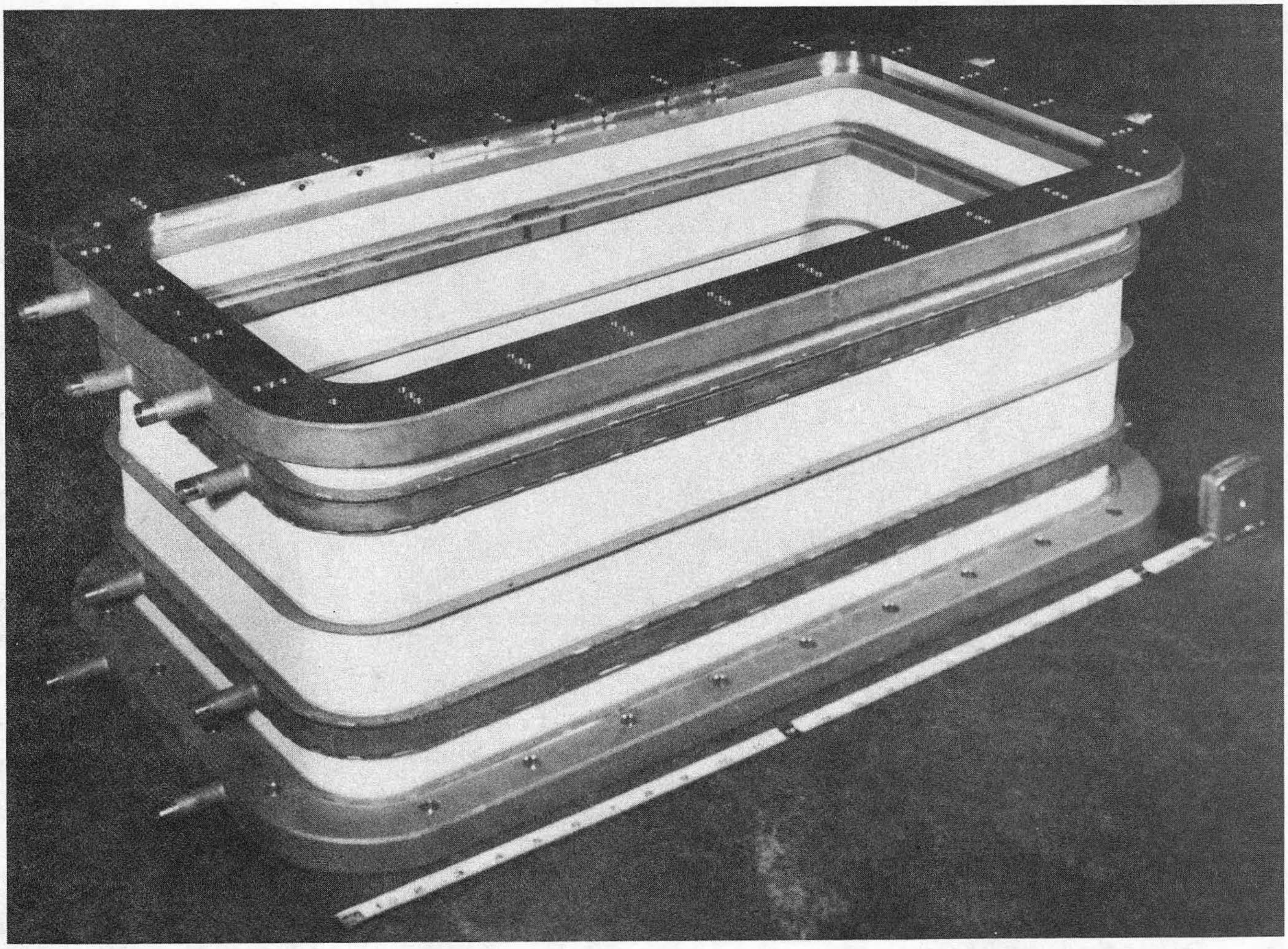
The large irregular shaped ceramic assembly was vacuum brazed without any metallizing or active metal process using a pre-placed braze filler. All 14 joints were Helium leak tight. The equivalent total joint length is 25 meters by 14 mm in width. The protracted temperature hold during the cooldown cycle gave the Titanium a thorough stress relief, and, aided by the Alumina backup ring, the stress buildup was kept to a minimum across the joint interface. The modular approach allowed for pre-brazed subsections to be placed into mating structural Titanium flanges and a subsequent glove-box weld to integrate the assembly. Fig. 3 shows the assembled structure.

References

1. J. A. Paterson, G. W. Koehler, R. P. Wells, and L. A. Biagi, "The Mechanical Design and Fabrication of an Convectively Cooled Ion Accelerator for Continuously Operating Neutral Beam Systems", Proceeding Engineering problems of Fusion Research, San Francisco, 1979.

2. J. A. Paterson, G. W. Koehler and T. J. Duffy, "The Development of Large Rectangular Ceramic Insulators for Ion Accelerators for the Neutral Beam Program", Journal of Nuclear Materials 85 and 86, 421-425, 1979.

3. D. Vanacek, Lawrence Berkeley Laboratory, Private communication.



CBB 817-6690

Fig. 3. Final Assembly With All Modules Welded Into Place

TECHNICAL INFORMATION DEPARTMENT
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720