Title

THE DESIGN AND FABRICATION OF A LARGE MAGNETIC CUSP TYPE OF PLASMA GENERATOR FOR THE PRODUCTION OF NEGATIVE IONS

Author

Biagi, L.A.

Publication Date

1981-10-01

Peer reviewed

LBL--12394

DE82 004027

MASTER

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

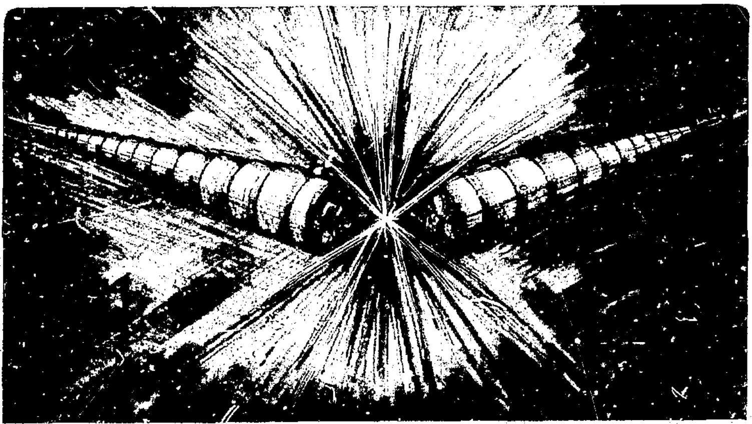
Accelerator & Fusion Research Division

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

THE DESIGN AND FABRICATION OF A LARGE MAGNETIC CUSP TYPE OF PLASMA GENERATOR FOR THE PRODUCTION OF NEGATIVE IONS

L.A. Biagi, K.W. Ehlers, K.N. Leung, C.A. Matuk, S.D. Moon, and J.A. Paterson

October 1981



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

LBL-12394

THE DESIGN AND FABRICATION OF A LARGE MAGNETIC CUSP TYPE OF PLASMA GENERATOR FOR THE PRODUCTION OF NEGATIVE IONS*

L.A. Biagi, K.W. Ehlers, K.N. Leung, C.A. Matuk, S.O. Moon and J.A. Paterson
Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720

SUMMARY

The design and fabrication techniques for a large "magnetic bucket" type of plasma source designed for the production of negative ions by surface conversion are described. These include the design of a converter structure, cesium oven and injector, variable aperture electrode, accelerator section as well as the features of the magnetic cusp geometry employed.

INTRODUCTION

Increased interest in the production of negative ions has resulted in the dedication of a test stand facility for research and development of a near term goal of 1 ampere of H^- or D^- at UC LBL. In this paper, we describe the design and fabrication of the plasma generator to be used on this test stand (Figure. 1).

CBB 814-3550

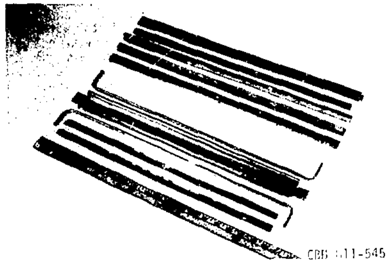
Figure 1

DESIGN AND FABRICATION TECHNIQUES

The design of this plasma source was developed from experience gained with a large rectangular source built for TFTR.[1] Although constraints placed on this design were not as severe as those of the TFTR 10 cm x 40 cm model, the configuration and thickness of the vacuum wall required stiffening members. Heat removal due to arc power impinging on the wall at the magnetic cusps was another consideration. These two problems were solved by the implementation of water cooled cooper heat sinks reinforced by stainless bars. These heat sinks were brazed as a sub-assembly using a paladium 25, copper 21, silver 54, braze filler alloy (Palcusil 25).[2]

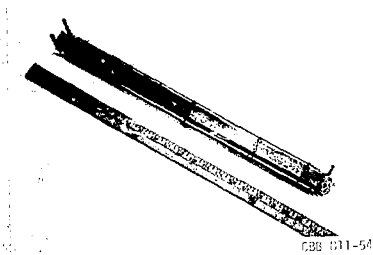
*This work was supported by the Director, Office of Energy Research, Office of Fusion Energy, Development and Technology Division of the U.S. Department of Energy under Contract No. W-7405-ENG-48.

Braze filler 0.05 mm (0.002") thick was used to braze the 304 stainless steel bars to the OFHC copper heat sinks. 6.3 mm dia. x 0.081 mm wall (0.25" x 0.032") OFHC copper tubes were brazed to the heat sinks at the same time with the same braze filler alloys (Figures 2 - 3). Samarium cobalt or ceramic magnets are then fitted into these sub-assemblies.



CBB 811-545

Figure 2



CBB 811-549

Figure 3

MAGNET COOLING

The following assumptions were made regarding magnet cooling. (1) The only temperature gradients considered were those along thin members, i.e., the stainless steel cusp wall and copper heat sink crosssection. (2) The copper heat sinks brazed to the stainless steel cusp wall were conservatively assumed to be at the same temperature as the stainless steel wall. (3) The line source heat load at the cusp lines (Point P) was conservatively assumed to be 6 W/cm. (4) Radiation load on cusp wall assumed to be 3 W/cm^2. (5) Natural convection from surfaces was neglected. (Figure 4)

The following determinations were calculated. Ignoring cooling between magnets, the steady state temperature profile between Point "P" and Point "X" is 9.2 °C. (Figure 5)

MSW

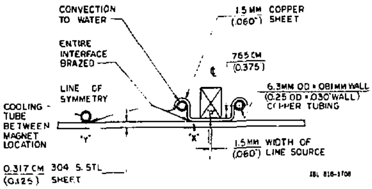


Figure 4

The temperature drop from Point "X" to water cooling line is 22 °C. The temperature drop across the wall of the water cooling line to water in the line (based on a water temperature of 20 °C) is 19.2 °C. The maximum magnet temperature under these conditions would be 99 °C. Maximum wall temperature between magnets with intermediate cooling water off would be 277 °C. Temperatures with intermediate cooling water on were calculated to be as shown.

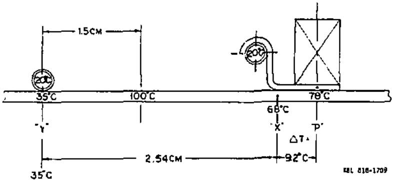


Figure 5

When the area between magnets is cooled during operation, cesium vapor condenses on the cooled surfaces. Cooling can be controlled to allow the condensed cesium to be vaporized.

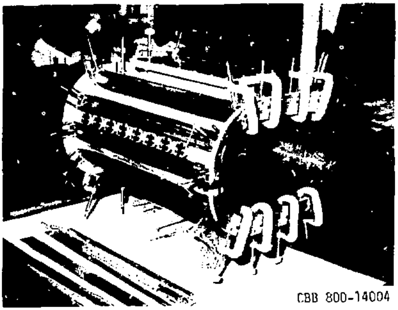
The cusp wall was made from 3.17 mm (0.125") thick type 304 stainless steel formed into two semicircular halves heliarc welded together. End flanges were then welded to complete the outer housing.

Prior to brazing, flange ports for filament feedthrough and converter assemblies were welded to the outer housing. The entire outer surface of the housing, ports, and flanges were then copper plated 7 - 12 microns thick (0.0002" - 0.0003"). This was done to provide a surface which could be brazed in a hydrogen atmosphere at a temperature below that at which the heat sink sub-assemblies were previously brazed.

The curvature and non-uniformity of the outer surface of this type of structure necessitated machining of the areas where the reinforced heat sinks were to be brazed (Figure 6). This also ensured maximum heat transfer into the heat sinks. The fixturing of the heat sinks to the outer housing was accomplished by first placing a 2.5 cm (1.0") x 53.5 cm (21.0") long x 0.05 mm (0.002") thick Cusil[2] copper-silver eutectic braze filler alloy foil in between the outer housing and the heat sink. These parts were all clamped into position using "C" clamps (Figure 7) and then tack welded at the interface of the reinforcing bars and the housing end flanges. The clamps were removed before brazing and three bands were symmetrically located around the entire assembly to provide clamping pressure during brazing (Figure 8).

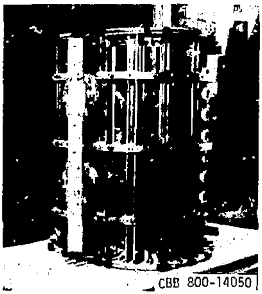
CBB 800-14010

Figure 6



CBB 800-14004

Figure 7

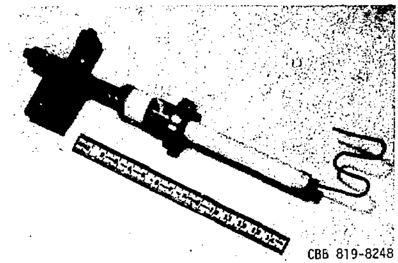


CBB 800-14050

Figure 8

FILAMENT FEEDTHROUGH ASSEMBLIES

The filaments used in this plasma generator are formed from type CS 218[3] tungsten rod 1.5 mm (0.06") diameter x 15 cm (6.0") long. The feedthrough assemblies utilize a coaxial "squirt tube" type of cooling to provide high current capability (125 A) (Figure 9). A molybdenum split collet type chuck capable of accomodating two filaments is stud mounted to the filament feedthrough assembly. An insulating tube of grade HP boron nitride[4] provides high temperature insulation from the plasma. The inner end of this tube utilizes a series of 0.254 mm (0.010") wide x 0.038 mm (0.015") deep grooves to prevent shorts due to tungsten evaporated from the filaments.



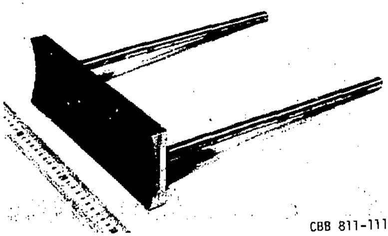
CBB 819-8248

Figure 9

CONVERTER STRUCTURE

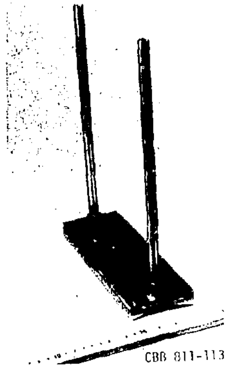
The converter structure is used to produce and focus negative ions. It is a water cooled assembly consisting of a curved OFHC copper substrate to which a 0.125 mm (0.005") molybdenum foil is brazed using Palcusil 25[2] braze filler alloy (Figure 10). Water cooling is fed to a slotted type 304 stainless plate through two 1.27 cm (0.5") O.D. x 0.8 mm (0.035") wall type 304 stainless steel tubes.

This plate is then mounted to the copper substrate by means of twenty 4 - 40 socket head cap screws and sealed with an "O" ring (Figure 11). Insulation from the plasma is provided by a boron nitride enclosure around the base and sides of the converter structure. Boron nitride tubes and plates insulate the support stems from the plasma. Water cooling is fed through the support stems which also provide the termination for feeding power to the converter.



CBB 811-111

Figure 10

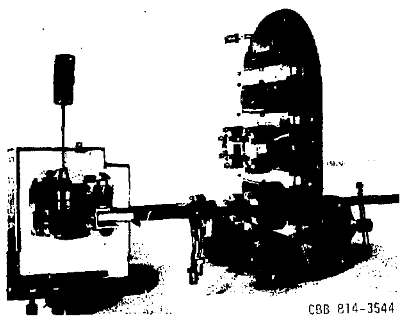


CBB 811-113

Figure 11

CESIUM OVEN AND INJECTOR

Cesium metal is placed in the stainless steel oven housing through a removable metal sealed flange. A stainless steel sheathed thermocouple is also fed through this flange. The oven is heated by means of four 750 W quartz lamps surrounded by glass rock insulation in a clam shell type structure. This unit with control capability of over 300 °C ± 1 °C was purchased commercially.[5] The oven assembly is connected to the injector by means of a compression type fitting on a metal sealed valve which provides control of cesium vapor flow (Figure 12).



CBB 814-3544

Figure 12

The oven and injector assembly are electrically isolated from the bucket structure. The injector is a single ended coaxial resistance heated tube that provides uniform heat distribution over its entire length. It employs a 6.3 mm (0.25") O.D. x 0.015 mm (0.006") wall x 53 cm (20.86") overall length inner tube. A 6.3 mm (0.25") O.D. x 0.015 mm (0.006") wall x 7.62 cm (3.00") long bellows is brazed in series with the inner tube at a point 12 mm from the opening to accomodate thermal expansion differences. Electrical isolation between the inner and outer tube provides a single ended feed for heating power. The 300 °C operating temperature necessitates water cooling of the viton "O" ring seals on the flanges of the feedthrough insulators. The power required for resistance heating the injector tube to 300 °C is 5.0 V at 20 A. The slotted exit opening on the inner injector tube is fitted with a flanged skirt that helps to focus the cesium vapor along the converter surface. The control valve is closed and the injector tube assembly is allowed to run hot to vaporize any cesium present before the source is let up to atmosphere.

VARIABLE APERTURE ELECTRODE

A variable aperture provides a shutter type mechanism which functions primarily to keep electrons from getting into the beam and to determine beam width. It is adjusted manually through an "O" ring sealed gland. The aperture is constructed of 3.12 mm (0.125") thick molybdenum plates that are water cooled. Cooling lines are fitted with stainless steel bellows sections that allow articulation of the aperture (Figure 13).

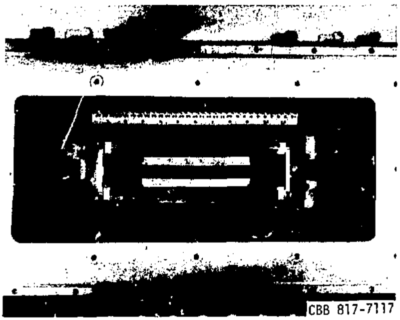


Figure 13

ACCELERATOR SECTION

The accelerator section is comprised of an aperture grid and focus grid (Figure 14), and a suppressor grid, exit grid combination (Figure 15). All grids are water cooled, with components brazed in a hydrogen furnace. The focus grid has the capability of being electrostatically biased to provide additional focusing of both the width and length of the beam. The focus grid and suppressor grid are supported from a cast epoxy insulator which electrically isolates the source from the vacuum system to a level of 40 kV.

ACKNOWLEDGEMENTS

The authors wish to thank all those who helped to produce this device, in particular, Richard Archer, Gordon Cave, Robert Reynolds, David Bishop and Arthur Hollister for their fabrication expertise; the various departments of the LBL mechanical shops for their contributions, and Pyromet Industries for their work in brazing. We would also like to express our appreciation of the diligent detail drawing done by Curtis Cummings and the work done by Carolyn Wong in the preparation of this paper.

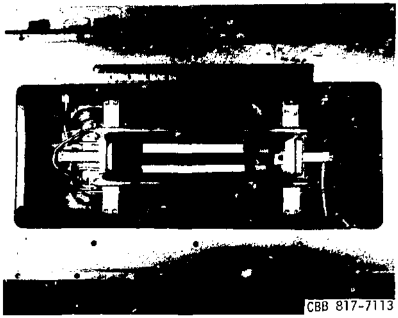


Figure 14

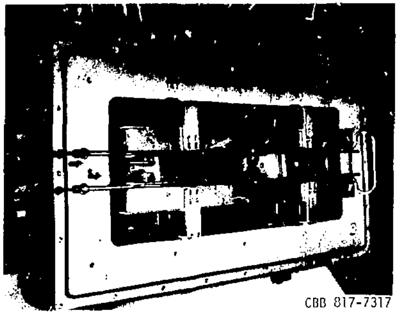


Figure 15

REFERENCES

1. L.A. Biagi, et al., "The Design of a Large Rectangular Magnetic Cusp Plasma Source for High Intensity Neutral Beam Injectors", Proceedings of the 8th Symposium on Engineering Problems of Fusion Research, San Francisco, CA, Nov., 1979, IEEE Pub. No. 79CH1441-5 NPS, Vol. II.

2. Western Gold and Platinum Co., Belmont, CA.

3. General Electric Co., San Jose, CA.

4. Carborundum Co., Electronic Products Division., Santa Clara, CA.

5. Eckoray Engineering, Carmichael, CA.