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### **Title**

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### **Publication Date**

1979-11-01

Peer reviewed

CONF-791102--134



# Lawrence Berkeley Laboratory

UNIVERSITY OF CALIFORNIA

## Accelerator & Fusion Research Division

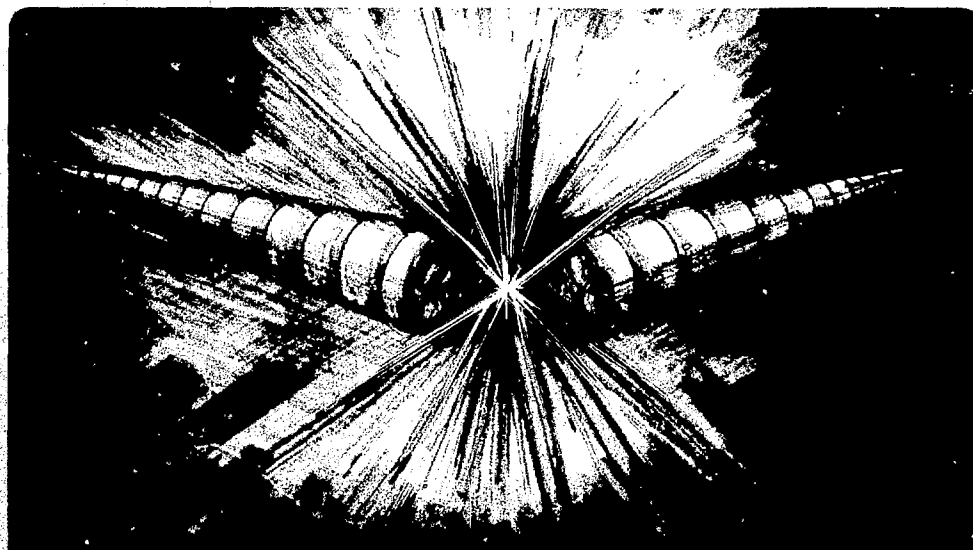
**MASTER**

Presented at IEEE 8th Symposium on Engineering Problems of Fusion Research, San Francisco, CA, November 13-16, 1979; also to be published in the Proceedings of the IEEE 8th Symposium

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November 1979



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LBL-10085

THE DESIGN AND FABRICATION OF A LARGE RECTANGULAR MAGNETIC CUSP  
PLASMA SOURCE FOR HIGH INTENSITY NEUTRAL BEAM INJECTORS\*

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Summary

The design and fabrication techniques for a large, rectangular "magnetic bucket" plasma source are described. This source is compatible with the accelerator structures for the TFTR and DIII neutral-beam systems.

Introduction

The plasma generator for the 120-kV, 65-A, 0.5-sec ion source system<sup>1,2</sup> developed for neutral-beam injection into Princeton's TFTR was an LBL field-free source.<sup>2</sup> To increase the atomic ion content of the accelerated beam, it was decided that the plasma generator should be replaced with a larger-volume "magnetic bucket" plasma source,<sup>3</sup> in which the walls are lined with permanent magnets in a cusp arrangement. The constraints on the design of this source

were: a) it had to fit the existing accelerator structure<sup>1</sup>, b) the (vacuum) walls had to support a differential pressure of two atmospheres, since the ion source system is surrounded by two atmospheres of SF<sub>6</sub> gas for high-voltage insulation, and c) the 23-cm-deep chamber had to be flanged so that an additional 23-cm section could be added to form a 46-cm-deep "bucket." In this paper we describe the design and fabrication techniques for this plasma generator (Fig. 1).

Design and Fabrication Technique

The permanent magnets are mounted outside of the vacuum, and it is desirable to have a relatively thin vacuum wall to achieve a high field strength on the vacuum side of the wall. Our design employs a vacuum wall of 3.17-mm (0.125") thickness, type 321 stainless steel (Fig. 2). This material was selected because of its low residual magnetic properties after aging.

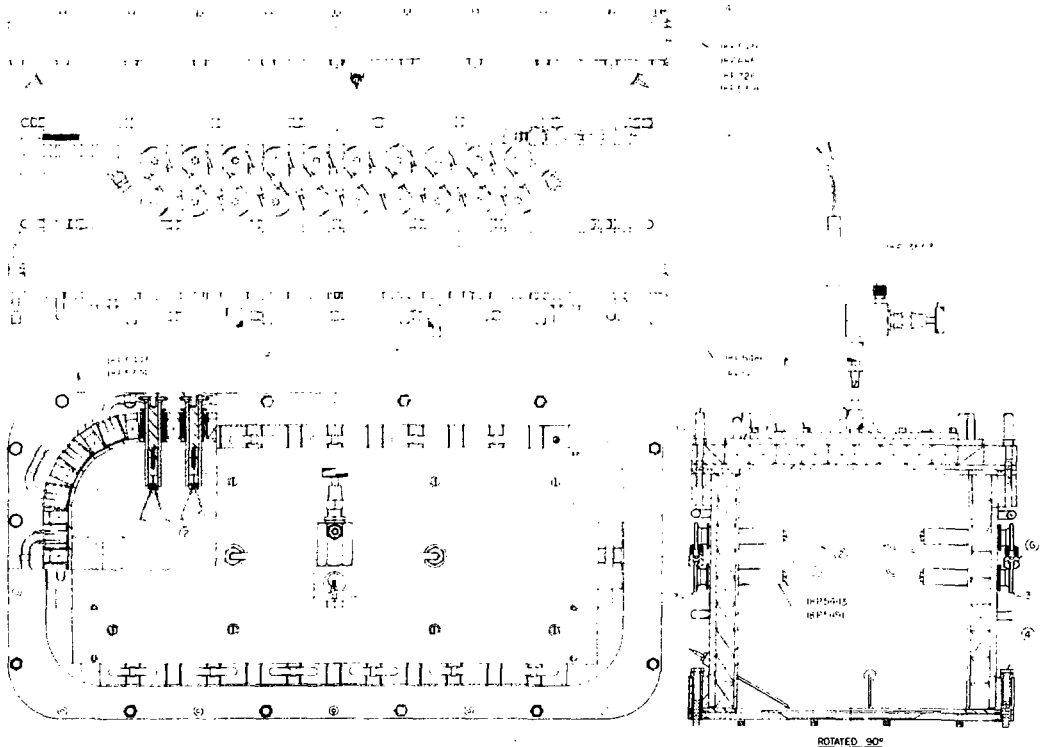


Figure 1. Schematic of Plasma Source

\*Work supported by U.S. Department of Energy, Office of Fusion Energy, under Contract W-7405-ENG-48.

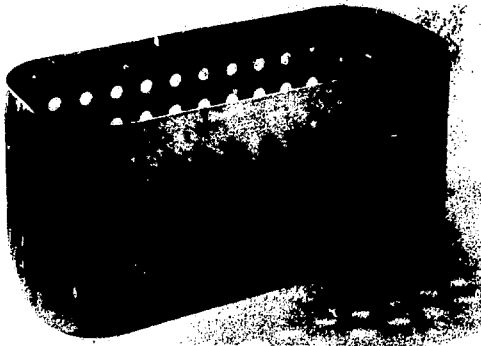


Figure 2. Vacuum wall of chamber.

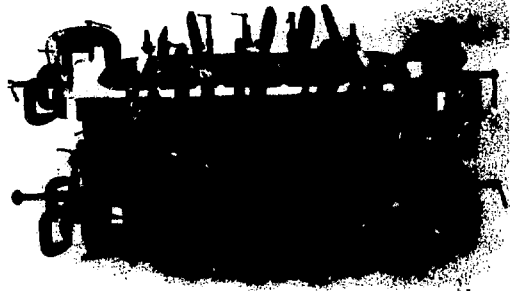


Figure 4. "Strong-back" stiffeners at flange faces of vacuum wall.

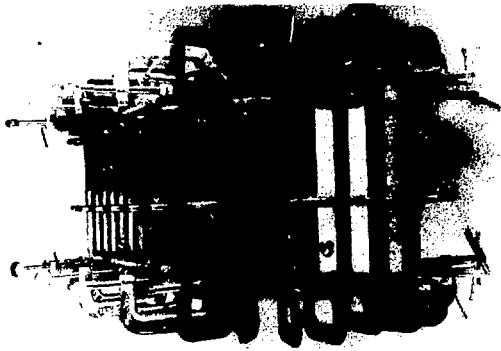


Figure 3. Vacuum wall with rectangular tubes for cooling and reinforcement.



Figure 5. End plate showing "strong-back" flange and cooling/reinforcing tubes.

Type 304 stainless steel tubes 2.54-cm (1.0") square x 1.6-mm (.065") wall (Fig. 3), brazed to the vacuum wall, provide reinforcement of the flat surfaces. These square tubes are further used to supply water cooling to the vacuum wall to remove heat developed by arc power impinging at the foci of the magnetic cusps. The deflecting loads being generated require additional reinforcement which is provided by the use of "strong-back" stiffeners at the flange faces of both ends of the vacuum wall (Fig. 4) and the end plate (Fig. 5).

The 36 cooling and reinforcing tubes are spaced to provide support for the 22.8-cm-long (9") magnet strips, made up of groups of three 2.54-cm x 1.27-cm x 1.9-cm (1.00" x 0.5" x 0.75") magnets glued together with cyanoacrylic cement. The magnets are polarized along the 1.27-cm (0.75") dimension. The permanent magnets are of the high strength Samarium-cobalt type with a residual induction,  $B_r$ , of 8200 gauss, and a coercive force,  $H_c$ , of 7300 oersteds. A backing piece of 9.64-cm x .127-cm x 16-cm (0.25" x 0.5" x 6.25") cold rolled steel is used to facilitate installation and clamping of the magnet strips. This arrangement produces fields at the cusps of approximately 3200 gauss.

The square reinforcing and cooling tubes are fabricated as a subassembly in the following manner. Tubes are cut and machined to length, and holes for water fittings, probes, gas feed, and filament feed-through tubes as required, are machined. The assembly of the tubes to the vacuum wall necessitates close tolerance on the size and location of the feed-through, probe and gas feed holes as well as the overall length of the tubes. "Squirt" tubes are employed to reduce dead space in the cooling tubes. Seven configurations of reinforcing/cooling tubes are employed. (Fig. 6). 1.9-cm-diam x 0.81-mm wall (0.75" x .032") stainless steel feed-through tubes are welded into the square sections along with the "squirt tubes," probe fittings, gas feeds, and end caps as required. The feed-through tubes are then hydraulically flared to provide a lip to which the feed-through insulator flanges can subsequently be fusion welded. To provide clean surfaces for brazing, cooling tube subassemblies and vacuum walls are electropolished.

A Pd(10%),Cu(32%) Ag(58%) braze filler alloy (Palcusil 10), .005-mm (.002") thick, is placed along the interface of the square tubes and the vacuum wall. All of the square tubes are then firmly clamped



Figure 6. Various configurations of cooling/reinforcing tubes.

(Fig. 3 and 4) and tack welded to fix them in place for brazing. At this time the filament feed-through tubes are also welded to the vacuum wall (Fig. 7) along with all of the various fittings necessary to



Figure 7. Inner weld for filament feed-through tubes.

complete the water cooling circuit. All fixturing used to clamp the square tubes to the vacuum wall is then removed. The ends of the cooling tubes and the edges of the vacuum wall are machined to provide a uniformly flat and parallel surface for brazing of the face flanges. The water cooling circuit is then checked for leaks.

Braze filler foil cut to match the configuration of the face flanges is placed over the ends of cooling tubes and sandwiched between the strongbacks and the face flanges. 10-32 stainless steel screws are used to clamp the strongbacks to the face flanges providing fixtures for these parts during the braze cycle. These screws are subsequently drilled out to provide the necessary mounting holes. The face flanges are welded to the vacuum wall and the cooling tubes are tack welded where they intersect the strong backs along the straight section of the assembly perimeter. All vacuum welds are checked for leaks. This requires internal bracing to avoid deflecting the thin vacuum-wall section. After vacuum integrity has been established the entire assembly is placed in a vacuum furnace and brazed at 850°C for 5 to 7 minutes. A vacuum environment is employed rather than dry  $H_2$  to avoid embrittlement of the type 321 Titanium-stabilized stainless steel from which the vacuum wall is fabricated. The structure is now ready for installation of the filament feed-through insulator assemblies.

The feed-through insulators are designed to provide high-current (125 amp) capability for heating the 1.5-mm diameter (.06") x 15-cm (6.0") long filaments. The conductors consist of a combination of copper and molybdenum collet chucks to allow filaments to be plugged in for easy replacements. Each molybdenum collet chuck can accept two filaments. The insulator is fabricated with two 304 stainless steel flanges brazed in a close coupled array. The copper conductors are brazed to a water-cooled flange which is then brazed to the outer flange on the insulator (Fig. 8).

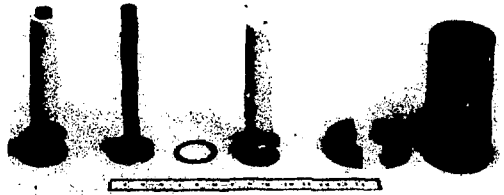


Figure 8. Filament feed-through subassembly.

The molybdenum chucks are joined to the copper conductor by means of a 10-32 stud. This subassembly is then welded to the vacuum wall with the proper orientation to provide the position required for installation of filaments.

General Electric Type 218 non-sag 1.5-mm-diam tungsten rod is used for filaments. They are formed in a non-inductive "W" configuration with approximately 20° of offset to avoid shorting when they are installed back-to-back in the dual filament chucks (Fig. 9).



Figure 9. Completed assembly with filaments installed. The magnets (not shown) are inserted in the slots between the square cooling/reinforcing tubes.

Gas is fed from a modified solenoid valve symmetrically through a manifold into the plasma chamber. Gas diverters are employed to enhance uniform distribution of gas.

### Acknowledgments

The authors wish to thank all those who were instrumental in making this design a reality. In particular, we want to acknowledge the expertise of Richard E. Archer and Gary E. Tisell during the machining and assembly phase, Rick Barnett and Ron Buracker for their work on the very demanding welding operations. Also Curtis Cummings for his excellent drawings and prints.

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