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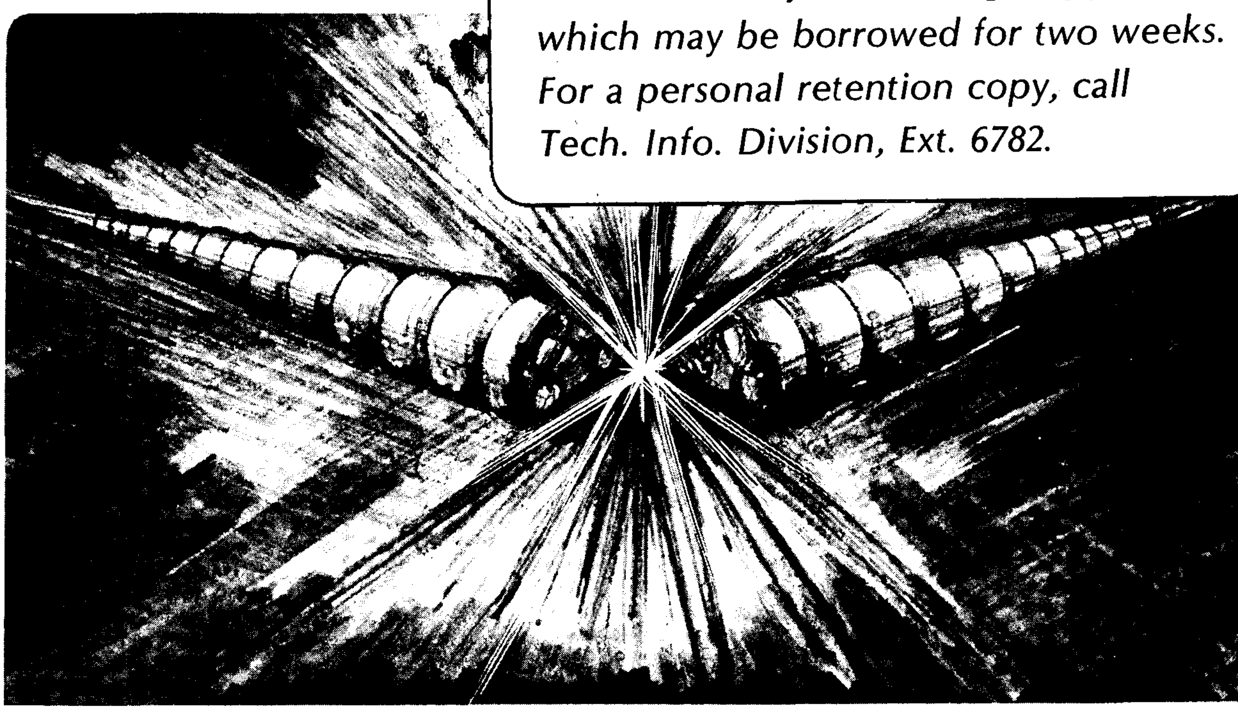

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DESIGN AND FABRICATION OF A SURFACE CONVERSION NEGATIVE ION SOURCE AND AN 80 keV PRE-ACCELERATOR*

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Abstract

The design and fabrication of a surface conversion negative ion source and an 80 keV pre-accelerator intended for use as a proof-of-principle demonstration leading to a radiation-hardened 400 keV TFF based beamline for the next generation mirror or tokamak reactor will be described in this paper.

Experience gained in a previous source[1,7] and accelerator module was utilized to redefine the overall design and construction for this second generation CW device. The source will provide 1 to 2 amps of H^- for acceleration by a 3 electrode 80 keV pre-accelerator.

Particular attention was placed on the mounting of the source to the primary high-voltage insulator, the insulator itself, magnet installation, converter shape and construction, cesium injector and exit aperture design, and accelerator construction, with an overall emphasis on serviceability.

Introduction

Negative-ion based neutral beams of hydrogen or deuterium atoms are a leading contender for heating magnetically confined plasma to fusion temperatures in tandem mirror and tokamak reactors.

This paper reports on a second generation evolutionary design[1,7], shown in Fig. 1, of a surface conversion negative ion source and 80 keV pre-accelerator which was designed, built and is presently being tested at the Lawrence Berkeley Laboratory.

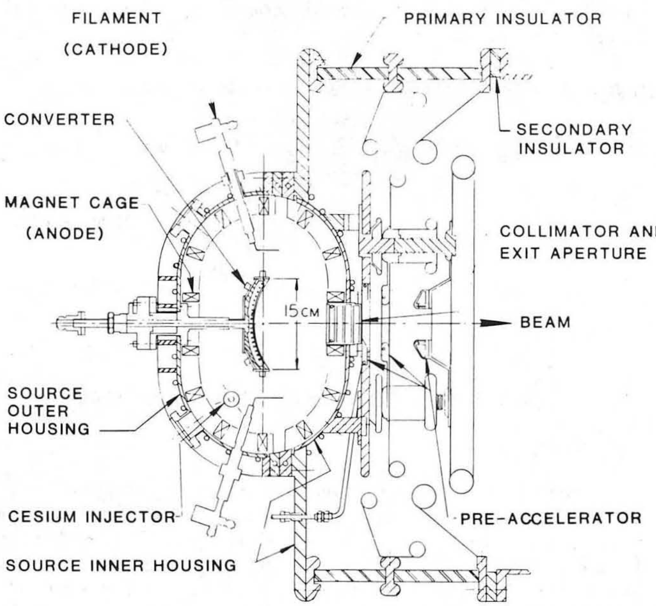

Fig. 1. Surface-conversion source and 80 keV pre-accelerator.

The linear accelerator is referred to as a pre-accelerator because its function will be to accelerate the beam from the source into a matching and transport device, followed by a final Transverse Field Focussing (TFF) accelerator[2] which will add 100 keV to the beam.

This source and pre-accelerator is the first step toward a negative-ion based beamline design utilizing transverse-field focussing with reactor-level power output.[2]

Functional Description

Hydrogen and cesium vapor enter the source chamber through remotely controlled valves. Cesium vapor is deposited on the cold converter face while the hydrogen[1] is heated to form a plasma by an arc struck between the tungsten filament wire cathodes and the magnet assembly anode.

The plasma is magnetically confined by the permanent magnets to prevent excessive loss on the inner source wall.

Cesium and hydrogen ions fall onto the converter, which is biased 100-150 volts negative relative to the anode. H^- ions produced at the converter surface are immediately attracted by the more positive plasma toward the exit aperture with an energy slightly in excess of 100-150 volts. Once outside the exit aperture, the beam gains 80 keV in the pre-accelerator and is directed into the TFF matching section and a final TFF accelerator which brings the final beam energy up to 180 keV.

Design Description

Major components in this device are the source housing, magnet cage assembly, converter, filament assembly, cesium injector, collimator and exit aperture, primary insulator and the pre-accelerator. A description of each of these items is given below.

Source housing

One of the primary goals was to develop a design that could be easily disassembled for access to the interior of the housing for cesium cleanup. This was achieved by splitting it on a centerline perpendicular to the beam direction.

The outer half of the source housing, as shown in Fig. 2 consists of: outer housing, half of magnet cage, filaments, converter and cesium injector.

The housing is fabricated from 6.35 mm (.25") 304L stainless steel. Component parts are either fusion welded or brazed in a hydrogen furnace using a brazing alloy consisting of Pd 25%, Cu 21% and Ag 54%.[4]

Copper tubing and stainless steel manifolds are brazed to the outer housing wall to provide the required heating or cooling.

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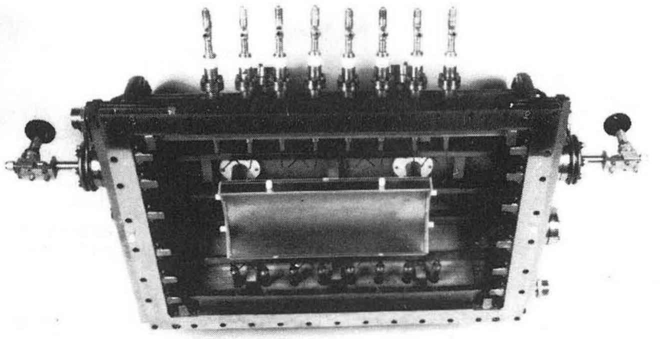

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Fig. 2. Outer source chamber housing and converter.

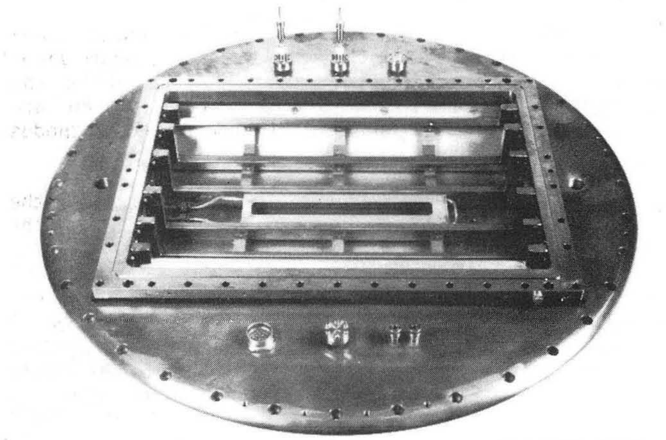

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Fig. 3. Inner source chamber housing assembly.

The inner source housing, as shown in Fig. 3, consists of the mounting flange which interfaces to the 80 keV primary insulator, the inner half of the magnet cage and the exit aperture. The pre-accelerator cantilevers off the outer wall of the source chamber.

The chamber wall weldment is made from 6.35 mm (.25") type 304L stainless steel. It is attached to the 25 mm (1.00") thick 304L stainless steel mounting flange with flat head screws. Oxygen-free copper cooling lines and stainless steel manifolds are brazed to this assembly in a hydrogen oven using a brazing alloy consisting of Pd 25%, Cu 21% and Ag 54%.[4]

Magnet cage assembly

The magnet cage assembly as shown in Fig. 4, functions to confine the plasma during operation. It consists of two non-symmetric halves that are split on the same plane as the source housing. Each half mounts inside its respective source housing. Earlier source designs mounted the magnets on the outside wall of the housing in air. They were relocated to the inside of the chamber to facilitate the design and improve plasma confinement.

Individual magnets are encapsulated in a rectangular 304L stainless steel tube with an iron flux concentrator on the inner facing pole and an iron strip on its outer facing pole. A cross section of an encapsulated magnet is shown in Fig. 5. An expected heat load of 15 watts per cm^2 will concentrate onthe inner-facing pole. Two cooling passages are provided in this area to keep the magnets under a maximum operating temperature of 250°C.

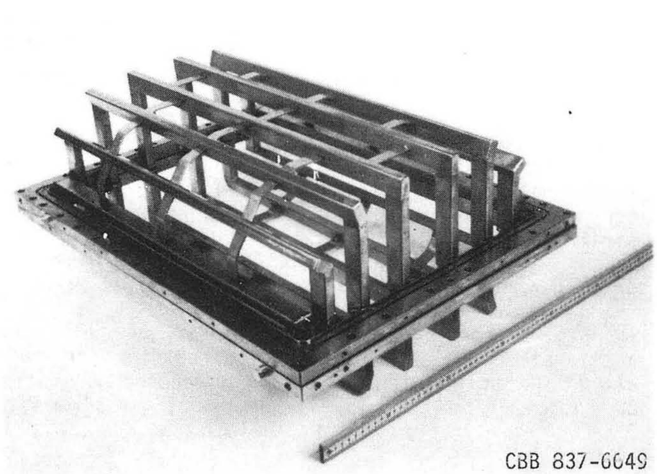

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Fig. 4. Magnet cage assembly.

The canned magnet segments are sealed by fusion welding end caps in place. These segments are held with screws to the rectangular frame which incorporates the cooling supply and return manifolds. Viton O-rings are used as water seals between the magnet segments and the mounting frame.

Two magnet types are used: Samarium-cobalt magnets[5] having a magnetization equivalent to 8000 oersteds and a ceramic type with about 2/3 that strength. The cross section of a magnet is 12.7 x 19.05 mm (0.5 x 0.75").

The ceramic magnets are used on the two rows adjacent to the exit aperture. They are used in this area because they produce a smaller deflection effect on the H^- ions while still confining electrons inside the plasma.

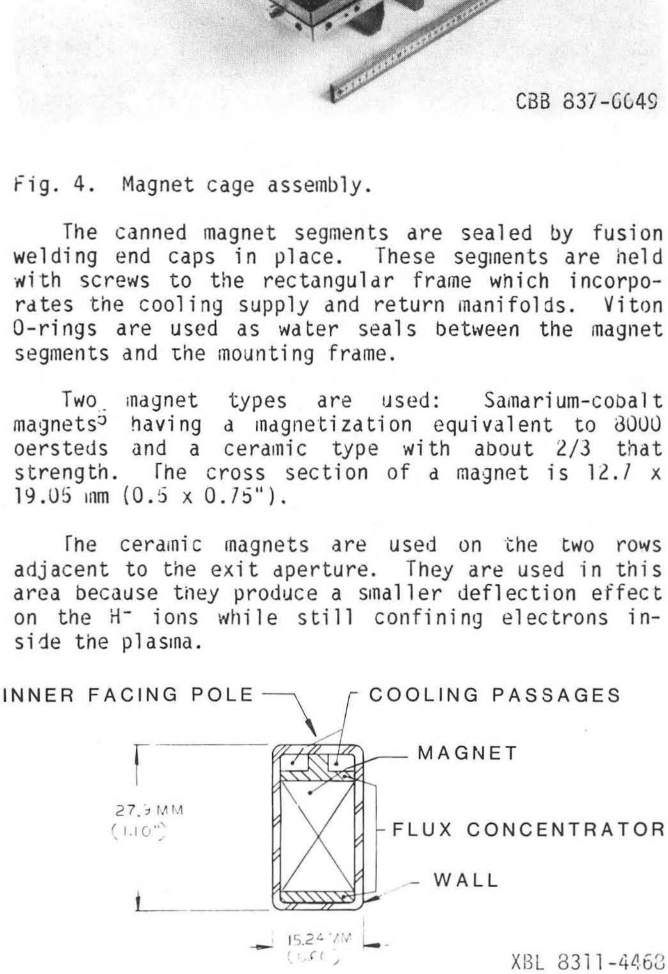

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Fig. 5. Cross section of magnet encapsulation.

Converter

The converter as shown prior to brazing in Fig. 6, is a one piece copper, stainless and molybdenum structure. Integral 4.76 mm dia. (0.187") x 305 mm (12.0") long gun drilled cooling passages are located below the concave conversion surface. Their size and spacing was selected to keep the surface temperature uniform and in a range where cesium would deposit on the converter face. Figure 7 shows the relationship of the cooling passages to the concave converter surface, which is faced with a 0.38 mm (.015") thick molybdenum sheet. Insulating quartz plates and tubes cover all other converter surfaces.

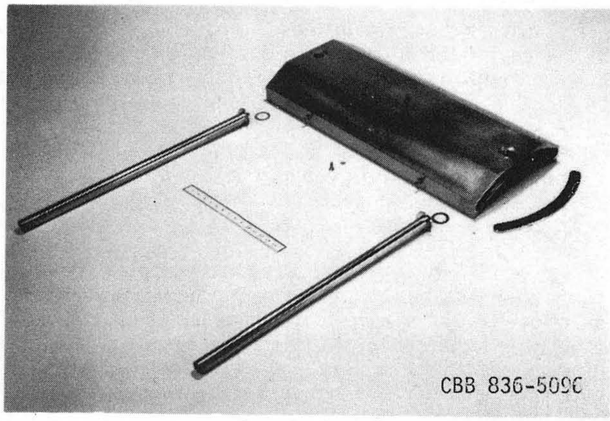

Fig. 6. Converter prior to brazing.

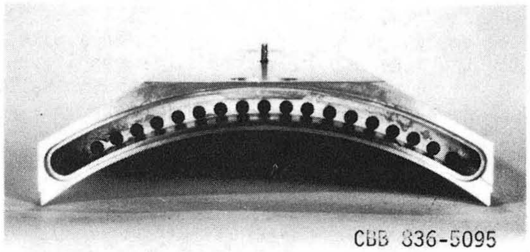

Fig. 7. End view of converter.

Filament feed-thru assembly

The filament assembly, shown in Fig. 8, is similar to earlier designs.[1] It is rated at 100 amps and 10 VDC. The filament chucks are cooled using "squirt tubes". Sixteen filament holder assemblies are located in the outer source housing assembly. As presently configured, there are a total of eight tungsten wire filaments with a diameter of 1.5 mm (0.06"). Filament lifetime is expected to be ~50 hours based on a 10% area reduction by evaporation. To improve filament life, a material change to Lanthanum hexaboride is currently being evaluated.[6]

Cesium injector assembly

The cesium injector viewed in Fig. 9 is conceptually similar to earlier designs, except for a much smaller reservoir, and shorter injection path to the chamber. There are provisions for mounting two injectors on opposing ends of the chamber. Injector valves are pneumatically operated for remote control.

The injector valve and reservoir are heated by four 750 watt quartz lamps which are surrounded by

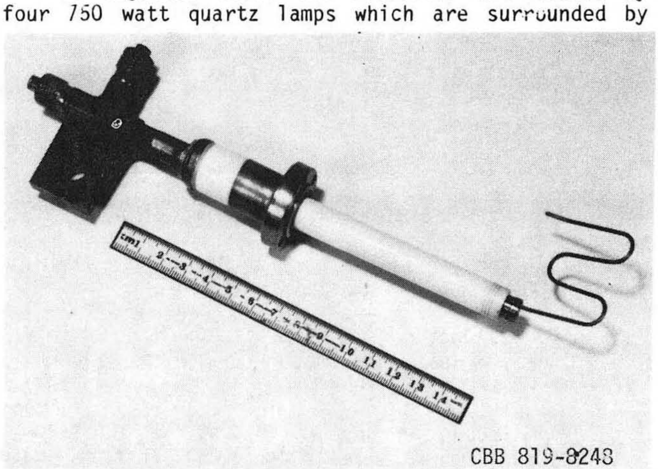

Fig. 8. Filament feed-thru assembly.

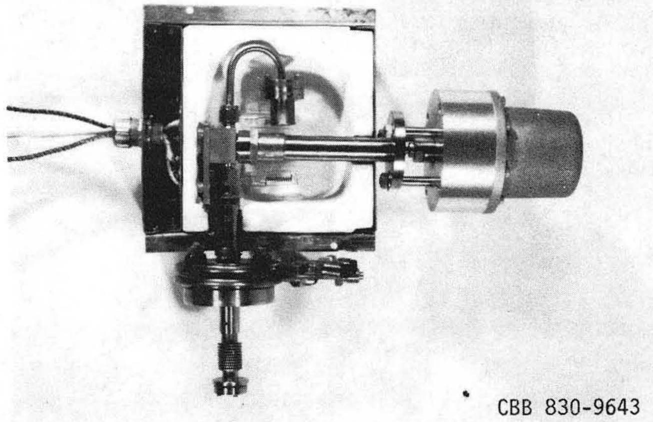

Fig. 9. Cesium injector assembly.

glass rock insulation. The injection tube is resistively heated from the control valve to the injection point to prevent the cesium from depositing on the tube prior to entering the chamber.

The injector valve is operated by a timer and the temperature can be regulated at temperatures between 200° - 300° C.

Collimator and Exit aperture

The collimator, seen in Fig. 10, has a fixed opening of 30 mm x 250 mm (1.18" x 9.84"). It is electrically insulated from the source housing and the pre-accelerator using a "Macor"[3] machinable glass ceramic insulator. It is currently thought that by insulating and biasing the aperture, the electron fraction of the beam can be reduced to only a few percent of the negative ion current.

Water cooling is provided to keep operating temperatures in a range where cesium will deposit rather than exit to the accelerator. Five baffle plates are located in the aperture to increase the cold trap area and improve electron capture.

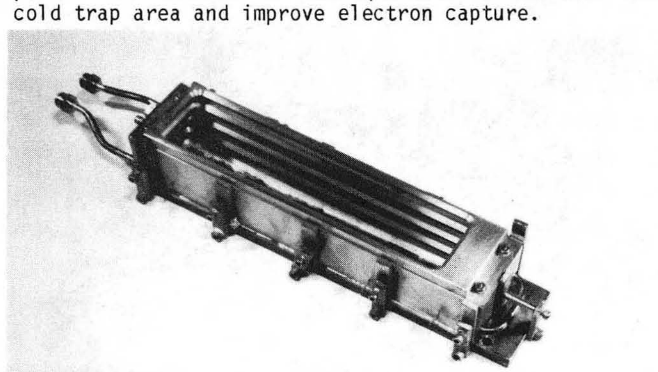

Fig. 10. Collimator and exit aperture shown mounted in its brazing fixture.

Primary source insulator

The primary insulator, seen in Fig. 11, is designed to hold 80 kV to ground and to withstand one atmosphere of external pressure. The metal flanges are 304 stainless steel and the insulator sections are vacuum cast epoxy (Shell Oil Co. Epon 826, 75%; Furane D40, 15%; and Dow Corning 736, 10%, by weight).

The stainless steel flanges are 914 mm (36") diameter and the epoxy insulating sections are 850 mm (33.5") outside diameter with a 19 mm (.75") wall. The overall width of the insulator assembly between flanges is 300 mm (11.81").

The stainless steel flanges and the epoxy insulators are bonded together with Emerson-Cummings 45 epoxy adhesive.

BBC 838-7559

Fig. 11. Primary source insulator.

Pre-accelerator

The pre-accelerator, as shown in Fig. 12, is a three electrode structure. The source electrode mounts directly onto the source chamber outer wall followed by the gradient and exit electrodes. They are separated with shielded insulators which are made from "MACOR"[7] machinable glass ceramic. Each electrode has its own water cooling circuit. Electrode material is oxygen-free copper and the supporting plates are 304 stainless steel.

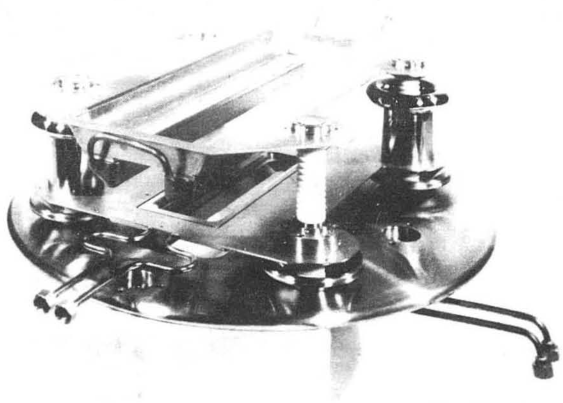

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Fig. 12. Pre-accelerator assembly. Several electrostatic shields have been removed to reveal details of the construction.

Applied voltages are as follows:

Source electrode	-	80 kV
Gradient electrode	-	67 $\pm$ 7 kV
Exit electrode	-	0

The structure is pre-assembled as a complete unit and then mounted on the outer wall of the inner source housing.

Initial Experience & Future Plans

Preliminary operation has started on the negative ion source, without the pre-accelerator installed, in order to perform density profile diagnostics. Addition of the pre-accelerator is scheduled for December 1983.

A primary goal of producing at least 1 amp of H^- was achieved in early November, 1983 when a steady state 1-1/4 amp was measured.

Two problems have occurred to date. The first was an overheating of the magnet cage assembly as a result of insufficient cooling water. Approximately half of the magnets lost their magnetism and had to be replaced. The repair work took two weeks. The demagnetized magnets were remagnetized by the manufacturer.

The second problem was a hot spot which has been discovered on the inner source wall; this has been attributed to poor thermal contact between a water manifold and the inner source wall. This condition is not causing an operational problem at this time. It will be repaired by heli-arc welding a brazing material into the affected area to improve thermal contact between the water manifold and the source housing.

Future testing plans are to install the 80 keV pre-accelerator and primary insulator with the goal of accelerating 1.25 amps of H^- at full voltage.

Testing of a smaller 8 cm (3.149") converter is also planned, to compare with the presently installed one which is 15 cm (5.905") wide.

A TFF matching and beam transport module is now in the design phase and we plan to have this device designed, built and installed by mid 1984.

Acknowledgments

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