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DESIGN AND FABRICATION OF THE BNL RADIO FREQUENCY QUADRUPOLE*

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Summary

The Brookhaven National Laboratory polarized H^- injection program for the AGS will utilize a Radio Frequency Quadrupole for acceleration between the polarized source and the Alvarez Linac. Although operation will commence with a few μ amperes of H^- current, it is anticipated that future polarized H^- sources will have a considerably improved output. The RFQ will operate at 201.25 MHz and will be capable of handling a beam current of 0.02 amperes with a duty cycle of 0.25%. The resulting low average power has allowed novel solutions to the problems of vane alignment, rf current contacts, and removal of heat from the vanes. The cavity design philosophy will be discussed together with the thermodynamics of heat removal from the vane. Details of the fabrication will be presented with a status report.

Introduction

Brookhaven National Laboratory will utilize a Radio Frequency Quadrupole for acceleration between the polarized H^- ion source and the Alvarez Linac. The RFQ is required to accelerate a maximum of 0.02 amperes from 20 kV to 760 kV and with a duty cycle of 0.25%. The rf power required to drive the RFQ will be provided by a subsystem of the existing linac rf system and will operate at 201.25 MHz. The low beam current results in a maximum of 150 watts of power to be dissipated in the RFQ structure. The extremely low average power dissipation has allowed the use of novel solutions to the questions of vane alignment and heat removal.

General Description

Figure 1 shows a typical cross section of the RFQ cavity. The cylindrical body is manufactured from C 1026 mechanical pipe initially 15" outside diameter with a 1.5" wall. Four extension manifolds are welded around the external circumference of the cavity which are used to house the vane mounting and adjustment systems and also to serve as a vacuum manifolding system. The cylindrical wall is penetrated at 132 points to allow for feed loop, detector loop, and plug tuner insertion. Each quadrant will have two feed loops, five detector loops, and twelve fixed plug tuners. There are 14 additional penetrations to allow for variations in the position of the fixed tuners and detector loops and to aid in the initial set up of the cavity.

The vane structures are fabricated from C 1020 steel plate and are designed to be mounted and adjusted from two support points for each vane. Two O.F.H.C. copper tuner bars are mounted on each vane and will provide the primary tuning adjustment for each quadrant. A flexible contact strip is clamped between the tuner bar and the vane. This strip is perforated to allow for vacuum pumping of the cavity and makes a flexible thermal and rf conduction path between the cavity wall and the vane. A water passage is machined into the cavity wall adjacent to the conduction strip contact point. All bolted up joints which form part of the rf circuit are made using spring rings as the rf contact member. The vane active profile will be machined on the vane blank at BNL using the "Oline" H.M.C. 3000 N.C. milling machine, which employs the "Fanuc" 6 M A controller. The vane tip profile has been supplied by the AT1 group of Los Alamos Scientific Laboratory and will be used, with the aid of a BNL developed preprocessor to produce the paper tapes necessary for the Fanuc controller.

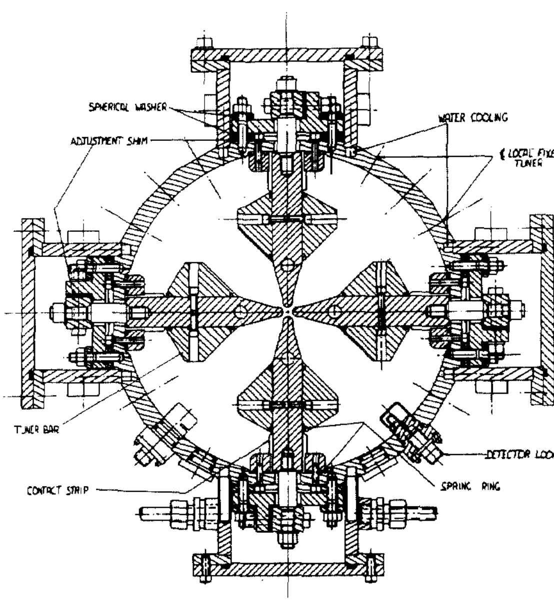

Fig. 1. RFQ cavity cross section

The active surfaces of both the cavity and the vanes will be copper plated using the "Levelling Acid" process after all machine work is complete. The cavity end sections will be manufactured from copper clad steel and will contain an adjustable tuner for each quadrant. A C.T.I. Cryo-Torr 8 vacuum pump will be used to provide primary vacuum, a 140 ℓ/sec ion pump will be used as a holding pump while regeneration of the cryopump takes place. The cavity is mounted on a conventional stand using a kinematic support and alignment system.

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Vane Mounting and Alignment

Almost all operating RFQ structures have been designed for high beam current, high duty cycle applications. Some 70% of the rf power dissipated in the cavity is deposited in the vane structure, the rf currents are at maximum on the vane surfaces. This high current, high duty cycle application has resulted in the development of very complex vane structure designs. The need to remove a considerable amount of heat from the vanes requires water cooling of the vane structure itself. The problem of making an adequate heavy current rf contact while still maintaining flexibility for alignment adjustment gives additional complications.

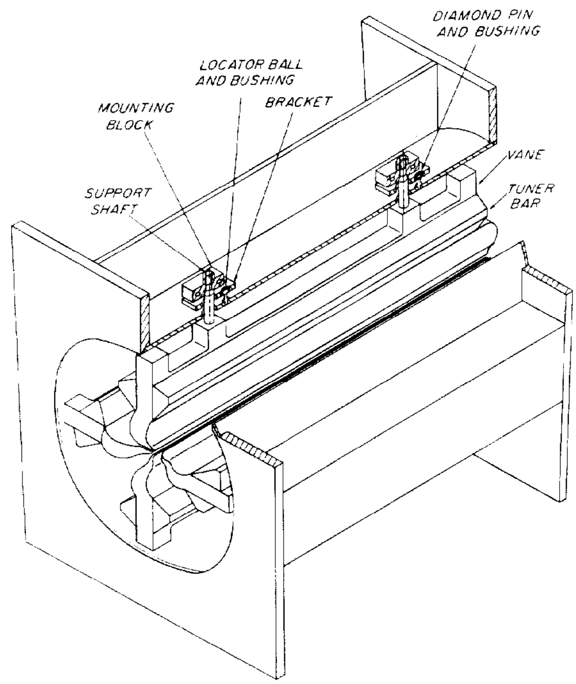

Fig. 2. Vane mounting and adjustment system

The low current, low duty cycle used in the BNL RFQ allows for simple solutions to both the heat removal and vane alignment problems. Figure 2 shows the method of vane support. Each vane is supported at two points on steel shafts which are located in matching tapers. Each shaft is bolted to a mounting block again using a matching taper. The mounting blocks are bolted to brackets which are then bolted to the exterior of the cavity. Spherical washer sets and adjustment shims are fitted between the cavity and bracket while adjustment shims are fitted between the bracket and the mounting block. A locator ball and bush are mounted between the cavity and bracket at one end of the vane while a diamond pin and bush are used at the other end of the vane.

Using the line between the locator ball and diamond pin as a reference, the vane may be adjusted radially, rolled, or pitched as required. The vanes carry a gun drilled hole and optical targets for initial alignment, final alignment employs the rf signal. Variation of the shim thickness can be made in .0001" steps, in sets of four shims using the Whitworth method of lapping. Optical alignment can be made to within .002" of a required position, thereafter rf measurements will indicate the required adjustment. Figure 3 shows the assembly of the vane mounting system.

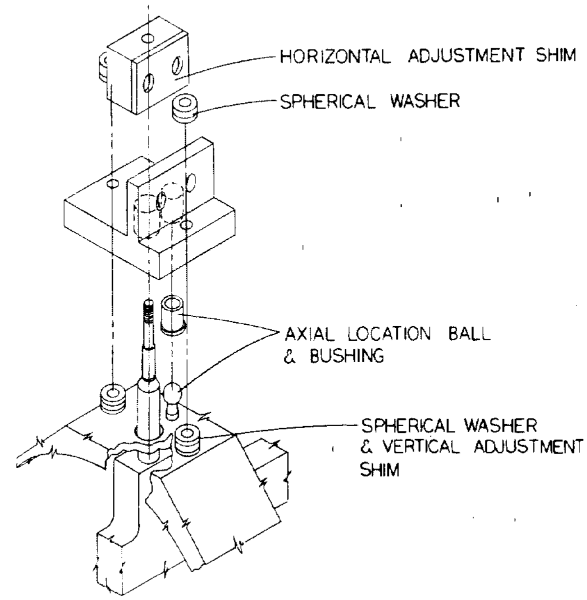

Fig. 3. Van support shaft, mounting block and bracket system

Thermal Analysis

The flexible contact strips provide both thermal and rf conduction paths to the cavity wall. The power dissipated in the surface of the vane is zero at the vane lip and is proportional to H^2 towards the cavity wall. In order to remove the heat from the vane a thermal gradient must exist which produces thermal stress and strain. The BNL vane mounting system is essentially a kinematic support system and will not resist bending along the vane axis, i.e., the stiffness of the vane is the only resistance to bending.

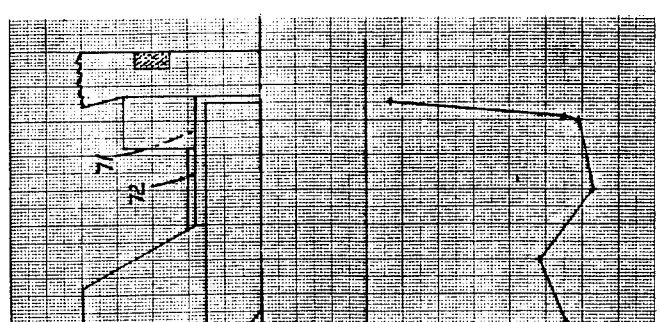

Fig. 4. Vane cross section, showing power and temperature distributions

A computer code has been used to analyze the temperature distribution under steady state conditions. Figure 4 shows both the power input and temperature distributions as computed by this code. Calculations show that under steady state conditions the center of the vane deflects towards the beam axis and the end moves away from the beam axis by 0.0003". This movement is within the machining tolerance applied to the vane tip profile and is therefore not considered important.

Present Status

All major components of the BNL RFQ are in the process of fabrication. Initial rf cold measurements will take place during the spring of 1983 using aluminum vanes. High power testing with copper plated steel vanes and with an H^+ source have been planned for late summer 1983 and final installation and operation should be complete by December 1983.