HIGH GRADIENT ACCELERATING COLUMN DESIGN AND CONSTRUCTION*

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Summary

A high voltage, high gradient accelerating column to provide good optics for high current beams has been built and tested by MURA. Design details were chosen to eliminate all possible sparking or corona discharges for reliable high voltage performance. The 12-in. accelerating gap features stainless steel spherical geometry electrodes shaped to produce a converging field. The electrodes are supported by titanium alloy spacers bonded to ceramic rings with a vinyl seal. There are 14 ceramic rings of 14 in. ID, 16 in. OD, and 1-15/32 in. long, giving a column length of 21 in. This column is insulated externally by sulfur hexafluoride gas at three atmospheres absolute pressure confined by a fiber glass pressure shell. The completed column has been tested at 600 kV. Work is being done on ceramic-to-metal seals to eliminate organic materials.

Introduction

Improved preinjectors are necessary to produce high current, low emittance beams to match new linac requirements. The duoplasmatron ion source with a plasma expansion cup is capable of producing several hundred milliamperes of ion beam having a low emittance. Short, high gradient structures are needed to accelerate the beam whilekeeping space charge effects small. The design and initial tests of the accelerating structure for the MURA high gradient accelerating column have been reported.[1,2] This paper will cover the mechanical design details and processes for construction of the entire column.

Figure 1 shows a cross-sectional drawing of the complete preaccelerator. The accelerating-focusing gap following the extraction gap is a temporary structure. It has been used to accommodate the beam from the ion source, which possessed a distortion-free emittance pattern only as a divergent beam. Although quite small aberrations result from use of this lens, the objective is to extract beam directly into the converging field of the high gradient column section without an intermediate lens when a new version of the ion source is installed.

*Work performed under the auspices of the U. S. Atomic Energy Commission.

Accelerating Electrodes

The 13 accelerating electrodes are of spherical geometry; the radius of curvature varying from 48 in. for the first electrode to 36 in. for the final electrode. The electrodes are placed on already existing equipotential surfaces provided by the shield structure which was obtained by water-tank techniques. The electrodes were machined from type 304 stainless steel disks 3/8 in. thick. The edges were thinned to 1/8 in. and then spun to the approximate design shape. Machining was done with a tracer attachment on a lathe, and final thickness at all points was approximately 1/16 in.

Shields were also 304 stainless and designed not only to hold the electrodes in position, but to give any particles from the beam at least two bounces before striking the ceramic rings of the column. The shields were fabricated from 1/8-in. thick sheet, rolled, welded, and machined. Electrodes are fastened to the shields by short 2-56 countersunk screws.

All corners of the electrodes and shields were rounded, and all surfaces were polished and buffed to a high glossy finish. Polishing was accomplished with rubber abrasive wheels and felt buffs.

Ceramic Column

Dense alumina rings of AD-85 were fabricated by Coors Porcelain Company with dimensions of 14-in. ID, 16-in. OD, and 1-15/32 in.-long. A small step 1/32-in. deep by 1/8-in. wide was machined on each corner to improve voltage-holding characteristics, and ends were ground flat within 0.001 T.I.R. and parellel within 0.003 T.I.R. The ceramic rings were bonded with vinyl to 0.031-in. thick titanium alloy sheet spacers and to titanium alloy ends. The sheets were Ti-4AL-3Mo-1V, and the ends were Ti-7AL-4Mo. Titanium was used since it not only has a thermal coefficient of expansion which closely matches that of the ceramic rings, thus reducing thermal stresses in the glued joints, but it has better voltage-holding qualities

than stainless steel.

Intense quality control was carried out to increase the probability of achieving 28 large vacuum-tight joints. All surfaces must be as clean as possible, so metal parts were first cleaned with xylene, then washed thoroughly, and finally cleaned with acetone. The pieces were then dried in an oven for a few minutes to drive off the solvents. Ceramic parts were cleaned with the same solvents, but they were also boiled in distilled water for a few minutes before drying in the oven. Extreme caution was used to avoid any fingerprints on the surfaces to be bonded.

The vinylite acetate was obtained from Union Carbide Corporation, South Charleston, West Virginia, in the form of small pellets. The basic procedure for its use was taken from a report by C. S. Lindenmeyer of ORNL, 1958. The pellets were dissolved in toluene to a viscosity of 19 seconds as measured by a ZAHN G-3 viscosimeter. This consistency has been found to work quite well in an artist's air brush with 35 lb pressure from a nitrogen bottle.

Vinyl was applied in a dust-free enclosure, and surfaces were sprayed to a thickness of 0.0025 to 0.0035 in. Shields were used to confine the spray to the bond areas, and parts were rotated by a variable speed motor to give uniform coating. This setup is shown in the photograph, Fig. 2. One side was coated and then the part was fired in a horizontal position at 150°C to 160°C for 30 minutes. The thickness of the coating was then checked with a micrometer before coating and firing of the other side took place.

All the ceramic rings, metal spacers, and end rings were assembled in a precision alignment fixture, weighted, and fired at 150°C for one and one-half hours. The oven was turned off and allowed to cool slowly. All joints proved to be vacuum tight. The completed column is shown in Fig. 3.

Outer Pressure Shell

Internal accelerating parts are designed for a possible accelerating voltage as high as 900 kV. The length of the ceramic-ring column is about 21 in., so it must be insulated externally for such high voltages. Sulfur hexafluoride gas is used at several atmospheres pressure, and is confined by a filament-wound fiberglass shell shown in Fig. 4. The fiberglass was wound, by Brunswick Corporation, Lincoln, Nebraska, onto stainless steel ends which were fabricated by MURA. Diameter is approximately 42 in. and length is 84 in. Wall thickness is 3/16 in. and consists of 1/8-in. fiberglass with two layers of 1/32-in. rubber for a gas-tight liner. The vessel was pressure tested at 200 psig by Brunswick, but for initial column testing a pressure of 30 psig is used.

Corona rings fit inside and outside the fiberglass shell. These were rolled from 1 x 2-in. aluminum giving diameters to fit the shell and machined to 7/8 x 1-1/2-in. cross section. Inside rings have two bolted lap joints for assembly, outside rings have one joint. The outer rings have a groove in which conducting rubber strips were compressed to make positive contact against the fiberglass at all points along the ring. Long 1/4-20 bolts go through the outer ring, through the fiberglass shell, and into the inner rings. Bolt sealing was accomplished by RTV rubber squirted into the holes during assembly.

Much hard work was put into the aluminum corona rings to achieve a mirror finish. This finish was probably better than necessary, but the exposed surfaces of all joints, holes and corners were rounded and buffed to minimize the possibility of sparking.

Voltage leads extend from the aluminum corona rings to the spacers between ceramic rings. The leads were fabricated of 3/8-in. stainless steel tubing, highly polished, and have spring extension joints for differential expansion. Figure 5 is a view looking at the source end of the column before attachment of the pressure can and shows the staggered arrangement of the leads.

The external corona rings are extended by 1/32-in. polished stainless steel sheet with the outer edge welded to 1-1/2-in. diameter stainless tubing. The inner diameter of the sheet fits into a groove on the aluminum corona ring. Four radial stiffeners are used on each sheet to reduce "oilcanning" deflections. A water resistor as used by Argonne National Laboratory is connected to the outside of each corona ring for voltage division. The resistor consists of 1/2-in. "Saran" tubing through which deionized water flows. Stainless steel pins extend through the tube wall for electrical connection.

Adjustable spark gaps are bolted through the corona ring sheets. Each gap was set to fire at 50 kV for initial voltage tests.

The central column is supported on a stainless steel vacuum can at the output end. The pressure can extension is also stainless, and has bellows at each end to allow radial misalignments as well as length changes. The pressure can allows access to the ion source. Figure 6 is a view of the various parts before final assembly with the accelerating electrodes expanded for the photograph.

Improved Assembly Techniques

Work is being done to achieve a ceramic to metal joint that is more reliable than vinyl or epoxy. Although MURA has had only small glass to metal joints break, elsewhere, glued columns have been known to fall apart. On an ion source test assembly, we have glued ceramic cylinders to stainless rings with LOCTITE ^{R} 310 Industrial Adhesive with excellent results. Joints are strong and vacuum tight, and no outgassing effect was noticed on the vacuum. This adhesive is a single-component, anaerobic, self-curing compound. Adhesive is applied to the joint area, parts are aligned and weighted, and the assembly left alone for 24 hours. Curing time can be reduced by increased temperature, but this room-temperature bond is more reliable than heating when dissimilar materials are joined.

An all-metal bond would be desirable. Usual brazing alloys for high vacuum require very high temperatures, so high that differential expansion between the ceramic rings and the metal spacers results in highly stressed joints. Quite low temperatures can be used, with pressure, in diffusion bonding techniques. Such metals as gold, silver, indium, and tin can diffuse at temperatures below 250^{o}C and pressures of a few thousand psi. Problems of this technique are flatness of mating parts, flatness of the metallizing, and integrity of the plating. We are presently testing a gold-gold diffusion bond, but work has not been completed.

References

1. C. D. Curtis and G. M. Lee, "Preaccelerator Column Design", MURA Report No. 707 (1965, unpublished).

2. C. D. Curtis, G. M. Lee, and J. A. Fasolo, Proceedings of the 1966 Linear Accelerator Conference, LA-3609, p. 365.

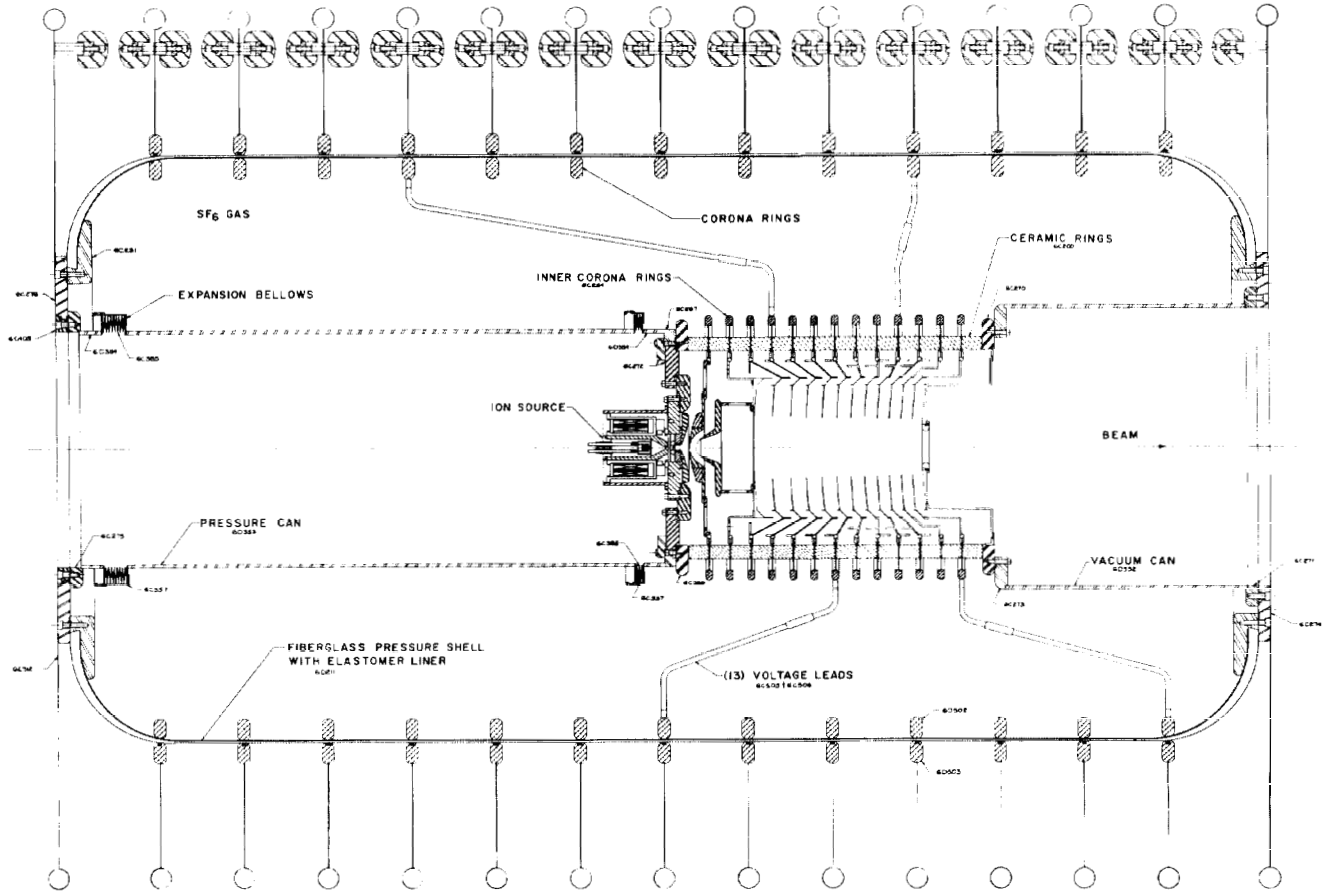

Fig. 1. A cross-section drawing of the preinjector assembly.

Fig. 2. Application of vinyl solution to the ceramic rings with an air brush.

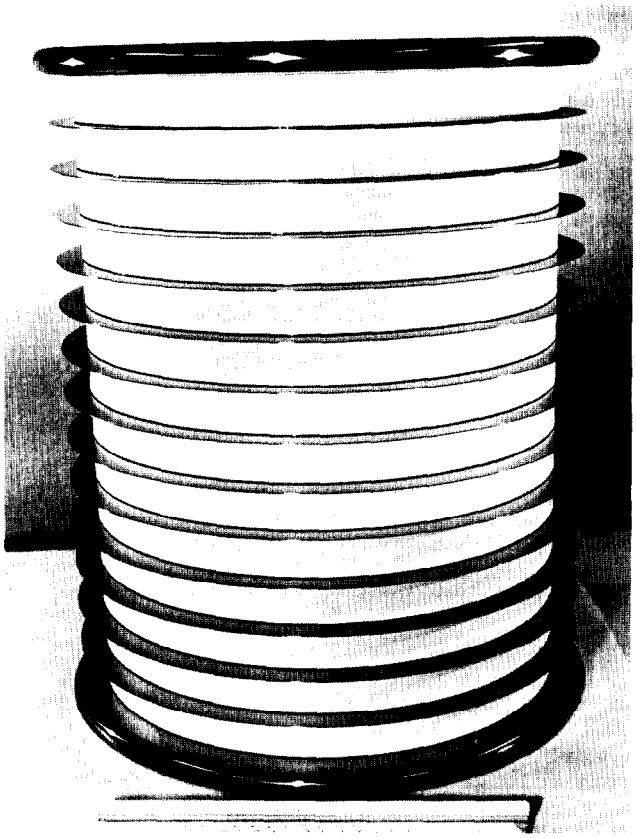

Fig. 3. The completed column showing the ceramic rings with titanium alloy spacers and ends.

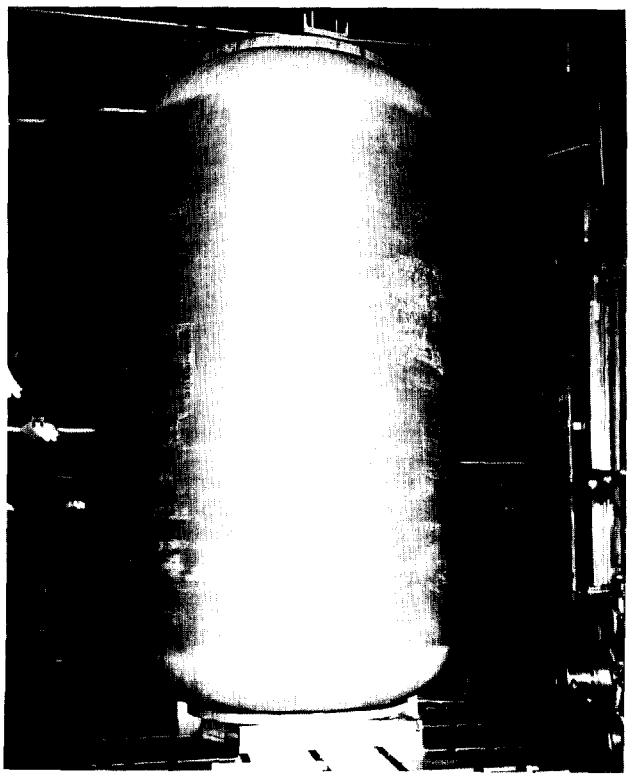

Fig. 4. The filament-wound fiberglass pressure vessel.

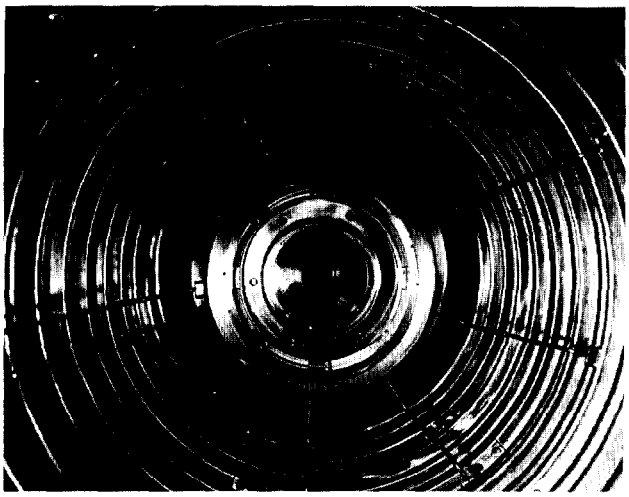

Fig. 5. A view looking at the source end of the column before attachment of the pressure can. High voltage leads from the corona rings to the column are shown.

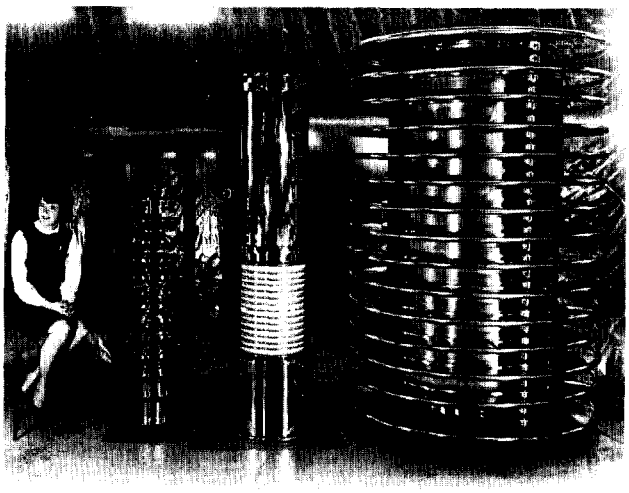

Fig. 6. A view of the various parts before final assembly with a model for size comparison. The electrodes are separated for the photograph.