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BROOKHAVEN NATIONAL LABORATORY TANDEM ACCELERATOR UPGRADING PROGRAM

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Summary

The three-stage Tandem Van de Graaff accelerator facility at Brookhaven National Laboratory has undergone various upgrading programs[1)] since the early 1970's. The original 10 MV waranteed MP Van de Graaff accelerator of 1970 now operates in excess of 14 MV because of many improvements over the years: the purpose of this paper is to report on the most recent improvements which have been completed and also on those that are presently under construction and being implemented.

The improvements that will be discussed are shown in Fig. 1 and listed as follows:

1) Extending the present MP-7 acceleration tube sections that consist of 72 1"-thick glass insulating sections to 88 glass insulating sections which then extends the tube section approximately 8 inches into the 24" long dead section of the support column. This modification will include ion vacuum pumping at five dead sections.

2) Install drive shaft power for the terminal and all dead sections that need power for vacuum pumping in both MP-6 and MP-7.

3) Install shorting pull cables in the MP-7 terminal and shorting rods at each dead section so that individual tube sections can be voltage conditioned separately.

4) Install solid skin terminal shells in both accelerators for better terminal spark protection of terminal components and improved electric field distribution in the vicinity of the terminal.

Discussion

1. Acceleration tube extension

The present 14"-diameter inclined-field HVEC stainless steel acceleration tubes consist of 72 one-inch thick glass insulator sections and end flanges. The 72" long insulated section just fits the available space between the dead sections along the support column of the accelerator which are each field free sections 24" long. Each acceleration tube section will have 8 additional glass sections added to each end so that the tube will extend 8" into the 24" dead section; each tube section will then be increased from 72 to 88 glass insulator sections. In addition to this modification, the end flanges on the acceleration tube sections have been completely redesigned. The special Carpenter 39 alloy steel flange that is glued directly to the last insulating glass electrode is welded to a double wall stainless steel bellows[2)] section which in turn is welded to a stainless steel flange with a rotating outer ring containing the bolt circle for

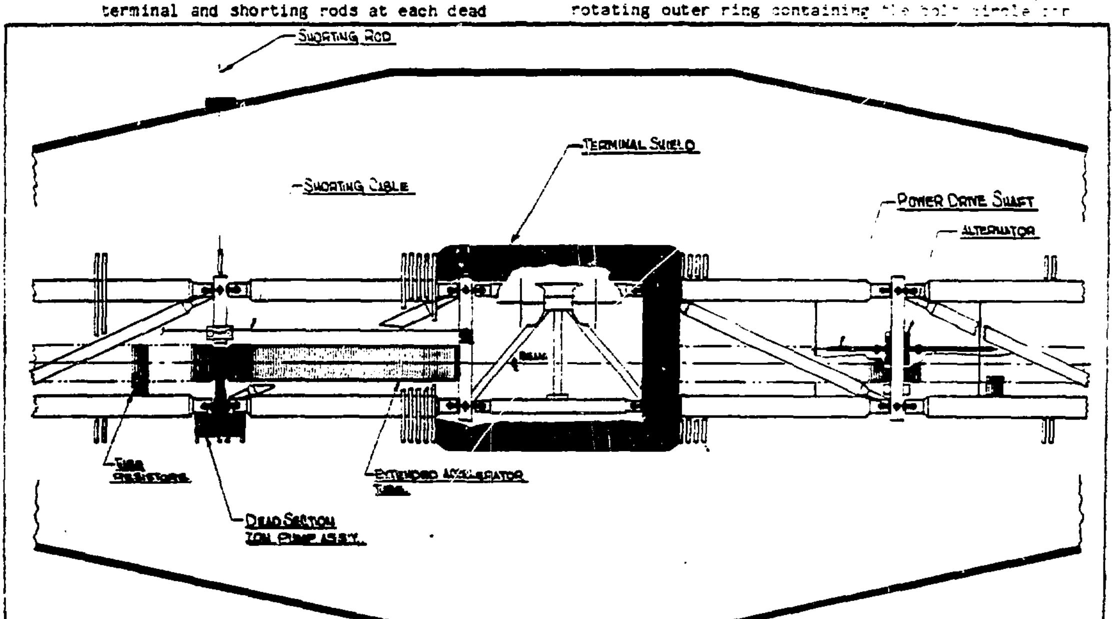

Fig. 1 Schematic representation of the elements involved in the present upgrade program.

convenience of alignment as shown in Fig. 2. This arrangement eliminates mechanical stresses on the Carpenter 39 steel flange that could lead to fracture of the glass to metal joint and also eliminates one set of O-ring seals that would otherwise be required.

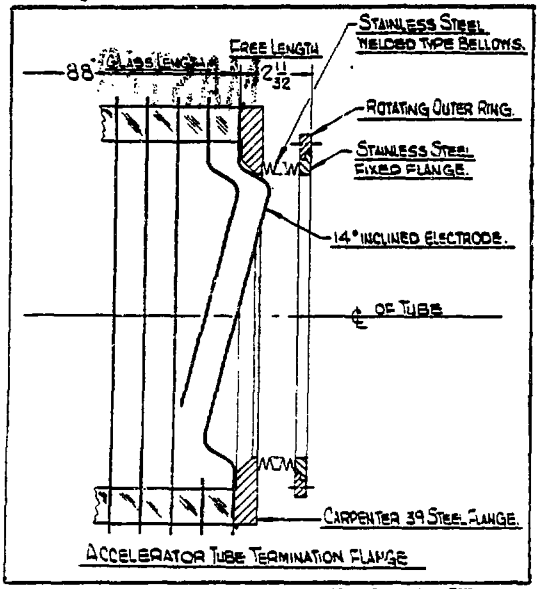

Fig. 2 End flange design details for the BNL extended acceleration tube.

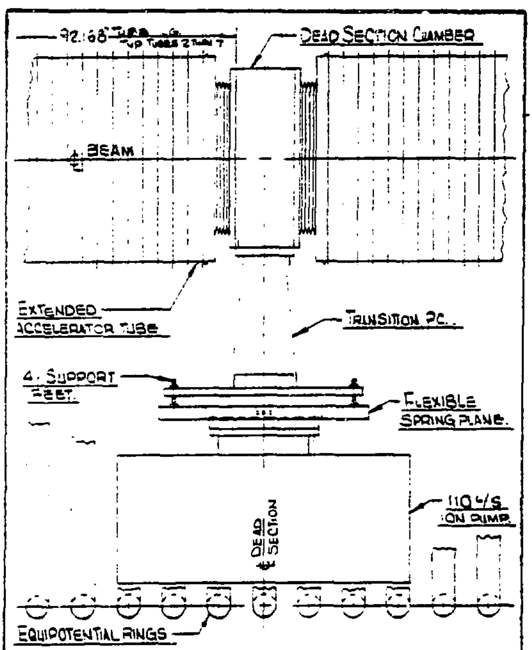

Fig. 3 Vacuum ion pump and new dead section installation arrangement.

The stainless steel flange on the end of the assembly seals directly to a double O-ring joint on a 4" long aluminum dead section that accommodates a vacuum pump coupling or the second stripper assembly between tube section 5 and 6 as shown in Fig. 3. This short 4" dead section contains magnetically-biased apertures that decouple the tube sections and restrict excess beam steering excursions, mostly eliminating the possibility of any beam striking tube electrodes. All the new short dead sections are mechanically centered and symmetric in the longer 24" column dead sections. A contoured ground surface shell will connect the 4" dead section in the center of the column structure to the 24" dead section of the outer column in a smooth way to keep the electric field more uniform and also to provide protection from electrical sparks and surges that could travel down the column and damage electrical components in a dead section like the power supplies for the vacuum pumps and other components.

Specially designed Varian ion pumps[3)] rated at 110 liters/second and tested to an external pressure of 15 atmospheres are installed underneath the spring plane and just inside the hoop rings as shown in the photo in Figs. 4 and 5 which shows a mock-up of the dead section region and its associated components. The pump is connected to the short dead section with a tapered transition section, whose minimum opening is equivalent to twice the open area through the inclined field electrodes. Cleats on the side of the tapered section with adjustable screws support the pump's weight and allow for appropriate alignment. All flange joints are sealed with double viton O-rings with a pumpout between

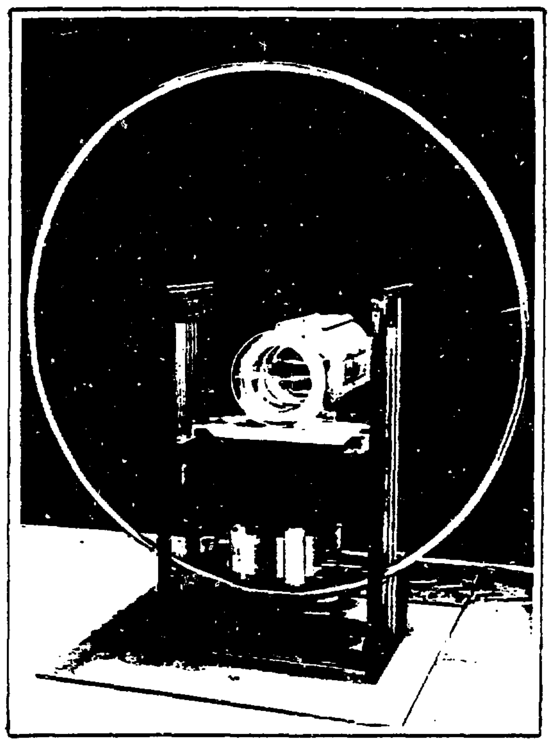

Fig. 4 Full scale mockup of acceleration tube. new 4" dead sections, tapered transition section, spring plane, ion pump, and potential gradient ring.

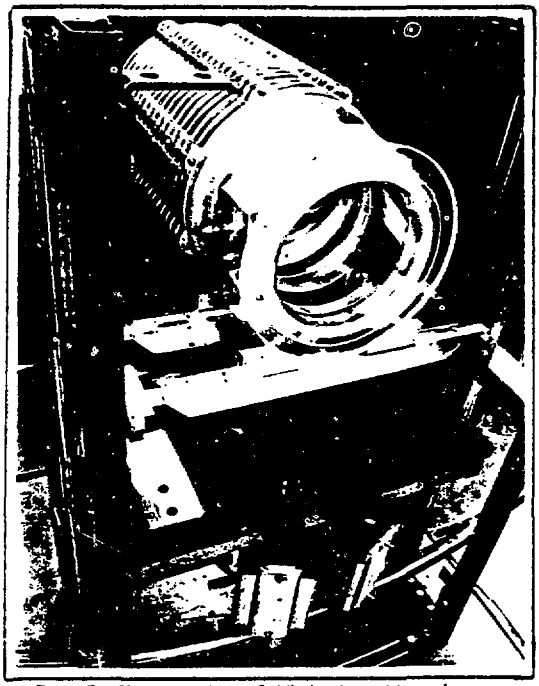

Fig. 5 Closeup view of 4" dead section showing pumpout connections for pressure testing.

the two O-rings so that each joint can be pressure tested at the rated operating pressure of 15 atmospheres.

Tube sections #1 and #8 are different from all the other tube sections in order to accommodate a number of straight electrodes at the entrance of tube section #1 and at the exit of tube section #8. The 88 glass tube section is extended 8 more insulating sections to 96 and the first 16 electrodes of that section will be straight electrodes operating at half the gradient of the inclined field regions. The half gradient is necessary to avoid electron loading in the straight region and the additional eight glasses keeps the gradient in the inclined field section the same as that in all the other tube sections. Straight electrodes pre-accelerate the soft ions being injected into the accelerator so that they program properly through the inclined field region of the acceleration tube. The first straight electrode is gridded and is used as a gridded lens at the entrance to the machine for optimum optical coupling. When the accelerator is used in the accel-decel mode or four-stage configuration as described elsewhere at this meeting,[4] energetic fully-stripped ions are decelerated coming out of the accelerator and it is impossible for these ions to get through the last inclined field section of normal tube section #8 when their energy is lower than a certain value (for example, 8 MeV, ^{32}S 16^+ ions). Consequently, by arranging tube section #8 to be the symmetric partner of tube section #1, the exiting heavy ions can be decelerated through straight electrodes eliminating this limitation. In tube section #8 the straight electrodes will also be equipped with half gradient resistors symmetrically with tube section #1.

Installation of the re-entrant acceleration tubes will occur during the summer months of 1981 and require three to four months for completion along with the other upgrade efforts mentioned in this paper. The completely upgraded machine is expected to start operations in the fall, with 17 MV corresponding to the 14 MV currently used in the research program. The present tube sections have actually been used in research for a few hours at terminal voltages as high as 14.7 and if the same gradients can be achieved with the new extended tubes, it would mean a possibility of operating at terminal voltages as high as 18 MV. This terminal voltage coupled with the three-stage injection capability of MP6 would make the overall maximum operating characteristics of the three-stage facility similar to the performance of a 20 MV two-stage tandem.

2. Insulated power shaft drive

A motor powered 2" diameter lucite drive shaft operates generators in the terminal and any dead sections requiring electrical power for vacuum pumping or other electrical components. The drive shaft systems were purchased commercially[5] and are installed in both the low and high energy ends of the machine. The drive motor is 7 hp and consequently can provide approximately 5 kw to the overall shaft system. Each generator has a throughput shaft and is capable of providing up to 3 kw of power. However, only a small fraction of the 3 kw will be used in the various dead sections and terminal. The maximum power contemplated for each drive shaft is less than 2 kw. The lucite drive shaft is bearing-supported at two-foot intervals along the column and at each end of the dead sections as shown in Fig. 6. Each of the two terminal generators can be switched separately into the terminal power load so that the two units operate as backups for whichever one is in operation. The present plans will provide power in dead sections #1,#2; #2,#3; #3,#4; and #6,#7.

3. Shorting cable and rod system for individual tube section voltage conditioning

Two spring-loaded windup pulleys were installed in the terminal in order to provide an electrical shorting system from the terminal down the column to successive dead sections in sequence from the terminal to ground. A 1/8" steel cable contained in the terminal mounted, windup pulley is coupled to a 1/8" monofilament nylon pull cable by crimping each end into a short section of

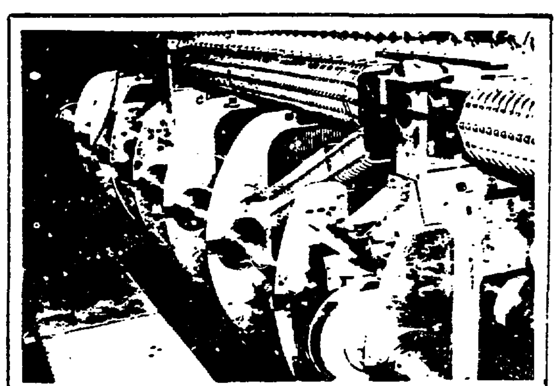

Fig. 6 Power drive shaft installation in MP6, similar to those that will be installed in MP7.

copper tubing. The nylon pull cable is reeled in and out on a Slosyn motor powered drum at each of the ground ends of the machine. The Slosyn drive system is locked at any particular dead section position by DC voltage applied to the motor. At each dead section the cable pulls through three pulleys with the center pulley opposed to the two outer pulleys and offset below the cable center by 0.5" to insure good electrical contact as shown in Fig. 1. The Slosyn powered drum is operated externally with a remote cable control and as the end of the cable is pulled through the dead section grounding pulleys, it can be observed through appropriate pressure windows in the pressure vessel at each dead section.

Quarter-inch diameter shorting rods as shown in Fig. 1 are also provided at each dead section that slide through a Teflon compression seal and are equipped with 1" diameter balls to contact the dead section and to avoid an accidental pull or blowout through the sliding compression seal. The nylon pull cable is arranged to go through the open region available in the outside section of the column structure and is well away from any of the mechanical components of the column. The nylon pull cable has not suffered any damage with this arrangement even though it has been exposed to terminal sparks in excess of 14 MV.

Initial conditioning results indicate that this system is of significant value for obtaining higher gradients in shorter periods of time and with greater safety than would otherwise be possible. The accelerator had been closed for six days following a three day tank opening during which the acceleration tubes had been let up to air. The maximum voltage reached during this period had been 12 MV. The accelerator was then conditioned in halves to 7.1 MV per half over a total time of two hours and the entire machine to 13.4 MV in an additional hour with tube section #1 being the limiting factor. Over the next few days experiments were performed with terminal voltages up to 12.7 MV. On the eleventh day after the tank was closed, individual tube sections were conditioned (in pairs) to 4 or 4.1 MV each in three-quarters to one hour except for tube #1 which only reached 3.4 MV. This is probably due to the higher gradient in tube section #1 resulting from the half-value resistors on the straight electrode section of the tube. This problem will be eliminated in the extended tube design by the addition of extra insulators. After this conditioning period the whole accelerator then conditioned to 14.5 MV in three quarters of an hour. Previous conditioning times without the availability of the shorting cables, after a machine opening, would routinely be in excess of two weeks to achieve routine operation at 14 MV or better.

4. Improved terminal design

A series of solid panels and spun ends fitted together to form a cylindrical, smooth skin terminal shield is being installed to replace the parallel bar scheme originally provided with the accelerator on both machines, MP6 and MP7. This smooth skin arrangement is similar to, but somewhat smaller than, that originally developed at Rochester[5] and is shown in Figs. 7 and 1. The new terminal shield is 80" in diameter as compared to 74" for the present system. The smooth structure consists of fifteen 24° contoured panels that form the cylindrical section, and each of the 24° panels is fastened with four captured screws. The spun ends are split and bolted together and supported on a horizontal diameter. The design reduces the electrical field strength at the ends of the terminal and adjacent

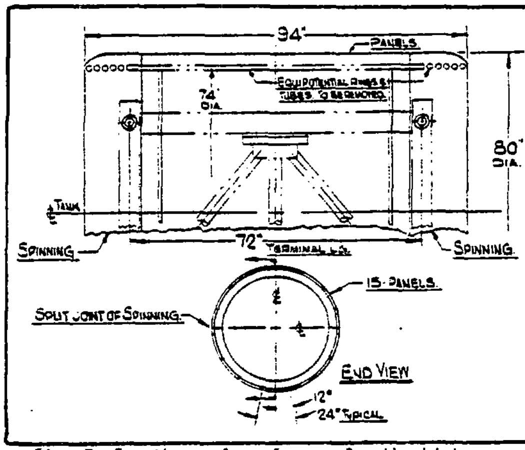

Fig. 7 Smooth panel enclosure for the high voltage terminal.

equipotential rings and provides a more uniform field distribution which should decrease the probability of sparking in the terminal region. The solid skin also provides better protection to all internal terminal components against surge damage from terminal sparks.

Conclusion

The sustained upgrade effort at the Brookhaven tandem facility has led to reliable performance at voltages and energies far in excess of the originally specified values. MP-7, being used at terminal voltages up to 14.7 MV, is at present the accelerator operating at the highest acceleration tube gradient. The further improvements now being implemented should lead to a three-stage capability comparable to the capability of a 20 MV tandem.

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