# UNIVERSITY OF ROCHESTER TANDEM UPGRADING

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## Summary

It has been clear for several years that some reasonably fundamental changes in the design of the High Voltage Engineering Corporation's MP tandem accelerator[1] are essential if this machine is to operate reliably at terminal potentials that are above 10 MV. Although the original specifications for the accelerator only guaranteed 10MV, the expectation was high that the actual voltage limit would be near 13-15MV. In practice, the voltage levels have only recently been achieved at the HVE test facility and at the AECL laboratories at Chalk River, Canada.

Starting in 1968, we at Rochester began a number of measurements to understand the basis of these machine problems. We are now completing a major upgrading program on the accelerator which will include modifications to the accelerator tube geometry, to the electrostatic structure of the terminal and support column, to the resistor divider chains of the machine, and to the vacuum system to allow terminal pumping.

The first stage of this program was to install a new terminal spinning which completely replaces the original longitudinal bars of the terminal. This terminal spinning, shown in Figure 1, has two major functions:

Firstly, it reduces the electrostatic field gradients at the surface of the rings which are in close proximity to the terminal; and secondly, it prevents the egress of dust from the charging belt. The shape chosen was selected by solving Laplace's equation for the electrostatic field within the generator with the aim of minimizing the electric field gradients in the region of the terminal. This new terminal has been in operation for two years now and appears to have had an important effect in reducing tank-to-terminal sparking. An important point that is not always recognized is that the $1/2cv^2$ stored electrostatic energy in the MP generator is in excess of 25,000 Joules[2] at 10MV. It is vitally important to keep this energy from damaging the column planes, grading resistors and tube construction during an electrostatic breakdown. Any mechanism which will significantly reduce the frequency of sparking, will reduce the likelihood of damage.

A second stage of this upgrading program which has been in operation now for nearly 18 months is the installation of a terminal pump to eliminate the gas flow from the stripping canal and for pumping the out-gasing products from the accelerator tubes. Terminal pumping is an essential part of the overall upgrading program because one of the fundamental problems of the accelerator is the low threshold voltage for the total voltage effect[3] which in turn is caused by the large aperture which are essential for pumping.

The principle of the system is shown in figure 2. It consists of cryogenic tips which operate at 20°K or below. At this temperature all gases, with the exception of $H_2$, He, Ne, have partial pressures well below $10^{-10}$ Torr. The system which is designed around a Cryogenic Technology 1 watt cooler,[4] has operated for periods up to 10 months with no maintenance. Before installation, a number of pump tests were made on the cryogenic unit, both at atmospheric pressure and at external pressures of up to 250 psi. There were many problems of leakage of tank gas into the cryogenic units, but these have now all been completely solved and the system operates with high reliability. Figure 3 shows the refrigerator head with an experimental cold-tip attached. Figure 4 shows the installation beneath the stipper housing. The power for the system is derived from a 60Hz, 3.5kVA, 2 phase alternator driven by the charging belt. During the past 18 months, the unit has been subjected to a large number of electromagnetic surges with no damage. Evacuation of the gas which is collected can be effected in half an hour by stopping the belt.

As mentioned previously, a major problem of large d.c. machines is the stored energy that is present in the electrostatic field. In the design of any machine that is to be successful, it is essential to avoid coupling this large stored energies into the comparatively fragile tube or resistor structures. At Rochester, we have given considerable thought to ways in which the effect of surge damage can be minimized. One important thing we have done to minimize the coupling of energy into the tube structure is to isolate the tube completely from the column except at those points where it passes through the three dead sections in the high and low energy ends of the accelerator. This is possible in the MP as the tube can be physically well separated from the column as can be seen in figure 5. This separation of the tube from the column necessitates a completely separate resistor chain to provide potential grading along the tube. This separate resistor grading has an additional virtue in that it guarantees that the potential along each tube section is uniform and that the gradient is not upset by local coronal discharges as is the case when the tube is closely coupled into the column. The most important effect, however, is that the spacing is such that the tube planes can be at substantially different voltages than the adjacent column members. Thus, when the machine suffers a terminal-to-tank spark, the enormous over-voltages which are induced in the conventional design, due to the capacitive division of voltages, no longer appear and the maximum over-voltage on any tube section is limited to about 1.4 times the normal voltage difference. A section of the parallel resistor chain is shown in Figure 6. One section of parallel resistors has been in operation for six months. During this period not one resistor has failed on the tube, while seven failed in the parallel column region.

Another problem of large electrostatic accelerators is that the grading resistors have often deteriorated rapidly. A number of tests, which have been conducted at Aldermaston, England in connection with the design of the proposed large tandem at Daresbury, have shown that resistor failure is predominantly due to the axial gradient of the column being imposed in a radial direction during transient surges. We have modified our resistors to eliminate this effect by using a high-grade metal oxide resistor which is enclosed in a sheath such as shown in Figure 7. These resistor protectors have sufficient gap to withhold the static dc potentials, but are close enough to the resistor element that the distributed capacitance between the surrounding tube and the resistor prevents any sharp-fronted transient voltage disturbance from appearing across a resistive element. To date, no resistors built with this construction have failed.

A central feature of the whole upgrading program is a tube of new design. This design which is based upon a spiral suppression of secondary particles, rather than the linear suppression technique of HVE, has had its optical properties calculated by R. Hyder of Oxford University. The optics of individual sections are arranged so that particles which enter on axis leave also on axis. Thus, with the parallel resistor arrangement described earlier, small beam motions should be completely eliminated. The design is such also that only three basic tube designs are needed for the whole accelerator. This simplifies considerably the number of needed spares.

1) Manufactured by the High Voltage Engineering Corp. Burlington,Mass

2) P.H. Rose and H.Milde. IEEE Trans.NS-18 63,1971
K.H.Purser,R.B.Liebert and A.N.Petersen IEEE Trans. NS-18,130,(1971)

The important differences between the old HVE tube and the new special design is that the new units are only 9-1/4 in. diameter, in comparison to the original 14 in. Thus, the tube has substantially lower capacitance per unit length. This reduction in diameter, together with the column decoupling, reduces the stored energy to feed micro-discharges by about one order of magnitude. To date, the tube of this design has shown that it is easily able to sustain 3.4 MV across a 6-foot section3so we are more than optimistic that our aim of 12-13 MV will be achieved in the whole generator. Figure 8 shows a mockup of the resistor mounted on a new spiral electrode. Figure 9 shows the spiral geometry for a test tube section to be installed in section number 4 in March 1973.

Finally, a substantial number of changes have been made in the column to improve the electromechanical connections. Basically, the need for such improvements stems from the fact that $SF_6$ gas is an excellent insulator and connections which are adequate in an atmosphere of ordinary air turn out to be excellent insulators with $SF_6$ insulation. The effect of these poor connections is that equipotential planes of the accelerator are not fixed at the design potential, but rather fluctuate randomly inducing local discharges and beam position instabilities. Most of these poor connections have now been corrected.

A statistical evaluation of the generator performance is shown in Figures 10, 11 and 12 for the years 1970, 71 and 72; the improvement with time is obvious. It should be noted that the peak at 5.3 MV during 1972 relates to $(^3He,n)$ pulsed beam runs.

3) Test carried out by Dr R.Hyder at Oxford University, using four sections of similar design in the EN tandem

4) Manufactured by the Cryogenic Technology Corporation, Waltham ,Mass.

5) K.H. Purser,A.Galejs,P.H. Rose,R.J. Van de Graaff,and A.B. Wittkower. Rev.Sci.Instruments 36,453,(1965)

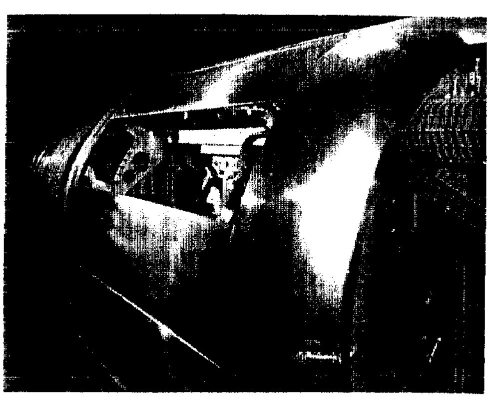
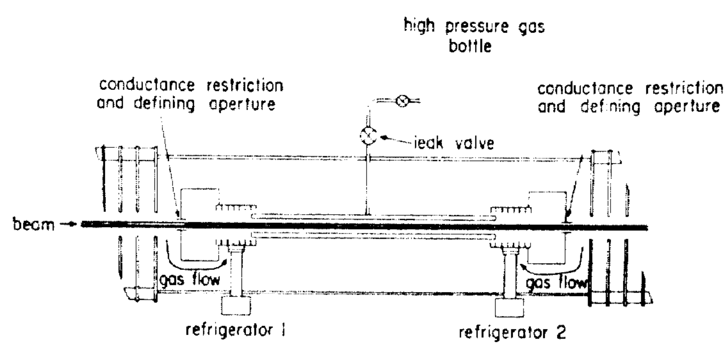


Figure 1.




Cryogenic Terminal Pumping Arrangement

Figure 2.

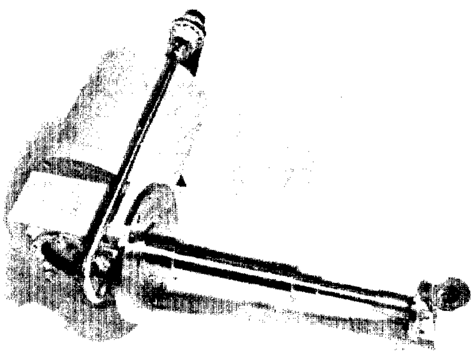


Figure 3.

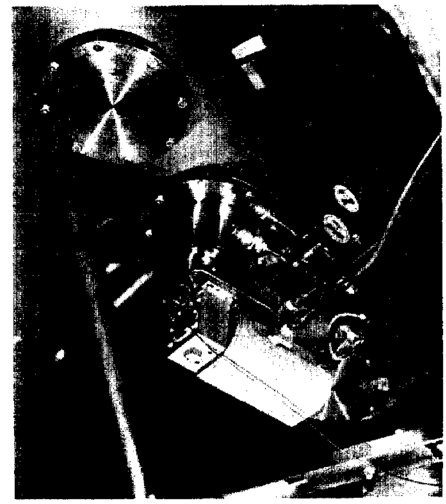


Figure 4.

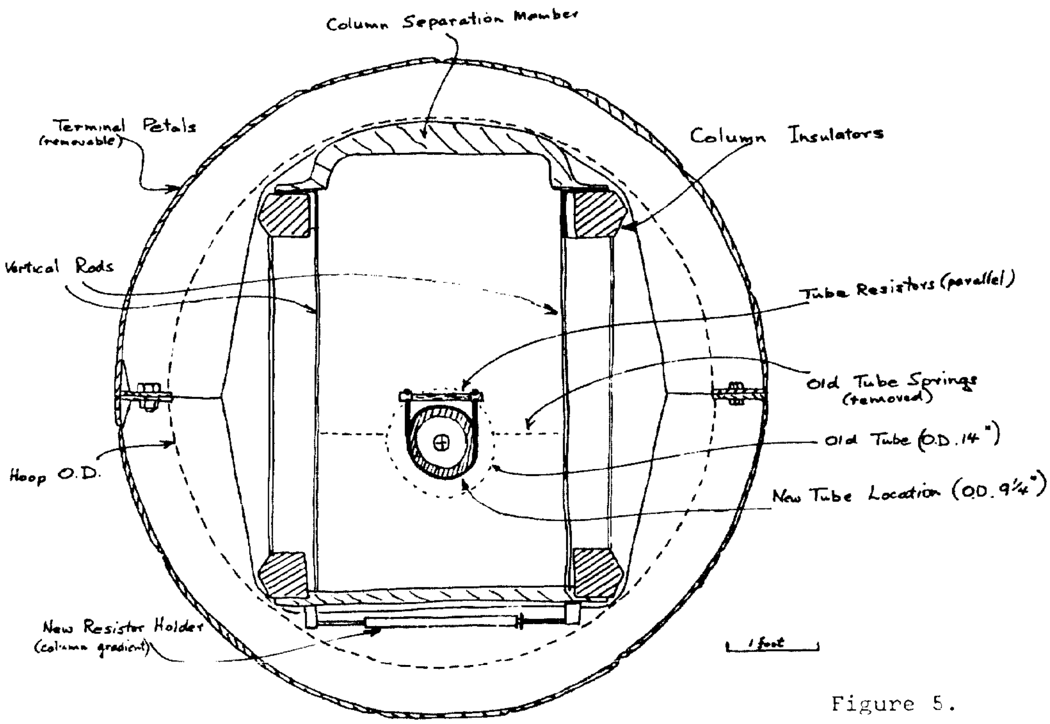



Figure 5.

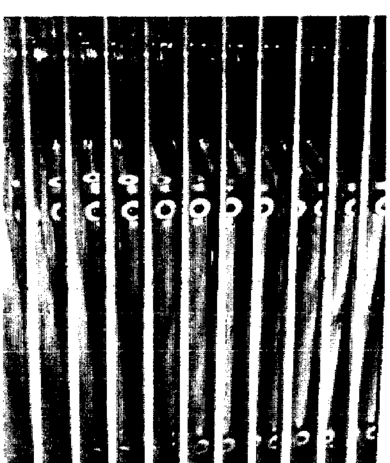


Figure 6.

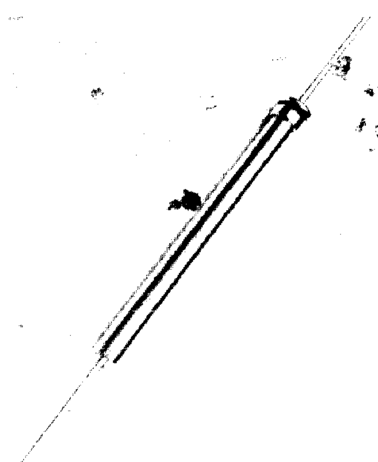


Figure 7.

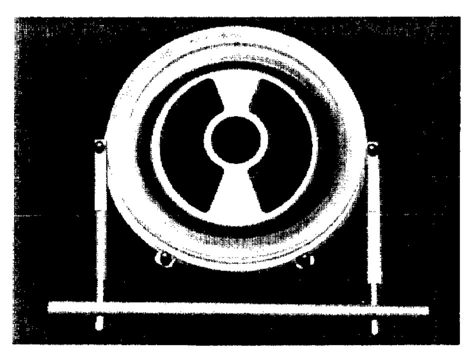


Figure 8.

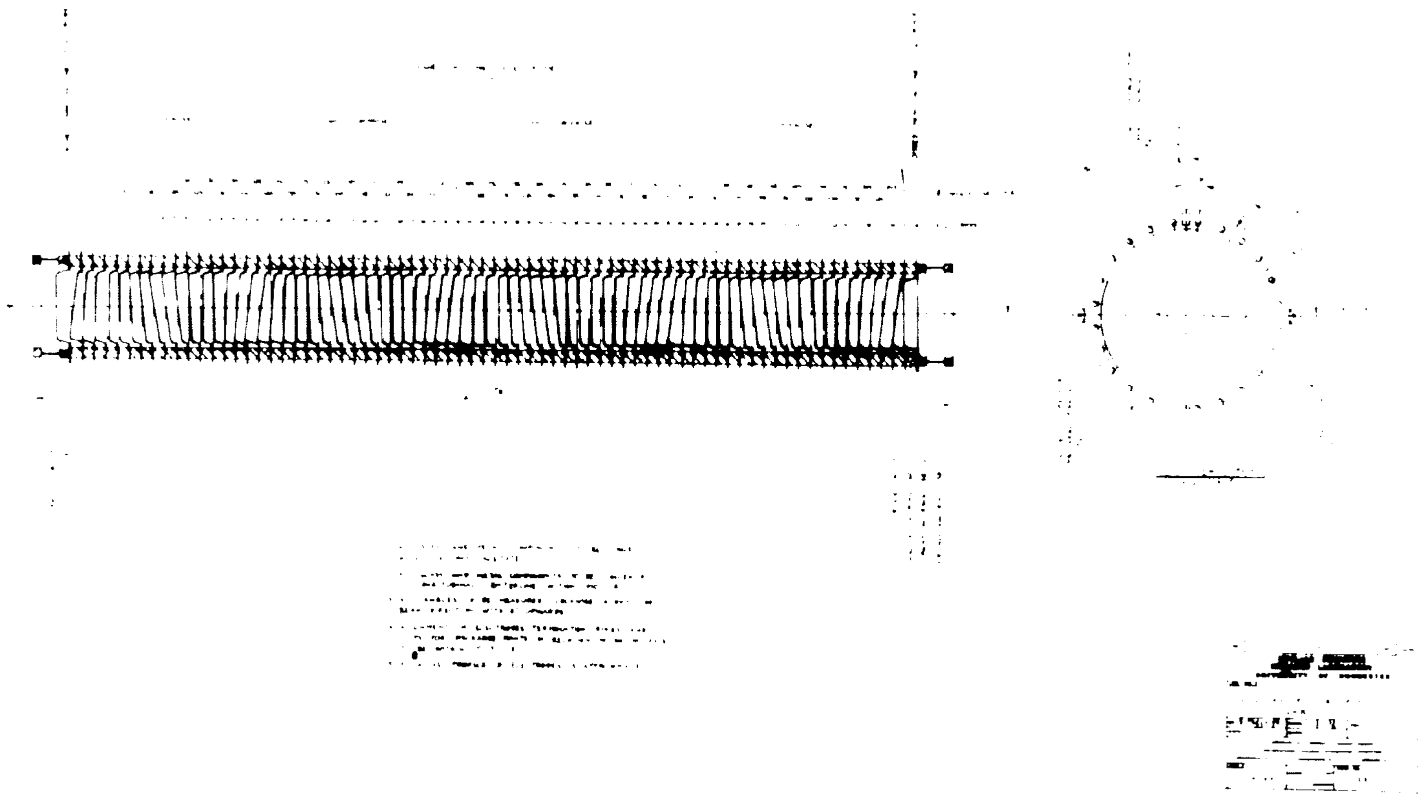


Figure 9.

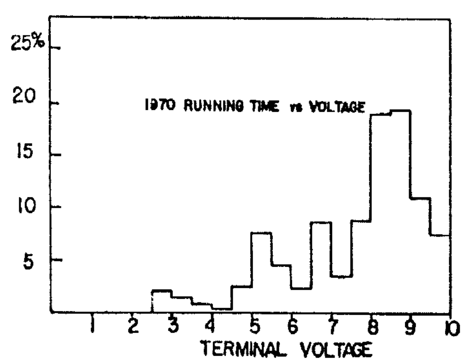



Figure 10.

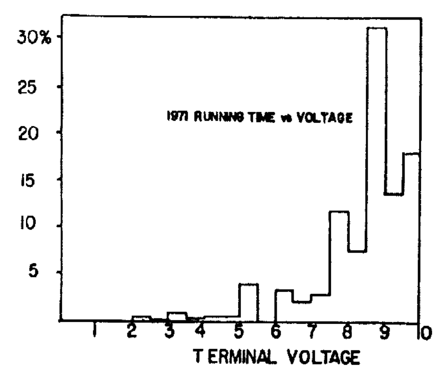



Figure 11.

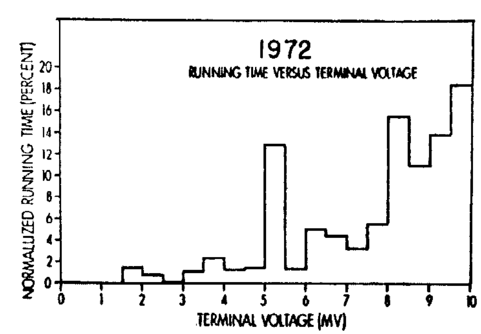



Figure 12.