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THE NEW LARGE TANDEM ELECTROSTATIC ACCELERATORS

James B. Ball
Oak Ridge National Laboratory,* Oak Ridge, Tennessee 37830

Introduction

Those of us who were schoolboys in the late 1930's can remember with some nostalgia those illustrated magazine covers showing the spectacular lightning displays produced by the large electrostatic generators being built by Van de Graaff and co-workers and the feature articles on these giant "atom smashers." To us, these spectacular machines seemed the hallmark of the scientist of that day.

The huge machine built by the MIT group and moved to Round Hill (Fig. 1) had two terminals, each 4.6 m (15 1/3 ft) in diameter and achieved potentials of about 3 MV. The concept of pressurizing such voltage generators, introduced by Herb, provided the advance needed to construct machines with such voltages but on a much diminished physical scale. It is only now in the past decade that we have reached again the dimensions of the early "Round Hill" machine--this time with pressurized machines operating not at a few million volts but at potentials in the 20- to 30-MV range.

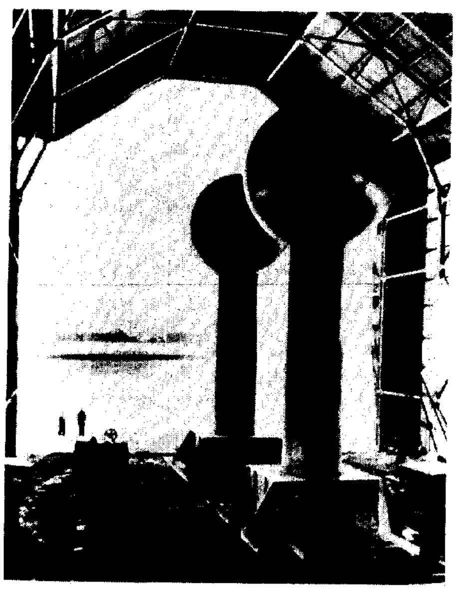

Fig. 1. Installation of the large high voltage generator at Round Hill, Conn. (Courtesy M.I.T. Museum and Historical Collections.)

After a peak of activity of building tandem Van de Graaffs in the 60's, why now this sudden resurgence of interest in electrostatic accelerators and the push to much higher energies? The high beam quality and flexibility of these accelerators makes them ideal for a general purpose research facility, meeting the needs of a diverse group of users. Most particularly, though, the emergence of heavy ion science as a frontier research area has pushed the electrostatic accelerator, with its very versatile negative ion source technology, again to a position of high activity.

The largest of this new generation of machines are listed in Table 1. In this paper I will review some of the special features of these accelerators as well as their present status. In addition, the application of clever techniques introduced at Strasbourg for upgrading some of the existing smaller machines will be discussed.

The Large Accelerators

Daresbury

As conceived in the early 1970's, this accelerator was to operate initially in the range of 20 MV on terminal but to be capable of development to 30 MV. The resultant design study chose the configuration illustrated in Fig. 2. (The scale of this can be gauged by noting the pressure vessel is 45 m high by 8.2 m in diameter.) A unique feature of this design is the intermediate potential shield. It is this intershield that will provide the reduction in radial electric field gradients required to raise the ultimate terminal potential to 30 MV. During the course of constructing this accelerator it has been decided to install this intershield from the outset rather than as a subsequent upgrade.

Table 1. The New Large Electrostatic Accelerators

Location	Design Voltage	Machine Type	Features	Status
Daresbury (DNSF), UK	30 MV	DNSF Design	Intermediate potential shield	Column voltage tests
Oak Ridge (HHIRF),TN, USA	25 MV	NEC 25URC	Folded	Commissioning tests with beam
Tokai (JAERI), Japan	20 MV	NEC 20UR	Folded	Commissioning tests with beam
Buenos Aires, Argentina	20 MV	NEC 20UD	Conventional	Under construction
Legnaro, Italy	16 MV	HVEC TU	Conventional	Commissioning tests with beam

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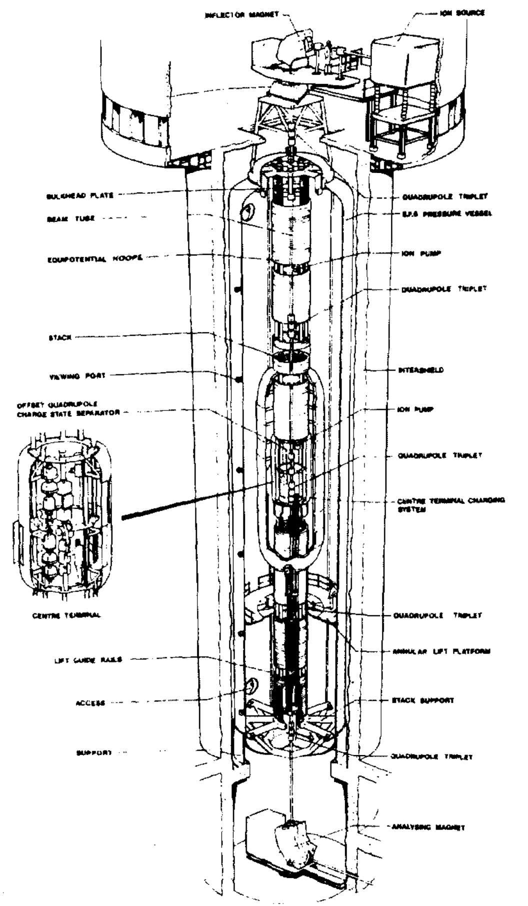

Fig. 2. Cutaway view of the DNSF 30 MV tandem.

The construction of this accelerator is now entering its final stages. Basic testing as a high voltage generator, without acceleration tubes or intershield, was performed in May and June, 1980. Voltage runs were conducted at various gas pressures. The results are summarized in Fig. 3 and compared to the calculated voltage at which sparking was expected to commence. The curve is a prediction based on experience with the 10 MV pilot machine at Daresbury. These results are quite encouraging in that there is no unexpected loss of voltage-holding capability at the higher voltages.

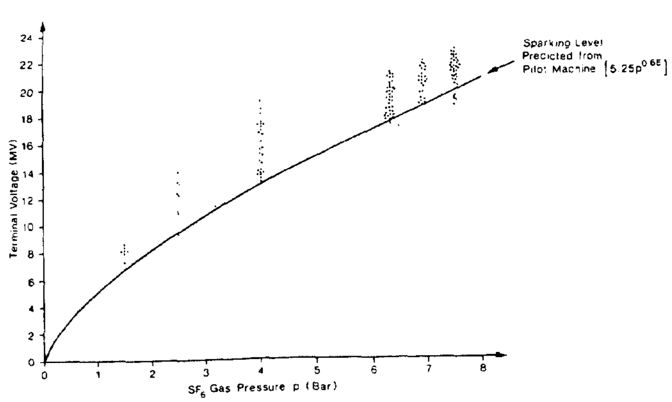

Fig. 3. Results from voltage holding tests on the main column structure of the DNSF tandem.

Following completion of these voltage tests the intershield was installed. Figure 4 shows a view of the installation in progress. At the end of the year, voltage tests were resumed with the intershield in place but still without acceleration tubes installed. These tests have been delayed by various difficulties and, of this writing, are still in progress. Voltages to about 25 MV have been achieved.

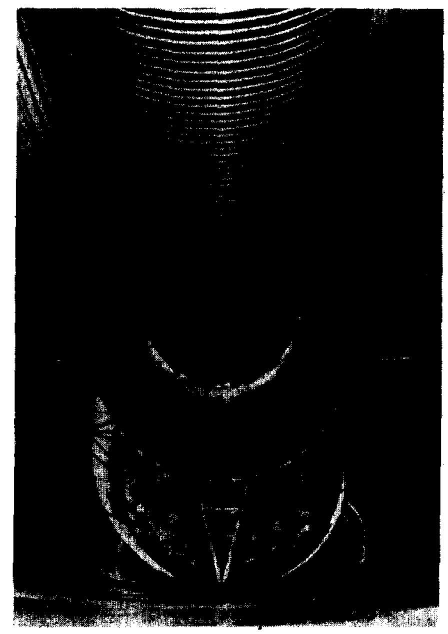

Fig. 4. Installation of the intershield on the DNSF accelerator.

Oak Ridge

The accelerator for the Holifield Heavy Ion Research Facility is the largest of several Pelletrons presently being built by National Electrostatics Corporation (NEC). A special feature of this machine is the "folded" configuration where both the low- and high-energy acceleration tubes are contained within the same column structure. This is illustrated in Fig. 5. Among the advantages seen for the folded tandem are the resultant reduction in pressure vessel size, reduced building height, reduced insulating gas (SF_6) inventory, a welcome reduction in stored energy, and such niceties as putting the ion sources at ground level. Although this configuration depends on proper operation of the 180-deg terminal bending magnet, an examination of Fig. 5 shows the complexity of a machine of this size and that there are, in fact, a large number of components that must operate correctly.

Again, for a size reference, the pressure vessel of this machine is 33 m high by 10 m in diameter. A view of the completed column structure, looking from the top of the pressure vessel is shown in Fig. 6. Voltage tests on the column, without acceleration tubes, were conducted in April and May, 1979. A top potential of 32 MV was achieved. The acceleration tubes were subsequently installed and first beam successfully accelerated through the machine in May, 1980. Since that time, demonstration tests with oxygen and iodine beams have been performed successfully

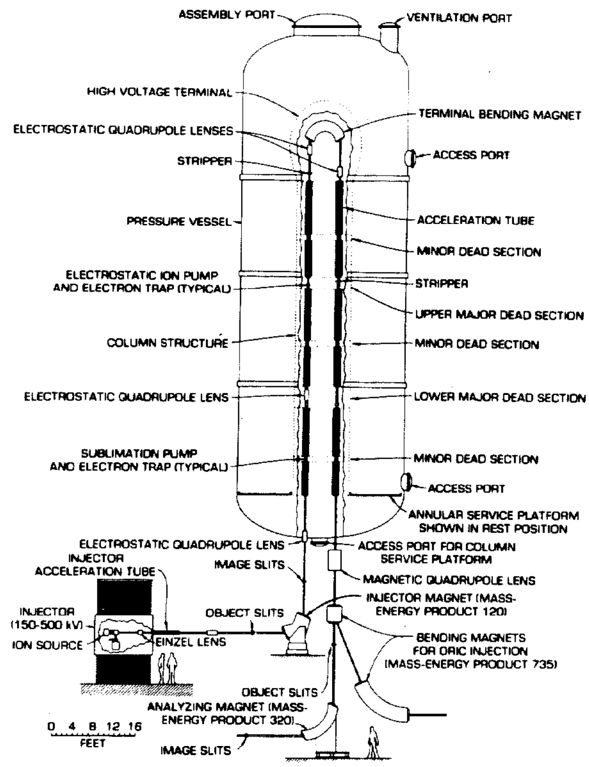

Fig. 5. Schematic view of the 25URC Pelletron.

Fig. 6. View of the high voltage terminal and column structure of the Holifield accelerator.

at specified terminal potentials of 7.5 MV and 17.0 MV. 17.0 MV. At the present time the accelerator is undergoing voltage conditioning in preparation for tests at 25 MV. To date, the highest terminal voltage with accelerated beam has been 21 MV and the highest voltage during conditioning with tubes has been 22½ MV. Further details on this accelerator are presented in the paper by Ziegler, et al., at this conference.

In January of this year, the Pelletron was operated as an injector for the Oak Ridge Isochronous Cyclotron and a 400-MeV oxygen beam obtained from the combined accelerators. More on this operation is presented in a paper by Lord, et al., at this conference.

Tokai

Except for the reduced size, the machine at the Japan Atomic Energy Research Institute (JAERI) is very similar to the Oak Ridge accelerator. One additional feature is a duoplasmatron ion source and fast pulsing system installed in the terminal. This system will be used for high-intensity light-particle beams, in turn to be used for generation of fast neutrons. A view of the 26.6-m by 8.3-m pressure vessel during construction is shown in Fig. 7.

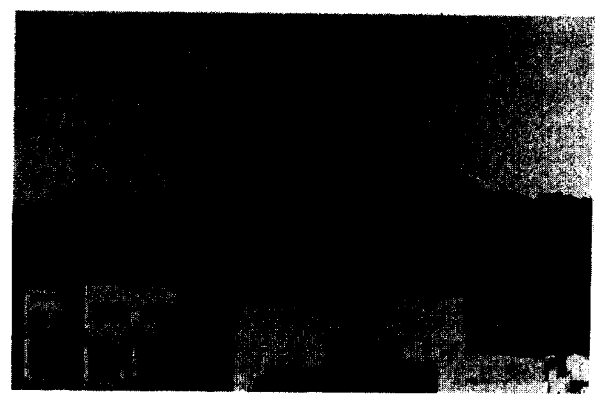

Fig. 7. Installation of the pressure vessel from the 20UR Pelletron at JAERI.

Voltage tests of the column structure, without accelerating tubes, were conducted in December, 1978, with potentials in the 23-24 MV range attained. First successful acceleration of beam on this accelerator was accomplished in October of 1979.

To date, demonstration tests with Cl and I ion beams have been performed at terminal potentials of 5 MV and 13 MV. The highest terminal potential with accelerated beam is presently 17 MV and voltage conditioning to 18½ MV has been achieved.

Buenos Aires

Of the three large machines built by NEC, this accelerator is the only one of conventional design in that it uses the linear configuration. Like the Daresbury machine, it is vertical with the negative ion sources located at the top of the tower housing the pressure vessel. During acceleration of heavy ion beams, charge-state selection following the terminal stripper will, in both linear machines, utilize an offset quadrupole triplet.

The status of this facility is that building construction is nearly complete, the pressure vessel is in place and has been tested successfully, and the accelerator components have been shipped and are in storage at Buenos Aires. Assembly of the column structure inside the pressure vessel is scheduled to begin in April, with voltage tests on the column, without tubes, planned for this September.

Legnaro

This accelerator, manufactured by High Voltage Engineering Corporation, is the only one of the large machines with a horizontal configuration. Rated at 16 MV, this accelerator is now undergoing commissioning tests with beam. Column voltage tests, without acceleration tubes, achieved a top voltage of 20 MV in May, 1980.

This machine has been running with acceleration tubes since late Fall (1980) and has now been conditioned to 14½ MV on terminal.

III. General Features

All of these new accelerators differ in some common areas from the conventional machines of the Sixties. One such area is the charging systems. All of the NEC built accelerators employ the Pelletron charging chains with their alternating conducting and insulating segments. The DNSF and Legnaro machines use an elaboration of this scheme, the Laddertron, developed as part of the Daresbury program. In all of these accelerators mechanical power is transmitted to the terminal and elsewhere throughout the column by means of insulated, rotating shafts and is completely independent of the electrostatic charging system.

Except for the accelerator at Legnaro, another area of significant change is in the control systems. Unlike the earlier servo-mechanical systems often actuated through long insulated rods, the control systems of the largest accelerators are computer based and utilize specially developed infrared digital light-links to communicate across regions of high voltage gradient. These computerized systems are more than a matter of simple convenience. These large machines are far more complex, with many more parameters to adjust and monitor, than their earlier counterparts. The NEC machines have control systems implemented to the extent possible, through standard CAMAC hardware. While also employing CAMAC, the Daresbury control hardware includes many features specially developed by that group. The Daresbury group has also developed quite sophisticated computer based graphics as a part of their operating system. To date, these digital systems have proven to be very effective and quite reliable despite the hostile environment.

An associated area where additional complexity has also become apparent is in the experimental devices associated with these new facilities. This increased sophistication in experiments is illustrated with three examples: Fig. 8 shows a 4π closely packed array of 72 NaI detectors, called a spin spectrometer, at the Oak Ridge Holifield Facility. Fig. 9 shows the newly completed neutron spectrometer at the JAERI facility. Fig. 10, again from the Holifield Facility, shows an interesting combination of technologies where particle and laser beams are used in a nuclear polarization experiment.

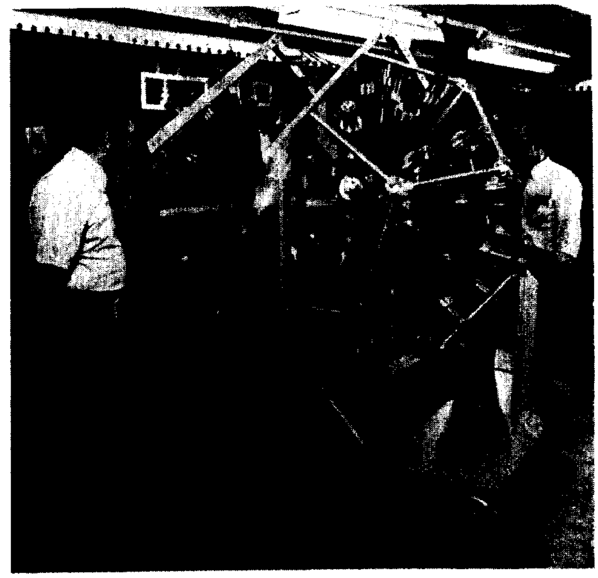

Fig. 8. The spin spectrometer at the Holifield Facility.

Fig. 9. Neutron spectrometer at JAERI.

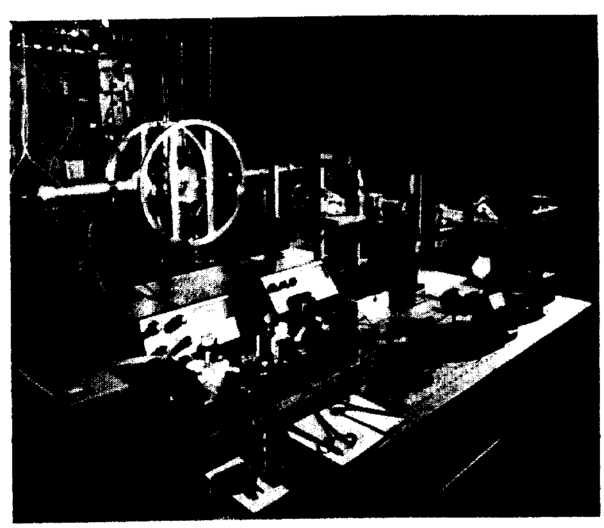

Fig. 10. Laser induced nuclear polarization experiment at the Holifield Facility.

Accelerator Upgrades

This past year has seen a most exciting development at the MP tandem at Strasbourg. Under the guidance of M. Letournel, the accelerator has been reconfigured with "extended" tubes. The general idea is illustrated in Fig. 11. The standard 72-in HVEC tubes have been lengthened by HVEC to 88 in. The Strasbourg group has modified the column dead sections to provide additional "active" space for the tube extensions and the tube and column gradients appropriately distributed. This modification has been completed and has been successful in raising the operating potential of this accelerator from 13 MV to 16 MV. Ahead are plans by Letournel to modify the end sections to accommodate a 96-in tube section and a clever modification to the column to produce an intermediate potential-like distribution, changes which he expects to enable the Strasbourg MP to reach 18 MV on terminal.

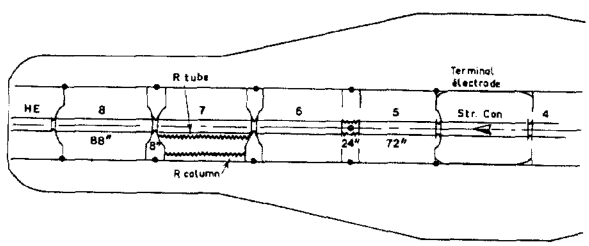

Fig. 11. Illustration of the scheme used at Strasbourg to install 88-inch acceleration tubes in place of standard 72-inch tubes by suitable modifications to the "dead" sections and potential grading systems.

The next application of this idea will be on MP-7 at Brookhaven National Laboratory. This machine will undergo an upgrading beginning this summer which will include 88-in extended tubes and 96-in end tubes. The Brookhaven group has operated MP-7 above 14.5 MV on terminal so that the planned "stretch" should be sufficient to obtain the desired 17 MV terminal potential.

Summary

Of the five large electrostatic tandem accelerators listed in Table 1, four have undergone column voltage tests and three are presently running commissioning tests with full beam capability. None of the machines has yet to achieve the full rated terminal potential with acceleration tubes installed. At this time each of these latter three machines has reached approximately 90% of full rating. The column voltage tests on these machines have given good assurance of the voltage holding capability of the basic generator structure. The ability to reach design voltages now depends on successful performance of the acceleration tubes. Although no clear sign of total voltage effect is indicated at this time, that would lead to degrading the rated tube gradients, the concern remains over the effects of the large amount of stored energy present in these accelerators and the effect of the huge currents generated during voltage breakdown.

Although full rated voltages on these new large machines will undoubtedly take time and patience to achieve, we can expect the first of these machines to begin operating for research purposes during the present year. The era of the large tandems has, in fact, begun.

Acknowledgements

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