T.I.F.R. VAN DE GRAAFF ACCELERATOR

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1. INTRODUCTION

THE Van de Graaff type electrostatic accelerator, in spite of its being in use for many years, retains its usefulness as a tool for research in low energy nuclear physics. A non-pressurized Van de Graaff accelerator cannot yield as high an accelerating voltage as a pressurized one; however, it is much simpler and considerably lower in cost. Work was therefore started on a non-pressurized accelerator at the Tata Institute of Fundamental Research, Bombay, with the two-fold objective of acquiring experience in the construction of electrostatic accelerators and carrying out a programme of research in low energy nuclear physics. The construction of the accelerator has been completed recently. Trial runs have shown that the accelerator, using a Philips Ion Gauge (PIG) type ion source, yields a maximum beam current of 10 μa. of H^+ and H_2^+ ions at a maximum energy of 300 Kev., which is the limit set by its present housing.

2. CONSTRUCTIONAL DETAILS

(*a*) *High voltage generation and measurement.*—An overall view of the accelerator is shown in Fig. 1. The high voltage terminal is a hollow aluminium shell, the top half of which can be lifted up. Its maximum diameter is 5 ft. 9 in. It rests on a vertical insulating column, 6 ft. tall and 28½ in. diameter, consisting of twelve hollow perspex cylinders, separated by nickel-plated brass rings which define equipotential planes. The ground terminal, an aluminium shell which can be split into two halves, is placed on the floor. The charging is done by an endless, rubber impregnated canvas belt, manufactured by Arthur S. Brown Mfg. Co., Tilton, N.H., U.S.A. It is mounted on two pulleys, the lower one being movable for adjusting the belt tension. Positive charge is sprayed on the belt at the ground end from a series of needles connected to a 15 KV. variable D.C. power supply. The lower pulley is rotated at a speed of 4,200 r.p.m. by a 2 H.P. motor, thus

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moving the belt at 4,200 ft./min. Transfer of charge to the upper dome from the belt is accomplished by means of two rows of needles mounted inside the high voltage terminal. The belt is prone to absorbing moisture very readily, thus lowering its resistance considerably. In order to remove this moisture, the belt is heated while it is running by two 2·5 K.W. heaters placed

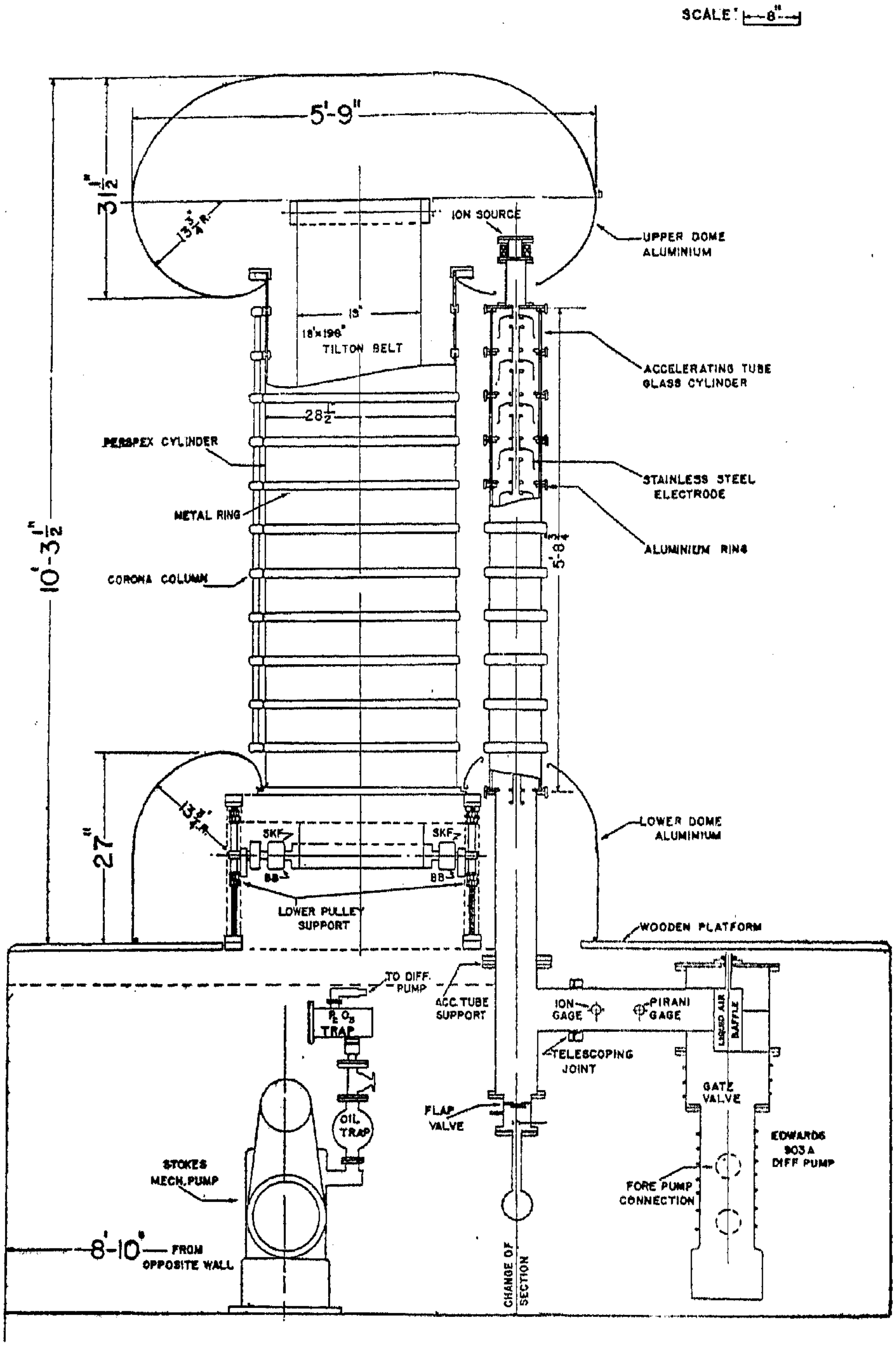

FIG. 1. T.I.F.R. Van de Graaff Accelerator

at the ground end. A second set of pulleys and corresponding motor have also been installed, so that charging can be done by two belts simultaneously if larger charging current is required.

Proper voltage distribution along the insulating column is achieved by means of ten corona needles, assembled and attached to the column as shown in Fig. 2. Brass rods, to which gramophone needles are soldered, are screwed in aluminium holders which are attached to the metal rings which define the equipotential planes. For varying the voltage distribution, each corona gap may be varied by screwing the needle in or out. During trial operation, each corona gap was set so as to spark over at a voltage of $\approx$50 KV across the gap. The corona gap thus served also as a protective device for the accelerating tube and the support column, by not allowing the voltage across any one section to exceed 50 KV.

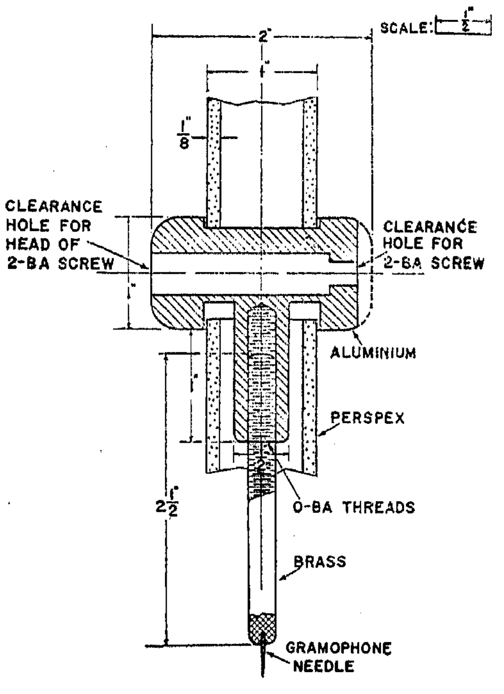

FIG. 2. T.I.F.R. Van de Graaff Accelerator Corona Needle Holders

Voltage on the high voltage terminal is measured by a generating voltmeter fixed to a vertical column near the accelerator. The signal of 200 cycles/second, generated in the voltmeter, is measured after amplification by an R–C coupled A.C. amplifier. A calibration curve was obtained by observing the signal for one suitable range of amplification, when the high voltage terminal was charged to known voltages by a 25 KV. power supply. Higher voltages could then be measured by using the same calibration curve, but different ranges of amplification. Relative amplifications for different ranges were determined independently using known signal voltages. It is estimated that voltages measured in this manner are accurate to ± 15%.

(*b*) *Accelerating tube.*—For the design of a good accelerating tube, the following features must be considered: (i) Impedance to pumping must be small so that high vacuum can be maintained inside the tube, (ii) Electron loading must be prevented by minimising continuous paths for the electrons to travel up the tube, and (iii) Accelerating gaps must be electrically shielded, to stop any local field from affecting the beam.

The accelerating tube here consists of ten identical sections, one of which is illustrated in Fig. 3. The insulator is a Pyrex glass cylinder, of $7\frac{1}{2}$ in. outer diameter and $\frac{3}{8}$ in. wall thickness. Aluminium end plates, $\frac{1}{2}$ in. thick, are attached to the two ends of the cylinder with cold setting araldite (Araldite Adhesive 103, CIBA Company, Bombay). The joint thus obtained is vacuum-tight and mechanically strong. Locally made neoprene O-rings are used

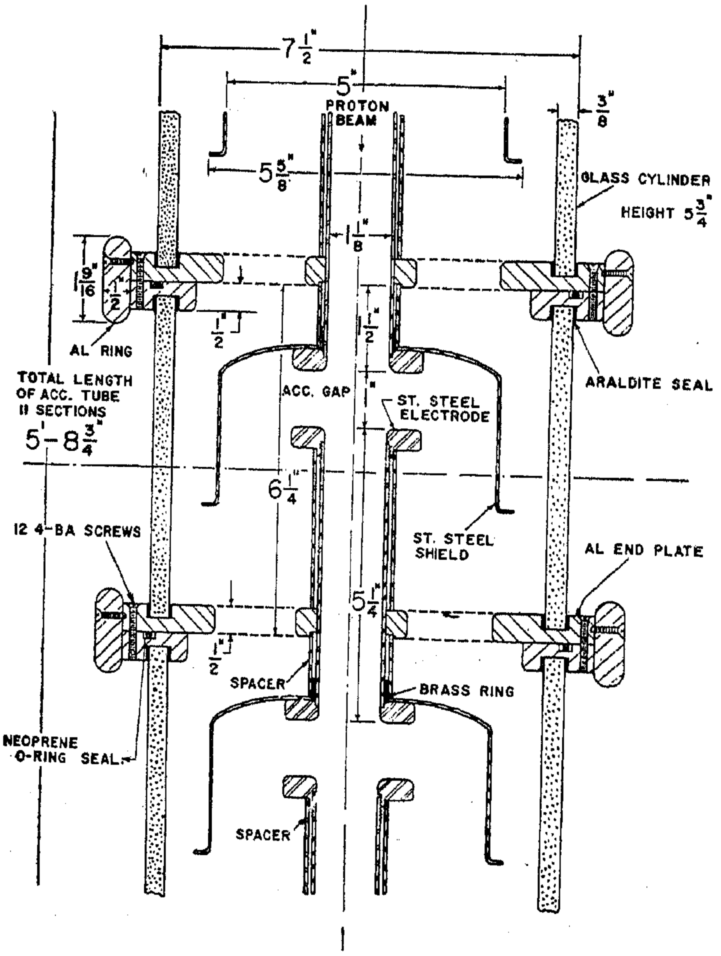

FIG. 3. T.I.F.R. Van de Graaff Accelerating Tube

between two sections for a vacuum seal. The electrode assembly, made of stainless steel, provides a uniform aperture of $1\frac{1}{8}$ in. diameter for the beam traversal and an accelerating gap of 1 in. per section. Aluminium rings with rounded ends cover the edges of end-plates at the joints between two sections. They are electrically connected to the metal rings of the support column, which define equipotential planes. Accelerating voltage is thus applied across each of the accelerating gaps.

(*c*) *Ion source and control system.*—A Philips Ion Gauge (PIG) type of ion source is used because it is extremely rugged and capable of giving large beam currents. The design is shown in Fig. 4. In a stainless steel chamber, of $1\frac{5}{8}$ in. inner diameter, a Philips type discharge is produced. An axial magnetic field is obtained by using a cylindrical permanent magnet and cylindrical pole pieces of iron. The anode is a ring of $\frac{1}{4}$ in. diameter

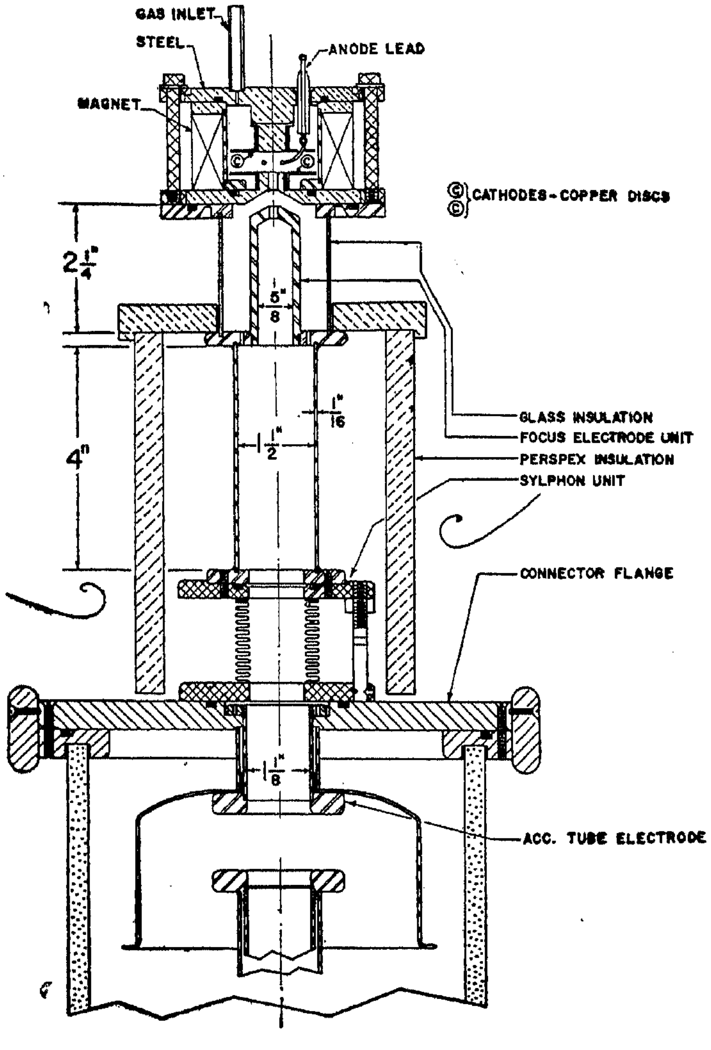

FIG. 4. T.I.F.R. Van de Graaff Accelerator Ion Source

made from 1/16 in. diameter copper wire. The ions produced come out from a 3/16 in. diameter hole in the lower pole face which is also the lower cold cathode. The emerging ion beam is then focussed by the focus electrode.

Anode and focus voltages are supplied, respectively, by 5 KV. and 25 KV. D.C. power supplies, situated on a platform inside the high voltage shell. Power is obtained from a 1 K.W., 1,600 cps. self-exciting generator, driven by a V-belt connected to the upper charging belt pulley. In order to vary the voltages from ground, power supply variacs are coupled to perspex tubes of 1 in. outside diameter, which go down to the ground end, where they are coupled to geared down reversible motors. These motors can be operated in either direction by means of spring switches on the control panel, thereby varying the voltages as desired. Control rod positions are remotely indicated by using potentiometers attached to them at the ground end.

Hydrogen gas to the ion source is supplied from a gas tank situated at the ground end and connected to the ion source through a garflex tubing. Gas flow is adjusted by means of two needle-valves, one of which can be controlled from the ground. This control and its indication are achieved by means of arrangements similar to those used for ion source voltage controls.

(*d*) *Vacuum system.*—The pumping system is situated in the experimental pit situated below the accelerator, as shown in Fig. 1. Edwards 903 A diffusion pump connected to a Stokes microvac model F mechanical pump through a P_2O_5 moisture trap, is used for obtaining high vacuum. Ion source, accelerating tube and its support tube made of brass are pumped through a liquid air baffle and a gate valve. Pumping speed of the diffusion pump with the gate valve attached is 900 litres/second at a pressure of 1×10^{-5} mm. of Hg. Pressure measurement up to 10^{-3} mm. of Hg is done by an Edwards Pirani Gauge; pressures lower than 10^{-3} mm. of Hg are measured by an Edwards ionization gauge. With the gas flow to the ion source closed off, a pressure of 1×10^{-5} mm. of Hg can be obtained in about two hours. After prolonged pumping, a pressure of 7×10^{-6} mm. can be obtained.

3. OPERATION

After pumping down the accelerating tube and drying the belt, high voltage shell is charged up and the ion source controls are adjusted to yield a focussed beam spot of $\approx \frac{1}{4}$ in. diameter on a piece of quartz situated at the ground end. For measuring the ion beam current on a microammeter quartz is rotated out of the beam path and replaced by a current collector.

The ion beam current consists of protons as well as molecular hydrogen ions. Without a magnetic analyser, it is difficult to know the percentage of each component. Operational characteristics of the accelerator at two different accelerating voltages are given in Table I.

TABLE I

Accelerating voltage	120 KV.	300 KV.
Ion beam current	40 μa.	9 μa.
Pressure	3×10^{-5} mm. of Hg	$4{\cdot}2\times 10^{-5}$ mm. of Hg
Ion source anode voltage	$\approx$ ·4 KV.	$\approx$ 1·5 KV.
Ion source focus voltage	$\approx$ 6 KV.	$\approx$ 8 KV.

The beam current is steady and it can be maintained at a fixed value by occasional manual adjustment of controls. The accelerating voltage tends to drift slowly until a temperature equilibrium is established and the charging belt is thoroughly dry; however, this can be compensated for by adjusting the charging voltage. There is periodic variation of accelerating voltage due to oscillations of the charging belt. It is planned to install a voltage stabilizing system for correcting such voltage variations.

4. CONCLUDING REMARKS

Under ideal conditions of operation, upper limit of the accelerating voltage of a non-pressurized Van de Graaff accelerator is set by the insulating components of the machine. In the present case, however, corona current losses from the high voltage shell are high, since the shell is less than 4 ft. from the sides of the room. High humidity in the room, not an unusual occurrence in Bombay, increases the surface leakage on insulators. As a result, a large fraction of the charge carried up by the belt is drained away and the attainable accelerating voltage is low.

In order to increase the attainable accelerating voltage, a second belt has been installed so that more charge can be sent up. Characteristics of the machine have changed considerably after installing the second belt and tests are under way to obtain the optimum performance. However, it is doubtful if the accelerating voltage can be increased beyond 500 KV. In a bigger, dehumidified room, it may be possible to obtain about a million volts without much difficulty.

It is of interest to note that the effort spent in developing the accelerator amounts to about 8 man-years of work by the scientific staff and 6 man-years of work by the workshop staff. The cost of equipment and materials used in the machine is about Rs. 50,000.

5. ACKNOWLEDGMENTS

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