THE PELLETRON ACCELERATOR

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Summary

A review is given of early development work at the University of Wisconsin on electrostatic accelerators insulated by high pressure gas. This work started in 1933 and led in 1940 to a 4.5MeV accelerator.

Starting in 1946 development work was initiated along three lines: 1) Bakeable high strength metal to ceramic bonding, 2) Organic-free pumping, 3) Metal charge carrying devices. In 1951 construction was started at the University of Wisconsin on an accelerator utilizing results of these three development programs.

In 1965 much development work was transferred to the National Electrostatics Corp. where the charging chain was developed. It consists of metal cylinders joined by links of solid insulating material. A 1MV column support unit was perfected which is used to construct column modules. A bakeable all metal and ceramic tube, free of organic vapors was developed. It consists of short sections bolted together with three sections per column module.

A three-stage accelerator was built and was tested with a beam up to energies of 22MeV. A two-stage accelerator to provide 28MeV protons (14MV on terminal) is under construction. A two-stage accelerator to give 40MeV protons (20MV on terminal) has been designed.

Early Development

A brief discussion of development work at Wisconsin over a period extending back to 1932 is first given because of the bearing of this work on design features of Pelletron accelerators.

Following shortly after publication of first results by Van de Graaff, Dr. G. G. Havens at the University of Wisconsin initiated work on a belt charged machine utilizing vacuum insulation for isolation of the terminal from the enclosing tank. The author joined in this work. A generator was built and in tests conducted over a period of about one year, a potential of 300KV was achieved. The voltage limitation was determined by vacuum discharge. There was no understanding of the discharge mechanism.

Conversion of the accelerator to utilize high pressure gas insulation was initiated by the author in 1933 and D. B. Parkinson and D. W. Kerst joined in this work. The accelerator of Figure 1 was completed in 1934[1]. The advantage of adding CCl_4 to high pressure air was discovered and with this mixture a potential of 1MV was achieved. An accelerating tube and ion source were developed and a Li(p,α) excitation curve was extended to 400KeV which was the upper energy limit permitted by the accelerating tube.

In 1936, D. Parkinson and D. W. Kerst[2] and the author initiated work that led, in 1937, to the machine of Figure 2. This accelerator introduced a radical departure from the geometry of Van de Graaff. Support members, belt and accelerating tube were enclosed in a region of uniform field provided by a ring system. This was the first "column". The form of modern accelerators was largely determined by this 1936 development. This machine operated with a beam up to 2.6MV. Developments at Wisconsin over the next few years, in which J. L. McKibben and C.M. Turner made major contributions led to rebuilding of the 1936 accelerator and provided in 1940 a new accelerator which operated with a beam up to 4.5MV[3]. This machine was utilized at the Los Alamos Scientific Laboratory from 1943 to 1946 and served at Wisconsin as the major facility for nuclear physics research from 1946 until 1960 when an HVEC EN accelerator was put into operation.

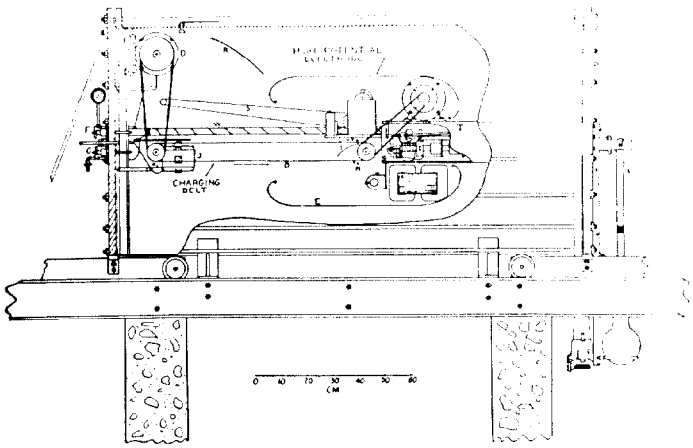

Fig. 1. First electrostatic accelerator insulated by high pressure gas, 1934.

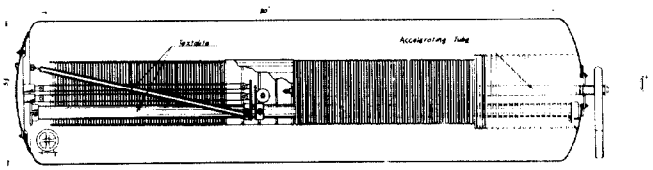

Fig. 2. First accelerator with "modern" column, 1937.

Later Development

Soon after resuming work at Wisconsin in 1946 the author initiated a development program directed toward improvement of electrostatic accelerators. This work was directed along three principal lines as follows:

1. Toward development of organic-free vacuum pumping methods to permit elimination of the diffusion pump.

2. Toward development of bonding techniques that would provide an all metal and ceramic accelerating tube, free of organic vapors.

3. Toward provision of metallic charge carriers and

elimination of charging current fluctuations and of the dust and lint of charging belts.

This program led to the development of the first successful getter-ion pump[4], Figure 3, to the first successful high temperature bonding of large alumina ceramic insulators to metals[5,6] and to the first successful use of metal charge carriers for multi-million volt application[6].

Figure 4 shows an accelerator designed in 1951 and built at Wisconsin utilizing these developments[6].

The accelerating tube utilized Al_2O_3 rings, coated with TiH_2 and bonded to molybdenum disks with a Cu Ag eutectic solder. Support posts also used this solder for bonding Al_2O_3 rings to Kovar disks.

The vacuum pump utilized Ti wire fed to the end of a rod heated by electron bombardment to provide continuous evaporation. Ion pumping was provided by a grid ionizer.

Metal charge carriers were paper staples fastened in an array onto a rubberized fabric belt. Charging was by induction. This method was first successfully tested by D. Ralph, then a student at Wisconsin.

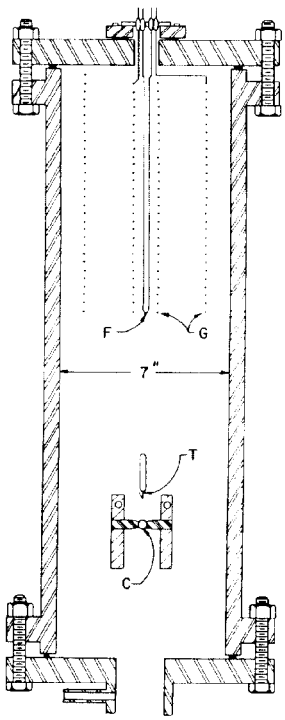

Fig. 3. First successful getter-ion pump. Titanium wire, T, is evaporated from the graphite crucible, C, to provide gettering action. Ion pumping is accomplished by a grid ionizer, G, utilizing electrons from filament, F.

For insulating gas a mixture of SF_6 and N_2 was used and potential distribution was provided by corona points enclosed in an all metal and ceramic tube to provide control of current drain by adjustment of corona tube pressure.

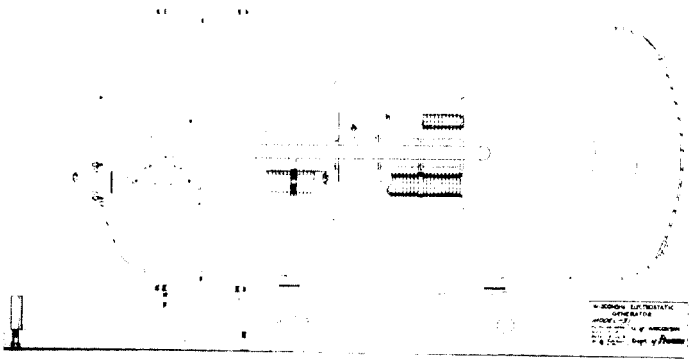

Fig. 4. First accelerator utilizing all metal and ceramic accelerating tube, metal charge carriers, and getter-ion pumping, 1955.

Without the accelerating tube this machine went to 7MV on the terminal. With the tube operating at 5MV discharges caused tube damage. We did not at this time have adequate means for tube protection. Later operation was limited to 3MV on the terminal.

Development work was continued on vacuum pumping, on bonding, on accelerating tube behavior and on charging.

Victor Fung, and later James Ferry, developed successfully "string of beads" charging. Metal cylinders attached to a cord of twisted nylon lines operated successfully between a set of pulleys in gradients of 1.5MV per foot.

A. Isoya[7], who visited at Wisconsin, adapted this charging method for a 7MV accelerator.

In 1965, development work on charging methods, on bonding, on accelerating tube behavior and on vacuum techniques was undertaken at National Electrostatics Corp.

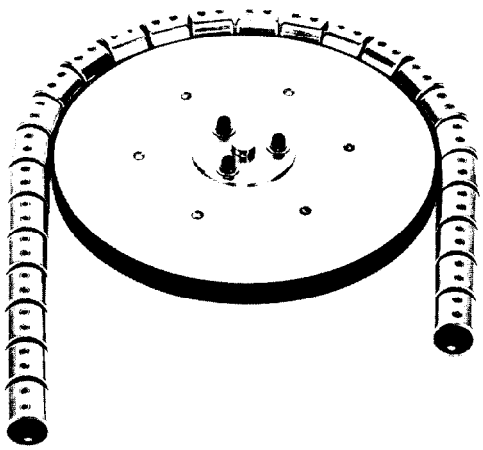

Fig. 5. Charging chain developed by National Electrostatics Corporation, rated at 150μa.

The Pelletron

Charging

The "string of beads" evolved at NEC to the charging chain of Figure 5. Here metal cylinders with rolled ends are connected by solid links of insulating material such as nylon. Charging pulleys are conducting or have a conducting rim and charge transfer takes place before the metal pellets leave the pulley or after they make contact on the return run. Charge transfer is controlled by U-shaped inductors that are arranged so that there is no sparking. Commonly, charge is balanced on the two runs of the chain. The chain of Figure 5 operating over pulleys of 30cm diameter is rated at 150μa. Chain life is very long with limits not yet determined. There is very little dust and no lint and voltage fluctuations due to charging are very low.

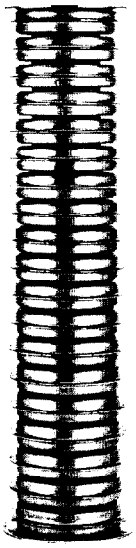

Fig. 6. All metal and ceramic insulating support post developed by National Electrostatics Corporation.

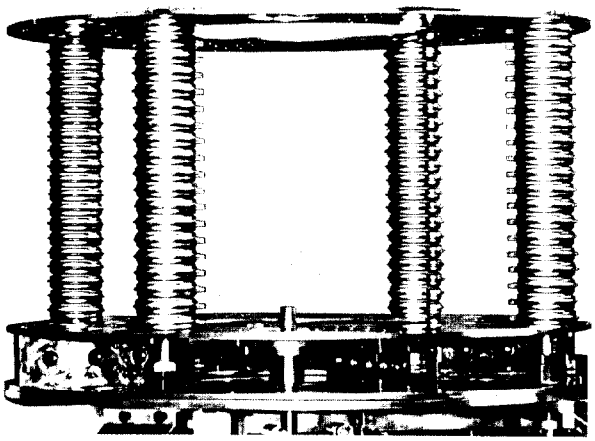

Fig. 7. Column module composed of four identical and interchangeable support posts bolted to metal coupling and transition sections. Each module with accelerating tube (not shown) carries a rating of one million volts.

Insulating Support Posts

Column support is provided by insulated posts, Figure 6, of laminated Al_2O_3 porcelain and Ti metal bonded with a metal. Posts have a modulus of 2.54 cm and are 45.7 cm long. Metal toroids projecting beyond the porcelain provide very complete spark gap protection . Tests included heating in an oven to about 75°C followed by sudden immersion in liquid nitrogen, followed by oven heating and then a tension test to 6000 kg force, without failure. All support posts are identical and interchangeable.

Machines over a broad range of sizes are made up by stacked support modules as shown in Figures 7 and 8. Each column module normally carries a rating of one million volts.

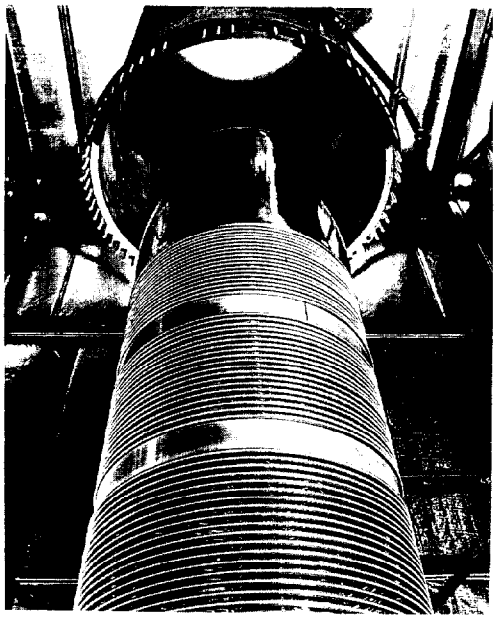

Fig. 8. View of upper three modules and high potential dome of model 4U single stage accelerator constructed for the University of Sao Paulo, Brazil, by National Electrostatics Corporation.

Accelerating Tube

NEC's standard line accelerators utilize accelerating tubes made up of sections as shown in Figure 9. Each section has a modulus of 1.27 cm and utilizes Al_2O_3 porcelain bonded to Ti metal disks with a metal bonding agent. Each bonded ring has four notches spaced around its inner rim. Internal electrodes with clamping projections are inserted after bonding and are locked into position. They are removable.

Three of the Figure 9 sections bolted together utilizing metal gasket seals occupy one column module. Between adjoining sections a decoupling diaphragm is inserted. Pumping speed through the tube is equal to that of a tube of about 6cm diameter.

Before operation and after letting up to moist air the tube is baked to a moderate temperature.

After a short conditioning period the tube easily holds 1MV per column module and voltage additivity is excellent. No inclined electric field and no magnetic fields are used.

The tube will tolerate gases such as argon, hydrogen, nitrogen or oxygen at relatively high pressures but they are not needed to suppress electron loading. Tubes have been operated at pressures of 2×10^{-8} torr. Small quantities of organic vapors are tolerated but large quantities cause electron loading.

All tube sections are identical and interchangeable. One tube section can be removed from an NEC accelerator without removing the rest of the tube. Internal electrodes can be removed from a tube section for inspection and ceramic surfaces can be sandblasted.

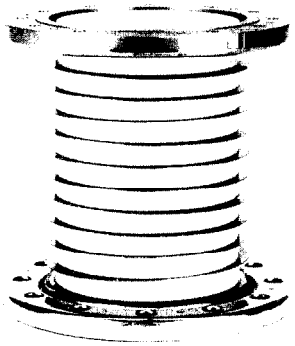

Fig. 9. All metal and ceramic accelerating tube shown without spark gaps. Three of these sections bolted together using metal gaskets occupy one column module.

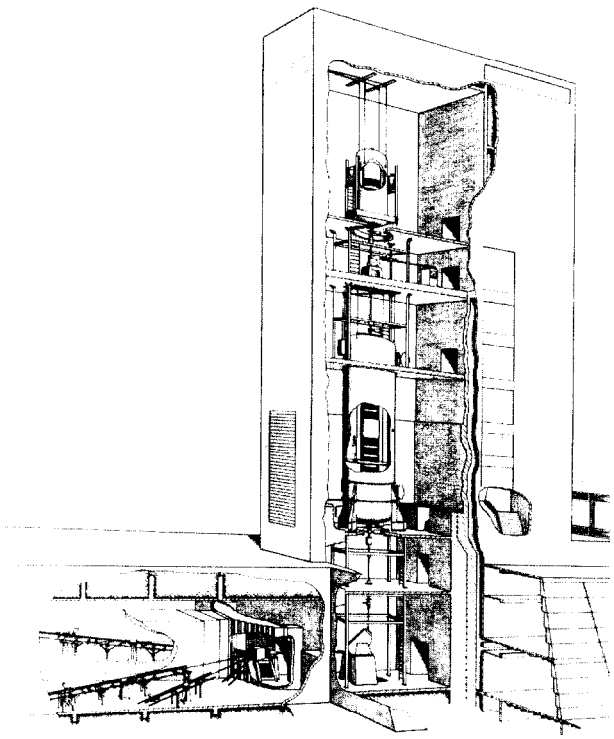

Fig. 10. Three stage 22MeV Pelletron accelerator facility built by NEC for the University of Sao Paulo, Brazil.

Pelletron Accelerators

Accelerators covering a broad range of sizes can be assembled utilizing the 1MV modules. Figure 10 shows a three-stage facility constructed by NEC which is now being assembled at the University of Sao Paulo. With +9MV on the 8UD unit and -4MV on the injector the facility provided 22MeV protons in tests at NEC.

A Pelletron, Model 14UD, guaranteed to operate with 14MV on the terminal is now under construction for the Australian National University. NEC now offers two-stage accelerators utilizing up to 20 column modules extending from ground to terminal and operating with 20MV on the terminal, Figure 11.

The smallest accelerator we have built with pellet chain charging is the 300KV electron accelerator shown in Figure 12, which will be utilized for high resolution neutron time-of-flight work.

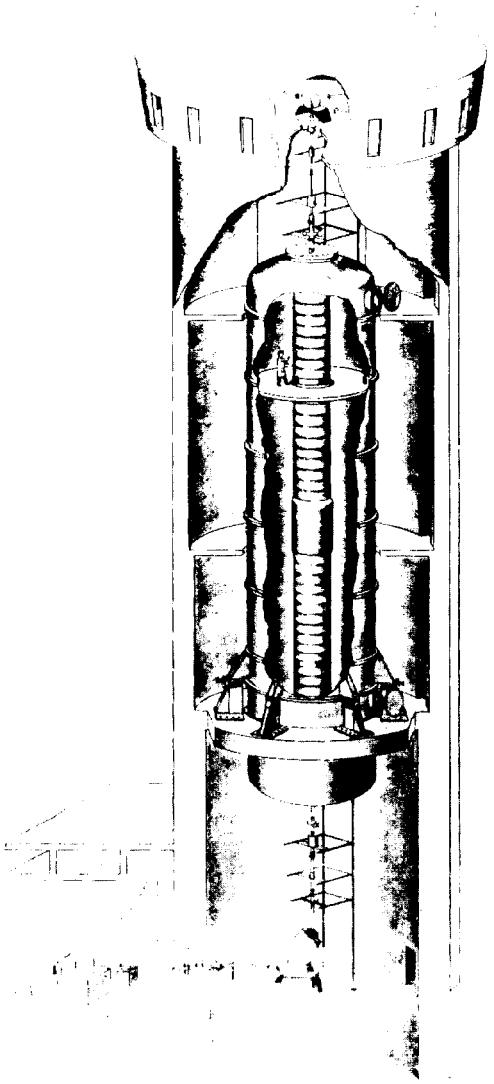

Fig. 11. Proposed model 20UD two-stage Pelletron operating with 20MV on the terminal would produce 40MeV protons.

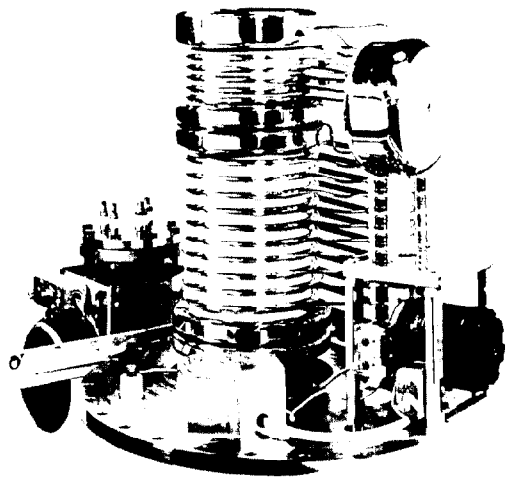

Fig. 12. A 300KV Pelletron is connected to an NEC fabricated, all metal and ceramic tube (15.24 cm. O.D.) in which light from a fast scintillator strikes the broad spherical photocathode and ejects electrons which are focused into a tight beam, accelerated to 300KeV, passed through a one mil aluminum foil into atmospheric air and onto a solid state detector. This "fast phototube" is used for high resolution neutron time-of-flight work.

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