

O_2^- , the mass and approximate radius corresponding to a bimolecular oxygen ion is substituted, the value of 2.94 is obtained for the mobility. In this calculation, the value of A is relatively insensitive to changes in σ and the factor $((m+M)/M)^{1/2}$ plays the important role. The relative difference between this value and that calculated for a monomolecular ion is nearly the same difference as observed experimentally. Thus it is suggested from this data that within the first 2×10^{-4} second, *the addition product to the initial monomolecular negative ion in O_2 is a molecule whose molecular weight is between 15 and 35*. This suggests either H_2O or O_2 . Subsequent ions have lower mobilities due either to the attachment of further molecules of impurity or the transfer of charge to some bulky impurity molecule inevitably present in the most stringently purified gas. Under such circumstances the factor A plays an increasingly important role, and the mass factor a lesser one.

Similar calculations may be carried out for air. If an ion be assumed of the same mass and radius which leads to a value of 2.94 in O_2 , a value of 2.88 is obtained for the mobility of such an ion in air. This is slightly lower than its mobility in O_2 and is in accord with the experimental results of 2.85 in O_2 compared to 2.8 in air. It is therefore suggested that the same ion was observed in both cases, and that the failure to observe a faster ion in air was due to the greater ion ages studied.

In N_2O the original ion formed may be O^- . Assuming this to be so, the calculated value for

the mobility is 2.73. This is much higher than the experimental value for the shortest ion ages measured, and therefore such an ion must lose its identity within 10^{-5} second. Using the molecular weight corresponding to the ion $(NO)_2^-$, a value for the mobility of 1.85 is obtained. It must be pointed out that the value of σ for this ion is very uncertain; great reliance cannot therefore be placed upon the calculated value for the mobility. It may be said, however, that the ion at an age of 10^{-5} second apparently has a mass at least that of $(NO)_2$, and increases its mass and diameter but little thereafter.

It has been suggested that in the process of negative ion formation in NH_3 the initial process is the dissociation of the molecule with the formation of NH^- . Although values of σ are not available for this molecule, the high value of the dielectric constant makes A insensitive to variations in σ , and the mass factor plays the dominant role. If an approximate value of 5×10^{-8} cm can be assigned to σ , one finds the mobility of an hypothetical NH^- ion to be 1.25. This is not substantially higher than the fastest mobility observed. If one employs a mass corresponding to $(NH+NH_3)^-$ one calculates a mobility of 1.06 which is obtained experimentally at an age of approximately 2×10^{-4} second. From the shape of the graph, a mobility of 1.25 for extremely short times seems probable. This ion apparently rapidly picks up an additional molecule and in less than 0.001" reaches a stable value of 0.85 which is characteristic of ions in even impure ammonia.

The Development and Performance of an Electrostatic Generator Operating Under High Air Pressure

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A belt type electrostatic generator has been developed which operates in a steel tank, 5½ feet in diameter and 20 feet long, under an air pressure of 100 lb./in.². The generator is provided with a high potential electrode system of a new design which serves both to give a high breakdown potential and to furnish a satisfactory potential distribution along the charging belts and the accelerating tube.

The maximum potential of the generator is about 2500 kv and the highest steady potential at which reliable data have been obtained is 2160 kv. An evacuated tube for acceleration of ions has been developed which withstands the highest generator potential. The apparatus has been successfully used in experiments on atomic disintegration.

INTRODUCTION

A FEW years ago an electrostatic generator of the Van de Graaff type was developed at this laboratory in which the apparatus was operated in a steel tank under high air pressure.¹ Because of the small size of the enclosing tank, the usable potential of this generator was limited to about 400 kv but its numerous advantages indicated the desirability of further development.

During the past year a second electrostatic generator has been constructed utilizing higher pressure and larger dimensions and has been successfully used in disintegration experiments. Although the generator is of the same type as the small generator referred to above, the increased dimensions of the new apparatus presented certain problems in the design of a satisfactory high potential electrode system; and for their solution a new type of electrode has been developed. This paper describes the development and performance of the large electrostatic generator, and because of the importance of the high potential electrode system for successful operation of the generator, considerable space is devoted to a description of its design.

DESIGN OF PRESSURE TANK

From a consideration of the performance of electrostatic generators of the Van de Graaff type developed here and at other laboratories, it was expected that the peak voltage of the proposed generator would be approximately proportional to the diameter of the enclosing tank, assuming a fixed air pressure and sufficient tank length. From this consideration, a tank having a very large diameter would be desirable but for convenience in operation and low cost of construction, it was decided to install the generator in one of the regular research rooms available at this laboratory. To satisfy this condition the tank diameter was chosen to be 5½ feet and, by making what seemed a reasonable assumption as to the lengths necessary for charging belts and the accelerating tube, the necessary tank length was determined to be 20 feet. The tank² was designed

¹ R. G. Herb, D. B. Parkinson and D. W. Kerst, R. S. I. 6, 261 (1935).

² We are indebted to The Chicago Bridge and Iron Works from whom the tank was purchased for their generous cooperation in working out the details of its construction.

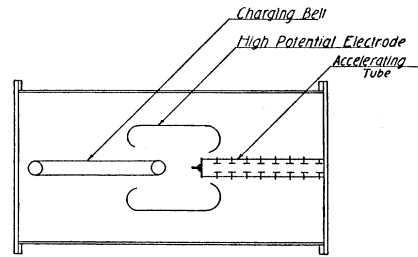


FIG. 1A. Sketch of the small electrostatic generator developed at the laboratory. Because of the short length of the accelerating tube and the comparatively large diameters of the steel tank and the high potential electrode, the tube operates satisfactorily without shielding.

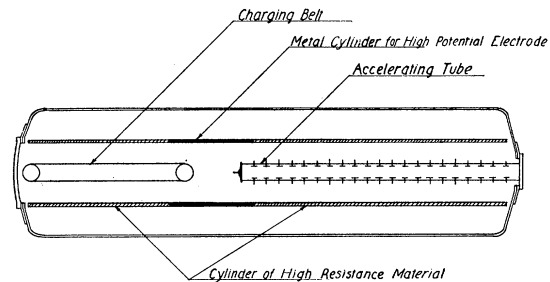


FIG. 1B. The electrode system shown in this sketch, if experimentally realizable, would be ideal for the large generator both to give a breakdown potential and to provide a satisfactory potential distribution along the charging belts and the accelerating tube. Cylinders of high resistance material were thought, however, to be impractical.

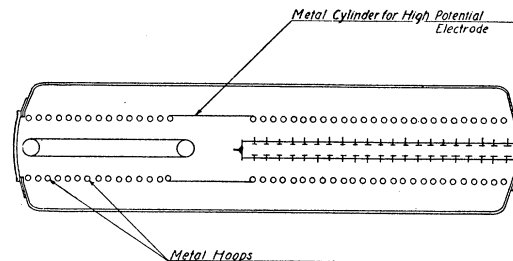


FIG. 1C. This sketch shows the electrode system adopted for the large generator. The hoop system was thought to provide the closest practical approach to the theoretically ideal arrangement shown in B.

for a working pressure of 100 lb./in.², thus giving a total pressure almost twice as high as that used for the small generator referred to above.

DESIGN OF HIGH POTENTIAL ELECTRODE SYSTEM

A length of about 11 feet was considered necessary for the accelerating tube to assure satisfactory performance at the maximum potential expected of the generator. Because of the great length of accelerating tube compared with the 2¾-foot radius of the surrounding tank, a

high potential electrode similar to that used on the small pressure generator (*A*, Fig. 1) would be unsatisfactory, since it provides no shielding for the accelerating tube and a corona discharge would surely take place between high potential sections of the tube and the wall of the tank. Another reason for departing from the usual electrode design is given by a consideration of the inner electrode system which will give a potential distribution most nearly like the potential distribution given by two concentric cylinders infinite in length. Perhaps the closest approach to this ideal potential distribution would be given by an arrangement as shown in *B*, Fig. 1, with a conducting cylinder which is at the highest potential being continued at both ends by a cylinder of high resistance material down which a leakage current flows to give a gradual drop in potential. Such an arrangement, if experimentally realizable, would probably give a breakdown potential close to the breakdown potential between cylinders of infinite length, but cylinders of high resistance material were thought to be impractical and the arrangement *C*, Fig. 1, was considered the best practical way to secure good potential distribution. The conducting hoops as shown in *C*, Fig. 1, must be insulated from one another with provision, however, for a small current from hoop to hoop which can be provided by a system of corona points or resistors of very high ohmage. With this arrangement the potential, which is highest on the main electrode of *C*, Fig. 1, will decrease from both ends of the electrode by a number of discrete steps and will reach ground potential at both ends of the enclosing tank.

In order to decide on the radius of the inner electrode system, use was made of the relation that, for concentric cylinders of infinite length, the radius of the inner cylinder should be given by $r=R/e$ for maximum breakdown potential, where R is the fixed radius of the outer cylinder and e is the base of the natural logarithmic system. This relation would determine a radius of 12.2 inches for the inner electrode system of the large electrostatic generator, but since the breakdown voltage is a slowly varying function of r in the region of optimum r , the radius of the inner electrode system was chosen to be $14\frac{7}{8}$ inches. This larger value of the radius was chosen so as to give ample room for charging belts and a power plant for the ion source.

Simple calculations were made in order to determine reasonable values for the diameter of the tubing from which the hoops were to be made and the air gap between the hoops, assuming the hoops to be made of round metal tubing bent into a circular form. Taking into account only the axial field, these calculations showed that for a generator potential of 3 MV the air gap between hoops could be safely made less than one-half the tubing diameter without danger of sparking from hoop to hoop. To allow for the added effect of the radial field, the ratio of tubing diameter to air gap was finally chosen to be 1.2. With this ratio determined to eliminate axial sparking, the absolute diameter of the tubing for the hoops was chosen partly from a consideration of the size most likely to give a high radial breakdown potential, but principally for convenience of construction. It seemed reasonable to assume that the breakdown potential should improve as

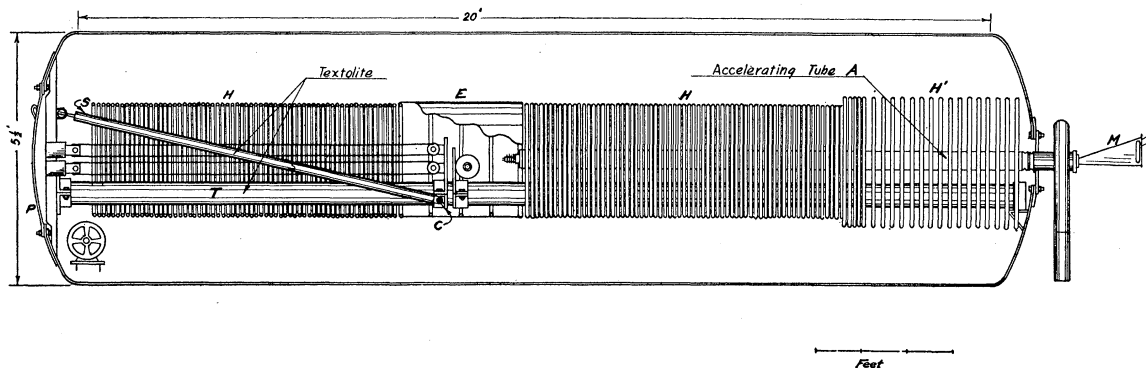


FIG. 2. Electrostatic generator.

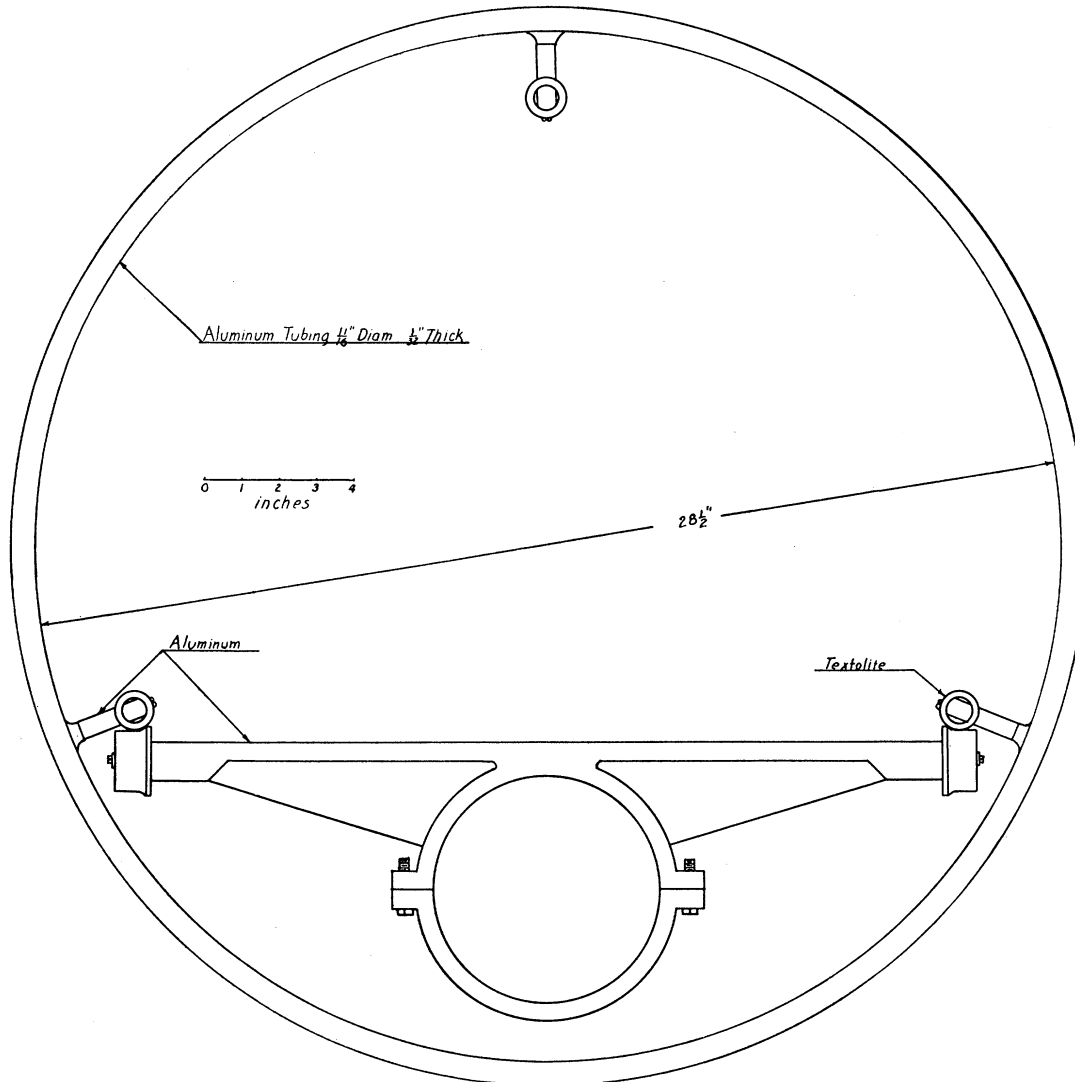


FIG. 3. Aluminum hoop and support.

the hoop tubing diameter and air gap become smaller, with their ratio held constant, since in the limit, with the hoop system degenerated into a system of closely spaced rings of fine wire, the potential distribution out a short distance from the system would be much like the potential distribution given by ideal cylinders of high resistance material. To best fulfill the conditions outlined above, of convenience of construction and high radial breakdown potential, the hoop tubing was chosen to have an outside diameter of $\frac{11}{16}$ inches and the hoops were spaced to have an air gap of $\frac{9}{16}$ inches.

DETAILS OF CONSTRUCTION OF HIGH POTENTIAL ELECTRODE SYSTEM

In Fig. 2, the general arrangement of the high potential electrode system is shown, but to avoid confusion, many of the details are not included in the diagram. Mechanical support for all inner apparatus is provided by the textolite tube *T* which has a 6-inch outside diameter and a $\frac{1}{4}$ -inch wall thickness, and extends along the entire length of the tank. For additional rigidity, two textolite tension members *S* with a $2\frac{1}{2}$ -inch outside diameter and a $\frac{1}{4}$ -inch wall thickness run parallel to each other from opposite sides of the

aluminum casting *C* to an angle iron support at the end of the tank. These two textolite tubes are spaced $17\frac{1}{2}$ inches apart, from center to center, leaving sufficient free space for the charging belts.

The hoops are made from straight aluminum tubing, half-hard, $\frac{1}{16}$ -inch outside diameter and $\frac{1}{32}$ -inch wall thickness, bent into accurate circles and soldered with Kester aluminum solder. Each hoop is provided with 3 soldered studs as shown in Fig. 3 and by means of three small textolite tubes, the hoops are connected into rigid cylindrical sections with a total of 4 sections of hoops *H* of Fig. 2. As a frame work for electrode *E*, Fig. 2, five aluminum hoops of the same size as those described above were mounted on 3 textolite tubes to form a section 30 inches long and over this frame, light weight galvanized sheet steel was bent and soldered.

To support electrode *E* and the four hoop sections, aluminum castings fitted with Bakelite rollers, as shown in Fig. 3, are clamped to the large textolite tube *T*, Fig. 2. Eighteen of these castings are used, spaced evenly along the entire length of the textolite tube. The four hoop sections and electrode *E* rest on these rollers and are ordinarily pinned together to form a rigid system with uniform hoop spacing. In order to have all apparatus inside the hoop system and the electrode easily accessible for adjustment or repair, the hoop section *H'*, Fig. 2, was made sufficiently large so that the smaller system *H* can be telescoped into it. Thus by unpinning the system *H*, Fig. 2, in the proper place and telescoping it into section *H'*, a space four feet long is left uncovered wherever needed and is easily accessible. Section *H'* is ordinarily clamped to the end of the tank but may be unclamped, and if the smaller hoop section has been telescoped inside, section *H'* may be made to rest on it and may then be rolled out to have the inner apparatus at this end of the tank uncovered and accessible.

Each hoop is equipped with a needle point and a plate mounted so as to form a corona system with the corona gaps set at about $\frac{1}{2}$ inch and with the needles turned so as to be negative. As all electrical contacts of the hoop system and electrode *E* with the inner apparatus are made automatically, the system can frequently be

unpinned, an adjustment made on apparatus inside, and the system repinned, ready for operation in 3 or 4 minutes. The 3-foot opening in the end of the tank which may be covered by plate *P*, Fig. 2, provides room for an operator to enter the tank, and when inside, an operator with rubber soled shoes can walk without difficulty alongside of the inner electrode system on the sloping wall of the tank.

CHARGING BELTS AND PULLEYS

The two charging belts are each 13 inches wide and are made of rubberized fabric of the type used in hospitals for sheeting, with the splice formed by vulcanizing. Pulleys for the charging belts are made of steel tubing 3 inches in diameter and 14 inches long with steel end plugs brazed into place and turned down to form shafts. The pulleys have no crowning except for a 1° taper at the ends along a distance of $\frac{1}{2}$ inch. A one horsepower d.c. motor is used for each belt and the speed of the charging belt pulleys is about 3600 r.p.m. The needle system for charging the belts (not shown in Fig. 2) is similar to that used on the small pressure generator developed at this laboratory except that the pulleys in the high potential electrode are insulated from the electrode and can therefore be used as inductor plates for feeding negative charge to the outgoing belts.

ACCELERATING TUBE

Experience with an accelerating tube made up in short sections from straight glass cylinders

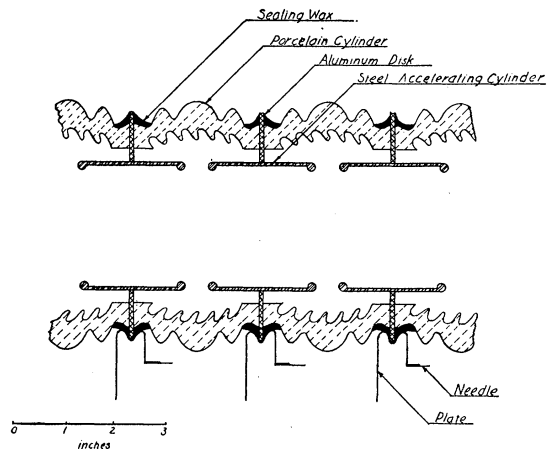


FIG. 4. Accelerating tube.

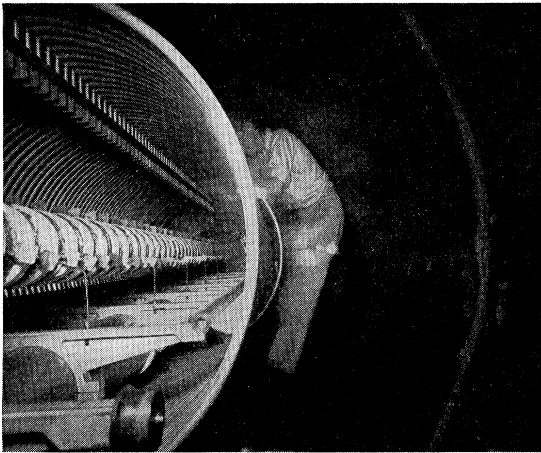


FIG. 5. Interior view of the generator showing the accelerating tube and the hoop system.

showed that the most serious factor limiting the voltage is a flash-over along the inner glass surface. Porcelain cylinders were therefore designed, corrugated inside and outside as shown in Fig. 4. A single porcelain section with electrodes as shown in the diagram withstood a potential of 100 kv satisfactorily. For the accelerating tube of the large generator 54 porcelain cylinders and metal electrodes were waxed together as shown in Fig. 4 using red sealing wax (American Express No. 2). The accelerating tube is supported inside the generator by heavy piano wire cradles at intervals of 15 inches along its entire length (Fig. 5) and sufficient flexibility to prevent strains and cracking is provided by a syphon bellows and gimbal ring joint just next to the end plate of the tank. This tube has caused very little trouble due to leaks and when first mounted in the tank, it pumped down to a pressure of 2×10^{-6} mm Hg.

While testing the performance of a single porcelain section in the small pressure generator, trouble was experienced with sparking along the external surface of the porcelain. This sparking occurred only when the porcelain section was evacuated and was practically unaffected by increasing the air pressure outside the section. Apparently charges on the inner surface of the porcelain caused irregular gradients on the external surface and consequent flash-over. This external sparking was later eliminated by wrapping a fine mesh brass gauze around the metal

disk at each end of the porcelain cylinder. The explanation of this behavior is probably as follows: points on the fine mesh gauze cause a small corona current through the air close to the surface of the porcelain which prevents the development of high potential gradients. Further tests showed that the gauze could be replaced by three needle points spaced evenly around the metal disk at the end of each porcelain cylinder. The accelerating tube was therefore equipped with a corona system as shown in Fig. 4 and Fig. 5 which serves two separate purposes. First, it gives a uniform potential drop from section to section along the entire length of the tube; and second, the corona current along the surface of each porcelain cylinder prevents the development of high gradients on the surface and thus prevents sparking. By a simple system of automatic contacts, the accelerating tube is connected electrically to the surrounding hoop system at intervals of 15 inches. Over the period of a few months during which the generator has been in operation, the accelerating tube has performed satisfactorily at all generator potentials.

PRODUCTION, FOCUSING AND MAGNETIC ANALYSIS OF POSITIVE IONS

Power for the ion source is provided by a 500-watt, 125-volt, self-excited a.c. generator driven from the inner pulley of the lower charging belt. By means of an RCA 866 rectifier tube and an 83 rectifier tube with the necessary transformers and condensers, d.c. potentials are supplied at 3000 volts and at 200 volts to run an ion source similar to that used by Tuve, Hafstad and Dahl. The rectifier tubes have operated without trouble with the air pressure in the tank up to 100 lb. and electric light bulbs of the ordinary type have also withstood the pressure satisfactorily except for one or two failures.

Focusing is accomplished by an adjustable corona gap across the first section of the accelerating tube. With the accelerating cylinders as shown in Fig. 4, no satisfactory focus could be obtained and the fluorescent spots formed by the ions on a quartz plate at the end of the magnetic analyzer were poorly defined. As these accelerating cylinders have a length of $2\frac{1}{8}$ inches and an inside diameter of about $2\frac{1}{4}$ inches, it

seemed probable that cylinders having a smaller inside diameter compared to their length would give better results. The first six accelerating cylinders at the high potential end of the tube were therefore made with the same length of $2\frac{1}{8}$ inches but were reduced to a diameter of one inch. After making this change, the ion beam has been well focused and, generally, by adjusting the corona gap across the first section of the tube, the fluorescent spots formed by the ions at the end of the magnetic analyzer can be brought down to a diameter of about 3 mm. In the brass box *M* of Fig. 2, the ion beam is separated into its mass spectrum by means of an electromagnet, and the ions to be studied are shot into the target chamber.

Hydrogen pressure in the ion source, filament heating current for the ion source, and the corona gap for ion focusing can all be adjusted from outside the tank by controls working through packing glands. A window in the wall of the tank and a mirror properly placed inside the tank enable operators to read meters inside the high potential electrode. The pumping system for evacuation of the accelerating tube consists of three brass diffusion pumps using Apiezon oil, and a Cenco Hypervac. The diffusion pumps are of the same type as those used for the high voltage work at the Department of Terrestrial Magnetism of the Carnegie Institute of Washington and were made up from drawings generously furnished by Dr. M. A. Tuve.

MEASUREMENT OF VOLTAGE

Voltage is measured by means of a generating voltmeter mounted on the side of the tank with the sectorized spinning disk flush with the wall, in an opening just opposite the high potential electrode. The alternating current generated by the spinning disk is rectified by means of a commutator and measured with a Leeds and Northrup galvanometer, sensitivity 2.99×10^{-10} amp./mm. A calibration of this voltmeter was made in the following way. With the small electrostatic generator which had been carefully calibrated by a method recently described in *The Physical Review*,³ a series of runs were taken

on the gamma-rays emitted by lithium bombarded by protons. Using two thick targets of pure evaporated lithium and two thin targets, nine separate runs were taken giving values for the peak of the gamma-ray resonance varying from 433 kv to 450 kv with an average at about 440 kv. This value of the resonance voltage agrees with the results of Hafstad, Heydenburg and Tuve, recently reported.⁴ With the large generator, four runs were then taken on the gamma-rays from lithium bombarded by protons using both thick and thin targets, and by assuming that the average value thus determined for the resonance peak was at a potential of 440 kv, the sensitivity of the generating voltmeter was determined.

The generating voltmeter was shown to have a linear scale by a study of the deflections of the proton beam and the hydrogen diatomic ion beam in the magnetic analyzer. With the voltage at V_1 , the magnetic field was adjusted to bring the proton beam through a $\frac{3}{16}$ -inch hole into the target chamber where it impinged on a glass plate and formed a fluorescent spot. Then, with the magnetic field held constant, the voltage was lowered until the diatomic ions entered the target chamber. If V_2 is this second voltage, its value, provided the voltmeter is linear, should be given by $V_2 = V_1/2$. By choosing a number of values for V_1 , the voltmeter was shown to be linear to within about 5 percent over the entire voltage range of the generator. A more accurate check was not possible because the spots formed by the ion beams at the time these tests were made were at some voltages larger than the $\frac{3}{16}$ -inch defining hole at the entrance to the target chamber.

ADDITIONAL APPARATUS

Compressor

Air is delivered to the tank up to the required pressure by a Quincy compressor, air-cooled, with a capacity of about 20 cubic feet per minute. For drying ingoing air, a steel cylinder filled with sodium hydroxide sticks is connected into the pipe line.

³R. G. Herb, D. B. Parkinson and D. W. Kerst, *Phys. Rev.* **48**, 118 (1935).

⁴L. R. Hafstad, N. P. Heydenburg and M. A. Tuve, *Phys. Rev.* **49**, 866 (1936).

Cooling System

An air blast from a vacuum cleaner blower provides cooling for the ion source. The blower is mounted on grounded angle iron supports near the motors which drive the charging belts, and the textolite tube *T*, Fig. 2, serves as a pipe line to deliver air to the ion source.

UPPER VOLTAGE LIMIT OF GENERATOR

With the tank at atmospheric pressure, the highest usable generator voltage is generally about 500 kv although the peak voltage is not sharply defined and often the generator can be held above 600 kv for short periods of time. As the air pressure is increased, the upper voltage limit becomes even less sharply defined than at low pressures so that a study of peak voltages as a function of pressure is not very satisfactory. Experience over a period of a few months, during which considerable data have been taken on proton induced reactions, definitely shows that the maximum usable potential of the generator does not increase linearly with air pressure. For a short period of time, the generator has been held at 2500 kv but up to the present time the highest potential at which reliable data have been obtained is 2160 kv. This maximum usable potential could probably be increased somewhat by a careful overhauling and a thorough cleaning of the apparatus.⁵

During the first high voltage trials with the tank at high pressure, the potential was limited to about 1.7 MV by sparking along the textolite tubes *S*, Fig. 2. The sparking distance along these tubes is about 7 feet whereas the radial distance

⁵ Some increase in the potential of an electrostatic generator can be obtained by the addition of CCl_4 vapor to the air. This effect was noticed by one of us (R. G. H.) three years ago while working with the small electrostatic generator and was then studied in considerable detail. A saturated vapor pressure of CCl_4 in air at atmospheric pressure was found to give a breakdown potential of about 1.7 times the breakdown potential of ordinary air. These results with air at atmospheric pressure were verified later by two different observers using an apparatus consisting of an adjustable sphere gap in a small pressure tank. A thorough investigation was then made using CCl_4 vapor in air at several different pressures up to a maximum of 75 lb. Publication was delayed because it was intended to look for similar effects caused by other vapors but details of the work will be published soon. In a recent issue of *Compte rendus* 202, 291 (1936), Joliot, Feldenkrais and Lazard report the discovery of this effect. They find that an electrostatic generator operated in air containing a high vapor pressure of CCl_4 gives a maximum potential twice as high as when operated in ordinary air.

from the high potential electrode to the wall of the tank is only 18 inches. Sparking such as this, along the surface of insulators, has also been experienced in the small generator and in all cases an increase of air pressure gave no improvement in the sparking potential. This behavior indicates that on long insulators irregular surface charges accumulate which may give a sufficiently high gradient at some point to initiate a discharge. The surface discharges along the textolite tubes, *S*, were eliminated by a corona system similar to that used on the accelerating tube to prevent accumulation of charges. Strips of fine brass gauze about $\frac{1}{4}$ inch wide were wrapped around the tubes at intervals of $2\frac{1}{2}$ inches, and at intervals of 15 inches, the gauze systems were connected to the surrounding hoops. Although these gauze systems draw very little current (probably less than 5 microamperes), they have successfully eliminated surface sparking.

Trouble has also been caused by surface sparking down the charging belts when large charging currents are being used at high potentials, but these can be avoided by keeping the charging current below about 200 microamperes when working at high generator potentials. As this current limitation is not serious for work with positive ions, no effort has been made to increase the usable charging current, but to adapt a generator of this type to high voltage x-ray production for which currents of several milliamperes are needed, further development work would be necessary.

After eliminating the surface sparking along the belts and the textolite supports, the upper voltage limit was determined by radial sparking between the high potential electrode and the wall of the tank with the sparks generally occurring at the ends of the electrode.

VOLTAGE CONTROL

Charge is put on the belts by a kenotron rectifier set and thus, by varying the resistance in the primary of the kenotron transformer, the generator voltage can be changed. When taking a run during which a steady generator potential is desired at some particular value, changes will occasionally occur so that the kenotron voltage must be varied to bring the electrostatic generator

back to the desired potential. Recently a control has been devised utilizing corona current from the high potential electrode and an amplifying system for automatically varying the kenotron voltage to keep the electrostatic generator at a constant potential. Generally during a run, the automatic control keeps the voltage of the generator constant to within about 1 percent and often to 0.5 percent. As improvements are still being made in the amplifying circuit, a complete description of the apparatus will be postponed until a later time.

High frequency fluctuations of the generator voltage cannot be detected with the generating voltmeter because of the long period of the galvanometer used. A study of high frequency fluctuations was therefore made utilizing corona current to a needle sticking through a hole in the wall of the tank. The only periodic voltage fluctuation detected had a magnitude of about 0.5 percent and as its frequency was the same as that of the charging belts, it was probably caused by the splice in the belts.

DISCUSSION

As the success of the electrostatic generator described in this paper, both for development of high potential and for utilization of that high potential, depends to a large extent on the arrangement of the inner electrode system, a brief discussion will be given of the advantages of this electrode design. The hoop system gives a uniform, axial field along the accelerating tube and along the belts. The distance provided for the tube and the belts is great compared with the radial distance from the high potential electrode to the wall of the tank and therefore when the generator is at its maximum potential, the field

inside the hoop system is far below the breakdown value. Metal castings and wires inside the hoop system cause no trouble if kept approximately parallel to the plane of the hoops and the accelerating tube with its metal electrodes and its corona system is operating under ideal conditions. As the high potential electrode (E , Fig. 2) may be left open at both ends, the space available for charging belts and the accelerating tube is limited only by the diameter of the cylinder.

A similar system could be used for an electrostatic generator in a large room at atmospheric pressure or in an upright pressure tank. Instead of the usual sphere mounted on insulating supports, a cylindrical column of hoops could be used, capped by a hemisphere. Ample room would then be available inside the hoop system for supports, belts and accelerating tubes.

From a consideration of the performance of the two generators developed at this laboratory it would seem that to obtain a further increase in potential an increase in the dimensions of the apparatus would be the safest way to proceed. Higher pressures might also give considerable improvement but the nonlinear increase of usable potential with pressure up to a pressure of 100 lb. makes the effectiveness of still higher pressure difficult to predict.

We wish to express our indebtedness to the late Professor C. E. Mendenhall and to Professor H. B. Wahlin for advice and generous support. We also wish to express our appreciation to Mr. J. P. Foerst and Mr. J. A. Johnson for their work on the construction of apparatus and to Mr. J. L. McKibben for valuable work in the development of the generator. We are indebted to the Wisconsin Alumni Research Foundation and the Bowman Cancer Foundation for generous financial assistance.

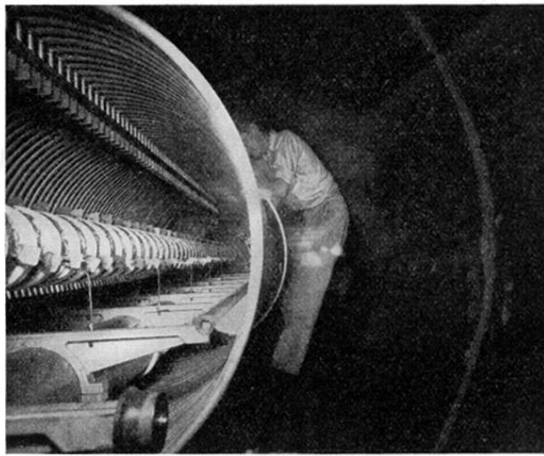


FIG. 5. Interior view of the generator showing the accelerating tube and the hoop system.