reference 2, only a 1 percent decrease in vibrational frequency is to be expected in going from CeO to LuO due to change in reduced mass, while approximate equality of the force constants governing the vibrations should exist because of the similarity in the outer electron configurations of these fourteen elements.

For qualitative chemical analysis the most intense bands for each of these molecules should prove more convenient than atomic lines for identifying the rare earths present in a mixture. This is especially true if the available spectrograph has not large dispersion. The wave-lengths of the heads of the most intense bands are listed in Table VI for all of the rare earth monoxide spectra so far analyzed. All bands degrade to the red.

Some of the rare earth elements apparently do not have any conspicuous band systems in the spectrum of the arc in air. In addition to the present search of the Nd spectrum, Meggers and Scribner report no characteristic bands for Yb[6] or from Tm[7] such as those found for Lu under identical conditions. Observations on the spectra of a number of the rare earths are lacking, of course, but it is apparent that for some of the atoms in this group oxide band systems of good intensity are missing. We venture to suggest that for such band systems to exist, a d electron must be present in the normal configuration of the rare earth atom. Lanthanum with its ds^2 configuration, together with a simple term scheme, has some seven well-developed monoxide band systems. Ce, Pr, Gd and Lu also have that same configuration in addition to 1, 2, 7 and 14 $4f$ electrons, respectively. Sm, Eu, Tm and Yb, on the other hand, have $4f^n6s^2$ normal configurations.

[6] W. F. Meggers and B. F. Scribner, Nat. Bur. Stand. J. Research 19, 651 (1937).

[7] W. F. Meggers, private communication.

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Electrostatic Generator Operating Under High Air Pressure—Operational Experience and Accessory Apparatus

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A description is given of experience gained in operation of the Wisconsin electrostatic generator with particular reference to the use of CCl_4 and CCl_2F_2 and to the problem of the fire hazard. Improvements in the charging belt system and the accelerating tube are discussed; and generator equipment, including the generating voltmeter, the voltage stabilizer and the ion source, is described.

Introduction

In general design the Wisconsin electrostatic generator (Fig. 1) has not been changed since described in the first publication.[1] Although the generator has been in operation for almost two years all the original Textolite supports and the aluminum hoops are still in good condition. Corona points for the distribution of potential along the hoop system and accelerating tube are still satisfactory, although the points appear to be very dull. Additional operational experience has been acquired, however, and improvements have been made in the charging belts and in the accelerating tube. With (CCl_4 air and CCl_2F_2 air mixtures) the generator has been operated at 2.4 Mv for data on proton-proton scattering. Trouble has been experienced due to fires, and alterations have been made to reduce the fire hazard. These experiences and improvements are described in the present paper, and in addition a description is given of certain accessory apparatus, including the generating voltmeter, the voltage stabilizer, and the ion source.

[1] R. G. Herb, D. B. Parkinson, D. W. Kerst, Phys. Rev. 51, 75 (1937).

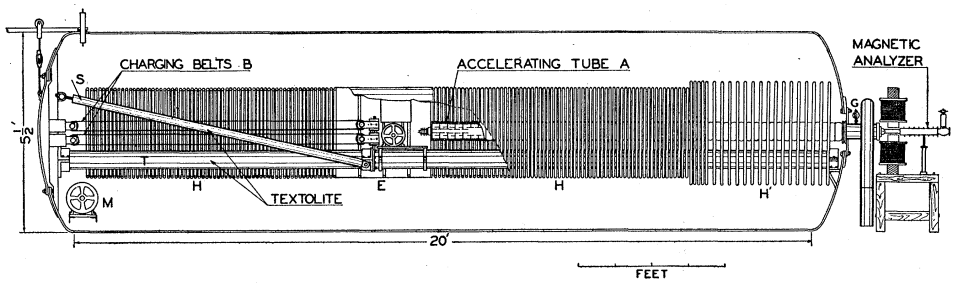

FIG. 1. Electrostatic generator. The steel tank enclosing the generator can be filled with air up to a pressure of 8 atmospheres. Charging belts B are made of rubberized fabric, 13 inches wide. Pulleys for the charging belts are 3 inches in diameter and run at a speed of 3600 r.p.m. Electrode E, made of galvanized iron, is at the highest generator potential. Aluminum hoops H and H' are mounted on small Textolite tubes so as to be insulated from one another. Corona current along the hoop system serves to maintain a uniform potential gradient from the maximum voltage at the electrode to ground at each end of the tank. Textolite tubes T and S support the entire structure inside the tank. Ions from a source in electrode E are shot through accelerating tube A to the end of the tank. Outside the tank the ion beam is deflected by a magnet and is directed into a target chamber.

Charging Belts and Pulleys

The charging belts originally used were made of rubberized sheeting of the type used in hospitals. They were fairly satisfactory, but were ripped by sparks unless very thoroughly dried. The belts now being used are made of balloon fabric[2] which although light in weight, is tough and serviceable, and is unaffected by sparks. When these belts were first used, however, the pulley alignment was found to be rather critical. The pulleys then had no crowning except for a 1° taper at each end over a distance of ½ inch. Recently this taper was changed to 2° along a distance of ¾ of an inch at each end, and since this change the belts have remained centered and have required very little attention.

Accelerating Tube

Improvement of focus

The accelerating tube has been modified in certain details since it was first described. It is made up of 53 porcelain cylinders separated by metal electrodes with joints sealed by wax. The porcelain cylinders which were installed when the generator was constructed have given no trouble and are still in use. All of these cylinders are the same as the end cylinder shown in Fig. 4. Most of the metal focusing electrodes have been unchanged since construction of the generator, but the first five electrodes nearest the ion source were modified several times during the first year the generator was in operation, and the design finally adopted has a telescoping construction as shown in Fig. 4. The inner cylinders which are responsible for the focusing are made with a small diameter since tests had indicated that for good focus the cylinders must have diameters small compared to their lengths. The large outer cylinders serve to shield the gaps from charge collected on the inner wall of the porcelains.

A corona gap system is provided for the tube to give proper potential distribution. Sections one and three, counting from the high potential end of the tube, have variable corona gaps which can be individually controlled from outside the tank, and section two is permanently shorted. Until recently other sections of the tube were each equipped with three fixed corona gaps (Fig. 2) spaced evenly around the tube. With this arrangement the ion beam could usually be brought to a good focus by adjustment of the variable corona gaps.

Some trouble was experienced, however, with control of the ion beam over a wide voltage range. The fixed gaps had to be set at about 2 cm for operation in the region of 2 Mv, since for shorter gaps the large current drain required high charging currents which caused sparking down the belts. However, with the gaps at 2 cm and a pressure of 8 atmospheres in the tank, corona current at voltages below 1200 kv was too small to maintain a uniform potential

[2] This belting was first used by Dr. Tuve and his associates at Washington, D. C. It is obtained from the Goodyear Rubber Company, Akron, Ohio.

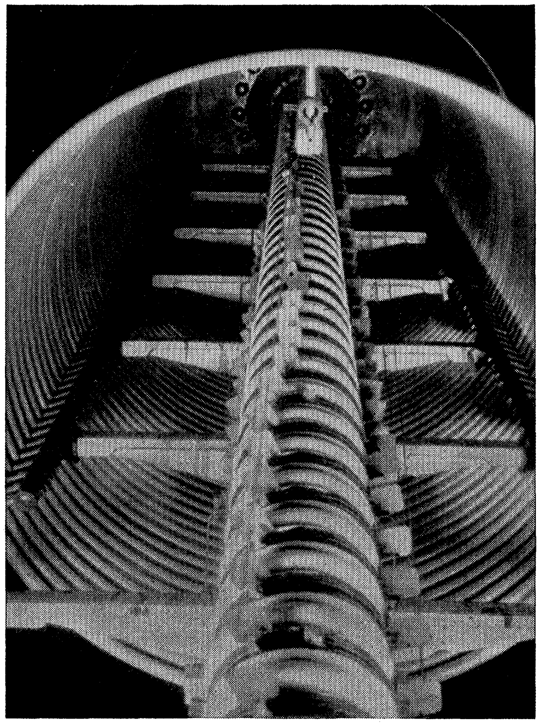

FIG. 2. View showing accelerating tube and hoop system. This photograph was taken before installation of the adjustable corona gap system along the tube.

distribution along the tube, and consequently difficulty was experienced in focusing the ion beam. This difficulty with focus has been eliminated by the installation of an adjustable corona gap system which can be controlled from outside the tank. Only one gap on each section of the tube has been made adjustable, the other two being permanently set at 2.5 cm. Needles of the adjustable gaps are mounted on a glass tube,* diameter $\frac{1}{2}$ inch, running parallel to the accelerating tube as shown in Fig. 3. The glass tube can be moved along its axis so as to vary the gaps from zero up to about 3 cm. This adjustable system is common to all sections of the tube with the exception of the first three, which are arranged exactly as before. The ion beam can now be well focused at any voltage above about 800 kv with 8 atmospheres pressure in the tank. Thus by using the diatomic beam it is possible to

* Note added in proof:—This glass tube (Pyrex) behaved satisfactorily for about three months and then shattered because of flash-over at high voltage. New tubing was installed twice but it failed almost immediately. Failure of the glass tubing was probably caused by small capillaries which are generally present in drawn Pyrex. The glass tube was replaced by a Dilecto rod grade XX of $\frac{1}{2}$ inch diameter which has given no trouble during a month of operation at potentials up to 2.2 Mv.

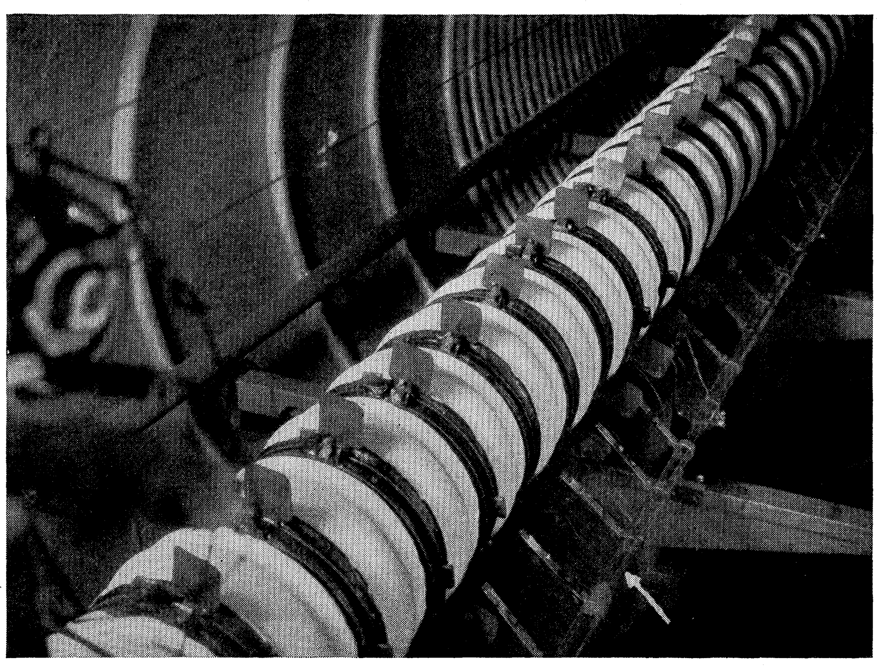

FIG. 3. View showing the accelerating tube and the adjustable corona gap system. The glass tube which supports the adjustable needles is indicated by the arrow.

work with ions having an energy as low as 400 Kev without releasing air from the tank.

Leaks

During the summer of 1937 the wax joints of the accelerating tube caused considerable trouble due to leaks which frequently developed when air pressure in the tank was increased above about 6 atmospheres. Red sealing wax (American Express No. 2) had been used for the joints. This wax is strong, but rather brittle, and apparently as the compressional force on the tube was increased, the strains developed due to uneven seating of the porcelain cylinders on the aluminum disks were sufficient to cause minute cracks to form. Practically all the trouble due to leaks in the tube was eliminated by covering the red wax with a coat of Picein wax (melting point 80°C) which is sufficiently plastic at room temperatures to take small deformations without cracking.

Performance at high voltage

When the generator is operated at its maximum steady voltage of 2.4 Mv the accelerating tube gives no trouble. However, during test work with CCl_4 and CCl_2F_2 in the tank, discharges sometimes took place in the tube causing the vacuum to go bad when the voltage was held at 2.5 Mv for periods of more than about one-half minute. It therefore seems that the maximum operating voltage of the generator is very near the maximum voltage which the tube will withstand continuously. For short periods of time the tube will withstand somewhat higher voltage, and when the generator voltage was held above 2.7 Mv for a few seconds, the tube did not break down.

Ion Source

After some experimentation with various kinds of ion sources the arrangement shown in Fig. 4 was adopted and has now been in use for about one year. High yields of ion current cannot be claimed for this source, but it has been almost entirely free of trouble since it was installed, and for use with a generator of the Wisconsin type reliability is of considerable importance.

A hairpin type filament is used, made of 16 mil tungsten wrapped with 5 mil nickel, and coated with a barium oxide-strontium oxide mixture. The filament has never burned out and has been

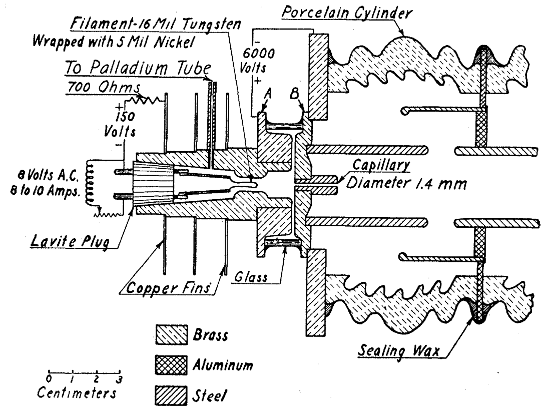

FIG. 4. Ion source and first section of accelerating tube.

recoated only once. Filament heating current is generally set at about 9 amperes, and the filament emission is usually between 100 and 200 milliamperes. The positive ion current to plate *B* has never been measured but judging from the behavior of similar sources tried at this laboratory, it is estimated that this current is never greater than 5 milliamperes.

Hydrogen from a supply tank in electrode *E*, Fig. 1, is admitted to the ion source through a palladium regulator tube which is electrically heated by current from the power supply in electrode *E*. By means of a string control the temperature of the palladium tube, and consequently the hydrogen flow, can be regulated from outside the tank. Pressure in the vacuum system is measured by means of a Western Electric ionization gauge (*G*, Fig. 1) mounted on the system near the end of the tank, but pressure in the ion source has never been measured. Data regarding yields from the ion source have all been obtained with the source installed on the generator and with the magnetically resolved ion beam passing through a $\frac{3}{16}$-inch hole into a target chamber. Ion current yields increase rapidly as hydrogen flow is increased, but the maximum proton current through the $\frac{3}{16}$-inch hole is limited to about three microamperes, since any further increase in hydrogen flow causes defocusing of the ion beam. With the hydrogen flow at its optimum, the pressure indicated by the ionization gauge is about 1.5×10^{-5} mm Hg. The hydrogen diatomic ion current is then somewhat less than the proton current, but as hydrogen

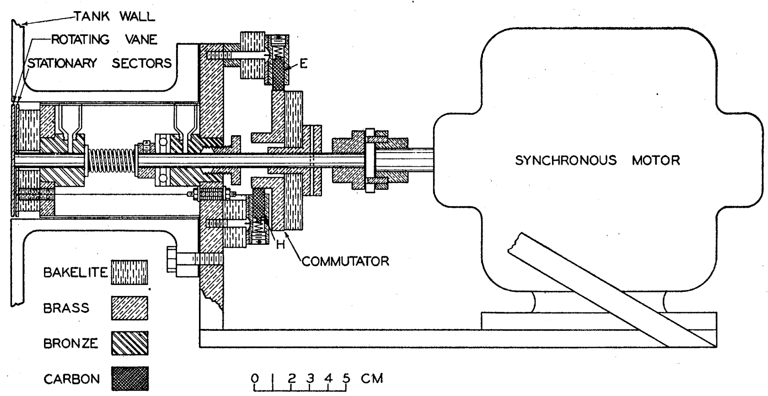

FIG. 5. Cross-sectional view of generating voltmeter.

flow is decreased the proportion of diatomic ion current to proton current increases, and when the pressure indicated by the ionization gauge is less than 5×10^{-6} mm Hg the diatomic ion current is approximately twice as great as the proton current. Ions of greater mass than the hydrogen diatomic ions are never present in appreciable quantities.

Fire Hazard

As many inquiries have been received regarding the fire hazard in the Wisconsin generator a description will be given of all fires that have occurred since construction of the generator. Provision was made for fire protection before the generator was put into operation. The tank was equipped with a two-inch gate valve for rapid release of high pressure air in case of fire, and a cylinder of CO_2 was left permanently connected so that the tank could be flushed with this gas after the air pressure had dropped close to atmospheric pressure.

The first fire occurred soon after completion of the generator when sparking tests were being run at high voltage with the tank at a pressure of 8 atmospheres. A Textolite tube of $\frac{1}{2}$-inch diameter and $\frac{1}{32}$-inch wall thickness was used to adjust corona gaps on the hoop system. This had become frayed by sparks and fire caught on a section that had been wrapped with friction tape. The fire was noticed soon after starting (probably less than one minute) because of a rapid drop in voltage, and when air pressure was released from the tank the fire went out. CO_2 was let into the tank but was probably not necessary. About 10 inches of the Textolite tube was burned, but no other damage was done. Tests had shown that the setting of the corona gaps on the hoops was not critical; the adjustable system with its Textolite tube was therefore discarded and stationary gaps set at about 2 cm were installed.

Fire number two was also caused by a spark at high voltage with 8 atmospheres pressure in the tank. It caught on a light pasteboard tube which served as an air line from a blower at one end of the tank up to the ion source. This fire also went out when pressure was released and nothing was damaged except the pasteboard tube. This tube was discarded and the main Textolite support (T, Fig. 1) was equipped to serve as an air line.

Fire number three was caused by a short circuit in the power supply for the ion source when tests were being made with the tank at atmospheric pressure. Considerable damage was done both to the power unit and to the high potential electrode. In rewiring the power supply, rubber and fabric insulation was reduced to a minimum, and bus bar wiring was installed wherever possible.

Another fire, which ruined a set of charging belts, occurred when the generator was not running. Voltage was accidently thrown onto the needles for the charging belts and was raised so high that intense sparking from the needles caused the belts to ignite. As the tank was then open the fire was put out with an extinguisher.

After these experiences with fires it was thought that all fire hazards had been eliminated, but recently, when running at 2.4 Mv, a wooden board under a driving motor (M, Fig. 1) caught fire. Although the motor frame was well grounded, apparently a surge due to a high voltage spark caused a discharge along the wood. This fire, like the others, went out when the air pressure was released, and nothing was damaged excepting the board. The motor support was then modified to eliminate all danger of fire.

When the generator was in its early developmental stage hundreds of sparks passed down the Textolite tension members without causing the slightest charring or fraying. The charging belts originally used (hospital sheeting) were sometimes ripped by sparks but were never set on fire, and the balloon fabric belts now used are unaffected by sparks.

These experiences indicate that textolite, unless extremely thin and fragile, can be safely used, and that rubberized charging belts, under ordinary circumstances, do not constitute a fire hazard. It does seem essential, however, to avoid the use of inflammable material as much as possible.

Use of CCl_4 and CCl_2F_2

With pure air at 8 atmospheres pressure in the generator the maximum usuable potential is limited to about 2.1 Mv by radial sparking from the high potential electrode. Humidity has no noticeable effect on sparking potential, but to avoid loss of charge due to conduction along insulators the relative humidity must be kept below about 35 per cent.

Investigations conducted at this laboratory[3, 4] showed that the dielectric strength of mixtures of air with a small percentage of CCl_4 or CCl_2F_2 is considerably greater than the dielectric strength of pure air. Pure CCl_2F_2 was found to have a dielectric strength of about three times that of air, and the dielectric strength of a CCl_2F_2 air mixture was found to increase very rapidly with concentration of CCl_2F_2 in the region of small concentrations.

Recently with CCl_4 and later CCl_2F_2 in the generator reliable data on proton-proton scattering was obtained at 2.4 Mv. With the tank at 8 atmospheres pressure, 4 kg of CCl_4 evaporated into the generator increased the direct spark-over voltage from about 2.1 Mv to 2.4 Mv. This amount of CCl_4 in the tank gives a vapor pressure of 33 mm of Hg which is approximately 33 percent of the pressure for saturation. When higher concentrations of CCl_4 were tried sparking along the charging belts limited the usable potential to a value considerably below 2.4 Mv. In our work at 2.4 Mv considerable trouble was experienced because of sparking down the control strings which run from the end of the generator up into the high potential electrode. Untreated cotton and silk lines were satisfactory in pure air but were torn to pieces by sparks when CCl_4 was used. These lines withstood the voltage satisfactorily when impregnated with paraffin, but stretched to such an extent in the CCl_4 atmosphere that they became useless as controls. Cuttyhunk fishlines (linen impregnated with tar) were then installed and have been entirely free of trouble at the highest potentials obtainable, using either CCl_4 or CCl_2F_2 in the tank.

During the test work with CCl_4 none of the materials in the generator were affected except the control strings, but later when 8 kg of CCl_4 was allowed to remain in the tank for several days the behavior of the generator indicated that either the belts or the Textolite supports had become conducting. It is possible, however, that this behavior of the generator was due to other conditions, and because CCl_4 has not been tried since then the effect cannot be considered as established.

For most of the work at 2.4 Mv, CCl_2F_2 was used in the generator. Five kg of CCl_2F_2 in the tank, giving a vapor pressure of 55 mm Hg (1.4 percent of saturation) increased the usable potential from 2.1 Mv to 2.4 Mv, and when greater concentrations were tried failure along the charging belts caused a decrease in the usable voltage. CCl_2F_2 appeared to have no effect on materials in the generator.

Experience with the use of CCl_4 and CCl_2F_2

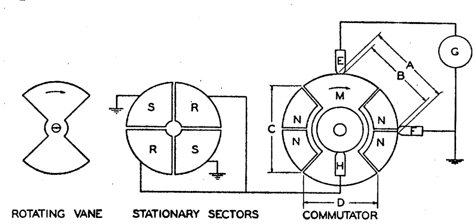

FIG. 6. Schematic diagram of voltmeter circuit.

[3] M. T. Rodine and R. G. Herb, Phys. Rev. **51**, 508 (1937).
[4] C. M. Hudson, L. E. Hoisington and L. E. Royt, Phys. Rev. **52**, 664 (1937).

and also with pure air at high pressure has shown that the voltage for flash-over along long insulators does not increase linearly with the dielectric strength of the gas or vapor surrounding the insulator, and that under certain circumstances the flash-over voltage may actually decrease when the dielectric strength of the gas is increased.

This effect puts a serious limitation on the maximum generator voltage since measurements on the dielectric strength of CCl_2F_2 indicate that by using a high pressure of this vapor in the generator its radial sparking potential could be increased to over 4 Mv.

The Generating Voltmeter

Construction

Generating voltmeters are now in common use and many have been described in the literature. It is believed however that the instrument to be described represents some improvement over others, both in simplicity and in reliability, and that a description of its performance on the Wisconsin electrostatic generator will be of value.

Figure 5 shows the construction of the voltmeter, and in Fig. 6 a diagram is given of the electrical circuit. The assembly is mounted on a flanged fitting which extends radially from the cylindrical wall of the tank opposite the high voltage electrode. The rotating vane, of $\frac{1}{16}$-inch brass, is mounted flush with the inner surface of the tank and is spun by direct drive from a synchronous motor. Stationary sectors R and S, also of $\frac{1}{16}$-inch brass, are screwed onto a heavy Bakelite disk with a clearance of about $\frac{1}{64}$-inch from the rotating vane. The rotating vane and stationary sectors S are grounded, and the sectors R are periodically connected through the commutator to a Leeds and Northrup galvanometer of sensitivity 2.99×10^{-9} amperes per mm. As the rotating vane turns, a charge which is proportional to the potential of the generator flows onto and off the sectors R, and feeds an alternating current into the commutator. Sectors N of the commutator are made of $\frac{1}{4}$-inch brass, fastened with screws to a Bakelite disk and are all insulated from one another and from ground. Carbon brush H makes permanent contact with sector M. An examination of the diagram will show that with orientations as given in Fig. 6 only those pulses are measured which are caused by sectors R being covered, the reverse pulses due to the uncovering of R being sent to ground. During development of the commutator it became evident that the galvanometer circuit must never be shorted by a sector of the commutator since if the circuit is shorted thermal e.m.f.'s at the brushes produce a current through the galvanometer. Thus in constructing the commutator the relative size of sectors M and N for a given arrangement of brushes E and F must be such that $B>D$ and $C>A$. Since the sectors N are all floating and are separate from one another and sector M is connected only to sectors R, the conditions given above establish the essential requirement that the circuit through the galvanometer never be closed, and thus trouble due to thermal e.m.f.'s is eliminated. If the voltmeter is turned on with the generator potential zero there is no noticeable deflection of the galvanometer G, and when measuring a high steady potential the galvanometer behaves as well as if a steady direct current were being measured.

It is possible that a commutator of the ordinary type could be used providing a high resistance were put in the galvanometer circuit to suppress thermal currents. This arrangement has not been investigated thoroughly, but when a resistance of 200,000 ohms was put in the galvanometer circuit the voltmeter sensitivity was changed by about 2 percent. There seemed to be a possibility that this change in sensitivity would depend on the capacity of the system, and that a change in the clearance between rotating and stationary sectors would therefore change the sensitivity. Another possible objection to a high resistance in the galvanometer circuit is that this arrangement would make insulation requirements from commutator and sectors R to ground more exacting.

To obtain reliable operation of the voltmeter the commutator must be provided with a grounded shield (not shown in drawings) since if the commutator can "see" a charged surface, such as an insulator which has picked up a charge, a current will be generated which will be superimposed on the current from the sectors and thus readings will be inaccurate.

Calibration

For calibration of the voltmeter, use was made of the gamma-ray resonance from lithium bom-

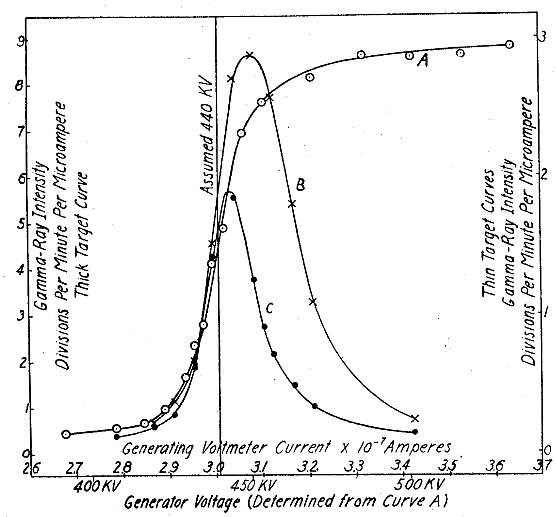

FIG. 7. Gamma-ray yield curves from lithium bombarded by protons. A Lauritsen type electroscope was used for measurement of gamma-ray intensity. Curve A was used for calibration of the generating voltmeter.

barded by protons. Hafstad, Heydenburg, and Tuve[5] studied this resonance by the use of a high resistance voltmeter and found a value of 440 kv for the resonance peak. At Wisconsin, an entirely independent determination was made of this resonance voltage by the use of a small electrostatic generator and results agreed well with those obtained at Washington. Several runs on the lithium gamma-ray resonance were then made with the large generator and when a potential of 440 kv was assumed for the resonance peak, the output of the voltmeter was determined to be 6.90×10^{-10} amperes per kilovolt.

During regular experimental work with high energy protons several checks have been made on the linearity of the voltmeter by changing from use of monatomic ions to the use of diatomic ions for bombardment. At a generator voltage V each proton of a diatomic hydrogen ion has an energy of $\frac{1}{2}$ eV and thus if the voltmeter is linear, monatomic ions at a voltmeter reading of V should give the same result as diatomic ions at a voltmeter reading of $2V$. This condition was found to be satisfied in all experiments within the limits of experimental error which were probably never better than 1 percent.

Recently the sensitivity of the voltmeter was rechecked by running yield curves for gamma-rays from both thick and thin lithium targets. Results are shown in Fig. 7. The position of maximum slope of curve A is assumed to be at 440 kv, and the voltmeter current at this position is 3.01×10^{-7} amperes, from which one obtains a sensitivity of 6.85×10^{-10} amperes per kilovolt. This sensitivity is approximately 0.7 percent lower than the value determined 18 months previous when the voltmeter was first calibrated. The peaks of the thin film curves C and B are shifted from the resonance peak indicated by curve A in the direction of higher voltage. This shift is caused by the finite thickness of the films and is greater for curve B since the film used for this curve was of greater thickness than the film used for curve C. Because of this shift in resonance peaks it seems that thin target yield curves are not satisfactory for calibration of voltage.

[5] L. R. Hafstad, N. P. Heydenburg and M. A. Tuve, Phys. Rev. **50**, 504 (1936).

Automatic Voltage Stabilizer

For most experimental work with the high voltage generator the voltage is set at some definite value and must be held to this value very closely while determining a reaction or scattering yield. Generator voltage depends upon the amount of corona current fed from needle points to the in-going sides of the charging belts. High voltage for the charging needles is supplied by a transformer and kenotron rectifier set, and consequently the potential of the electrostatic generator can be varied by changing the voltage applied to the transformer.

Comparatively long period drifts in generator voltage are easily corrected by manually operated rheostats in series with the primary of the transformer supplying the rectifier set. However, small short period fluctuations of the order of a second or two cannot be followed accurately by the manually operated rheostats.

For this reason an automatic voltage stabilizer was designed by one of the authors (JLM) to keep the voltage more closely to a given value than was possible with manual control. The stabilizer consists of a two-stage direct coupled amplifier whose input is a voltage derived from corona current to a needle projecting into the tank opposite the high voltage electrode Needle setting can be changed from 0 to 2 cm projection by means of a small reversible motor controlled by a switch which is placed so as to be convenient

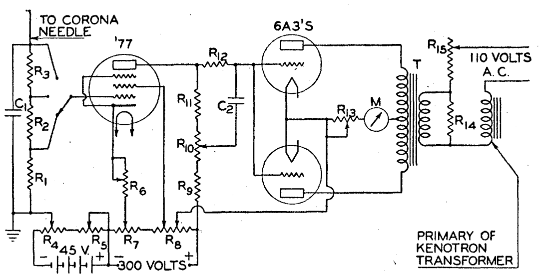

FIG. 8. Circuit diagram of voltage stabilizer. $R_1=1$ megohm wire wound. $R_2=0.5$ megohm wire wound. $R_3=0.5$ megohm wire wound. $R_4=25{,}000$ ohm potentiometer for voltage control. $R_5=5000$ ohm variable for fine adjustment of voltage. $R_6=5000$ ohm variable gain control. $R_7=1000$ ohm potentiometer for mu balance. $R_8=50{,}000$ ohm resistor with taps. $R_9=0.5$ megohm. $R_{10}=9$ resistors of 50,000 ohms mounted on a selector switch. $R_{11}=1$ megohm. $R_{12}=4$ megohm. $R_{13}=2500$ ohm resistor with taps. R_{14} and $R_{15}=$ rheostats for control of high voltage. $C_1=0.5$ microfarad. $C_2=1.5$ microfarad. $T=$ Thordarson T5604 radio power transformer. $M=$ milliameter : 0–100 milliamperes.

for the operator. The output of the amplifier controls the current in the primary of the transformer supplying the kenotrons.

The circuit diagram is given in Fig. 8. A corona current of 10 to 40 microamperes flows to ground through the resistors R_1, R_2, and R_3. The voltage drop across a selected number of these resistors is amplified by a type 77 screen grid tube, and the plate circuit is direct coupled to the grids of two 6A3 power tubes. Resistor R_8 is set to maintain a potential of 100 volts on the screen of the 77 tube, and to give suitable bias to the grids of the 6A3's. R_7 provides a mu balance to counteract line voltage fluctuations entering through the power supply, and R_{13} is set to limit the maximum value of plate current of the 6A3's to about 80 milliamperes. No d.c. potential is applied to the plates of the 6A3's; their voltage supply is the transformer T, and thus the amount of power drawn from the secondary of T is determined by the grid potential of the 6A3 tubes. The primary of T parallels part of the manually operated rheostats which control the potential of the kenotron rectifier set. Since the impedance of the primary of T depends on secondary load, a variation in load will cause a variation in the voltage of the kenotron set. Generator voltage will not respond immediately, however, because of the finite speed of the charging belts and the generator capacity. This time lag causes troublesome hunting of the stabilizer unless suitable time constants are introduced into the circuit. If condenser C_2 is not used hunting occurs with a period of about $\frac{1}{2}$ second. It can be eliminated by using the maximum value of R_6 and by sufficient reduction of the plate load resistor of the 77 tube, but the gain of the amplifier is then insufficient for good regulation. A condenser across the entire plate load resistor increases the period of the hunting action but gives little improvement in performance.

Trouble due to hunting has been practically eliminated by the introduction of two different time constants into the circuit. Condenser C_2 is placed across only a selected fraction of the plate load resistor, as shown in Fig. 8, making amplifier response partially fast and partially slow. The ratio of rapid to slow speeds of correction is not critical over a certain range and can be easily adjusted to eliminate hunting with the amplifier gain set sufficiently high for good regulation.

Because of small rapid fluctuations in corona current which sometimes occur when the generator voltage is constant, a smoothing condenser C_1 is placed across the input resistance. The size chosen gives satisfactory smoothing action and is not large enough to cause hunting of the stabilizer.

Best operation is obtained if the time constants of all other portions of the circuit are kept as small as possible. No condenser is used to smooth the voltage applied to the charging needles by the kenotron rectifier set.

To set the stabilizer into operation the generator voltage is adjusted to approximately the desired value by means of R_{15}, and the distance which the corona needle projects into the tank is adjusted to give the best performance of the stabilizer. By means of R_4 or the fine control R_5 the generator voltage is then set accurately at the desired value.

When the generator is in good condition and the stabilizer has been properly adjusted the voltage is held constant to within approximately 0.5 percent.

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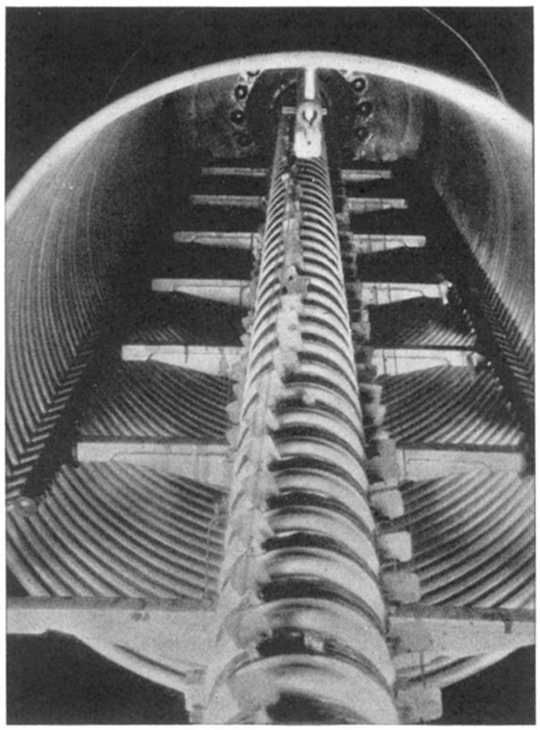

FIG. 2. View showing accelerating tube and hoop system. This photograph was taken before installation of the adjustable corona gap system along the tube.

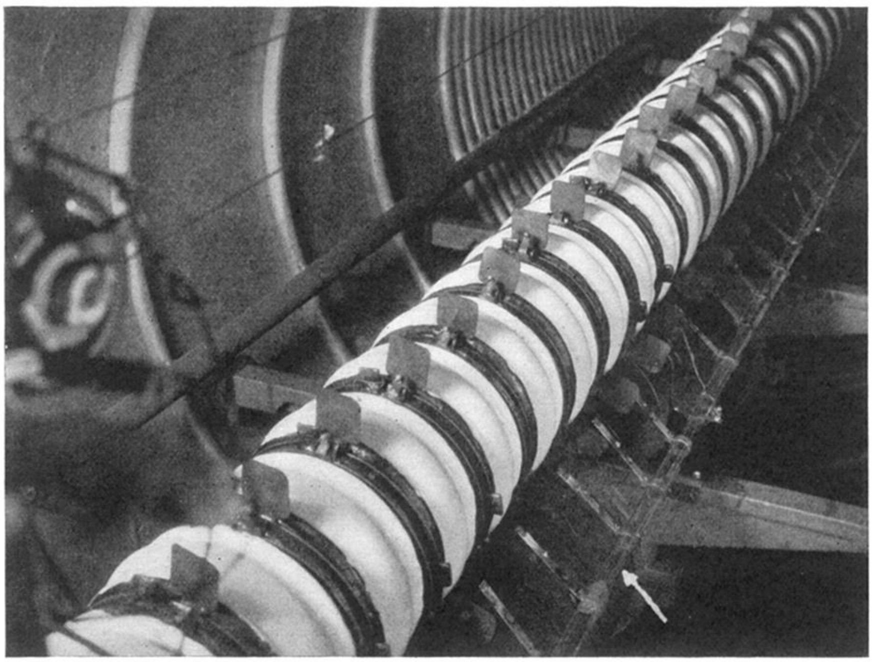

FIG. 3. View showing the accelerating tube and the adjustable corona gap system. The glass tube which supports the adjustable needles is indicated by the arrow.