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HIGH-VOLTAGE ELECTROSTATIC GENERATOR FILLED WITH KEROSENE

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[Note: The following is a translation of a Russian article appearing in Zhurnal Tekhnicheskoy Fiziki Vol. IX, No. 23 (1939), pages 2090-3. It was written by S. A. Bobkovskiy, B. M. Gokhberg, A. F. Ioffe, and N. M. Reynov, who are affiliated with the Leningrad Physicotechnical Institute, Academy of Sciences USSR. The article was submitted 4 Oct '39.]

1. General Description of the Generator

The electrostatic generator of high dc voltages was constructed according to a single-rotor model described in previous articles.

In an iron container 1 (Figure 1) 4 meters high and 2.7 meters in diameter was installed a rotor 2 of height 1.2 meter and diameter 2 meters.

The rotor was built up from ebonite plates held fast between wood bolts (which had been carefully cooked in sulfur). In the slots of the rotor's generating surface were inserted flat aluminum tubes (with strongly rounded edges), which transported the charges during rotation of the rotor: the rotor's cylinder rotated on the ebonite shaft 3 whose lower end rested on a pivot held firmly in the base of the container. The upper end of the shaft passed through the cover of the container and rotated in a bearing set in a special support. This same support held a countershaft, by which the rotor was belt driven from a low-speed electric dc motor possessing power up to 20 kilowatts.

The rotor's cylinder was secured fast to the shaft in such a position that with respect to height its center line was somewhat lower than the middle of the container. The rotor's shaft was displaced relative to the container's axis in such a manner that the lateral surface of the rotor on one side approached the wall of the container within about 10 cm, and on the other side was about 60 cm away.

On the container wall, in a place closest to the rotor, was set a moveable grounded screen a (see Figure 1), which served as one of the condenser's faces - the other face (namely, the aluminum tube in the rotor) of the condenser being charged from a low-voltage source.

The screen was curved in such a way that its edge gradually receded further and further from the lateral surface of the rotor (See Figure 1). The minimum distance between the rotor's lateral surface and screen varied within the limits from 1 to 2 cm. Upon the grounded screen was attached an insulated brush by which the charge was fed to the rotor's plates (at voltage V_1), when the plates were located at a minimum distance from the screen. The primary voltage V_1 was led into the container through an ebonite insulator maintained at a voltage up to 120 kv.

On the opposite side of the container, where the lateral surface of the rotor was the farthest removed from the container walls, a second "high-voltage" screen b, which was connected to a brush that picked up charges from the approaching plates of the rotor, was attached to an insulating ebonite case.

The entire container was filled with pure kerosene possessing very high electrical resistance of the order of 10^{13} to 10^{14} Ohm-cm for fields equal to 100 kv/cm. (Note: The method of purification and the properties of kerosene were described in an article by M. V. Glikina and B. M. Gokhberg, in Zhurnal Tekhnicheskoy Fiziki, Vol. IX, page 730, 1939). The small viscosity and high electrical strength of kerosene (exceeding 200-220 kv/cm), it seemed, justified its use as the insulating medium. However, the favorable results obtained in investigations with kerosene in small models were unfortunately not repeated in the transition to the large generator. The mechanical losses turned out to be too large, and the electrical strength was quite insufficient; this, as will be shown below, was connected with the difficulty of removing small quantities of physical admixtures from the entire apparatus. In all, 19 to 20 tons of kerosene were required to fill the container.

In the upper part of the high-voltage screen was fastened a platform 4 which projected somewhat over the rotor; on this platform were installed a storage battery, rheostat, and one end of a wide ebonite tube 5, whose other end passed outside through the wall of the container. The tube was about 2 meters long and its internal cavity did not come in contact with the kerosene in the container. This permitted one to carry out replacements of the cathode-ray tube or high-voltage resistance (the tube and resistance are pushed into the ebonite tube), when filling the container with kerosene /Note Russian Editor's: The cathode-ray tube or high-voltage resistance were inserted into the ebonite tube_7.

When the cathode-ray tube was pushed in, the heater (the incandescent cathode filament) was hooked up to the storage battery installed near the high-voltage screen. The heating of the filament was regulated by a rheostat controlled by a long ebonite rod projection frommthe container through the cover. The storage batteries for heating the filaments were located in a special case inserted in a slot on the platform near the high-voltage screen; the batteries were connected to the heaters. The battery case also could be replaced during the filling of the container with kerosene.

After the installation of the cathode-ray tube or resistance the internal cavity of the tube was filled with kerosene.

2. High-Voltage Resistance and Cathode-Ray Tube

We measured the voltage developed by the generator by graduated high-voltage resistances and by the deflection, in a magnetic field, of an electron beam during operations with the cathode-ray tube.

(a) Resistance. We used two types of resistances. At first we utilised a tube made of special alkali glass possessing considerable conduction. The tube's length was 1.5 meter. Along the entire length of the tube, on individual portions of it, we conducted preliminary measurements of the tubes resistance for various field gradients up to intensities of 15 to 20 kv/cm; that is, up to these fields which we could expect during measurements on the generator. This preliminary calibration was done in pure kerosene under the same conditions that the resistances encountered in the generator.

However the resistances made of alkali glass were not completely reliable and required frequent controls; therefore we switched to "India-ink" resistances.

"India-ink" resistances were made from strips of Watman's paper dipped in India ink and then covered with a thin layer of shellac. The shellac preserves the resistances both from the influence of moisture in the air and also from the action of the kerosene; ten series-connected resistances were wound in a spiral on a glass tube 1500 mm long and 110 mm in diameter. [Note: In this case we used a tube made of good insulating glass and thus the resistance was determined actually only by the magnitude of the "India-ink" resistance.]

Each of the resistances were calibrated up to 100 kv, and all 10 resistances were selected identically. In the limit up to 100 kv each resistance remained constant, and thus we obtained resistances that operated dependably up to potential differences of 1000 kv.

(b) Cathode-ray tube. The tube design developed by L. A. Artsimovich and G. Ya. Shchepkin was selected after a number of preliminary tests. The conditions governing the tube's operation presented the following design requirements:

1. In connection with the relatively small length of the tube it was necessary to ensure an especially careful homogeneous distribution of potential in the tube.

2. It was necessary to preserve the vacuum-sealing paste (namely, picein) from the corrosive action of the kerosene.

3. A high vacuum of the order 10^{-6} mm/Hg was to be obtained.

4. Good focussing of the electron beam was required.

5. Finally, the tube had to have a device for the escape of electrons into the atmosphere.

Figure 2 represents schematically the tube. A glass tube 1, length 1500 cm and diameter 110 mm, served as the main body or base of the tube, the glass having walls from 2 to 4 mm thick. Within the glass tube were cylinders made up of sections 2, composed of red copper. The ends of the sections were rounded. Collars 3 were slipped on a section, which were held fast by means of adjusting screws 4 to the glass tube; at the same time these collars removed the possibility of spark-over along the wall of the glass tube: the capping attachments of the adjusting screws were sealed with picein. On the load-bearing surface of the tube opposite the collars 3 were installed metal rings 9 with rounded edges, which (i.e. rings) enclosed the adjusting screws 4. In order to have a homogeneous distribution of potential between the sections in the tube, the "India-ink" resistances 8 connected with the rings 9 were wound in a spiral on the outside. The whole tube was divided into ten sections. The total resistances in the tube amounted to about $5 \cdot 10^{10}$ ohms.

The cathode was mounted on a copper lid 6, which was held with picein to the end of the glass tube. The cathode was detachable, with reserve filaments and a focussing electrode 5. The disposition of individual cathode parts was selected so as to obtain good focussing of the electron beam.

The anode was made of copper tube 100 mm in diameter and 600 mm long, which (i.e. tube) was connected at one end to the glass tube and had at the other end a gridlike window covered with aluminum foil 40 microns thick. The outlet to the vacuum pump was not far from the place where electron beam issued.

All connections in the tube were sealed with picein and then with a layer of shellac in order to protect the picein from the corrosive kerosene.

A focussing coil was located on the anode tube for the purpose of auxiliary concentration of the electron beam.

3. Measurements of the Voltage Developed by the Generator

The first measurements of the voltage developed by the generator were carried out at large resistances for a very small current strength under conditions close to idling. The dependence of the secondary voltage upon the primary voltage is shown in Figure 3. For a leam gap between the rotor's plates and the grounded screen, the primary voltage was successfully raised to 50 kV; in this case the secondary voltage (determined with the aid of the resistance) reached as high as 1600 kV. Observations through a small aperture in the container showed that there were discharges in the kerosene around the high-voltage electrode; the disruptive distance in the kerosene reached 40 to 45 cm, but in individual cases it was 50 cm. It can be noted that when the apparatus was first filled with pure kerosene the field intensity near the grounded screen exceeded considerably the above-indicated 50 kV/cm (up to 80 kV/cm); later on, however, neither pure kerosene nor its replacement were successful in giving these high values again.

After prolonged operation of the generator, a number of defects appeared which in the end led to a considerable lowering of the secondary voltage and failed to give the desired results. The main defects were as follow:

1. The ebonite shaft of rotor began to show a noticeable sag (exceeding 6 mm), which correspondingly varied the gap between the operating surface of the rotor and the grounded screen (total gap was always 10 mm) and did not permit the primary voltage to be raised to the magnitude planned.

2. During the generator's operation, unavoidable impurities, drawn in by the electrical field in the gap between the grounded screen and the rotor's plates, created considerable nonhomogenicities in the field or even formed bridges, which led to rupture.

These circumstances, after prolonged operation of the generator, did not allow one to raise the primary field intensity above 25 to 30 kV/cm, thus lowering almost by two times the intensity achieved in the first tests; correspondingly the secondary voltages were successfully raised only to 800 to 900 kV.

For comparatively small "training" of the cathode-ray tube, an electron beam was produced with a voltage of the order of 800 kV, which the generator developed at this time.

Measurements of the speed of the electrons, which were carried out by observations of their deflection in a magnetic field, actually showed a voltage of 750 to 800 kV in the tube.

The electron beam emerging in the air quickly scattered, forming an elongated corona at the aperture, which shone with a bluish light. The fluorescing screen shone, within the limits of the luminescent corona, with an entense light which was clearly visible in the bright daylight. The length of the corona measured with the aid of the fluorescing screen, gave the "practical" value of the free-path length of the electrons in the atmosphere. For a voltage in the tube of 750 to 800 kV the corona's length was 2300 mm. The strength of the electron current was 20 to 50 micro-amperes.

With an electron beam of given speed and intensity, experiments were conducted, which however cannot be described in the confines of this article.

We take this opportunity to thank L. A. Artsimovich and G. Ya. Shchepkin, who designed and constructed the cathode-ray tube and took part in the testing of the generator with the tube; we also thank laboratory assistants D. V. Filippov and A. N. Voronin, who played a large part in all stages of the work.

[Note: No bibliography.]

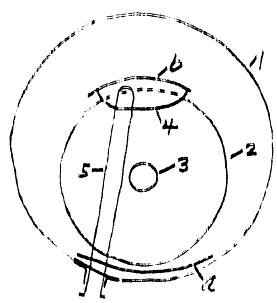

Figure 1

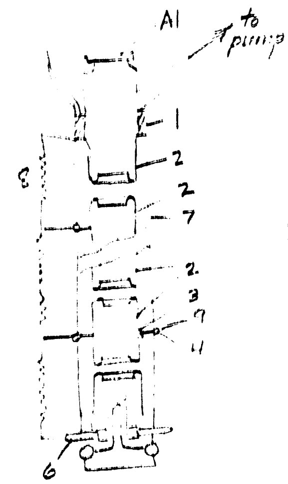

Figure 2

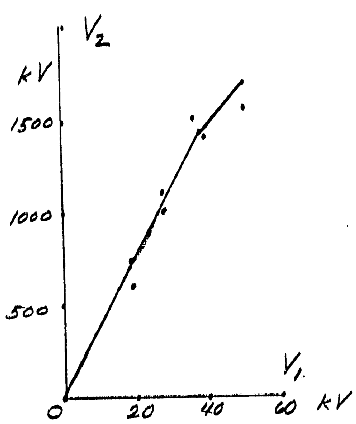

Figure 3

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