THE VELOCITY DISTRIBUTION OF ELECTRONS ISSUING FROM SMALL HOLES

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Abstract

The velocity distribution of a beam of 50-volt electrons issuing from a hole 0.022 cm in diameter in a copper plate 0.02 cm thick has been measured. Seventy percent of the electrons were found to retain approximately their initial velocity. By coating the sides and edges of the hole with lampblack 95 % of the electrons were transmitted without appreciable energy loss. Similar results were obtained with grids of 100 mesh copper gauze.

Introduction.—Preliminary to the construction of a magnetic electron velocity filter, some experiments were undertaken to determine the effect of passage through small holes or fine-mesh gauzes on the velocity distribution of an electron beam. Lehman and Osgood[1] found that with velocities of the primary beam corresponding to from 200 to 1000 volts less than 1% of the electrons passing through a hole 0.19 mm in diameter in a copper plate 0.135 mm thick retain their initial velocity. Since in similar experiments with 50-volt electrons we

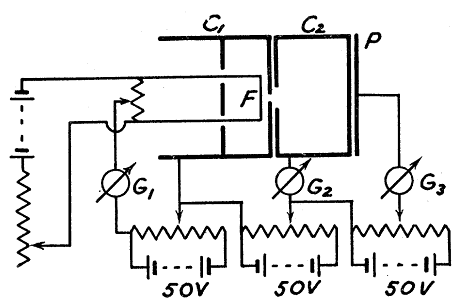

Fig. 1.

were able by using non-reflecting surfaces to get through more than 90% of the electrons with their initial velocity, it seems worth while to publish a brief description of our experiments.

Experimental arrangement. The apparatus is shown diagrammatically in Fig. 1. The source of electrons is a platinum filament F coated with calcium oxide operating on a potential-drop of 2 volts. Surrounding this is the cylindrical copper cage C_1, pierced by a hole 0.022 cm in diameter at a point opposite the center of the filament. The copper in

[1] Lehman and Osgood, Proc. Cambridge Phil. Soc. **22**, 731 (1925).

the neighborhood of the hole is 0.02 cm thick, and the distance to the filament is about 0.1 cm. C_2 is a similar cage 2 cm long with a hole 0.5 cm in diameter in the end facing C_1. The ends of the cages are discs which screw into place so that they may readily be replaced by grids, in which case the copper plate P is used to measure the current traversing the second of these. It is about 0.1 cm from C_2. All the cages have an inner diameter of 3 cm. The cages, plate, and filament are mounted rigidly with respect to one another and are suspended with the axis of the cylinders parallel to the earth's magnetic field in a tube closed by a ground-glass stopper (set in sealing wax) and connected with a liquid-air trap, a McLeod gauge, and vacuum pumps. G_1, G_2, and G_3 are galvanometers measuring the total current, the current from C_2, and the plate current, respectively.

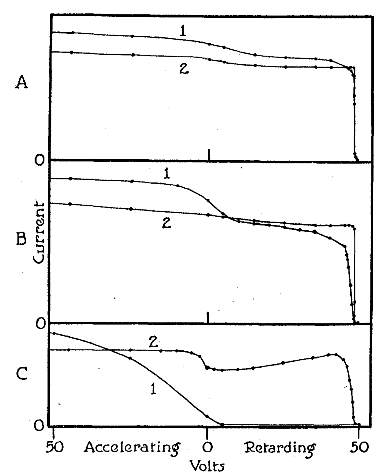

Fig. 2.

The general procedure was as follows. The apparatus was pumped out to a pressure of 10^{-4} to 10^{-5} mm, and the pumps were kept running during all the measurements. An accelerating potential of 50 volts was established between C_1 and the filament, and the temperature of the latter adjusted till a convenient emission resulted. The current through G_2 was then measured with various retarding potentials between C_1 and C_2. When the end of C_2 was replaced by a grid, the plate-current was read on G_3 with various retarding potentials between C_2 and the plate.

Experimental results. The experimental curves are reproduced in Fig. 2. Curve $A(1)$ was obtained with the hole 0.022 cm in diameter. The metal parts were baked out in vacuum at about 400° before placing in the apparatus, but no attempt was made to reduce the surface layer of copper oxide. The current to cage C_2 is plotted against the retarding or accelerating potential between C_1 and C_2. It is apparent from the curve that about 70% of the electrons (based on the current at zero volts) retain nearly their original velocity. To determine whether low velocity reflection and secondary emission were affecting the distribution, the end of C_1 was now coated with lampblack in a candle flame, since Gehrts[2] has shown that a lampblacked surface is a good absorber for electrons. Curve $A(2)$ shows the result obtained using the same total emission as for curve $A(1)$. About 95% of the electrons have their initial velocity. It is also interesting to note that the actual number of electrons retaining their initial velocity is nearly the same in the two cases, so apparently the only action of the soot is to remove from the beam all those electrons which strike even a glancing blow, thus preventing reflection and secondary emission, and eliminating the low-energy group previously present. Another distribution curve was taken after sooting C_1 and C_2 completely; but the curve was practically the same as $A(2)$, showing that C_2 was an efficient Faraday cage.

These are much better distributions than were obtained by Lehman and Osgood in the experiments above cited. The difference may be due to the higher voltage at which they worked, since it is known that the reflection of electrons from copper increases with the voltage up to 200–300 volts. The nature of the surface as determined by the previous treatment of the copper would also affect the reflection. In some earlier experiments where a crude apparatus was used, in which the metal parts were not baked out, we obtained curves somewhat similar to theirs, but after sooting the copper surfaces the results were as good as with the apparatus described above.

Since, in most of the experiments in electron impact work, the electrons traverse wire gauze grids, an experiment was tried to determine the effect of lampblack under these conditions. The hole in C_1 was replaced by a circular grid of 100 mesh copper gauze 0.5 cm in diameter, while the end of C_2 opposite the plate was replaced by a similar grid 2.5 cm in diameter. Curve $B(1)$ is a distribution curve of the current reaching C_2 in the absence of lampblack. In this case only about 60% of the electrons retained approximately their initial velocity, while the majority of these have suffered a small energy decrease. Curve $B(2)$ shows the distribution after the grids and cages had been

[2] Gehrts, Ann. d. Physik. **36,** 995 (1911).

sooted. It is apparent that about 90% of the electrons have their initial velocity. The absolute magnitudes have no meaning, since the emission was much higher in the second case.

To demonstrate further the effect of carbon, distribution curves of the plate current were taken first without and then with lampblack. These are reproduced in curves $C(1)$ and $C(2)$, respectively, in which the plate current is plotted against the accelerating or retarding voltage between C_2 and P. $C(1)$ is similar to curves obtained by Lawrence[3] with a very short Faraday cage. $C(2)$ shows a much better distribution, but it is poor compared to the curves above, which probably indicates that carbon is not a perfect absorbent. $C(1)$ is plotted to a much smaller current scale than $C(2)$, since the form of the curve and not the magnitude of the current is important.

The authors wish to express their thanks to Dr. G. Glockler for his help and advice; also to the Carnegie Institution of Washington for financial assistance received from a grant made to Prof. A. A. Noyes.

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[3] Lawrence, Proc. Nat. Acad. Sci. **12,** 29 (1926).