Letters to the Editor

NOTES ON POINTS IN SOME OF THIS WEEK'S LETTERS APPEAR ON P. 1018.

CORRESPONDENTS ARE INVITED TO ATTACH SIMILAR SUMMARIES TO THEIR COMMUNICATIONS.

A Method of Investigating Electron-Inertia Effects in Thermionic Tubes

IT is well known that the phenomena exhibited by thermionic vacuum tubes begin to alter when the frequency of the potential applied to their electrodes is increased so as to approach the inter-electrode transit-time of the electrons. It is convenient to group all these phenomena under the name of electron-inertia effects. They include the production of high-frequency oscillations by the magnetron and the Barkhausen-Kurz method, and the occurrence at very high frequencies of a phase shift of the conductance of a diode and of the mutual conductance of a triode, and increased damping in the grid circuit of a triode.

Many theoretical investigations of these effects have been made, but it is not easy to subject them to experimental test because of the difficulties encountered in working at the very high frequencies involved. It is, for example, very difficult to measure the amplitudes or phase relations of the potentials and currents, and if it is desired to apply high-frequency potentials to the electrodes in a search for resonance effects, it is generally necessary to do so by means of a Barkhausen-Kurz oscillator, the amplitude and frequency of which are not conveniently varied. If the frequencies of the oscillations involved in these investigations could be made very much smaller, the experiments would be much easier, and could be carried out in considerably greater detail.

This desirable effect can be achieved if, instead of electrons, more massive ions are used. It can be demonstrated that, in a tube with given potentials on the electrodes, the equations of motion for an ion of mass M are the same as those for an electron of mass m, provided the emission current is decreased in the ratio $\sqrt{m/M}$ and the time in all the equations is increased in the ratio $\sqrt{M/m}$. As a source of positive ions, it is convenient to use either a tungsten filament situated in a vapour of cæsium, according to the method first explained by Langmuir[1], or a platinum strip coated with an emitting substance, as described by Jones and Blewett[2].

In an investigation of some electron-inertia effects, we have used tubes of both kinds. A cæsium tube was made from the electrode system of an A.T. 40 triode, and a tube with plane electrodes having a variable spacing was used with a lithium emitter of the Jones and Blewett type. The more detailed experiments were made with the cæsium tube. An accelerating potential was applied to the grid and a small retarding potential to the plate, so that in the absence of any oscillating potentials no current was received by the plate. An ordinary retroactive oscillator was used to apply to the plate a high-frequency potential of amplitude less than the steady retarding potential. For most values of grid potential, no steady plate current was observed, but certain values of potential gave rise to a flow of plate current. The value of grid potential which gave rise to this plate current was dependent upon the frequency of the oscillating potential applied to the plate, and the phenomenon was presumably due to a resonance between the frequency of the applied E.M.F. and the frequency of oscillation of the ions about the grid wires. Similar results have been given by Gill and Donaldson[3] for an electron triode. If this is the correct explanation, the theoretical relation[4]

$$\lambda \sqrt{E_g} = 2{,}000\, d_g \sqrt{M/m} \qquad (1)$$

should hold between the grid potential (E_g) in volts, the wave-length (λ) in cm. corresponding to the applied frequency, and the grid diameter (d_g) in cm. This relation was, in fact, found to hold approximately. The wave-lengths lay between 300 m. and 800 m. for values of E_g between 450 and 75 volts, whereas if electrons had been used the wave-lengths would have been of the order of 1 m. It was found that the closeness with which expression (1) was obeyed depended on the amplitude of the applied potential, and on the emission current. We hope to give a detailed account of these effects elsewhere: the purpose of the present note is simply to direct attention to the method of investigation.

Similar effects were observed when the plane electrode tube was used with lithium ions. Equation (1) was again found to hold approximately, and was also found to represent correctly the effect of altered electrode spacing. With the lighter lithium ions the wave-lengths involved were of the order of 100 m. for potentials of the order of 200 volts and electrode spacing of the order of 1 cm.

It should be pointed out that since the emission currents in the case of positive ions are small, the effective impedance of a tube is large, and it has not been possible to use the above-mentioned tubes to produce oscillations of the Barkhausen-Kurz type. By making a cæsium vapour tube with a large emitting surface and by keeping the bulb at a high temperature so as to increase the emission current, we hope to be able to produce Barkhausen-Kurz type oscillations and investigate the mechanism of their production.

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[1] Langmuir and Kingdon, *Proc. Roy. Soc.*, **107**, 61 (1925).

[2] Jones and Blewett, *Phys. Rev.*, **50**, 464 (1936).

[3] Gill and Donaldson, *Phil. Mag.*, **15**, 1177 (1933).

[4] Megaw, *J. Inst. Elec. Eng.*, **72**, 313 (1933).