

June 18, 1940.

A. M. SKELLETT

2,205,072

SPACE DISCHARGE APPARATUS AND CIRCUITS THEREFOR

Filed Oct. 6, 1937

2 Sheets-Sheet 1

FIG. 1

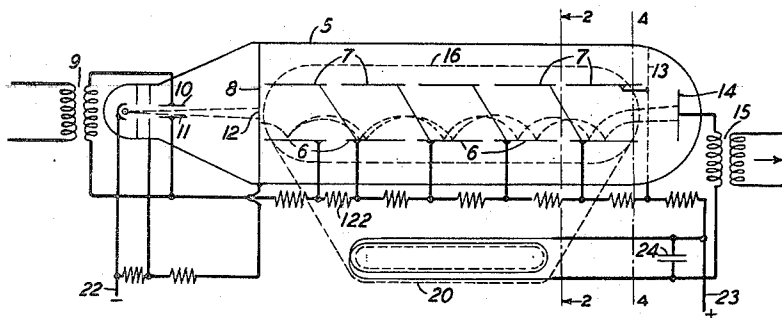


FIG. 2

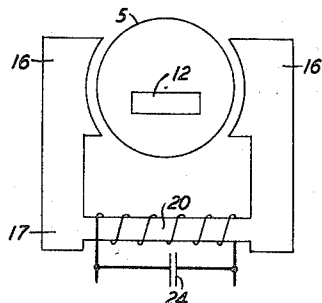


FIG. 3

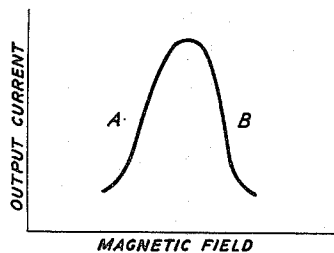
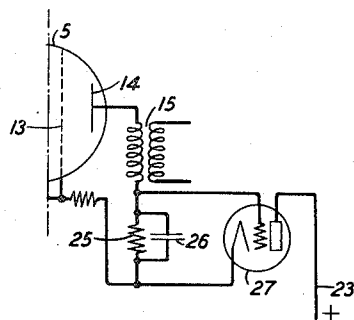


FIG. 4



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FIG. 5

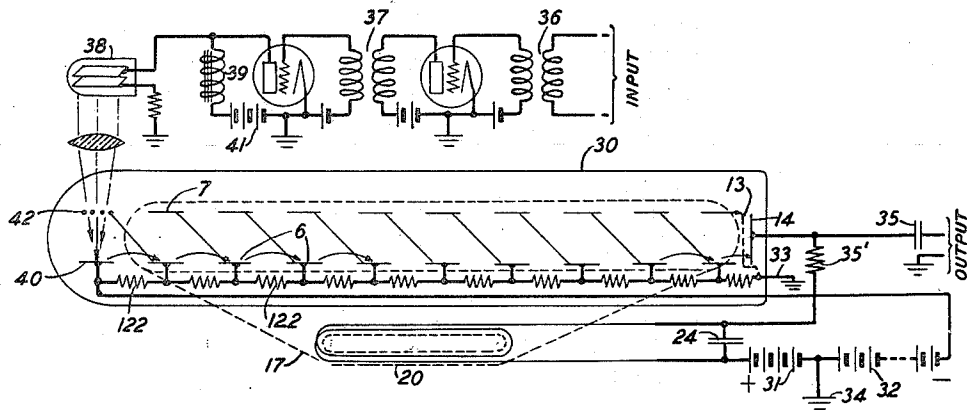
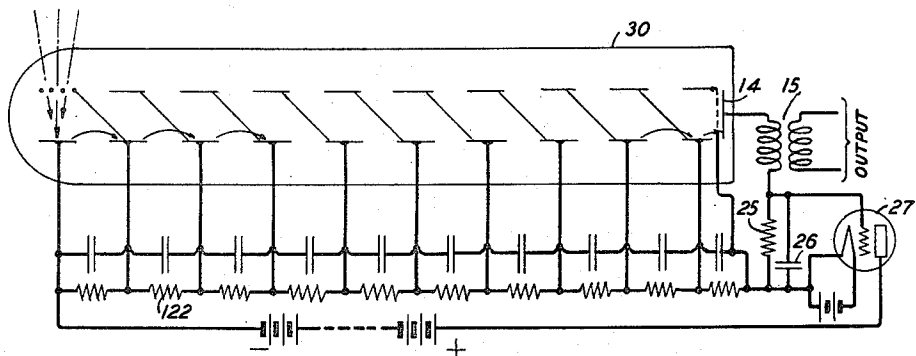


FIG. 6



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SPACE DISCHARGE APPARATUS AND
CIRCUITS THEREFOR

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Application October 6, 1937, Serial No. 167,525

15 Claims. (Cl. 179-171)

The present invention relates to space discharge apparatus and circuits therefor, in which use is made of secondary electron emission produced by successive impacts of electrons on emissive surfaces. Devices of this sort are commonly termed electron multipliers and will be so referred to in this application.

This application is a continuation in part of my prior application, Serial No. 93,536, filed July 31, 1936, for Space discharge apparatus and circuits therefor.

Representative objects are to improve upon the structure and mode of operation of electron multipliers and upon the circuits used with such apparatus, and particularly to stabilize their operation.

The nature and objects of the invention will be more clearly understood from the following detailed description when read in connection with the accompanying drawings.

In the drawings,

Fig. 1 is a longitudinal view of one type of tube structure and circuit embodying a stabilizing feature of the invention;

Fig. 2 is a cross-sectional view taken along the line 2-2 with some details omitted;

Fig. 3 shows a curve to be referred to in connection with the description of the operation of the invention;

Fig. 4 shows a view of a stabilizing circuit that may be used in lieu of that of Fig. 1; and

Figs. 5 and 6 show alternative types of structures and circuits in accordance with the invention.

Amplifying devices employing electron multiplication have the characteristics of direct current amplifiers. Also the more successful ones to date work under conditions of voltage saturation in so far as the emitter surfaces are concerned. In other words the emitting surfaces do not have a region of heavy space charge immediately above them; the emitted electrons are drawn off by a positive potential gradient at the surface. Now it is well known to workers in the art that a region of space charge next to an electron emitting surface, particularly those composite surfaces that are most efficient as electron emitters, has a stabilizing effect on the emission. Thus the electron multiplier of the usual sort when utilized as an amplifier does not have as good stability as the more conventional types of amplifier and means for stabilizing such devices would be very useful. Such stabilization is secured by means of the present invention in two general ways as will now be described. The

first method is by causing the output current to react on the magnetic field used for focusing the electron stream, and the second method is by causing the output current to vary the direct supply of voltage applied to the emitter and deflector plates of the device.

The first of these two methods is illustrated in connection with Fig. 1 in which an elongated tube 5 includes a series of secondary emitter plates 6 and a series of deflector plates 7. To the left of the apertured plate 8 any suitable type of primary electron source may be used, that shown being the electron beam type generally similar to that described in connection with Figs. 3 and 4 of the parent application. Input waves applied through input transformer 9 apply varying potentials to the beam deflecting plates 10 and 11 causing more or less of the electron beam to enter the aperture 12 and impinge on the first secondary emitter plate 6. It will be understood that the aperture 12 is positioned so as normally to lie slightly to one side of the electron beam. Secondary electrons are released from the successive emitter plates 6 and those from the final plate 6 pass through the screen 13 to the output or anode plate 14 producing variable current flow in the primary winding of output transformer 15.

The position of one pole face of the focusing magnet is indicated by dotted lines at 16 in Fig. 1 and the structure of the magnet itself will be more apparent from the sectional view of Fig. 2. The magnet 17 having pole faces 16, 16, may be either a permanent magnet or an electromagnet. In this case it is assumed to be a permanent magnet with a superposed winding 20 for varying the strength of the magnetic field. This winding 20 is connected between the primary winding of output transformer 15 and the positive pole 23 of the source of supply voltage shown connected between terminals 22 and 23. A relatively large capacity 24 in shunt with winding 20 permits current variations of signaling frequency to return directly to the supply source. Relatively slow variations in the output current representing instability in operating characteristic pass through the winding 20 and vary the strength of the focusing field of the magnet 17 to react on and change the value of the output current in direction and amount to improve the stability of operation of the device.

The action is illustrated by Fig. 3 which shows a typical curve plotted between strength of magnetic field and magnitude of output current. By operating on the steep portion of this curve at

either point A or point B a small change in strength of magnetic field produces a relatively large change in output current and it is only necessary to observe a proper relation between direction of winding of the coil 20 and the direction of the effect of change of magnetic field on output current to secure a compensation for instability by this means.

The second method of correcting for instability may be accomplished by the apparatus shown in Fig. 4 which may replace the portion of the apparatus in Fig. 1 shown to the right of the broken line 4-4. In this case no use is made of the coil 20, the terminals of which may therefore be left open. The positive pole 23 of the voltage supply source leads to the anode of a three-element tube 27, the cathode of which is connected in series through a resistance 25 and primary winding of output transformer 15 to the anode 14 of the tube 5. Resistance 25 is bypassed by condenser 26. Variations in output voltage of signaling frequency produce no effect on the tube 27 since they are by-passed by condenser 26. The grid of the tube 27 is biased by current flow through resistance 25 which may be supplemented with other biasing means, if desired, or necessary to give the tube 27 a normal internal resistance of appropriate value. Relatively slow variations in output current representing unstable operation develop potential differences between the terminals of resistor 25 which are applied to the grid of the tube 27 and vary its internal impedance and consequently the voltage supplied to the potentiometer 122 from which the voltage is taken off for the various emitter plates.

It is found that the supply voltage characteristic of the device is of the same general shape as the curve of Fig. 3 and by working on the low voltage side of the characteristic, that is, where

$$\frac{di}{dE}$$

is positive, the circuit of Fig. 4 will provide stabilizing action. If desired, the tube 27 may be a screen grid or pentode type of tube or any other suitable type.

In operation a small decrease in the amplification of the device 5 will cause a corresponding decrease in the output current through resistance 25 and tube 27 causing the grid of the tube to go more positive and the internal resistance of tube 27 to be lowered. More current will then flow through the potentiometer 122 raising the voltage supplied to the electron emitter plates and increasing the amplification up to its normal value. An increase in amplification above normal results in similar manner in a decrease in the supply of voltage and stabilization at the working value.

In the foregoing description one use that may be assumed as an example is in radio or carrier operation in which in the absence of signals a constant amplitude carrier wave is impressed on the device. Signal modulations appear as amplitude variations of the carrier wave. Condenser 24 or 26 would by-pass both the signal and the carrier frequency components and the stabilizing feedback would respond to relatively slow changes in output current as described.

It was stated above that electron multipliers are usually operated at voltage saturation by which is meant that an increase in anode voltage produces substantially no increase in the number of electrons drawn from the emitting

surfaces. A source of instability in electron multipliers lies in the variable emitting efficiency of the secondary emitting surfaces. This may vary from moment to moment or from hour to hour. While the variations are random throughout the device the variations in the case of the initial stages have greatest effect because of the large amplification of the voltage from these stages. The compensation can, however, take place throughout the tube by either of the methods.

Referring now to Fig. 5, the tube 30 may be of generally similar construction to tube 5 but is provided with a photoelectric cathode 40 at the input end and in the example to be described is arranged to transmit steady direct current in the absence of applied signals. The secondary emitter plates 6, 6 and deflector plates 7 may be as previously described.

A divided battery 31, 32 grounded at 34 supplies potential to the secondary emitters 6 which are connected to points along potentiometer 122. The end of the resistance 122 nearest to the anode 14 is grounded at 32. The same type of stabilizing means is shown in this figure as in the case of Fig. 1 and comprises magnet 17 provided with stabilizing winding 29 shunted by capacity 24 and connected in series with the anode supply voltage.

The input circuit to the device 30 may be from a microphone or any suitable type of electrical pick-up and is shown as including input transformer 36 and a multistage amplifier 37 the output of which is connected to a neon tube 38. This tube is connected across the plate choke 39 and plate battery 41 in series with a suitable amount of resistance and the terminal voltage across the neon lamp is such as to bring it to a normal value of illumination, preferably at about the middle of its characteristic. The light from the neon lamp 38 is focussed by a suitable lens system on the photoelectric cathode 40.

In the absence of impressed signal waves steady illumination on the cathode 40 liberates primary electrons which are driven over to the first secondary emitter plate 6 by the aid of the positive voltage on grid 42 as well as the action of the magnetic field from the magnet 17. The secondary electrons emitted from the first plate 6 are similarly directed against the second emitter plate and so on as described previously.

Input waves at 36 vary the illumination produced by neon lamp 38 and thus vary the strength of the primary electron current. In this way the amplified output is caused to follow the signal variations. The secondary electrons emitted from the last cathode emitter 6 pass through the screen 13 to the anode 14 and the signal variations are transmitted through capacity 35 to the output circuit with the aid of coupling resistance 35'.

It is thus seen that the signal variations take place about a normal steady value of current. Any tendency for relatively slow variations to occur in this direct current is opposed by the corresponding variations of current through the winding 29. It will be understood that in any particular case the voltage supply, the strength of the magnetic field and the number of turns in the winding 29 may be suitably proportioned to secure the degree of stabilization required.

Fig. 6 shows the same type of tube as Fig. 5 and assumes the same type of input circuit. It also assumes a magnetic field normal to the plane of the drawing produced by a suitable magnet. Fig. 6 illustrates the application of the second of the two general methods of stabilization referred

heretofore to the type of tube 30 disclosed in Fig. 5. The regulator tube 27 may be similar to that of Fig. 4 and similarly connected in circuit, the corresponding circuit elements being similarly numbered. In the case of Fig. 6 as in Fig. 5 in the absence of applied signals a steady value of output current is obtained and tube 27 operates near the middle of its characteristic. When signals are applied the output current continues to have this steady value except for the instantaneous signal variations which, however, do not affect tube 27. Slow variations which change the steady value of the output current vary the impedance of tube 27 and in turn vary the voltage applied to the potentiometer 122. The direction of the changes is such as to compensate for the assumed slow variations.

What is claimed is:

1. In a space discharge device electron multiplier, means comprising surfaces from which secondary electrons are produced by successions of impacts, an output electrode and an output circuit, means producing a focusing field for directing electrons against said surfaces, and means controlling said field in accordance with fluctuations of current in said output circuit in a manner to oppose such fluctuations.

2. The combination with an electron multiplier device having a magnetic field, an output electrode and output circuit for said device, and a stabilizing winding connected to said output circuit and positioned to exert a control upon said field.

3. The combination with an electron multiplier device, an output electrode and an output circuit therefor, a source of voltage for supplying the actuating potentials to said device, and means controlled by the output current for controlling the voltage applied to the device from said source.

4. In electron multiplier apparatus, cathode emitter surfaces, means producing a primary electron stream, means producing a field directing such stream against the first cathode surface with sufficient velocity to produce secondary emission therefrom, said field-producing means causing the resulting secondarily emitted electrons to impact the next cathode surface to release further secondary electrons therefrom, and causing a repetition of such action until the required degree of amplification is attained, an output circuit for the amplified currents, and means causing fluctuations in the output current to react upon said field-producing means.

5. In electron multiplier apparatus, means comprising surfaces from which secondary electrons are produced by successions of impacts, an output electrode and an output circuit, means for placing direct current potentials on said surfaces, means producing a focusing field for directing electrons against said surfaces, the angle of incidence and the velocity of the electrons against said surfaces and, therefore, the effectiveness of said impacts in producing secondary electrons being jointly determined by the two factors of strength of focusing field and potentials on said surfaces, and means controlled in response to variations in current in the output circuit that are slow in comparison with signal variations for varying one of said two factors in direction and extent to compensate said variations.

6. In electron multiplier apparatus, means comprising surfaces from which secondary electrons are produced by successive impacts, an output electrode and an output circuit, externally controlled means imparting velocity to the sec-

ondarily emitted electrons for directing them against the successive surfaces, and means responsive to relatively slow fluctuations in output current for controlling said second-mentioned means in a direction to counteract said fluctuations.

7. In electron tube apparatus, a plurality of surfaces adapted to emit secondary electrons efficiently as a result of impacts of incident electrons, an input circuit and an output circuit therefor, circuits for causing impacts of electrons on said surfaces in succession to provide for amplification between a wave applied to said input circuit and the resulting output wave, said circuits including a supply circuit for supplying a direct current voltage to said surfaces, and means controlled in response to relatively slow variations in the supply current for controlling the impact of electrons upon said surfaces to vary the amplification factor in direction and extent to compensate said variations.

8. The combination of an electron multiplier comprising an evacuated enclosure including a plurality of secondary electron emitting plates from which electrons are emitted successively by impact of incident electrons, means controlling the path taken by the emitted electrons from one such plate to the next, said multiplier being subject to variable operation tending to produce variations in output current, and means acting in response to such variations for modifying the action of said controlling means to oppose such variations.

9. In an electron multiplier, a succession of secondary emission members, means for causing successive impacts of electrons from member to member to produce amplification by electron multiplication, said multiplier being subject to variable operation tending to produce variations in output current, and means compensating such variations comprising means operating in response thereto for varying the amplification factor of said multiplier.

10. The method of regulating the output current of a magnetic electron multiplier in which an electrostatic field of an intensity dependent on supply voltage and a magnetic field across said electrostatic field constrains an electron discharge to impinge on a secondary electron emitter, which consists in changing the strength of the magnetic field in response to changes in the supply voltage to maintain the strength of the magnetic field proportional to the intensity of the electrostatic field for minor variations in the supply voltage.

11. The method of neutralizing the effect of minor variations in operating voltage on the output current of a magnetic electron multiplier in which an electron discharge is directed to a secondary electron emitter by crossed electrostatic and magnetic fields which consists in counteracting the effect on the electron discharge of changes in intensity of the electrostatic field due to variations in supply voltage by producing in response to said variations corresponding and proportional changes in the strength of the magnetic field.

12. The method of obtaining a substantially constant output current from a magnetic electron multiplier dependent on crossed electrostatic and magnetic fields and operated from a voltage supply subject to minor variations which consists in increasing and decreasing the strength of the magnetic field in response to minor variations in supply voltage and simultaneously with

and in proportion to increases and decreases in the intensity of the electrostatic field due to minor increases and decreases in the supply voltage.

13. A magnetic electron multiplier comprising
5 a secondary electron emitter, an accelerating electrode for producing an electrostatic field to draw electrons away from said emitter, a resistor having a point intermediate its ends connected to said accelerating electrode, and a magnet having
10 an exciting coil with one end connected to an adjoining end of said resistor for producing across said electrostatic field a magnetic field which varies in strength with variation in voltage between the other ends of said coil and said resistor.

14. A magnetic electron multiplier comprising
15 a secondary electron emitter, an accelerating electrode spaced from and opposite to said emitter, a source of distributed voltage having an intermediate point connected to said accelerating
20 electrode to produce an electrostatic field to draw electrons away from said emitter, and a magnet for producing across said electrostatic field a homogeneous magnetic field parallel to said emit-

ter and having an exciting coil connected to said source to render the strength of the magnetic field dependent on the voltage of said source and proportional to the strength of said electrostatic field.

15. A magnetic electron multiplier having electrodes including an electron source, an output anode, a secondary electron emitter, and an accelerating electrode, said emitter and said accelerating electrode being mounted parallel to each
10 other between said source and said anode and on opposite sides of the path of an electron discharge from said source to said anode, a voltage divider comprising a resistor with intermediate points connected to said electrodes, and an elec-
15 tromagnet with an exciting coil connected in circuit with said resistor for producing between said emitter and said accelerating electrode a magnetic field parallel to said emitter and transverse to the path of discharge from said source to said
20 anode and responsive to variations in potential impressed on said resistor.

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