

June 18, 1940.

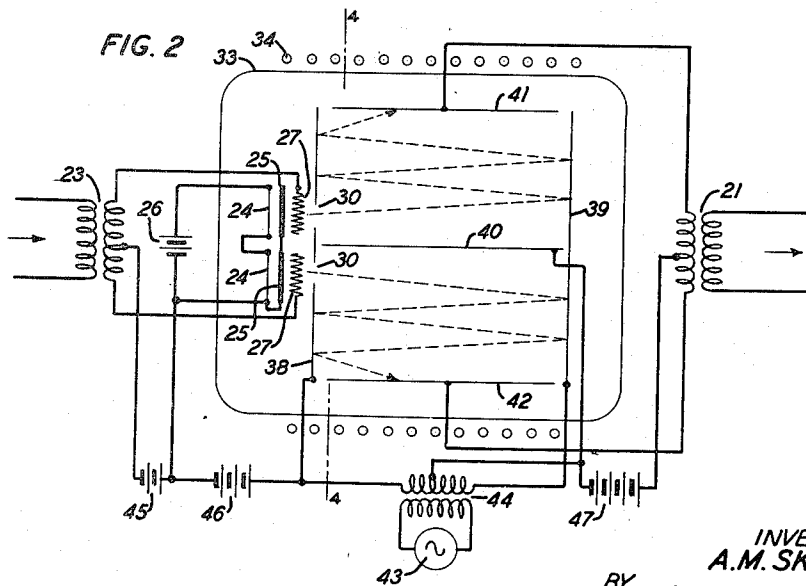
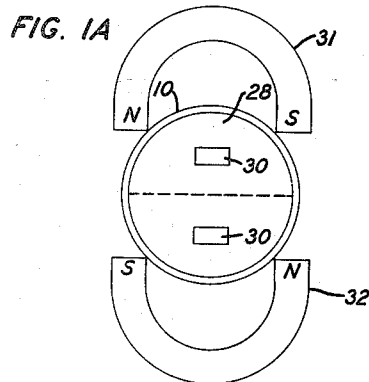
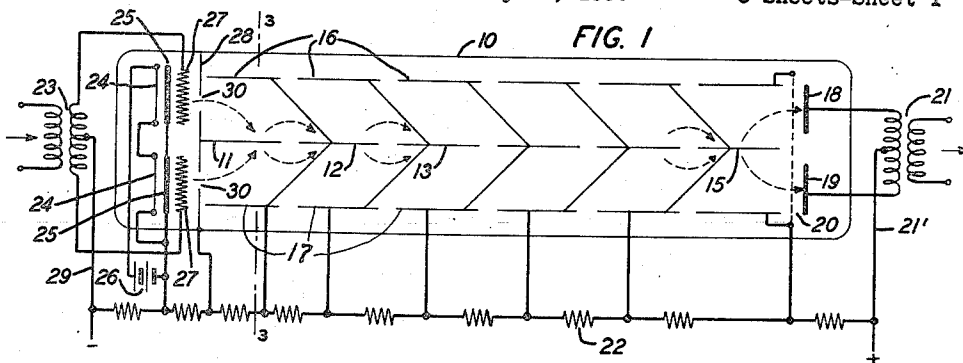
A. M. SKELLETT

2,205,071

SPACE DISCHARGE APPARATUS AND CIRCUITS THEREFOR

Filed July 31, 1936

3 Sheets-Sheet 1



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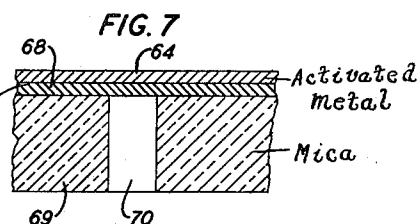
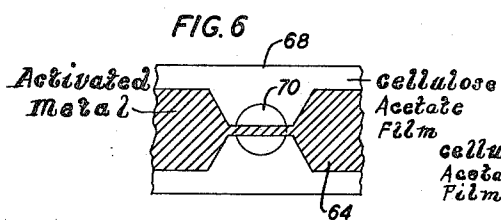
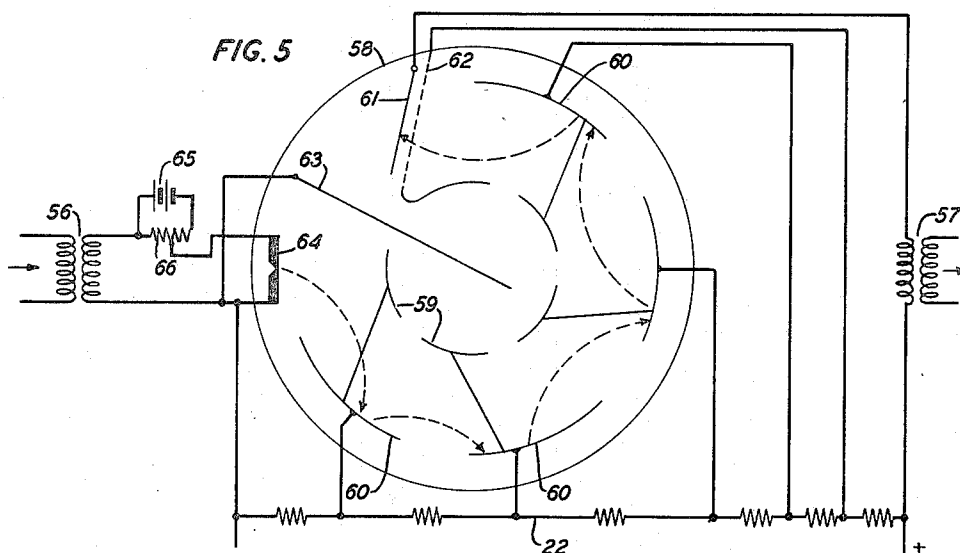
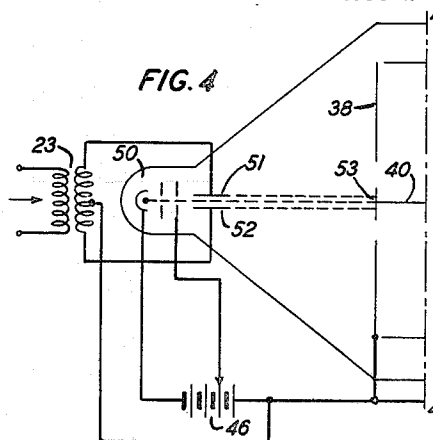
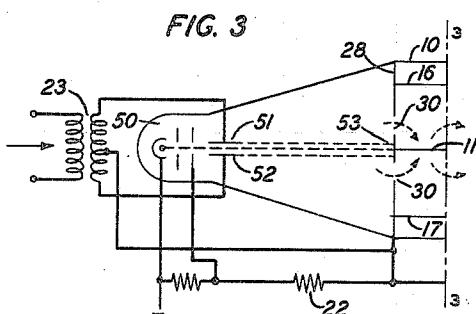
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SPACE DISCHARGE APPARATUS AND CIRCUITS THEREFOR

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3 Sheets-Sheet 2



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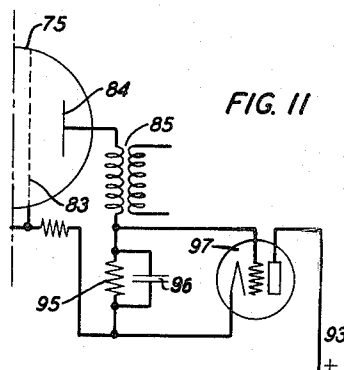
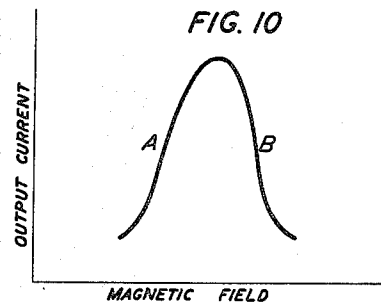
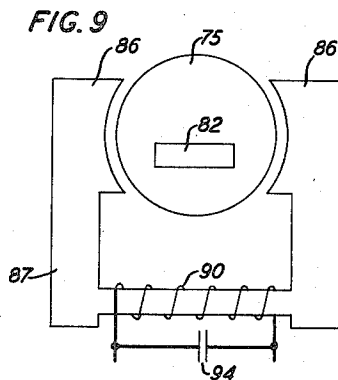
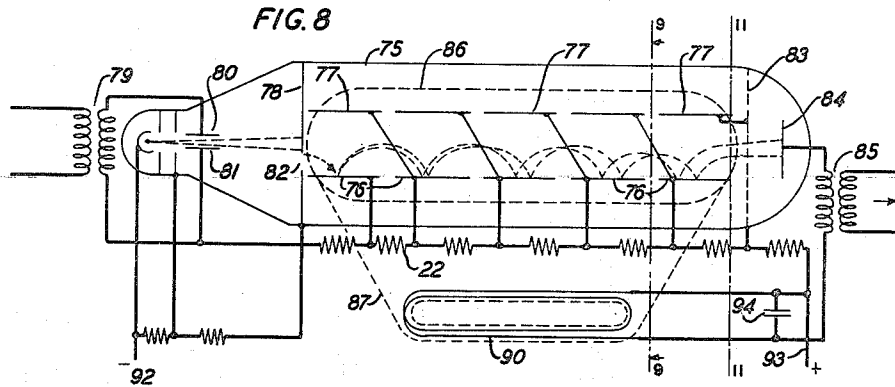
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SPACE DISCHARGE APPARATUS AND CIRCUITS THEREFOR

Filed July 31, 1936

3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

2,205,071

SPACE DISCHARGE APPARATUS AND
CIRCUITS THEREFOR

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Application July 31, 1936, Serial No. 93,536

13 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.

Representative objects of the invention are to improve upon the structure and mode of operation of such apparatus and upon the circuits used with such apparatus.

More specifically, it is an object of the invention to provide a circuit in which the operation of an electron multiplier is stabilized.

Another object is a duplex or push-pull type of electron multiplier, the two sides of which preferably operate in alternation.

The various objects and features of the invention will be made more apparent from the following detailed description of representative embodiments of the invention as illustrated in the accompanying drawings in which

Fig. 1 is a schematic diagram partly in section of a tube structure and circuit therefor in accordance with the invention;

Fig. 1A shows a detail of the tube structure of Fig. 1;

Fig. 2 is an alternative type of tube structure and circuit therefor in accordance with the invention;

Figs. 3 and 4 show alternative types of electron sources which may be substituted for the corresponding portions of either Fig. 1 or Fig. 2;

Fig. 5 shows an electron multiplier tube structure and circuit therefor of a different type in accordance with one form of the invention;

Figs. 6 and 7 are detailed showings of a type of electron source illustrated in the structure of Fig. 5 but also capable of general use;

Fig. 8 is a longitudinal view of a modified type of tube structure in accordance with the invention embodying a stabilizing feature of the invention;

Fig. 9 is a cross-sectional view taken along the line 9—9 with some details omitted;

Fig. 10 shows a curve to be referred to in connection with the description of the operation of Fig. 8; and

Fig. 11 shows a view of a stabilizing circuit that may be used in lieu of that of Fig. 8.

It is known that electron multiplier amplifiers have proved effective in producing very large amounts of amplification and that their operation compares favorably with that of conventional vacuum tube amplifiers, particularly with

respect to the noise level. So far as known, one of the most effective ways of producing the electrons initially for subsequent multiplication by such apparatus has been by means of a photoelectric cathode where the signal or other variations to be amplified is in the form of a modulated light wave. This method of producing the initial electrons appears to have serious limitations when the signal or other variations to be amplified are in the form of small currents produced outside of the electron multiplier tubes.

It has, of course, been suggested that the photoelectric emitter at the input might be replaced by a thermionic cathode and a grid. A serious limitation to this simple change is that the modulation of the direct current to the first multiplier stage is likely to be extremely small and since this modulation is constant throughout the multiplier the direct current component at the output will often be large in comparison with the signal. For useful operation, the electron current to the first multiplication stage should be modulated by the signal to a degree approaching as nearly as possible 100% modulation. This means that where a cathode and grid or any other type of electron emitter and input control are used, they should operate in analogous manner to the so-called class B or class C operation of the conventional amplifier. These considerations have led the applicant to devise electron multiplier apparatus working on the duplex or push-pull principle, typical forms of which will now be described with reference to the drawings.

Referring first to Fig. 1, an elongated evacuated envelope 10 is shown as provided at its left-hand end with suitable electron emitter and input elements to be described, with a central row of emitters 11, 12, 13, etc., an upper row of deflecting plates 16 and a lower row of deflecting plates 17. The emitter plates, 11, 12, 13, etc. are suitably coated on both their upper and lower surfaces to promote liberation of secondary electrons under electron impact, such as by depositing caesium on an oxidized plate of silver or in any other suitable manner. In the right-hand end portion of the envelope 10 are anodes 18 and 19 separated from the rest of the structure by a grid or shield grid 20 preferably extending all the way across the tube. Anodes 18 and 19 are connected to the primary of output transformer 21. Each emitter plate 11, 12, 13, etc., is connected to the corresponding deflecting plate of the upper row 16 and of the lower row 17 and to a point on the potentiometer 22 which is supplied with suitable terminal voltage as indicated. It will

be understood that each emitter plate and its corresponding deflector plate are at a more positive potential than the set of emitter and deflector plates immediately preceding them.

In the structure illustrated in Fig. 1 the electron emitter and input structure comprises heating filaments 24, 24 supplied with heating current from battery 26, and cathodes 25, 25 which are heated by the filaments 24, 24 to render them suitably emissive. Grids 27, 27 are positioned between the cathodes 25, 25 and the multiplier chamber and are connected to the terminals of input winding 23. A shield or screen 28 extends across the tube and divides the structure into two portions except for the windows illustrated at 30, 30. The detailed Figure 1A shows the general shape and position which these apertures 30, 30 in the plate 28 may have. Fig. 1A also shows a pair of permanent magnets 31 and 32 situated with respect to tube 10 so as to produce a magnetic field in the upper portion of the tube, opposite in sign to that produced in the lower portion of the tube. No attempt has been made to show these magnets in connection with Fig. 1 since it would needlessly complicate the drawings. It is to be understood, however, that preferably a number of magnets such as 31 will be positioned along tube 10 and a similar series of magnets 32 will also be positioned along the tube 10 so as to produce the oppositely directed magnetic fields in the upper and lower halves of the tube throughout the multiplier portion of the device.

In the operation of the structure and circuit according to Fig. 1, the grids 27, 27 are polarized by the connection of conductor 29 to the potentiometer 22 by a sufficient negative voltage relative to the cathodes 25, 25 so that in the absence of applied waves through the input coil 23, no electrons are permitted to pass through the windows 30, 30 to the multiplier portion of the apparatus. It will be noted that a relatively high positive voltage is applied to the plate 28 so as to attract electrons towards the apertures 30, 30 when either grid 27, 27 has its voltage sufficiently shifted in the positive direction. When signals are applied from the input circuit through the input coil 23, one grid 27 is instantaneously driven positive while the other one is driven more negative. When the variation applied to one of the grids in the positive direction sufficiently overcomes the normal bias, electrons are permitted to pass through the corresponding aperture and enter the electron chamber. Under the influence of the magnetic field these electrons are deflected towards the plate 11 which they strike at sufficient velocity to release a larger number of secondary electrons. These secondary electrons are constrained by the magnetic field and by the higher positive potential of the next set of emitter and deflector plates (towards the right in Fig. 1) to follow a curved path and strike the second emitter plate 12 from which they release. This process continues throughout the length of the multiplier portion of the tube, the secondary electrons emitted from the final plate 15 passing through the screen grid 20 to either anode 18 or 19 as the case may be. Thus the upper and lower portions of the multiplier structure come into play alternately under control of the input wave and produce amplified current flow to either anode 18 or 19. The amplified output currents are transmitted through the output coil 21 into the outgoing circuit.

The invention is not limited to the case in

which the two sides or portions of the electron multiplier structure are included within the same envelope nor to the case in which one set of emitter plates 11, 12, 13, etc., is used in common by both portions of the electron multiplier structure since other constructions will suggest themselves to those skilled in the art.

Referring to Fig. 2 the electron emitter and input structure may be the same as that of Fig. 1, corresponding elements being indicated by the same reference characters. In this case the envelope is represented at 33 and the multiplier portion of the apparatus is comprised between the vertical plates 38 and 39 and the horizontal plates 41 and 42 positioned generally as shown. A central shield member 40 extends lengthwise of the chamber and preferably entirely across it. The end plate members 38 and 39 have applied to them a high frequency or radio frequency voltage from source 43 connected to transformer 44. Shield 40 is maintained neutral with respect to this high frequency voltage by being directly connected to the middle of the secondary winding of the transformer 44. The plates 41 and 42 are maintained at relatively high positive voltage with respect to the shield 40 by means of battery 47. In this figure the means for biasing the grid 27 with respect to the cathodes 25, 25 is shown as battery 45 while a battery 46 supplies a positive voltage to plate 38 relative to cathodes 25, 25. In this figure, as in Fig. 1, the grid bias is maintained at such high negative value that in the absence of input waves to be amplified no electrons are permitted to enter the electron multiplier chamber through the apertures 30, 30.

When the potential of either grid 27 varies sufficiently in a positive direction to permit electrons to enter the corresponding aperture 30, the electron comes under the influence of the high frequency field and is caused to traverse a path to and fro roughly as indicated in dotted lines in the drawings. Supposing that the high frequency field is at the moment under consideration such as to make the end plate 39 positive with respect to plate 38, the electron is accelerated towards the right in the figure, that is towards the plate 39. It will be understood that plates 38 and 39 are suitably coated to render them emissive to liberate secondary electrons under electron impact. At a suitable instant the high frequency field reverses in sign so that plate 39 becomes negative with respect to plate 38. The electron in question, however, has been accelerated so that it strikes the plate 39 driving out a larger number of secondary electrons which are immediately driven toward the left in the figure, that is toward the plate 38 under the influence of the high frequency electrical field. At the same time these electrons are attracted toward either plate 41 or 42, as the case may be, because of the high positive voltage existing on these two plates. The resultant path is the zigzag dotted line referred to whereby after a succession of impacts on the plates 38 and 39 the secondary electrons, greatly increased in number, finally reach the plate 41 or 42.

As in the case of Fig. 1 the upper and lower parts of the multiplier chamber of Fig. 2 act in alternation, depending upon the reversal of sign of the input waves through transformer 23. The amplified output flows alternately through the upper and lower halves of the primary of the output transformer 21 and induces amplified output voltage in the outgoing circuit.

The foregoing description has assumed that 75

there was not necessarily any magnetic field in the tube. Generally improved results are attained by use of a magnetic field which may be produced for example by applying direct current to the winding 34 surrounding the envelope 33. The field so produced is in the horizontal direction parallel to the plane of the paper. This field causes the electrons to take a spiral rather than simply a zigzag path and prevents them from straying across to anodes 41, 42 from their points of emission on the surfaces of plates 38, 39. The back and forth lines of flight in Fig. 2 should in this case be pictured as the edge-on view of a spiral.

Referring now to Fig. 3, the structure shown in this figure is alternative to and may be substituted for the portion of the structure of Fig. 1 lying to the left of the broken line 3—3. This alternative structure comprises at the left-hand end of the tube 10 an electron gun, generally indicated at 50, of known construction for producing a concentrated beam of electrons passing between the deflector plates 51 and 52. The details of the electron gun structure are not shown but may be, for example, of the type disclosed in U. S. Patent 1,632,080 to J. B. Johnson, June 14, 1927, or any other suitable type. In the absence of input waves, that is, in the normal condition, the electron beam impinges on the central portion 53 of the plate member 28 so that none of the electrons enter the multiplying chamber through either aperture 30, 30. It is desirable that the edges of the electron beam be made as sharp as possible and this may be attained by suitable electron focusing in a manner known in the art. Signal waves applied to the input transformer 23 vary the potentials on the plates 51 and 52 causing the beam to be swung upward or downward in the figure so that a variable portion of the beam, depending on the signal amplitude, enters one or the other aperture 30, 30.

In order to prevent secondary emission from the plate 28, particularly the central portion 53, the surface may be coated with carbon or, alternatively, a shield (not shown) may be placed in front of the plate 28. The position of the field magnets (see Fig. 1A) is such that there is but small stray field in the portion of the apparatus shown in Fig. 3 capable of affecting the direction of the electron beam. If found desirable, however, in any case magnetic shielding can be used for the portion of the device shown in Fig. 3. For example, member 28 could be made of magnetic material and could be supplemented by further magnetic shielding within or without the tube. Since the electron velocity is high in this portion of the device any existing stray field would have less effect on the beam direction than it would on the electrons inside the multiplier.

The type of electron source shown in Fig. 3 possesses advantages over that shown in Fig. 1 for certain uses, for example for relatively small input potentials. If the input potentials are too small, the velocity distribution of the electrons in the structure of Fig. 1 might be such that comparatively few electrons are passed into the multiplication chamber. With the structure of Fig. 3 the electron velocity may be made high regardless of the value of the input potentials.

The structure shown in Fig. 4 is alternative to and may replace the portion of the structure of Fig. 2 shown to the left of the broken line 4—4. In view of the description given of Fig. 3 no detailed description of Fig. 4 is deemed necessary since the drawings, together with the reference

characters, make it clear how the substitution of this structure in the structure of Fig. 2 could be made.

In the structure of Fig. 5 which represents a plan view of the apparatus, envelope 58 is in the form of a squat cylinder including an outer row of emission plates 60 in the form of arcs of a circle and an inner row of deflector plates 59 also arranged in a circle concentric with plates 60. The progress of the electron stream is indicated by the dotted arrow line as extending from the electron source 64 (to be described later) against the inner surfaces of the emission plates 60 in succession around the device and finally to the output plate or anode 61 in front of which is a screen grid 62. In this figure the magnetic field is normal to the plane of the paper as indicated by the curvature of the electron paths. Each pair of plates 59, 60, extending counter-clockwise around the device, is maintained at higher potential than the preceding pair by suitable connection to points on potentiometer 22. A centrally positioned shield 63 prevents direct passage of electrons across the device from the relatively low potential plates 59, 60 near the input of the device to the relatively high potential plates near the output side of the device.

The initial electron source 64 consists of a small thin film of metal adapted to be variably heated by the input waves and coated on its surface with suitable electron emitting material. This may be constructed as shown in Figs. 6 and 7, of which Fig. 6 represents a plan view and Fig. 7 a section. A mica support 69 has a central aperture 70 through it and is covered over with a thin sheet of cellulose acetate 68 on the top of which is deposited a thin layer of metal 64, applied by sputtering the metal or evaporating it on the surface of the acetate film. The metal is then activated to render it thermionically emitting. The metal film 64 is cut away at its middle portion as shown in Fig. 6 so that only a very narrow portion lies over the aperture 70. This type of structure has been used by applicant in making thin film thermocouples and applicant has found that thermocouples constructed in this way are capable of responding to very small temperature variations at frequencies up to and beyond 20,000 cycles per second.

Referring again to Fig. 5, the electron emitter 64 is supplied with a normal or biasing current from battery 65 through regulating potentiometer 66 to produce a mean value of heating current and a corresponding mean value of emitted electrons. Speech waves or other signal waves applied through input transformer 56 cause instantaneous increases or decreases in the temperature of the element 64 with corresponding increases and decreases in the number of electrons emitted from instant to instant and these variations in the number of electrons emitted are amplified by the multiplier apparatus in a manner that will be obvious in view of the description of the previous figure. For some purposes the battery 65 and resistance 66 may be omitted.

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. 8 in which an elongated tube 75 includes a series of secondary emitter plates 76 and a series of deflector plates 77. To the left of the apertured plate 78 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. Input waves applied through input transformer 79 apply varying potentials to the beam deflecting plates 80 and 81 causing more or less of the electron beam to enter the aperture 82 and impinge on the first secondary emitter plate 76. It will be understood that the aperture 82 is positioned so as normally to lie slightly to one side of the electron beam. Secondary electrons are released from the successive emitter plates 76 as in the previous figures and those from the final plate 76 pass through the screen 83 to the output or anode plate 84 producing variable current flow in the primary winding of output transformer 85.

The position of one pole face of the focusing magnet is indicated by dotted lines at 86 in Fig. 8 and the structure of the magnet itself will be more apparent from the sectional view of Fig. 9. The magnet 87 having pole faces 86, 85 may be either a permanent magnet or an electromagnet. In this case it is assumed to be a permanent magnet with a superposed winding 90 for varying the strength of the magnetic field. This winding 90 is connected between the primary winding of output transformer 85 and the positive pole 93 of the source of supply voltage shown connected between terminals 92 and 93. A relatively large capacity 94 in shunt with winding 90 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 90 and vary the strength of the focusing field of the magnet 87 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. 10 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 90 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. 11 which may replace the portion of the apparatus in Fig. 8 shown to the right of the broken line II—II. In this case no use is made of the coil 90, the terminals of which may therefore be left open. The positive pole 93 of the voltage supply source leads to the anode of a three-element tube 97, the cathode of which is connected in series through a resistance 95 and primary winding of output transformer 85 to the anode 84 of the tube 75. Resistance 95 is bypassed by condenser 96. Variations in output voltage of signaling frequency produce no effect on the tube 97 since they are bypassed by condenser 96. The grid of the tube 97 is biased by current flow through resistance 95 which may be supplemented with other biasing means if desired or necessary to give the tube 97 a normal internal resistance of appropriate value. Relatively slow variations in output current representing unstable operation develop potential differences between the terminals of resistor 95 which are applied to the grid of the tube 97 and vary its internal impedance and consequently the voltage supplied to the potentiometer 22 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. 10 and by working on the low voltage side of the characteristic, that is, where

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

is positive, the circuit of Fig. 11 will provide stabilizing action. If desired, the tube 97 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 75 will cause a corresponding decrease in the output current through resistance 95 and tube 97 causing the grid of the tube to go more positive and the internal resistance of tube 97 to be lowered. More current will then flow through the potentiometer 22 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.

Either of the two stabilizing methods illustrated in connection with Figs. 8 to 11 may be used in connection with the circuit structures of any of the other figures in which a magnetic field is used, or in the case of Figs. 2 and 4 if a magnetic field is not used to assist in focusing the electron beam, the second of the two stabilizing methods may still be used. For example, in connection with Fig. 1 it is only necessary to include a suitable winding, such as winding 90 of Fig. 8, on each of the field magnets 31, 32 (of Fig. 1A) and to connect them with proper polarity in the output lead 21'. Alternatively, a tube similar to tube 97 of Fig. 11 may be connected between the positive end of the potentiometer 22 of Fig. 1 and the positive terminal of the supply source, with the resistor 95 of Fig. 11 connected in the anode lead 21' of Fig. 1. It is believed that it will be obvious from this description how the stabilizing methods may be applied to the other figures.

The stabilizing circuits and methods are claimed in my copending application Serial No. 167,525, filed October 6, 1937.

It will be understood that the various struc-

tures and circuits disclosed herein are to be taken as illustrative rather than as limiting and that various modifications and departures from the detailed disclosure may be made within the spirit and terms of the appended claims.

What is claimed is:

1. In space discharge apparatus a duplex electron multiplier having an exciting stage comprising a source of electrons and means to control by waves to be amplified the admission of electrons to the electron multiplier, said means permitting electrons to enter either side of the electron multiplier only when input waves are incident upon the apparatus and then to enter only one side of the multiplier at a time depending upon the polarity of the input wave at the particular instant, means preventing primary electrons entering the electron multiplier from passing directly to the multiplier output, said control means comprising a pair of control elements, an input circuit connected between said elements, and an electrical connection between a point of electrical symmetry in said input circuit and a point of electrical symmetry in said duplex electron multiplier for maintaining said apparatus in electrical symmetry.

2. In space discharge apparatus, an electron multiplier structure comprising two symmetrical portions, a common output circuit differentially connected to said two portions, means to initiate electron discharge in the inputs of said portions in alternate time portions respectively of an input control wave, means to prevent primary electrons from passing directly from the said inputs to said output circuit, an input circuit differentially related to said two portions and a connection between said input circuit and said electron multiplier structure for maintaining said input circuit in electrical symmetry with respect to said multiplier structure.

3. In space discharge apparatus, a duplex electron multiplier structure comprising symmetrical halves with means in each half for producing multiplication of electrons by successive impacts with secondary emission plates, a plurality of said plates being common to both halves of said device, means to apply input variations differently to said two halves, and an output differentially connected to said two halves.

4. Apparatus according to claim 3, including means preventing electron flow in either half of said structure in the absence of applied input variations.

5. Apparatus according to claim 3 in which the electron multiplier structure comprises a succession of plates positioned along the axis of the device, said plates being rendered suitably emissive on their opposite surfaces, and means in each half of the structure causing impacts of electrons on opposite sides of said plates.

6. In a duplex or push-pull amplifier, an evacuated enclosure comprising an electron multiplier structure divided into two portions, an output electrode in each portion, an output circuit differentially connected to said output electrodes, a shield containing apertures admitting to each portion of said multiplier, an electron emitting cathode in front of said shield, a pair of electron control members between said cathode and said shield, an input circuit differentially connected to said control members, a circuit conductively connecting said shield, said cathode and the mid-point of said input circuit, means normally biasing said control members in a direction to prevent passage of electrons

through either of said apertures and to such an extent that in the absence of input waves, no electrons are permitted to pass into the electron multiplier, means coating the surface of said shield rendering it a poor emitter of secondary electrons, and means preventing electrons that pass through said shield from traveling directly to a said output electrode.

7. Apparatus according to claim 1 in which the preventing means comprises means for providing a magnetic field for preventing primary electrons entering the electron multiplier from passing directly to the multiplier output.

8. Apparatus according to claim 2 in which the means to prevent comprises means for providing a magnetic field for preventing primary electrons entering the electron multiplier from passing directly to the multiplier output.

9. In space discharge apparatus a duplex electron multiplier structure comprising a chamber having opposite walls and separated by a central shield into two portions, means to apply input variations differentially to said portions, means rendering said walls suitably emissive, means to apply an alternating field to said walls to cause successive impacts against said walls, an output plate in each portion, and means maintaining said plate positive with respect to said central shield.

10. A symmetrical duplex electron multiplier including two parallel branches each branch containing a series of multiplier stages, a common connection for the initial stages, an output electrode in each branch, an output circuit connected across said output electrodes, an exciting stage comprising a source of electrons and a pair of control elements for controlling admission of electrons to said branches alternatively under control of input waves, an input circuit connected across said pair of control elements, an electrical connection between the mid-point of said input circuit, said common connection for the initial electron multiplier stages and the mid-point of said output circuit for preserving the electrical symmetry of the multiplier, and means associated with the multiplier stages in said branches for preventing direct passage of primary electrons entering said branches from passing directly to said output electrodes.

11. A space discharge device comprising a signal input portion and an amplifying portion consisting of two electron multipliers each including a series of emitting surfaces and means for causing electron multiplication by successive impacts of electrons against said surfaces, said signal input portion comprising a source of electrons and means for causing electrons therefrom to impinge on the first emitting surface of one or the other of said multipliers alternatively under control of impressed potentials, depending upon the polarity of the signal at a particular instant, said last means including a pair of input control elements, a signal input circuit having its opposite terminals connected to said input control elements, and an electrical connection from the middle point of said signal input circuit to the first emitting surface of each of said multipliers for fixing the average potential of said pair of input control elements symmetrically with respect to said emitting surfaces and to said signal input circuit.

12. In space discharge apparatus, a duplex electron multiplier having an exciting stage comprising a source of electrons and means to control by input waves to be amplified the admission

of electrons to the electron multiplier, said means permitting electrons to enter either side of the electron multiplier only when input waves are incident upon the apparatus and then to enter only one side of the multiplier at a time depending upon the polarity of the input wave at the particular instant, said means comprising a pair of control elements, an input circuit having its opposite terminals connected to said control elements and having a center tap point, connections from said center tap point to said source of electrons and to a point of electrical symmetry in said duplex electron multiplier, said connections maintaining the apparatus in electrical symmetry.

13. In space discharge apparatus a duplex electron multiplier having an exciting stage comprising a source of electrons and means to control by waves to be amplified the admission of electrons to the electron multiplier, said means

permitting electrons to enter either side of the electron multiplier only when input waves are incident upon the apparatus and then to enter only one side of the multiplier at a time depending upon the polarity of the input wave at the particular instant, said multiplier comprising in each of its two sides a succession of electron emitting surfaces, means to apply successively higher positive potentials to said surfaces and means directing electrons toward the successive emitter surfaces, said control means comprising a pair of control elements, an input circuit connected between said elements, and an electrical connection between a point of electrical symmetry in said input circuit and a point of electrical symmetry in said duplex electron multiplier for maintaining said apparatus in electrical symmetry.

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