

May 30, 1939.

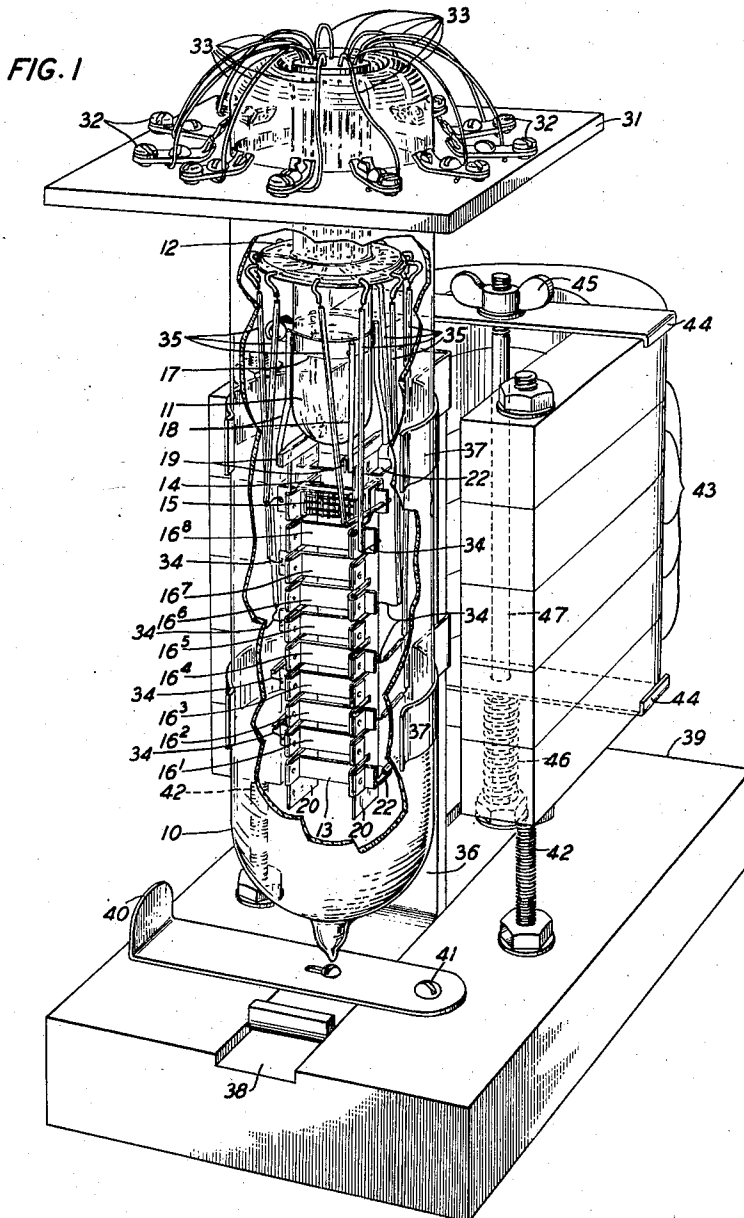
G. K. TEAL

2,160,796

ELECTRON DISCHARGE APPARATUS

Filed Nov. 20, 1936

3 Sheets-Sheet 1



INVENTOR
G.K. TEAL
BY

Walter C. Kiesel
ATTORNEY

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G. K. TEAL

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FIG. 2

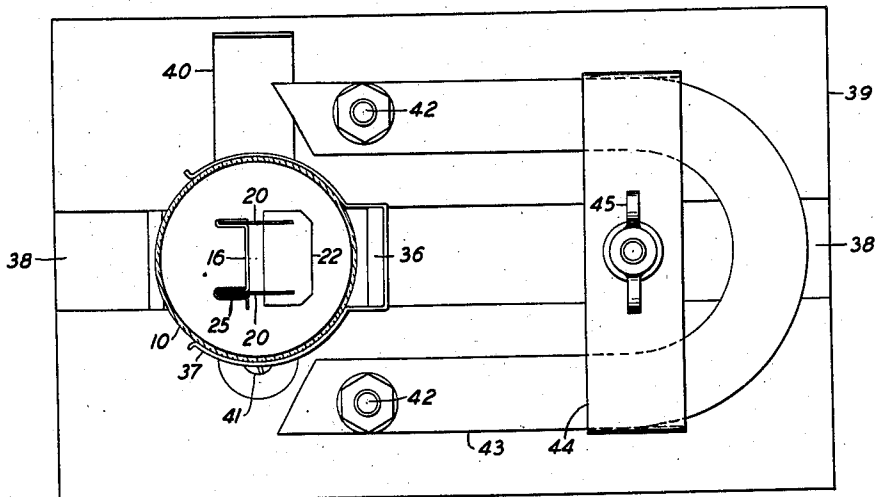


FIG. 3

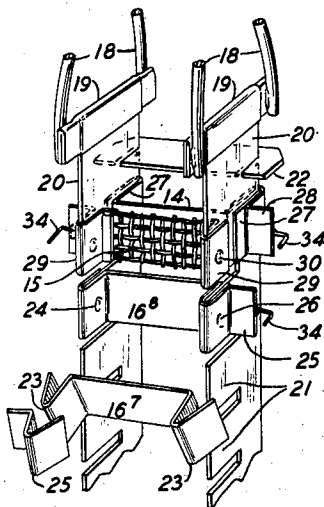
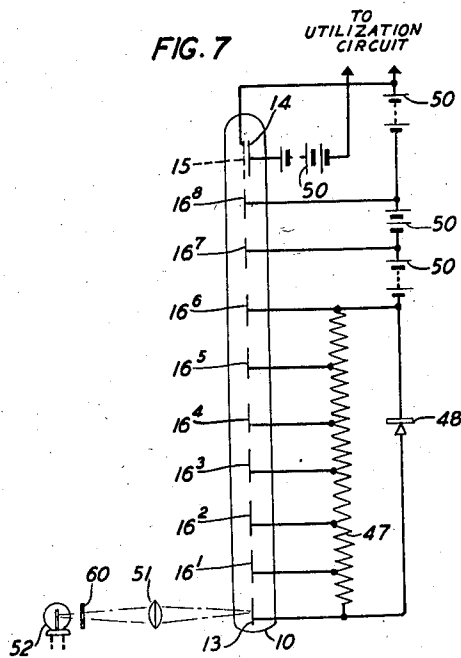


FIG. 7



INVENTOR
G. K. TEAL

BY

Halter C. Kiesel
ATTORNEY

May 30, 1939.

G. K. TEAL

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FIG. 4

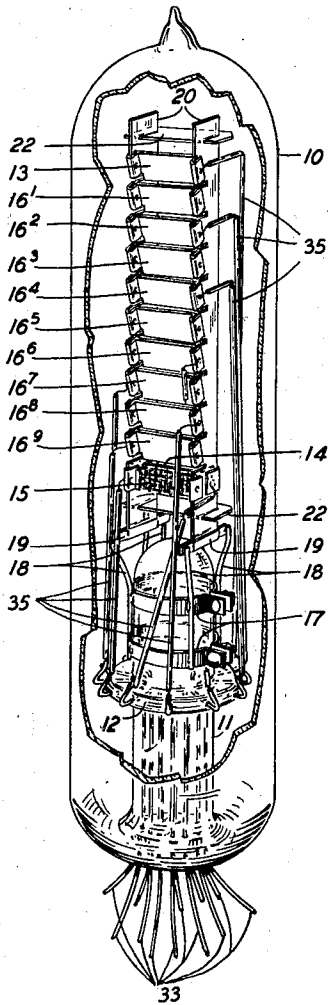


FIG. 5

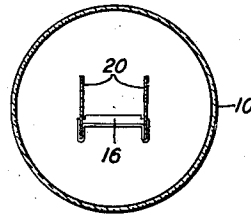
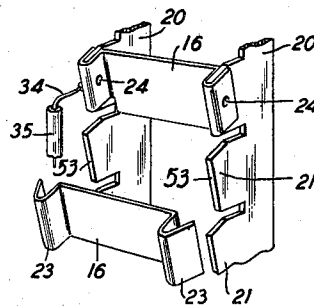


FIG. 6



INVENTOR
BY G. K. TEAL

Walter C. Kiesel
ATTORNEY

UNITED STATES PATENT OFFICE

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ELECTRON DISCHARGE APPARATUS

Gordon K. Teal, New York, N. Y., assignor to
Bell Telephone Laboratories, Incorporated,
New York, N. Y., a corporation of New York

Application November 20, 1936, Serial No. 111,808

11 Claims. (Cl. 250—166)

This invention relates to electron discharge apparatus and more particularly to such apparatus adapted to amplify high frequency impulses and including electron discharge devices having secondary electron emitting electrodes.

One object of this invention is to enable the economic, efficient and facile attainment of large and high fidelity amplification of high frequency impulses.

Another object of this invention is to enable the accurate determination of the characteristics of amplifiers utilizing electron discharge devices.

Another object of this invention is to obtain a high signal to noise ratio in electronic amplifiers.

Still another object of this invention is to simplify the structure of multi-stage electron discharge apparatus and to reduce the number of component parts thereof requisite to produce a high degree of amplification.

A further object of this invention is to expedite the fabrication of electron discharge devices having a multiplicity of electrodes.

In one illustrative embodiment of this invention, electron discharge apparatus comprises an electron discharge device including a primary cathode, a collector electrode or anode, and a plurality of auxiliary or secondary cathodes disposed between the primary cathode and the collector electrode. The various cathodes may be channel shaped, disposed edge to edge and in alignment and have one, preferably the inner, surface, or both surfaces, thereof coated with a material capable of producing copious emission of electrons.

Each of the secondary cathodes is operated at a positive potential, the potential on each of these cathodes being greater than that upon the next preceding one with reference to the primary cathode. The collector electrode or anode is operated at a positive potential greater than that upon the secondary cathode furthest removed from the primary cathode. During operation of the device a strong magnetic field is produced at substantially right angles to the axis of alignment of the several cathodes.

When the primary cathode is activated, as for example by a beam of light focused upon the emitting surface thereof, the electrons emitted, thereby are directed to and impinge upon the first of the secondary cathodes, under the influence of the magnetic field and the potential upon this secondary cathode. As a result, secondary electrons are released from the first secondary cathode and these electrons under the influence of the magnetic and electro-static fields extant

in the device, are directed to and impinge upon the next secondary cathode to cause the release of secondary electrons therefrom. This action is repeated to the last secondary cathode, that is, the one furthest removed from the primary cathode, and the electrons released therefrom are attracted to the collector electrode or anode and constitute an available output current for a utilization circuit connected, for example, to the primary cathode and the collector electrode.

Inasmuch as the several secondary cathodes have surfaces coated with a material having good secondary electron emitting properties, each primary or secondary electron impinging thereon will cause the release of a plurality of secondary electrons. Hence, a large electron multiplication occurs between the primary cathode and the collector electrode so that in effect the signal corresponding to the activating source for the primary cathode is greatly amplified as represented by the electron flow to the collector electrode or anode. Variations in the intensity of the activating source will result in corresponding variations in the electron current to the collector electrode or anode and hence in the output current of the device.

The invention and the various features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawings, in which

Fig. 1 is a view in perspective of electron discharge apparatus illustrative of one embodiment of this invention, a portion of the enclosing vessel of the electron discharge device being broken away to show the internal structure more clearly;

Fig. 2 is a top view, partly in cross-section, of the apparatus shown in Fig. 1, the magnet being modified to show another form thereof;

Fig. 3 is an enlarged, partly exploded detail view in perspective illustrating structural details of the electron discharge device shown in Fig. 1;

Fig. 4 is an elevational view in perspective of an electron discharge device illustrative of another embodiment of this invention;

Fig. 5 is a view in cross-section of the cathode structure of the device shown in Fig. 4;

Fig. 6 is an enlarged detail view in perspective and partly exploded illustrating the association of the cathodes and the supports therefor in the device shown in Fig. 4; and

Fig. 7 is a circuit diagram of space discharge apparatus constructed in accordance with this invention.

Referring now to the drawings, the apparatus shown in Fig. 1 includes an electron discharge

device comprising an elongated cylindrical enclosing vessel 10 having a stem 11 at one end provided with an intermediate, integral annular flange 12. A unitary electrode assembly is

- 5 mounted upon the stem 11 and includes a primary cathode 13, a collector electrode or anode 14, a screen or shield electrode 15 and a plurality of auxiliary or secondary cathodes 16¹ to 16ⁿ, inclusive.
- 10 The several electrodes are mounted upon a supporting structure comprising a split metallic band or collar 17 clamped about the stem 11, a plurality, for example four, of rigid supports 18 extending from the band or collar 17, and a
- 15 pair of grooved or channel shaped cross-pieces 19 affixed to the supports 18. Each of the cross-pieces 19 clamps and securely holds an elongated insulating member or upright 20, for example a strip of mica, having a plurality of fingers 21.
- 20 The insulating members 20 preferably are mounted parallel to each other and are maintained in proper spaced relation by cross-members or braces 22, which also may be strips of mica, having slots in which the insulating members are
- 25 frictionally fitted.

- As shown more clearly in Figs. 2 and 3, each of the cathodes is channel shaped, for example in the form of a rectangulated U, and the sides or arms 23 thereof are bent about and grasp corresponding of the fingers 21 on the insulating up-
- 30 rights 20. The arms 23 may be indented as indicated at 24 to lock the cathodes to the uprights 20. Each cathode has secured thereto a metallic clip 25, which serves as a terminal lug to which
- 35 a leading-in conductor may be affixed. As indicated at 26, the clips 25 may be indented to lock them to the arms 23 of the cathodes. The primary and secondary or auxiliary cathodes are mounted in alignment with corresponding sur-
- 40 faces thereof in common planes. The spacing between juxtaposed edges of the cathodes may be of the order of $\frac{1}{32}$ inch.

- The several cathodes may be formed of strips of silver or copper having portions thereof, preferably only the surface of the portion between
- 45 the arms 23, treated to render them capable of copious electron emission. For example, these portions may be oxidized, as by a high potential discharge, and treated with caesium to provide a
- 50 coating or surface containing caesium oxide, silver and some free caesium.

- The anode or collector electrode 14, as shown clearly in Fig. 3, is of the same form as the cathodes and has its arms 27 bent around and
- 55 locked to the insulating uprights 20, one of the arms having affixed thereto a terminal clip 28 similar to the clips 25. The base of the anode preferably is disposed parallel to the bases of the cathodes and slightly displaced from the common plane thereof.
- 60

- The shield or screen electrode 15 includes a flat relatively coarse mesh portion supported by metallic clips 29 grasping the uprights 20 and locked thereto by indentations 30. Preferably
- 65 the mesh portion is of substantially the same area as the base of the anode or collector electrode 14 and is disposed substantially coplanar with the bases of the primary and secondary cathodes.

- Disposed about the stem end of the enclosing
- 70 vessel and frictionally mounted thereon is an insulating base 31 which carries a plurality of terminal members 32, one for each of the electrodes of the device. Leading-in conductors 33 are connected to the terminal members 32, extend
- 75 inwardly of the stem 11, and are sealed in uni-

form space relation in the annular flange 12. Suitable conductors 34 are affixed at one end to the projecting ends of the leading-in conductors 33 and at the other end to the clips 25, 28 and 29 on the cathodes, anode and screen electrode, respectively. Preferably all but the ends of the conductors 34 are encased in insulating material, such for example, as glass sleeves 35.

The electron discharge device heretofore described may be mounted on a carrier which includes a rigid L-shaped support 36 and resilient bowed arms 37 mounted on the support 36 and adapted to grasp the enclosing vessel 10. The lower arm of the support 36 is fitted slidably in a track or groove 38 in a suitable base 39 and has affixed thereto a finger piece or bracket 40, which is pivoted at one end on the base 39 as by a screw 41.

Mounted upon the base 39, as by bolts 42, is a permanent magnet structure which may be composed of a plurality of strongly magnetized horseshoe magnets 43. The several magnets may be clamped together between brackets 44 drawn toward each other by a wing nut 45 and spring 46 mounted on a bolt 47 extending from the base 39.

The magnet structure produces an intense magnetic field at substantially right angles to the longitudinal axis of the electron discharge device and substantially parallel to the bases of the cathodes 13 and 16 and immediately adjacent the electron emitting surfaces thereof. The position of the device relative to the magnet may be adjusted by means of the finger piece 40 so that the emitting surfaces of the cathodes are in the strongest or most intense portion of the magnetic field. In order to obtain sharper focussing of the electron streams, the magnet may have its poles so related that a curved magnetic field is produced adjacent the electrodes. For example, the poles may have chamfered faces as shown

40 in Fig. 2. Also, as described more fully in the copending application of William A. Knoop, Serial No. 111,796, filed November 20, 1936, the magnet may be so constructed that the magnetic field is of greatest intensity in the vicinity of the primary cathode and decreases uniformly in intensity to in the vicinity of the collector electrode. As shown in Fig. 1, the magnet preferably extends somewhat above the anode 14 and slightly beyond the primary cathode 13.

During operation of the apparatus, the secondary cathodes 16 are operated at positive potentials with respect to the primary cathode, the potential upon each secondary cathode being higher than that upon the next preceding one with reference to the primary cathode. For example, the first secondary cathode 16¹ may be operated at of the order of 135 volts positive with respect to the primary cathode 13, the secondary cathode 16² at of the order of 270 volts positive, and each succeeding secondary cathode at of the order of 135 volts positive higher than the next preceding one so that the secondary cathode 16ⁿ is of the order of 1080 volts positive with respect to the cathode 13. The shield or screen electrode 15

65 may be operated at a potential of the order of 135 volts positive with respect to the secondary cathode 16ⁿ and the collector electrode or anode 14 may be operated at a potential of the order of 250 volts positive with respect to the secondary cathode 16ⁿ.

As shown in Fig. 7, the potentials for a number of the secondary cathodes 16 may be obtained from a potentiometer 47, which may be supplied from a suitable source such as a recti-

fier 48. Because of the heavy current drain, the potentials for the secondary cathodes, for example 16⁷ and 16⁸, and for the screen 15 and anode or collector electrode 14, preferably are obtained from separate sources such as batteries 50 connected in series as shown.

The primary cathode 13 may be energized by a beam of light focussed upon the activated portion thereof through a lens 51 and emanating from a suitable source, such as a lamp 52, the intensity of the light beam being variable as by a suitable film 60. Under the influence of such a light beam, the primary cathode 13 emits electrons and these electrons, under the influence of the magnetic field in the vicinity of the cathode 13 and the electrostatic fields obtaining because of the positive potentials upon the other electrodes of the device, are attracted to and impinge upon the secondary or auxiliary cathode 16¹. The velocity of these impinging electrons is relatively high so that secondary electrons are released from the activated or coated portion of the cathode 16¹. The intensity of this secondary electron emission will be dependent primarily upon the character of the coating upon the cathode 16¹ and the potential of this cathode with respect to the primary cathode. For example, if the emitting surface be of caesium treated silver oxide, as heretofore described, and the cathode 16¹ be operated at a potential of the order of 135 volts positive with respect to the cathode 13, the secondary electron stream from the cathode 16¹ will be approximately 3 to 7 times as great as the primary electrons emanating from the primary cathode 13. In effect, therefore, the primary electron stream is multiplied and as a result an amplification of the signal corresponding to the light beam energizing the primary cathode obtains.

The secondary electrons emanating from the cathode 16¹, under the influence of the magnetic and the electrostatic fields extant adjacent this cathode, are directed toward and impinge upon the secondary cathode 16². These electrons are adsorbed by the cathode 16² and produce a copious emission of other secondary electrons from this cathode. For each electron impinging upon the cathode 16², a plurality of secondary electrons are released therefrom so that effectively a second electron multiplication and hence amplification of the signal obtains.

The above described multiplication and amplification is repeated at each of the secondary cathodes 16 so that the secondary emission from the last cathode 16⁸ is immensely greater than the primary emission from the primary cathode 13. For example, if there are eight secondary cathodes 16 in the device, the electron current obtainable from the cathode 16⁸ may be of the order of 18,000 times the primary electron current from the cathode 13 so that in effect an amplification of the order of 18,000 obtains.

The secondary electrons emanating from the cathode 16⁸ are directed to and adsorbed by the anode or collector electrode 14 and constitute the output current of the device. This current may be employed in any suitable utilization circuit associated with the anode or collector as shown in Fig. 7.

The shield electrode 15 serves to screen the end cathode 16⁸ from the anode or collector electrode 14 and thereby presents undesired reaction of variations in the anode or collector potential upon the cathode 16⁸ and hence minimizes distortion in the output current of the device.

It has been found that the operating characteristics of the device, principally the relation between the output current and the intensity of the light beam energizing the cathode 13, are materially dependent upon the design of the secondary cathodes 16. For most purposes it is desirable that the output current-light beam intensity characteristic be substantially linear throughout the output current range corresponding to the range of intensities of the light beam played upon the primary cathode 13. This desirable relationship may be obtained by making the width of the secondary cathodes 16 approximately 5 times the depth thereof and the longer dimension approximately twice the shorter dimension. For example, it has been found that if the secondary cathodes are approximately 1.2 centimeters by approximately 0.6 centimeter and 0.25 centimeter deep and are spaced of the order of 0.125 centimeter, the output current will vary substantially linearly with the intensity of the light beam over a range from substantially zero to at least 10 milliamperes. If non-linear characteristics are desired, they may be obtained by increasing the depth of the secondary cathodes.

It may be pointed out also that the channel shaped form of the several cathodes results in reduction of the lateral dispersion of the primary and secondary electron streams, so that concentrated electron beams obtain and a high operating efficiency results.

This desirable concentration of the electron beams may be enhanced by disposing the secondary cathodes 16 and the primary cathode 13 at a small angle, for example of the order of twenty degrees, to the longitudinal axis of the electrode structure as shown in Figs. 4, 5 and 6. The electron discharge device shown in these figures is substantially the same as that shown in Fig. 1, except that the cathodes 13 and 16 are tilted and the fingers 21 on the insulating members 20 are provided with edges 53 sloping at the same angle as the cathodes. The device may be mounted in the same manner as the device shown in Fig. 1 and connected in a circuit such as shown in Fig. 7.

Although specific embodiments of this invention have been shown and described, it will be understood, of course, that these embodiments are merely illustrative of this invention and that various modifications may be made therein. For example, although eight secondary cathodes are shown in the device of Fig. 1 and nine in the device shown in Fig. 4, a greater or lesser number may be employed. Furthermore, although the primary cathodes 13 are disclosed as of the photoelectric type they may be of other types, for example, thermionic, directly or indirectly heated, and a separate grid or control electrode may be utilized for modulating the primary electron stream from the primary cathode 13 to the first secondary cathode 16¹ in accordance with a signal to be amplified. Moreover, in modifications of the embodiments heretofore described, the anode or collector electrode 14 may be disposed with its electron receiving surface at substantially right angles to the axis of alignment of the cathodes and both surfaces of the primary and secondary cathodes may be provided with a layer or coating of electron emitting materials. Similarly, the shield or screen electrode 15 may be disposed at right angles to the axis of alignment of the cathodes. Two screen electrodes may be provided adjacent opposite surfaces of the anode or collector electrode 14 when both surfaces

of the cathodes are sensitized and the anode or collector electrode is substantially parallel to the cathodes. Other modifications may occur to those skilled in the art without, however, departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. Electron discharge apparatus comprising a primary cathode, a collector electrode, a plurality of secondary cathodes between said primary cathode and said collector electrode, said secondary cathodes having electron focussing flanges electrically connected thereto and forming channels constituting a path for the electron streams, and mounted end to end and in alignment with one another, and a coating of electron emissive material upon the inner surface of said channels.

2. Electron discharge apparatus comprising an enclosing vessel, a pair of insulating uprights mounted in said vessel, a primary cathode, a collector electrode, a plurality of secondary cathodes disposed between said primary cathode and said collector electrode and in alignment with one another, and having electron focussing flanges electrically connected thereto and forming channels constituting a path for the electron streams, said flanges bent about and grasping said uprights, and an electron emissive coating upon the inner surface of said channels.

3. Electron discharge apparatus comprising a primary cathode, a collector electrode and a plurality of aligned secondary cathodes between said primary cathode and said collector electrode, said secondary cathodes having electron focussing arms electrically connected thereto and parallel to the axis of alignment of said secondary cathodes forming channels of a depth less than the width thereof, the width being determined by the spacing of said arms, said channels constituting a path for the electron streams, and the inner surface of said channels having thereon a coating of electron emissive material.

4. Electron discharge apparatus comprising a primary cathode, a collector electrode, and a plurality of secondary cathodes disposed between said primary cathode and said collector electrode, and metallic means electrically integral with said secondary cathodes and at opposite sides thereof for laterally confining the electron streams from said primary and secondary cathodes.

5. Electron discharge apparatus comprising a primary cathode, a collector electrode, and a plurality of auxiliary electrodes between said cathode and said collector electrode, said auxiliary electrodes having secondary electron emitting portions in alignment with one another and said cathode, and having integral portions on opposite sides of the axis of alignment of said emitting portions for laterally confining the electron streams emanating from said primary cathode and said portions to aligned paths.

6. Electron discharge apparatus comprising a primary cathode having a plane emitting portion, a collector electrode, a plurality of secondary cathodes between said primary cathode and said collector electrode having electron emitting portions disposed edge to edge and substantially coplanar with said plane emitting portion and in alignment therewith, and members at opposite sides of said emitting portions and electrically integral therewith for laterally confining the electrons emanating from said emitting portions to restricted paths.

7. An electron multiplier comprising a primary cathode, a collector electrode, and a plurality of similar, equally spaced, successively mounted secondary cathodes between said primary cathode and said collector electrode, said secondary cathodes having channel-shaped emissive portions, the inner surface of which is electron emissive.

8. Electron discharge apparatus comprising a primary cathode, a collector electrode, and a secondary cathode between said primary cathode and said collector electrode and in alignment therewith, said secondary cathode having electron focussing flanges electrically connected thereto forming a channel constituting a path for the electron stream, the inner surface of said channel being exposed and secondary electron emissive.

9. Electron discharge apparatus comprising a primary cathode, a collector electrode, a plurality of secondary cathodes between said primary cathode and said collector electrode, said secondary cathodes having channel-shaped portions disposed edge to edge and with corresponding surfaces thereof substantially coplanar, the inner surfaces of said portions being exposed, and a secondary electron emissive coating upon said inner surfaces.

10. Electron discharge apparatus comprising a primary cathode, a collector electrode, a plurality of secondary cathodes between said primary cathode and said collector electrode, said secondary cathodes having rectangulated U-shaped portions disposed edge to edge and with corresponding surfaces thereof in common planes, the inner surfaces of said portions being exposed, and a secondary electron emissive coating upon said inner surfaces.

11. Electron discharge apparatus comprising a primary cathode, a collector electrode, and a plurality of substantially rectangulated U-shaped secondary cathodes between said primary cathode and said collector electrode, said secondary cathodes having their inner surfaces exposed and adapted to emit secondary electrons, and the arms of each of said secondary cathodes being spaced from each other a distance greater than the dimension of said arms at right angles to the bases of said secondary cathodes.

GORDON K. TEAL.