

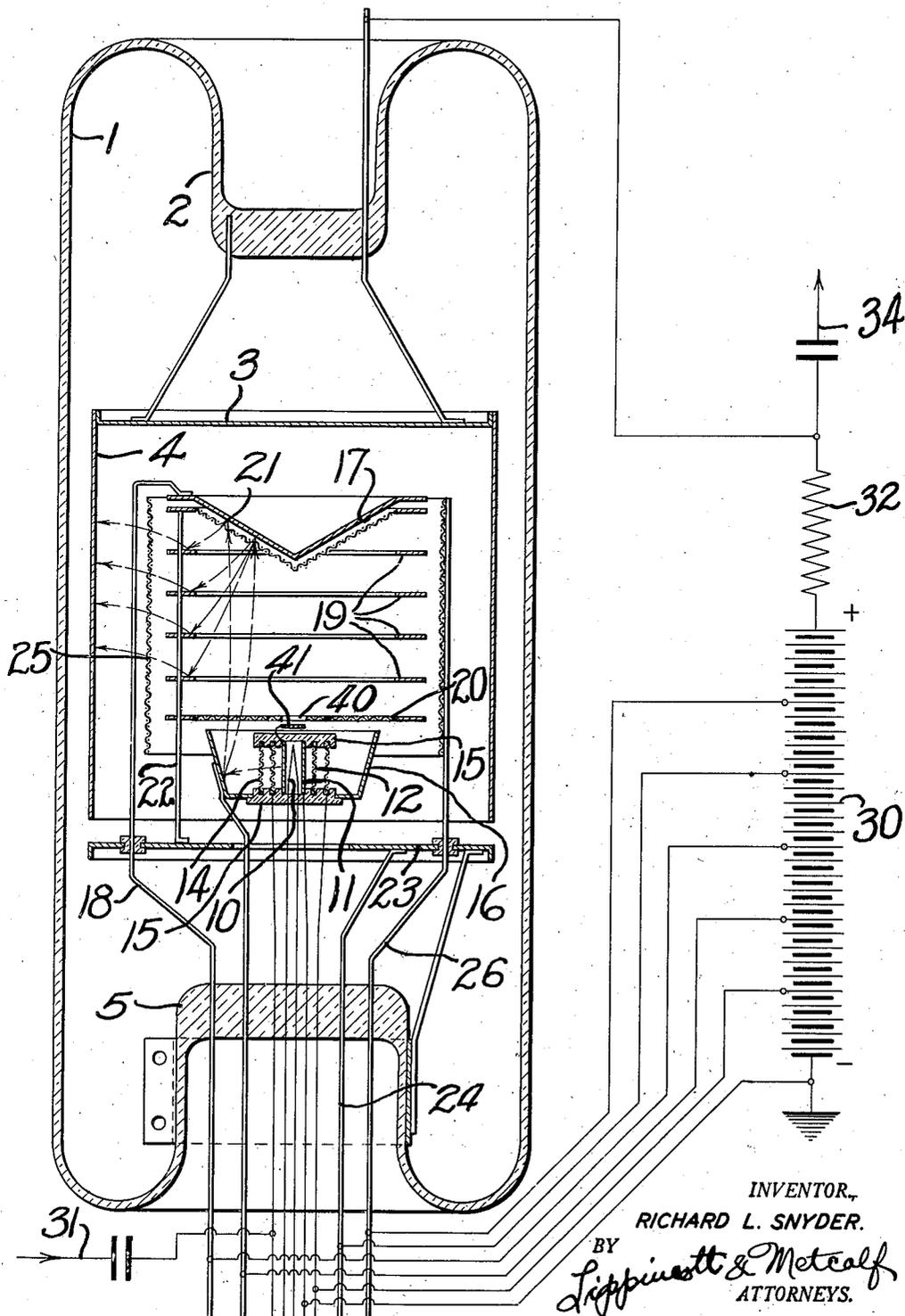
Oct. 7, 1941.

R. L. SNYDER

2,257,985

POWER MULTIPLIER

Filed Aug. 3, 1938



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# UNITED STATES PATENT OFFICE

2,257,985

## POWER MULTIPLIER

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mesne assignments, to Farnsworth Television  
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Application August 3, 1938, Serial No. 222,813

6 Claims. (Cl. 250—175)

My invention relates to electron multipliers, and particularly to a means and method for handling currents of high electron density in an electron multiplier.

The primary object of my invention is to provide a means and method of increasing the effective area of a secondary electron emitting electrode, so as to decrease the average current density.

Another object of my invention is to provide an electron multiplier which will handle large electron currents.

A still further object of my invention is to provide an electron multiplier construction having a secondary electron emitting electrode therein, designed and positioned to offer a large impacting area to a primary stream.

My invention possesses numerous other objects and features of advantage, some of which, together with the foregoing, will be set forth in the following description of specific apparatus embodying and utilizing my novel method. It is therefore to be understood that my method is applicable to other apparatus, and that I do not limit myself, in any way, to the apparatus of the present application, as I may adopt various other apparatus embodiments, utilizing the method, within the scope of the appended claims.

Referring to the drawing, the figure is a longitudinal sectional view, partly schematic, of an electron multiplier tube embodying my invention, together with one circuit exemplifying the use of the device.

In the ordinary type of direct-current electron multiplier having a plurality of surfaces serially energized and serially impacted by a stream of electrons to produce secondary emission at a ratio greater than unity, considerable difficulty has been encountered when trying to run the electron currents into high values, because in directing the electron stream from one impacted surface to another, the electron stream is more or less confined to a limited cross section, and consequently only a limited area of the emitting electrode is impacted, because of the focusing action of the electrode configuration. Space-charge saturation is therefore quickly reached when using high currents, and my invention broadly concerns the use of a particular type of electrode which will decrease the average current density and therefore allow higher currents to be handled by the device before space charge limitations occur.

My invention is clearly illustrated in the drawing, where a preferred construction is shown.

Referring thereto, an envelope 1 is provided at one end with a reentrant stem 2, carrying a cup-shaped anode 3 having cylindrical sides 4 extending along the envelope 1 adjacent the side walls thereof. I prefer that the output anode 3—4 be the only electrode supported from stem 2. The remainder of the structure is supported on an opposite reentrant stem 5, and for clearness of illustration I have shown, only diagrammatically, the supports for the input system, which comprises a heater 10 surrounded by a unipotential cathode 11, an input grid 12, and an accelerating grid 14, all of which are concentrically arranged and positioned by insulating spacers 15 above and below the assembly.

The lower of the two spacers 15 engages an aperture in the truncated apex of a concentric cone-shaped first secondary-emissive stage 16. Thus, electrons leaving the input structure will impact the angularly positioned side walls of the first stage 16, which is open at the base thereof. Above the open base of first stage 16 and spaced therefrom, is a conical second stage 17, the apex of the cone lying in the axis of the input system and pointing thereto. The second stage 17 is supported on a riser 18 passing through the stem to form an exterior connection thereto.

Surrounding the space between the open end of the first stage 16 and the conical second stage 17 are a series of parallel annular washers 19, preferably equally spaced between the first and second stages, and carrying, below, a planar screen 20 just above the open end of first stage 16, and above, a conical screen 21 following the contour of the second stage 17 and spaced just below the surface thereof facing the input system. The annular washers 19 constitute the third stage of the device. The annular rings are supported on a third-stage riser 22 attached to a shield plate 23, and shield plate 23 is supported on lead 24 passing through stem 5. Immediately surrounding the third-stage washers 19 is an accelerating screen cylinder 25, concentric with anode 3—4, and this accelerating screen is provided with an exterior lead 26.

All of the electrodes may be energized from a single source 30, the negative end of which is grounded and also connected to the unipotential cathode 11. The control grid 12 is connected to a signal input line 31, and accelerating grid 14 is connected to source 30 at a point higher in positive potential than the cathode. First stage 16 is connected to be at a still higher potential, conical second stage 17 is supplied with a still higher positive potential, washers 19 and con-

ected screens 20 and 21 at the next highest potential, accelerating screen 25 still higher in potential, and anode 3-4 at the highest positive potential, through output resistor 32 across which power may be abstracted by output line 34. It is, of course, to be understood that these potentials are purely relative, and that the circuit, as shown, simply teaches one way in which the tube may be energized. Other circuits will be clearly apparent to those skilled in the art.

In operation, with all the electrodes energized, electrons from the unipotential cathode 11 are accelerated through the input grids to impact the inner angular surface of first stage 16, and the potentials are so arranged and the surface impacted is so treated that secondary emission at a ratio greater than unity is obtained. While there are a large number of ways in which this emission may be obtained, well known to those skilled in the art, I have found that one such method is to make all of the multiplying stages of silver, oxidize the silver, and treat the silver oxide with caesium vapor until the desired secondary emission ratio is obtained. Under this method I have found that secondary-emission ratios may be obtained as high as 10 or 12 to 1 when the electrons are traveling at high velocity.

Screen 20 immediately above the open end of first stage 16 acts as an accelerating electrode for the secondary electrons emitted from first stage 16, and they are drawn through the screen into the space surrounded by the annular washers 19. The planar screen 20, the conical screen 21, and washers 19 constitute a Faraday cage in which the electrons may travel until they pass through conical screen 21 to impact conical second stage 17. In my application entitled Electron multiplier tube, Serial No. 177,065, filed November 29, 1937, now Patent No. 2,172,155 issued September 5, 1939, I have disclosed and claimed the use of this Faraday cage with a conical electron receiving electrode, and I have explained therein that it is preferable to modify the field adjacent the apex of the cone in order that the electrons shall distribute themselves on the side walls of the cone. For that reason I may provide, if I desire, the planar screen 20 with an aperture 40, and immediately below this aperture, position a field-determining electrode 41, connected to unipotential cathode 11, whose influence, acting through the aperture 40 to the apex of the conical screen 21 and second stage 17, produces a negative field which tends to spread the electrons from the first stage over the side walls of second stage 17. However, other arrangements may be utilized if desired to ensure proper impact areas on conical stage 17.

When the electrons from the first stage 16 impact second stage 17, more secondary electrons are generated, and these are accelerated in lines approximately perpendicular to the surface of the second stage because of the close proximity of conical screen 21, which, being higher in potential than the second stage, acts as an accelerating electrode to direct the electrons away from the second stage. The annular washers 19, being spaced, are impacted by electrons, from different regions of second stage 17, and thus the third stage, being composed, as it is, of spaced surfaces angularly positioned with respect to the side walls of the conical stage 17, provides a greatly enlarged impact surface, thus greatly reducing electron density over the impact areas of the third stage. Secondary electrons generated by impact upon the surfaces of washers 19 are

withdrawn therefrom by accelerating screen 25 to impact anode 3-4, and inasmuch as the washers 19 are spaced, the impact area on anode 3-4 will be greatly increased, being that area opposite the entire expanse covered by washers 19. Thus, electron density between the third stage and the final anode 3-4 is also relatively low.

Before discussing the manner in which third stage 19 operates, it will be well to give a definition of the meaning of the term "electron-permeable," as it will be utilized in this application. Broadly, third stage 19 is a stage where primary electrons arrive at one side of the secondary-emitting stage and depart to the other side, in contrast to a secondary-emitting stage consisting of a single solid electrode, such as stage 17, where a reversal of the direction of the total electron stream takes place. In third stage 19, the general direction of the total electron stream in respect to the multiplying stage remains the same before and after multiplication.

As another example of this type of stage, a wire mesh grid may be cited. If a stream of primary electrons is directed toward such an electrode from one side, a portion of that primary stream will pass through the openings in the wire mesh without impacting the wire at all. The remaining portion of the stream will impact the wire. The ratio between impacting and non-impacting portions of the electron stream depends upon the ratio of solid-to-void in the wire mesh structure. Thus, it may be seen that such an electrode is semi-permeable to arriving primary electrons.

Furthermore, the impacting portions of the electron stream liberate secondary electrons at the front side of the screen which must be pulled through the openings in the screen to the back side thereof. Only the provision of a suitable potential gradient can pull the secondary electrons through the openings to the other side of the screen. It is not believed that it is possible to pull all emitted secondary electrons through the openings, that is, to obtain complete saturation. Thus, semi-permeability may be spoken of for the emitted secondary electrons as well as for the impacting primary electrons.

Considering again, therefore, third stage 19 as a unit consisting of a plurality of solid elements, in this case the superimposed washers, it will be seen that all straight lines thereon from intermediate stage 17 will intersect solid portions of stage 19, the straight lines representing theoretical electron paths, as shown. Hence, stage 19 is substantially non-permeable for all electrons emitted from intermediate stage 17, and there is no portion of the electron stream lost as far as multiplication is concerned.

Considering then the secondary electrons emitted from the elements of stage 19 by impacting electrons arriving from stage 17, it will be seen that there is nothing to obstruct the free flow of electrons away from the elements of stage 19 through accelerating cylinder 25 to cup-shaped anode 3-4. A suitable potential gradient will therefore give saturation of this secondary electron stream, and therefore stage 19 is not only substantially non-permeable to arriving primary electrons but also substantially permeable to departing secondary electrons.

A further modification of my device may be made in those cases where extremely large currents are to be handled by the multiplying tube. For such purposes, it is preferred to form the envelope in such a fashion that the outer surface

of collecting anode 3—4 may be exposed to a cooling stream of air, water, or any other cooling medium. While I have not shown this modification in the drawing, it will be obvious to those skilled in the art that such a structure might be formed by making the envelope 1 in two parts and forming a seal between one end of anode 3—4 with one portion of the envelope and between the other end of anode 3—4 and the remaining portion of the envelope. The outer surface of the anode then acts as a continuation of the envelope walls, and to resist the stress placed upon it due to the high evacuation of the tube, the anode must be formed in such a way as to produce great mechanical strength. This, and other similar embodiments which will be apparent to those familiar with the technique of vacuum tube construction, are included within the scope of the claims herein appended.

I claim:

1. An electron multiplier, comprising an evacuated envelope having therein an electron source, a plurality of secondarily emissive multiplying stages, an electron-permeable screen surrounding said multiplying stages and forming to a Faraday cage, the last of said stages being completely non-permeable to electrons emitted from the next previous stage and being completely permeable to secondary electrons emitted by said last stage, and means for withdrawing electrons from said last stage.

2. An electron multiplier, comprising an evacuated envelope having an electron source therein, a plurality of secondarily emissive cathode surfaces positioned serially from said source, control means disposed between said source and the first of said secondarily emissive cathode surfaces, means forming a Faraday cage about said secondarily emissive cathode surfaces, the last of said cathode surfaces being substantially impermeable to electrons emitted from the next to last cathode surface, and means for collecting said electrons from said last cathode surface outside of the Faraday cage.

3. An electron multiplier, comprising an evacuated envelope having therein a unipotential cathode, a heater disposed within said cathode, an apertured control screen concentrically disposed about said cathode, a second apertured control screen concentrically disposed thereabout, a first multiplying stage comprising a frustro-conical electrode having a secondarily emissive interior surface formed about said cathode and said control screens coaxially therewith, a second multiplying stage formed by a

conical electrode disposed coaxially with said first stage and having its apical portion directed theretoward, said apical portion being secondarily emissive, an apertured cylindrical screen disposed coaxially with and between said conical and said frustro-conical electrodes, a third multiplying stage disposed within said cylindrical screen and comprising a plurality of flat annular rings disposed coaxially and symmetrically within said cylindrical screen, said rings having secondarily emissive surfaces on the sides thereof facing said conical electrode, and a collecting anode positioned around said cylindrical screen.

4. An electron multiplier substantially as claimed in claim 3, having an annular accelerating electron-permeable electrode disposed centrally within the third stage, and a focusing electrode positioned between said annular accelerating electrode and said unipotential cathode, said focusing electrode being connected to said cathode.

5. An electron multiplier substantially as claimed in claim 3, having an annular accelerating electron-permeable electrode disposed centrally within the third stage, a focusing electrode positioned between said annular accelerating electrode and said unipotential cathode, said focusing electrode being connected to said cathode, and an electron-permeable screen formed congruent with and supported near said conical electrode, said electron-permeable screen being connected to and supported with said third stage.

6. An electron multiplier having an envelope containing a plurality of cathodes capable of emitting secondary electrons at a ratio greater than unity upon electron impact therewith, and an electron source for originating a stream of electrons which creates an augmented stream by secondary electron emission from each cathode in turn, one of said cathodes comprising a plurality of spaced and substantially parallel secondary-emissive surfaces position one above another, together with field determining electrode means on one side of said parallel surfaces for directing arriving electrons against said surfaces at an angle preventing passage of arriving electrons between said surfaces, and collecting electrode means on the other side of said parallel surfaces for removing secondary electrons created by impact of said arriving electrons in a path substantially parallel to the extent of said surfaces and in a direction away from interference with said arriving stream.

RICHARD L. SNYDER.

CERTIFICATE OF CORRECTION.

Patent No. 2,257,985.

October 7, 1941.

RICHARD L. SNYDER.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 2, first column, line 18, after "emission" insert --ratio--; page 3, first column, line 25, claim 1, strike out the word "to"; and second column, line 42, claim 6, for the word "position" read --positioned--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 2nd day of December, A. D. 1941.

(Seal)

Henry Van Arsdale,  
Acting Commissioner of Patents.