Oct. 4, 1960 F. STERZER 2,955,225

ELECTRON COLLECTOR

Filed May 2, 1958

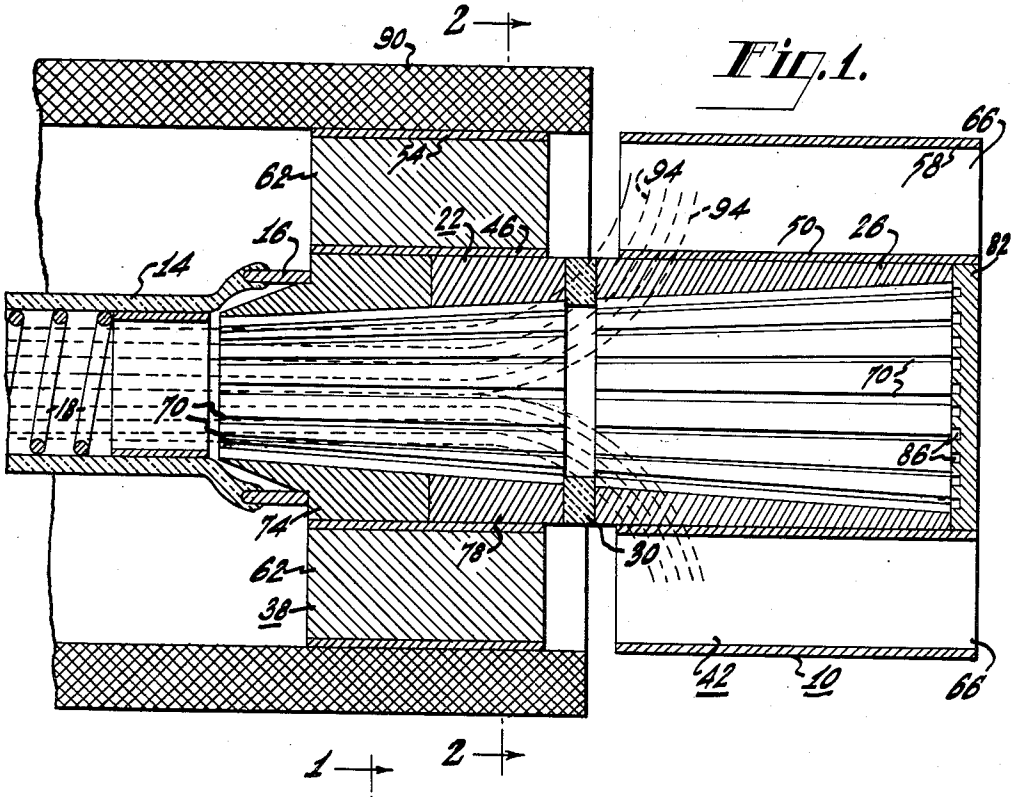


Fig. 1.

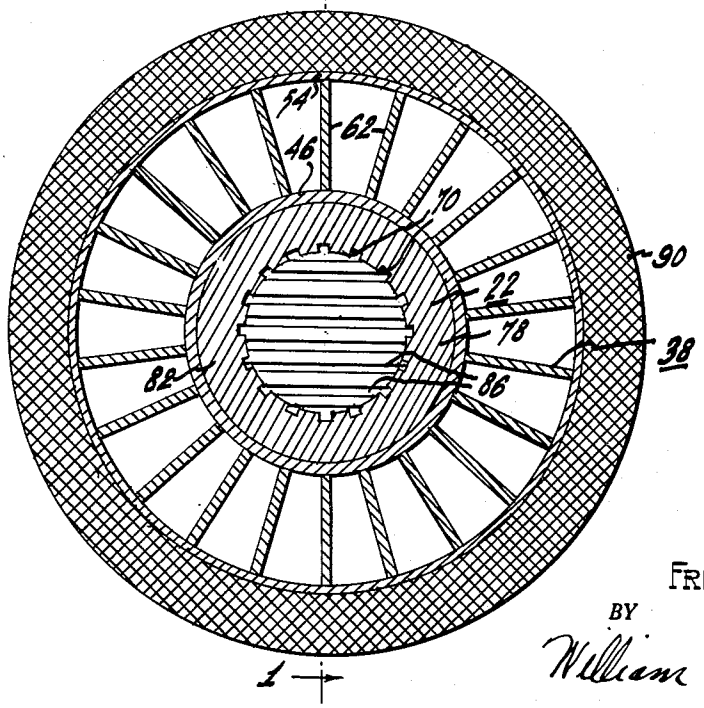


Fig. 2.

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2,955,225

Patented Oct. 4, 1960

2,955,225

ELECTRON COLLECTOR

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Filed May 2, 1958, Ser. No. 732,621

8 Claims. (Cl. 315—3.5)

This invention relates to electron discharge devices utilizing electron beams having a distribution of electron velocities and particularly to apparatus for collecting electrons from such a beam.

Certain present-day electron tubes, e.g., the velocity modulated beam type utilize such electron beams and may therefore incorporate the present invention. For this reason and for the sake of brevity, clarity, and convenience, this invention will be described as incorporated in a conventional traveling wave tube. It will be appreciated, however, that the invention is broadly applicable wherever efficient collection of a multi-velocity electron beam is desired.

In the conventional traveling wave tube an electron beam traverses an RF delay electrode such as a conductive helix where it is velocity modulated, gives up energy in amplifying a wave traveling along the helix, and is then collected by an electron collector. According to usual practices the electron collector comprises a single electrode which is maintained at a single potential equal to or only slightly lower than the potential of the helix. However, in the case of high power traveling wave tubes, electron collection according to such conventional practices becomes quite inefficient. To this end, especially designed collectors can be more efficiently operated at potentials considerably depressed below the potential of the helix and, in fact, plural-stage collectors comprising a plurality of collector electrodes maintained at a corresponding plurality of different depressed voltages can be efficiently utilized.

In a conventional traveling wave tube most of the electrons in traversing the helix interact with the RF fields and are slowed down. The velocities of the electrons according to convention may be expressed in volts. If an electron has been decelerated by an amount corresponding to $\Delta V=V_h-V_e$, where V_h=the voltage on the helix and V_e=the voltage of an electron entering the collector region, then it follows from conservation of energy that the lowest potential at which this electron can be collected is given by $V_{c\min}=\Delta V$.

Thus, it can be seen that for any electron to be collected by a collector, the collector potential must be equal to or greater than the amount which the electron has been slowed down, or stated otherwise, it must be equal to or greater than the helix potential minus the electron potential.

Although some electrons in traversing the helix will be slowed down to such an extent that a collector potential at or near the helix potential will be necessary in order to collect them, other electrons will not be so slowed and will, in fact, emerge with higher velocities. These higher velocity electrons can, according to the electron collection theory expressed above, be collected at a potential lower than the potential necessary to collect the slower electrons. For this reason it becomes apparent that many of the electrons can be collected by a collector having a potential depressed below the helix potential. Extending this principle, and considering that

the electrons emerge from the helix having a distribution of velocities, a series of collectors—or a plural electrode collector—can be employed to efficiently collect the various electrons at the lowest possible collector potentials.

According to the above-stated theory of electron collection, advantages of using depressed collector potentials can be seen. When an electron collector is operated with a single potential high enough to collect the slowest electrons, the higher velocity electrons, in being collected, will give up their excess velocity energy to the collector in the form of heat. This heat must be dissipated by some means. Such dissipation becomes a very important consideration in high power traveling wave tubes where the power necessary to operate the cooling means is often greater than the power dissipated in the collector. And even in medium power tubes, excessive collector heating often necessitates the resorting to liquid cooling rather than permitting the simpler air cooling.

The use of depressed voltage collectors also provides important advantages in the minimization of excessive X-ray radiation from the collector. This may mean substantial savings in the amount of shielding required around the tube. Depressed collector voltages also mean a lower D.C. power input requirement to the tube. Since the overall efficiency of the tube is equal to the RF power output divided by the D.C. power input, an increase of tube efficiency results.

However, when the collector is operated at considerably depressed potentials, several harmful effects can occur which are negligible if the collector is operated at a potential near that of the helix. In the region between the depressed collector and the helix, an electrostatic field is set up which tends to draw the secondary electrons emitted by the collector to the helix. Care must be taken to prevent any secondary electrons from escaping from the collector and impinging upon the helix.

Space charge repulsion can also be seriously harmful in depressed potential collector operation. In the traveling wave tube where an electron beam is magnetically focused through a long tube, as the potential of the collector is reduced the electron flow becomes unstable, and most of the electrons are turned back. This effect is due to the negative space charge of the electrons which depress the potential at the center of the beam. The collector must therefore be designed so that no instabilities will occur at the depressed collector voltages. In this connection it should be noted that the closer the beam is to the electrode surface the more the potential of the electrode may be depressed before the beam becomes unstable.

It is therefore an object of my invention to provide an improved electron collector for efficiently collecting a multi-velocity beam of electrons, i.e., one having a distribution of electron velocities.

Another object of my invention is the provision of an improved plural-stage electron collector wherein the undesirable effects of depressed potential collection of a multi-velocity beam of electrons are minimized.

Briefly, according to my invention a plural-stage electron collector comprises a preferably cup-shaped elongated hollow conductive member axially segmented and with the segments insulated from each other. To prevent excessive escape of secondary electrons, the cup is fabricated with a magnetic section at its closed end and a non-magnetic section at its open end to shape the magnetic focusing field of the tube so that no electrons are collected near the open end of the cup. To further inhibit secondary electron escape the inside cylindrical wall of the cup is coated with a material of low secondary emission yield, is grooved, and is made convergent toward the open end.

In the drawings:

Fig. 1 is a longitudinal section view of the collector end of a traveling wave tube illustrating a segmented electron collector according to my invention; and

Fig. 2 is a transverse section view taken along line 2—2 of Fig. 1.

In the drawings, an electron collector **10** is shown sealed to the end of an envelope **14** of a conventional traveling wave tube by an expansion-matching ring **16** of a material such as a Kovar alloy. The end of a conventional helix **18** is shown mounted within the envelope **14**. The electron collector **10** comprises an elongated, longitudinally-segmented cup and includes an open-ended front segment **22** and a closed-ended back segment **26** sealed together in end-to-end relation with a separating ceramic ring **30**. Heat-radiating structures **38** and **42** are mounted respectively about the front segment **22** and the back segment **26**. The two radiating structures comprise respectively inner cylinders **46** and **50**, outer cylinders **54** and **58**, and a plurality of longitudinally extending radial vanes **62** and **66** mounted therebetween.

The inside longitudinal wall of the electron collector **10**, including the front segment **22** and the back segment **26**, is convergent toward its open end and is provided with a plurality of longitudinal grooves **70** equally spaced around the periphery thereof. The front segment **22** is itself segmented into two parts. An open-ended front part **74** is composed of an electrically conductive, non-magnetic material, such as copper. A back part **78** sealed to the ceramic ring **30** is composed of an electrically conductive, magnetic material such as cold rolled steel. Likewise, the back segment **26** of the collector **10** is composed of an electrically conductive, magnetic material.

The end wall **82** of the back segment **26** of the electron collector **10** is provided with a plurality of grooves **86** which may, for example, be in the form of concentric circles or chordal lines as shown. All surfaces inside the collector cup are coated with carbon in order to minimize the secondary electron emission.

A solenoid **90** coaxially disposed with the electron collector **10** extends along the traveling wave tube and approximately halfway along the electron collector **10**. The solenoid **90** serves to provide an axial magnetic focusing field to prevent beam divergence as it traverses the helix **18** and also to provide a divergent magnetic field within the electron collector **10**. The divergent field is illustrated by the dotted lines **94** of Fig. 1. As will be appreciated from such illustration, the copper front part **74** of the front segment **22** serves to maintain the magnetic field parallel for a distance part way through the front segment **22**. Divergence of the magnetic field begins only after the magnetic lines of force reach the magnetic back part **78**. Thus, low velocity electrons, which are collected by the front segment **22**, impinge mostly on the back part **78** thereof. By maintaining low velocity electron impingement on the back part **78** of the front segment **22**, escape of secondary electrons from the open end of the collector **10** is greatly minimized. In accordance with the theory of electron collection and depressed voltage collectors as hereinbefore discussed, the higher velocity electrons pass beyond the ceramic ring **30** and are collected by the back segment **26** which is operated at a potential depressed below the potential on the front segment **22**.

According to a preferred embodiment construction of my invention incorporated in a 100 watt traveling wave tube, the inside cylindrical wall of the electron collector **10** is provided with a convergent taper of approximately 10°. The grooves **70** in the inside cylindrical wall are 0.045 inch deep and 0.040 inch wide. The lands between the grooves **7** are 0.040 inch wide at the small diameter end of the inside cylindrical wall and taper to a greater width toward the end wall **82** corresponding to the wall taper. The overall length of the electron collector **10** is 2.0 inches; the copper front part **74** of the front segment **22**, 0.4 inch; the back part **78** of the front segment **22**, 0.3 inch; the thickness of the ceramic ring **30**, 0.05 inch; and the length of the back segment **26**, 1.25 inches. The outside diameter of the front and back segments **22** and **26** is 1.0 inch; the thickness of the end wall **82**, 0.1 inch; the thickness of the cylindrical wall of the back segment **26** adjacent the end wall **82**, 0.050 inch; and the thickness of the cylindrical wall of the copper front part **74** of the front segment **22** near the expansion matching ring **34**, 0.4 inch. Such a preferred embodiment has been operated with, for example, potentials of 4400 volts on the helix **18**; 2300 volts on the front segment **22**; and 1450 volts on the back segment **26**. With these conditions an overall efficiency of 57% was measured. The efficiency measurement of a prior art single stage collector with corresponding helix current was measured at only 40%.

What is claimed:

1. An electron collector for collecting a beam of electrons comprising an elongated hollow member including a front segment and a back segment disposed coaxially end-to-end and insulatively mounted to each other, the inside wall of said hollow member being convergent toward and opening at the front end thereof, said front segment including a first portion at the front end thereof and a second portion adjacent said back segment, said first portion consisting of an electrically conductive non-magnetic material and said second portion and said back segment both consisting of an electrically conductive magnetic material.

2. An electron collector for collecting a beam of electrons comprising an elongated hollow member including a front segment and a back segment disposed coaxially end-to-end and insulatively mounted to each other, the inside wall of said hollow member being convergent toward and opening at the front end thereof, said front segment including a first portion at the front end thereof and a second portion adjacent said back segment, said first portion consisting of an electrically conductive non-magnetic material and said second portion and said back segment both consisting of an electrically conductive magnetic material, and means for providing a magnetic field extending into the open end of said hollow member, said magnetic field being substantially axially parallel to substantially the far end of said first portion and then being divergent.

3. An electron collector for collecting a beam of electrons comprising an elongated hollow member including a front segment and a back segment disposed coaxially end-to-end and insulatively mounted to each other, the inside wall of said hollow member being grooved and convergent toward and opening at the front end thereof, said front segment including a first portion at the front end thereof and a second portion adjacent said back segment, said first portion consisting of electrically conductive non-magnetic material and said second portion and said back segment both consisting of an electrically conductive magnetic material, and means for providing a magnetic field extending into the open end of said hollow member, said magnetic field being substantially axially parallel to substantially the far end of said first portion and then being divergent.

4. An electron collector for collecting a multi-velocity beam of electrons comprising an elongated cup-like member including an open-ended front segment and a closed-ended back segment disposed coaxially end-to-end and insulatively mounted to each other with a separating ceramic member, the inside longitudinal wall of said cup-like member being longitudinally grooved and convergent toward the open end thereof, said front segment including a first portion at the front end thereof and a second portion adjacent said back segment, the openings in said first and second portions being of substantially equal axial lengths, said first portion consisting of an electrically conductive non-magnetic material and said

second portion and said back segment both consisting of an electrically conductive magnetic material, and means for providing a magnetic field extending into the open end of said cup-like member, said magnetic field being substantially axially parallel to substantially the far end of said first portion and then being divergent.

5. An electron collector for collecting a multi-velocity beam of electrons comprising an elongated cup-like member including an open-ended front segment and a closed-ended back segment disposed coaxially end-to-end and insulatively mounted to each other with an intermediate ceramic ring, the inside longitudinal wall of said cup-like member being longitudinally grooved and convergent toward the open end thereof, at a taper of approximately 10°, the inside closed-end wall being grooved along parallel chordal lines, both said longitudinal and said closed-end walls being coated inside with a material of low secondary emission yield, said front segment including a first portion at the front end thereof and a second portion adjacent said back segment, the openings in said first and second portions being of substantially equal axial lengths, said first portion consisting of an electrically conductive non-magnetic material and said second portion and said back segment both consisting of an electrically conductive magnetic material, and solenoid means surrounding and extending substantially along said front segment for providing a magnetic field extending into the open end of said cup-like member, said magnetic field being substantially axially parallel to substantially the far end of said first portion and then being divergent.

6. In a traveling wave tube in which an electron beam is projected along a delay electrode for interaction with the field of said electrode and thence to a collector electrode; the combination with said delay electrode of a collector electrode comprising an elongated hollow conductive means including a front segment and a back segment disposed in end-to-end relation and insulated with respect to each other and said delay electrode, said front segment including a front portion of non-magnetic material and a back portion of magnetic material, at least the front portion of said back segment being of magnetic material.

7. The combination defined in claim 6, wherein the inside wall of said hollow conductive means is grooved and convergent toward the front end thereof.

8. The combination defined in claim 6, further including means for providing a magnetic field extending with substantially parallel flux lines into the front end of said hollow conductive means to substantially the far end of said front portion and then being divergent.

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