

Nov. 11, 1958

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2,860,277

TRAVELING-WAVE TUBE COLLECTOR ELECTRODE

Filed Sept. 2, 1955

Fig. 1

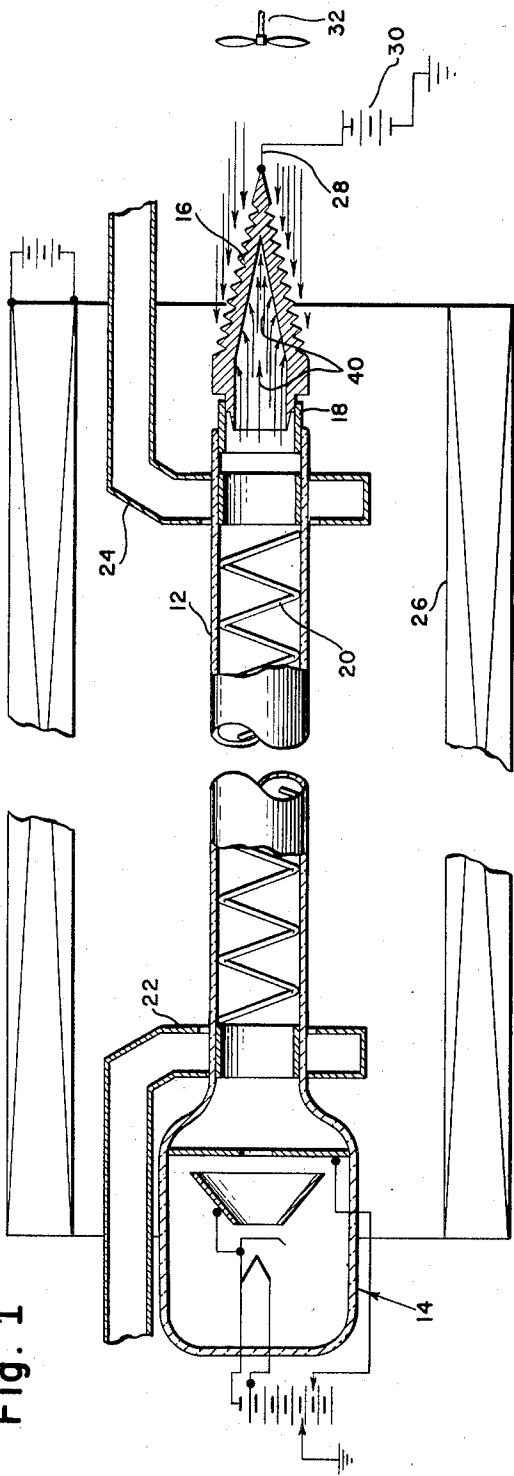


Fig. 2

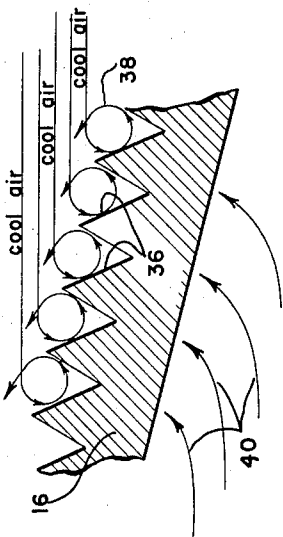
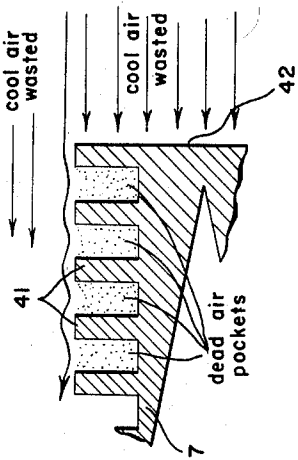


Fig. 3



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1

2,860,277

TRAVELING-WAVE TUBE COLLECTOR
ELECTRODE

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Application September 2, 1955, Serial No. 532,289

5 Claims. (Cl. 315—3.5)

This invention relates to traveling-wave tubes, and more particularly to an improved electrode for collecting the electron beam of the traveling-wave tube.

A microwave traveling-wave tube comprises typically an evacuated envelope, an electron gun disposed at one end of the envelope for producing an electron stream along a predetermined path, and a conductive helix for propagating electromagnetic waves which is disposed about the path, whereby the electric fields of the waves may interact with the electron stream. At the end of the electron path opposite the electron gun and beyond the conductive helix is placed a collector electrode for collecting the stream electrons and dissipating their kinetic energy.

In low-power applications the shape and dimensions of the collector electrode are not critical and the electrode may be a simple disc disposed transverse to the electron stream to intercept the stream. It has, however, been found to be desirable to provide the electrode with a concave shape so that secondary electrons from the electrode will not interfere with the fields in the helix. In high-power applications heat dissipation in the collector electrode becomes a serious problem, and more collecting area must be provided; and, further, forced cooling is needed to preclude damage to the collector electrode and to increase the amount of power dissipation possible by the collector electrode.

Conventional high-power, cooled collector electrodes are large and bulky which precludes simple plug-in installation, because when the collector electrode is larger than the glass envelope it must be installed after the tube has been passed through the confining magnet or solenoid and microwave couplings. Such is usually a very delicate task and not desirable for application in the field. Also, such large collector electrodes have a large amount of inertia and may cause breakage of the glass envelope of the tube.

It is, therefore, an object of the present invention to provide a collector electrode for a traveling-wave tube which has a large electron collecting area.

It is another object to provide such an electrode which is efficiently cooled to increase its power dissipation by forced cooling.

It is still a further object to provide such an electrode with a surface for air stream cooling which is shaped in a manner to cause turbulent air flow at practically all points over its surface.

It is yet a further object to provide an electrode of the type referred to which presents a large proportion of its surface area to a stream of coolant; and which presents substantially all of that surface to the coolest portion of the coolant stream.

It is still a further object to provide an electrode of the diameter described which has a very small moment of inertia about its support for minimizing damage to the traveling-wave tube or its envelope due to mechanical shock.

It is another object to provide a collector electrode

2

which is sufficiently small in overall diameter that a traveling-wave tube utilizing it may be easily plugged in without requiring the securing of cooling means to the tube after it is installed.

Briefly, in accordance with the invention, these objects are achieved in the following manner:

An elongated hollow cone with a relatively thin wall is disposed at the end of traveling-wave tube in a manner such that the interior surface of the cone intercepts the electron stream using substantially all of the area of the interior surface of the cone. The exterior surface of the cone is disposed such that the axis of the cone is parallel to a stream of coolant flowing in a direction opposite to the electron stream. This exterior surface has "threads," the threads being disposed axially and being progressively larger in diameter from the apex of the cone to the base of the cone.

The novel features which are believed to be characteristic of the invention, both as to its organization and method of operation, together with further objects and advantages thereof, will be better understood from the following description considered in connection with the accompanying drawing in which an embodiment of the invention is illustrated by way of example. It is to be expressly understood, however, that the drawing is for the purpose of illustration and description only, and is not intended as a definition of the limits of the invention.

In the drawing:

Fig. 1 is a sectional view of a typical traveling-wave tube utilizing the collector electrode structure of this invention;

Fig. 2 is an enlarged sectional view of a portion of a collector electrode in accordance with the invention; and

Fig. 3 is a sectional view of a portion of a conventional collector electrode.

Referring to the drawing and particularly to Fig. 1, a traveling-wave tube 10 is shown having an elongated glass envelope 12 at the left end of which is an electron gun 14 interconnected with appropriate sources of heating, focusing, and accelerating voltage. At the right end of traveling-wave tube 10 is shown collector electrode 16 which is sealed to glass envelope 12 through a Kovar seal 18. A slow-wave structure, such as helix 20, is disposed within envelope 12 between electron gun 14 and collector electrode 16. Input waveguide 22 is electrically coupled in a conventional manner to the left hand end of helix 20; and output waveguide 24 is in like manner electrically coupled to the right hand end of helix 20. Solenoid 26 is disposed about the traveling-wave tube as shown to constrain and confine the electron stream within and along helix 20. Collector electrode 16 is electrically coupled by conductor 28 through a suitable potential source 30 to ground. A blower shown schematically at 32 is disposed in a manner to force cooling gas or air past collector electrode 16.

Referring to Fig. 2, a portion of collector electrode 16 of Fig. 1 is shown in more detail. An electron stream is shown schematically at 40 and traverses the tube from the left, impinging upon the inner surface of collector electrode 16. Electrode 16 is preferably made of a metal of high thermal conductivity, such as copper, and in accordance with this invention may be made very thin, of the order of one-sixteenth of an inch. Threads 36 provided in the outer surface are shaped in such a manner that the cooling air will have a turbulent flow, as indicated by curved arrows 38, and hence provide more efficient cooling of the troughs of each of the threads. Due to the conical shape of the electrode, the cooling air which impinges upon the threads near the base of the cone is substantially as cool as that air which impinges upon the apex or tip of the cone, the only variation in this being caused by the turbulent mixing of the hot air

3

along the smaller diameter threads with the stream of cooling air, which then impinges on the threads of greater diameter toward the base of the conical electrode. This obviously results in very high efficiency of cooling and it has been found that such a configuration is easily capable of dissipating heat corresponding to electric energy of the order of 70 watts. The depth of the individual threads, as well as their pitch and their actual angular dimensions is best determined empirically with each particular application. The design of the cooling surface is determined, of course, in a manner to cause optimum turbulence and mixing of the cooling air stream as it passes over and impinges upon the serrated or threaded conical surface while minimizing mass and wall thickness of the electrode for a given heat dissipation and a given tube envelope diameter while providing adequate mechanical strength.

Fig. 2 shows also the operation of the cooling electrode in detail. The parallel stream of cool air shown by arrows 40 impinges upon each of threads 36, and as shown by the arrows representing the coolant, there is a turbulent flow of coolant deep down into each trough which minimizes dead air pocketing. It is obvious from the figure that the air which flows against the threads to the left is substantially as cool as that which flows against the threads to the right, to thus provide very efficient cooling.

In contrast, a typical prior art collector electrode 17 is shown in Fig. 3. Cooling fins 41 are disposed, as shown in an air stream. Here most of the air in the stream does not thermally interact with the collector because of its conventional cylindrical shape. Much of the air stream is intercepted at end face 42 where a pressure head is built up which tends to insulate that portion of collector 17 from the air stream. That portion of the air stream which passes over cooling fins 41 is heated as it moves to the left; and this greatly limits the efficiency of heat transfer from collector to air stream.

It is thus seen that in accordance with the present invention the electron stream 40 as it enters the magnetic shield of collector electrode 16 disperses and impinges along the conical interior surface of the electrode and imparts its kinetic energy to the electrode tending to heat it. The charge collected by electrode 16 is then carried by conductor 28 through potential source 30 to ground. The electrode is meanwhile externally cooled by the cooling stream of air which turbulently flows past the serrated outside surface of collector electrode 16.

Very important advantages of this type of structure for a collector electrode stem from its light weight. First, its moment of inertia is greatly decreased both because of its thin wall and because its center of gravity is moved toward the Kovar seal support. These advantages obviously are very important in modern mobile or airborne equipment which are subjected to severe mechanical shock or vibration; second, the collector electrode is easier to build; and, third, cheaper because of the smaller amount of material used.

There has thus been disclosed a collector electrode for a traveling-wave tube which has a large electron collecting area, and which is efficiently cooled to permit high-power operation. Further, the area of the electrode which is presented to the cooling air stream is shaped in a manner such as to cause each differential segment of that area to be exposed to cool air instead of to air which has been heated by passing over previous segments of the collector area. The electrode disclosed also has a very small moment of inertia for making traveling-wave tubes more reliable for use in environments which are subject to mechanical shock. And of considerable importance is that although the collector electrode of the invention is capable of high-power dissipation, it has an overall diameter which is no greater than that of the glass envelope; so that a tube utilizing the disclosed collector electrode may be simply plugged

4

into a pre-existing hollow cylindrical socket with the collector cooling means preattached.

What is claimed is:

1. A high-power traveling-wave tube comprising: means for emitting and projecting a beam of electrons along a predetermined path; a thin walled, light weight electron collector for collecting the electron beam; a slow-wave structure disposed along and enclosing a portion of said path; cooling means disposed externally to said path and adapted to direct a stream of coolant over said thin walled collector, said collector having a concave internal surface and a substantially conical outer surface, said inner surface being disposed in a manner such that said electrons impinge upon said inner surface while the stream of coolant impinges upon the outer surface of said collector, said outer surface being provided with relatively deep serrations, whereby a large area of said external surface is presented to the stream of coolant made turbulent by said serrations for efficient cooling of said collector.

2. In a traveling-wave tube having means for projecting an electron stream, a thin walled, light weight collector electrode of the character which is force cooled in a stream of coolant for high power operation of the tube, said collector comprising: a thin walled light weight metallic conical member disposed in a manner to intercept said electron stream, substantially all of the outer surface of said thin walled conical member being deeply serrated, whereby said outer surface is adapted to present a larger cooling area to the stream of coolant and provides turbulent flow over each serrated portion of the exterior surface of said conical member.

3. In a high-power traveling-wave tube, a collector electrode adapted to be force cooled in a stream of coolant, said collector electrode comprising: a light weight thin walled, hollow, metallic conical member having an outer surface provided with threads of diameter varying from the apex to the base of said member, the axes of said threads being mutually coincident with the axis of said member, whereby a large proportion of the external surface of said collector electrode may be presented to a stream of coolant made turbulent by said threads.

4. In a high-power traveling-wave tube of the character adapted to be plugged into a pre-existing hollow cylindrical socket having a predetermined inner diameter and having an outer cylindrical envelope having an outer diameter substantially equal to said predetermined diameter and which encloses a slow-wave structure, a collector electrode contiguous to the envelope, and cooling means for projecting a stream of coolant over the collector electrode, the collector electrode comprising: a thin walled light weight hollow metallic cone disposed with its axis parallel with the axis of said envelope in a manner such that the apex of the cone is pointed away from the slow-wave structure, the base of said cone being secured to said envelope and being no larger in transverse dimension than said outer diameter of said envelope for permitting and facilitating installation into said hollow cylindrical socket, the exterior conical surface of said cone being threaded to present a larger area to a stream of coolant and to cause a mixing, turbulent, thermal interaction between said collector electrode and the coolant over substantially all of the external surface of said collector electrode, whereby the portions of said external surface near the base of said cone are presented to coolant substantially as cool as those portions of said external surface near the apex of said cone to increase cooling efficiency.

5. In a high-power traveling-wave tube of the character adapted to be plugged into a pre-existing hollow cylindrical socket having a predetermined inner diameter and having an outer elongated cylindrical envelope having an outer diameter slightly less than said predetermined diameter and which encloses a slow-wave structure and having a collector electrode contiguous to the envelope, the

5

collector electrode comprising: a thin walled light weight hollow metallic conical member disposed with its axis substantially parallel with the axis of the slow-wave structure in a manner such that the apex of the conical member is pointed away from the slow-wave structure, the base or largest diameter portion of said conical member which is contiguous to said envelope being no larger in diameter than said envelope for permitting and facilitating plug-in installation into said hollow cylindrical socket, the exterior conical surface of said member being threaded or ridged, whereby when a stream of coolant is directed toward said collector electrode along a line substantially parallel with the axis of said member the conical shape permits the portions of said external surface near the base of said conical member to be presented to coolant substantially as cool as are those portions of the conical

6

surface near the apex or point of said conical member, and the ridges being effective to cause a mixing, turbulent, thermal interaction between said collector electrode and the coolant over substantially all of the external surface of said collector electrode to increase cooling efficiency.

References Cited in the file of this patent

UNITED STATES PATENTS

10	2,112,958	Gutton et al. ----- Apr. 5, 1938
	2,295,680	Mouromtseff et al. ----- Sept. 15, 1942
	2,466,064	Wathen et al. ----- Apr. 5, 1949
	2,486,398	Feenberg ----- Nov. 1, 1949
	2,619,611	Norton et al. ----- Nov. 25, 1952
15	2,774,006	Field et al ----- Dec. 11, 1956
	2,794,143	Warnecke et al. ----- May 28, 1957