

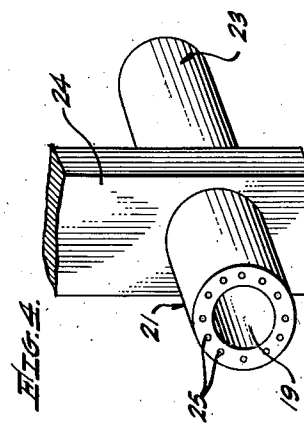
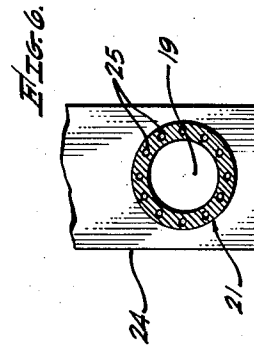
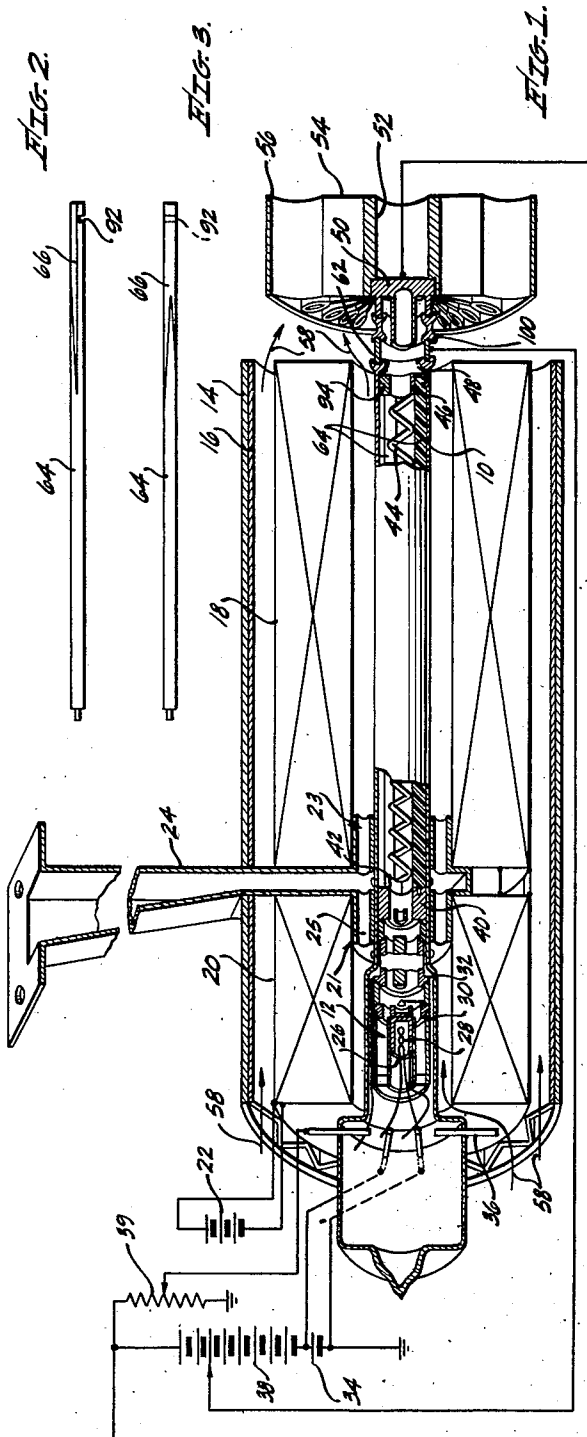
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TRAVELING WAVE TUBE

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TRAVELING WAVE TUBE

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This invention relates to waveguides and more particularly to electromagnetic coupling means between a rectangular waveguide and the slow-wave structure of a traveling-wave tube.

Traveling-wave tubes are electron-stream type tubes which essentially comprise an evacuated envelope, an electron gun disposed at one end of the envelope for producing an electron stream, a collector electrode disposed at the opposite end of the envelope to intercept the stream electrons and a slow-wave structure disposed about the stream for propagating an electromagnetic wave.

The largest disadvantage in the economic exploitation of typical present day traveling-wave tubes is the focusing solenoid which must necessarily be disposed concentrically about the tube envelope to constrain or to focus the electron stream. The initial cost of the solenoid may be larger than the cost of most of the other tube elements. Furthermore, the large size, weight and power consumption of the solenoid make the efficient design of a traveling-wave tube very difficult.

In designing a solenoid for a traveling-wave amplifier, the axial magnetic field which must be maintained within the tube determines the radial thickness of the solenoid. The power consumption of the solenoid is proportional to its average diameter. It is thus desirable to make the diameter of the envelope of a traveling-wave tube as small as practicable. The electron gun of a tube generally has the largest diameter of any of the tube elements, but a reduction in size of the gun has been accomplished. Such a gun has been disclosed and claimed in copending application entitled "Cathode Support," Serial No. 462,870, filed concurrently herewith by John A. Dallons and assigned to the assignee of the present application. The use of such a gun, however, often requires that a cooling fluid, such as air, be circulated about the tube envelope. This is due to the limited cooling area about an envelope having a relatively small diameter.

A transverse rectangular waveguide is generally employed to introduce efficiently wave energy into or extract it from a traveling-wave tube helix or other slow-wave structure. For the effective utilization of such a waveguide, a matching sleeve is employed to prevent energy radiation loss; however, the sleeve is usually required to fit contiguously about the tube envelope. Such a sleeve consequently impedes or prevents the circulation of cooling air axially along the tube envelope.

It is therefore an object of the invention to provide means whereby a traveling-wave tube envelope may be effectively cooled by the circulation of a fluid such as a gas over the entire length of the envelope.

Another object of the invention is to provide a waveguide assembly for extracting wave energy from or introducing wave energy to a traveling-wave tube slow-wave structure without impeding the axial flow of cooling fluid along the length of the tube envelope.

In accordance with the present invention two perforated, sleeve-type waveguide appendages forming part of an input or output structure are employed about a

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traveling-wave tube envelope. The appendages are constructed in a manner to prevent the escape of wave-energy impressed on or extracted from the slow-wave structure of the amplifier but to provide longitudinal passages which allow the axial circulation of a cooling fluid.

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.

Fig. 1 is a sectional view of a traveling-wave tube amplifier or oscillator embodying the present invention with associated circuits;

Fig. 2 is an elevational view of a dielectric rod supporting the conductive helix of the oscillator of Fig. 1;

Fig. 3 is a plan view of the rod shown in Fig. 5;

Fig. 4 is a broken away, oblique view of the waveguide assembly forming part of the oscillator of Fig. 1;

Fig. 5 is a sectional view of the assembly of Fig. 4; and

Fig. 6 is a longitudinal sectional view of the waveguide assembly of Fig. 4.

Referring now to Fig. 1 a traveling-wave tube oscillator is shown comprising an evacuated envelope 10 having an enlarged portion at the left extremity thereof for housing an electron gun 12. Shown disposed concentrically about envelope 10 is an outer metallic cylinder 14 inside of which a crimped or folded metallic member 16 is disposed having smooth axial surfaces for conducting heat from two focusing solenoids 18 and 20 which are disposed concentrically about envelope 10 and axially spaced from each other. Focusing solenoids 16 and 18 are supplied with current by source 22 to produce an axial magnetic field along the longitudinal axis of the envelope whereby an electron stream may be confined. The field produced by solenoids 18 and 20 may be about 600 to 1200 gauss.

Electron gun 12 comprises a cathode 26 with a filament 28, a focusing electrode 30 and an accelerating anode 32. Filament 28 is heated by means of a source of potential 34, the negative terminal of which is connected to ground. Focusing electrode 30, which has a frusto-conical internal surface of revolution disposed at an angle of 67½ degrees with respect to its axis of symmetry, is maintained at the same potential as cathode 26 by an appropriate connection to one of the radial pins 36 shown in Fig. 1. Cathode 26 is maintained at ground potential. Anode 32 is maintained at a potential from 1000 to 3000 volts positive with respect to cathode 26 by means of a connection to another one of the radial pins 36 which is, in turn, connected to the positive terminal of a source of potential 38, the negative terminal of which is connected to the positive terminal of potential source 34.

Disposed concentrically within the tube envelope in the direction of electron flow is a ferrule 40, a matching appendage or tab 42, a conductive helix 44, a terminating conductive cylinder 46, a conductive coating 48 and a collector electrode 50. The helix 44 is supported by three dielectric rods 64. Conductive coating 48 may be obtained simply by brushing a liquid suspension of silver onto envelope 10. The relatively thick silver coating 48 may thus provide a stop against which the conductive cylinder 46 may be pushed. Collector 50 is preferably made of a conductive material such as copper to conduct away heat generated by the stream electrons impinging thereon. A concentric cylinder 52 is disposed contiguously to and projecting from collector 50 and a plurality of con-

ductive fins 54 is positioned radially from cylinder 52 to a second or outer cylinder 56.

Collector 50 is maintained at an appropriate potential somewhat above the potential of terminating cylinder 46 and coating 48 by means of an appropriate connection to the positive terminal of potential source 38. This is done to suppress secondary electron flow to coating 48. All the metallic elements 40, 42, 44, 46 and 48 are maintained at the same potential by means of a connection from a tap on potential source 38 to a conductive cylinder 62 on which coating 48 has been partially disposed. Conductive cylinder 62 is connected at its left extremity to the envelope 10. At its right extremity cylinder 62 is connected to collector 50 by means of a short glass cylinder 100 to provide a seal between the envelope and the collector.

The oscillator of Fig. 1, called a backward-wave oscillator, preferably has a termination near the collector end of the tube including three helix supporting rods 64 shown in Fig. 1. Figs. 2 and 3 illustrate one of the dielectric rods 64 which have a lossy coating 66 disposed on their right end in a tapered manner to prevent another type of traveling-wave tube self-oscillation which occurs as a result of waves reflected from both ends of the tube.

A transverse conductive rectangular waveguide segment 24, which is preferably made of copper is provided in accordance with the present invention for extracting wave energy from the oscillator. Waveguide segment 24 has two central apertures in its walls from which two appendages 21 and 23 extend at right angles to segment 24 and about envelope 10. The appendages 21 and 23 have a plurality of longitudinal apertures 25 extending through them parallel to the axis of the appendages. The physical structure of segment 24 and appendages 21 and 23 is better illustrated in Figs. 4, 5 and 6. The appendages 21 and 23 have a length about equal to the inside diameter of a large central aperture 19 corresponding to the outer diameter of envelope 10. The appendages 21 and 23 are thus made sufficiently long to attenuate the higher order modes of wave propagation which they might otherwise radiate. The aperture 19 is made small enough to appear as a cut-off waveguide to waves propagating in the higher order modes. Attenuation is effectively provided with the large aperture 19 by its substantial length. Attenuation is further provided with greater efficiency by longitudinal apertures 25 because attenuation is inversely proportional to radius in a cylindrical waveguide. Another purpose of longitudinal apertures 25 of appendages 21 and 23, as shown, is to permit the circulation of a cooling fluid such as air, about the envelope 10. Wave energy may thus be efficiently extracted from the tube helix 44 without producing concomitant energy radiation and without impeding the axial circulation of a cooling medium about the envelope 10.

In the operation of the disclosed microwave oscillator, the electron stream is generated by the electron gun 12. The stream is directed through the helix 44 to collector electrode 50. Due to thermal noise within the stream a backward wave is induced on the helix, the wave propagating toward the electron gun 12. The backward wave has a phase velocity which is actually in the direction of electron flow, an energy exchange interaction between the stream and the wave may thereby be produced. The wave caused thereby is amplified as it progresses toward the gun 12. An alternating current representing the energy of the wave then flows within the matching tab 42, and waveguide segment 24 is excited. The waveguide segment 24 then directs the wave energy to a utilization device. This is accomplished without incumbent energy radiation, because the longitudinal apertures 25 and the large central aperture 19 act as cut-off waveguides. The envelope 10 is cooled by an axial flow of a cooling medium over the complete length of the envelope, the cooling medium being permitted to circulate through the longi-

tudinal apertures 25 of the waveguide appendages 21 and 23.

A forced draft of air may be produced between cylinder 14, sheet 16 and the outer surfaces of solenoids 18 and 20, and also through the appendages 21, 23 of waveguide segment 24 and between the inner surfaces of solenoids 18, 20 and envelope 10. The air may then ultimately flow about collector cylinders 56 and 52 and fins 54. The direction of air flow is indicated by arrows 59. Although the direction of air flow is not particularly critical, since the collector end of the envelope 10 will generally be at a higher temperature than that of the gun 12, the direction of air flow from left to right is preferable to provide countercurrent heat exchange.

What is claimed is:

1. In a traveling-wave tube having an evacuated envelope, a waveguide assembly comprising a rectangular waveguide segment having two juxtaposed apertures in two opposite walls thereof, the envelope being disposed therethrough transverse to said segment, and two girdling collars disposed about the envelope adjacent to opposite sides of and in contact with said segment, said collars having a plurality of longitudinal registering passages to permit the circulation of a cooling medium lengthwise of and externally about the envelope through said passages and through the apertures in said segment, said collars having a length substantially equal to their inside diameters, whereby said passages form a plurality of waveguides for attenuating waves propagated in higher order modes having frequencies falling within the operating band of said tube.

2. In a traveling-wave tube having an evacuated envelope, a waveguide assembly comprising a waveguide segment having two juxtaposed apertures in two opposite walls thereof, the envelope being disposed therethrough transverse to said segment, and two tubular appendages disposed about the envelope adjacent to opposite sides of and in contact with said segment, said appendages having a plurality of longitudinal passages to permit the circulation of a cooling medium lengthwise of and externally about the envelope through said passages and through the apertures in said segment, said appendages having a length substantially equal to their inside diameter, whereby said passages form a plurality of waveguides for attenuating waves propagated in higher order modes having frequencies falling within the operating band of said tube.

3. A traveling-wave tube comprising an evacuated envelope, an electron gun disposed at one end of said envelope for producing an electron stream along the longitudinal axis of said envelope, a slow-wave structure disposed about said stream for propagating electromagnetic waves, a collector electrode disposed at the end of said envelope opposite said electron gun for intercepting the stream electrons, a plurality of cooling fins extending radially from said collector electrode externally of said envelope, a rectangular waveguide segment having two juxtaposed apertures in two opposite walls thereof, said envelope being disposed therethrough transverse to said segment, and two girdling collars disposed about said envelope adjacent to opposite sides of and in contact with said segment, said collars having a plurality of longitudinal registering passages in communication with the space between the apertures of said segment to permit the circulation of a cooling medium lengthwise of and externally about said envelope and said cooling fins, said collars having a length substantially equal to their inside diameters, whereby said passages form a plurality of waveguides for attenuating waves propagated in higher order modes having frequencies falling within the operating band of said tube.

4. A traveling-wave tube comprising an evacuated envelope, an electron gun disposed at one end of said envelope for producing an electron stream, means for directing said stream along the longitudinal axis of said

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envelope, at least one solenoid disposed about said envelope for providing an axial magnetic field through said stream, a slow-wave structure disposed about said stream for propagating electromagnetic waves, a collector electrode disposed at the end of said envelope opposite said electron gun, a plurality of cooling fins extending radially from said collector electrode externally of said envelope, a waveguide segment having two juxtaposed apertures in two opposite walls thereof, said envelope being disposed therethrough transverse to said segment, and two tubular appendages disposed about said envelope adjacent to opposite sides of and in contact with said segment, said appendages having a plurality of longitudinal passages extending through the space formed by the apertures of said segment to permit the circulation of a cooling medium

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between said solenoid and said envelope and about said cooling fins, said appendages having a length substantially equal to their inside diameter, whereby said passages form a plurality of waveguides for attenuating waves propagated in higher order modes having frequencies falling within the operating band of said tube.

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