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HELIX STRUCTURE FOR TRAVELING-WAVE TUBES

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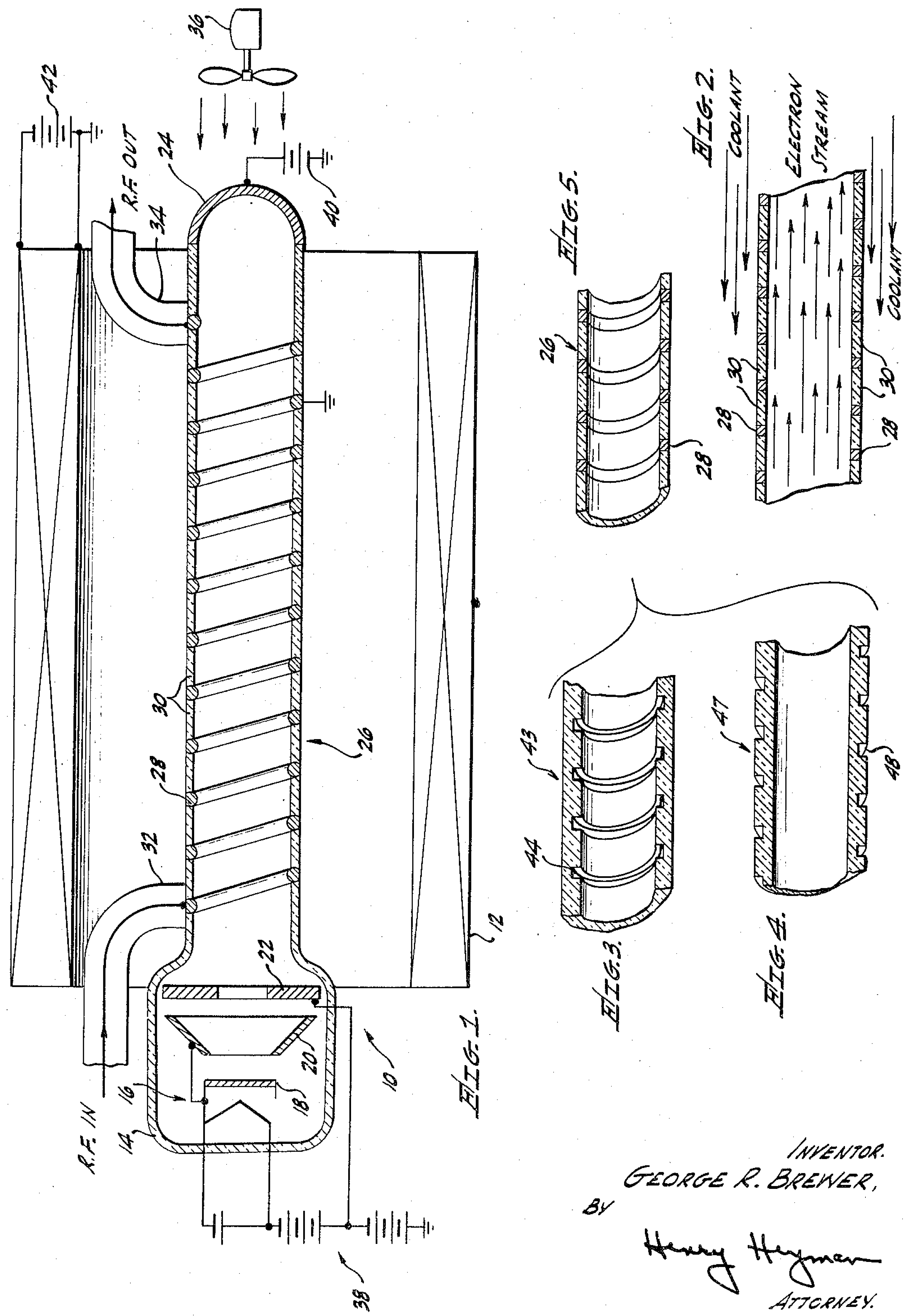

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HELIX STRUCTURE FOR TRAVELING-WAVE TUBES

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This invention relates generally to traveling-wave tubes and particularly relates to an improved helix structure having high power dissipation capability.

A traveling-wave tube conventionally consists of a slow-wave structure such as a helix along which electromagnetic waves are caused to propagate in a manner such that the velocity of propagation in the axial direction is substantially less than the velocity of light. Then along the interior of the helix an electron stream is projected at a velocity approximately that of the axial velocity of the traveling waves along the helix. An interchange of energy is thus possible between the electron stream and the traveling-wave. In the case of a forward-wave amplifier the electron stream velocity is caused to be slightly greater than the velocity of axial propagation of the traveling-waves along the helix and electromagnetic "pushing" of the traveling-waves results in an amplification thereof. In a backward-wave amplifier the electron stream is caused to amplify a traveling wave propagating in a direction opposite to the direction of travel of the electron stream; and the backward wave chosen to be so amplified corresponds to that Fourier component of a forward traveling wave which would be amplified along with the fundamental forward traveling wave.

In any such traveling-wave tube having maximum efficiency of operation the electron stream is caused to traverse the length of the helix and pass as closely as possible to the helix itself in order to achieve maximum coupling between the traveling-waves and the electron stream. If the electron stream is caused to pass too closely to the helix, an excessive proportion of the electrons in the stream impinge upon the helical conductor and excessively heat it which in turn decreases the efficiency of the tube and endangers it mechanically due to thermal expansion. Ordinarily an optimum is sought between very close coupling of the electron stream to the helix and keeping the electron stream separated from the helix so as to create no serious heat dissipation problems. In order to allow closer coupling and therefore more heating effect, the outside of the helix is often cooled by the passage of a suitable coolant flowing as nearly as possible to the outside of the helix. Ordinarily, however, the helical conductor is supported within a vacuum-tight glass envelope, the heat conducting limitations of which severely reduce the efficiency of heat exchange between helix and coolant.

It is therefore the principal object of this invention to provide, in a high power traveling-wave tube, a helix which may be cooled by the flow of a coolant in a manner such that the heat to be dissipated need not flow through an envelope.

Briefly, in accordance with this invention this and other objects are achieved by providing a combined helical conductor and envelope for vacuum purposes in which the helix is adjacent to the beam (heat source) on the inside and exposed directly to the coolant (heat sink) on the outside. A helix is provided which is filled and sealed between its turns by a dielectric material such as glass or a ceramic to thereby provide a vacuum tight helix serving as an envelope.

The novel features which are believed to be characteristic of this 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 several embodiments of the invention are 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 schematic view, partly in section, of a traveling-wave tube embodying, in accordance with the present invention, a combined helix and a vacuum envelope.

Fig. 2 is a sectional view of a portion of the slow-wave structure and envelope of Fig. 1.

Figs. 3 and 4 are sectional views of alternative embodiments of a portion of an envelope at one stage of its manufacture.

Fig. 5 is a sectional view of a portion of a combined helix and vacuum envelope in accordance with the present invention.

Referring now to the drawing and particularly to Fig. 1 in which the invention is embodied in a forward-wave amplifier as an example. Traveling-wave tube **10** is shown surrounded along most of its length by a solenoid **12**. At the left hand end of tube **10** an enlarged glass portion **14** is provided for housing an electron gun **16** which includes a cathode **18**, a focusing electrode **20**, and an accelerating anode **22**. A collector electrode **24** is disposed at the right hand end of tube **10** for intercepting the electron beam emitted by electron gun **16**. Disposed between electron gun **16** and collector electrode **24** and surrounded by solenoid **12** is a combined slow-wave structure and envelope **26**. A helix **28** which may be made of a metallic wire or ribbon is axially aligned contiguous to the path of the electron stream emitted by electron gun **16**. Interposed between the turns of helix **28** is a dielectric material **30** such as glass or ceramic which is bonded to the helix continuously along its length and which is sealed to glass housing **14** at its left extremity and to collector electrode **24** at its right extremity to provide a vacuum-tight envelope for the electron beam. Coupled in a conventional manner to the emitter end of helix **28** is an input transmission line **32**. In like manner an output transmission line **34** is coupled to the collector end of helix **28**.

Between solenoid **12** and helix **28** a cylindrical passage is provided for the flow of coolant which is pumped or blown by a suitable device indicated schematically by a pump **36**. Appropriate D. C. voltage sources necessary for the operation of tube **10** are shown schematically by **38** at the electron gun end of tube **10** and at **40** at the collector end and at **42** for the solenoid.

It is seen that the coolant forced by pump **36** passes directly over helix **28**. The electrical properties of the coolant inherently affect the propagation characteristic of helix **28** in that the dielectric properties of the coolant may change the velocity of propagation and the impedance of the helix while the loss characteristic of the coolant introduces loss to the wave propagating on the helix. However, it has been found that practically any gas is satisfactory and is in fact an improvement over the conventional glass envelope as regards its loss factor. Almost any liquid having mobility and heat transfer properties together with low dielectric coolant and loss is also satisfactory. For example, in the order of increasing dielectric constant and loss factor as given by the Von Hipple tables, heptane, carbon tetrachloride or tetrachloroethylene may be used very satisfactorily and all these liquids have considerably less loss than a conventional glass envelope.

Referring to Fig. 2 the structure and operation of helix **28** with interposed glass **30** is shown in more detail. The electron stream acting as a heat source is shown to pass contiguously to the helix on its inner surface while coolant as a heat sink is caused to flow contiguously to the outside surface of the helix in counter current heat exchange.

In Fig. 3 there is shown in section a portion of a ceramic or glass cylinder **43** which has been provided with a spiral groove **44** along its inner surface. Fig. 4 shows a similar cylinder **47** with a spiral groove **48** provided in its outer surface. The combined helix and glass envelope of this invention may be provided by threading either of these grooves **44** or **48** with helix **28**. The helix **28** may then be soldered in place or otherwise bonded to the glass or ceramic **43** or **47**. In the example shown in Fig. 3 the excess glass outside the helix is then ground away to form the finished vacuum-sealed helix **26** as shown in Fig. 5. Alternatively if the example of Fig. 4 is used the interior excess glass is ground away so that the electron beam may pass contiguous to helix **28** and provide again the structure as shown in Fig. 5.

An important advantage inherent in the slow-wave structure of the present invention is that the critical spacing or interstices between the turns of the helix is securely maintained by the interposed rigid dielectric.

A further method in which the structure of this invention may be provided would be to wind helix **28** upon a mandrel and then wind between its turns a helix of softened malleable glass having the same thickness as the wire or ribbon of helix **28** to thus eliminate the step of grinding away excess glass.

Still another method is to wind helix **28** upon a mandrel, shrink thereover a glass cylinder, and then grind away excess glass outside the helix so that coolant may be passed in direct contact with the helix over its outside surface.

In the operation of the tube of the present invention electron gun **16** emits a beam which is caused to pass as nearly as possible to the inner surface of helix **28** as the stream traverses the tube toward collector **24**. The electrons may pass as closely as desired to the helix because the coolant forced by pump **36** passes very efficiently in direct contact with the outside surface of helix **28** to thereby increase by a factor of more than 10 the heat transfer from helix to coolant.

There has thus been disclosed a combined helical slow-wave structure and vacuum envelope in which the electron stream of a high-power traveling-wave tube may

pass as closely as desired to the interior surfaces of the slow-wave structure while allowing a coolant to pass directly over the outside surface of the helix to thus greatly increase the efficiency and power dissipating property of a traveling-wave tube.

What is claimed is:

1. A traveling-wave tube comprising: means for projecting an electron beam along a predetermined path; a collector electrode for intercepting said beam; and a combined slow-wave structure and vacuum envelope disposed about said path, said slow-wave structure including at least one helical conductor directly exposed on its inside surface to said electron stream and directly exposed on its outside surface to a coolant, and dielectric material in the interstices between successive helical conductors and hermetically bonded to said conductors.

2. A traveling-wave tube comprising: means for projecting an electron beam along a predetermined path and a combined helical slow-wave structure and vacuum envelope consisting of a composite cylinder disposed about said path in axial alignment therewith for propagating electromagnetic waves therealong in energy exchange relation with said electron beam and comprising alternate axial segments of a helical dielectric ribbon and a helical metallic ribbon, said dielectric ribbon and said metallic ribbon being bonded together with the dielectric ribbon being interposed between successive turns of the metallic ribbon and joined hermetically thereto to provide a cylinder whose wall is vacuum tight and the outer surface of which consists alternately of said dielectric and metallic ribbons.

3. A traveling-wave tube comprising: means for projecting an electron beam along a predetermined path; a collector electrode for intercepting said beam; and a combined helical slow-wave structure and vacuum envelope disposed about said path including a helical dielectric ribbon and a helical metallic ribbon, said dielectric ribbon and said metallic ribbon having substantially equal radial thickness when assembled in a helix hermetically bonded together to provide a composite cylinder whose wall is vacuum tight, with the outer periphery of said helical metallic ribbon forming a part of the outside of the wall.

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