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TRAVELING WAVE TUBE

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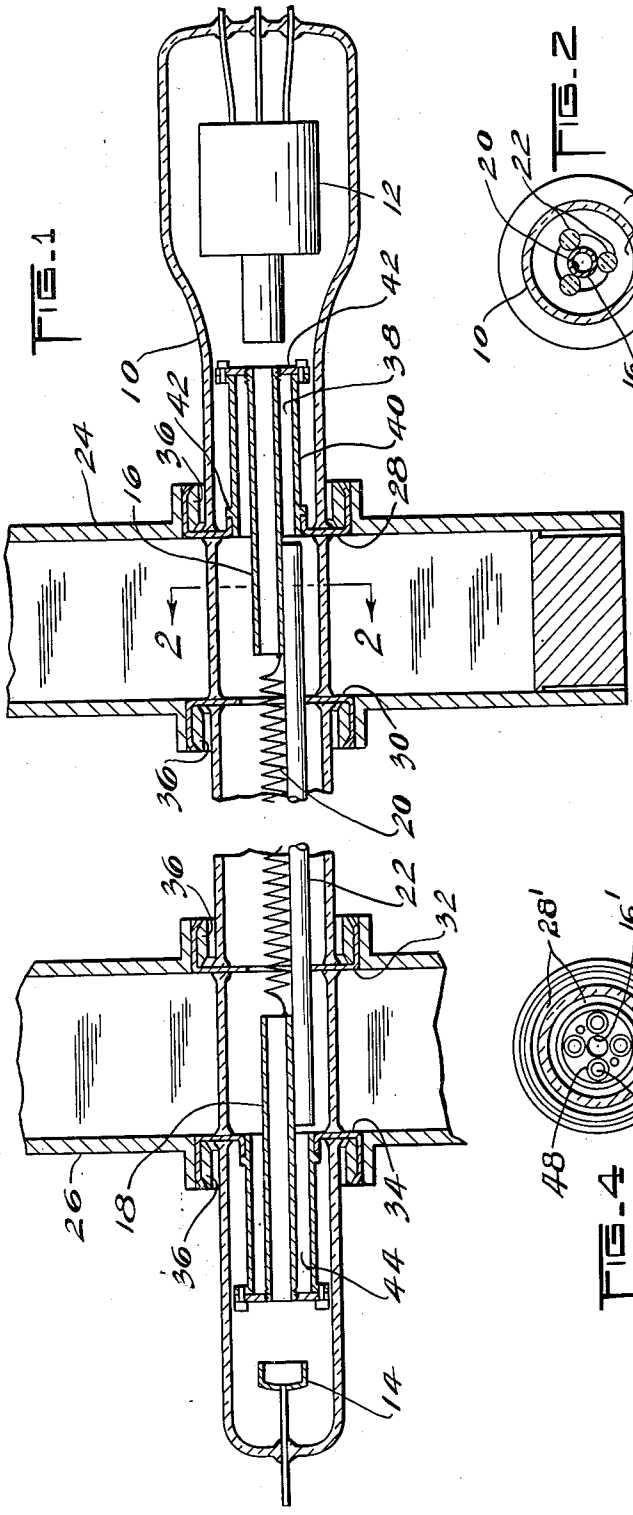


FIG. 1

FIG. 2

FIG. 4

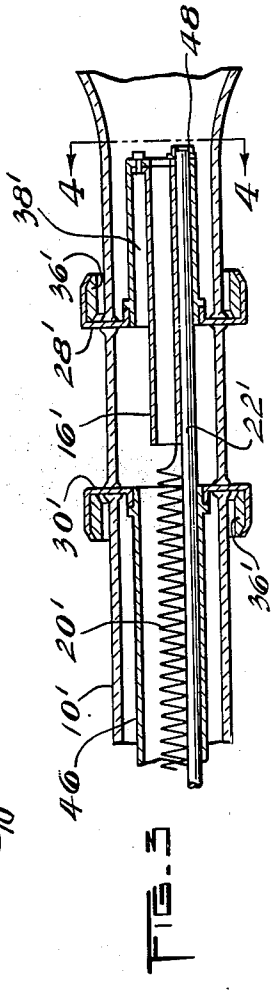


FIG. 3

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TRAVELING WAVE TUBE

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7 Claims. (Cl. 315—3)

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The present invention relates to traveling-wave tubes, a type of electronic amplifier. This type of tube ordinarily includes an electron gun at one extremity, an electron collector at the opposite extremity, signal input and output coupling devices or probes near each extremity, and a hollow transmission line between the probes. The transmission line is foreshortened, to be of greater effective length than the physical distance between the input and output probes, and is commonly in the form of a helix or it may include two or more helices. An envelope of glass or equivalent material encloses the several elements described. Low-loss rods of ceramic, quartz or like material space the hollow transmission line inward of the glass envelope to fix the position and maintain alignment of the transmission line, and to avoid thermal damage to the glass envelope due to heating of the helix, and to avoid attentuation in the usually soft and relatively lossy glass wall. An electron beam is directed longitudinally within the transmission line, and interacts with the fields along the line to yield amplified signal energy.

Wave guides are ordinarily used for coupling signals into and out of the traveling-wave tube, these wave guides being penetrated by the traveling-wave tube. The wave guides surround the tube in the regions of the input and output coupling devices. A choke is included near each probe for impedance matching, and to prevent stray coupling and loss of energy toward the ends of the traveling-wave tube. Because the tube envelope constitutes a sleeve of insulating material, the chokes used heretofore necessarily have been of the open-termination nominally half-wave variety. The traveling-wave tube is intrinsically a long and slender structure, and this length is extended by the half-wave chokes required.

With respect to this prior art construction, there is the possibility of circumferential moding about the holes in the wave guides that receive the traveling-wave tube. This possibility can be reduced, and higher operating frequencies attained, by decreasing the outer diameter of the tube envelope so as to decrease the required size of the hole in the wave guide. This expedient, of course, has its limitations.

Traveling-wave tubes of the foregoing variety are improved in several respects in accordance with this invention through the use of discs or rings sealed through the envelope wall. The inner edges of such rings are formed to receive the low-loss rods or like insulating support that carries the transmission line, thereby making unnecessary the otherwise close tolerance required of the straightness and of the inner diameter of the glass tubing used in forming the envelope of the conventional tube. Such ring, or disc as it is

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alternatively termed, can be used to advantage at any point along the tube where mechanical support is desired. However, it is of special value in the regions of the input and output coupling devices where pairs of disc terminals can be spaced apart a distance equal to a transverse dimension of the input and output wave guides, thereby extending the wave-guide walls into intimate relation with the probes. The holes through the several discs are no longer required to be large enough to admit the tube envelope, but can be made considerably smaller, and accordingly the possibility of circumferential moding is reduced. The disc terminal which penetrates the tube envelope enables the use of shorted nominally quarter-wave matching stubs within the tube envelope in place of the longer open half-wave stubs used with tubes of the prior-art construction.

The novel features of the invention are defined in the appended claims, and will be better appreciated from the following detailed disclosure of two illustrative embodiments in the accompanying drawings, in which:

Fig. 1 is a longitudinal cross-section of a traveling-wave tube embodying novel features of the invention, additionally including input and output wave guides;

Fig. 2 is a transverse sectional view along the line 2—2 of Fig. 1;

Fig. 3 is a fragmentary view of a traveling-wave tube like that of Fig. 1 in all respects except for the modified details illustrated; and

Fig. 4 is a transverse sectional view along the line 4—4 of Fig. 3.

Referring now to Fig. 1, a traveling-wave tube is shown having an enclosing envelope 10, conveniently of soft glass, an electron gun 12 at one extremity, and collector electrode 14 at the opposite extremity, this tube being about thirty times as long as its diameter. An input coupling device or probe 16 near gun 12 and an output coupling device or probe 18 near collector 14 are of hollow form and provide a path for the electron beam that is to travel lengthwise of the tube. A transmission line 20 is supported between probes 16 and 18 by three longitudinally disposed low-loss rods 22 (see Fig. 2), advantageously of hard glass. This transmission line, physically foreshortened in relation to its electrical length, here takes the form of a helical conductor, and is of such proportions that the signal induced at the input end will travel along the conductor at a speed which has a retarded component along the traveling-wave tube commensurate with the speed of the electrons in the beam. Low-loss rods 22 permit the use of a kind of glass throughout the tube which is of such nature that seals for emerging electrode leads can be readily formed. A magnetic coil (not shown) ordinarily encircles the

traveling-wave tube between the input and output probes for establishing an axial magnetic field that maintains focus of the electron beam in its transit from one end of the tube to the other. An input wave guide **24** operating in the TE_{01} mode is associated with probe **16** with the electric field along the probe, and an output wave guide **26** is similarly associated with output probe **18**.

The mechanics of amplification in the traveling-wave tube are understood generally, and are the same for the prior-art construction as in the present improved form of traveling-wave tube. Oscillatory energy is coupled from rectangular input wave guide **24** to probe **16** and input end of helix **20**. Because of interaction between the induced wave which then travels along the helical wire at roughly the speed of light and the electron beam which travels a straight line path along the tube axis and the axis of the helix at a much lower speed, the electrons in the electron beam become bunched, and energy of the bunched electron beam is in turn abstracted by succeeding portions of the helix which also accentuate the bunching of the electrons. The oscillatory energy which appears at the output end of helix **20** and output probe **18** is much greater than that at the input end, and is coupled into output wave guide **26**. Lumped attenuators (not shown) are provided at one or more points along the helix to suppress reflected waves.

Discs **28**, **30**, **32** and **34** are sealed through the wall of envelope **10** in alignment with the respective walls of wave guides **24** and **26**. Discs **30** and **32** are circularly apertured to provide a passage for helix **20**, and the circular aperture of each disc is notched at three points to receive three rods **22** snugly. Rods **22** are accurately positioned by means of the simple and easily formed metal discs **30** and **32** that are sealed through the tube wall, with their apertures centered about the tube axis and their rod-receiving recesses in alignment. Better accuracy at lower cost can be realized with this arrangement than in the prior-art construction where the inside wall of the glass tubing forming the envelope, closely controlled for diameter and straightness, is relied on to confine the low-loss rods against the helix.

A portion of each disc **28**, **30**, **32** and **35** outside envelope **10** is spun over a stiffening ring **36**, the discs here being formed of thin sheet-copper. In some instances, it is desirable to provide a disc centrally apertured as in Fig. 2 for mechanical support of the helix or like element at a point between the input and the output wave guides, and where no external electrical contact is required. The external portion of the disc and its ring **36** may be omitted in such case.

Discs **28** and **34** are formed alike, and, in the form of traveling-wave tube shown in Fig. 1 these discs act as mechanical supports and electrical contacts for the input and output coupling devices **16** and **18** respectively. They also enable the use of nominally quarter-wave chokes or matching stubs comparable to the open half-wave lines outside the tube envelope used with prior art traveling-wave tubes.

Probe or coupling device **16** is supported centrally within rods **22**, and this probe is extended axially toward the electron gun. It constitutes the inner conductor of coaxial choke **38**, the outer conductor **40** of which is joined to the probe by shorting ring **42**. The opposite open end of outer conductor **40** is fitted snugly into a cylindrical portion formed integrally with the internal part of disc terminal **28**, a shoulder **42** being formed externally on outer conductor **40** to limit its displacement down the traveling-wave tube to the position shown. Sealed-in disc **28** thus acts as a continuation of one wall of wave guide **24**, and, with shorted stub **38**, provides a matching impedance between the wave-guide and the probe, and effectively closes off any leakage of oscillatory energy toward the gun end of the tube.

Sealed-in disc **34** is formed similarly and supports another shorted quarter-wave stub **44** as well as output probe **18**. Helix **20** is joined to probes **16** and **18**, being tensioned between them and thus urges the externally shouldered quarter-wave coaxial lines endwise against the respective discs **28** and **34**. The diameter of the central apertures in discs **28** and **34** is so small that a relatively high operating frequency would have to be reached before raising the possibility of circumferential moding, as true also of discs **30** and **32**. This contrasts with the inherently larger holes in the wave-guides penetrated by the glass envelope of the prior art traveling-wave tube described. Discs **28** and **34** also limit the endwise displacement of rods **22**. It will thus be apparent that sealed-in discs **28**, **30**, **32** and **34** support the input and output probes and, via rods **22**, support the helix **20** as well. There is an evident advantage in substituting the accurately controllable metal discs as the spaced point-supports for the high-frequency electrodes rather than to rely on the straightness and accurate diameter of the inner bore of the glass tubing. In forming the seals, precaution must naturally be taken to assure axial alignment of the several discs, advantageously utilizing internal jigging and sealing procedures as in copending application, Serial No. 612,029, filed August 22, 1945, by Paul Haas.

Figs. 3 and 4 illustrate a modification of the traveling-wave tube shown in Fig. 1. Where applicable, primed numerals are used to designate parts corresponding to those of Fig. 1. Only input probe **16'** and terminals **23'** and **33'** for coupling to the input wave guide are shown, the output components being reversely symmetrical. Metal tube **46** is enclosed within envelope **10'** to form a shield about helix **20'**, such shield sometimes being considered necessary. Low-loss rods **22'**, preferably of a ceramic material in this instance, are confined against helix **20'** to support it within shield **46**, the shield being in turn supported at each end by one of the sealed-in discs, as **30'**. Rods **22'** extend into shorted matching stubs **38'** and are constrained against endwise displacement by eyelets at each end of each rod, only one **48** of which is shown in Fig. 3 gripping a rod **22'**. As shown in Fig. 4, four rods **22'** are used in this instance. Spacing is allowed to accommodate differences in thermal expansion of the several parts.

Rods **22'** support the input and output probes and the connecting helix **20'** and are in turn supported not by the inside surface of the glass tubing, but by discs sealed through the wall of the tube envelope. The discs constitute mechanical support; they extend the wave-guide walls thereby reducing the diameter of the necessary apertures; and the sealed-in discs enable use of short-circuited coaxial stubs of comparatively short axial dimension in substitution for the prior-art open half-wave stubs.

While the invention is shown as having particular application to the form of traveling-

wave tube employing a helical wire as the foreshortened transmission line for the traveling wave, several of the features of the invention will be found to have application to other forms of traveling-wave tubes. This, and other applications of the invention and varied detailed modifications will occur to those skilled in the art. Therefore, the appended claims should be allowed such broad interpretation as is consistent with the spirit and scope of the invention.

What is claimed is:

1. A traveling-wave tube comprising a generally tubular long and slender glass envelope, an electron gun at one extremity, an electron collector at the opposite extremity, a tubular input probe near said electron gun, a tubular output probe near said collector, a helical-wire transmission line between said probes, said probes and said transmission line providing a path for an electron beam from said gun to said collector, a plurality of low-loss rods in external engagement at spaced peripheral points with said probes and with said transmission line, a pair of discs sealed through said glass envelope and in contact with said rods near the extremities of said transmission line, said rings having formed portions receiving said rods and preventing peripheral displacement of the rods circumferentially about the helical-wire transmission line, short-circuited coaxial lines joined each to one of said probes and utilizing as its central conductor an extension of a respective probe, said short-circuited lines extending oppositely from said probes toward the extremities of the envelope, an additional pair of metal discs sealed through the glass envelope at the input ends of said shorted lines and in supporting relation thereto, the two metal discs associated with each of the respective probes being spaced apart to act as continuations of input and output wave guides.

2. An electron discharge device comprising an envelope, an electron gun for producing a beam of electrons, a pair of disc terminals sealed through the envelope transversely and apertured centrally, thus allowing penetration by the electrons, said discs providing externally available terminals, and a coaxial line within said tube short-circuited at one end and having the outer conductor of the opposite open end secured to one of said discs, the center conductor of said coaxial line being tubular and providing a patch for the electrons.

3. A traveling-wave tube comprising a glass envelope, means to project an electron beam longitudinally of said envelope, a pair of disc terminals sealed through said envelope and having externally available portions for connection to a wave guide, a probe within the tube between said discs, and a short-circuited coaxial line joined to said probe and to one of said discs at the open end of the line, the center conductor of said line being tubular to provide a path for the electron beam.

4. A traveling-wave tube comprising a long and slender generally tubular glass envelope having a pair of metal discs sealed through the envelope wall at an input end, an electron gun at said input end, an electron collector at the opposite end of said envelope, another pair of metal discs sealed through said envelope wall adjacent said collector, a pair of short-circuited quarter-wave coaxial chokes each carried by a respective one of the discs closest to said electron gun and said collector, the center conductor of said coaxial chokes being tubular and providing a path for an electron beam between said gun and said collector, and probes extending into the space between the input and the output pair of discs, said probes being electrically and mechanically connected to said center conductors.

5. A traveling-wave tube comprising a long and slender generally tubular glass envelope having an electron gun at one end and an electron collector at the opposite end, an input pair of disc terminals sealed through said envelope adjacent the electron gun, an output pair of disc terminals sealed through the envelope adjacent the collector end of said envelope, a pair of short-circuited coaxial lines each having its open end connected to a respective one of the disc terminals closest to said electron gun and to said collector, the center conductor of each coaxial line having a tubular extension into the regions between the input discs and the output discs, a helical-wire transmission line joined to the tubular extensions, and supporting means for said probes and said transmission line supported by those disc terminals opposite the quarter-wave lines, said supporting means including plural low-loss rods in lateral engagement with said probes and said helical-wire transmission line.

6. A traveling-wave tube comprising a generally tubular glass envelope, means for projecting an electron beam axially within said tube, wave transmission means including a helical conductor substantially coaxial with said tube, plural metal rings sealed through said envelope at axially spaced points, and low-loss insulating means confined radially between said rings and said helical conductor, said insulating means extending along the helical conductor and providing an aligning support therefor.

7. A traveling-wire tube comprising a tubular envelope, means for projecting an electron beam axially within said envelope, a helical wire within said envelope, plural substantially straight low-loss insulating rods about said helical wire, and plural discs spaced apart and sealed transversely through said envelope, said discs being in engagement with said rods and confining the helical wire substantially coaxially within the envelope, said discs having axially aligned notches confining the rods against peripheral displacement.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,064,469	Haeff	Dec. 15, 1936
2,153,728	Southworth	Apr. 11, 1939
2,367,295	Llewellyn	Jan. 16, 1945
2,400,753	Haeff	May 21, 1946
2,450,026	Tomlin	Sept. 28, 1948
2,488,906	Gardner	Nov. 22, 1949
2,521,760	Starr	Sept. 12, 1950

OTHER REFERENCES

Article by Kompfer, pp. 124–127, Proc. of I. R. E. and Waves and Electrons, vol. 35, No. 2, February 1947.

Article by J. R. Pierce, pp. 439–442, Bell Lab. Record, December 1946.