Nov. 28, 1961 J. J. CALDWELL, JR 3,011,085

TRAVELING WAVE TUBE

Filed Sept. 30, 1955 2 Sheets-Sheet 1

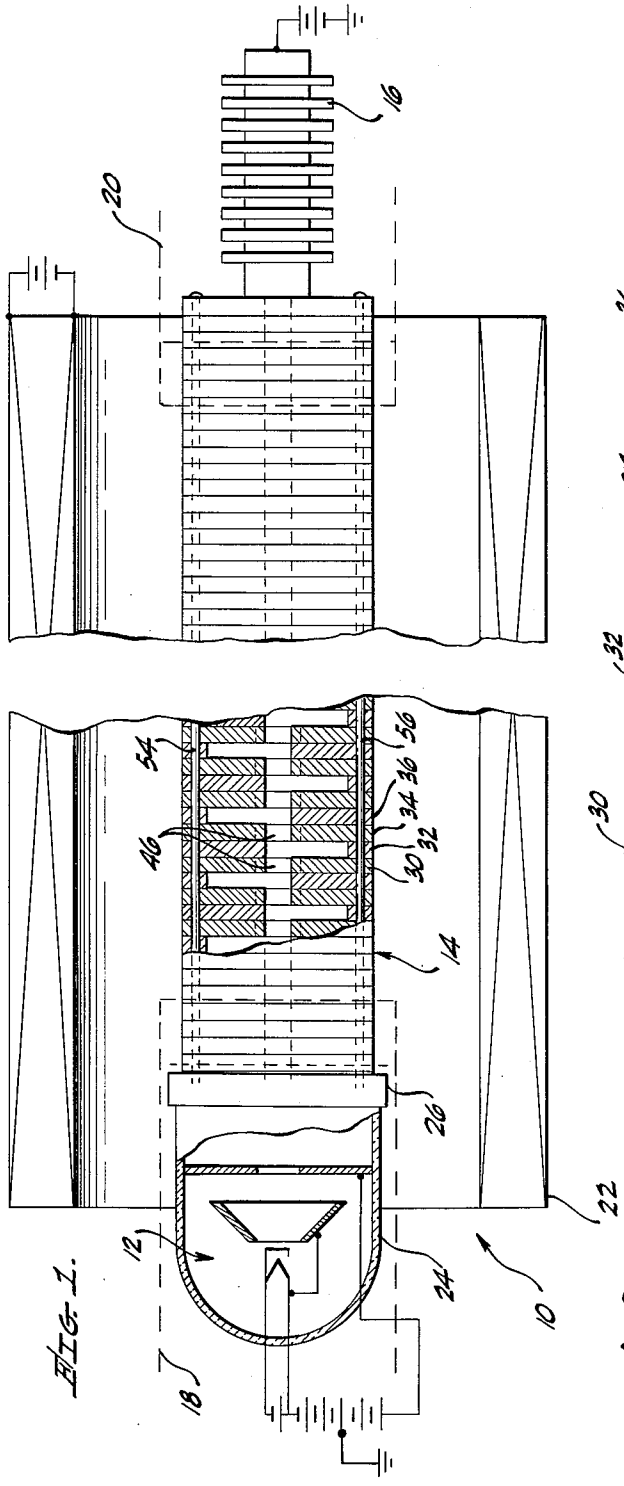

FIG. 1.

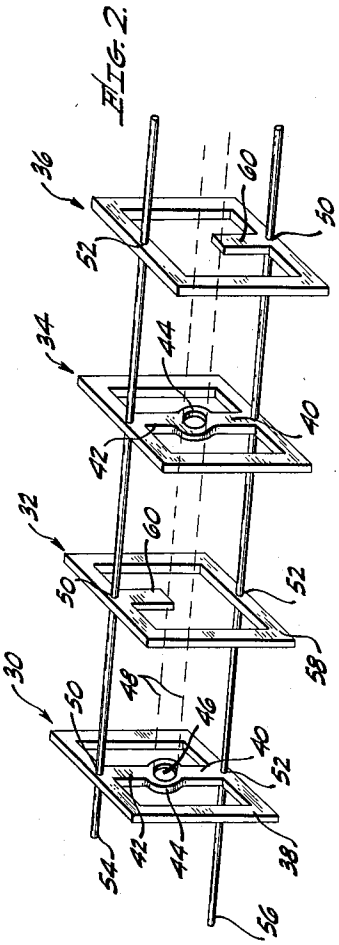

FIG. 2.

INVENTOR.
JOSEPH J. CALDWELL, JR.,
BY
Henry Heyman
ATTORNEY.

Nov. 28, 1961 J. J. CALDWELL, JR 3,011,085

TRAVELING WAVE TUBE

Filed Sept. 30, 1955 2 Sheets-Sheet 2

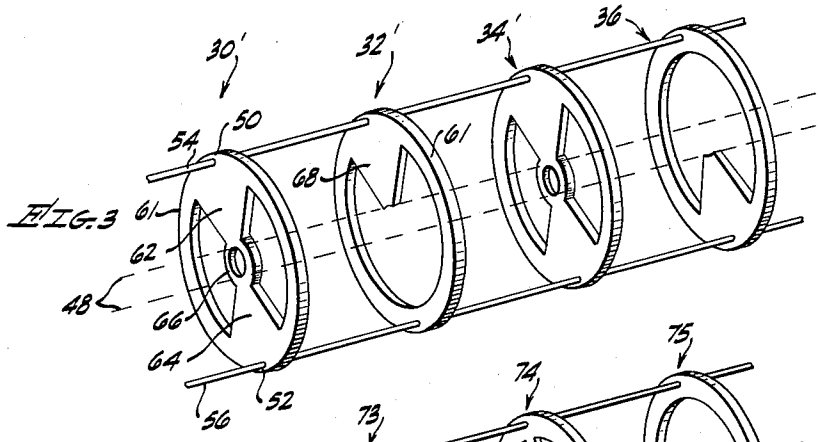

FIG. 3

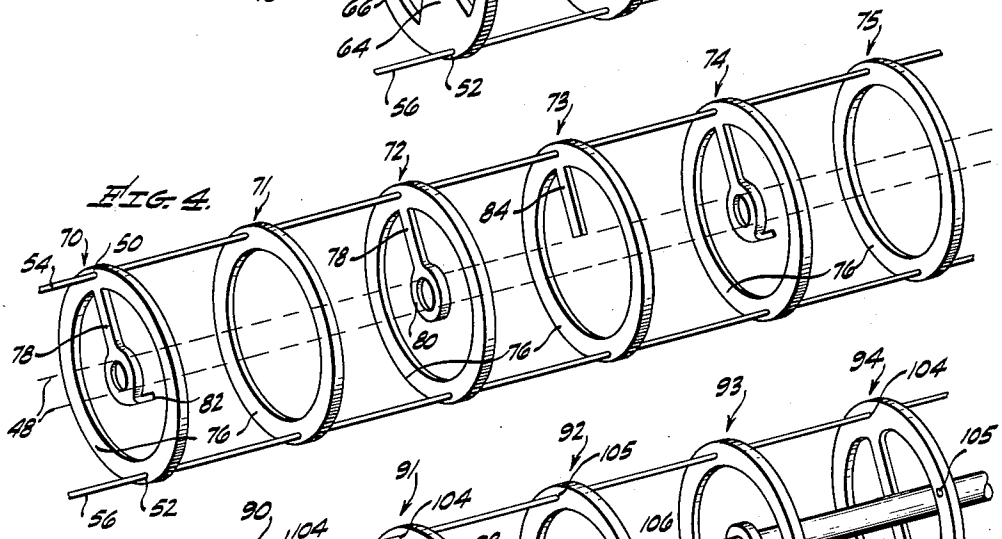

FIG. 4.

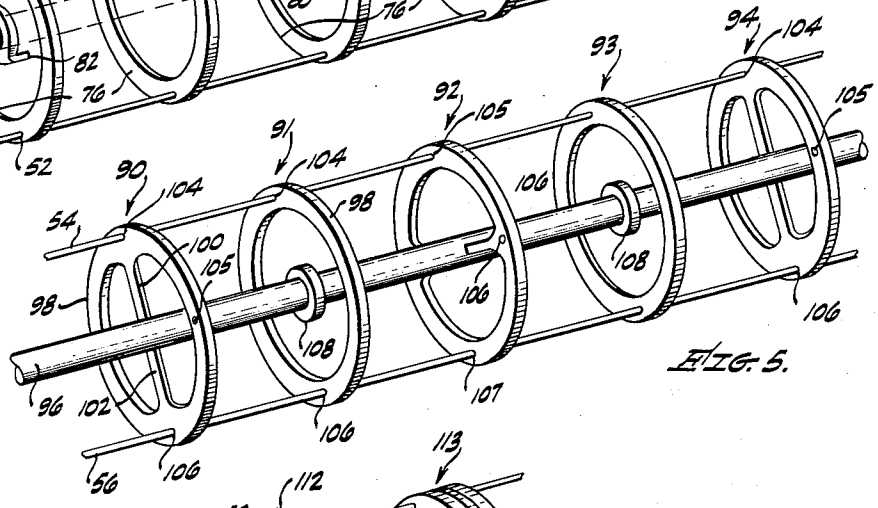

FIG. 5.

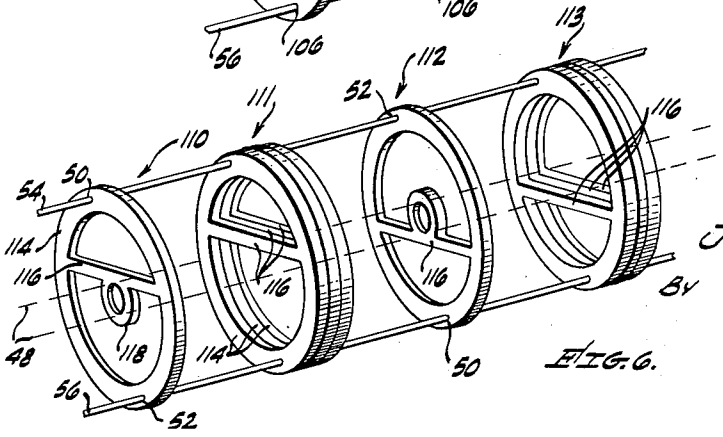

FIG. 6.

INVENTOR.
JOSEPH J. CALDWELL JR.,
BY
Henry Heyman
ATTORNEY.

United States Patent Office 3,011,085 Patented Nov. 28, 1961

3,011,085

TRAVELING WAVE TUBE

Joseph J. Caldwell, Jr., Palos Verdes Estates, Calif., assignor to Hughes Aircraft Company, Culver City, Calif., a corporation of Delaware

Filed Sept. 30, 1955, Ser. No. 537,646
3 Claims. (Cl. 315—3.5)

This invention relates to traveling-wave tubes and more particularly to an improved stub-loaded slow-wave structure for traveling-wave tubes and its method of manufacture.

Traveling-wave tubes generally comprise an evacuated envelope, a slow-wave structure disposed within the envelope for propagating electromagnetic waves at a velocity substantially less than the velocity of light, and an electron gun disposed at one end of the envelope for projecting an electron stream in energy exchange relationship with the traveling waves propagated along the slow-wave structure.

Heretofore the slow-wave structure adapted for propagating the traveling electromagnetic waves has been manufactured by precision milling of slots in a cylindrical metallic tube, or, in some applications, by the actual winding of a wire helix on a mandrel or by various other precision machining techniques which required great skill, much time and elaborate equipment in order to insure the precision required in this art. Further, in accordance with past techniques it was very difficult to change the type of metal along the length of the slow-wave structure. The prior art techniques have also required that after construction of the slow-wave structure, it be enclosed in an evacuated envelope as a separate and special step. This gave rise to many problems of supporting the slow-wave structure within the envelope while maintaining critical distances between the slow-wave structure and the envelope while aligning it with the electron stream.

It is therefore an object of the present invention to provide a slow-wave structure which is not subject to the above discussed disadvantages of prior art slow-wave structures.

It is another object of the present invention to provide a method of manufacturing a slow-wave structure which does not require the precision techniques of the prior art.

It is a further object to provide a slow-wave structure which has very accurate dimensions and which is exceedingly inexpensive.

It is yet another object to provide such a slow-wave structure which may be composed of various metals along its length.

It is still another object to provide a slow-wave structure which forms an envelope adapted to be evacuated without the necessity of transversely supporting the slow-wave structure within a separate envelope.

In accordance with the present invention these objects are achieved by providing relatively thin metallic stampings or discs having the shape appropriate for the desired cross-section of a slow-wave structure including the outer envelope and permitting passage of the electron beam. The stampings are then "stacked" on aligning rods or the like and brazed or otherwise bonded to form a gas-tight, elongated slow-wave structure.

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 drawings in which several embodiments of the invention are illustrated by way of example. It is to be expressly understood however, that the drawings are for the

purpose of illustration and description only and are not intended as a definition of the limits of the invention.

In the drawing:

FIG. 1 is an elevational view, partly in section, of a traveling-wave tube embodying a slow-wave structure in accordance with the present invention; and

FIGS. 2 to 6 are exploded views in perspective of portions of various embodiments of slow-wave structures according to the present invention.

Referring now to FIG. 1 of the drawings, a traveling wave tube 10 is shown which includes an electron gun 12 for projecting an electron beam along the traveling wave tube along and within a slow-wave structure 14. A collector electrode 16 is provided for intercepting the electron stream. An input waveguide 18 shown in dotted lines couples microwave energy to slow-wave structure 14 and output waveguide 20 couples microwave energy from slow-wave structure 14. The structure of the type of coupling to the slow-wave structure which may be utilized here is disclosed and claimed in the co-pending application by Thomas E. Everhart, Serial No. 537,744, filed concurrently herewith and assigned to the assignee of the present application, now U.S. Patent No. 2,936,395, issued May 10, 1960.

Substantially surrounding tube 10 is a solenoid 22 for confining, constraining, and focusing the electron stream along a path between gun 12 and collector 16 within slow-wave structure 14. A glass end portion 24 encloses gun 12 and is secured by means of a Kovar seal 26 to slow-wave structure 14, the structure of which in accordance with this invention, may include its own gas-tight envelope. Appropriate operating voltage sources are schematically shown connected to the electrodes of gun 12 and to collector electrode 16.

The slow-wave structure 14 includes a plurality of metallic stampings or discs 30, 32, 34 and 36 which are more clearly shown in the exploded perspective view of FIG. 2. Stamping 30 includes an outer quadrangular strip 38 which supports loading stubs 40 and 42. Disposed within strip 38 and supported by loading stubs 40 and 42 is an inner ring 44. An aperture 46 in ring 44 is aligned with like apertures in identical stampings as indicated by dotted lines 48 to allow passage of the electron stream from electron gun 12. Aligning holes 50 and 52 provided on opposite sides of the outer strip of each stamping are adapted to receive aligning rods 54 and 56 to facilitate accurate stacking of the plurality of stampings.

Stamping 32 likewise includes an outer quadrangular strip 58 but which supports only one loading stub 60 whose length is just sufficient to approach dotted lines 48 without extending into the electron stream. Again aligning holes 50 and 52 are adapted to receive aligning rods 54 and 56 respectively to facilitate stacking.

The shape of stamping 34 is identical to that of 30, and in like manner stamping 36 has a shape identical to that of stamping 32 except that it is rotated through 180° about the electron stream so that aperture 50 receives aligning rod 56 and aperture 52 receives aligning rod 54.

FIG. 2 shows only one set of stampings while a plurality of such sets stacked adjacent to each other is required in the fabrication of slow-wave structure 14. In manufacturing slow-wave structure 14 a plurality of the stampings as shown in FIG. 2 is assembled along aligning rods 54 and 56 to form a slow-wave structure of the desired length. Then while the assembly is longitudinally clamped or compressed, the entire structure may be heated and brazed together to form a single air-tight slow-wave structure. For the brazing operation the stampings may be prepared by plating each with a brazing alloy or by making very thin stampings of brazing alloy and interposing these between the stampings of the slow-

wave structure during assembly. Alternatively, the stampings may be prepared by covering them with a brazing metal in powdered form in a suitable binder which will melt away during the brazing process.

With reference to FIGS. 1 and 2, the characteristic of the slow-wave structure may be visualized readily. Stub **42** of stamping **30**, stub **60** of stamping **32** and stub **42** of stamping **34** together form one loading stub. Stubs **40** and **60** of stampings **34** and **36**, respectively, begin the next loading stub. Microwave energy travels to the right through the first of these composite loading stubs, **42**, **60**, **42**, splits at ring **44** of stamping **34**—half the energy going clockwise and half going counter-clockwise, recombines and travels on through the next loading stub **40**, **60**, **40** and so on to the right along slow-wave structure **14**.

As suggested before, it may be desirable to change the metallic composition along the length of slow-wave structure **14**. For example, while most of the stampings would normally be of molybdenum or copper, a built-in attenuator for damping undesired oscillation may be provided by inserting one or more stampings of non-magnetic stainless steel. Stainless steel might be chosen because of its lower conductivity and because it would not disturb the longitudinal magnetic field produced by solenoid **22**. It may also be desirable to change the thickness of the stampings along the length of slow-wave structure **14**, because it is well known that the operating parameters of the traveling wave tube depend upon the pitch of the slow-wave structure. In accordance with the present invention a variable pitch slow-wave structure may be easily fabricated by merely changing the thickness of the stamping stock, while prior art techniques require complicated and expensive variations in the milling or winding techniques as the slow-wave structure is manufactured. Clearly, a slow-wave structure fabricated in accordance with the invention is extremely versatile and inexpensive thus providing a valuable aid, especially in laboratory instrumentation and experimentation.

The structure of FIG. 3 represents a generalized slow-wave structure of the type shown in FIGS. 1 and 2. One set of the stampings utilized to make up this version is illustrated in FIG. 3 where stampings **30'**, **32'**, **34'** and **36'** are disposed along aligning rods **54** and **56**. In accordance with this embodiment stamping **30'** has an outer circular ring **61** which supports two loading stubs **62** and **64** diametrically opposed and which support, in turn, an inner ring **66**. The aperture of ring **66** is of diameter such that ring **66** contiguously surrounds the electron beam represented by the dotted lines **48**. The shape of loading stubs **62** and **64** is here generalized by making them broader at their base along outer ring **61** in a radial sector shape. Stamping **32'** also includes the outer ring **61** but which supports only one loading stub **68** which generally has the same shape as do stubs **62** and **64** but which extends to the electron stream path represented by dotted lines **48**. Stamping **34'** is identical to stamping **30'** and stamping **36'** is identical to stamping **32'** except that it is inverted or rotated through 180° as is stamping **36** with respect to stamping **32**.

FIG. 4 represents a single-loaded version of the slow-wave structure according to this invention. FIG. 1, FIG. 2 and FIG. 3 each show doubled-loaded versions, that is, every other loading stub is on the opposite side of the electron stream. In the embodiment of FIG. 4 however, all the loading stubs are on the same side of the electron stream. Stampings **70**, **71**, **72**, **73**, **74** and **75** are shown exploded along aligning rods **54** and **56**. Outer circular rings **76** are identical in each of the stampings **70** through **75**. Ring **76** of stamping **70** supports the single-loaded stub **78** which in turn supports an inner ring **80**. Dotted lines **48** again represent the electron stream path which is contiguously surrounded by ring **80**. Outer ring **76** of stamping **71** supports no loading stubs and is merely a spacing member. Outer ring **76** of stamping **72**, similarly to stamping **70**, supports a single-loaded stub which supports an inner ring **80**. In order to couple traveling wave energy to the right from stamping **70** to stamping **72** a longitudinal stub **82** extending along the electron stream is provided on stamping **70** which is supported by and may be integral with ring **80** opposite loading stub **78**. Longitudinal stub **82** is just long enough to make contact with ring **80** of stamping **72** when the stampings are adjacent to each other. Stamping **73** again comprises an outer ring **76** which supports a single loading stub **84** which extends to the electron stream path. Stamping **74** is identical to stamping **70** and thus when assembled the loading stubs **78**, **84**, **78** of stampings **72**, **73**, and **74** form one composite loading stub through which traveling wave energy travels to the right. All the loading stubs in this embodiment are in line as assured by aligning rods **54** and **56** passing through appropriate aligning holes **50** and **52** in each stamping.

Referring to FIG. 5 there is shown a bifilar slow-wave structure in accordance with this invention. Previous figures show unifilar embodiments, that is the previous slow-wave structures are electrically equivalent to a contrawound helix wound with one conductor going clockwise and one conductor going counter-clockwise along the length of the tube while the embodiment of FIG. 5 is electrically equivalent to two conductors wound in each rotational direction, that is, the structure is equivalent to four conductors. A set of stampings **90**, **91**, **92**, **93** and **94** is again shown exploded along aligning rods **54** and **56**. In this embodiment a temporary central aligning rod **96** is utilized for reasons which will become apparent below. Stamping **90** includes an outer ring **98** which supports two diametrically opposite loading stubs **100** and **102** which extend to the surfaces of aligning rod **96** which for purposes of description represents the electron stream as did dotted lines **48** in the previous figures. Outer ring **98** is provided with four aligning apertures **104**, **105**, **106** and **107** (aperture **107** not shown). Aligning rods **54** and **56** pass through aperatures **104** and **106**. Stamping **91** comprises two separate rings, outer ring **98** and inner ring **108** which are not connected. Aligning holes **104** and **106** receive aligning rods **54** and **56** respectively. Inner ring **108** is temporarily supported by aligning rod **96** and permanently supported by the loading stubs of stampings **90** and **92** when the slow-wave structure is assembled. Stamping **92** is identical to stamping **90** except that it is rotated through 90° so that aligning apertures **105** and **107** receive aligning rods **54** and **56** respectively. Stamping **93** is identical to stamping **91** and stamping **94** is identical to stamping **90** but is rotated through 90° with respect to stamping **92** so that apertures **104** and **106** receive aligning rods **54** and **56**. When this structure is assembled as noted before each inner ring **108** is supported at four points by two sets of loading stubs such as **100**, **102**. Aligning rod **96** may be of a material such as stainless steel which does not braze so that it may be removed after the brazing operation to clear the passage-way for the electron stream.

FIG. 6 illustrates a further example of the invention in which loading planes are provided instead of loading stubs in a unifilar embodiment. Such a configuration may be valuable in experimentation or instrumentation for attenuating certain waveguide modes of propagation outside of the helix. Again a circular outer shape is provided by a set of stampings **110**, **111**, **112**, and **113**. Stamping **110** includes an outer ring **114** which supports a transverse loading bar **116** forming a chord and which in turn supports an inner ring **118**. Again aligning rods **54** and **56** pass respectively through aligning apertures **50** and **52** disposed in outer ring **117** diametrically opposite each other and symmetrically with respect to bar **116**. Stampings **111** are identical and may be any number, one or more, depending on the length of the loading plane desired. Each of stampings **111** includes an outer ring **114** each of which supports a transverse loading bar **116** disposed parallel to each other. Again dotted lines **48** rep-

resent the electron stream path which passes through inner ring **113** and contiguous to the loading plane fabricated of the loading bars **116** of stamping **110** and of stampings **111**. Stamping **112** is identical to stamping **110** except that it is inverted so that aligning apertures **52** and **50** receive aligning rods **54** and **56** respectively. Stampings **113** are identical to stampings **111** except that they also are inverted with respect to each other so that their loading bars **116** form a loading plane on the side of the electron stream opposite that of the loading plane formed by the bars of stampings **110** and **111**.

There have thus been disclosed several embodiments of a slow-wave structure which are exceedingly simple and inexpensive to fabricate. Obviously the various stampings required may be produced on a mass production basis by unskilled labor whereas the slow-wave structures of the past were individually manufactured by precision operation of milling or winding machines. The advantages stemming from not needing an outer glass envelope are many but the chief ones are that the precision aligning required when a slow-wave structure is supported within the glass envelope are eliminated and of course, the fragile glass envelope itself is not needed thereby making the structure considerably more rugged. A great advantage of the present invention to be stressed is the unusual versatility provided by fabricating a slow-wave structure with stampings that may be of varying thicknesses, several may be included together to form one thicker stamping or the material of the stamping itself may be changed as before described.

What is claimed is:

1. A traveling-wave tube including a laminated slow-wave structure comprising a plurality of three groups of laminations stacked along the axis of said tube and each having a continuous peripheral conductive portion defining a central region therewithin, individual laminations of the first of said groups having a conductive portion projecting inwardly to a predetermined radius from said peripheral conductive portion in a predetermined direction, individual laminations of the second of said groups having a conductive portion projecting inwardly to said predetermined radius from said peripheral conductive portion in the direction opposite to said predetermined direction, individual laminations of the third of said groups having a conductive annular member centrally disposed in said central region and having an inner radius equal to that of said predetermined radius, said laminations of said third group further including conductive portions extending from said peripheral conductive portion to said annular conductive portion in both said directions, the individual laminations of said first and second groups being alternately disposed along said axis in planes perpendicular thereto with ones of said laminations of said third group being interposed therebetween for spacing adjacent ones of said laminations of said first and second groups and to provide a stub loaded, circuitous path for electromagnetic wave energy propagating along said slow-wave structure in the direction of said axis.

2. In a traveling wave tube which includes electron beam producing means for projecting a stream of electrons along a predetermined path in energy exchange relationship with traveling microwaves propagating at less than the speed of light, a laminated slow-wave structure for propagating said traveling microwaves comprising: a set of first stampings, each having an outer ring and in inner ring, said inner ring being adapted to contiguously surround the electron stream and being secured to said outer ring by a pair of loading stubs disposed symmetrically opposite each other between said inner and outer rings; a set of second metallic stampings each having an outer ring of substantially the dimensions of those of said outer ring of said first stamping, a loading stub supported by said outer ring of said second stamping and extending to a point adjacent the electron stream, alternating ones of said second stampings being inverted with respect to each other, and the slow-wave structure being bonded together in a manner such that said outer rings form an air-tight envelope for the slow-wave structure.

3. The structure according to claim 2 in which said loading stubs have the shape of radial sectors.

References Cited in the file of this patent

UNITED STATES PATENTS

2,458,802	Spencer	Jan. 11, 1949
2,643,353	Dewey	June 23, 1953
2,653,270	Kompfner	Sept. 22, 1953
2,683,238	Millman	July 6, 1954
2,794,146	Warnecke et al.	May 28, 1957
2,800,604	Beaver	July 23, 1957
2,801,361	Pierce	July 30, 1957
2,806,973	McEwan et al.	Sept. 17, 1957
2,817,037	Peter	Dec. 17, 1957
2,837,696	La Rue	June 3, 1958

FOREIGN PATENTS

699,631	Great Britain	Nov. 11, 1953