

April 30, 1957

J. A. MORTON
TRAVELING WAVE TUBE

2,790,926

Filed Jan. 27, 1951

2 Sheets-Sheet 1

FIG. 1

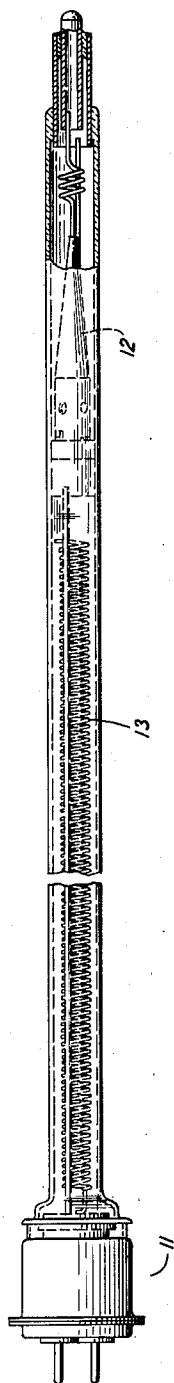


FIG. 3

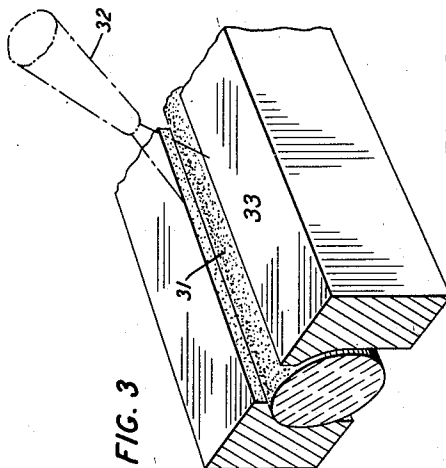


FIG. 4B

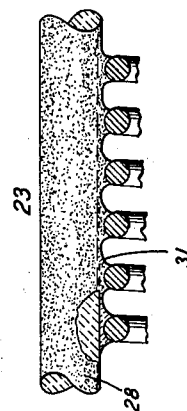


FIG. 4A

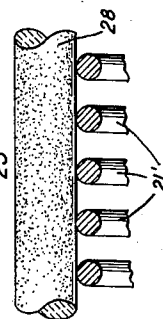
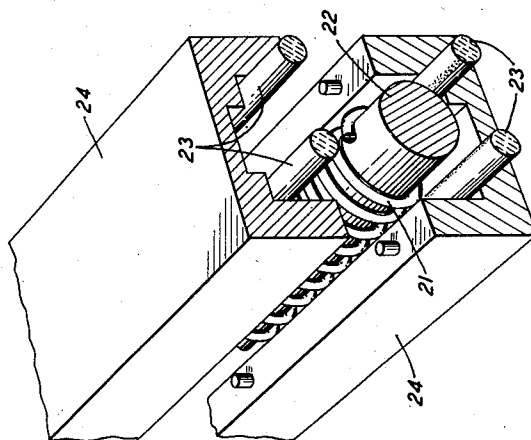


FIG. 2



INVENTOR
J. A. MORTON
BY *J. A. Morton*
ATTORNEY

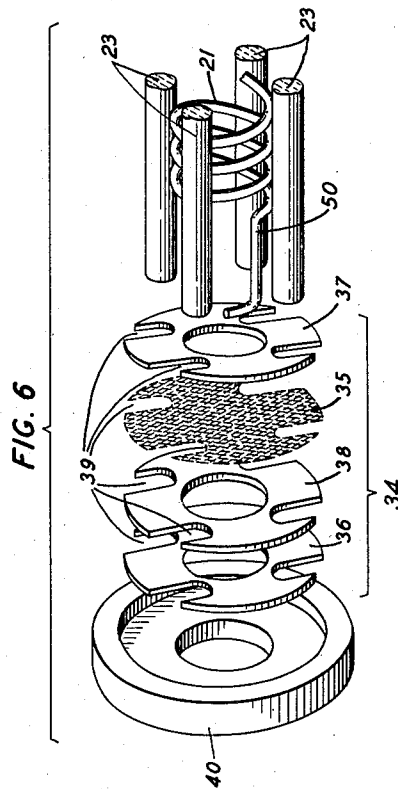
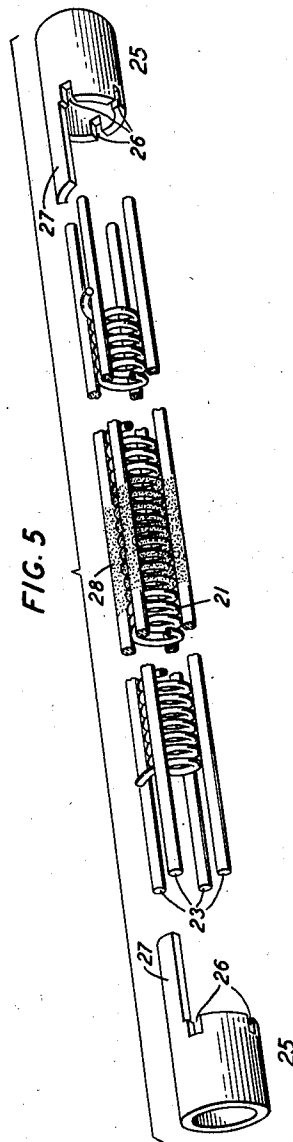
April 30, 1957

J. A. MORTON
TRAVELING WAVE TUBE

2,790,926

Filed Jan. 27, 1951

2 Sheets-Sheet 2



INVENTOR
J. A. MORTON
BY *J. A. Morton*
ATTORNEY

1

2,790,926

TRAVELING WAVE TUBE

Jack A. Morton, Neshanic Station, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application January 27, 1951, Serial No. 208,204

5 Claims. (Cl. 315—3.5)

This invention relates to helix structures and methods of manufacturing such structures and more particularly to helical transmission paths in high frequency space discharge devices of the type wherein a stream of electrons is projected along a portion of wave transmission path several wavelengths long, such that the electron stream may interact with the electric field of a high frequency wave transmitted along said path.

An object of this invention is to obtain a mechanically rigid helix.

A more specific object is to produce a uniform and mechanically rigid helical transmission line for a device of the type described above.

Another object is to reduce the noise inherent in such a device.

Another object is to produce an externally supported helical transmission line which will be free from relative movement of the helix and supporting means.

A further object is to insure that the pitch of the helix will be accurately maintained throughout its useful life.

Still another object is to produce an externally supported helical transmission path having an intermediate portion of high attenuation.

It is also an object to rigidly bind a helical transmission path both to external supporting means and to means to couple said path to an external circuit.

In devices of the type described above, which are now known as traveling wave tubes, it is well known that the phase velocity of the high frequency wave must be approximately equal to the average velocity of the electron stream in order that there will be an appreciable energy transfer. The velocity of the high frequency wave in air will be on the order of the speed of light, while the velocity of the electrons emitted by an electron gun having a beam voltage of about 1500 volts will be on the order of $\frac{1}{13}$ the speed of light.

In traveling wave tubes of the type described in Patent 2,602,148, issued July 1, 1952 of J. R. Pierce; synchronous velocities are approximated by causing the high frequency, or traveling waves, to follow a helical transmission path of the proper pitch while the trajectory of the electron stream is a path adjacent and parallel to the longitudinal axis of the helical path. A series of cylindrical support rods of any suitable insulator material which will not introduce excessive loss or capacitance to the helix are used to position the helix in the glass envelope in order to facilitate projection of the electron stream along the length of the coil without great loss of electrons to the coil conductor.

In traveling wave tubes, it has been necessary to make special provision for preventing self-sustaining oscillation which may result from waves reflected from the output section due to an improper impedance match of the helix to the output section. One method for preventing reflected waves has been to match the helical transmission line to the output by means of a lumped resistor as disclosed in United States Patent 2,300,052 to N. E.

2

Lindenblad. Another method, for example, applies a coating of high loss conductive material, such as aquadag, over the center portion of the helical coil support rod to attenuate any reflected waves. The effective amplifying length of the helix will of course be reduced since there will be practically no interaction in the region of the loss material. It is therefore expedient to confine this region to as small a portion of the rod length as possible. In short, high loss per unit length of loss material is desirable. In addition to attenuating reflected waves, this coating of loss material over the center portion of the support rod also promotes isolation of the input and output sections of the amplifier and therefore tends to limit disturbances due to reflection therebetween.

It has been found that a possible source of noise in tubes of this type is the variable pressure and hence variable contact resistance and capacitance between the loss coated support rods and the helix. The present invention reduces such noise by reducing variations in contact pressure due to variations in diameter and straightness of the rod, unequal coefficient of expansion, and physical movement of the helix relative to the support rod.

For maximum gain, the pitch of the helix must be chosen so that the field intensity vectors from wire to wire down the tubes will add in phase as the wave progresses down the helical path. It is therefore necessary not only to wind the helix with the proper pitch but also to minimize the possibility of pitch variation after the winding process. These variations are also minimized by the technique of the present invention so that the maximum attainable gain may be maintained for the life of the tube.

In accordance with the specific embodiment of the present invention hereinafter described in detail, a unitary helix and support rod assembly are constructed with high mechanical rigidity and uniformity. The helix is wound on a mandrel and the support rods are glazed to the helix. The rods are glazed to the helix before the mandrel is removed so that the pitch of the helix will be maintained during the glazing process. After the mandrel is removed, loss material for attenuating reflected waves is applied to the extent desired along the center portion of the entire assembly. Wave-guide couplers and/or a collimating grid may be incorporated in the unitary assembly if desired by also glazing them to the support rods.

The invention itself together with further objects and advantages thereof may be better understood by reference to the following detailed description in connection with the drawings, in which:

Fig. 1 is a pictorial representation of a device of the type to which the methods of the invention may be applied;

Figs. 2 and 3 illustrate steps in the fabrication of a unitary helix;

Figs. 4A and 4B compare results obtained by use of the methods of the present invention with those of prior art practice;

Fig. 5 is a perspective view, exploded in part, of a unitary helix assembly adapted for use in a traveling wave tube; and

Fig. 6 is a view similar to that of Fig. 5 of a portion of a unitary helix assembly adapted for use in a hybrid traveling wave tube.

Referring now to Fig. 1, a hybrid tube such as is more fully disclosed in my application Serial No. 208,203, filed January 27, 1951, comprises a source of electrons 11, such as an electron gun, and a collector 12 which cause a stream of electrons to be propagated along a path adjacent and parallel to the longitudinal axis of a helical

3

transmission line 13. In the embodiment of Fig. 1, signal waves to be amplified are caused to modulate the stream of electrons by a control grid at the electron stream source. The amplified signal is taken from the end of the helix remote from the electron source 11 by wave-guide means (not shown) excited by the helix. The present invention, however, is equally applicable to devices of the type disclosed in the aforementioned Pierce application wherein the signal waves are launched down the helix by wave-guide means similar to the manner in which the amplified waves are taken from the helix at its remote end as just described. And, since the present invention is concerned with the construction of a unitary helix assembly, it will also be apparent that such devices may be employed as amplifiers, modulators or oscillators without departing from the scope and spirit of the invention.

Referring now to Fig. 2, a helix 21 is first accurately wound with the proper prescribed pitch on a mandrel 22 which may be collapsible so as to facilitate later removal. The mandrel should be sufficiently long so that it will extend beyond the helix at either end for reasons which will hereinafter become apparent.

The helix wire may be steel or any suitable conducting material; molybdenum has been found to be quite satisfactory. It is desirable to employ a mandrel of the same material as the coil so that later heat treatment, while the coil is still on the mandrel, will not distort the pitch of the helix due to unequal coefficients of expansion. For purposes of illustration, the assembly will be described as comprising a helix and a mandrel both of molybdenum. Following the winding process, the helix may be normalized in any well-known manner, such as by heat treating in a non-oxidizing atmosphere at a temperature sufficient to relieve the stresses introduced during the winding process.

The cylindrical support rods 23 for the helix 21 may be of ceramic material, preferably one with low dielectric loss. This material should also have approximately the same coefficient of expansion as the helix in order to preserve the helix pitch, both during subsequent firing and also after final assembly. Zircon, a compound containing zirconium oxide, has been found to satisfy these requirements when used in combination with a molybdenum helix. These rods should also have relatively uniform diameters and straight sides although these dimensional requirements are not as rigid as if the rods were to be held in contact with the helix merely by the pressure of a glass envelope.

The glaze material should be such as to match the expansion coefficient of the helix and the rods. And, as well as the helix and the rods, it must also be capable of withstanding thermal stresses which will result from the fabrication process about to be described. A glass-like material consisting of approximately 6.3 percent Li_2O , 5.9 percent CaO , 16.5 percent BaO , 21.4 percent Al_2O_3 , 50.4 percent SiO_2 has been found satisfactory in combination with a molybdenum helix and zircon support rods. And, as most glazing materials, it has the property of a good insulator, an important property as will hereinafter become apparent.

To insure a uniform glaze coating on the rods, all but a portion of the circumference is masked as shown in Fig. 3. The glaze 31, in powdered form, is mixed with sufficient alcohol so that it may be sprayed upon the exposed longitudinal edge of the rods to uniform thickness by controlling the pressure and distance of the spray gun 32 from the rods. A thin knife blade may be guided along the surface of the mask 33 to slice the glaze to a uniform thickness.

The support rods 23 are then placed in position, symmetrically spaced about the circumference of the helix 21, by means of a jig 24 as shown in Fig. 2. The rods are, of course, oriented so that the edge bearing the glaze material will come into contact with the helix.

4

The rods 23 in the upper half of the jig 24 may be held in place in the jig during assembly by a small amount of amyl acetate dabbed along the rods. This substance will evaporate at a relatively low temperature during subsequent firing.

In tubes as disclosed in the aforementioned Pierce application, the signal waves may be launched down the helix at its input, or taken from the helix at its output, or both, by means of metallic couplers 25 such as shown in Fig. 5. These couplers, which would also be of molybdenum in the embodiment being described, may also be glazed to the support rods 23 to aid in obtaining a mechanically rigid helix assembly. Before the jig 24 is closed, glaze material is applied to the ends of the support rods 23 which are, of course, cut to the proper length. The couplers 25, if two are desired, are fitted over the aforementioned extended ends of the mandrel 22 and are brought into position relative to the helix 21 and rods 23 so that the rods are firmly sealed in the inserts 26 provided in the couplers 25. The helix 21 may then be welded at either end to the antenna portion 27 of each coupler.

The halves of the jig 24 are now securely joined and the entire assembly placed in a hydrogen furnace. The assembly is fired so that the glaze material will flow and is controlled so that undue thermal stresses will not develop. In the specific embodiment being described, the temperature is raised gradually over a fifteen minute period to 1240°C . and there maintained for approximately five minutes. The assembly is then removed from the furnace and cooled. Cooling is also preferably controlled, being retarded so as to prevent thermal stresses, particularly in the rods and glaze. The jig and mandrel may then be removed. The helix and support rods and coupler, if any, are now a mechanically rigid assembly.

The loss material 28, for example aquadag, is then sprayed over the center section of the entire assembly, namely, rod, glaze and helix to the thickness desired. A mask may be employed to control the length of the center portion which is to receive the loss material.

With reference now to Figs. 4A and 4B, it may be seen that the method described produces a structure having definite advantages over those of the prior art. If the loss material is first applied to the rods 23 and the rods then placed in contact with the helix 21 by external pressure, as was the prior art practice hereinbefore described and as is illustrated in Fig. 4A, the electric field existing between the wires 21', which are each at a different potential, will cause currents to flow in the loss material over the surface of the rod. In series with the effective resistance of the loss material is the contact resistance of the wires 21', which, as previously explained, may vary from wire to wire due to irregularities in rod or wire dimension, or, due to relative movement of the helix 21 and rod 23 because of insufficient pressure on the rod. Such movement will also cause the contact capacitances to vary, and, as previously explained, these variations have been found to be a source of noise.

The present technique prevents the relative movement of the rod and helix by rigidly binding the wires to the rods by the glazing processing as illustrated in Fig. 4B. This not only helps to make and hold contact capacitance uniform but it also eliminates the effect of contact resistance because the glaze 31 insulates the wires from the zircon rods 23. The aquadag coating 28 being over the wires, the currents due to the aforementioned electric field are bridged over the wires and are not a function of contact resistance. Since there is loss material on the wires as well as on the rods, and, due to the more rigid contacts, there is a higher loss per unit length over the assemblies of the prior art in a ratio of about three to one. Consequently, where the loss region originally extended, for example, for about three inches over the center portion of the rods, the same attenuation of the reverse waves may now be obtained with a loss region of

5

only one inch. The loss-free interaction region has thus been increased by two inches resulting in a higher gain per given total length of helix.

In a hybrid tube such as disclosed in my aforementioned application, the helix may be connected at its input end to a grid which aids in collimating the stream of electrons. As shown in the exploded view of Fig. 6, the collimating grid 34 comprises a tungsten mesh 35 held by a frame comprising two conducting ring-like discs 36 and 37 which would be of molybdenum in the illustrative embodiment being described herein. A nickel disc 38 is inserted between the mesh 35 and one disc 36 to aid in welding the mesh and its frame 36, 37 together.

The helix 21 and support rods 23 are placed in the jig as previously described except that the rods 23 are allowed to extend beyond the jig 24 at the end to receive the grid 34. Also, the mandrel 22 is withdrawn slightly from this end so that the helix may be deformed at one end as shown at 50 in Fig. 6 to effect a good impedance match to the grid 34.

The grid 34 assembly is welded together and fired in a hydrogen furnace to remove any oxides, particularly those formed from the welding process. It is then fitted on the ceramic rods 23 by means of the slots 39 provided in the grid. A small portion of each rod 23 is allowed to project beyond the grid 34. A coupler 25, if desired, is fitted to the opposite end of the helix 21 as previously described and the helix is welded at each end to the coupler 25 and grid 34 respectively. Glaze material is applied to the protruding rods 23 about the grid 34 frame as well as about the coupler 25, and the grid 34 is properly aligned relative to the helix 21. The jig 24 is then closed and the assembly fired and cooled as previously described. After cooling, the ends of the rods extending beyond the grid 34 may be filed flush with the grid so that the grid and rods will fit securely against the dished ceramic piece 40 which aids in final assembly with the electron source 11 of Fig. 1.

Tantalum wire may be used for the helix and is desirable in certain respects particularly since it has the property of a getter. Such a property is highly desirable particularly in a traveling wave tube since plasma ion oscillations are also a source of noise and any means which will tend to hold a hard vacuum and thus prevent any ionization are to be viewed with favor. It is, however, necessary to vacuum fire tantalum since it becomes brittle if fired in a hydrogen furnace. Steatite, a compound disclosed in United States Patent 2,332,343 to M. D. Rigterink dated October 19, 1943, is suggested as a suitable support rod material for use in combinations with a tantalum helix.

Although the invention has been described as relating to specific methods and materials adapted to specific devices, many variations and modifications thereof will readily occur to one skilled in the art without deviating from the spirit of the invention.

What is claimed is:

1. A traveling wave tube comprising a wire helix, means to project a stream of electrons along and within said helix, a plurality of insulating support rods spaced about the outer periphery of said helix and extending substantially parallel to the longitudinal axis thereof, a layer of a glaze material along a narrow restricted longitudinal

6

portion of said rods adjacent said helix and between said rods and said helix, said glaze material having a thermal coefficient of expansion matching that of said helix, having a high melting point, and bonding said helix to said rods, said glaze material further defining uniform fillets between each turn of said helix and said rods, and a coating of a high loss conductive material over at least a portion of said rods, said glazed layer, and said helix.

2. A traveling wave tube comprising a wire helix, means to project a stream of electrons along said helix, a plurality of support rods spaced about the outer periphery of said helix and extending substantially parallel to the longitudinal axis thereof, a layer of a glaze material along a narrow restricted longitudinal portion of said rods adjacent said helix and between said helix and said rods, said glaze material having a thermal coefficient of expansion matching that of said helix and bonding said helix to said rods, said glaze material further defining uniform fillets between each turn of said helix and said rods, input and output coupling means supported by said rods and electrically connected to the ends of said helix, a glaze material rigidly bonding said rods at their ends to said coupling means, and a coating of a high loss conductive material over a portion of said rods, said glazed layer, and said helix.

3. A traveling wave tube in accordance with claim 2 wherein said layer of glaze material comprises a glaze comprising primarily SiO_2 and Al_2O_3 .

4. A traveling wave tube in accordance with claim 3 wherein said glaze consists essentially of SiO_2 , Al_2O_3 , BaO , CaO , and Li_2O .

5. A traveling wave tube comprising a wire helix, means to project a stream of electrons along and within said helix, a plurality of insulating support rods spaced about the outer periphery of said helix and extending substantially parallel to the longitudinal axis thereof, and a layer of an insulating glaze material along a narrow restricted longitudinal portion of each of said rods adjacent said helix and between said rods and said helix, said glaze material having a thermal coefficient of expansion matching that of said helix, having a high melting point, and bonding said helix to said rods, and said glaze material further defining uniform fillets between each turn of said helix and said rods to attain a uniform transmission characteristic along said wire helix.

References Cited in the file of this patent

UNITED STATES PATENTS

1,307,510	Nicolson	June 24, 1919
1,892,819	Van Gessel	Jan. 3, 1933
2,174,853	Bowie	Oct. 3, 1939
2,277,150	Scharfnagel	Mar. 24, 1942
2,507,709	Gronros	May 16, 1950
2,541,843	Tiley	Feb. 13, 1951
2,549,551	Walsh	Apr. 17, 1951
2,567,415	Walsh	Sept. 11, 1951
2,602,148	Pierce	July 1, 1952

OTHER REFERENCES

Article by A. V. Hollenberg, Bell System Tech. Jour. for January 1949, pages 52-58.