Oct. 23, 1962 J. B. FITZPATRICK 3,059,669

COIL WINDING APPARATUS AND METHOD OF MAKING A WIRE COIL

Filed Feb. 15, 1960

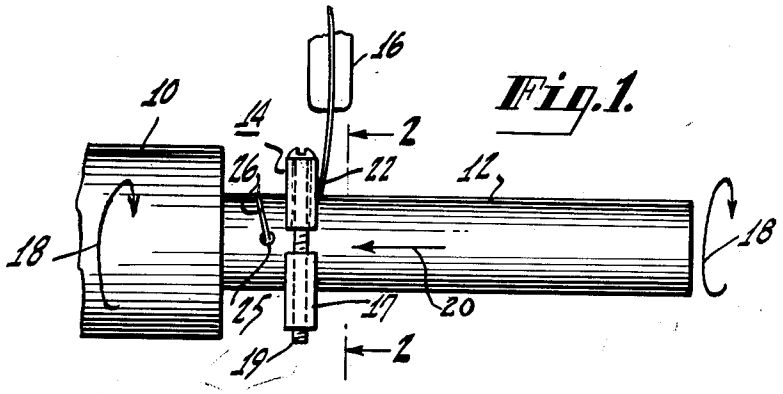



Fig. 1.

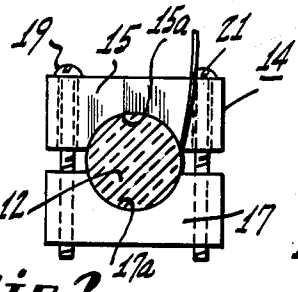



Fig. 2.

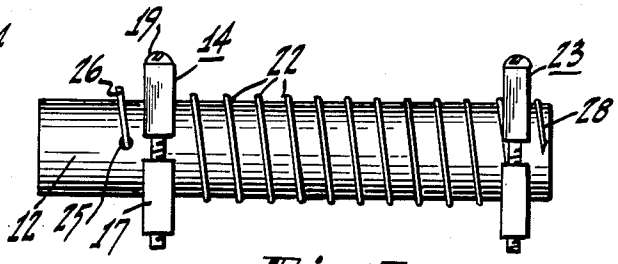



Fig. 3.

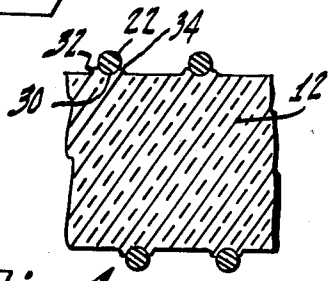



Fig. 4.

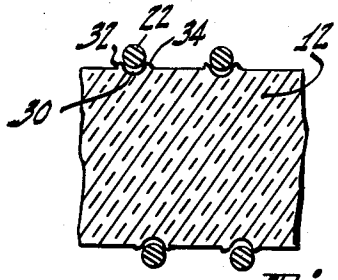



Fig. 5.

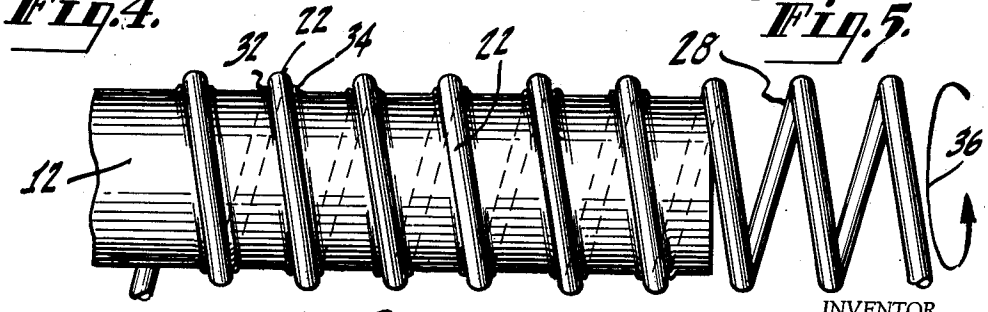



Fig. 6.

INVENTOR.
John B. Fitzpatrick
BY
L. A. Larsen
Attorney

United States Patent Office

3,059,669

Patented Oct. 23, 1962



3,059,669

# COIL WINDING APPARATUS AND METHOD OF MAKING A WIRE COIL

John B. Fitzpatrick, Bloomfield, N.J., assignor to Radio Corporation of America, a corporation of Delaware

Filed Feb. 15, 1960, Ser. No. 8,854
10 Claims. (Cl. 140—71.5)

This invention relates to an apparatus for and method of winding coils of wire such as tungsten, to form coiled structures useful, for example, as cathode heaters in electron tubes, or helices in traveling wave tubes.

Coils of the type referred to have been made heretofore, by winding suitable wire on a mandrel, and thereafter heat treating the coil so made, to relieve strains induced therein by the bending stresses imparted to the wire by the coiling operation. One convenient way of heat treating the coil has involved heating the coil and mandrel in wet or dry hydrogen, vacuum or other reducing or inert atmospheres to a temperature at which the strains aforementioned are relieved.

The problems associated with this method are cost, need for expensive equipment, delay in obtaining finished coils and deformation of the coil or helix when removing from the mandrel.

Deformations in the shape of coils are objectionable in applications thereof requiring a coil of uniform curvature and in which the turns thereof are required to be uniformly spaced. Thus, when the coiled structure is used as a cathode heater, absence of coil uniformity throughout its length, will produce non-uniform heating along the length of a cathode with which the coil is used. Such non-uniform cathode heating may give rise to erratic operation of an electron tube in which the cathode is employed. An even stricter demand for coil uniformity exists in utilization thereof as a helix in a traveling wave tube. A predetermined critical interaction required by the helix and a beam in such tube may be seriously impaired by even a slight departure of the coil from such uniformity.

Accordingly, it is an object of the invention to fabricate coiled wire structures having a relatively high order of uniformity in the spacing between, and curvature of, the turns thereof.

Another object is to provide method and structure means for removing a heat treated wire coil from a mandrel without deforming the coil.

Another aim is to provide a coil making apparatus wherein the mandrel on which the coil is wound is made of an insulating material, thereby permitting the coil to be heat treated by the passage of electric power therethrough prior to removal of the coil from the mandrel.

Briefly considered, one embodiment of an apparatus according to the invention, and presented by way of example, may comprise a coil winding machine having a mandrel made of an insulating material such as aluminum oxide. The mandrel is removably mounted on the apparatus so that the mandrel and a wire coil of tungsten, for example, wound thereon may be removed from the apparatus. According to a method aspect of the invention, the mandrel and coil thereon are placed in a reducing atmosphere, such as dry hydrogen, and terminal portions of the coil are connected to a suitable source of electric power. In view of the insulating character of the mandrel, such power flows only through the coil and serves to heat it to a temperature sufficiently high to relieve any strains therein. The mandrel material is preferably of a type (aluminum oxide) that has a higher coefficient of expansion than the wire (tungsten) coiled thereon. Consequently, heat transferred to the mandrel by the heated coil wire during the heat treatment, will cause the mandrel to expand to a greater degree than the wire. The resultant



radial pressure of the wire on the mandrel will produce a helical groove therein accommodating the wire coil. This groove is of advantage both during the heat treatment step, and when the coil is removed from the mandrel. Thus the groove preserves the shape of the coil during heat treatment and constitutes a screw-thread along which the heat treated wire coil may be removed as by unscrewing, and which serves to preserve the shape of the coil, during the removal operation.

The apparatus and method referred to, contribute to the fabrication of a coil closely conforming to predetermined structural standards. The utilization of a mandrel made of insulating material for example, the heat treating of the coil wound thereon while engaged by the mandrel, and the removal of the heat treated coil from the mandrel in an operation involving restraint by the mandrel against coil deformation, are important factors in attaining the desirable results aforementioned.

Further objects and features of the invention will become apparent as the present description continues.

Reference now to the accompanying drawing, for a detailed consideration of an embodiment of the invention, will reveal that:

FIG. 1 shows a side elevation of a portion of a coil-winding apparatus that may be used in practicing the invention;

FIG. 2 is a sectional view taken along the line 2—2 of FIG. 1 and shows a clamping means for restraining the leading end of a wire during a winding of the wire on a mandrel;

FIG. 3 is a fragmentary side view of the mandrel after a wire coil has been wound thereon and suitably clamped;

FIG. 4 is a longitudinal sectional view greatly enlarged of a portion of the mandrel with a coil thereon, and shows a condition produced by an outward radial pressure of the mandrel on the wire coil thereon, during heat treatment of the coil while on the mandrel;

FIG. 5 is a sectional view similar to that of FIG. 4, except that it depicts a condition following a cooling of the mandrel and wire coil after heat treatment; and

FIG. 6 is a side view of a portion of the mandrel after a wire coil wound thereon has been heat treated, cooled to the ambient temperature, and partly removed from the mandrel as by unscrewing.

The apparatus shown in FIG. 1 comprises a chuck **10** forming part of a winding mechanism of any known type and therefore not requiring illustration. A mandrel **12** is removably fixed to chuck **10** and is shown with a clamp **14**. A wire feeding mechanism **16**, which may be of any conventional type and, therefore, not shown in full, serves to feed wire to the mandrel. The clamp **14** may have a structure, as shown in FIG. 2, comprising blocks **15**, **17** made of copper, for example, having facing cavities **15***a*, **17***a* adapted to engage in a snug fit a transverse portion of mandrel **12** with one end portion of wire thereon. The two blocks may be tightly clamped about the mandrel and the wire thereon, by means of two screws **19**, **21**. The chuck, in the illustration presented, is rotatable in an angular direction indicated by the arrow **18**, on an axis including the longitudinal axis of mandrel **12** when engaged by the chuck, and is movable in a rectilinear path in the direction indicated by the arrow **20**. The wire feeding mechanism **16** in the instant example, is stationary during a wire feeding operation. Such operation is initiated by feeding the leading end **26** of wire **22** through a hole **25** in the mandrel and clamping the leading portion of the wire **22** between mandrel **12** and the clamp **14**. Thereafter, mechanisms (not shown) producing rotation and rectilinear travel of the chuck **10** are actuated. The mechanisms referred to may be adjusted in well known

manner to provide any desired relationship between the rate of rotation and axial displacement of the mandrel 12, to produce a coil having any desired number of turns per inch. The trailing end portion 28 of the coil so formed is held against displacement from the mandrel by a clamping tool 23 similar to that shown in FIG. 2.

According to one aspect of the invention, the mandrel 12 is made of an insulating material such as a material having a high aluminum oxide content, such as alundum. The use of alundum is particularly advantageous when the wire 22 is made of tungsten. In this situation, both the insulating character of the mandrel, as well as its coefficient of expansion are put to advantageous use, as will be explained in the following.

During a coil winding operation, the wire feeding mechanism is adjusted to produce a drag on the wire 22 having a value of about five pounds. This drag assures a snug engagement between the wire 22 in coil form, and the mandrel 12, as shown in FIG. 3.

After the coil forming operation has been completed, and the end portions of the coil are engaged by clamps 14 and 23, the mandrel 12 is removed from its engagement with chuck 10, as shown in FIG. 3, and is placed in a flashing bottle (not shown) containing dry hydrogen. To prevent convection flow of air in the bottle, the flashing bottle may have dimensions requiring dispositions of the mandrel with the coil and clamps thereon, in a vertical position. In such position, one terminal of a suitable electrical power supply may be connected to one clamp 14, which may be made of an electrically conducting material such as copper aforementioned, and the other terminal may be connected to the other clamp 23. Alternatively, the terminals of the power supply may be connected to the end portions 26 and 28 (FIG. 3) of the wire 22. Such connections permit desired electrical power to pass through the coil. The insulating character of the mandrel 12 involves no appreciable drain from such power. The electrical power source is suitably controlled, as by a rheostat (not shown), to gradually and slowly build up the power passing through the coil until the coil temperature reaches a value of from 1200 to 1600° C. The power supply is held at a value producing this temperature, from one to ten minutes, and the power through the coil is then slowly reduced to zero.

During the foregoing heat treatment of the coil of wire 22, both the wire and the mandrel expand. Expansion of the mandrel occurs as heat is conducted to it by the heated wire coil. The turns of such coil, when intended for service as the helix of a traveling wave tube, for example, are relatively closely spaced i.e. of the order of 8–10 mils. Such close spacing results in an appreciable amount of heat transfer to the mandrel so that the mandrel acquires substantially the same temperature as the wire coil during the heat treatment.

Since a material, such as alundum of which the mandrel 12 may be composed, has an appreciably higher coefficient of expansion than tungsten of which the wire 22 may be made, a relatively high magnitude radial force is exerted by the mandrel on the coil made of wire 22, during the heat treatment. It has been found by applicant that this force finds release in two ways, both of which involve a surface deformation of the mandrel. Since tungsten is characterized by a relatively high hot strength, and since the coil ends are effectively anchored by clamps 14 and 23, no appreciable portion of the force aforementioned finds release in the tungsten coil.

The two types of mandrel deformation referred to are illustrated in FIG. 4. One type comprises a recess 30 formed by a partial embedment of the wire 22 in the mandrel material. The other type comprises raised lips 32, 34, resulting from a lateral displacement of the mandrel material. The recess 30 and the lips 32, 34 follow the wire 22 and are therefore, helical. They may be stated to constitute a screw thread impression on the mandrel surface.

After the wire 22 and mandrel 12 have cooled to the ambient temperature, both the mandrel and wire have contracted to their initial forms shown in FIGS. 5 and 6. This involves displacement of the wire turns from the helical recess 30 as shown in FIG. 5. However, such displacement is not sufficient to remove the wire turns from restraint against lateral movement, provided by lips 32, 34. But since the lips 32, 34 were formed to accommodate a larger transverse portion of wire 22 than that engaged by lips in FIG. 4, the aforementioned lateral restraint does not involve any appreciable friction.

The displacement of the wire 22 from the recess 30 and the absence of any appreciable frictional restraint by the lips 32, 34, permit a convenient removal of the finished coil of wire 22 from the mandrel 12, with assurance of freedom from deformation of the coil during such removal. Thus, after the coil ends are suitably disengaged from restraint by clamps 14 and 23, the coil of wire may be engaged at its free end portion 28 and rotated in the direction of the arrow 36, as shown in FIG. 6, for unscrewing the coil from the screw thread formed by the recess 30 and lips 32, 34. This manner of removal of the coil from the mandrel is feasible both when the screw thread extends to the end of the mandrel from which the coil is unscrewed, or terminates short of such end. Where the thread terminates at a region spaced from the removal end of the mandrel, such region does not present opposition to the removal of the coil since portions of the mandrel free from the screw thread impression have a diameter permitting a free sliding movement thereon of the coil, as shown in FIGS 3 and 5. Furthermore, the transition zone from the thread formed by recess 30 and lips 32, 34 to the adjacent unthreaded portion of the mandrel is smooth and offers no appreciable resistance to the travel of the coil wire thereacross.

The tungsten wire 22 may be on any desired size. The invention has been practiced successfully with wire sizes of 5, 7 and 10 mils. The depth of recess 30 varies slightly with different wire sizes. The variations are so slight however, that the depth in each case can be stated to be about one-half mil. The height of the lips 32, 34 from the adjacent mandrel surface also varies only slightly with different wire sizes, and be stated generally to be about one quarter mil. The foregoing values were determined with a mandrel diameter of from about 96 to about 117 mils.

While the foregoing embodiment has involved a combination of a tungsten wire with an aluminum oxide mandrel, it is feasible according to the invention, to employ other combinations of wire and mandrel materials, provided the mandrel material is electrically insulating and the wire has a smaller coefficient of expansion than the mandrel. In each of such instances, it is feasible to practice the method aspects of the invention, involving heat treatment of the wire while on the mandrel by having an electric current pass therethrough, formation of a screw-like track on the mandrel by the difference in expansion characteristics of the mandrel and wire, and substantially frictionless removal of the finished coil from the mandrel, by simply unscrewing the coil from the aforementioned track. The foregoing method not only protects the coil from deformation during the heat treatment thereof, but also isolates the coil from deforming forces during removal thereof from the mandrel.

What is claimed is:

1. A coil winding apparatus of the type comprising a rotatable chuck, an elongated mandrel removably mounted at one end thereof on said chuck, means for feeding a wire transversely of said mandrel, said feeding means and said chuck being relatively movable in a direction parallel to the axis of said mandrel for forming a coil embracing and in contact with said mandrel and having end portions adjacent to the end portions of said mandrel, said mandrel being made of an insulating material having a greater coefficient of expansion than said wire, so that the degree of expansion of the mandrel is greater than the coil during a subsequent heat treatment, thereby resulting

in a partial embedment of the coil in the material of the mandrel to form a helical groove about the mandrel, and releasable means urging said end portions of said coil adjacent said end portions of said mandrel with a force adjustable to a magnitude to restrain relative movement of said coil end portions and said mandrel end portions, except temperature induced expansive movements, during temperature induced differential radial expansions of said mandrel and coil, said helical groove having a smaller radius at the bottom thereof than the radius of said coil after said temperature induced expansions are relieved, said difference in radius substantially weakening the frictional engagement between said coil and mandrel to a magnitude less than that of the engagement between said mandrel and coil immediately following the winding of said coil on said mandrel, and means for heating said wire coil and said mandrel while said coil is on said mandrel, to a temperature sufficiently high to relieve strains in said coil whereby said coil may be removed conveniently from said mandrel after said heat treatment solely by axially rotating said coil on said mandrel, for preserving the heat-treated coil from deformation.

2. In a wire winding apparatus comprising a chuck rotatable on a predetermined axis and movable rectilinearly on said axis and means for feeding a tungsten wire in a path normal to said axis and spaced from said chuck along said axis for forming a wire helix on said mandrel, the improvement comprising a mandrel removably fixed to said chuck and in a position wherein its axis coincides with said predetermined axis, said mandrel being made of an insulating material of high aluminum oxide content and having a larger coefficient of expansion than tungsten, releasable clamping means adapted to snugly engage end portions of said mandrel after said wire has been wound thereon, said clamping means being adjustable for restraining displacement of the wire from the mandrel and means for heating said wire coil and said mandrel while said coil is on said mandrel to a temperature sufficiently high to relieve strains in said coil, said clamping means restraining displacement of said coil from said mandrel during differential expansions of said mandrel and wire in response to heat produced by said heating means, whereby said wire may be conveniently heat treated while on said mandrel by the passage of electric current therethrough, said differential expansions forming a persistent helical groove in the surface of said mandrel for restraining deformation of the wound wire and for providing a screw thread for rotational removal thereof from said mandrel.

3. In a coil winding apparatus including a chuck, an elongated mandrel removably mounted at one end thereof on said chuck, said chuck being rotatable on and rectilinearly movable along the axis of said mandrel, and means for feeding a wire having a predetermined coefficient of expansion transversely of said mandrel for forming a wire coil thereon; the improvement characterized in that said mandrel is made of an insulating material having a higher than said predetermined coefficient of expansion and in that adjustable clamping means snugly engage end portions of said mandrel after said coil has been wound thereon and extend over said end portions, and means for heating said mandrel while said coil is thereon for producing a helical groove about the mandrel, the walls of said groove being spaced from said wire of said coil after said mandrel and wire have cooled from the temperature produced by said heating means, for contributing to convenient rotational removal of the heat treated coil from said mandrel.

4. In a coil winding apparatus for winding to coil form a wire made of a metal having a predetermined coefficient of expansion; a mandrel made of a material having a higher than said predetermined coefficient of expansion, means for winding said wire snugly about said mandrel to provide a coil thereon, releasable means engaging end portions of said mandrel and adapted to clamp end portions of said wire coil to said mandrel, means for heating said wire coil and said mandrel while said coil is on said mandrel to a temperature sufficiently high to relieve strains in said coil, said releasable means being adjustable to restrain relative movement, except temperature induced expansion movements in response to said heating means, of said coil and mandrel in response to differential radial expansions of said coil and mandrel, so that the coil is at least partially embedded in the material of said mandrel to form a helical groove about the mandrel, said groove being defined by lips extending from said surface and on opposite sides of the wire of said coil, whereby said coil may be removed from said mandrel by unscrewing the same from said helical path while said wire is protected from deformation by said lips.

5. Method of making a wire coil comprising winding a wire having a predetermined coefficient of expansion snugly on a mandrel having a higher than said predetermined coefficient of expansion to form a wire coil on said mandrel, releasingly clamping end portions of said wire to end portions of said mandrel with a force adjusted to restrain said wire end portions from forceful displacement from said mandrel during predetermined differential radial expansions of said mandrel and coil, heating said coil while on said mandrel to produce said differential radial expansions for relieving strains in the wire of said coil, said higher coefficient of expansion of said mandrel producing a mechanical reaction between said mandrel and coil resulting in the formation of a helical track on said mandrel confining the wire of said coil, releasing said wire end portions from said mandrel, and axially rotating said coil on said mandrel in a direction for removing the coil from the mandrel, said helical track preserving said coil from deformation during said removal thereof from said mandrel.

6. Method of making a wire coil comprising winding a wire coil on a mandrel, expanding the mandrel radially while said coil is thereon, and to a greater degree than said coil, whereby said coil forms a persistent helical deformation in the surface of said mandrel defining helical spaced walls engaging opposite sides of the wire turns of said coil, contracting said mandrel radially to a greater degree than said coil while confining a portion of the wire of said coil between said walls, and angularly moving said coil in a path between said walls, for removing said coil from said mandrel with assurance of freedom from deformation of said coil.

7. Method of making a wire coil comprising snugly winding a tungsten wire on a mandrel having a relatively high aluminum oxide content to provide a wire coil on said mandrel, releasingly fixing end portions of said coil against relative movement with respect to said mandrel, heating said coil and mandrel to a temperature for relieving strains in said wire and for causing said mandrel to expand radially against restraint by said coil, with sufficient force to produce a persistent helical groove accommodating the turns of said coil in a surface of said mandrel engaged by said turns, cooling said mandrel and coil for loosely engaging said wire by said groove, and axially rotating said coil on said mandrel, whereby the coil is removed with freedom from deformation, from one end of said mandrel.

8. Method of making a wire coil comprising winding a tungsten wire having a size of from about 5 mils to about 10 mils on a mandrel of from about 96 mils to about 117 mils in diameter and made of an insulating material having a higher coefficient of expansion than tungsten, to provide a coil snugly engaging the mandrel and having relatively closely spaced turns, releasingly fixing end portions of said coil to said mandrel with a force adjusted to prevent relative movement of said end portion and said mandrel in response to a force of a predetermined magnitude, passing electric current through said coil to heat the same to a temperature of from about 1200° C. to about 1600° C. whereby said mandrel is heated by heat from said coil to a temperature whereat it expands under restraint by said coil with a force of said predetermined magnitude and a persistent screw-thread track is formed

on a surface portion of said mandrel engaged by the wire of said coil, cooling said mandrel and coil to a temperature at which said track contracts to a magnitude preserving engagement between said coil and track and rotating said coil only, for unscrewing the same from said track.

9. Method of making a wire coil comprising winding wire to coil shape on a mandrel, simultaneously heat treating said coil while on said mandrel to relieve strains therein and forming a persistent helical track in the surface of said mandrel and partly confining the wire of said coil, cooling said mandrel and coil to only partly release said coil from said track, and moving said wire in one direction along said track for removing said coil from said mandrel after said heat treatment while preserving the coil from deformation.

10. Method of making a wire coil comprising snugly winding a tungsten wire on a mandrel made of insulating material to form a wire coil, releasingly fixing end portions only of said coil to said mandrel, then heating the wire coil while on said mandrel to relieve strains in the wire and to form a helical groove in said mandrel receiving a portion of said wire, loosening the engagement between said wire and groove while preserving said wire partly in said groove, and advancing the wire of said coil in said groove for mechanically removing the wire coil from the mandrel while preserving the coil from deformation.



References Cited in the file of this patent

UNITED STATES PATENTS

| | | |
|---|---|---|
| 1,976,522 | Rose | Oct. 9, 1934 |
| 2,402,122 | Bullinger | June 18, 1946 |
| 2,429,087 | Aughtie et al. | Oct. 14, 1947 |
| 2,441,228 | Schneider et al. | May 11, 1948 |