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M. P. HNILICKA, JR

3,233,154

SOLENOID COIL WOUND WITH A CONTINUOUS SUPERCONDUCTIVE RIBBON

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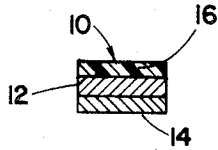


Fig. 1

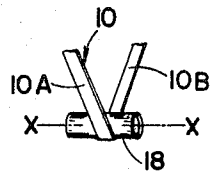


Fig. 2

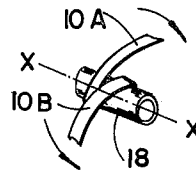


Fig. 3

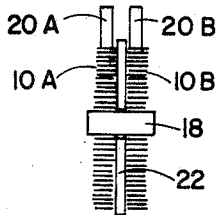


Fig. 4

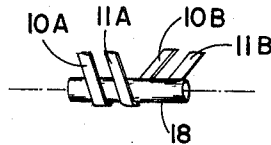


Fig. 2A

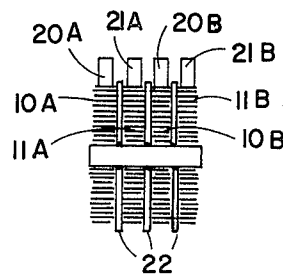


Fig. 4A

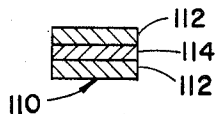


Fig. 5

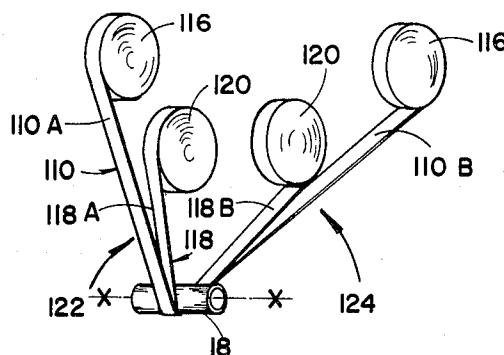


Fig. 6

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SOLENOID COIL WOUND WITH A CONTINUOUS SUPERCONDUCTIVE RIBBON

Milo P. Hnilicka, Jr., Concord, Mass., assignor, by mesne assignments, to National Research Corporation, a corporation of Massachusetts

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5 Claims. (Cl. 317-158)

The present invention relates to electromagnetic coils such as solenoids and the like and more particularly to superconducting electromagnetic coils.

It is a principal object of the invention to provide superconductive coil units which may be tested individually and assembled into larger coils.

It is a further object of the invention to provide a superconductive coil which is suitable for use as a solenoid or the like under conditions of change from the superconductive to the resistive states.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the apparatus possessing the construction, combination of elements and arrangement of parts which are exemplified in the following disclosure and the scope of the application of which will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention reference should be had to the following detailed description taken in connection with the accompanying drawing wherein:

FIG. 1 is a schematic cross-section view of a ribbon superconductor used in a first preferred embodiment of the invention;

FIGS. 2-4 are diagrammatic views of the construction of the first embodiment of the invention, FIGS. 2A and 4A being variants of the construction shown in FIGS. 2 and 4.

FIG. 5 is a schematic cross-section view of a ribbon superconductor used in another preferred embodiment of the invention; and

FIG. 6 is a schematic isometric view of the process of a second embodiment of the invention.

Referring now to FIG. 1 there is shown a ribbon 10. The ribbon has a width on the order of tenths of an inch and a total thickness on the order of thousandths of an inch and a length of hundreds of feet. The middle layer 12 of the ribbon is a superconductive material such as niobium. The niobium is coated with insulation to permit contact with the adjacent turns in a tightly wound coil. The insulation coating comprises a normal state conductor layer 14, such as copper and a dielectric layer 16, such as Teflon.

The process of forming the ribbon into a solenoid is now shown starting with reference to FIG. 2. A central portion of the ribbon is bent about a cylindrical core 18 to divide the ribbon into two legs 10A and 10B. The legs are then wound in opposite clockwise senses about the axis X-X of core 18, as shown in FIG. 3. Continual winding of the legs in opposite directions at the same speeds produces the solenoid shown in FIG. 4. Each of the legs 10A and 10B is formed into a flat pancake spiral of tightly wound ribbon. The ends 20A and 20B of the ribbon are outside the spirals. This is of special importance in superconducting solenoids. It is objectionable to have an end of the coil at the center of the spiral because the presence of a contact in a high magnetic field can create a weak electrical link in the superconductive coil. A double bend of the ribbon would be required with a spiral starting at the inside of the coil. This would be mechanically awkward and tend to introduce distortion in the magnetic field axis. The process of the present invention avoids these fabrication difficulties. The result-

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ant product, with the twin spirals between the ends of the ribbon, provides superior electrical and mechanical characteristics.

Referring now to FIG. 2A, there is shown a possible variant within the scope of the present invention. Two ribbons 10 and 11, of the type shown in FIG. 1, are simultaneously wound about a core 18 in the same manner as described previously so that the legs 10A and 10B of ribbon 10 form spirals 10A and 10B in FIG. 4A and the legs 11A and 11B of ribbon 11 form spirals 11A and 11B of FIG. 4A. As in the original embodiment, the ends 20A and 20B of ribbon 10 are separated by two spirals and the ends 21A and 21B of ribbon 11 are separated by two spirals. This is a less preferred embodiment.

Referring back to FIG. 4, it is noted that the spirals 10A and 10B are coaxial and very close to each other. Annular disc 22 is inserted to insulate lateral ends of the spirals from contact. The disc may be Teflon tape or a pair of C-shaped mica strips. Annular discs 22 are also placed between coils 10 and 11A to avoid high voltage discharges between coils of FIG. 4A.

The solenoid of FIG. 4 can be arranged in longitudinal array with similar solenoids to form a long magnet. Additionally, solenoids of the design of FIG. 4 with varying core diameters can be radially grouped, one within the other. A variety of solenoids of the design of FIG. 4 with different sizes can be produced as off-the-shelf items. Such solenoids can be assembled into larger solenoids. Where the larger assembly is found defective, the solenoids can be checked out individually and the defective one removed while retaining the rest of the solenoids. Each coil unit can be checked out before assembly to insure good quality control.

For simplicity, encapsulation means are omitted from the drawings. However, it will be appreciated that the spirals 10A and 10B of FIG. 4 should be restrained against movement due to sizable magnetic field transients. Restraining panels should bear against the outer faces and outer turns of the spirals. Additionally, an adhesive should be applied to the ribbon as it is wound so that adjacent turns of the spirals will be bonded.

In operation, a typical solenoid is dipped in a liquid helium bath. A current source is connected to ends 20A, 20B of the ribbon 10 to pass a current through the two spirals to create a strong magnetic field within the core 18. Since the superconducting layer 12 carries the current without resistance, both layers 14 and 16 of the coating act as insulation. The layer 12 may be restored to the normal conducting state by excessive current, an increase in temperature or the presence of an external magnetic field of several kilogauss strength. Then layers 12 and 14 are both conductive and reliance is placed on layer 16 to avoid short circuiting between adjacent turns.

The copper layer 14 is necessary to help dissipate the tremendous energies released during electromagnetic transients. Additional load resistors are provided in the external circuitry.

While the superconductive layer 12 has been described as niobium above to provide a simple example, the material of choice is the compound Nb_3Sn formed into superconductor ribbon as described in the copending application of Allen, Das and Stauffer, Ser. No. 207,320, filed July 3, 1962, and the copending application of Allen and Stauffer, Ser. No. 225,784, filed September 24, 1962. Such ribbons may be coated with copper and Teflon or else used in accord with the techniques of the second preferred embodiment of the invention described below.

Referring now to FIG. 5, there is shown a cross-sectional view of a ribbon superconductor 110 comprising layers 112 of niobium bracketing a layer 114 of Nb_3Sn . The ends of the ribbon 110 are wound into spools 116.

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An insulating ribbon 118 is interleaved with the ribbon 110. The ends of the ribbon 118 are wound into spools 120. A central portion of ribbon 118 is bent around core 18 to divide the ribbon into legs 118A and 118B which are wound with the legs 110A and 110B, respectively, of the superconductor ribbon. The pairs of legs are wound in opposite clockwise senses, as indicated by the arrows 122 and 124 to form two flat pancake spirals between the ends of ribbons 110 and 118.

The preferred material for ribbon 118 is a sheet of Mylar coated with a thin film of aluminum. The thickness of the Mylar can be on the order of thousandths of an inch and the aluminum coating on the order of micro-inches. This permits very long length ribbons to be used consistently with compactness of the finished spirals.

Since certain changes can be made in the above construction and apparatus without departing from the scope of the invention herein involved, it is intended that all matter contained in the above description shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A superconducting coil comprising a pair of pancake spirals wound from a single continuous ribbon of superconductive material with the outer turns of the spirals being the ends of the ribbon, means insulating adjacent turns of superconductive material from each other.

2. The article of claim 1 wherein the insulating means comprises a normal state material coating on the superconductive material.

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3. The article of claim 2 wherein the insulating means comprises a conducting layer and a dielectric layer.

4. The article of claim 1 wherein the insulating means comprises a second ribbon interleaved with the above said ribbon.

5. A superconducting coil comprising a pair of coaxial pancake spirals in face-to-face relation separated by a disc, both spirals being wound from a single continuous flat ribbon of superconductive material with the outer turns of the spiral being the ends of the ribbon, the spirals comprising a substantially equal number of turns and having substantially the same inner and outer diameters and widths, and means insulating adjacent turns of superconductive material from each other.

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BERNARD A. GILHEANY, *Primary Examiner*.

JOHN F. BURNS, *Examiner*.