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SUPERCONDUCTING MAGNET WITH PLANAR WINDINGS ORIENTED TRANSVERSELY TO THE MAGNETIC FIELD

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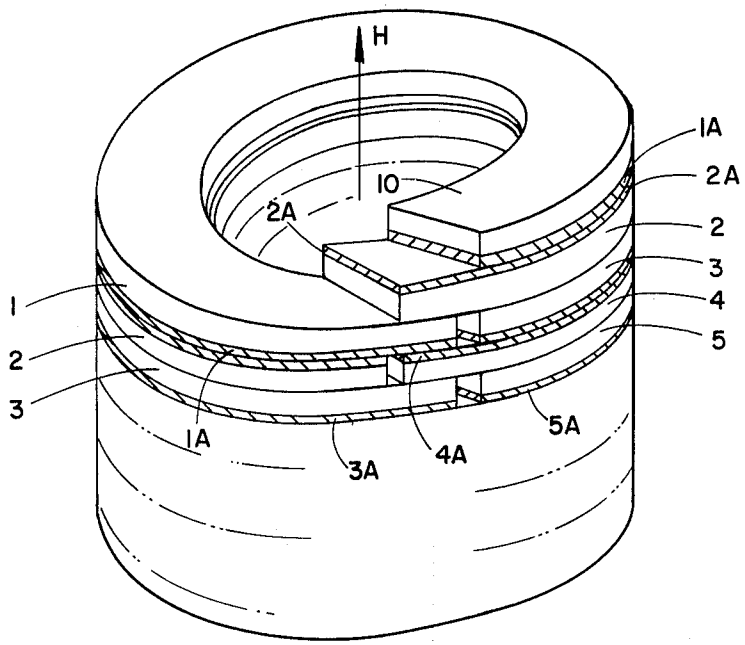

Fig. 1

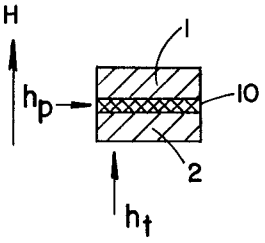

Fig. 2

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3,227,930

SUPERCONDUCTING MAGNET WITH PLANAR WINDINGS ORIENTED TRANSVERSELY TO THE MAGNETIC FIELD

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The present invention relates to hard superconductor solenoid magnets and more particularly to magnets made of hard superconductive metals having the Beta-tungsten structure, preferably of niobium stannide.

It is a characteristic of niobium stannide that if a planar section of it carries current in a magnetic field, transverse to the direction of current flow, it will have a higher critical current if the transverse field attacks it parallel to its plane then if the field attacks it transversely to its plane.

It is therefore an object of the invention to provide a superior magnet taking advantage of this characteristic.

It is a further object of the invention to provide a magnet of simple design so that it is practical to manufacture.

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

The invention accordingly comprises the process involving the several steps and the relation and the order of one or more of such steps with respect to each of the others, and the product possessing the construction, combination of elements and arrangement of parts which are exemplified in the following detailed 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 drawings wherein:

FIG. 1 is an isometric view of a magnet at an intermediate stage of manufacture; and

FIG. 2 is a cross-section of a portion of the completed magnet showing its relation to the magnetic field.

Referring to FIG. 1, there is shown a superconductive magnet made in accord with a preferred embodiment of the invention. The magnet comprises a stack of niobium plates **1**, **2**, **3**, **4**, **5**, etc. Each plate is essentially planar and made from an annular washer which is radially slit to form a C-shape. Adjacent plates are in pairs such as **1** and **2**, and plates **3** and **4**, etc. The upper plate of each pair comprises a coating of tin on its underside and the lower plate of each pair comprises a coating of tin on its upper face; e.g., tin coating **1A** on plate **1** and tin coating **2A** on plate **2**.

The plates are interleaved so that end portions of each pair overlap end portions of the next adjacent pair. Thus a helical path of tin coating is formed through the magnet. This helix is later converted to niobium stannide in the manner described below, to form a resultant helix of niobium stannide with adjacent turns separated by a normal state material—niobium. Niobium is generally thought of as superconductive material too. However, at liquid helium temperatures and fields in excess of about 8 kilogauss or carrying high currents, the superconductivity of the niobium is quenched while the niobium stannide remains superconductive up to much higher limits. Thus the niobium may be considered as one of the normal state materials separating adjacent turns of niobium stannide.

Current is passed through the niobium stannide helix and it produces the magnetic field indicated by the arrow H.

The manner of producing the niobium stannide is now

explained. The structure of FIG. 1 is inserted in a cylinder fitting tightly over the stack of discs. Clamping blocks are applied on both ends of the stack to apply pressure to the stack. This assembly is placed in an inert atmosphere furnace and heated at 1000° C. for one hour. The tin melts and diffuses into surface layers of the niobium to react with it to form niobium stannide. Escape of the tin is limited by the confining cylinder. The plates are thus bonded to the diffusion layers of niobium stannide. The advantage of the present invention will now be appreciated by referring to FIG. 2 which shows a cross-section cut through discs **1** and **2** of FIG. 1 after heat treatment. The pair of plates brackets a planar layer **10** of niobium stannide. The layer **10** extends perpendicular to the direction of the magnetic field H generated by the magnet. Thus, the field tends to enter the layer in the manner indicated by the arrow h_p. The current carrying capacity of the layer is several times greater in this orientation than it would be if the field were trying to enter the layer **10** transversely, as indicated by the arrow h_t.

Many varients can be made from the preferred embodiment within the scope of the present invention. For instance, the coatings **1A**, **2A**, **3A**, etc. of FIG. 1 can be replaced by discs of tin inserted in their space between the niobium plates. The end portions of the tin discs should be thin enough to ensure good contact when niobium stannide is subsequently formed by heat treatment. Where coated foil is used to make the washers **1**, **2**, **3**, **4**, **5**, etc. shown in FIG. 1, the coating should be carried out in accord with the cladding techniques taught in the copending application of Allen, Das and Stauffer, Serial No. 207,320, filed July 3, 1962. The washers can be stamped out from the coated foil and split radially to form their C-shapes.

The niobium plate should be thin foil a few mils thick, but may comprise a thick section on the order of a few inches. Thin foil is preferred since it allows more turns of helix to be formed. The annular shape of the plates can be square or rectangular or elliptical rather than circular, as shown in the drawings.

The drawings show the plates as open loops. However, they can be made as closed loops, e.g., circular, unbroken plates of niobium alternating with circular diffusion layers of niobium stannide in parallel with each other. An external magnet can be used to product current in the closed niobium stannide loops by induction.

In addition to the layers shown in FIG. 1, an additional helix of insulating material, such as Teflon, can be provided. The insulating helix would pass between plates **2** and **3**, then between plates **3** and **4** for the small portion where the upper face of **3** abuts the lower face of **4**, then between plates **4** and **5**, etc.

The time and temperature of heat treatment may be varied.

Since certain changes may be made in the above product 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 magnet comprising a plurality of adjacent assemblies, each assembly made up of a pair of upper and lower parallel annular plates of normal state material bracketing a planar section of superconducting material, the plane of said superconducting material being substantially perpendicular to the magnetic field generated by the magnet, and wherein the construction is in segmented form by the provision of a plurality of said adjacent assemblies making end-to-end connection by the overlapping of an upper disc of one assembly with the lower disc of the other, with the overlapping

sections bracketing superconducting material therebetween.

2. A superconducting magnet comprising at least one assembly made up of a pair of upper and lower parallel annular plates of normal state material bracketing a planar section of superconducting material, the plane of said superconducting material being substantially perpendicular to the magnetic field generated by the magnet, and wherein said plates form C-shapes.

3. A magnet comprising alternating layers of normal state material and hard superconductor material with the hard superconductor being elongated in cross-section, the plane of the elongated dimension being substantially perpendicular to the magnetic field produced by the magnet, the magnet being constructed and arranged to provide a central core passage through the alternating layers, said core passage extending substantially perpendicular to said layers.

4. The magnet of claim 3 wherein the hard superconductor is an alloy of the Beta tungsten structure.

5. The magnet of claim 4 wherein the hard superconductor is niobium stannide.

6. The magnet of claim 3 wherein the layers are helical in form.

7. The magnet of claim 3 wherein the layers are coaxial circles.

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