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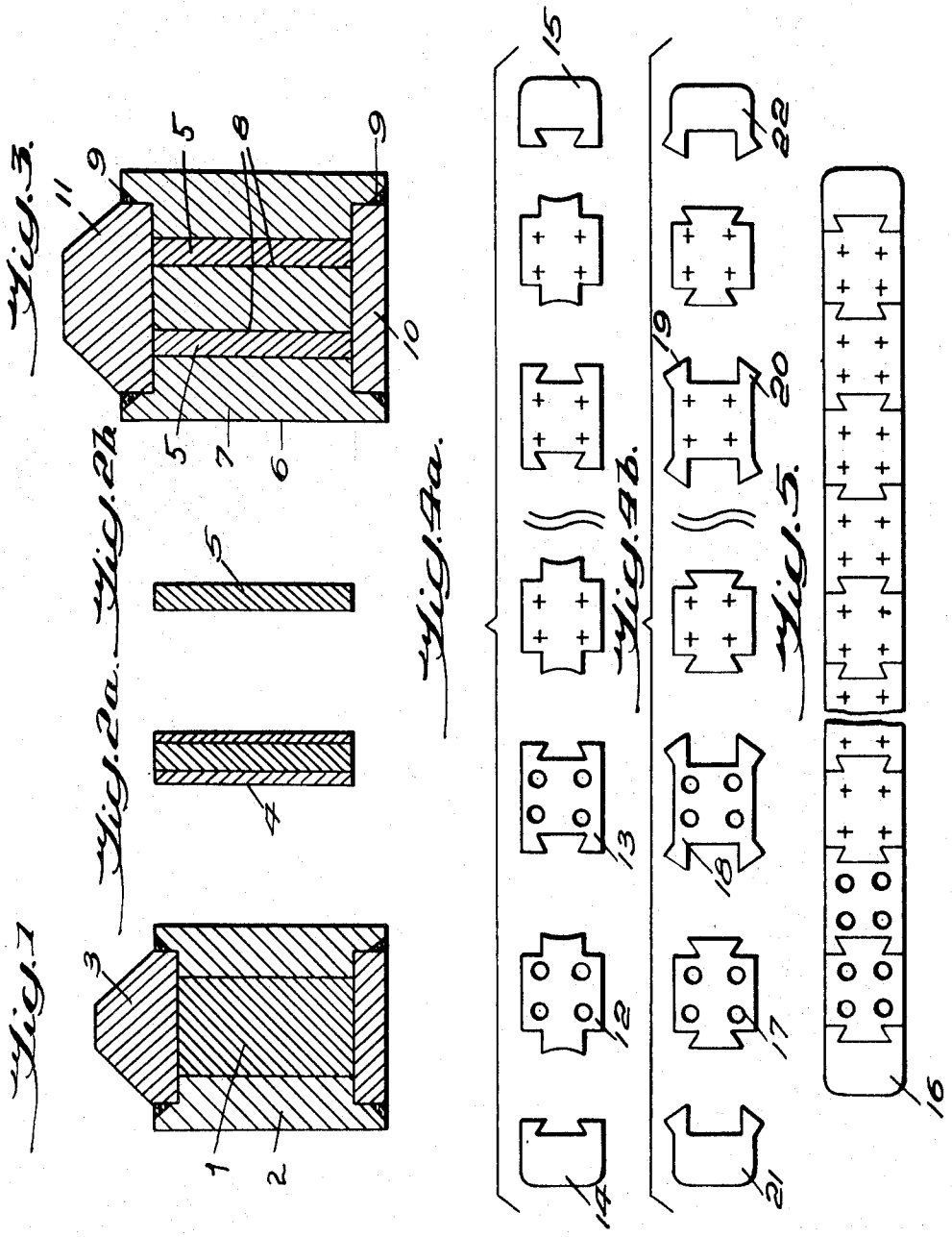

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PROCESS FOR THE PRODUCTION OF SUPERCONDUCTIVE METALLIC CONDUCTORS

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ABSTRACT OF THE DISCLOSURE

A process for producing a superconductive metallic conductor having a strip-shaped form in which a plurality of rods of superconductive material are introduced into bores in press blocks made of a stabilizer material. These blocks are then pressed out into continuous lengths having a substantially rectangular profile. A first group of these lengths is then drawn or rolled to provide a first group of profiled wires having ribs along opposite sides, a second group of these lengths is similarly worked to provide a second group of profiled wires having grooves along opposite sides, and the wires of the first and second groups are then joined together in alternation and in side-by-side relation such that the ribs and grooves interconnect. The joined together lengths are then worked again to establish the final profile of the conductor.

The invention relates to a process for the production of superconductive metallic conductors consisting of a normally conductive stabilizer metal in which superconductive wires distributed over the cross-section of the conductor are embedded.

Superconductive materials which change over into the normally conductive state only when relatively high critical magnetic field-strengths are reached have been developed in recent years. These so-called "hard" superconductors have made it possible for the first time to construct superconductive magnet-coils for the purpose of generating magnetic fields of 30–50 kilogauss and more.

In constructing such magnet-coils, it has proved to be advantageous in practice to use strip-shaped conductors made of copper or other normally conductive metal of high electrical conductivity, wires of superconductive metal being embedded in such conductors, distributed over their cross-section. The normally conductive metal then serves as the so-called stabilizer metal which briefly assumes the current-carrying function should the superconductor suffer an undesired change into the normally conductive state. The effect of this is that the conductor as a whole can become normally conductive only in steps, and as a result the risk of the magnet-coil being destroyed by overheating is greatly reduced.

According to a known process for the production of such a conductor, a copper strip comprising a plurality of suitably shaped longitudinal grooves is first produced. A superconductive wire is now pressed into each of these longitudinal grooves, and the grooves are thereafter closed up to a suitable smaller cross-section by rolling or drawing the conductor strip. This process involves the use of superconductive wires of relatively small diameter which are themselves very expensive to produce.

It is the object of the invention to indicate a process for the production of superconductive and more particularly strip-shaped conductors which is considerably cheaper than known processes even with a relatively large conductor weight per unit length, that is to say with relatively large conductor cross-sections and when relatively great lengths are being produced, and moreover gives satisfactory results with machines of moderate capacity as regards the pressing and drawing devices required.

The process according to the invention is characterized by shaping superconductive rods, by introducing these rods into bores in a plurality of press-blocks of stabilizer metal, by gas-tight closure of the bores in each press-block in the absence of oxygen by at least one closure piece of stabilizer metal, by continuous pressing of these press-blocks and subsequent drawing and/or rolling out to profiled wires with grooves and ribs, by subsequent joining of these profiled wires in such a manner that each rib on a profiled wire engages in a groove in a neighboring profiled wire, and by rolling and/or drawing the joined profiled wires together to the final profile of the conductor.

The invention will be explained by way of example hereinafter with reference to the accompanying drawings wherein:

FIG. 1 is a view in section of an ingot of superconductive material encased by a copper sheath prior to being pressed out;

FIG. 2*a* is a view in section of a short piece of the ingot after being drawn out into a continuous length;

FIG. 2*b* is a view similar to FIG. 2*a* from which the copper sheath has been removed;

FIG. 3 is a view in section of a press-block in which are incorporated a plurality of the short lengths of the ingot as shown in FIG. 2*b*; and

FIGS. 4*a*, 4*b* and 4*c* show three different variants of the press-block after being pressed out into a continuous length.

With reference now to the drawings and to FIG. 1, the superconductive material, with a composition of for example 58% by weight of niobium and 42% by weight of titanium, is available in the form of ingots of about 3–5 kg. each.

A cylindrical member **1** (FIG. 1) is produced from each ingot by suitable treatment. This superconductive member **1** is inserted into a pot-like sheath **2** made of copper which is closed in air-tight fashion by a conical closure piece **3** by electron-beam welding in a vacuum. The member **1** thus provided with a copper sheath **2**, **3** constitutes a press-block which is pressed out into a continuous length in a suitable press at a temperature of about 700 to 850° C. The pressed-out continuous length is now subjected to a drawing operation and finally straightened. While hot-pressing is in progress, the air-tight copper sheath prevents any contact between the superconductive niobium-titanium alloy and the atmospheric oxygen and thus prevents the formation of troublesome oxides of the components of the alloy.

The continuous length thus produced, comprising a superconductive core inside an external copper jacket is now cut up into a plurality of pieces **4** (FIG. 2*a*) of equal length from which the copper jacket is removed, for

example by treatment which involves cutting away material, so that solid cylindrical rods **5** (FIG. 2*b*) of superconductive material are finally obtained.

The next step of the process is to prepare a series of press-blocks **6** according to FIG. 3. Each of these press-blocks **6** consists of a substantially cylindrical main member **7** made of copper and comprising, for example, four bores **8** distributed over its cross-section, a rod **5** of superconductive material being inserted into each bore. In order to close the bores **8**, the main member **7** is closed in air-tight fashion by closure pieces **10** and **11** by electron-beam welding at **9** in a vacuum.

Each of the press-blocks **6** thus completed is thereafter pressed out into a continuous length of substantially rectangular cross-sectional profile at a temperature of 700 to 850° C. Two types of profiled wires are now produced from these continuous pressings by multiple cold drawing.

According to a first variant, profiled wires **12** and **13** having the cross-sectional shapes shown in FIG. 4*a* are produced. In this connection, the shape of the profile imparted in the course of the preparatory continuous pressing closely approaches the shape of the profile which it is desired subsequently to obtain in each case by cold drawing. After the drawing operation, the profiled wires are straightened with the aid of traditional means.

According to this first variant shown in FIG. 4*a*, the profiled wires **12** comprise a rib with parallel flanks on each of two opposite sides, the surfaces of the crowns of the ribs being made slightly concave, while the profiled wires **13** comprise a swallow-tail groove on each of two opposite sides.

In order to produce the strip-shaped conductor, an odd number of profiled wires **12** and an even number of profiled wires **13** are joined together, as shown by the variant according to FIG. 4*a* and in the sequence which may be seen thereon, with profiled copper wires **14** and **15** each provided on one side with a swallow-tail groove, in such a manner that each rib on a profiled wire engages in a groove in the neighboring profiled wire. The profiled wires joined in this way are now drawn together through a die having a substantially rectangular aperture. During this drawing operation, the ribs on the profiled wires **14** are pressed into the adjoining swallow-tail grooves, and are deformed in such a manner that finally they completely fill the said grooves. This ensures that there will be a permanent positive link between the profiled wires to form the desired final profile of the strip-shaped conductor **16** illustrated in cross-section in FIG. 5.

According to a further advantageous variant (FIG. 4*b*), profiled wires **17** and **18** are now produced in a similar manner to the profiled wires **12** and **13** according to the first variant in order to produce the conductor strip **16** (FIG. 5). In this connection, the profiled wires **17** comprise ribs of swallow-tail cross-section on two opposite sides, while the profiled wires **18** are provided on two opposite sides with grooves of rectangular cross-section each bounded by two ribs increasing in width from the foot of the rib to the crown thereof.

In this connection, the plane surface **19** of the crown of the rib is at least substantially at right-angles to the oblique external flank **20** of the relevant rib. As in the case of the variant according to FIG. 4*a*, an odd number of profiled wires **17** and an even number of profiled wires **18** are now also joined together in the case of this variant (FIG. 4*b*), in the sequence which may be seen therefrom, with two profiled copper wires **21**, **22** whereof each comprises on one side a groove after the manner of the grooves in the profiled wires **18**. The profiled wires thus joined are now rolled together to form the coductor strip **16** of substantially rectangular final profile. In the course of the rolling operation, the ribs on the profiled wires **18**, **21** and **22** are forced inwards until they engage flush behind the swallow-tail ribs on the neighboring profiled wires **17**, and thus positively link the profiled wires together to form the conductor strip **16**, in a similar manner to the first variant.

We claim:

1. The process for producing relatively wide ribbon-like superconductive metallic conductors consisting of a normally conductive stabilizer metal in which a large number of superconductive wires distributed over the cross-section of the conductor are embedded which comprises the steps of

(a) shaping superconductive rods,

(b) introducing said rods into bores in a plurality of press blocks made from stabilizer metal,

(c) closing off said bores by at least one closure piece of stabilizer metal in the absence of oxygen,

(d) pressing out said press blocks into a continuous length having a substantially rectangular profile,

(e) drawing and/or rolling out a first group of said rectangularly profiled lengths to provide a first group of profiled wires having ribs formed respectively along opposite sides thereof,

(f) drawing and/or rolling out a second group of said rectangularly profiled lengths to provide a second group of profiled wires having grooves formed respectively along opposite sides thereof,

(g) joining together the wires of said first and second groups in alternation and in side-by-side relation such that the ribs of the wires of said first group are received in the grooves of the wires of said second group, and

(h) rolling and/or drawing said joined-together wires of said first and second groups to establish the final profile of the conductor.

2. The process as defined in claim **1** wherein copper is used as the stabilizer metal.

3. The process as defined in claim **1** wherein aluminum is used as the stabilizer metal.

4. The process as defined in claim **1** wherein the step of shaping superconductor rods includes the steps of enclosing a cylindrical member of superconductive material in a gas-tight sheath of stabilizer metal in the absence of oxygen to establish a press block, pressing out said block into a continuous length, drawing and/or rolling said pressed out block to form a superconductive rod sheathed with the stabilizer metal, and cutting up said sheathed rod into lengths.

5. The process as defined in claim **4** wherein said sheath of stabilizer metal is removed from said superconductive rod prior to inserting the latter in said press blocks.

6. The process as defined in claim **1** wherein the ribs formed along opposite sides of said wires of said first group have parallel flanks and concave crown surfaces and wherein said grooves formed along opposite sides of said wires of said second group have a swallow-tail configuration.

7. The process as defined in claim **1** wherein said ribs formed along opposite sides of said wires of said first group have a swallow-tail cross-section, and wherein said grooves formed along opposite sides of said wires of said second group are of rectangular configuration and are each bounded by two rib portions increasing in width from the base of the rib portion to the crown thereof.

8. The process as defined in claim **7** wherein the crown of each rib portion which bounds a groove is a plane surface disposed at least substantially at a right-angle to an external oblique surface of said rib portion.

9. The process for producing a comparatively wide ribbon-like superconductive metallic conductor consisting of a normally conducting stabilizer metal in which are embedded a large number of superconductors distributed over the cross-section of the conductor which comprises the steps of:

(a) shaping superconductive rods,

(b) introducing a number of such rods into parallel spaced bores provided in each of a number of press blocks made from a stabilizer metal,

(c) closing off the bores in said press blocks by at least one closure piece of stabilizer metal in the absence of oxygen,

(d) working each of said blocks to elongate the same and provide respectively a continuous length of wire constituted by the parallel spaced superconductors embedded in the stabilizer metal, said lengths of wire having a substantially rectangular configuration and with the sides of the wires profiled to establish interengageable ribs and grooves,

(e) assembling and joining said profiled wires in side-by-side relation with a rib provided along one side of one wire engaged with a groove provided along one side of an adjacent wire so as to form a composite ribbon-like conductor whose width corresponds to the sum of the widths of the individual wires thus joined together, and

(f) final working said joined together wires to attain a secure fit between the inter-engaged ribs and grooves and establish the final profile for the composite conductor.

10. The process as defined in claim **9** wherein the profiled wires of one group are provided with ribs along opposite sides thereof and the profiled wires of another group are provided with grooves along opposite sides thereof for engagement with the ribs of the wires of the first mentioned group.

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