

- [54] **CARRIER FOR CONDUCTORS IN AN ELECTRICAL CABLE FOR LOW TEMPERATURE**
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[51] **Int. Cl.**..... **H01v 11/00**
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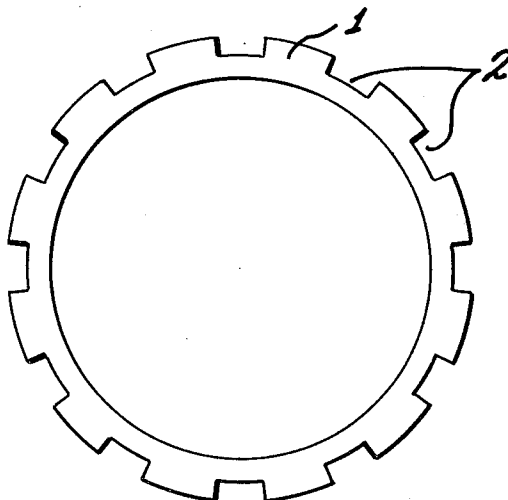
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[57] **ABSTRACT**
The individual conductors of a cryogenic cable are supported in the innermost tube of the cable assembly, having plural concentric corrugated tubes for establishing a controlled temperature gradient, in that short tube sections with peripheral longitudinal grooves are linked together, leaving a gap between each two sections, and in a chain-like configuration; the conductors are preferably wrapped helically around this carrier assembly.

9 Claims, 3 Drawing Figures



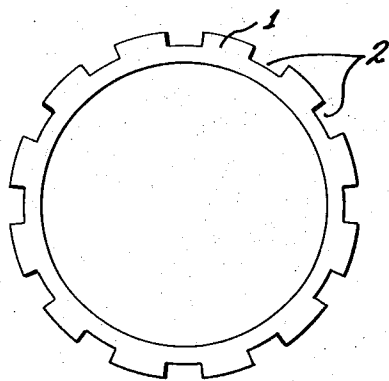


FIG. 1

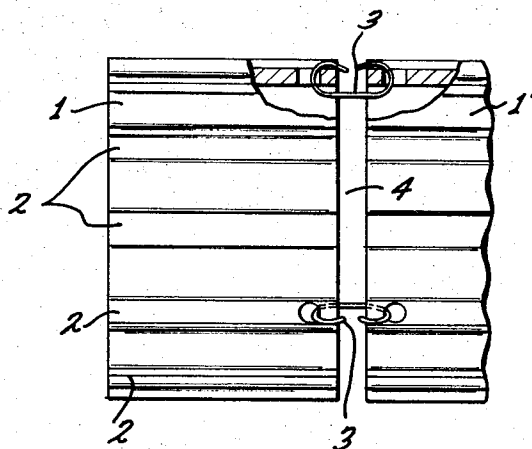


FIG. 2

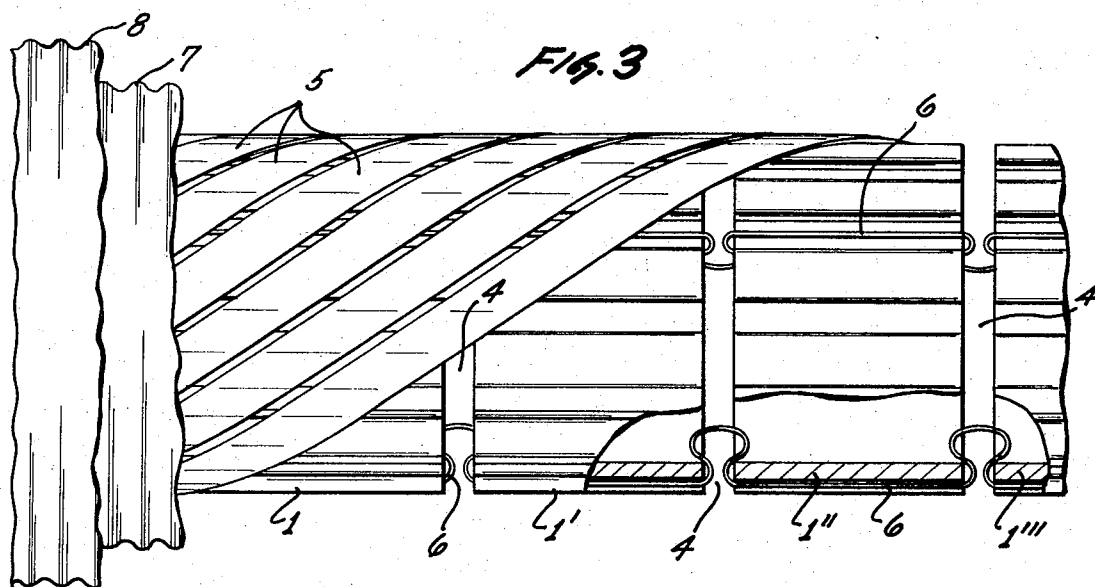


FIG. 3

CARRIER FOR CONDUCTORS IN AN ELECTRICAL CABLE FOR LOW TEMPERATURE

BACKGROUND OF THE INVENTION

The present invention relates to an electrical cable operated at low temperatures such as a cryogenic cable operated with superconduction of the electrical conductor therein, and which includes several concentric, preferably corrugated metal tubes for thermal insulation of the conductors which are disposed in the innermost tube and held therein through suitable support structure. This innermost tube is usually also flown through by a coolant which maintains the superconductive state of the conductors.

The French Pat. No. 70.13096 discloses a conductor support for and in such a superconductor cable comprised of a helix made of plastic or metal and having additional ribs for strengthening. The conductors are disposed on this helix. This arrangement has the disadvantage that upon applying axial expansion force upon the helix outer diameter is decreased while axial compression increases the diameter. Thus, the geometry of the cable construction is per se indefinite because either or both types of forces may be set up. Moreover, strips or wires used as conductors are supported by the helix in spaced apart points only. The distance between the support points may vary and the support surfaces may decrease if the helix has re-enforcing ribs.

German printed patent application No. 2,020,735 discloses a support for conductors in a cryogenic cable, having support rings and plastic rods combined in a cage-like configuration. Plastic ribbons are spirally wound around the rods to enhance stability. The same basic problem outlined above arises also here in that the cage offers too little support area for the superconductor strips or wires. Upon bending the cable, the conductors may kink.

It has to be considered that superconductor ribbons are usually of laminated construction made by cladding or the like, and upon kinking the superconductive layer may break. The manufactures of such superconductors usually state a smallest permissible radius of curvature for bending, sharper curving and bending will indeed lead to cracks across the superconductive layer. Another drawback of the cage construction is to be seen in that the annular support elements impede vigorous flow of the cryogenic coolant.

DESCRIPTION OF THE INVENTION

It is an object of the present invention to provide for a support of conductors in a cable so that the conductors will not be damaged even if made as rather delicate strips and if the cable is reeled or laid in a curve when installed.

It is another object of the present invention to provide for a support of conductors in a cryogenic cable wherein the conductors are readily exposed to a liquid coolant from all sides while fresh coolant is available for long portions of the cable and for immediate contact with the conductors.

In accordance with the preferred embodiment of the invention it is suggested to provide individual cylindrical, tubular elements with longitudinally running grooves as support and carrier for the conductors. These elements are loosely interconnected in a chain-like manner, leaving gaps inbetween so that liquid flowing through the elements may pass through the gaps

and flow also through the grooves serving as channels accordingly. The conductors, strips or wires, are disposed on the assembled carrier elements and wound thereon, preferably in helical fashion for uniformity of support and uniform contact with the coolant. Upon bending such a cable the helical conductors are not bent locally or even kinked, the helix is merely expanded or contracted locally so that only slight tension or relaxation of tension is set up in the (helical) direction of extension of the conductors. The diameter of the carrier and support assembly is not changed in such a situation.

The elements are preferably interconnected by wire clips, arranged e.g. 120° around the end-face peripheries of respective two axially adjoining elements. The wire clips are preferably provided for establishing overall flexibility as well as length compensation as occurring on low temperature contraction. In lieu of individual clips, meandering wires may be used for interconnection which is particularly beneficial for compensation of length changes.

DESCRIPTION OF THE DRAWINGS

While the specification concludes with claims particularly pointing out and distinctly claiming the subject matter which is regarded as the invention, it is believed that the invention, the objects and features of the invention and further objects, features and advantages thereof will be better understood from the following description taken in connection with the accompanying drawings in which:

FIG. 1 is front view of a conductor support element in accordance with the preferred embodiment of the invention;

FIG. 2 is a side elevation of such an element as connected to another one; and

FIG. 3 is a side elevation of a multiple element assembly with superimposed conductors.

Proceeding now to the detailed description of the drawings, the Figures illustrate support elements 1 for electrical conductors. The support elements are cylindrical or drum shaped, short tube sections with annular cross-section, i.e. they have a large, hollow tubular interior. The outer periphery of the elements 1 is provided with longitudinally i.e. axially running grooves 2 establishing channels for the coolant liquid.

The elements are relatively short; generally speaking their axial dimensions are comparable to their respective radial dimensions. In the drawing they are shown to be slightly shorter than they are wide with regard to their outer diameter. Superconductive strips 5 are wound helically upon a tube section assembly such as the tubes 1, 1', 1'', 1''' etc. in FIG. 3.

The elements such as 1, 1' etc., are linked together in a chain-link configuration in that they are axially concatenated on a common axis and interconnected e.g. through wire clips 3. A definite space is established as a gap 4 between adjacent tubes, which must be sufficient to establish overall flexibility of the assembly. Since some contraction is expected on cryogenic cooling the bores receiving the clips are significantly wider than the clip wire is thick.

This aspect should be considered in some detail. Elements 1, 1' etc. are preferably made of plastic, but they have a thermal expansion, or, better, contraction which is about 10 times as large as for metal parts (e.g. the wire clips) when considering a range of 300° Kelvin.

This is the reason the holes must be larger than the wire of the wire clips so that these holes can contact without binding the clips. Moreover, upon contraction of the tube sections as a whole, some give should be provided here.

The clips 3 shown in FIG. 2 are individual clips just looped through the large holes. An extensive looping on a multiple clip basis is shown in FIG. 3, the connecting elements being wires 6 of meandering configuration with inwardly extending loops and running in one of the grooves of the elements along the longitudinally periphery.

The meander shape of the wires 6 interconnecting the several carrier and tube sections as shown in FIG. 3 permits each carrier element to contract axially, but the wires 6 maintain the overall spacing as their contraction is about the same (or can be made to be about the same) as the resulting axial contraction of the conductor tapes or strips 5. The loops of the clips readily compensate any differences. Moreover, they provide for resilient interconnection as between the contracting and, therefore, mutually retracting elements 1, 1', 1'' etc.

The clips or wires are arranged preferably to have three equidistantly spaced connections between adjacent sections 1, 1'; 1', 1'' etc, i.e. these connecting elements are spaced apart by 120°.

Coolant, such as liquid helium, that fills the interiors of the tubes can escape radially through the gaps 4 and flow freely through the ducts or channels established by the grooves 2. This way coolant envelopes the superconductors 5 and cools them intensively, and there is continuous exchange of liquid coolant as between the channels or grooves and the interior of the tubular, sectionized carrier assembly.

Since the conductors are wrapped spaced apart, there remain gaps in registering relation with gaps 4; also, short portions of the grooves or channels 2 are not covered. Thus, the overall assembly as far as carrier with conductors is concerned is not impervious to the coolant but the coolant can pass through for immediate contact with the outside of the conductors.

As indicated schematically, the carrier assembly is disposed in a corrugated tube 7 which in turn is held in another corrugated tube 8; others may be provided for a controlled temperature gradient as between the exterior and the interior, bridging up to or more than 300° Kelvin temperature difference.

The conductor supporting element is not only usable for superconductive cables but can also be used e.g. in cryoresistive cables i.e. for low temperature cable using copper or aluminum tapes, strips or wires. However, the utilization of the assembly in superconductor arrangements is of particular interest when the ribbons are made of laminated construction with a thin layer of a material that is commonly used for superconduction. The construction prevents kinking of these tapes and the superconductive layer is, therefore, protected against such kinking.

As stated, the liquid coolant can readily be brought into intimate contact with the conductors, even if the cable is quite long. The carrier elements are hollow cylinders with large inner diameter and without offering any obstruction to the flow of coolant. The larger the diameter the lower is the flow resistance of the conduit arrangement. Thus, liquid helium can flow through greater lengths of the cable without requiring pumping.

The gaps between the short section carriers permit frequent exchange of coolant as between the bulk flowing through the tubular assembly and the portion flowing through the peripheral ducts 2. Also, insulation (not shown) is expected to be disposed above the conductors and the liquid helium continuously wets this insulation. It should be noted that this coolant does not only have the function of maintaining the superconductive state, but serves as dielectricum as well which is of advantage if the voltage transmitted via the cable is quite high.

The grooves 2 provide for extensive flow of coolant in the immediate vicinity of the conductors 5. Since conductors 5 are wrapped around the carriers 1, 1' etc. in helical configuration they are all exposed to exactly the same amount of open space above the ducts—grooves, and they are supported by exactly the same amount of ridge surface between the grooves. Hence, the conditions for cooling as well as for support of the conductors are quite uniform. The support surface are closely spaced along each helical conductor, particularly if the pitch angle is such that the conductor strips cross the ridges—grooves at not too shallow an angle.

Insulation is not shown in the drawings, but it can readily be seen that insulation can be wound on top of the illustrated assembly without affecting the strength and configuration of the conductor support. In particular any tension on the insulation and reacted into the assembly will not change the geometry thereof so that the conductor tapes or strips are not subject to detrimental tension, overall or localized.

Another advantage is to be seen in the simplicity of making the spacer assembly. They can be made e.g. on a continuous basis. A teflon hose may be made (e.g. extruded) with grooves and the individual ring segments are simply cut from that hose; provided with clip holes and clipped together. The wires 6 do not have to extend individually for the length of the assembly, but suffice to hold together several of these sections. There may be an azimuthal overlap in that new wires do not all begin at the same section!

The invention is not limited to the embodiments described above but all changes and modifications thereof not constituting departures from the spirit and scope of the invention are intended to be included.

What I claim is:

1. In an electrical cable to be operated at low temperatures and having several concentric tubes and electrical conductors in the innermost tube to be placed therein in immediate contact with a coolant flowing through the innermost tube, a carrier assembly for the conductors comprising:

a plurality of individual, cylindrical short tube sections as carrier elements having longitudinally running grooves in their outer periphery; and connecting elements interconnecting the carrier elements with a gap between adjacently positioned carrier elements so that liquid coolant as flowing through the elements may pass through the gap for flow in and along the grooves, the conductors being disposed on the elements as interconnected.

2. In a cable as in claim 1, wherein the conductors are helically wound onto the element to cross grooves and ridges between the grooves at a relatively steep angle, the conductors being supported by the grooves.

3. In a cable as in claim 1, the connecting elements being individual clips.

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4. In a cable as in claim 3, the clips being made of metal.

5. In a cable as in claim 4, the tube sections having relatively large holes for receiving the clips to tie adjacent sections together.

6. In a cable as in claim 1, the connecting elements being meander shaped wires.

7. In a cable as in claim 1, the individual sections being cut from a hose.

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8. In a cable as in claim 1, the connecting elements being distributed about the axial ends of respective two sections interconnected and held in each of them loosely with play sufficient to prevent binding upon strong thermal contraction of the section.

9. In a cable as in claim 1, wherein the connecting elements between respective two carrier elements are distributed at 120° distance.

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