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Kubo et al.

[11] **3,801,723**

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[54] **STRUCTURE OF THE TERMINAL PORTION OF A CABLE**

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[73] Assignee: **The Fujikura Cable Works, Limited,** Tokyo, Japan

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[30] **Foreign Application Priority Data**

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[51] **Int. Cl.......................... H01b 7/34,** H02g 15/22
[58] **Field of Search** .... 174/DIG. 6, 15 R, 16 BH, 174/16 R, 15 BH, 15 C, 9

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[57] **ABSTRACT**

A conductor portion of the terminal portion of a cable is encased in a terminal box having an inlet and outlet provided for accommodating the circulation through the terminal box of a liquid nitrogen coolant. The conductor portion is connected to a conductor leading wire which extends through a bushing up to a normal temperature area. The terminal box and part of the bushing are housed within a tank and the tank has an inlet and outlet provided for accommodating the circulation through the tank of a liquid coolant. The bushing has an inlet and outlet provided for accommodating circulation through the bushing of liquid nitrogen coolant. With the structure so arranged the conductor of the cable is led out up to a normal temperature area with a temperature gradient formed along the conductor leading wire.

4 Claims, 3 Drawing Figures

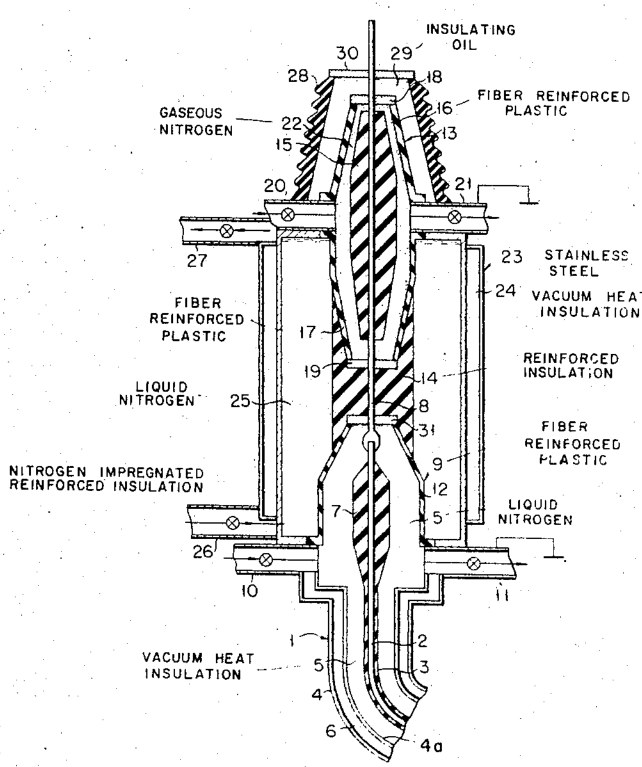
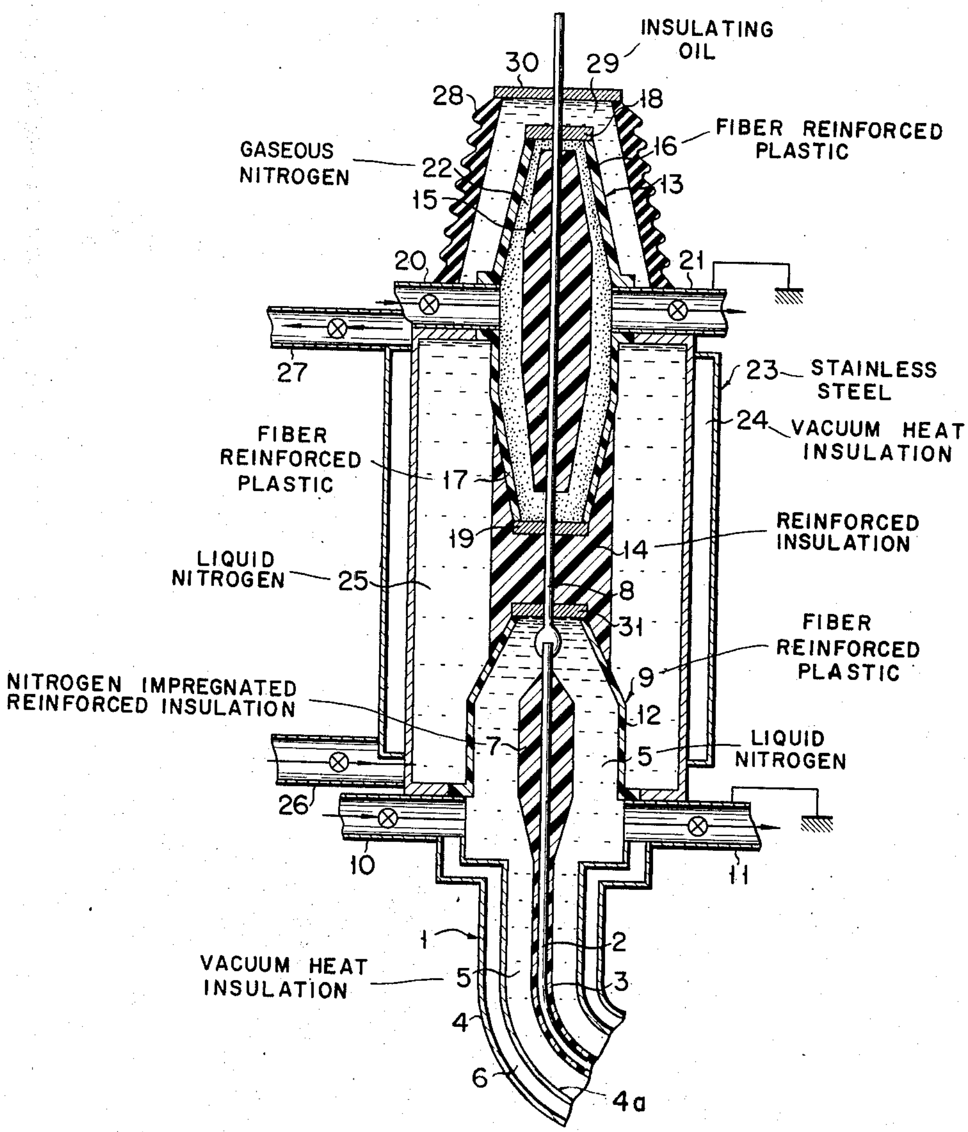


FIG. 1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STAINLESS STEEL
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VACUUM HEAT INSULATION
FIBER REINFORCED PLASTIC
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FIG. 2

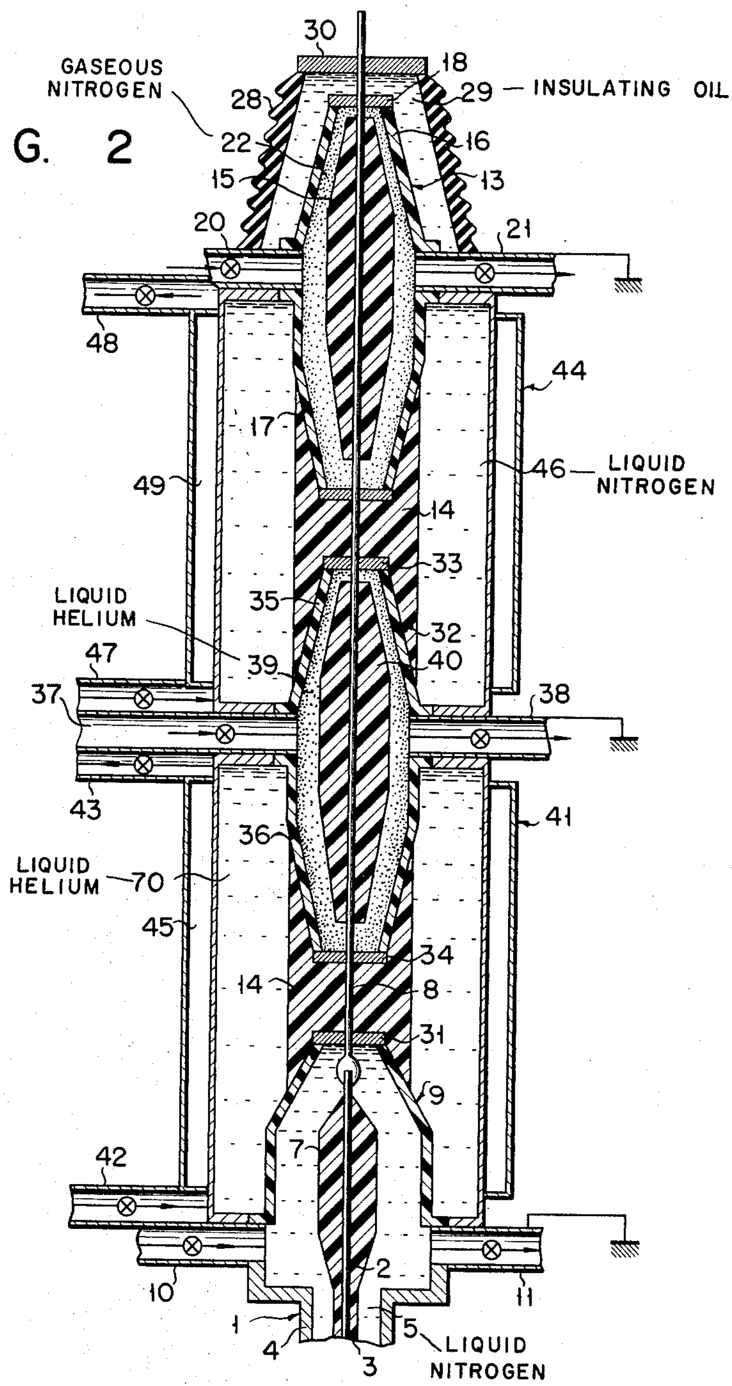
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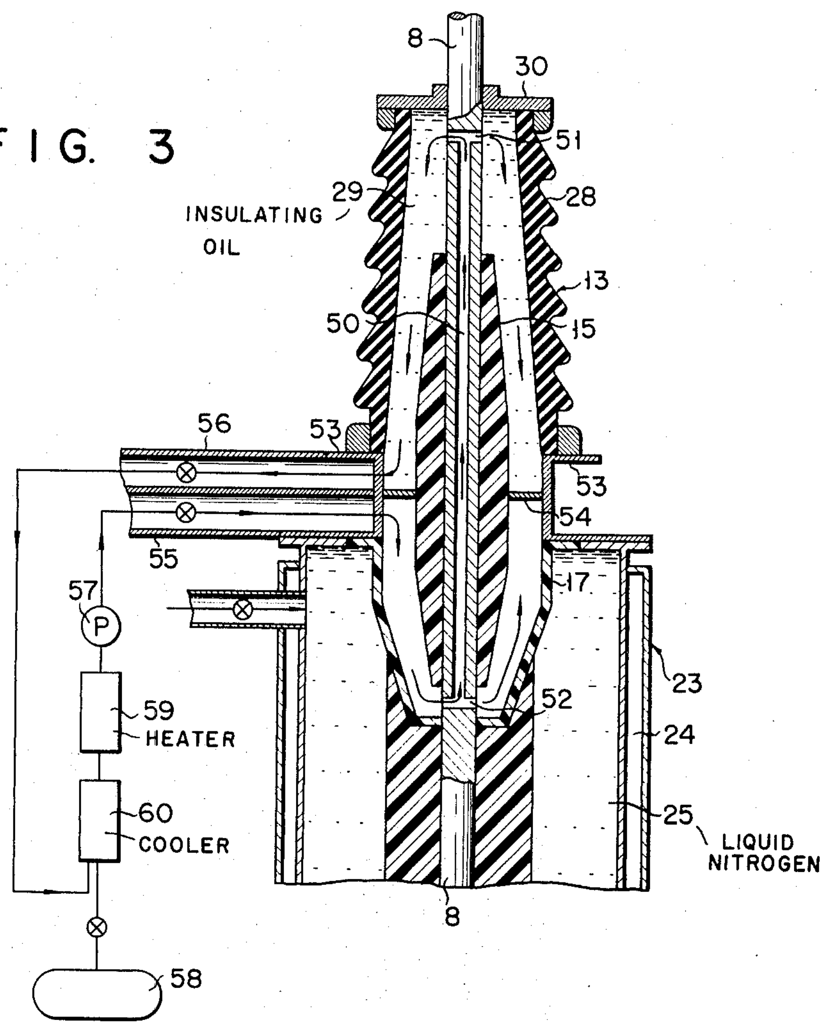
FIG. 3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STRUCTURE OF THE TERMINAL PORTION OF A CABLE

This invention relates to a structure of the terminal portion of a cable conductor excellent in heat insulating and electrical characteristics, in which the terminal portion of the conductor is led out up to a normal temperature area through a conductor leading wire.

The terminal portion of a conventional superconductive cable or very low temperature cable is so constructed that the terminal portion of a conductor is led out up to a normal temperature area through a conductor leading wire connected to the conductor. The heat radiation of the conductor or the conductor leading wire is apt to be unstable depending upon the temperature conditions of an outer atmosphere with the result that the electrical characteristics, such as a dielectric strength, dielectric constant, tan δ etc., of an insulating material used for the conductor or the conductor leading wire are disadvantageously affected to cause a temperature variation.

The object of this invention is to provide a structure of the terminal portion of a cable capable of leading out a conductor up to a normal temperature area in a state stable from the heat insulating and electrical viewpoint with an optimal temperature gradient formed along a conductor leading wire according to the kind of cables.

Another object of this invention is to provide a structure of the terminal portion of a cable capable of preventing the deterioration of an insulating characteristic brought about by the freezing of an insulating oil within a bushing through which a conductor leading wire extends.

To attain the aforementioned object a conductor portion of the terminal portion of a cable is connected to a conductor leading wire and encased within a terminal box; the conductor leading wire is led out up to a normal temperature area in a manner to extend through a bushing; the portion of the bushing and the terminal box are housed within a tank; and the circulation of a respective coolant within the terminal box, tank and bushing permits the conductor leading wire to be led out up to a normal temperature area with a temperature gradient formed along the conductor leading wire. As a result, there is obtained a structure of the terminal portion of a cable more stable in heat insulating and electrical insulating characteristics.

To attain another object of this invention, a hollow passageway is provided along the longitudinal direction of the conductor leading wire extending through the bushing, and the circulation of an insulating oil through the bushing prevents freezing of the insulating oil, thus permitting insulating characteristics to be maintained.

The present invention can be more fully understood from the following detailed description when taken in connection with reference to the accompanying drawings, in which:

FIG. 1 shows a construction of the terminal portion of a very low temperature cable which is one embodiment of this invention;

FIG. 2 is a view in cross section showing a construction of the terminal portion of a superconductive cable which is another embodiment of this invention; and

FIG. 3 is a cross sectional view of the internal structure of another bushing corresponding to the bushing portion as shown in FIGS. 1 and 2.

Referring to FIG. 1 there is shown a construction of the terminal portion of a very low temperature cable adapted to be used at a temperature approximate to about −200°C. A cable **1** has a coolant of liquid nitrogen **5** filled between an insulating layer **3** of a conductor **2** and a pipe **4**. The interior of the pipe **4** constitutes a vacuum heat insulating layer **6**. The terminal portion of the conductor **2** is reinforced with a reinforced insulating layer **7** made of such as an insulating paper, plastic insulating paper, etc., and is connected to a conductor leading wire **8**. The terminal portion of the conductor **2** is encased within a terminal box **9**. Within the terminal box **9** is filled liquid nitrogen coolant in communication with the interior of pipe **4a** which is within pipe **4**. The terminal box **9** has an inlet pipe **10** and an outlet pipe **11** to permit the liquid nitrogen **5** to be circulated in a direction indicated by arrows, thereby maintaining substantially constant the cooling temperature of that portion of the conductor within the terminal box **9**. As an inner pressure resisting, reinforced barrel constituting the terminal box, use is made of F. R. P. (Fiber Reinforced Plastic) capable of coexisting with the liquid nitrogen. The top of the reinforced barrel is blocked by a metal fitting **31**. The liquid nitrogen used is of the order of 5 to 10Kg/cm² at 75° to 100°K. The reinforced insulating layer has the liquid nitrogen impregnated therein.

The conductor leading wire **8** extends through a bushing **13** and may be led out up to a normal temperature area. Between the terminal box **9** and the bushing **13** another reinforced insulating layer **14** is arranged. Even when the terminal box and the bushing are moved closer to each other, an insulation breakage due to an along-the-surface stress can be prevented. The bushing **13** has an upper inner pressure resisting reinforced barrel **16** and a lower inner pressure resisting, reinforced barrel **17**. The top and bottom of the bushing are blocked by metal fittings **18** and **19** respectively. At the connecting portion of the barrels **16** and **17** inlet and outlet pipes **20** and **21** are connected to permit a coolant gaseous nitrogen **22**, for example, of the order of 10 Kg/cm² at 200°K to be circulated in a direction indicated by arrows. The conductor leading wire **8** within the bushing **13** is reinforced at its circumference with an insulating layer **15**.

The lower reinforced barrel **17** of the bushing **13**, the reinforced insulating layer **14** and the terminal box **9** are all housed within a tank **23**. The tank **23** is manufactured from stainless steel, etc., at the outside of which is formed a vacuum heat insulating layer **24**. Within the tank **23** a liquid nitrogen coolant **25** of the order of 5 to 10 Kg/cm² at **95°** to **100°K** is filled. To the upper and lower sides of the tank **23** inlet and outlet pipes **26** and **27** are connected to allow the coolant to be circulated in a direction indicated by arrows. At the outside of the reinforced barrel an insulator **28** is capped through an interior space in which an insulating oil **29** is filled. The top of the insulator tube is blocked by a metal fitting **30**.

With the terminal portion of the cable so constructed Joule heats radiated from the conductor and conductor leading wire and a heat transmitted from a normal temperature area are cooled by the liquid nitrogen **5** circulated within the terminal box **9**, the liquid nitrogen **25** circulated within the tank **23** and the nitrogen gas circulated within the bushing **13** with the result that the conductor can be led out up to a normal temperature area with a temperature gradient formed along the conductor leading wire. In this case, an optimal electrical insulation can be made for each part of the cable by selecting the kind of coolants. For example, for the section of the terminal box **9** the reinforced barrel and the nitrogen coolant are used; for the section of the tank **23** the liquid nitrogen **25** and reinforced insulating layer are used; and for the section of the bushing the insulator tube, reinforced barrel **16** and reinforced insulating layer **15** are used.

Let us explain the structure of the terminal portion of a superconductive cable used at a temperature approximate to about −273°C.

The structure of this superconductive cable is substantially the same as that of the very low temperature cable as explained in FIG. **1** except that two tanks are provided with a bushing connected therebetween. The explanation of identical parts is therefore omitted. A conductor leading wire **8** is led out up to the normal temperature area through first and second bushings **32** and **13**. The first bushing **32** consists of internal pressure resisting, reinforced barrels **35** and **36** and pipes **37** and **38** provided at the connecting portion of the barrels **35** and **36**. The top and bottom of the bushing are closed by metal fittings **33** and **34**. Within the bushing a liquid helium coolant **39** of the order of 1.5 Kg/cm^2 at 4.7°K is flowed in a direction indicated by arrows with the bushing filled with the coolant. Around the connecting wire within the bushing **32** a reinforced insulating layer **40** is provided. The lower reinforced barrel **36** of the bushing and the terminal box **9** are housed within a first tank **41** in which, for example, a liquid helium gas of the order of 1.5 Kg/cm^2 at 4.7°K is filled as a coolant **70**. The coolant can be circulated through the interior of the tank from an inlet pipe **42** to an outlet pipe **43**. At the outside of the first tank **41** a vacuum heat insulating layer **45** is provided.

A second tank **44** houses an upper inner pressure resisting, reinforced barrel **35** of the first bushing **32** and a lower inner pressure resisting, reinforced barrel **17**. Within the tank a liquid nitrogen **46**, for example, of the order of 5 to 10 Kg/cm^2 at 95° to 100°K is filled as a coolant. The coolant is circulated through the interior of the tank from an inlet pipe **47** at the lower portion of the tank to an outlet pipe **48** at the upper portion thereof. At the outside of the second tank **44** a vacuum heat insulating layer **49** is provided. With the above-mentioned embodiment the conductor of the cable is led out up to a normal temperature area with a temperature gradient formed along the conductor leading wire. As a result, stability is obtained from the heat insulating or electrical insulating standpoint as in the embodiment of FIG. **1**. Particularly the coolants are so placed along the conductor leading wire that a liquid nitrogen cooling area is formed between the liquid helium cooling area and the normal temperature area. This minimizes an increase in temperature of the liquid helium, permitting a cooling efficiency to be enhanced. A optimal temperature gradient can be obtained by selecting, according to the kind of cables used, the kind of coolants and the order of their placement, the pressure and temperature of the coolant within the tank, the amount of flow of the coolant and so on.

FIG. **3** shows the internal structure of a bushing corresponding to the bushing of the embodiments as shown in FIGS. **1** and **2** and adapted to prevent an insulating oil within the bushing from freezing. As shown in FIG. **3** a conductor leading wire **8** extending through the bushing **13** is bored along a center axis to provide a hollow passageway **50** the top and bottom of which is communicated, through communication passageways **51** and **52**, with the interior of an insulator tube **28** in which an insulating oil is filled.

The insulator **28** of the bushing **13** and a lower inner pressure resisting, reinforced barrel **17** are supportingly connected through a metal supporter **53** the interior of which is partitioned by a partition plate **54** to provide upper and lower segments. To the part of the metal supporter **53** pipes **55** and **56** are connected. Through a circulation circuit outside the bushing leading to the pipes **55** and **56** an insulating oil is introduced into the lower segment of the metal support and passed up through the hollow passageway **50** of the conductor leading wire **8** to the upper segment of the metal support and then to the outside circulation circuit.

The circulation circuit is hydraulically operated by an oil pump **57** and hydraulic tank **58**. Provided between the oil pump **57** and hydraulic tank **58** are a heating device **59** for maintaining the temperature of the insulating oil **29** at more than the melting point when cooling is necessary before the electrical conductor of the cable conductor, and a cooling device **60** for cooling the temperature of the insulating oil **29** when the temperature of the conductor leading wire **8** is raised to more than necessary extent at the time of the conduction of the cable conductor. Where the insulating oil is contacted with an air at the normal temperature to attain such an object, then a heating device may be omitted. The circulation circuit may be used in a form that the cooling device **60** is omitted. When an insulating oil is circulated within the bushing using such circulation circuit, there is no fear that the insulating oil will be frozen, even if liquid nitrogen whose freezing point is about −200°C is nearer to the insulating oil whose freezing point at the lower portion of the bushing is about −60°C. If the insulating oil is frozen to cause a smooth flow of the insulating oil to be disadvantageously affected, voids will be created in the inner wall of the insulator tube with the result that a corona discharge occurs at the void in the inner wall of the insulator tube with the consequent destruction of the inner wall. According to this invention the degeneration of an electrical insulating characteristic is also prevented. Furthermore, a coolant effect can be enhanced. As a result, an enhanced current capacity of the cable can also be attained.

What we claim is:

1. A structure of the terminal portion of a cable comprising: a conductor leading wire connected to the terminal of a cable conductor; a terminal box forming a first chamber containing the terminals of said conductor leading wire and said cable conductor; means associated with said terminal box for accommodating a flow of liquid nitrogen through said first chamber; a bushing forming a second chamber surrounding a segment of said conductor leading wire leading out from said terminal box; means associated with said bushing for accommodating a flow of gaseous nitrogen through said second chamber; an insulator tube surrounding a portion of said bushing and cooperating therewith to form a third chamber adapted to contain insulating oil; a tank forming a fourth chamber containing the other portion of said bushing and said terminal box; and, means associated with said tank for accommodating a flow of liquid nitrogen through said fourth chamber; whereby said conductor leading wire extends out from said structure to a normal temperature area, with a temperature gradient being maintained along the segments of said cable conductor and said conductor leading wire contained within their respective aforesaid chambers.

2. A structure of the terminal portion of a cable according to claim 1 wherein said conductor leading wire extending through the bushing has a hollow passageway along the axial direction thereof; and said bushing is partitioned by a partition plate into chamber segments to permit the insulating oil filled within the two chamber segments to be circulated through the hollow passageway of the conductor leading wire, and pump means for circulating the insulating oil through the two chamber segments of the bushing.

3. A structure of the terminal portion of a cable comprising: a conductor leading wire connected to the terminal of a cable conductor; a terminal box forming a first chamber containing the terminals of said conductor leading wire and said cable conductor; means associated with said terminal box for accommodating a flow of liquid nitrogen through said first chamber; a first bushing forming a second chamber containing a segment of the conductor leading wire leading out from said terminal box; means associated with said first bushing for accommodating a flow of liquid helium through said second chamber; a first tank forming a third chamber containing a portion of said terminal box

and a portion of said first bushing contained therein; means associated with said first tank for accommodating a flow of liquid helium through said third chamber; a second bushing forming a fourth chamber containing a segment of the conductor leading wire leading out from said first bushing; means associated with said second bushing for accommodating a flow of gaseous nitrogen through said fourth chamber; an insulator tube surrounding a portion of said second bushing and cooperating therewith to form a fifth chamber; means associated with said insulating tube for accommodating a flow of insulating oil through said fifth chamber; a second tank forming a sixth chamber containing portions of said first and second bushings therein; and means associated with said second tank for accommodating a flow of liquid nitrogen through said sixth chamber; whereby said conductor leading wire extends out from said structure to a normal temperature area, with a temperature gradient being maintained along the segments of said cable conductor and said conductor leading wire contained within their respective aforesaid chambers.

4. A structure of the terminal portion of a cable according to claim 3 wherein said conductor leading wire extending through said second bushing has a hollow passageway along the axial direction thereof; and said second bushing is partitioned by a partition plate into two segments to permit the insulating oil filled within the two segments to be circulated through the hollow passageway of the conductor leading wire, and pump means for circulating the insulating oil through the two segments of the bushing.

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