TEMPERATURE-RESPONSIVE TRANSMISSION LINE CONDUCTOR FOR DE-ICING

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Fig. 1.

Metal having Curie temperature of 32°F to 50°F.

Fig. 2.

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The present invention relates to overhead electric transmission line conductors. It is well known that electric power companies have had, since the first power was transmitted on overhead lines, a very serious problem of destruction of these lines by the formation of ice on the conductors. For example, as stated on page 1356 of the Seventh Edition of the Standard Handbook for Electrical Engineers, A. E. Knowlton Editor-in-Chief, McGraw Hill Book Company, Inc., New York, 1941, "Abnormal vertical load is imposed when wires are coated with ice, which may be sufficient to increase their normal weight from 200% to 400%." Thus, to maintain service and avoid expensive repairs, it has been necessary to make the towers supporting the conductors far stronger than need be for ordinary stresses such as those created by wind loads. In addition, because the conductors presently in use are unable to support the added weight of the ice forming thereon, it has been the practice to insert steel wires in the conductors in order to provide further strength. Neither or both of these solutions is completely adequate. For example, both are quite expensive. Furthermore, the addition of steel wire inserts to the conductors decreases their conductivity. Thus, the art has been faced with a very difficult problem that even becomes more magnified where access to the transmission lines is very disadvantageous, as well as being difficult, e.g., where the lines span water. Although many attempts were made to overcome the foregoing difficulties and other disadvantages, none, as far as I am aware, was entirely successful when carried into practice on an industrial scale.

It has now been discovered that overhead electric transmission line conductors substantially resistant to the formation of ice may now be produced.

It is an object of the present invention to provide an overhead electric transmission line conductor which, in use, is substantially resistant to ice formation and/or ice accumulation.

Another object of the invention is to provide a unique process for maintaining overhead electric transmission line conductors substantially free of ice when freezing temperatures are encountered.

Other objects and advantages will become apparent from the following description taken in conjunction with the accompanying drawing in which:

FIG. 1 is an illustration of an overhead electric transmission line spanning a difficulty accessible area where icing conditions are encountered; and

FIG. 2 is an enlarged cross-sectional view of a conductor of the transmission line of FIG. 1.

Generally speaking, the present invention contemplates a novel overhead electric transmission line conductor which, when carrying alternating electric current, is resistant to ice formation and/or ice accumulation thereon. According to this invention, the overhead electric conductor comprises an electrically conductive material having a Curie temperature of about 32° F. to about 50° F.

It is an important aspect of the present invention that the electric transmission line conductor comprises material having a Curie temperature of about 32° F. to about 50° F., and, advantageously, about 35° F. to about 40° F., e.g., about 37° F. Magnetic materials when carrying electric current exhibit greater line losses than do non-magnetic materials operating under substantially the same conditions, etc. It has been discovered that these line losses manifest themselves in the form of heat and this heat can be utilized to substantially inhibit the formation of ice on the electric conductor when electricity in the form of alternating current is passed therethrough. Thus, since ice generally forms at about 32° F. under normal conditions the Curie temperature of the material should be at least about 32° F. Moreover, when the temperature of the conductor exceeds the Curie temperature the material transforms into the non-magnetic state thus minimizing line losses whenever currents pass through the materials.

The electrically conductive materials of this invention having Curie temperatures as heretofore set forth include metals, alloys, dispersion-hardened metals and alloys, other metal-containing materials which are electrically conductive such as metal filled plastic and semi-conductors, etc. Advantageously, the conductive material is a nickel-containing alloy or an alloy having a major proportion of metal selected from the group consisting of cobalt, iron, nickel and combinations thereof. In addition, the alloys may contain up to 50% of copper, molybdenum, silicon, silver, platinum group metals, gold, zinc, aluminum, magnesium, manganese, beryllium, etc., and combinations thereof. In addition, alloys substantially free of iron, nickel, cobalt and combinations thereof, e.g., Heusler alloys, having Curie temperatures as hereinbefore set forth are also within the scope of the present invention. Such alloys have useful electrical and/or magnetic properties and characteristics. More advantageous, the material is a nickel-containing alloy having a nickel content of at least about 50% by weight of the alloy, e.g., an alloy containing about 35% to about 37% copper with the balance being essentially nickel. Such a nickel-copper alloy has Curie temperatures ranging from about 32° F. at about 37% copper to about 50° F. at about 35% copper. Such an alloy also has good strength and corrosion resistance even in marine atmospheres.

Among the materials having the characteristics and/or properties hereinbefore mentioned are those set forth in the table, although there are other materials having such characteristics, etc., as those skilled in the art will readily understand and appreciate.

<table>
<thead>
<tr>
<th>TABLE</th>
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<table>
<thead>
<tr>
<th>Nominal composition,</th>
<th>Curie temperature, percent by weight:</th>
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<tbody>
<tr>
<td>36% copper, balance nickel</td>
<td>37° F.</td>
</tr>
<tr>
<td>10% molybdenum, balance nickel</td>
<td>37° F.</td>
</tr>
<tr>
<td>4.5% silicon, balance nickel</td>
<td>37° F.</td>
</tr>
<tr>
<td>30% nickel, balance iron</td>
<td>37° F.</td>
</tr>
<tr>
<td>40% nickel, 15% chromium, balance iron</td>
<td>37° F.</td>
</tr>
</tbody>
</table>
Small additions of ingredients to the materials of this invention such as are used as deoxidants, mellalizers, etc., will, of course, shift the Curie temperature somewhat at those skilled in the art will readily understand. Advantageously, the electrically conductive materials of this invention are of a high purity since unwanted impurities cause the desirable magnetic and/or magnetic and electrical characteristics to deteriorate in many instances. For example, a high purity alloy such as one made by vacuum melting or by powder metallurgical techniques is advantageous since the substantially pure alloy shows a sharper rise in permeability as the temperature decreases than does a less pure alloy, e.g., an air-melted alloy. Thus, more energy is usually available in a high purity line conductor to resist the formation and/or accumulation of the ice thereon when the ambient temperature falls below the Curie temperature of the material. However, less pure materials may be used provided they have Curie temperatures within the hereinbefore mentioned ranges.

In carrying the invention into practice, it is advantageous that the electric transmission line conductor comprises an electrically conductive material having, in addition to a Curie temperature as heretofore mentioned, an electrical conductivity of at least about 0.005 mho per centimeter (mho/cm.) cube \( \times 10^6 \) at 32°F, and, advantageously, at least about 0.021 mho/cm. cube \( \times 10^6 \) at 32°F, in order to insure that the material is as good a conductor as possible when the ambient temperature is above the Curie temperature of this material. In addition, at temperatures below the Curie temperature, when the material is magnetic and when it is carrying alternating current, the eddy current losses substantially increase with the conductivity. Thus, a material having the aforementioned conductivities exhibits greater line losses and these greater line losses are advantageous in substantially inhibiting ice formation when the ambient temperature is freezing. Among the materials having the foregoing characteristics are metals and alloys having a major proportion of metal selected from the group consisting of cobalt, iron, nickel and combinations thereof. In addition, these alloys may also contain up to 50% copper, molybdenum, silicon, silver, platinum group metals, gold, zinc, aluminum, magnesium, beryllium, etc., and combinations thereof, Heusler alloys, etc. Advantageously, the material is a nickel-containing alloy having a nickel content of at least about 50% by weight of the alloy. For example, a particularly advantageous alloy is an alloy containing about 35% to about 37%, e.g., 36% copper with the balance essentially nickel as this alloy has a conductivity of the order of about 0.021 mho/cm. cube \( \times 10^6 \) at 32°F.

In FIG. 1 of the accompanying drawings, an illustrative embodiment of an overhead electric transmission line 11 is shown suspended from supporting towers 12 and spanning a difficulty accessible area (body of water 13). Conductor 14 of transmission line 11 is depicted in cross section in FIG. 2 and is comprised to metal 15 having a Curie temperature of about 32°F to about 50°F, e.g., an alloy containing about 36% copper with the balance essentially nickel.

For the purpose of giving those skilled in the art a better understanding of the invention and a better appreciation of the invention, the following illustrative example is given:

**Example**

64 parts of carboloy nickel powder are mixed with 36 parts of copper powder until the mixture is substantially homogeneous. The mixture is then sintered and thereafter compacted and drawn into 0.062" wire. The wire is thereafter tested and it is determined to have a Curie point of about 37°F. By measuring the permeability at a series of temperatures using a permeameter, the conductivity was determined to be 0.021 mho/cm. cube \( \times 10^6 \) at 32°F. The wire is placed in an atmosphere having a temperature of about 30°F, and is connected to a generator so that about 5 amperes flow through the wire. Water is then sprayed upon the wire and observations are made to determine whether any ice is formed. No ice formation is observed. The temperature of the atmosphere is then lowered to about 20°F and the aforementioned procedure is repeated. Again no ice formation is observed.

The present invention is particularly applicable to overhead electric transmission line conductors for use over difficultly accessible areas in which freezing temperatures and ice formation are encountered whether used as the conductor itself or clad on copper or other high conductivity alloy or whether it is to be used as the outer strand of a multiwire cable or any cable configuration. In addition, the present invention can suitably be put to use where temperature drop to freezing and below particularly where minimum maintenance is a requirement. Furthermore, the present invention is applicable in any electrical apparatus that may be subjected to ice formation on its conductive elements.

Although the present invention has been described in conjunction with preferred embodiments, it is to be understood that other modifications and variations are considered to be within the purview and scope of the invention and the appended claims.

I claim:

1. A temperature-responsive, de-icing electric transmission line conductor adapted for use in the overhead position and in difficulty accessible areas where freezing temperatures are encountered comprising an alloy containing about 35% to 37% copper with the balance essentially nickel and having a Curie temperature of about 32°F to about 50°F; said conductor being characterized in unattended operation by exhibiting greater line losses manifested as heat when the conductor is below about 32°F than when above about 50°F when alternating current is passed therethrough, whereby formation of ice on said conductor is inhibited.

2. A temperature-responsive, de-icing electric transmission line conductor adapted for use in the overhead position and in difficulty accessible areas where freezing temperatures are encountered comprising a nickel-containing alloy having a Curie temperature of about 32°F to about 50°F and having a conductivity of at least about 0.005 mho per centimeter cube \( \times 10^6 \) at 32°F; said conductor being characterized in unattended operation by exhibiting greater line losses manifested as heat when the conductor is below about 32°F than when above about 50°F when alternating current is passed therethrough, whereby formation of ice on said conductor is inhibited.

3. A temperature-responsive, de-icing electric transmission line conductor adapted for use in the overhead position and in difficulty accessible areas where freezing temperatures are encountered comprising an electrically conductive material having a Curie temperature of about 32°F to about 50°F and having a conductivity of at least about 0.005 mho per centimeter cube \( \times 10^6 \); said conductor being characterized in unattended operation by exhibiting greater line losses manifested as heat when the conductor is below about 32°F than when above about 50°F when alternating current is passed therethrough, whereby formation of ice on said conductor is inhibited.

4. A temperature-responsive, de-icing electric transmission line conductor adapted for use in the overhead position and in difficulty accessible areas where freezing temperatures are encountered comprising an electrically conductive material having a Curie temperature of about 32°F to about 40°F.

5. A process for inhibiting formation of ice upon an electric transmission line for transmitting alternating cur-
rent in areas where freezing temperatures are encountered which comprises using in said transmission line a temperature-responsive, de-icing electric transmission line conductor comprising a nickel-containing alloy characterized by a Curie temperature of about 32° F. to about 50° F. by passing alternating current therethrough, thereby developing greater line losses manifested as heat when said conductor is below about 32° F. than when above about 50° F.

6. A process as set forth in claim 5 wherein the conductor is an alloy containing about 35% to about 37% copper with the balance being essentially nickel.

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JOHN F. BURNS, Primary Examiner.
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