Sept. 8, 1970 TOSHIYUKI HAYAMI 3,527,874

CROSSLINKED POLYETHYLENE OIL FILLED HIGH VOLTAGE POWERED CABLE

Filed Sept. 14, 1967

Fig. 2

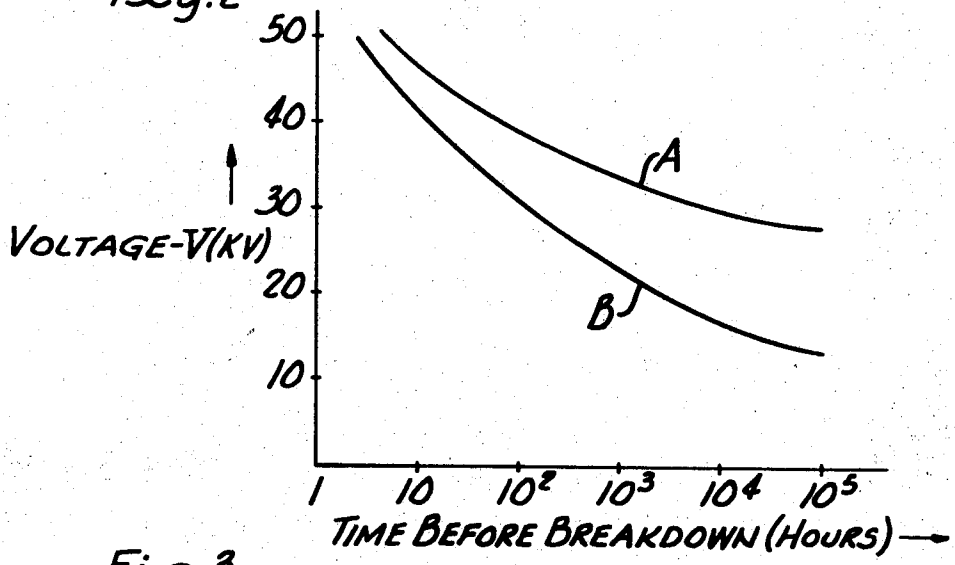


Fig. 3

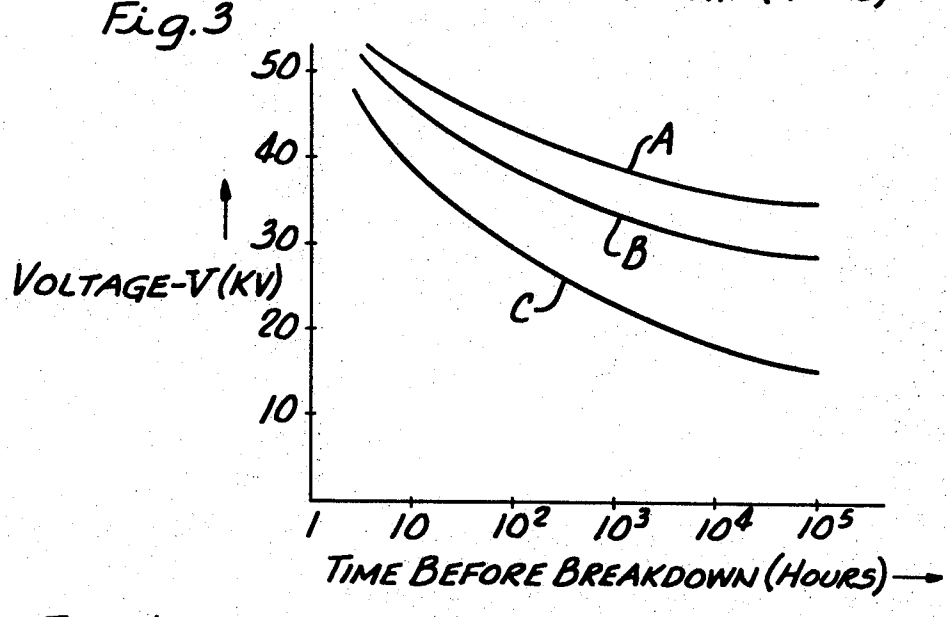
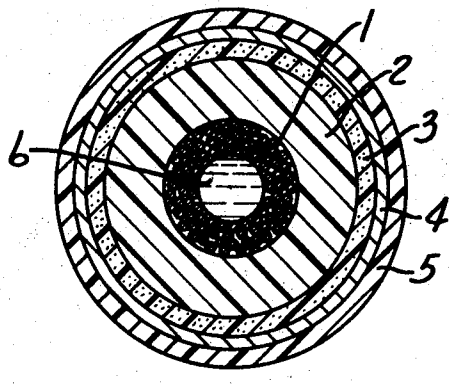


Fig. 1



INVENTOR.
TOSHIYUKI HAYAMI
BY
CAROTHERS & CAROTHERS
HIS ATTORNEYS

United States Patent Office 3,527,874 Patented Sept. 8, 1970

3,527,874

CROSSLINKED POLYETHYLENE OIL FILLED HIGH VOLTAGE POWERED CABLE

Toshiyuki Hayami, Osaka, Japan, assignor to Sumitomo Electric Industries, Ltd., Osaka, Japan, a company of Japan

Filed Sept. 14, 1967, Ser. No. 667,778
Claims priority, application Japan, Sept. 27, 1966, 41/90,009, 41/90,010
Int. Cl. H01b 7/34, 9/36
U.S. Cl. 174—24 3 Claims

ABSTRACT OF THE DISCLOSURE

Crosslinked polyethylene cable core for high voltage use made by extruding a crosslinked polyethylene insulating layer over a conductor, in which silicon oil or a mixed oil consisting of silicon oil and a hydrocarbon is always present on the interface between the conductor and the insulating layer to prevent the generation of corona from this electrically weak point.

The present invention relates to an improvement in crosslinked polyethylene high voltage cables.

With crosslinked polyethylene high voltage power cable cores manufactured by the extrusion process, it is not possible to completely eliminate gaps and injuries on the interface between the conductor and the insulation, or small voids formed in the insulation, or foreign bodies which find their way into the cable, etc., so that there may develop electrically weak points where the corona effect takes place upon application of a high voltage to the cable and, as a result, causes insulation breakdown.

The present invention is directed to the provision of high voltage power cables of excellent electrical properties, preventing the generation of corona at such electrically weak points.

This invention is characterized in that the core is provided with a crosslinked polyethylene insulating layer, and the interfaces of the conductor and this insulating layer are maintained filled with silicon oil. A semi-electroconductive layer is provided on the outside of the insulating layer.

A second characteristic of the present invention is as follows: Since silicon oil can hardly be absorbed in crosslinked polyethylene insulation, it may fail to give sufficient reinforcement to the weak points caused by voids and foreign bodies in the insulation, even though it can reinforce the weak points on the interfaces of the insulation and the conductor. On the other hand, hydrocarbon insulating oils such as polybutane, etc. are not good for practical use in cables because they cause crosslinked polyethylene to remarkably swell. In view of the above, it is the object of the present invention to obtain cables which are excellent both electrically and mechanically by giving full display to the merits of the two kinds of oil through mixing of a hydrocarbon oil and silicon oil at a certain ratio.

That is to say, the present invention is characterized in that when provision is made for a cable core having a central conductor and an insulating layer, the interfaces of the conductor and the insulating layer are filled with a mixed oil consisting of silicon oil and hydrocarbon oil and a semi-electroconductive layer is provided on the outside of the insulating layer.

Other objects and advantages appear hereinafter in the following description and claims.

The accompanying drawings show, for the purpose of exemplification without limiting the invention or the claims thereto, certain practical embodiments illustrating the principles of this invention wherein:

FIG. 1 is a sectional view of a power cable embodying the embodiments of the present invention.

FIG. 2 shows the $V-t$ characteristic curves of the cable of this invention and that of a conventional cable without oil.

FIG. 3 shows the $V-t$ characteristic curve of another embodiment of the present invention.

In FIG. 1, there is shown a hollow conductor **1** having an oil passage in its interior, and a cable insulating layer **2** formed integrally on the conductor by extruding crosslinked polyethylene insulation over the conductor. A semi-electroconductive layer **3** is placed on the outside of the cable and is formed by extruding semi-electroconductive polyolefine rendered electroconductive, for example by addition of carbon black. A metallic shielding layer **4** is made by winding copper tape or extruding lead, aluminum or the like over the semi-electroconductive layer **3**. An outer anti-corrosion layer of polyvinyl chloride, chloroprene or the like is provided over the shielding layer **4**. Silicon oil **6** is provided in the interior of the conductor **1**.

The method of manufacturing the cable of the present invention may be as follows: An uncrosslinked polyethylene insulating layer **2** containing a crosslinking agent, such as di-α-cumyl peroxide (D.C.P.), is extruded onto a conductor to cover the same, and crosslinking is caused to take place at a high temperature under high pressure, such as, respectively, 150° C. or higher and 10 atmospheric pressures or more. An outer sheath is then applied over cable cores made in the above-mentioned way, and then silicon oil is poured into one end of the conductor. For pouring the oil into the conductor, it is preferable to first previously evacuate the conductor interior with the object of filling the whole of the cable interior with the silicon oil. The semi-electroconductive layer **3** on the outside may be extruded together with the insulating layer **2** or may be applied after the insulating layer **2** has been crosslinked.

It is not always necessary that the conductor be a hollow conductor. A decision as to whether a hollow conductor or an ordinary conductor should be used should be made after considering the cable size, length, etc. The essential requirement is that silicon oil be present at all times between the conductor and the insulation.

As to the oil pressure regulating device, a suitable one may be selected after considering the installation condition of the cable, the quantity of the oil, etc. In some cases no such device is necessary.

FIG. 2 shows a comparison between the $V-t$ characteristic curve of the cable of the present invention and that of a crosslinked polyethylene cable without oil filling. The specimens are crosslinked polyethylene cable, 100 mm.^{2} with an insulation thickness of a 3 mm., Curve A is for the cable of the present invention and the curve B for the cable without oil filling.

The degree of swelling of the crosslinked polyethylene, the insulation layer **2** for the cables of the present invention, was measured by immersing it in silicon oil having a viscosity of 10 centistokes heated to weather temperature, 80° C., 100° C., 120° C. and 150° C. According to the results, the degree of swelling was 0.2% or less even in the case where the oil was heated to 150° C. (The limit for weight ratio measurement is 0.2% or more.)

It was also found that the electrical properties ($\epsilon \tan \delta \rho$) of crosslinked polyethylene immersed in silicon oil for one month remained entirely unchanged as compared with the same properties before immersion. In the above formula ϵ stands for the dielectric constant,

tan δ stands for the dielectric tangent and ρ the specific volume resistivity.

crosslinked polyethylene immersed in various oils is shown in Table II below.

TABLE II

	Hydrocarbon oil (polybutane, insulating oil for oil-filled cables)	Silicon oil	Silicon oil containing 3% hydrocarbon oil	Silicon oil containing 10% hydrocarbon oil
Degree of swelling at 80° C	2-3 times	Almost no swelling (0.2% or less).	3	10

The construction according to the present invention being as described above, silicon oil fills up thin layer gaps which may be present due to poor adhesion between conductor and insulation, scars which may exist on the conductor, etc., so that corona effect does not take place in interface between the conductor and the insulating layer. Cables having good properties with respect to high voltage applications are thus obtained, and it is possible to make the design stress higher than in the case of plastic cables without oil. The cables will have a longer life for high voltage use. Furthermore, as silicon oil is used, the insulation is not swollen due to the oil even at a high temperature, so that thermally stable cables may be obtained in the case of the present invention. Also, as silicon oil has almost the same dielectric characteristics as crosslinked polyethylene, the dielectric properties of the insulation are not impaired by the introduction of the oil. Thus it is possible to obtain cables having good dielectric properties of dielectric constant (ϵ), dielectric tangent (tan δ), etc. The cables have also a great advantage of a very large current carrying capacity, the product of dielectric constant and dielectric tangent being 1/10–1/30 times that of oil-filled paper cables. It is well known that crosslinked polyethylene having netted molecular structure as a result of molecular cross-linking has a greater resistance to heat than polyethylene. In the case of oil-filled cables like that of the present invention, the property to resist environmental stress cracking (E.S.C.) due to ambient medium is a problem. However, there is no need for concern in this connection because crosslinked polyethylene is far superior to polyethylene in this respect. As a result it enhances the dependability of the cables.

The Table I below shows the result of tests to compare the E.S.C. of polyethylene and crosslinked polyethylene.

TABLE I

Specimen	Time before cracking
Polyethylene (Low density)	Within 4 hours, 10 out of 10 specimens cracked.
Crosslinked polyethylene (above polyethylene subjected to crosslinking.)	300 hours: 10 of 10 specimens free from cracking.

The tests were made by immersing in silicon oil of 50° C. the specimens of polyethylene and crosslinked polyethylene which had been bent to a certain shape and measuring the time that passed before the specimens cracked. From the test results shown in the above Table I, it can be seen that crosslinked polyethylene has excellent resistance to E.S.C.

As described above, the cable made according to the present invention has excellent dielectric characteristics and has a good stability, it being possible to take a higher design stress than in the case of the plastic cables heretofore in use. It is therefore possible to apply the invention to high voltage power cables of 275 kv. or 500 kv. class.

Another embodiment of the present invention involves the filling of the cable conductor with a mixed oil of silicon oil and a hydrocarbon oil instead of silicon oil used in the first embodiment. The degree of swelling of

FIG. 3 shows a comparison of the $V-t$ characteristic of crosslinked polyethylene, 3 mm. thickness and 100 mm.^{2}. Curve A is for the cable according to the present invention filled with silicon oil with 5% hydrocarbon oil, curve B for the cable filled with silicon oil only, and curve C is for the cable without any oil filling. From the results shown in FIG. 3, it can be seen that the cable according to the present invention having curve A is superior to B and C with respect to the $V-t$ characteristic.

As previously explained, the cables of the present invention have better electrical properties because reinforcement can be provided not only in connection with electrically weak points on the interface between the conductor and the insulation but also in connection with electrically weak points caused by bubbles and foreign bodies which are liable to take place in the insulation by providing a mixture of silicon oil and hydrocarbon oil to continually maintain on the conductor side of a crosslinked polyethylene cable formed in one body by an extruder.

The quantity of a hydrocarbon oil added to silicon oil is preferably between 1% and 30%, inclusive.

I claim:

1. In a high voltage cable having improved dielectric properties, a conductor, a crosslinked polyethylene insulating layer extruded on said conductor, said cable characterized by an insulation oil mixture of silicon oil with a hydrocarbon oil content in the range of 1 to 30 percent supplied interior of said insulating layer to maintain said oil mixture in continuous attendance at the interface between said conductor and the inner surface of said insulating layer to prevent the generation of corona.

2. The high voltage cable of claim 1 characterized by a semi-electroconductive layer extruded over said insulating layer.

3. The high voltage cable of claim 1 characterized in that said conductor is stranded and has a hollow interior to receive said insulation oil mixture.

References Cited

UNITED STATES PATENTS

3,077,510	2/1963	Olds	174—25
3,244,800	4/1966	McLaughlin et al.	174—110
3,329,764	7/1967	Tanges	174—74
3,297,819	1/1967	Wetmore	174—127
3,078,333	2/1963	Kang	174—26 X
2,377,689	6/1945	Hyde	174—25 X

FOREIGN PATENTS

697,963	11/1964	Canada.
940,269	10/1963	Great Britain.
958,418	5/1964	Great Britain.

OTHER REFERENCES

Insulating Materials For Design and Engineering Practice, John Wiley & Sons, Inc., 1962, pp. 241–243.

LARAMIE E. ASKIN, Primary Examiner

A. T. GRIMLEY, Assistant Examiner

U.S. Cl. X.R.

174—15, 102, 120