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Pasini

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[54] **MIXED FLUID IMPREGNANT FOR OIL FILLED ELECTRIC CABLES**

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[52] **U.S. Cl.** ..... **174/25 C**; 174/17 LF; 252/66

[51] **Int. Cl.²**: **H01B 9/06**

[58] **Field of Search** ..... 174/17 R, 17 LF, 24, 25 R, 174/25 C, 25 P, 26 R, 23 C; 252/58, 59, 65, 66

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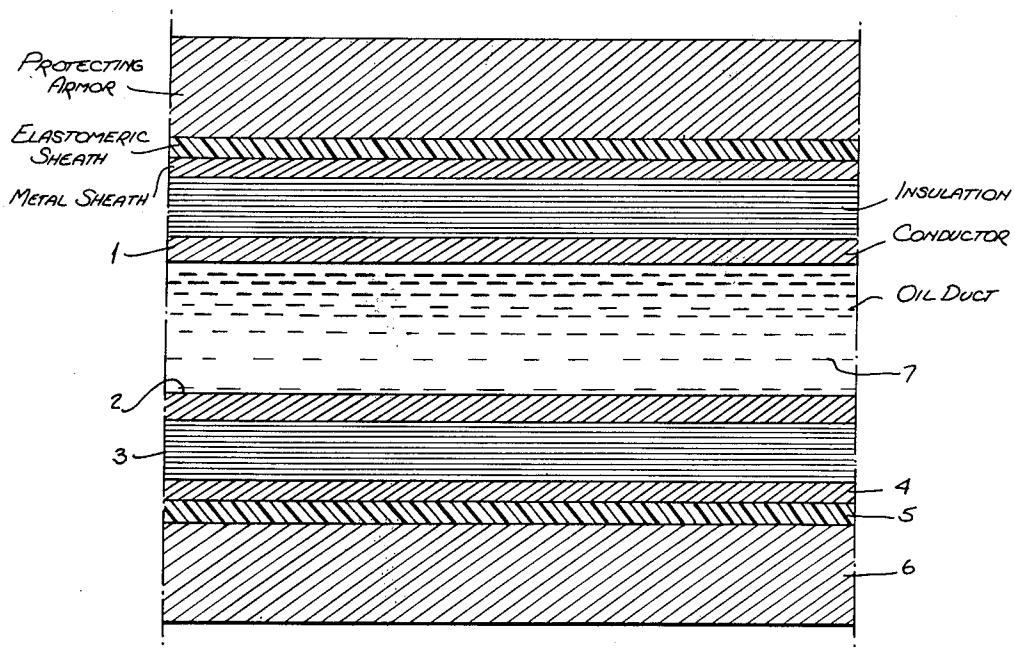
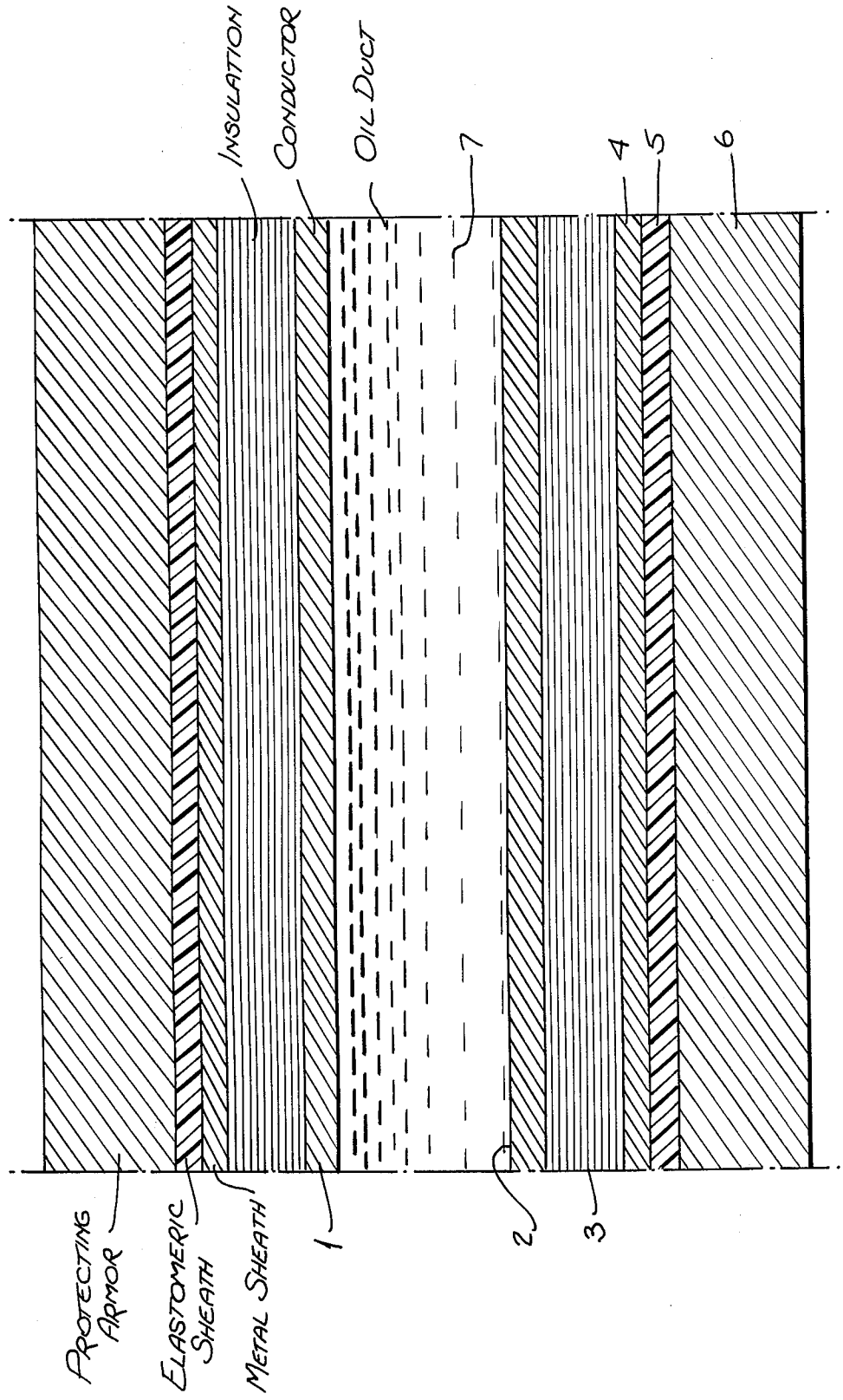
[57] **ABSTRACT**

An underwater electric power cable in which the normal liquid impregnant, such as alkylaryl derivatives, polybutenes, polyisobutylenes, mineral oils, etc. having a specific gravity less than the specific gravity of water, is mixed with a second liquid having a specific gravity higher than that of water in proportions which will provide a mixture having a specific gravity substantially equal to that of the water in which the cable is immersed. The second liquid is miscible with the first liquid, and has low dielectric losses, a low dielectric constant, a viscosity at least as low as that of the first liquid and a boiling point of at least 150°C. A halogenated hydrocarbon, such as hexachlorobutadiene, is a preferred second liquid.

8 Claims, 1 Drawing Figure




INSULATION
CONDUCTOR
OIL DUCT
7
4
5
6
PROTECTING ARMOR
ELASTOMERIC SHEATH
METAL SHEATH
1
2
3

MIXED FLUID IMPREGNANT FOR OIL FILLED ELECTRIC CABLES

The present invention relates to an improvement in power cables of the type known as "oil-filled cables."

The expression "oil-filled cables" refers to cables having a composite insulation formed by paper and by a liquid dielectric and of the self-contained type. In such cables, said liquid dielectric can flow outwardly or inwardly with the expansion or contraction cycles which may happen due to the thermal variations of the cable, the solid insulation of the cable being thereby continuously and completely maintained in an impregnated condition.

Both synthetic products, e.g., alkyl-aryl derivatives, polybutenes and/or polyisobutylenes, etc., and products of natural origin, e.g., mineral oils, have been used and are at present employed as liquid dielectrics in such cables. The expression "fluid impregnants" will be used in the present description to designate the various known types of liquid dielectrics, both synthetic and natural.

Among the fluid impregnants of synthetic origin, preferred impregnants are alkylbenzenes, the employment of which is known from Italian Pat. No. 594,475 which indicates that dodecylbenzene is particularly suitable as an impregnant for cables of the oil-filled type for high voltages.

Italian Pat. No. 809,256 discloses the use of alkylbenzenes other than dodecylbenzene, which are characterized by the fact of having, with respect to the latter, a considerably lower viscosity. The same patent suggests, as most appropriate alkylbenzenes, those having a viscosity ranging between 2 and 10 centiStokes at 20°C and a flash point in open cup (Marcusson) higher than 100°C.

The extremely low viscosity of the latter impregnants permits the limiting of the size of the transient pressure variations and consequently, permits limiting in an appropriate manner, the service pressure in cables of long length, as, for example, those for submarine use.

The alkylbenzenes disclosed in said Italian patents have at 20°C a specific gravity ranging, as an average, from 0.85 to 0.88 g/cm^3.

Other synthetic products which can be used as impregnants for oil-filled cables are polybutenes and/or polyisobutylenes, materials whose specific gravity at 20°C varies between 0.84 and 0.90 g/cm^3 according to their mean molecular weight.

Among the products of natural origin, mineral oils are known, which, as a function of their chemical structure and of their mean molecular weight, have a specific gravity at 20°C which is generally between 0.85 and 0.90 g/cm^3.

From the foregoing, it will be noted that all the fluid impregnants, be they natural or synthetic, have a specific gravity lower than that of water, and, in particular, than that of sea water, which, at 20°C, can be found to have a specific gravity between 1.02 and 1.03 g/cm^3.

For cables to be laid underwater, the specific gravity difference between the impregnant and the water receiving the cable produces, in the immersed cable and the water at the same level, a difference in the hydrostatic pressure between the inside of the cable and the water surrounding it. The effects of this unbalance between the outer and the inner pressures become critical when the cables are laid in deep sea and have, therefore, a relatively long length. In fact, the lead forming the cable sheath tends to collapse under the outer hydraulic pressure which is greater than the inner one, and this requires a compensatory increase of the inner service pressure of the cable.

This expedient, namely, an increase of the pressure inside the cable, can prove difficult in practice when said inner pressure is already relatively high to take into account the transient pressure variations related to cables of long length.

The present invention has, as one object, the elimination of the hereinbefore-mentioned disadvantages by providing an oil-filled cable in which the inner hydrostatic pressure is balanced as much as possible with respect to the pressure of the receiving ambient. This object is achieved by adding to the usual fluid impregnant of the cable a liquid having a specific gravity significantly higher than that of the water receiving the cable and in such a proportion as to bring the specific gravity of the fluid impregnant very near or even equal to the specific gravity of the water of said receiving ambient.

Obviously, the liquid to be added to the fluid impregnant must be mixable, or miscible, with the latter and must have appropriate dielectric characteristics, in particular, low dielectric losses and a low dielectric constant. It must also have suitable physical characteristics, such as, a viscosity equal to or lower than that of the fluid impregnant to which it is added and has a reasonably high boiling point, preferably higher than 150°C, to avoid evaporation thereof during degassing of the mixture.

The main object of the present invention is to provide improved underwater power cables, in particular, submarine cables intended for high voltages, which comprise natural or synthetic products as fluid impregnants, the fluid impregnant of the cable being mixed with a liquid dielectric which is miscible with the impregnant and which has appropriate dielectric and physical characteristics. In particular, the liquid dielectric has a specific gravity higher than the specific gravity of the water of the ambient intended to receive said cables, and is mixed with the fluid impregnant in such proportions as to bring the specific gravity of the mixture to a value near that of the specific gravity of the water of said ambient.

Other objects and advantages of the invention will be apparent from the following detailed description of a preferred embodiment thereof, which description should be considered in connection with the accompanying drawing, the single FIGURE of which illustrates, in longitudinal cross-section, a portion of a known type of submarine cable. Although one type of cable is illustrated, it will be understood that the invention may be used with cables of a construction different from the cable illustrated.

In the drawing, a hollow conductor **1** defines an oil duct **2**. Around the conductor **1** there is insulation **3** formed by layers of paper which are impregnated with oil under pressure. The insulation **3** is surrounded by a metal sheath **4** which in turn is surrounded by an elastomeric sheath **5**. The cable is protected by a layer or layers **6** of a known type, such as frettage, armor, etc. The oil duct **2** is filled with the oil mixture **7** of the invention and this mixture is also supplied to the insulation **3** from the duct **2** in a known manner.

In a preferred embodiment of the invention, said liquid dielectric is a halogenated hydrocarbon. In fact,

it has been found that the halogenated hydrocarbons are those which best meet the specific gravity and mixability requirements necessary to carry the invention into effect.

Among halogenated hydrocarbons, chlorinated hydrocarbons are of particular interest, and among the latter, hexachlorobutadiene is surprisingly suitable and has the following characteristics:

Specific gravity at 20°C, g/cm³: 1.68
Boiling point at 760 mm Hg, °C: 210–220
Kinematic viscosity at 20°C, cSt: 2
Dielectric losses at 50Hg, 20°C, tan δ: 0.0005
Dielectric constant at 20°C, Σ_r: 2.5.

Besides possessing general physical characteristics appropriate for the stated uses, hexachlorobutadiene is perfectly mixable, in any proportion, with the natural and synthetic impregnants commonly employed in oil-filled cables.

By way of example, the variation of the specific gravity of mixtures constituted by linear decylbenzene and hexachlorobutadiene of commercial grade is set forth hereinafter as a function of the weight percentage of added hexachlorobutadiene:

Decylbenzene Wt. %	Hexachlorobutadiene Wt. %	Specific Gravity at 20°C g/cm³
100	0	0.852
95	5	0.878
90	10	0.904
85	15	0.930
80	20	0.956
75	25	0.982
70	30	1.008
65	35	1.034

The percentages set forth hereinbefore are, of course, illustrative only for the specific materials tested. It is to be understood that, as a function of the type of fluid impregnant considered and of its specific gravity, it will be necessary to determine for each case the percentage of hexachlorobutadiene to be added to the fluid impregnant to obtain a mixture having the desired gravity. It has been found that the percentage of hexachlorobutadiene necessary to obtain mixtures having a specific gravity approximately that of sea water (1.02 – 1.03 g/cm³ at 20°C) is smaller than 50 percent by weight of all of the fluid impregnants generally used.

Although a preferred embodiment of the present invention has been described and illustrated, it will be understood by those skilled in the art that various modifications may be made without departing from the principles of the invention.

What is claimed is:

1. A liquid-filled underwater, electric power cable comprising a conductor surrounded by insulation, said insulation being impregnated with a mixture of a first liquid having a predetermined viscosity, a predetermined boiling point, a specific gravity less than that of water, low dielectric losses and a low dielectric constant with a second liquid miscible with said first liquid, a viscosity at least as low as that of said first liquid, a boiling point at least as high as 150°C, a specific gravity higher than that of water and dielectric losses and a dielectric constant respectively substantially at least as low as said dielectric losses and said dielectric constant of said first liquid, said first liquid being at least 50 percent by weight of the mixture and the weight of the second liquid being at least equal to the amount thereof required to provide a specific gravity of the mixture substantially equal to the specific gravity of water.

2. A cable as set forth in claim **1** wherein said first liquid is selected from the group consisting of alkyl-aryl derivatives, polybutenes, polyisobutylenes, and mineral oils and said second liquid is a halogenated hydrocarbon.

3. A cable as set forth in claim **2** wherein said first liquid is an alkylbenzene.

4. A cable as set forth in claim **3** wherein said second liquid is a chlorinated hydrocarbon.

5. A cable as set forth in claim **4** wherein said chlorinated hydrocarbon is hexachlorobutadiene.

6. A cable as set forth in claim **5** wherein said first liquid is decylbenzene and the weight percentage of hexachlorobutadiene is from 20 up to 50 percent of said mixture.

7. A cable as set forth in claim **1** wherein the specific gravity of said first liquid is between 0.84 and 0.90 g/cm³ and the viscosity of said first liquid is between 2 and 30 centiStokes at 20°C.

8. An electric power cable fluid impregnant comprising at least 50 percent by weight of a first liquid having a predetermined viscosity, a predetermined boiling point, a specific gravity less than that of water, low dielectric losses and a low dielectric constant mixed with a second liquid miscible with said first liquid, a boiling point at least as high as 150°C, a specific gravity higher than that of water, and dielectric losses and a dielectric constant respectively substantially at least as low as said dielectric losses and said dielectric constant of said first liquid, the weight percent of said second liquid being at least sufficient to provide a specific gravity for the mixture which is substantially equal to the specific gravity of water.

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