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Electric power cable impregnated
with insulating liquid

- The present invention is concerned with electric power cables of the kind comprising a conductor provided with at least one longitudinal conduit and surrounded by solid layered insulation, the layered insulation being
- 5 impregnated with and the conduit being filled with an insulation liquid. The invention is particularly concerned with electric cables of this kind which are suitable for underwater use, particularly for laying at great depths.
- 10 The insulation liquid used in cables for submarine use should have at least the following properties:
- its density should be as close as possible to that of sea-water so as to prevent or minimise any difference
 - 15 between the hydrostatic pressure inside and outside the cable which could cause stress in the armouring and the covering sheath of the cable. The greater the depth at which the cable is laid, the greater this problem becomes;
 - the viscosity of the insulation liquid should be such
 - 20 that whatever the temperature to which the cable is subjected and whatever the position and attitude of the cable, the insulation liquid in the conduit should be able to move through the cable;
 - the dielectric loss factor, $\text{tg} \delta$, of the insulation
 - 25 liquid which affects the efficiency of power transmission,

must be low and stable over extended periods of time;
- the gas absorption capacity of the insulation liquid, known in this art as "gassing", should be good so as to minimise the risk of breakdowns.

5 There are very few liquids which have this combination of properties and which are, therefore, suitable for use as insulation liquids in cables of the kind referred to. There are even fewer liquids which are suitable for use as insulation liquids in submarine
10 cables which are to be laid at great depths since in this usage the density and dielectric loss factor become particularly important. The density must be as near as possible to that of sea-water so as to reduce as far as possible the mechanical stress on the cable and dielectric
15 loss factor must be as low as possible so that the longest possible lengths of cable can be laid.

 The compounds which have been used as insulation liquids in submarine electric cables of this kind are mineral oils and alkylbenzenes in which the alkyl group
20 contains from 9 to 12 carbon atoms, such as decylbenzene. The properties of these compounds approximate fairly well to those required, but these compounds are still some way from providing the optimum combination of properties, particularly as required for submarine cables to be used
25 at great depths.

 It has been proposed in European Patent Specification 1494 to use certain aryl alkanes having at least two separate (uncondensed) benzene rings and from one to six aliphatic non-cyclic carbon atoms per benzene
30 ring, including 1-phenyl-1-xylyl-ethane and mono-isopropyl-biphenyl, as the insulation liquid in power cables comprising layered insulation formed of wound polyolefin tape or paper/polyolefin laminate tape.

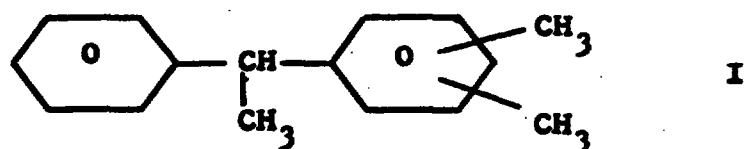
 British Patent Application 2062671A describes the
35 use of inter alia 1-phenyl-1-xylyl-ethane as the

insulation liquid in power cables comprising layered insulation formed of wound synthetic resin tape, such as polypropylene tape, alone or a combination of such tape and paper tape.

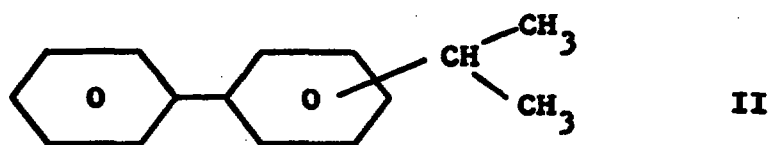
5 We have now found that the use in combination of paper tape alone to form the layered insulation and of 1-phenyl-1-xylyl-ethane and/or mono-isopropyl-biphenyl as the insulation liquid in a power cable of the kind in question provides cables which are parti-
10 cularly suitable for submarine use.

According to the present invention, therefore, there is provided an electric power cable for submarine use, which comprises an inner conductor having at least one longitudinal conduit therethrough, and solid layered
15 insulation around the conductor, the conduit being filled with an insulation liquid and the solid layered insulation being impregnated therewith, the layered insulation consisting of layers of wound paper tapes and the insulation liquid consisting of at least one compound of the formula:

20



25 or



30 In order that the invention may be more fully understood, a preferred embodiment of electric power cable will now be described, by way of example only, with reference to the single Figure of the accompanying drawing which is a longitudinal section of a length of
35 the cable.

The cable shown in the Figure is of conventional construction and comprises, from the outside inwards, an armouring layer 1, a sheath of elastomeric material 2, and a tubular metallic sheath 3 which is suitably formed 5 of lead. Coaxially within the sheath 3, there is located a tubular copper electric conductor 4, the space between the outside of the conductor 4 and the metal sheath 3 being filled by a solid layered insulation 6 formed of a plurality of windings of paper tape which is 10 impregnated with the insulation liquid. The interior of the tubular conductor 4 provides a conduit 5 which is filled with the same insulation liquid as is present in the layered insulation 6.

The compounds of formula I used according to
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the invention are 1-phenyl-1-xylyl-ethane and single compounds of this formula or mixtures of isomers of this formula can be used. The compounds of formula II are mono-isopropyl-diphenyl and single compounds of this formula or mixtures of isomers of this formula can be used. The preferred isomers of formula II are para- and meta- mono-isopropyl-diphenyl. Mixtures comprising one or more compounds of formula I and one or more compounds of formula II can also be used.

Of these compounds, mono-isopropyl-diphenyl is preferred as it has very good resistance to ageing in the presence of metals, such as copper and lead.

The following Table summarises certain of the chemical and physical characteristics of the compounds of formulae I and II and the same characteristics of the most widely used insulation liquid for cables, decylbenzene.

Table

Characteristic	Phenyl-xylyl-ethane	Mono-iso-propyl-diphenyl	Decylbenzene
Density at 20°C, g/cc	0.9874	0.9841	0.8613
Flash point in open cup, °C	153	155	124
Viscosity at 20°C, cp.	8.3	9.5	5
Dielectric loss factor, tgδ, at 100°C	0.0003	0.0003	0.0001

It will be seen from the above Table that the density of the compounds of formulae I and II is nearer to that of sea-water than that of decylbenzene. A submarine cable including a compound of formulae I or II

will, therefore, be subject to less mechanical stress than one containing decylbenzene. It is accordingly possible to reduce the armouring of a cable, while obtaining the same safety factor, as compared with an
5 otherwise similar cable containing decylbenzene as the insulation liquid.

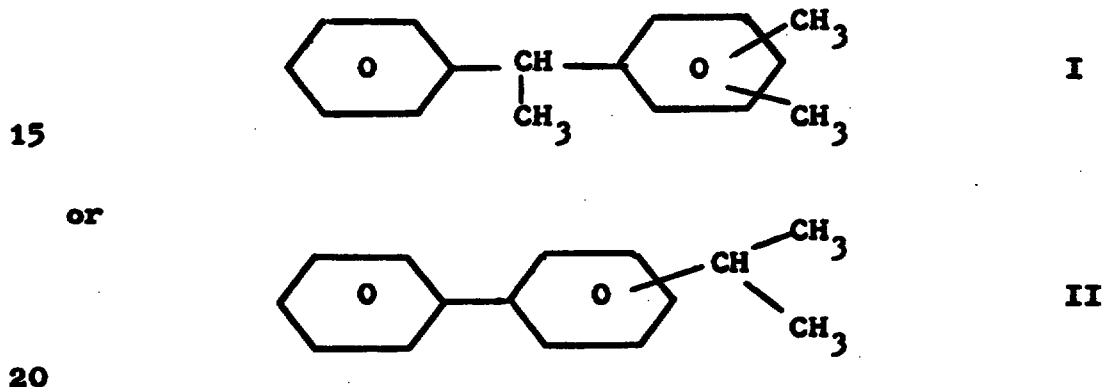
At the same time, the dielectric loss factor of the compounds of formulae I and II is substantially equivalent to that of decylbenzene.

10 A further advantage of the compounds of formulae I and II is that they have a high gas absorption capacity so that they provide a substantial margin of safety against the risk of breakdown.

The compounds of formulae I and II have higher
15 flash points than decylbenzene. This enables the manufacturing process of the cables to be simplified and reduces the risk of fire during manufacture of the cables.

CLAIMS:

1. An electric power cable for submarine use, which comprises an inner conductor having at least one longitudinal conduit therethrough, and solid layered insulation around the conductor, the conduit being filled with an insulation liquid and the solid layered insulation being impregnated therewith, the layered insulation consisting of layers of wound paper tapes and the insulation liquid consisting of at least one compound of the formula:



2. An electric cable according to claim 1, in which the insulation liquid is a mixture of one or more compounds of formula I and one or more compounds of formula II.
3. An electric cable according to claim 1, substantially as herein described with reference to the accompanying drawing.

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