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(72) Inventor: Narve Skaar Pedersen



## (54) FLAME RESISTANT CABLE STRUCTURE

(71) We, A/S NORSK KABELFABRIK, a company incorporated in accordance with Norwegian law, of Kjerraten 16, N-3001 Drammen, Norway, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a flame resistant cable structure comprising one or more electrical conductors. The application of cable structures embodying the invention is both in the field of telecommunication and power supply.

The requirements which electrical installation on oil drilling platforms and/or production platforms have to meet, are in many ways stricter than those of conventional installations on mainland sites. The reason for this is that the conditions concerning a possible fire on such platforms are substantially more hazardous than the corresponding conditions on the mainland, and proper functioning of the current-carrying cables upon the occurrence of fire is therefore of very great importance for the safe rescue of the crew on the platforms. If a fire should occur on a platform, many of the most important components on board are likely to be connected through cables extending through the area or areas of fire. The fire-resisting ability of such cables is therefore very important, so that the cables can perform their functions as long as possible, without the current supply, the control systems, the communication systems etc. breaking down, and thereby paralysing the rescue work. Cables which are used for electrical installations on drilling platforms must therefore be designed while bearing in mind that besides being resistant to flames and heat, they must not contribute to the spreading of the fire or develop noxious gases at extreme temperatures.

Furthermore, the cables must be designed with a view to achieving sturdy mechanical properties, so that even during ordinary working conditions on the platforms they remain operable throughout their designed lifetime.

According to this invention there is provided a flame resistant cable structure, comprising

one or more conductors, a micatape surrounding the or each conductor, an insulating layer comprising heat resistant rubber surrounding the micatape, a layer of thermoplastic elastomer filled with aluminium hydroxide surrounding the insulating layer, a braided metal armour on the outside of the thermoplastic elastomer, an unbraided glass fibre layer positioned between the thermoplastic elastomer layer and the braided metal armour, and an outer sheathing comprising chlorine sulphonated polyethylene or ethylene propylene rubber.

In the following the invention will be further described, by way of example, reference being made to the drawing, which illustrates various flame resistant cable structures embodying the invention. In the drawing:

Figure 1 is a perspective view of the end of a cable structure embodying the present invention, with parts thereof cut away to show the components of the structure.

Figure 2 is a perspective view similar to Figure 1, of another cable structure embodying the invention.

Figure 3 is a view similar to Figures 1 and 2, and illustrates a further cable structure embodying the invention.

Figure 4 is on a larger scale a cross-section of a conductor having a two-layer insulation.

Figure 5 is on a smaller scale a diagrammatic cross-section through a conductor pair surrounded by a plastic tape.

Figure 6 is a diagrammatic cross-section through a conductor pair having their own earth conductor and screen.

Figure 7 is a diagrammatic cross-section which illustrates four conductor pairs having individual earth conductors and a common screen.

Figure 8 is a diagrammatic cross-section illustrating two conductor pairs which, besides having their own earth conductor, also have a common earth conductor and a common screen.

Figures 9 and 10 illustrate alternative embodiments of the conductor pairs.

Figure 11 is a cross-section through another cable embodying the invention.

The cable structure which is illustrated in

Figure 1 and which is generally designated by 1, comprises insulated single conductors 2, which are shown on a larger scale in Figure 4. As seen from Figure 4, the single conductors 2, which may be annealed copper, are surrounded by a micatape 3 and an insulating layer 4 of heat resistant rubber. The conductors may be twisted together two by two into pairs and kept separated from the other conductors by means of a plastic tape, as is illustrated at 5 in Figures 5 and 6, and together with each of the wound conductor pairs an earth conductor 6 may be included, as is illustrated in Figures 1 and 6. This earth conductor may of course be omitted, as is illustrated in Figure 5. For clarity the plastic tape 5 is omitted in Figure 1.

Around each conductor pair and an earth conductor 6 there is wound an aluminium-plastic laminate 7 serving as an electric screen for the individual conductor pairs. Such a laminate is illustrated both in Figure 1 and Figure 6, and around these pairs of screened conductors there is wound a common polyester tape 8 (Figure 1).

Outside the tape 8 there is deposited a layer 9 of thermoplastic elastomer which is filled with aluminium hydroxide, and on top of this layer there is wound an unbraided glass fibre mat 10 which, together with the thermoplastic elastomer 9, is embraced by a braided metal armour 11. The outer sheathing of the cable structure is designated by 12 and is manufactured from chlorine sulphonated polyethylene.

Experiments have shown that even if a cable designed as described above is subjected to fire, the electric properties will be maintained over very long periods of time even at very high temperatures. A cable of a type similar to that described above has been subjected to flame tests at temperatures of 650, 800 and 1100°C respectively. During the test the cable was placed under electrical tension, and for all temperatures the lapse of time prior to the electrical break-down of the cable was more than 30 minutes. Further, a cable as described above has been subjected to a flame test according to IEC 331, i.e. to 750°C for a period of 3 hours. During the test the cable was under full electrical operating voltage. Neither during the flame test nor during the subsequent voltage test did any faults occur.

Vibration experiments have also been carried out for a flame tested cable of the above described type, cable samples subsequent to the flame test being placed in a vibration apparatus and subjected to vibration in the frequency range of 10 - 100 Hz for one hour, the cable sample concurrently being subjected to normal operating voltage. The test results indicated that no electric faults could be traced after the vibration test.

The cable sample was thereafter insulation tested, which indicated a dielectric strength of approximately 1 - 1.6 kV.

During the flame test it was observed that

the cable sample was burning very steadily. No substantial degree of temperature rise in the interior of the cable was observed and neither did any swelling of the cable occur. This is due to the fact that the thermoplastic elastomer is filled with aluminium hydroxide which at approximately 150°C evaporates H<sub>2</sub>O with subsequent cooling of the cable components located inside it.

During fire the thermoplastic material 9 and the layer of unbraided glass fibre 10 will form a pulverulent ash which insulates the electrical conductors against excess temperatures, said ash also affording an excellent support for the conductors. The pulverulent ash is in turn kept in position by the metal armour 11 located between the outer sheathing 12 and the thermoplastic elastomer 9 with the glass fibre mat 11. Besides, a comparatively low smoke development was observed during the test.

From further observations made during the tests it has been ascertained that during the tests the combustion energy of the cables is approximately 10% below that of corresponding known cables. The corrosive effect of the gases generated at moderate temperatures, i.e. at 150 - 200°C, is substantially lower in the cable illustrated compared with known cables. Similarly the generation of CO of the new cable is substantially lower than that of known cables. This is also the case with the generation of HCl at 280, 650 and 1000°C.

Experiments have also shown that the development of dense smoke during fire is much lower in connection with the cable illustrated compared with conventional cable structures.

Besides, the present cable structure meets all the conditions required by IEC-standards inclusive IEC 331 (fire test for mineral insulated cables).

Preferably a synthetic rubber such as ethylene propylene rubber or silicone rubber is chosen as insulation (4) for the individual conductors.

As mentioned the thermoplastic elastomer (9) which serves as a filling sheathing and which may be an ethylene propylene elastomer, is filled with aluminium hydroxide for achieving the desired thermal properties. This composition is especially developed for the present cable and has an oxygen index larger than 35%. Besides giving the cable a good mechanical strength, this filling sheathing also provides support for the individual conductors. During fire, the filling sheathing acts as a cooling and heat insulating element for the screen laminate (7) and the individual conductors. The ageing properties of the material are very good compared with e.g. the outer layer of chlorine sulphonated polyethylene (12).

The mechanical protection is maintained by the metal armour (11) and the outer sheathing (12) of chlorine sulphonated polyethylene. The outer sheathing has an oxygen index higher than 35% and is the cable component generat-

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ing HCl when the cable is subjected to flames and elevated temperatures. Chlorine sulphonated polyethylene has, however, good properties as to mechanical strength and resistance against oil. By replacing the outer sheathing 12 of chlorine sulphonated polyethylene with a sheathing of ethylene propylene rubber the generation of HCl during fire may be reduced.

In addition the cable exhibits bending properties and strength properties which render it very well suited for installations in marine working environment.

Another embodiment of the cable structure is illustrated in Figure 2. This differs from the structure according to Figure 1 in that the individual conductors 2', which are kept together two by two by means of respective plastic tapes 5', have a common plastic tape 13 and a common screen 14 wound thereabout. A single common earth conductor 6' is positioned between the plastic tape 13 and the screen 14. This embodiment is further illustrated in Figure 9 and is to be regarded as a screened twisted structure.

In Figure 3 there is illustrated a third embodiment of the cable and this differs from the embodiment of Figure 2 only in a different arrangement of the individual conductors 2''. These are here arranged arbitrarily, but have wound thereabout a tape 13' of polyester and a screen 14'. Between the screen 14' and the tape 13' there is as before provided a common earth conductor 6''. The embodiment is further illustrated in Figure 10. It is to be understood that the difference between the embodiments of Figures 9 and 10 is the use of plastic tape 5' in Figure 9, whereas this is omitted in the embodiment of Figure 10, the inner circles representing the circumference to be occupied by the twisted conductor pairs.

In Figures 7 and 8 there are illustrated alternative embodiments as to how the cable pairs can be arranged in four or two pairs respectively, within a common screen 15. In Figure 7 each pair of the individual conductors 2'' has its own earth conductor 16, whereas in the embodiment according to Figure 8 a common earth conductor 17 is added. In Figures 7 and 8, 16' designates a metal foil, and in Figure 8, 18 designates the circumference occupied in the cable by the individual pairs with earth conductor. If desired, 18 may designate a plastic tape.

In Figure 11, which illustrates a simplified cross section of a cable structure embodying the invention, 12 designates as before the outer sheathing of either chlorine sulphonated polyethylene or ethylene propylene rubber which surrounds the braided armour 11. This in turn embraces the insulating layer 9 of thermoplastic elastomer. This layer fills the possible empty spaces which may exist between the conductor pairs, said layer forming a baking material for the non-braided glass mat 10.

If the cable is used as a three-conductor

power cable, three conductors of the type illustrated in Figure 4 and being surrounded by micatape embraced by the layer of heat resistant rubber insulation, are twisted together and surrounded by the thermoplastic elastomer 9, the non-braided glass mat 10, the braided armour 11 and the outer sheathing 12, as illustrated in Figure 11. Any earth conductors and screens may then be deleted.

The cables illustrated meet the fire resistance conditions required by IEC, experiments having proved the cables to have fire resisting properties superior to those of previously known cables of similar type.

Compared with conventional cables the cable structure exhibits undisturbed functional properties during and after a fire even during heavy vibration. Similarly the development of dense smoke, CO or HCl from the cable during fire is substantially reduced.

WHAT WE CLAIM IS:—

1. A flame resistant cable structure, comprising one or more conductors, a micatape surrounding the or each conductor, an insulating layer comprising heat resistant rubber surrounding the micatape, a layer of thermoplastic elastomer filled with aluminium hydroxide surrounding the insulating layer, a braided metal armour on the outside of the thermoplastic elastomer, an unbraided glass fibre layer positioned between the thermoplastic elastomer layer and the braided metal armour, and an outer sheathing comprising chlorine sulphonated polyethylene or ethylene propylene rubber.

2. A structure as specified in claim 1, in which the cable is a three-conductor power cable, wherein the three conductors, each of which is surrounded by micatape embraced by a layer of heat resistant rubber insulation, are twisted together and surrounded by the thermoplastic elastomer filled with aluminium hydroxide.

3. A structure as specified in claim 1, including at least two conductors, each of which is covered by a micatape and heat resistant rubber, surrounded by pairs by a plastic tape, in which an earth conductor extends along each pair of conductors and together with the respective conductor pair is embraced by a metal foil screen.

4. A structure as specified in claim 3, in which bundles of screened conductor pairs are embraced by a common metal foil.

5. A structure as specified in claim 1, including at least two conductors, each of which is surrounded by a micatape and a heat resistant rubber surrounded by pairs by a plastic tape, and in which bundles of conductor pairs with a common earth conductor are surrounded by a common metal foil screen.

6. Structure as specified in any of claims 1 to 5, in which the insulating layer embracing the individual conductor(s) is ethylene propylene rubber.

7. Structure as specified in any of claims 1 to 5, in which the insulating layer embracing the individual conductors is silicone rubber.

8. A cable structure substantially as described hereinbefore with reference to Figure 1 or 2 or 3 of the accompanying drawings.

(REDDIE & GROSE)  
Agents for the Applicants,  
16 Theobalds Road  
London WC1X 8PL

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