

[54] **LOW CAPACITANCE AND LOW LEAKAGE CABLE**

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[51] Int. Cl. **H01b 7/04**

[58] Field of Search **174/110 F, 116, 121 A**

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[57] **ABSTRACT**

A cable is described in which elongated fillers and elongated conductors are arranged such that the conductors are placed in the interstices of the fillers to provide a low capacitance and low leakage cable. In addition, a cylindrical wall may be provided surrounding the cable, with the wall and fillers being comprised of a flexible material having a low dielectric constant and having a substantial flame-retardant capability.

9 Claims, 3 Drawing Figures

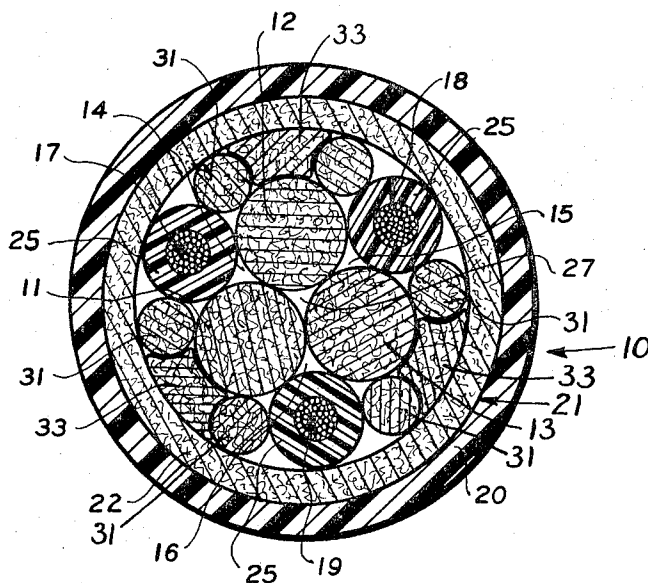


FIG. 1.

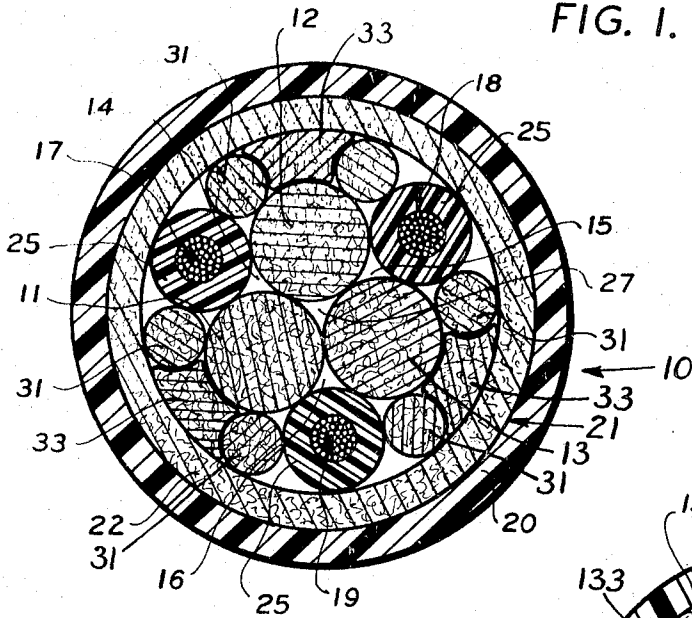


FIG. 2.

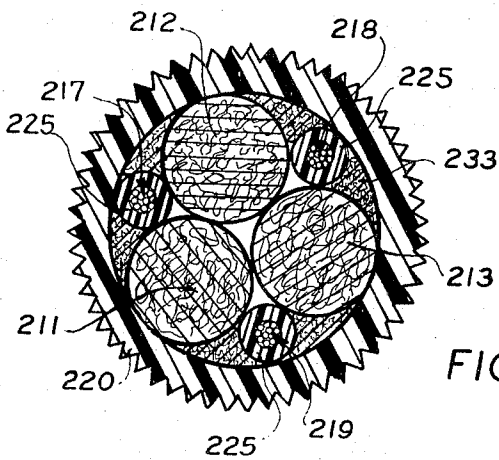
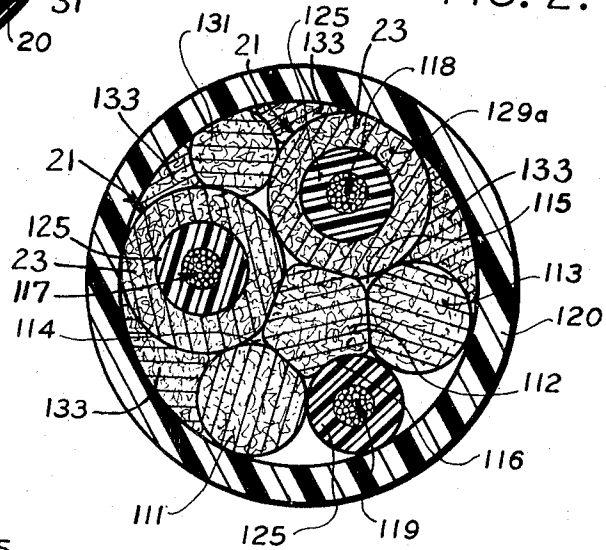


FIG. 3.

LOW CAPACITANCE AND LOW LEAKAGE CABLE

This invention relates to electrical cables having an outer protective jacket or sheath with three or more internal conductors separated by longitudinally extending fillers and having low capacitance and low leakage characteristics.

The present invention is particularly directed to, but is not limited to, cables commonly designated as low leakage SJT cables, which must meet rigorous standards of low capacitance and of low leakage between conductors and low leakage through the outer protective jacket. Also, such cables must meet rigid standards of flammability resistance and crush resistance.

Instrument manufacturers, for example, those that make electronic medical instruments for connection by such cables to wall-mounted electrical outlets have a market preference for low capacitance and low leakage cables having diameters less than one-half inch. However, the requirements for such a small diameter for such a cable is at cross purposes with the goal of providing a low capacitance and low leakage cable, as the greater the spacing between the conductors the lower the capacitance will be therebetween. Also, a larger wall thickness for the cable jacket will assist in reducing leakage through the cable jacket.

Further complicating the design of such SJT cables is the desirability of making the cable flexible. Because the cable has three conductors and filler material therein, it will have a certain stiffness which should not be compounded by the use of a stiff jacket material. While a good resistant jacket may be from polyvinyl chloride (PVC), the addition of sufficient plasticizer to the PVC to increase its flexibility results in an increased dielectric constant and leakage through the jacket.

Additionally, complicating the design of such SJT cable is the requirement that it withstand physical abuse such as being rolled over by hospital carts or other heavy equipment without shorting or increasing substantially the capacitance and/or leakage of a cable. If the cable were damaged in this manner, a high leakage current could endanger a hospital patient in the event of a failure of a ground system for the cable.

A conventional low leakage SJT cable comprises a relatively stiff jacket of polyvinyl chloride severely limiting its flexibility and four elongated cord fillers of solid polyethylene within the jacket and coextensive with three internal conductors. The solid polyethylene fillers have been found to have dielectric constants of about 2.3; and hence exhibit a relatively high inter-lead and lead-to-ground capacitance. Additionally, it has been found that the solid polyethylene cords have poor flame resistance and as a result could be easily damaged by flames.

Accordingly, an object of the present invention is to provide a new and improved electrical cable of the foregoing kind.

Other objects and advantages of the invention will become apparent to those skilled in the art from the following description taken in connection with the accompanying drawings in which:

FIG. 1 is a cross-sectional view of an electrical cable embodying the features of the invention;

FIG. 2 is a view similar to that of FIG. 1 illustrating another embodiment of the invention; and

FIG. 3 is a view similar to FIG. 1 illustrating a further embodiment of the invention.

As shown in the drawings for purposes of illustration, the invention comprises a cable 10 having at least three elongated insulating fillers 11, 12 and 13 in the form of elongated rods or cords defining three longitudinally extending recesses 14, 15 and 16 for receiving three elongated electrical conductors 17, 18 and 19 which extend longitudinally of the cable 10. Surrounding the filler cords and the electrical conductors is an outer encircling jacket 20 of protective material which resists abrasion, cutting and flames.

Heretofore, in known and conventional SJT low leakage cables having three such internal conductors within an outer surrounding jacket, the conductors have been separated by four solid fillers such as cords of solid polyethylene. In this prior art cable, one of the solid polyethylene fillers was located at the central axis for the cable and the other three solid polyethylene fillers were spaced equal-angularly about and abutting the centrally located cord. The outer three fillers extended radially to the outer jacket and were spaced circumferentially leaving three spaces into each of which was placed one of the respective conductors. The solid polyethylene fillers have a dielectric constant of about 2.3. The inter-lead leakage was found to be about five or six microamps per 10-foot length which is close to the upper limit of the standard. The outer jacket of this conventional cable was made of PVC with little plasticizer therein resulting in a stiffer jacket but reducing the jacket's dielectric constant to about 3 or 4; but nonetheless, the cable's leakage through the jacket was about 16 microamps per 10-foot length. This also is at the upper end of the standard.

While the outer PVC jacket of the above-described conventional SJT cord has some resistance to flammability, the inner solid polyethylene fillers burn quite readily making this cord subject to failing a standard flammability test. Moreover, in this prior art cable, the conductors were aligned with slippage planes formed between the outer orbitally positioned polyethylene fillers and the inner centrally located polyethylene cord. Such slippage planes allow conductors to be squeezed inwardly toward each other thereby increasing the likelihood of high inter-lead leakage.

From the foregoing, it will be seen that need exists for an improved low-leakage cable of relatively small diameter having better flexibility, improved resistance to flammability and pressure, and better ability to meet the standards for inter-lead and ground-to-lead leakage through the jacket. Such cables must be capable of being mass produced and on a low cost, commercially competitive basis.

In accordance with the present invention, the cable 10 may be provided with a more flexible outer sheath 20 than the sheath of the above-described prior art cable and with a lower capacitance and leakage than the prior art cables. This is achieved, in the embodiment of the invention shown in FIG. 1, by the use of a sheath material having more plasticizer and by an internal wall means 21 having a dielectric constant of less than about two, preferably in the form of a cylindrical wall 22 encircling all of the filler cords 11, 12 and 13 and the electrical conductors 16, 17 and 18 and disposed just within the outer sheath 20. As will be explained in greater detail in connection with FIG. 2, the internal wall means 21 may be in the form of overcoats 23 of insulating material around power conductors 117 and 118. Additionally, rather than the solid polyethyl-

ene cords of the prior art, the filler cords 11, 12 and 13 of the present invention are made of soft, flexible flame-resistant material having a dielectric constant of less than about 2.15 or 2.2 thereby reducing the capacitance between conductors. In illustrated cable 10, both the inner wall means 21 and the filler cords 11, 12 and 13 are of a flame retardant, cellular polyethylene having a dielectric constant of less than two. The preferred material for the internal cords is a flame-resistant cellular polyethylene sold under the tradenames Rulan 2 and 3 by DuPont de Nemours Company of Wilmington, Del.

The spacing of the conductors 17, 18 and 19 has been kept within the desired small diameter, e.g., about 0.580 inch for No. 16 conductors by maximizing the conductor separation for a given cable diameter. It has been found that by making the ratio of the diameter of the fillers 11, 12 and 13, to the diameters of the insulated conductors 17, 18 and 19 about one and preferably slightly in excess of one that the spacing between conductors may be maximized for a given diameter. This is in contrast to the above-described conventional cable which had a larger diameter for equivalent leakage.

Referring now more particularly to FIG. 1, the cable illustrated therein is designed for use in connecting electronic medical instruments to wall-mounted electrical outlets. Three electrical conductors 17, 18 and 19 are used, one of which may serve as ground and the other two for carrying single phase a-c. As may be seen in FIG. 1, each of the conductors is surrounded by a wall 25, respectively, of electrical insulation. The electrical insulation may be of any suitable material, such as a polyethylene.

As previously mentioned, in order to minimize leakage currents, the cable of the invention is designed to have a very low inter-lead and lead-to-ground capacitance. This is accomplished by maximizing the conductor separation for a given cable diameter and by providing a cable construction which maintains this separation even though the cable is crushed by such objects as hospital carts.

In the embodiment of FIG. 1, the objects of the invention are accomplished by the provision of three elongated fillers 11, 12 and 13, which extend the length of the cable in engagement with each other. The arrangement of the fillers provides three elongated recesses 14, 15 and 16 extending the length of the cable. In particular, the axes of the fillers, which are of generally circular cross-section, are provided at 120° intervals symmetrically about the axis of the cable, indicated by the point 27 in FIG. 1. Thus, the insulated conductors 17, 18 and 19 are positioned in the recesses 14, 15 and 16, respectively, formed by the particular arrangement of the three fillers 11, 12 and 13. When more than three conductors are employed in the cable, the spacing between the elongated recesses, in which the conductors are disposed, should be 360° divided by the number of conductors. Under the present invention, cables (not shown) may be made with a larger number of conductors.

The materials of which the fillers are comprised should be a flexible low dielectric material which is also flame resistant and which has sufficient mechanical strength so as to not remain permanently deformed in the event it is subject to high-crushing loads. It has been found that for satisfactory operation, such a material

must have a dielectric constant of less than about two (preferably around 1.5 to 1.6) and must have a substantial flame-retardant capability. It should also be crush resistant, that is, it should be soft and spring back after crushing. Preferably, the material should also have a sufficiently high tensile strength to resist damage in processing and in use.

The cable 10 described herein has a substantial flame-retardant capability. One flammability test the illustrated cable 10 will pass is Underwriters' Laboratories, Inc., Factory Inspection Procedure as set forth by U. L. Subj. 758, Section G, pages 95B, 95C, 95D, and 95E. This test often designated as UL FR-1 vertical flame test requires, that after five successive 15 seconds on and 15 seconds off applications of a test flame having a temperature of 1,500°F, as follows:

1. the cable will not flame for more than one minute after the test flame is removed;
2. a paper flag located on the cable 10 inches above the test flame shall not burn more than a certain amount; and
3. dripping of material from the cable shall not ignite cotton which is underneath the cable under test.

The crush resistance of the material of which the fillers are comprised should be such that the material is capable of substantially resuming its original cross-sectional shape after being crushed. Satisfactory material for use as fillers may be foam "Teflon," polypropylene film yarn, foam polyvinylchloride and cellular polyethylene. To achieve the desired resistance to flammability, flame retardants can be added to the material.

The conductors are surrounded by a cylindrical wall 22 of a low dielectric material which may be identical with the material comprising the fillers 11, 12 and 13. The cylindrical inner wall means 21 surrounds the assemblage of insulated conductors and fillers and assists in minimizing the capacitance between the conductors and ambient surroundings. The outer jacket 20 completes the exterior structure of the cable and covers the fillers and conductors, along with the wall means 21. The material of which the outer jacket is comprised is preferably polyvinyl chloride which has plasticizer added thereto to make it flexible not withstanding its increased dielectric constant. If desired, the jacket could be modified to provide axial serrations on the inside or outside thereof to minimize capacitance across the jacket. In such a case, the cylindrical wall may be dispensed with.

In order to insure the spacing between the conductors, such that their axes lie at 120° intervals with respect to the axis 27 of the cable, further fillers are provided. These fillers comprise minor diameter elongated fillers 31 arranged in pairs on opposite sides of each of the insulated conductors 17, 18 and 19. The minor fillers are preferably of low dielectric material, and may be comprised of the same material as that of which the major elongated fillers 11, 12 and 13 are comprised. In order to maintain separation between the minor fillers 31, suitably shaped strength members 33 are provided. These strength members may be made of a stiffer material, such as polypropylene fibers, in order to maintain separation between the minor low dielectric fillers.

In obtaining the minimum capacitance for a given cable size, it is advantageous to follow some general proportional relationships. In the embodiment of FIG. 1, the dial ratio of the diameter of the major fillers 11, 12 and 13 to the diameter of the insulated conductors

17, 18 and 19 is one, and is preferably between about 1.3:1 and 0.7:1. For optimum design, the conductors 16, 17 and 18 should be located diametrically opposite the major fillers. This yields a cable of minimum diameter for a given design capacitance.

More particularly, a highly satisfactory cable in accordance with the design of FIG. 1 has been constructed in which the conductors 17, 18 and 19 were No. 16 size, and were provided with a polyethylene wall of insulation of 0.029 inch thickness. The major low dielectric material fillers 11, 12 and 13 had diameters of 0.135 inch and the minor fillers 31 and diameters of 0.085 inch. The inner wall means was 0.035 inch thick and the outer jacket 20 was 0.045 inch thick. The nominal outer diameter of the cable thus constructed was 0.580 inch. During manufacture, the soft cellular polyethylene wall means tends to be compressed slightly by the jacket 20.

The foregoing described cable, in tests, exhibited a leakage current between the conductors of only 4.22 microamperes per 10 feet of cable at 120 volts, 60 hz a-c. Capacitance between conductors at 1 khz was measured at less than 14 pf per foot. The described cable also passed the flammability test UL FR-1, as above described. Tests also indicated a high resistance to high voltage break down between conductors and the cable was substantially uneffected, both in shape and in leakage current after a 6,000 lb. fork-lift truck was passed over the cable lengthwise with the cable lying flat on a cement floor. More over, measurements of leakage current at various degrees of deformation of the cable indicated that the cable was substantially uneffected, even when crushed to a substantially flat shape (i.e. three-sixteenths inch thick).

Referring now to FIG. 2, an alternative embodiment of the invention is shown. In the embodiment of FIG. 2, parts of elements of the cable construction similar in nature and function to those of FIG. 1 have been given identical reference numerals preceded by a 2. Thus, as was the case in FIG. 1, the cable illustrated in FIG. 2 comprises three major elongated fillers 111, 112 and 113 extending the length of the cable in engagement with each other. The fillers are arranged in a group to form three elongated recesses 114, 115 and 116 in which three insulated conductors 117, 118 and 119, respectively, are disposed. As was the case in FIG. 1, the conductors 117, 118 and 119 are each surrounded by a wall of suitable insulation.

Unlike the embodiment of FIG. 1, wherein the major elongated fillers were arranged symmetrically about the axis of the cable, the arrangement of the fillers 111, 112 and 113 in FIG. 2 is asymmetrical with respect to the axis of the cable. More particularly, the major fillers are arranged in the embodiment of FIG. 2 such that one of the conductors 119 engages all three of the fillers 111,

As was the case in the embodiment of FIG. 1, a cylindrical wall means 21 of low dielectric material surrounds the conductors. In the case of the embodiment of FIG. 2, however, the two conductors 117 and 118 are each surrounded by the separate cylindrical overcoats 23. The outer surface of the layers of low dielectric overcoats 23 on each of the conductors 117 and 118 engages the fillers in the recesses 114 and 115 defined thereby. A single minor low dielectric filler 131 is provided engaging the two insulated and sheathed conductors 117 and 118 on the sides opposite thereof

from the major low dielectric filler 112. The remaining space inside the surrounding jacket 120 is at least partially filled by four strengthening members 133 of an identical nature to that used in the embodiment of FIG. 1.

Although the cable of the embodiment of FIG. 2 may not exhibit as lengthy a flex life as that of FIG. 1, nevertheless, the cable of FIG. 2 provided similar test results when tested in the same manner as that described in connection with FIG. 1.

As to the relative sizes of the outer diameters of the various elements of the embodiment of FIG. 2, the ratio of the outer diameter of the sheathed conductors 117 and 118, that is the outer diameter of the surrounding low dielectric wall means 21 to the outer diameter of the insulated conductor 119 should be about 1.5:1. The diameter or major dimension in the case of the major low dielectric fillers 111, 112 and 113 to the outer diameter of the insulated conductor 119 should be about unity.

More specifically, a satisfactory cable has been constructed in which number 18 conductors were used for the conductors 117 and 118, and a number 16 conductor used for the conductor 119. All conductors were jacketed with a wall of polyethylene insulation 0.025 inch thick, and the conductors 117 and 118 were surrounded by overcoats 23 of low dielectric material 0.045 inch thick. The approximate diameters or major dimensions of the major low dielectric fillers 111, 112 and 113 were about 0.125 inch, and the diameter of the major low dielectric filler 131 was 0.102. The outer nominal diameter of the cable was 0.505 inch and the thickness of the outer jacket 120 was 0.045 inch.

Referring now to FIG. 3, still another embodiment of the invention is shown. Elements of the embodiment of FIG. 3 which have characteristics and functions similar to those of FIG. 1 have been given identical reference numerals preceded by a 2. The embodiment of FIG. 3 is designed for a nominal diameter which is about twice that of the embodiment of FIGS. 1 and 2. The elongated fillers 211, 212 and 213 are comprised of a suitable low dielectric material, but the dielectric constant need not be as low as that of the previous embodiments, since the separation between the conductors 217, 218 and 219 is substantially greater. The outer jacket 220 is serrated on its outer surface to decrease the capacitance to the outside. In the embodiment of FIG. 3, the ratio of the outer diameter of the major fillers or low dielectric fillers to the insulated conductors is between about 3:1 and about 4:1.

It may therefore be seen that the invention provides an improved electrical cable exhibiting very low capacitance and leakage current, and an ability to withstand strong abuse. The configuration provided by the cable of the invention is such as to maximize separation between the conductors, and the material utilized for the cable provided very low inter-lead and lead-to-ground capacitance and high flame resistance. For a given conductor size, it is possible to build a cable having less diameter for a given capacitance level than prior art designs.

Various modifications of the invention in addition to those shown and described herein will become apparent to those skilled in the art from the foregoing description and accompanying drawings. Such modifications are intended to fall within the scope of the appended claims.

What is claimed is:

1. A cable comprising at least three elongated fillers extending the length of the cable in engagement with each other, said fillers being arranged in a group to form at least three elongated recesses extending the length of the cable, at least three elongated conductors extending the length of the cable, each of said conductors lying against the outside of said group of fillers in a respective one of said recesses formed thereby, cylindrical wall means surrounding said conductors, said wall means and said fillers being comprised of a material having a dielectric constant less than about two and having a substantial flame-retarding capability, and an outer jacket of insulation for said cable covering said fillers and said conductors.

2. A cable according to claim 1 wherein said fillers are arranged symmetrically about the axis of said cable, and said outer jacket is formed of polyvinyl chloride having a plasticizer added to make it flexible and having a dielectric constant of four or more.

3. A cable according to claim 1 wherein said fillers and said wall means are formed of a foamed or cellular plastic having a flame retardant added thereto.

4. A cable according to claim 1 wherein said wall means comprises a separate cylindrical wall of cellular polyethylene dielectric material having a flame retardant surrounding each of at least two of said conductors.

5. A cable according to claim 1 wherein the material of which said fillers are comprised is capable of substantially resuming its original cross-sectional shape after subjection to a compressive load.

6. A cable according to claim 1 wherein said fillers are spaced symmetrically about a longitudinal axis for said cable and in which the conductors are spaced from each other at equal angles about said axis.

7. A cable comprising three elongated fillers extending the length of the cable in engagement with each

other, said fillers being arranged in a group to form three elongated recesses extending the length of the cable, said fillers being arranged symmetrically about the axis of said cable, three elongated conductors extending the length of the cable, each of said conductors lying against the outside of said group of fillers in a respective one of said recesses formed thereby, an outer jacket of insulation for said cable covering said fillers and said conductors, a cylindrical wall of low dielectric material surrounding said group of conductors on the inside of said outer jacket of insulation, said cylindrical wall being comprised of a material having a dielectric constant of less than about two and having a substantial flame-retardant capability.

8. A cable comprising three elongated major fillers of low dielectric material extending the length of the cable in engagement with each other, said fillers being arranged in a group to form three elongated recesses, two of said recesses being on one side of the group and the third recess being on the other side, said fillers being arranged asymmetrically with respect to the axis of said cable, a pair of elongated conductors extending the length of the cable, each of said pair of conductors including a central wire and a surrounding insulating layer, an overcoat wall of soft foamed or cellular plastic surrounding and in contact with said insulating layers of each of said pair of conductors to reduce the capacitance therebetween, a third conductor extending the length of the cable and lying against the outside of said group of fillers in the third one of said recesses formed thereby on the side of said group opposite said first-named elongated conductors, and an outer jacket of insulation for said cable covering said fillers and said conductors.

9. A cable according to claim 8 wherein the ratio of the major dimension of said fillers to the diameter of the conductors is about unity.

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