Oct. 12, 1965

F. W. WAKEFIELD

ELECTRIC CABLE

Filed June 18, 1962

3,211,821

FIG. 1

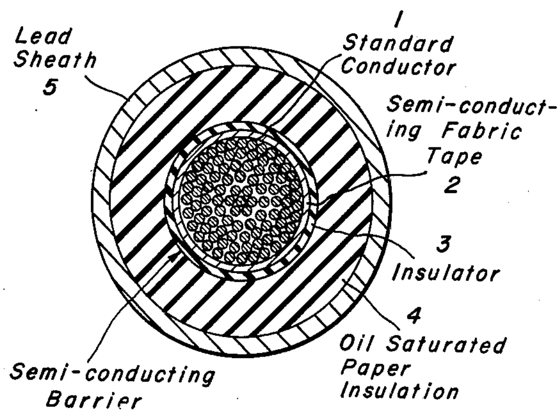


FIG. 2

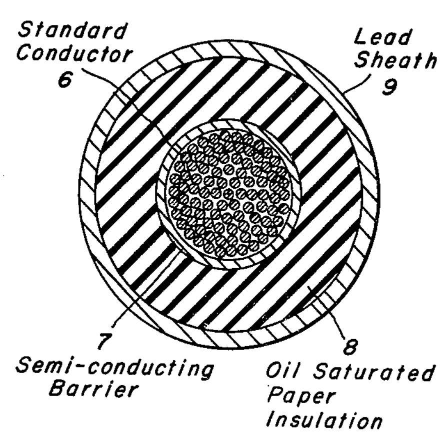
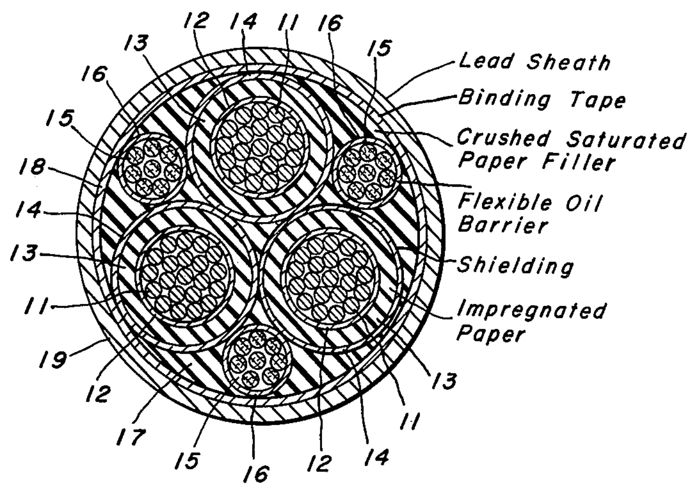


FIG. 3



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ELECTRIC CABLE

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13 Claims. (Cl. 174—26)

This application which is a continuation-in-part of my copending application Serial No. 64,852 filed October 25, 1960 now abandoned, which in turn is a continuation-in-part of my abandoned application Serial No. 803,940 filed April 3, 1959, relates to an electric cable and more particularly to an oil impregnated solid type metal covered power cable. Such cables have been extensively used for a long time and have the advantages of having low losses and being relatively cheap to manufacture. However, they have certain disadvantages which reduce their service life. The saturating oil completely permeates the paper insulation and stranded copper conductor with a chemical reaction taking place between the saturating oil and the copper conductor which adversely affects the electrical properties of the saturating oil. When the cable transmits power the copper conductor becomes hot, thus accelerating the chemical reaction and causing the deteriorated oil to migrate into the paper insulation. This condition is especially bad because the paper insulation nearest the conductor is most affected, this being the position where the voltage stress across the insulation is maximum.

When a solid type paper cable is installed on an incline the saturating oil migrates, by gravity, from the high points to the low points. Most of this migration takes place through the spaces in the stranded conductor, which is the hottest part of the cable during load cycles and where the resistance to axial flow is less. The dry paper insulating at the cable high spots result in ionization and hot spots which eventually lead to a voltage failure caused by thermal instability.

When a solid type paper cable is heated, the increase in volume due to the expansion of the lead covering is much less than the volume increase of the saturating oil, with the result that high pressure builds up inside the cable. This internal pressure is sufficient to cause permanent expansion of the lead covering or sheath. During periods of light load the cable cools off and the saturating oil contracts, thus causing very low pressure gas voids inside the cable. Severe ionization takes place in these low pressure voids and usually starts a tracking type failure near the conductor where the volts per mil stress is the highest. Once the first few tapes near the conductor have been punctured it is easier for the carbon track to continue through the insulation and cause a voltage failure.

In some instances a layer or layers of various types of material have been used between the conductors and the paper insulation, but these materials have not been satisfactory for various reasons. The material may not be impervious to the oil so that the oil will migrate into the conductor, the material may not be oil resistant so that it will contaminate the oil and raise its power factor, and/or the material may not be sufficiently resilient to prevent the formation of low pressure voids in the paper insulation.

In order to overcome some of these difficulties oil filled cables have been provided, but these require oil reservoirs at frequent intervals and require gas supply apparatus which must be maintained and supervised. Also pressure is usually applied to the outside of the cable insulation. Even after draining the cable core at an elevated temperature there is usually enough saturant remaining in the insulation to gather in the pressure tubes

and follow to the lowest point of the installed cable. Once the pressure tubes are filled for a considerable distance with the viscous saturant it is difficult for pressure compensation to take place, especially during light cable loads when it is most required to prevent tracking. Manufacturing cost is high and in case of gas pressure failure damage may occur due to tracking before the tube can be corrected.

It is therefore an object of my invention to provide an improved oil impregnated insulated cable which eliminates or greatly reduces the aforementioned disadvantages.

Another object is to provide such a cable having built-in pressure compensation.

Still another object is to provide such a cable which has a much longer life than the solid type cable previously used.

These and other objects will be more apparent after referring to the following specification and attached drawings, in which:

FIGURE 1 is a cross section of a preferred embodiment of the cable of my invention;

FIGURE 2 is a view, similar to FIGURE 1, showing a second embodiment of my invention; and

FIGURE 3 is a cross sectional view of a multi conductor cable utilizing my invention.

Referring more particularly to FIGURE 1 of the drawings, reference numeral **1** indicates a conductor which is preferably stranded copper wire. According to my invention I provide a resilient oil impervious and oil resistant semi-conducting barrier around said conductor. As shown in FIGURE 1 this barrier includes a semi-conducting fabric tape **2** adjacent the conductor **1** and an insulating layer **3** around the fabric tape **2**. The insulator **3** is preferably irradiated polyethylene, but may be cross linked polyethylene. Oil impregnated paper insulation **4** surrounds the layer **3** and a lead sheath **5** surrounds the insulation **4**. The materials of layer **3** are oil resistant, relatively impermeable to air and oil, and able to withstand temperatures of at least approximately 115° C. without substantial deterioration. Other physical properties are as follows:

Properties:	Irradiated polyethylene
Percent power factor—60 cycles	0.05%.
S.I. C 60 cycles	2.3.
Electric strength	1800 volts per mil.
Volume resistivity	10^{15} ohm-cm.
Moisture resistance	Good.

The oil is that commonly used in electric cables. One particular type often used is Sun Oil's XX Heavy Cable Impregnating Oil which is a mineral oil having the following properties:

Gravity API/60° F.	21.2
Flash, ° F.	470
Fire, ° F.	550
S.U. viscosity at 210° F.	101.9
Pour test, ° F.	−5
Color, ASTM D–155	2¼
Color, ASTM D–1500	L 2.5
Neut. No.	Neutral
Demulsibility	Good
Emulsibility	Good
Brightness	Bright
Initial percent power factor at 100° C.	0.37

Of the above properties the viscosity and the initial percent power factor are the most significant. To prevent undue migration of the oil the viscosity should not be below 80 and for manufacturing reasons the viscosity should not exceed 1000. This is true of all impregnating oils used in solid type impregnated paper cable.

In making the cable it is preferred that the layers **2** and **3** be applied in tape form. The layer **3** may also be applied to the conductor **1** by extrusion. The paper insulation **4** is then applied in the usual manner and the assembly is placed in an oil saturating tank where heat and vacuum is applied to remove moisture from the assembly. During the drying process sufficient heat is supplied to bond the semi-conducting tapes into a semi-conducting layer. The ends of the dry assembly are positioned in the tank above the saturating oil level, the ends of the copper strands sealed with solder and the entire cross-section of the ends sealed with oil resistant tape, thus preventing the oil from entering the stranded conductor **1**. After completing the oil saturation process the assembly is allowed to cool and the lead sheath **5** immediately applied to complete the cable.

Since the saturating oil does not contact the conductor **1** there can be no chemical action between the saturating oil and the copper. Since the oil in the conductor is eliminated, less than normal expansion of the lead sheath will occur during heat cycles. When the cable cools off the air entrapped in the conductor **1** will expand and prevent any very low pressure voids from forming in the paper insulation **4**, especially near the conductor **1**. When the saturating oil expands, the resilient barriers **2** and **3** will be forced into the interstices of the stranded conductor and when the saturating oil contracts the air pressure in the conductor will force the barrier back, thus providing a pressure compensating effect. Since the oil can move only within the paper insulation, less migration of saturating oil will occur. Other solids may be used in place of the paper.

When the barrier is made in the manner described above, using irradiated polyethylene, tests have proved that the normal rate of oxidation of the oil is not increased at elevated temperatures and hence there is little or no effect on the power factor. The life of such cable is approximately 2½ times the life of ordinary solid type cable.

In the embodiment of my invention shown in FIGURE 2 a stranded conductor **6** is surrounded by a resilient oil impervious and oil resistant semi-conducting barrier **7** which is preferably irradiated polyethylene made semi-conducting by adding carbon particles thereto. Oil impregnated paper insulation **8** surrounds the barrier **7** and a lead sheath **9** surrounds the insulation **8**. This cable is made in essentially the same manner and will function in essentially the same manner as the cable of FIGURE 1.

In the embodiment of my invention shown in FIGURE 3 three spaced apart electrical conductors **11** are provided. A resilient oil impervious and oil resistant semi-conducting barrier **12** surrounds each conductor and oil impregnated paper insulation **13** surrounds the barrier **12**. The members **11**, **12** and **13** are essentially the same as the corresponding members in FIGURES 1 and 2. Shielding **14** surrounds the insulation **13**. A plurality of stranded members **15** are arranged in the valleys between the conductors **11** on the outside of the insulating material **13** and the shielding **14**. The stranded members **15** may be metallic ground wires, but are preferably non-metallic material such as manila rope which can be deformed under pressure. A barrier **16** of the same type as barrier **12** is arranged around each stranded member **15**. Crushed oil saturated paper filler **17** fills the voids between shielding **14** and barriers **16**. Binding tape **18** is arranged over the entire assembly beneath a lead sheath **19**.

In making the cable of FIGURE 3 the barrier **12** is applied in the manner set forth above and will bond to the paper insulation **13**, but not to the conductor **11**. The paper insulation **13** is applied in the usual manner and the shielding **14**, which is preferably copper tape, is applied at the same time as the paper. The insulated conductors are then stranded together and the covered members **15** positioned between the insulated conductors **11** as shown. The crushed paper fillers are then applied according to standard practice and the metallic binder tape **18** applied overall. The cable is then positioned in the saturating tank with the cable ends sealed with a material, such as an epoxy resin, and positioned above the oil level in the saturating tank. The cable is vacuum dried at a temperature between 110 and 120° C. which is sufficient to heat seal the polyethylene around the stranded conductors **11** and around the stranded members **15**. The hot saturating oil is excluded from the conductors **11** and members **15** by means of the oil barriers **12** and **16**. The entrapped air in the conductor strands compensates for pressure changes on the inside area of the cable insulation and the entrapped air in the stranded members **16** compensates for pressure changes occuring on the outside area of the cable insulation. The members **15** should be as large as possible. If the members **15** are manila rope the cable pressure will be reduced by the rope assuming an elliptical shape so as to reduce its cross sectional area. Thus, the barriers **12** and **16** are forced into the outside surface depressions of members **11** and **15** due to increasing internal cable pressure caused by the saturating oil, especially when it is heated. When the saturating oil cools and contracts, the entrapped air in members **11** and **15** will expand barriers **12** and **16**, respectively, and thus tend to adjust the oil-paper volume within the sheath **19**. No excessive strain will be exerted on the lead sheath **19** because the barriers **12** and **16** will change their volumes at much lower pressures than the lead sheath **19**. The cable pressure and vacuum peaks are also at a minimum because the oil is excluded from the members **11** and **15** so that there is less saturant per unit length in the cable than that normally present.

Ordinarily most saturant migration due to gravity takes place inside the copper strand and since no oil is present in the copper strands saturant migration is greatly reduced. Also, there is not contact of the oil with the copper which acts as a catalyst to aid deterioration of the oil.

While several embodiments of my invention have been shown and described, it will be apparent that other adaptations and modifications may be made without departing from the scope of the following claims.

I claim:

1. An electric cable comprising a plurality of spaced apart stranded electrical conductors, a resilient oil impervious and oil resistant semi-conducting barrier surrounding each conductor, said barrier being made of a material able to withstand temperatures of at least approximately 115° C. without substantial deterioration, a solid insulating material impregnated with a mineral oil surrounding each barrier, shielding surrounding said insulating material, a plurality of stranded members arranged between said conductors on the outside of said insulating material, a resilient oil impervious and oil resistant semi-conducting barrier surrounding each of said stranded members, a metal sheath surrounding said last named barriers and shielding, and an oil impregnated filler between said metal sheath and said last named barriers and shielding, said barriers confining said oil to the space outside of said conductors.

2. An electric cable according to claim **1** in which said first named semi-conducting barriers include a semi-conducting layer adjacent the conductor surrounded by a layer of insulating irradiated polyethylene.

3. An electric cable according to claim **1** in which said semi-conducting barriers include irradiated polyethylene impregnated with conducting material.

4. An electric cable according to claim **1** in which said stranded members are made of compressible material.

5. An electric cable according to claim **4** in which said first named semi-conducting barriers include a semi-conducting layer adjacent the conductor surrounded by a layer of insulating irradiated polyethylene.

6. An electric cable according to claim **4** in which said semi-conducting barriers include irradiated polyethylene impregnated with conducting material.

7. An electric cable comprising three spaced apart electrical conductors, a resilient oil impervious and oil resistant semi-conducting barrier surrounding each conductor, said barrier being made of a material able to withstand temperatures of at least approximately 115° C. without substantial deterioration, a solid insulating material impregnated with a mineral oil surrounding said barrier, a shielding layer surrounding said insulating material, three stranded members arranged between said conductors on the outside of said insulating material, a resilient oil impervious and oil resistant semi-conducting barrier surrounding each of said stranded members, a metal sheath surrounding said last named barriers and shielding, a binding tape on the inside of said metal sheath, and an oil impregnated filler between said binding tape and said last named barriers and shielding, said barriers confining said oil to the space outside of said conductors.

8. An electric cable according to claim 7 in which said first named semi-conducting barriers include a semi-conducting layer adjacent the conductor surrounded by a layer of insulating irradiated polyethylene.

9. An electric cable according to claim 7 in which said semi-conducting barriers include irradiated polyethylene impregnated with conducting material.

10. An electric cable according to claim 7 in which said stranded members are made of compressible material.

11. An electric cable according to claim 10 in which said first named semi-conducting barriers include a semi-conducting layer adjacent the conductor surrounded by a layer of insulating irradiated polyethylene.

12. An electric cable comprising a plurality of spaced apart stranded electrical conductors, a resilient oil impervious and oil resistant semi-conducting barrier surrounding each conductor, a solid insulating material impregnated with a mineral oil surrounding each barrier, shielding tape surrounding said insulating material, a plurality of stranded members arranged between said conductors on the outside of said shielding tape, a resilient oil impervious and oil resistant semi-conducting barrier surrounding each of said stranded members, a metal sheath surrounding said last named barriers and shielding, an an oil impregnated filler between said metal sheath and said last named barriers and shielding, each of said first named barriers including a semi-conducting fabric tape and a tape of a compound of the class consisting of irradiated polyethylene and cross linked polyethylene surrounding said semi-conducting tape, said barriers confining said oil to the space outside of said conductors.

13. An electric cable comprising three spaced apart stranded electrical conductors, a resilient oil impervious and oil resistant semi-conducting barrier surrounding each conductor, a solid insulating material impregnated with a mineral oil surrounding said barrier, a shielding tape surrounding said insulating material, three stranded members arranged between said conductors on the outside of said insulating material, a resilient oil impervious and oil resistant semi-conducting barrier surrounding each of said stranded members, a metal sheath surrounding said last named barriers and said tape, a binding tape on the inside of said metal sheath, and an oil impregnated filler between said binding tape and said last named barriers and said shielding tape, each of said barriers including a semi-conducting fabric tape and a tape of a compound of the class consisting of irradiated polyethylene and cross linked polyethylene surrounding said semi-conducting tape, said barriers confining said oil to the space outside of said conductors.

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