March 15, 1932. M. HÖCHSTÄDTER 1,849,624

HIGH TENSION CABLE

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Fig.1.

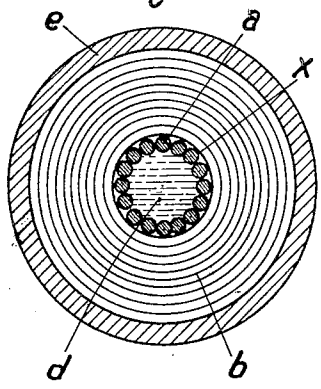



Fig.2.

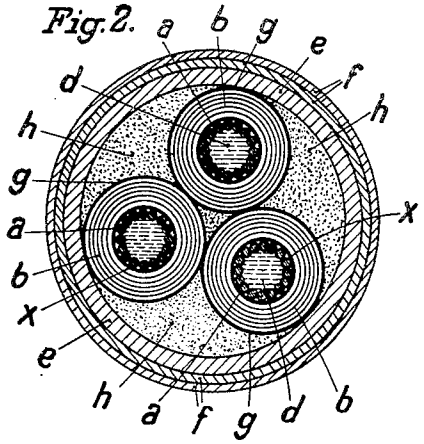



Fig.3.

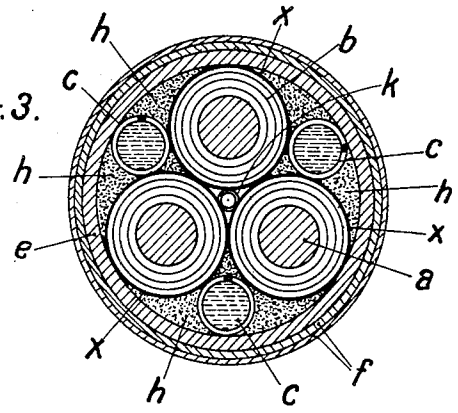
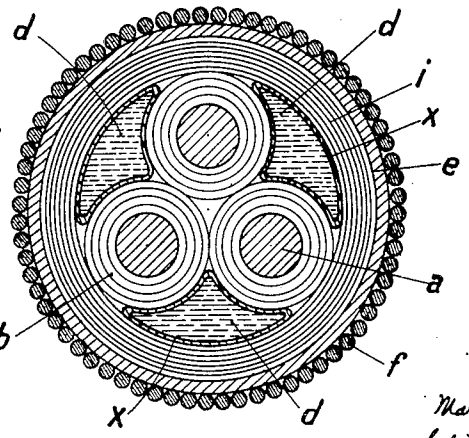



Fig.4.




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Fig. 5.

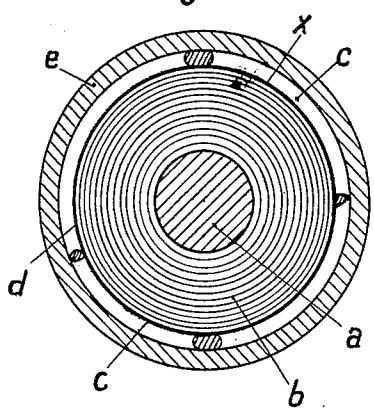



Fig. 6.

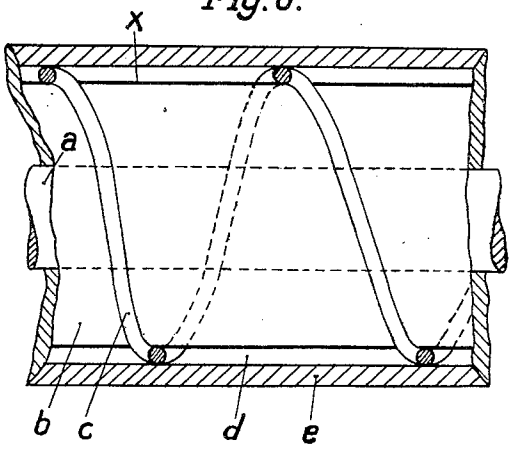



Fig. 7.

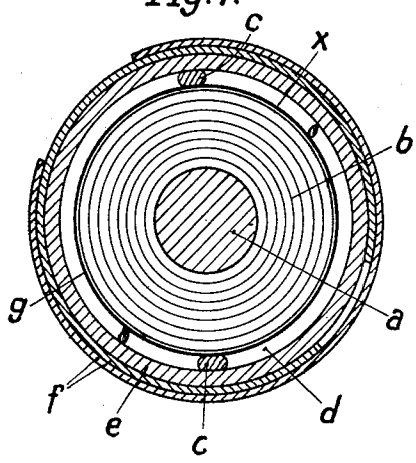



Fig. 8.

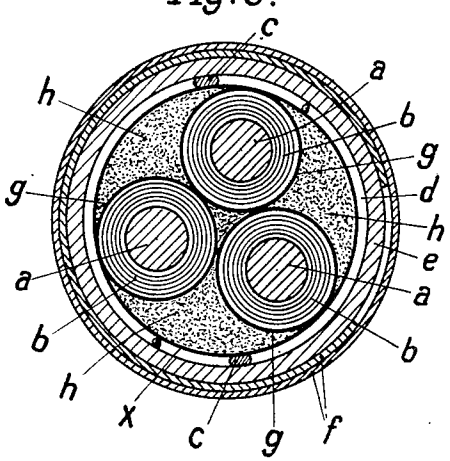
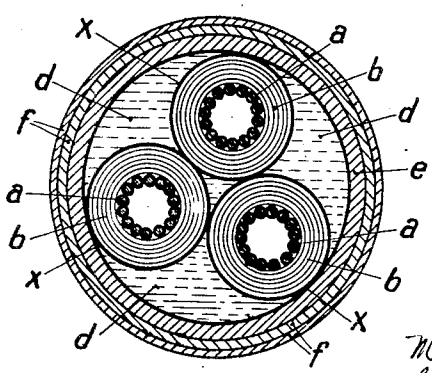



Fig. 9.




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1,849,624

# UNITED STATES PATENT OFFICE

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## HIGH-TENSION CABLE

Application filed December 27, 1926, Serial No. 157,400, and in Germany January 6, 1926.

The reliability in working of an electric cable is increased in respect to its tension-stress if its insulating material is put under pressure. This is, up to date, gained by providing, apart from its electrical insulating layer, tubes with permeable walls in the cable for receiving and conducting a liquid, or gaseous pressure medium, placed under pressure at suitable points by outer, mechanical means.

The said permeable walls permit an unobstructed and direct development of the hydrostatic pressure of the pressure liquid upon all points of the inner or outer surface of the conductor insulation and also impregnation of the cable already provided with an outer protective covering by the said tubes. On account of the permanent connection between pressure medium and insulating material existing under this arrangement with permeable walls, certain difficulties will arise.

The insulating impregnating material has to be identical with the pressure medium, viz. has to be still liquid under the lowest working temperatures. This is however often undesirable for electrical reasons. The pressure tubes must furthermore generally be evacuated in the factory before shipping the cables. The conductor insulation loses hereby its impregnating material partly or wholly and a second impregnation is consequently necessary after the cable has been laid, which takes time and is less reliable. Impregnation previous to the lead covering according to the usual method and under utilization of the everywhere existing working equipments, can hardly be effected with the liquid pressure medium. Employment of an impregnating material, differing from the pressure medium, as for instance a thick liquid, is very difficult, as both mediums will later mix in an uncontrollable manner, especially under higher working temperatures. Impregnating multiple-conductor cables after stranding, offer great difficulties, viz. the conductors would have to be impregnated singly before stranding.

By employment of the present invention it is possible to eliminate these difficulties. The invention offers consequently great advantages in the employment of artificial pressure in cables, particularly in cables of the ordinary production, with common impregnating-compound, differing from the pressure medium.

The invention is based upon the perception, that it is not necessary to keep the pressure liquid in bodily contact with the impregnating material of the insulating layer, but that the favourable influence of the pressure upon the increase of the working reliability of the cable takes effect even if between pressure medium and insulation an impermeable membrane is provided. The same must however be sufficiently flexible to permit transmission of the pressure of the pressure medium to the insulation and, if possible, uniformly at all points.

According to the invention, sufficiently impermeable and sufficiently flexible layers are arranged between the insulating material proper and the channels for receiving and conducting the pressure medium in the cable. If tubes with permeable walls are besides employed in the pressure channels, it is done for other reasons, for example, mechanical reasons.

Several methods of executing the invention are illustrated by the accompanying drawings, in which

Fig. 1 is a section of a single-conductor cable with an impermeable layer on the hollow copper conductor.

Fig. 2 shows in section a stranded three-core cable with metallized conductors, wherein an impermeable layer, (membrane) is provided for the hollow copper conductor of each core.

Fig. 3 is a section through a cable with solid copper conductors, in which the pressure channels are arranged in the filling spaces. The impermeable layer is located on the surface of the insulation of the conductors.

Fig. 4 illustrates a section through a stranded three-core cable with belt insulation and pressure channels of special shape instead of the material for the fillers.

Fig. 5 shows the cross section of a single conductor cable with the membrane on the surface of the insulation and the pressure

channel between this surface and the outer protective covering.

Fig. 6 is a longitudinal section thereof.

Fig. 7 is a section of an armoured single-conductor cable with metallized insulation, membrane and a pressure channel according to Fig. 5.

Fig. 8 shows a stranded three-core cable with metallized cores, membrane enclosing the three metallized cores, and pressure channel between this membrane and the outer protective covering.

Fig. 9 shows a stranded three-core cable with metallized cores similar to Fig. 2, with hollow conductors, in which the pressure channels are however not arranged inside of the conductors, but occupy the space of the fillers. The membrane is located on the surfaces of the insulated cores.

The single conductor cable according to Fig. 1 consists of the metal conductor $a$, the insulation $b$ and the lead covering $e$. The conductor $a$ is hollow, the interior $d$ serves as pressure channel. The active insulation $b$ is separated from the metal conductor by a membrane $x$.

Manufacturing and laying of this cable can be effected in the usual manner, viz. a membrane $x$ is placed upon the copper conductor $a$ and the insulating material $b$ spun over, whereupon the cable can be impregnated with any desired impregnating material. The lead covering $e$, is put on thereafter.

The membrane $x$ can be made in different ways of one or several layers, if it complies with the two-fold condition of the impregnating material in the insulation $b$ and the pressure medium in the channel $d$, i. e. being sufficiently impermeable and at the same time sufficiently flexible.

This membrane $x$ may therefore consist of conductive or non-conductive material, it may have the shape of a thin cylinder with or without seam, or the shape of a wound tape.

In the latter case, a paper or textile tape is preferably selected, impregnated with synthetic resin or a similar substance. The tape and the membrane formed thereby, becomes impermeable likewise at the overlapped edges of the tape, as they are pasted together under application of heat during drying of the insulating layer $b$ before impregnation of the same. An impermeable layer is thus obtained, which attaches itself as an impermeable flexible membrane to the inner surface of the conductor insulation $b$, as the membrane consists practically of the same material, (paper) of which the insulation $b$ is built up with the exception of the impregnation.

Manufacturing this cable in well known manner, it differs from an ordinary single-conductor cable only by the inserted membrane $x$ and the hollow space $d$. Upon laying, the hollow space $d$ can easily be filled with the pressure medium, for instance a thin liquid oil, after the adhering moisture has been removed for example by the employment of a vacuum and heat, or simply by means of warm air being passed through.

A continuation of the pressure channel across the junction $d$ is practically effected through the joint boxes of a cable section. The outer pressure generators, for instance pressure-pumps, batteries of gas flasks, etc. by which the pressure of the pressure medium is produced, are preferably connected where cable terminal boxes exist.

Fig. 2 shows the cross-section of a stranded three-core cable with metallized cores, in which each core is built up according to Fig. 1. $f$ is the double, steel tape armour, $g$ the electric conductive layer on the core surfaces, which may be metallized in accordance with known methods to render the cable free from ionization. This metallizing is advantageously permeable to permit impregnation. $h$ are the fillers consisting usually of jute or similar material.

Production of the entire cable-strand under lead is effected in the usual way as shown under Fig. 1, viz. the hollow copper conductors $a$ are spun over with the membrane $x$ and the insulating material $b$, stranded together and with the material $h$, impregnated, covered with lead and armoured. Laying and placing under pressure is likewise effected as described in the mode of execution illustrated by Fig. 1.

The membrane $x$ prevents penetrating of the impregnating compound into the channels $d$ during impregnation, as well as diffusion between the compounds in $b$ and $d$ in operation. It transmits however the pressure of $d$ upon $b$ mechanically, whereby the increase in disruptive strength of the insulation $b$ is produced.

The arrangements according to Figs. 1 and 2, when in service, have the disadvantage, that the pressure medium is under high electrical tension, so that corresponding arrangements must be provided on the pressure generators outside. This drawback has been avoided in the methods of execution according to Figs. 3, 5, 6, 7, 8 and 9, as the walls of the pressure channel are grounded. In the arrangement according to Fig. 4, the pressure channels carry only a certain fraction of the electrical working tension.

Fig. 3 shows a stranded three-core cable with metallized cores and solid conductors. in which the filler spaces serve as pressure channels and the membrane $x$ is, according to the invention, arranged on the surfaces of the cores.

Flexible tubes $c$, permeable for the pressure medium, are arranged in the filler spaces, they may consist for instance of spirally wound wire and allow room for conveying the pressure medium. The remaining space

of the fillers is occupied by filling material. The permeable tubes and the filling material are however not essential for carrying out the present invention. The arrangement inside of the filler spaces may be otherwise, as for instance shown in Fig. 9 in which the filling spaces are entirely filled up with the pressure medium.

Manufacturing the cable in accordance with Fig. 3, differs from that of Figs. 1 and 2. The conductors *a*, provided with the insulation *b*, are first impregnated as single cores and, after leaving the impregnating vessel, are provided with the impermeable membranes *x*.

This membrane can be made in different ways, as for instance, so that it answers simultaneously the purpose of metallizing. In this case, illustrated in Fig. 3, the cores may be impregnated unmetallized and afterwards covered by a metallized paper tape, the metal coating of which is not perforated; and the paper may besides be coated with synthetic resin or impregnated, so that the overlapped wrapping with this material under subsequent heating becomes pasted together at the overlapped edges and forms a perfectly tight, firmly adhering membrane serving simultaneously as protection against ionization. The adherence at the edges is not however necessary to provide a sufficiently impermeable layer.

Other methods of metallizing may be employed in place of that above described. If the cores are already in metallized condition, viz with permeable metal surfaces, they are impregnated and the impermeable layer is after impregnation, for instance, produced by drawing the cores through a suitable liquid or paste, which hardens afterwards. A paper, or textile tape impregnated with synthetic resin may for instance be wound over the permeable metallizing.

If the conductive contact between the metallized core surfaces and the outer lead covering is to be maintained, suitable arrangements have to be made. The liquid, or paste coating may for instance after impregnation be removed from such parts of the core surface as project somewhat consequent to the overlapped metallizing. If a special impregnated tape is applied, the desired contact may be obtained by insertion of metal wires in the tape in known manner.

Three or more of the thus finished single cores are now stranded with the necessary fillers *h*, and the tubes *c*, the lead covering *e* and armouring *f* being placed in position thereafter.

The thus manufactured cable is treated after laying similarly as described above. If the material of the fillers is nonhygroscopic, or has already been impregnated before the stranding, very little moisture has to be removed from the pressure channels, and drying and filling are, after erecting the cable, consequently very simple.

In Fig. 4, an ordinary stranded three-core cable with belt insulation *i* and wire armour *f* is illustrated, in which the pressure channels are contained within impermeable flexible tubes *x*, having the shape of the filler spaces and occupying their space, so that other filling material is not required. The pressure tubes *x* can of course not fill their purpose perfectly, as they contact upon only a part of the insulation surface, otherwise, this cable may be made in the usual manner and impregnated. The cable according to Figs. 5 and 6 is not armoured. The single conductor cable, according to Fig. 7, is however equipped with double, steel tape armour. Fig. 5 shows an impermeable membrane *x* on the surface of the insulation, the pressure channel *d* being located between this membrane and the outer lead covering *e* and kept free for the pressure medium by a spiral *c* made of sufficiently resisting material.

In Fig. 7 it is presumed, that the single conductor cable is made free from ionization, viz that it carries a metallization *g*, besides having the membrane *x*.

In Fig. 8 is illustrated an armoured three-core cable with metallized cores *a*, *b*, *g*, in which the membrane *x* is provided on the outer surface of the cable under the lead covering.

The pressure channel *d* is again between the core and the lead covering, kept free by the spiral *c*.

The cables according to Figs. 5 and 8 can be made in the ordinary way and impregnated, the membrane being applied after impregnation. The cable is handled after laying, as described above.

In Fig. 9 another embodiment of an armoured, stranded three-core cable with metallized cores is illustrated, similar to that of Fig. 3. Its pressure channels occupy the whole space of the fillers and are limited by the metallized membranes *x* on the surfaces of the cores and the lead covering *e*. The copper conductors *a* are hollow. This cable is preferably produced dry under lead and armoured. The strands *b* can then be dried and impregnated from the hollow metal conductors and this may be done either simultaneously with the filling of the pressure chambers *d*, or not. The impregnating compound for the insulation *b* can be identical with, or different from the pressure medium in the channels *d*.

This mode of execution according to Figure 9 offers therefore great freedom in respect of selecting the impregnating material and pressure medium and enables the pressure to be exerted from both sides of the insulation, from outside and inside, if a sufficiently thin liquid medium is employed in the high tension conductor *a*, as well as in the chan-

nels *d*. This mode of execution has however in the latter instance the disadvantage of a second impregnation after laying the cable. If in the hollow conductors *a*, the usual impregnating compound is however employed, this drawback is eliminated.

In the described modes of execution, the armour *f* opposes the pressure exerted by the pressure medium towards the outside. In the absence of armour, the lead covering may be substituted by an alloy of such strength that it withstands this pressure, or the cable may be drawn through sufficiently resisting pipes or ducts.

The pressure channels *d* of the constructions according to Figs. 3, 5, 6, 7, 8 and 9 require no special connectors in the joint boxes, but they may be simply in free communication with the interior of the boxes, if this interior space of the joint boxes is filled with the pressure medium. The joint boxes must of course in such case be constructed pressure proof. This offers to the joint boxes like advantage for their own working reliability as pressure does for the cable itself.

In the foregoing description I have spoken, with regard to certain figures of the annexed drawings, of the use of the invention for metallized cables according to known processes, but it is to be understood that the invention is capable of quite general application and that it can be employed in connection with all high tension cables of whatever composition or mode of manufacturing.

I claim:—

1. A high tension cable comprising a conductor, insulating material for said conductor, a pressure channel having an impervious flexible wall in engagement with and adapted to be pressed against said insulating material, and a pressure medium in said channel.

2. A high tension cable comprising a conductor, insulating material for said conductor, impregnating material for said insulating material, a pressure channel having an impervious flexible wall in engagement with and adapted to be pressed against said insulating material, and a pressure medium in said channel different from said impregnating material.

3. A high tension cable comprising a conductor, insulating material for said conductor, a pressure channel having an impervious flexible wall in the form of a sheath on said insulating material, adapted to be pressed against said insulating material, and a pressure medium in said channel.

4. A high tension cable comprising a conductor, insulating material for said conductor, a pressure channel having an impervious flexible wall in the form of a tape-like winding containing synthetic resins on said insulating material, adapted to be pressed against said insulating material, and a pressure medium in said channel.

5. The method of manufacturing and installing high tension cables which comprises assembling conductors and insulating material with an impervious flexible wall on the insulating material, impregnating the insulating material, providing a pressure channel in pressure communication with said wall, and filling said pressure channel with a pressure medium independently of the operation of impregnating said insulating material.

6. A high tension cable comprising conductors, insulating material therefor, an impervious flexible wall surrounding said insulating material, a pressure channel in which said conductors with their insulating material and said wall are disposed, and a pressure medium in said channel.

7. A high tension cable comprising conductors, insulating material therefor, an impervious flexible wall surrounding said insulating material, an outer protective covering, a pressure channel between said impervious flexible wall and said outer protective covering, and a pressure medium in said pressure channel.

In testimony whereof I have affixed my signature.

MARTIN HÖCHSTÄDTER.