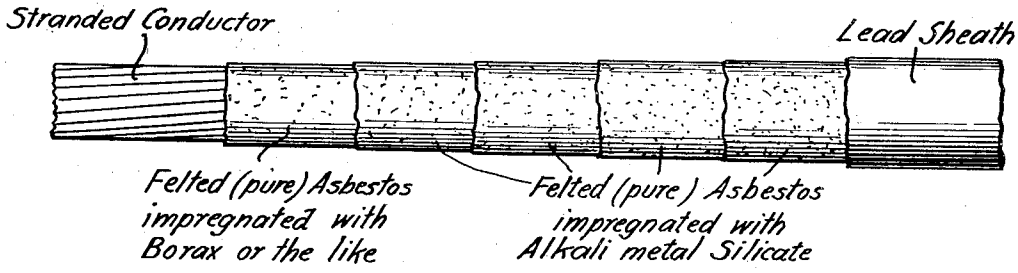
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INSULATED ELECTRICAL CONDUCTOR

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INSULATED ELECTRICAL CONDUCTOR

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This invention relates to insulated electrical conductors and has for its object the provision of an improved article of this character. The invention is especially directed to the provision of an improved electric cable for low voltage power networks, and contemplates for such purposes an electric cable having an insulating medium capable when subjected to the elevated temperature incident to the occurrence of a short-circuit or similar fault of providing an effective arc-extinguishing means.

Since the advent of the low voltage network system of power distribution imposes conditions of service that are new, in that overloading of conductors cannot be protected against by the usual forms of electrical protective devices such as circuit breakers and the like, it becomes necessary, in the event of a short circuit or other fault, for the conductor, itself, to melt and burn clear. This type of clearing is always accompanied by arcing and the usual forms of insulating material disintegrate and permit the arc to travel along the ducts in which the cables are installed to a point where physical separation in manholes introduces a sufficient gap to quench the arc. The destruction of long lengths of cable results and often the fault is communicated to other circuits and widespread damage results with failure of service over considerable areas.

In addition to the damage to equipment, a further and more serious hazard is introduced by the explosions resulting from the ignition by the arc of gases produced by the disintegration of the insulating materials heretofore used. Many cases of damage to outside property and injury to persons are on record from this cause.

Networks are also being adopted for power distribution in tall buildings where cables run in both vertical and horizontal ducts and the same conditions of burn-off and explosion and fire hazard exist.

The insulated electrical conductor of the invention is particularly suited for use in low voltage power networks. It is characterized by having, inherent in its structure, suitable means or agencies acting upon the occurrence of a short-circuit or similar fault to reduce the duration of arcing to a minimum. Such reduction to a minimum of the duration of arcing prevents extended destruction of equipment as well as communication of fault conditions to other circuits. Moreover, the occurrence of explosions or fires in the underground system and manholes is completely avoided and eliminated in the insulated conductor of the invention, because no inflammable, explosive or toxic gases are evolved from the insulated conductor as a consequence of or in extinguishing arcing.

In its broad aspect, the insulated electrical conductor of the invention comprises a metallic conductor surrounded by an insulating medium incapable of evolving an inflammable, explosive or toxic gas at elevated temperatures, incident to the occurrence of a short-circuit or similar fault, and adapted when subjected to such elevated temperatures to form a vitreous-like compound around the metallic conductor. The insulating medium possesses the required physical and electrical characteristics to permit ordinary handling and working during installation and normal service of the cable or the like, and the formation of the vitreous-like compound takes place only when the insulating medium is subjected to elevated temperatures. It is now my preferred practice to make up the insulating medium principally of asbestos impregnated with an alkali-metal silicate, such as sodium silicate. When so made up in accordance with the invention, the insulating medium contains such an amount of the alkali-metal silicate as to unite with asbestos to form a vitreous-like compound about the metallic conductor when subjected to the elevated temperature incident to the occurrence of a short-circuit or similar fault. In its preferred form, the insulating medium composed of asbestos impregnated with an alkali-metal silicate is separated from the metallic conductor by an intermediate medium capable of inhibiting penetration of the alkali-metal silicate to the surface of the metallic conductor. This intermediate medium may advantageously be a layer of asbestos initially impregnated with boric acid, borax or other substance adapted to react with the alkali-metal silicate to form a barrier preventing the penetration of the silicate to the surface of the metallic conductor. The asbestos in the entire insulation surrounding the metallic conductor is free of cotton or other organic material volatilizable at elevated temperature.

The single figure of the accompanying drawing diagrammatically illustrates an insulated electrical conductor embodying the novel features of the invention. As illustrated in the drawing, the metallic conductor is composed of stranded copper wire. The metallic conductor is covered with several layers of pure asbestos containing no cotton or other organic material. The first layer of asbestos is impregnated with a solution of boric acid (or the like) and the subsequent layers of asbestos are impregnated with an al-

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kali-metal silicate, such as sodium silicate, in varying concentrations to provide necessary flexibility. The asbestos is applied in the form of untwisted rovings having a central reinforcing thread or filament of pure asbestos yarn and the adjacent rovings provide inter-entanglement of fibres and each layer is compressed to form a continuous homogeneous covering of a felted nature.

In manufacturing the insulated conductor of the invention, a layer of untwisted asbestos rovings (free of cotton or other organic matter) is applied to the metallic conductor. The asbestos is then impregnated with an aqueous solution of boric acid, or the like, as, for example, by passing the metallic conductor with its first covering of felted asbestos through the boric acid solution, allowing sufficient time for the solution to thoroughly saturate the asbestos. As the conductor emerges from the boric acid solution, it is squeezed by revolving means so as to compress the insulating wall and wring out the excess of the solution. The conductor then passes through revolving dies which further compress and smooth the asbestos covering. The next layer of untwisted asbestos rovings is applied to the still-moist first layer, and the so-formed conductor is then passed through a solution of sodium silicate, or other appropriate alkali-metal silicate. On emerging from the silicate solution the conductor is again subjected to the wringing and smoothing operations previously described. Additional layers of untwisted asbestos rovings are then applied and similarly impregnated with the sodium silicate solution, until an insulating medium of the contemplated thickness has been thus built. Usually three or more layers of silicate-impregnated asbestos are applied to the conductor, each succeeding layer being subjected to the wringing and smoothing operations hereinbefore described. The insulated conductor is then subjected to vacuum drying at a temperature of about 225° F., in the course of which substantially all water is driven off. If desired, the insulated conductor may be finally covered with the usual lead sheath to form the completed cable.

The purpose of impregnating the first or inner layer of asbestos with boric acid, borax, or the like, is to prevent the penetration of the alkali-metal silicate, in its subsequent applications, to the surface of the metallic conductor, with the resultant adherence of the insulation to the conductor. Such adherence of the insulation to the conductor makes it difficult to strip the insulation from the conductor when making electrical connections, and the coating of the conductor with the alkali-metal silicate hinders soldering when making splices or connections.

Other agents than boric acid or borax may be employed for the purpose in hand. The principle involved is to cause the solution of the alkali-metal silicate to gel when it penetrates the second layer of asbestos and meets the boric acid or borax in the first layer. Any mild acid salt will accomplish the same result, since the alkali-metal silicate is alkaline and it is only necessary to neutralize this alkalinity to cause it to form a gel. The formation of this gel so impedes the penetration of the alkali-metal silicate that it does not reach the metallic conductor. The boric acid or borax solution does not coat the metallic conductor, and does not interfere with subsequent soldering, since borax acts as a flux. Moreover, boric acid or borax does not cause the insulation to adhere to the conductor. Using borax, the impregnating solution is preferably maintained at a temperature of about 50° C., while with boric acid the solution may be used cold or at ordinary room temperature.

I prefer to use sodium silicate because of its ready commercial availability and cheapness. Other alkali-metal silicates, such as potassium silicate, may however be used. I prefer an alkali-metal silicate of a high percentage of silica (SiO_2) with respect to the alkali-metal oxide (e. g. Na_2O), because such silicates are of lower alkalinity and their vitrifying action at elevated temperature (more particularly described hereinafter) yields a tube of greater mechanical strength. I have employed with excellent results a sodium silicate of the form of Na_2O, $3.3SiO_2$.

Without intending to limit or restrict the invention in any manner whatsoever, I give in the following table the impregnants of the various asbestos layers in an insulated conductor constructed in accordance with my now preferred practice of the invention:

Asbestos layer	Impregnant		
No. 1	2 lbs. boric acid to 1 gal. of water.		
No. 2	80% sodium silicate.	*20% water	Spg. 34° Bé.
No. 3	50% sodium silicate.	50% water	Spg. 24° Bé.
No. 4	33⅓% sodium silicate.	66⅔% water	Spg. 17° Bé.
No. 5	20% sodium silicate.	80% water	Spg. 10° Bé.
No. 6	10% sodium silicate.	90% water	Spg. 5° Bé.

* Spg. of sodium silicate 40° Bé.

The insulated conductor when completed contained approximately 15% of dry silicate of soda and approximately 3% of boric acid by weight on the asbestos.

When the insulated conductor of the invention is subjected to a short-circuit or other fault, and consequently to temperatures above the melting point of copper, the asbestos and silicate of soda (or other alkali-metal silicate) combine to form a strong tube-like structure of vitreous character which acts as an insulating barrier to prevent propagation of arcing and attendant prolonging of short-circuits resulting in extended destruction of the conductor and other adjacent equipment. The exact reaction that takes place is as yet undetermined. Inasmuch as asbestos is a composite silicate of magnesium and small amounts of other metals with a certain amount of water of crystallization it appears probable that at elevated temperatures above 1000° C. this water is driven off and as sodium meta-silicate melts at 1088° C. it flows into the dehydrated magnesium silicate and reacts therewith to form a complex silicate of sodium and magnesium which fuses into a vitreous-like tube surrounding the metallic conductor. A rearrangement of the acid and alkali ions probably takes place to bring about a state of chemical equilibrium. In any event, upon the occurrence of a fault, the resulting high temperature fuses the asbestos and silicate of soda into a vitreous-like or porcelain-like tube surrounding the metallic conductor. This tube is of sufficient strength to confine the molten copper (or other metal of the conductor) until it flows out at the point of fault. The arc gap is ultimately so lengthened by the melting of the metallic conductor that the arc is extinguished. Thus, the characteristic feature of the

insulated conductor of the invention is the provision around the metallic conductor, upon the occurrence of a fault, of a protective tube of vitreous-like character which permits the molten copper to flow out at the point of fault, and the arc is ultimately extinguished by the increased length of melted conductor. This is virtually extinguishing the arc mechanically, that is by increase of the electrical resistance between the unconsumed ends of the metallic conductor.

One of the characteristic features of the insulated conductor of the invention is that no cotton or other organic substance is associated with the asbestos insulation. In fact, the insulation contains no compound (other than a small amount of water) which evolves gas at the elevated temperature incident to the occurrence of a short-circuit or other fault. Thus, owing to the nature of the materials entering into the insulating medium of the conductor there is no carbonization at elevated temperature and the only gas evolved is steam from the combined water in the asbestos and silicate. Consequently, with the insulated conductor of the invention, no inflammable or explosive gases are produced at any temperatures, and faults in underground systems are cleared without the evolution of any smoke or gas in sufficient quantity to cause concern to persons in the immediate vicinity.

The insulating medium of the conductor of the invention when not water-proof should be enclosed in an outer sheath similar to cables insulated with paper, varnished cambric, etc. In the event of a pin-hole in the usual lead sheath admitting moisture, the insulating medium becomes electrically conducting and the leakage current produces sufficient heat to dry out the moisture, whereupon the insulation regains its initial dielectric strength.

Another distinctive feature of the insulating medium of the conductor of the invention is that it will not fail dielectrically twice in the same place. When broken down by high voltage, the heat produced at the point of failure by the arc passing through the insulating wall vitrifies the spot which then has higher dielectric strength than before. Subsequent failures will always occur at some other point.

The insulated electrical conductor of the invention is not materially different in flexibility or other physical properties from the usual forms of insulated cable, and the vitreous formation does not occur until fault conditions generate temperatures ranging from that of molten copper to that of the electric arc.

I am aware that silicate of soda has heretofore been used for the purpose of flame-proofing otherwise inflammable materials used for electrical insulation. In the insulated conductor of the invention, the alkali-metal silicate serves a distinctly different purpose. There is in the insulating medium of the conductor of the invention no organic or inflammable material, and the alkali-metal silicate acts as a fusible cement to combine at elevated temperature with the dehydrated asbestos (magnesium silicate) to form a mechanically strong tube-like barrier around the metallic conductor which by that time has reached the molten state. This barrier of vitreous-like character ultimately brings about a mechanical extinguishing of the arc without at any time evolving any gas of inflammable, explosive or toxic character.

None of the materials in the insulating medium of the conductor of the invention deteriorates with age, and the insulated conductor is therefore completely permanent.

I claim:

1. An insulated electrical conductor comprising a metallic conductor surrounded by an insulating medium incapable of evolving an inflammable or explosive gas at elevated temperature and consisting principally of asbestos impregnated with sodium silicate, the concentration of sodium silicate progressively decreasing from the interior towards the exterior of the insulating medium.

2. An insulated electrical conductor comprising a metallic conductor surrounded by an insulating medium incapable of evolving an inflammable or explosive gas at elevated temperature and consisting principally of asbestos impregnated with an alkali-metal silicate, and a layer of asbestos intermediate said metallic conductor and said surrounding insulating medium impregnated with an agent inhibiting the penetration of said alkali-metal silicate to the surface of said metallic conductor.

3. An insulated electrical conductor comprising a metallic conductor surrounded by an inner layer of asbestos impregnated with borax, and one or more layers of asbestos impregnated with an alkali-metal silicate surrounding said inner layer, the asbestos in all of said layers being free of cotton or other organic material volatilizable at elevated temperature.

4. An insulated electrical conductor comprising a metallic conductor surrounded by an insulating medium incapable of evolving an inflammable or explosive gas at elevated temperature and consisting principally of asbestos impregnated with sodium silicate in such amount as to unite with asbestos to form a vitreous-like compound about the metallic conductor when subjected to the elevated temperature incident to the occurrence of a short-circuit or similar fault, and a layer of asbestos intermediate said metallic conductor and said insulating medium containing an agent serving to inhibit the penetration of said sodium silicate to the surface of said metallic conductor.

5. An insulated electrical conductor incapable of evolving an inflammable or explosive gas at elevated temperatures which comprises a metallic conductor insulated by flexible insulation including non-brittle fibrous material in an amount sufficient to retain at least a part of the insulation on the conductor, said insulation being capable of forming a vitreous-like tube when subjected to elevated temperatures without evolving an inflammable or explosive gas.

6. An insulated electrical conductor incapable of evolving an inflammable or explosive gas at elevated temperatures which comprises a metallic conductor insulated by flexible insulation including a plurality of silicates one of which fuses and another does not at a temperature approximating the melting point of copper, said silicates being capable of reacting to form a vitreous-like tube when subjected to elevated temperatures without evolving an inflammable or explosive gas.

7. An insulated electrical conductor incapable of evolving an inflammable or explosive gas at elevated temperatures which comprises a metallic conductor insulated by flexible insulation including asbestos and a substance which will combine therewith to form a vitreous-like tube when subjected to elevated temperatures without evolving an inflammable or explosive gas, the amount

of asbestos being sufficient to retain at least a part of the insulation on the conductor.

8. An insulated electrical conductor incapable of evolving an inflammable or explosive gas at elevated temperatures which comprises a metallic conductor insulated by flexible insulation including asbestos impregnated with an alkali-metal silicate, the amount of asbestos being sufficient to retain at least a part of the insulation on the conductor, said insulation being capable of forming a vitreous-like tube when subjected to elevated temperatures without evolving an inflammable or explosive gas.

9. An insulated electrical conductor incapable of evolving an inflammable or explosive gas at elevated temperatures which comprises a metallic conductor insulated by flexible insulation consisting principally of asbestos impregnated with an alkali-metal silicate, said insulation being capable of forming a vitreous-like tube when subjected to elevated temperatures without evolving an inflammable or explosive gas.

10. An insulated electrical conductor incapable of evolving an inflammable or explosive gas at elevated temperatures which comprises a metallic conductor insulated by flexible insulation including asbestos impregnated with an alkali-metal silicate in such amount as to unite with the asbestos to form a vitreous-like compound when subjected to the elevated temperature incident to the occurrence of a short-circuit or similar fault, without evolving an inflammable or explosive gas, and a medium intermediate said metallic conductor and said insulation for inhibiting the penetration of said alkali-metal silicate to the surface of said metallic conductor.

11. An insulated electrical conductor incapable of evolving an inflammable or explosive gas at elevated temperatures which comprises a metallic conductor insulated by flexible insulation consisting principally of asbestos impregnated with an alkali-metal silicate, and a medium intermediate said metallic conductor and said insulation for inhibiting the penetration of said alkali-metal silicate to the surface of said metallic conductor, said insulation being capable of forming a vitreous-like tube when subjected to elevated temperatures without evolving an inflammable or explosive gas.

12. An insulated electrical conductor incapable of evolving an inflammable or explosive gas at elevated temperatures which comprises a metallic conductor insulated by flexible insulation consisting principally of asbestos impregnated with sodium-silicate, and a medium intermediate said conductor and said insulation containing an agent adapted to react with said sodium silicate to form a barrier preventing the penetration of the sodium-silicate to the surface of said metallic conductor, said insulation being capable of forming a vitreous-like tube when subjected to elevated temperatures without evolving an inflammable or explosive gas.

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