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ELECTRIC TRAILING CABLES WITH FAILURE LIMITING MEANS

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Fig. 1.

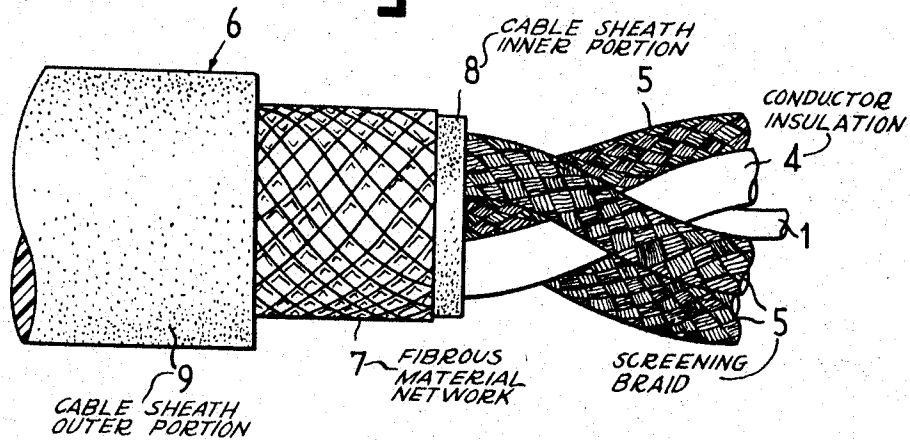


Fig. 2.

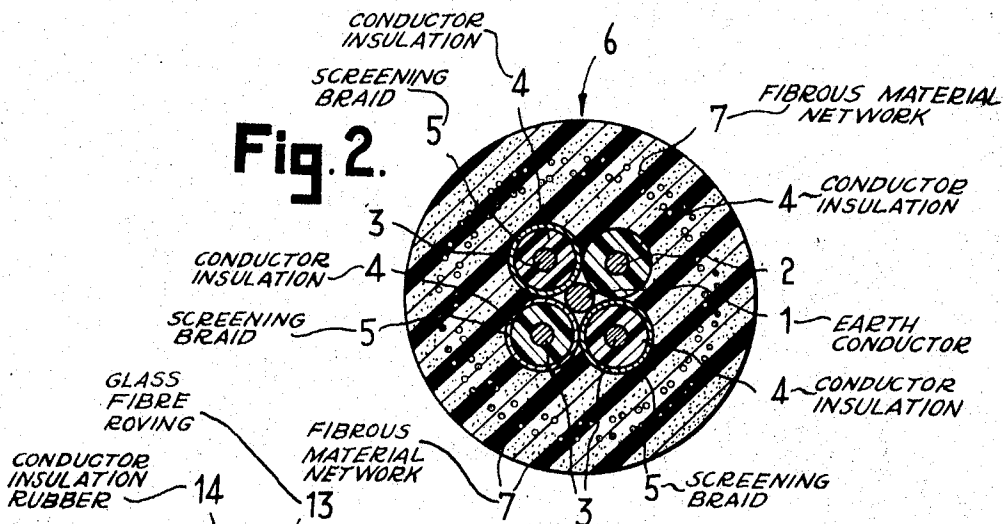
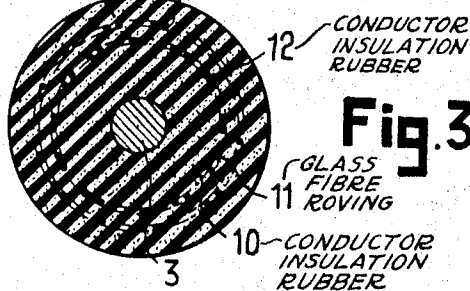


Fig. 3.



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ELECTRIC TRAILING CABLES WITH FAILURE LIMITING MEANS

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8 Claims. (Cl. 174—113)

This invention relates to electric cables and in particular to electric power cables of the kind having a flexible outer sheath of rubber, synthetic rubber or other elastomeric material, which surrounds an insulated and screened conductive core. Due to its flexibility an electric cable of the above kind has application as a trailing cable supplying power to mobile electrical apparatus, for instance as a trailing cable for portable mining apparatus.

A typical cable of the above kind comprises a conductive core consisting of three power conductors and a pilot conductor laid around a central earth conductor, the power conductors being individually insulated with vulcanised rubber or a synthetic elastomer composition, screened, laid-up and sheathed overall with a heavy duty polychloroprene or other suitable elastomer. The screening may be by means of an all metal (e.g. tinned copper) braid, a metal/synthetic fibre composite braid, or a covering of conductive rubber compound. In the latter case, the central earth conductor is usually covered with conductive rubber to form a cradle centre around which the insulated power conductors are laid.

In the event of a power conductor of the cable breaking, as a result for instance of extreme tension or repeated localised flexing, there exists the danger that if the cable is on load, i.e. passing current, at the time the break occurs, an arc may form between the broken ends of the conductor causing a rapid build up of gas pressure due to volatilisation of copper and pyrolysis of the conductor insulation. Thus, if such an arc is struck, gas under high pressure is produced which may rupture the conductor insulation and thus be released into the inter-sheath space, that is the space bounded by the sheath. This gas contains incandescent particles so that if the sheath also ruptures there is a risk of emission of flame from the ruptured sheath, with consequent risk of explosion or of injury to personnel.

The probability of the emission of incandescent gas (flame) from the cable is largely dependent on the energy released from the gas stored in the insulation envelope and released into the inter-sheath space. This energy is, to a first approximation, proportional to the pressure and volume of the contained gas. The insulation is elastic in nature and yields to the pressure of the gas developed within it by the arcing. In cables where the insulated conductors are screened by having a metallic braid applied over the insulation, the screen provides a means of reinforcement for the insulation envelope which it contains, but this reinforcing effect may decrease with the service of the cable as the screen is weakened by flexing.

Even in a new cable the screen will yield under the gas pressure generated by the arc to an extent dependent on its construction, an extreme case being when conducting rubber screening is employed. Under these circumstances, the volume of gas contained in the expanded insulation envelope surrounding the broken conductor can be large so that when this gas is released into the inter-sheath space there is a high probability of explosion occurring since the sheath cannot be relied upon to contain the

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large explosive energy concentrated at the point of rupture of the conductor insulation. The rupture of the sheath is often instantaneous under these conditions and there is no possibility of relying on conventional protective devices, such as gate end boxes for mining equipment, to prevent the immediate explosion.

According to the invention, there is provided an electric cable comprising a number of conductors, respective insulation coverings of elastomeric material for individual ones of said conductors, a flexible outer sheath of elastomeric material surrounding said conductors as a whole, fibrous material reinforcing said outer sheath to enhance its circumferential strength, and fibrous material reinforcing each individual conductor insulation covering to enhance its circumferential strength, the reinforcing fibrous material for the sheath having an elongation at break which is so related to the elongation at break of the reinforcing fibrous material for each individual conductor insulation covering that, under arcing conditions at a break in an insulated conductor of the cable, the energy released into the inter-sheath space on rupture of the insulation covering of that conductor can be reliably contained, at least temporarily, by the reinforced cable sheath.

By reinforcing each individual conductor insulation covering with fibrous material in accordance with the invention, the extent to which the insulation covering can yield under internal gas pressure is considerably reduced so that the volume of gas which will be contained in the insulation covering surrounding a broken conductor is correspondingly reduced. Therefore, the explosive energy, which is dependent on the volume of gas present, is also reduced.

Preferably, the reinforcing fibrous material for each individual conductor insulation covering is embedded within the insulation covering. It is desirable that the reinforcing fibrous material shall be of open construction, such as an open weave, roving or braiding, in order to obtain bonding therethrough of the insulation covering embedding it. Glass continuous filament yarn applied in the form of roving or braiding is eminently suitable as it is intrinsically strong. Furthermore, when applied as a roving or braiding, it is flexible, if suitably formed and does not, therefore, reduce the flexibility of the cable by any material extent. Moreover, glass has only a very small elongation at ultimate break and in this respect glass fibre continuous filament yarn having an elongation at break of about 1½% has been found to be eminently suitable for the purposes of the invention.

By reinforcing the cable sheath with fibrous material in accordance with the invention, the sheath can expand or distend, before rupture, and the resulting increase in volume of the inter-sheath space brings about a corresponding reduction of gas pressure. This enables the evolved gases to be confined, at least temporarily, within the cable. The sheath material can incorporate as reinforcement, preferably embedded, a high tensile synthetic fibrous material having sufficient elongation, before break, to allow the previously mentioned expansion or distension of the sheath under gas pressure. In this case, the reinforcing fibrous material preferably has an elongation of at least 20% while having sufficient tensile strength to reinforce the sheath to offset possible weakness thereof arising from cuts or other incidental damage. In this instance, the reinforcing fibrous material is suitably of nylon, polypropylene or polyethyleneterephthalate preferably in the form of a continuous filament yarn, and it can be formed either as an open weave, as a roving or as a braiding: an open construction such as any of these is desirable when the reinforcing fibrous material is embedded in the sheath

in order to obtain bonding therethrough of the material embedding it.

Under arcing conditions at a break in a conductor of cable constructed in accordance with the invention, the reinforcement of the conductor insulation covering will limit the expansion of this insulation, and therefore of the volume of gas contained by it. The pressure at which the conductor insulation covering ruptures would be higher than in the case of an unreinforced conductor insulation covering of the same material, but the energy released into the inter-sheath space on rupture will be significantly less because of the reduction of volume. It has been found that this lower energy release can be reliably contained in the reinforced cable sheath, at least for a sufficient time to enable a protective device to disconnect the cable from the supply.

In order that the invention may be more fully understood reference will now be made by way of example to the accompanying drawing in which, very diagrammatically:

FIG. 1 is a progressively broken away side view of a typical electric cable constructed in accordance with the invention;

FIG. 2 is an end sectional view of the cable of FIG. 1; and

FIG. 3 is an end sectional view of a modified form of insulated conductor for the cable of FIGS. 1 and 2.

Referring to FIGS. 1 and 2, the electric cable there shown comprises a central earth conductor 1 about which a pilot conductor 2 and three power conductors 3 are laid-up. The pilot conductor 2 and each of the power conductors 3 are individually insulated by means of insulating material 4 and each of the power conductors 3 is individually screened by means of composite metal/textile (e.g. tinned copper/nylon) braid 5. The conductive core of the cable as formed by the various conductors 1, 2 and 3 is surrounded by a sheath 6 of heavy duty polychloroprene. In conformity with the invention there is incorporated in the sheath 6 an open weave, or braid, or roving network 7 of fibrous material serving as high tensile circumferential reinforcement for the sheath 6. A high tensile elastic material of over 90,000 lb. per sq. in. U.T.S. and an elongation at break of at least 20% would be suitable for the fibre network, for example nylon, polyethyleneterephthalate or polypropylene. In the manufacture of the cable, sheath 6 is formed as inner and outer portions 8 and 9 by separate lappings or extrusions with the reinforcing network 7 being embedded between separate lappings or extrusions, the outer portion 9 bonding to the inner portion 8 through the interstices of the fibrous network 7.

The insulation 4 of the power conductors 3 may also be reinforced suitably with glass fibre, as shown in FIG. 3. Thus, each power conductor 3 has a layer of insulation rubber 10 over which is applied a roving of glass fibre 11. This roving 11 is covered by a second (thin) layer of insulation rubber 12 and a second glass fibre roving 13, preferably of opposite lay to the roving 11, is applied over the second layer of insulation rubber 12. Another layer of insulation rubber 14 is then applied over this second roving 13 and the whole vulcanised so as to form for the conductor 3 a reinforced insulation in which the glass fibre rovings 11 and 13 are solidly embedded in the insulation rubber (10, 12, 14). Reinforcement of the conductor insulation may likewise be effected by applying the glass fibre as a braid rather than as a roving. Over the reinforced insulation rubber the conventional screening material, for instance a conducting rubber layer or metal braid as in FIGS. 1 and 2, is then applied.

For some applications it has been found advantageous to use a composite insulation construction for the core conductors, this being more resistant to damage than is the conventional rubber insulation. Such a composite insulation may consist of an inner layer of good insulant, such as vulcanised natural rubber, S.B.R., butyl rubber

or ethylene propylene rubber bonded to an outer layer of vulcanised chlorsulphonated polyethylene. The dielectric properties of vulcanised chlorsulphonated polyethylene are inadequate for it to comprise the whole insulation thickness of the conductor insulation. Owing to its excellent mechanical properties it can, with advantage, be used as the outer layer of a composite insulation. Additionally, a layer of vulcanised chlorsulphonated polyethylene may be included between the conductor and the insulating rubber layer, this chlorsulphonated polyethylene layer being bonded to the insulating rubber layer. Such a composite insulation can be reinforced with glass fibre interposed between layers in the manner described above.

What we claim is:

1. An electric cable comprising:

- (a) a number of conductors,
- (b) respective insulation coverings of elastomeric material for individual ones of said conductors,
- (c) a flexible outer sheath of elastomeric material surrounding said conductors as a whole,
- (d) fibrous material reinforcing said outer sheath to enhance its circumferential strength, and
- (e) fibrous material reinforcing each individual conductor insulation covering to enhance its circumferential strength,

the reinforcing fibrous material for the sheath having a high percent elongation at break and the reinforcing fibrous material for each individual conductor insulation covering having a low percent elongation at break so that, under arcing conditions at a break in an insulated conductor of the cable, the energy released into the inter-sheath space on rupture of the insulation covering of that conductor can be reliably contained, at least temporarily by the reinforced cable sheath.

2. An electric cable as claimed in claim 1, wherein each of said fibrous materials is embedded in the elastomeric material which it reinforces.

3. An electric cable as claimed in claim 2, wherein said fibrous materials are of open construction to permit bonding therethrough of the elastomeric material embedding them.

4. An electric cable comprising:

- (a) a number of conductors,
- (b) respective insulation coverings of elastomeric material for individual ones of said conductors,
- (c) a flexible outer sheath of elastomeric material surrounding said conductors as a whole,
- (d) fibrous material reinforcing said outer sheath to enhance its circumferential strength, said fibrous material having an elongation at break of at least 20% and being a material in the group consisting of nylon, polypropylene and polyethyleneterephthalate, and
- (e) glass textile fibrous material reinforcing each individual conductor insulation covering to enhance its circumferential strength, said glass textile fibrous material having an elongation at break of about 1½%.

5. An electric cable according to claim 4, in which the elastomeric material constituting the sheath is heavy duty polychloroprene and is formed as inner and outer portions, and the reinforcing fibrous material therefor is an open fibrous network embedded between said inner and outer portions which are bonded together through interstices of the fibrous network.

6. An electric cable as claimed in claim 5, in which the elastomeric material constituting each individual insulating covering is formed from at least two successively applied layers of rubber which are vulcanised together with an embedded open network of reinforcing glass textile fibrous material.

7. An electric cable as claimed in claim 5, in which the elastomeric material constituting each individual con-

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ductor insulation covering is formed as a composite insulation comprising an inner layer of a material taken from the group consisting of vulcanised natural rubber, S.B.R., butyl rubber and ethylene propylene rubber, bonded to an outer layer of vulcanised chlorsulphonated polyethylene with an open network of said reinforcing fibrous material embedded in the composite insulation.

8. An electric cable as claimed in claim 7, in which a layer of vulcanised chlorsulphonated polyethylene is included between the conductor and the insulating rubber layer, these two layers being bonded together.

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