July 16, 1957 T. R. SCOTT 2,799,608

ELECTRIC CABLES

Filed July 13, 1951

FIG. 1.

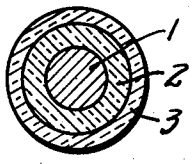


FIG. 2.

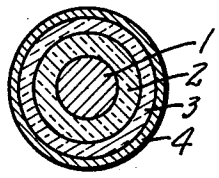
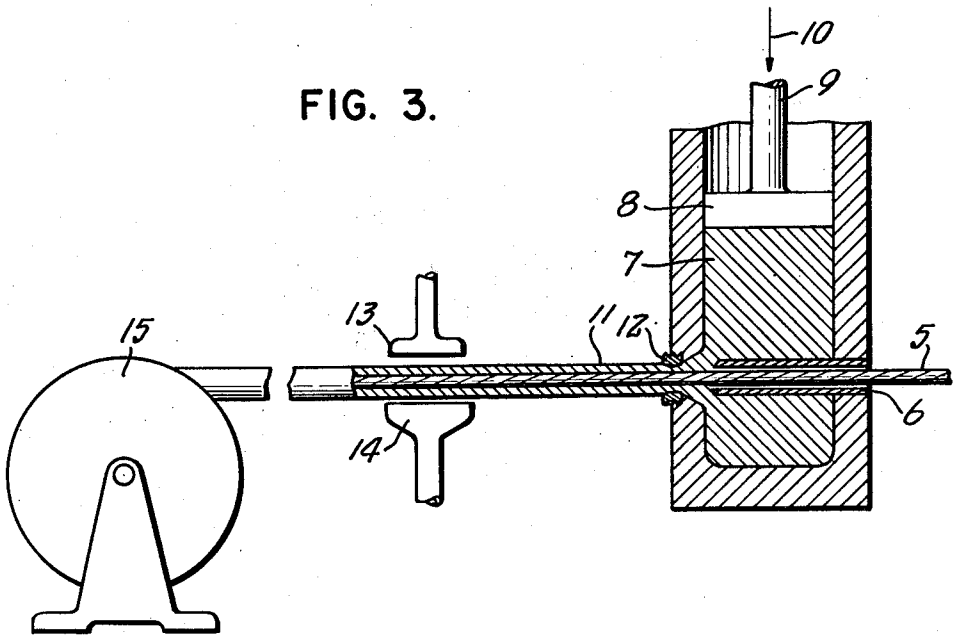


FIG. 3.



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ELECTRIC CABLES

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7 Claims. (Cl. 154—2.25)

This invention relates to electric cables and more particularly to such cables having cores in which the insulation of the conductors is principally paper as in the ordinary forms of electric communication cables or power cables.

These cables are normally provided with outer wrappings, in contact with the sheath, of one or more lengths of paper or fabric. In some cases the paper or fabric is metallized, that is to say, a thin film of aluminium or the like is caused to adhere to the outer surface of the paper. Such cores will be referred to hereinafter as heat sensitive cores.

It is the object of the invention to provide a process by means of which such cables may be sheathed with a closely fitting sheath of aluminium.

It has hitherto been assumed that it is impracticable to cover such cores with an aluminium sheath by direct extrusion since paper or fabric will not stand exposure to the temperatures required for a period during which they must be exposed to those temperatures during such extrusion, and we have verified the last mentioned statement by experiment. The actual time/temperature relationship obtained is a complex function. It depends on the design of the die, the design of the press, the size of the aluminium billet used, the quality of the aluminium, the speed of extrusion etc. In general, however, times of the order of one or two seconds at temperatures in the range 350° C.–500° C. are involved. Experiment has shown that it is possible to arrange extrusion so that the time of exposure is less than one second provided temperatures up to 500° C. are permissible. It has therefore been proposed to draw the cable core into a previously manufactured aluminium tube of somewhat greater diameter than the cable core and then to swage or roll down the tube until it fits tightly on the cable core. If this swaging or rolling is carried out at normal ambient temperature hardening of the aluminium occurs and subsequent deterioration of the sheath results. In order to avoid this work-hardening and deterioration it would be necessary to carry out the swaging or rolling at high temperatures and to maintain those temperatures for a sufficient time to allow recrystallisation of the aluminium, that is annealing. The relations between the purity of the aluminium used, the temperature to which it is subjected and the times required at that temperature for the annealing of the aluminium are shown in the following table:

Recrystallisation times in seconds

Purity of Aluminium	99.99%	99.8%	99.5%
Temperatures, ° C.			
350	0.5	7	45
400		2	12
450		0.5	3
485			1.5
495			<1.0

We have found that at 350° C. paper or fabric can be exposed to that temperature for a period up to 2 seconds without appreciable deterioration or degradation. As a criterion of the degradation of the cotton fabric or paper due to exposure to elevated temperature we have taken the reduction of tensile strength observed. This indicates closely the breakdown of physical and chemical structure of the cellulose fibres.

Taking 20% reduction of tensile strength as a maximum permissible degradation, although obviously in practice every effort will be taken to minimize the degradation, the following values are obtained:

Temp. (° C.):	Time (secs.)
350	4½
400	½

It should be noted that these values applied only to paper wrapping in contact with the sheath. The layer under the contact layer will be relatively unaffected at the temperatures quoted although at higher temperatures it also will be substantially reduced in tensile strength. As the temperature is raised more and more layers become affected. It will be seen therefore that it is possible to carry out this process of drawing down at 350° C. only for aluminium of a purity of 99.99%. At 400° C. the tensile strength of the outer layer of paper is reduced by about 25% after two seconds exposure and therefore the working of 99.8% aluminium at this temperature in order to draw it down in contact with a heat sensitive core is not possible without undue deterioration of the core. If however, the temperature be raised to 440° C. the tensile strength of the paper is practically unchanged by exposure for a period of 1 second so that at that temperature it would be possible to draw down 99.8% pure aluminium on to the heat sensitive core. We have found however, that the process cannot be carried out with 99.5% aluminium, this is because although the time required for the annealing of aluminium of 99.5% purity decreases as the temperature increases, the amount of deterioration caused to paper or fabric for a given time of exposure increases much more rapidly.

In British Ptent No. 631,127 published May 19, 1950, we have described and claimed a continuous process for sheathing an insulated cable core comprising the steps of continuously extruding a tube of aluminium so that it surrounds said cable core, but is held in spaced relation therefrom, the temperature of said cable core being kept below that at which damage will be caused thereto by the high temperature employed in the extrusion press, and drawing down said extruded tube shortly after it leaves the extrusion head so as to form a closely fitting sheath surrounding said cable core said drawing down taking place when the tube has travelled to a point at which the temperature thereof has fallen to a value at which damage will not be caused to the cable core, but which is above the recrystallisation temperature of the metal forming the sheath. It will be seen that this process is subject to the same limitations as that previously described.

We have discovered that by acetylating paper or fabric up to at least 20% i. e. with up to 20% combined acetic acid content the degree of heat exposure that can be tolerated without appreciable deterioration of the mechanical or electrical properties is considerably increased, and therefore, that by making the outer wrappings of a heat sensitive core of such acetylated paper or fabric it is possible to carry out any of these processes with aluminium of less purity than hitherto. According to the present invention there is provided an aluminium sheathed electric cable in which the insulated core is provided with

at least one layer of acetylated paper, fabric or the like adjacent to the aluminium sheath.

It is to be noted that a core of the kind described suffers no appreciable deterioration after exposure to a temperature of 120° C. for a period of seven days whether the outer layer is plain or acetylated paper.

The invention further provides a process for sheathing with aluminium of at least 99.5% purity a heat sensitive insulated electric cable core comprising providing the said core with an outer layer of paper or fabric acetylated up to at least 20% combined acetic acid content, establishing a firm contact between a sheath of said aluminium and said outer layer at a temperature in the range between 350° C. and 500° C. and cooling said sheath to a temperature not exceeding 120° C. after a period of time of sufficient duration to allow the aluminium to become recrystallised but not of sufficient duration to allow the said outer layer to be degraded to such an extent that its tensile strength is reduced by more than 20%.

We have found that at 495° C. acetylated paper loses only about 20% of its tensile strength after exposure for one second, whilst acetylated cotton fabric loses only 10% of its tensile strength under the same conditions. As 99.5% aluminium can be completely annealed at 495° C. applied for one second it will be seen that an aluminium sheath may be applied to a cable having a heat sensitive core by any of the three processes described above by use of the invention without damage to the core.

Taking again the criterion of 20% reduction of tensile strength we obtain for acetylated paper:

Temp. (° C.):	Time (secs.)
350	17½
400	3½
460	1½
495	1

Acetylated cotton fabric gives somewhat better results, probably on account of the increased thickness compared with paper.

It will be seen therefore that 99.8% purity aluminium can easily be annealed while in contact with the cable core at temperatures from 350° C. upwards. If the annealing time is kept to the minimum the loss of tensile strength for acetylated paper will be as shown below:

Temp. (° C.)	Time (secs.)	Reduction in tensile strength (percent)
350	7	0
400	2	0
450	½	<10

It is thus clear that by using the means proposed herein any method of annealing aluminium of purity not less than 99.8% in contact with the cable core can be employed without appreciable degradation of the core.

It is thus possible to extrude the sheath at any suitable temperature and speed and thereafter swage and anneal sheaths comprising aluminium of said purity.

For aluminium of purity in the range of 99.8%–99.5% it is necessary to achieve temperatures of the order of 500° C. for times of exposure up to one second and this is possible by utilising the means described at the expense of loss of tensile strength less than 20%.

It is known particularly in power cables to use an outer layer of paper metallized on the outside. Such a layer affords a certain amount of protection to a core subjected to elevated temperatures, but the protection is insufficient if the paper has not been acetylated in accordance with the present invention. Thus at 495° for an exposure of 1 second a layer of plain paper metallized on the outside

suffers a loss in tensile strength of 30% instead of 60% suffered by plain paper not metallized. It will be seen that the use of metallized paper by itself is insufficient to permit the satisfactory application of a sheath of aluminium of a purity 99.5% to 99.8%.

It is clear that the outer layer of paper acetylated in accordance with the present invention may be provided with a metallized outer face in order still more to diminish the reduction of tensile strength of the paper at elevated temperatures and so improve the quality of the sheathed cable.

It has to be understood that while we have referred specifically to grades of aluminium designated as 99.99% purity, 99.8% purity and 99.5% purity we are in fact dealing with a range of purity from 99.5% to 99.99% or even higher. Commercial aluminium is found to vary between about 99.5% to 99.7%, the main impurities being iron and silicon.

99.99% purity aluminium is specially refined and is more costly. By blending varying amounts of 99.99% purity with the normal commercial grade any desired purity level in the range 99.5% to 99.99% can be obtained at a cost. The lower the purity in this range the less the degree of flexibility in the process of applying an aluminium sheath in contact with a heat sensitive core. The conditions for annealing merge with those for extrusion and little is gained by separating the two phases of the process. From about 99.8% upwards, on a purity basis, it is however possible to carry out swaging and annealing if desired at temperatures and times which differ from those most desirable in the extrusion process. For example at 99.8% purity it may be desirable to extrude at about 480° C. at speeds of from 30 ft./min. upwards giving times of exposure if direct contact with the heat sensitive core is established of, according to one convenient arrangement, 2 seconds. Such an arrangement would unduly deteriorate the outer layer even if it comprises acetylated fabric or paper. In such an arrangement it is preferable to extrude oversize, i. e. with an annular air space, cool the sheath to between 350°–400° C. before swaging down and to cool again after 7 seconds to 2 seconds of direct contact. The second cooling spray can be arranged so that it comes closer to the swaging arrangement as the speed of travel of the cable decreases. In the limit the spray can come right up to the point of direct contract when the speed is zero. This would correspond with a similar movement of the cooling spray in the case of direct extrusion to deal with undue reduction of speed or total stoppage, the cooling being effected right up against the die during said stoppage. Such adjustment of cooling is well known in the art of sheathing cables with lead.

The following table gives a summary of the data relating to the maximum time for which it is safe to expose the outer layer of acetylated paper or fabric to a predetermined temperature and also shows the minimum time necessary to effect recrystallisation of an aluminium sheath of 99.5% purity.

Temperature °C.	Maximum safe time of exposure of acetylated paper (seconds)	Minimum time for recrystallisation of aluminium of the three purities shown (seconds)		
		99.99%	99.8%	99.5%
300	60	2.0	30	200
350	15	0.5	7	45
400	5	<0.1	2	12
450	3	<0.1	0.5	3
495	1	<0.1	0.1	<1

It can be seen that if aluminium of the 99.5 purity grade is used the process described can only be applied if temperatures not less than 450° C. are employed. If

aluminium of higher purity is used lower temperatures can be employed, and except at the highest temperatures the recrystallisation times are considerably less than the times for which it is safe to expose the acetylated material to the recrystallisation temperature. It follows that normally it is possible to select the temperatures and times in such a way that the degradation of the paper or fabric is much less than the empirical limit of 20% loss of tensile strength.

In order to illustrate one example of the process described above, reference may be had to the accompanying drawing, which is entirely schematic and in which:

Fig. 1 is a cross-section of a cable core;

Fig. 2 is a cross-section of a modified cable core which may be used in place of the core shown in Fig. 1, and

Fig. 3 represents diagrammatically equipment enabling the process which is the subject of the invention to be carried out.

Referring to the drawing, Fig. 1 shows a cable core comprising an inner copper conductor **1**, a layer of paper insulation **2**, and a layer of acetylated paper or fabric **3**. In Fig. 2 the layer of acetylated paper or fabric **3** is covered by a metalized film **4**.

Fig. 3 shows a cable core **5** fed through a hollow mandrel **6** passing through the extrusion chamber **7** of a press suitable for extruding aluminium tubes. The extrusion chamber **7** is charged with heated aluminium or alloy in which aluminium predominates and which completely fills the chamber.

When the ram **8** is pressed into the extrusion chamber **7**, as for example, by hydraulic pressure applied to the member **9** along the line indicated by the arrow **10**, an aluminium tube **11** will be extruded directly over the core **5** through the annular die **12**. The aluminium tube **11** is extruded at a temperature in the range between 350° C. and 500° C. but, as previously explained, the actual temperature depends on the size of the tube and the construction of the extrusion press.

The tube **11** cools rapidly after leaving the extrusion die **12** but after traveling a certain distance it is cooled to a temperature not exceeding 120° C. by cooling means comprising jets of water or other fluid, or jets of air or other gas. A cooling device consisting of a water spray **13** is shown in the drawing, water draining away via a sink **14**. The completed cable is wound on a suitable take-up drum **15**. The period of time taken by the cable in traveling from the die **12** to the cooling means **13**, **14**, is of sufficient duration to allow the aluminium to become re-crystallized but not of sufficient duration to allow the outer layer of acetylated paper or fabric **3** (Figs. 1 and 2) to be degraded to such an extent that its tensile strength is reduced by more than 20%.

While the principles of the invention have been described above in connection with specific embodiments, and particular modifications thereof, it is to be clearly understood that this description is made by way of example and not as a limitation on the scope of the invention.

What I claim is:

1. A process for sheathing with aluminium of at least 99.5% purity a heat sensitive insulated electric cable core comprising providing the said core with an outer layer of paper acetylated with up to 20% combined acetic acid content establishing a firm contact between a sheath of said aluminium and said outer layer at a temperature in the range between 350° C. and 500° C. and cooling said sheath to a temperature not exceeding 120° C. after a period of time of sufficient duration to allow the aluminium to become recrystallized but not of sufficient duration to allow the said outer layer to be degraded to such an extent that its tensile strength is reduced by more than 20%.

2. A process for sheathing with aluminium of at least 99.5% purity a heat sensitive insulated electric cable core comprising providing the said core with an outer layer of fabric acetylated with up to 20% combined acetic acid content, establishing a firm contact between a sheath of said aluminium and said outer layer at a temperature not exceeding 495° C. and restricting the period during which said temperature is maintained to one second or less.

3. A process for sheathing with aluminium of at least 99.5% purity a heat sensitive electric cable core comprising providing the said core with an outer layer of paper acetylated with up to 20% combined acetic acid content, establishing a firm contact between a sheath of said aluminium and said outer layer at a predetermined temperature not exceeding 495° C. and maintaining said temperature for a time sufficient to effect recrystallisation of the aluminium but not exceeding the time which would result in said outer layer being degraded so that its tensile strength would be reduced more than 20%.

4. A process for sheathing a heat sensitive insulated electric cable core with aluminium comprising providing the said core with an outer layer of fabric acetylated with up to 20% combined acetic acid content, extruding a tube of aluminium of at least 99.5% purity around said core but spaced therefrom whilst keeping the temperature of said core below that at which damage will be caused thereto, reducing the diameter of said tube to form a closely fitting sheath at a predetermined temperature not exceeding 495° C., maintaining said temperature for a time sufficient to effect recrystallisation of the aluminium but not exceeding the time which would result in said outer layer being degraded so that its tensile strength would be reduced more than 20%.

5. A process for applying an aluminium sheath to a heat sensitive insulated electric cable core comprising the step of providing said core with an outer layer of paper acetylated with up to 20% combined acetic acid content, drawing the cable core into a tube of aluminium having a purity not less than 99.5% and of larger internal diameter than the external diameter of the core, reducing the diameter of said tube until it forms a closely fitting sheath around said cable core, heating the sheath to a predetermined temperature not exceeding 495° C., maintaining said temperature for a time sufficient to effect recrystallisation of the aluminium but not exceeding the time which would result in said outer layer being degraded so that its tensile strength would be reduced by more than 20%.

6. A process according to claim 5 in which the said times for which the predetermined temperature is maintained so as to effect recrystallisation of the aluminium but not to degrade the outer layer of acetylated paper do not exceed the values given in the table below,

Predetermined temperature in ° C.	Purity of aluminium		
	99.99%	99.8%	99.5%
	Maximum time in seconds		
300	60	60	----------
350	15	15	----------
400	5	5	----------
450	3	3	3
495	1	1	1

7. A process according to claim 5 in which the outer surface of the acetylated paper has a metal foil adhering thereto.

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