Sept. 8, 1942. C. A. PIERCY ET AL 2,295,290

ELECTRIC POWER CABLE

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Fig. 1.

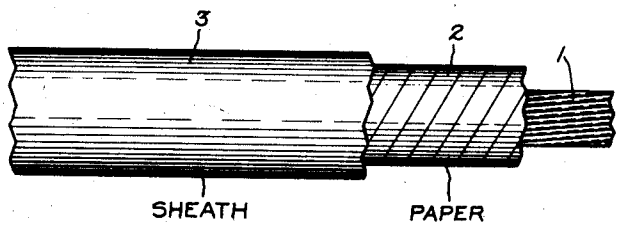
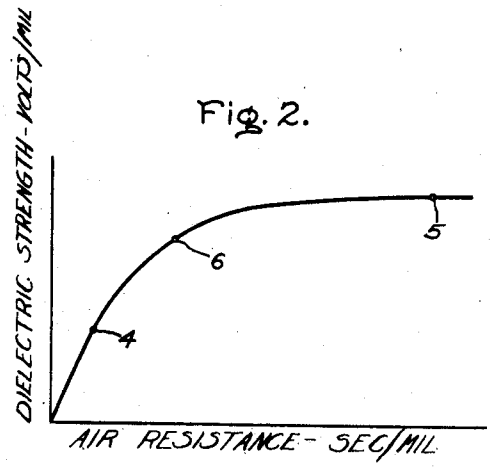


Fig. 2.



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ELECTRIC POWER CABLE

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2 Claims. (Cl. 174—120)

The present invention relates to electric cables of the type having conductors which are insulated with layers of paper tape wrapped thereon.

At the present time, two principal types of cable paper are in use, one having a low density of the order of .81 and the other having a high density of the order of 1.00 and usually higher.

The standard specifications for the low density paper call for a density of .81, an air resistance in seconds per mil of thickness of 51, a dielectric strength in volts per mil of 1140 and a minimum length of fiber of 1.77 millimeters. The high density paper initially has characteristics generally similar to the above but is subsequently subjected to heavy pressure as by calendering rolls which greatly increases the density and imparts to the surfaces thereof a glazed or glossy finish. The heavy rolling pressure increases the dielectric strength in volts per mil to 1440 which is advantageous but which is accompanied by certain disadvantages compared to the low density paper, i. e., the heavy pressing or rolling results in less uniform formation of the paper structure, a greater length of time is required to vacuum dry it due to the high density, a greater length of time is required to impregnate it for the same reason, the glazed or glossy surfaces due to calendering permits films of impregnant to exist as such between layers in the finished cable which are objectionable, and the paper has a higher power factor thereby increasing the electric losses of the cable when in service which is highly objectionable. High density paper also has the effect of increasing the stiffness of the cable, and renders the application of the paper tapes more difficult, especially to conductors of relatively small diameter. Furthermore, the calendering of the paper increases the cost over non-calendered paper by about 25%.

It has been the considered opinion of engineers and cable manufacturers that the breakdown strength and life of cable paper increases with increase in density; however, it has been determined by exhaustive tests that such is not the case but the contrary for such increase in density results in a decrease of dielectric strength and life of a cable insulated with supercalendered high density paper. It has also been found that, with an increase in density, there is a uniform rise in power factor which results in greater losses in the cable. One well known authority on the subject of insulating papers has found by elaborate test that an increase in the density of the paper, other things being equal, of 60 per cent results in a decrease of dielectric strength by 30 per cent and its accelerated voltage life test is shorter by 47 per cent.

These values are given from tests which simulate the application of paper tapes to the conductor of an actual cable using supercalendered high density paper. One reason for this lower electrical life as given by this authority is that the free oil film located between opposed glazed surfaces of the layers of paper is overstressed. The high density of such paper gives a higher dielectric constant thus transferring a greater proportion of the total voltage to the oil film between the layers.

The object of our invention is the provision of an improved electric cable especially for high tension current having as its insulating medium improved paper which is characterized by shorter than usual fibers accompanied by moderately high resistance to air flow, relatively low density to facilitate the removal of air and moisture from the paper and the subsequent impregnation thereof, and a high dielectric strength measured in volts per mil.

For a consideration of what we believe to be novel and our invention, attention is directed to the accompanying description and the claims appended thereto.

In the drawing, Fig. 1 illustrates a cable primarily intended for the transmission of high tension electric current, and Fig. 2 is a curve illustrating the relation of air flow, resistance and density of our improved paper with respect to normal and supercalendered papers.

1 indicates a conductor which may be constructed in any suitable way. Desirably, it is stranded to make it reasonably flexible. The conductor may have a hollow core, if desired for any purpose, or it may be composed wholly of strands. In this particular, the standard practice may be followed. Over the conductor is tightly applied insulation in the form of paper tapes 2 applied layer by layer to the necessary thickness, depending upon the voltage of the current to be conveyed by the conductor. The edges of the tape are desirably clean cut and as close together as possible to avoid the formation of voids or spaces. The tapes are also desirably so arranged that each layer covers the joint between adjacent turns of the layer immediately beneath it. Enclosing the insulation is an impervious sheath 3, desirably but not necessarily made of metal such as lead. The surfaces of the paper tapes while relatively smooth to the touch are free of glaze and are of such character as

to prevent the formation of free oil films with their tendency to migrate.

The paper is made of a good grade of wood pulp from which foreign matter is removed as fully as possible. In the ordinary low density cable paper, the minimum length of the fibers is 1.77 mm. and in the high density paper 1.80 mm. We substantially depart from this prior practice and use materially shorter fiber having an average minimum length of 1.40 mm. This difference in length may readily be obtained by suitable modification or adjustment of known standard apparatus used by paper makers in the treatment of wood pulp. It may here be noted that in paper making, it is generally considered important to use long fibers rather than short fibers, especially as in the present case where the paper has to be tough and strong so as to resist to a high degree the tendency of the tapes to tear during application to the conductor. While a decrease in length from a minimum of 1.77–1.80 mm. to 1.40 mm. may to the casual observer seem a small change, in the cable paper making industry where the standard has for so long a period of time been of the order of 1.77–1.80 mm., it is a substantial one. The wood pulp used in making our improved paper is treated in substantially the same way as in the manufacture of other cable papers, the principal exception being that the fibers employed are appreciably shorter. A careful washing of the pulp to remove impurities and chemicals is, of course, of prime importance.

Because the color of the finished paper is unimportant, the necessity of bleaching operations is largely or wholly avoided, thereby resulting in a decreased cost. When finished, the paper is brown in color, and by suitable machines is cut into tapes with clean cut edges and reeled ready for application to the conductor, in this latter respect being handled like other cable papers.

As the result of a long series of experiments, we have determined that the use of short fibers having an average length of the order of 1.40 mm. as distinguished from the long fibers of 1.77 to 1.80 mm. in the paper has an important bearing on its electrical characteristics when applied to electric cables. In particular, the dielectric strength is increased from the order of 1140 for low density cable paper to the order of 1450. In other words, it has a dielectric strength equivalent to the highest calendered papers without the disadvantage thereof, and is cheaper to manufacture since the operations incident to calendering are eliminated. Moreover, we have determined by suitable tests that it is not only unnecessary but highly undesirable to calender cable paper. The resulting paper in our case is free of glazed surfaces, thereby preventing the formation of free films of impregnating compound between layers.

As all cables are tested shortly after being removed from the impregnating tanks and after the lead sheath has been applied, the test results are universally very good and do not show the bad results of the highly glazed surface of the superdense paper. When, however, load cycles are put on the leaded cable in service, the situation changes, the lead sheath is expanded by the expanding compound, thus allowing free compound from the upper section of the cable to drain into the lower section. As explained above, the tapes of supercalendered paper have highly glazed surfaces and free oil films exist between the layers of tapes. After operating load cycles have expanded the lead sheath, these oil films will drain to the bottom of the cable due to the low resistance to flow or retardation by the highly glazed surface of the super-calendered paper. This naturally causes a multitude of voids in the upper portion of the cable insulation, thus starting electric discharge, known as ionization, across the voids which in the early stages causes an increase in electrical losses in the cable insulation. This means that the cost of transmitting a given amount of electrical energy is increased. As this ionization progresses, it generates additional heat in the insulation, thus causing a reduction in the carrying capacity of a given cable. This condition of the oil films or compound between the layers of supercalendered tapes draining from the top portion of the insulation toward the bottom with the resulting electrical discharges continues until the heat generated by the ionization causes further and excessive drainage of the impregnating compound which ultimately causes the cable to have an electrical failure or burnout.

Due to the character of the surface of our paper as contrasted to the highly glazed surface of the superdense paper, the oil or compound between the layers of tapes is mechanically held in position, thus preventing the condition described above.

The calendering of cable paper, as indicated above, results in high density which means that it is more difficult to remove air and moisture therefrom in contrast to low density paper. High density paper requires a greater length of time to impregnate with oil or compound which is so essential in cables than does low density paper. Any increase of time required to evacuate and dry the paper and to impregnate it means greater cost of the cable and less effective use of the very large tanks and other apparatus necessarily employed.

The increase in the time required to vacuum dry and impregnate the supercalendered high density paper of 1.00 and above means that the paper insulation is subjected for a longer period of time to an elevated treating temperature, i. e., 115° C. approximate average. As a result, the mechanical strength of the paper tapes is weakened thus causing them to break and tear more easily when the cable is bent during the remaining manufacturing operations and during installation of the cable for service which requires reeling and unreeling. It is considered good cable design to retain, as nearly as possible, all the original mechanical properties of the paper tape in the finished cable.

In contrast with the so-termed high density cable paper usually having in practice a density of over 1.00, our paper is practically the same as regards density as that of low density paper, being of the order of .82 as compared to .81. Our paper also is distinguished from the previous low density cable paper in respect to air resistance in seconds per mil, being substantially higher. In the former case, the air resistance is 51, in our case 144, and 436 in the high density calendered paper.

Air resistance as measured in the cable art on a Gurley densometer indicates seconds per mil thickness of paper required for a certain amount of air under equal pressure to pass through a given area thereof. Our paper having 144 sec./mil and supercalendered high density with 436 sec./mil air resistance proves in an indirect way the statement that high density paper requires a

longer time to remove the air and moisture during the vacuum drying and also requires a longer time to get the impregnating compound into the paper. A curve indicating air resistance in sec./mil as the abscissa and dielectric strength as the ordinate rises very quickly, then flattens out, as indicated in Fig. 2. In this figure, 4 indicates the dielectric strength of the usual low density cable paper, 5 that of supercalendered high density cable paper, and 6 that of our improved moderately high air resistance and low density cable paper.

Our paper was developed to come on the most efficient part of the curve, that is to obtain the greatest dielectric strength at the lowest cost, thus our moderately high air resistance low density paper falls on the knee of the curve. Supercalendered high density paper (1.00–1.20) weighs more than low density paper, as well as ours, and hence costs more because cable papers are sold on a per pound basis. The increase in cost is directly proportional to the weight or densities. In spite of the increased density and weight, supercalendered paper has practically the same dielectric strength as our paper. Thus, our paper is a new development in the manufacturing field of cable paper, being one which gives the most efficient paper insulation for electrical stress from a cost standpoint, as well as other advantages hereinbefore mentioned.

The following table indicates some of the important differences in cable papers. In this table, column A is representative of ordinary cable paper, column B is representative of our improved moderately high air resistance low density paper, and column C is representative of the usual type of high density calendered cable paper:

	A	B	C
Density	.81	.82	1.00
Air resistance—sec./mil	51	144	436
Dielectric strength—volts/mil	1,140	1,450	1,440
Formation (fibers per unit area)	320	450	360
Hydration—c. c.	350	200	350
Fiber length—mm.	1.77	1.40	1.80
Appearance of fibers	(1)	(2)	(1)

[1] Ragged and broomed ends of the fibers in the paper.
[2] Short fibers with clean cut ends of the fibers in the paper.

All of these terms are well known in the industry but following are short explanations of each term.

Density of paper is the weight of the paper expressed in grams per cubic centimeter.

Air resistance-sec./mil gives the time required for a given volume of air to pass through a given unit area of the paper, maintaining comparable temperature, humidity, pressure, etc.

Dielectric strength is measured by the volts per mil thickness of the paper required to cause electric failure of the paper when placed between 2" diameter electrodes. Of course, the papers before testing should receive the same treatment for removing the air and moisture and be impregnated with the same kind of compound.

Formation.—This is determined or measured on a Thwind-Albert formation tester. The values derived from this instrument are for comparative purposes and cannot be defined in units. The higher the reading, the better the formation.

Hydration c. c. is the number of cubic centimeters of water drained from the prepared pulp. The lower the number of c. c. drained, the greater the hydration of the pulp fiber.

Fiber length is the actual length of the average fibers in the paper tapes expressed in millimeters.

Appearance of the fibers is made by the microscopic examination of the fibers in the paper.

From the foregoing table, it will be observed that our cable paper distinguishes importantly from the others in that it has higher air resistance than low density cable paper and only about one-third of that of high density paper but our paper has equivalent dielectric strength.

We attribute the moderately high air resistance at least in part to the use of short fibers, since each occupies less space and hence making for more efficient arrangement of the fibers, thus producing paper with a greater number of fibers located in a given unit area.

Because the fibers are more numerous in a given area, due to their small size, they mat more closely together and because they are subjected to only moderate compression, they do not for that reason interpose such resistance to the removal of air and other gas preparatory to impregnation as they would if the paper was so processed as to have high density with calendar finished surfaces. Experience has amply demonstrated that as regards the removal of gas and moisture and impregnation, our cable paper is as good as that of the low density paper yet has important advantages thereover.

It is particularly to be noted that the dielectric strength of our improved cable paper is substantially greater than of the prior art low density cable paper being of the order of 1140 for the old and 1450 for ours. Stated another way, our cable paper has all of the advantages of the low density cable paper, avoids the objections of high density or supercalendered cable paper, and since the calendering operations are entirely eliminated, the cost of making it is correspondingly decreased. Also, for a given thickness of insulation, the cost of the paper is less, giving lower cost for finished cable.

For the sake of simplicity, our invention is illustrated in connection with a single conductor cable but it is equally applicable to multi-conductor cables. Stated another way, our improved paper is applicable as insulating material to the various types of cables without limitation to their otherwise specific construction.

Since the surfaces of our paper are not calendered but are of a character normally to hold oil or compound in place between layers over their entire surfaces, the drainage that is common in highly calendered papers is avoided.

We have determined that our paper having an air resistance of 144 has a high value as an insulating medium measured in volts per mil per unit of thickness, being substantially higher than that of ordinary cable papers, and is highly efficient in that it has a lower power factor per unit weight, and being lighter in weight costs less on a per pound basis than calendered paper.

Briefly summarized, the objections to superdense or highly calendered paper are as follows:

1. The cost is higher.
2. The power factor is higher.
3. It takes longer to dry preparatory to impregnation.
4. It takes a longer time to impregnate.
5. It permits of draining of compound between layers due to its glazed surfaces.
6. It reduces the life of the cable due to drainage.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. A cable comprising conductor means, an enclosing impervious sheath therefor, insulation for the conductor means made of tightly wound paper tapes arranged in layers thereon and an impregnating material for the insulation within the sheath, the paper being characterized by having short fibers of approximately 1.40 mm. length or less to increase their number per unit area and being characterized by a density of the order of .82 and a dielectric strength of the order of 1450, the paper having unglazed surfaces which mechanically retain the impregnating material so as to prevent as fully as possible the formation and migration of films of impregnating material between the layers.

2. A cable comprising conductor means, an enclosing impervious sheath therefor, insulation for the conductor means made of tightly wound paper tapes arranged in layers and an impregnating material for the paper tapes within the sheath, the paper being characterized by having short fibers of approximately 1.40 mm. length or less to increase their number per unit of area and being characterized by a density of the order of .82, an air resistance of the order of 144 and a dielectric strength of the order of 1450, the paper having unglazed surfaces which mechanically retain the impregnating material so as to prevent as fully as possible the formation and migration of films of impregnating material between the layers.

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