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ELECTRIC CABLE

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My invention relates to electric cables for high voltages, more particularly to an impregnated paper cable for use under such conditions of service that ionizable voids cannot be formed as a result of cyclical expansion and contraction of the oil and other components of the cable.

In appearance it is scarcely distinguishable from an ordinary cable of this type but it differs therefrom in the use and disposition of two types of paper which may be obtained as articles of commerce on specification from makers of cable paper. These types of paper will be distinguished herein as types N and S. The two types of paper differ in the slopes of their stress-strain curves, as illustrated in diagram shown as Figure 3.

The object of this invention is to prevent void formation in impregnated paper insulated power cables such as ordinarily result from cyclic loading. It is therefore pertinent to consider what happens in a cable under such conditions and this is most readily accomplished by considering a specific example.

For this purpose we study a 500,000 circular mil cable with 750 mils of insulation. The distribution of materials under the sheath at 20° C., will be as shown in columns 1 and 2 of the following table. When heated to 70° C., the approximate distribution of materials will be as shown in columns 3 and 4. The expansion of the copper, paper fibers and lead are neglected as inconsequential to our present purpose.

	Percent by volume—			
	At 20° C.		At 70° C.	
	1	2	3	4
Copper.....	9	9	9	9
Paper fibers.....	42	42	42	42
Oil in tapes.....	33	33	33	33
Oil between tape faces.....	8	40	9.5	50.5
Oil in edge spaces.....	5		5	
Oil in strand spaces.....	3		3	
Total.....	100	100	101.5	101.5

If the viscosity of the oil is great enough to prevent the oil being forced out, the increase of oil volume of 1.5% will cause a linear stretch of the tapes of about 0.75%.

Referring to diagram, Figure 3, it will be seen that type N paper will have a stress of 8500 lbs./sq. in. while type S paper will have a stress of 10,800 lbs./sq. in. Furthermore, at all elongations the stress in type S paper is greater than

in type N paper. If therefore, the insulation be made in two layers, one of type S and one of type N paper and if the type S paper be applied over the type N paper, the type S paper will keep the type N paper in compression and so prevent the formation of voids between tape faces, at all temperatures, both in the rising and falling temperature periods of the load cycle, until the cable returns to its original condition.

It is relatively far more important to prevent void formation in the inner layers of paper than in the outer, as the electric stresses which cause ionization in the voids are greater at the inner layers. Hence the importance of keeping the inner layers tight, especially in the cooling periods of the load cycle, by having them held in an elastic grip by the outer layers whenever they have been stretched from their original condition.

It is, of course, possible to use three or more grades of paper differing in the slopes of their stress-strain curves, always applying the papers in the order of increasing tensile stress for a given elongation, from the conductor outward. In this way each layer will tighten the one within it. Ordinarily, however, two types of paper are sufficient.

Two types of paper were used having stress-strain characteristics as shown in diagram, Figure 3. It was found that a cable made with 60 tapes of type S paper over 160 tapes of type N paper, lasted through at least twice as many cycles of accelerated load cycle aging tests as cable made in the way now customary in the industry. This result was obtained in test after test and, some 16 cables of this type were subjected to accelerated load cycle aging test.

This result was surprising as type S paper is generally denser than type N paper and the way now customary in the industry is to make cables with the inner layers of denser paper than the outer layers.

Comparative load cycle life tests were made of cables with different kinds and combinations of insulating papers, and the results diagrammed as shown in Figure 4.

The rise in power factor in the course of these cycles of load was taken as the measure of deterioration of the cable.

Curve A refers to a cable made entirely of type N paper; curve B to a cable made entirely of type S paper; curve C to a cable with type S paper adjacent to the conductor and type N paper outside. Curve D refers to a cable made in accordance with the present invention, i. e., with type N paper inside and type S paper outside.