# Consideration of Transformer Insulation

**First of a Series of Articles on the Transformer to Appear in the Power Edition. This one Deals with Insulation. Others will Deal With Drying Out Transformers, Cooling of Transformers, Transformer Oil, Transformer Cases, Terminals and Bushings, Transformer Connections and Transformer Testing. This will be a Very Complete and Reliable Series of Articles.**

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While the subject of insulation is a very broad one, more or less essential to all branches of electrical construction, I shall deal only with its particular application to transformers. The principal characteristics of insulation for transformers, however, apply in a large measure to almost all electrical apparatus, the difference being more in degree and application rather than in principle.

The electrical characteristics of a transformer are mostly dependent upon the quality, arrangement and proportion of the iron and copper that enter into its construction; that is to say, they are practically independent of the insulation. This statement may seem absurd on the face of it, since a transformer will not operate without insulation in its make-up, but the fact remains that the less space occupied by the insulation, the more efficient the transformer will be with a given amount of iron and copper. Insulation, however, of necessity performs a very important function; for in a transformer the conductors are usually in the form of wire, wound into one or more coils, each comprising several layers of one or more turns per layer. In operation, each turn, layer and coil is at a potential different from its adjacent turn, layer or coil, and the whole operates at some potential different from that of the earth. The separate parts of course must be insulated one from the other and the whole from the earth.

### The Requirements of Insulation.

The primary function of insulation, then, is to insulate; to enable an electrical conductor to carry a current at some definite potential. The structure of the transformer and the conditions under which it usually operates are such that its insulation is subject to various forces, electrical, mechanical and chemical. The life of a transformer, then, depends upon the firmness of the insulation put into it to survive the various conditions under which it is forced to operate.

In the study of this subject one is naturally led to ask, Why does a thing insulate? R. A. Fessenden has well expressed it by saying: "A thing insulates because it is possessed of two distinct properties; first, the ability to stand the mechanical and electrical stresses" (and I wish to add another—chemical) "due to the voltage used; and second, a conductivity such that but a negligibly small current can flow through it and leak away. In other words, it will neither allow the current to break through it nor to steal through it. The first property is called by Maxwell the dielectric strength of the insulator. The other property is called the ohmic resistance. The two together form its insulating power."

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Electrical work is divided into two branches wherein the requirements for insulation are widely different. In apparatus used for the transmission of intelligence (telephony and telegraphy) the voltages are low, so the dielectric strength is of relatively small importance; but the currents used are small, the circuits long, and an insulating material of high ohmic resistance is needed. On the other hand in apparatus designed for the generation and transmission of electrical energy, where the currents are large and where the voltages are high, dielectric strength is the property mainly desired, as the leakage of a small amount of current is not objectionable. This difference of requirement for an insulator is the two branches of electrical work naturally gives to the general term "insulation" a double significance—to one branch meaning something having high ohmic resistance, and to the other meaning something which has dielectric strength. This double meaning has often lead to confusion, for their meaning is quite different, since an insulator may have a high ohmic resistance and at the same time not resist high voltage to breakdown.

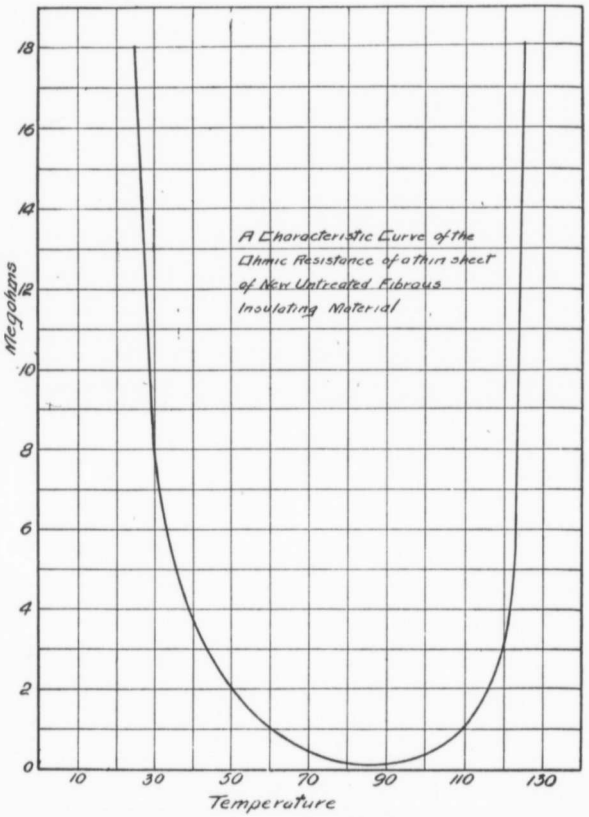


Fig. 1—Characteristic Curve of the Ohmic Resistance of a Thin Sheet of New Untreated Fibrous Insulating Material.

### Dielectric Strength Necessary in Electrical Apparatus.

In the insulation of electrical apparatus used for the generation and transmission of