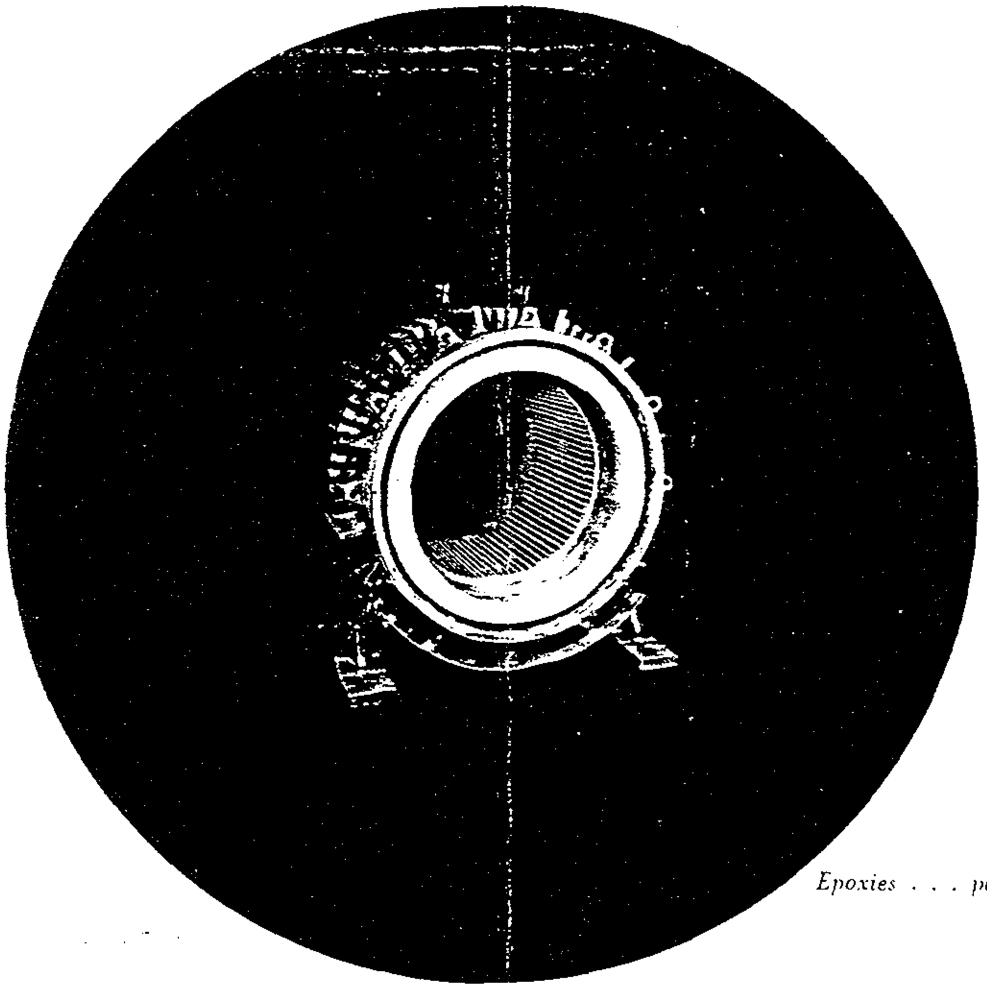
September 1956

Insulation



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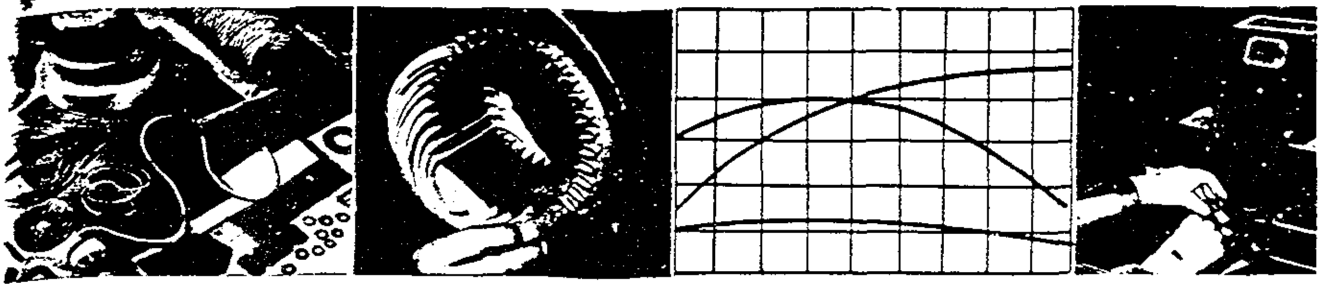
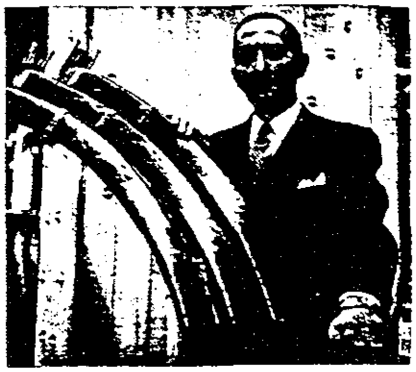
ɪnsulation Engineering Fundamentals—No. 8



ᒥhe Selection and Application)f Insulating Materials



ghth of a series of monthly articles on insulation engineering fundamentals by aham Lee Moses, Manager, Services Engineering Department, Transportation d Generator Division, Westinghouse Electric Corporation, East Pittsburgh, nnsylvania. Mr. Moses is widely recognized as a leading authority on insula-n and is the author of more than 100 technical articles and papers as well as ɔook on electrical insulation. He has figured importantly in many insulation velopments.

·neral Considerations ,r Insulation Selection

The insulation for coils must meet eral important requirements. It ıst have a satisfactory level of dielec- strength. high electrical resistivity. d suitably low dielectric loss. Very en. resistance of insulation to mois-e absorption is of great importance. ese primary characteristics deter-ne the electrical effectiveness of the ulation. Insulation must also fulfill ny important physical functions. It ıst withstand normal mechanical ıse during manufacturing. as well as ısonable physical forces under oper-ıg conditions. Physical characteris- that are important include com-ssive strength. flexural strength, r strength. tensile strength, resist-e to abrasion. and bond strength. quently. it is necessary that insula-n be capable of a reasonable amount deformation without significant loss its characteristics.

The chemical properties of insula-n are also of great importance. It usually desirable that insulation be istant to lubricating oils and com-n solvents, and in certain applica-ıs insulation should also resist weak ds and alkalies. The importance of fire resistant insulation is steadily growing. At higher voltages. insula-tion should be resistant to corona and to the resultant chemical degradation from exposure to ozone and nitrous oxide usually produced by corona. Thermal stability should be considered a chemical characteristic of insulation. as it is one of the most significant prop-erties determining the life of windings. Because the coils of machines are generally surrounded by insulation and supported on insulation parts. the heat generated within the winding must flow through insulation. Therefore, the thermal conductivity of insulating ma-terials and composite insulating sys-tems is an important design factor.

Practical design of electrical equip-ment generally involves considerable compromise and the exercising of engi-neering judgment. There is no univer-sal insulating material and no single component will have all of the desired properties at precisely the optimum levels. In selecting insulating materials, it is desirable to have a simple but standardized approach. The following step-by-step procedure is a useful one:

1. Tabulate the requirements of the specific problems and enumerate the conditions under which the equipment is expected to operate.
2. Consider whether the mechanical, electrical, chemical, or thermal aging properties will be predomi-nant in the operation of the equip-ment.
3. Review tables of material charac-teristics and select materials for each function which have suitable general properties meeting the pri-mary requirements as outlined.
4. Select several possible materials which might be considered for each part of the insulation system. Compare the normal characteris-tics of the materials as such with the required characteristics for the application. In this connection. en-gineering judgment must be exer-cised as to the degree that fabrica-tion and processing may reduce (or increase) the level of the required characteristics.
5. Review the economics of the mate-rials chosen in the light of their cost. space factor. and effect on general design. Material selection should not be based entirely on ob-taining the highest level of char-acteristics nor on cost. The best overall economic design involves a great deal of experience and

sound judgment.

6. The required dielectric characteristics should be specifically reviewed on the basis of working dielectric stress and the required level of dielectric proof test. Both aspects should be reviewed to determine whether a suitable factor of safety exists in both cases. A factor of 2 is commonly used as the ratio of the intrinsic dielectric strength of the materials and the level of the required over-voltage that will be applied to the finished coil.

Specific Considerations For Insulation Selection

The selection of specific insulation materials is not a highly developed science. It is necessary to review principles and objectives with specific relation to the type of coil construction employed. It often becomes necessary to use examples and illustrations to describe conventional practice. Usually, for any particular application, there are numerous materials from which to choose. The one finally selected involves judgment and compromise and will depend upon many factors, such as:

1. Dielectric strength requirements.
2. Mechanical characteristics desired.
3. Temperature classification.
4. Special service conditions encountered such as severe moisture, chemical contamination, abrasive atmosphere and fungus growths or bacteria such as encountered in the tropics.

A brief summary of typical materials frequently used for various purposes illustrates specific applications.

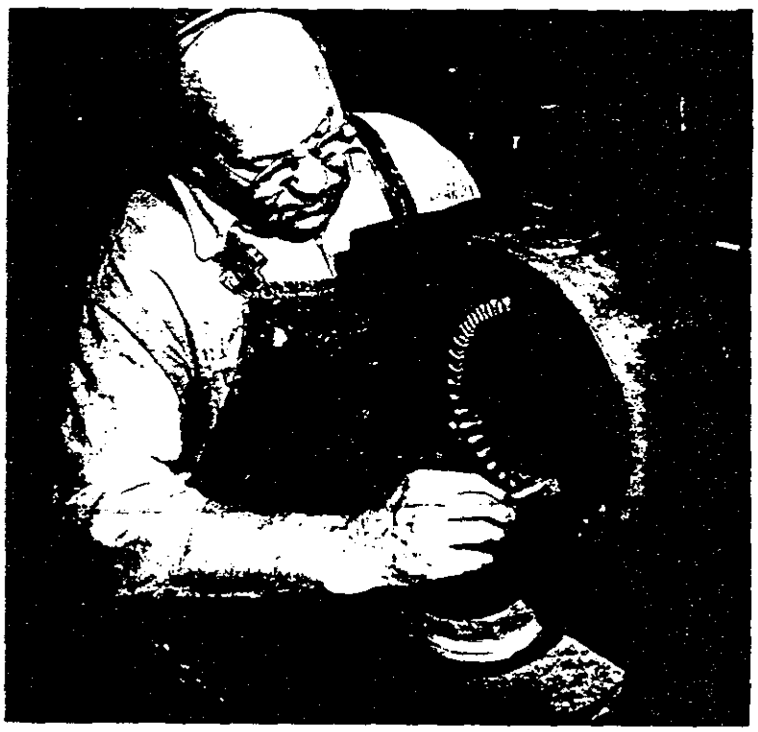
1. *Conductor insulation*—between strands and/or turns.
   a. Enamel
   b. Paper
   c. Cotton
   d. Silk
   e. Asbestos
   f. Fiber glass—continuous filament, sliver, or woven tape
   g. Mica tape
2. *Ground insulation*—basic insulation between winding and core. This must withstand full operating voltage for the life of the winding as well as over-voltage tests required by industry standards. The following materials are typical:
   a. Varnish treated cloth (wrapper or tape)
   b. Resin films (wrappers or tape)
   c. Fishpaper and treated cloth (as slot cell)
   d. Fishpaper and mica (both as wrapper and slot cell)
   e. Paper-backed mica wrapper
   f. Glass-backed mica wrapper
   g. Continuous mica tape
   h. Molded mica cells
   i. Fabricated cells employing laminated and molded materials

Note: On certain large or important equipment, especially for high voltage use, mica is often employed as the basic ground insulation regardless of temperature classification.

3. *Binder tapes* are for structural and finishing purposes only. Their function is more mechanical than electrical, but they serve as the basis for the final water-proofing coating provided by the varnish treatment. Materials in common use include:
   a. Cotton tapes
   b. Asbestos tapes
   c. Fiber glass tapes
   d. Synthetic resin fabric tapes
4. *Varnishes and resin impregn*... are a vital part of the electrica... sulation system. They coat the ... faces and fill or impregnate the ... sulation voids of electrical w... ings. Such resinous treatment ... creases the resistance of the ins... tion to penetration of moist... dirt, chemical contaminants, a... foreign materials. They also m... mize the effect of conducting c... pounds and particles on expo... creepage surfaces. Varnishes a... serve important mechanical ne... In windings, varnish treatm... provides adhesion of windings ... coils in slots and assures suffici... rigidity in the insulation and wi... ings to withstand vibration a... mechanical shock. Proper filling ... internal voids with varnish resi... promotes better heat dissipation ... well as eliminating internal coro... Filling of voids and proper seali... of the insulation surfaces grea... increase insulation life, and ther... fore, the life of the equipme... Varnishes and the processes f... their application are discussed ... length separately.

Ground Insulation

The major insulation between th...



In these motor slots, all rag paper is being used for ground insulation. Excel Electric Service Co.

ding and core is called "ground ...lation." This may take any one of ...ral forms referred to earlier and be applied in a variety of ways.

...lot Cell—The slot cell is the sim... form of ground insulation and ...ost commonly used on small ran... wound motors. It is also used on ...e other special types of windings. ... random windings, slot cells need ...possess two rather contradictory ...racteristics — crease retention and ...h dielectric strength (after being ...eased to fit the slot). For this reason, many slot cells are made of two ma...rials. The outer component is often ... paper that retains any preforming. The inner sheet is generally a flexible high dielectric strength film which is relatively unaffected by creasing. Numerous commercial combinations of this type exist.

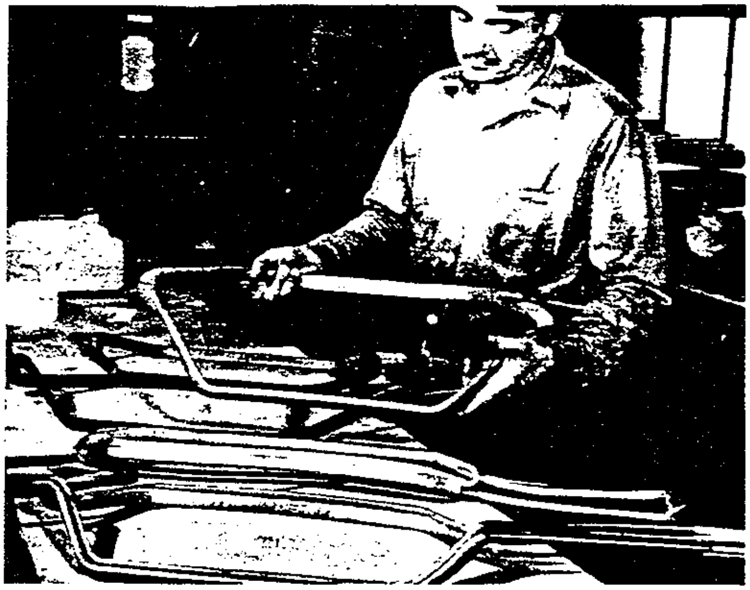
Wrapper—The wrapper is a sheet form dielectric material applied to the straight portion of a coil to form a tube of high intrinsic breakdown strength. Such materials should be flexible, easily applied, and retain their shape while adhering to the conductors of the coil. Wrappers are applied as one or more wraps plus a good overlap on one side or top of the coil. They are identified as 1½, 2½, 3½, etc. turns (or sometimes as 1¼, 2¼, 3¼ turns).

Taped Insulation—The most versatile method of insulating coils is taping. This method is used not only for ground insulation, but for conductors, turns, windings, and surface binding. A more detailed discussion follows.

Turn Insulation

Turn insulation of armature and field coils is generally provided by some standard form of wire covering such as enamel, cotton, silk, asbestos, or fiber glass. In the larger and special wire sizes, mica tape may be applied directly to the strap before it is formed into an armature coil. Where the shape of an armature coil is of such a nature that the turn insulation may be damaged in the forming, it may be necessary to patch the wire covering in order to reinforce it at the points where forming damage has occurred. On some special coils of unusual shapes, the bare copper may be formed to shape before the insulation is applied. In such cases, it is common practice to use mica tape for the turn insulation. Sometimes, glass fiber tape or cotton tape may be used if the thermal and voltage requirements will permit.

Varnish treatment provides a number of advantages including mechanical bonding. Excel Electric Service Co.



Taping is the most versatile method of insulating coils. Excel Electric Service Co.

Application of Insulating Tapes

Automatic machine taping is usually applicable only to wire and strap. Therefore, complex shapes of coils usually require hand taping or hand guiding of taping machines. This involves considerable manual labor requiring special skills and dexterity. An experienced taper gives the appearance of working swiftly and easily with little effort. Labored application of tape is apt to be indicative of inexperience, which may result in a poor quality insulated product. Insulating tapes are applied in several ways, for example:

1. *Spaced*—adjacent convolutions of tape do not quite touch in most places, although they may occasion-

ally touch at spots. This is a rapid, low cost procedure used for structural support rather than maximum insulation.

2. *Butted*—tape applied in this manner is intended to give a smooth, even appearance without openings. It necessitates careful workmanship which involves more time and expense than spaced tape. Primarily, this is used for surface binding of best appearance where space is important.
3. *Over-Lapped*—tape is applied in a lapped spiral so that there is at least one thickness of tape at all points with a minimum overlap equal to one-third of the tape width. (Usually it is uneconomical to apply tape more than *half lapped*. For space conservation and optimum results, tape should be just slightly less than half lapped.) This is the best form of tape application for dielectric barrier insulation. For binder tapes, it provides the best support but occupies more space than other types of taping.

Tape can be easily applied by one of the foregoing methods to a straight uniform section. However, most coils are not straight or uniform throughout their whole length. The taping of complex coil shapes requires the exercise of considerable care and skill, with special training. Tape should be applied smoothly in such a manner that the true objective of the insulation will be attained. Where a dielectric barrier is desired, operators must guard against *"camouflaging"* a coil instead of *insulating* it (this difference cannot be distinguished by visual observation after the product is completed). Where insulating tapes are applied for dielectric barrier action, it is important that each turn of the tape be adequately lapped at the area of greatest periphery of the coil, even though this results in excessive lapping on the shorter periphery. Sometimes, the tape may be reduced in width at the shorter periphery by trimming it with scissors as each turn is applied. Where tape is trimmed, care must be exercised to be sure that the tape is not trimmed excessively, and that a satisfactory l. of tape is obtained between adjace turns of tape at every point.

Tape applied as a dielectric barr is almost always over-lapped and th is usually specified as "half-lapped."

Internal binder tapes are frequen spaced.

Surface finishing tapes are usual butted on the slot part (to save space and over-lapped on the coil ends (i diamonds) for best binding action ar physical support.

Birds, Bees, and Baltimor

The small boy had just asked h father: "Where did I come fro daddy?" The boy seemed to listen a tentively and at the end of the ex planation his father asked him, "Wh made you ask son?"

The boy was playing with an ai plane model and replied casually: "O nothing 'specially, Dad, 'cept I hear the new boy at school say he came fro Baltimore and I wondered where came from." —*The Kablegra*