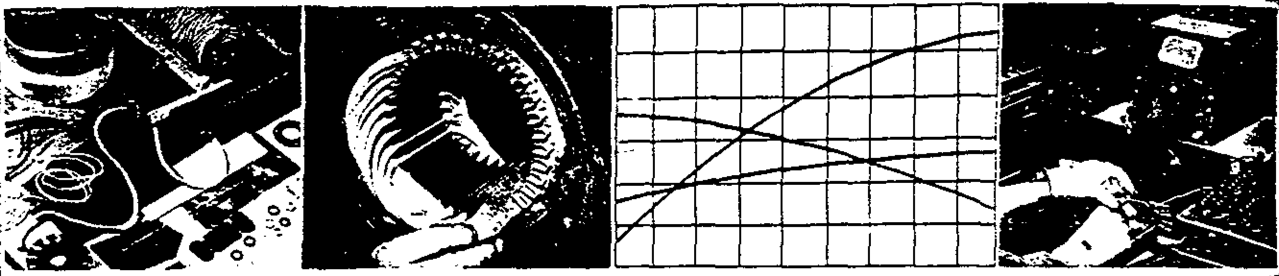
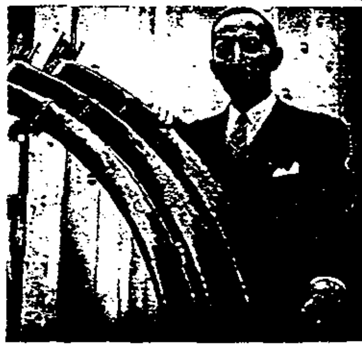


Insulation Operating Problems Encountered on Equipment



Twenty-second of a series of monthly articles on insulation engineering fundamentals by Graham Lee Moses, Manager, Services Engineering, Large Rotating Apparatus Department, Westinghouse Electric Corporation, East Pittsburgh, Pa. Mr. Moses is widely recognized as a leading authority on insulation and is the author of more than 100 technical articles and papers as well as a book on electrical insulation. He has figured importantly in many insulation developments. All illustrations courtesy Westinghouse Electric Corporation.

Electric equipment encounters many serious aging and contaminating conditions during operation which may reduce the effectiveness and reliability of the insulation. Thermal aging is the most consistent, and probably predominating, degrading effect. It renders insulation vulnerable to moisture, dirt, and chemical contaminants. It also may reduce the electric strength of solid dielectric barriers by 50 percent or more. The effect of thermal aging on creepage surfaces is far less pronounced. However, dirt and chemical contaminants, especially when associated with moisture, predominate in their effects on the electric strength of creepage surfaces.

Contamination of electrical insulation by dirt or chemicals is an insidious type of hazard that frequently appears as a mysterious failure which baffles the investigator. When carefully studied, failures of this type are often found to be the result of small quantities of ionizable substances which are insulators when dry but are highly conducting when humidified. The presence of such ionizable materials on insulation creepage surfaces or *within the body* of an insulation may produce high conductivity when exposed to mild humidity. The inconsistent behavior of such materials in insulation may allow apparatus to pass over-voltage tests when dry and yet fail under *operating conditions at much lower* voltage after exposure to moisture. If such ionizable materials are covered and protected by an effective varnish coat, the winding may withstand humidification in the early stages of operation and fail later with little or no warning. Aging of the protective varnish coat permits these contaminants to become more active hazards to insulation reliability.

There are numerous ionizable contaminants which may have such deleterious effects on insulation. Acid soldering fluxes are the most usual offenders. Uninformed workmen, especially *repairmen, will frequently* use acid fluxes because of the ease of making soldered joints. This easy soldering work "builds in" serious hazard into the electric equipment. There are many less obvious but equally dangerous sources of chemical contamination. These include protective hand creams and even *germicide additions* to lubrication oils used for mold release. In one case of trouble the adhesives used in attaching asbestos paper to wire contained ionizable salts which caused turn-to-turn failures. Motors operating in chemical plants or motors *that might* be exposed to salt spray encounter more obvious sources of contamination with ionizable materials.

Insulation contaminants frequently contribute to the failure of electrical insulation. Such contaminants include *moisture, salt, oil, carbona*ceous materials, and dust. These contaminants may adversely affect both the physical and electrical properties of electrical insulation. The general conditions observed lead to the following conclusions:

1. A liquid may supply adhesion for the solid contaminants into a *conducting film.* The condition is worse if the solid contaminant can also be wet by water.
2. Carbon or metal particles are always a serious potential hazard.
3. Contamination by conducting particles may result in a very low surface breakdown even if no ionizable materials are present.
4. Ionizable contaminants such as

metallic salts may result in surface breakdowns at very low voltages with relative humidity well below the dew point.

There are a large number of factors which enter into such electrical breakdown across creepage surfaces and laboratory evaluation is difficult. It is often difficult to reproduce or simulate the actual failure conditions. The important thing is to understand and guard against such troubles.

Effect of Acid Soldering Fluxes

An operating failure which resulted from insulation contamination with acid flux is shown in Figure 1. This failure occurred on a commutator at operating voltages of less than 50 volts bar-to-bar. When the commutator was dismantled and tested bar-to-bar for insulation resistance, it was found that 70 out of 300 mica segments had far below normal insulation resistance. The normal value was above 10 megohms while the contaminated segments were less than 0.1 megohm. Upon applying an overpotential test, it was found that the bars with low insulation resistance stood a 200-volt test, but failed at 400 volts. On the other hand, all segments with normal insulation resistance withstood a 600-volt test and failed at not less than 800 volts. It is important to note that dismantling the commutator for examination permitted evaporation of some of the moisture. After this occurred, more than 200 volts were required to break down these creepage surfaces which failed in operation at less than 50 volts. This illustrates the difficulty of tracing chemical contamination effects. Chemical and conductivity tests on the mica segments clearly showed acid soldering flux contamination of the areas in trouble.

Effect of Hand Creams

Protective hand creams are used quite commonly by workmen who apply insulation and wind machines. The use of these hand creams is frequently encouraged in varnish treatment rooms, in coil insulating sections, and in wire insulating departments to reduce dermatitis hazards. Such creams are very effective in prevention of skin irritations due to varnish, solvents, and adhesives—and many are harmless to insulation. However, some of these creams which are not harmful to the skin contain ionizable compounds which may be corrosive to copper or harmful to insulation. Hand creams can be classified as follows:

Vanishing creams which fill the skin pores with soap and facilitate removal of soil when washing.

Creams which leave a thin film of resin or wax on the skin and thus prevent the irritants from direct contact with the skin.

Creams which fill pores and cover the skin with harmless fats, which repel water soluble irritants and prevent entrance of petroleum oils, greases, and coal-tar derivatives.

Mild creams containing non-irritant chemicals intended to detoxify the irritants.

Creams which cause inert powders to adhere to the skin, forming a physical barrier against skin irritants.

Exhaustive tests made on all of these classes of materials showed that the creams made from soap bases, and which were alkaline in reaction, became conducting at higher humidities. Their use resulted in lowered insulation resistance of materials contaminated by them. Such hand creams were also found to reduce the dielectric breakdown after the test samples had been humidified approximating summer weather conditions. The hand creams found most troublesome were alkaline soap-base and the vanishing cream type. One of these soap-base hand creams was found to make subsequent varnish treatment quite difficult as streaks of the cream dissolved into the varnish and prevented good wetting of the insulation. This cream melted and ran during subsequent baking. The varnish treatment resulted in a very poor film with greatly reduced dielectric strength even when dry.

The most satisfactory types of hand creams are those which leave a thin film of natural resin or wax on the hands. The use of these hand creams is not detrimental to insulation if moderation is practiced in application. The hand creams used by persons handling insulation should be approved not only by industrial hygiene authorities, but by responsible insulation engineers with an understanding of the problem.

Effect of Germicides

Figure 2 shows a creepage failure

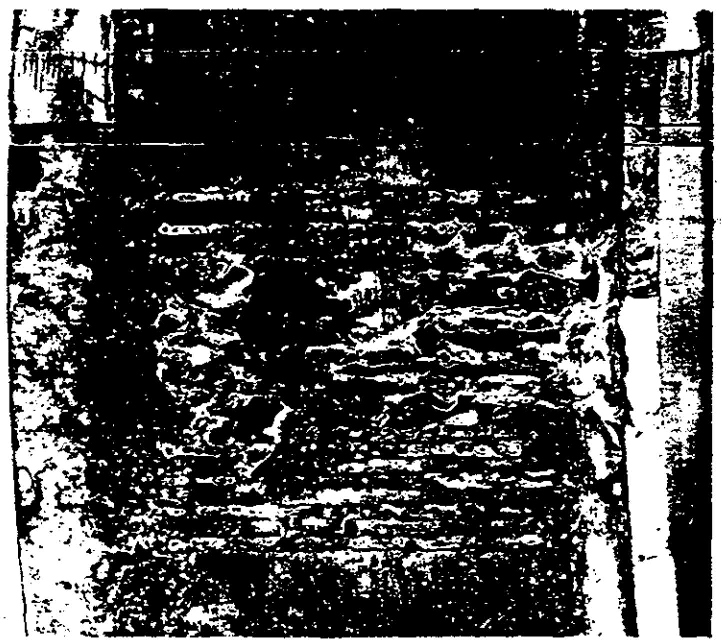


Figure 1, insulation failure on commutator V-ring contaminated by acid soldering flux.

of an armature coil resulting from a very obscure contaminant. On the coil shown, a surface creepage distance of approximately one inch failed on a one minute high-potential test of 3000 volts, 60 cycles. This failure was traced to the presence of ionizable germicides in the mold lubricant on the pressing blocks which were used for consolidating this insulation. This was very difficult to trace and hard to correct as the supplier of the mold lubricant had "improved" his product with complete innocence and ignorance. This emphasizes the need for controlling the complete quality of all materials used in connection with insulation.

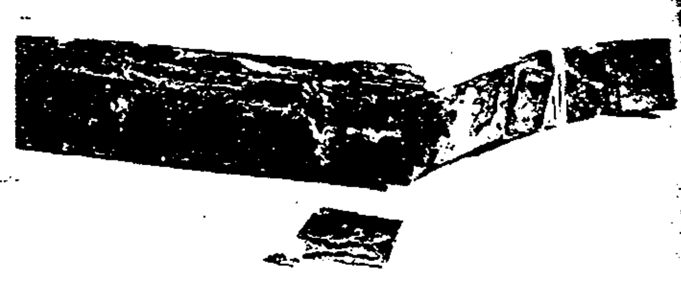


Figure 2. creepage failure on armature coil insulation contaminated by germicide in mold lubricant.

Equipment Operating In Chemical Atmospheres

Electric equipment operating in chemical atmospheres frequently experiences excessive contamination from ionizable compounds. These contaminants may soak into the solid insulation and collect on the creepage surfaces. Similar contamination may occur on motors in marine service where they may be subjected to salt spray or salt laden air. Subsequent evaporation of the water leaves a layer of salt which will collect water and ionize under electric stress. Atmospheres encountered in chemical plants often contain high concentrations of ionizable materials which are deposited on windings with resultant hazards to reliable operation. Many of these ionizable chemicals have a very high insulation resistance when dry, but when humidified the insulation resistance changes by a tremendous factor, often a million to one or more. These materials not only form conducting paths across the creepage surfaces, but may be deposited in cracks in varnish films and around leads. This contaminating material should be washed out and the winding dried as a regular maintenance procedure. Subsequently, the surface should be sealed by additional varnish treatments. Such ionizable materials should be removed as thoroughly as possible before additional varnish treatments are applied. If any residue remains, the ionizable materials will be sealed

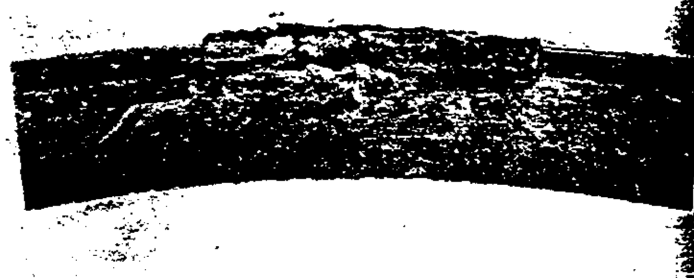


Figure 3. commutator V-ring failure resulting from salt water contamination.

Figure 4, severe surface creepage damage resulting from carbon contamination.

inside so as to present a major hazard.

A commutator mica V-ring that failed in service many months after salt water contamination is shown in Figure 3. Dryout after immersion did not prevent failure later when exposed to moderate humidification.

Carbon Black Contamination

Carbon particles form tracks over insulation creepage surfaces and present serious operating hazards. Accumulations of carbon pick up moisture, oil, and chemicals making the formation of low resistance paths easy under moderate electric stress. A failure of this type is shown in Figure 4.

One particularly serious source of carbon contamination in rubber mills is the very fine carbon soot used in fabricating tire stocks. These particles are so fine that they not only cling to creepage surfaces but penetrate the very fine cracks in leads and varnished surfaces. There has been some suspicion that they may pass through varnish films just as moisture vapor is transmitted by osmosis. These particles are so highly conducting that serious tracks form and insulation failure is frequent on rubber mill motors. Only the very finest kinds of insulation will resist penetration of these minute particles. Other insulations require constant cleaning and revarnishing, or more elaborate maintenance.

Determining Failure Cause

Where failures occur on equipment having a general condition of roasted insulation, or generally embrittled insulation, the basic cause is probably thermal aging. Even here a secondary factor may have triggered the failure after thermal aging rendered the insulation vulnerable.

Chemical contamination or dirt failure is apt to exhibit long burned tracks across creepage surfaces. When tested dry, the insulation may have very high insulation resistance. Unusual susceptibility of insulation resistance to moisture is indicative of chemical contamination.

Where failures are localized and no general over-heating is observed, the cause may be attributable to mechanical damage or differential movement of windings and supports.

Corona attack usually leaves the winding coated with a white or gray powder at points of high electric stress if the insulation is not eaten away. Severe and prolonged corona will eat away organic materials such as paper, cotton, and varnishes but will have little effect on inorganic materials such as mica splittings and glass fibers. Serious corona attack usually leaves insulation with a "moth-eaten" look with the surface penetrated by tiny holes.

Surplus Searchlight For 6300°F Tests

A U. S. Army surplus searchlight and the sun are being used at the B. F. Goodrich Research Center for testing of materials at temperatures as high as 6300° F. The equipment permits harnessing of the sun's rays and concentration of their intense heat in a spot about ¼-inch in diameter.

The chief value of the facility is said to be its ability to create a clean heat—there is no contamination of the sample as might be the case with other heating methods involving furnace elements or containers. The intense heat is concentrated at the focal plane of the searchlight's mirror. The sample holder can be moved by remote control during tests. Temperature control is maintained by off-focus operation and by a shielding cylinder.

Insulation Standards Covered at AIEE Meeting

Three papers covering insulation standards, evaluation, and classification were among the highlights of the Fall General Meeting of the American Institute of Electrical Engineers, held last month in Chicago. One paper was a report by Standards Coordinating Committee No. 4 on the recent revision of AIEE Standard No. 1. The other papers were devoted to guides for thermal evaluation of insulating materials and systems and international activities in the temperature classification of insulations.

New Concepts

Under the chairmanship of F. J. Vogel, Allis-Chalmers Manufacturing Co., Coordinating Committee No. 4 has incorporated new concepts in the recently issued revision of AIEE No. 1, "General Principles upon Which Temperature Limits Are Based in the Rating of Electric Equipment"—these changes were explained and discussed in the report delivered at the meeting. The new standards provide more freedom and flexibility in the selection of insulating materials and temperature limits for particular applications, and at the same time they also permit more realistic and practical appraisal and use of insulations.

As explained in the report, the principal purpose of the AIEE No. 1 revision is to distinguish between insulating materials and complete insulation systems so that materials can be temperature-classified and selected independently of systems and vice versa. With classification based on the results of thermal evaluation tests rather than being limited solely by material composition and the organic or inorganic nature of the material, it can be claimed that a new era in insulation classification has officially started. The committee report pointed out that the revision was made necessary by the increased variety of insulation materials available and their wide range of properties—and recognition of the fact that many components make up a complete insulation system with each component having a different function to perform and each being subjected to different mechanical and electrical stresses, and often to different temperatures. The revision makes a clear distinction between the temperature classification of insulating materials and the assignment of limiting temperatures for complete *insulation systems*. Temperature limits for both materials and systems may be based on experience or tests. Materials of different temperature classes may be used as components of any insulation system and the limiting temperature assigned to a material or system may be different, depending on the size and type of equipment and its intended use.

New Definitions Of Insulation Classes

The report by Coordinating Committee No. 4 also explained the important changes in definitions of insulation classes incorporated in the revision of AIEE No. 1. An important feature is that materials are grouped in numerical temperature classes: 90C (Class O), 105C (Class A), 130C (Class B), 155C (Class F), 180C (Class H), 220C (no letter), and Over 220C (Class C). It is expected that the numerical designations will be used but that the customary letter designations will continue in use for some time.

Two new insulation classes have been added. The new 155C class corresponds to the Class F recently adopted by the International Electrotechnical Commission. It is defined as: "Materials or combinations of materials such as mica, glass fiber, asbestos, etc., with suitable bonding substances. Other materials or combinations of materials, not necessarily inorganic, may be included in this class if by experience or accepted tests they can be shown to be capable of operation at 155C."

The new 220C class is defined as: "Materials or combinations of materials which by experience or accepted tests can be shown to be capable of operation at 220C."

Inclusion of the wording, "by experience or accepted tests," in the new definitions for all insulation classes, represents an important milestone. Development of test procedures for the thermal evaluation of insulating materials is within the scope of the AIEE Dielectrics Committee. The appropriate AIEE technical committees are responsible for developing test procedures for the thermal evaluation of complete insulation systems—typical examples of procedures already developed are AIEE No. 510, "Test Procedure for Evaluation of Systems of Insulating Materials for Random-Wound Electrical Machinery" and No. 511, "Test Procedure for Evaluation of Systems of Insulating Materials for Electric Machinery Employing Form-Wound Pre-Insulated Coils."

The committee report concluded with a review of the history of AIEE insulation classification and in addition, stated, "In view of the continued rapid development of new insulating materials, and the ever greater number and variety of types and uses of electric equipment, it is probable that a further revision of AIEE No. 1 will be advisable in a few years."

Guides for Thermal Evaluation

A second paper presented at the meeting was concerned with guides for thermal evaluation of insulating materials and systems. By Graham Lee Moses, Westinghouse Electric Corp., and J. F. Dexter, Dow Corning Corp., it dealt with two supplements to AIEE No. 1, designated as AIEE Nos. 1D and 1E (published for trial use). No. 1D is titled, "Guide for the Preparation of Test Procedures for the Thermal Evaluation of Electrical Insulating Materials." No. 1E is a similar guide for insulation systems for electric equipment.

In their paper, the authors explained that the objective of supplements 1D and 1E is to provide a general outline and guide for the