RESEARCH ON MATERIALS

Material Research Laboratory

Today any development of electric machines and apparatus can hardly be gained without development and improvement of materials. For instance, design and construction of generators are already so thoroughly investigated, so that smaller size and higher efficiency can be attained only with the improvement of materials for construction, core and insulation, etc. Our Material Laboratory devotes most of its efforts on testing, investigating and developing of all kinds of materials necessary to manufacture electric machines and apparatus. Some recent results of our efforts are described.

Non-Destructive Tests of the High Voltage Generator Coil

Among the various test methods proposed for the non-destructive testing of high voltage generator coils, "d.c. high voltage test" and "a.c. high voltage test" are fundamentally investigated. In the d.c. high voltage test, the "polarization index" and the "fault ratio" are efficient to detect moisture in coil insulation, though their theoretical explanations are not yet given. We have clarified by fundamental investigations the relationship between moisture content and the polarization index. Furthermore, the mechanism of the so-called "voltage effect," i.e. the decrease of the insulation resistance of the moist coil with increasing applied voltage, and the increase of the temperature coefficient of the insulation resistance with moisture content could be explained. The voltage effect can not be observed by coils with voids after it dried.

In the a.c. high voltage test moisture adsorption, occurrence of voids and deterioration of insulation are detected usually by the aid of tan δ-voltage and tan δ-temperature characteristics. We have found that the static capacitance of coil insulations increases with the begin of void discharges and explained theoretically that at high voltage the increasing atio of the capacitance is greater than that of tan δ. With the increase of capacitance and tan δ increases the a.c. charging current. Therefore voids in the insulation can be detected by measuring the a.c. charging current-voltage characteristics.

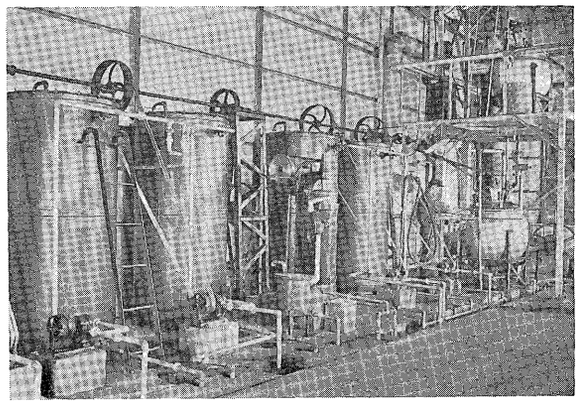
Impulse Breakdown Strength of Non-inflammable Oil and Oil-impregnated Pressboard

It is sometimes said that the impulse breakdown strength of the transformer filled with non-inflammable oil is lower than those filled with mineral oil. We have investigated whether this is really the case or not. By comparing the breakdown strength of mineral oil and non-inflammable oil with various electrodes and gap length, we have found that the non-inflammable oil has higher strength not only for 50 cycle long time voltage, but also for impulse voltage. The values of the impulse ratio are 1.94 for mineral oil, and 1.98 for non-inflammable oil. In the case of mineral oil impregnated pressboards, the 50 cycle long time breakdown voltage is rather lower, but the impulse breakdown voltage is higher than two times of that. Non-inflammable oil impregnated pressboards have, on the other hand, high long time voltage breakdewn strength and rather lower impulse voltage breakdown strength. Therefore the impulse ratio of mineral oil impregnated pressboards is high (=2.00) and those of non-inflammable oil impregnated pressboards is low (=1.14). By the case of combined oil and oil impregnated pressboard insulation the impulse breakdown voltage is nevertheless higher with non-inflammable oil than with mineral oil, which due to the facts, that because of the higher dielectric constant (=4.8) of the non-inflammable oil the field distribution between oil and impregnated pressboard is more uniform by non-inflammable oil and that the impulse breakdown voltage of non-inflammable oil itself is higher.

A New Method for Testing Electrical Steel Sheets

Recently a new type of electrical steels, known as "oriented" electrical steels has been brought to the market. These steels have a unique feature that the axes of their crystal grain are nearly parallel and aligned in the direction of rolling, which has been accomplished by special cold rolling and heat treatments. Because of their remarkable advantages of lower core loss and very higher permeability in the rolling direction over hot rolled electrial steels, they will be widely used as the core material for transformers of various sizes. One drawback of these steels is that they are highly stress sensitive, i.e. their magnetic properties become worse by any mechanical stress caused by punching, shearing, bending, etc. Therefore it is necessary to give sheets a stress-relieving annealing after cut to final size. We have constructed a large annealing furnace with a controlled atmosphere—dried pure hydrogen or hydrogen + nitrogen.

To confirm whether the anneal has been properly accomplished or not, the magnetic properties of the sheets must be tested before and after the anneal. Since sheets are cut to their final forms, various sizes in length and width, the well known Epstein apparatus can not be used, which necessitates 30 mm × 250 mm or 30 mm × 500 mm sample. We have developed a new testing method, which enables to measure absolutely and exactly the magnetic properties of single sheet of wide variety of size. This new method employs a magnetizing coil of ample dimensions to insert the specimen sheets of various width. The length of the coil is arbitrary. We have used, for example, a magnetizing coil of 180 cm length and 90 cm width. A unique feature of this new method is that the secondary coil is wound in a limited central region, say 30 cm of the magnetizing coil, where the specimen will be uniformly magnetized. Since the sample sheet in the magnetizing coil can not be uniformly magnetized over its entire length in the magnetizing coil, we can not measure true magnetic inductions and core losses by fixed magnetizing forces, if we wind the secondary coil over the entire length of the magnetizing coil. On the other hand, if we wind the secondary coil over only the central region of the magnetizing coil, another error occurs due to the variable coupling coefficient between the coils. We have investigated this situation fundamentally and found that an absolute and exact measuring is possible, if we calculate the magnetic properties from two fold measurements by different external circuit resistance. This method has been compared with the result of Epstein method using properly prepared samples and proved good agreements.

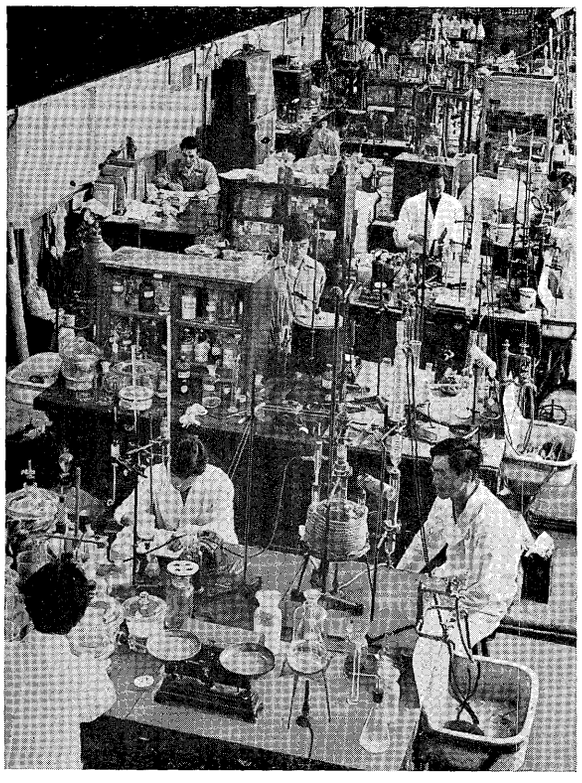


Fabrik of Phenolic Resin

Materials for Rectifiers

Materials, employed for sealing firmly the joint to the tank with the conductors such as cathode, exciting anode and others which penetrate the vacuum steel tank and not only maintaining vacuum but having required mechanical strength and electrical characteristics, have been studied together with the manufacturing process and their testing method. On completion, pumpless air-cooled mercury rectifiers, for the first time in Japan, have successfully been built by the Company. In the pumpless air-cooled mercury rectifier, it is a prime requisite to have high temperature in the initial chemical formation in order to maintain high vacuum for a long period. Also from the viewpoint of resistibility against the backfire during operation, withstanding temperature as high as possible is highly desirable. To meet the requirements, glass was thought of as the material. Characteristics demanded from glass in this respect are : good affinity with the steel tank and conductors, the same expansion and contraction characteristics with the metal according to effect of heating and cooling high mechanical strength, maintaining, for a long time, electric characteristics against temperature rise and free from devitrification and deterioration. To obtain glass of such special features as mentioned, diversified studies using every possible means have been made such as : physical, chemical, mechanical and electrical research of glass and its boundary surface of glass to metal sealing, photoelastic analysis to verify the strain inside the glass mathematically and resistibility against vacuum by the use of a mass spectrometer. As a result important findings on fitting material, processing and testing method have been made to establish a special technique in this respect and special glass is produced in the research laboratory.

The study is further kept on the material, process and testing method of high voltage mercury rectifiers in preparation for forth coming high voltage d-c transmission.



Chemical Division of Material Research Laboratory

The reactor core of the mechanical rectifire is required to have a reasonable rectangular hysteresis loop. It involves a number of difficulties in the component of core material, condition of rolling, heat treatment and other various conditions, which, however, have been overcome by painstaking effort and materials with required characteristics have been made available. When this material has been employed in the core assembling, there were still many problems. And also various materials to be used for contacting parts of the mechanical rectifier have been studied. After solving these problems one by one, the Company has been successful in completing the first mechanical rectifier in Japan.

Materials for Transformers

Insulation oil used for cooling and insulation of transformers is subjected to a number of unfavorable conditions such as effect of various materials coming in contact with the insulation oil—specially metal including copper and iron and paper and other organic material—and temperature rise and oxygen dissolved in oil or contained in air. They affect not only the insulation oil but other various materials, spoiling cooling effect and electric characteristics. To prevent such deterioration of oil as mentioned above, various constructional contrivances have been made on the transformer. As a result of studies, it has been made a practice to give a thorough vacuum drying to the machine and impregnate with carefully deaerated and dehydrated oil. After that, nitrogen gas is filled to seal the surface of oil to prevent the deterioration of the oil. Study of paper permitted a proper selection of the kind, and use it together with the precaution of oil as mentioned above, has made it successful in building a transformer having a small value of $\tan\delta$.

Another method of preventing the oil deterioration is made by adding inhibitor to the oil. This agent is named "Fujinox". The testing method of deterioration characteristics of oil has not yet reached any definite conclusion. A reliable process is now under investigation. Judgement of transformer faults by means of the Buchholz relay has been established with a method of analyzing gases produced.

In city districts, demand for noninflammable transformer has become quite active and dry type transformers without insulation oil or those using synthetic oil are now being manufactured. The Company is successful in producing such materials having required characteristics as to be used for this purpose. Fuji Synchlor—synthetic oil named by the Company—is now available.

Rubber packings used for oil-immersed apparatus such as transformers and circuit breakers are required to have characteristics of unchanging good packing action for a long period under severe conditions where temperature rises above 100°C and compressibility reaches 50%. Nitrile rubber is used as a principal ingredient and rubber of special components has been successfully produced. It has oil resistance, heatproofness and low compressible permanent strain.

Materials for Rotating Machines

It is imperative to prevent the formation of corona on generator coils, otherwise it will promote the deterioration of insulating materials. Comprehensive studies have been made on necessary materials for corona prevention, and further on the process and materials to limit voids leading to corona formation. As a result, improvement on the voltage-temperature characteristics of $\tan\delta$ has been available with success. Mica products employed for coil insulation are being manufactured in the Company's laboratory, whereby required characteristics are being assured.

Regarding materials for underwater motors, study has been made on electric wires and their contacting ing method, rust prevension of metals and problems of bearings, resulting in practically faultless materials. Causes of lowering of motor insulation resistance has been examined to set up a countermeasure. Materials for motors used in chemical factories to withstand chemicals such as acid, alkali, freon and other substances, have been improved together with

their treatment.

In order to improve the characteristics of open slot motors equal to semi-enclosed slot motors, wedges having magnetic characteristics have been successfully produced.

Insulating materials covering class A to H and their treatment have been studied extensively under the Company's insulation treatment committee. Various kinds of insulating Varnish are being manufactured in the laboratory.

In the field of prime movers, various heat resistant materials for gas turbines, lubricating materials, fuel, packings for water wheels and coupling rubber have been investigated to meet the specification.

Apparatus, Circuit Breakers and Others

Phenol-resin products as a part of small sized contactors are required to have enough strength against impact considering their complicated shape. After careful investigation of necessary molding conditions and base material, specification on materials has been established.

Since the hydro circuit breaker employs special liquid for interruption, special attention has been paid to its resistance materials.

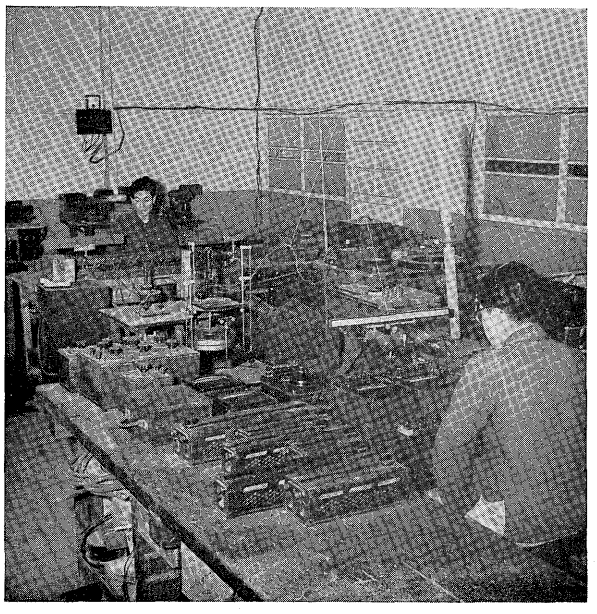
Specially materials for arc extinction chamber is subjected to impulsive, mechanical forces of steam generated during operation, which prohibits the use of porcelain in spite of its good electric characteristics. Special plastic materials have been adopted successfully for the purpose.

Phenol resin paper tubes—the most popular materials for oil immersed apparatus—have difficult problems on their electrical and mechanical characteristics. Hence, reserches have been made on paper, resin, process of applying resin to paper and manufacturing of tubes, with the results that a lot of improvements have been obtained.

Home appliences and measuring instruments have been also taken up as subjects of study on their materials and treatment. Various materials and methods have been also investigated of their insect-proofness and mold-proofness.

Treatment on Surface

In the surface treatment such as plating and painting on metal parts for the sake of rust prevention and good appearance, it requires constant efforts to employ ever advancing technique to accomplish satisfactory results. The laboratory has established a surface treatment committee to determine a standard of surface treating technique. Purchasing of materials, testing of materials, standard of processing and inspection of treated surface are all objects of study.



Magnetic Testing Room

Treatment of Insulation

Establishment of insulating materials and a treating and handling method of insulation, that is, technique of insulation treatment is a very important problem. In the Company, a committee has been formed with the laboratory as the center and sectional committee meetings have been also held to study synthetic resign, insulation varnish and other materials separately, thus trying utmost to improve insulation treatment standard technique by following steady progress of materials and engineering.

Various problems now under investigation and suggestions with respect to insulating materials are represented by the following subjects. Resistibility of insulating materials against corona formation, their endurance against arcing and its testing method, weather-proofness, mutual relation among insulation resistance, dielectric strength, impulse dielectric strength and dielectric loss, insulation characteristics of insulation materials in the air and insulation oil (mineral oil and synthetic oil), insulation characteristics of combined insulation material, heat resistance testing method, moisture resisting testing method, life test, insulation treatment classified according to applications, development of gas insulator and high dielectric constant and low power factor material, development of application of varied synthetic resins, etc.