F-RESIN (FUJI-RESIN) INSULATION COIL

By

Teruhisa Shimizu
(AC Machine Div., Design Dep't.)

Noboru Iseki
(Physical Research Div., Research Dep't.)

Rikuo Taniguchi
(Chemical Research Div., Research Dep't.)

I. INTRODUCTION

Coil insulation of high-voltage and large capacity rotating machine determines its reliability and continuity of service, and hence considerable efforts have been expended on the development of insulating materials and applying processes. Generally, the mica folium type of insulation and the asphalt-bonded continuous mica tape type of insulation are the most typical constructions of insulation which have been and still are used.

Mica folium, consisted of wide sheets of fabricated mica backed with thin paper and bonded together with shellac, is applied to the straight part of the coils by means of so-called Haefly machine which heat and roll the folium on the coils. The coil ends are then insulated with multiple layers of varnished cambric tape. This insulation is excellent from the electrical standpoint, but has a mechanically uncontinuous part at the joint between the mica folium on the straight part of the coils and taping layers on the end turns. As machines become larger and especially coil length become longer, special consideration for the insulating structure of the joint parts must be taken.

The asphalt-bonded mica tape type of insulation has continuous, joint-free layers through the coils, but it has some difficulties by the thermoplastic nature of the asphaltic bond. The dimensional changes brought about by the large differences in expansion of the metal parts and insulation during operating temperature cycles, cause the permanent migration of the asphaltic bond beyond the stator iron in the end turns and as the result the de-lamination of the insulation layers.

By the remarkable progress of high polymer chemistry new insulations which are applied by synthetic resins in place of natural resins as shellac, asphalt and so forth have been developed. These are (1) polyester bonded mica tape insulation which is impregnated under vacuum into the mica tape layers by the liquid resin consisted of unsaturated polyester and vinyl monomer and (2) silicone rubber insulation which is filled uncured silicone rubber paste into the silicone rubber tape layers and molded under heat and pressure. The former has adequate elasticity in high operating temperature and can adjust itself to the dimensional changes brought about by the thermal expansion and contraction of the coil during operating temperature cycles. This behavior is more suitable character than the earlier insulations but because of the great curing shrinkage of the impregnating polyester considerable difficulties are experienced in processing coil insulation. The later is mechanically and thermally ideal as coil insulation because silicone rubber has superior elasticity and excellent resistance to heat aging, but it has also some difficulties. This micaless silicone rubber insulation is lower in dielectric strength than the other insulation and if one wish to reinforce it with mica, rubber is not satisfactory for mica bonding. It is a great problem that void spaces of insulation cannot be completely filled with the silicone rubber paste, because vacuum impregnating process cannot be adopted.

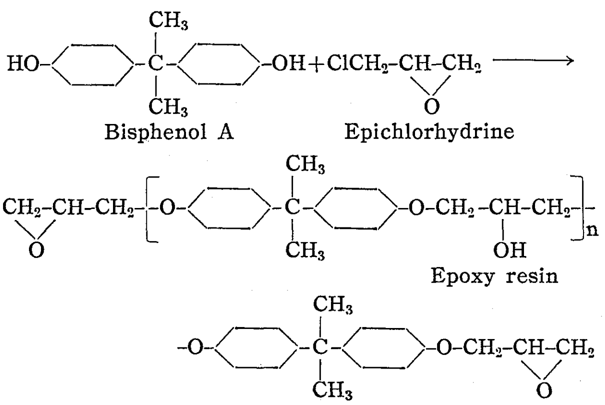
Fuji Denki has been making considerable efforts to develop the high-voltage coil insulation. As the result of having studied properties of various insulating materials, processing methods and especially, thermal stability and corona resistance of the high-voltage coil insulation, we have finally developed the impregnating resin consisted of a resin containing epoxide groups and its hardener.

This epoxy resin and its hardener combination, being low viscous at moderate temperature, is adequate for impregnation and the thermosetting solid resin mechanically not only adjust itself to the dimensional changes of the coils and resist mechanical shock, but also has excellent electrical properties, oil-resistance, moisture resistance and heat aging resistance which are essential to a epoxy resin. We named this resin " F-Resin " (Fuji-Resin) and accomplished new processing method for high-voltage coil insulation. This F-Resin insulated coil, though mica being not used, has superior properties from various points of view than older insulations as shown following and thus now being applied to a water-wheel generator.

II. PROPERTIES OF "F-RESIN"

Of the many synthetic resins which have been produced successively by rapid progress in the development of high polymer chemistry, epoxy resin is the most noteworthy materials which has closely connection with electrical industry. It is used widely as casting, encapsulating and impregnating material, adhesives, bonding material in laminates and coating material of the various electrical machines and apparatuses, because of its excellent chemical and electrical properties.

Commercial epoxy resins have polieter structure consisted of bisphenol A and epichlorhydrine. The mol ratio of these two components or reactive condition makes possible to produce resins of various molecular weight as shown following.



When n=0~1, resin is viscous liquid and when is more than 2, solid resin. Epoxide groups $\left(\underset{\text{O}}{\text{-CH-CH}_2}\right)$ at the both sides of the molecule is very reactive and react with polyamine, organic acid or acid anhydride at normal or moderate temperature to produce a cross-linked, thermosetting solid resin, which has excellent mechanical and electrical properties. This chemical reaction occurs without the formation of any gaseous or liquid by-products, thus making possible almost complete filling of the void spaces. Superior properties of F-Resin insulation coil are due to the originally excellent properties of epoxy resin.

F-Resin, taken into consideration of properties as impregnant and processing of coil insulation, is manufactured by combining properly epoxy resin and its hardener. Thus it can easily be impregnated into small gaps of the coil insulation layers because it is quite freely flowing at impregnating temperature and the composite resin in place shows very low shrinkage when converts to a solid resin. This is satisfactory character for the impregnating operation. The solid F-Resin also has excellent mechanical and electrical properties as can be seen from Table 1 comparing with earlier shellac and unsaturated polyester resin. Very high dielectric strength is a special excellence of F-Resin. This obviously makes for a higher quality insulation. Table 2 shows the properties of F-Resin insulated layers, which is the combination of F-Resin and glass tape, comparing with shellac bonded mica folium insulation and polyester bonded glass-mica insulation. It will be observed that the tensile and bending strength which guarantees the mechanical properties of the coil is appreciably

Table 1. Properties of insulating materials

Item	Shellac	Polyester	F-Resin
Linear expansion coefficient	114×10^{-6}	126×10^{-6}	75×10^{-6}
Tensile strength kg/mm²	1.7~2.0	3.5~4.5	6.5~8.5
Flexural strength kg/mm²	2.0	8.0~10.0	12.2~13.8
Impact strength (charpy) kg-cm/cm²	1.7	2.0~2.5	2.6~2.9
Compressive strength kg/mm²	6.8	13~15	13.3
Volume resistivity Ω-cm	8.2×10^{15}	1.7×10^{16}	4.2×10^{16}
Dielectric strength kV/mm	20	28	33~38

Table 2. Properties of coil insulating layers

Item	Shellac bonded mica folium	Polyester bonded glass mica	F-Resin bonded glass
Linear expansion coefficient	8.8×10^{-6}	10.7×10^{-6}	19×10^{-6}
Flexural strength kg/mm²	17.3	14	30.7
Flexural modulus kg/mm²	4,200	2,500	2,100
Dielectric strength kV/mm	30	30	35
Thermal conductivity W/m°C	0.24	0.3	0.4
Dielectric constant	3.8	4.0	3 6

Table 3. Chemical and solvent resistance of F-Resin

Chemicals	Appearance	Solvents	Appearance
10% NaOH	No change	Ethyl alcohol	No change
10% HCl	〃	Benzene	〃
10% H_2SO_4	〃	Gasoline	〃
20% NaCl	〃	Chlorinated insulating oil	〃

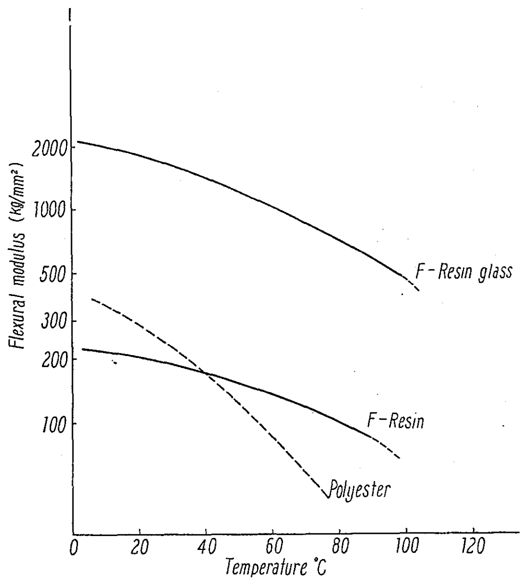


Fig. 1. Flexural modulus vs. temperature characteristics of F-Resin polyester and F-Resin glass layer

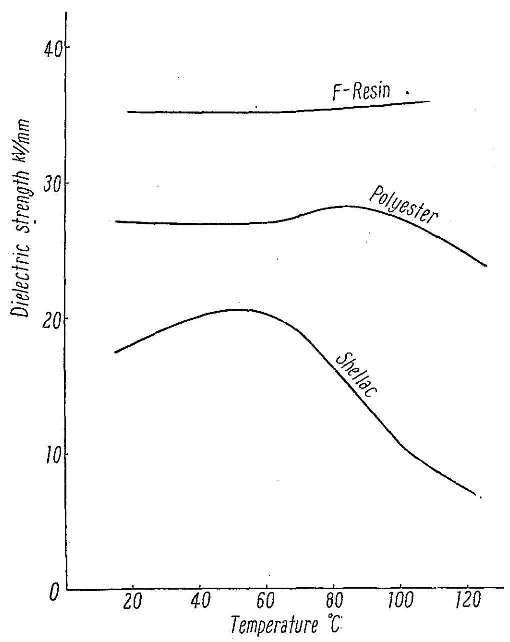


Fig. 2. Break down voltage vs. temperature characteristics of various insulating materials

strong and heat expansion coefficient is so similar to copper that this can minimize the effect produced by heat cycles of the coil.

High conductivity of this insulation raises the cooling effect of the coil. Fig. 1 shows the flexural modulus versus temperature characteristics of F-Resin, Polyester and F-Resin bonded insulation layer. As the modulus of F-Resin insulated layer remarkably goes down at high temperature, this insulation possesses the inherent ability of accommodating itself to the deformation resulted from differential thermal expansion of iron, copper and insulation.

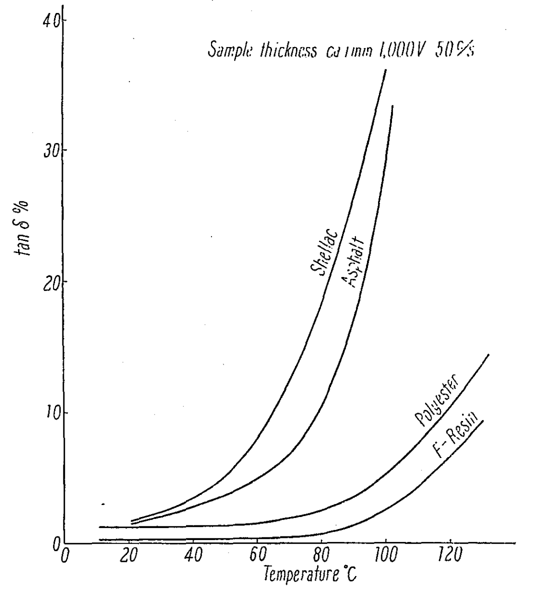


Fig. 3. Tan δ vs. temperature characteristics of various insulating materials

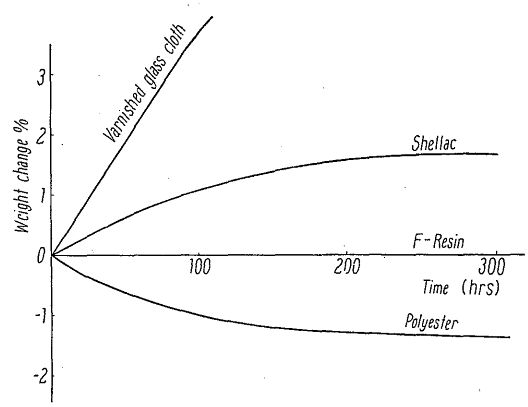


Fig. 4. Weight change of various insulating materials heated at 90°C in ♯90 turbine oil

The dielectric strength versus temperature relations for F-Resin, polyester and shellac are compared in Fig. 2. The dielectric strength of F-Resin is approximately same from normal to operating temperature. This performance offers promise of the greater reliability for coil insulation as compared with old shellac and asphaltic compound. The temperature effect on tan δ at 50 cycles is presented in Fig. 3. In every temperature tested tan δ of F-Resin is appreciably not only lower than the other materials such as shellac, asphalt and polyester but also at operating temperature it shows nearly small increase while the tan δ of shellac and asphalt rises sharply with temperature increase. As shown in Table 3, solvent and chemical resistance of F-Resin is very excellent. It did not show any change through 1 month immersion in weak acid and alkali or aliphatic and aromatic solvents at normal temperature. Superior oil resistance also is characteristic of F-Resin. Fig. 4 shows the weight change of various insulating

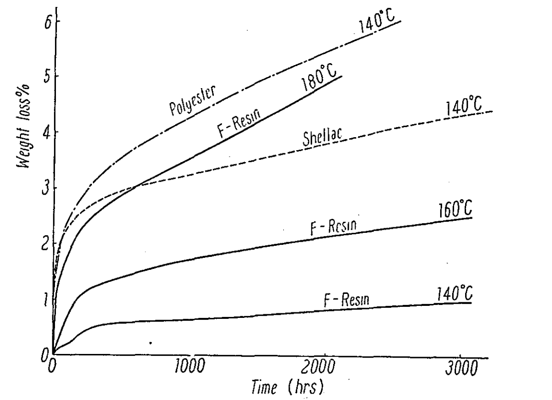


Fig. 5. Weight loss curve of F-Resin by heat aging

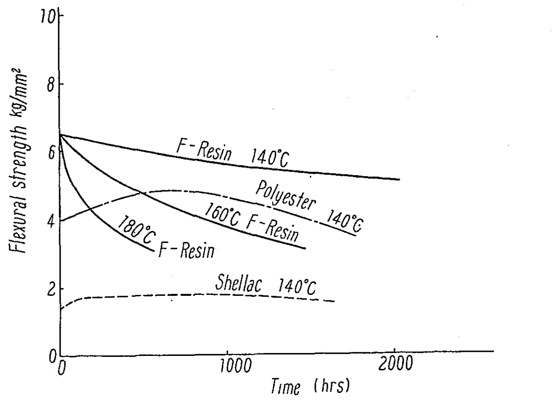


Fig. 6. Change of tensile strength by heat aging

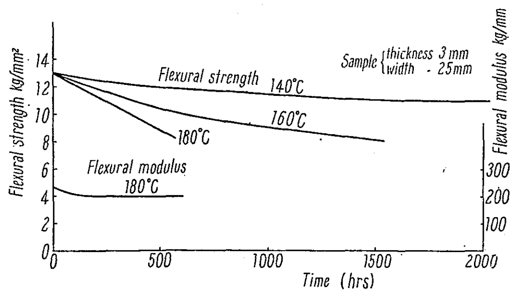


Fig. 7. Change of flexural strength and flexural modulus by heat aging

materials which are immersed in ♯ 90 turbine oil heated at 90°C for about 300 hours. F-Resin did not show any weight change and any swelling or dissolving did not occur. This keeps coil insulation safe against contact with lubricating oil.

The resistance to heat aging of an insulating system is one of the very important criterion of insulating quality. Heat aging characteristics of the insulating materials influence directly the life of electrical rotating machines and therefore the mechanical and electrical behavior of F-Resin when heated continuously at 140, 160, 180°C was carefully investigated. Changes of weight, tensile strength, bending strength and flexural modulus, compressive strength and dielectric strength are respectively observed from Fig. 5, 6, 7, 8 and 9. Changes of

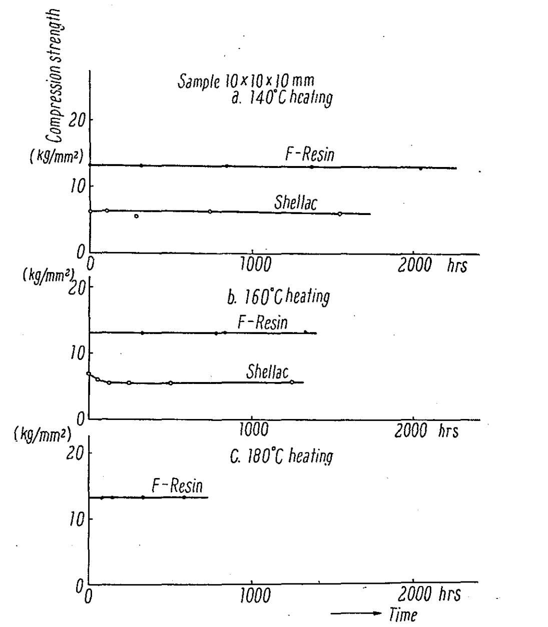


Fig. 8. Change of compressive strength of F-Resin by heat aging

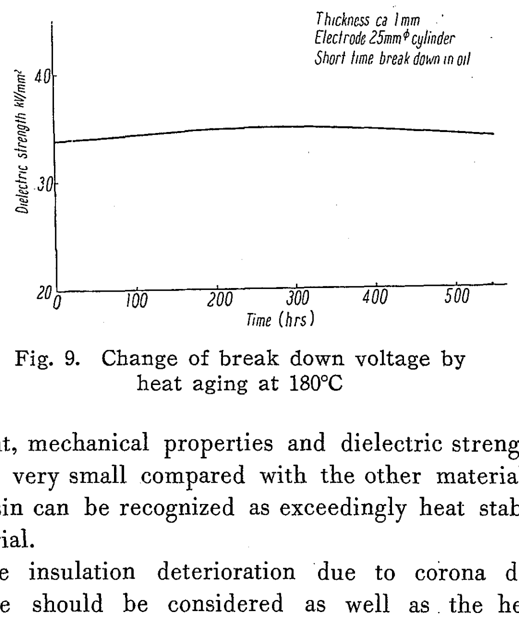


Fig. 9. Change of break down voltage by heat aging at 180°C

weight, mechanical properties and dielectric strength being very small compared with the other materials, F-Resin can be recognized as exceedingly heat stable material.

The insulation deterioration due to corona discharge should be considered as well as the heat aging. In the older type high voltage coil, the corona discharge can not be avoided at normal operating voltage, on that reason the organic materials used for bond and impregnation are gradually injured from corona, consequently the dielectric strength decreases. This necessitates to use of high corona resistance materials.

We conducted the corona resistance test according to the French method proposed to IEC among the various kinds of the test method. As shown in Fig. 10 and 11, a stable corona discharge can be obtained in the air space between two sheets of glass. Inserting each specimen (0.2 to 0.3 mm thick, 100× 100 mm) to the air space, at continuous voltage application of 50 cycles 13,200 volts, the effects of corona were investigated. The change of several

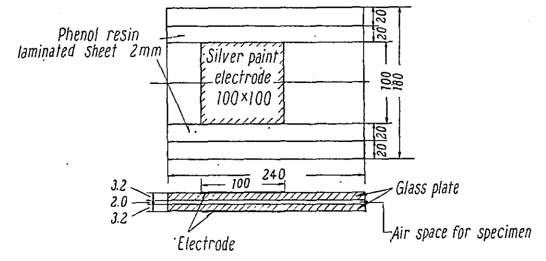


Fig. 10. Cell for corona aging

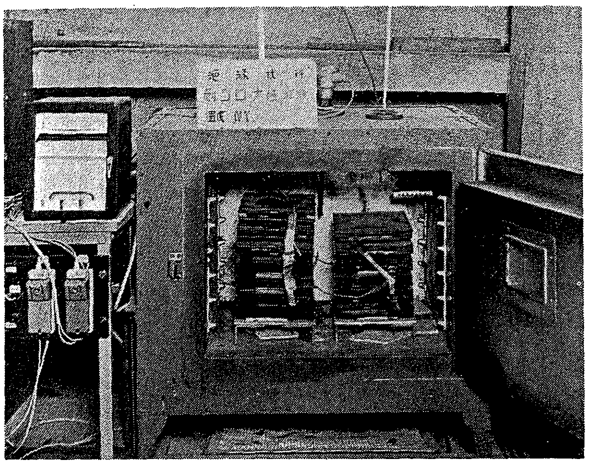


Fig. 11. Equipment for corona aging (100°C)

properties, such as visual observation, weight, dielectric strength, tan , insulation resistance and tensile strength, were used to evaluate the effect of corona erosion. The test results of the F-Resin and shellac-insulation, in addition Samica for reference, are shown in Fig. 12 to 17.

F-Resin, having a exceptionally high dielectric and mechanical strength, indicates a very high corona resistance. As compared with it, most kinds of resin, such as shellac, are suspectible to injury from corona. " Impossible to test " shown in the curve of shellac-glass indicates that the specimen is damaged as hard as impossible to test. Especially the cellulose material, such as paper, is so susceptible to injury from corona that disappears within a short time. The low corona resistance of Samica depends upon the dispersion of oil-modified varnish for bonding and the separation of the mica flake. The corona resistance of Samica would increase, if the higher corona resistance material such as epoxy resin would be used for bonding. Even the inorganic material such as mica and glass, having a very high corona resistance in com-

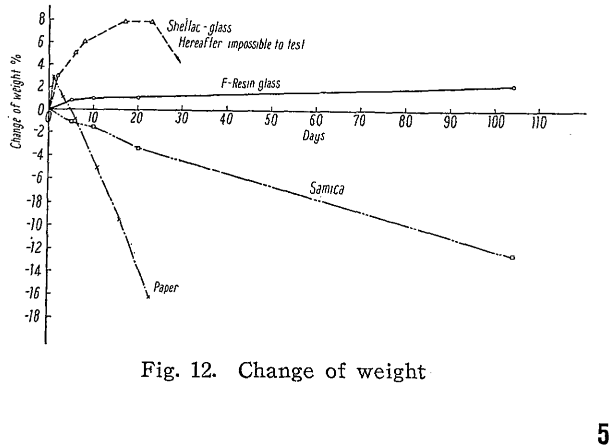


Fig. 12. Change of weight

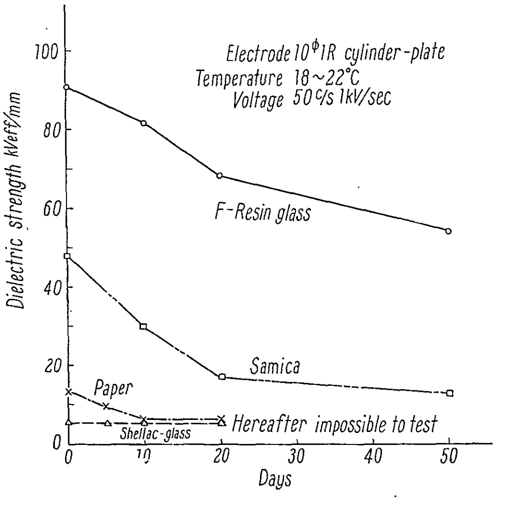


Fig. 13. Change of breakdown voltage

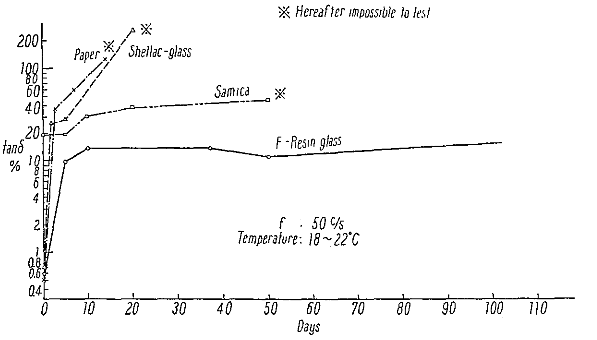


Fig. 14. Change of tan δ

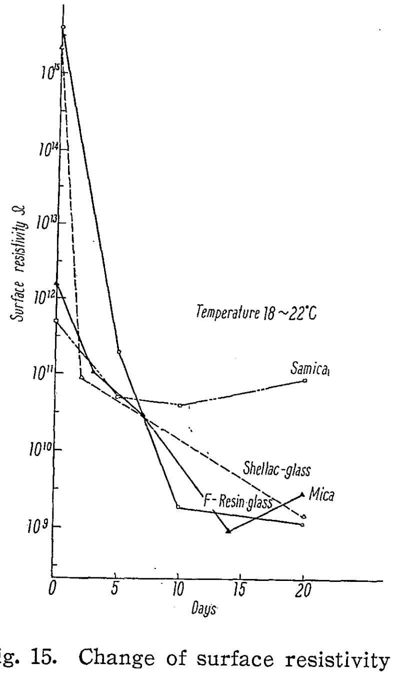


Fig. 15. Change of surface resistivity

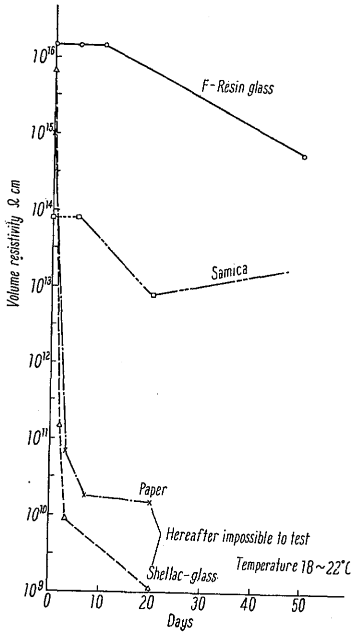


Fig. 16. Change of volume resistivity

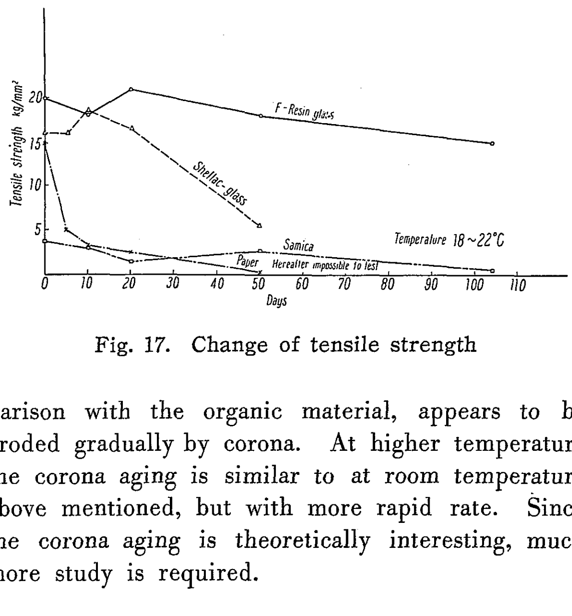


Fig. 17. Change of tensile strength

parison with the organic material, appears to be eroded gradually by corona. At higher temperature the corona aging is similar to at room temperature above mentioned, but with more rapid rate. Since the corona aging is theoretically interesting, much more study is required.

III. CHARACTERISTICS OF F-RESIN COIL

1. Comparison with the older type insulation

The sheet-wrapped insulation which is wrapped and baked with mica paper, bonded with thermosetting resin, such as shellac, nowadays being applied in Europe, is a mechanically and electrically compact insulation, but it is stated that the coil at the air duct portion bulges during operation because of softening of bond at high temperature. The compound insulation which is taped with mica tape and vacuum-impregnated with asphalt-compound, having been adopted mainly in America, is nearly free from air space, but it is stated that the dielectric strength at higher temperature decreases by softening of compound and the movement or separation of mica and bulge of insulation take place.

It is recently recognized that the degradation caused by corona is unexpectedly serious, but in the older type coil of 6,600 volts rated voltage and higher the corona discharge occurs more or less at normal working voltage. Therefore it has become a most important problem to prevent it.

F-Resin coil, which is a micaless insulation considering the present of air space in mica layer and the inadequate bonding force between mica and bonding material, has thoroughly resolved all kinds of the weak points of older type coil. F-Resin coil, where the insulating tape and F-Resin become as one body and form a homogeneous insulation layer, has not only a electrically, mechanically and thermally superior properties but also perfectly void-free insulation layer, consequently does not exhibit a corona discharge during operation. The details are presented below.

2. Insulation resistance

F-Resin coil has a extremely high insulation resistance. The dependence of the insulation resistance on time and temperature about the new and older type coil of 11,000 and 6,600 volts rated voltage are shown in Fig. 18 and 19. Both coils are at wholly dry condition, because their polarization index (P.I.) is about 5, but the value of insulation resistance of the F-Resin coil is about 1 to 2 figures higher than the older type coil.

Since F-Resin coil is nearly nonhygroscopic, the predriving of generator for drying is not necessary even at humid region as the tropics. The change of the volume and surface resistance of coils, which were exposed to atmospheric condition of 90 percent relative humidity for about six months, is shown in Fig. 20. The insulation resistance of F-Resin coil scarcely reduces by moisture absorption and even

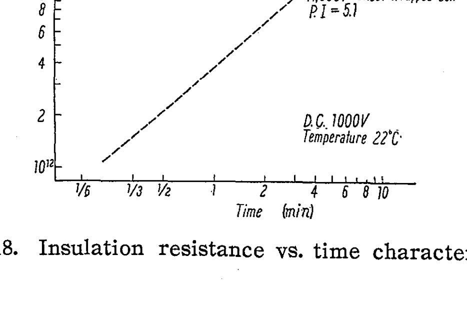


Fig. 18. Insulation resistance vs. time characteristics

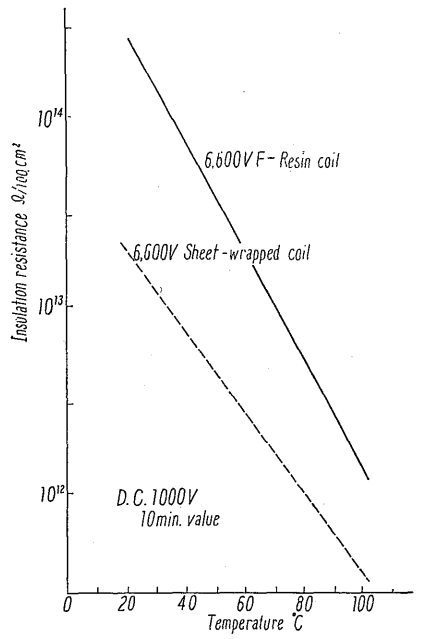


Fig. 19. Insulation resistance vs. temperature characteristics

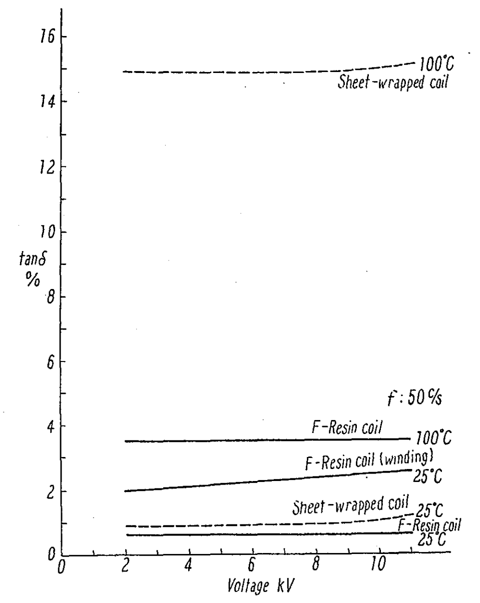


Fig. 21. Tan δ vs. voltage characteristics (11,000 V insulation)

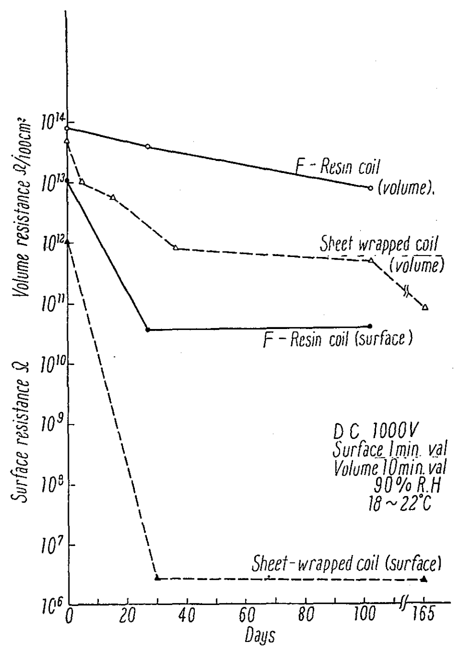


Fig. 20. Humidity test of coil (11,000 V insulation)

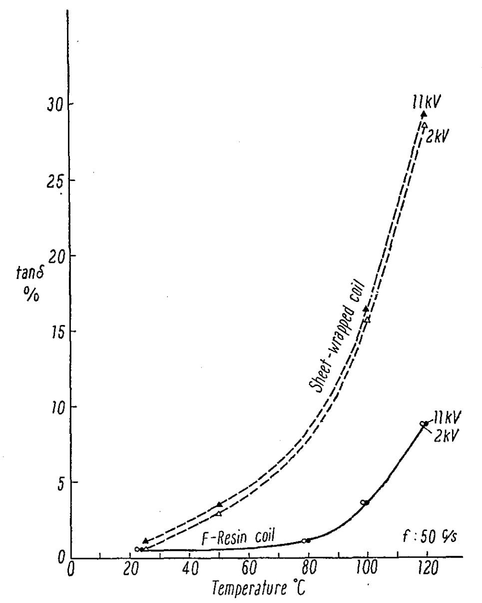


Fig. 22. Tan δ vs. temperature characteristics (11,000 V insulation)

after humidity equilibrium sufficiently high. The insulation resistance of the older type coil falls widely due to moisture absorption of cellulose materials, especially at the surface, causing the serious decrease of that of generator. But in the case of F-Resin coil, such a trouble would not take place.

3. Tan δ and internal corona

F-Resin coil indicates a exceptionally low tan δ and superior temperature characteristics of tan δ. Tan δ versus voltage and tan δ versus temperature characteristics are shown in Fig. 21 and 22. The tan δ value is 1 percent or less at room temperature and does not become more than several percent even at high temperature of service condition. This verifies that the insulating material used is superior and the manufacturing condition of the coil is well controlled.

The most striking advantage of F-Resin coil is that there is no void at all in the insulation. whereas the older type compound-coil is apt to contain voids in the insulation because of the difficulty of perfect impregnation of compound within the permissible temperature range without the degradation of the organic material. In the sheet wrapped coil the presence of voids can not be avoided because of the formation of gaseous by-product at hardening of the thermosetting resin. On the contrary F-Resin permeates completely to the interior of the insulation layer by a single operation of vacuum–and high pressure impregnation because of its excellent fluidity. As F-Resin is a solventless varnish and does not produce any volatile matter, even any small space can be filled perfectly with the resin. Since the contraction at hardening is extremely small, the coil is formed so accurately according to the expected dimension by the use of a moulding press favorable to handling that does not leave a air space. Therefore the corona discharge does not occur up to the rated voltage and tan δ versus voltage curve is perfectly flat as seen in Fig. 21. In the older type insulation the increment of tan δ per 1 kV is about 0.2 percent even at best coil, but in F-Resin coil it is easy to bring it to nearly zero (with guarded electrode).

In the case of the such coil having a small degree of void, it is nearly impossible by tan δ test to detect the existence of void. To detect such a few and minute void and measure quantitatively the corona intensity, a corona pulse detector has been developed and utilized. Fig. 23 indicates the corona pulse measuring apparatus and its circuit connection which amplifies the pulsive voltage due to corona at the terminal of detecting resistance R and measures its magnitude and numbers by the counter. The corona pulse curves of the new and older type coil 11,000 volts rated voltage are indicated by Fig. 24. The older type coil exhibits the corona discharge at about normal working voltage (6,400 volts) and its intensity increases rapidly at higher voltage. On the other hand F-Resin coil never exhibits the corona discharge up to rated voltage (11,000 volts) and will initiate above the rated voltage but very feeble.

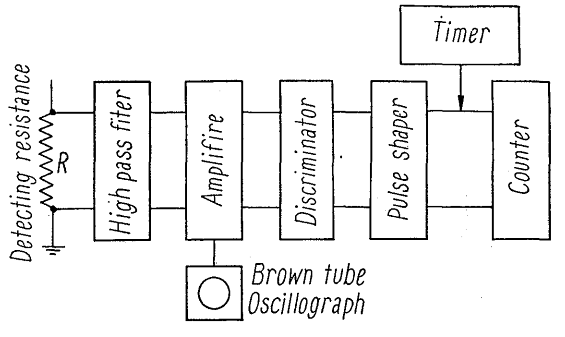


Fig. 23 (a) Schematic diagram of corona pulse counter

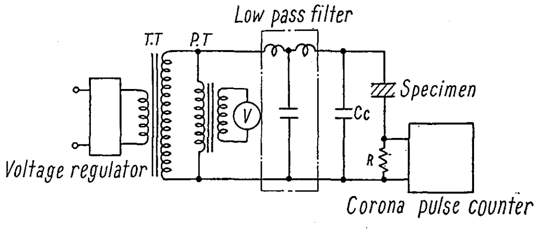


Fig. 23 (b) Schematic diagram of corona test circuit

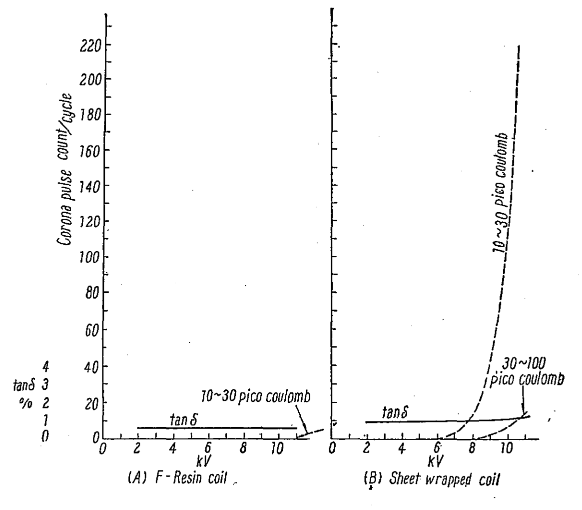


Fig. 24. Corona-voltage characteristics (11,000 V insulation)

4. Surface corona

The surface corona is a important problem as well as the internal corona. It is divided to slot–and end corona. The elimination of the slot corona is relatively simple and it is satisfactorily done by coating the coil surface of slot portion with a low resistance varnish. The low resistance varnish, having a suitable electrical resistance, should have a good adhesion, mechanical strength and a excellent heat resistance. A new type of the low resistance varnish, having a especially good adhesion to F-Resin coil, has been developed and used.

To increase the corona starting voltage to above

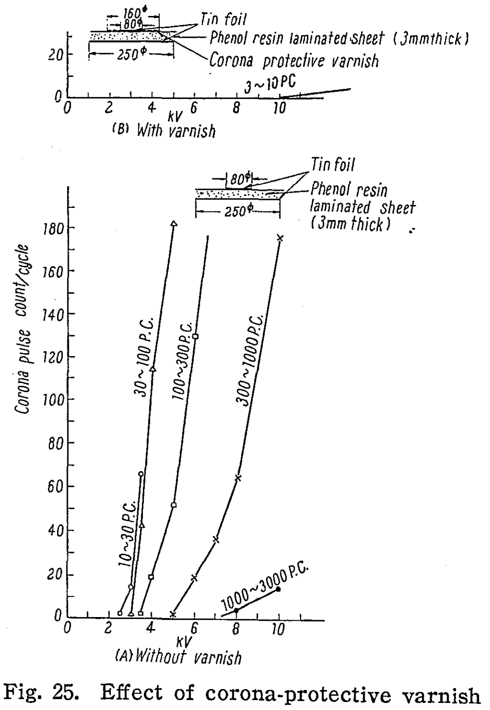


Fig. 25. Effect of corona-protective varnish

10,000 volts, it is most important to suppress the surface corona at the end of coil. To do it a high resistance varnish and its coating technique were studied. On example of the test results, indicating the effect of the corona protective varnish, is shown in Fig. 25. In Fig. 25 (A), the case of without the corona protective varnish, the corona initiates at 2,000 volts and increases remarkably in magnitude and repetition rate at 10,000 volts. On the other hand in Fig. 25 (B), the case of with varnish, it is wholly suppressed up to 10,000 volts. A new type of high resistance varnish, having a good adhesion to F-Resin coil and a superior thermal stability, has been developed and used. To check a poor coating, every coil is tested by corona pulse method in a model slot. (The curves in Fig. 24 also is obtained in a model slot.)

5. Breakdown voltage versus time (V-t) characteristics

The increase in the voltage and output of generators requires in technically and economically the insulation of higher dielectric strength per unit thickness. Since F-Resin has extremely high dielectric strength and there is no void in the insulation, the F-Resin coil has a quite high dielectric strength. The dielectric strength of the asphalt compound at 80°C decreases to 50 percent of that of room temperature, consequently that of the compound-coil at 100°C is about 15 percent lower than at room temperature, on the other hand, as the dielectric strength of F-Resin does not decrease up to 120°C, that of F-Resin coil is nearly constant up to 120°C.

The dielectric strength of insulation is usually measured by short time voltage application, but the essential matter for actual use is that the insulation should never break down at normal working voltage. When a-c voltage is applied to a insulation in a long time, the breakdown voltage of the insulation decreases with time of voltage application due to temperature rise caused by dielectric loss and degradation of insulation caused by corona discharge. Therefore, even if the short-time breakdown voltage is high, the long time a-c breakdown voltage of the insulation, indicating a large amount of tan δ loss or a intense corona discharge at working voltage, will be lower.

Since F-Resin has a very small tan δ and a excellent corona resistance in comparison with the other organic materials and in the insulation the corona discharge does not occur at working voltage, the long-time a-c break down voltage does not decrease with time of voltage application. To confirm it, V-t characteristic tests of F-Resin coil are being conducted during long time. From the results obtained till the present time, we can conclude that F-Resin coil is a very satisfactory insulation.

6. Dielectric deterioration due to heat and voltage cycle

The deterioration due to heat cycle is one of the most important factor in the mechanism of dielectric deterioration of generator coil. The investigation about it is divided into two parts.

1) Dielectric deterioration of slot portion

An accelerated deteriorating test of heat and voltage cycle about the slot portion of F-Resin and the sheet-wrapped coil was conducted. Since the sheet-wrapped coil bulges by heating, it was bound by metal fittings in a same manner that it is held in slot. The metal fittings consist of four parts to imitate the air duct and the distance between each fittings in 10 mm (Fig. 26). Since F-Resin coil does not bulge, it was heated without fitting. They were subjected in an oven to the repetition of the cycle,

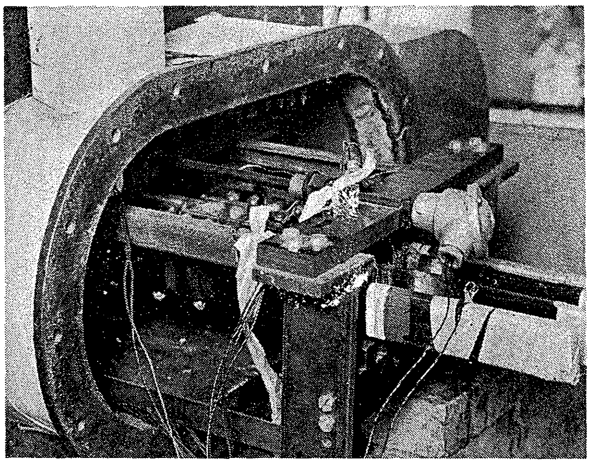


Fig. 26. Coil for heat cycle test

that consists of an application of 11,000 volts and keeping temperature at 130°C for six days, subsequently at no voltage and room temperature for one day, and the change of dimension, tan δ and corona were investigated. The results are shown in Fig. 27 to 29. The sheet-wrapped coil at air duct portion bulges remarkably in width (width of slot) until 500 hours (Fig. 27, 30) and fixes later. The tan δ increases gradually and the corona intensity becomes very strong. These facts demonstrate that the voids in the insulation gradually become larger. On the contrary, F-Resin coil does not bulge at all even after heating and voltage application (Fig. 27, 30), therefore the tan δ is constant up to the rated voltage and corona intensity does not change.

2) Nonreversible elongation of coil at the end

One of the important matters among the deterioration mechanism of long generator coil is that the insulation moves from the conductor by repetition of expansion and shrinkage due to heat cycle. The large nonreversible elongation of the compound coil

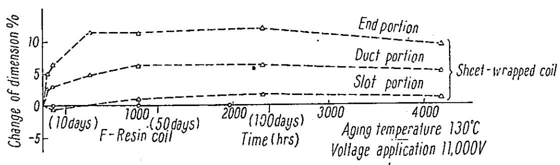


Fig. 27. Change of dimension by heat aging (11,000 V insulation)

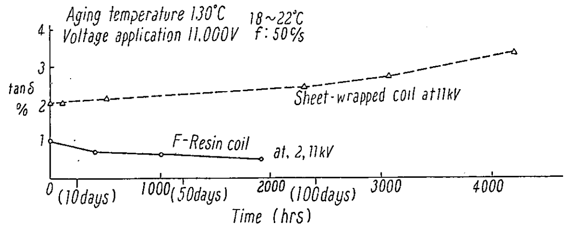


Fig. 28. Change of tan δ by heat aging (11,000 V insulation)

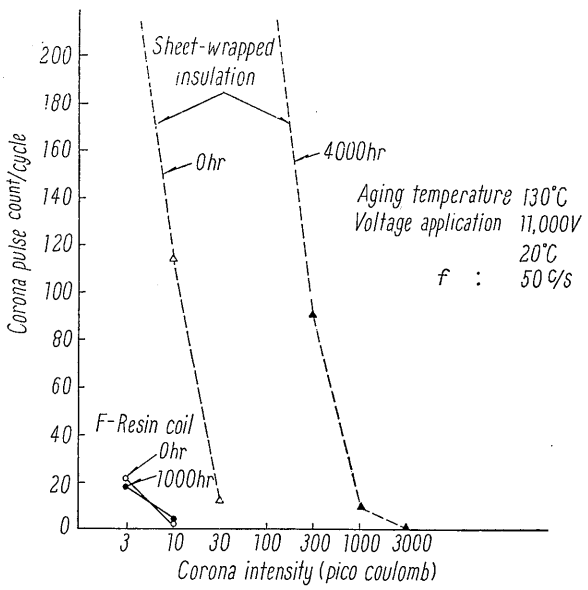
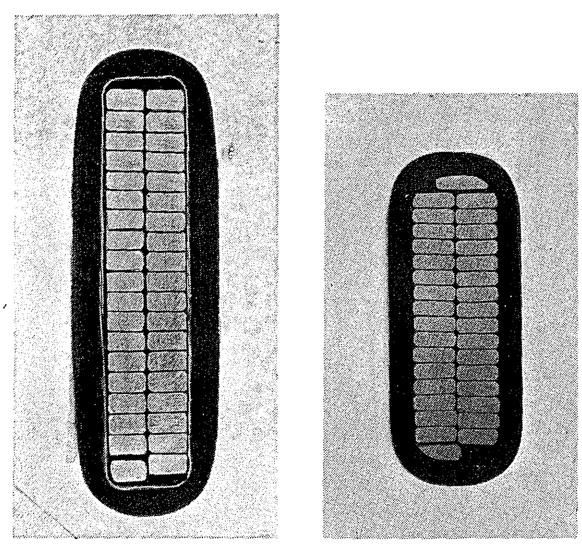


Fig. 29. Change of corona by heat aging (11,000 V insulation)



(A) Sheet-wrapped coil (air-duct portion) (B) F-Resin coil

Fig. 30. Section of coil (after aging 130°C, 1,000 hrs)

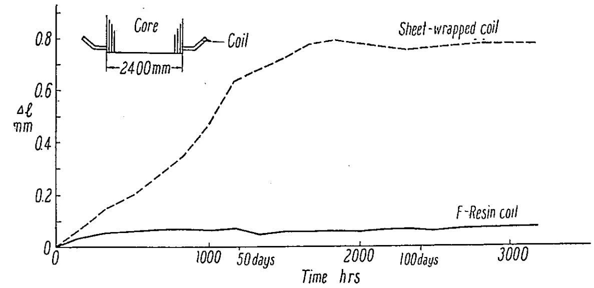


Fig. 31. Nonreversible elongation of insulation by heat aging

by heat cycle is a matter of course because of its thermal fluidity. A comparison of nonreversible elongation between F-Resin and the sheet-wrapped coil, indicating a relatively small amount of nonreversible elongation, is shown in Fig. 31. This is the result of the deterioration test where coils are held in a model core (2,400 mm core length) and subjected to repetition of the cycle that consists of an application of 13,200 volts and keeping temperature at 120°C for six days, subsequently at no voltage and room temperature for one day. The nonreversible elongation of F-Resin coil is so small that is out of the question.

As the tests, mentioned in section 5 and 6, are being continued at the present time, in near future shall be presented in details.

IV. SUMMARY

1) The largest advantage of epoxy resin, being the chief element of F-Resin, is that it diffuses thoroughly through the every part of the insulation by only once of impregnation and produce no volatile matter at the hardening. Since F-Resin consists of the suitable combination of the epoxy resin and its hardener especially in order to adopt the impregnating operation, the degree of the shrinkage due to hardening is very small, and the bonding force with any other material is exceptionally strong, it is the

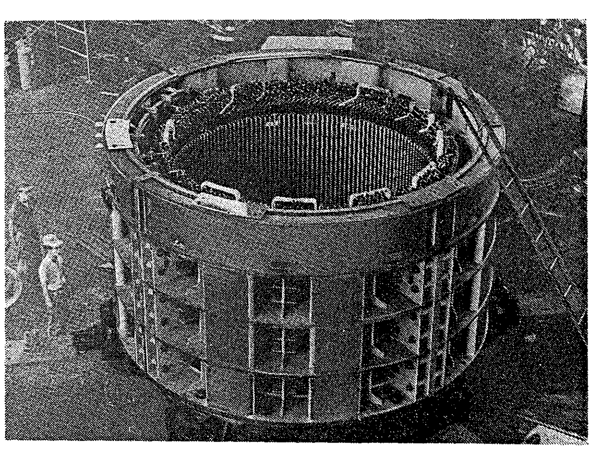


Fig. 32. Stator of 11 kV 35,000 kVA generator

most suitable material to form the void-free insulation.

This resin also exhibits a good electrical and mechanical properties over the wide range of temperature, a excellent chemical and oil resistance, and an unusual resistance against heat and corona discharge as compared with any other organic material, consequently it permits to elevate the reliability of the high voltage coil.

2) The most important advantage of F-Resin coil is that there is none of void in the insulation. In the older type insulation the exhibition of corona discharge during operation can not be avoided, consequently not only the organic but even the inorganic materials are susceptible to injury from corona. Since F-Resin coil does not exhibit the corona discharge during operation, it has completely resolved the fundamental shortcoming of the older type coil by a single effort.

3) F-Resin coil has a very good mechanical and electrical properties as compared with the older type coil even at high temperature. In addition the resistivity to moisture is very high, therefore the drying of the generator prior to the running will not be required even at high humid region as the tropics.

4) The durability of F-Resin coil is being investigated by a long-time systematic experiment and already several significant informations have been obtained. In F-Resin coil there are no movement, separation and bulging of the insulation, therefore the formation of air space in the insulation does not take place during operation. A V-t characteristics test by long-time voltage application is being conducted. From the results it is verified that the reliability for the insulation is sufficiently satisfactory.

5) The quality of the insulation depends upon not only the insulation design and the material properties, but also manufacturing technique very much. Therefore we have made much efforts for the establishment of manufacturing manner and operating condition, and the maintenance of its quality level.

But the development of the insulating material and manufacturing technique is ever lasting. We should make every possible effort for the much more improvement of F-Resin coil.

At present time the first generator, where F-Resin coil is adopted in practical use, 35,000 kVA water wheel generator, has been in service (Fig. 32). The detailed information will be reported before long.