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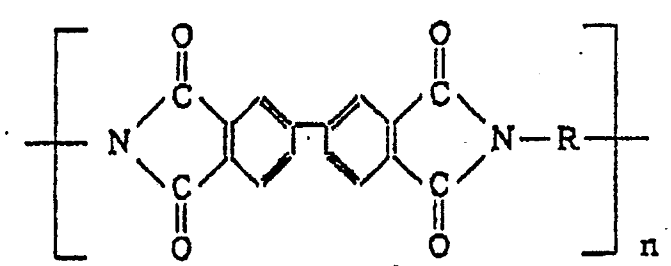
(54) Insulation for revolving-armature coil.

(57) An insulation structure for revolving-armature coil, according to the present invention, principally uses a polyimide file tape or sheet as at least a part of element wire insulation and insulation to the earth. The tape or sheet is formed of a polyimide composition generally expressed by the following formula:



Synthetic resin compound containing polyimide resin and epoxy resin as principal material and an acid anhydride type hardening agent is impregnated and hardened.

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INSULATION FOR REVOLVING-ARMATURE COIL

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to an insulation for a revolving-armature coil with high thermal resistance.

Description of the Background Art

In the modern technologies, requirement for smaller size and lighter weight electric revolving machines becomes stronger. Particularly, for electric motors as prime mover of vehicles, it is becoming quite important task for making the motor smaller and lighter. One approach for achieving this task is to improve heat-resisting property of insulation of the coil of the motor.

As insulation material, inorganic material and organic material can be used. Inorganic material generally has higher heat-resisting ability. On other hand, organic material may provide better workability and function ability. In view of heat-resisting ability and workability, polyimide resin is often used for electrical equipments which require high heat-resisting ability.

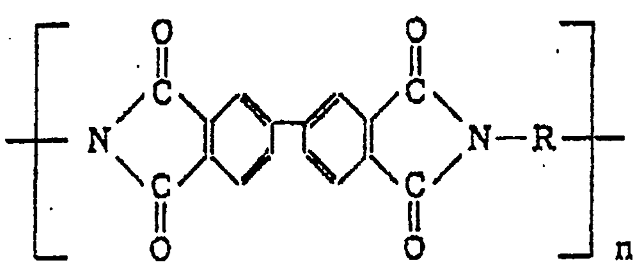
In general, for low voltage revolving-armature coil, coil conductor is wrapped with insulative film tape or insulative film sheet for element wire insulation and insulation to the earth. In order to improve heat radiation, mechanical strength and so forth, or in order to prevent local discharge, synthetic resin is impregnated in gaps in the insulative film tape or sheet. In case that particularly high heat-resisting ability is required, polyimide type film and polyimide type resin are used as insulating film and impregnating resin.

In order to use polyimide resin as the impregnating resin, it is preferred to have long pot life and low viscosity for obtaining better impregnation ability. Furthermore, for the insulating system, it is required to have good compatibility between the impregnating resin and element wire or between the impregnating resin and the film for insulation to the earth, and have sufficiently high heat-resisting ability. However, such insulating system has not been realized yet.

SUMMARY OF THE INVENTION

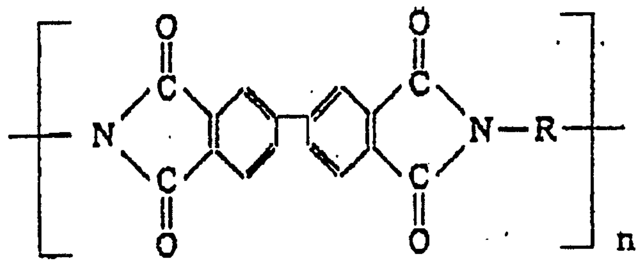
It is therefore an object of the present invention to provide an insulation for electric machines, such as an electric revolving-armature, which may provide satisfactorily high heat-resisting ability and workability.

In order to accomplish the above-mentioned and other objects, an insulation structure for revolving-armature coil, according to the present invention, principally uses a polyimide file tape or sheet as at least a part of element wire insulation and insulation to the earth. The tape or sheet is formed of a polyimide composition generally expressed by the following formula:



Synthetic resin compound polyimide resin and epoxy resin as principal material and an acid anhydride type hardening agent is impregnated and hardened.

According to one aspect of the invention, an insulation structure for an electric conductor comprises an insulation layer composed of a polyimide film layer formed by wrapping a polyimide film having chemical structure as expressed by the following formula on a conductive wire:

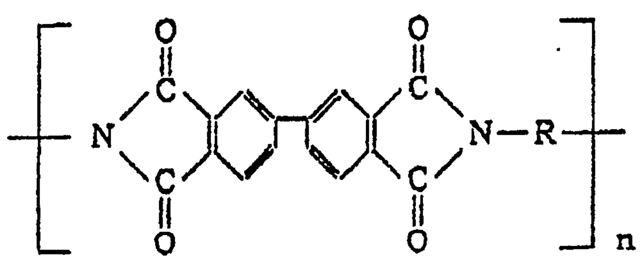


and an impregnating resin compound composed of polyimide resin and epoxy resin as primary component and acid anhydride type hardening agent and being impregnated to the polyimide layer and hardened.

The insulation structure may be applied for a revolving-armature coil.

According to another aspect of the invention, a process for forming insulation for an electric conductor comprises the steps of:

forming an insulation layer composed of a polyimide film layer formed by wrapping a polyimide film having chemical structure as expressed by the following formula on a conductive wire:



and impregnating a resin compound composed of polyimide resin and epoxy resin as primary component and acid anhydride type hardening agent to the polyimide layer and hardening the impregnated resin compound.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood more fully from the detailed description given herebelow and from the accompanying drawings of the preferred embodiment of the invention, which, however, should not be taken to limit the invention to the specific embodiment but are for explanation and understanding only.

In the drawings:

Fig. 1 is a plan view of a model coil used for performing experiments in implementation of insulating structure according to the present invention

Fig. 2 is a section taken along line II - II of Fig. 1

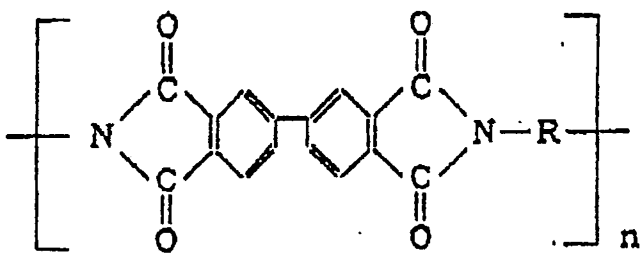
Fig. 3 is a graph showing variation characteristics of tan δ_0 of the coil versus temperature

Fig. 4 is a graph showing variation characteristics of tan δ_0 of resin plate versus temperature and

Fig. 5 is a graph showing thermal degradation-dielectric strength characteristics in the model coil of Fig. 1

DETAILED DESCRIPTION OF THE INVENTION

As set forth above, an insulation structure for a revolving-armature coil, according to the present invention, principally uses a polyimide file tape or sheet as at least a part of element wire insulation and insulation to the earth. The tape or sheet is formed of a polyimide composition generally expressed by the following formula:



.... (1)

Synthetic resin compound containing polyimide resin and epoxy resin as principal material and an acid anhydride type hardening agent is impregnated and hardened.

The inventors have found that the polyimide compound expressed by the formula (1) has good compatibility with the resin compound composing polyimide resin and epoxy resin as principal material and further composing acid anhydride type hardening agent. The resin compound has good impregnation ability in relation to the polyimide film. Utilizing the aforementioned materials, it has been found that, with the proposed combination, thermal degradation of the polyimide film is successfully prevented for remarkably enhancing heat-resisting ability of the insulation structure.

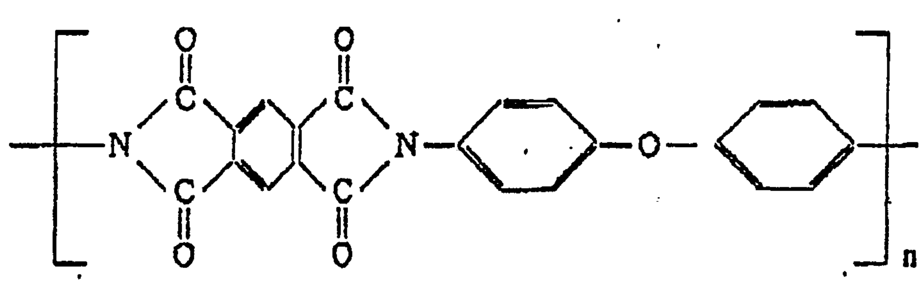
In order to perform experiments for demonstrating advantages of the present invention, a model coil, as shown in Figs. 1 and 2, was prepared. Flat type copper wire 1 (1.8 x 5.0 mm) with polyimide type enamel coating layer as an element wire insulating layer 2, was selected as an element wire 3. Three element wires 3 are arranged in parallel in side-by-side relationship to form a set. Two sets of three wires were piled as shown in Fig. 2 in order to form a coil conductor. The coil conductor was shaped into hexagonal shaped configuration as shown in Fig. 1. The length ℓ of the straight section is 200 mm.

For the coil conductor thus prepared was wrapped by a polyimide film in a manner of half lapping for three plies. The polyimide film was selected to have the chemical structure as expressed in the formula (1). In practice, in the shown model coil, polyimide film sold as UPILEX R (tradename) from Ube Kosan K.K.. Over the polyimide film wrapped on the coil conductor, glass tape of 0.13 mm thick was wrapped for one ply in order to form earth insulation layer 4.

For the straight portion of thus formed coil conductor, 180 mm length of iron model slot 4 was attached. The model slot 4 is so installed for the coil conductor for establishing tight contact with the mating surfaces of the coil conductor in order to form a coil assembly.

The coil assembly was then subject degasing process in a vacuum chamber at 100 °C for four hours. Thereafter, vacuum impregnation of resin compound. The resin compound was composed of a polyimide resin and an epoxy resin as principal material. Acid anhydride type hardening agent was added to the mixture of the polyimide resin and epoxy resin for formulating the impregnating resin compound. Resin impregnated assembly was then subject hardening treatment. The hardening treatment was initially performed in a drying furnace at 150 °C for sixteen hours for pre-cure and subsequently at 200 °C for twelve hours for after-cure.

In order to compare with the example prepared through the process set forth above, a comparative example of model coil was also prepared. In preparation of the comparative example, a polyimide film made of a material having chemical structure expressed below was selected.



· (2)

In the practical implementation, as the polyimide film, a KAPTON (tradename) available from DuPoint was used. The polyimide film used in the comparative example had equivalent heat-resisting ability to that used in the invention.

Variation characterisrics of tan δ_0 of the example and the comparative example versus temperature is shown in Fig. 3. In Fig. 3, there is additionally shown the variation characteristics of tan δ_0 of the example, for which earth insulation was provided without impregnation of resin compound, versus temperature. In Fig. 3, solid lines show the variation characteristics of tan δ_0 of example and comparative example, for which impregnation of polyimide resin compound was performed, and broken lines shows the variation characteristics of tan δ_0 of example and comparative example, for which impregnation of polyimide resin compound was not performed

As can be seen from Fig. 3, before impregnation of resin compound, both of the example and comparative example have low value of tan δ_0. Therefore, no substantial difference of tan δ_0 in the example and the comparative example could be observed. On the other hand, the comparative example for which polyimide resin compound impregnation and hardening was performed, shows substantial increase of tan δ_0. On the other hand, the example with polyimide resin compound impregnated insulating structure shows much smaller increase of tan δ_0.

Another experiments were performed for checking variation of tan δ_0 of an impregnation polyimide resin compound plate. For performing experiments, a plate of 2 mm thickness was prepared with the polyimide resin compound. The result is shown in Fig. 4. As can seen from Fig. 4, tan δ_0 at 200 °C was approximately 5%.

From these result, it can be confirmed that the polyimide film formed of the material expressed by the foregoing formula (1) has good compatibility to the polyimide resin compound containing polyimide resin and epoxy resin as principal component and acid anhydride type hardening agent for impregnating the latter.

For the model coil, thermal degradation test was performed for checking heat-resisting ability of the example and the comparative example. Test was performed by placing the model coils within a constant temperature bath, in which temperature was maintained constant at 270 °C. Fig. 5 shows lowering rate of dielectric strength after thermal degradation versus the initial dielectric strength. The dielectric strength was measured at the model slot section s and the coil end section e indicated in Fig. 1. As can be seen from Fig. 5, the dielectric strength of the comparative example was lowered in a short period. Form this, it can be confirmed that thermal degradation in the comparative example was substantial. Particularly,as can be seen from Fig. 5, the degradation at the stop section s in the comparative example, as represented by drop of the dielectric strength, was substantially great. In contrast to this, thermal degradation caused in the example is moderate. In the example, there cannot be observed any difference of dielectric strength at the slop section and the coil end section.

Further experments were performed for testing insulation performance of the insulation structure according to the present invention. In the example, a sample which is prepared by providing polyimide film insulation layer for element wire insulation on the copper wire as EXAMPLE 1. The polyimide film was UPILEX R from Ube Kosan K.K. and is expressed by the foregoing formula (1). For another sample as EXAMPLE 2, the polyimide film is used for insulation to the earth. In further example as EXAMPLE 3, the polyimide film is used both for element wire insulation and insulation to the earth. In order to compare these examples, a sample as comparative example was also prepared utilizing polyimide film having composition expressed by the foregoing equation (2), e.g. KAPTON from DuPonte, for element wire insulation and insulation to the earth.

Insulation treatment was performed in the following manner. For bear flat type copper wire of 1.8 mm x 5.0 mm, 0.05 mm thick and 12 mm width of polyimide film was wrapped for one ply with half lapping to form the element wire insulation. Two element wire insulated wires were arranged in side-by-side relationship to form a set. Four sets of wires are piled one another for forming the coil conductor. The coil conductor was shaped into hexagonal configuration with 200 mm length of straight portion. For thus constructed coil conductor, 0.05 mm thick and 19 mm width of polyimide film was wrapped for three plies in half lapped manner. Over the polyimide film layer, glass fiber fabric tape of 0.13 mm thick was wrapped for one ply in half lapping manner. An iron plate model slot of 180 mm length and 5 mm thick was attached for both sides of the coil so that the iron plate is tightly attached to the coil for forming coil assembly. Impregnation of resin compound containing polyimide resin and epoxy resin as principal component and acid anhydride type hardening agent, was then performed for the coil assembly. Then, hardening treatment was performed.

For EXAMPLEs 1 through 3 and the COMPARATIVE EXAMPLE, thermal degradation test was performed. In the test, the EXAMPLESs 1 through 3 and the COMPARATIVE EXAMPLE are heated in the constant temperature bath at 285 °C for twelve days. After expiring the testing period, the dielectric strength was measured. The result of measurement is shown in the appended table. In the table, the dielectric strength is shown as a ratio (%) versus the initial dielectric strength before performing testing.

As can be seen from the appended table, the EXAMPLEs 1 through 3 had much higher resistance against thermal degradation. Namely, the average dielectric strength of respective EXAMPLEs 1 through 3 are higher than 60% of the initial value. This value is much higher than that of the COMPARATIVE EXAMPLE. From this, the insulation structure according to the present invention can provide good and high heat-resisting ability.

As will be appreciated, the present invention can fulfills all of the objects and advantages sought therefor.

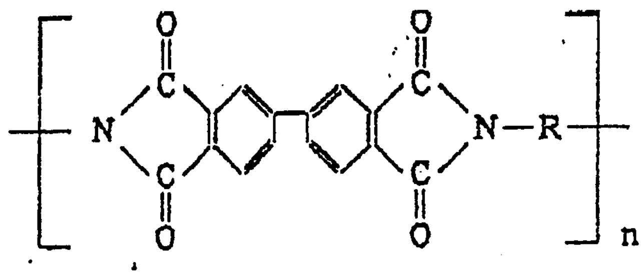
While the present invention has been disclosed in terms of the preferred embodiment in order to facilitate better understanding of the invention, it should be appreciated that the invention can be embodied in various ways without departing from the principle of the invention. Therefore, the invention should be understood to include all possible embodiments and modifications to the shown embodiments which can be embodied without departing from the principle of the invention set out in the appended claims.

TABLE

Kind		Element Wire Insulation Dielectric Strength (%)	Earth Insulation Dielectric Strength (%)
Example 1	1	57.5	8.0
	2	63.0	7.2
	3	61.0	6.0
	x	60.5	7.1
Example 2	1	8.2	65.3
	2	5.0	62.1
	3	7.3	58.0
	x	6.1	61.8
Example 3	1	58.0	62.0
	2	63.0	58.5
	3	62.5	68.3
	x	61.2	62.9
Comparative	1	7.5	5.3
	2	10.2	6.0
	3	6.3	6.0
	x	8.0	5.7

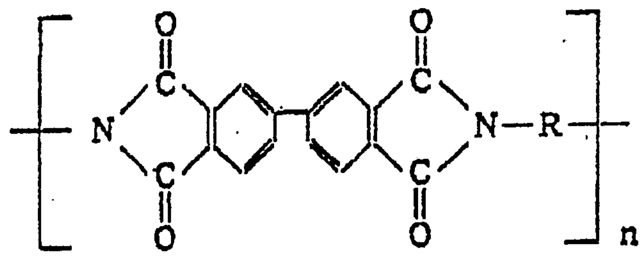
Claims

1. An insulation structure for an electric conductor comprising an insulation layer composed of a polyimide film layer formed by wrapping a polyimide film having chemical structure as expressed by the following formula on a conductive wire.



and an impregnating resin compound composed of polyimide resin and epoxy resin as primary component and acid anhydride type hardening agent and being impregnated to the polyimide layer and hardened.

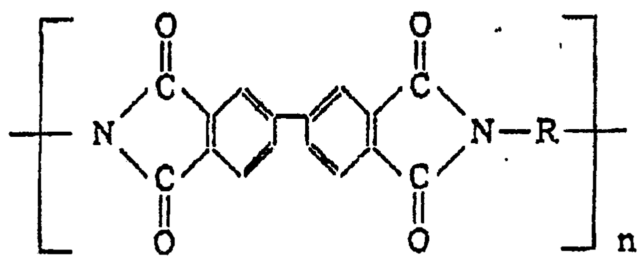
2. An insulation structure for a revolving-armature coil comprising an insulation layer composed of a polyimide film layer formed by wrapping a polyimide film having chemical structure as expressed by the following formula on a conductive wire:



and an impregnating resin compound composed of polyimide resin and epoxy resin as primary component and acid anhydride type hardening agent and being impregnated to the polyimide layer and hardened.

3. A process for forming insulation for an electric conductor comprising the steps of:

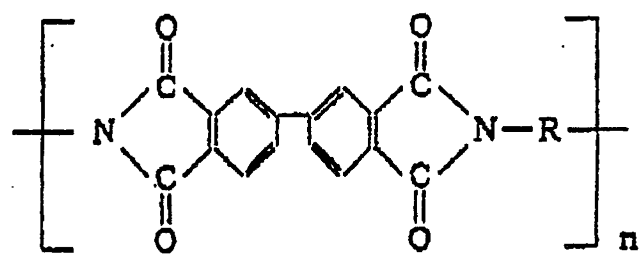
forming an insulation layer composed of a polyimide film layer formed by wrapping a polyimide film having chemical structure as expressed by the following formula on a conductive wire:



and impregnating a resin compound composed of polyimide resin and epoxy resin as primary component and acid anhydride type hardening agent to the polyimide layer and hardening the impregnated resin compound.

4. A process for forming an insulation for a revolving-armature coil comprising the steps of:

forming an insulation layer composed of a polyimide film layer formed by wrapping a polyimide film having chemical structure as expressed by the following formula on a conductive wire:



and impregnating a resin compound composed of polyimide resin and epoxy resin as primary component and acid anhydride type hardening agent to the polyimide layer and hardening the impregnated resin compound.

FIG.1

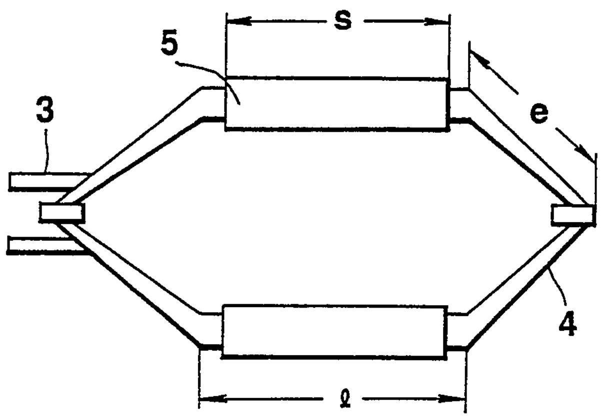
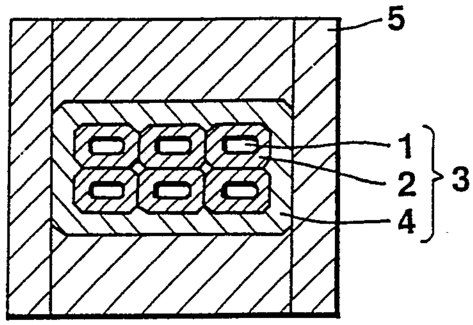


FIG.2



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Nouvellement déposé

FIG. 3

tanδ0-TEMPERATURE CHARACTERISTICS

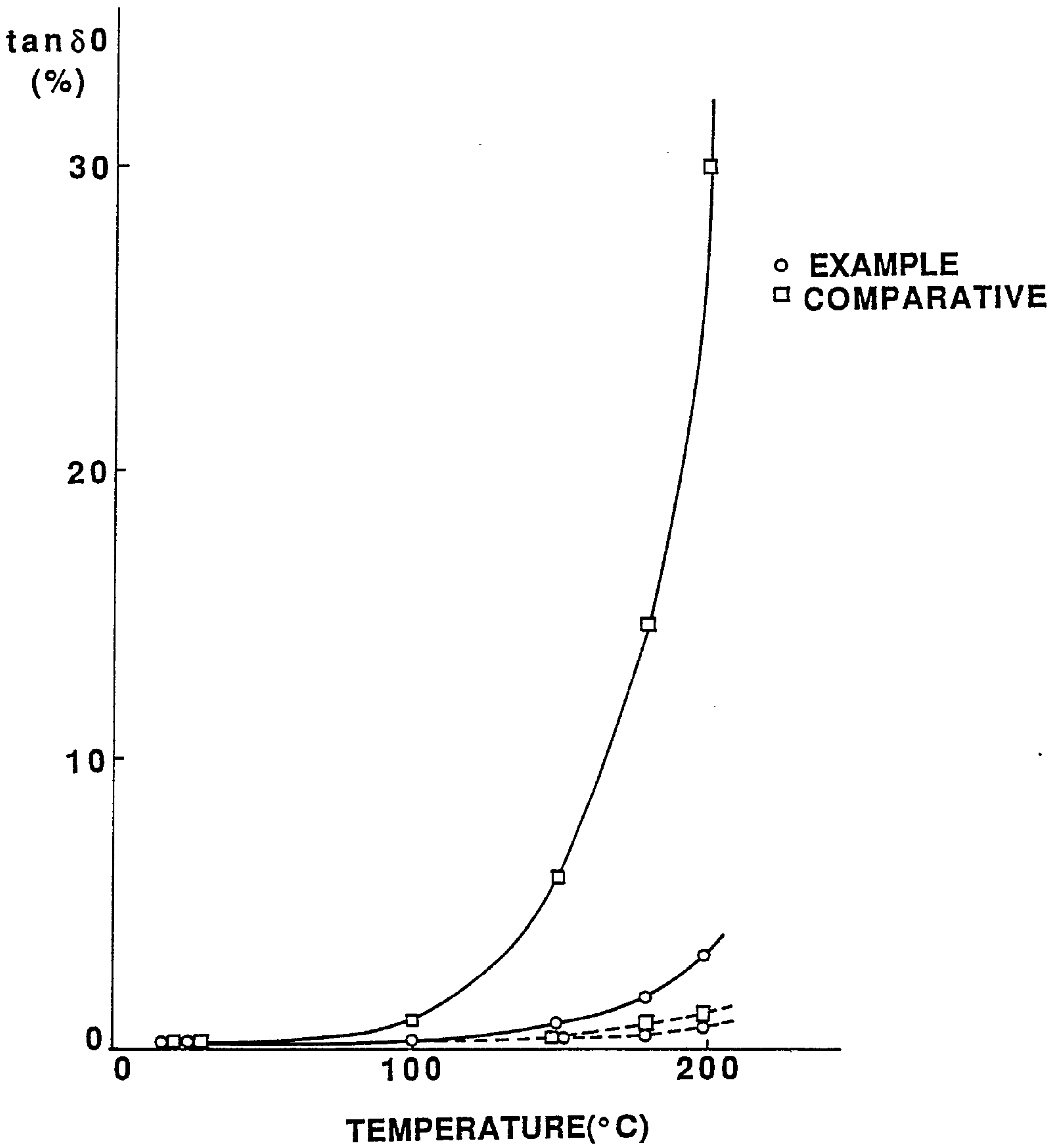
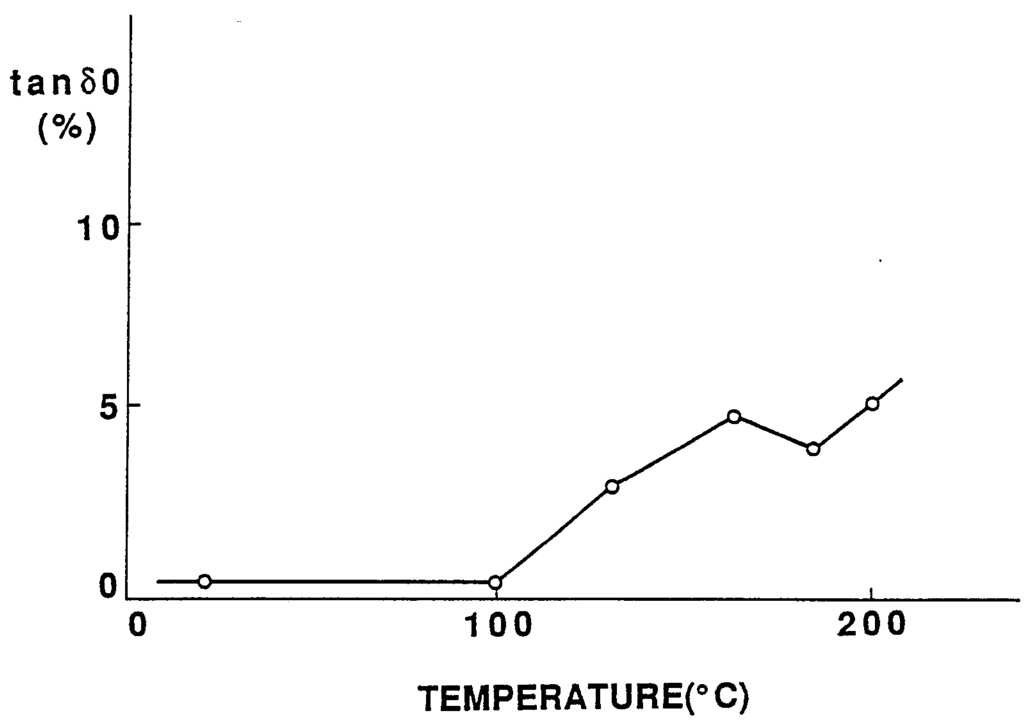


FIG.4

tanδ0-TEMPERATURE CHARACTERISTICS



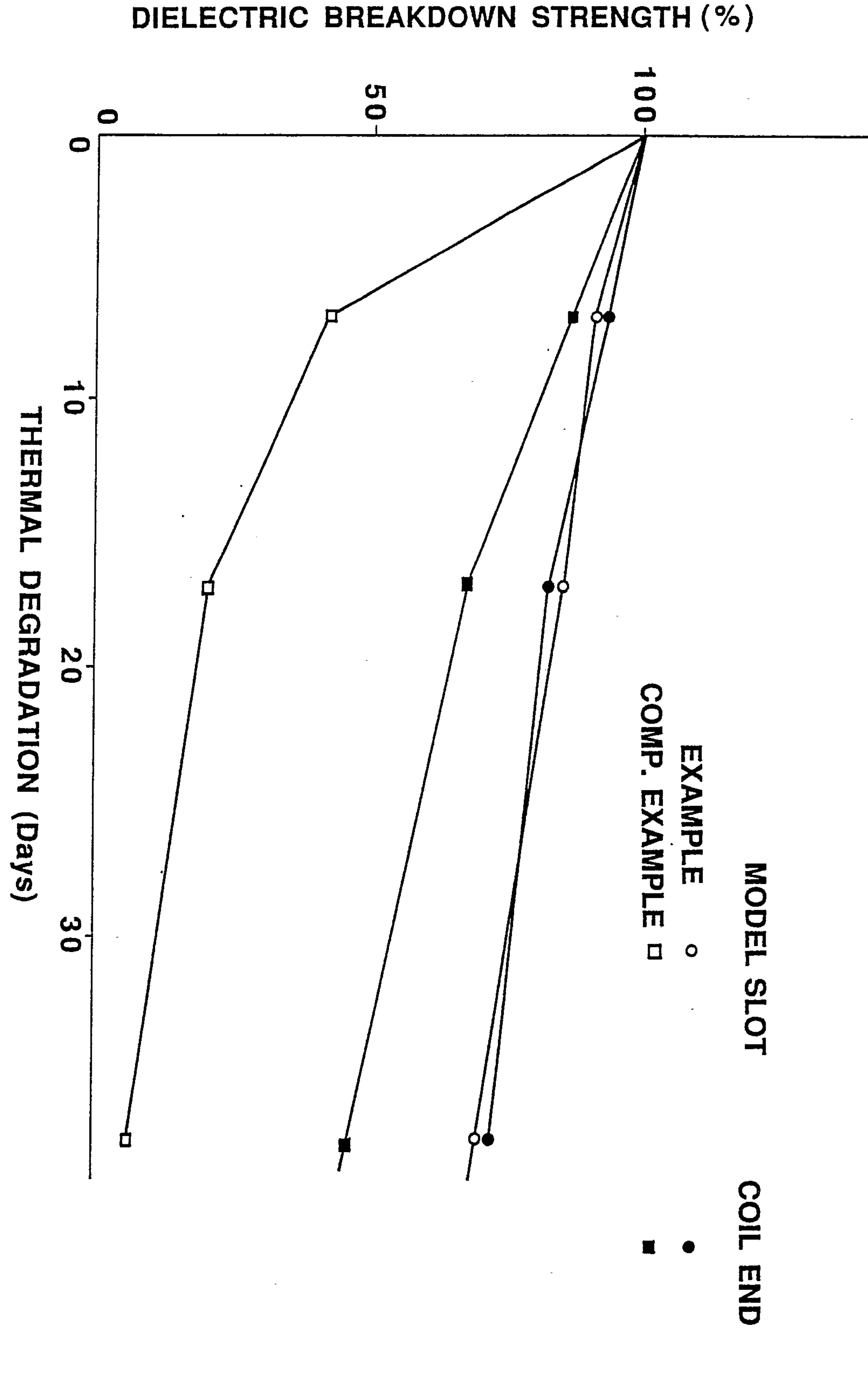

DIELECTRIC BREAKDOWN STRENGTH (%)
100
50
0
0
10
20
30
THERMAL DEGRADATION (Days)
MODEL SLOT
COIL END
EXAMPLE
COMP. EXAMPLE

FIG. 5