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On the estimation of new life model of transformer insulation material under combined electrical and thermal stress

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ABSTRACT

Title of Thesis: On The Estimation of New Life Model of Transformer Insulation Material Under Combined Electrical and Thermal Stress

Chiming Lin, Master of Science in Electrical Engineering, 1991

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Results of combined electrical and thermal aging and only thermal aging studies conducted on a ‘fish’ paper insulation material are presented in this thesis.

The model for aging has been proposed which is essentially the Arrhenius equation with a weighted factor $\{\exp -Ç\xi/kT\}$ to describe the enhanced reaction rate process under combined thermal and electrical stress. A procedure has been described for evaluation of parameters of this new model.

It is seen that life estimates obtained with this model are close enough to the experimental results.

In addition, reliability data were also generated on the same material using electrical noise. It is seen that there is a high correlation between the electrical noise (measured at room conditions) and the material catastrophic failure when subjected to combined thermal and electrical stress. In another experiment we found that the noise increase is more when material is subjected to thermal/electrical stress rather than only thermal stress. This part of experimental result suggests that electrical noise can be used as a possible sensor for impending equipment shut downs or maintenance schedules.

ON THE ESTIMATION OF NEW LIFE MODEL OF TRANSFORMER INSULATION MATERIAL UNDER COMBINED ELECTRICAL AND THERMAL STRESS

BY

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CHAPTER 1

INTRODUCTION

Improving and estimating the life and reliability of the dielectric materials has drawn the attention of researchers in the recent years. A combination of thermal, electrical, and mechanical stresses is known to have a more deterious effect than those stresses cause individually.

Accelerated life testing of products and materials is used to get such information quickly. Accelerated testing is achieved by subjecting a sufficient number of test specimens to conditions that are more severe than the normal operating conditions.

The Arrhenius equation is commonly used to extrapolate life data obtained from units tested at different constant elevated temperatures to obtained an estimate of life distribution, using some statistical methods, at normal temperatures. It is believed that activation energy is necessary to initiate a reaction, such as oxidation which is formed proportional to the term exp $(-E/kT)$.

But it is seen that material degradation is much faster when subjected to combine thermal and electrical stress and Arrhenius equation does not fit here. Hatch and Endicott have 'first' treated the combined stress degradation of insulation as an Eyring model. But the absence of specific methods for determing the constants makes the Eyring equation difficult to apply to the life estimation. Ramu has suggested a model for aging which is essentially a power low but parameters of which were treated as temperature dependent. He suggested a large number of experiments involving purely electrical, purely thermal and combined stress aging tests for evaluation of parameters values.

In order to include the effects of both thermal and electrical stresses acting together that we suggest Arrhenius equation should be weighted by a factor exp $(-\c{C}\xi/kT)$ to describe the enhanced reaction rate process. The failure data were acquired through single and combined stress accelerated aging tests on a 'fish' paper insulation material.

Object of Thesis:

1. To evaluate the parameters of proposed life model for a paper insulation material subjected to combine thermal and electrical stress.
2. To verify life estimates obtained with this model to the experimental results.
3. To find whether there is a correlation between the electrical noise (measured at room conditions) and the material catastrophic

failure.

4. To obtain a pattern of noise increase with time when material is subjected to combine thermal electrical stress and thermal stress only.

Plan of Thesis:

Chapter two covers some basic dielectric properties along with the breakdown mechanisms of solid dielectrics.

Chapter three describes for obtaining the constants of a proposed life estimation model.

Chapter four presents the experimental set-up in detail.

Chapter five addresses experiment results and discusses the proposed model

Chapter six gives the conclusion of the proposed model.

CHAPTER 2

SOLID DIELECTRICS

2-1 INTRODUCTION

Insulating materials are considered to be virtually nonconductors of electricity. In practice a material is considered an insulation if it is of such low conductivity that the flow of current through it is small enough to be ignored. The amount of current that can be tolerated depends on the nature of the application and helps determine which material is suitable as an insulator for that application.

The mechanical and physical of insulation material are often as important as the electrical properties. Sometimes certain properties which are desirable from the electrical point of view turn out to be undesirable from the physical point of view. This is because in addition to insulating electrical circuits, the material usually must provide mechanical support for the conducting elements, or perform other physical functions in the structure.

The properties of dielectric materials fall into the following categories:

1.) Physical

2.) Electrical

3.) Mechanical

4.) Chemical

2-2 PHYSICAL PROPERTIES

2-2-1 MOISTURE ABSORPTION

This usually causes serious depreciation of electrical properties, particularly in oil and fibrous materials. Swelling, wraping corrosion and other effects often result. Under severe conditions of humidity in tropical climates, moisture causes serious deterioration.

It is usual to determine the absorbency of solid dielectrics by ascertaining the weight of water absorbed by a standared specimen when immersed for a specific period. However, the quantity of water absorbed is not a reliable criterion of the electrical performance of a material if taken in isolation.

2-2-2 THERMAL EFFECTS

The thermal characteristics of a dielectric material are often one of the key factors that influence its choice and application as an insulation material. Among the important thermal characteristics of such materials are the following: ignitability, flammability, ability to self-extinguish, liability to carbonize or track, specific heat, coefficient of expansion and thermal resistivity or conductivity.

The operating temperatures of the inorganic insulants such as, porcelains and glasses are limited by softening, or by measurable and reversible changes of conduction like dielectric loss or dielectric strength, or by the risk of fracture due to differential thermal stresses occassioned by uneven heating, changes of section or constraint by other materials.

Typical symptoms at sustained high temperatures include shrinkage, hardening, spontaneous cracking or crazing, loss of strength, embrittlement, discoloration, distortion and, in extreme cases, charging. These symptoms are generally due to, or accompanied by loss of weight resulting from component evaporation and oxidation or pyrolysis forming volatile substances such as CO, CO_2, water and organic compounds of small molecular weight. Other symptoms was include the continuation of the cross-linking process, condensation reations between the products of oxidation or other complex reactions affecting the elastic modulus and causing hardening and embrittlement of the material.

2-3 ELECTRIC PROPERTIES

Electrical properties include dielectric strength, permittivity and loss tangent.

2-3-1 DIELECTRIC STRENGTH

Dielectric strength is the property of an insulating material which enable it to withstand electric stress without failure. It is usually expressed in term of the minimum electric stress that will cause failure or breakdown of the dielectric under specified conditions, shape of electrode, temperature, and method of application of voltage. The electric stength of most material falls with rise in temperature and it is therefore important to carry out test for this property at suitable elevated temperatures.

Other parameters that influenced the breakdown of solid insulation are: sample thickness, heat conductivity, absorption of moisture, surface contamination, physical damage caused by mishandling, vibrations or shock, manufacturing defects and the previous history of the material. The dielectric strength of a solid insulating material is the breakdown voltage divided by the sample thickness, expressed in volt per mil.

2-3-2 PERMITTIVITY

This property is specific to a material under given conditions of temperature, frequency, moisture contents, etc. When two or more dielectrics are in series and an electrical stress is applied across them, the voltage gradient across each individual dielectric is inversely propotional to its permittivity. This is particularly important when air space(voids) exist in solid dielectrics, as the permittivity of these are always higher than that of air, hence the air is liable to have the higher stress and may fail and cause spark-over through the air in consequence.

2-3-3 DIELECTRIC LOSS

A capacitor with a perfect dielectric material between its electrodes and with a sinusoidal alternative voltage applied takes a pure capacitive current I = WCV with a leading phase angle of 90^0. In practice, conduction and hysteresis effects are present, the phase-angle is less than 90^0 by small angle δ. As a result the power factor is no longer zero and it can be estimated as $\cos(90-\delta)=\sin\delta$ which can be approximated to $\tan\delta$, the latter is called Loss Tangent. The power loss is, to close approximation, $P = V^2\omega C \tan\delta$ where $\omega = \pi f$ From this it is obvious that the power loss is proportional to frequency variations.

It is been observed by various workers that the loss tangent increases considerably with rises in temperature and humidity. Since at the same time the permittivity of the material also rises, the total dielectric loss increases considerably. This can accelerated the electrical breakdown of a thick insulation material under A.C. stress, as the losses cause an interanl temperature rise.

2-4 TYPES OF BREAKDOWN

2-4-1 ELECTRICAL BREAKDOWN

This type of breakdown is known as purely electrical breakdown because secondary processes do not occur. It is the destruction of a dielectric by the forces of an electric field. An electrical breakdown results as a 'result of interaction of free charged particles, accelerated by an electric field, with the particles of a dielectric. This phenomenor occurs because of inelastic displacement of bound charges in a dielectric under the action of an external electric field.

The insulation resistance decreases as the applied electric field increases. This due to the fact that loosely bound charges, which do not migrate at low fields, are liberated by higher fields and thus contribute to the increased conductivity. The conductivity increases with the applied field, while at the same time the bonds between the remaining dielectric particles are ruptured, until ultimately dielectric breakdown occurs. The breakdown occurs at different level of electric field, depending on the bonding strength of the molecules of the material under test. It is characterized by puncture of the material after the maximum field has been applied.

2-4-2 ELECTROTHERMAL BREAKDOWN

When voltage is applied to a dielectric it generates heat, the temperature of the dielectric rises and the losses become greater This process is intensified until the dielectric is heated so much that it gets damaged, and as a result the breakdown of the dielectric occurs at a very low a voltage at which it would never develop at a low temperature and an undamage material.

When the electric field is strong enough for heat to be generated faster than it can be disspated, the temperature will rise and breakdown may take place due to thermal run-away or thermal breakdown. Thus, breakdown can be caused by an electron avalanche when irreversible chemical changes due to temperature rise have taken place and the breakdown strength of the material has been lowered sufficiently. Because the electrothermal breakdown is usually a very slow process additional failure mechanisms come into play after a certain time. As result one can not be sure at which point the electrothermal breakdown mechansism became an electrochemical one.

Hence a given dielectric material can not be described by one definite mechanism of breakdown. If the conditions of the experiment are changed one kind of breakdown may be observed to pass into the other. There are many factors which could lead to this situation namely changs in temperature, voltage, frequency cooling conditions, etc.

2-4-3 ELECTROCHEMICAL BREAKDOWN

This section will mainly concern itself not with breakdown mechanism but wtih processes which ultimately lead to dielectric failur. The actual breakdown is usually due to thermal instability although internal discharges many also precipitate failure. Intrinsic breakdown is possible but for the reasons in progressive loss of insulating properties is more possible, such as when a dielectric slowly becomes a semi-conductor or even a poor conductor. Often the final breakdown is mechanical. Electrochemical deterioration is one aspect of the problem of chemical stability. It has so far been tacitly assumed that dielectrics are chemically definable and permanent, but it is legitimate to include the particular forms of chemical instability to be decribed, since by not very obvious actions they so often produce gross effects on insulating properties.

When chemical changes take place in an insulating material due to moisture, high AC/DC electric field and other polutants, chemical deterioration occurs causing the dielectric to fail earlier. This is an electrochemical type of breakdown. It is accpted as axiomatic that the breakdown strength of a solid dielectric is decreased by the presence of impurities. Impurities in the dielectric will permit concentration of leakage current giving rise to a local high temperature condition that can degrade the insulation. Leakage current caused by impurities in the vicinity of the electrodes can cause an electrolytic deterioration of the electrodes, forming chemical products that further deteriorate the insulaation. Surface impurities like salt, alkalis, etc, along with moisture can simplify the process of carbonization, permitting heavy conduction currents and associated voltage surface tracking. Most impurities and absorbed moisture will have a lower breakdown strength than the solid insulation, and their breakdown increases the voltage stress at the adjacent insulation. Hence in strigent applications it is sometimes desirable to treat the surface with a water-repellent dielectric, such as a silicone, or to arrange to dissipate any frictional electrostatic changes on the material to prevent the deposition of dust, or to fabricate the component containing the dielectric in a dry and dust free atmosphere.

2-4-4 IONIZATION INDUCED BREAKDOWN

Ionization breakdown arises from ionizing processes caused by partial discharges in a dielectric. It occurs most frequently in dielectrics with air voids. At high fields, the ionization of air voids is attended by the formation of ozone, fast ions and evolution of heat. All these factors gradually impair the insulation and reduce its breakdown voltage.

Since the breakdown strength for a gas is considerably less than for a solid insulating material, discharges can occur across gas voids at voltage considerably below the breakdown strength of the above. These discharges, either on the surface of the dielectric or internally in any cavities or regions of higher conductivity can lead to premature breakdown. The discharge mechanism works as follow: a discharge across a void, which act as a small capacitor, causes an equal charge to appear on both sides of void, the voltage drop across the void itself is lowed and the discharge may stop.

2-5 DEGRADATION UNDER THERMAL AND ELECTRICAL STRESS

In the early days empirical models for predicting the life of insulation under thermal and electrical stress when they are acting individually were proposed by Dakin and Peck respectively. Despite the physical intuition that these models were based on, they became an empirical guide being applied, even to this day, by power engineers in order to estimate the insulation life. Ramu [25, 52] after taking into consideration the above states that, while the degradation due to thermal aging is treated as a reaction rate process, the electrical degradation is expressed as a power law and from this as result he proposes a hybrid formula containing both laws. Boulter [94] states that short term or immediate changes in physical and electrical properties must be recognized. He also asserts that the voltage effects are more important in high voltage machines. The cause of insulation failure during aging when the temperature and voltage are high under combined electrical and thermal stresses is proposed to be due to the sustained higher thermal state of the system brought about by external heating and the heat generated by increasing intensity of partial discharges [24]. This results in erosion of the material. As the erosion progresses, the intensity of discharges further increases. It has been recognized that the synergistic effects of thermal and electrical stresses degrades the insulation faster than had the stresses been acting individually.

Thermal aging mechanism is complex and varies with material composition and service conditions. Some of the the typical mechanisms of degradation include loss of volatile constituents, oxidation which may result in embrittlement, hydrolytic cleavage by reaction with moisture under the influence of heat and other factors leading to molecular breakdown, chemical breakdown of constituents with formation of degradation products typified by the liberation of hydrochloric acid which to further decomposition.

Recommended procedures for the evaluation of insulating materials can be found in ASTM Standards, part 29 D-149, IEEE standars 98-1972 and 99-1970 and from Military Standar, test methods for Electronic and Electronic Component Parts, MIl-STD-202. In these standars information is given for selecting and preparing suitable speciments for the intended tests and their submission to various stress. Experimental procedures, equipment ranges and specifications, enviromental conditions, failure criteria and references to statistical analysis of data is included. For example the analysis of complete data, when all test are run to failure, is presented in IEEE Publication 101. The above standars can be used as an aid in selecting insulating materials for use in electrical equipment in a varity of conditions but do not address directly the complex dielectric breakdown mechanisms.

It was important to distinguish between thermal breakdown occuring due to a combination of stresses. It is a well documemted fact that elevated temperatures can cause a number of deteriorating effects over a period of time on solid insulating material and that all thermal ageing data was universally treated as a Arrhenious relationship. It was noted that electrical stresses can cause changes in the properties of a dielectric material.

2-6 ELECTRICAL NOISE AND RELIABILITY

Corona may also take place in internal voids in insulation due to the ionization of the gas in the void but engineers describe it mostly as a luminous discharge caused by the ionization of the air in close proximity with a conductor. The level of ionization created by corona can be measured in term of noise voltage, in microvolt or db. Thus the level of noise voltage can be used in determining the size of voids or the level of impurities in the material. It is a useful tool in giving a realistic evaluation of the quality of the material, with indications of the permissible manufacturing tolerances, or the rate of deterioration of the insulation.

A certain amount of noise exits in all dielectrics. Never the less dielectric materials producing high amount of noise are prone to a much higher failure rate at an earily time frame than those exhibiting lower noise levels. From the above it is evident that noise can be used to form a screening process in order to evaluate the reliability of a dielectric material.

The amount of noise generated depends, among other things upon: Applied electrical stress, Condition of insulation, Area under study and Ambient atmospheric conditions like humidity, temperature etc.

CHAPTER 3

DESCRIPTION FOR OBTAINING THE CONSTANTS OF A PROPOSED LIFE ESTIMATION MODEL

3-1 INTRODUCTION

The Arrhenius model is commonly used to extrapolate life data obtained from units tested at different constant elevated temperatures to obtain an estimate of the life distribution at normal temperatures. There is no unique model available for units subjected to simulataneous electric and thermal stresses at the same time. In our one of laboratory investigations on a paper insulation material, we noticed that the same percent fall in dc resistance has occured much early compared to the case where material was subjected to thermal stress only (Refer to Figs.3 & 8)

The Arrhenius model is described as under

$$\tau' = k' \, e^{(E/kT)} \qquad \text{------(3-1)}$$

where

τ': Time to reach a fixed value of the original material dc resistance. The material is subjected to only thermal stress.

E : Activation energy, ev

T : Temperature, ^{0}K

k : Boltzman constant, ev/^{0}K

k' : A constant

Based upon our experimental findings as shown in Fig. 13, we are proposing a modification to the above Arrhenius model as under

$$\tau'' = \mathbf{k'}\ \mathbf{e}^{E/kT} \cdot \mathbf{e}^{-Ç\xi/kT}$$

or $$\tau'' = \mathbf{k'}\ \mathbf{e}^{(E-Ç\xi)/kT} \qquad \text{------(3-2)}$$

τ'': Time to reach the same fixed value of the original material dc resistance. But here material is subjected to combined electric/thermal stresses.

Ç : A constant having unit of coulomb-m

ξ : Applied electrical field stress in v/m

If the 'fixed' value was considered as 10%, the τ' and τ'' were found as 200 hrs. and 96 hrs. respectively (Refer to Fig. 13). Since τ'' is much less than τ', we propose a modification [$\mathbf{e}^{-Ç\xi/kT}$] in equation (3-1).

3-2 EVALUATION OF CONSTANT E

Taking **ln** of equation (3-2), we get

$$\ln \tau'' = \ln k' + E/kT - \varsigma\xi/kT \qquad \text{------(3-3)}$$

If applied electric stress, ξ is zero, then equation (3-3) becomes

$$\ln \tau'' = \ln k' + E/k(1/T) \qquad \text{------(3-4)}$$

Equation (3-4) is a straight line if plotted as **ln** τ'' on y-axis and (1/T) on the x-axis. The intercept value will, then, be equal to **ln k'** and slop of the line is (E/k). Refer to Fig.1. Select the two different temperatures as T_1 and T_2. The τ_1' and τ_2' are corresponding time for material resistance decay to the same level. From the graph, slop is

$$\text{Slope} = (\ln\tau_2' - \ln\tau_1')/(1/T_2 - 1/T_1)$$

But slope is also equal to (E/k). Equating we get

$$E/k = (\ln \tau_2' - \ln \tau_1')/(1/T_2 - 1/T_1)$$

from which the constant E can be found i.e.

$$E = k(\ln \tau_2' - \ln \tau_1')/(1/T_2 - 1/T_1) \qquad \text{-------(3-5)}$$

3-3 EVALUATION OF CONSTANT K'

substituing the value of E from equation (3-5) into (3-4) and upon simplification, we get

$$\ln k' = \ln \tau'' - (1/kT)\ [(\ln \tau_2' - \ln \tau_1')/(1/T_1 - 1/T_2)]$$

$$k' = e^{[\ln\tau'' - (1/kT)\{(\ln\tau_2' - \ln\tau_1')/(1/T_1 - 1/T_2)\}} \quad \text{------}(3\text{-}6)$$

where T is any test temperature and τ'' is the corresponding time for material resistance to decay to the same level.

3-4 EVALUATION OF CONSTANT (Ç)

Substituing the value of constants E and **k'**, as previously determined in equations (3-5) and (3-6), into the equation (3-3) and upon simplification, we get

$$(Ç\xi/kT) = [\ln k' + (E/kT) - \ln \tau'')$$

or

$$Ç = (kT/\xi)[\ln k' + (E/kT) - \ln \tau'') \quad \text{------}(3\text{-}7)$$

where T and ξ be any test temperautre and electrical stress and τ'' be the corresponding time for material resistance to decay the same value.

3-5 DESIGN OF EXPERIMENT FOR OBTAINING CONSTANTS E AND K'

Measure the dc resistance for group of samples at room conditions. Then subject these samples to one elevated temperature simultaneously in the same enviromental chamber. Measure the resistance at each preset time intervals. Plot a graph between percent change in resistance against time at that temperature. Repeat the experiment at least five different temperatures.

Next define the failure model of material. The material is considered failed when its resistance has reached to a value 10% of its original data. Let us assume at temperature T, τ is the corresponding time for material to reach to the above condition. Select different temperatures and for each temperature determine experimentally the value of this 'τ'.

Next plot **ln** τ against 1/T as shown in Fig.4. Select six different temperatures for a better results.This graph can be used later for estimation of constants E and **k'**.

3-6 DESIGN OF EXPERIMENT FOR OBTAINING CONSTANT Ç

Measure the dc resistance for group of samples at room conditions. Then subject them to elevated combined electrical and thermal stresses at the same time and in the same enviromental chamber. Measure the resistance at regular interval of time. Prepare a chart for percent change in the resistance with time at given applied electrical and thermal stresses. Repeat the work at least at one more electric/thermal stress conditions. From these data and previously known values of E and **k'**, we can estimate the constant Ç.

CHAPTER 4

EXPERIMENTAL SET-UP

4-1 DC RESISTANCE MEASUREMENT

An ASTMD149 test fixture holding an insulation specimen (electrode area 10.2 sqcm) was connected in series with a regulated dc high potential source (Northeast Sc. Corp. model RE-500z), a 100 gigaohm resistance, a 5mA fuse and a picoammeter(Keithley model 485) as shown in Fig.2. The size of each specimen was 2.5 x 2.5 inches.

In this part of the experiment the dielectric was subjected to a direct-current test so the insulation resistance could be measured. The following facts should be noted. The final test voltage was reached in three discrete steps(500Vdc per step).It was considered normal procedure to wait for the leakage current to stabilize at each step. As long as the leakage current at the first two steps stabilized after a few seconds, the insulation was considered good and the test was continued. When the final test voltage was reached, the high voltage was left on and the leakage current was noted after four minutes had elapsed. It was decided to take all leakage current readings after a four minute period for the majority of the samples because the absolute value is not critical. In order to control factors like temperature and humidity the experiments were carried out in an area of the laboratory that previously was part of a clean room. The humidity was controlled with a dehumidifier and the room temperature was varying within acceptable limits.

The polarization index was checked for every three samples. Polarization index is the ratio of insulation resistance at a given test voltage(1.5KVdc)after a ten minute stabilization time to the value of insulation resistance at the end of one minute. Samples that had a polarization index less than two were not considered forthe thermal aging test. According to a number of researchers on the insulation field, value as high as ten are commonly reached in insulation test to be used for motors and generatros. If the polarization index is low (less than two) excessive moisture or contanmination is usually to blame.

The insulation resistance test, excluding the polarization index, was performed every time the samples were removed from the enviromental chamber where they were exposed to thermal aging.

4-2 SET-UP FOR THERMAL AGING

Six temperatures were selected in order to study the effect of thermal aging on insulation resistance. Each group contains 25 samples. The temperatures selected were 100^{0}C, 90^{0}C, 80^{0}C, 70^{0}C, 60^{0}C

& 50^{o}C. One has to appreciate the fact that over 250 samples were destroyed until the proper testing and measuring techniques were implemented. It was determined experimentally that the more consisted measurements were achieved after the vulcanized fibre had been removed from the eviromental chamber and remained exposed to room condition for 8 hours. After that period had ellaped the specimens were tested for insulation resistance. It was determined when the collected data was analyzed that a more frequent monitoring of the leakage current is required at least during the first 240 hours of the thermal aging test. Assigning a sufficients number of samples with a known zero hour resistivity to this task will provide a higher resolution data for the constants appearing in the proposal life model.

The procedural steps followed in the thermal aging test were the following. The samples were tested for insulation resistance, marked and numbered then they were placed into the preheated enviromental chamber. The data appearing in the appendix covers a period from zero hour to 496 hour. When the samples were put into the environmental chamber care was taken to prevent them from being exposed to uneven temperature or to overlap each other; this was necessary to avoid possible diffusion of moisture or other volatile chemicals from one sample to another.

4-3 SET-UP FOR VARYING ELECTRIC STRESS AND CONSTANT THERMAL STRESS AGING

This experiment was performed using Blue-M enviromental chamber. The purpose of this experiment was to measure the dc resistance variation of dielectric material under a constant temperature and voltage at different interval of time. The temperature stress(80C) but four different electric stresses were applied one to another. The electric stresses selected were 900v, 800v, 700v and 600v. Number of samples in each group were 30. The dc resistance was measured at end of each interval following a procedure described in Section 4-1.

4-4 EXPERIMENTAL SET-UP FOR NOISE MEASUREMENT

It is evident that under the application of high voltage dielectrics generate some amount of electrical noise. This noise could be at the surface or within the volume of the dielectrics. Befor noise measurement, the equipment will be set up for measurement. There are two different experiments in this work. The first part involved the measurement of electrical noise of a solid dielectric material,vulcanized fiber,and the classification of specimen into one of three noise groups (low noise0-2.8 microvolt, medium noise 2.8^{+}-5 microvolt, high noise 5^{+}microvolt).In the second part of the exeperiment an equal number of samples of each noise category were put under accelerated life testing conditions involving a synergy of thermal, electrical and mechanical stress.

In order to achieve accurate noise reading,and avoid interference of background noise, a shielded room with an attenuation of 100db was used. The shield room was made by Shielded Ace(model MR 6E6-GA-1),with some modifications. The salient features was the special grounding employed and the filtering of the power supply. The grounding consisted of:three copper clad grounding rods, with a diameter of one inch and length of ten feet driven under the foundation of a new building under construction at the time. The rods were seperated from each other by a distance of thirty feet forming an equilateral triangle. The three rods were interconnected with heavy wire and the common connection was brought in the building with a shielded wire of the 50 OHMS type. Both the shielding and the center core were connected together at this point to the ground but the shielded room itself was connected only to the center wire. This was done in order to minimize any RF noise picked up by the outer shielding. A corona free high voltage supply was obtained from a Hipotronics A.C. dielectric/breakdown test set(model 750-2/D149).

The supply was connected with an ASTM D149, sheet and plat material, test fixture. The test fixture was modified in the Lab. by adding an antenna of 100 turns arround the plexiglass holding the electrodes. Then the test fixture was directly coupled with a

Singer EMI meter(modle NM-17/27). The EMI meter could provide the intesity of the noise level either in db or microvolt simultaneously.

The purpose of the above set up is to enable to, make noise measurements which are not influenced by erratic RF pickups, measure the noise of each specimen and according to its noise level to assign it in one of the noise groups mentioned earlier.

The procedure followed during noise measurements was the following. A three by three inch specimen of vulcanized fiber was placed between the test fixtures electrodes. In order to eliminated surface noise due to air gaps and to measure volume noise two circular pieces of conducting silicon rubber were glued on the electrodes. The final test voltage was 1500Vac and it was raised in five discrete steps of 300 Volts second each. The bandwith of the EMI meter was set at 10KHz and the frequency at 6MHz. The noise was measured using the EMI meter.

4-5 EQUIPMENT SET-UP FOR ACCELERATED LIFE TESTING

This is second test of the first group of exeperiments mentioned earlier. After the samples were classified in one the three noise level groups they were placed between electrodes fitted on two heavy alluminum plates. To allow safe handling, the top surface of the upper plate was insulated with a layer of teflon. A 5mA fuse connected in serieses with each electrode, was used to protect the source and to allow easy detection of a failed samlple. Each plate was holding 30 specimens and the fuses of the top plate were all connected in a paralles fashion. The failure criterion for a sample was established as a dielectric puncture indicated by the blown fuse in series with each sample. The plates were held in place by six crews which were tighten with a torque meter to provide the required pressure of 40 lbs/feet.

This set-up ensured that all the samples were submitted to identical stress conditions. The environmental chamber used was an industrial Blue-M(model AC7502TDA-3)and the one phase transformer used had a turns ratio of 1:122. The circuit included an isolstion transformer with a turns ratio 1:1, a digital multimeter,and a spike protector with the broadband noise filter (Archer model 61-2780).

The isolation trasformer was used in order to provide galvanic isolation (the circuit downstream to have its own ground). The spike protector with the broadband noise filter was used in order to protect the experiment from a high voltage electrical pulse, from a few hundred to several thousand volts, and line noise. Spikes are caused when a large motor-driven appliance or machinery turns on and off. Futhermore the damage of electrical spikes is cumulative and as a result each additional spike increase the possibility of premature failure. Line noise is caused by continuously running motores that create a "Rough edge"on what should be smooth wave of AC voltage. The filter system smooths the AC voltage supply. The above device was used due to the abudance of motor driven devices in the ajoint labs.

CHAPTER 5

RESULTS AND DISCUSSION

INTRODUCTION

This chapter presents the life data for a paper insulation material(commonly called as Fish paper)used by transformer industry.

The material dc resistance has been chosen as a parameter for reliability prediction. When material resistance has reached to a level of 10% to its original value, the material is characterized as "failed" from reliability point. Several experiment results are presented here as under:

5-1 THERMAL AGING TEST AT 80^{0}C

In this experiment 25 samples where subjected to thermal stress at 80^{0}C all put inside the same enviromental chamber and at the same time. Table 2-4 gives the measured resistance data at room conditions as well as at different aging hours. The mean and standard deviation were, then, calculated for these 25 samples at different test measurements. These results are given in Table 2-4. From the mean resistance data, a new data Table 2-4A was generated showing mean resistance in p.u. system. The zero hour mean resistance has been chosen as a base. Using the results of Table 2-4A, a graph between the mean p.u. resistance and time in hour was plotted as shown in Fig.3. It is seen that the material p.u. mean resistance level was reduced to 10% value in 200 hour.

5-2 COMBINED AGING TEST AT 80^{0}C AND 600Vac

The second test was conducted at 800Vac and 80^{0}C. 30 samples were tested under accelerated life conditions in the same enviromental chamber and at the same time. Table 5-1 gives the measured resistance data at room conditions as well as at different aging hours. The mean and standard deviation were, then, calculated for these 30 samples at different test measurements. These results are given in Table 5A. From the mean resistance data, a new Table 5A was generated showing mean resistance in p.u.. The zero hour mean resistance has been chosen as a base. Using the results of Table 5A, a graph was plotted as shown in Fig.6. It was seen that the material p.u. resistance level is reduced to 10% value in 96 hours.

From above two experiments, it is clear that the material has failed early when subjected to combined stresses of temperature and voltage compared to thermal stress case . In other words, time to reach 10% of the original mean resistance value is appreciably low compared with the data of material subjected to only temperature stress. (i.e. τ'= 200 hrs. with 80^{0}C stress , τ'' = 96 hrs. with 80^{0}C and 800 Vac stresses). Refer to Figs.3 & 8.

5-3 THERMAL AGING TEST RESULTS

In each test, 25 samples each temperature, were subjected to thermal aging for varying hours. The individual sample and group mean resistance at different test hours are listed in Table 2-1 through 2-7. The mean resistance value for each test is listed in Table 2-1A through 2-7A. Fig.4(generated by Table 1) shows the material resistance decay pattern with time at a given temperature. When material mean p.u. resistance has reached to a level of 10% (of its original value), the decay time was found as 389 hrs. at 50^0C, 266 hrs. at 60^0C, 238 hrs. at 70^0C, 200 hrs. at 80^0C, 144 hrs. at 90^0 C and 120 hrs. at 100^0C respectively. This graph and data were used for calculatingthe value of constants **k'** and E.

5-3-1 CALCULATION FOR CONSTANT E AND k'

The expression for the constant E is given as under:

$$E = k\ ([\ln \tau_2' - \ln \tau_1')/(1/T_1 - 1/T_2) \qquad \text{-------}(5\text{-}1)$$

From Fig.4, a new graph has been prepared as shown in Fig.5 between 1/T in Kelvin and $\ln\tau$. Using Fig.5 at

$1/T_2 = 0.003095$ (or at $T_2 = 323\ ^oK$)

$\ln \tau_2' = 5.945$ (or $\tau_2' = 382$ hrs.)

and

$1/T_1 = 0.00277$ (or at $T_1 = 360\ ^oK$)

$\ln \tau_1' = 5.1$ (or $\tau_1' = 164$ hrs.)

Substituting these values into equation (5-1) above, we get

$E = \{(5.945-5.1)k\}/(0.003095-0.00277)$

$= 2600k$ ($k = 0.86174 \times 10^{-4}$ ev/^{o}k)

or $E = 0.225$ ev ------(5-2)

The expression for constant **k'** is given by

$$K' = e^{[\ln \tau - E/kT]} \quad \text{-------(5-3)}$$

(Refer to equation (3-6) on page 20)

Substituting the values of parameter E and T and τ of thermal aging test into equation (5-3), we get

$$k' = e^{[\ \ln 245 - (0.225/0.86174 \times 10^{-4} \times (273+68))}$$

or **k'** $= 0.118$ ------(5-4)

5-3-2 DETERMINATION OF CONSTANT Ç

Next, we run a new experiment for obtaining the value of the constant Ç (i.e. Combined aging test at 80^{0}C and 600V). The data are given in Table 3-1 and 3A. The thirty samples were subjected to simulataneous stress of 80^{0}C and ac 600V inside the same enviromental chamber and at the same time. Using the data of Table 3-1 and 3A, a graph was constructured between the mean p.u. material resistance versus time in hours as shown in Fig.6. It is seen that the material p.u. mean resistance level is reduced to 10% value in 118 hours.

The expression of the constant Ç (see page 20,section 3-4) is given

$$Ç = (kT/\xi)\ [\ \ln \mathbf{k'} + E/kT - \mathbf{ln}\ \tau''] \quad \text{------(5-5)}$$

From graph of Fig.5, $\tau 6''$ = 118 hrs. at $T = (273+80)^{0}K$ (or $80^{0}C$) and $\xi = 600/(2.54\text{x}10^{-4})$ v/m, substituting these values and the values of E and **k'** previously determined in the equation (5-5), we get

$$Ç = [0.86174\text{x}10^{-4}\ (273+80)/(600/2.54\text{x}10^{-4})][\ln 0.118 + 0.225/0.86174\text{x}10^{-4}(273+80) - \mathbf{ln}\ 118]$$

or $Ç = 0.626\text{x}10^{-8}$ Coulomb-m -------(5-6)

5-4 PROPOSED MODEL

Substituting the values of parameters E, **k'** and Ç into the equation 3-1 page 18, the life model for fish paper insulation material will be as under.

$$\tau = 0.118\ \mathbf{e}^{[0.225\ -\ 0.626\times10^{-8}\ \xi]/kT} \quad ------(5\text{-}7)$$

5-5 COMPARISON BETWEEN THEORITICAL LIFE ESTIMATIONS AND EXPERIMENTAL RESULTS

The model in equation (5-7) was used to estimate the life at the following combined stress conditions, namely 700V/80C, 800V/80C, 900V/80C and 600V/60C. The computed values were 106.8 hrs., 101 hrs., 93.2 hrs. and 178.2 hrs. resepectively also shown in Table 11.

Next we run four different combined stress experiments at above mentioned conditions. The degradation results are given in Fig.7 to Fig.10.. From these graphs, we obtained the life time for the similar level of degradation as before. These values were 118 hrs.(with elevated stresses of 80^0C, 600V), 108 hrs.(with elevated stresses of 80^0C, 700V), 96 hrs.(with elevated stresses of 80^0C, 800V), 87 hrs.(with elevated stresses of 80^0C, 800V) and 174 hrs.(with elevated stresses of 60^0C, 600V). also indicated in Table 11. On comparison we find that theorical life estimates are quite near with the expreimental results.

5-6 RELATIONSHIP BETWEEN THE ELECTRICAL NOISE AND MATERIAL LIFE

The purpose of this experiment is to find whether failure rate would correlate with the electrical noise (measured at zero hour and room conditions). The initial electrical noise value was measured in μV using EMI meter(type singer NM-27A). The applied voltage was set at 1000Vac. The measurement was carried at 6 MHz and 50 KHz bandwith inside a very good shielded room. The ninty samples each 2.5" x 2.5" size were tested. The initial noise data are given in Table 8.

All these samples were, then, subjected to combined elevated stress of 70^{0}C and 800Vac inside an enviromental chamber at the same time. There were three test plates each containing 30 samples. Each sample's catastrophic failure status was sensed by a 5 mA series fuse. The failure state of each sample was monitored time to time and results are given in Table 8.

A graph between the initial noise for each sample and an individ catastrophic failure time was plotted as shown in Fig.11. Following Lotus 1-2-3 program a regression line was obtained. Following statistical theory, a coefficient of correlation between the noise level and the time to failure was determined and found as 0.669. This shows that high noise units fail early in this accelerated test. In

Other words, units having low noise will last longer. This information can be used to develop a proper theory for quality controlling of a material for reliability.

5-7 ELECTRICAL NOISE PATTERNS DURING COMBINED THERMAL/ELECTRICAL STRESS AND ONLY THERMAL STRESS

In this test, samples having same initial noise level were subjected to thermal only testing (at 80C). In another experiment, similar kind of samples were subjected to combined electrical and thermal testing (at 800Vac and 80C). The life data were collected for increase in noise at reqular test hours until 326 hrs. The noise increase pattern is shown in Fig.12 and Table 9. It is seen that noise level increases with time in both those experiments but amount of increase is seen more when material is subjected to combined electrical and thermal stress. The reason for this increase may be due to enlarged voids sizes or new cracks due thermal aging. If we can develop a suitable sensor for diagnosis of electrical noise in equipment under operation, this information may be valuable for scheduling maintenance work or on deciding the equipment replacement.

CHAPTER 6

CONCLUSION

Reliability studies were carried out on a paper insulation material commonly known as "Fish" paper. This material is used by transformer manufacturing industry.

It has been noticed that material failure occurs early when subjected to combined electrical and thermal stresses compared to only thermal stress case.

Based upon these observations, a new life estimation model has been proposed for a paper insulation material. Laboratory set-up were designed & a procedure has been developed to obtain the constants of the proposed model as shown Table 10. The new model developed has the form

$$\tau = 0.118\ e^{[0.225\ -\ 0.626\mathrm{x}10^{-8}\ \xi]/kT}$$

The experimental data were generated to prove the validity of the proposed model. The theorical calculated time as obtained from the proposed model was seen matching with the experimental value as indicated Table 11.

Furthermore, it is seen that quantum of increase in electrical noise was more when material is subjected to combined thermal and electrical stresses compared to only thermal stress case.

In another experiment when material was subjected to both thermal and electrical stresses , it was found that these exists a high correlation between the electrical noise (generated in the bulk of material) and the catastrophic failure. This noise information might be useful in determining a preventive maintenance schedules or replacing an old equipment.

TABLE 1

Time to each 0.1 p.u. resistance	At actural Temperature in °C	Temperature in Kelvin °K	lnτ	1/°K
120	100	373	4.787	0.002680
144	90	363	4.969	0.002754
200	80	353	5.298	0.002832
238	70	343	5.472	0.002915
266	60	333	5.583	0.003003
389	50	323	5.963	0.003095

TABLE 2-1A

Per unit material resistance subjected to only thermal stress

Time in Hour	R(pu) at 50C
0	1
24	1.183718
48	1.533003
72	2.473597
96	2.034653
120	1.254675
144	0.617711
168	0.440594
192	0.298679
216	0.238173
240	0.167216
264	0.133663
288	0.133113
312	0.121562
336	0.116061
360	0.108360
384	0.102860
408	0.095709
432	0.090759
456	0.086908
480	0.083058
504	0.080308

P.S. This table was determined from Table 2-1.

TABLE 2-1

Laboratory life data on the leakage current and material resistance when subjected to 50 C only

SAMPLE#	I(0)	R(0)	I(24)	R(24)	I(48)	R(48)
1	0.824628	1.819	0.695732	2.156	0.538406	2.786
2	0.820120	1.829	0.675371	2.221	0.576258	2.603
3	0.839395	1.787	0.645161	2.325	0.577367	2.598
4	0.822819	1.823	0.633713	2.367	0.498007	3.012
5	0.825082	1.818	0.697350	2.151	0.481540	3.115
6	0.834260	1.798	0.711574	2.108	0.517598	2.898
7	0.820120	1.829	0.747011	2.008	0.538213	2.787
8	0.829646	1.808	0.743310	2.018	0.575373	2.607
9	0.826901	1.814	0.729571	2.056	0.560957	2.674
10	0.822368	1.824	0.689338	2.176	0.562851	2.665
11	0.836120	1.794	0.696378	2.154	0.538406	2.786
12	0.819224	1.831	0.646551	2.32	0.579374	2.589
13	0.818777	1.832	0.717360	2.091	0.555967	2.698
14	0.819224	1.831	0.750750	1.998	0.500333	2.998
15	0.832870	1.801	0.802997	1.868	0.537827	2.789
16	0.823271	1.822	0.743310	2.018	0.565397	2.653
17	0.823271	1.822	0.682438	2.198	0.497512	3.015
18	0.831485	1.804	0.696378	2.154	0.546448	2.745
19	0.826901	1.814	0.771604	1.944	0.536097	2.798
20	0.834260	1.798	0.649913	2.308	0.554323	2.706
21	0.817884	1.834	0.717017	2.092	0.490998	3.055
22	0.823723	1.821	0.708215	2.118	0.540151	2.777
23	0.830564	1.806	0.720115	2.083	0.515641	2.909
24	0.820568	1.828	0.642398	2.335	0.560538	2.676
25	0.818777	1.832	0.692840	2.165	0.536097	2.798
26	0.827814	1.812	0.673249	2.228	0.521195	2.878
27	0.818777	1.832	0.682438	2.198	0.531349	2.823
28	0.823271	1.822	0.649069	2.311	0.554323	2.706
29	0.822819	1.823	0.709891	2.113	0.562218	2.668
30	0.817884	1.834	0.651324	2.303	0.535140	2.803
MEAN	0.825094	1.818066	0.696756	2.152833	0.538180	2.787166
STD.SV	0.005922	0.012984	0.040669	0.123288	0.026637	0.141421

Continued to page 44

P.S. A figure in parenthesis represents time of measurement is hours.

TABLE 2-1

Laboratory life data on the leakage current and material resistance when subjected to 50 C only

I(72)	R(72)	I(96)	R(96)	I(120)	R(120)
0.333555	4.497	0.407166	3.684	0.655881	2.287
0.356379	4.209	0.395569	3.792	0.624479	2.402
0.357313	4.198	0.405186	3.702	0.702905	2.134
0.348675	4.302	0.397456	3.774	0.611496	2.453
0.325874	4.603	0.394425	3.803	0.671140	2.235
0.329380	4.554	0.393391	3.813	0.600480	2.498
0.348189	4.308	0.435161	3.447	0.613999	2.443
0.365141	4.108	0.394425	3.803	0.649631	2.309
0.337761	4.441	0.431530	3.476	0.613999	2.443
0.333185	4.502	0.418176	3.587	0.599041	2.504
0.320924	4.674	0.398618	3.763	0.678426	2.211
0.321750	4.662	0.408385	3.673	0.714966	2.098
0.318201	4.714	0.421703	3.557	0.710227	2.112
0.366837	4.089	0.406834	3.687	0.711237	2.109
0.354693	4.229	0.408496	3.672	0.744786	2.014
0.328803	4.562	0.394321	3.804	0.746640	2.009
0.340831	4.401	0.386100	3.885	0.678426	2.211
0.331711	4.522	0.422178	3.553	0.655881	2.287
0.320034	4.687	0.395465	3.793	0.734214	2.043
0.322372	4.653	0.385901	3.887	0.682749	2.197
0.319488	4.695	0.409276	3.665	0.651324	2.303
0.326299	4.597	0.404094	3.712	0.651890	2.301
0.325168	4.613	0.384122	3.905	0.651324	2.303
0.321612	4.664	0.422297	3.552	0.579822	2.587
0.318945	4.703	0.422416	3.551	0.616269	2.434
0.338447	4.432	0.405515	3.699	0.646273	2.321
0.325874	4.603	0.440270	3.407	0.699953	2.143
0.326228	4.598	0.422416	3.551	0.578703	2.592
0.325097	4.614	0.384319	3.903	0.709891	2.113
0.333555	4.497	0.384812	3.898	0.642673	2.334
0.333503	4.4977	0.405412	3.699933	0.657606	2.281
0.014110	0.183104	0.015572	0.139937	0.047079	0.162821

Continued to page 45

TABLE 2-1

Laboratory life data on the leakage current and material resistance when subjected to 50 C only

I(144)	R(144)	I(168)	R(168)	I(192)	R(192)
1.328609	1.129	1.503006	0.998	2.737226	0.548
1.218521	1.231	13.88888	0.108	2.483443	0.604
1.366120	1.098	1.872659	0.801	2.139800	0.701
1.368613	1.096	1.849568	0.811	2.259036	0.664
1.334519	1.124	1.901140	0.789	2.617801	0.573
1.135503	1.321	1.928020	0.778	2.929687	0.512
1.241721	1.208	1.896333	0.791	2.958579	0.507
1.231527	1.218	1.903553	0.788	2.868068	0.523
1.379944	1.087	1.865671	0.804	2.450980	0.612
1.238645	1.211	1.477832	1.015	2.873563	0.522
1.366120	1.098	2.133712	0.703	2.952755	0.508
1.489572	1.007	2.164502	0.693	2.935420	0.511
1.222493	1.227	1.488095	1.008	2.712477	0.553
1.513622	0.991	1.802884	0.832	2.964426	0.506
1.482213	1.012	1.661129	0.903	2.664298	0.563
1.513622	0.991	1.856435	0.808	2.868068	0.523
1.350135	1.111	1.664816	0.901	2.568493	0.584
1.353790	1.108	1.827040	0.821	2.369668	0.633
1.163692	1.289	1.849568	0.811	2.762430	0.543
1.144164	1.311	1.611170	0.931	2.512562	0.597
1.381215	1.086	2.161383	0.694	2.946954	0.509
1.438159	1.043	1.672240	0.897	2.808988	0.534
1.182965	1.268	1.872659	0.801	2.935420	0.511
1.218521	1.231	1.687289	0.889	2.555366	0.587
1.503006	0.998	1.872659	0.801	2.467105	0.608
1.364877	1.099	1.910828	0.785	2.707581	0.554
1.488095	1.008	1.932989	0.776	2.819548	0.532
1.344086	1.116	2.145922	0.699	2.762430	0.543
1.522842	0.985	1.901140	0.789	2.555366	0.587
1.483679	1.011	1.854140	0.809	2.568493	0.584
1.334796	1.123766	1.872347	0.801133	2.761938	0.543096
0.119948	0.102369	2.170833	0.153702	0.219513	0.048876

Continued to page 46

TABLE 2-1

Laboratory life data on the leakage current and material resistance when subjected to 50 C only

I(216)	R(216)	I(240)	R(240)	I(264)	R(264)
3.416856	0.439	4.983388	0.301	6.072874	0.247
2.970297	0.505	5.016722	0.299	5.952380	0.252
3.464203	0.433	5.033557	0.298	6.493506	0.231
3.012048	0.498	4.531722	0.331	6.276150	0.239
2.988047	0.502	5.084745	0.295	6.437768	0.233
3.588516	0.418	4.531722	0.331	5.928853	0.253
3.424657	0.438	5.190311	0.289	6.147540	0.244
3.658536	0.41	5.244755	0.286	6.024096	0.249
3.667481	0.409	4.983388	0.301	6.550218	0.229
3.640776	0.412	5.190311	0.289	6.122448	0.245
3.676470	0.408	4.716981	0.318	5.928853	0.253
3.464203	0.433	4.823151	0.311	5.836575	0.257
3.562945	0.421	5.084745	0.295	5.976095	0.251
3.588516	0.418	5.244755	0.286	6.172839	0.243
3.177966	0.472	4.823151	0.311	6.302521	0.238
3.605769	0.416	5.226480	0.287	6.465517	0.232
3.579952	0.419	4.854368	0.309	6.048387	0.248
3.171247	0.473	5.434782	0.276	6.437768	0.233
3.667481	0.409	4.731861	0.317	5.976095	0.251
3.401360	0.441	5.033557	0.298	6.329113	0.237
3.722084	0.403	4.559270	0.329	6.122448	0.245
3.640776	0.412	4.823151	0.311	5.952380	0.252
3.432494	0.437	5.263157	0.285	6.172839	0.243
3.472222	0.432	4.672897	0.321	5.952380	0.252
3.472222	0.432	5.033557	0.298	6.302521	0.238
3.512880	0.427	4.716981	0.318	6.637168	0.226
3.667481	0.409	4.518072	0.332	6.198347	0.242
3.562945	0.421	4.918032	0.305	5.882352	0.255
3.496503	0.429	5.154639	0.291	6.302521	0.238
3.614457	0.415	4.885993	0.307	6.147540	0.244
3.463936	0.433033	4.931506	0.304166	6.164383	0.243333
0.207527	0.028105	0.244134	0.015179	0.213442	0.008311

Continued to page 47

TABLE 2-1

Laboratory life data on the leakage current and material resistance when subjected to 50 C only

I(288)	R(288)	I(312)	R(312)	I(336)	R(336)
6.276150	0.239	6.578947	0.228	7.177033	0.209
6.048387	0.248	6.410256	0.234	6.726457	0.223
6.666666	0.225	6.787330	0.221	7.009345	0.214
6.696428	0.224	7.109004	0.211	7.211538	0.208
6.637168	0.226	7.177033	0.209	7.575757	0.198
6.097560	0.246	6.849315	0.219	7.281553	0.206
6.756756	0.222	7.211538	0.208	7.462686	0.201
6.329113	0.237	6.787330	0.221	7.109004	0.211
6.787330	0.221	6.912442	0.217	7.211538	0.208
6.382978	0.235	6.637168	0.226	6.787330	0.221
6.072874	0.247	6.437768	0.233	6.666666	0.225
6.329113	0.237	6.607929	0.227	7.009345	0.214
6.147540	0.244	6.465517	0.232	6.787330	0.221
6.465517	0.232	6.578947	0.228	6.880733	0.218
6.607929	0.227	6.880733	0.218	7.177033	0.209
6.666666	0.225	6.787330	0.221	7.109004	0.211
6.465517	0.232	6.726457	0.223	6.944444	0.216
6.666666	0.225	6.912442	0.217	7.211538	0.208
6.172839	0.243	6.437768	0.233	6.880733	0.218
6.666666	0.225	6.849315	0.219	7.211538	0.208
6.410256	0.234	6.787330	0.221	7.009345	0.214
6.578947	0.228	6.849315	0.219	7.109004	0.211
6.382978	0.235	6.696428	0.224	6.944444	0.216
6.172839	0.243	6.437768	0.233	6.666666	0.225
6.666666	0.225	6.880733	0.218	7.731958	0.194
7.109004	0.211	7.389162	0.203	7.575757	0.198
6.355932	0.236	6.726457	0.223	7.109004	0.211
6.147540	0.244	6.465517	0.232	6.696428	0.224
6.666666	0.225	7.042253	0.213	7.246376	0.207
6.329113	0.237	6.787330	0.221	7.177033	0.209
6.448839	0.2326	6.764882	0.221733	7.079924	0.211866
0.252798	0.009046	0.244282	0.007886	0.267426	0.007902

Continued to page 48

TABLE 2-1

Laboratory life data on the leakage current and material resistance when subjected to 50 C only

I(360)	R(360)	I(384)	R(384)	I(408)	R(408)
7.692307	0.195	7.978723	0.188	8.522727	0.176
7.042253	0.213	7.389162	0.203	7.978723	0.188
7.462686	0.201	7.978723	0.188	8.875739	0.169
7.614213	0.197	8.021390	0.187	8.241758	0.182
7.978723	0.188	8.287292	0.181	8.522727	0.176
7.731958	0.194	8.064516	0.186	8.426966	0.178
8.021390	0.187	8.241758	0.182	8.720930	0.172
7.389162	0.203	7.614213	0.197	8.379888	0.179
7.731958	0.194	8.152173	0.184	8.522727	0.176
7.352941	0.204	8.021390	0.187	8.670520	0.173
7.109004	0.211	7.537688	0.199	8.474576	0.177
7.211538	0.208	7.425742	0.202	7.936507	0.189
7.389162	0.203	7.692307	0.195	8.287292	0.181
7.575757	0.198	7.978723	0.188	8.771929	0.171
7.978723	0.188	8.241758	0.182	8.620689	0.174
7.575757	0.198	7.8125	0.192	8.720930	0.172
7.8125	0.192	8.021390	0.187	8.426966	0.178
8.021390	0.187	8.426966	0.178	8.875739	0.169
7.731958	0.194	8.021390	0.187	8.928571	0.168
7.462686	0.201	8.152173	0.184	8.771929	0.171
7.246376	0.207	7.936507	0.189	8.928571	0.168
7.425742	0.202	8.064516	0.186	8.720930	0.172
7.692307	0.195	8.021390	0.187	8.670520	0.173
7.042253	0.213	7.692307	0.195	8.522727	0.176
8.021390	0.187	8.426966	0.178	8.620689	0.174
8.152173	0.184	8.426966	0.178	8.928571	0.168
7.8125	0.192	8.196721	0.183	8.620689	0.174
7.009345	0.214	7.425742	0.202	8.152173	0.184
7.978723	0.188	8.474576	0.177	9.036144	0.166
7.614213	0.197	8.241758	0.182	9.036144	0.166
7.582139	0.197833	7.987220	0.1878	8.587786	0.174666
0.323248	0.008513	0.302804	0.007259	0.281140	0.005832

Continued to page 49

TABLE 2-1

Laboratory life data on the leakage current and material resistance when subjected to 50 C only

I(432)	R(432)	I(456)	R(456)	I(504)	R(504)
8.928571	0.168	9.615384	0.156	10.41666	0.144
9.146341	0.164	9.803921	0.153	10.06711	0.149
9.316770	0.161	9.677419	0.155	10.27397	0.146
8.670520	0.173	9.090909	0.165	9.615384	0.156
8.875739	0.169	9.259259	0.162	10.48951	0.143
8.720930	0.172	9.090909	0.165	10.13513	0.148
9.202453	0.163	9.615384	0.156	10.48951	0.143
8.771929	0.171	9.202453	0.163	10.41666	0.144
9.036144	0.166	9.493670	0.158	10.06711	0.149
9.090909	0.165	9.554140	0.157	10.63829	0.141
8.875739	0.169	9.259259	0.162	10.13513	0.148
8.474576	0.177	9.036144	0.166	10.13513	0.148
8.571428	0.175	8.771929	0.171	9.868421	0.152
9.090909	0.165	9.554140	0.157	10.48951	0.143
9.146341	0.164	9.740259	0.154	10.41666	0.144
9.036144	0.166	9.493670	0.158	10.06711	0.149
9.036144	0.166	9.740259	0.154	10.56338	0.142
9.493670	0.158	9.868421	0.152	10.41666	0.144
9.316770	0.161	9.554140	0.157	10.63829	0.141
9.036144	0.166	9.677419	0.155	10.27397	0.146
9.316770	0.161	9.615384	0.156	10.48951	0.143
9.036144	0.166	9.740259	0.154	10.20408	0.147
8.928571	0.168	9.259259	0.162	10.41666	0.144
9.090909	0.165	9.554140	0.157	10.56338	0.142
9.090909	0.165	9.554140	0.157	10.06711	0.149
9.615384	0.156	9.933774	0.151	10.79136	0.139
8.928571	0.168	9.202453	0.163	10.63829	0.141
8.771929	0.171	9.036144	0.166	10.86956	0.138
9.677419	0.155	9.933774	0.151	10.86956	0.138
9.740259	0.154	10.06711	0.149	10.86956	0.138
9.057971	0.1656	9.489666	0.158066	10.37105	0.144633
0.300670	0.005438	0.308917	0.005214	0.298975	0.004214

TABLE 2-2A

Per unit material resistance subjected to only thermal stress

Time in Hour	R(pu) at 60C
0	1
24	1.181085
72	2.832348
120	1.709296
192	0.260612
276	0.094572
348	0.077915
516	0.069317

This table was determined from Table 2-2.

TABLE 2-2

Laboratory life data on the leakage current and material resistance when subjected to 60 C only

SAMPLE#	I(0)	R(0)	I(24)	R(24)	I(72)	R(72)
1	0.813008	1.845	0.720115	2.083	0.3	5
2	0.813890	1.843	0.683994	2.193	0.287026	5.226
3	0.812127	1.847	0.689021	2.177	0.287026	5.226
4	0.813008	1.845	0.700934	2.14	0.288018	5.208
5	0.802997	1.868	0.687127	2.183	0.313021	4.792
6	0.809935	1.852	0.734933	2.041	0.288018	5.208
7	0.813890	1.843	0.679963	2.206	0.293025	5.119
8	0.810810	1.85	0.689021	2.177	0.283983	5.282
9	0.812127	1.847	0.688073	2.18	0.288018	5.208
10	0.813008	1.845	0.689021	2.177	0.294985	5.085
11	0.809061	1.854	0.683060	2.196	0.290979	5.155
12	0.815217	1.84	0.687127	2.183	0.293025	5.119
13	0.808189	1.856	0.689021	2.177	0.304012	4.934
14	0.808189	1.856	0.685871	2.187	0.293025	5.119
15	0.809061	1.854	0.685871	2.187	0.274977	5.455
16	0.806885	1.859	0.685871	2.187	0.305002	4.918
17	0.806018	1.861	0.687127	2.183	0.266998	5.618
18	0.810810	1.85	0.689021	2.177	0.266998	5.618
19	0.8	1.875	0.706880	2.122	0.301023	4.983
20	0.809935	1.852	0.694123	2.161	0.301023	4.983
21	0.815217	1.84	0.683060	2.196	0.314993	4.762
22	0.816104	1.838	0.689972	2.174	0.268000	5.597
23	0.817884	1.834	0.721153	2.08	0.269010	5.576
24	0.818777	1.832	0.700934	2.14	0.271985	5.515
25	0.808189	1.856	0.704887	2.128	0.274022	5.474
MEAN	0.810951	1.84968	0.693994	2.1614	0.288062	5.2072
STD.DV	0.004294	0.009821	0.013454	0.040655	0.013835	0.250793

Continued to page 52

P.S. A figure parenthesis represents time of measurement in hours.

TABLE 2-2

Laboratory life data on the leakage current and material resistance when subjected to 60 C only

I(120)	R(120)	I(192)	R(192)	I(276)	R(276)
1.407129	1.066	3.151260	0.476	8.474576	0.177
1.639344	0.915	3.968253	0.378	8.571428	0.175
1.102130	1.361	3.340757	0.449	8.522727	0.176
0.135001	11.111	2.196193	0.683	6.410256	0.234
0.168995	8.876	3.649635	0.411	10.06711	0.149
0.632111	2.373	2.049180	0.732	7.352941	0.204
1.352569	1.109	3.957783	0.379	6.880733	0.218
1.963350	0.764	3.807106	0.394	6.048387	0.248
0.759109	1.976	3.496503	0.429	8.021390	0.187
0.366032	4.098	4.983388	0.301	10.41666	0.144
0.391951	3.827	3.086419	0.486	8.670520	0.173
0.156006	9.615	2.906976	0.516	7.936507	0.189
0.438981	3.417	2.737226	0.548	8.108108	0.185
0.450992	3.326	3.597122	0.417	8.426966	0.178
0.507958	2.953	3.694581	0.406	8.571428	0.175
0.507958	2.953	3.649635	0.411	8.379888	0.179
0.484027	3.099	3.225806	0.465	7.5	0.2
0.996677	1.505	2.351097	0.638	10	0.15
0.137994	10.87	4	0.375	8.771929	0.171
1.046025	1.434	2.941176	0.51	8.108108	0.185
1.082251	1.386	2.100840	0.714	9.554140	0.157
0.523012	2.868	4.043126	0.371	10.06711	0.149
1.079913	1.389	3.865979	0.388	8.823529	0.17
1.429933	1.049	3.614457	0.415	8.064516	0.186
0.892857	1.68	2.097902	0.715	7.614213	0.197
0.441072	3.4008	3.123178	0.48028	8.230904	0.18224
0.496317	3.101121	0.726634	0.120817	1.075824	0.024735

Continued to page 53

TABLE 2-2

Laboratory life data on the leakage current and material resistance when subjected to 60 C only

I(348)	R(348)	I(516)	R(516)
13.51351	0.111	14.15094	0.106
10.71428	0.14	11.11111	0.135
8.670520	0.173	10	0.15
7.177033	0.209	10.79136	0.139
10.06711	0.149	11.11111	0.135
9.677419	0.155	12	0.125
9.202453	0.163	10	0.15
12.71186	0.118	13.15789	0.114
9.090909	0.165	10	0.15
10.71428	0.14	11.36363	0.132
10.06711	0.149	11.45038	0.131
9.868421	0.152	14.01869	0.107
11.62790	0.129	12	0.125
8.771929	0.171	9.036144	0.166
10.71428	0.14	11.27819	0.133
12.39669	0.121	12.93103	0.116
9.740259	0.154	11.45038	0.131
10.48951	0.143	11.02941	0.136
10.94890	0.137	11.19402	0.134
8.287292	0.181	12.93103	0.116
10.27397	0.146	11.02941	0.136
11.11111	0.135	11.90476	0.126
9.036144	0.166	10.06711	0.149
10.41666	0.144	12.93103	0.116
9.803921	0.153	10.13513	0.148
10.01602	0.14976	11.34301	0.13224
1.385862	0.020725	1.281725	0.014566

TABLE 2-3A

Per unit material resistance subjected to only thermal stress

Time in Hour	R(pu) at 70C
0	1
24	1.966212
72	4.199455
120	4.199455
192	0.192915
276	0.081198
348	0.073569
516	0.05831

P.S. This table was determined from Table 2-3.

TABLE 2-3

Laboratory life data on the leakage current and material resistance when subjected to 70 C only

SAMPLE#	I(0)	R(0)	I(24)	R(24)	I(72)	R(72)
1	0.808189	1.856	0.425049	3.529	0.201992	7.426
2	0.806018	1.861	0.417014	3.597	0.195007	7.692
3	0.809061	1.854	0.426985	3.513	0.184003	8.152
4	0.809935	1.852	0.426985	3.513	0.205987	7.282
5	0.807754	1.857	0.425049	3.529	0.193000	7.772
6	0.809061	1.854	0.400962	3.741	0.193000	7.772
7	0.832870	1.801	0.412995	3.632	0.187009	8.021
8	0.832870	1.801	0.437956	3.425	0.200991	7.463
9	0.830105	1.807	0.437062	3.432	0.234009	6.41
10	0.821018	1.827	0.420993	3.563	0.219010	6.849
11	0.821917	1.825	0.415052	3.614	0.177999	8.427
12	0.813890	1.843	0.417014	3.597	0.175994	8.523
13	0.815217	1.84	0.410958	3.65	0.164998	9.091
14	0.816104	1.838	0.411974	3.641	0.163008	9.202
15	0.816104	1.838	0.425049	3.529	0.271985	5.515
16	0.815217	1.84	0.430045	3.488	0.214010	7.009
17	0.825991	1.816	0.427960	3.505	0.201992	7.426
18	0.824175	1.82	0.427960	3.505	0.217013	6.912
19	0.821917	1.825	0.423968	3.538	0.207986	7.212
20	0.821917	1.825	0.426985	3.513	0.211000	7.109
21	0.822819	1.823	0.428939	3.497	0.197005	7.614
22	0.821018	1.827	0.411974	3.641	0.205002	7.317
23	0.820120	1.829	0.411974	3.641	0.182993	8.197
24	0.820120	1.829	0.410958	3.65	0.176991	8.475
25	0.821018	1.827	0.400962	3.741	0.188988	7.937
MEAN	0.818509	1.8326	0.420290	3.56896	0.196535	7.6322
STD.DV	0.007475	0.016721	0.009647	0.082474	0.022411	0.797167

Continued to page 56

P.S. A figure in parenthesis represents time of measurement in hours.

TABLE 2-3

Laboratory life data on the leakage current and material resistance when subjected to 70 C only

I(120)	R(120)	I(192)	R(192)	I(276)	R(276)
1.811594	0.828	4.573170	0.328	10.20408	0.147
3.416856	0.439	4.120879	0.364	9.433962	0.159
1.565762	0.958	3.836317	0.391	9.036144	0.166
3.846153	0.39	5.494505	0.273	9.615384	0.156
1.940491	0.773	4.054054	0.37	10.27397	0.146
1.513622	0.991	4.746835	0.316	10.34482	0.145
1.378676	1.088	4.746835	0.316	7.653061	0.196
1.306620	1.148	4.838709	0.31	10.20408	0.147
1.611170	0.931	4.398826	0.341	10	0.15
1.666666	0.9	5.119453	0.293	10.94890	0.137
1.891551	0.793	4.273504	0.351	9.493670	0.158
1.285347	1.167	3.363228	0.446	9.868421	0.152
1.420454	1.056	4.746835	0.316	10	0.15
1.469147	1.021	4.901960	0.306	11.53846	0.13
2.551020	0.588	5.454545	0.275	11.45038	0.131
1.028806	1.458	3.947368	0.38	10.71428	0.14
1.813784	0.827	5	0.3	10.71428	0.14
1.789976	0.838	4.601226	0.326	9.677419	0.155
1.716247	0.874	4.213483	0.356	10.48951	0.143
1.623376	0.924	4.587155	0.327	10.63829	0.141
1.992031	0.753	5.639097	0.266	10.06711	0.149
1.102941	1.36	3.703703	0.405	10.56338	0.142
1.585623	0.946	4.716981	0.318	10.27397	0.146
2.118644	0.708	5.791505	0.259	11.27819	0.133
1.541623	0.973	4.249291	0.353	10.41666	0.144
1.649656	0.90928	4.525706	0.33144	10.12692	0.14812
0.629067	0.238294	0.599187	0.044357	0.796074	0.012990

Continued to page 57

TABLE 2-3

Laboratory life data on the leakage current and material resistance when subjected to 70 C only

I(348)	R(348)	I(516)	R(516)
11.71875	0.128	14.56310	0.103
10	0.15	14.56310	0.103
10.34482	0.145	15.30612	0.098
12	0.125	13.88888	0.108
11.81102	0.127	15.625	0.096
12.82051	0.117	15.46391	0.097
8.928571	0.168	12.71186	0.118
11.53846	0.13	13.27433	0.113
11.81102	0.127	15.625	0.096
11.53846	0.13	14.28571	0.105
10	0.15	12.19512	0.123
10.20408	0.147	11.62790	0.129
10.06711	0.149	14.42307	0.104
11.90476	0.126	13.51351	0.111
12.39669	0.121	13.63636	0.11
11.19402	0.134	15.78947	0.095
12.39669	0.121	15.30612	0.098
10.86956	0.138	14.56310	0.103
11.62790	0.129	14.42307	0.104
12.5	0.12	15.15151	0.099
10.63829	0.141	14.85148	0.101
11.81102	0.127	15	0.1
11.81102	0.127	15.30612	0.098
12	0.125	15	0.1
12.5	0.12	12	0.125
11.28838	0.13288	14.22070	0.10548
0.969666	0.012248	1.166487	0.009351

TABLE 2-4A

Per unit material resistance subjected to only thermal stress

Time in Hour	R(pu) at 80C
0	1
24	2.812534
48	6.098637
72	0.180381
192	0.108446
276	0.069206
348	0.053405
516	0.042506

P.S. This table was determined from Table 2-4A

TABLE 2-4

Laboratory life data on the leakage current and material resistance when subjected to 80 C only

SAMPLE#	I(0)	R(0)	I(24)	R(24)	I(48)	R(48)
1	0.810810	1.85	0.3	5	0.125	12
2	0.810372	1.851	0.287026	5.226	0.125	12
3	0.810372	1.851	0.289017	5.19	0.128008	11.718
4	0.815217	1.84	0.287026	5.226	0.182993	8.197
5	0.810372	1.851	0.288018	5.208	0.184003	8.152
6	0.809061	1.854	0.3	5	0.167000	8.982
7	0.810372	1.851	0.311009	4.823	0.188017	7.978
8	0.810372	1.851	0.291999	5.137	0.123001	12.195
9	0.809061	1.854	0.290023	5.172	0.135001	11.111
10	0.808189	1.856	0.288018	5.208	0.122000	12.295
11	0.809061	1.854	0.285008	5.263	0.123001	12.195
12	0.810372	1.851	0.284846	5.266	0.123987	12.098
13	0.808189	1.856	0.293025	5.119	0.125	12
14	0.809061	1.854	0.289017	5.19	0.126008	11.904
15	0.810372	1.851	0.287026	5.226	0.187009	8.021
16	0.810372	1.851	0.284037	5.281	0.183016	8.196
17	0.810372	1.851	0.284037	5.281	0.116000	12.931
18	0.808189	1.856	0.285986	5.245	0.119000	12.605
19	0.806885	1.859	0.288018	5.208	0.125997	11.905
20	0.806885	1.859	0.290979	5.155	0.128998	11.628
21	0.808189	1.856	0.293025	5.119	0.112007	13.392
22	0.809061	1.854	0.294002	5.102	0.131004	11.45
23	0.809061	1.854	0.295043	5.084	0.123001	12.195
24	0.806885	1.859	0.296033	5.067	0.127011	11.81
25	0.809061	1.854	0.298329	5.028	0.129010	11.627
MEAN	0.809445	1.85312	0.291094	5.15296	0.134608	11.1434
STD.DV	0.001672	0.003819	0.006175	0.106383	0.025132	1.689956

Continued to page 60

P.S. A figure in parenthesis rrepresents time of measurement in hours.

TABLE 2-4

Laboratory life data on the leakage current and material resistance when subjected to 80 C only

I(72)	R(72)	I(192)	R(192)	I(276)	R(276)
4.076086	0.368	7.5	0.2	11.62790	0.129
4.531722	0.331	7.692307	0.195	12.93103	0.116
4.531722	0.331	7.075471	0.212	12.09677	0.124
7.109004	0.211	8.333333	0.18	11.81102	0.127
5.208333	0.288	6.437768	0.233	10.71428	0.14
4.155124	0.361	7.692307	0.195	12.39669	0.121
4.249291	0.353	7.211538	0.208	11.90476	0.126
5.434782	0.276	7.692307	0.195	12.29508	0.122
5.136986	0.292	7.8125	0.192	11.27819	0.133
4.464285	0.336	7.281553	0.206	11.90476	0.126
4.021447	0.373	7.692307	0.195	11.36363	0.132
4.901960	0.306	8.474576	0.177	12.09677	0.124
4.518072	0.332	7.142857	0.21	11.27819	0.133
4.629629	0.324	7.142857	0.21	11.71875	0.128
5.725190	0.262	8.426966	0.178	12.09677	0.124
4.285714	0.35	7.281553	0.206	11.71875	0.128
4.518072	0.332	7.653061	0.196	11.11111	0.135
6.25	0.24	8.522727	0.176	12.71186	0.118
6.637168	0.226	7.8125	0.192	11.36363	0.132
7.009345	0.214	8.287292	0.181	12.71186	0.118
4.658385	0.322	7.8125	0.192	11.90476	0.126
4	0.375	6.382978	0.235	11.45038	0.131
5.813953	0.258	7.5	0.2	11.71875	0.128
4.043126	0.371	6.912442	0.217	11.45038	0.131
4.843918	0.309666	7.529805	0.199208	11.79554	0.127166
1.343118	0.050889	1.586282	0.015446	2.373233	0.005654

Continued to page 61

TABLE 2-4

Laboratory life data on the leakage current and material resistance when subjected to 80 C only

I(348)	R(348)	I(516)	R(516)
14.42307	0.104	18.98734	0.079
15.46391	0.097	20.27027	0.074
14.15094	0.106	20.54794	0.073
15	0.1	18.29268	0.082
14.70588	0.102	16.12903	0.093
15	0.1	18.98734	0.079
16.30434	0.092	18.98734	0.079
15.15151	0.099	18.51851	0.081
14.56310	0.103	17.85714	0.084
15.15151	0.099	19.23076	0.078
15.46391	0.097	18.98734	0.079
16.48351	0.091	19.48051	0.077
17.64705	0.085	22.72727	0.066
15.78947	0.095	18.51851	0.081
15.30612	0.098	18.29268	0.082
14.15094	0.106	18.51851	0.081
14.01869	0.107	18.75	0.08
19.48051	0.077	24.59016	0.061
14.01869	0.107	20.83333	0.072
19.23076	0.078	22.72727	0.066
15	0.1	17.04545	0.088
14.15094	0.106	20.27027	0.074
14.56310	0.103	16.30434	0.092
14.85148	0.101	17.85714	0.084
14.80278	0.098041	18.50844	0.078541
3.340755	0.008126	4.228303	0.007427

TABLE 2-5A

Per unit material resistance subjected to only thermal stress

Time in Hour	R(pu) at 90C
0	1
24	4.305432
48	7.340909
72	0.171286
96	0.135809
120	0.111419
144	0.097560
168	0.085365
192	0.074833
216	0.068181
240	0.062084
264	0.055986
288	0.054323
312	0.052660
336	0.051552
360	0.050443
384	0.048226
408	0.046008
432	0.044900
456	0.043791
480	0.042128
504	0.041019

P.S. This table was determined from Table 2-5.

TABLE 2-5

Laboratory life data on the leakage current and material resistance when subjected to 90 C only

SAMPLE#	I(0)	R(0)	I(24)	R(24)	I(48)	R(48)
1	0.827814	1.812	0.192455	7.794	0.113173	13.254
2	0.831946	1.803	0.192702	7.784	0.113241	13.246
3	0.831485	1.804	0.192455	7.794	0.114425	13.109
4	0.829187	1.809	0.192209	7.804	0.114626	13.086
5	0.832870	1.801	0.192036	7.811	0.112688	13.311
6	0.831485	1.804	0.193648	7.746	0.113267	13.243
7	0.829646	1.808	0.192702	7.784	0.112968	13.278
8	0.827357	1.813	0.192777	7.781	0.114346	13.118
9	0.827814	1.812	0.193000	7.772	0.112798	13.298
10	0.832408	1.802	0.191987	7.813	0.112680	13.312
11	0.837520	1.791	0.191791	7.821	0.113284	13.241
12	0.832870	1.801	0.192752	7.782	0.113558	13.209
13	0.828271	1.811	0.191155	7.847	0.113739	13.188
14	0.831946	1.803	0.191619	7.828	0.112764	13.302
15	0.830564	1.806	0.193224	7.763	0.113541	13.211
16	0.832870	1.801	0.193124	7.767	0.112883	13.288
17	0.827357	1.813	0.192209	7.804	0.112790	13.299
18	0.830564	1.806	0.192926	7.775	0.112748	13.304
19	0.829646	1.808	0.199680	7.512	0.112798	13.298
20	0.831485	1.804	0.195083	7.689	0.113473	13.219
21	0.828271	1.811	0.192975	7.773	0.113739	13.188
22	0.837053	1.792	0.193075	7.769	0.112688	13.311
23	0.831485	1.804	0.192258	7.802	0.113045	13.269
24	0.829187	1.809	0.192950	7.774	0.112680	13.312
25	0.826446	1.815	0.192777	7.781	0.113903	13.169
26	0.826901	1.814	0.192159	7.806	0.112798	13.298
27	0.832408	1.802	0.193124	7.767	0.112883	13.288
28	0.834260	1.798	0.192332	7.799	0.112629	13.318
29	0.832408	1.802	0.195720	7.664	0.115225	13.018
30	0.838926	1.788	0.197212	7.606	0.112688	13.311
MEAN	0.831082	1.8049	0.193123	7.767066	0.113265	13.2432
STD.DV	0.003063	0.006635	0.001699	0.066963	0.000663	0.076952

Continued to page 64

P.S. A figure in parenthesis represents time of measurement in hours.

TABLE 2-5

Laboratory life data on the leakage current and material resistance when subjected to 90 C only

I(72)	R(72)	I(96)	R(96)	I(120)	R(120)	I(144)
4.823151	0.311	6.172839	0.243	7.177033	0.209	8.426966
4.854368	0.309	5.905511	0.254	7.462686	0.201	8.875739
4.716981	0.318	6.122448	0.245	6.976744	0.215	7.853403
4.983388	0.301	5.725190	0.262	6.607929	0.227	7.772020
4.731861	0.317	6.493506	0.231	7.425742	0.202	9.316770
4.983388	0.301	6.276150	0.239	7.537688	0.199	9.493670
5.067567	0.296	6.024096	0.249	6.849315	0.219	7.462686
4.672897	0.321	6.072874	0.247	7.317073	0.205	8.287292
4.559270	0.329	6.493506	0.231	8.720930	0.172	9.036144
4.983388	0.301	6.122448	0.245	6.637168	0.226	7.537688
4.716981	0.318	5.905511	0.254	7.042253	0.213	7.853403
4.807692	0.312	5.725190	0.262	7.246376	0.207	8.287292
4.966887	0.302	6.147540	0.244	7.425742	0.202	9.036144
4.559270	0.329	6.302521	0.238	7.462686	0.201	8.108108
5.208333	0.288	5.859375	0.256	7.537688	0.199	8.620689
5.050505	0.297	5.905511	0.254	7.653061	0.196	9.146341
4.672897	0.321	6.493506	0.231	8.108108	0.185	9.202453
4.966887	0.302	6.072874	0.247	6.880733	0.218	7.978723
4.807692	0.312	6.172839	0.243	6.696428	0.224	7.978723
5.033557	0.298	5.660377	0.265	7.389162	0.203	8.152173
4.854368	0.309	6.276150	0.239	8.426966	0.178	9.803921
4.777070	0.314	5.976095	0.251	7.575757	0.198	9.090909
4.823151	0.311	5.535055	0.271	6.880733	0.218	8.021390
5.033557	0.298	6.198347	0.242	7.211538	0.208	8.064516
4.716981	0.318	6.302521	0.238	8.379888	0.179	9.493670
4.559270	0.329	6.607929	0.227	8.196721	0.183	8.982035
4.672897	0.321	5.905511	0.254	7.575757	0.198	8.287292
5.376344	0.279	6.097560	0.246	7.109004	0.211	7.853403
5.033557	0.298	6.410256	0.234	8.064516	0.186	8.720930
4.731861	0.317	6.578947	0.228	8.720930	0.172	9.202453
4.850706	0.309233	6.105834	0.245666	7.433102	0.2018	8.484162
0.192508	0.012054	0.272715	0.011040	0.581203	0.015138	0.638798

Continued to page 65

TABLE 2-5

Laboratory life data on the leakage current and material resistance when subjected to 90 C only

R(144)	I(168)	R(168)	I(192)	R(192)	I(216)	R(216)
0.178	9.615384	0.156	11.11111	0.135	12.19512	0.123
0.169	10.06711	0.149	11.62790	0.129	12.39669	0.121
0.191	9.554140	0.157	10.48951	0.143	11.62790	0.129
0.193	9.036144	0.166	10.63829	0.141	11.36363	0.132
0.161	10.86956	0.138	11.62790	0.129	13.39285	0.112
0.158	10.20408	0.147	12.39669	0.121	13.04347	0.115
0.201	7.978723	0.188	9.090909	0.165	10.48951	0.143
0.181	10.13513	0.148	12.5	0.12	12.71186	0.118
0.166	10.94890	0.137	12.39669	0.121	12.29508	0.122
0.199	9.868421	0.152	10.48951	0.143	11.36363	0.132
0.191	9.554140	0.157	10.86956	0.138	12.60504	0.119
0.181	8.720930	0.172	10.63829	0.141	12.19512	0.123
0.166	9.615384	0.156	11.62790	0.129	11.36363	0.132
0.185	8.928571	0.168	10.56338	0.142	11.62790	0.129
0.174	10.48951	0.143	11.11111	0.135	12.39669	0.121
0.164	10.86956	0.138	11.62790	0.129	12.71186	0.118
0.163	10.06711	0.149	11.62790	0.129	12.39669	0.121
0.188	9.677419	0.155	10.48951	0.143	11.90476	0.126
0.188	9.036144	0.166	10.48951	0.143	11.19402	0.134
0.184	9.202453	0.163	10.13513	0.148	11.90476	0.126
0.153	10.94890	0.137	11.62790	0.129	12.60504	0.119
0.165	9.677419	0.155	11.19402	0.134	12	0.125
0.187	9.554140	0.157	10.34482	0.145	11.36363	0.132
0.186	9.036144	0.166	11.19402	0.134	12.29508	0.122
0.158	10.86956	0.138	11.62790	0.129	13.88888	0.108
0.167	9.677419	0.155	10.27397	0.146	11.81102	0.127
0.181	9.740259	0.154	11.36363	0.132	12.19512	0.123
0.191	8.426966	0.178	10.56338	0.142	11.81102	0.127
0.172	10.13513	0.148	11.81102	0.127	12.39669	0.121
0.163	10.13513	0.148	11.11111	0.135	12.71186	0.118
0.1768	9.696186	0.1547	11.03752	0.1359	12.10328	0.123933
0.013148	0.745317	0.012201	0.744514	0.009389	0.685078	0.007023

Continued to page 66

TABLE 2-5

Laboratory life data on the leakage current and material resistance when subjected to 90 C only

I(240)	R(240)	I(264)	R(264)	I(288)	R(288)	I(312)
12.82051	0.117	14.15094	0.106	15.30612	0.098	15.95744
13.76146	0.109	17.24137	0.087	18.51851	0.081	19.23076
13.39285	0.112	14.56310	0.103	15.15151	0.099	15.78947
12.39669	0.121	13.39285	0.112	14.15094	0.106	15.15151
13.76146	0.109	15.78947	0.095	16.48351	0.091	17.24137
14.85148	0.101	16.48351	0.091	17.24137	0.087	18.51851
11.36363	0.132	12.39669	0.121	13.15789	0.114	14.15094
14.85148	0.101	16.12903	0.093	16.85393	0.089	18.07228
14.28571	0.105	16.30434	0.092	17.44186	0.086	19.23076
12.19512	0.123	12.82051	0.117	13.63636	0.11	14.15094
14.42307	0.104	16.12903	0.093	17.04545	0.088	18.29268
13.51351	0.111	14.70588	0.102	15.46391	0.097	15.95744
12.5	0.12	13.88888	0.108	14.70588	0.102	15.625
12.60504	0.119	14.56310	0.103	15.46391	0.097	15.95744
13.39285	0.112	14.42307	0.104	14.85148	0.101	15.625
13.76146	0.109	16.30434	0.092	16.85393	0.089	18.51851
13.15789	0.114	14.15094	0.106	14.85148	0.101	15.30612
13.39285	0.112	14.28571	0.105	15.46391	0.097	16.48351
12.29508	0.122	13.15789	0.114	13.76146	0.109	14.70588
13.51351	0.111	14.42307	0.104	15.30612	0.098	15.78947
14.85148	0.101	16.12903	0.093	17.24137	0.087	18.51851
12.93103	0.116	16.30434	0.092	17.04545	0.088	18.51851
12.09677	0.124	12.71186	0.118	13.39285	0.112	13.88888
13.27433	0.113	14.56310	0.103	15.30612	0.098	16.48351
15.46391	0.097	18.07228	0.083	18.51851	0.081	18.98734
14.42307	0.104	16.30434	0.092	18.29268	0.082	19.23076
13.27433	0.113	14.42307	0.104	15.30612	0.098	16.48351
12.71186	0.118	13.88888	0.108	14.70588	0.102	15.15151
13.27433	0.113	14.15094	0.106	15.46391	0.097	16.12903
15.30612	0.098	17.64705	0.085	18.51851	0.081	19.73684
13.38887	0.112033	14.84168	0.101066	15.70132	0.095533	16.58680
0.991591	0.008231	1.465761	0.009818	1.541906	0.009261	1.724280

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TABLE 2-5

Laboratory life data on the leakage current and material resistance when subjected to 90 C only

R(312)	I(336)	R(336)	I(360)	R(360)	I(384)	R(384)
0.094	17.04545	0.088	18.07228	0.083	18.98734	0.079
0.078	20	0.075	20.83333	0.072	22.05882	0.068
0.095	15.625	0.096	16.85393	0.089	18.29268	0.082
0.099	15.95744	0.094	17.24137	0.087	18.51851	0.081
0.087	18.29268	0.082	19.23076	0.078	20.54794	0.073
0.081	19.23076	0.078	21.12676	0.071	23.07692	0.065
0.106	14.70588	0.102	15.625	0.096	17.64705	0.085
0.083	19.73684	0.076	21.73913	0.069	24.59016	0.061
0.078	21.12676	0.071	23.80952	0.063	28.30188	0.053
0.106	15.15151	0.099	16.85393	0.089	18.51851	0.081
0.082	18.98734	0.079	21.12676	0.071	24.59016	0.061
0.094	16.48351	0.091	17.44186	0.086	19.23076	0.078
0.096	16.48351	0.091	17.44186	0.086	19.23076	0.078
0.094	16.85393	0.089	18.07228	0.083	19.73684	0.076
0.096	16.48351	0.091	17.04545	0.088	18.51851	0.081
0.081	19.48051	0.077	21.12676	0.071	23.07692	0.065
0.098	16.12903	0.093	17.04545	0.088	20.27027	0.074
0.091	17.24137	0.087	18.07228	0.083	19.73684	0.076
0.102	15.625	0.096	16.12903	0.093	17.85714	0.084
0.095	16.48351	0.091	17.85714	0.084	18.98734	0.079
0.081	19.23076	0.078	20.54794	0.073	22.05882	0.068
0.081	19.48051	0.077	21.12676	0.071	23.07692	0.065
0.108	14.85148	0.101	15.78947	0.095	17.24137	0.087
0.091	17.04545	0.088	18.51851	0.081	20.27027	0.074
0.079	20	0.075	21.73913	0.069	25.42372	0.059
0.078	20	0.075	21.12676	0.071	23.07692	0.065
0.091	17.44186	0.086	18.51851	0.081	21.12676	0.071
0.099	16.48351	0.091	17.44186	0.086	19.48051	0.077
0.093	17.24137	0.087	18.07228	0.083	20	0.075
0.076	21.12676	0.071	23.07692	0.065	25.86206	0.058
0.090433	17.47572	0.085833	18.71101	0.080166	20.65167	0.072633
0.009268	1.858820	0.008896	2.202341	0.008996	2.738531	0.008776

Continued to page 68

TABLE 2-5

Laboratory life data on the leakage current and material resistance when subjected to 90 C only

I(408)	R(408)	I(432)	R(432)	I(480)	R(480)
20.83333	0.072	23.07692	0.065	24.19354	0.062
23.80952	0.063	25.42372	0.059	26.78571	0.056
19.23076	0.078	19.73684	0.076	20.83333	0.072
19.73684	0.076	21.12676	0.071	22.38805	0.067
22.05882	0.068	24.19354	0.062	25.86206	0.058
25.42372	0.059	29.41176	0.051	31.91489	0.047
18.51851	0.081	19.23076	0.078	20.54794	0.073
27.27272	0.055	28.84615	0.052	31.91489	0.047
31.25	0.048	36.58536	0.041	40.54054	0.037
19.48051	0.077	20.83333	0.072	22.72727	0.066
26.78571	0.056	29.41176	0.051	31.25	0.048
21.73913	0.069	23.4375	0.064	24.59016	0.061
21.12676	0.071	22.05882	0.068	23.4375	0.064
22.38805	0.067	23.80952	0.063	25.86206	0.058
20	0.075	21.12676	0.071	22.72727	0.066
25.42372	0.059	32.60869	0.046	35.71428	0.042
22.05882	0.068	23.07692	0.065	24.19354	0.062
22.05882	0.068	23.4375	0.064	24.59016	0.061
19.48051	0.077	21.12676	0.071	22.72727	0.066
20.54794	0.073	23.07692	0.065	24.59016	0.061
23.4375	0.064	26.31578	0.057	28.84615	0.052
25.42372	0.059	27.27272	0.055	29.41176	0.051
18.51851	0.081	20	0.075	21.73913	0.069
21.73913	0.069	23.80952	0.063	27.27272	0.055
31.91489	0.047	38.46153	0.039	41.66666	0.036
26.78571	0.056	30	0.05	32.60869	0.046
23.07692	0.065	26.78571	0.056	31.91489	0.047
22.05882	0.068	24.19354	0.062	27.77777	0.054
22.05882	0.068	26.31578	0.057	31.25	0.048
28.30188	0.053	31.91489	0.047	34.88372	0.043
22.61306	0.066333	24.77973	0.060533	26.86567	0.055833
3.472864	0.009126	4.759798	0.010088	5.470950	0.009993

TABLE 2-6A

Per unit material resistance subjected to only thermal stress

Time in Hour	R(pu) at 100C
0	1
24	6.745087
48	10.02919
72	0.154969
96	0.122964
120	0.104997
144	0.092083
168	0.079169
192	0.073554
216	0.064008
240	0.060078
264	0.053902
288	0.051656
312	0.049410
336	0.047725
360	0.045480
384	0.043795
408	0.042672
432	0.040988
456	0.039865
480	0.037619
504	0.037057

P.S. This table was determined from Table 2-6.

TABLE 2-6

Laboratory life data on the leakage current and material resistance when subjected to 100C only

SAMPLE#	I(0)	R(0)	I(24)	R(24)	I(48)	R(48)
1	0.839865	1.786	0.124854	12.014	0.083883	17.882
2	0.850822	1.763	0.124802	12.019	0.083967	17.864
3	0.855188	1.754	0.124947	12.005	0.084184	17.818
4	0.834260	1.798	0.125135	11.987	0.084043	17.848
5	0.844594	1.776	0.123619	12.134	0.083981	17.861
6	0.842223	1.781	0.123680	12.128	0.084019	17.853
7	0.840807	1.784	0.126188	11.887	0.083850	17.889
8	0.836120	1.794	0.124781	12.021	0.084426	17.767
9	0.844594	1.776	0.124947	12.005	0.084279	17.798
10	0.840807	1.784	0.124823	12.017	0.084236	17.807
11	0.842223	1.781	0.125031	11.997	0.084043	17.848
12	0.834260	1.798	0.125083	11.992	0.083878	17.883
13	0.843170	1.779	0.124854	12.014	0.084043	17.848
14	0.844594	1.776	0.124875	12.012	0.083794	17.901
15	0.840807	1.784	0.124812	12.018	0.083808	17.898
16	0.832408	1.802	0.126518	11.856	0.083878	17.883
17	0.838457	1.789	0.124916	12.008	0.083444	17.976
18	0.845070	1.775	0.124875	12.012	0.084683	17.713
19	0.839395	1.787	0.126432	11.864	0.083361	17.994
20	0.838926	1.788	0.125062	11.994	0.083780	17.904
21	0.840807	1.784	0.125198	11.981	0.083850	17.889
22	0.840807	1.784	0.124885	12.011	0.084019	17.853
23	0.844594	1.776	0.124843	12.015	0.083878	17.883
24	0.842223	1.781	0.125250	11.976	0.083784	17.903
25	0.837053	1.792	0.125052	11.995	0.084052	17.846
26	0.837988	1.79	0.125114	11.989	0.084335	17.786
27	0.840807	1.784	0.123619	12.134	0.083761	17.908
28	0.848416	1.768	0.125062	11.994	0.083859	17.887
29	0.848896	1.767	0.121684	12.327	0.083826	17.894
30	0.844594	1.776	0.124885	12.011	0.084321	17.789
MEAN	0.841798	1.7819	0.124855	12.0139	0.083975	17.86243
STD.DV	0.004875	0.010290	0.000859	0.083566	0.000266	0.056574

Continued to page 71

P.A. A figure in parenthesis represents time of measurement in hour.

TABLE 2-6

Laboratory life data on the leakage current and material resistance when subjected to 100C only

I(72)	R(72)	I(96)	R(96)	I(120)	R(120)
5.226480	0.287	6.849315	0.219	7.936507	0.189
5.395683	0.278	6.578947	0.228	8.474576	0.177
5.597014	0.268	6.880733	0.218	8.196721	0.183
5.016722	0.299	6.880733	0.218	7.853403	0.191
5.226480	0.287	7.109004	0.211	8.021390	0.187
5.454545	0.275	7.177033	0.209	8.379888	0.179
5.639097	0.266	7.281553	0.206	9.036144	0.166
5.813953	0.258	7.462686	0.201	7.772020	0.193
5.244755	0.286	6.726457	0.223	8.522727	0.176
5.244755	0.286	6.787330	0.221	9.090909	0.165
5.836575	0.257	6.849315	0.219	8.064516	0.186
5.415162	0.277	6.787330	0.221	9.433962	0.159
5.681818	0.264	7.211538	0.208	7.978723	0.188
5.639097	0.266	6.880733	0.218	7.731958	0.194
5.928853	0.253	6.578947	0.228	8.522727	0.176
5.791505	0.259	6.493506	0.231	7.692307	0.195
5.617977	0.267	7.211538	0.208	8.152173	0.184
5.434782	0.276	6.550218	0.229	7.614213	0.197
5.319148	0.282	7.317073	0.205	8.426966	0.178
5.617977	0.267	6.787330	0.221	7.653061	0.196
5.813953	0.258	6.787330	0.221	7.731958	0.194
5.226480	0.287	6.302521	0.238	7.317073	0.205
5.244755	0.286	6.465517	0.232	7.211538	0.208
5.434782	0.276	6.607929	0.227	7.575757	0.198
5.119453	0.293	6.493506	0.231	7.281553	0.206
5.016722	0.299	7.352941	0.204	7.978723	0.188
5.474452	0.274	6.666666	0.225	7.614213	0.197
5.208333	0.288	6.465517	0.232	8.021390	0.187
5.033557	0.298	7.109004	0.211	7.978723	0.188
5.434782	0.276	6.787330	0.221	8.021390	0.187
5.426263	0.276433	6.834750	0.219466	8.011393	0.187233
0.256574	0.013006	0.302845	0.009601	0.514777	0.011502

Continued to page 72

TABLE 2-6

Laboratory life data on the leakage current and material resistance when subjected to 100C only

I(144)	R(144)	I(168)	R(168)	I(192)	R(192)
8.982035	0.167	10.34482	0.145	11.11111	0.135
9.202453	0.163	10.63829	0.141	11.02941	0.136
8.522727	0.176	10.86956	0.138	11.81102	0.127
9.146341	0.164	10.27397	0.146	10.86956	0.138
8.720930	0.172	10.63829	0.141	10.94890	0.137
9.433962	0.159	9.933774	0.151	11.62790	0.129
9.615384	0.156	10.86956	0.138	11.81102	0.127
8.152173	0.184	9.554140	0.157	10.48951	0.143
8.982035	0.167	10.86956	0.138	11.45038	0.131
9.677419	0.155	10.86956	0.138	11.71875	0.128
9.740259	0.154	10.86956	0.138	11.27819	0.133
9.933774	0.151	11.27819	0.133	11.71875	0.128
9.202453	0.163	10.94890	0.137	11.81102	0.127
9.202453	0.163	10.79136	0.139	11.36363	0.132
9.933774	0.151	10.86956	0.138	11.71875	0.128
8.620689	0.174	10.94890	0.137	11.71875	0.128
9.493670	0.158	11.11111	0.135	11.71875	0.128
9.036144	0.166	11.02941	0.136	11.71875	0.128
9.933774	0.151	11.27819	0.133	12.19512	0.123
8.522727	0.176	10.20408	0.147	12.29508	0.122
8.670520	0.173	10.06711	0.149	10.94890	0.137
8.620689	0.174	10.63829	0.141	11.45038	0.131
8.287292	0.181	9.554140	0.157	10.48951	0.143
8.982035	0.167	10.34482	0.145	10.94890	0.137
8.152173	0.184	9.036144	0.166	9.868421	0.152
9.036144	0.166	10.86956	0.138	11.71875	0.128
9.202453	0.163	10.63829	0.141	11.27819	0.133
9.493670	0.158	11.11111	0.135	11.71875	0.128
9.433962	0.159	11.11111	0.135	11.71875	0.128
9.740259	0.154	10.94890	0.137	11.36363	0.132
9.092746	0.164966	10.58823	0.141666	11.37225	0.1319
0.517290	0.009499	0.533855	0.007652	0.518331	0.0063

Continued to page 73

TABLE 2-6

Laboratory life data on the leakage current and material resistance when subjected to 100C only

I(216)	R(216)	I(240)	R(240)	I(264)	R(264)
12.93103	0.116	13.76146	0.109	15.625	0.096
12.19512	0.123	12.93103	0.116	15.78947	0.095
13.76146	0.109	14.28571	0.105	15.95744	0.094
11.81102	0.127	12.82051	0.117	13.88888	0.108
13.15789	0.114	14.42307	0.104	16.48351	0.091
13.39285	0.112	14.28571	0.105	15.30612	0.098
12.71186	0.118	13.39285	0.112	15.95744	0.094
12.39669	0.121	13.15789	0.114	15.15151	0.099
12	0.125	13.27433	0.113	14.42307	0.104
13.39285	0.112	14.15094	0.106	15.46391	0.097
13.51351	0.111	14.56310	0.103	15.625	0.096
13.76146	0.109	14.85148	0.101	17.04545	0.088
13.88888	0.108	14.70588	0.102	16.48351	0.091
12.93103	0.116	14.01869	0.107	16.12903	0.093
14.70588	0.102	15.30612	0.098	16.48351	0.091
13.76146	0.109	16.12903	0.093	16.85393	0.089
13.27433	0.113	14.28571	0.105	15.15151	0.099
13.39285	0.112	14.01869	0.107	15.15151	0.099
14.42307	0.104	15.78947	0.095	16.48351	0.091
13.88888	0.108	14.85148	0.101	15.625	0.096
13.04347	0.115	13.39285	0.112	14.42307	0.104
12.60504	0.119	13.27433	0.113	14.28571	0.105
12.71186	0.118	13.15789	0.114	14.70588	0.102
12.39669	0.121	12.82051	0.117	14.15094	0.106
12.29508	0.122	13.15789	0.114	14.56310	0.103
13.88888	0.108	14.56310	0.103	15.625	0.096
13.76146	0.109	14.56310	0.103	16.12903	0.093
14.42307	0.104	15.30612	0.098	16.85393	0.089
13.27433	0.113	13.88888	0.108	15.30612	0.098
12.29508	0.122	12.82051	0.117	14.85148	0.101
13.15789	0.114	14.00996	0.107066	15.48520	0.096866
0.741035	0.006423	0.888269	0.006642	0.852994	0.005371

Continued to page 74

TABLE 2-6

Laboratory life data on the leakage current and material resistance when subjected to 100C only

I(288)	R(288)	I(312)	R(312)	I(336)	R(336)
16.30434	0.092	17.24137	0.087	18.51851	0.081
16.48351	0.091	17.64705	0.085	19.23076	0.078
16.85393	0.089	18.29268	0.082	19.73684	0.076
14.56310	0.103	15.95744	0.094	17.24137	0.087
18.75	0.08	19.73684	0.076	21.12676	0.071
16.12903	0.093	17.24137	0.087	19.23076	0.078
16.48351	0.091	17.85714	0.084	18.51851	0.081
17.04545	0.088	18.51851	0.081	19.73684	0.076
16.48351	0.091	18.29268	0.082	19.23076	0.078
17.64705	0.085	20.27027	0.074	21.73913	0.069
17.24137	0.087	18.98734	0.079	20.54794	0.073
18.98734	0.079	21.12676	0.071	22.05882	0.068
19.23076	0.078	21.12676	0.071	22.72727	0.066
18.51851	0.081	19.73684	0.076	21.12676	0.071
18.51851	0.081	20.27027	0.074	22.05882	0.068
19.48051	0.077	21.73913	0.069	23.4375	0.064
17.24137	0.087	18.98734	0.079	20.83333	0.072
17.64705	0.085	18.51851	0.081	19.73684	0.076
17.85714	0.084	19.73684	0.076	21.12676	0.071
17.24137	0.087	18.75	0.08	19.48051	0.077
15.95744	0.094	18.51851	0.081	19.48051	0.077
16.48351	0.091	17.44186	0.086	22.05882	0.068
16.48351	0.091	18.07228	0.083	21.73913	0.069
16.85393	0.089	19.23076	0.078	21.12676	0.071
17.44186	0.086	19.73684	0.076	22.05882	0.068
17.04545	0.088	19.23076	0.078	20.54794	0.073
17.44186	0.086	20	0.075	22.38805	0.067
18.07228	0.083	19.48051	0.077	21.12676	0.071
17.24137	0.087	18.51851	0.081	19.23076	0.078
16.85393	0.089	17.85714	0.084	19.23076	0.078
17.22158	0.0871	18.85211	0.079566	20.44525	0.073366
1.053769	0.005356	1.269282	0.005370	1.441159	0.005237

Continued to page 75

TABLE 2-6

Laboratory life data on the leakage current and material resistance when subjected to 100C only

I(360)	R(360)	I(384)	R(384)	I(408)	R(408)
19.23076	0.078	19.73684	0.076	20.83333	0.072
20.83333	0.072	21.42857	0.07	22.05882	0.068
20.83333	0.072	22.72727	0.066	23.80952	0.063
19.23076	0.078	20.54794	0.073	21.12676	0.071
23.07692	0.065	24.59016	0.061	26.78571	0.056
19.73684	0.076	21.12676	0.071	23.80952	0.063
19.48051	0.077	21.12676	0.071	22.38805	0.067
20.54794	0.073	22.38805	0.067	23.4375	0.064
20.54794	0.073	22.05882	0.068	24.59016	0.061
24.19354	0.062	26.78571	0.056	29.41176	0.051
22.38805	0.067	23.80952	0.063	27.27272	0.055
24.59016	0.061	26.31578	0.057	28.84615	0.052
25.42372	0.059	27.77777	0.054	29.41176	0.051
22.05882	0.068	23.07692	0.065	25.86206	0.058
23.80952	0.063	26.31578	0.057	28.84615	0.052
26.78571	0.056	27.77777	0.054	30	0.05
22.72727	0.066	23.4375	0.064	25.86206	0.058
20.83333	0.072	22.38805	0.067	27.77777	0.054
22.72727	0.066	23.80952	0.063	25.86206	0.058
20.54794	0.073	22.38805	0.067	24.19354	0.062
20.83333	0.072	22.05882	0.068	24.19354	0.062
24.59016	0.061	26.31578	0.057	28.30188	0.053
22.72727	0.066	24.19354	0.062	27.77777	0.054
23.07692	0.065	24.59016	0.061	27.77777	0.054
25.42372	0.059	27.77777	0.054	30.61224	0.049
22.72727	0.066	24.19354	0.062	26.31578	0.057
24.19354	0.062	25.86206	0.058	28.30188	0.053
23.07692	0.065	24.19354	0.062	26.31578	0.057
20.83333	0.072	22.38805	0.067	23.4375	0.064
20	0.075	21.12676	0.071	22.38805	0.067
22.05882	0.068	23.53556	0.063733	25.62642	0.058533
2.005621	0.006038	2.245226	0.005938	2.723033	0.006349

Continued to page 76

TABLE 2-6

Laboratory life data on the leakage current and material resistance when subjected to 100C only

I(432)	R(432)	I(480)	R(480)
22.38805	0.067	23.80952	0.063
23.07692	0.065	24.59016	0.061
26.31578	0.057	27.77777	0.054
22.72727	0.066	24.59016	0.061
29.41176	0.051	32.60869	0.046
26.78571	0.056	28.30188	0.053
25.86206	0.058	28.84615	0.052
25.42372	0.059	26.78571	0.056
26.78571	0.056	28.84615	0.052
31.25	0.048	32.60869	0.046
28.84615	0.052	31.25	0.048
31.91489	0.047	34.09090	0.044
31.91489	0.047	33.33333	0.045
28.30188	0.053	31.91489	0.047
31.91489	0.047	34.09090	0.044
30.61224	0.049	32.60869	0.046
27.77777	0.054	29.41176	0.051
28.30188	0.053	31.25	0.048
28.30188	0.053	31.91489	0.047
26.78571	0.056	30.61224	0.049
26.31578	0.057	28.30188	0.053
31.25	0.048	33.33333	0.045
31.91489	0.047	33.33333	0.045
32.60869	0.046	34.88372	0.043
32.60869	0.046	34.09090	0.044
26.78571	0.056	28.84615	0.052
31.25	0.048	33.33333	0.045
28.30188	0.053	30.61224	0.049
24.19354	0.062	26.31578	0.057
23.07692	0.065	24.59016	0.061
27.74352	0.054066	29.86065	0.050233
3.109962	0.006239	3.233255	0.005760

TABLE 3A

Per unit resistance when material is subjected to thermal and electrical stress.

Time in Hours	R(pu)at 600V/80C
0	1
12	1.796
24	2.64
36	3.67
48	2.732
60	0.233
72	0.159
84	0.13
96	0.115
108	0.104
120	0.097
144	0.088
168	0.079
180	0.074
192	0.07
216	0.061

P.S. This table was derived from Table 3-1.

TABLE 3-1

Laboratory life data on the leakage current and material resistance when subjected to 600 Vac and 80 C

SAMPLE#	I(0)	R(0)	I(12)	R(12)	I(24)	R(24)
1	0.565184	2.654	0.331272	4.528	0.228798	6.556
2	0.565824	2.651	0.329163	4.557	0.228554	6.563
3	0.574052	2.613	0.327296	4.583	0.228206	6.573
4	0.589854	2.543	0.331345	4.527	0.226654	6.618
5	0.610997	2.455	0.332889	4.506	0.230556	6.506
6	0.616016	2.435	0.329236	4.556	0.221533	6.771
7	0.608025	2.467	0.326370	4.596	0.227169	6.603
8	0.599280	2.503	0.331491	4.525	0.227514	6.593
9	0.598086	2.508	0.336549	4.457	0.231196	6.488
10	0.612995	2.447	0.332446	4.512	0.230167	6.517
11	0.616776	2.432	0.336096	4.463	0.222419	6.744
12	0.583430	2.571	0.318945	4.703	0.223181	6.721
13	0.615763	2.436	0.326370	4.596	0.227066	6.606
14	0.579822	2.587	0.329091	4.558	0.224282	6.688
15	0.585023	2.564	0.323624	4.635	0.227998	6.579
16	0.603136	2.487	0.324324	4.625	0.226483	6.623
17	0.576479	2.602	0.320307	4.683	0.234045	6.409
18	0.598802	2.505	0.326157	4.599	0.226723	6.616
19	0.590318	2.541	0.348351	4.306	0.220490	6.803
20	0.612745	2.448	0.324534	4.622	0.223147	6.722
21	0.622665	2.409	0.325874	4.603	0.222717	6.735
22	0.612995	2.447	0.332225	4.515	0.223413	6.714
23	0.611496	2.453	0.326299	4.597	0.221434	6.774
24	0.594766	2.522	0.334224	4.488	0.229182	6.545
25	0.612494	2.449	0.324044	4.629	0.227066	6.606
26	0.603378	2.486	0.332963	4.505	0.223147	6.722
27	0.598563	2.506	0.324114	4.628	0.227169	6.603
28	0.587314	2.554	0.314663	4.767	0.225937	6.639
29	0.605815	2.476	0.351452	4.268	0.223313	6.717
30	0.578927	2.591	0.339136	4.423	0.227686	6.588
MEAN	0.597701	2.5114	0.332520	4.511	0.226241	6.6314
STD.DV	0.015832	0.067393	0.007560	0.102442	0.003207	0.093827

Continued to page 79

P.S. A figure in parenthesis represents time of measurement is hours.

TABLE 3-1

Laboratory life data on the leakage current and material resistance when subjected to 600 Vac and 80 C

I(36)	R(36)	I(48)	R(48)	I(60)	R(60)	I(72)
0.162460	9.233	0.221434	6.774	2.572898	0.583	3.759398
0.165034	9.089	0.217612	6.893	2.590673	0.579	3.875968
0.163238	9.189	0.217991	6.881	2.617801	0.573	3.722084
0.166463	9.011	0.217233	6.905	2.546689	0.589	3.649635
0.161672	9.278	0.213918	7.012	2.551020	0.588	3.865979
0.167822	8.938	0.216231	6.937	2.617801	0.573	3.787878
0.166777	8.994	0.214530	6.992	2.487562	0.603	3.768844
0.167672	8.946	0.214776	6.984	2.454991	0.611	3.649635
0.159778	9.388	0.217643	6.892	2.508361	0.598	3.623188
0.165636	9.056	0.214224	7.002	2.551020	0.588	3.787878
0.162284	9.243	0.220815	6.793	2.529510	0.593	3.712871
0.161186	9.306	0.217928	6.883	2.555366	0.587	3.685503
0.160754	9.331	0.220848	6.792	2.529510	0.593	3.640776
0.159829	9.385	0.219330	6.839	2.483443	0.604	3.759398
0.160754	9.331	0.218213	6.874	2.595155	0.578	3.731343
0.160136	9.367	0.217296	6.903	2.487562	0.603	3.512880
0.160170	9.365	0.220490	6.803	2.568493	0.584	3.926701
0.159540	9.402	0.217928	6.883	2.645502	0.567	3.865979
0.161099	9.311	0.221010	6.787	2.631578	0.57	3.694581
0.161568	9.284	0.218213	6.874	2.551020	0.588	3.731343
0.160651	9.337	0.217612	6.893	2.533783	0.592	3.875968
0.165837	9.045	0.219490	6.834	2.564102	0.585	3.768844
0.160754	9.331	0.217296	6.903	2.595155	0.578	3.554502
0.166057	9.033	0.223747	6.704	2.572898	0.583	3.865979
0.161220	9.304	0.221500	6.772	2.577319	0.582	3.759398
0.163434	9.178	0.221173	6.782	2.572898	0.583	3.787878
0.162636	9.223	0.214500	6.993	2.564102	0.585	3.703703
0.162937	9.206	0.227755	6.586	2.683363	0.559	3.731343
0.163256	9.188	0.219555	6.832	2.622377	0.572	3.886010
0.162478	9.232	0.217896	6.884	2.479338	0.605	3.90625
0.162734	9.217466	0.218606	6.862866	2.560309	0.585866	3.753058
0.002469	0.138523	0.002942	0.091480	0.052290	0.011963	0.101061

Continued to page 80

TABLE 3-1

Laboratory life data on the leakage current and material resistance when subjected to 600 Vac and 80 C

R(72)	I(84)	R(84)	I(96)	R(96)	I(108)	R(108)
0.399	4.587155	0.327	5.016722	0.299	5.494505	0.273
0.387	4.424778	0.339	5.033557	0.298	5.395683	0.278
0.403	4.716981	0.318	5.244755	0.286	5.905511	0.254
0.411	4.615384	0.325	5.434782	0.276	6.048387	0.248
0.388	4.716981	0.318	5.208333	0.282	6.198347	0.242
0.396	4.615384	0.325	5.263157	0.285	6.048387	0.248
0.398	4.477611	0.335	4.983388	0.301	5.281690	0.284
0.411	4.658385	0.322	5.033557	0.298	5.882352	0.255
0.414	4.559270	0.329	5.300353	0.283	6.122448	0.245
0.396	4.601226	0.326	5.415162	0.277	6.072874	0.247
0.404	4.518072	0.332	5.067567	0.296	5.928853	0.253
0.407	4.573170	0.328	5.208333	0.288	6.198347	0.242
0.412	4.746835	0.316	5.263157	0.285	6.097560	0.246
0.399	4.464285	0.336	5.067567	0.296	5.905511	0.254
0.402	4.731861	0.317	5.319148	0.282	5.952380	0.252
0.427	4.518072	0.332	4.950495	0.303	5.190311	0.289
0.382	4.573170	0.328	5.033557	0.298	5.395683	0.278
0.388	4.531722	0.331	5.244755	0.286	5.859375	0.256
0.406	4.587155	0.327	5.395683	0.278	5.905511	0.254
0.402	4.601226	0.326	5.067567	0.296	5.338078	0.281
0.387	4.658385	0.322	5.454545	0.275	5.747126	0.261
0.398	4.615384	0.325	5.208333	0.288	5.434782	0.276
0.422	4.716981	0.318	5.319148	0.282	5.747126	0.261
0.388	4.451038	0.337	5.208333	0.288	5.813953	0.258
0.399	4.573170	0.328	5.172413	0.29	5.338078	0.281
0.396	4.658385	0.322	5.067567	0.296	5.859375	0.256
0.405	4.518072	0.332	5.208333	0.288	5.514705	0.272
0.402	4.601226	0.326	5.016722	0.299	5.244755	0.286
0.386	4.716981	0.318	5.395683	0.278	5.703422	0.263
0.384	4.672897	0.321	5.136986	0.292	5.747126	0.261
0.399966	4.598405	0.3262	5.191322	0.288966	5.729564	0.2618
0.010873	0.086636	0.006161	0.144416	0.008117	0.301928	0.014041

Continued to page 81

TABLE 3-1

Laboratory life data on the leakage current and material resistance when subjected to 600 Vac and 80 C

I(120)	R(120)	I(144)	R(144)	I(168)	R(168)	I(180)
6.072874	0.247	6.880733	0.218	7.978723	0.188	8.474576
6.122448	0.245	6.666666	0.225	7.109004	0.211	7.425742
6.172839	0.243	6.756756	0.222	7.211538	0.208	8.064516
6.382978	0.235	6.976744	0.215	7.8125	0.192	8.287292
6.493506	0.231	6.849315	0.219	7.653061	0.196	8.152173
6.465517	0.232	6.944444	0.216	7.317073	0.205	7.772020
5.597014	0.268	6.122448	0.245	6.880733	0.218	7.575757
6.437768	0.233	6.912442	0.217	7.281553	0.206	7.978723
6.382978	0.235	6.944444	0.216	7.575757	0.198	7.936507
6.465517	0.232	7.042253	0.213	7.317073	0.205	7.853403
6.172839	0.243	6.787330	0.221	7.731958	0.194	7.978723
6.437768	0.233	6.880733	0.218	7.936507	0.189	8.474576
6.382978	0.235	6.880733	0.218	7.653061	0.196	8.196721
6.276150	0.239	6.944444	0.216	7.772020	0.193	8.287292
6.172839	0.243	6.607929	0.227	7.653061	0.196	8.379888
5.576208	0.269	6.696428	0.224	7.389162	0.203	7.936507
5.905511	0.254	6.578947	0.228	7.246376	0.207	8.152173
6.355932	0.236	6.756756	0.222	7.075471	0.212	7.537688
6.072874	0.247	6.912442	0.217	7.389162	0.203	8.196721
5.859375	0.256	6.696428	0.224	7.211538	0.208	7.772020
6.198347	0.242	6.880733	0.218	8.196721	0.183	8.620689
6.147540	0.244	6.976744	0.215	8.064516	0.186	8.670520
6.302521	0.238	6.912442	0.217	7.772020	0.193	8.241758
6.172839	0.243	6.696428	0.224	7.653061	0.196	8.241758
5.859375	0.256	6.329113	0.237	7.537688	0.199	8.196721
6.355932	0.236	7.042253	0.213	7.772020	0.193	8.108108
6.122448	0.245	7.075471	0.212	8.021390	0.187	8.571428
6.048387	0.248	6.818181	0.22	7.978723	0.188	8.426966
6.097560	0.246	6.666666	0.225	7.075471	0.212	7.653061
6.172839	0.243	6.756756	0.222	7.575757	0.198	8.108108
6.176123	0.243233	6.799773	0.2208	7.561423	0.198766	8.096437
0.234111	0.009576	0.202085	0.006886	0.334588	0.008853	0.317895

Continued to page 82

TABLE 3-1

Laboratory life data on the leakage current and material resistance when subjected to 600 Vac and 80 C

R(180)	I(192)	R(192)	I(216)	R(216)
0.177	9.146341	0.164	10.86956	0.138
0.202	7.8125	0.192	9.036144	0.166
0.186	8.670520	0.173	9.493670	0.158
0.181	8.522727	0.176	10.06711	0.149
0.184	8.571428	0.175	10.41666	0.144
0.193	8.108108	0.185	9.493670	0.158
0.198	7.978723	0.188	9.036144	0.166
0.188	8.720930	0.172	9.316770	0.161
0.189	8.426966	0.178	9.803921	0.153
0.191	8.108108	0.185	9.036144	0.166
0.188	8.426966	0.178	9.740259	0.154
0.177	9.259259	0.162	10.86956	0.138
0.183	8.571428	0.175	9.433962	0.159
0.181	8.720930	0.172	9.493670	0.158
0.179	9.259259	0.162	10.13513	0.148
0.189	8.426966	0.178	9.677419	0.155
0.184	8.426966	0.178	9.615384	0.156
0.199	8.108108	0.185	9.146341	0.164
0.183	8.771929	0.171	9.740259	0.154
0.193	8.196721	0.183	9.803921	0.153
0.174	9.146341	0.164	10.56338	0.142
0.173	9.202453	0.163	10.13513	0.148
0.182	8.571428	0.175	9.868421	0.152
0.182	8.720930	0.172	9.615384	0.156
0.183	8.571428	0.175	9.615384	0.156
0.185	8.426966	0.178	9.803921	0.153
0.175	9.036144	0.166	10.27397	0.146
0.178	8.928571	0.168	10.06711	0.149
0.196	8.152173	0.184	9.259259	0.162
0.185	8.571428	0.175	9.868421	0.152
0.185266	8.568164	0.175066	9.752925	0.1538
0.007370	0.385328	0.007489	0.485776	0.007489

TABLE 4A

Per unit resistance when material is subjecte to thermal and electrical stress.

Time in Hours	R(pu)at 700V/80C
0	1
12	1.913
24	2.847
36	3.961
48	1.15
60	0.218
72	0.152
84	0.127
96	0.108
108	0.101
120	0.091
144	0.081
168	0.07
180	0.064
192	0.059

P.S. This table was derived from Table 4-1.

TABLE 4-1

Laboratory life data on the leakage current and material resistance when subjected to 700 Vac and 80 c

SAMPLE#	I(0)	R(0)	I(12)	R(12)	I(24)	R(24)
1	0.585251	2.563	0.306748	4.89	0.207583	7.226
2	0.603136	2.487	0.298388	5.027	0.213128	7.038
3	0.585023	2.564	0.309405	4.848	0.217928	6.883
4	0.600480	2.498	0.301023	4.983	0.204582	7.332
5	0.589854	2.543	0.307251	4.882	0.202675	7.401
6	0.612745	2.448	0.305748	4.906	0.204387	7.339
7	0.574272	2.612	0.298566	5.024	0.216700	6.922
8	0.591949	2.534	0.304383	4.928	0.199946	7.502
9	0.605815	2.476	0.305935	4.903	0.200160	7.494
10	0.588466	2.549	0.307377	4.88	0.201018	7.462
11	0.585480	2.562	0.312304	4.803	0.210911	7.112
12	0.576701	2.601	0.306560	4.893	0.213523	7.025
13	0.598563	2.506	0.300661	4.989	0.216888	6.916
14	0.597371	2.511	0.312956	4.793	0.213492	7.026
15	0.590783	2.539	0.317931	4.718	0.202647	7.402
16	0.603136	2.487	0.299520	5.008	0.217612	6.893
17	0.580720	2.583	0.312825	4.795	0.216013	6.944
18	0.576036	2.604	0.312304	4.803	0.206839	7.252
19	0.613246	2.446	0.337761	4.441	0.212947	7.044
20	0.590783	2.539	0.301446	4.976	0.199362	7.524
21	0.576258	2.603	0.306560	4.893	0.205620	7.295
22	0.576701	2.601	0.299820	5.003	0.204582	7.332
23	0.608025	2.467	0.306560	4.893	0.202812	7.396
24	0.580945	2.582	0.331345	4.527	0.208188	7.205
25	0.591249	2.537	0.305872	4.904	0.213159	7.037
26	0.576258	2.603	0.326512	4.594	0.214776	6.984
27	0.612745	2.448	0.326157	4.599	0.198438	7.559
28	0.608025	2.467	0.333111	4.503	0.211118	7.105
29	0.595710	2.518	0.309405	4.848	0.205535	7.298
30	0.599041	2.504	0.293140	5.117	0.204498	7.335
MEAN	0.592492	2.532733	0.309919	4.8457	0.208236	7.209433
STD.DV	0.012116	0.051669	0.010851	0.163940	0.006048	0.209062

Continued to page 85

P.S. A figure in parenthesis represents time of measurement is hours.

TABLE 4-1

Laboratory life data on the leakage current and material resistance when subjected to 700 Vac and 80 c

I(36)	R(36)	I(48)	R(48)	I(60)	R(60)	I(72)
0.143650	10.442	0.502008	2.988	2.712477	0.553	4.032258
0.140409	10.683	0.492772	3.044	2.717391	0.552	3.968253
0.149491	10.034	0.480615	3.121	2.742230	0.547	3.968253
0.148338	10.112	0.502344	2.986	2.835538	0.529	3.937007
0.150799	9.947	0.518134	2.895	2.664298	0.563	3.816793
0.150996	9.934	0.501169	2.993	2.788104	0.538	3.916449
0.153029	9.802	0.499334	3.004	2.707581	0.554	3.90625
0.149328	10.045	0.498007	3.012	2.617801	0.573	3.731343
0.150120	9.992	0.502176	2.987	2.737226	0.548	3.937007
0.151545	9.898	0.518134	2.895	2.712477	0.553	3.865979
0.149670	10.022	0.483247	3.104	2.568493	0.584	3.703703
0.148265	10.117	0.490837	3.056	2.798507	0.536	3.916449
0.150105	9.993	0.481695	3.114	2.722323	0.551	3.787878
0.145772	10.29	0.495703	3.026	2.777777	0.54	3.856041
0.150920	9.939	0.499168	3.005	2.636203	0.569	3.886010
0.150935	9.938	0.501002	2.994	2.613240	0.574	3.926701
0.147492	10.17	0.501840	2.989	2.717391	0.552	3.989361
0.151103	9.927	0.496360	3.022	2.732240	0.549	3.816793
0.148279	10.116	0.518492	2.893	2.722323	0.551	3.865979
0.150135	9.991	0.480923	3.119	2.737226	0.548	3.875968
0.146756	10.221	0.516351	2.905	2.654867	0.565	3.957783
0.151270	9.916	5.226480	0.287	2.722323	0.551	3.968253
0.151791	9.882	0.481540	3.115	2.840909	0.528	4.021447
0.151637	9.892	0.468018	3.205	2.782931	0.539	3.865979
0.149625	10.025	0.521195	2.878	2.793296	0.537	3.875968
0.159795	9.387	0.522830	2.869	2.688172	0.558	3.978779
0.149476	10.035	0.516528	2.904	2.712477	0.553	3.926701
0.148853	10.077	0.519930	2.885	2.788104	0.538	3.968253
0.150662	9.956	0.497017	3.018	2.659574	0.564	3.978779
0.148250	10.118	0.482315	3.11	2.722323	0.551	3.886010
0.149617	10.03003	0.657205	2.9141	2.720861	0.5516	3.904414
0.003146	0.211494	0.848613	0.495426	0.063634	0.013001	0.077270

Continued to page 86

TABLE 4-1

Laboratory life data on the leakage current and material resistance when subjected to 700 Vac and 80 c

R(72)	I(84)	R(84)	I(96)	R(96)	I(108)	R(108)
0.372	4.615384	0.325	5.454545	0.275	5.725190	0.262
0.378	4.615384	0.325	5.474452	0.274	5.882352	0.255
0.378	4.761904	0.315	5.597014	0.268	5.836575	0.257
0.381	4.731861	0.317	5.576208	0.269	6.048387	0.248
0.393	4.504504	0.333	5.454545	0.275	5.952380	0.252
0.383	4.629629	0.324	5.395683	0.278	5.747126	0.261
0.384	4.731861	0.317	5.639097	0.266	5.882352	0.255
0.402	4.746835	0.316	5.434782	0.276	5.597014	0.268
0.381	4.823151	0.311	5.474452	0.274	5.617977	0.267
0.388	4.573170	0.328	5.454545	0.275	5.905511	0.254
0.405	4.518072	0.332	5.376344	0.279	5.813953	0.258
0.383	4.658385	0.322	5.576208	0.269	6.072874	0.247
0.396	4.587155	0.327	5.639097	0.266	6.172839	0.243
0.389	4.629629	0.324	5.281690	0.284	5.639097	0.266
0.386	4.559270	0.329	5.338078	0.281	5.576208	0.269
0.382	4.477611	0.335	5.514705	0.272	5.882352	0.255
0.376	4.658385	0.322	5.395683	0.278	5.703422	0.263
0.393	4.531722	0.331	5.395683	0.278	5.836575	0.257
0.388	4.746835	0.316	5.494505	0.273	5.882352	0.255
0.387	4.792332	0.313	5.376344	0.279	6.097560	0.246
0.379	4.716981	0.318	5.639097	0.266	6.072874	0.247
0.378	4.807692	0.312	5.725190	0.262	6.147540	0.244
0.373	4.746835	0.316	5.597014	0.268	6.097560	0.246
0.388	4.672897	0.321	5.244755	0.286	5.681818	0.264
0.387	4.518072	0.332	5.474452	0.274	5.952380	0.252
0.377	4.716981	0.318	5.376344	0.279	5.928853	0.253
0.382	4.746835	0.316	5.597014	0.268	6.147540	0.244
0.378	4.731861	0.317	5.376344	0.279	5.882352	0.255
0.377	4.746835	0.316	5.514705	0.272	5.813953	0.258
0.386	4.658385	0.322	5.434782	0.276	5.859375	0.256
0.384333	4.665215	0.321666	5.477445	0.273966	5.881878	0.255233
0.007725	0.096328	0.006689	0.113035	0.005642	0.169688	0.007378

Continued to page 87

TABLE 4-1

Laboratory life data on the leakage current and material resistance when subjected to 700 Vac and 80 c

I(120)	R(120)	I(144)	R(144)	I(168)	R(168)	I(180)
6.172839	0.243	7.109004	0.211	7.575757	0.198	8.196721
6.666666	0.225	7.246376	0.207	8.108108	0.185	8.670520
6.607929	0.227	7.317073	0.205	8.474576	0.177	9.090909
6.578947	0.228	7.575757	0.198	9.202453	0.163	9.803921
6.355932	0.236	7.317073	0.205	8.928571	0.168	9.554140
6.437768	0.233	7.246376	0.207	8.021390	0.187	8.474576
6.465517	0.232	7.317073	0.205	8.152173	0.184	8.928571
6.329113	0.237	7.537688	0.199	8.928571	0.168	9.677419
6.578947	0.228	7.281553	0.206	8.928571	0.168	9.740259
6.465517	0.232	7.352941	0.204	8.875739	0.169	9.615384
6.465517	0.232	7.317073	0.205	8.196721	0.183	8.720930
6.666666	0.225	7.614213	0.197	8.720930	0.172	9.036144
6.578947	0.228	7.352941	0.204	8.379888	0.179	9.433962
6.465517	0.232	7.281553	0.206	8.152173	0.184	8.982035
6.410256	0.234	7.009345	0.214	8.474576	0.177	9.803921
6.607929	0.227	7.537688	0.199	8.474576	0.177	9.036144
6.493506	0.231	7.211538	0.208	8.426966	0.178	9.493670
6.410256	0.234	7.281553	0.206	9.259259	0.162	9.615384
6.329113	0.237	6.976744	0.215	8.241758	0.182	8.670520
6.607929	0.227	7.653061	0.196	8.928571	0.168	9.433962
6.726457	0.223	7.575757	0.198	8.720930	0.172	9.677419
6.550218	0.229	7.281553	0.206	8.720930	0.172	9.868421
6.521739	0.23	7.109004	0.211	8.196721	0.183	8.875739
6.437768	0.233	7.389162	0.203	8.064516	0.186	9.036144
6.493506	0.231	7.009345	0.214	8.196721	0.183	9.493670
6.550218	0.229	7.281553	0.206	8.474576	0.177	9.554140
6.578947	0.228	7.425742	0.202	8.241758	0.182	9.259259
6.578947	0.228	7.211538	0.208	8.522727	0.176	9.740259
6.355932	0.236	7.009345	0.214	8.196721	0.183	9.259259
6.437768	0.233	7.317073	0.205	8.474576	0.177	8.928571
6.497544	0.230933	7.304890	0.205466	8.458646	0.177333	9.234557
0.118011	0.004234	0.180051	0.005064	0.377152	3.056034	0.436769

Continued to page 88

TABLE 4-1

Laboratory life data on the leakage current and material resistance when subjected to 700 Vac and 80 c

R(180)	I(192)	R(192)
0.183	8.875739	0.169
0.173	9.493670	0.158
0.165	9.803921	0.153
0.153	10.34482	0.145
0.157	10.48951	0.143
0.177	9.036144	0.166
0.168	9.803921	0.153
0.155	10.86956	0.138
0.154	10.56338	0.142
0.156	10.20408	0.147
0.172	9.259259	0.162
0.166	9.677419	0.155
0.159	10.48951	0.143
0.167	9.933774	0.151
0.153	10.86956	0.138
0.166	10.13513	0.148
0.158	10.27397	0.146
0.156	10.56338	0.142
0.173	9.493670	0.158
0.159	10.48951	0.143
0.155	10.63829	0.141
0.152	10.48951	0.143
0.169	9.433962	0.159
0.166	9.868421	0.152
0.158	10.41666	0.144
0.157	10.48951	0.143
0.162	10.41666	0.144
0.154	10.48951	0.143
0.162	9.740259	0.154
0.168	9.868421	0.152
0.162433	10.05586	0.149166
0.007885	0.524203	0.008029

TABLE 5A

Per unit resistance when material is subjected to thermal and electrical stress.

Time in Hours	R(p.u)at 800V/80C
0	1
12	2.184
24	3.54
36	4.807
48	0.384
60	0.198
72	0.15
84	0.122
96	0.101
108	0.087
120	0.075
144	0.057
168	0.042

P.S. This table we was derived from Table 7-1

TABLE 5-1

Laboratory life data on the leakage current and material resistance when subjected to 800 Vac and 80 C

SAMPLE#	I(0)	R(0)	I(12)	R(12)	I(24)	R(24)
1	0.6	2.5	0.249003	6.024	0.168899	8.881
2	0.589159	2.546	0.292911	5.121	0.171919	8.725
3	0.603136	2.487	0.284037	5.281	0.168653	8.894
4	0.598563	2.506	0.281162	5.335	0.172334	8.704
5	0.586166	2.559	0.248838	6.028	0.165672	9.054
6	0.607041	2.471	0.276395	5.427	0.175274	8.558
7	0.585480	2.562	0.254971	5.883	0.165800	9.047
8	0.612745	2.448	0.273074	5.493	0.171057	8.769
9	0.605326	2.478	0.278499	5.386	0.174459	8.598
10	0.598324	2.507	0.278035	5.395	0.168880	8.882
11	0.596658	2.514	0.276395	5.427	0.168842	8.884
12	0.598802	2.505	0.258977	5.792	0.168463	8.904
13	0.612745	2.448	0.278499	5.386	0.166796	8.993
14	0.604351	2.482	0.272776	5.499	0.170979	8.773
15	0.597133	2.512	0.279850	5.36	0.166814	8.992
16	0.602651	2.489	0.270172	5.552	0.168444	8.905
17	0.595947	2.517	0.277366	5.408	0.171722	8.735
18	0.589854	2.543	0.277983	5.396	0.178613	8.398
19	0.597371	2.511	0.281004	5.338	0.173450	8.648
20	0.601202	2.495	0.272628	5.502	0.166407	9.014
21	0.601684	2.493	0.282698	5.306	0.166057	9.033
22	0.599280	2.503	0.266477	5.629	0.166260	9.022
23	0.589622	2.544	0.282698	5.306	0.167710	8.944
24	0.600480	2.498	0.277520	5.405	0.167822	8.938
25	0.596658	2.514	0.282698	5.306	0.168842	8.884
26	0.598086	2.508	0.277520	5.405	0.166333	9.018
27	0.600961	2.496	0.267713	5.603	0.164744	9.105
28	0.593589	2.527	0.276344	5.428	0.175274	8.558
29	0.603378	2.486	0.281320	5.332	0.166463	9.011
30	0.601926	2.492	0.281056	5.337	0.165636	9.056
MEAN	0.598874	2.5047	0.274239	5.469666	0.169219	8.864233
STD.DV	0.006484	0.027155	0.009996	0.208987	0.003435	0.176737

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P.S. A figure in parenthesis represents time of measurement is hours.

TABLE 5-1

Laboratory life data on the leakage current and material resistance when subjected to 800 Vac and 80 C

I(36)	R(36)	I(48)	R(48)	I(60)	R(60)	I(72)
0.124553	12.043	1.518218	0.988	3.073770	0.488	3.978779
0.124305	12.067	1.421800	1.055	2.988047	0.502	4
0.124347	12.063	1.423149	1.054	3.086419	0.486	4.076086
0.125125	11.988	1.588983	0.944	2.762430	0.543	3.978779
0.124626	12.036	1.679731	0.893	3.012048	0.498	4.032258
0.124605	12.038	1.696832	0.884	3.138075	0.478	4.087193
0.124771	12.022	1.659292	0.904	3.138075	0.478	3.90625
0.124875	12.012	1.510574	0.993	2.982107	0.503	3.957783
0.124038	12.093	1.648351	0.91	3.073770	0.488	4.065040
0.124626	12.036	1.659292	0.904	3.171247	0.473	4.021447
0.124233	12.074	1.491053	1.006	3.024193	0.496	3.968253
0.125177	11.983	1.543209	0.972	2.929687	0.512	3.694581
0.124131	12.084	1.353790	1.108	2.982107	0.503	3.989361
0.124543	12.044	1.434034	1.046	3.042596	0.493	4.076086
0.124090	12.088	1.696832	0.884	2.819548	0.532	4.032258
0.124709	12.028	1.588983	0.944	3.073770	0.488	3.846153
0.124357	12.062	1.677852	0.894	3.218884	0.466	4.010695
0.125187	11.982	1.594048	0.941	2.982107	0.503	3.978779
0.125146	11.986	1.525940	0.983	3.131524	0.479	4.143646
0.124646	12.034	1.506024	0.996	2.737226	0.548	3.865979
0.124233	12.074	1.356238	1.106	3.112033	0.482	4.065040
0.125135	11.987	1.787842	0.839	2.982107	0.503	4.065040
0.124326	12.065	1.518218	0.988	2.851711	0.526	4.098360
0.124141	12.083	1.698754	0.883	3.164556	0.474	3.978779
0.124460	12.052	1.549586	0.968	3.105590	0.483	3.968253
0.124781	12.021	1.554404	0.965	2.970297	0.505	4.065040
0.124615	12.037	1.436781	1.044	2.994011	0.501	3.816793
0.124771	12.022	1.679731	0.893	3.138075	0.478	3.968253
0.124636	12.035	1.696832	0.884	3.086419	0.486	4.087193
0.124885	12.011	1.549586	0.968	3.144654	0.477	3.968253
0.124601	12.03833	1.560278	0.961366	3.025820	0.495733	3.990776
0.000336	0.032449	0.110521	0.069101	0.117832	0.020004	0.093130

Continued to page 92

TABLE 5-1

Laboratory life data on the leakage current and material resistance when subjected to 800 Vac and 80 C

R(72)	I(84)	R(96)	I(96)	R(96)	I(108)	R(108)
0.377	5.033557	0.298	5.836575	0.257	6.787330	0.221
0.375	4.823151	0.311	5.597014	0.268	6.437768	0.233
0.368	4.934210	0.304	5.928853	0.253	6.578947	0.228
0.377	4.885993	0.307	6.048387	0.248	7.211538	0.208
0.372	4.761904	0.315	6.147540	0.244	6.849315	0.219
0.367	4.823151	0.311	6.048387	0.248	6.578947	0.228
0.384	4.901960	0.306	6.072874	0.247	6.849315	0.219
0.379	4.672897	0.321	5.928853	0.253	6.607929	0.227
0.369	5.244755	0.286	5.859375	0.256	6.637168	0.226
0.373	5.067567	0.296	5.514705	0.272	6.696428	0.224
0.378	5.395683	0.278	5.928853	0.253	6.880733	0.218
0.406	4.934210	0.304	6.122448	0.245	7.075471	0.212
0.376	4.658385	0.322	5.882352	0.255	6.912442	0.217
0.368	4.746835	0.316	6.024096	0.249	7.352941	0.204
0.372	4.901960	0.306	5.836575	0.257	6.756756	0.222
0.39	5.067567	0.296	6.198347	0.242	7.352941	0.204
0.374	5.119453	0.293	5.882352	0.255	6.696428	0.224
0.377	5.067567	0.296	5.597014	0.268	7.352941	0.204
0.362	4.934210	0.304	5.952380	0.252	6.787330	0.221
0.388	4.731861	0.317	6.048387	0.248	7.211538	0.208
0.369	5.084745	0.295	5.905511	0.254	7.042253	0.213
0.369	4.918032	0.305	6.147540	0.244	6.944444	0.216
0.366	4.807692	0.312	6.072874	0.247	6.607929	0.227
0.377	4.934210	0.304	5.928853	0.253	6.849315	0.219
0.378	4.901960	0.306	5.813953	0.258	7.425742	0.202
0.369	5.033557	0.298	6.198347	0.242	7.281553	0.206
0.393	4.885993	0.307	5.976095	0.251	7.042253	0.213
0.378	4.672897	0.321	5.928853	0.253	6.696428	0.224
0.367	4.518072	0.332	6.072874	0.247	6.726457	0.223
0.378	4.901960	0.306	5.703422	0.263	6.944444	0.216
0.375866	4.905701	0.305766	5.935109	0.252733	6.895494	0.217533
0.009035	0.003435	0.011089	0.170686	0.007429	0.269186	0.008361

Continued to page 93

TABLE 5-1

Laboratory life data on the leakage current and material resistance when subjected to 800 Vac and 80 C

I(120)	R(120)	I(144)	R(144)	I(168)	R(168)
7.537688	0.199	11.02941	0.136	15.95744	0.094
7.177033	0.209	10.86956	0.138	13.15789	0.114
7.575757	0.198	10.56338	0.142	14.15094	0.106
8.379888	0.179	9.933774	0.151	13.88888	0.108
7.731958	0.194	10.27397	0.146	14.15094	0.106
8.241758	0.182	10.79136	0.139	13.63636	0.11
7.978723	0.188	10.56338	0.142	15.30612	0.098
8.108108	0.185	10.41666	0.144	15.95744	0.094
8.379888	0.179	11.27819	0.133	13.27433	0.113
8.241758	0.182	10.41666	0.144	12.93103	0.116
8.064516	0.186	9.933774	0.151	14.28571	0.105
8.670520	0.173	9.803921	0.153	13.39285	0.112
8.474576	0.177	10.41666	0.144	13.04347	0.115
8.152173	0.184	10.56338	0.142	15.95744	0.094
7.692307	0.195	10.86956	0.138	13.88888	0.108
7.772020	0.193	10.13513	0.148	14.42307	0.104
7.731958	0.194	10.41666	0.144	15.625	0.096
8.720930	0.172	10.94890	0.137	17.04545	0.088
7.978723	0.188	10.56338	0.142	15.95744	0.094
8.196721	0.183	11.19402	0.134	14.28571	0.105
8.474576	0.177	10.86956	0.138	12.71186	0.118
7.772020	0.193	10.48951	0.143	13.39285	0.112
8.152173	0.184	10.79136	0.139	14.42307	0.104
8.522727	0.176	10.86956	0.138	15.30612	0.098
8.196721	0.183	10.48951	0.143	15.30612	0.098
8.064516	0.186	10.41666	0.144	13.76146	0.109
7.731958	0.194	9.433962	0.159	12.93103	0.116
6.944444	0.216	10.13513	0.148	13.88888	0.108
7.211538	0.208	9.868421	0.152	13.39285	0.112
8.379888	0.179	11.36363	0.132	14.28571	0.105
7.984386	0.187866	10.50420	0.1428	14.24050	0.105333
0.432292	0.010541	0.448838	0.006193	1.114876	0.007900

TABLE 6A

Per unit resistance when material is subjecte to thermal and electrical stress.

Time in Hours	R(pu)at 900V/80C
0	1
12	2.72
24	3.894
36	6.294
48	0.341
60	0.185
72	0.14
84	0.107
96	0.093
108	0.077
120	0.065

TABLE 6-1

Laboratory life data on the leakage current and material resistance when subjected to 900 Vac and 80 C

SAMPLE#	I(0)	R(0)	I(12)	R(12)	I(24)	R(24)
1	0.612244	2.45	0.217548	6.895	0.158696	9.452
2	0.585937	2.56	0.217296	6.903	0.149536	10.031
3	0.614754	2.44	0.217643	6.892	0.151914	9.874
4	0.566037	2.65	0.214163	7.004	0.155215	9.664
5	0.604838	2.48	0.210851	7.114	0.147289	10.184
6	0.585937	2.56	0.213766	7.017	0.148323	10.113
7	0.572519	2.62	0.206782	7.254	0.149566	10.029
8	0.590551	2.54	0.231231	6.487	0.144480	10.382
9	0.588235	2.55	0.217801	6.887	0.151775	9.883
10	0.602409	2.49	0.214530	6.992	0.153484	9.773
11	0.583657	2.57	0.214561	6.991	0.151469	9.903
12	0.563909	2.66	0.220653	6.798	0.151622	9.893
13	0.592885	2.53	0.212826	7.048	0.151026	9.932
14	0.581395	2.58	0.221467	6.773	0.165636	9.056
15	0.612244	2.45	0.220458	6.804	0.148294	10.115
16	0.604838	2.48	0.217296	6.903	0.149432	10.038
17	0.568181	2.64	0.205535	7.298	0.151929	9.873
18	0.604838	2.48	0.220815	6.793	0.149328	10.045
18	0.574712	2.61	0.212947	7.044	0.151760	9.884
20	0.579150	2.59	0.220490	6.803	0.150105	9.993
21	0.583657	2.57	0.212524	7.058	0.148265	10.117
22	0.585937	2.56	0.217928	6.883	0.151118	9.926
23	0.604838	2.48	0.217643	6.892	0.150090	9.994
24	0.585937	2.56	0.205817	7.288	0.145843	10.285
25	0.574712	2.61	0.212886	7.046	0.147521	10.168
26	0.590551	2.54	0.217928	6.883	0.147550	10.166
27	0.574712	2.61	0.220296	6.809	0.152983	9.805
28	0.579150	2.59	0.219138	6.845	0.153170	9.793
29	0.583657	2.57	0.216294	6.935	0.151775	9.883
30	0.581395	2.58	0.213614	7.022	0.149506	10.033
MEAN	0.587794	2.553333	0.202745	6.945366	0.150957	9.9429
STD.DV	0.013917	0.060018	0.005101	0.163706	0.003882	0.245332

Continued to page 96

P.S. A figure in parenthesis represents time to measurement is hours.

TABLE 6-1

Laboratory life data on the leakage current and material resistance when subjected to 900 Vac and 80 C

I(36)	R(36)	I(48)	R(48)	I(60)	R(60)	I(72)
0.093557	16.033	1.775147	0.845	3.151260	0.476	3.521126
0.092586	16.201	1.662971	0.902	3.218884	0.466	3.605769
0.094369	15.895	1.655629	0.906	3.275109	0.458	3.614457
0.093557	16.033	1.820388	0.824	3.370786	0.445	3.605769
0.093791	15.993	0.085212	0.835	3.006012	0.499	3.676470
0.094912	15.804	1.732101	0.866	2.988047	0.502	3.432494
0.094132	15.935	1.835985	0.817	3.164556	0.474	3.464203
0.092421	16.23	1.661129	0.903	3.464203	0.433	3.554502
0.094434	15.884	1.694915	0.885	2.994011	0.501	3.676470
0.093908	15.973	1.773049	0.846	3.205128	0.468	3.512880
0.092086	16.289	1.702610	0.881	3.348214	0.448	3.562945
0.091452	16.402	1.822600	0.823	3.012048	0.498	3.605769
0.095517	15.704	1.781472	0.842	3.086419	0.486	3.504672
0.092194	16.27	1.646542	0.911	2.935420	0.511	3.529411
0.093867	15.98	1.811594	0.828	3.211991	0.467	3.640776
0.093075	16.116	1.736111	0.864	3.105590	0.483	3.588516
0.092001	16.304	1.768867	0.848	3.363228	0.446	3.623188
0.093644	16.018	1.734104	0.865	3.218884	0.466	3.676470
0.097389	15.402	1.746216	0.859	3.112033	0.482	3.424657
0.095032	15.784	1.662971	0.902	3.177966	0.472	3.448275
0.088282	16.991	1.646542	0.911	3.348214	0.448	3.649635
0.092438	16.227	1.679731	0.893	3.144654	0.477	3.562945
0.093138	16.105	1.696832	0.884	3.211991	0.467	3.529411
0.094912	15.804	1.708428	0.878	3.239740	0.463	3.472222
0.094049	15.949	1.734104	0.865	3.177966	0.472	3.554502
0.093621	16.022	1.766784	0.849	3.218884	0.466	3.554502
0.093644	16.018	1.700680	0.882	2.952755	0.508	3.512880
0.096104	15.608	1.677852	0.894	3.151260	0.476	3.588516
0.088271	16.993	1.659292	0.904	3.440366	0.436	3.562945
0.093086	16.114	1.651982	0.908	3.073770	0.488	3.512880
0.093382	16.06936	1.667728	0.870666	3.173036	0.472733	3.558975
0.001852	0.325304	0.299293	0.029150	0.137797	0.020417	0.070060

Continued to page 97

TABLE 6-1

Laboratory life data on the leakage current and material resistance when subjected to 900 Vac and 80 C

R(72)	I(84)	R(84)	I(96)	R(96)	I(108)	R(108)
0.426	5.639097	0.266	6.355932	0.236	7.425742	0.202
0.416	5.244755	0.286	6.302521	0.238	7.246376	0.207
0.415	5.319148	0.282	6.329113	0.237	7.575757	0.198
0.416	5.395683	0.278	6.355932	0.236	7.978723	0.188
0.408	5.639097	0.266	6.437768	0.233	7.692307	0.195
0.437	5.535055	0.271	6.072874	0.247	7.731958	0.194
0.433	5.617977	0.267	6.198347	0.242	7.692307	0.195
0.422	5.681818	0.264	6.410256	0.234	8.108108	0.185
0.408	5.395683	0.278	7.317073	0.246	7.317073	0.205
0.427	5.494505	0.273	6.024096	0.249	7.109004	0.211
0.421	5.639097	0.266	6.787330	0.221	7.281553	0.206
0.416	5.597014	0.268	6.329113	0.237	8.021390	0.187
0.428	5.415162	0.277	6.048387	0.248	7.731958	0.194
0.425	5.639097	0.266	6.147540	0.244	7.537688	0.199
0.412	5.597014	0.268	6.637168	0.226	8.021390	0.187
0.418	5.300353	0.283	6.276150	0.239	8.108108	0.185
0.414	5.434782	0.276	6.147540	0.244	7.575757	0.198
0.408	5.319148	0.282	6.493506	0.231	6.880733	0.218
0.438	5.190311	0.289	6.302521	0.238	8.152173	0.184
0.435	5.395683	0.278	6.097560	0.246	7.317073	0.205
0.411	5.791505	0.259	6.578947	0.228	7.575757	0.198
0.421	5.208333	0.288	6.147540	0.244	7.5	0.2
0.425	5.597014	0.268	6.048387	0.248	7.211538	0.208
0.432	5.597014	0.268	6.976744	0.215	7.317073	0.205
0.422	5.725190	0.262	6.302521	0.238	7.978723	0.188
0.422	5.454545	0.275	6.172839	0.243	7.653061	0.196
0.427	5.576208	0.269	6.276150	0.239	8.287292	0.181
0.418	5.415162	0.277	6.880733	0.218	8.241758	0.182
0.421	5.639097	0.266	6.329113	0.237	7.211538	0.208
0.427	5.395683	0.278	6.302521	0.238	7.978723	0.188
0.421633	5.491823	0.273133	6.369541	0.237333	7.648688	0.196566
0.008320	0.156988	0.007864	0.293465	0.008622	0.367301	0.009478

Continued to page 98

TABLE 6-1

Laboratory life data on the leakage current and material resistance when subjected to 900 Vac and 80 C

I(120)	R(120)
9.036144	0.166
9.615384	0.156
9.036144	0.166
9.433962	0.159
9.677419	0.155
9.493670	0.158
9.202453	0.163
9.493670	0.158
8.196721	0.183
8.522727	0.176
8.241758	0.182
8.522727	0.176
9.036144	0.166
8.928571	0.168
8.620689	0.174
9.090909	0.165
8.720930	0.172
9.036144	0.166
8.571428	0.175
9.146341	0.164
8.982035	0.167
9.146341	0.164
9.554140	0.157
9.433962	0.159
9.036144	0.166
8.720930	0.172
9.146341	0.164
9.375	0.16
8.928571	0.168
9.740259	0.154
9.056255	0.165966
0.403816	0.007529

TABLE 7A

Per unit resistance when material is subjected to thermal and electrical stress

Time (Hours)	600v/60c R(pu)
0	1
120	0.208
144	0.152
168	0.106
192	0.085
216	0.076
240	0.072

P.S. This table was derived from TABLE 7-1.

TABLE 7-1

Laboratory life data on the leakage current and material resistance when subjected to 600Vac and 60C

SAMPLE#	I(0)	R(0)	I(120)	R(120)	I(144)	R(144)
1	0.594294	2.524	2.846299	0.527	3.916449	0.383
2	0.593589	2.527	2.835538	0.529	4.032258	0.372
3	0.595710	2.518	2.862595	0.524	3.856041	0.389
4	0.594294	2.524	2.929687	0.512	3.865979	0.388
5	0.595710	2.518	2.912621	0.515	4.010695	0.374
6	0.593824	2.526	2.798507	0.536	4.132231	0.363
7	0.594766	2.522	2.819548	0.532	3.768844	0.398
8	0.595474	2.519	2.918287	0.514	3.740648	0.401
9	0.594294	2.524	2.935420	0.511	3.826530	0.392
10	0.594766	2.522	2.862595	0.524	3.886010	0.386
11	0.595947	2.517	2.840909	0.528	3.836317	0.391
12	0.594059	2.525	2.819548	0.532	3.926701	0.382
13	0.594766	2.522	2.952755	0.508	3.978779	0.377
14	0.593354	2.528	2.846299	0.527	3.896103	0.385
15	0.595947	2.517	2.793296	0.537	4.065040	0.369
16	0.596184	2.516	2.862595	0.524	3.816793	0.393
17	0.594766	2.522	2.906976	0.516	4.043126	0.371
18	0.594294	2.524	2.840909	0.528	4.143646	0.362
19	0.593354	2.528	2.929687	0.512	3.926701	0.382
20	0.594766	2.522	2.808988	0.534	3.768844	0.398
21	0.596184	2.516	2.873563	0.522	3.740648	0.401
22	0.592417	2.532	2.906976	0.516	3.886010	0.386
23	0.594294	2.524	2.873563	0.522	3.989361	0.376
24	0.593119	2.529	2.835538	0.529	3.731343	0.402
25	0.594294	2.524	2.879078	0.521	3.926701	0.382
26	0.595947	2.517	2.901353	0.517	4.065040	0.369
27	0.595474	2.519	2.895752	0.518	3.865979	0.388
28	0.594294	2.524	2.923976	0.513	4	0.375
29	0.593589	2.527	2.819548	0.532	3.875968	0.387
30	0.595474	2.519	2.862595	0.524	3.978779	0.377
MEAN	0.594640	2.522533	2.869166	0.5228	3.913383	0.3833
STD.DV	0.000982	0.004169	0.043092	0.007842	0.112220	0.010942

Continued to page 101

P.S. A figure in parenthsis represents time of measurement is hours.

TABLE 7-1

Laboratory life data on the leakage current and material resistance when subjected to 600Vac and 60C

I(168)	R(168)	I(192)	R(192)	I(216)	R(216)	I(240)
5.576208	0.269	6.880733	0.218	7.575757	0.198	7.978723
5.434782	0.276	7.009345	0.214	7.8125	0.192	8.152173
5.617977	0.267	6.944444	0.216	7.978723	0.188	8.426966
5.576208	0.269	7.177033	0.209	7.772020	0.193	8.241758
5.905511	0.254	7.425742	0.202	8.241758	0.182	8.720930
5.208333	0.288	6.849315	0.219	8.379888	0.179	9.036144
5.681818	0.264	6.726457	0.223	7.978723	0.188	8.620689
5.395683	0.278	7.281553	0.206	8.241758	0.182	8.426966
5.514705	0.272	6.944444	0.216	7.731958	0.194	8.108108
5.639097	0.266	7.009345	0.214	7.537688	0.199	8.108108
6.048387	0.248	6.666666	0.225	7.317073	0.205	8.021390
5.859375	0.256	6.578947	0.228	7.462686	0.201	7.853403
5.597014	0.268	7.211538	0.208	7.978723	0.188	8.771929
5.836575	0.257	6.944444	0.216	7.692307	0.195	8.152173
5.639097	0.266	7.211538	0.208	7.8125	0.192	8.152173
5.474452	0.274	6.787330	0.221	7.978723	0.188	8.241758
5.376344	0.279	7.537688	0.199	7.575757	0.198	8.108108
5.703422	0.263	6.880733	0.218	7.731958	0.194	8.064516
5.882352	0.255	7.281553	0.206	8.108108	0.185	8.670520
5.976095	0.251	7.109004	0.211	8.333333	0.18	8.670520
5.681818	0.264	6.880733	0.218	7.692307	0.195	8.108108
6.024096	0.249	6.976744	0.215	7.772020	0.193	8.152173
5.395683	0.278	7.575757	0.198	8.021390	0.187	8.474576
5.434782	0.276	6.912442	0.217	7.692307	0.195	8.021390
5.617977	0.267	7.246376	0.207	7.978723	0.188	8.287292
5.681818	0.264	6.944444	0.216	8.241758	0.182	8.474576
5.535055	0.271	6.666666	0.225	7.731958	0.194	8.241758
5.576208	0.269	6.637168	0.226	7.281553	0.206	7.936507
5.300353	0.283	6.976744	0.215	7.978723	0.188	8.522727
5.474452	0.274	7.075471	0.212	7.772020	0.193	8.108108
5.614472	0.267166	7.002801	0.2142	7.836990	0.1914	8.285766
0.209315	0.009859	0.251216	0.007578	0.277638	0.006785	0.282174

Continued to page 102

TABLE 7-1

Laboratory life data on the leakage current and material resistance when subjected to 600Vac and 60C

R(240)
0.188
0.184
0.178
0.182
0.172
0.166
0.174
0.178
0.185
0.185
0.187
0.191
0.171
0.184
0.184
0.182
0.185
0.186
0.173
0.173
0.185
0.184
0.177
0.187
0.181
0.177
0.182
0.189
0.176
0.185
0.181033
0.006019

TABLE 8

Catastrophic Failure Data at 700 Vac/80 C

SAMPLE#	Hours to Failure	Initial noise in uV
1	312	8
2	318	6
3	324	7.5
4	324	9
5	336	7.5
6	336	7.5
7	336	7
8	348	7.5
9	348	8
10	348	6.5
11	348	6.5
12	360	7
13	360	6.8
14	360	7
15	360	6.2
16	360	6.5
17	360	6.2
18	360	6.8
19	360	7
20	366	6
21	366	5.5
22	366	4
23	366	4
24	366	4.2
25	366	3.8
26	366	5
27	366	4.5
28	366	4.5
29	366	4.5
30	366	4.5
31	366	5
32	366	4.8
33	372	5.5
34	372	5.5
35	372	5.2
36	372	5.5
37	372	5.5
38	372	5.5
39	372	6.2
40	372	4

Continued to page 104

P.S. The data noise was measured at 700Vac, 6 MHz and at room conditions.

TABLE 8

Catastrophic Failure Data at 700 Vac/80 C

SAMPLE#	Hours to Failure	Initial noise in uV
41	372	6.2
42	372	4
43	372	4.8
44	372	4
45	372	2.7
46	372	2.7
47	372	2.7
48	378	2.5
49	378	2.1
50	378	2.5
51	378	2.5
52	378	2.5
53	378	2.5
54	378	2.2
55	378	2.5
56	378	2.5
57	378	2.5
58	378	2.5
59	384	3.8
60	384	3.5
61	384	4
62	384	3.5
63	384	3.2
64	384	3.5
65	384	3.2
66	384	3.2
67	384	3.5
68	384	3
69	384	3.2
70	384	4
71	384	3.5
72	384	3.5
73	384	3
74	384	3.5
75	384	2.5

Continunued to page 105

TABLE 8

Catastrophic Failure Data at 700 Vac/80 C

SAMPLE#	Hours to Failure	Initial noise in uV
76	384	2.2
77	384	2
78	384	1.6
79	384	2.5
80	384	2.2
81	384	2
82	384	2.4
83	384	2.2

Coefficient of correlation= 0.669
Between noise and time to failure

TABLE 9

Electrical Noise Data During Life

Time in Hour	Noise in uV at 800Vac/80C	Noise in uV at 80C only
0	3.6	3.6
96	5.6	5
144	6.3	5.7
192	6.5	6.2
240	6.9	6.5
252	7	6.6
264	7.1	6.7
276	7.2	6.7
288	7.3	6.8
302	7.5	6.9
326	7.6	6.9

TABLE 10

Evaluation of Model Parameters

TEST RUN	Parameters: E (ev)	Parameters: K'	Parameters: ς (coulomb-m)	Failure Mode
Thermal stress aging at 80 C	0.225	0.118		TypeII Censored
Combined stress aging at 600v/80c			0.626×10^{-8}	TypeII Censored

TABLE 11

Life Estimates Data

Stress condition	Life Estimates	
	From Proposed Model(in hrs.)	Experimental Results(in hrs.)
700V, 80C	106.8	108
800V, 80C	101	96
900V, 80C	93.2	87
600V, 60C	178.2	174

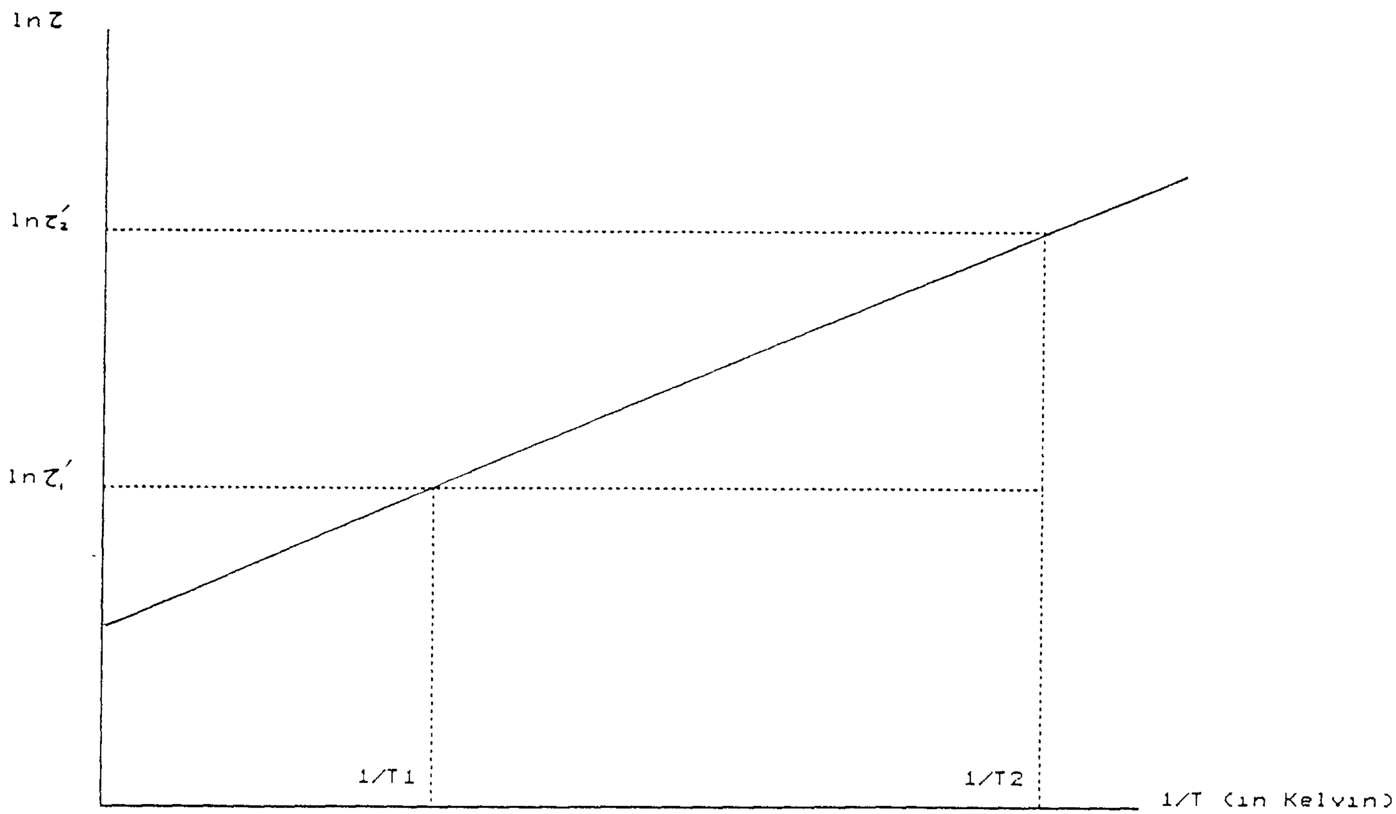

Fig. 1 Relationship 1/T versus ln τ

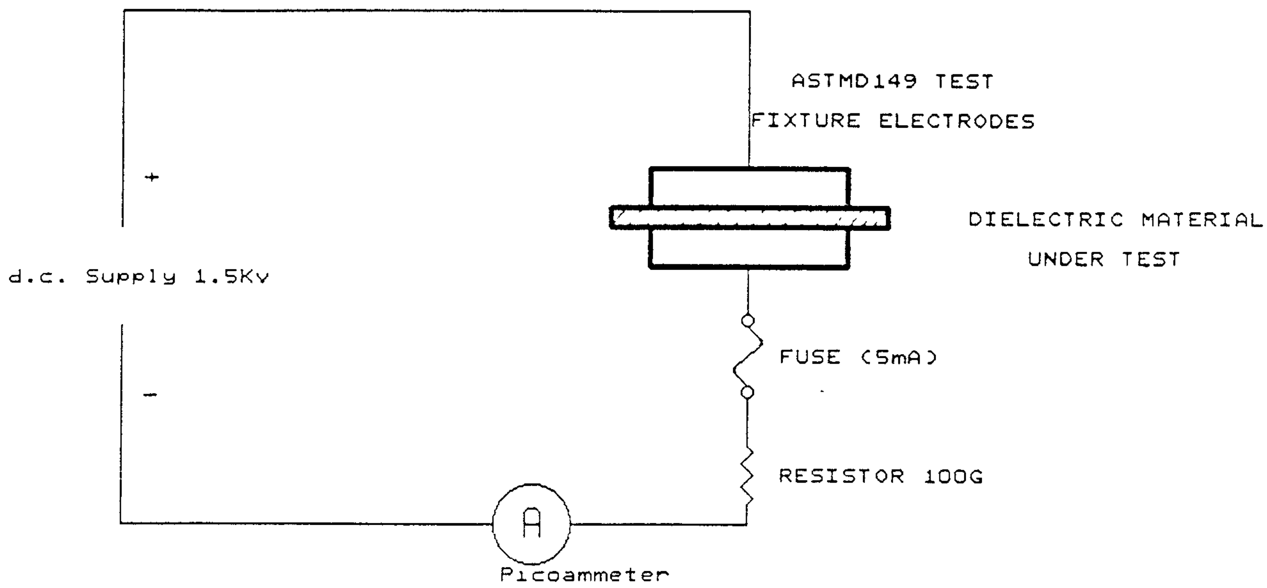

Fig. 2 Resistance measurement set-up

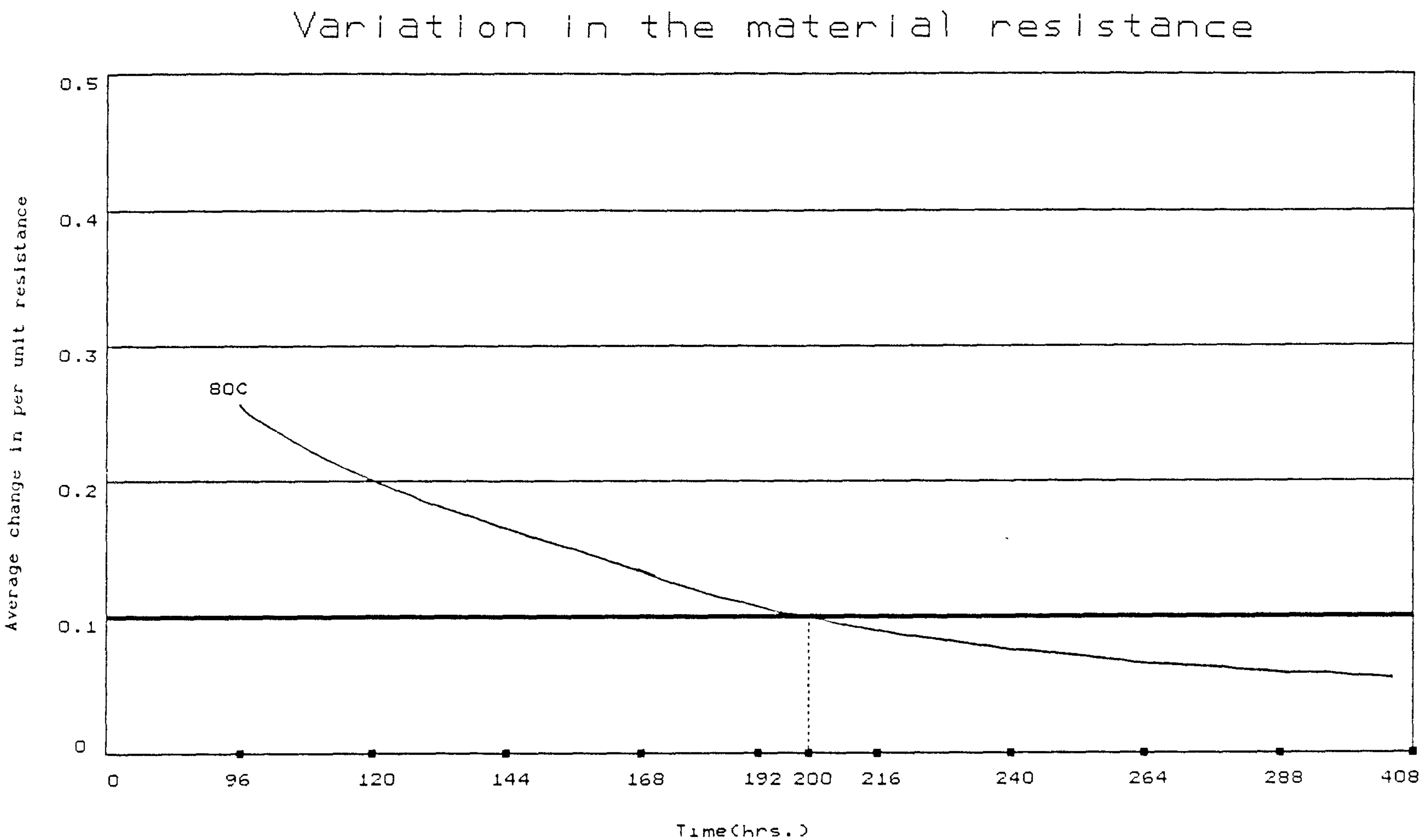

Fig.3 Material Degradation Pattern
at Thermal (80C) Stress Only

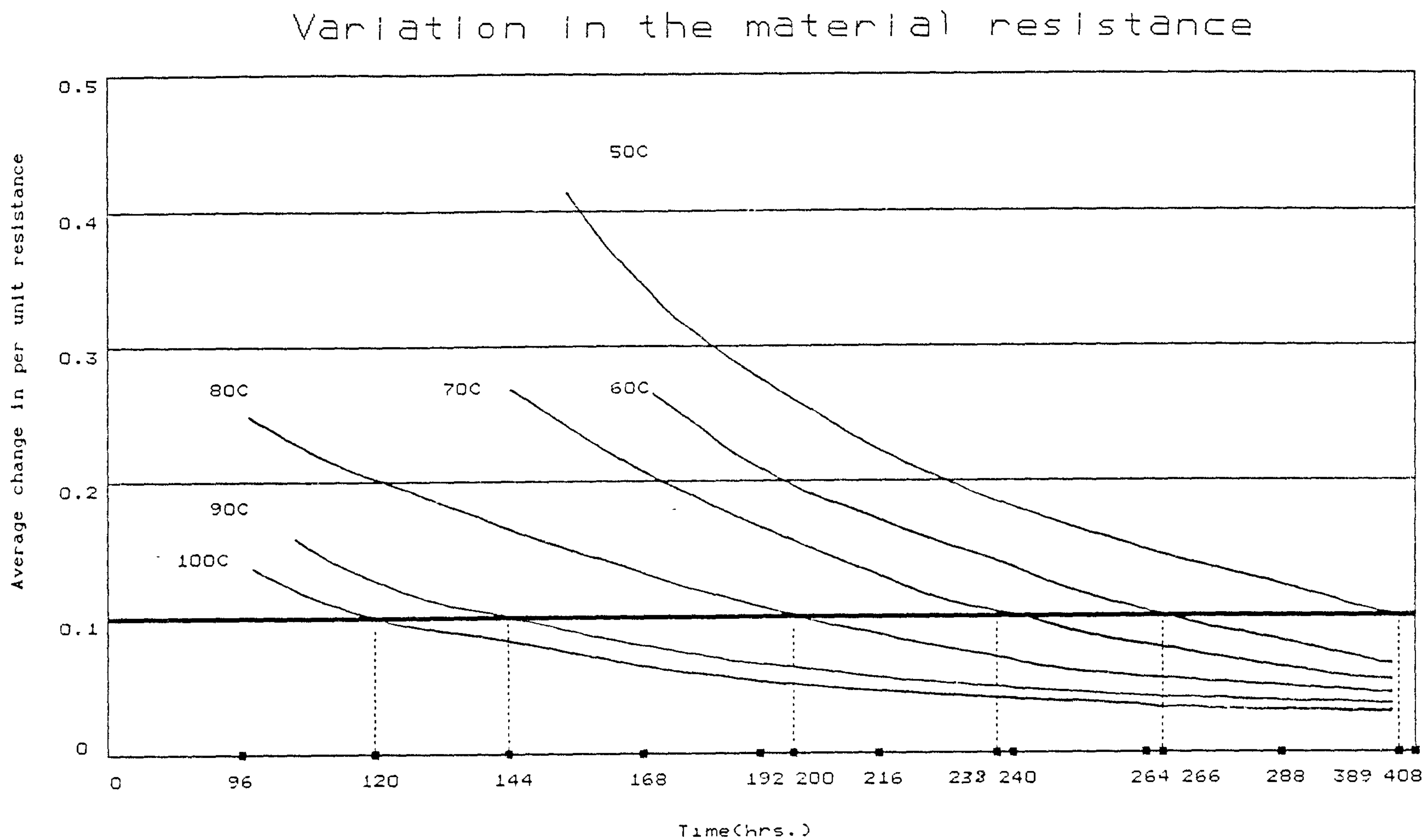

Fig.4 Material Degradation Pattern
at Thermal Stress Only

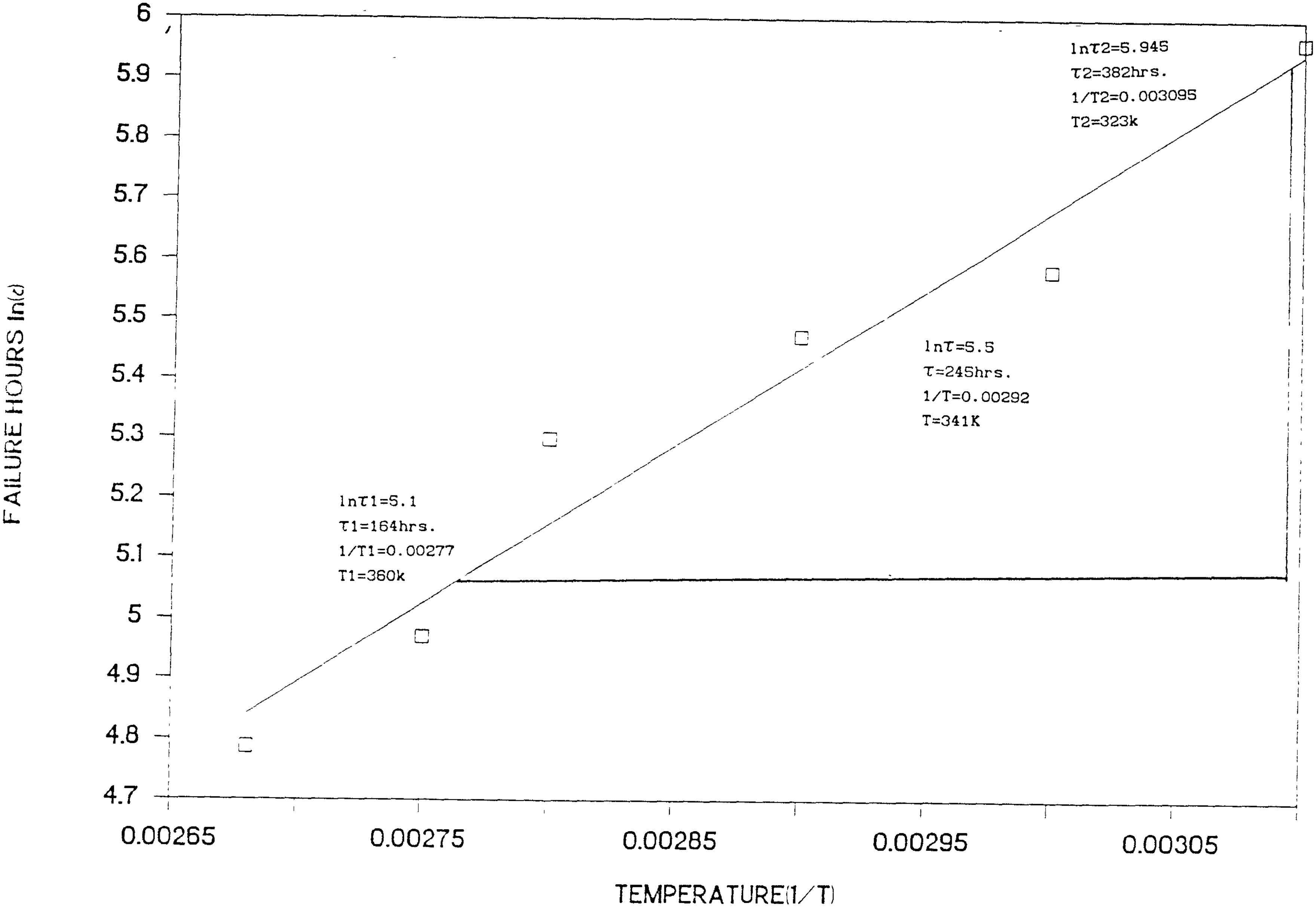

Fig.5 lnτ versus 1/T Graph

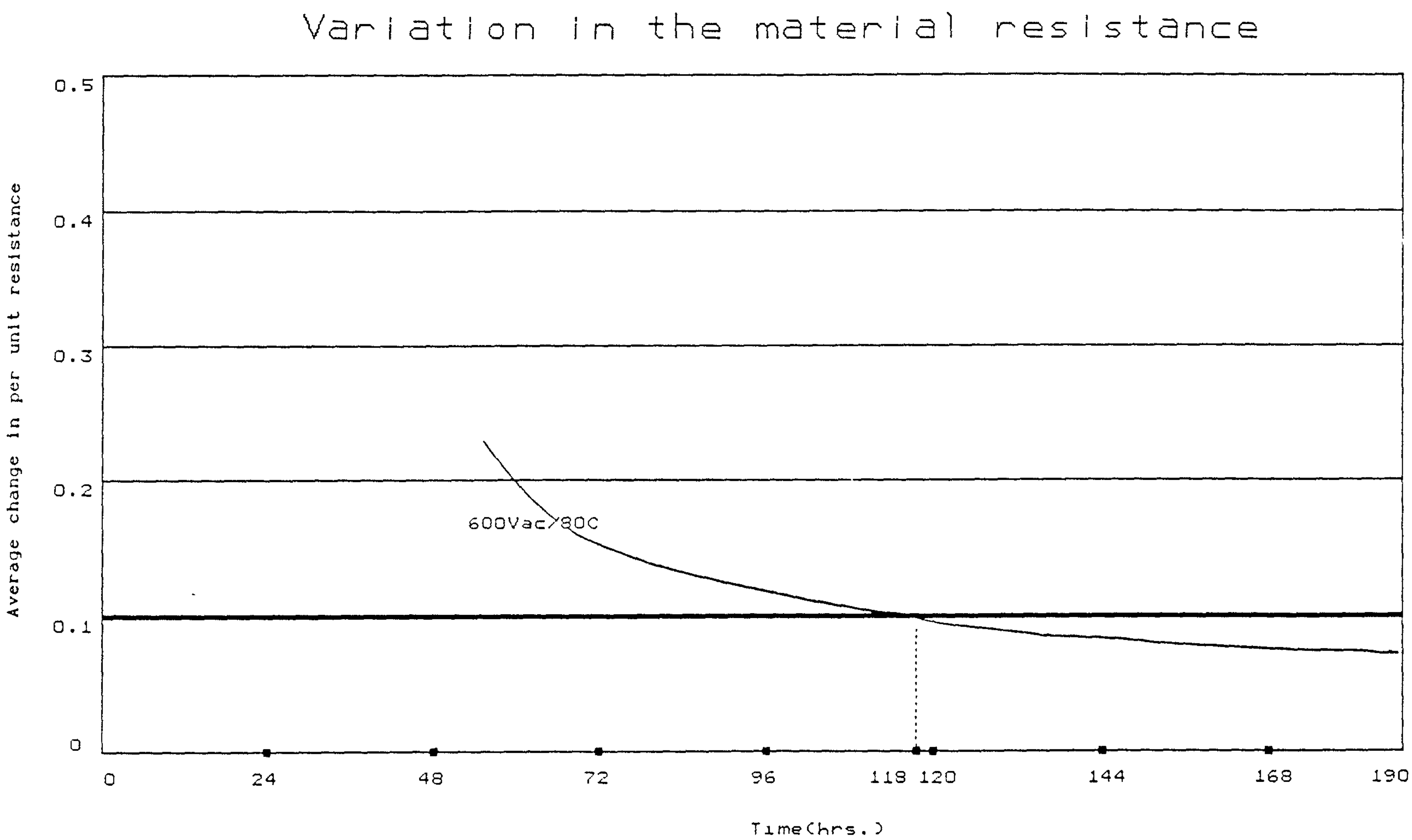

Fig.6 Material Degradation Pattern at Combined Electrical (600Vac) and Thermal (80 C)

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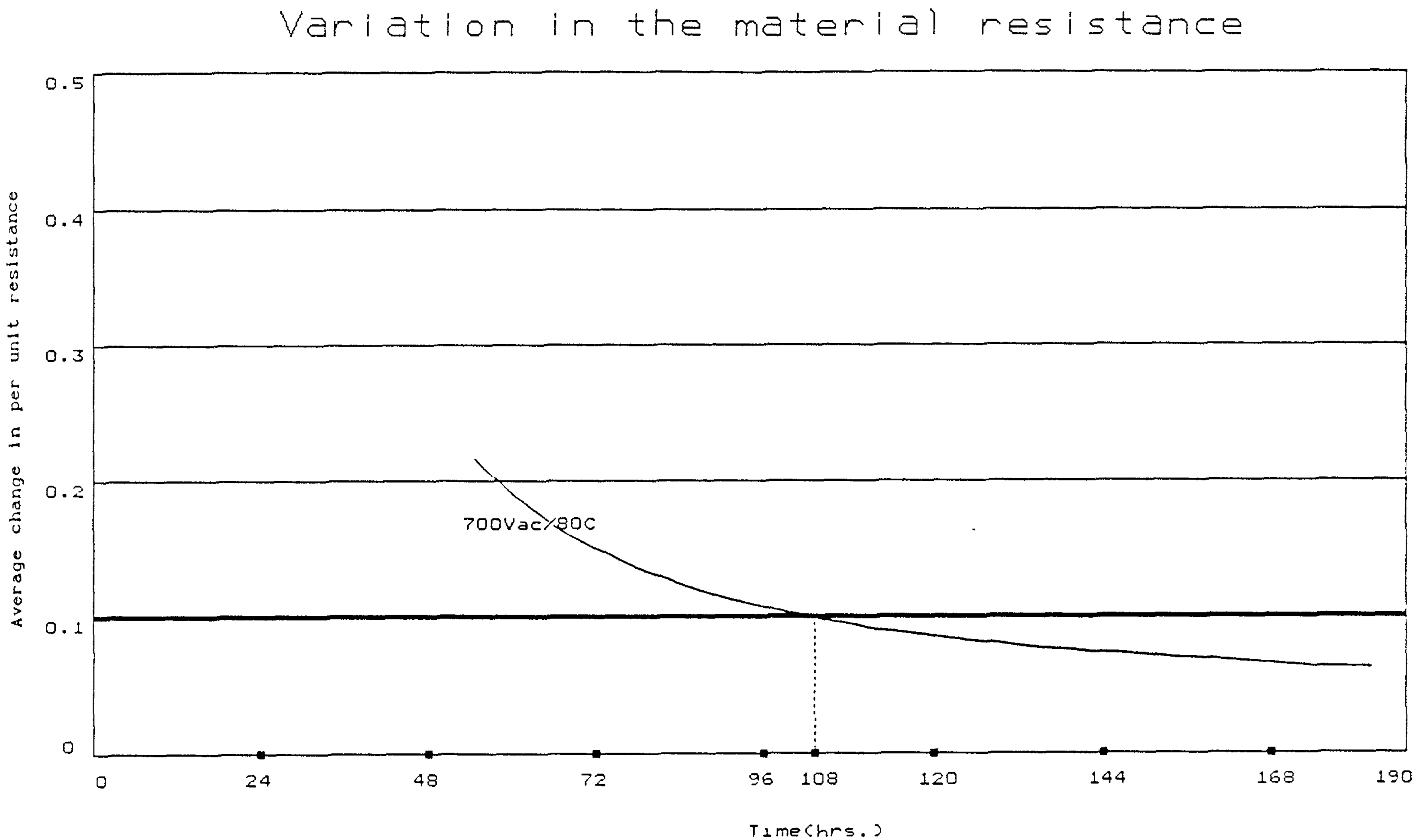

Fig.7 Material Degradation Pattern at Combined Electrical (700Vac) and Thermal (80 C)

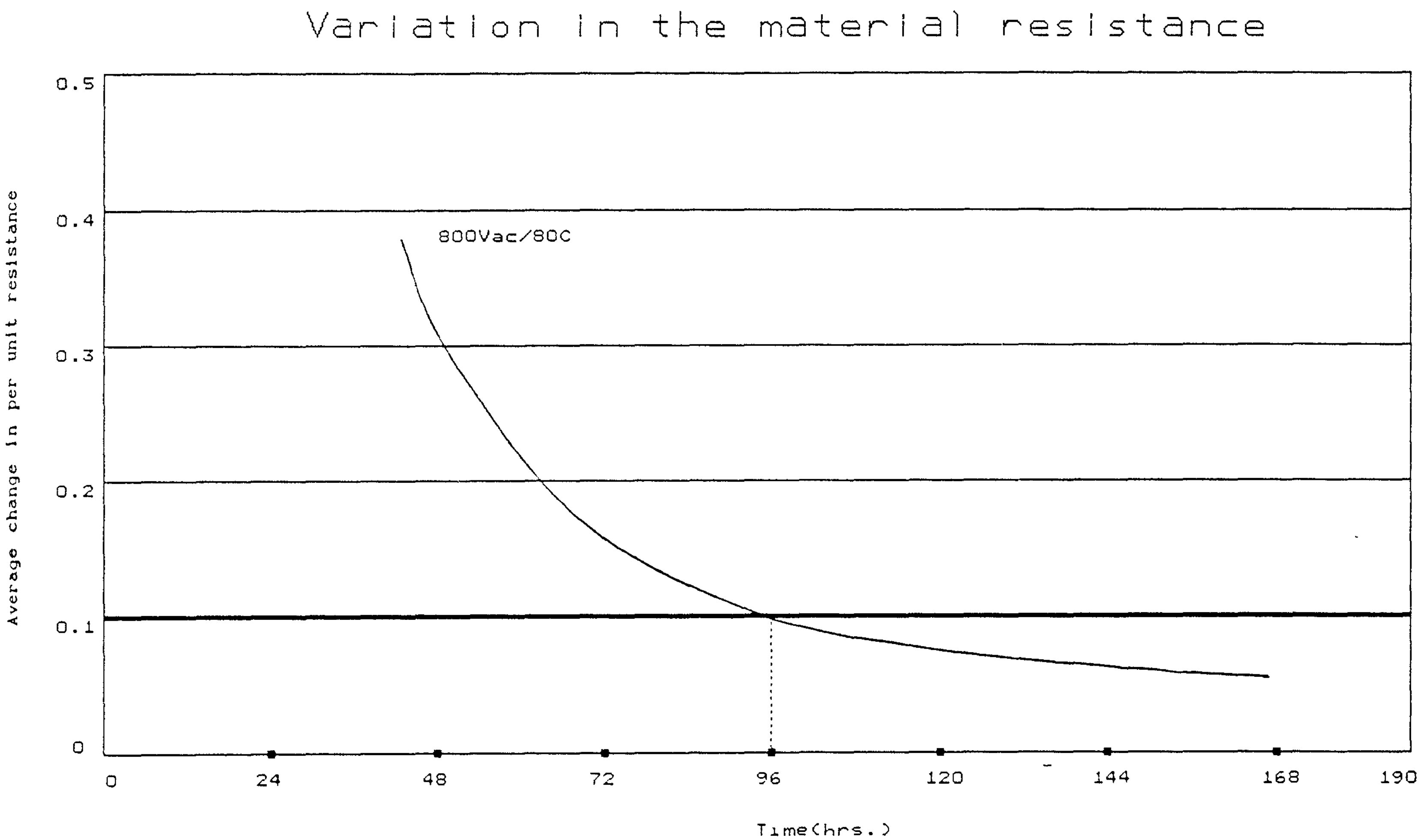

Fig.8 Material Degradation Patern at Combined Electrical (800Vac) and Thermal (80 C)

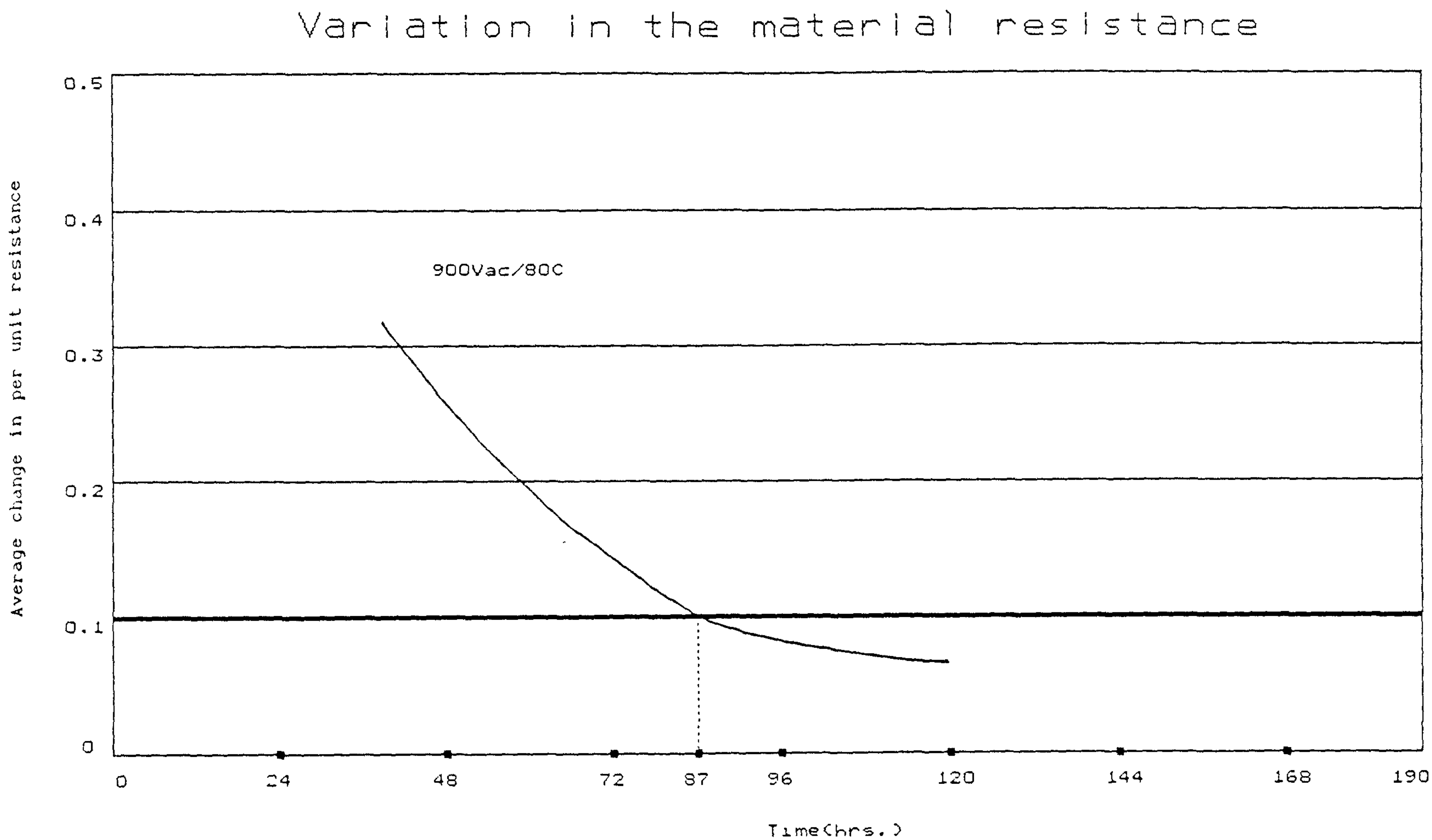

Fig.9 Material Degradation Pattern at Combined Electrical (900Vac) and Thermal (80 C)

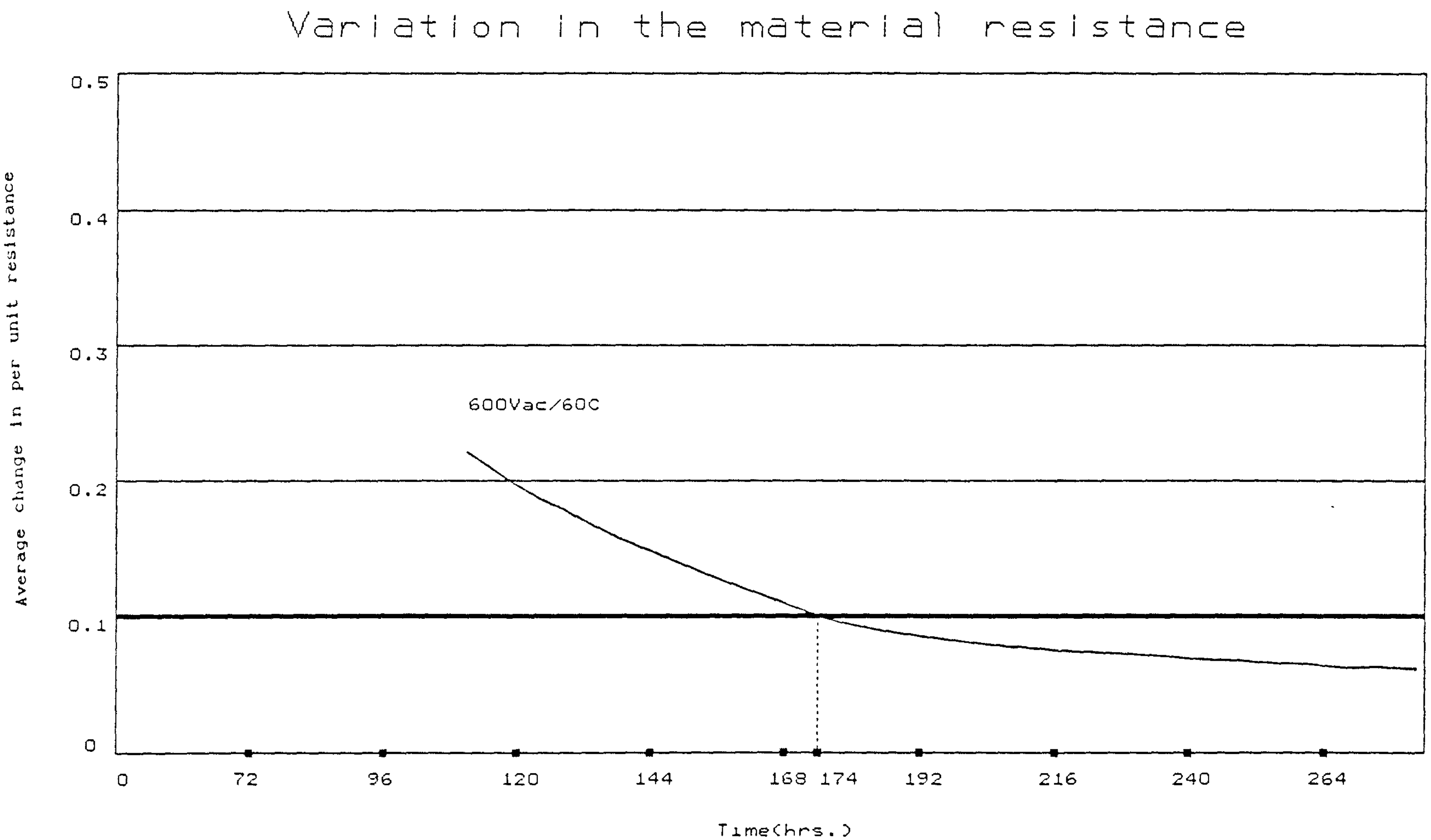

Fig.10 Material Degradation Pattern at Combined Electrical (600Vac) and Thermal(60 C)

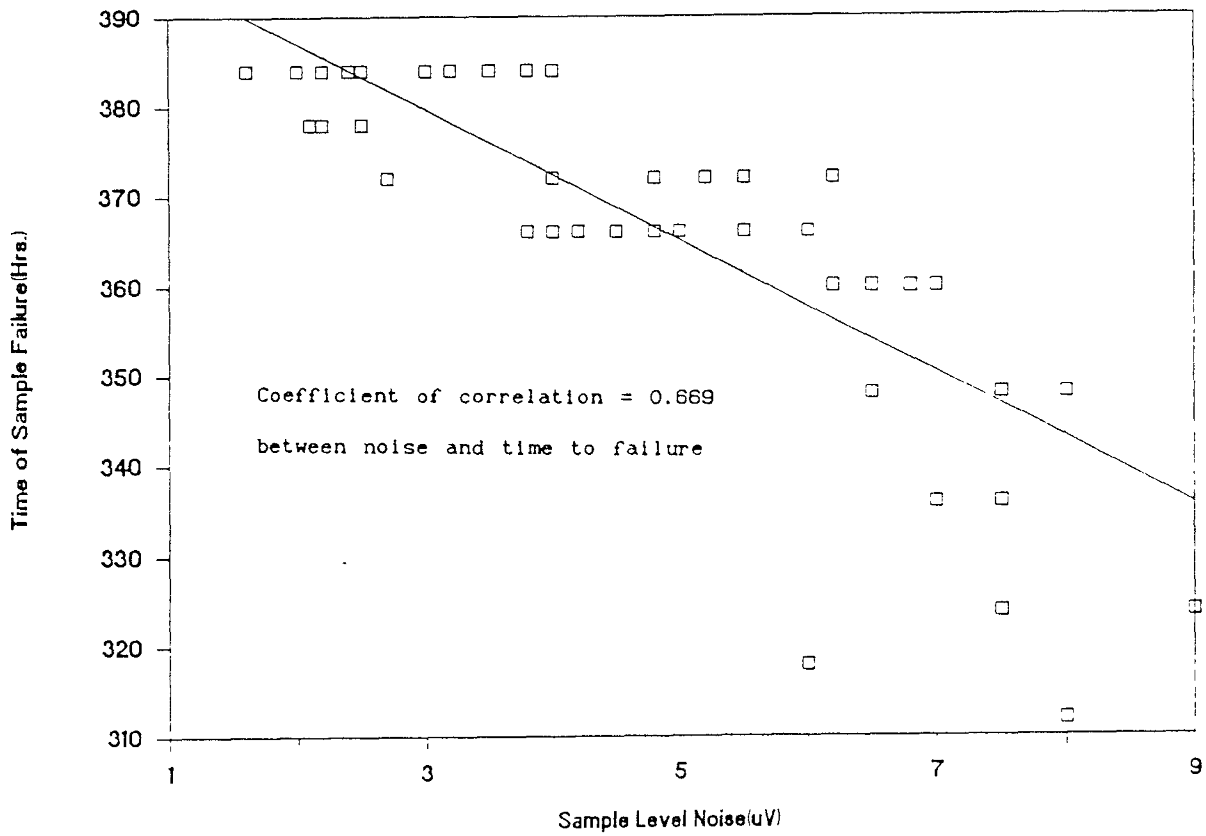

Fig.11 Failure Data at 700Vac/80C

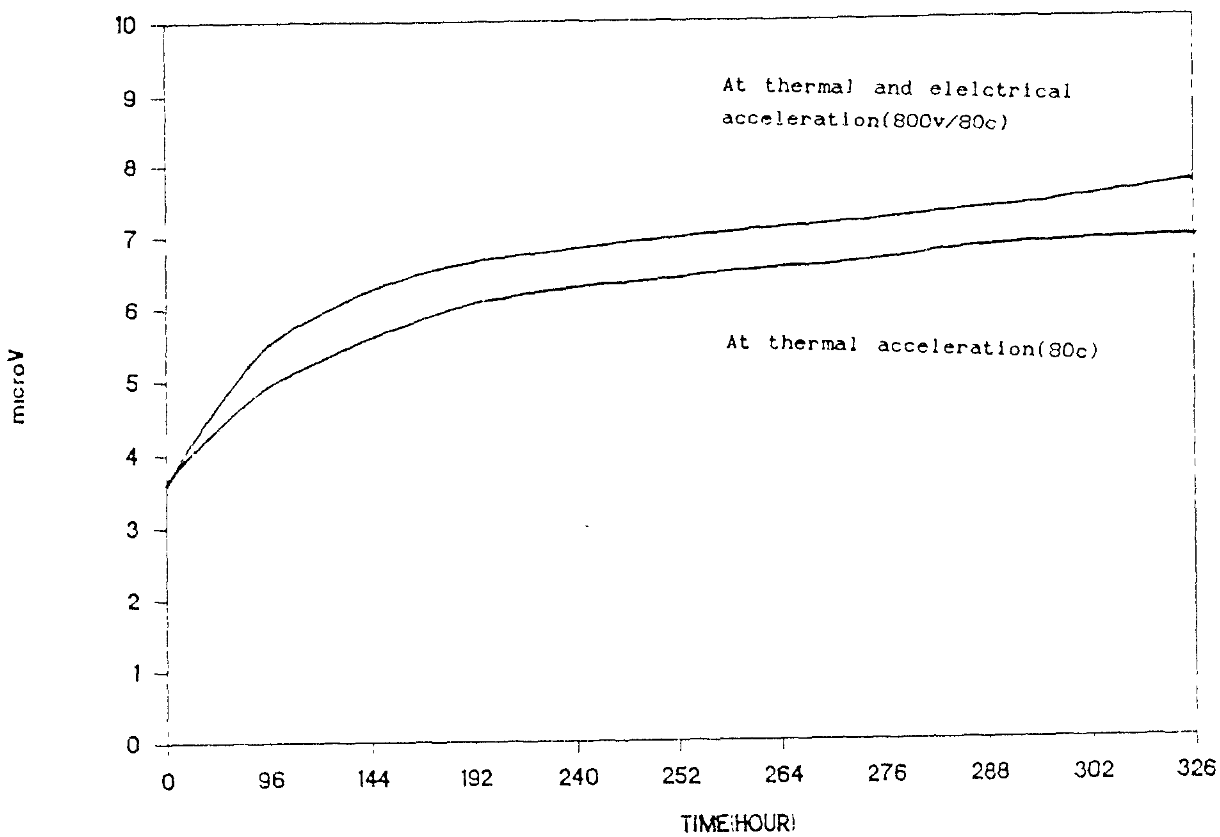

Fig.12 Electrical Noise Variation during Life

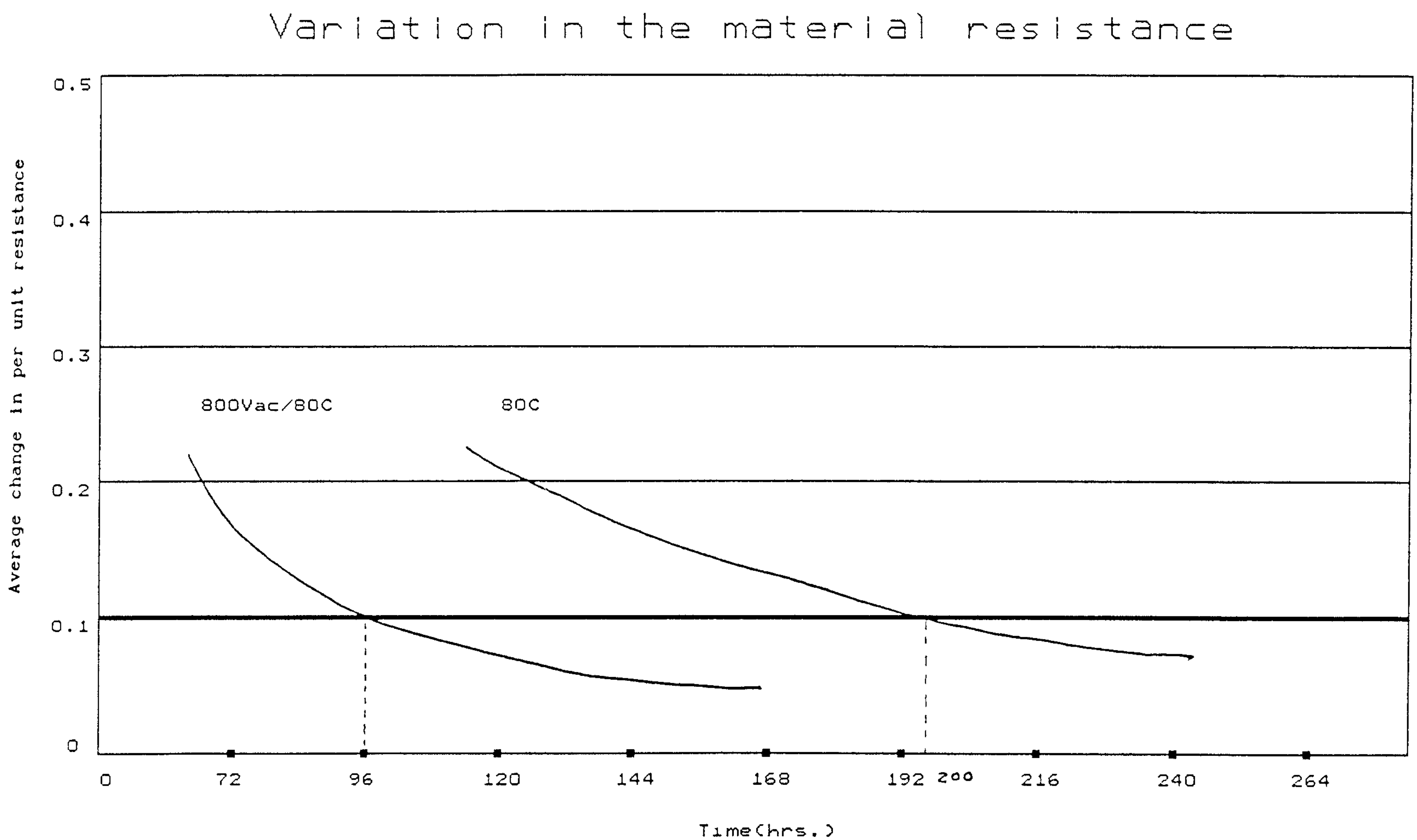

Fig.13 Material Degradation Pattern
under 80C and 800Vac/80C

BIBLIOGRAPHY

BIBLIOGRAPHY

1. S. B. Pandey and R. P. Misra, "Failure of Solid Dielectrics under Electric/Thermal Stress"17th Inter-ram Conference, Hersay, Pa.350-55, June 1990

2. R. P. Misra, S. B. Pandey, V. Sundaresan "Reliability Prediction of Solid Dielectric Using Electrical Noise as A Screening Parameter" accepted for publication in the IEEE Trans. on Reliability, April 1991.

3. George A. Donos "Reliability Prediction of Vulcanized Fibre Using Electrical Noise As A Screening Parameter" Master Thesis at N.J.I.T.

4. L. Simoni"Application of A New Geometrical Approach to Determination of Combined Stress Endurance of Insulating Materials", IEE Trans. on Elec. Insul. vol.23, pp 489-492, 1988

5. G. C. Montanari and Mario Cacciari"A Probabilistic Life for Insulating Materials Showing Electrical Thresholds" IEEE Trans. on Elec. Insul. vol.24, no.1, 1988

6. P. R. Misra, S. B. Pandey, V.Sundaresan"Insulation Screening for

Reliability Using Electrical Nlise under Power Voltage Excitation", Proc. of the IASTED Symposium on Reliability and Quality Control, Paris, June 22-23, 1988

7. H. Hirose"A Method to Estimate the Life Time of Solid Electrical Insulation IEEE Trans. on Elec.Insul. vol.22, pp 745-753, 1988

8. P. Chiou"A Preliminary Test Estimator of Reliability in A Life-Testing Model" IEEETrans. Rel.vol R-36, Oct. 1987

9. R. Gerhard"Electrets:Dielectrics with Quasi-Permanent Charge or Polarization" Conference on Electrical Insulation and Dielectric Phenomena, Oct. 1987

10. H. I. Wintle"A Noise on Electrothermal Breakdown in Insulation", IEEE Trans. on Elec. Insul.vol 24, no.1, 1988

11. M. I. Soomro"Life Testing of WSolid Dielectric Materials" Master Thesis at N.J.I.T., Newark, 1987

12. Harold Zapolsky, "The Depolarization Field Inside A Homogenous Dielectric:A New Approach" Amer. J. Phy. vol 55, no.1, Jan. 1987

13. H. Fujita "An Analysis of Mechanical Stress in Solid Dielectrics Caused by Discharge in Voids" IEEE Trans.Elec. Insul. vol. EI-22,

Jun. 1987

14. X. Yin and B. Sheng "Some Aspects of Accelerated Life Testing by Progressive Stress" IEEE Trans.Rel. vol R-31, no.1, Apr. 1987

15. M. Abdel Salam and E. K. Stanek "Otiminzing Field Stress on HV Insulators" IEEE Trans. Elec.Insul. vol.EI-22, Apr. 1987

16. R. P. Misra and S. B. Pandey "Noise as A Tool for Reliability" 14th Inter-ram Conforence the Electric Power Industry, Torondo, 1987

17. G. C. Montanari and G. Pattini"Thermal Endurance Evaluation of Insulating Materials: A Theoretical and Paractical Analysis" IEEE Trans.Elec.Insul. vol.EI-21 pp 69-77, Feb. 1986

18. T. Mizutaniand M. Ieda"Electrical Conduction In Solid Dielectrics" IEEE Trans.Elec.Insul. vol.EI-21 no.6 pp 833-839

19. J. Lewiner"Evaluation of Experimental Techniques for The Study of The Electrical Properties of Insulating Materials" IEEE Transaction on Power Apparatus and Systems vol.Pas-104, no.1, Jan.1985

20. T. Kaneko"Thermal Aging" IEEE Trans. Elec.Isul. vol.EI-21 no.6 pp 907-911, Dec. 1986

21. Y. Kako " Multi-Factor Aging of Insulation Systems: Infinite Sequential Stressing Method"IEEE Trans.Elec.Insul. vol.EI-21 no.6 pp 913-917, Dec. 1986

22. P. Guerin and Hoang Giam"Pressure and Temperature Dependence of The Dielectric Breakdown of Polyethylene Used in Submarine Power Cable" Jr.Appl.Physics vol.57 no.10 pp 4805-07, May 1985

23. B. Uoda, C. I. Keda, M. Kanaoka"Development of 500KV Cross-Linled Polyethylene Insulation Power Cable" IEEE Transactions on Power Apparatus and Systems vol.Pas-104, no.1, Jan. 1985

24. S. Regarajan and M. D. Agarwal"Behavior of High Voltage Machine Insulation System in the Presence of Thermal and Electrical Stresses" IEEE Trans.Elec.Insul. vol.EI-20 no.1 pp 104-110, Feb. 1985

25. T. S. Ramu"On the Estimation of Life Power Apparatus Insulation Under Combined Electrical and Thermal Stress" IEEE Trans.Elec.Insul. vol EI-20 no.1 pp 70-78, Feb.1985

26. R. A. Thomas"Life Prediction of Cable Insulation Material Based on Weibull Accelerated Testing Without Failure" IEEE Trans.Elec.Insul. vol.EI-20 no.1 pp 79-82, Feb. 1984

27. J. P. Vigouroux and C. L. Gressus "Electrical Surface Breakdown:

Secondary Electron Emission and Electron Spectroscopy of Insulators" Scanning Electron Microsxope Part II pp 513-20, 1985

27. N. Schwesinger and J. Goebel"On the Correlation of Field Strength and Failure Point Directly in Soild Insulating Materials" Z.Tech.Hochsch(Germany) vol.30 no.6 pp 111-17, Mar. 1985

28. T. Hasman"Partial Discharge in Gaps Between Insulation and Electrodes" Electrotech.Obn. vol. no.3 pp 111-17, Mar. 1985

29. Eun-Shik Jeung, Chang Nam Kangi and H.P.Chung"A Study of The Dielectric Strength of Composite Materials"Trans.Korean Inst.Elec. vol.34 no.8 pp 323-330, 1985

30. J. K. T. Oleson "Electrical Noise In Many Things" Eleknik. (Denmark) vol.2 no.11 pp 36-41, Nov. 1985

31. L. Simoni"General Equation of The Decline in The Electrical Strength for Combined Electrical and Thermal Stresses " IEEE Trans.Elec.Insul. vol.EI-19 no.1 pp 45-51, Feb. 1984

32. A. K. Jonscher and R.Lauste"On A Commulative Model of Dielectric Breakdown in Solids" IEEE Trans.Elec.Insul. vol.EI-19 no.6 pp 567-77 Dec. 1984

33. T. D. Eish and Y. A. Abid"Temperature Influence on the Anomalous Breakdown Phenomena in Solid Dielectrics" Ann.Rep. on Conf. on Elec.Insul. and Dielec. Phen. pp 273-78, Otc. 1984

34. N. J. Pearman and M. H. S. A.Rageb"An Approach to the Prediction of the Life of Electrical Insulation" IEEE Trans.Elec.Insul.vol.EI-19 no.2 pp 107-13, Apr. 1984

35. M. Ieda "Electrical Conduction and Carrier Traps in Polymeric Materials" IEEE Trans.Elec.Insul. vol.EI-19 pp 162-178, 1984

36. T. Hasman"Partial Discharges in Dielectric Cavities Respecting Their Leakage" Electroteck Obz. vol.73 no.4 pp 208-12, Apr. 1984

37. K. Stimper"Mechanism of Deterioration of Electrical Insulating Surfaces" IEEE Int'l Symp. pp 4224-30, Apr. 1984

38. M. A. Chaudhry, A. R. Haider and A. K. Janscher"Dielectric Effects of Moisture in Layered and Porous Materials" 4th Int'l.Conf. on Dielec. Mat. Mass. and Appl. pp 84-87, Sept. 1984

39. A. S. Pillai and R. Hackman"Electrial Breakdown in Solid Insulators in Air and in Vacuum" Proc. 4th Int'l Symp. pp 42230, Apr-May 1984

40. A. Nossier"Discharge Detection and Measurement in Voids in Solid Dielectrics" IEEE Int'l Symp. Elec.Insul.Cat.no. (84CM1964-6.EI) Montreal pp 336-38, June 1984

41. J. C. Devins"The Physics of Partial Discharge in Solid Dielectrics" IEEE Trans.Elec.INsul.vol.EI-19 no.5 pp 475-95, Oct.1984

42. T. Hibma and P. Oflunger"Electrofracture Mechanics of Dielectric Aging" Ann.Rep. of Conf. on Elec. INsul. and Dielec. Phen. pp 85 38, Oct. 1984

43. S. Zoledziowski and A. Sierota"Physical and Statistical Aspects of Breakdown Characteristics of Solid Dielectrics" 4th Inte'l Conf. on Dielec. Mat. Meas.and Appl.(England)pp 88-87, Sept. 1984

44. G. Carrara and S. Yakov"Statistical Evaluation of Dielectric Test Methods" Engg.Elec.(Italy) vol.60 no.1 pp 12-19, 1983

45. G. C. Stone and J. F. Lawless"Weibull Statistical Analysis of Aging of Solid Dielectric Insulation" IEEE Int'l.Symp on Elec.Insul. pp 13-16, June 1983

46. Anon."Partial Discharge by High AC and DC Voltage" Elec.Engg. Electron(Portugal) no.185 pp 107-11, 1983

47. K. Kadotani and Y. Kako"New Voltage Endurance Curves for Combind Thermal and Electrical Aging of Coil Insulation" IEEE Trans.Elec.Insul. vol.EI-18 no.1 pp 53-58, Feb. 1983

48. L. Thione and R. Cortina"Study of Corona Performance of UHV Insulator Sets" IEEE Trans.Power App. and Sys. vol.102 pp 2269-77, 1983

49. M. V. Sokolova"Characteristics of a Discharge in an Air Gap with An Electtode Coated with Solid Dielectric" Electrichestro(USSR) no.12 pp 53-56, Dec. 1983

50. C. M. Cooke"Discharge Inception by Particles Near Insulator Surfaces:The Proximity Effects" IEEE Conf.Rec. of 1983 Interfacial Phen. in Practical Insul.Sys., Sept. 1983

51. A. J. Pearmain and M. H. A. Rageb"Life Testing of Solid Insulating Materials" IEEE Int'l Conf. on Conduction and breakdown of Solid Dielectrics pp 296-300, June 1983

52. T. S. Ramu and K. P. Mamooty"Analysis of Combined Electrical and Thermal Stresses Aging of Capacitors and Rotating Machine Insulation" IEEE Conf. on Elec.Insul. and Dielec.Phen. pp 135-39

53. K. Kadotani and Y. Kako"An Analysis of Combined Stress

Degradation of Rotating Machine Insulation" IEEE Tans. Elec.Insul. vol.EI-18 no.12 pp 642-50, Dec. 1983

54. Y. Kasco, K. Kadotani and T. Tsukui, "Combined Stress Degradation of Rotating Machine Insulation", IEEE Trans. Elec. Tnsul, vol. EEI-18, no.6, Dec. 1983, pp 642-650

55. C. M. Cook"Pratial Discharge Induced by Small Floating Potential Mettalic Elements" Ann.Rep. Conf. on Elec.Insu. and Dielec. Phen pp 137-40, Oct. 1982

56. F. J. Lebok"Thermal Endurance Data for Solid Insulating Materials" IEEE Trans.Elec.Insul. vol.EI-17 no.1 pp 53-63, Feb. 1982

56. M. Fatouhi"Examination of Kerr Effects of Non-Uniform Electrical Fields" IEEE Int'l Symp. on Elec. Insul. pp 35-72, July 1982

57. N. J. Klein"Dielectric Breakdown" Jr.Appl.Physics pp 53, 1982

58. W. Schuller " Transformer Noise" Noise Control Engg. vol. no.3 pp 111-16, 1982

59. M. N. Joshi"Ensuring Product Reliability Through Dielectric Strength Testing" Electron Test vol.5 no.1 pp 36-41, 1982

60. G. Montanari, P. Gianni and L. Simoni" The Electri Strength Measurement for Aging Evaluation in Multiple Stress Tests" IEEE Int'l.Symp. on Elec. Insul. pp 9-12, June 1982

61. Wang and Foster "Feature of Electric Breakdown" IEEE Trans.Elec.Insul. vol.EI-17 no.1 pp 203, 1982

62. P. Paloneimi"Multiple-Stress Endurance on High Voltage Motor Insulation with Equal Acceleration on Each Stress" IEEE Trans.Elec.Insul. vol.EI-17 no.3 pp 353-61, June 1982

63. W. J. Carter"Paractical Aspects of Apparent Change Partial Discharge Measurements" IEEE Trans. Power App.Sys. vol.PAS-101 no.7 pp 1985-9, 1982

64. E. O. Foster"In Search for Universal Features of Electrical Breakdown in Solid Liquids and Gases" IEEE Trans.Elec.Insul. vol.EI-17 no.6 pp 517-21, Dec. 1982

66. M. Caccari"Life Predictions for Insulating Materials Subjected to Combined Thermal and Electrical Stresses" Energy Elec. vol.59 no.10 pp 440-46, 1982

67. J. D. Rudell and J.G.Cherenevak"Ionization Induced Breakdown and Conductivity of Satellite Dielectrics" IEEE Trans.Nucl.Sc. vol.59

no.29 pp 1754-59 1982

68. L. Simoni "On Compatibility Between thermal and Electrical Stresses" IEEE Trans.Elec.Insul. vol.EI-17 no.4 pp 373-75, 1982

69. J. J. O'Dwyer"breakdown in Solid Dielectrics" IEEE Trans.Elec.Insul. vol.EI-17 no.6 pp 484-87, Dec. 1982

70. Z. Lechowski"A New Outlook on breakdown Action Caused by Partialf Discharge in Laminar Insulating Systems" Energetyka. vol.35 no.5 pp 177-81 May 1981

71. M. Vitnia"Location of Partial Discharge Sites" IEEE Trans.Power App. and Sys.vol.PAS-100 no.1 pp 163, 1981

72. A. Ryukowski"Short Time AC breakdown Characteristics of Polyethylene Aged Under Multiple Stress Conditions. IEEE Trans Power App. and Sys. vol.PAS-100 no.4 pp 1829-37

73. P. Poleniemi"Theory of Equalization of Thermal Aging Process of Electrical Insulating Materials in Thermal Endurance Tests" IEEETrans.Elec.Insul. vol.EI-16 no.1 pp 1-30, Feb. 1981

74. T. Nite and H. Kuwahara"Time Dependence of Breakdown Voltage and Endurance Testing of Compressed Gas Insulation" IEEE Trans. Power

App. and Sys. vol.PAS-100 no.6 pp 3055-65, 1981

75. S. Yoryaachin and S. Shilov"Investigating the Influfence of Temperature and Humidity on the Characteristics Izv.Vuz. Energ.no.11 pp 92-96, 1981

76. Y. KakoM. Takamura and T.Tsuki"Correlation between Nondestructive and Destructive Tests on High Voltage Machine Insulation" IEEE Trans.Elec.Insul. vol.EI-16 no.2 pp 118-27 Apr. 1981

77. Y. Bagalei and L. Shchebenyuk"Lifetime of Paper-Epoxy Dielectric in An Electrical Field" Izv.Vuz. Blektromekh no.4 pp 47-461 Apr. 1981

78. S. E. Kiersztyn"Fformal Theoretical Foundation of Electrical Aging of Dielectrics" IEEE TransPower App.and Sys. vol.PAS-100 no.11 pp 4333-38 Nov. 1981

79. J. J. O'Dwyer and B. Beers"Thermal Breakdown in Dielectrics" Ibid pp 193-98 1981

80. A. Veverka and K. Zalis"Total Measurement of Partial Discharges" Elech.Obz vol.70 pp 675-9 Dec. 1981

81. A. Bulinski, J. Densley and T. S. Sundershan " The Aging of Insulation at Cryogenic Temperature" IEEE Trans.Elec.Insul. vol.EI-16

pp 83-88 Apr. 1981

82. Z. Lechowski "A New Outlook on Breakdown Action Caused by Partial Discharge in Laminar Insulating Systems" Energetyka. vol.Ei-16 no.4 pp 277-89, Aug. 1981

83. G. Pattini and L. Simoni"Discussion on Modeling of Voltage Endurance" IEEE Trans.Elec.Insul. vol.EI-15 no.3 pp 225-40 June 1980

84. A. Islef"Insulation Under the Action of Moile high Current Discharges" Ibid pp 68-73, 1980

85. P. Thoma"Dielectric Aspects of Pre-Breakdown Phenomena in Insulators" IEEE Trans.Elec.Insul. vol.EI-15 no.1 pp 8-17, Feb. 1980

86. R. Dixon"Thermal Aging Predictions From an Arrhenius Plot with Only One Data Point" IEEE trans.Elec.Insul. vol.Ei-15 no.4 pp 331-34, June 1980

87. J. S. Simmens"Diagnostic Testing of High Voltage Machine Insulation --A Review of Ten years Experience in the Field" IEEE Proc. vol.127 no.3 pp 134-54, 1980

88. M. Ieda"Dielectric Breakdown Process in Polymers" IEEE Trans.Elec.Insul. vol.EI-15 pp 206-224, 1980

89. P. Paloneimi"Multi-Stress Endurance Test on High Voltage Machine Insulation with Equal Acceleration on Each Stress" IEEE Int'l.Sym. on Elec. Insul. pp 30-33, June 1960

90. P. Thoma"Dielecttric Aspects of Pre-Breakdown Phenomena in Insulators" IEEE Trans.Elec.Insul. vol.EI-15 no.1 pp 8-17 Feb.1980

91. P. P. Budenstien"On the Mechanism of Dielectric Breakdown in Solids" IEEE Trans.Elec.Insul. vol.EI-15 no.3 pp.225-40, June 1980

92. A. Greenwood"High-Field Conduction and Breakdown in Solid Dielectrics" IEEE Trans.Elec.Insul. vol.EI-15 no.3 pp.139-51 Apr.1980

93. EPRI Final Report"A Review of Equipment Aging Theory and Technology" Electric Power Research Institute, Palo Alto, California, Sept. 1980

94. H. Boulter "Machanical Stresses as Aging Factor of Electrical Insulation" DRAFT 63WG7, 1976