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A STUDY OF INSULATION TRACKING TEST METHODS WITH PARTICULAR EMPHASIS ON THE 'DIP TRACK' METHOD.

BY

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A STUDY OF INSULATION TRACKING TEST METHODS WITH PARTICULAR EMPHASIS ON THE 'DIP TRACK' METHOD

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ABSTRACT

The tracking properties of Paper phenolic, Glass Fiber Laminate, P.V.C. and Epoxy were investigated, using the I.E.C. test and the Dip Track test.

The effect of different contaminants on Paper Phenolic was investigated using the Dip Track test.

It was shown that the correlation between the Dip Track test and the I.E.C. Test is good.

It was also shown that for Paper Phenolic, increasing the electrode spacing does not produce a proportional increase in reliability.

It was concluded that the principal advantages of the Dip Track Test are, shorter test time, ability to test specimens of various shapes and sizes and a simple electrode system.

CONTENTS

LIST OF ABBREVIATIONS

I.E.C.	International Electrotechnical Commission.
P.V.C.	Polyvinyl Chloride.
C.T.I.	Comparative Tracking Index(Voltage corresponding to 50 drops on the curve between the number of drops and the applied voltage),
A.S.T.M.	American Society for Testing and Materials.

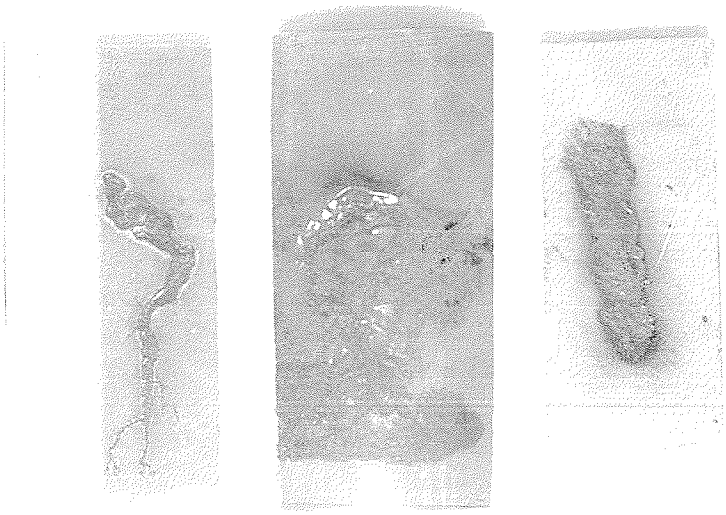
1. INTRODUCTION

GENERAL

Flashovers on panelboards, small circuit-breaker components, power transmission lines and other electrical equipment due to the deposition of pollution can be a major problem in many systems. Under polluted conditions the surface of the insulator can breakdown due to the formation of conducting tracks or by erosion. This study is primarily concerned with this type of tracking failure of insulation.

1.1 THE PHENOMENON OF TRACKING

When an electrically stressed insulating material is exposed to conditions which contaminate its surface e.g. moisture and conducting dust, there is a much larger leakage current across the surface of the insulator than that experienced with clean insulator surfaces. This leakage current generates heat, which causes a dry nonconducting region to form. This region is immediately bridged by a tiny discharge , since the stress locally exceeds the breakdown stress of air owing to the highly distorted electric field formed under such conditions. This small discharge (scintillation), can decompose the insulation, and if this cycle is repeated, over a period of time it can cause irregular conducting tree-like tracks to form on the insulation surface (Fig. 1.1). These conducting tracks may grow, finally bridging the gap between the electrodes causing



PAPER PHENOLIC P.V.C. GLASS FIBER LAMINATE

TRACKING FAILURE OF INSULATION

FIGURE 1.1

tracking failure. Some materials will erode under such conditions, and will fail due to erosion.

1.2 TRACKING TEST METHODS (See Table 1.1)

An insulator's resistance to tracking under polluted conditions is an important consideration when it is considered for an outdoor application. The evaluation of the tracking properties under polluted conditions is becomming increasingly important with the introduction of new synthetic materials suitable for various outdoor applications.

Many attempts have been made at designing a test method which would classify different insulating materials according to their tracking properties under laboratory conditions, but none of the existing methods is entirely satisfactory. This is due to the fact that there can be many different service conditions with regard to the composition, the degree of pollution and various other factors, and it is impossible for one test to simulate such a wide range of service conditions.

The first laboratory 'wet' tracking test, the 'Contaminate drop test' originated in Switzerland in the year 1930. Five years later it appeared in the United States as the "Detroit Edison" tracking test. In England it was adopted by Metropolitan Vickers, and was further modified to 'Admiralty Test' by the British Navy. Various versions of this test appeared in Europe and United States, and finally in

TEST METHOD	APPX. EQUIPMENT COST	AVERAGE TEST TIME	SAMPLE SIZE	VOLTAGE RANGE	TEST VARIABLE	CONTAMIN-ANT	ELECTRODES	REPRODU-IBILITY
I.E.C. Publication 112	$1000/-	THIRTY MINUTES	3/4 inch by 3/4 inch	750 VOLTS	VOLTAGE	.1% NH_4Cl + WETTING AGENT	BRASS	FAIR
DUST/FOG ASTM TEST D2132	-	100 to 2000 HOURS	4 inches by 4 inches	1500 VOLTS	TIME	SALT AND WATER SPRAY	STAINLESS STEEL	POOR
INCLINED PLANE ASTM TEST D 2303	-	FEW HUNDRED HOURS	2 inches by 5 inches	7500 VOLTS	VOLTAGE OR TIME	0.1%NH_4Cl + WETTING AGENT	STAINLESS STEEL	FAIR
ENDURANCE WHEEL	-	FEW HUNDRED HOURS	2.5 inch by 8 inches	20,000 VOLTS	TIME	TAP WATER SPRAY	ALUMINUM OR BRASS	-
DIP TRACK	$600/-	FIFTEEN MINUTES	1.5 inch by 1.5 inch	4000 VOLTS	VOLTAGE	0.1%NH_4Cl +WETTING AGENT	40 mil NICHROME WIRE	GOOD

TABLE 1.1 COMPARISON BETWEEN TRACKING TEST METHODS (8)

Norway under the direction of P.D. Poppe a modified tracking test was developed, which was adopted by the International Electrotechnical Commission (I.E.C.) and published in 1959. The inability of the I.E.C. test to discriminate between the better track resistant materials necessitated the development of other tracking tests such as Dust and Fog Test (3), Inclined Plane Test (6), and the more recent "Endurance Wheel Test (7) and the Dip Track Test.

1.2.1 I.E.C. TEST

This test method is discussed in detail in the next chapter.

1.2.2 DUST AND FOG TEST

This test was first proposed by Albright and Starr (11) and modified by Sommermann (14). The basic purpose was to obtain a better agreement with service experience. To simulate service conditions more closely, solid contaminant in dust form was used with a constant spray, unlike other tests where drops of electrolyte are allowed to fall between the electrodes. The materials which do not fail by tracking do so by erosion. This method can grade some of the better track resistant materials which do not track in the I.E.C. test. Also, correlation with the service conditions is quite good.

One of the disadvantages of this test is that a large variability of results for the same material is some times

obtained. Such a variability can be expected in any such test method where the initiation of tracking or erosion can take place anywhere on the surface under test, since this initiation is of a random nature. Another disadvantage of this test method is that for some materials the duration of test is excessive (more than a few thousand hours). A Complete description of this test appears elsewhere (13).

1.2.3 THE INCLINED PLANE LIQUID CONTAMINANT TEST

Mathes and Mc Gowan published this method of tracking resistance measurement in 1961(6). This test was aimed at better reproducibility of the tests by attempting to control the test parameters more closely than the Dust and Fog test where controlling of the solid dust type contaminant is rather difficult. In this test a sample of 2 inches by 5 inches is mounted with the flat face on the under side at an angle of 45 degrees to the horizontal (hence the name Inclined Plane Test). Stainless-steel electrodes are fastened to this sample and the liquid contaminant is made to flow between the two electrodes. The rate of application of the contaminant is closely controlled by using a plunger arrangement. Voltage is used as the test variable unlike the Dust and Fog test where time is the test variable.

With this method, the 'wet' tracking resistance of a wide variety of materials can be evaluated in about four hours. The reproducibility is quite good. An erosion test can

be made on the non-tracking materials by fixing the duration and the test voltage, and measuring the weight of the material lost (6). This test is discussed by Mathes and Mc Gowan and appears as a standard test method in the book of ASTM Standards (12).

1.2.4. DIP TRACK TEST

This test method is discussed in detail in the next chapter.

1.2.5 TRACKING ENDURANCE WHEEL TEST

In this test, the specimens are mounted radially around the rim of a 4 ft. diameter metal wheel. The specimens are energized at 20 k.v. and the wheel is driven at half r.p.m. Each specimen is wetted once each revolution, while at the bottom position (7). It is possible to evaluate better track resistant materials using this method. The correlation of the results of this test with those of Inclined Plane and outdoor exposure tests is good. The test time varies from less than an hour for non-resistant materials to over 500 hours for some epoxy formulations. This test has been used successfully by Ontario Hydro, A.B. Chance and Detroit Edison.

1.3 BASIC IDEAS AND THEORETICAL CONSIDERATIONS

1.3.1 FACTORS IN INSULATION SURFACE BREAKDOWN (10)

The following factors are known to determine the

mechanism of insulation breakdown.

1. Physical and chemical properties of the insulation.
2. Surface finish and surface contaminants.
3. The type of discharge.
4. Atmospheric conditions such as temperature, relative humidity, gases released from the decomposing insulator and the temperature of the insulation surface relative to ambient.
5. Frequency, waveform and magnitude of the applied voltage.

Table 1.2 shows the process and the products involved in an insulator breakdown. One or more of these processes are operative in a given situation.

FACTORS IN BREAKDOWN	PROCESSES	PRODUCTS
INSULATION + IMPURITIES + DISCHARGE	1. HEAT 2. HEAT + O_2 (Combustion) 3. ULTRAVIOLET RADIATION 4. SHORT LIVED ACTIVE PRODUCTS OF DISCHARGE e, O, N, O_3, N_2^+, O_2^+, etc. 5. STABLE ACTIVE PRODUCTS OF DISCHARGE: N_2, NO_2, HNO_3, O_2.	1. CARBON 2. POLAR COMPOUNDS 3. FUSED INORGANIC FILLERS

TABLE 1.2 PROCESSES IN INSULATION BREAKDOWN

1.3.2 ROLE OF CARBON IN TRACKING

It is well recognized that the formation of free carbon causes insulation tracking, however the materials which have a high carbon content may not have poor tracking properties since the way in which carbon is combined with other molecules is also of prime importance in determining the tracking properties of a material. If the rate of removal of carbon is higher than the rate of formation of carbon due to chemical and/or physical processes, the material will resist tracking (3), (2).

1.3.3 GROWTH OF DISCHARGE ON POLLUTED INSULATION SURFACE

The discharges on a polluted insulation do not necessarily lead to flashover. Under certain conditions, the polluted insulators exhibit sparks, which extinguish after having spanned only a fraction of the insulator surface. The phenomena which cause this extinction are not fully understood. Alston and Zoledziowski(1) have derived a quantitative criterion for such extinction, which agrees with experimental results obtained by several independent investigators. It requires the voltage across the insulator and the length of the discharge to be greater than the critical values V_c and X_c respectively for the discharge to grow into a flashover, where

$$V_c = A^{1/(n+1)} L r_c^{n/(n+1)}$$

$$X_c = L/(n+1)$$

A and n are constants, depending on the type of the discharge and the medium in

which the discharge occurs.

L = the distance between the electrodes,

r_c = the resistance of the polluted surface per unit length,

X_c = the length of the discharge.

Fig. 1.2 shows the above quantities and the Fig. 1.3 shows the relation between the applied voltage and the length of the discharge. V_M is value of the voltage across the insulator for the conditions in which the discharge will extinguish i.e. discharge current $i=[nAx/r_c(L-x)]^{1/(n+1)}$.

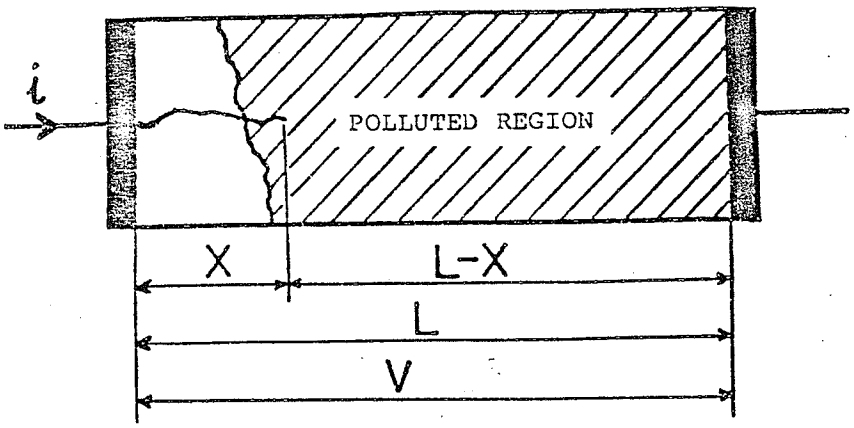


FIG. 1.2

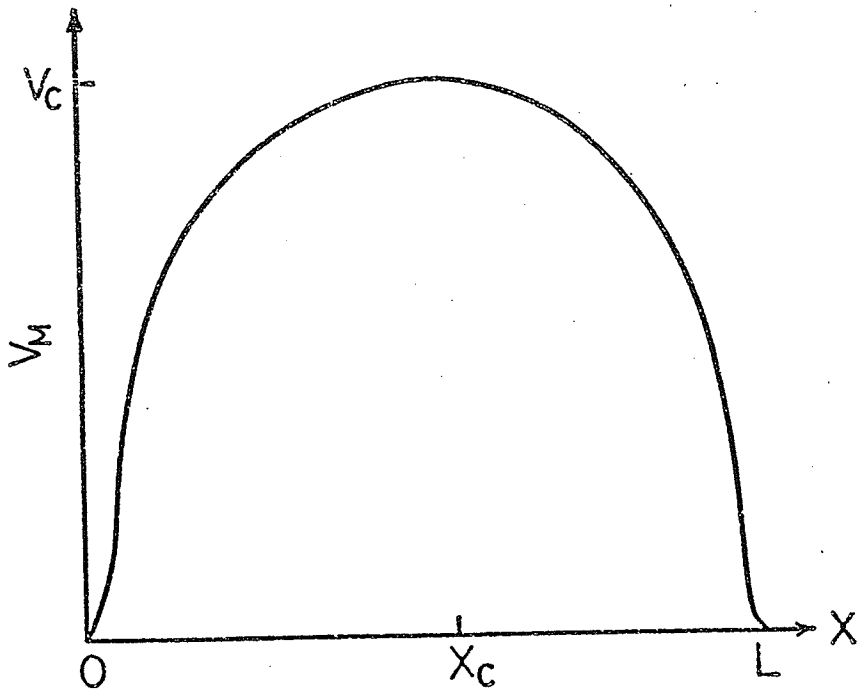


FIG. 1.3

DEPENDENCE OF V_M ON X.

2. EXPERIMENTAL APPARATUS AND PROCEDURE

2.1 THE I.E.C. TEST(4)

This test method was used to provide a comparison for the results obtained from the Dip Track Test. The materials evaluated using the I.E.C. Test were, paper phenolic, glass fiber laminate and epoxy mouldings. Rigid P.V.C. tube sections and P.V.C. tapes did not fail due to tracking in this test.

2.1.1 DESCRIPTION OF THE APPARATUS

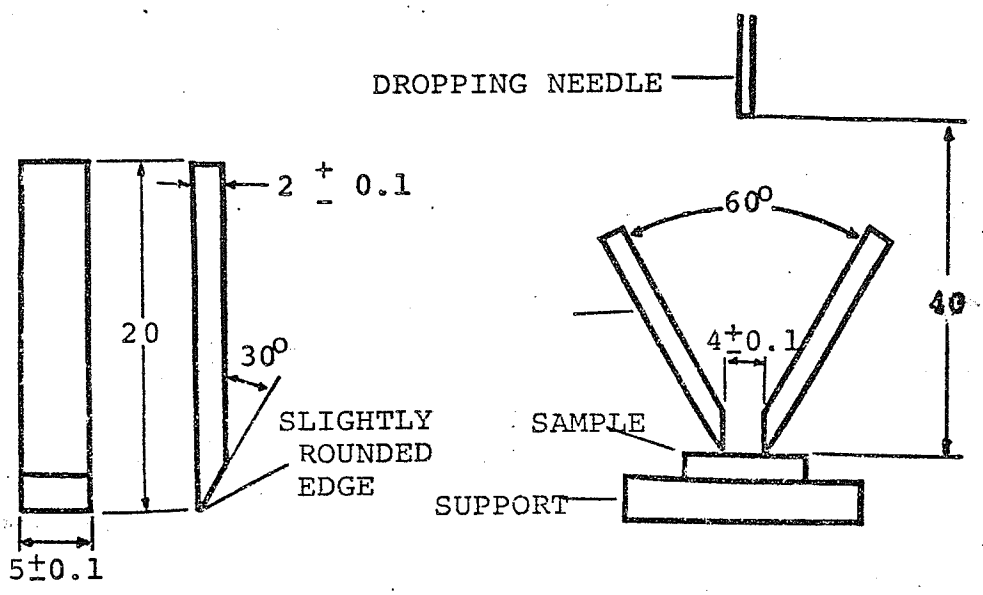
The test set-up consisted of four major parts, the electrode system, the dropping device, the power supply and the timer. The electrodes were placed on the specimen and energized by the power supply. Drops of the contaminant were allowed to fall between the electrodes every thirty seconds and the time elapsed for the formation of permanent tracks on the surface of the sample was noted.

The Electrode System

The electrode arrangement is shown in Fig. 2.1.

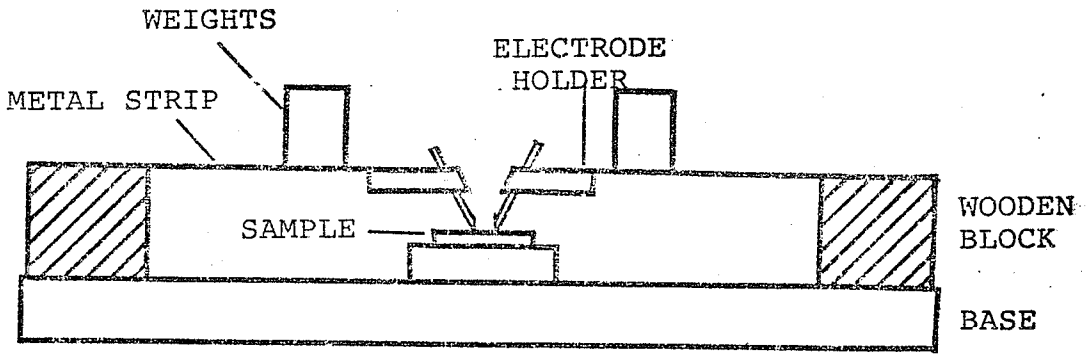
The Dropping Device

The dropping device consisted of a 250 ml. cylindrical separatory funnel, to which a rubber hose was connected. The other end of this hose was connected to a hypodermic needle with the end filed off square which acted



(A) (B)

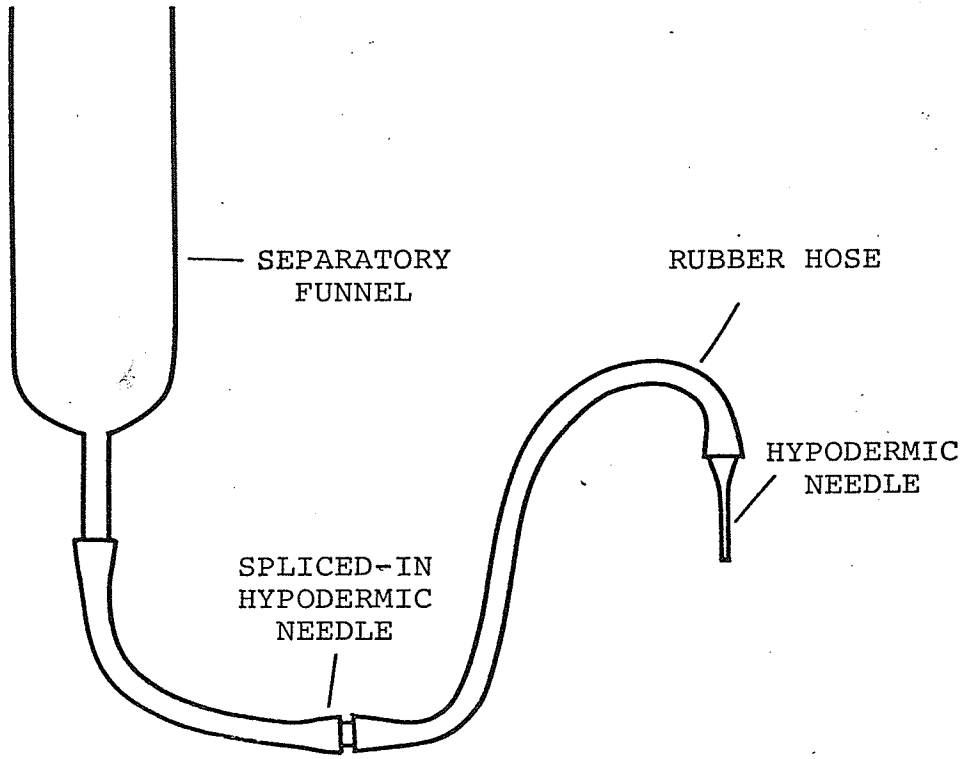
ALL DIMENTIONS IN M.M.



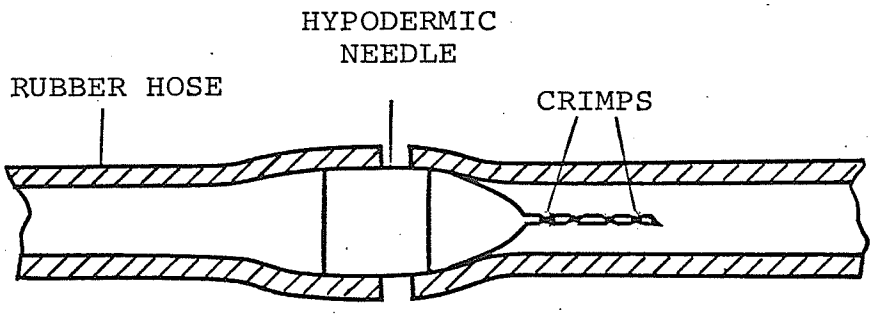
(C)

(A) ELECTRODE, (B) TEST CELL
(C) ARRANGEMENT OF ELECTRODES

FIG. 2.1



DROPPING ARRANGEMENT



FLOW REDUCING ARRANGEMENT

FIG. 2.2

as the dropping needle. To reduce the flow at the dropping end, another hypodermic needle was spliced into the hose (Fig. 2.2). This needle was crimped at four places using a pair of round nose pliers in such a way that one drop per second flowed out of it under the pressure of two feet head of water. This reduction in flow can also be produced by using a glass pellet in the hose(4)(5). The separatory funnel and the dropping needle were held upright on separate stands with sliding clamps in order to allow the adjustment of the dropping height.

The Power Supply

It consisted of a step-up transformer fed by a variac. A 'buck and boost' arrangement was used in the secondry circuit of the transformer to make smooth adjustment of the voltage possible. The 'buck and boost' unit was very useful when the tests were being made in the Comparative Tracking Index range, because a relatively small change in the voltage caused a large change in the time to breakdown. Fig. 2.3 shows the circuit used.

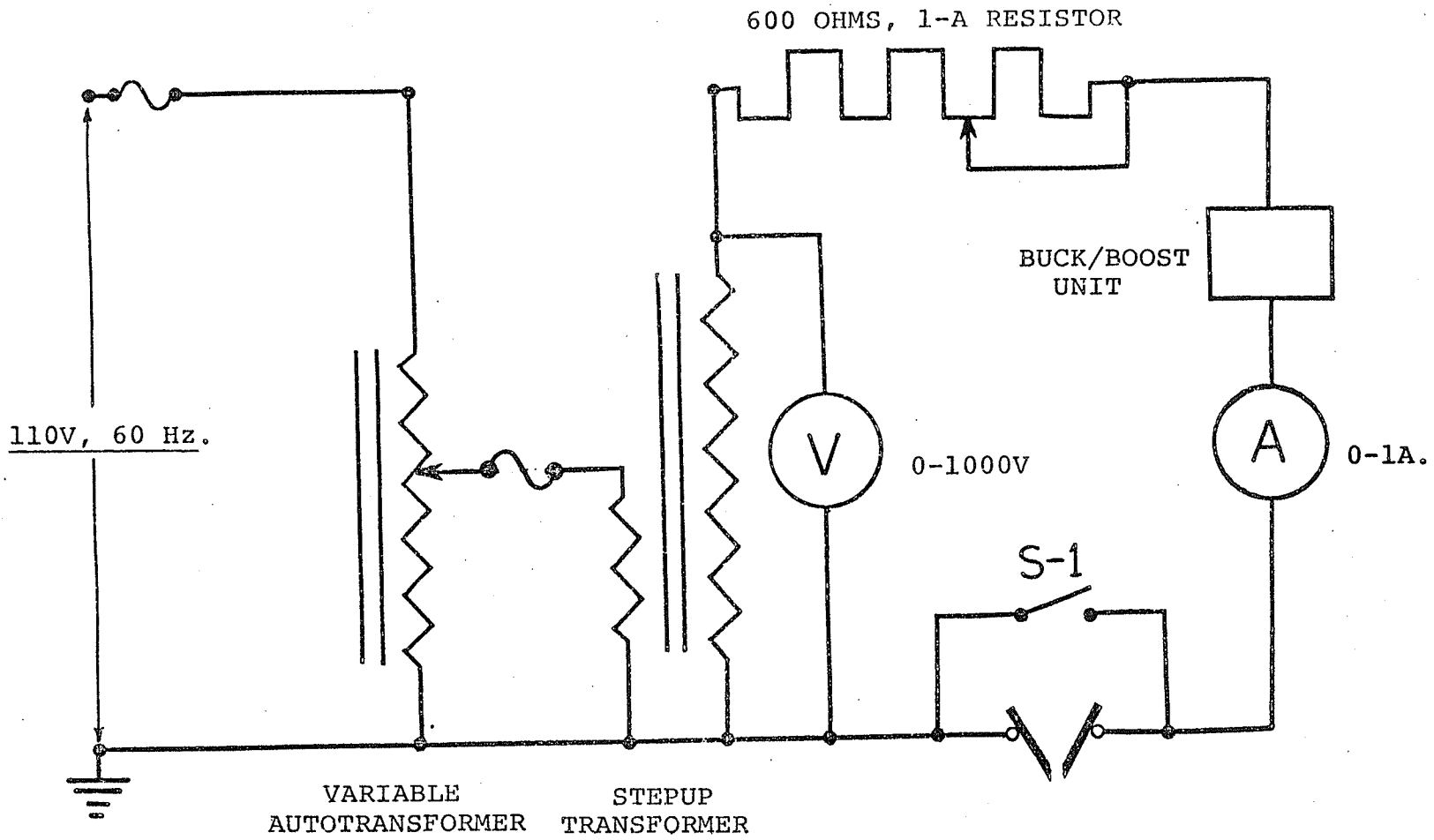
The Timer

A digital timer was used to time the experiment.

The actual physical set-up is shown in Fig. 2.4.

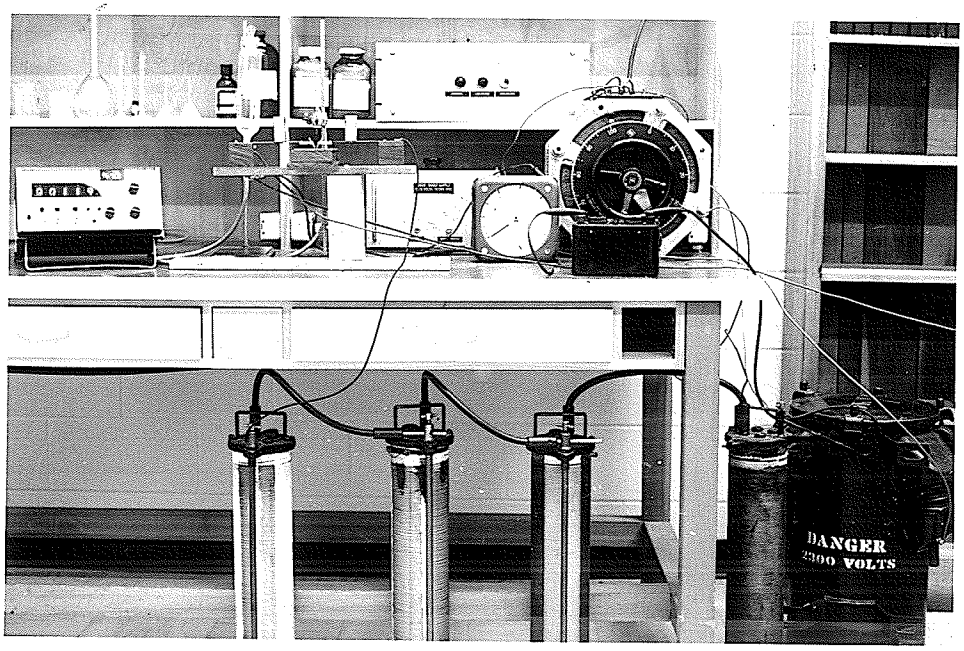
2.1.2 THE TEST PROCEDURE

Before starting the test, the drop rate of the contaminant was adjusted to two drops per minute and at least 20 drops were allowed to flow, since the first few drops



CIRCUIT DIAGRAM OF THE I.E.C. TEST

FIG. 2.3



THE I.E.C. TEST

FIG. 2.4

have a high concentration if the apparatus has not been used for some time. The electrodes were cleaned and reshaped by grinding or filing if eroded. The sample was then placed under the electrodes and the flatness of the edges of the electrodes against the surface of the sample was checked by shining a flashlight and looking for light from the opposite side. The distance between the electrodes was now adjusted to 4 m.m. using dial type calipers. The electrodes were shorted using the switch S1 and the short circuit current set at 1.0 amp; at the desired voltage. The contaminant and the timer were now started, and the switch S1 was opened. During the experiment the rate of the contaminant drops and the voltage level were checked from time to time, and adjusted as required. The failure of the sample was indicated by the flow of more than 0.5 amps. in the circuit. The time was noted for the failure of the sample at the applied voltage. By testing samples at different voltages, a curve relating the number of drops and the voltage was constructed and the voltage corresponding to 50 drops was taken as the Comparative Tracking Index(CTI).

THE CONTAMINANT

The contaminant used was 0.1% Ammonium Chloride solution. Drops of volume 23 $m\,m.^3$ were allowed to fall between the electrodes every 30 seconds from a height of less than 4 cms. from the surface of the sample.

Electrode Cleaning

After each test the electrodes were cleaned with Ethanol to remove the deposited carbon and other chemicals. Reshaping was done after testing four to five specimens or sooner if necessary.

Samples

Samples cut to various sizes were used, however 2 inch by 1 inch was found to be suitable. Four tests were made on each sample at a reasonable distance from the point where the previous tests were made.

No effort was made to clean the samples before testing.

Drop Size

The volume of the drops was 23 $m.m.^3$. The dropping needle was cleaned with Ethanol from time to time to prevent the drops from adhering to the outside walls of the needle.

Number of tests

Five to ten tests were made at each voltage and the average of these was used .

2.2 THE DIP TRACK TEST

This test was published by C.F. Wallace and C.A. Baily in 1967. The authors claimed this test to have the following advantages over the other previously used tests (9).

1. The testing time is short.
2. Excellent reproducibility.
3. It is possible to test non-flat samples.
4. Correlation with other tests is good.

2.2.1 DESCRIPTION OF THE APPARATUS.

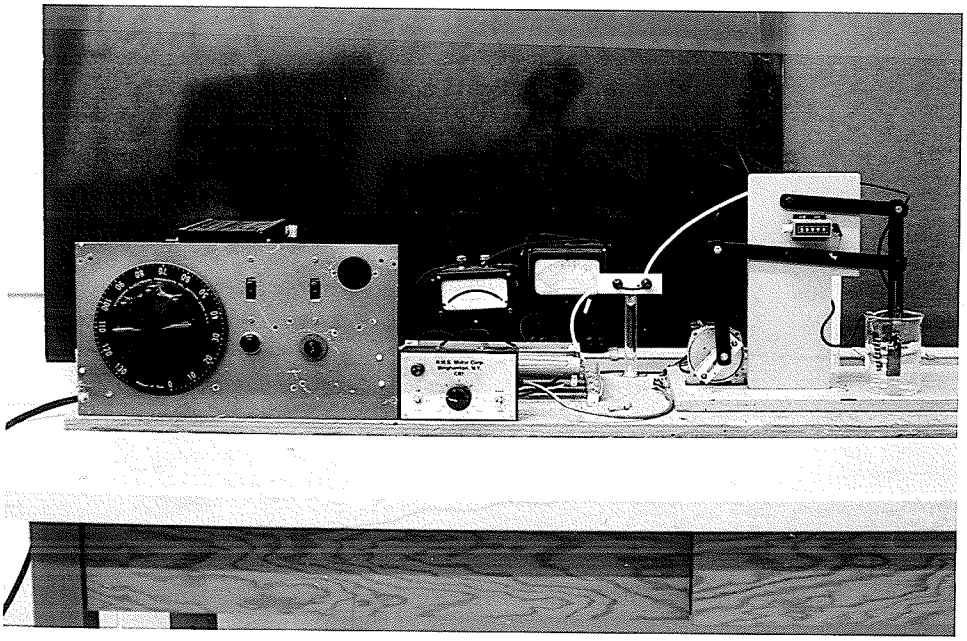
The test set-up consisted of a sample and electrode holder, a dipping mechanism, a power supply and a timer. The actual physical setup is shown in Fig. 2.5.

The sample and electrode holder

The sample and electrode holder was made from a small clip which held the sample and another clip soldered to the first one held the high voltage electrode, just touching the sample (9). The sample holder was attached to the dipping arm. A slot was provided in the dipping arm to adjust the height of the holder.

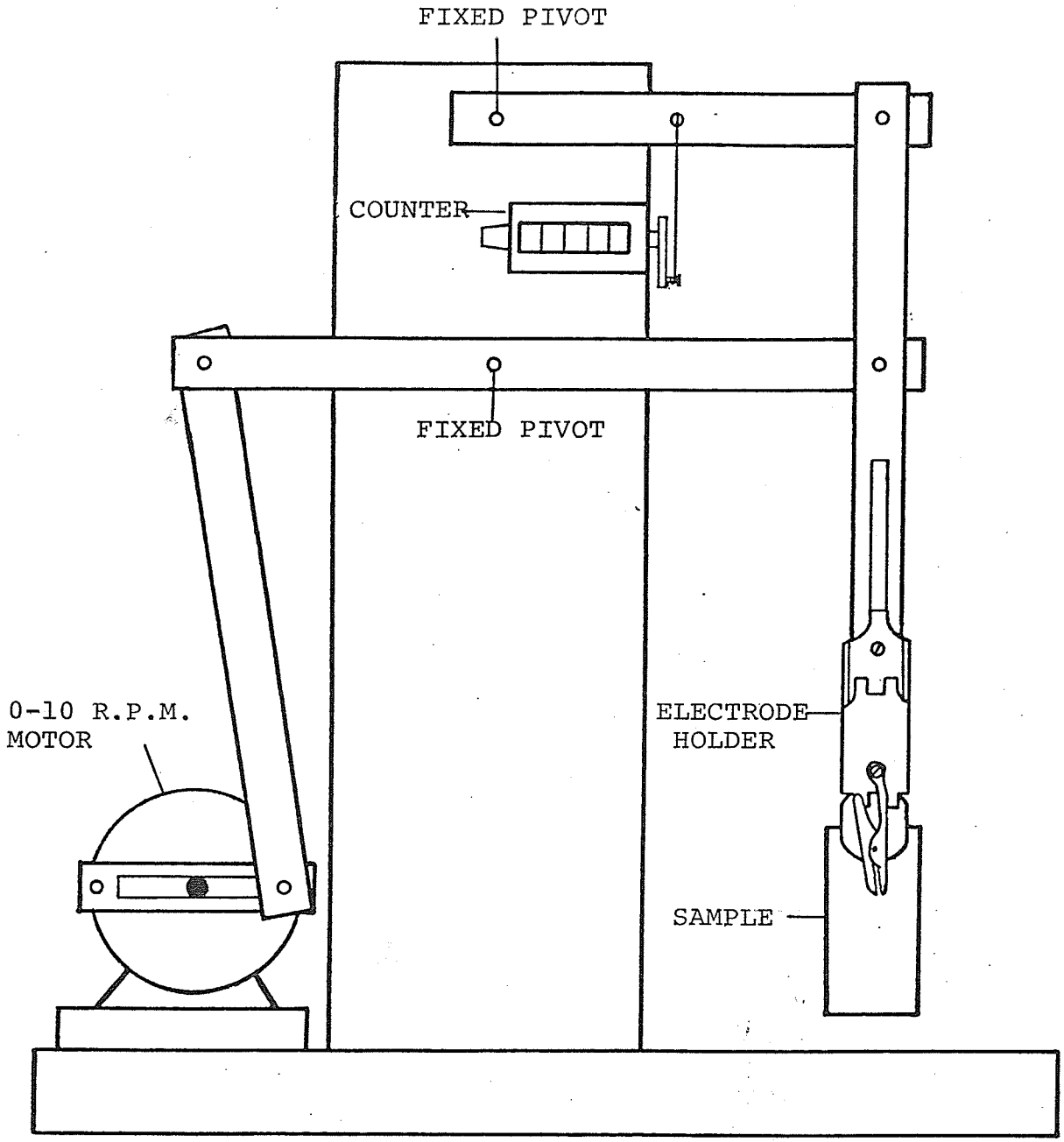
The Dipping Mechanism

The mechanical schematic of the arrangement used is shown in Fig. 2.6. The arms were made from 3/8 inch bakelite,



THE DIP TRACK TEST

FIG. 2.5



MECHANICAL ARRANGEMENT FOR DIP TRACK TEST

FIG. 2.6

and the whole mechanism was mounted on a base made from 3/4 inch plywood. A resettable mechanical counter was used to register the number of dips. The whole mechanism was driven by a small 0 to 10 r.p.m. motor with electronic speed control. A crank arrangement was used with provision for setting the throw of the dipping arm from 0 to 2.5 inches.

The Power Supply

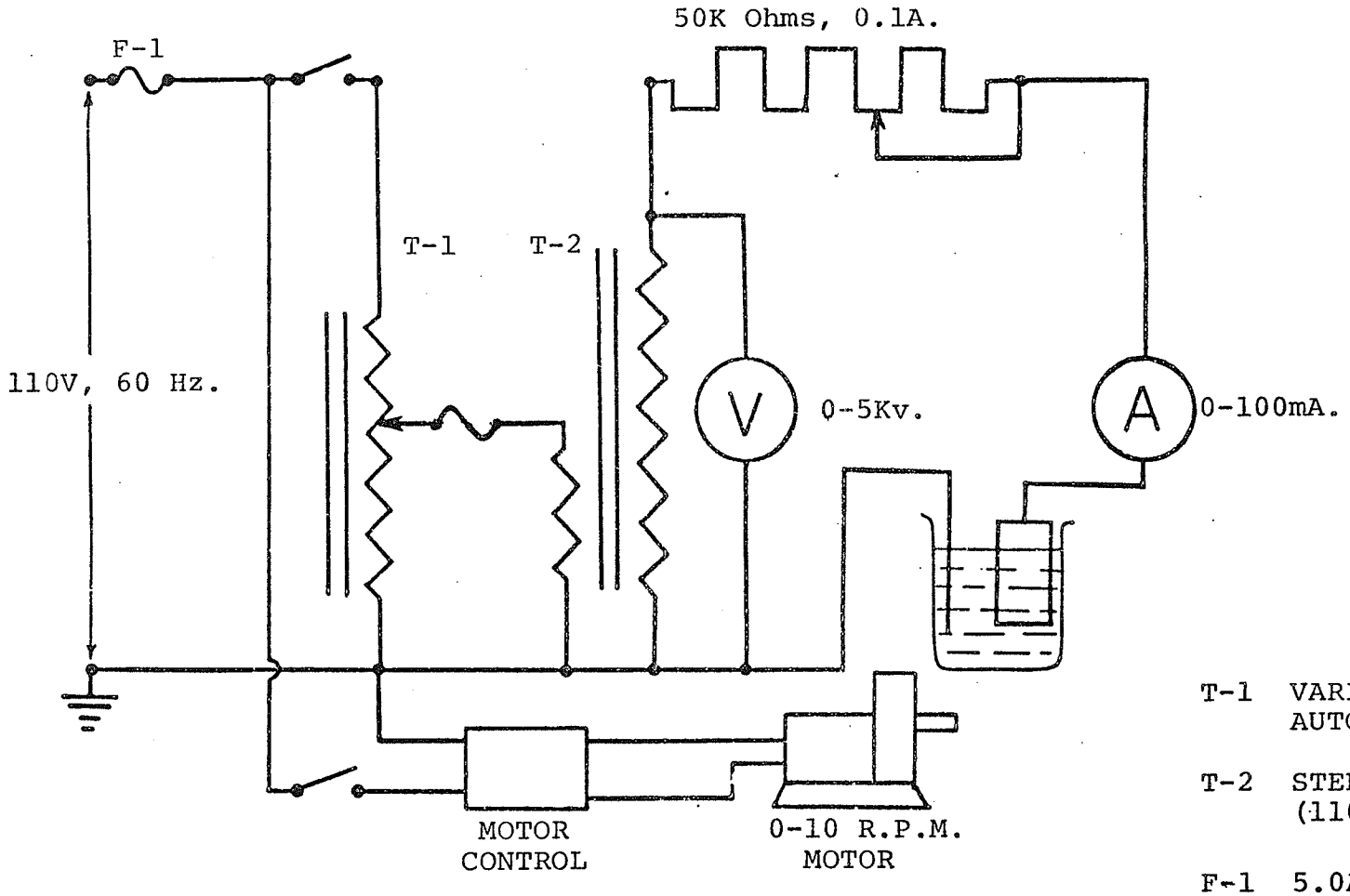
A step-up transformer (110/3420 V, 500 mA.) was fed by a variac and the output of the transformer had four 50 watt variable resistors in series, adding to 30,000 ohms. A voltmeter and ammeter were provided in the secondary circuit. The circuit is shown in Fig. 2.7.

The Timer

A digital timer was used to time the experiment.

2.2.2 TEST PROCEEDURE

The throw of the dipping arm and the speed of the motor were set at 1 inch and 4 r.p.m. respectively before each test. The sample and the electrode were placed in their respective holders, with the electrode just touching the surface of the sample and at approximately 45 degrees to the surface. The dipping arm was now brought to its lowest position. A 250 m.l. beaker was placed under the dipping arm and the contaminant was poured into the beaker until the tip of the high voltage electrode was about 1/16 inch under the contaminant. The low voltage electrode was now placed in the contaminant and the



T-1 VARIABLE AUTOTRANSFORMER

T-2 STEPUP TRANSFORMER (110/3420 V, 0.5A)

F-1 5.0A FUSE

CIRCUIT DIAGRAM OF THE DIP TRACK TEST

FIG. 2.7

power supply switched on. Short circuit current was adjusted to 100 mA. at the desired voltage and the motor was started. The failure of the sample was indicated by a steady flow of more than 50 mA. through the circuit, at that time the power supply and the motor were turned off and the number of dips required to fail the sample at the preset voltage was noted and a curve was constructed from the above data. The voltage corresponding to 40 drops was reported as the tracking voltage.

The Contaminant

The contaminant used was 0.1% solution of Ammonium Chloride with 0.02% Triton X-100 non-ionic wetting agent added to it. Fresh contaminant was used for each test.

The Electrodes

The high voltage electrode was a 3 cm. length of 0.036 inch Nichrome wire. The contaminant was the low voltage electrode.

Samples

The most suitable size of samples was 3/4 inch by 2 inches. Various other sizes were used. No effort was made to clean the samples before testing.

Number Of Tests

Four to five tests were made at each voltage and the average of these was used.

3. EXPERIMENTAL RESULTS AND DISCUSSIONS

In this section the results obtained from the I.E.C. and the Dip Track tests are presented and discussed. A comparison is made between the two tests. In all, over 1000 tests were made, at room temp. of 24°C.

The C.T.I. and the tracking voltage of four materials were evaluated after each of the following treatments.

1. SAMPLES were soaked in 5% salt solution for two weeks and tested after removing from the solution and wiping the surface dry.
2. Samples were soaked in transformer oil for two weeks and tested after removing from oil and wiping the surface.
3. A layer of white petroleum jelly (0.1 gm/sqcm.) was evenly applied just before testing the samples.

The results of the tests are presented in Table 3.1, and the normalized values with respect to glassfiber laminate in Table 3.2, to provide a comparison between the tracking properties of the different materials, and to illustrate the correlation between the two tests.

		GLASS FIBER LAMINATE	EPOXY MOULDINGS	P.V.C. (RIGID TUBE)	PAPER PHENOLIC	BAKELITE
I.E.C. TEST (C.T.I. in VOLTS)	WITHOUT TREATMENT	290	230	*	107	110
	TRANSFORMER OIL	310	238	*	115	
	NaCl SOLUTION	281	232	*	108	
	WHITE PETROLIUM JELLY	*	*	*	265	
DIP TRACK TEST (TRACKING VOLTAGE IN KV)	WITHOUT TREATMENT	2.20	3.30	1.05	0.96	0.70
	TRANSFORMER OIL	2.18	3.45	1.10	0.90	
	NaCl SOLUTION	1.40	3.40	1.10	0.84	
	WHITE PETROLIUM JELLY	4.50**	3.50	1.90	0.95	

* THE SAMPLES DID NOT TRACK.

** THE VALUE SHOWN WAS ESTIMATED GRAPHICALLY.

TABLE 3.1

NORMALIZED VALUES OF CTI AND TRACKING VOLTAGE

		GLASS FIBER LAMINATE	EPOXY MOULDINGS	P.V.C. (RIGID TUBE)	PAPER PHENOLIC	BAKELITE
I.E.C. TEST	WITHOUT TREATMENT	2.77	2.20	*	1.00	1.02
	TRANSFORMER OIL	2.90	2.30	*	1.10	
	NaCl SOLUTION	2.68	2.20	*	1.02	
	WHITE PETROLIUM JELLY	*	*	*	2.50	
DIP TRACK TEST	WITHOUT TREATMENT	2.77	4.10	1.05	1.20	0.88
	TRANSFORMER OIL	2.63	4.35	1.40	0.90	
	NaCl SOLUTION	1.75	4.30	1.40	0.84	
	WHITE PETROLIUM JELLY	5.60 **	4.30	2.38	0.95	

* THE SAMPLES DID NOT TRACK.

** THE VALUE SHOWN WAS ESTIMATED GRAPHICALLY.

TABLE 3.2

3.1 PAPER PHENOLIC

This material was dark brown in color and the thickness was 0.125 inch. The C.T.I. and the tracking voltage are shown in Table 3.1. The effect of changing electrode spacing on surface breakdown was also investigated. Fig. 3.1 shows the family of curves obtained for different electrode spacings in the I.E.C. test. The voltage corresponding to 50 drops on curve B (Fig. 3.1) is equal to the C.T.I. of paper phenolic. The actual set of readings from which this curve was obtained is presented in Table 3.3. It was found that the scatter of the readings could be minimized by checking the flatness of the electrodes against the surface of the sample, and also by cleaning the electrodes before each test. Fig. 3.4, shows the relation between the electrode spacing and the number of drops needed for breakdown, evaluated at a voltage equal to the C.T.I. of paper phenolic. Fig. 3.2 shows the effect on the time to breakdown of paper phenolic for different depths of dip, in the dip track test. These tests were made at 960 volts. (Tracking voltage of paper phenolic).

Table 3.4 shows a typical set of readings of the Dip Track test. For all the materials, the percent standard deviation was lower for the dip track test than for the I.E.C. test. In both test methods, the percent standard deviation increased for lower test voltages.

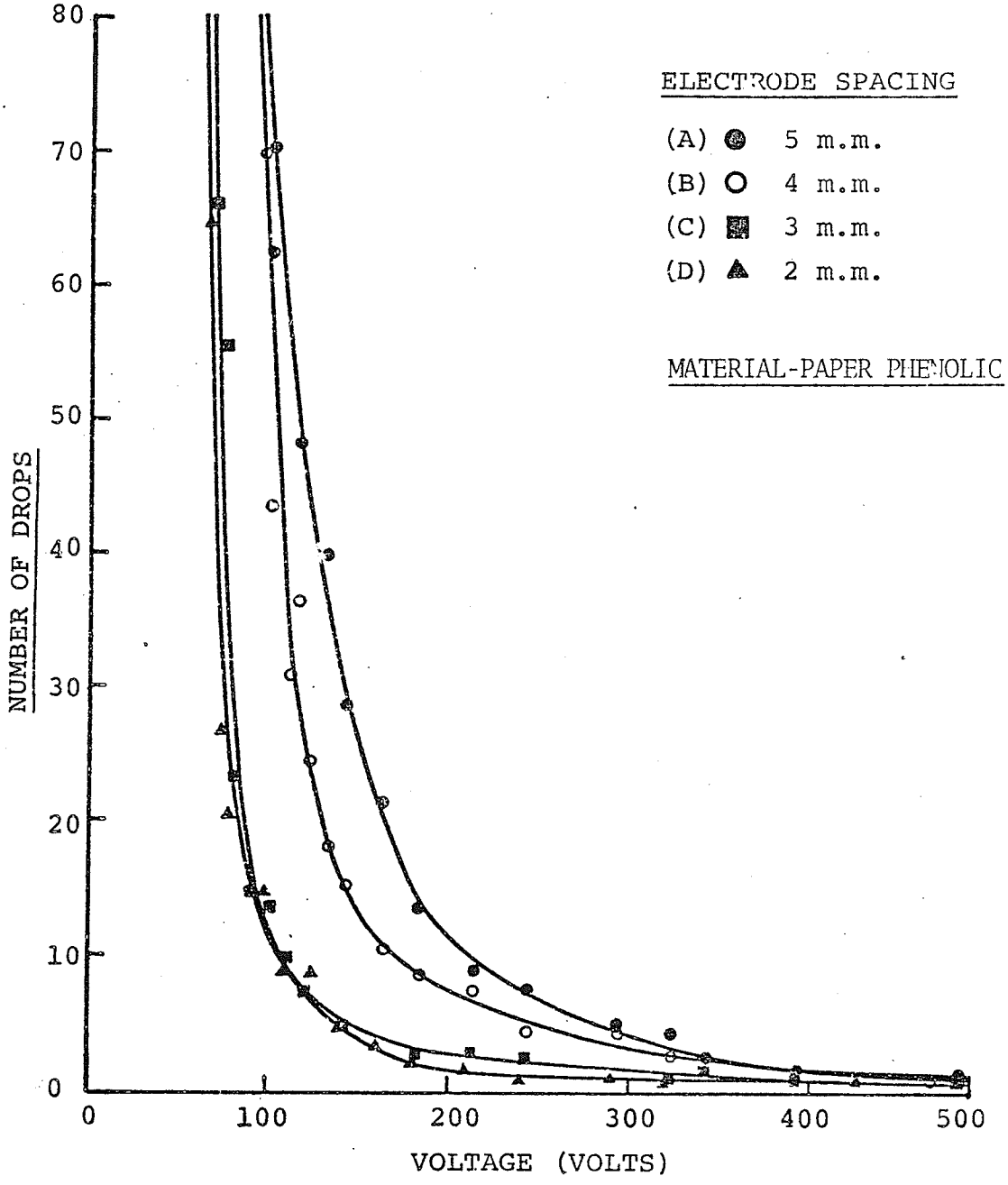


FIGURE 3.1

EFFECT OF ELECTRODE SPACING ON CTI.

VOLTAGE (VOLTS)	PERCENT STANDARD DEVIATION	NUMBER OF DROPS TO BREAKDOWN
475	0	1, 1, 1, 1, 1
320	23	3, 4, 2, 3, 3
290	12	5, 5, 4, 5, 4
240	93	8, 3, 3, 5, 4
210	27	9, 5, 10, 6, 8
180	22	7, 9, 12, 8, 8
160	8	10, 12, 10, 11, 10
140	30	15, 10, 23, 14, 15
130	14	15, 22, 18, 19, 17
125	16	27, 18, 28, 26, 24
115	27	25, 43, 22, 34, 30
110	34	37, 55, 21, 34, 36
100	42	39, 31, 58, 29, 41, 81, 23, 46.
95	42	110,40, 61, 49, 90

TABLE 3.3

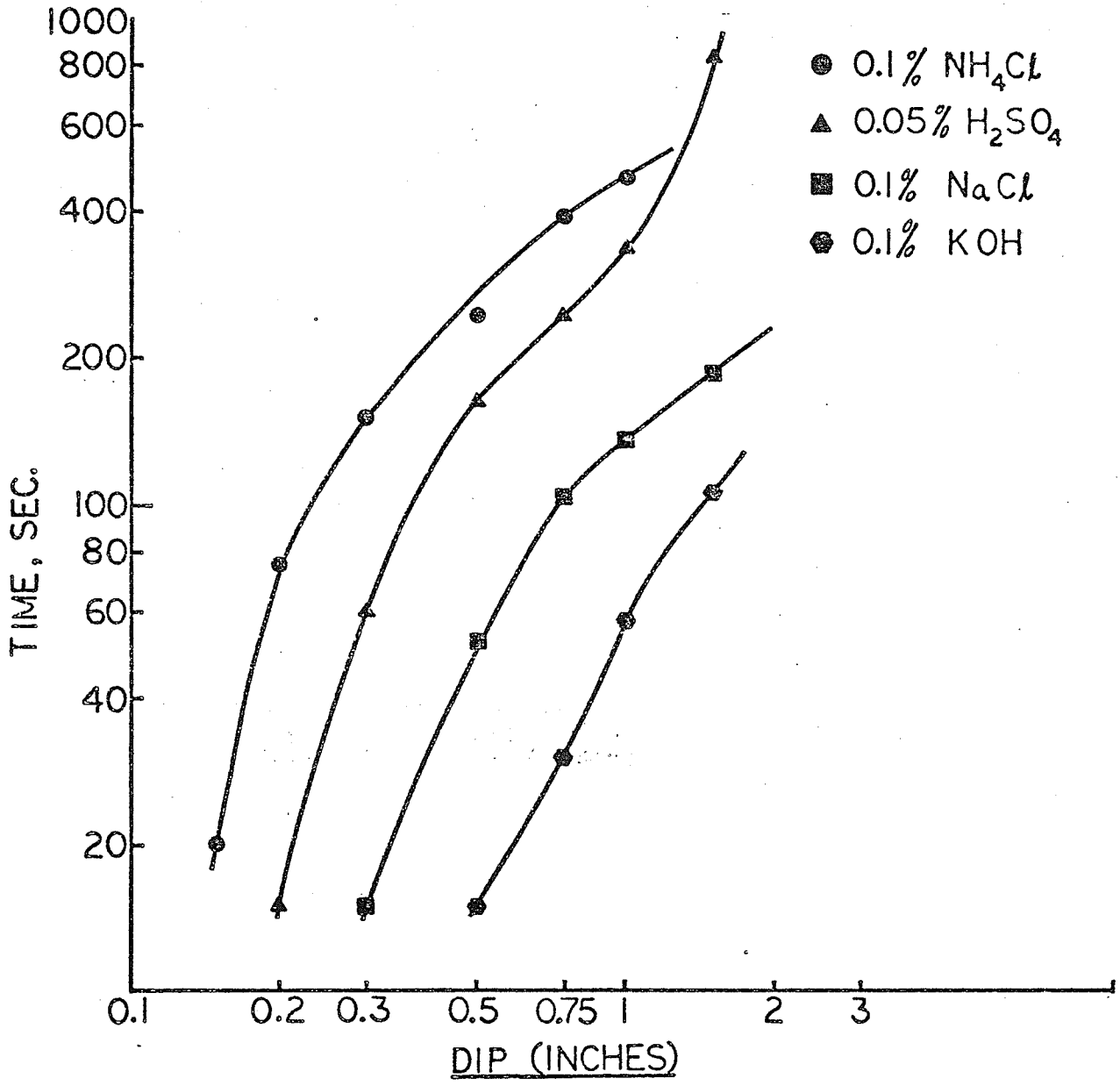


FIGURE 3.2

EFFECT OF DIP LENGTH ON TRACKING FAILURE

VOLTAGE (K.V.)	PERCENT STANDARD DEVIATION	NUMBER OF DIPS TO BREAKDOWN
2.3	0	1, 1, 1, 1, 1
2.0	0	1, 1, 1, 1, 1
1.5	14	3, 3, 4, 3, 3
1.35	17	4, 6, 5, 5, 4
1.2	21	8, 5, 6, 6, 7
1.1	28	25, 18, 15, 20, 21
1.05	19	51, 45, 42, 36, 61
1.00	18	80, 51, 79, 70, 61

TABLE 3.4

The effect on time to breakdown of paper phenolic for different dip lengths was also investigated using 0.1% NH_4Cl, 0.05% H_2SO_4, 0.1% NaCl and 0.1% KOH solutions as contaminants. The results are plotted in Figure 3.2.

Figure 3.3 shows the relation between the number of dips to breakdown and the dip rate, and also between the time to breakdown and the dip rate. These tests were made on paper phenolic at a voltage equal to its tracking voltage.

3.2 GLASS FIBER LAMINATE

This material was red in color and the thickness of the samples was 0.163 inches. It had the highest C.T.I. of all the materials tested. This material showed a significant variation in it's C.T.I. for treated samples. C.T.I. increased for the samples treated with transformer oil and decreased for the samples treated with salt solution. The samples coated with white petroleum jelly did not track within the voltage range of the I.E.C. test. The variation in the C.T.I. treated samples may be due to the absorbent fibers in the material.

Samples of this material had a tendency to track prematurely along the edges. To prevent this, the edges of the samples were dipped in paraffin wax prior to testing.

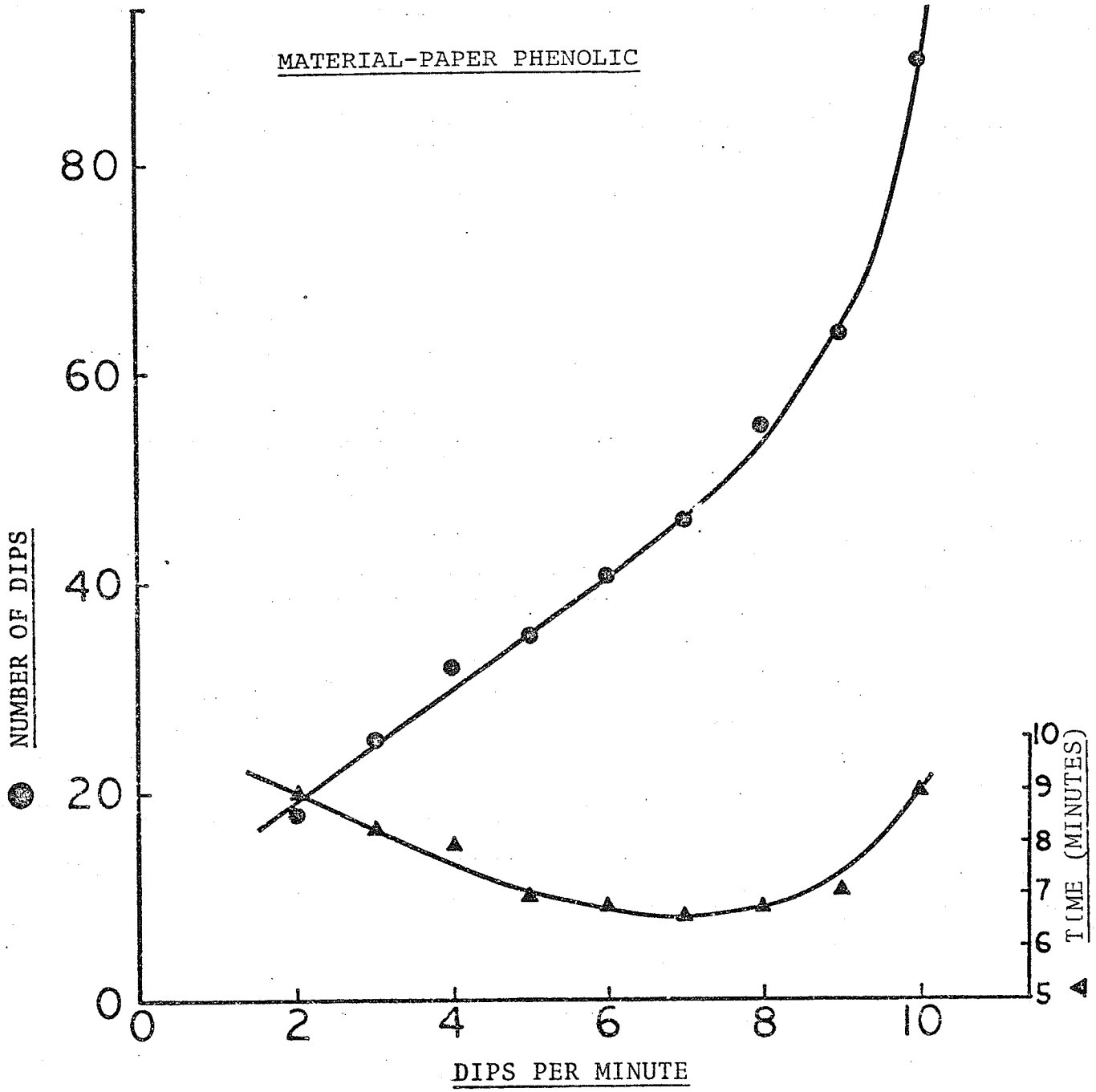


FIGURE 3.3

EFFECT OF DIPPING RATE ON TIME TO BREAKDOWN

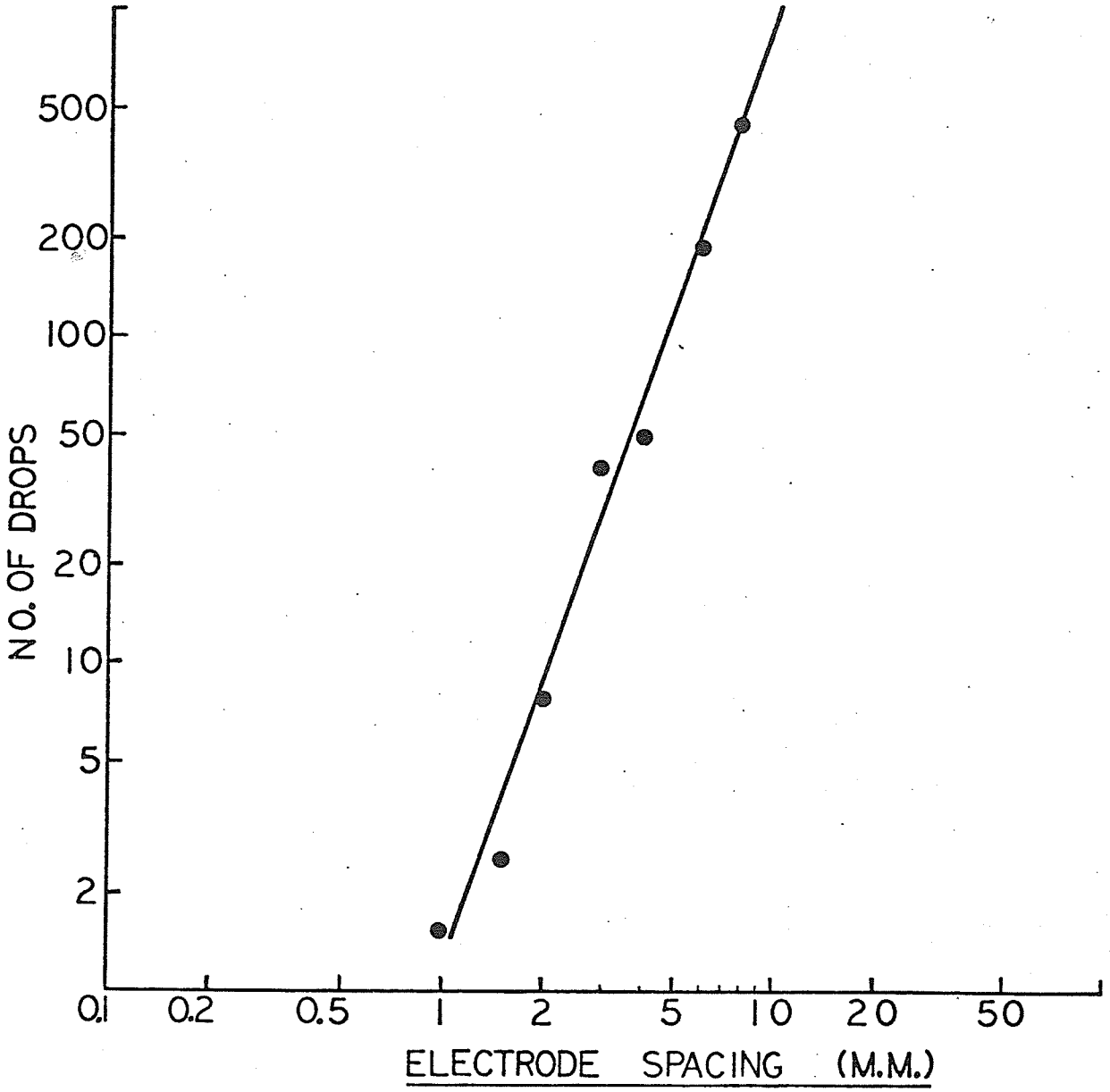

500
200
100
50
20
10
5
2
NO. OF DROPS
0.1
0.2
0.5
1
2
5
10
20
50
ELECTRODE SPACING (M.M.)

FIGURE 3.4

3.3 EPOXY MOULDINGS

Samples were made by removing the material from busbars and cutting it to the required size. Most samples were 0.4" thick. This material had the highest tracking voltage in the dip-track test. There was no significant change in the C.T.I. and the tracking voltage for the treated samples, except in the I.E.C. test, where the sample coated with petroleum jelly did not track even at the highest voltage setting. It was found that the samples with rough surface tracked at a lower voltage than the samples with a smooth surface.

3.4 P.V.C.

The outside surface of sections of P.V.C. tubing (outer diameter = 1.9", wall thickness = 0.2") were tested. Samples for the I.E.C. test were prepared by grinding to obtain a flat surface of approximately 1 sq cm. The samples did not track in the I.E.C. test, although considerable erosion was observed. The tracks tended to spread over a large area on the surface of the samples. Wider samples were tested, but no significant change in the tracking voltage was observed.

3.5 COMPARISON BETWEEN THE I.E.C. AND THE DIP TRACK METHOD

Table 3.2 shows that the correlation between the two tests is good. The only material that had any significant variation was Epoxy. The dip track test rated it nearly twice as high as the I.E.C. test. It seems that the dip track test is not as sensitive as I.E.C. test in discriminating between the treated and the untreated samples, which may be due to the higher voltage used in this test. The I.E.C. test can be accelerated by increasing the dropping rate, as long as the test voltage is sufficiently high to dry out the contaminant before the next drop falls. The dip track test can not be accelerated significantly by increasing the dipping rate. Fig. 3.3 shows relation between the dipping rate and time to breakdown of paper phenolic. Other materials may give different results.

Using the Dip Track test, materials can generally be evaluated in less than half the time, required for the I.E.C. test.

The Dip Track test uses Nichrome wire as the electrode, it is easily replaceable, and no special cleaning or reshaping is required. In the I.E.C. test, cleaning and reshaping the electrodes is very important.

The Dip Track test uses larger quantities of contaminant and larger samples than the I.E.C. test.

Dip Track test can evaluate better tracking resist-

ant materials than the I.E.C. test.

Dip Track test has lower scatter in the readings than the I.E.C. test, hence fewer readings suffice.

Samples of various shapes can be tested in the Dip-Track test and the surface need not be flat, as in the case of the I.E.C. test.

3.6 CONCLUSION

The studies presented in this thesis provide a comparison between the tracking properties of Paper Phenolic, Glass Fiber laminate, Epoxy mouldings and rigid P.V.C. tubing material. Effect of changing spacing between the electrodes was also investigated for different contaminants.

The following table shows the tracking test results.

MATERIAL	THICKNESS	C.T.I. (IEC Test)	Tracking Voltage (Dip Track Test)
Glass Fiber Laminate	0.16"	290V	2.2 kV
Epoxy	0.4 "	230V	3.3 kV
P.V.C.	0.2 "	-	1.05 kV
Paper Phenolic	0.125"	107V	0.96 kV
Bakelite	0.06"	110V	0.7 kV

All materials tested showed an increase in C.T.I. when tested with a layer of white petroleum jelly.

Glass fiber laminate is adversely affected by salt solution, therefore allowances should be made when it is used

in salty environments like seacoast, ships etc.

Where tracking is a possibility a material with a higher C.T.I. or higher tracking voltage should be substituted, to improve the reliability since increasing the clearance (electrode spacing) does not increase the time to breakdown in the same proportion.

For a given concentration, the severity of contamination of salts is in the following order. KOH, NaCl, NH_4Cl.

Transformer oil did not adversely affect the tracking properties of any material.

Correlation between the I.E.C. and the dip track test was found to be good for the materials tested.

Acidic contamination was found to be more severe than salts used, on paper phenolic.

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