# Effect of Contamination on the Formation of Electrical Tracking on Epoxy Resin Materials

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***Abstract*—Contamination on the surface of the insulator becomes a serious problem in power system operation. Especially for the tropics area, humidity and rainfall play an important role in filling soaked by the water on the surface of the insulator, which resulted in the presence of contamination and leakage current flowing on the surface of the insulator. Contamination layers are practically insulators used on the surface of the transmission or distribution lines, especially in areas of heavy industry, or on the beach. Naturally, there will be widespread contamination on the surface. This will increase the leakage current, especially if the contamination of surface wet by fog, dew or light rain especially acid rain. This leakage current will initiate a process of heat conduction which occurs on the surface of an insulator, so that electricity will be formed or dry band area which ultimately lead to flashover. The parameter of leakage current and critical flashover voltage can be used to analyze the performance of insulators.**

**This paper presents the influence of contaminants to leakage current charracteristics and the formation of the electrical tracking on the surface of epoxy resin samples. The tests based on the method of Inclined-Planed Tracking (IPT) IEC 587:1984 with ammonium chloride $NH_4Cl$ as contaminants. The industrial and coastal contaminants are used for explain the effect of contaminant on surface tracking process . The flow rate of contaminant is 0.3 mL/min. AC high voltage 50 Hz was applied to the top electrodes.**

**Based on the results of the measurements, we know that the contaminants affect significantly to the leakage current characteristics and the timing of discharges current occurs and the formation of electrical traces.**

**Keywords: Contact angle, electrical tracking, discharges current.**

## I. INTRODUCTION

Currently, polymer materials were developed and began to be used as an insulator on the electrical power transmission line, because it has a better dielectric properties compared with porcelain and glass[1]. Based on some performance analysis of insulator that has been done, it was found that most damage to the structure of insulators is the result of electrical tracking process on the surface of insulators. Electrical tracking process is a typical phenomenon which occurs on the surface of the insulator as a result of spots discharge arising at the surface induced. All were a result of wetting the surface and the level of contamination. Once the electricity tracking this happens, the nature of the insulator surface will be reduced and cannot be updated anymore. To enhance the capabilities and performances of insulator, the phenomenon of electrical tracking is investigated by world researchers [2,3,4,5].

Epoxy resins are used in a large number of fields including surface coatings, adhesives, in potting and encapsulation of electronic components, in tooling, for laminates in flooring and to a small extent in molding powders and in road surfacing.

Compared with the polyesters, epoxy resins generally have better mechanical properties and, using appropriate hardeners, better heat resistance and chemical resistance, in particular, resistance to alkali. The electrical properties of epoxy resins have a dielectric constant about 3.4 – 5.7, and a dielectric strength about 100 – 220 kV/cm. Power factor of resin epoxy resins are about 0.008 – 0.04[6].

According Berahim[7,8] epoxy resin is a hydrophilic material, therefore, in particular, in the tropical area; humidity and rainfall play an important role in accelerating of degradation process on the surface of the insulator. Contamination layer will formed on the surface of the insulator and it would be spread on the surface. Leakage current will increase, especially when the insulator surface is wet caused by fog, dew or light rain. Leakage current will initiate a process of heat conduction which occurs on the surface of an insulator and finally flashover or insulation breakdown would occur. According Tumiran[9], by using degradation and chemical structure analysis of the RTV silane epoxy resins can be know that silane treatment of the filler can be improved overall the electrical performance of RTV epoxy resins insulation material in some operating environments.

In this paper, the influence of contaminants on the formation of electrical tracking on epoxy resin material was carried out. Kinds of contaminants used were $NH_4Cl$ contaminant, coastal contaminants and industrial contaminants.

## II. LEAKAGE CURRENT AND CONTAMINATION

Most of high voltage insulators are being used in outdoor applications. Environmental pollution can cause the insulators to become progressively coated with dirt and chemicals in the long run. This pollution coating does not have a detrimental effect when the insulator is dry. The electrostatic field determines the voltage distribution of such a dry insulator and a very small capacitive leakage current (LC) flow across the entire insulator. However in the presence of wet atmospheric conditions, the contamination particles on the insulator surface will dissolve into the water and provide a continuous path between the high voltage electrode and ground.

When the insulator is wet, a resistive surface LC flows, which is generally many orders of magnitude higher than the capacitive current in the case of dry insulators[10]. This LC results in non-uniform heating of the contamination layer that eventually causes dry bands to be formed at the narrow sections where the surface LC density is highest. The voltage distribution along the surface of wet polluted insulators is very non-uniform when a dry band is formed in series with the conductive film. Since the resistance of the dry band is very high, the whole applied voltage across the insulator appears across the dry band. As a result, the breakdown occurs across the dry band when it reaches the air critical flashover voltage and generates small sparks between the separating moisture films. This process acts effectively as an extension to the electrodes. The heat resulting from the small sparks causes carbonization and volatilization of the insulation and leads to formation of permanent “carbon track” on the surface. The process is cumulative and continuous, and insulation failure occurs when carbonized tracks bridge the distance between the electrodes [11]. This phenomenon, called “surface tracking” commonly occurs on the insulator surface under wet contaminated conditions.

The phenomenon of tracking severely limits the use of organic insulations in the outdoor environment. The rate of tracking depends upon the structure of the polymers and adding appropriate fillers to the polymer that inhibit carbonization can drastically slow it down.

The degradation process of the materials due to the electrical discharge stress is influenced by the characteristics of LC and surface tracking behavior. This chapter begins with the review on the LC analysis and the effect of LC flow on the performance of the existing polymeric insulating materials. Furthermore, the review discusses the surface tracking and erosion properties of the polymeric materials from the previous works. The test methods used for evaluating the resistance to tracking and erosion of insulating materials used under severe ambient conditions are also discussed.

## III. TEST SET UP AND PROCEDURE

To understand the influence of contaminants on electrical tracking process, the inclined plane tracking (IPT) test is used as specified in IEC 587:1984. Preparation was conducted as follow:

### *1) Test Sample and Electrode*

There are two type samples. First sample without filler and the second sample with silicon rubber as filler The test materials used were epoxy resins with the dimensions 50 mm x 120 mm with a thickness of 6 mm. Test samples must be drilled to place electrodes as illustrated in Fig. 1

Electrodes in this experimental were made from stainless steel material. The sample and electrodes are shown in Fig. 1 and Fig. 2 respectively.

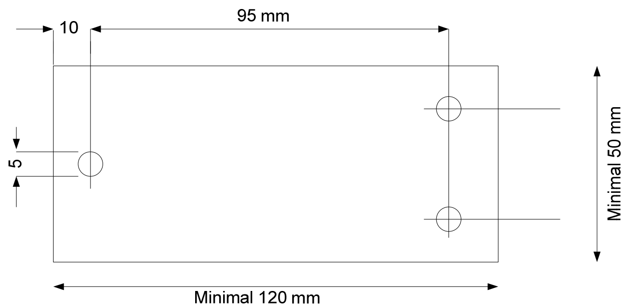
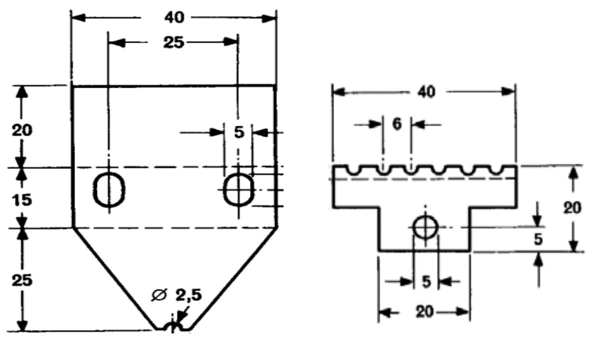



Fig. 1 test sample and it dimensions[12]

Electrodes in this experimental were made from stainless steel material. The electrodes and sample are shown in Fig. 2 (all dimension in mm).




(a) (b)

Fig. 2 (a) Top, (b) Bottom of the electrodes[12]

### *2) Contaminant and Filter paper*

There are three kind of contaminants used in this work. The first contaminant had concentration of 0.1 ± 0.002 % by mass of $NH_4Cl$ (ammonium chloride) and it conductivity is 2170 µS/cm. Other contaminant was from industrial and coastal area. Detail of contaminant data are as follow:

TABLE I ELEMENTS AND CONTENT OFINDUSTRIAL CONTAMINANTS[13]

| Contaminant from Semen Gresik industrial | | | |
|---|---|---|---|
| Name | content | data (ppm) | weight (mg) |
| K+ | KCl | 3.4035 | 6.5016 |
| Na+ | NaCl | 310.46 | 789.6483 |
| Ca++ | $CaCl_2$ | 23994 | 6658335 |
| Mg++ | $MgCl_26H_2O$ | 76786 | 6494816 |
| Conductivity | | | 3540 µS/cm |

TABLE II ELEMENTS AND CONTENT OF COASTAL CONTAMINANTS[13]

| Contaminant from Parangtritis beach | | | |
|---|---|---|---|
| Name | Content | Data (ppm) | Weight (mg) |
| K+ | KCl | 1.1 | 2.0872 |
| Na+ | NaCl | 183.3 | 466.2196 |
| Ca++ | $CaCl_2$ | 35135 | 974996 |
| Mg++ | $MgCl_26H_2O$ | 28807 | 2436592 |
| Conductivity | | 1420 µS/cm | |

These contaminants were flowed on the surface of materials using a peristaltic pump. There were eight layers of filter-papers as a reservoir for the contaminant, which were clamped between the top electrode and the specimen. The approximate dimensions were given in Fig. 3.

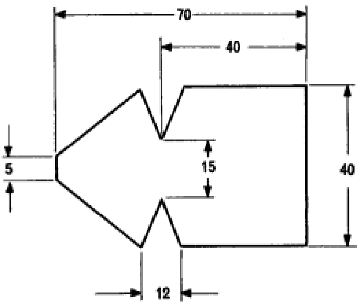


Fig. 3. Filter paper and it dimensions[12]

*Test Circuit*

The tests were carried out using a high voltage AC 50 Hz. The test voltage 3.5 kV was applied to the top electrode while an electrolyte flowed along the underside of the sample. In this test, the constant voltage method was used, and the time to start tracking was also determined. The schematic diagram for this test is illustrated in Fig. 4.

High voltage AC 50 Hz with a voltage of 3.5 kV generated from 5 kVA transformer test. Resistor 22.000 Ω is used to resist the current flowing on the surface of the material in the event of discharge. Peristaltic pump used to drain the solution of contaminants. Discharge current will be read and recorded by Oscilloscope in time of discharge on the surface of the material. Measurement data in the form of discharge current and discharge time of the first occurrence then stored and used to analyze the surface condition, the effect of contaminants on the electrical tracking processes in the surface of insulation.

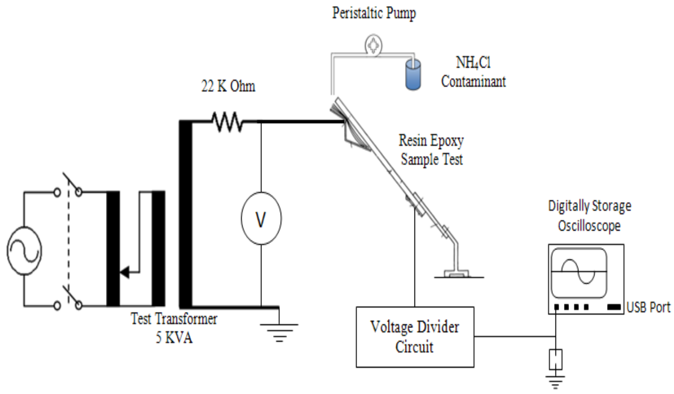


Fig. 4 schematic diagrams for this test

## IV. RESULTS FROM THE LABORATORY

Discharge current, the first time of discharge and surface conditions of sample as a function of the contaminant degree, expressed by conductivity value. The discharge started to occur at 4746 second for coastal contaminant ( 1420 µS/cm) and at 550 second for NH4Cl (2170 µS/cm) and at 818 second for industrial contaminant (3540 µS/cm).

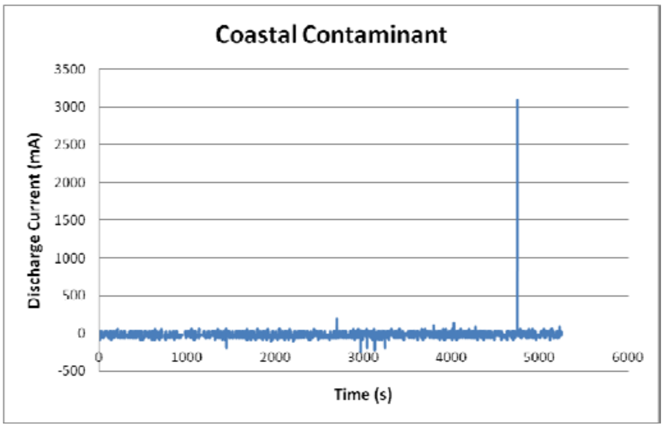


Fig. 5 Leakage current with coastal contaminant

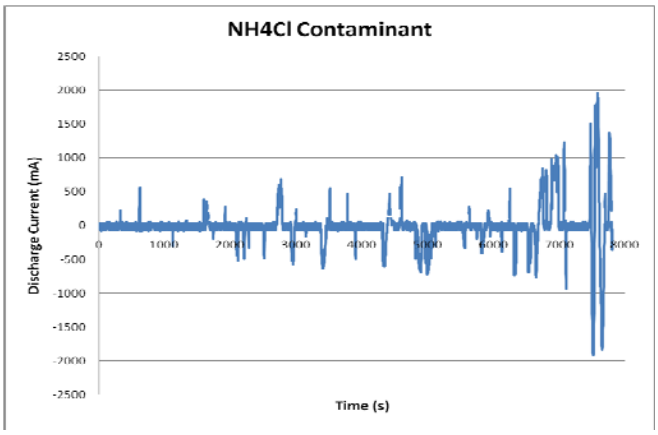


Fig. 6 Leakage current with NH4Cl contaminant

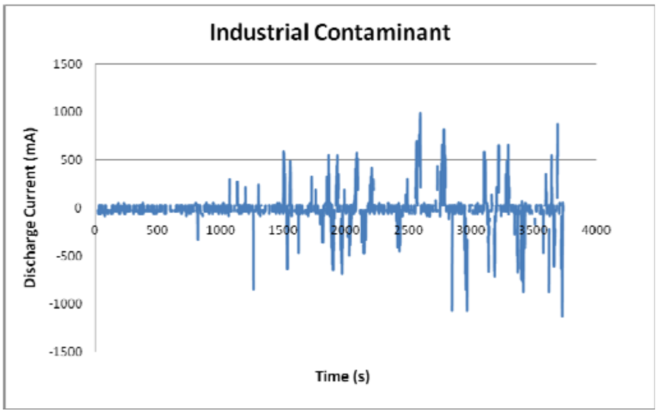



Fig. 7 Leakage current with industrial contaminant

TABLE III CONDUCTIVITY, CURRENT AND DISCHARGE TIME

| Contaminant | Conductivity (µS/cm) | Current (mA) | time (sec.) |
|---|---|---|---|
| Coastal | 1420 | 3084,9 | 4746 |
| $NH_4Cl$ | 2170 | 535 | 550 |
| Industrial | 3540 | -327,6 | 818 |

Conditions of sample surface also as a function of the contaminant conductivity.

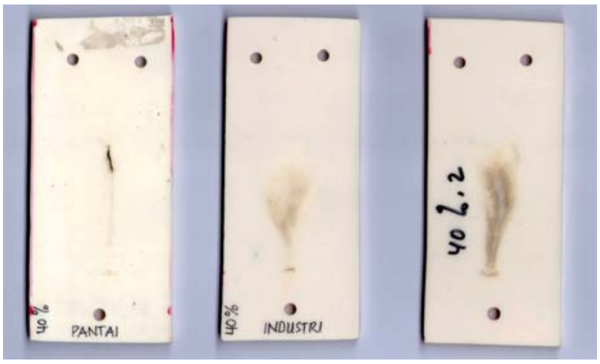



Fig. 8 Surface conditions after test

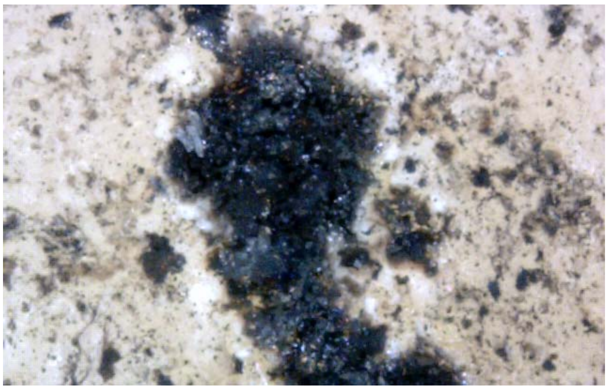


Fig. 9 Surface conditon with coastal contaminant

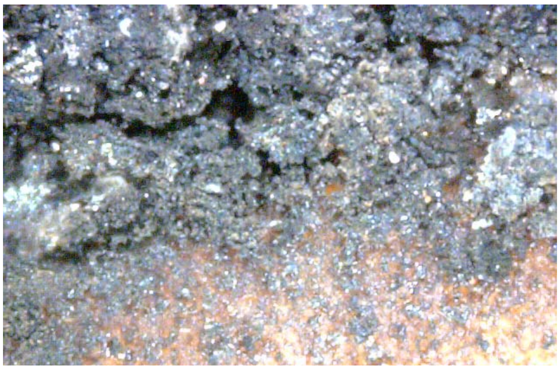


Fig. 10 Surface conditon with NH4Cl contaminant

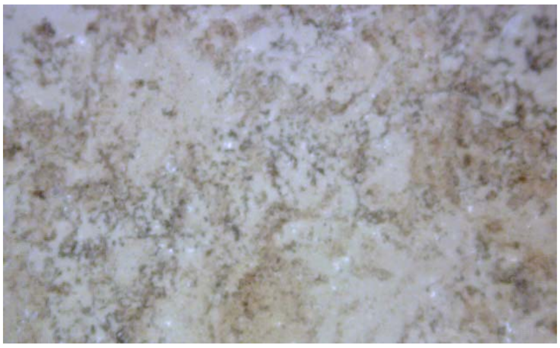


Fig. 11 Surface conditon with industrial contaminant

From the Fig. 9, 10 and 11, we know that the most damage of sample surface was with coastal contaminant ( fig.9). The forming of carbon was happend at the sampel surface. This is also happend at the sampel with $NH_4Cl$ contaminant (fig. 10), however, samples with industrial contaminants have damaged the surface that is wider than the coastal contaminant ( like bush).

## V. CONCLUSION

Based on the results of a research project in Laboratory , it can be concluded that contaminants significantly affect the electrical tracking process. Influence of these contaminants can be analyzed using discharge current parameters, the timing of discharge and material surface conditions.

Therefore, the need for special treatment on the sample under conditions of coastal contaminants, so that the material's performance can be improved, especially against the occurrence of electrical tracking.

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