INFLUENCE OF CONTAMINATED DROPS ON POLYMERIC INSULATION SURFACES IN THE VICINITY OF HIGH VOLTAGE TRACKING

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تأثير الجزيئات الملوثه على أسطح عازلات البولمر القريبه من تأثيرمساريه الجهد العالى

الخلاصـــــة :ـ

مقاومـــة العـــوازل الكهربائية الموجودة فى الخلاء للاجهادات الكهربائية تتطلب بالضرورة ضمن الدراسة العامة لمستويات سلوك العزل ، بحث مقاومة العزل المعرض للتأثيرات المسارية عليه التى تسببها الجهود العاليه . من هذا المنطلق فإن تأثير التلوث المتواجد فى صورة جزئيات (نقاط أو رزاز ملوثة) والقريبة من التأثير المسارى للجهد العالى على أسطح العازلات البولمرية قد تم تناولها فى هذا البحث . وجدير بالذكر أن المواد العازلة البولمرية التى أجريت عليها التجارب كانت البكاليت ، البلاستيك والبوليسترين. هذا وقد تم دراسة سلوك تيارات الزحف التى تعرضت لها أسطح عازلات البولمر تحت تأثير معدلات مختلفه لمقادير الجهد العالى للتيار المتغير طبقاً للاسس العالمى رقم ٥٨٧ . وقد إتضح أن تيارات الزحف السارية على أسطح عازلات البولمر تحت تأثير الجهود العالية (فى حدود من ١ الى ٦ ك.ف) تعتمد على عدة عوامل منها مقدار الجهد المسلط ومقدار تغير التلوث وحجمه. أضف الى ذلك أنه قد تم بحث عملية التجويف التى تنشأ نتيجة للتفاعل الكيماوى بين جزئيات التلوث وسطح العازل أثناء تعرضه لتيارات الزحف المسارية . كما تم كإقتراح أن نسبة تيارات الزحف المسارية للقيمه العظمى الى القيمة المتوسطة يمكن أن تستخدم كمؤشر وا لمعرفة مدى التآكل (التجويف) على أسطح عازلات البولمر.

ABSTRACT

The resistivity of electric outdoor insulations against electric stresses is determined decidingly among other characteristics forming the insulation coordination systems by its insulation against high voltage tracking. From this point of view, the effect of contamination on polymeric insulation surfaces in the vicinity of high voltage tracking is presented. The polymeric

insulating materials treated in this work are Bakelite (Ba), Polyvinylchloride (PVC) and Polystyrene (PS). Behaviour of creepage current under some typical ratings of high voltage a.c. according to the IEC standard 587 is introduced. The insulation against h.v.tracking is dependent on the amplitude of the applied voltage stress, changes in the degree of contamination and on its size on the insulation surface. Erosion process due to the chemical reactions between pollution and insulation surface during the creepage stress has been investigated. Results suggest that the peek to average current ratio during creepage stress up to the end point of h.v. tracking may be used to determine the value of erosion depth of polymeric materials.

INTRODUCTION

The increasing use of solid organic insulating materials in h.v. equipment has occasioned growing interest in the study and assessment of the effect of creepage stresses on the insulation surface. Polymeric insulators subjected to high voltages suffer from the degradation by tracking [1-4]. It is believed that tracking arises as a result of pure thermal decomposition and polymer damage by electron bombardment. A high electric stress can be created at the interface between conductor and polymeric insulator due to the presence of non-uniform fields. This stress leads to local discharges with corona effects, even when the voltage difference between electrodes is not enough to cause complete flashover [5,6]. However, interruption of moisture films is caused by drying the surface following the heating effect of leakage current. Sparks are drawn between the separation moisture films, which acts as extensions to the electrodes and damage is done [1].

Most of work done in this field has concerned generally with organic materils. Recently, the polymeric insulation materials are widly used. Therefore, it is important to determine and implement further experiments required to define the behaviour of these polymeric materials. So, this paper presents the evaluation of polymeric insulating materials for use under outdoor high voltage application by measuring the creepage characteristic as well the resistance to tracking using a liquid contaminant and in ned plane specimens as recommended in IEC standard, pub 587 [7]. The present series of measurements are carried the same polymeric materials as used in the our previous [8-10]. In case of Bakelite insulator, it is found that a voltage tracking up to 600 volt the creepage current has a value than that of another polymeric materials and carboniza takes place rapidly before forming erosion.

As part of this work, the experiments have been developed to measure the creepage current of polymeric insulating materials during the high voltage stress up to 6 kV to the end point of h.v. tracking. The erosion rate due to the heating effect and the chemical reactions between contamination and insulation surface have been investigated as a function of the insulation weight loss. However, the erosion depth has been measured and evaluated as a function of average to peak current ratio.

EXPERIMENTAL METHOD

Tests have been carried out using the arrangement illustrated in Fig. 1. The voltages up to 6 kV, 50 Hz have been applied between electrodes by using 80 kV, 25 kVA high voltage transformer in conjunction with an induction regulator as a smooth control unit and a measuring voltmeter on the primary side (0 - 220 volt) as well as a measuring sphere-gap type MKTW-5R on the h.v. side (0-80 kV output).

Two stainless steel electrodes contacted the polymeric insulator are placed 50 mm apart as those used in the IEC standard, publication 587. The specimen is set up with its longer axis at 45° to the vertical and the electrodes are attached to the underside, as shown in Fig. 2.

The insulants treated in this work are bakelite (Ba), polyvinylchloride (PVC), polystyrene(PS). The samples measure 50 mm x 120 mm with 4 mm in thickness.

The appliction of liquid contaminant can be done by dripping the solution in order of 0.1% ammonium chloride in distilled water into the filter paper pad with a fixed flow rate. A 200 watt resistor is connected in series with each specimen on the high voltage side. These processes are made according to the IEC standard 587 [7] as given in Table I.

Table I Test voltage, contaminant flow rate and series resistor.

Test voltage (kV)	Contaminant flow rate (ml/min)	Series resistor (kΩ)
1	0.075	1
2	0.15	10
3	0.30	22
4	0.60	33
5-6	0.90	33

tests, the method is chosen as a contact tracking voltage the creepage stress and the distance between electrodes is ed to 50 mm. Through this IEC standard distance, a partia- conducting path is created by localized deterioration on the eric insulating surface. The track starts at the lower elec- de and the end point is reached when the track reaches a mark the specimen surface at 25 mm from the lower electrode as shown in Fig. 2. As in our previous paper of low voltage tracking [10], a data acquisition processing is also used in the present work under h.v. tracking to register the creepage current values flowing into the circuit.

Fig. 3, shows the graph of the creepage current behaviour obtained by using a data acquisition processing. To conferm the accuracy of these results, a portable pen-recorder instrument (type 30570) is used. The creepage current is, also, directly recorded on the chart as demonstrated in Fig. 4. It is seen from the two figures 3,4 that, a consistent result of creepage current behaviour for both two procedures. However, a data acquisition processing is used in most experiments.

RESULTS OF EXPERIMENTS

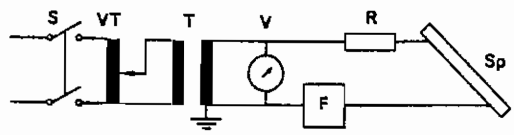
The experiments start with a creepage distance of 50 mm between the h.v. electrodes. According to the IEC standard, publication 587 [7], the contaminant conductivity on the insulation surface is 2.5 ms/cm (or 395 ohm-cm resistivity). The voltage is maintained constant during 6 hours. It is found that, for the polymeric insulating materials under test, no h.v. tracking occurs at most different ranges of IEC 587 up to 6 kV as shown in Table II.

Table II Creepage stress during 6 hours.

Material	Ba	PS	PVC
conductivity(ms/cm)	2.5	2.5	2.5
Voltage(kV)	2-6 kV	2-6 kV	2-6 kV
Aver. current	3-4.3	2.6-2.8	2.9-2.98
Tracking condition		no tracking occurs.	

Chossing another value of contaminant conductivity higher than that of 2.5 ms/cm, the tracking test can be accelerated in the laboratory within the information of IEC standard 587. Fig. 5, shows the creepage current behaviour for PVC at contaminant conductivity of 7.5 ms/cm and applied h.v. a. c. of 6 kV. It is seen from the figure that, the PVC insulator can withstand the creepage stress during 6 hours and then tracked directly. The other insulators of Ba and PS are tracked at a time less than 6 hours at the same condition of contaminant (7.5 ms/cm) as shown in Figs. (3 or 4),6. Thereby, the PVC is found to possess the best h.v. tracking behaviour than that of Ba and PS. This insures that, the polymeric insulating material of Ba has the worst h tracking and the PS is the second worst one. This result is sistent with our previous work in [8,9] carried out at voltage up to 600 volt. In a word, regardless of voltage v (low or high), the worst behaviour of insulating materials can determined, i.e., the worst level of insulation creepage/track behaviour (CTB) is independent of the applied voltage value.

Fig. 7, shows the relation between the erosion depth and the creepage distance up to the end point of tracking at 25 mm from the lower electrode. Fig. 8 shows the phtographes of h.v.tracking for both polymeric insulating materials Ba, PS and PVC. It is clear from the two figures that, the erosion depth decreases with increasing the distance from the lower elecrode. Fig. 9, illustrates the erosion depth versus the applied h.v. a.c. for both



S = power supply switch
VT = variable ratio transformer
T = high-voltage transformer
R = series resistor
V = voltmeter
Sp = specimen
F = overcurrent device, fuse or relay

Fig. 1. Test circuit.

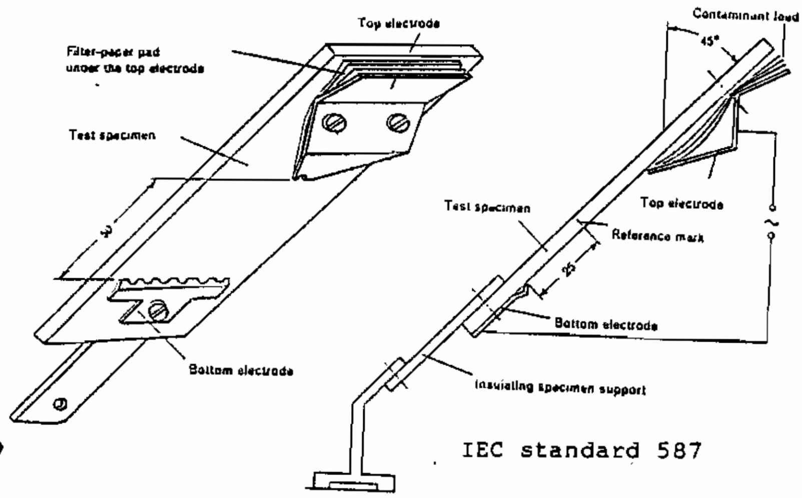


Fig. 2. Assemply of the electrodes.

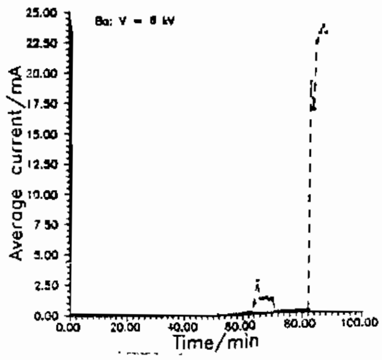


Fig. 3. Creepage current behaviour for Ba at 6 kV and 7.5 ms/cm by using a data-acquisition processing.

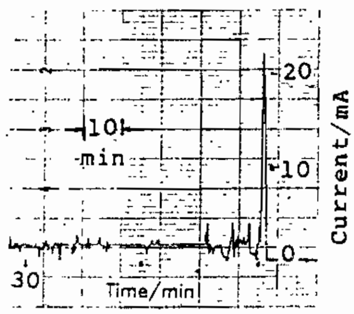


Fig. 4. Creepage current behaviour for Ba at 6 kV and contaminant conductivity at 7.5 ms/cm by using Pen-recorder.

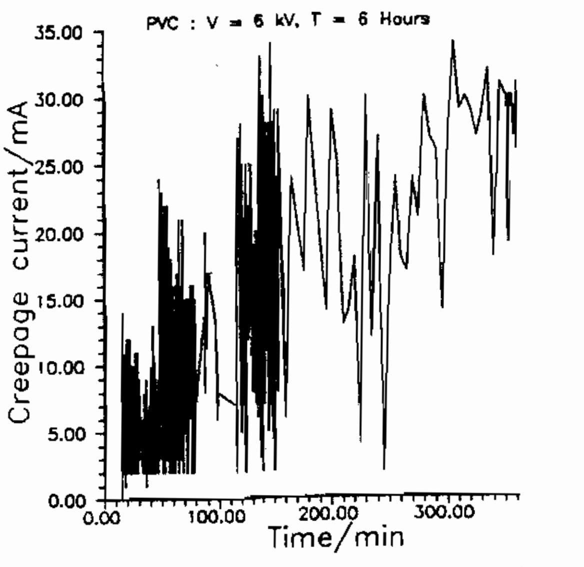


Fig. 5. Creepage current behaviour for PVC at 6 kV and 7.5 ms/cm.

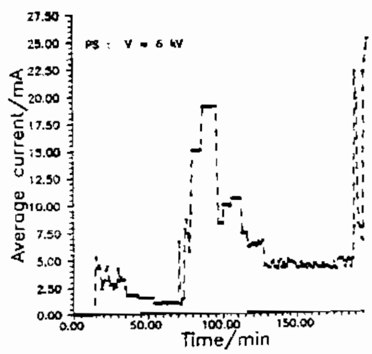


Fig. 6. Creepage cu behaviour for 6 kV and 7.5 m

insulating materials of Ba, PS and PVC. It can be seen that, the erosion depth increases with decreasing the applied voltage. Although the tracking time in case of PVC is greater than that of Ba and PS, the insulation surface of Ba and PS can not withstand the creepage stress for a long time period and the degradation by tracking is going rapidly. This phenomenon may be due to the stronger effect of sparks which causes an increase of the carbonization traces between the separation moisture film on the insulation surface for both Ba and PS. Additional information is provided by the actual measurements of erosion as the insulation weight loss. Fig. 10. shows the relation between the insulation weight loss and the creepage time up to the end point of tracking. It is seen from the figure that, the insulation weight loss increases with increasing the creepage time. The slop of the curve can be regarded as an erosion rate (mg/h), i.e. the degradation on the surface due to the carbonization tracks can be obtained as a function of the insulation weight loss.

Fig. 11, illustrates the behaviour of average creepage current as the voltage is raised for different values of electrolyte conductivity. At values of low voltages, in the range (0-2 kV), the current is proportional to both voltage and electrolyte conductivity, so the contaminant film acts as an aques resistor. After that, a dry band formation occurs at certain point in direction of high voltages and therefore the creepage current flow is no longer continuance over the entire a.c. cycle. In addition, discharging can occure in intermittent bursts. Similar behaviour have been found elsewhere [11] for another insulating materials. Fig. 12, shows both average and tracking current as a function of applied voltage a.c. It is seen from the figure that, the average and tracking currents increase with increasing the applied voltage and they have greater values when using the Ba insulator than that of PS and PVC insulators at high values of applied voltages, vice versa they have lower values for Ba insulator at low voltages. This means that, the heating effect due to the higher values of creepage current at high voltages causes an increase in the evaporation process of contaminant moisture film on the insulation surface more than that at low voltages and this depend the type of the polymeric material.

shows the peak to average current ratio as a function of h.v. a.c. It is seen from the figure that an increase of voltage increases the peak to the average current ratio. ns that the increase of the discharge current magnitude n increase in the heat energy. This leads to decrease the depth due to the evaporating effect. This result may be to point out the value of erosion as a function of the peak erage current ratio when subjecting the insulating materials the creepage stress.

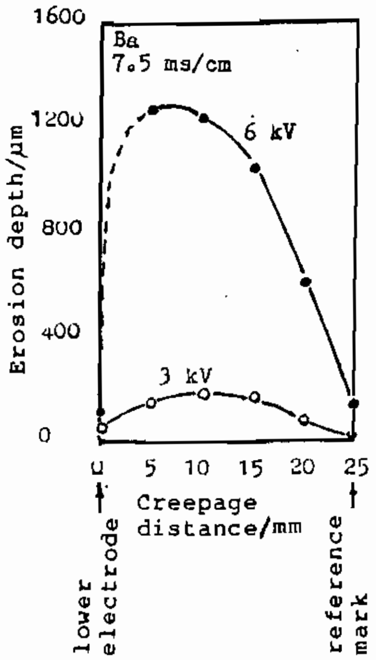


Fig. 7. Erosion depth versus creepage distance from the lower electrode

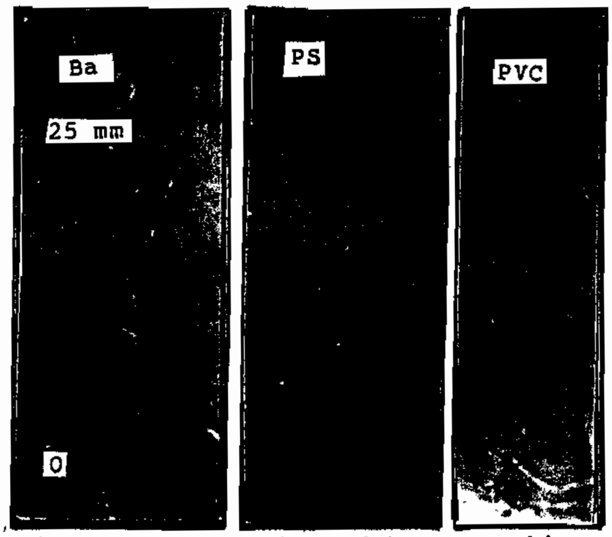


Fig. 8. Photographes of h.v. tracking for Ba, PS and PVC at electrolyte conductivity of 7.5 ms/cm and 3 kV appl. voltage.

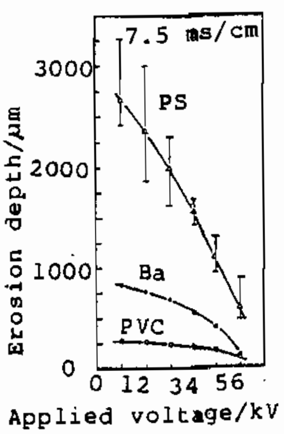


Fig. 9. Erosion depth versus applied h.v. a.c.

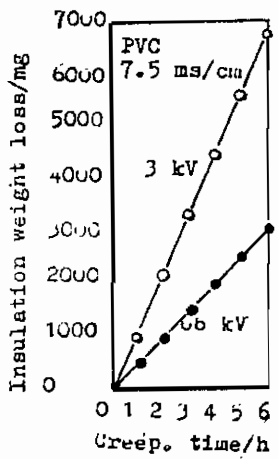
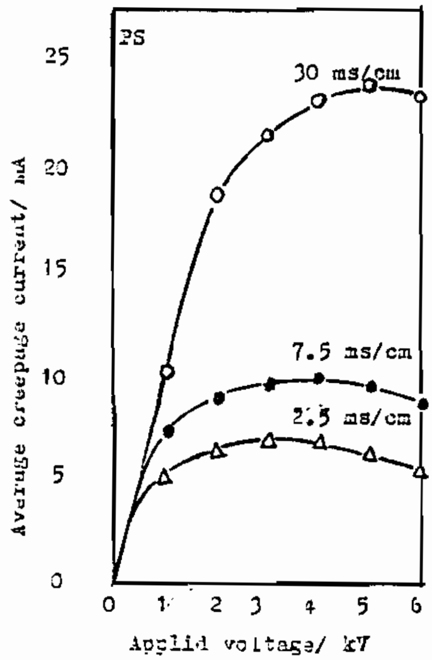
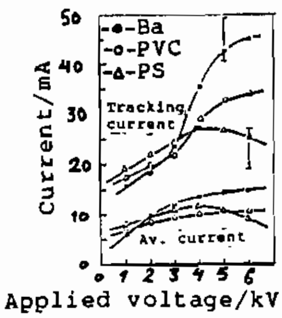


Fig. 10. Insulation weight l versus creepage time to the end point h.v. tracking.

Fig. 11. Average creepage current to electrolyte conductivity as a function of appl. voltage





. 12. Tracking current and averag creepage current versus applied h.v. a.c.

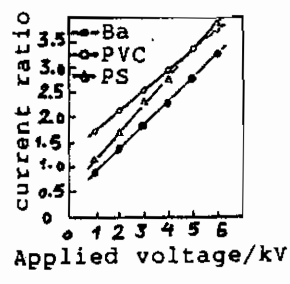


Fig. 13. Peak to average creepage current ratio versus applied h.v. a.c.

CONCLUSIONS

The following conclusions have been drawn from investigating the effect of creepage stress on the h.v. tracking of polymeric materials :-

- The characteristic of Ba has the worst h.v. tracking, i.e., the same as that for low voltage tracking. The PS is followed to Ba as a second worst one. Therefore, regardless of voltage value (low or high), the worst behaviour of insulating materials can be determined, i.e., the worst level of behaviour is independent of the applied voltage value.

- The degradation on the polymeric surface due to the carbonization tracks can be obtained as a function of the insulation weight loss.

- The result of peak to average current ratio obtained during creepage stress up to the end point of h.v. tracking may be used to point out the value of erosion depth of polymeric materils.

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