

Internal Discharge in Cavities in Solid Dielectric Materials

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ABSTRACT

Internal discharges in cavities in solid dielectrics lead to the degradation, deterioration and complete failure of insulating materials. This would shorten the life time of the electrical equipments. This may affect the reliability of the power supply. A new technique for detecting and measuring internal discharges in cavities in solid dielectrics under alternating voltage conditions has been developed by using an Electrical research association detector (ERA detector model 5) and a multi channel pulse height analyzer. The system was calibrated by feeding voltage pulses of known magnitude into the circuit from a pulse function generator. The technique enabled the study of the magnitude and the repetition rate, of discharges in artificial air filled cavities in polythene samples. The loss tangent was measured using a H.V Schering Bridge. The inception and extinction voltages for samples were determined before each experiment. The measurements were compared and showed a high consistency.

The results obtained showed that for all cavity locations the discharge inception and extinction voltages decreased as the cavity area was increased, this was found in both cylindrical and spherical cavities. Again this can be attributed to the increase in the number of discharging sites on the surfaces of the cavity. In polythene a sample with cavity facing the high voltage electrode the discharges behaved in a different manner from that facing earthed electrode.

The general theme that the repetition rate and magnitude of discharges decrease with the time of voltage application, this is due to the semi conducting deposits accumulated on the cavity surfaces.

1: Introduction

High voltage solid insulators usually serve as supports of high voltage electrodes. They constitute a weak point in any insulator system. The electric field distribution is distorted inside the gap due to the presence of the insulator. The distortion will be higher if voids (cavities) are presented within the solid insulator. Therefore, proper design of any HV device requires a complete knowledge of the electric field distribution [1].

Such voids may contain air or low pressure gases and such gases have a lower dielectric strength compared to the rest of the system insulation. Consequently, these voids are weak and may have the highest electric field stress concentration which initiates deep pits, micro channels, treeing, deterioration of dielectric and its complete failure. Many of the complex features of the electric failure of the insulation are explained

by thermal instability, electrochemical deterioration, chemical deterioration, or the main contributing factor of partial discharges, in the gas filled cavities or voids in the insulation. The last of these mechanisms of failure became of increasing importance to engineers and was chosen to be the subject of the present research [2-5].

Most of the earlier work in this field was concerned with the measurement of the energy dissipated in the dielectric due to these discharges (integrated method). The present investigations were initiated with carrying out detailed study of these discharges. The magnitude, the repetition rate and the distribution of these discharges were measured using a multi channel pulse height analyzer. The inception and extinction voltages of the test samples were determined by observing the discharges on an Electrical research association detector (ERA model 5) and a pulse oscilloscope. The loss angle of the dielectrics samples were carried out using a high voltage Schering Bridge.

2: Experimental Apparatus and Technique.

2.1: Detection Circuit:

The straight detection method was the one adopted in the present study. As shown in Fig (1) it consisted of: A discharge - free 15 Kv. 180 PF blocking condenser K. Its function was to bypass the high frequencies from the high voltage source, i.e. it may act as a low pass filter to prevent interference from source. A detection resistance R, 750 kilo-ohm, across which discharge pulsed, could be detected and examined, was connected in series with the sample. Connecting the detector in this way helps in minimizing the interference from the other circuit components. A coupling capacitance C_q, 20 PF was used for calibration. The capacitance of the test cell with the dielectric sample placed in was measured in each experiment using a universal -bridge and found to have a value of about 100 PF. The high voltage blocker, the test cell coupling capacitance as well as the detector were housed in a screened cage as an extra precaution to avoid external interference.

As a routine check for external interference blank sample (sample without cavity) was stressed from time to time at a voltage higher than the normal test voltage, and, in all cases, the count rate was found insignificant up to an applied voltage of 15 kV. As the highest test voltage was about 8 kV. It was considered that the circuit would be discharge free at test voltages & that all discharges observed would be occurring in, the cavity of the sample.

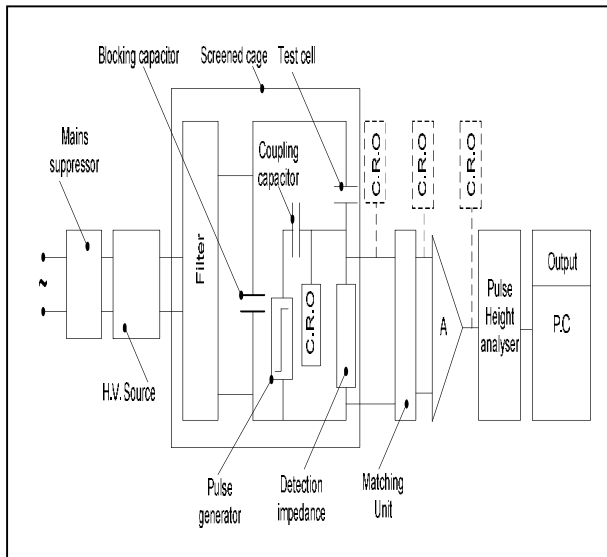


Fig. (1) Discharge Detection and Measuring Apparatus

2.2: Test Cell:

For measurement on polythene samples the test cell, shown in fig.(2) was designed and built. The polythene samples were mounted between two horizontal circular plane electrolytic pure copper electrodes. The upper electrode was the high voltage one and had a diameter of 5 cm. The lower one was connected to earth and had a diameter of 8 cm. To ensure intimate contact between the test sample and electrodes surfaces a lead weight was mounted on the upper electrode, the weight had an outer diameter of 7 cm, inner diameter of 3 cm, and a height of 8 cm. The main body of the cell was made of Perspex tube which was wedged in the lower electrode base and welded with it using araldite. To eliminate edge discharges from the electrodes they were carefully rounded and the whole electrode system was immersed in paraffin oil which had no chemical action on polythene.

2.3: Preparation of Samples:

The test samples constructed of separate sheets of polythene film. The sample had a circular shape of about 7 cm diameter and a thickness varied from (0.38mm) to (1.16 mm) according to the geometry of the enclosed cavity. The polythene sheets were carefully cleaned in carbon tetrachloride before assembly and dried with clean drying paper. The method adopted was to heat a clean soldering head to a high temperature and with its tip move on the circumference, then immediately the edges are welded together, and the sample was completely sealed. The compactness was assured by the lead weight placed on the assembly.

3: Measurement of Loss Angle

3.1: Introduction:

As previously discussed, measuring the loss angle as a function of the applied voltage is one of the main tests generally accepted to determine the quality of the insulation. The loss angle value of a dielectric gives an idea about the total amount of energy dissipated in enclosed cavities due to

electrical discharge. In a trial to correlate the integral amount of energy dissipated due to discharges with their number and repetition rate, it was decided to measure the loss angle of the test sample.

3.2: High Voltage Schering Bridge:

It measures the dielectric loss angle, as well as its resistance and capacitance, the measurements are carried out by comparing the object under test with a discharge - free standard condenser (C_N) of known capacitance. To avoid interference and to safe guard the user the whole bridge was properly screened.

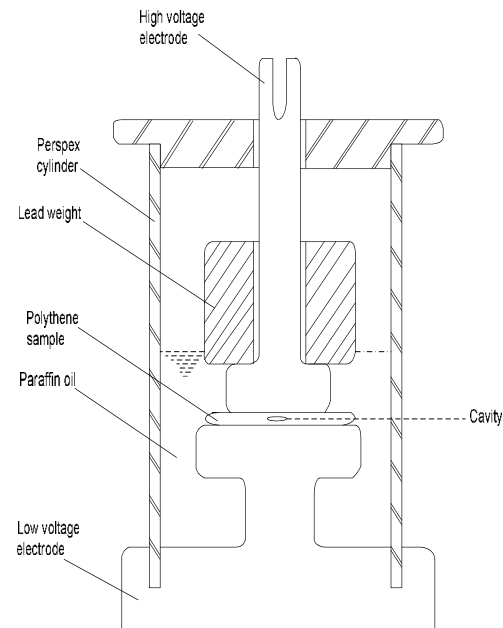


Fig. (2) Test Cell

4: Experimental Results and Discussion

The purpose of this work was to study:

1. The repetition rate of discharges of different magnitudes using a multi channel pulse height analyzer.
2. The inception and extinction voltages of the dielectric under different test conditions.
3. The amount of energy dissipated in the cavities due to the electrical discharges by measuring the loss angle of the dielectric.

4.1: Repetition Rate of Discharges:

The knowledge of inception and extinction voltages alone was not sufficient to ensure the economically reliable operation of an insulation assembly in service. To measure the actual characteristics of the discharges, the pulse height analyzer was used to determine the repetition rate. The normal procedure to determine the repetition rate was to apply a continuous constant a.c voltage of required magnitude.

Test (I):

The test sample was made of polythene sheets (10 mm. thick.) with a closed cavity of 6 mm diameter. Firstly the inception voltage of the sample was determined and found to be 2.2 kV. The sample was stressed at a voltage equal to 1.2 times the inception voltage for about 200 hours.

The repetition rate of discharges of different magnitudes is illustrated in fig.(3). It can be described as follows:

- 1- As the sample was first stressed, discharges of magnitude less than 15 pc had a steady pattern for about an hour, whilst larger discharges showed a tendency to decrease in number.
- 2- After 0.8 of hour, discharges of magnitude greater than 52 pc ceased and only smaller ones remained.

It is shown from the figure that, two erratic periods were noticed, one after 40 hours from stress application, while the other took place in the vicinity of 100 hours. The first erratic period was characterized by the great reduction in the number of discharges, while the second period during which the discharges behaved very erratically was followed by gradual appearance of the discharges. A few hours after the elapse of the second erratic period all discharges detected at the beginning of the test came into play again.

In a trial to find out the effect of removing or re - applying the electrical stress from and on dielectric in use the following was carried out at the end of the test run.

At the end of test (after the elapse of about 155 hour from stress application) the applied stress was decreased gradually to zero and the sample was left unstressed for two minutes. Then the same electrical stress was gradually applied. The sample was left stressed for over an hour during which the discharges were analyzed on the pulse height analyzer at close intervals

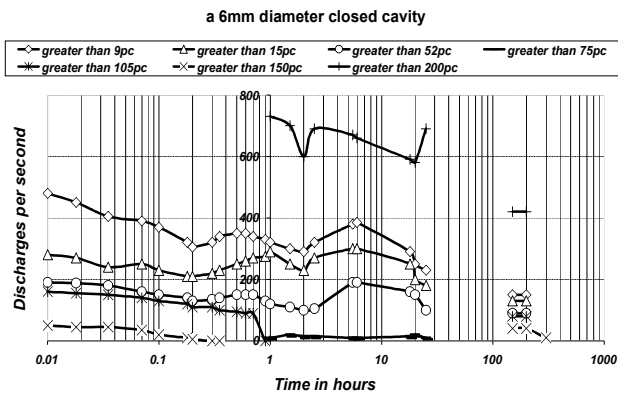


Fig. (3) Test (I): 6 mm Diameter Closed Cavity

Test (II):

The test sample was made of polythene sheets (10 mm. thick.) with a a 6 mm diameter circular cavity facing the high voltage electrode, the inception voltage of the sample was 2.1 kV. The sample was stressed at a voltage equal to 1.2 times the inception voltage and the test lasted for about 100 hours.

The results obtained from this experiment are given in Fig.(4) the discharges behavior can be summarized as follows:

- 1- During the first few hours of stress application small magnitude discharges (< 1 pc) were fairly steady while larger discharges kept on appearing and disappearing in a rather erratic manner.
- 2- During the period 3 hour to 20 hour large discharges ceased completely and only smaller one (<1 pc) could be counted on the analyzer.

- 3- Later and starting from about 20 hours from stress application very large discharges (having magnitude of 100 pc) appeared and remained consistent.

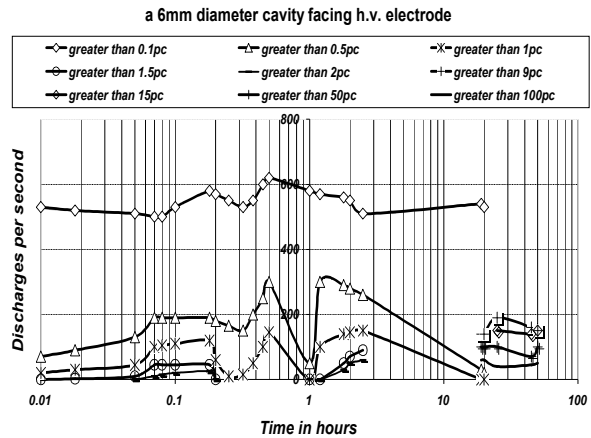


Fig. (4) Test (II): 6 mm Diameter Cavity Facing H.V Electrode

4.2: Measurement of Inception and Extinction Voltages:

Knowing that in practice cavities enclosed in solid insulation normally have different sizes and positions, it was decided to prepare samples having a variety of cavity shape and position and to measure their inception and extinction voltages. In practice such measurements give an indication about the maximum permissible operating voltage. For this measurement the applied voltage was gradually raised till pulses corresponded to internal discharges first appeared. The applied voltage at this moment was to consider being the inception voltage (V_i).

The test sample was left under inception stress for 5 minutes at the end of which the applied voltage was reduced till extinction of discharges occurred. The extinction voltage (V_e) was taken as the voltage at the time when pulses were absent for a period of 0.5 second [6].

The inception and extinction voltages are plotted in figs. (5 & 6) and listed in tables (1, 2) as functions of the cavity diameter and width. As it can be noticed, the discharges inception and extinction voltages decrease as the area of the cavity increases; this is probably due to a large number of discharging sites. When the cavity was facing the high voltage electrode the inception and extinction stresses were higher than the samples with cavities facing the low voltage electrode.

The discharge extinction voltage was about 10 % below the inception. In some experiments, after recording the inception and extinction voltages, the sample was re - stressed. The inception and extinction voltages in this case were found to be slightly higher than the first readings. This may be due to the remnant voltage left across the cavity after the previous discharging.

Table (1) Inception voltage at different cavity diameter and position

	4mm	6mm	8mm
Closed cavities	2.4	2.2	1.8
Cavities facing H.V electrode	2.45	2.1	2
Cavities facing L. V electrode	2.38	2.15	1.95
Open cavities from one side	1.98	1.95	1.85
Open cavities from both side	1.5	1.4	1.36

Table (2) Extinction voltage at different cavity diameter and position

	4mm	6mm	8mm
Closed cavities	2.2	2	1.65
Cavities facing H.V electrode	2.22	2	1.9
Cavities facing L.V electrode	2.2	2.1	1.6
Open cavities from one side	1.82	1.8	1.75
Open cavities from both side	1.36	1.32	1.28

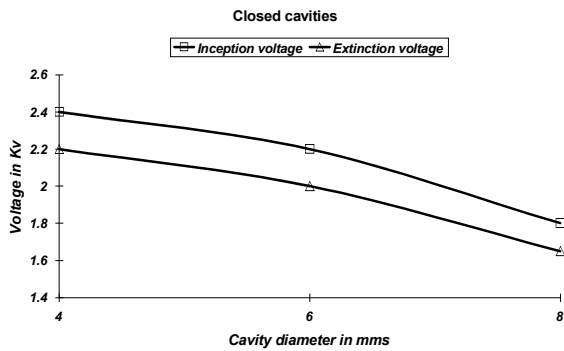


Fig.(5) Inception and Extinction voltages in closed cavities

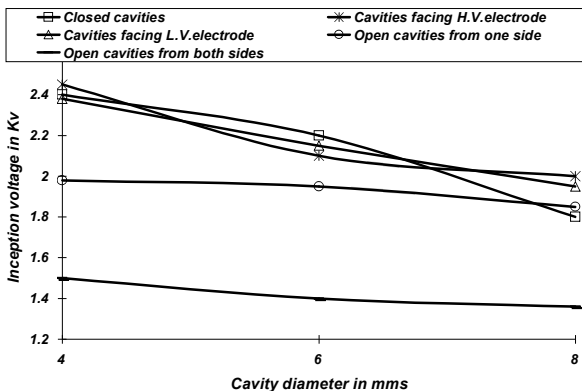


Fig (6) Relation between inception voltage and cavity diameter for different cavity position

4.3: Measurement of Loss Angle:

4.3.1: Effect of Cavity Diameter.

Fig.(7) shows the results obtained from three test runs on samples with closed cavities with different diameter namely 4, 6, and 8mm. Two distinct observations could be made from the Figure. Firstly increasing the diameter increased the loss angle at all voltages. Secondly the voltage at which a knee in the relationship took place (inception voltage) decreased with the Increase in the cavity diameter, these two observations are consistent with each other and in agreement with the results obtained from the study of the repetition rate of the discharges.

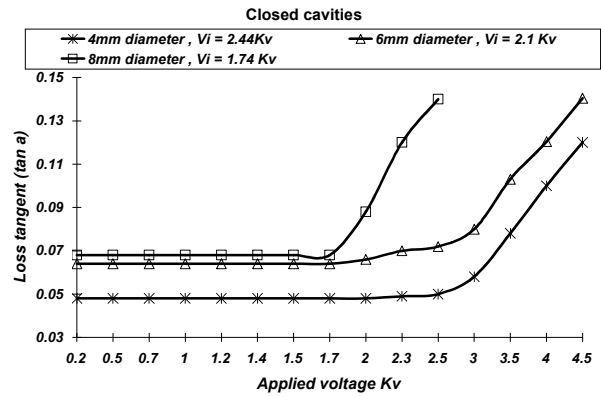


Fig. (7) Relation between loss angle and applied voltage for different cavity diameter.

4.3.2: Effect of Cavity Depth:

Fig.(8) shows the results obtained from three test runs on samples with closed cavities of 4 mm diameter with different depths namely 0.0127, 0.0254 and 0.0381 cm respectively. It is shown from the figure that increasing the cavity depth increased the inception voltage if the test sample as well as its loss angle. However, the Increase in the fewer angles with the increase of the cavity depth showed a tendency to be altered as the applied voltage was raised above the inception voltage as can be observed in the figure. Results shown in Fig (9) showed that the loss angle increased with cavity depth', although a higher voltage is necessary to initiate the discharging process. However it would be incorrect to conclude from these results that the energy loss will always be greater in the deeper cavities since, in accordance with Pashen's law, assuming a constant pressure within the cavities, there is an optimum cavity depth for which the breakdown voltage is minimum.

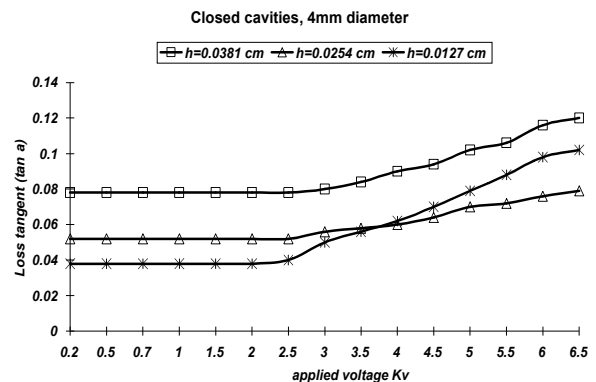


Fig. (8) Relation between loss angle and applied voltage for different cavity depth.

4.3.3: Effect of Cavity positions:

Fig. (10) Shows the results obtained from another tests runs on three samples with a circular cavity of 4 mm diameter. One was open from one side while the two was open from both sides and the thread cavities facing the high voltage electrode. The inception voltage values obtained are almost the same like the ones measured earlier using a different technique. The results which are given in Figure show how the loss angle of the sample of bigger cavity was always higher than the smaller one, whilst the reverse can be noticed with

respect to the inception voltage.

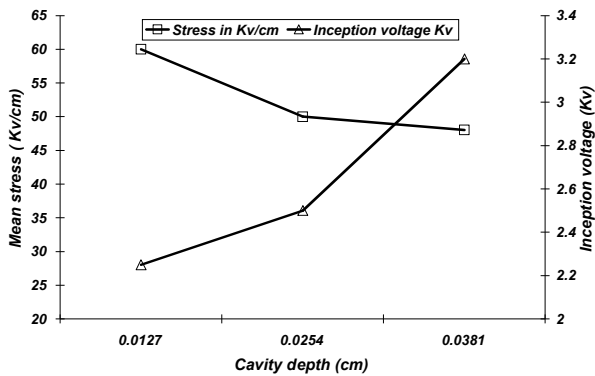


Fig. (9) Relation between inception voltage and mean stress for different cavity depth.

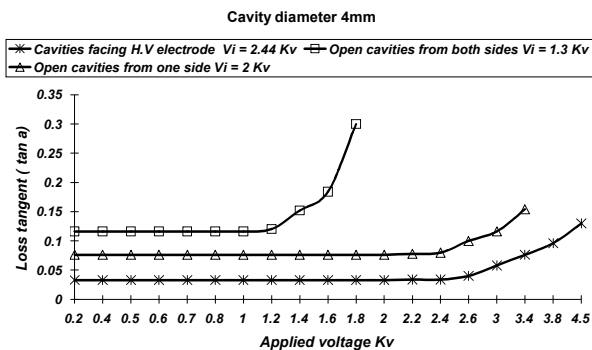


Fig. (10) Relation between loss angle and applied voltage for different cavity positions

5: Conclusions:

- 1- The results obtained from the study of the repetition rates of discharges of different magnitudes, showed clearly how discharges of different magnitudes behaved differently with time.
- 2- In polythene samples having gaseous closed cavities discharges of all magnitudes were found to decay with time from the first moment of stress application, with large discharges decaying much faster than small ones.
- 3- As the cavity diameter was increased; keeping the cavity depth the same, more discharges of large magnitudes could be detected. For all discharges magnitudes there is an increase in number. This is due to the increase in number of discharging sites on the surfaces of the cavity.
- 4- In polythene a sample with cavity facing the high voltage electrode the discharges behaved in a different manner from the closed ones or the one facing the L.V electrode.
- 5- The results obtained showed that for all cavity locations the discharge inception and extinction voltages decreased as the cavity area was increased, this was found in both spherical and cylindrical cavities. Again this can be attributed to the increase in the number of the discharging sites on the surfaces of the cavity.
- 6- The discharge extinction voltage was about 10% below the inception. This may be due to the remnant voltage left across the cavity after the previous discharging. This remnant voltage is due to static charges, either produced when the cavity was formed or left after previous discharges.

- 7- High voltage Schering Bridge considered a sensitive and accurate method of qualitative indication of internal discharges. Results from Schering Bridge showed also that the amount of energy loss increased with the cavity area for all locations of cavities. Also for the same cavity area samples having cavities facing high voltage electrode consumed less energy than samples with closed cavities.
- 8- Comparing values of inception voltages obtained from measurements on Schering Bridge with that obtained from the straight detection method experiments showed good agreement. These results are in excellent agreement with the results obtained from the theoretical results of voltages calculated.

6: REFERENCES:

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