FORCES AFFECTING INSULATING LIQUIDS UNDER THE INFLUENCE OF HIGH ELECTRIC FIELDS

BY

SALEM MAHMOUD EL HANAFY SALEM EL KHODARY

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Prof. Dr. ABDEL-RAZAK I. NOSSEIR

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بسم الله الرحمن الرحيم

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لجنة الحكم على الرسالة

١ ـ الاستاذ الدكتور / محمد محمود خليفة
الاستاذ ورئيس قسم هندسة القوى والالات الكهربية
بكلية الهندسة ـ جامعة القاهرة

٢ ـ الاستاذ الدكتور / سليمان محمد الدبيكى
الاستاذ بكلية الهندسة ـ جامعة عين شمس

٣ ـ الاستاذ الدكتور / عبد الرزاق ابراهيم نصير
الاستاذ بكلية الهندسة ـ جامعة عين شمس
والمشرف على الرسالة

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A B S T R A C T

A novel testing technique has been developed by which it was possible to monitor and measure the induced pressure produced at the surface of an electrode system immersed in a dielectric liquid.

New experimental results on the electrical pressures generated in liquid dielectrics under high direct voltages, and under different test conditions are presented in this thesis. Non-uniform field configurations were used; the electrodes comprised cone-plane configuration; the cone electrode was drilled along its axis for air injection.

The testing technique involved the introduction of an air bubble at the epex of the pointed cone electrode. The bubble was carefully injected through the electrode into the liquid with aid of a bubble injection system which formed an integral part of the test apparatus. It was possible to monitor and measure the internal pressure of the injected bubble at different applied voltages and gap spacings. Tests were carried out on samples of air-saturated transformer oil, siliconeoil, and n-hexane.

A family of relationships between the internal pressure and the square of the applied voltage, under constant hydrostatic pressure, for the four tested gaps, under direct applied voltages with reverse polarity are presented. Also the rate at which the pressure builds up in the liquid due to the sudden application of high applied voltage of either polarity has been investigated.

Results show that the internal pressure of the air bubble increases,at first,linearly with the square of applied voltage. This linear relation is followed by a saturation region at higher applied voltages in most liquids. Also results show that the times required for the build-up of pressures may be attributed to the migration of charge carriers and the formation of space charges. The rate of decay of induced pressure due to the sudden removal of applied voltage and simultaneous earthing of the electrodes has also been investigated. Results show the presence of a "hysteresis" in the pressure-time characteristics for all used dielectric liquids.

Analysis of the experimental data and obtained relationships have been introduced. The value of electric field at each applied voltage for each dielectric liquid used has been derived. A relationship between the internal bubble pressure and the value of electric field inside the air bubble is presented for the used liquids.

A relation between the electric field inside the bubble with the time correspondant is also presented, this relationship shows the build up of electric field inside the bubble under sudden voltage application.

A comparison between the variation of the internal bubble pressure with both the square of the applied voltage, and time duration for the three used liquids is presented.

As far as the author is aware, present results are novel and have not been reported before.

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CHAPTER (1)

INTRODUCTION

It is well known that the application of a high electric field to a liquid dielectric creates an internal pressure. Evaluation of the induced electrical pressure in insulating liquids has been largely based on theoretical assumptions and mathematical derivations which have been at variance. The net induced electrical pressure could be the resultant of a number of electrically induced pressures, e.g. electrostatic, electrostrictive, dielectrophoretic, electrophoretic ... etc. The problem is further complicated since some of these electrically induced pressures may assist or oppose each other, depending on the prevailing test conditions.

The present thesis contains an investigation of bubble behaviour and characteristics in insulating liquids under high electrical direct fields.

The thesis contains five chapters as follows:

Chapter (2) gives a review of previous work, which has a direct bearing on the present thesis. This chapter includes the early history of the subject and the theory of force generation in liquid dielectrics. The action of electrophoretic and dielectrophoretic forces, with dielectric is discussed.

Chapter (3) contains a description of the experimental apparatus used in the investigation. A novel feature of the present work is the use of a new experimental technique which has been developed, by which it was possible to measure the internal pressure of a controllable injected air bubble. Direct applied voltages with reverse polarity up to 30 kV are used.

Chapter (4) presents the obtained experimental results. This includes experimental observation of bubble behaviour under direct applied voltage of both polarity, and the experimental results of the internal pressure of air bubble under the effect of applied voltage. Experiments were carried out using transformer oil, silicone oil and n-hexane as the test liquids. The investigation also included the effect of applied voltage duration on the internal bubble pressure for the previously mentioned test liquids. The chapter also includes a study of the applied forces on air bubble-liquid boundary at the cone electrode surface.

Chapter (5) contains an analysis and discussion of test results. This includes a general comparison and analysis of the main results together with a discussion and an attempt to explain the observed phenomena during experimental work.