UNIVERSITI PUTRA MALAYSIA

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By

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DEDICATION

This work is dedicated in memory of my late grand father Shaikh Usman Bin Sulayman, who has spent his life teaching and showing people the way of Allah (SWT) May He reward him with Jannatil Firdaus.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Master of Science

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December, 2004

Chairman: Senan Mahmood Abdullah, Ph. D.

Faculty: Engineering

Electrical insulating and dielectrical materials can be broadly divided into; gaseous, liquids, vacuum and solids. These materials are widely used in electrical components like, circuit breakers, transformers, cables and capacitors. Liquids dielectrics in particular are preferred because of their ability to have self-cure to situations leading to partial or total discharges.

Petroleum and mineral based fluids have, for almost half a centuary, been used for cooling and insulation purposes. Their popularity stems out of their availability and cheapness. However recent evidence has shown deficiencies with these fluids. They have low properties especially flash and fire points and most importantly low dielectric break down voltage. The most serious of these shortcomings is the inability to meet up with health and environmental laws. This is because they are not organic and hence not

biodegradable; their spillage takes very long time to decompose. These developments have led to seeking alternatives in vegetable based fluids. The fluids that have been tested and to be used as dielectric fluids include Castor oil, Coconut oil, Soya bean oil, and Rapeseed oil.

The present work has measured the properties of palm oil against the IEEE C637 and ASTM D section for possible use as a dielectric fluid. The results show that refined palm oil has break down voltage of 75 KV/mm, flash point (>220), fire point (>220) and moisture content (0.08%). Hence these have shown the potential of palm oil as a dielectric fluid. However future work should focus on further investigation before field application. Malaysia as country stands a lot of gains in this type of research, since it is the world leader in the palm oil production.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

MENILAI POTENSI MINYAK KELAPA SAWIT SEBAGAI CECAIR BENDALIR DIELEKTRIK DALAM APLIKASI VOLTAN TINGGI

Oleh

UMAR USMAN ABDULLAHI

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Penebat elektrik dan bahan dielektrik boleh diklasifikasikan kepada gas, cecair, vakum dan pepejal. Bahan-bahan ini banyak digunakan dalam industri pembuatan komponen elektrik seperti pemutus litar, pengubah, kabel elektrik dan pemuat. Cecair dielektrik lebih digemari kerana keupayaannya untuk mengubah situasi yang menjurus kepada separuh atau keseluruhan nyahcas.

Hampir separuh abad, bendalir berasaskan petroleum dan mineral telah digunakan sebagai penyejuk dan penebat kerana ia mudah didapati dan murah. Walau bagaimanapun, penemuaan terbaru membuktikan bendalir ini mempunyai kekurangan di mana titik kilat dan titik nyalanya adalah rendah. Tambahan pula yang paling penting

bendalir ini mempunyai voltan pecah tebat dielektrik yang rendah. Ini menyebabkan ia tidak dapat memenuhi akta kesihatan dan alam sekitar serta ia juga merupakan bahan bukan organik. Oleh itu, bendalir ini akan mengambil masa yang panjang untuk proses penguraian sekiranya berlaku tumpahan kerana ia tidak dapat diuraikan secara biologi atau pembiorosotan. Pembangunan dan kemajuan telah mencari alternatif lain bagi menggantikannya seperti bendalir yang berasaskan minyak sayuran. Minyak sayuran yang boleh digunakan sebagai bendalir dielektrik adalah minyak castor, minyak kelapa, minyak soya, minyak bijan dan sebagainya.

Ujikaji sifat-sifat minyak kelapa sawit dilakukan berpandu kepada seksyen IEEE C637 dan ASTM D. Ini bagi membuktikan bahawa minyak kelapa sawit boleh digunakan sebagai bendalir dielektrik. Keputusan ujikaji menunjukkan minyak kelapa sawit yang telah melalui proses penapisan mempunyai voltan pecah tebat iaitu 75 kV/mm. Manakala titik kilatnya (<200), titik nyala (>200) dan kandungan lembapan (0.08%). Ini membuktikan bahawa minyak kelapa sawit sesuai digunakan sebagai bendalir dielektrik. Walau bagaimanapun kajian yang lebih terperinci harus dijalankan sebelum ia dipraktikkan. Usaha bagi mengalakkan kajian seperti ini adalah perlu memandangkan Malaysia merupakan negara pengeluar utama minyak kelapa sawit.

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LIST OF ABBREVIATIONS

KV	Kilovolt
KVA	Kilovolt Ampere
PCB	Polychlorinated Biphenyls
CPO	Crude Palm Oil
RBDPO	Refined Bleached Deodorized Palm Oil
RBDPKO	Refined Bleached Deodorized Palm Kernel Oil
CPOF5μM	Crude Palm Oil Filtered to 5 Microns
CPOF2.5μM	Crude Palm Oil Filtered to 2.5 Microns
CPOF0.47μM	Crude Palm Oil Filtered to 0.47 Microns
NTU	Naphthalene Turbidity Unit
NV	Neutralization Value

CHAPTER ONE

INTRODUCTION

1.1 Background

Insulating materials used in electrical engineering applications are divided into gaseous, vacuum, liquids and solids. The function of an insulating material in electrical medium is to resist and prevent the conduction of electricity between two or more conducting materials. The conductors conduct and allow the passage of current through them. The dielectric strength of insulating materials and electric stress developed in them when subjected to high voltages are important factors in high voltage applications. The electric stress to which an insulating material is subjected to is numerically equal to the voltage gradient, and is equal to the electric field intensity,

$$E = - \nabla . \phi \quad (1)$$

where E is the electric field intensity, ϕ is the applied voltage, ∇ and (read as del) is an operator defined as,

$$\nabla = a_x \partial/\partial x + a_y \partial/\partial y + a_z \partial/\partial z \quad (2)$$

and a_x, a_y and a_z are components of position vector $r = a_x x + a_y y + a_z z$. The most important property of any dielectric material is its dielectric strength, and it is defined as the maximum dielectric stress the material can withstand (Naidu and Kamaraju ,2004). Another definition is the voltage at which current starts increasing at very high values unless controlled by external impedance of the circuit. The dielectric strength depends on a variety of parameters such as temperature, pressure, humidity, field configurations,

nature of applied voltage, imperfections of dielectric material, material of electrodes and surface conditions of electrodes etc.

Liquid dielectric materials are used for dual purposes in high voltage applications for insulation and dissipation of heat. The advantage of liquid dielectric fluid over other insulating materials is their ability to provide self-healing to puncture path. Temporary failures due to over voltages are reinsulated quickly by liquid flow to the attacked areas. Owing to this reason they serve as a good remedy to partial discharge phenomenon.

For over one hundred years, petroleum-based mineral oils purified to "transformer oil grade" have been used in liquid-filled transformers. Synthetic hydrocarbon fluids, silicone, and ester fluids were introduced in the latter half of the twentieth century, but their use is limited to distribution transformers. Several billion litres of transformer oil are used in transformers worldwide. The popularity of mineral transformer oil is due to availability and low cost, as well as being an (excellent dielectric and cooling medium). Ever since the world oil reserves were tapped in the 1940s, petroleum products have become widely available. Petroleum-based products are so vital in today's world that their unavailability, at any time, is unimaginable. Transformers and other oil-filled electrical equipment indeed, use only a tiny fraction of the total petroleum consumption, yet even this fraction is almost irreplaceable (Oommen, 2002).

The creation of nondecaying waste materials like mineral oils, combined with a growing consumer population, has resulted in a waste disposal crisis. One of the solutions to this crisis lies in developing alternative dielectric fluids. In the framework of sustainable development principles, the search for "green products" as an alternative to mineral oil has been carried out because of its non-fossil origin. Vegetable oil can be an appropriate response to environmental, safety and health problems could also reduce the exploitative cost of transformers. These vegetable oils have been found to meet the technical requirements of a conventional dielectric fluid. Their high biodegradability and other non-toxicity are among other properties that make these natural oils interesting raw materials for the development of new environmentally friendly dielectric fluids (Oommen, 1999).

1.2 Motivation and Problem Statement

The presently used transformer fluid and indeed for other electrical equipment have been found to suffer form deficiencies that are increasingly making it obvious of their unsuitability for the insulation and cooling of electrical equipment. Conventional mineral oils in transformer oils can pose threat to environment if spilled, due to their negative environmental impact; their use is now banned in many countries (source). Silicon (Mineral Oil) has a very high flash point (low flammability) and it is generally used in places where safety is highly desired. It is the most expensive oil of all types (Oommen, .2002, Oommen, 1999).

Most transformers and capacitors use dielectric fluid based on polychlorinated biphenyls (PCBs). These products, although having fire-resistant and other properties, required for use in electrical equipment, present some major disadvantages. These disadvantages are linked to the toxic nature of PCBs and their potential contamination with, or transformation into dibenzo furans. Negative biological effects have been coming to light over many years and are now well established. Unfortunately PCBs have already been in widespread use for about 40 years in transformers and capacitors, and it is now necessary to put forward practical solutions for eliminating PCBs wherever they may occur. The first problem that countries with PCB transformers still in operation have to face is how to locate and identify this equipment. A decision will then have to be taken as to when, and how, the contaminated equipment will be managed, reclassified and eventually eliminated (Abeysundara et. al 2001, Oommen, 1999 and Bertrand et al 2003).

Fluid spills have been of great concern for years, especially for units in populated areas and near waterways. Environmental Protection Agencies (EPA) has strict regulations regarding fluid spills and cleanup. Any large spills must be reported, especially on water where the spill leaves sheen. Spills on land are less regulated, even though they also have considerable consequences; hence transportation of oil in tank carloads is permitted (Oommen, 1999).Malaysia has recorded cases of persistent transformer failures due t leakages; these are shown in Appendix C. As result of this, an environmentally friendly transformer fluid will be desirable. But no suitable and cost effective fluid is available. Full biodegradability is the ultimate to be expected of any environmentally friendly fluid. Natural biofluids are fully biodegradable, and in this

category falls agriculturally based vegetable fluids. Synthetic esters developed recently are similar to vegetable oils in biodegradability, however not equal.

Having to occasionally cleanup mineral oil spills from transformers, researchers began searching for better transformer cooling oil. They worked with agricultural products research program to develop the biodegradable transformer oil, which has received in U.S. six patents. NPPD, PowerTech Laboratory and the Electric Power Research Institute in the USA are helping with the testing of this earth-friendly transformer fluid, which is now being marketed. (Oommen 1999, Oommen et al 1998 and Brent, 2003).

These development have seen the emergence of alternative source of liquid dielectric that are from vegetable origin These oils have been developed consequently, in most part of the world to alleviate the perennial problems associated with petroleum and mineral oils.

The present work is going to use methods employed by other researchers in evaluating the insulating properties of palm oil, with a view of seeing whether or not it can be used as a dielectric fluid. The time is now ripe for the expedition into local resources to solve the problems of humankind locally, and obtain a place for the country in this wind of change, which encompasses a shift from environmentally hazardous resources, for the production of goods and services, to safe and environmentally friendly renewable resources The palm oil will be used for this work, it is an indigenous resource of