



UNIVERSITI PUTRA MALAYSIA

**EVALUATION OF PALM OIL POTENTIALITY AS A LIQUID
DIELECTRIC FLUID IN HIGH VOLTAGE APPLICATIONS**

UMAR USMAN ABDULLAHI

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**MASTER OF SCIENCE
UNIVERSITI PUTRA MALAYSIA
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**EVALUATION OF PALM OIL POTENTIAL AS A LIQUID DIELECTRIC
FLUID IN HIGH VOLTAGE APPLICATIONS**

By

UMAR USMAN ABDULLAHI

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in
Fulfilment of the Requirements for the Degree of Master of Science**

December 2004



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

**EVALUATING OF PALM OIL POTENTIAL AS LIQUID DIELECTRIC
IN HIGH VOLTAGE APPLICATIONS**

By

UMAR USMAN ABDULLAHI

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 century, 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

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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, penemuan 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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I certify that an Examination Committee met on 7th December 2004 to conduct the final examination of Umar Usman Abdullahi on his Master of Science thesis entitled “Evaluation of Palm Oil Potential as Liquid Dielectric in High Voltage Applications” in accordance to with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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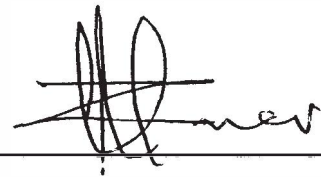


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DECLARATION

I hereby declare that the thesis is based on my original except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.



UMAR USMAN ABDULLAHI

Date

10/01/05

TABLE OF CONTENTS

	<i>Page</i>
DEDICATION	ii
ABSTRACT	iii
ABSTRAK	v
ACKNOWLEDGEMENT	vii
APPROVAL SHEETS	ix
DECLARATION	xi
TABLE OF CONTENTS	xii
LIST OF TABLES	xv
LIST OF FIGURES	xvii
LIST OF ABBREVIATIONS	xviii
CHAPTER	
I INTRODUCTION	1
Background	1
Motivation and Problem statement	3
Research objectives	6
Scope of the work	6
Limitations	7
Benefits	7
Organization of the thesis	8
II LITERATURE REVIEW	9
Dielectric Fluids	9
Foreword	9
Liquid Dielectric Materials	9
Classifications	11
Heating and Property Testing	14
Heating	14
Property Testing	15
Petroleum and Mineral Oils	17
Deficiencies and Need for Alternatives	18
Vegetable Oils	23
Historical Perspective	24
Methodologies for the Production of Vegetable Transformer Oil	26
Chemical Composition	28
Synthesis, Purification and Testing	29



	Oxidation Stability	30
	Products Patented	32
	BIOTEMP	33
	Envirotemp FR3®	34
	Present Research Efforts	35
	Rapeseed oil	36
	Cocoanut Oil	37
	Indian Beach Oil	39
	Palm Oil	42
	Introduction	42
	Properties and Advantages of Natural Red Palm Oil	44
	High Stability To Oxidation	44
	Good Natural Properties	44
	CPO	46
	RBDPO	46
	RBDPKO	47
	Summary	47
III	METHODOLOGY	48
	Introduction	48
	Collection of samples	48
	Experiments performed	49
	Vacuum filtration of CPO	49
	Sampling	51
	Turbidity	51
	Moisture Analysis	52
	Dielectric Breakdown Voltage	54
	Flash and Fire Points	55
	Thermal Conductivity	57
	Viscosity	58
	Oxidation Stability	61
	Other Tests	63
	Specific Gravity (Relative Density)	63
	Visual Examination	63
	Summary	64
IV	RESULTS AND DISCUSSION	65
	Introduction	65
	Turbidity and Moisture Content of Samples	65
	Turbidity	65
	Moisture Contents	67
	Turbidity and Breakdown Voltage	68
	Moisture Content and Breakdown Voltage	71
	Viscosity against Temperature	72



Properties of RBDPO	75
Flash point	77
Fire point	78
Relative Density (Specific Gravity)	78
Thermal Conductivity	78
Visual Examination	79
Oxidation Stability	79
Simulating the Effect of Impurities	81
Neutralization Value of the original sample	81
Neutralization Value when exposed to moisture.	82
Effect of adding acid.	83
Effect of adding more acid	84
Effect of highest quantity of acid.	85
Summary	86
V CONCLUSION AND RECOMMENDATIONS	87
Conclusion	87
Recommendations for future work	86
REFERENCES	89
APPENDICES	92
CONFERENCE ACCEPTANCE LETTER	108
BIODATA OF THE AUTHOR	109



LIST OF TABLES

Table		Page
2.1	Dielectric Properties of Some Liquid Dielectrics	13
2.2	Typical Fatty Acid Compositions of Some Vegetable Oils	29
2.3	Properties of Biotemp	34
2.4	Properties of Environtemp	35
2.5	Different Oil Esters Compared with Rapeseed Oil	37
2.6	Coconut Oil being Measured against IEC 60296	39
2.7	Properties of MEKO Compared with other Insulating fluids	40
2.8	Malaysian Export of Crude and Processed Palm Oil (1960-1999)	43
2.9	Some Properties of Crude Palm Oil	45
2.10	Free Fatty Acids Composition of Crude Palm Oil	45
3.1	Determination of Viscosity	60
4.1	Turbidity of Different Oil Samples	66
4.2	Moisture Content of Oils in %	68
4.3	Breakdown Voltages and Turbidity	69
4.4	Breakdown Voltage and Moisture Content	72
4.5	Variation of Viscosity with Temperature for RBDPO	73
4.6	The Properties of RBDPO Compared with Mineral Oil	76
4.7	Oxidative Stability of RBDPO	79
4.8	Neutralization Value of RBDPO	82
4.9	Neutralization Value of RBDPO exposed to moisture	82



4.10	Oxidation Stability with 3.33ml of HCL	83
4.11	Oxidation Stability with 6.67ml of HCL	84
4.12	Effect of highest quantity of acid	85

LIST OF FIGURES

Figure		Page
2.1	Mounting of Outdoor Transformers	20
2.2	Properly Stabilized and Poorly stabilized/Inferior Oils	32
2.3	Heating and Cooling of Coconut Oil	38
2.4	Breakdown Voltage of Coconut Oil versus Time	38
2.5	Properties of Karanji (MEKO) compared with other Oils.	41
3.1	Vacuum Filtration set	50
3.2	Turbid Meter	52
3.3	Moisture Analyzer	54
3.4	Dielectric Breakdown Voltage Measurements Equipment	55
3.5	Flash and Fire Point Measurement set up	57
3.6	Thermal Conductivity Measurement Apparatus	58
3.7	Viscosity Measurement set up	61
3.8	Oxidation Stability Measurement set up.	63
4.3	Plot of Viscosity against Temperature for RBDPO	73

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
CPOF5 μ M	Crude Palm Oil Filtered to 5 Microns
CPOF2.5 μ M	Crude Palm Oil Filtered to 2.5 Microns
CPOF0.47 μ M	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,

$$E = - \nabla \cdot \phi \dots\dots\dots (1)$$

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

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

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 (Abeyundara 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 to 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

