"I hereby declare that I have read through this report entitle "Study on Dielectric Strength improvement of Reclaimed Used Transformer Oil using Fuller Earth" and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)



Signature : _____

Supervisor's Name : PUAN NOR HIDAYAH BINTI RAHIM

Date :

# STUDY ON DIELECTRIC STRENGTH IMPROVEMENT OF RECLAIMED USED TRANSFORMER OIL USING FULLER EARTH

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**A report submitted in partial fulfilment of the requirements for the degree of**

**Bachelor of Electrical Engineering (Industrial Power)**



**Faculty of Electrical Engineering**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**2016**

"I declare that this report entitles "Study on Dielectric Strength improvement of Reclaimed Used Transformer Oil using Fuller Earth" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree



Signature : _____

Supervisor's Name : MUHD HAIRILL NEIMI BIN AHMAD

Date :

To my beloved mother and father

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# ABSTRACT

Transformer is a device which is critical, high in load and the most expensive part in generation and distribution system. Transformer oil is used as the medium for insulation to avoid the transformer produce more heat due to the process of energy transfer. Most of factor that contributes to the transformer failure is the physiochemical reactions such as heat, oxygen and moisture content had effect the transformer oil. So, there will be increment in terms of water content and total acid number for the transformer oil. Then, this will affect breakdown voltage (BdV) of the oil which make the BdV decrease. Therefore, this project was conducted in order to produce a new oil from the used oil of a transformer. In order to justify the oil is suitable for transformer operation, Karl Fischer, Total Acid Number (TAN) and BdV test will be used to observe the changes in terms of water content, acid number and breakdown voltage of the reclaim oil. Standard of ASTM D1816-84a will be used as the guidelines in the testing BdV procedure and confirmation of the finding. The result will be shown the effect of multiple stage of reclaim oil to the performance of the oil in terms of water content, total acid number and breakdown voltage. By using Karl Fischer and TAN test, total of water content and acid number which able to remove must be more than 50%. Other than that, BdV test should increase the value of breakdown voltage for multiple stage of reclaim oil more than 50%. So, it will expect to get the improvement for dielectric strength on used transformer service oil for reclaimed oil.

# ABSTRAK

Pengubah adalah sebuah peranti yang kritikal, mempunyai beban yang tinggi dan peranti yang paling mahal di dalam sistem penjanaan dan pengedaran. Minyak pengubah digunakan sebagai medan untuk penebat bagi mengelakkan pengubah menghasilkan haba yang lebih tinggi kesan daripada proses pemindahan tenaga yang berlaku. Antara faktor yang menyumbang kepada kegagalan pengubah adalah tindak balas kimia seperti haba, oksigen dan kandungan air yang telah memberi kesan kepada minyak pengubah. Oleh sebab itu, terdapat kenaikan dari segi kandungan air dan jumlah asid bagi minyak pengubah tersebut. Seterusnta, keadaan ini akan memberi kesan kepada keruntuhan voltan (BdV) minyak. Oleh itu, projek ini direka bagi menghasilkan minyak baru berdasarkan minyak yang telah digunakan oleh pengubah. Bagi memastikan minyak ini sesuai untuk beroperasi di dalam pengubah, ujian Karl Fischer, Total Acid Number (TAN) dan BdV akan digunakan untuk melihat perubahan dari segi kandungan air, jumlah asid dan keruntuhan voltan minyak yang telah dikitar semula itu. Piawaian ASTM D1816-84a akan digunakan sebagai garis panduan bagi prosedur dan pengesahan keputusan di dalam ujian BdV. Keputusannya akan menunjukkan kesan kitaran semula minyak yang berganda terhadap prestasi minyak dari segi kandungan air, jumlah asid dan keruntuhan voltan. Ujian Karl Fischer dan TAN seharusnya menghapuskan jumlah kandungan air dan jumlah asid melebihi 50%. Selain daripada itu, ujian BDV perlu meningkatkan nilai keruntuhan voltan melebihi daripada 50%. Jadi,

peningkatan daya kekuatan elektrik diharap dapat dilihat melalui minyak yang telah dikitar semula ini pada penghujung eksperimen ini.

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# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| TNB | - | Tenaga Nasional Berhad |
| DDF | - | Dielectric Dissipation Factor |
| DDP | - | Dissolved Decay Products |
| kV | - | Kilovolt |
| KFC | - | Karl Fischer Coulometer |
| TAN | - | Total Acid Number |
| BdV | - | Breakdown Voltage |
| PPM | - | Part Per Million |
| RPM | - | Rotation Per Minute |
| IFT | - | Interfacial Tension |
| NN | - | Neutralisation Number |
| OQIN | - | Oil Quality Index Number |
| °C | - | Degree Celsius |
| ml | - | Milliliter |
| ATR | - | Attenuated Total Reflectance |
| FYP | - | Final Year Project |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Research Background

In electrical energy supply, power transformer is one of the important assets in order to make sure that the voltage can step up and step down well to the desired value. Power transformer works so that the consumers receive enough energy for their daily use. So that, it is very important to make sure that the transformer is in good condition so that the operation performed by the transformer is always in good condition.

There are many types of transformer that always use in industry such as dry type transformer and liquid oil type transformer. In Malaysia, liquid oil type transformer is widely used nowadays. This type of transformer contains oil which will be functioning as electrical insulator and the medium to decrease the heat generated by the windings. Basically, there are two types of insulation oil which always use in Malaysia such as mineral based oil and

vegetable based oil. From day to day, the age of the transformer's oil increase and this factor indirectly give effect to the performance of the transformer's oil.

In Tenaga Nasional Berhad (TNB), there will be a team which will do their routine to check the condition of the transformer. Basically, this team will check whether there is oil leakage at the transformer, the input and output voltage of the transformer and clean the area around the transformer. In a certain range of month, this team also will make a shutdown process to change the transformer's oil. The aim of this precaution is to make sure that the transformer can operate continuously without having any massive problem.

Power transformer basically is a critical, highly loaded and the most expensive component in electricity generation and distribution network. This appliance needs extra surveillance. By comparing new transformer's oil and used transformer's oil, their differences will be clearly seen by seeing their colour and viscosity. In order to know the content inside the used transformer's oil, various techniques can be implementing to check the properties of the transformer's oil such as Karl Fischer, Total Acid Number, Breakdown Voltage (BdV), Dielectric Dissipation Factor (DDF), Dissolved Decay Products (DDP), Turbidity, Interfacial Tension, Water Content and Ultraviolet-Visible Spectrophotometer (UV-Vis). Karl Fischer is one of the techniques that can be used to check the amount of water content inside the oil. These techniques will give the value of water content inside the oil in Part Per Million (PPM) unit. This experiment was done by using used transformers oil with a type of adsorbent in multiple stage. At the end of the experiment, the result will show the effect of adsorbent on the reclaim oil by using Breakdown Voltage (BdV) test, moisture test and total acid number (TAN) test.

## 1.2 Problem Statement

Nowadays, transformer is one of the important electrical devices in electrical system. This device is the most expensive devices for electrical generation and distribution network. So it is important to keep the transformer in well condition for a long term. For transformer with oil insulation type, there will be a lot of problem will be face by using this type of transformer. Begin with the new transformer oil, the oxidation process of the transformer will make the transformer oil darken and high viscosity. Other than that, the sludge will be formed and it will trap inside the porous structure of the insulation paper. In order to keep the transformer in well condition, the transformers will have maintenance proves for a fixed duration. This process takes high cost. It is because the cost of transformer oil is already high and the process of changing the transformer oil is also high. So, there will be another alternative that can be used to decrease the cost of transformer's maintenance. By using reclaimed oil, cost for buying new oil can be reducing and reclamation method can be used for 2 or 3 times for the same used oil.



## 1.3 Motivation

This project was created based on past year research which approve that used oil such as Synthetic Ester, Natural Ester, Mineral Oil, Silicone Fluid and Transformer Oil can be used again after a few process take place [1]. There will be a lot of methods introduced by the researcher to recycle the used oil such as Percolation Method and Mechanical Agitation. These methods can remove the unused particles which these particles will make the oil become more acidity and increase in term of viscosity [3]. This process can be illustrating

same as the dialysis process for the human's kidney. This process begins by observing the effects of adsorbent used on breakdown of valence bonds in unstable hydrocarbon and volatile molecules. Therefore, it is motivated to observe the effect of moisture, acid number and breakdown voltage on the oil that has been reclaimed. The flow of current inside the transformer will produce heat inside the transformer. The heat will be steam and will produce water that will give effect to the value of the breakdown voltage and chemical bonding of the oil. After the oil having reclamation process in five stages, the oil will be having the moisture test and TAN test at each stage and also BdV test for the final stage oil. As a result, this project will contribute to give more information on the effect of multiple stages of reclamation to the total moisture, acid number and breakdown voltage of the reclaim oil.

## 1.4 Objective

The objectives of this experiment are listed below;

1. To perform reclamation process on used transformer service oil using Fuller's Earth adsorbent.
2. To determine the total acid number, water content and breakdown voltage of the reclaimed transformer service oil.
3. To analyse the performance of reclaimed transformer service oil in term of its total acid number, water content and breakdown voltage.

## 1.5 Scope

The scopes for this experiment are listed below;

1. Used oil is obtained from the 29 years age of ACEC type transformer at the electrical substation in Batu Pahat, Johor.
2. Fuller's earth was used as the adsorbent.
3. Contact process and percolation process will be used for oil reclamation process.
4. In contact process, adsorbent will be mixed with used oil for four hours with speed of 750 rotations per minute (rpm).
5. Standard used for BdV test is ASTM D1816-84a.
6. Karl Fischer method will be used by using 899KF Coulometer to determine the amount of water in oil sample.
7. 848 Titrino Plus produce by Metrohm will be used for Total Acid Number (TAN) test.



## 1.6 Report Outline

This report contains five chapters which include Chapter 1, Chapter 2, Chapter 3, Chapter 4 and Chapter 5. Chapter 1 will cover the introduction of the project which includes project background, project motivation, problem statement, project objectives and scope of the project. Chapter 2 is the chapter for literature review which includes the theory and basic idea that related to the project based on the previous research. This chapter will be focusing on the effect of contaminants on the transformer oil. After that, Chapter 3 will review the method that has been used to complete the project. Chapter 4 will explain more about the

result that have been obtained through the experiment. The result that have been obtained will be discussed and analyse in this chapter. In the last chapter which is Chapter 5 will create a conclusion for overall project that have been take place. This chapter will conclude whether the objectives for the project have been achieved or vice versa. There will be suggestion that can be used for further research of the study in the future.

# CHAPTER 2

# LITERATURE REVIEW



## 2.1 Introduction

In this chapter, there will be summary and synthesize of the article that have been used as the references for this project. All of the useful information will be cited and the cited can be referring in the references part.

## 2.2 Transformer

In an electrical system, transformers are critical, high in load and the most expensive part in electrical generation and distribution network [1]. Basically, transformer can be used to increase or decrease voltage to the desired value of voltage. Transformer usually builds up by core, winding and insulation material. There are five types of transformer which include pole mounted transformer, house hold transformer, dry type transformer, current transformer

and oil immersed power transformer [2]. Basically, power transformer is filled with the liquid insulation oil which large amount of this fluid will acts as to insulate electrically and dissipate heat that generated by the windings [2]. So, insulation oil should provide high insulating to protect other equipment from having massive problem.

## 2.3 Insulation Oil

Insulation oil is the basic part inside a transformer. Insulation oil has been used as insulation and cooling fluid inside a transformer [3]. Nowadays, modern transformer composed of many kinds of insulation materials is an integral insulation system [4]. There were two types of basic insulation materials which are usually used nowadays which are liquid insulation and solid insulation [4]. Transformer oil is one of the examples for liquid insulation and rubber seals are the example for solid insulation. In order to make sure that the transformer in safe service, transformer oil should have great compatibility with the insulation materials. Insulating means that the materials which will be act as the insulating material should be able to protect the equipment from collapse. It is because when a transformer collapses, it will give massive impact to other components of generation and distribution network. So, it is very important to make sure that the insulation oil could protect the transformer during the transformer's operation.

## 2.4 Replacing Transformer Oil

Transformer is one of the important electrical appliances in electrical generation and distribution. It will increase or decrease the value of voltage to the desired value of voltage. By increasing the voltage value, current losses can be reducing by referring the concept of equation V=IR. Based on the equation, the value of current will decrease if the value of voltage increases by using the same load. So, this electrical appliance very important to be maintaining so that the process of increasing and decreasing voltage can be continuing in the future. Inside of a transformer contain litres of mineral oil which provide a medium for heat transfer to remove heat from its source of generation [5]. Besides give better insulating properties, mineral oil also protects paper and wood for the transformer. Transformer continues the process of step up and step down the voltage for so many years without stop. With the help of this oil, the heat produce from the transformer can be reducing. Heat was produce due to the energy losses from the operation of transformer.

When the transformer was in operation, transformer oil will be risk to heat, moisture and oxygen [6]. Although in the sealed transformer, paper will produce moisture when there is breakdown of oil. This will cause the colour, acidity and viscosity of the transformer oil will be affected. The changes in term of properties in transformer oil will change the performance of transformer oil. Performance such as breakdown voltage and flash point will be affected due to the properties change of the transformer oil. When the oil is oxidised, it will produce sludge, acids and other oxidation product [6]. Oxidized oil will be losing its dielectric stability and the oil will become corrosive and eventually solidifies sludge deposit on various parts of the transformer.

Oxidized oil which cannot be used for further transformer oil containing at least 80 percent of useable hydrocarbons [6]. Due to this fact, this oil is not suitable anymore to be the transformer oil. During the maintenance process, this oil will be replaced by the new oil. Process of replacing used oil with the new oil will involving high cost and time. Another alternative have been observed is re-used the used oil by eliminating the oxidized products and give back the properties of the oil. Inside a transformer, sludge was very dangerous to the transformer. The most serious effect when the sludge was formed in the cellulose is the insulation will shrink. There were two cycles which were contributed to the oxidation of transformer oil which are the formation of soluble oxidation process was begin after the oil were put in the service. Second cycles which are contributed to the oxidation of transformer oil is the change of the soluble oxidation products into insoluble compound [6]. Precipitated sludge will be further oxidized and become insoluble. So, it will give effect to the acidity and interfacial tension. It can be concluding that there will be strong relationship between oil acidity, interfacial tension and sludge content.



Based on the previous study based on some guidelines for interfacial tension (IFT), there will be differences new oil and used oil. By dividing IFT to the Neutralisation Number (NN) and Oil Quality Index Number (OQIN), the differences of the oil can be clearly seen in the Table 2.1 [7];

Table 2.1: Classification of Transformer Oil [7]

| | | | |
|---|---|---|---|
| **1. Good Oils** | | | |
| NN | 0.00 -0.10 | IFT | 30.0 -45.0 |
| Colour | Pale Yellow | OQIN | 300-1500 |
| **2. Proposition A Oils** | | | |
| NN | 0.05 -0.10 | IFT | 27.1 -29.9 |
| Colour | Yellow | OQIN | 271 -600 |
| **3. Marginal Oils** | | | |
| NN | 0.11 -0.15 | IFT | 24.0 -27.0 |
| Colour | Bright Yellow | OQIN | 160 -318 |
| **4. Bad Oils** | | | |
| NN | 0.16 -0.40 | IFT | 18.0 -23.9 |
| Colour | Amber | OQIN | 45 -159 |
| **5. Very Bad Oils** | | | |
| NN | 0.41 -0.65 | IFT | 14.0 -17.9 |
| Colour | Brown | OQIN | 22 -44 |
| **6. Extremely Bad Oils** | | | |
| NN | 0.66 -1.50 | IFT | 9.0 -13.9 |
| Colour | Dark Brown | OQIN | 6 -21 |
| **7. Oils in Disastrous Condition** | | | |
| NN | 1.51 or more | | |
| Colour | Black | | |

From Table 2.1, it can be clearly seen that the colour of oil become darken from the original colour which in pale yellow after the oil have been oxidized to the oxygen, heat and moisture. Number of OQIN for new oil is 1500 while for bad oil have OQIN less than 100. Colour of the oil darkens after the oil having deterioration process [7]. Bad oils must be replaced with the oil that capable to give protection to the transformer. So, a few methods can be used to replace the oil such as purification, percolation, re-refining, reconditioning and reclamation.

First method which can be used for oil maintenance is purification. Purification is the process of purified the oil by means of mechanical filtration and mechanical extraction [7]. This method will reduce the amount of moisture inside the oil and remove the oil particulates.

Then, another method that can be used for oil maintenance is percolation. Percolation method has two types which are percolation by gravity and percolation by pressure [8]. Percolation by gravity use gravity as the medium to make the oil flow through certain amount of adsorbent into a flask. In the other hand, percolation by pressure use pump to force the oil pass through the adsorbent [8]. Basically both methods having the same concept but different equipment were used for both methods.



Third method can be discussed for the oil replacing is re-refining. Re-refining will include a combination of distillation and acid, caustic solvent, clay or hydrogen treating and other physical and chemical means [7][8]. This process will produce liquid which are suitable for further use as electrical insulating liquids.

Another method which is suitable for replacing oil transformer is reconditioning process. Reconditioning process will remove insoluble contaminants, moisture and dissolved gases from used oil. This process will involve settling, filtering, centrifuging and vacuum drying or degassing [7] [8].

Last method which is suggested due to the factor of low cost method and environment friendly factor is reclamation. Reclamation is the process of removing contaminants and product of degradation such as acidic, polar and colloidal materials from used electrical insulating liquids by chemical or adsorbent means [7] [8]. Reclamation will involve the use of method and processes which will produce oil composition with beneficial change. This process will remove oxidation product from the oil but it will not remove the sludge at the unit. This method should be done often to avoid more sludge produce at the unit.

Reclamation process will remove oxidation product by using certain amount of adsorbent. Adsorbent will remove the particle and change the oil characteristic approaching to the new oil. This method will improve the colour of the oil, viscosity and acidity of the oil. Reclamation process can reduce the cost of changing the oil transformer and make the used oil useful although the characteristic of the oil has approaching the bad oil.



## 2.5 Adsorbent

In reclamation process, adsorbent plays main role to separate the oxidized product and the oil particle. It will have a process which is called as adsorption. Adsorption is a process in which one substance attracts and holds the other substance tenaciously to its surface area [1]. Most of the contaminants in oil are polar in nature and are therefore can be easily adsorbed. Fuller's earth, bentonite, activated attapulgite, and molecular sieves are some of the example for adsorbent.

1. Fuller's Earth

By referring to the IEEE Standard 637 [3], besides being mineralogical specie, fuller's earth can be a class of naturally occurring adsorbent clays. It contains internal and external polar active sites, which will allow the oil with non-polar components to pass through without retention but which retains the polar contaminants or degradation compounds dissolved in oil [6]. There are also different types of clays such as sepiolite, bentonite, attapulgite and montmorillonite. This product were made based on silicate anions ($Si_2O_5$) which is condensed with octahedral layers of the type X (OH) where X could be magnesium or aluminium [OR3]. After being drying and processing by activation acid it will be in the form of fine powder which the colour could be grey, buff, brown or blue. Fuller's Earth has the capability to removes moisture and neutralises carboxylic acids, adsorb polar and improve discoloration to make the oil clear [3, 7].



2. Activated Attapulgite

Activated attapulgite also one of the example for adsorbent in oil reclamation process. It is in the form of clays which can be widely available today. According to IEEE Standard 637 [8], activated clay can help to neutralize sizeable quantities of acid. Amount of removing acid number were related to the neutralization number which will depends on many factor since the adsorption is a dynamic equilibrium process. Factors that affect the rate and capacity of adsorption is temperature, flow

rates, viscosity of oil, residence time and initial level of acid. Figure 2.1 can be used as a guideline for typical expected value only;

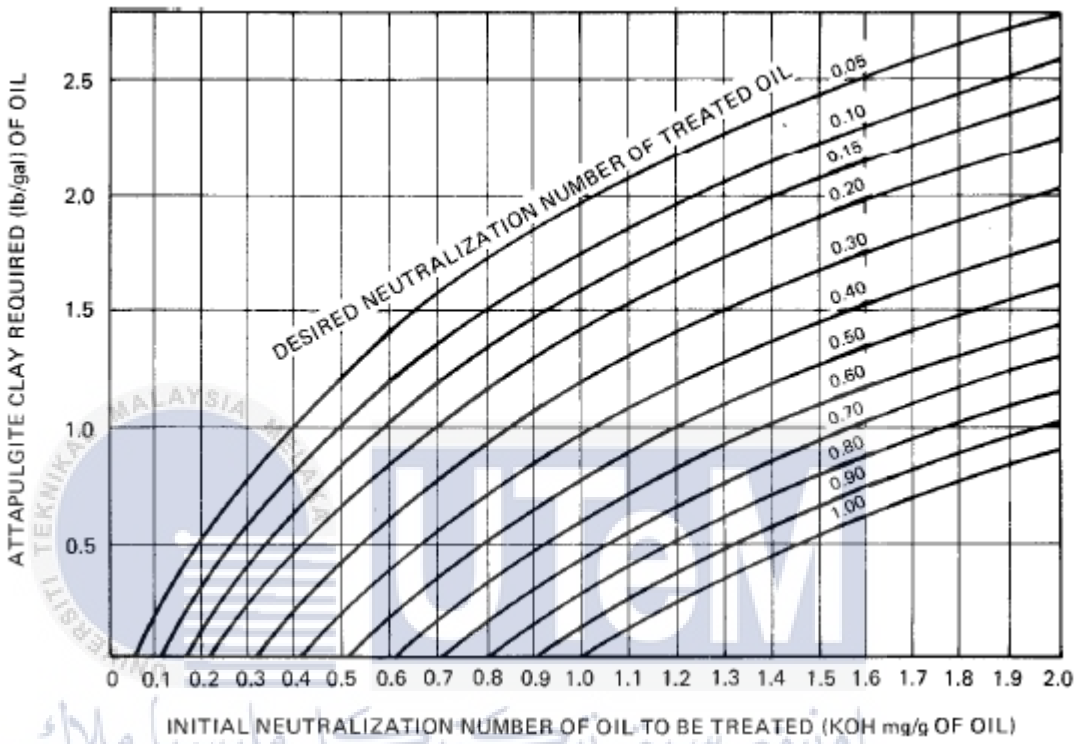


Figure 2.1: Adsorption of Activated Attapulgite Clay [8]



3. Molecular Sieves

Molecular Sieves is a group of unique crystalline adsorbent. It is capable to separate substances based on their molecular size [8]. Besides have a strong affinity in water, molecular sieves are uniformly porous. Materials of molecular sieves can be known as zeolites [8]. According to the IEEE Standard 1637 [8], zeolites are aluminosilicates with the unusual characteristic of being able to undergo dehydration

with essentially no change in crystal structure. Usually the type 4A is used with transformer oil and has an unusual affinity for polar compounds, particularly water. Molecular sieves 4A are available in bulk quantities and can be regenerated. It is the most expensive adsorbent compare to others.

4. Activated Bentonite

Activated Bentonite also is an example for adsorbent. Activated bentonite was able In absorption of contaminants, suspended matters, residue and elimination of impurities such as ash content, carbon content in used oil [14]. It is also state that the transformer oil which reclaim by using Bentonite will produce enhanced results. All of the oil properties in term of breakdown voltage, viscosity and acidity will be changed.

According to IEC no.296 [14], transformer oil has breakdown voltage from 30 kV to 50 kV. When purification process takes place, the range of breakdown voltage of used transformer oil has been wide which is from 22 kV to 64 kV. By using bentonite as the adsorbent for the used transformer oil, the range of breakdown voltage will become wider which is from 22 kV to 68 kV.

By comparing in term of the viscosity of the transformer oil, there will be also changes happen to the viscosity of the transformer oil when it has been purified by the adsorbent. Normal viscosity of used transformer oil is 1.74 Engler and after purification process, the viscosity decrease to 1.72 Engler and the value will be the same after single year operating. When the used oil has been purified by using Bentonite adsorbent, the viscosity of the oil will show the lowest value among used

oil and used oil that have been purified. For Bentonite purification, the viscosity is 1.70 Engler [15]. In terms of the colour, used transformer oil is dark after purification while the colour of transformer oil after Bentonite treatment is clear continuous until one year of operating [15].

According to IEC No.296 [14], in concentrated oil, total acidity is 0.03 mg KOH/g. At the initial state of transformer oil which is before purification and before Bentonite cure, the total acidity is 0.2 mg KOH/g. After purification process, total acidity removes by nearly 60% (0.08 mg KOH/g of oil) and 92% for Bentonite cured oil (0.016 mg KOH/g of oil). After partial year of aging, the total acidity of purified transformer oil will increase to 0.09 mg KOH/g of oil, but it was remains unchanged the value of 0.016 mg KOH/g of oil for the Bentonite cured transformer oil. For the results of aging after one year, the total acidity of purified transformer oil increased to 0.11 mg KOH/g of oil, while 0.022 mg KOH/g of oil for the Bentonite cured transformer oil. Even after one year of operating, the reusing transformer oil either with purification or Bentonite cure shows zero of ash contents and carbon contents [15] [16].



## 2.6 Breakdown Voltage (BdV) Test

Another testing will be take places in this experiment is BdV test. BdV test is used to measure the ability of oil to withstand with the electrical stress without any failure. BdV value will be changes due to the effect of water content inside the oil. By referring to the standard of MS IEC 60156:2012, the gap between two electrodes is fixed with a gap of 2.5 mm. Figure 2.2 shows the preparation for BdV test;


Figure 2.2: Preparation of BdV Test by using Megger OTS60PB

Based on Figure 2.2, the operation of the equipment can be described as follow [17];

1. In the dielectric liquid, there will be an AC voltage is applied at controlled rate to two electrodes immersed.
2. Specified distance according to the standard will be set as the gap between two electrodes.
3. As the current across through the gap, voltage is recorded which represent the dielectric breakdown of the liquid.

From the display at the top of the Megger, there will be the result of BdV for oil sample. As the conclusion, increased of moisture in oil sample will decrease the value of BdV.

## 2.7 Weibull Probability Plot

In order to study dielectric failure, statistical techniques, parametric and non-parametric technique have been used to study this case. Between both parametric and non-parametric technique, both have its own differences. In parametric tests, the data collected can be modelled based on theoretical distribution while its differences for non-parametric test. This test was more suitable for cases where the data can not be assumed [20]. Analysis by using non-parametric tests were not powerful compare with analysis by using parametric tests. Parametric tests were the best choice to observe the breakdown voltage for dielectric material.

Two types of parametric tests which always being used to analyse the breakdown voltage for dielectric material which are Gaussian and Weibull distributions. When talking about the breakdown voltage of dielectric material, breakdown voltage is referring to the ability of the material to withstand voltage at the risk of breakdown. Gaussian distributions technique can be used to find the breakdown voltage for the dielectric material by determining the mean and standard deviation first. Equation 2.1 and Equation 2.2 show the equation for mean and standard deviation for Gaussian distributions [20];



$$Mean = \bar{x} = \frac{1}{n}\sum_{i=1}^{n} X_i \tag{1}$$

$$\text{Standard Deviation} = \sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x - \bar{x})^2} \tag{2}$$

In 1951, Weibull have providing the distributions on a model failure. This distribution was published to study the failure that is caused by a weak link. The failure happens due to the any of the links were failed to operate [21]. The failure can be expressed in the Equation 2.3 where $P_n$ is stand for probability of failing due to $\varphi(x)$, a function of load $x$;

$$P_n = 1 - e^{-n\varphi(x)} \tag{3}$$

Based on article in (22), the writer, Morcos believes that Weibull distributions is seems to fit the data better comparing with other distributions technique. So, this technique is often used to model the breakdown voltages. By considering this reason, Weibull distributions technique will be selected in order to analyse statistical data for breakdown voltage. Weibull distributions technique will give approximate value for time of failure which is at 63.2% from the Weibull Probability Plot. Equation 2.4 shows the equation for Weibull distributions [23];



$$Q(T) = 1 - e^{-(\frac{T}{\eta})^{\beta}} \tag{4}$$

Where $\beta$ is stand for the slope parameter while $\eta$ is stand for scale parameter. Basically, it is simple to determine the Weibull slope parameter, $\beta$, because the slope of the line on the Weibull probability plot is equal to the Weibull slope $\beta$.This can be illustrate as shown in Figure 2.3;

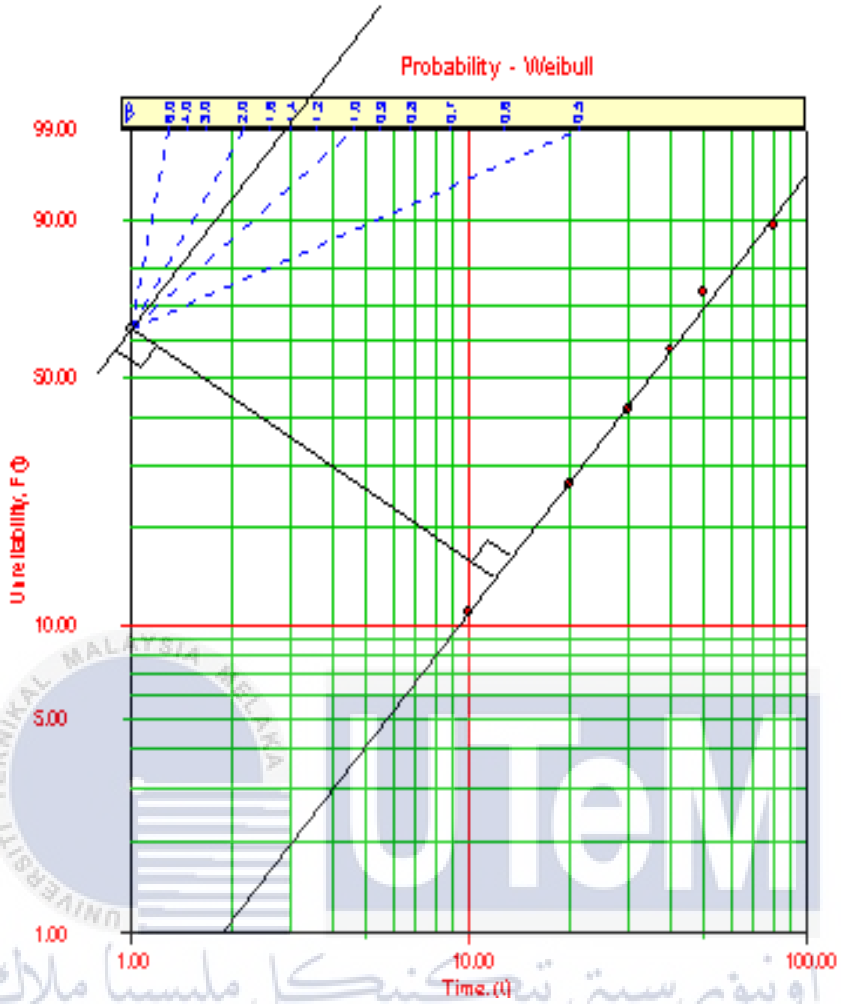


Figure 2.3: $\beta$ Estimation for Weibull Distributions [23]



By substituting $T = \eta$ in the Equation 2.4, resulting Q(t) of the equation will be equal to 63.2%.

$$Q(T) = 1 - e^{-(\frac{T}{\eta})^{\beta}}$$

$$Q(T) = 1 - e^{-1}$$

$$Q(T) = 0.632$$

$$Q(T) = 63.2\%$$

By referring to the above derivation, 63.2% is the best fit-line unreliability for the model line intersects with a horizontal line [23]. So, the x-axis which intersect the line of 63.2% of y-axis will represents the approximate value of breakdown voltage based on the data that have been taken.

## 2.8 Review of Previous Related Works

This part present two research study that related with this project which are 'The Gassing Tendency of Various Insulating Fluids under Electrical Discharge' and 'Ages Oils Reclamation: Facts and Argument Based on Laboratory Studies'. Both of these articles wrote by J. S. N'Cho, I. Fofana, A. Beroual, T. Aka-Ngnui and J. Sabau.

### 2.8.1 The Gassing Tendency of Various Insulating Fluids under Electrical Discharge [1]



Authors for this article have done a few experiments by following the standard of ASTM D6180. The experiment begins by reclaiming the service aged oil by using three commercially Fuller's Earth. According to [1], the first fuller's earth is the normal fuller's earth while the second and third fuller's earth is fuller's earth which has been improved by acid wash clays. The service aged oil sample was taken from Canadian utility company ageing power transformer. This oil was reclaimed in laboratory condition.

At the end of this experiment, authors in [1] have state that the amount of gases evolved by the in-service deteriorated oil samples, decreases after the selective removal of dissolved and insoluble decay products by reclamation. It also can be seen that the graph for

Dissolved Decay Product (DDP) decrease after reclamation process takes places. As the conclusion, Fuller's Earth adsorbent able to remove the DDP which have been affected the transformer oil.

### 2.8.2 Aged Oils Reclamation: Facts and Argument Based on Laboratory Studies [7]

Authors in [7] have realized that there will be service aged oil in transformer can be used again by using a few methods with the help of adsorbent which will remove the oxidized product of the used oil. By using Fuller's Earth adsorbent and following the standard of ASTM D6802 and D6181, the experiment was done by reclaiming the service aged oil 15 cycles in order to remove decay products.

Authors in [7] also have classified the type of oil in terms of the color of the transformer oil. Good transformer oils will have pale yellow color while yellow color of transformer oils represents that the oil is a preposition oils. Bright yellow transformer oil represents marginal transformer oils. Transformer oil will be categorized as bad oils as it color have been turn to amber. Make it worst, the brown color represent very bad oil and dark brown color will show that the oil is extremely bad oils. The oil is in the worst condition if the transformer oil is black in color.



Other than that, authors in [7] have introduced three different processes to treat the service aged oil which is reclamation, refining and reconditioning. Authors in [7] have use reclamation process for the experiment and the result have shown that Dissolved Decay Product have slightly remove for every cycle of reclamation process. As the conclusion, Fuller's Earth adsorbent able to remove DDP of service aged transformer oil and make the oil can be used again.

# CHAPTER 3

# METHODOLOGY

## 3.1 Introduction

In this chapter, there will be quick review on the method that have been used to complete the experiment from the beginning until the ending. There will be also detailed explanation on the method that have been used for the experiment operation and the materials that have been used for the experiment.



## 3.2 Flow Chart of Project Experiment

Previous chapter were discussing about the review that have been done and related theory that need to be covered before beginning this experiment. The methods that have been used for this experiment also come from the literature reviews that have been done before the experiment start. Literature reviews were complete by referring trusted journals, magazines, standard and books. Figure 3.1 shows the flowchart of project experiment;

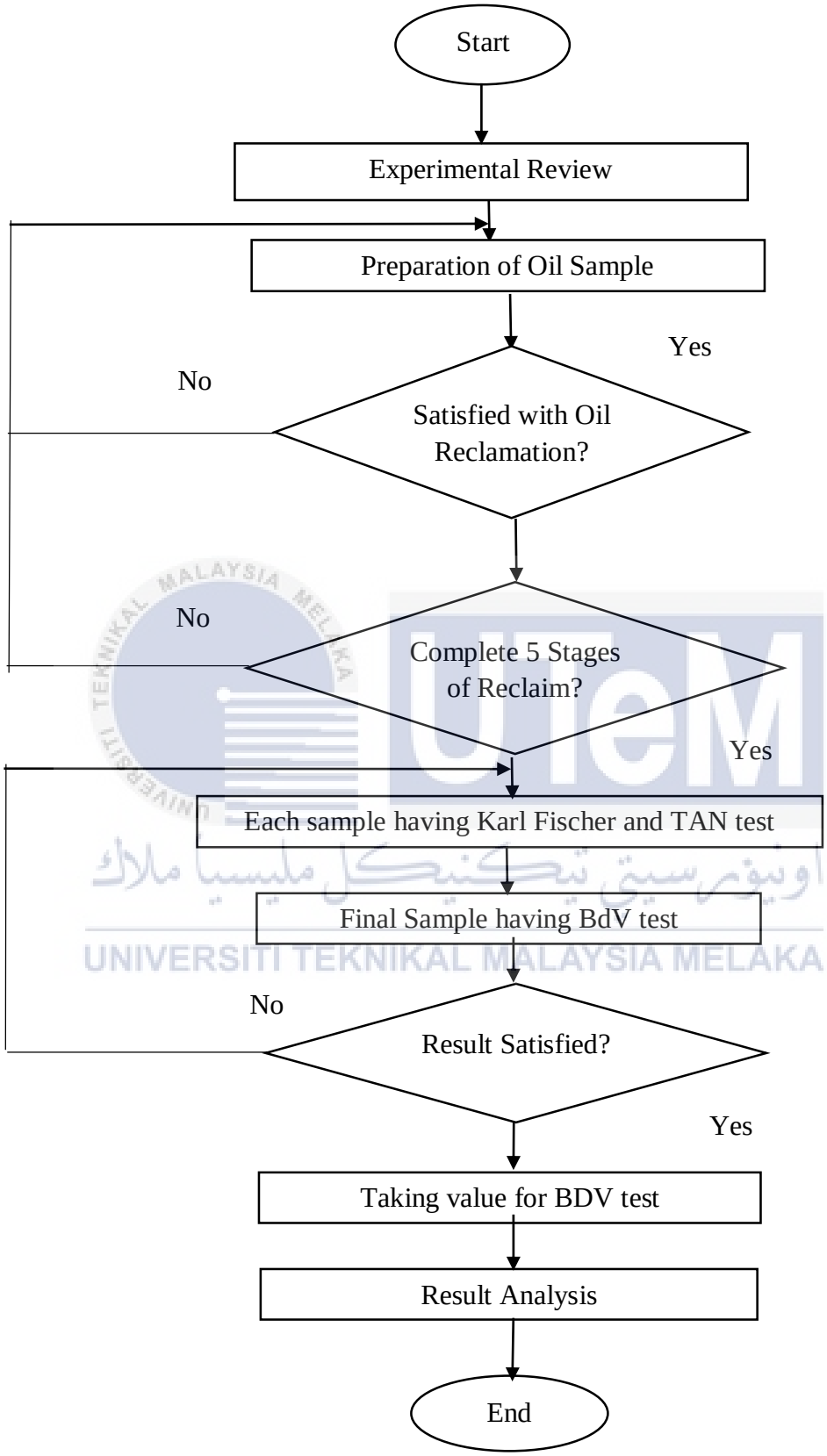


Figure 3.1: Flow Chart of Project Experiment

## 3.3 Experimental Review

At this stage, there will be a lot of revision had been done to understand the concept and related theory for this experiment. Journals, previous research IEEE report, related magazines and books will be use as the main references so that the information that has been given in the source can be trusted for the next step. This information has been used as the reference when running the experiment and this information also will be cited in the report.

Based on the experiment that had been done, experimental review was done in order to find a lot of information about the related materials such as suitable oil age that will be used in the experiment and type of adsorbent use. Besides that, previous research contains a lot of discussion, result and method that had been used to complete the experiment. So, the result, discussion and method will be the references when completing the experiment.

## 3.4 Stages of Reclamation for Used Oil



For this experiment, there will be 5 stages of reclamation that have been done. At every stage, 40 millilitre (ml) of reclaimed oil will be taken for Karl Fischer test and TAN test. The test has been done by using the equipment that have been supplied inside the High Voltage Laboratory of Faculty of Electrical Engineering.

Used oil was taken from mineral oil inside a transformer which has been operating for 29 years**.** The transformer had been shut down and the process of replacing used oil with new oil was completed. Then, a few litres of used oil were taken into the laboratory and experiment will operate by using the used oil.

Used oil has high viscosity, acidity and moisture due to oxidation process during the operation of transformer. In order to remove the oxidation product, the oil will have the process of reclamation first. The oil will be adding by certain amount of adsorbent and will be mixed for a few hours with 60 degree Celsius (°C) temperature. As mention in literature review part, there will be a few method of oil reclamation. For this experiment, contact process and percolation method will be used as the method of reclamation for the used oil.

According to [3], 1000 ml of used oil will be pour into a beaker and the oil will be heated up on magnetic hot stirrer with speed of 750 rpm until the temperature had achieved 60°C. In order to avoid shortage of oil due to five sampling process, 2000 ml of used oil were used for the experiment. While waiting for the oil to heat up, the 100-gram adsorbent was prepared. Figure 3.2 shows 100-gram adsorbent was prepared;




Figure 3.2: Adsorbent

After the used oil has achieved 60°C, the adsorbent will be pour slowly into the oil and both substances will be stir for 4 hours [3]. This process is known as contact process. Figure 3.3 shows the preparation of used oil for contact process;


Figure 3.3: Contact Process



After 4 hours, the oil will have filtering process. Filtering process will be filtering the used oil that has been mixed with adsorbent into a flask. Inside the flask have been connected to a vacuum pump so that the condition in the flask is in vacuum condition and there will be no air which will produce moisture inside the flask. Besides that, vacuum pump will force the used oil pass through filter paper. This concept shows the percolation concept which has been review in Chapter 2. Filtering process will separate the molecule of the reclaimed oil and adsorbent. Used oil that has been filter inside the flask will be known as reclaim oil. Figure 3.4 shows the concept of percolation process;

Figure 3.4: Percolation Process

For each stages, it will be taking 5 hours to complete a stage of reclamation process. So, the oil will be placing inside a beaker which covered by Cling Wrap and the beaker was placed at the dark place of the cupboard inside the High Voltage Laboratory. For every stages, sampling process will be takes place which will be discussed in next topic.

## 3.5 Oil Sampling

Oil sampling is the process of preparation reclaimed oil based on used oil that has been reclaimed. Reclaim oil will be place inside a 40 ml bottle and the oil will be taken to be tested with Karl Fischer and TAN test in order to observe the characteristic of the reclaim oil compare with the used oil. If the result of Karl Fischer and TAN test satisfied show decrement compare to the used oil, the next step will continue which will prepare the oil for BdV test. Figure 3.5 shows the bottle that will be used for sampling for each stage and Figure 3.6 shows the bottle that will be used for final stage of reclaim oil;

Figure 3.5: Sampling at Each Stage

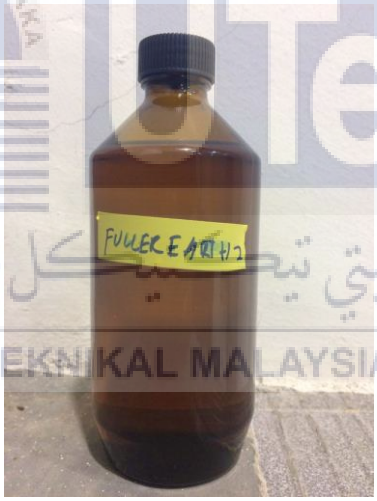


Figure 3.6: Sampling for Final Stage

## 3.6 Karl Fischer (Water Content) Test

Karl Fischer Test is one of the test which able to determine the amount of water inside oil that have been measured. Karl Fischer use a device which is call coulometer and this device will give measuring in Part Per Million (PPM) unit. Figure 3.7 shows the coulometer;

Figure 3.7: Coulometer



Procedure to use Coulometer were explained as below;

1. Press “ON” button.
2. Press arrow button down to select “Method”, press “OK” button.
3. Select “KFC” for Karl Fischer, select “Load” and press “OK” to confirm load method. Figure 3.8 (a) and Figure 3.8 (b) shows the point that need to be selected;


(a) (b)

Figure 3.8 (a,b): Procedure to Select KFC Method

4. Then, press key "Start" to condition the vessel.
5. Once the screen show the condition is **OK** or the drift value is below **20** and without fluctuation, the 899KF Coulometer is ready for sample injection. (a beep sound will hear when the conditions OK). Figure 3.9 (a) and Figure 3.9 (b) illustrate this statement;




(a) (b)

Figure 3.9 (a,b): Illustration for Procedure Number 5

6. Prepare 0.1ml/1ml oil sample by using a syringe.
7. Tare syringe with sample to zero, then press key “Start” and inject sample into the vessel through the septum.
8. Immediately weight again the syringe with remainder sample and then press key “OK” to key in the sample weight at once and press key “ENTER” to confirm the sample weight. Figure 3.10 (a) and Figure 3.10 (b) illustrate this statement;


(a) (b)

Figure 3.10 (a,b): Taking the Value of Remaining Weight into the Sample Size

9. After that, the screen will show the results in PPM unit.
10. Repeat step 1 until 9 for another sample.
11. To shut down the Coulometer, press and hold the “ON” button.

## 3.7 Total Acid Number (TAN) Test

In order to use 848 Titrino plus which produce by Metrohm company, a few step need to be follow before following the measuring procedure. TAN test is one of the test to observe the total amount of acid number inside the oil sample and the measuring is in mgKOH/g. Figure 3.11 shows the 848 Titrino Plus model which use for TAN Test;

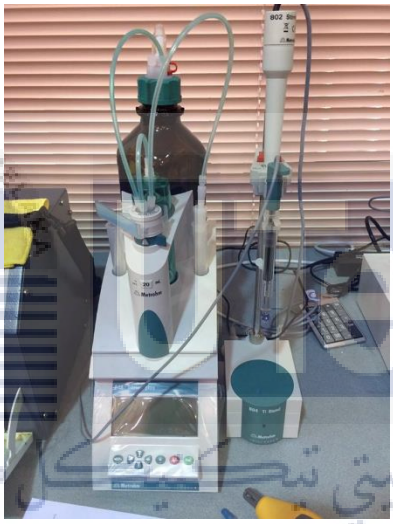

Figure 3.11: 848 Titrino Plus



a) **Set Up**

1. Press “ON” button.
2. Set up apparatus such as electrode, tubing and stirrer.
3. Rinse and fill the burette with KOH inIPA (0.1mol/L).
4. Standardize the KOH in IPA 0.1 mol/L.

b) **Calibration**

1. Calibrate the electrode with buffer solution.

   *(If use other brand, please select from the method parameters and save the method)*

2. Make sure the slope is between 97% to 103%.

c) **Standardization**

1. Weight around 0.1 gram of KHP into beaker, add approximately 80 mililitre (ml) of Distilled Wter, threate with KOH in IPA 0.1 mol/L.
2. Result/ titer value will save automatically into system. Titer (Factor) result normally around 1. Figure 3.12 shows the sample for KOH;

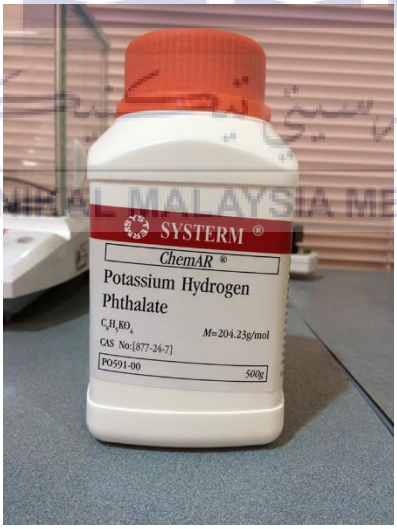


Figure 3.12: Potassium Hydrogen Phthalate (KOH)

d) **Blank Titration**

1. Perform blank titration dairy. Measure 10 ml of solvent (IPA) into titration vessel and titrate with KOH in IPA of 0.1 mol/L.
2. Duplicate the blank titration.
3. Blank value will be auto save at Common Variable.

e) **Sample Titration**

1. Weight around5 gram of sample into titration vessel.
2. Add 20 ml of IPA solvent.
3. Titrate with KOH in IPA until pH 11.5.
4. TAN result is shown at the screen.

f) **Rinsing Electrode**

1. Rinse electrode with titration solvent IPA then follow by Distilled Water. Keep the electrode moist with the electrolyte.



## 3.8 BdV Test

BdV test is done to measure the ability of reclaimed oil to withstand the electrical stress without having failure during the operation [11]. This test should be done by using Megger OTS60PB due to the additional moisture is added to the oil sample. This moisture will be represented the oxidized product inside the transformer. Figure 3.13 shows the method to place the sample oil inside Megger OTS60PB;


Figure 3.13: Sample Oil inside Megger OTS60PB for BdV Test

This test will be done consequently by refer to the ASTM D1816-84a standard. The procedure for the BdV test as below [11];

1. Megger tester is turned on.
2. Sample from the bottle is filled in test cell about 350ml
3. Test cell is placed inside the Megger testing area. Make sure that the electrodes sink in the oil and the cover is closed.
4. Then, select standard of ASTM d1816-84a and run the Megger tester.
5. This testing will be conducted six times and value of the average voltage will be appearing at the end of the test.
6. Record the value of six time testing and the average value.

## 3.9 Weibull Probability Plot

1. Open the software of Minitab 16.
2. By using the data taken at the laboratory, fill in the 50 reading for BdV obtained in the worksheet as shown in Figure 3.14;

| C1 |
| --- |
| 5th Stage of Reclaim Oil (kV) |
| 10 |
| 14 |
| 17 |
| 16 |
| 17 |
| 16 |
| 16 |
| 16 |
| 14 |
| 16 |
| 16 |
| 16 |
| 18 |
| 14 |

Figure 3.14: 50th reading of BdV fill in Worksheet



3. Then, click on the 'Graph' and select 'Probability Plot'.
4. Select 'Single' icon and click 'Ok'. Figure 3.15 shows the box for procedure number 4.

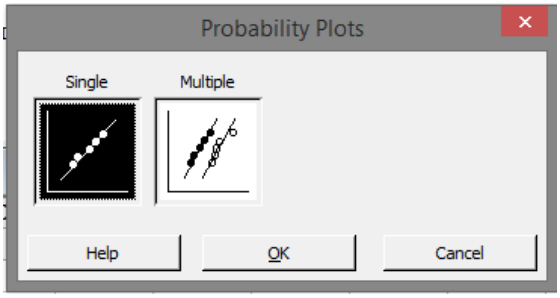


Figure 3.15: Dialog Box for Procedure Number 4

5. Click the data that has been filled in at the left pane and a dialog box for Graph Variables will automatically show. Then, click ‘Ok’. Figure 3.16 shows the dialog box for Graph Variables;

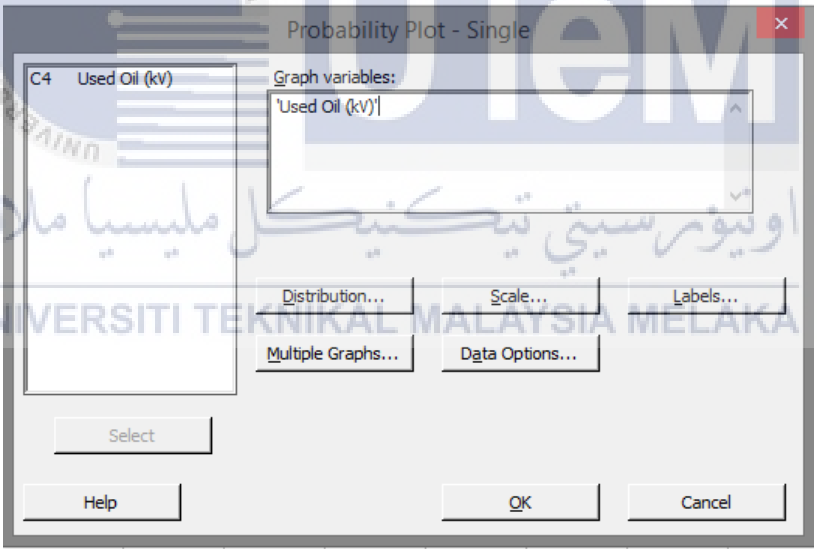




Figure 3.16: Dialog Box for Graph Variables

6. Then, a pop up window will which show the probability plot will appear. The scale value is the estimate value for 63.2%. To mark the value on the plot, right click on the plot and choose ‘Add’, then select ‘Percentile Lines’. Add 63.2 value in the first

box. Click ‘Ok’. Figure 3.17 shows the approximate value for Weibull Probability Plot;

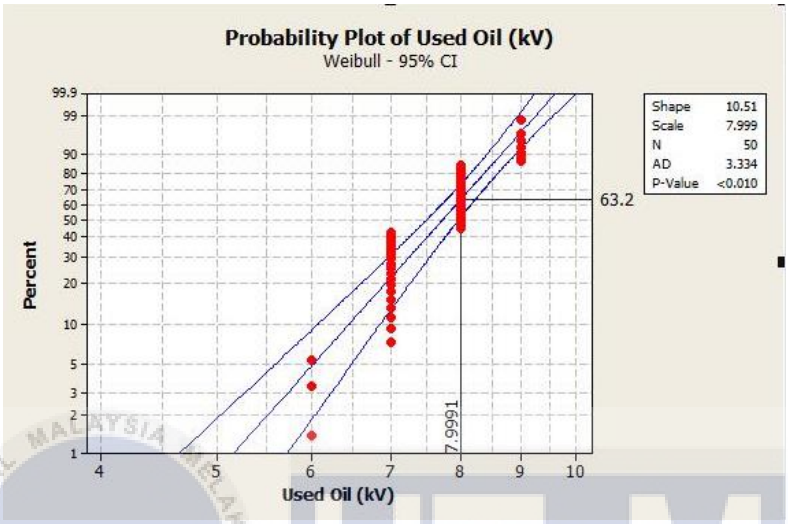


Figure 3.17: Approximate Value of Weibull Probability Plot

## 3.10 Result Analysis



After collecting data from Karl Fischer test, TAN test and BdV test, the data were analysing in terms of the ability of the reclaimed oil to withstand electrical stress without failure, colour, viscosity and performance of the oil. For Karl Fischer test, the result was accepted by observing the decrement of amount of water content inside the reclaim oil. From the theory, it is clearly seen that the total amount of water content was decrease from the used oil which is the highest water content until the multiple stage of reclaim oil. For TAN test, the result should be in the same trend as Karl Fischer test. It is because as the oil having more reclamation process, the acidity of the oil will decrease and nearly the original oil. So that, the TAN test should show the decrement reading from the used oil until highest stage of

reclaim oil. For BdV test, the breakdown voltage was only measured at the final stage of reclaim oil. This is because of the lack of equipment, time and oil have limited the experiment. So, the collected data were taken and tabulated in Table B.1 which was shown in Appendix B. Weibull Probability Plot will be used in order to determine the approximate value of BdV after 50 reading were taken based on two oil samples.

. All the data collected from the three test were tabulated in table. The table was creating in order to give an organised result to the observer. Then, the result for both test will be analysed completely by referring to the literature review and related theory that have been done. After that, a conclusion will be made based on the result and discussion of the experiment. Further discussion on this finding will be explained in Chapter 4 which is Result and Discussion.

# CHAPTER 4

# RESULT AND DISCUSSION

## 4.1 Introduction

In this chapter, there will be results that have been obtained at the end of the experiment. These results were including the Karl Fischer Test, and TAN Test for multiple stage of reclaim oil and BdV Test for final stage of reclaim oil. The results were analysed and discussion will be made based on the results that have been obtained.



## 4.2 Results of Reclaimed Oil using Fuller's Earth Adsorbent

Used oil which is obtained from 29 years of transformer have been reclaimed by using contact process with fuller earth adsorbent and the oil have been filtered by using percolation method. As the result, it can be clearly seen that the colour of the oil has been changed from

stage to another after the percolation process have been done. Figure 4.1 shows the different between used oil and reclaim oil from the first stage until the fifth stage;

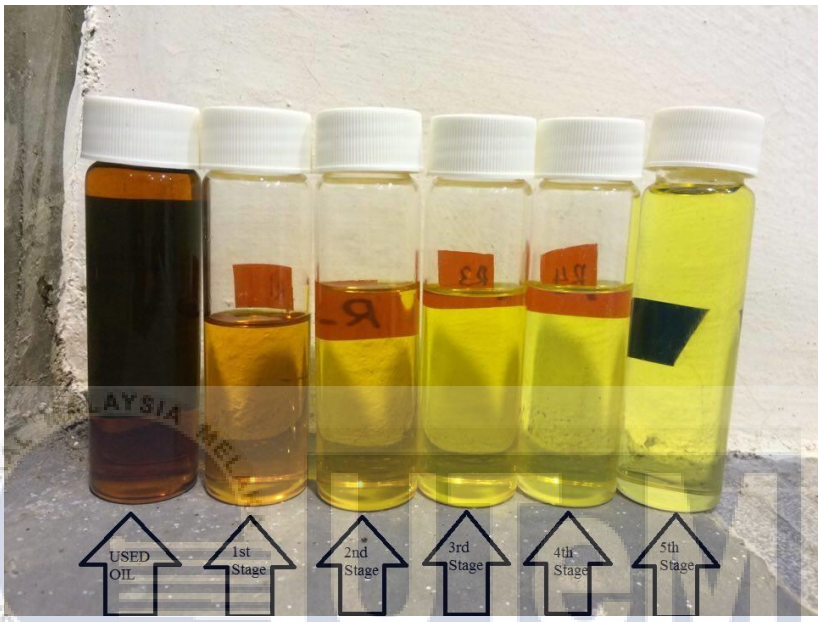


Figure 4.1: Colour Different between Used Oil and Multiple Stage of Reclaimed Oil



Based on the colour different comparison in Figure 4.1, the colour become brighter as the reclaimed process is continuously repeated. At the fifth stage of reclamation, the colour of the reclaim oil is the brightest compare with other stage of reclamation. By comparing the colour of the fifth stage of reclaim oil and used oil, there is massive different between both oil. Used oil is the darkest while the fifth stage of reclaim oil is vice versa. It is because as more reclamation process take place for this experiment, Fuller's Earth adsorbent helps the used transformer service oil to remove the Dissolved Decay Product (DDP). DDP is one of the factor that contribute to make the oil darken and reduce the functionality of the oil. By removing the DDP, the originality of the oil will come back slowly as more reclamation

process takes place. So, this will make the colour of the oil to be more bright compare with before reclamation process take place.

## 4.3 Karl Fischer Test

Karl Fischer test were operated in order to determine the water content for each of the oil sample. This method uses 899KF Coulometer to measure the water content inside the oil sample. There were six samples will be tested by using 899KF Coulometer. Table 4.1 shows the result for water content in each sample;

Table 4.1: Water Content and Percentage of Decrement for each Oil Samples

| Type of Oil | Water Content in PPM | Decrement Percentage (%) |
|---|---|---|
| Used Oil | 77.2 | 0 |
| 1st Stage Reclaimed Oil | 48.0 | 37.82 |
| 2nd Stage Reclaimed Oil | 42.5 | 44.95 |
| 3rd Stage Reclaimed Oil | 37.3 | 51.68 |
| 4th Stage Reclaimed Oil | 33.8 | 56.22 |
| 5th Stage Reclaimed Oil | 32.5 | 57.90 |



Based on Table 4.1, the water content shows the decreasing trend as more stage of reclamation process were take place. Used oil state the highest water content among 6 samples which is 77.2 PPM. This value indicates the reference value in order to observe the

decrement of water content inside the used transformer service oil. As more reclamation process takes place, the water content keep decreasing until the reclaim oil obtain 32.5 PPM at the fifth stage of reclamation process. For new oil, highest water content based on the datasheet is 30 PPM [19]. In this case, more reclamation required in order to remove more water until the reading for reclaim oil below than 30 PPM.

From Table 4.1, decreasing trend for the water content inside the reclaim oil show that adsorbent Fuller's Earth was helping the oil to remove water content inside the reclaim oil after reclamation process takes place. The decrement of water content inside the reclaim oil can be illustrating as the graph in Figure 4.2 and Figure 4.3. From these figures, it shows the trend of water content decrement which present in percentage;

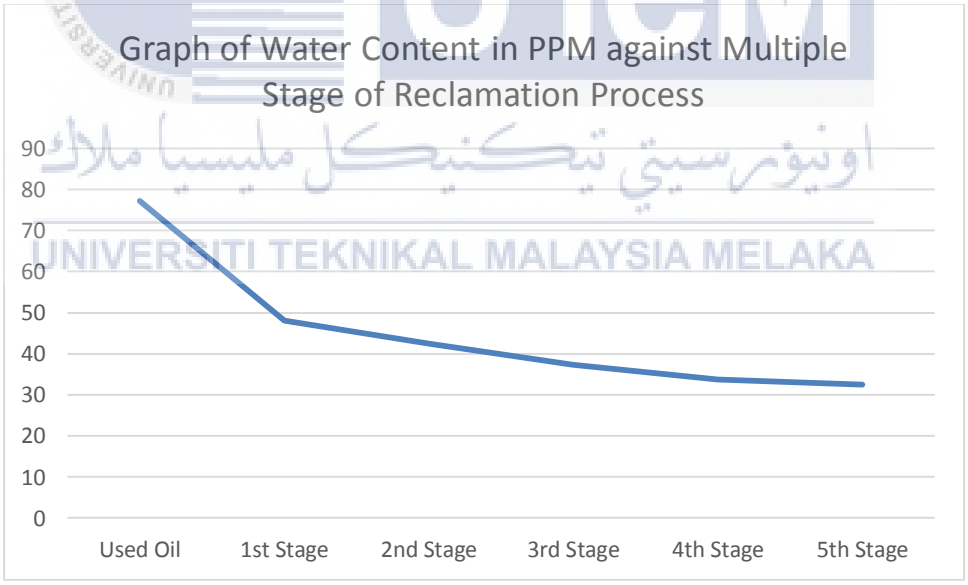


Figure 4.2: Graph of Water Content in PPM against Multiple Stage of Reclamation Process

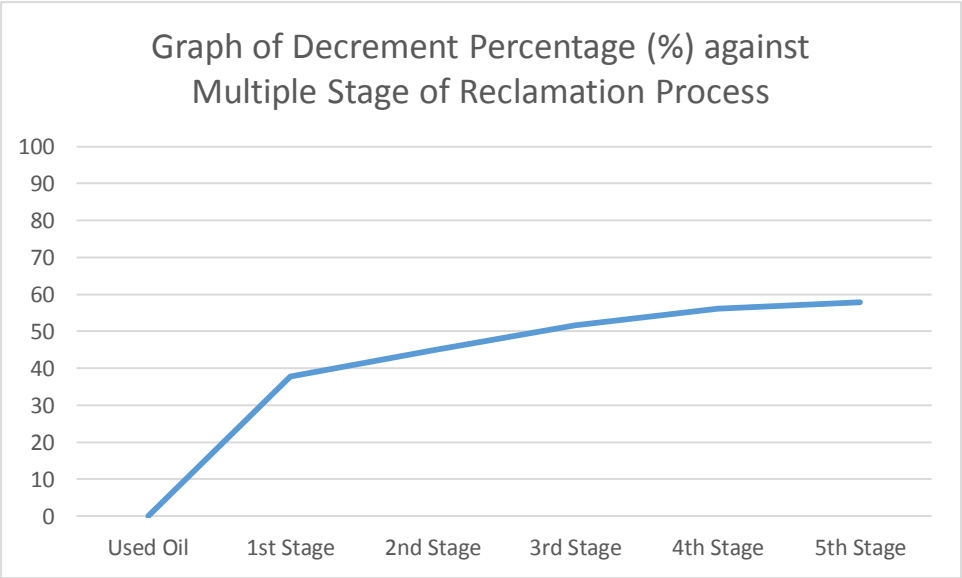


Figure 4.3: Graph of Decrement Percentage of Water Content against Multiple Stage of Reclamation Process

From Figure 4.2, water content inside the oil sample decrease as more reclamation process take places. Based on Figure 4.3, the oil has remove 37.82% water content at the first stage of reclamation. When the reclamation process was repeated for second time, percent of water content which manage to be removing is 44.95%. At the third stage of reclamation process, 51.68% of water content have been removed from the oil. 56.22% of water content able to be removing for the fourth stage of reclamation while 57.90% of water content can be removing at the final stage of reclamation process. Based on Table 4.1, percentage of water content that have been remove increase from 0% until 57.90%.

The amount of water that manage to be removing increase as more reclamation process take place. This condition happens because Fuller's Earth adsorbent which used in contact process able to remove residues dissolved in oil [7]. This make the Fuller's Earth adsorbent very effective in order to remove the water content inside the service oil. Based on

paper in [7], Fuller's Earth has the ability to remove moistures and improve discoloration which resulting the oil to be more clear as shown in Figure 4.1. By removing the water content inside the oil, the originality of the oil will be able to be obtaining by increase the number of reclamation process by using Fuller's Earth adsorbent. So, the result for Karl Fischer test for reclaim oil were accepted due to the decrement water content which measured in PPM inside the oil sample.

## 4.4 Total Acid Number (TAN) Test

TAN test takes place in order to observe the acid content inside the oil sample. All of 6 samples have been used for this test. 848 Titrino Plus produce by Metrohm company will be used to determine the amount of acid number inside the oil sample. Table 4.2 shows the results for all of 6 samples which measure in mgKOH/g;

Table 4.2: Acid Number and Percentage of Acid Decrement in Each Oil Sample

| **Type of Oil** | **Acid Number (mgKOH/g)** | **Decrement Percentage (%)** |
|---|---|---|
| Used Oil | 0.1096 | 0 |
| 1st Stage of Reclaimed Oil | 0.0743 | 32.20 |
| 2nd Stage of Reclaimed Oil | 0.0690 | 37.04 |
| 3rd Stage of Reclaimed Oil | 0.0546 | 50.18 |
| 4th Stage of Reclaimed Oil | 0.0522 | 52.37 |
| 5th Stage of Reclaimed Oil | 0.0378 | 65.51 |

Based on Table 4.2, the results show the decreasing trend from the used oil until the 5th stage of reclaimed oil. This prove the theory that have state that as the number of reclamation increase, the total acid number inside the oil sample will be decrease. From this statement, as more process of reclamation take place for the same oil sample, the oil will be able to remove more contaminant which contribute to increasing in acidity and as the effect, this process will give the original characteristic to the oil sample slowly. Figure 4.4 shows the trend for total acidity number of the oil samples and Figure 4.5 shows the decrement percentage of acid number which present in percentage;

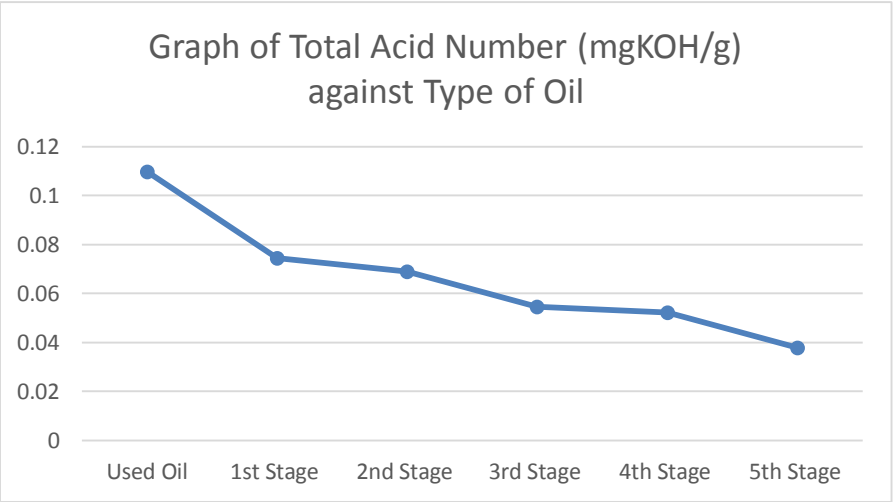


Figure 4.4: Trend of Total Acid Number for each Oil Sample

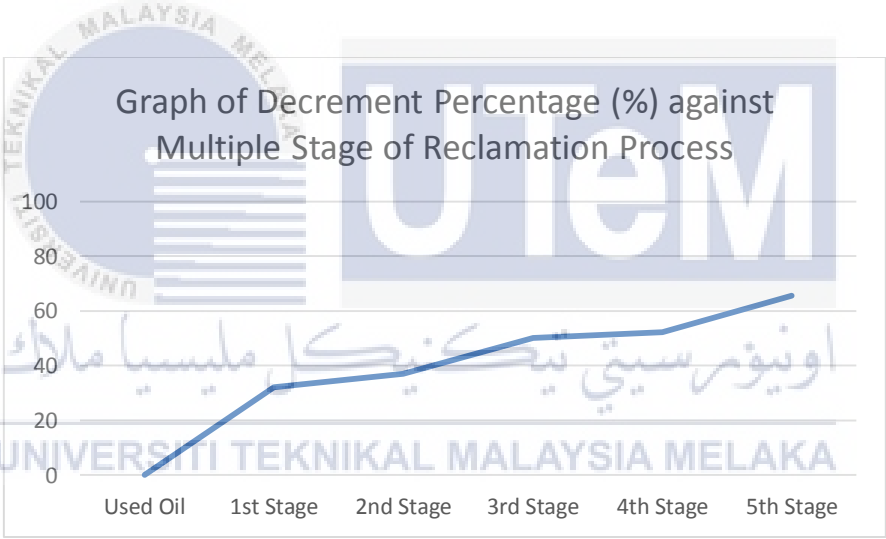




Figure 4.5: Graph of Decrement Percentage of Acid Number against Multiple Stage of Reclamation Process

Based on Figure 4.4, the amount of total acid number inside the oil sample decrease as more reclamation process take place. In the other hand, Figure 4.5 shows percentage of total acid number that manage to be removing after multiple stage of reclamation take place. The graph in Figure 4.5 shows increasing trend which means that the amount of acid remove

inside the oil increase after a few process of reclamation process take place. At first, the total acid number that manage to be removing is 32.20%. For the second reclamation process, 37.04% of total acid number manage to remove. Then, 50.18% and 52.37% of acid number have been remove in third and fourth stage of reclamation. At the final stage, total of 65.51% of acid number able to remove. As more reclamation process take place, total acid number for reclaim oil decrease. This situation happens because of the ability of Fuller's Earth adsorbent to neutralises carboxylic acid and absorb polar [7]. As the reclaim oil pass through the Fuller's Earth adsorbent, the impurities will be removing. Impurities can be divided into two categories which are soluble (dissolved) product and insoluble (suspended) product [7]. Impurities such as alcohol and organic acid will be removed by Fuller's Earth adsorbent. So, this will directly decrease the total amount of acid number inside the reclaim oil. As more reclamation process take place, more impurities will able to be removing. In that case, this will minimize the total acid number inside the oil and increase the percentage of removing acid number for the reclaim oil. The result was accepted due to the decrement total acid number inside the oil sample and increment total number of acid that able to be removing after more reclamation process take place.



## 4.5 Breakdown Voltage (BdV) Test

For the 5$^{th}$ stage of reclaimed oil, the oil sample will be test for breakdown voltage (BdV) by using Megger OTS60PB. This test will measure the ability for the oil to face electrical stress without failure. At first, used oil which 29 years operation inside the transformer have been test for BdV test. Then, the BdV test was continued by testing the breakdown voltage for 5$^{th}$ stage of reclaim oil. BdV for used oil and 5$^{th}$ stage of reclaim oil

have been measured by using Megger OTS60PB and the result is shown in the Appendix B which are in Table B.2 and Table B.3. Weibull Probability Plot is used in order to get the approximate value for BdV. After 50 reading were taken, Minitab 16 software will be use in order to determine the approximate value for BdV by using Weibull Probability Plot. Weibull Probability Plot will estimate the reading for BdV at 63.2% of the graph. Figure 4.6 shows the approximate voltage for used oil by using Weibull Probability Plot;

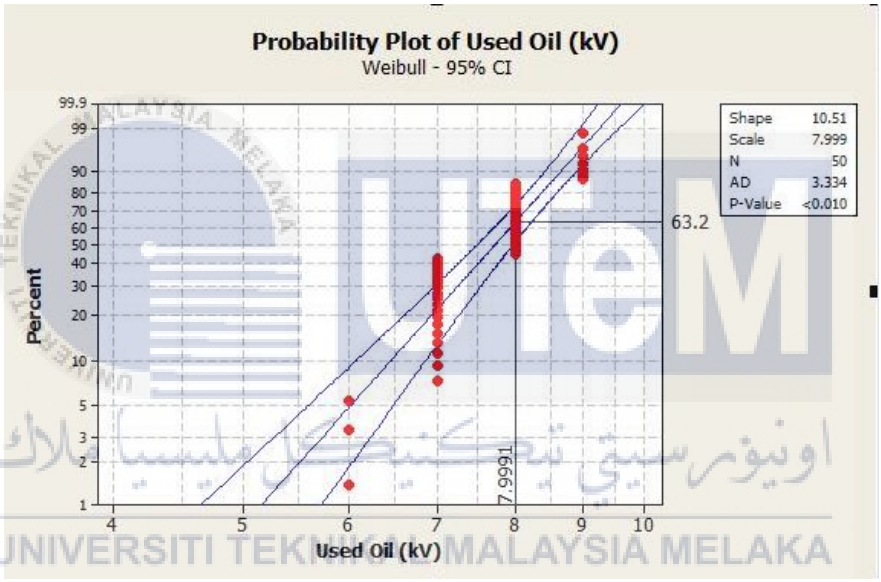


Figure 4.6: Weibull Probability Plot for Used Oil

Based on Appendix B, Table B.2, the breakdown voltage for used oil does not have massive differences when breakdown voltage was measured for 50 times. So that, Figure 4.6 show the Weibull Probability Plot based on the 50 readings of BdV test for the used oil. Based on Figure 4.6, Weibull Probability Plot have shown that 63.2% of the graph is at the point of 7.9991 kV. This means that the approximate breakdown voltage for used oil is 7.9991 kV or 8 kV. In that case, this oil can not be able to withstand the electrical stress

inside the transformer. So, this oil is taking out from the transformer and new transformer's oil will replace this oil in order to avoid the transformer from having failure.

According to [7], oxidation process which takes places inside the transformer will produce moisture. This moisture will increase the dielectric dissipation factor which may result in the increase of the electrical breakdown if it is appears as free water in highly stressed region. In other hand, increase in terms of contaminant inside the oil will decrease the ability of the oil to withstand to the electrical stress.

After five stage of reclamation process takes place for this experiment, the oil was taken for BdV test and 50 readings were taken for Weibull Probability Plot. Table B.3 in Appendix B shows the BdV for 5th stage of reclaim oil while Figure 4.7 shows the Weibull Probability Plot for 5th stage of reclaim oil;

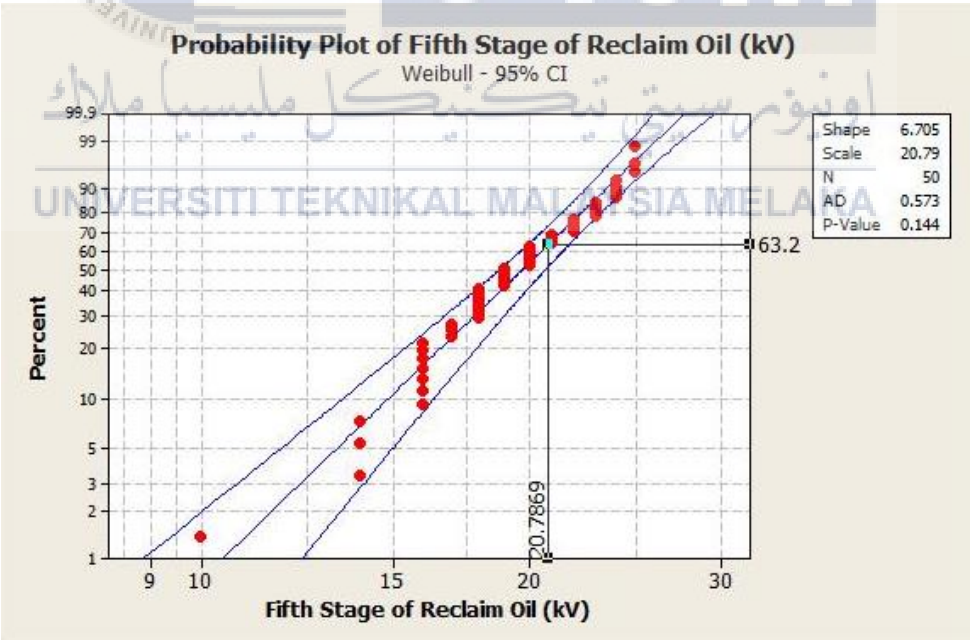


Figure 4.7: Weibull Probability Plot for 5th Stage of Reclaim Oil

Based on Appendix B, Table B.3, the value of breakdown voltage for 5th stage of reclaim oil were increase drastically. There were massive differences between both value. Due to increasing number of breakdown voltage for 5th stage of reclaim oil, Weibull Probability Plot have stated that 63.2% from the reading of breakdown voltage for 5th stage of reclaim oil is at 20.7869 kV. So, the approximate value of breakdown voltage for 5th stage of reclaim oil is around 21 kV. By comparing the value of approximate value breakdown voltage for used oil and 5th stage of reclaim oil, the approximate value of breakdown voltage increased after 5 stage of reclamation process takes place. During reclamation process, Fuller Earth's adsorbent had removed a lot of contaminant product which contribute to decrease the breakdown voltage of the oil. By removing the contaminant, the oil will be able to get the original characteristic slowly from a stage to another stage of reclamation process. Table 4.3 shows the comparison of BdV for used oil and 5th stage of reclaim oil by referring Weibull Probability Plot;



Table 4.3: BdV for Used Oil and 5th Stage of Reclaim Oil

| **Type of Oil** | **Breakdown Voltage refer to Weibull Probability Plot (kV)** | **Increment Percentage (%)** |
|---|---|---|
| Used Oil | 7.9991 | 0 |
| 5th Stage of Reclaim Oil | 20.7869 | 159.87 |

After 5 stage of reclamation process take place, the breakdown voltage for the same oil increase for 159.87% which from 7.9991 kV to 20.7869 kV. Decrement in terms of its

total acid number and water directly contribute to the increment value for breakdown voltage of the reclaimed oil. Based on the increment of breakdown voltage, the BdV result for 5$^{th}$ stage of reclaim oil can be accepted due to massive improvement that can improve the characteristic of the oil become better after reclamation process take place.

# CHAPTER 5

# CONCLUSION AND RECOMMENDATION



## 5.1 Introduction

In this chapter, there will be a simple conclusion based on the objectives that have been made in Chapter 1. Conclusion is one of the platform to see whether the objective that have been decide in Chapter 1 are manage to be achieved or vice versa. For recommendation, there will be suggestion to update the information for the research that could be done in the future.

## 5.2 Conclusion

This experiment was conducted in order to reduce the maintenance cost for a transformer. From years to years, transformer oil will have high oxidation product and this factor will make the breakdown voltage decrease. Some of the factor which effect the

effectiveness of the oil is increment of water content and acid number inside the oil due to contaminant product. This happen due to aging process inside the transformer. Other than that, the decrement in breakdown voltage makes the transformer oil become irrelevant to be used as insulation inside the transformer. It is because the transformer oil will not be able to withstand to the electrical stress anymore.

After completing this experiment for Final Year Project (FYP), it is successfully to produce reclaimed oil by using used transformer service oil which was reclaimed by using Fuller's Earth adsorbent. The differences between used oil and multiple stage of reclaim oil can be clearly seen at the Section 4.2. This section has shown the differences between used oil and multiple stage of reclaim oil in terms of the colour of the oil.

In terms of characteristic, the result already mentioned detailed in Chapter 4 which is all differences of characteristic in terms of total acid number, water content and breakdown voltage of the reclaimed transformer service oil was explained.

The colour of the oil change to brighter for each stage after reclamation process take place. Therefore, after reclamation process take place, water content was able to be removing around 57.90% which made the final oil contain only 32.5 PPM of water compare 77.2 PPM of water before reclamation process take place. Thus, it shows that Fuller's Earth adsorbent able to remove the water content of the oil. By removing the water content of the oil, the originality of the oil can be get back slowly as more reclamation process take place.



65.51% of acid number able to be removing after five reclamation process take place. This make the total acid number inside the oil reduce from 0.1092 mgKOH/g to 0.0378 mgKOH/g. Thus, this situation shows that Fuller's Earth adsorbent help to neutralise the carboxylic acid inside the oil. Other than that, this type of adsorbent able to remove impurities inside the oil such as Alcohol and Organic Acid. By removing the impurities, decreasing

trend for Total Acid Number were shown in Chapter 4.4. All of these results were accepted due to the decreasing trend that have been decided before the experiment begin.

The breakdown voltage able to increase from 7.9991 kV to 20.7869 kV which represent increment of 159.87%. Based on the result that had been obtained, the decrement value of total acid number and water content had contributed to the increment of breakdown voltage. So, this result was accepted due to massive increment from used oil until $5^{th}$ stage of reclamation process. Therefore, it can be observed that by using Fuller's Earth adsorbent is possible to produce reclaimed oil by using used transformer service oil. It proves that the dielectric strength for reclaim oil was increased and show the improvement of the dielectric strength performance. As the final conclusion, this experiment has contributed to the recycle of used transformer oil in order to reduce the cost of changing oil transformer and to protect the environment.

## 5.3 Recommendation



For future research, there will be a few suggestions that could be made in order to study liquid type of insulation. The price of replacing transformer oil and maintenance keep increasing nowadays, an alternative should be done to avoid this problem become worst in the future. Oil reclamation will help to reduce the cost of maintenance for a transformer. This method will recycle the service oil through a few process. In future, this research should be continuing in order to observe how many the used transformer service oil can be recycled. After a few process of reclamation, this oil may be can not be able to recycle anymore. So, the transformer need to replace the oil with the new transformer oil. It was suggested to

explore on how many time for a sample of used transformer service oil should be done in the future to know the level of effectiveness for each recycle process.

For further research, the performance for each stage of reclamation process in terms of BdV should be observe. So, for each stage, minimum of 1000 ml of reclaim oil should be preparing in order to observe the BdV for each stage of reclamation process. The preparation of oil sample for each stage will taking long period. So, this test should be begin early of the semester due to the factor of lack of time and lack of apparatus inside the High Voltage Laboratory. This test will see the improvement of BdV of the reclaim oil for each stage of reclamation process. This suggestion can be used in order to study more detailed on the performance of the reclaim oil.

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# APPENDIX A


Figure A.1: Nameplate of Transformer for Used Oil

# APPENDIX B

Table B.1: Template of BdV Test for Used Transformer Service Oil

| Used Oil | BdV (kV) | Used Oil | BdV (kV) |
|---|---|---|---|
| 1 | | 26 | |
| 2 | | 27 | |
| 3 | | 28 | |
| 4 | | 29 | |
| 5 | | 30 | |
| 6 | | 31 | |
| 7 | | 32 | |
| 8 | | 33 | |
| 9 | | 34 | |
| 10 | | 35 | |
| 11 | | 36 | |
| 12 | | 37 | |
| 13 | | 38 | |
| 14 | | 39 | |
| 15 | | 40 | |
| 16 | | 41 | |
| 17 | | 42 | |
| 18 | | 43 | |
| 19 | | 44 | |
| 20 | | 45 | |
| 21 | | 46 | |
| 22 | | 47 | |
| 23 | | 48 | |
| 24 | | 49 | |
| 25 | | 50 | |

Table B.2: BdV for Used Oil

| Used Oil | BdV (kV) | Used Oil | BdV (kV) |
|---|---|---|---|
| **1** | 7 | **26** | 8 |
| **2** | 7 | **27** | 8 |
| **3** | 7 | **28** | 7 |
| **4** | 7 | **29** | 9 |
| **5** | 7 | **30** | 8 |
| **6** | 6 | **31** | 9 |
| **7** | 8 | **32** | 7 |
| **8** | 8 | **33** | 7 |
| **9** | 7 | **34** | 7 |
| **10** | 8 | **35** | 8 |
| **11** | 8 | **36** | 7 |
| **12** | 8 | **37** | 7 |
| **13** | 9 | **38** | 7 |
| **14** | 7 | **39** | 9 |
| **15** | 7 | **40** | 8 |
| **16** | 7 | **41** | 8 |
| **17** | 8 | **42** | 8 |
| **18** | 8 | **43** | 7 |
| **19** | 9 | **44** | 8 |
| **20** | 8 | **45** | 8 |
| **21** | 8 | **46** | 6 |
| **22** | 9 | **47** | 8 |
| **23** | 9 | **48** | 8 |
| **24** | 8 | **49** | 6 |
| **25** | 8 | **50** | 7 |

Table B.3: BdV for 5th Stage of Reclaim Oil

| 5th Stage Reclaim Oil | BdV (kV) | 5th Stage Reclaim Oil | BdV (kV) |
|---|---|---|---|
| **1** | 10 | **26** | 20 |
| **2** | 14 | **27** | 17 |
| **3** | 17 | **28** | 21 |
| **4** | 16 | **29** | 12 |
| **5** | 17 | **30** | 14 |
| **6** | 16 | **31** | 21 |
| **7** | 16 | **32** | 18 |
| **8** | 16 | **33** | 19 |
| **9** | 14 | **34** | 19 |
| **10** | 16 | **35** | 17 |
| **11** | 16 | **36** | 22 |
| **12** | 18 | **37** | 19 |
| **13** | 14 | **38** | 23 |
| **14** | 16 | **39** | 20 |
| **15** | 18 | **40** | 23 |
| **16** | 18 | **41** | 21 |
| **17** | 18 | **42** | 20 |
| **18** | 18 | **43** | 24 |
| **19** | 20 | **44** | 25 |
| **20** | 20 | **45** | 19 |
| **21** | 22 | **46** | 20 |
| **22** | 24 | **47** | 20 |
| **23** | 23 | **48** | 25 |
| **24** | 23 | **49** | 21 |
| **25** | 18 | **50** | 22 |