MOHAMMED SHEKH DIB AN INVESTIGATION OF BIODIESEL BLEND PROPERTIES AT
CONSTANT STORAGE TEMPERATURE

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A THESIS SUBMITTED TO THE
GRADUATE SCHOOL OF APPLIED
SCIENECES
OF
NEAR EAST UNIVERSITY

BY
MOHAMMED SHEKH DIB

In Partial Fulfillment of the Requirements for
the Degree of Master of Science
in
Mechanical Engineering

NICOSIA, 2018

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Approval of Director of Graduate School of Applied Sciences

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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To my parents…..

ABSTRACT

Rapidly growing world population, rapid modernization of technology, industrialization and thus the energy demand in the world have increased. Reduction of non-renewableenergy sources such as natural gas and coal has led people to alternative energy sources. Biodiesel is among one of the most important alternative energy sources. Fats produced from fatty seed plants, waste frying oils or animal fats are fuels produced by reaction of short chain alcohol with a transesterification process in the presence of a catalyst. The biodiesel fuel used in this experiment was produced using waste frying oil by an oil producer in South Cyprus. The purpose of this study was to investigate the influence of storage period of biodiesel sample B20% biodiesel with 80% eurodiesel which stored at 40 ° C constant temperature on kinematic viscosity and density at different temperatures. In addition to this, pour point and cloud point was investigated. Biodiesel sample parameters which are kinematic viscosity, density, cloud point and pour point had been tested in Near East University Mechanical Engineering laboratory. Acid number and oxidation stability parameters had been tested at a licensed laboratory in South Cyprus. The experimental measurements in this study were conducted at temperatures between -11°C and 90°C, according to ASTM standards. Experimental results showed that kinematic viscosity and density decrease with increasing temperature. An increase in kinematic viscosity and density is observed with the increase in storage period.

Keywords**:** Bio-diesel; cloud point; density; euro-diesel; kinematic viscosity.

ÖZET

Hızla artan dünya nüfusu, teknolojinin hızla modernleşmesi ve sanayileşme olarak dünyadaki enerji talebini artmıştır. Doğalgaz ve kömür gibi yenilenemez enerji kaynaklarının azalması, insanları alternatif enerji kaynaklarına yöneltmiştir. Biyodizel de önemi gün geçtikçe artan alternatif enerji kaynakları arasında en önemlilerindendir. Yağlı tohum bitkilerinden elde edilen yağların, evsel kızartma yağlarının veya hayvansal yağların bir katalizör eşliğinde transesterifikasyon süreci ile kısa zincirli bir alkol ile reaksiyonu sonucunda üretilen bir yakıttır. Bu deneyde kullanılan biyodizel yakıt Güney Kıbrıs'taki bir yağ üretim firması tarafından atık kızartma yağı kullanılarak üretilmiştir. Bu çalışmanın amacı, 40˚Csabit sıcaklıkta depolanan biyodizel numunesinin B20% ve D80% depolama süresinin farklı sıcaklıklardaki kinematik viskozite ve yoğunluğu üzerindeki etkisini araştırmaktır. Bunlara ek olarak biyodizel numunesinin Bulutlanma Noktası ve Akma Noktası da incelenmiştir. Biyodizel numunesine ait kinematik viskozite, yoğunluk, bulutlanma noktası ve akma noktası parametreleri Yakın Doğu Üniversitesi Makine Mühendisliği Bölümü Laboratuarı'nda yapılan deneysel çalışmalar sonucu elde edilmiştir. Asit sayısı ve oksidasyon kararlılığı parametreleri ise Güney Kıbrıs'ta sertifikalı bir petrokimya laboratuarı tarafından analiz edilmek suretiyle neticeye ulaşılmıştır. Bu çalışmadaki deneysel ölçümler ASTM standartlarına göre -11˚C ila 90˚C arasındaki sıcaklıklarda yapılmıştır. Elde edilen deneysel sonuçlar neticesinde, sıcaklığın artmasıyla kinematik viskozite ve yoğunluğun azaldığını gözlenmiştir. Depolama süresindeki artış ile birlikte kinematik viskozite ve yoğunlukta bir artış gözlenmektedir.

***Anahtar Kelimeler*:** Akma noktası, bulut noktası, euro dizel, kinematik viskozite,
soğuk akış özellikleri, yoğunluk.

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LIST OF SYMBOLS USED

e	Strain rate	s^{-1}
g	Acceleration due to gravity	m/s^2
H	Mass percentage of hydrogen in the gas	-
K	Viscometer constant	$mm^2/s/s$
L	Length of viscometer	m
Q	Volumetric flow rate	m^3/s
R	Capillary radius	m
r	Radian length	m
t	Shear time	s
V	Volume	m^3
v_r	Velocity in radial direction	rad/s
v_Z	Velocity in flow direction	m^3/s
v_θ	Velocity in angular direction	rad/s
x	Elemental length	m
y	Correlation factor	-
z	Length in flow direction	m

GREEK SYMBOLS

$\boldsymbol{\upsilon}$	Kinematic viscosity	mm^2/s
$\boldsymbol{\sigma}$	Shear stress of fluid element	Pa
$\boldsymbol{\tau}$	Alternative form of shear stress	Pa
$\boldsymbol{\varepsilon}$	Strain rate	-
$\boldsymbol{\mu}$	Dynamic Viscosity	Pa.s
$\boldsymbol{\rho}$	Flow density	kg/m^3

LIST OF ABBREVIATIONS

ASTM	American Society for Test Materials
AV	Acid Value
AVE	Average
BD	Bio-Diesel
CFPP	Cold Filter Plugging Point
CGS	Centimeter-Gram-Second
CIE	Compression Ignition Engine
CN	Cetane Number
CP	Cloud-Point
ED	Euro-Diesel
EN	European-Standard
FAME	Fatty Acid Methyl Ester
FP	Flash-Point
FIE	Fuel Injection Equipment
FTIR	Fourier Transform Infrared Spectroscopy
HEFRR	High Frequency Reciprocating Rig
HC	The kinetic energy correction factor
HMN	Heptamethylnonane
IP	International Publishing Standards Methods
ISO	International Standard Organization
LTFT	Low Temperature Flow Test
NC	Number of Carbon Atoms
ND	Number of Double Bonds
PCT	Patent Cooperation Treaty
PP	Pour Point
POM	Polyoxymethylene
QN	Low Heating Value
SI	System Institute
SSU	Saybolt Second Universal

CHAPTER 1
INTRODUCTION

1.1 General View

Fast growing population, rapid modernization of technology yields industrialization has increased the requirement for energy of the world. Reduction in non-renewable energy resources such as natural gas and coal make the people questing in new type of energy resources. Even scientists say that, all fossil fuel resources will be depleted about 2040 (Showstack, 2016). Because of these facts, experts focus on alternative renewable resources such as solar energy, hydro power, biofuel, biomass, tidal energy, wind energy, nuclear energy etc.

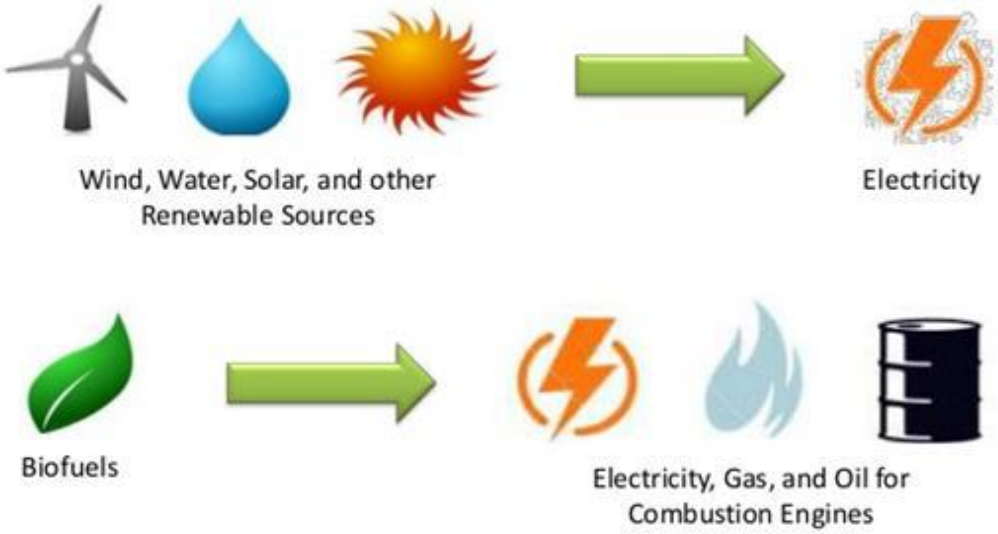


Figure1: Differentiations of biofuels. (http://www.greencarcongr/2018/02/20180201 toyota.html)

Renewable energy sources are useful for electric power but they can’t be properly used for transportation sector (Figure 1.1). Biofuels are liquid fuels which are the most suitable renewable energy source type used in transportation so that is why biofuels differ from others. We can obtain these biofuels from a range of sources, forming different type of forms. Source Types:

- Maize
- Grass
- Miscanthus
- Algay
- Waste cooking Oil
- Fertilizer
- Whey
- Plant residues
- Foms
- Ethanol
- Biodisel
- Biobutanol
- Biomass Pellets
- Synthetic Natural Gas

1.2 Thesis Aim

The aim of this work is to determine influence of storage period on the properties of B20% biodiesel and D80% euro-disel sample prepared from waste vegetable oils. Fuel properties that are examined:

- Kinematic Viscosity
- Density
- Cold Flow Properties:
    1. Cloud Point
    2. Pour Point

3. Cold Filter Plugging Point

- Acide Value
- Oxidation Stability

1.3 Novelty

The novelty of this thesis is based on its specificity in the investigation of the cold flow properties of 20% bio-diesel and 80% euro-diesel from North-Cyprus maintained at 40^{o}C for an extended storage time to observe the change in the properties of the binary blend. Recordings the effect of temperature on the kinematic viscosity and density of the binary fuel blend at varying temperatures ranging from -11 ^{o}C to 90 ^{o}C at different times was obtained after the binary fuel blend was subjected to varying temperature. Furthermore, measurements and recordings of the cloud point and pour point of the fuel blend will be included in the experiment.

1.4 Literature Review

It is understood from literature that some researchers have used different methods in their work dealing with the study of the properties of varying biodiesel blends. The demand of liquid fuels is steadily on the rise, as a result of this rise, priority is shifting towards maintaining a high quality of the fuels under long term storage is a qualitative criterion. There are various internal and external factors that tends to affect the chemical and physical properties liquid fuels over a long period of time in storage, the effect of storage on the properties of the fuel affects the performance characteristics of the products. The stability of liquid fuels is affected by various factors which several scientists and researchers have carried out diverse experimental and theoretical analysis to better understand the reason why liquid fuel is expected to maintain its stability and high quality even after a long time in storage. There are vast array of research work in line with this quest, and there are findings related to the degradation of performance characteristics of traditional fuel as relating to the oxidation process.

Materials are subjected to corrosion or deterioration due to chemical or electrochemical interactions between the material and the environment within which it is placed. Corrosion is more related to environment and surrounding conditions of the material. Metals are not the only victims of corrosion, and due to the fact that it involves chemical reaction between the surrounding and the material, this makes corrosion a common engineering problem which cannot be easily avoided whenever petroleum products are made to come in contact with metal parts and alloys during production, storage, distribution, transportation, or operation. There are certain constituents of the fuel that causes corrosion and these constituents include water soluble inorganic acids and bases, sulphur compounds and organic compounds.

Atmospheric oxygen and Hydrocarbons readily react with one another during storage knowing that hydrocarbons are the essential components of petroleum based fuels and cannot be avoided. This reaction of the atmospheric oxygen and hydrocarbon causes a chain reaction which will cause contamination of the storage tanks and further more promote corrosion of the pipelines used for transfer, the particles of the corroded pipelines will in turn clog the filtration system and cause more problems in the fuel distribution system.

Experimental data and various models was used by (Geacai et al. 2015) to assess the degree of correctness of the calculation of the kinematic viscosity of the biodiesel fuel free from additive and also for bio-diesel mixed with euro-diesel. The viscosity of the blends was calculated using complementary empirical formulations or the refractive index of the blends.

An examination of the impact of aging biodiesel forming deposits inside regular Fuel Injection Equipment (FIE) was carried out by (Saltas et al 2017). In their work, an analysis was done on the constituents of the FAME, the rate of degradation of the fuel and its major properties. A proposal of an assessment that will be used as a reference test of the predisposition of diesel engine fuels to produce deposits was given.

An investigation of the oxidative degradation of mixtures of biodiesels was carried out using Fourier transform infrared spectroscopy (FTIR) and some other equipment was done by (Zhou et al 2017). In their investigation, they discovered that the

TDDES method proved to give superior forecasting operation for FTIR and TGA in oxidative degradation evaluation.

Syam et al. (2013) analyzed the properties of biodiesels produced from waste frying oil. A biodiesel yield of 99% was obtained by them. The properties of the biodiesel produced were in the acceptable standard specification range and was conform the operating condition of diesel engines.

Banga and Varshney (2010) did a study on the effect of contaminants that are produced during the process of transesterification of the fuel blend and furthermore studied how to eliminate the contaminants. Their work also dealt with the effect of elongated time in storage on the performance characteristics of the blend.

Ullah (2013) conducted an examination of the effect of aging biodiesel and diesel gasoline mixture while placed in the proximity of polymer. They used polymers to simulate the environment of a car. The fuel blends were kept in a polymer material for 100 hours at 85^oC. An observation of the influence of the polymer on the fuel blend was done by monitoring the polymer and also to observe the fuel and polymer compatibility. The polyoxymethylene (POM) polymer was used, this is similar polymer used in vehicles. Various schemes such as the Open and nitrogen scheme, with and without antioxidants scheme was generated. It was observed that there was no change discovered in the fuel while aging within the proximity of the polymer. Furthermore, the polymer was allowed to age for 1600 hours while the fuel was being changed weekly (100 hours) and after which samples was collected after every 400 hours. An investigation of the alteration of the chemical composition using IR spectroscope and scanning electron microscope was carried out, also fuel penetration in the polymer, swellings of the material and residue on the surface of the polymer was also investigated at each aging interval. There was no substantial change observed during this period of aging in the inert system. The open system detected more quantity of residue. It was observed that after 1200 and 1600 hours, the residue was polymerized on the surface of the polymer. It was also observed that there was a substantial reduction of the strength of the polymer due to the presence of surface cracks which was validated using the charpy impact test.

1.5. Thesis Overview

This thesis has 5 chapters as structured below.

Chapter 1 this section of the thesis deals with the introduction of the work. The definition and aim of the thesis is outlined and a brief literature review of the work is discussed.

Chapter 2 Deliberate on the theories, general review of several aspects of the bio-diesel and euro-diesel. Theory behind the capillary viscometer and the properties of the biodiesel is also discussed. Standards and their brief definition is also included in this chapter.

Chapter 3 is a more detailed explanation of the samples of the biodiesel and euro-diesel used. In this chapter, the experimental setup and measurement procedures are presented

Chapter 4 contains deliberation and interpretation of the results obtained from the mixture of biodiesel and euro-diesel

Chapter 5 contains the conclusion and recommendations due to the behavior observed of the fuel blend

CHAPTER 2
THEORY

In determining the suitability of biodiesel fuel as a potential replacement to diesel fuels already in use today, it is important to study the properties and the effect of temperature of the properties of both biodiesel and euro-diesel. An analysis of the following properties of biodiesel euro-diesel fuel mixture are usually conducted oxidation stability, flash point, iodine value, acid value, cloud point, pour point, kinematic viscosity and density are some of the properties of the biodiesel and biodiesel and euro-diesel fuel mixture.

2.1 Cold Flow Properties

Normally, all fuels for compression ignition engines (CIE) could lead to starting problems at low temperatures, because of the fuel’s deteriorating properties at low temperatures. The cause of these issues is the formation of small crystals suspended within the liquid form, which could clog gas filters in part or completely. Due to the sedimentation of these crystals at the inner walls of the tubes of the fuel system, the drift segment through the pipes is reduced, causing poor engine fuelling. In extreme conditions, when low temperatures persist longer (e.g. overnight), the piping system may be completely blocked through the solidified gasoline. The cloud drift performances of the fuels can be qualified through the cloud point (CP), the pour point (PP), the cold filter plugging point (CFPP) and viscosity (υ). A substitute for CFPP is the low-temperature flow test. Lately, the US introduced a brand-new technique for assessing the cold flow attributes of biodiesel, referred to as cold soak filtration test. The cloud point, pour point, cold filter plugging point is the various cold flow properties, which will be examined in this work.

2.1.1 Cloud point

The point on the temperature scale where crystals begin to form inside the fuel is called the cloud point (CP). At sufficiently low temperatures of the biodiesel where precipitation of wax crystals is obtained means that the cloud point is reached. First, the formation of solidified wax crystal nuclei is in the range of cooling temperatures. These wax crystals are submicron in size are not visible to an unaided eye. As the temperature decreases, the crystals begin to develop. The temperature level with which the formed crystals become visible (crystal diameter of about 0.5µm) to the naked eye is known to be the cloud point due to the nature of the dull appearance of the suspension developed by formation of crystals. At temperature levels lower than the CP, the formed crystals might settle in the bottom of a reservoir or might end up plugging filtration line or filters. Thus, the CP is known to be the most used determinant of low-temperature range within which biodiesel fuel is operable. It is generally known that the cloud point of petroleum diesel is lower than the cloud point of biodiesel. The feedstock used in the production of biodiesel fuel is the determining factor of the characteristics of the cloud point of the biodiesel (Barabás & Todoruţ, 2010; Barabás & Todoruţ, 2011). The cloud point of biodiesel fuels ranges between -5 °C and 17 °C. A representation of the cloud point is shown pictorially in Figure 2.1. The American Standard test method (ASTM D 2500-09) used for determining cloud point of petroleum products is shown in Appendix 1.

Figure 2.1: Cloud point. (https://www.youtube.com/watch?v=aX2gyZXPgdc)

2.1.2 Pour-point

Many Agglomerated crystals are formed in fuel at a certain temperature, and this makes the fuel to stop flowing due to the gel nature of these crystals in the fuel. The measured temperature range where this tends to occur is taken as the pour point. This situation occurs at temperature below the CP of the biodiesel and the microcrystals come together to form larger clusters, which furthermore may interfere with the ease of at which the fuel flows inside the channels of the fuel system of the engine. Just as the feedstock is the dominating factor in determining the cloud point, the value of the pour point is also dependent on the feedstock that was used in the production of the biodiesel. The temperature range of pour point varies between -15 °C to 16 °C. The measurement of CP and the PP is relatively easy, but they are only used to determine the lower extreme temperature value at which the fuel is usable. In suitable conditions and situations, the fuel may still prove to be usable at the indicative cloud point level, however this is not possible at the pour point. The cloud point is an overestimation of the minimal usable temperature of the fuel. While the pour point is an underestimate of the minimal working temperature of the fuel. (Barabás & Todoruţ, 2011). A pictorial representation of the pour point is shown in

Figure 2.2 below. And the ASTM D 97-05 for pour point of petroleum products is the American Standard Test Method given in Appendix 2.

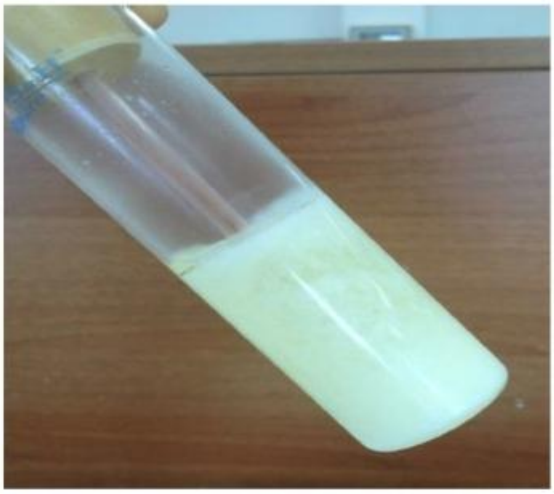


Figure 2.2: Pour point

2.1.3 Cold filter plugging point

The minimum temperature value where the blends of the fuel can flow through any of the filter is called the Cold Filter Plugging Point. Clogging of the fuel blends is generally known to begin after this temperature. The American Standard Test Method for CFPP of diesel and heating fuel is given in Appendix 3.

2.2 Flash-Point

This is the lowest temperature value correlating to a 101.3kPa barometric pressure (1 atm) at which the ignition supply can be used to ignite the gas within defined conditions. This is a criterion used to categorize fuels for the purpose of storage, distribution and delivery as related to the degree of hazard. There is no direct impact of flash point on the combustion of the fuel; high values of flash point mean that the fuel is safer in connection to delivery, fuel dealing with and storage requirement. The volatility of the fuel varies inversely with its flash point. The minimum flash point for a biodiesel fuel in the US is 93°C, in Europe it is 120°C while in Brazil it is 100°C. As the quantity of the unused alcohol increases, the flash point of the biodiesel decreases at a faster rate (Methanol has a flashpoint of 11°C -12°C and 13°C -14°C for ethanol). Knowing the relationship between the flash point of a biodiesel and the quantity of alcohol; a measurement of the flashpoint of a biodiesel can be used to help in determining the presence of methanol or ethanol in a biodiesel. An example on how the flashpoint of a biodiesel can be used to detect the presence of the quantity of alcohol; a 0.5% of methanol in a biodiesel fuel will reduce the flashpoint from 170°C to 50°C. The ASTM standard enforces a minimum value of 130°C flashpoint if the flashpoint is used to determine the content of methanol in a biodiesel. Due to the fact that the maximum allowable concentration level of methanol causes a flashpoint reduction below 130°C for 0.2%w/w biodiesel, therefore the restriction of the ASTM standard may be considered too excessive. The American Standard Test Method ASTM D 93-10 is used for flash point of petroleum products.

2.3 Acid Value

This is the neutralization number or the mass in milligrams of potassium hydroxide (KOH) needed to counterbalance the acidic elements in a sample of one gram. This value is used to predict the presence of acidic molecules in a sample of biodiesel. It is a common practice to titrate a finite quantity of sample liquified in organic solvent with a solution of known concentration of potassium hydroxide and with phenolphthalein as a colour indicator.

The possibly observed acidic compounds in the biodiesel are the residual mineral acids due to the process of production or the post-hydrolysis procedure of the esters and oxidation by-products that are in different natural acid shape or from the hydrolysis procedure from which residual free fatty acid form (Berthiaume & Tremblay, 2006). This is a factor that directly measures the constituents of free fatty acids present in a biodiesel, therefore the corrosiveness of the fuel, the presence of water content in a biodiesel and the possibility of filter blockage can be determined. Excess free glycerin content can cause issues relating to functionality at critical extreme temperature values and the fuel filter blockage. This factor by relation can be utilized to predict how fresh the biodiesel may be. Oxidation of fuel caused by an extended period of storage is likely to be identified by the high acid price (Barabás &Todoruţ, 2011). The American Standard Test Method ASTM D 664-04 given in Appendix 4 is used for the acidic value of petroleum products.

2.4 Oxidation Stability

During the period of storage of biodiesel, oxidation of the fuel can interfere with the quality of the fuel when there is an interaction with air and with water hydrolytic degradation may occur. The oxidative balance and the hydrolytic balance of the fuel are the qualifiers for both operations. It is common for the biodiesel to be oxidized during the course of storage whilst waiting for transportation or while inside the vehicle fuel tank. The stability of biodiesel can mean either of the issues: stability related to long period of storage or stability due to aging at high temperatures and pressures in the fuel system of an engine when the fuel undergoes cyclic circulation (NREL, 2009).

The stability due to storage is a very significant scenario for biodiesel and it is the ability of the biodiesel fuel to modifications due to chemical reaction in the course of a long-term storage. Typically, the modification due to long term storage consists of oxidation due to the interaction between the fuel molecules and the atmospheric oxygen (Gerpen, 2005).

The composition of the biodiesel fuel extensively influences its stable nature when in contact with atmospheric oxygen. Some unsaturated fatty acid possesses high propensity to oxidation, such fatty acids are mostly the polyunsaturated fatty acids such as the C18:2 and the C18:3. Hydro peroxides that are usually one atom of hydrogen and a few amounts of oxygen atoms remain connected to the fatty acid chain after oxidation. The materials of the storage container can act as a catalyst for the oxidation reactions. There is a production of hydro peroxides after the oxidation chemical reactions. This might eventually form a chain fatty acid, ketones and aldehydes. Massive molecules can be formed by the polymerization of hydro peroxides. The viscosity of biodiesel is increased by oxidation. It is also known that the acid value is increased by oxidation in which there is a change in the yellowish color to a brownish color with a production of hard deposits in the engine's fuel system (Pipes and filters), quantities such as the heating value and lubricity of the biodiesel is decreased by oxidation. In the presence of water, the esters can hydrolyse to fatty acids of long chain, which causes a rise in the acid value (Gerpen, 2005). Different reactions of degradation of trans-esterification and oxidation can be catalyzed by these acids. The water present may be as a pollutant used for hydrolysis (Engelen, 2009). The European Standard Test Method EN 15751:2014, given in Appendix 5 is the oxidation stability for products of petroleum.

2.5 Cetane Number

One of the property of the value of ignition fuels for compression ignition engines (CIE) is the Cetane Number, this property is a dimensionless index. The cetane number is used to explain the ease of self-ignition of a fuel. Knowing well that the Compression ignition engines gain their relevance in the ability of igniting fuels by compression without spark plugs. Therefore, the cetane number is a key factor to look out in choosing fuel for compression ignition engines. The theoretical range of cetane number is between 15 – 100; the boundary condition is described by the two fuels used as reference fuels during the computational experiment of the cetane number: hydrocarbons such as linear-chain hydrocarbon, hexadecane (C16H34, which is known as n-cetane), have a cetane number of 100 and are highly sensitive to ignition, while other hydrocarbons that are strongly branched-chain 2,2,4,4,6,8,8-heptemathylnonane (HMN, also commonly known as isocetane) have same chemical formulation of C16H34 have cetane number of 15 and are highly resistive to ignition. The volumetric percentage of standard cetane in a standard cetane and HMN mixture, that has identical detonation features and properties as the fuel used for test. The formulation of the cetane number is expressed below.

$$CN = n - cetane\,(\%, \mathrm{v/v}) + 0.15 * HMN(\%, \mathrm{v/v}) \quad (2.1)$$

The CN reveals the delay in ignition; this delay is the gap between the time it takes for the fuel to be injected right into the combustion chamber and when the air-fuel aggregate is detonated. The lag in ignition timing depicts how low the cetane number of a fuel is and vice versa. The optimized functioning of the engine is controlled by the higher and the lower bounds of the cetane value of the fuel. An engine's ability to start with less effort is directly linked to the cetane number; i.e a low cetane number will cause an engine to give a hard start, and at low temperatures the operation of the engine becomes loud and ragged and the engine becomes devoid of combustion in its cycles, and this will cause incomplete combustion which in turn increase the level of hydrocarbon emission which are pollutions that the engine produces. On the other hand, a high cetane number will cause the engine to experience early completed ignition before a right air-fuel mixture occurs, such encounters in the engine causes the engine to produce more exhaust smoke which is also due to incomplete combustion as a result of the premature ignition of the fuel. Extremely high cetane number will cause an early ignition of the fuel near the injector which will cause the engine to overheat, and this will produce fuel particles that are not burned to block the nozzle of the injector. The right cetane number will cause the engine to be more efficient and run properly, thus it is vital to know the appropriate ranges of the cetane number that will not be problematic to the running efficiency of the engine. The desirable upper and lower range of CN (Figure 1) is between 41 and 56, and it should be noted that the CN should not exceed 65 to avoid premature detonation of the fuel before the desired mixture of air-fuel is obtained (Băţaga et al., 2003).

A graphical representation of the brake specific consumption and ignition delay vs cetane number of fuel is given in Figure 2.3 below.

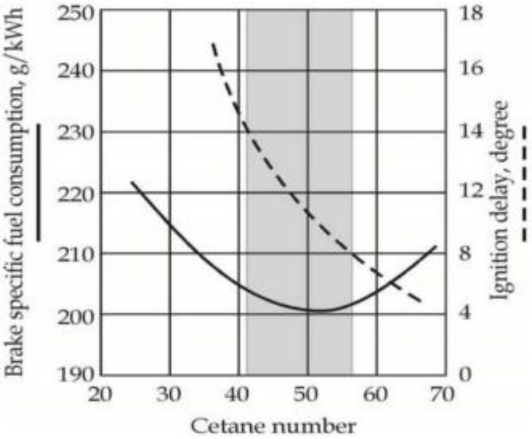


Figure 2.3: Brake specific fuel consumption and ignition delay vs. fuel cetane number. (National Renewable Energy Laboratory NREL. (2009). Biodiesel Handling and Use Guide – Fourth Edition.).

The acceptable cetane number of biodiesel varies in different countries and regions, the cetane number accepted in the European Union is 51, and in the US it is 47, while in Brazil it is 45. The minimum acceptable cetane number for diesel oil in the US is 40 (ASTM D 975) and in Europe it is 51 (EN 590). (Bamgboye & Hansen, 2008; Barabás & Todoruţ., 2010).

2.6 Heat Of Combustion

The heat of combustion which is also known as the heating value is defined as the amount of heat given off per unit combustion of air and fuel mixture in a closed system of constant volume. Only fuels with constituents of carbon, oxygen, nitrogen, hydrogen, and Sulphur usually give off end products after combustion in the form of water and some forms of gases such as sulphur dioxide, nitrogen and carbon dioxide, when the preliminary and ultimate temperature of oxygen – fuel and the products is 25^{o}C. The unit of measurement of the unit quantity of the fuel may be in kilogram or square meter or in mol. Therefore, heating value has units of kj/kg, kj/kmol. The heat of combustion per unit volume of the fuel or the volumetric heat combustion can be determined by multiplying the quantity of the heat of combustion in mass by the density of the fuel (mass/volume). The diesel engine uses a volume – dosed fueling system, and such fueling system does not give much credit to the mass heat of combustion but much attention is given to the volumetric heat of combustion. To obtain the uncultivated heating value of a fuel, the products of the combustion of the fuel must be cooled to the initial temperature recorded at the beginning of the combustion and the water vapour produced due to combustion must be allowed to condense and then the gross heating value can be gotten. To obtain the net or lower heating value (Q_n), the latent heat that is given off due to the vaporization of the water which is produced in the process of combustion must be subtracted from the total heating value.

The relationship between the net heat of combustion and the gross heat of combustion is expressed by the formulation below in equation 2.2.

$$Q_n = Q_g - 0.2122.H \tag{2.2}$$

Where H is the mass percentage of hydrogen in the gas.

The exhaust gases in internal combustion engines usually have higher temperature in comparison to the temperature of a boiling water, (water vapour is discharged), in the assessment of the heating values of fuels such as biodiesels, the lesser heating value carries more relevance. Fatty acid esters experience increasing heating values with increase of the chain length of molecule with the amount of carbon atoms (NC) and the heating value decreases as the magnitude of unsaturation and the variety of double bonds (ND). Unsaturated esters have inferior mass heating value than the saturated esters, but due to the fact that they are denser, unsaturated esters have greater volume heating value than that of saturated esters. (Barabás & Todoruţ, 2011). The American standard test method for heat of combustion of petroleum products is the ASTM D240-02.

2.7 Lubricity

Mechanical parts robbing off each other’s surfaces experiences friction. A fuel’s friction reducing ability is known as its lubricity. It is important for a fuel to possess this ability in order to prevent premature failure of an engine’s fueling components such as the pumps and the injectors due to friction. (Schumacher., 2005). In the use of ultra-low Sulphur fuels (ULSD), lubricity is an important factor to consider. There are methods to measure the lubricity of fuels and one of the method for measuring the lubricity of any fuel is done with High Frequency Reciprocating Rig (HFRR) test methods which is given under ISO 12156-1. Under EN 590 for diesel fuel, the supreme improved wear scar diameter (WS 1.4) is given as 460 μm. The lubricity of a reformulated diesel fuel is lesser and additives to boost the lubricity of the fuel should be introduced to the fuel. This additive should be well-matched with the fuel and other compounds present in the fuel, This will avoid unwanted excessive wear of the engine parts due to the fuel. It is understood that biodiesel possesses high level of lubricity. Thus, biodiesel can be implemented as lubricity improver (Barabás & Todoruţ, 2011). The standards of lubricity are the ISO 12156-1 for the International Standard and the EN 590 for the European standard.

2.8 Density

The density (ρ) of a fuel is the mass per unit volume of a fuel computed in vacuum. Density of a fuel is a temperature dependent property so therefore the quality standard requires that the density of a fuel should be taken at 15 ^{o}C. The performance of any fuel is directly affected by the density of the fuel knowing that the following properties of the fuel is strongly related and affected by the density of the fuel, some of these properties include; the heating value, the kinematic viscosity and the cetane number. The diesel engine’s power is determined by the amount in volume of air-fuel combusted in the combustion chamber, the density of the fuel affects the effective volume of the air-fuel mixture in the combustion chamber because diesel engine fuel systems measures the amount of fuel by the means of volume measurement which is a composition of the ratio of the effect of the density and the mass of the delivered fuel for combustion. A change in density will directly cause a change in the amount of mass of fuel available for mixture with air and therefore the power delivered after the combustion process is affected by the density of the fuel. Knowing that the density of the fuel evidently affects the performance of the fuel in an engine, it is necessary to take the density into account in the manufacturing, delivery, distribution and storage of biodiesel. Temperature and time of storage usually alters the density of fuel thereby increasing the atomization and adversely affect the lubrication of the components of the injection system. Biodiesel has higher density when compared to the conventional petrol diesel fuel and this is determined by the composition of acid and level of purity (Barabás & Todoruţ, 2011). The density of petroleum products is determined using the American Standard Test Method ASTM D941 – 88 given in Appendix 6.

2.9 Viscosity

The ability of a liquid to resist flow or the ability of a fluid to resist the tendency of movement because of the molecular interactive forces within the fluid is known as Viscosity and this is the opposite of fluidity. Viscosity stands to be one of the utmost vital properties of bio-diesel because it affects the effortlessness of initiating ignition of an engine as well as the rate of flow of the fuel in the fuel delivery system of the engine and the quality of the air-fuel mixture (Alptekin and Canakci, 2009). It is important to find the optimum value of the viscosity of a fuel because a fuel with high viscosity will tend to gain higher inertia in the fuel system of an engine, it will also deliver excessive amount of fuel mass in huge drops for combustion which will evidently lead to improper combustion and more toxic release of exhaust gases after combustion. And if the viscosity of a fuel is too low, the engine will experience free spray and little mass of fuel will be delivered for mixture with air which will adversely affect the performance of the engine in power delivery. This causes inadequate saturation and the production of dark smoke as exhaust products due to the absence of oxygen close to the injector during combustion (Băţaga et. al., 2003). Therefore, there are higher and lower limits of the viscosity of a fuel for optimum performance.

High viscosity will cause the formation of deposits in the combustion chamber to increase, and this in turn causes a demand in power of the fuel pump to be able to convey or pump the fuel from the tank into the combustion chamber. An excessive viscose fuel will cause an increase in tearing and wearing of the parts of the fuel delivery system due to the high demand of mechanical effort needed to push the fuel through the system. When a fuel is very viscose, it affects the functionality of the fuel at low temperatures due to the inverse temperature – viscosity relationship. The properties of lubrication are depicted by the viscosity due to time of storage and temperature, this property also have effect on the rate of wear and tear of the fuel system of the engine. The lubricity of a fuel is influenced by the viscosity of the fuel which help to lubricate the injectors and pumps. Electronegative oxygen present in biodiesel makes biodiesel fuels extra polar than diesel gasoline; and due to this, biodiesel has better viscosity in comparison to that of diesel fuel. From literature we it is known that pure ethyl esters have higher viscosity than methyl esters (Dabir et al., 2007). The determination of the viscosity of petroleum products is done using the American Standard Test Method ASTM D445-06 given in Appendix 7.

There are two distinct forms of Viscosity mentioned below:

a. Absolute or dynamic viscosity
b. Kinematic viscosity

The force applied in tangent per unit of area that is needed to make one layer (A) to slide over another layer (B) is known as the dynamic viscosity as shown in the figure 2.4. In the figure 2.4 shown below, the force F makes the layer A to slide over layer B with a velocity of v_1 while layer B slides over layer A with a velocity of v_2. Knowing that a fluid's viscosity is known as the opposing force of a fluid's flow, this relationship is described mathematically below as;

Shear stress = τ (Strain or shear rate)
where μ is the dynamic viscosity.

Figure 2.4 gives a simple pictorial explanation of a simple shear of a liquid film

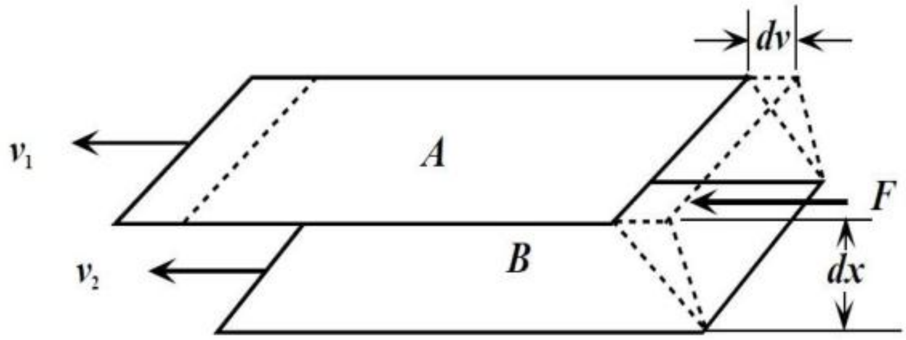


Figure 2.4: Simple shear of a liquid film. (https://www.mne.psu.edu/cimbala/ /cimba-Learning/Fluid/Fluid_Prop/fluid_property.htm)

The mathematical expressions are given below to analyze the viscosity of the fluid placed between the two layers in figure 2.4. if τ be the shear stress and e become the strain rate

$$\tau = \mu e \tag{2.3}$$

The strain rate is generally expressed as

$$e = \frac{1}{x}\frac{dx}{dt} = \frac{V}{x} \tag{2.4}$$

With x taken as the length, while t is taken as the time recorded and dx/dt is the velocity v. thus, an expression of the dynamic viscosity is shown below

$$\mu = \tau \frac{x}{v} \tag{2.5}$$

For the computation of the kinematic viscosity, an accurate knowledge of the density of the fluid is needed at that temperature and pressure, the kinematic viscosity is given mathematically as;

$$v = \frac{\mu}{\rho} \tag{2.6}$$

2.9.1 Importance of viscosity

Viscosity of the biodiesel directly affects the behavior and performance of engines that is why it is accepted as an important property. Creation of engine sediment caused by viscosity affecting the atomization of a fuel upon injection into the combustion chamber (Knothe et al, 2005b). That means, fluids having lower viscosities flow easier compared that having higher viscosity value ones, even so it does not mean that we want a fuel with low viscosity or high viscosity. Right proportion is the real issue for getting the best engine efficiency. Low viscosities don't ensure sufficient lubrication for the sensitive fit of fuel injection pumps. In contrast high viscosities guide to the formation of large droplets on
injection (resulting in poor combustibility, raised exhaust smoke and emissions) (CennatekBioanalytical Services, 2013).

2.9.2 Fluid flow and viscosity

For the purpose of quality control, the viscosity values of a liquid is usually required by process engineers, while the job of setting the optimum conditions needed for chemical reactions and operations with the use of the parameters is done by the design engineers. The determination of the power required for the unit operations which involves storage, injection, design, pump characteristics, pipeline design and delivery of a liquid shows that the viscosity of the fluid is very critical.

The viscosity of a fluid usually determines the flow properties of that fluid and these properties are generally categorized into three (3) classes:

a) Newtonian
b) Time dependent Non-Newtonian
c) Time independent Non-Newtonian

A Newtonian fluid is characterized by the consistency in its viscosity when there is an existence of an applied shear stress. While the viscosity of the non-Newtonian liquid is determined by the applied shear stress and time. If the shear rate of a fluid is altered and the shear stress does not change proportionally, it is said that the fluid is time independent non-Newtonian fluid. (Dabir et al., 2007).

2.9.3 Viscometers

It is very crucial to measure the viscosity of fluids around us in every aspect of life. Many industrial systems requires a reasonable knowledge of viscosity. Experimental data is used to prove various theories that have been developed over the years for the prediction and computation of viscosity. Instruments used for the measurement of viscosity have classified extensively:
Some of these viscosity measurement instruments combine the working characteristics of two or three types of viscometers, example of such viscometers include Friction tube, Brookfield, Viscosity sensitive rotameter, continuous consistency viscometers and Norcross. There are also some automated devices used for the purpose of process control and uninterrupted measurement of viscosity. So many other instruments used for measuring viscosity are termed after developers in the field and are factory-made by standard instrument producers that offered for each of the categories (Dabir et al., 2007).

2.9.4 Capillary viscometers

The viscosity of Newtonian Fluid is commonly measured using the Capillary viscometers. These viscometers have the advantage of the ease of operation, little quantity of the fluid is required as sample, the simplicity of controlling the temperature, and it is not expensive. This viscometer, got its name from the mode with which it is used to measure the viscosity of a fluid. The fluid is permitted to drift through the duct of the instrument and the volumetric flow rate will be measured by calculating the time taken for the fluid to flow through two marked graduation points in the capillary. The stream of the fluid in the capillary of the viscometer is affected either by gravity (the gravity type viscometer) or by an outside force. The liquid is driven across the capillary at an already fixed rate in the use of an equipment where an external force is applied, and the reduction of pressure through the capillary tube is measured. A direct computation of the viscosity of a fluid can be given by the Capillary viscometer from the drift rate, pressure and diverse dimensions of the devices. Nevertheless, a lot of the capillary viscometers requires an initial calibration with one or two other fluids with identified viscosity to acquire “constants” for the specific viscometer in use (Dabir et al., 2007).

The 5 major modules of a capillary viscometer is given below

1. A liquid reservoir,
2. A capillary of acknowledged dimensions,
3. A provision for measuring and controlling the implemented stress,
4. A means of measuring the glide charge, and
5. A thermostat to hold the desired temperature.

The above components have been used in modified versions to make several styles and types of the capillary viscometers (Dabir et al., 2007). There are generally, three (3) groups of commercially produced capillary tubes and this is based on the designs.

1. Modified Ostwald viscometers,
2. Suspended-level viscometers
3. Reverse-flow viscometers.

2.10 Total Acidic Number

The quantity used to determine the acidity of a substance is called the Total Acidic Number or the total acidic value. The substance could be any substance such as euro-diesel or bio-diesel or blends of them both as in this case. This is the amount of potassium hydroxide in milligrams that is essential to counterbalance the acidic concentration of 1 gram of a sample of a substance.

CHAPTER 3

MATERIALS AND EXPERIMENTAL SET-UP

3.1 Bio-Diesel and Euro-Diesel

The sample of euro-diesel blend used in this work is certified, quality controlled with allotted license of worth from oil refineries limited on the 6th of July 2017. The sample was taken before it was loaded at the Haifa oil docks from stock tank No 453/510. The properties of this euro-diesel are given in Table 3.2.

A bio-diesel that is FAME based is used in this study. This type of bio-diesel is commonly produced using the transesterification process. Generally, the process of transesterification is a chemical reaction between triglyceride and alcohol in the while alkaline catalyst (NaOH, KOH) is present to produce fatty acid methyl esters. The standard and properties of the bio-diesel used in this report is given in Table 3.1 while the standard of the euro-diesel sample is given in Table 3.2 below.

3.2 Measurement of Kinematic Viscosity

For the purpose of this work to better understand the reaction of the bio-diesel and euro-diesel fuel blend over a long period of time, the measurement of viscosity is very crucial. It is worth noting that the kinematic viscosity of a fluid is directly linked to the temperature and this is a storage time dependent factor. The viscosity is measured using equipment called viscometers. While a rheometer is used for measurement of viscosity.

3.2.1 Ubbelohde viscometer

A German Chemist called Leo Ubbelohde invented the Ubbelohde viscometer. This viscometer uses the working principles of the capillary viscometer to measure viscosity. The major advantage of the Ubbelohde viscometer is that values gotten are not dependent on the total volume of the sample, this type of viscometer is recommended for solutions of higher viscosity cellulose polymer. The temperature constant used in this viscometer is the same for all temperature; this viscometer requires little quantity of sample during experimentation and the possibility of errors is considerably low and it is inexpensive. In the Figure 3.1 below, the details of the Ubbelohde is shown.

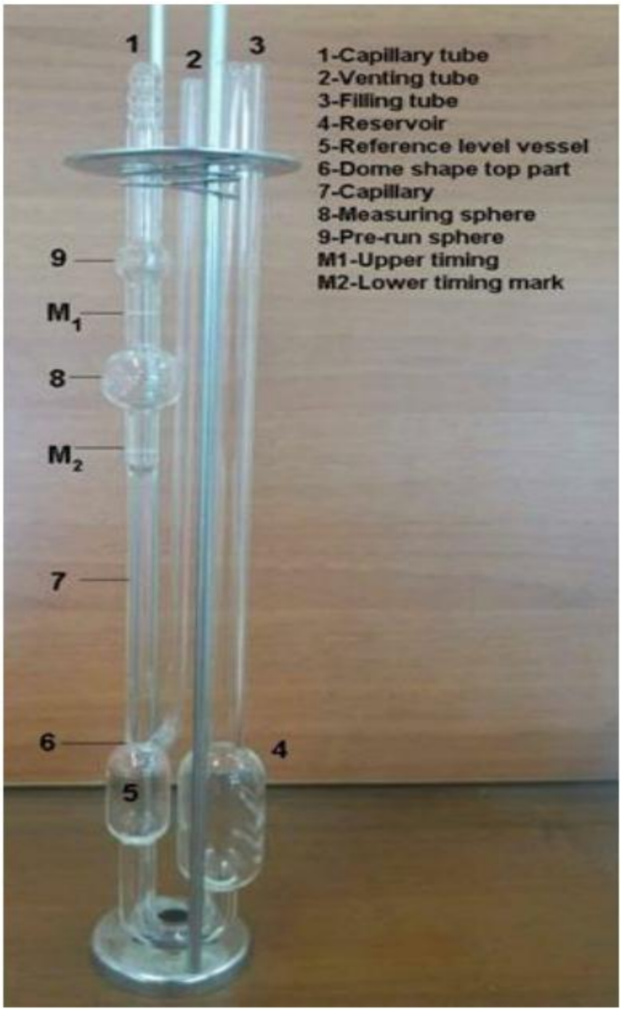


Figure 3.1: Ubbelohde viscometer

Generally, the viscometer consists of the capillary tube (1), the venting tube (2), the filling tube (3), the reservoir (4) the reference level (5) the top part which is dome-shaped (6) the capillary (7), the measuring sphere (8), the pre-run sphere (9), M_1 upper timing mark and M_2 timing mark.

The reservoir (4) is the point in which the samples are being introduced via the filling tube (3), it is important that the viscometer is completely filled and is bubble and particulate free. The most important thing to look out for is the desired temperature of measurement, and once this temperature is reached, a finger is positioned on the venting tube (2) then drew through the capillary tube (1). When this is done, the suction is disconnected from the capillary tube (1) and the finger initially placed over the venting tube (2) is removed. Then the liquid is permitted to flow back across the measuring bulb then the time taken to travel from point M_1 to M_2 is recorded using a stop watch, and that is the measured viscosity. The steps for measuring viscosity explained are used for the Ubbelohde viscometer.

It is usually recommended to use the Ubbelohde viscometer other than other types of viscometer to calculate the viscosity of a fluid due to its ease of usage, speed, satisfactory level of accuracy and the ability to retain the same constant for all temperature in the course of the experimental exercise. It was effective in the determination of translucent Newtonian liquids in the ranges of 0.3 to about 100, 000cSt (mm^2/s). This device is inexpensive and needs small quantity of sample fluid for measurement. Some of the shortcomings of the Ubbelohde viscometer is the possibility of blockage and slight deviation in the temperature of the cooling bath or the glass beaker will affect the level of accuracy of the Ubbelohde viscometer. The type of Ubbelohde viscometer used for transparent fluid is the kinematic energy correction Ubbelohde viscometer in appendix 7 and the Ubbelohde technical specification is included in appendix 7. The reason why the Ubbelohde viscometer is highly recommended is because it has broad range of applications and it permits the measurement of transparent fluids at high temperature. Three kinds of viscometers are used in this work due to the range of measurement, these are the Ic, Oc and I. The tables given below displays the Ubbelohde viscometer and their technical specifications.

Table 3.1: Types of Ubbelohde Viscometers for Transparent Fluids. (http://mall.scilab.kr/pdt/N05042000009307)

Size no:	Approximate Constant, K (mm^2/s)/s	Kinematic Viscosity Range (mm^2/s)	Inside Diameter of Tube, R, mm (±2%)	Volume, Bulb C, ml (±5%)	Inside Diameter of Tube P, ml (±5%)
0	0.001	0.3* to 1	0.24	1.0	6.0
Oc	0.003	0.6 to 3	0.36	2.0	6.0
Ob	0.005	1 to 5	0.46	3.0	6.0
I	0.01	2 to 10	0.58	4.0	6.0
Ic	0.03	6 to 30	0.78	4.0	6.0
Ib	0.05	10 to 50	0.88	4.0	6.0
2	0.1	20 to 100	1.03	4.0	6.0
2c	0.3	60 to 300	1.36	4.0	6.0
2b	0.5	100 to 500	1.55	4.0	6.0
3	1.0	200 to 1000	1.83	4.0	6.0
3c	3.0	600 to 3000	2.43	4.0	6.0
3b	5.0	1000 to 5000	2.75	4.0	6.5
4	10	2000 to 10, 000	3.27	4.0	7.0
4c	30	6000 to 30,000	4.32	4.0	8.0
4b	50	10,000 to 50,000	5.20	5.0	8.5
5	100	20,000 to 100,000	6.25	5.0	10.0

Table 3.2: Ubbelohde Technical Specification. (dutch.alibaba.com/product-detail/laboratory-viscosity-tube-viscometer-cannon-fenske-bulb-60655646228.html).

Type No	Capillary No	Capillary Dia I± 0.01(mm)	Constant K (mm^2/s)s	Measuring Range (mm^2/s)
52503	Oc	0.36	0.002856	0.6-3
52510	I	0.58	0.009820	2-10
52513	Ic	0.78	0.02944	6-30

For example to determine the kinematic viscosity of this blend of fuel (20% BD + 80% ED) at 40^{o}C, the following procedure and calculation is done.

Capillary Constant (K) = 0.009820 (mm^2/s) s

Average flow time (t) = 312.333s

The kinetic energy correction factor (HC) y for 312.3333 = 0.1004 by interpolation

$\upsilon = K (t-y)$

$\upsilon = 0.009820 (312.333-0.1004) = 3.0661mm^2/s$

3.3 Cooling Bath System

This system is shown in Figure 3.2 below. This system was utilized to cool the blend of fuel from 20^{o}C to -11^{o}C so as to determine the viscosity of the fuel blend.

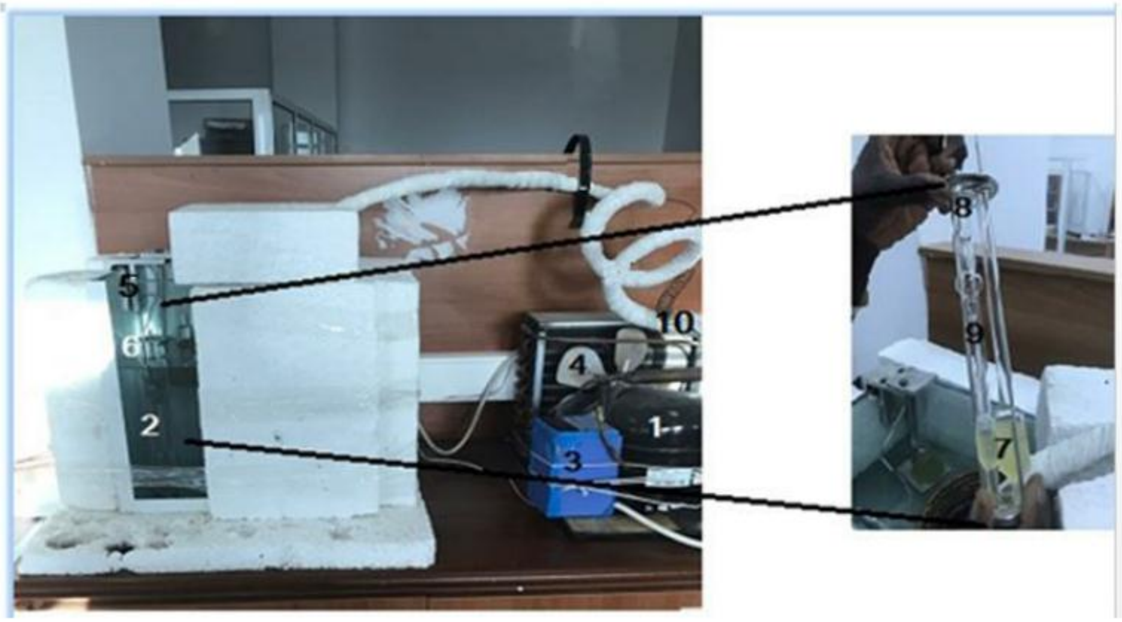


Figure 3.2: Cooling Bath System

This system comprises of the following components

1. Compressor
2. Cooling bath glass
3. Thermostat
4. Radiator
5. Holder
6. Alcohol as a cooling bath
7. Samples
8. Capillary holder
9. Ubbelohde capillary viscometer
10. Coil

The samples of bio-diesel (7) are inserted in the ubbelohde capillary viscometer (9) that is supported by the capillary holder (8) in a vertical position and allowed to be immersed into the cooling bath in which the alcohol is used as the cooling liquid because of its resistance to freezing at extreme low temperatures such as -

114^{o}C. The compressor (1) is connected with a coil (10), which helps in cooling the liquid bath while the compressor is being ventilated by the radiator (4). The thermostat (3) is used to control the cooling temperature as it turns on and off to regulate the temperature as needed in the cooling bath. The cooling bath is thermally isolated by the use of thick layers of foam to keep the inner chambers of the cooling bath stabilized while the cooling bath is also insulated from gaining heat from the surrounding when the cooling bath is operating at low temperature with the used of fiber materials.

3.3.1 Alcohol

Atmospheric pressure and the composition of alcohol affects the freezing point of alcohol and a slight change in the atmospheric pressure and the composition of the alcohol inevitably causes a change in the freezing point. Particulates of water in an alcohol will cause its freezing point to be higher than usual. Due to this understanding that pure alcohol freezes at about -114^{o}C and water freezes at 0^{o}C, alcohol is taken as the best suitable cooling bath liquid for this work. The alcohol used in this work is purchased from local stores in Northern Cyprus.

3.3.2 Temperature regulation

The processes undergone in this work requires that the temperature of all the parts of the liquid of the cooling bath be kept homogenously which is why the thermostat is very important for this purpose of regulating the temperature of the cooling bath. The method of cooling the cold bath is done by sensing the presence of hot air and ejecting the hot air from the system rather than introducing cool air into the system. There is a control knob on the thermostat which allows the user to control the temperature as desired. The thermostat maintains the preset temperature by regulating the amount of electricity power supplied to the compressor. It is commonly said that if the thermostat is considered as the brain of the cooling system, then the compressor serves its heart. The water in the glass beaker is manually mixed so as to maintain temperature homogeneity all through the water. The thermometer used in this experiment is shown is Figure 3.3 while the thermostat used is shown in Figure 3.4 below.

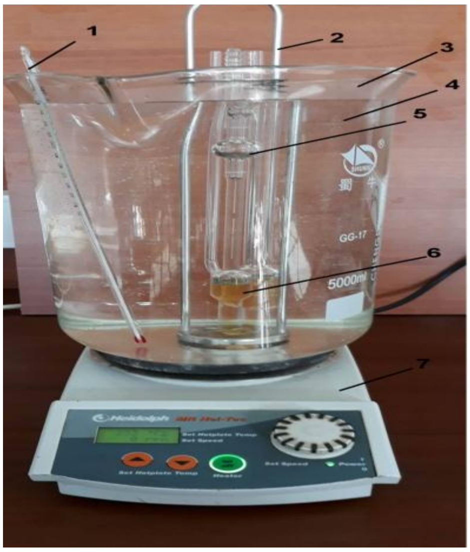


Figure 3.3: Thermometer placed in the glass beaker to measure high temperature.

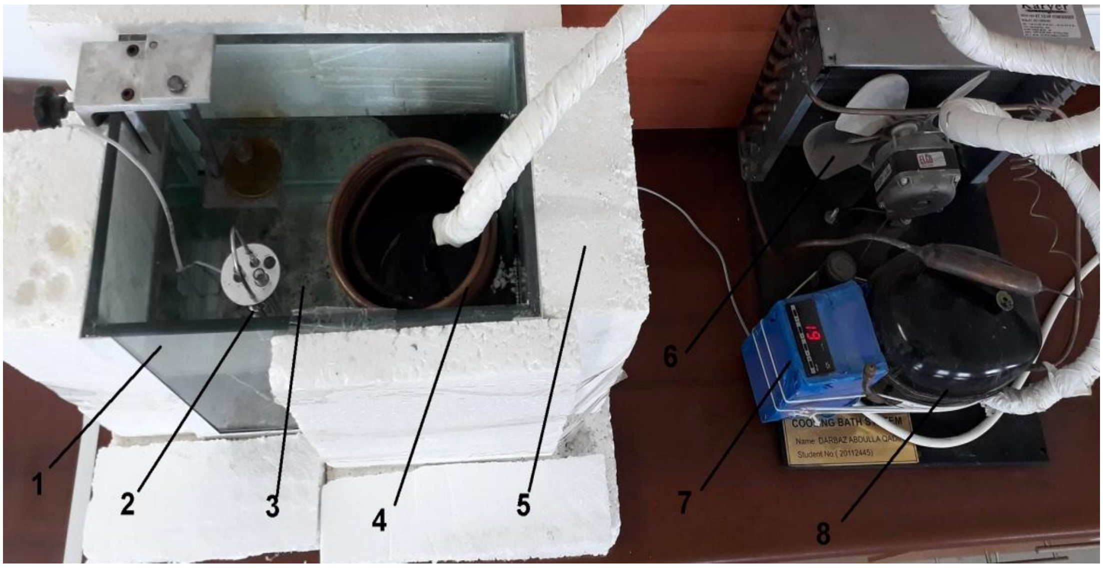


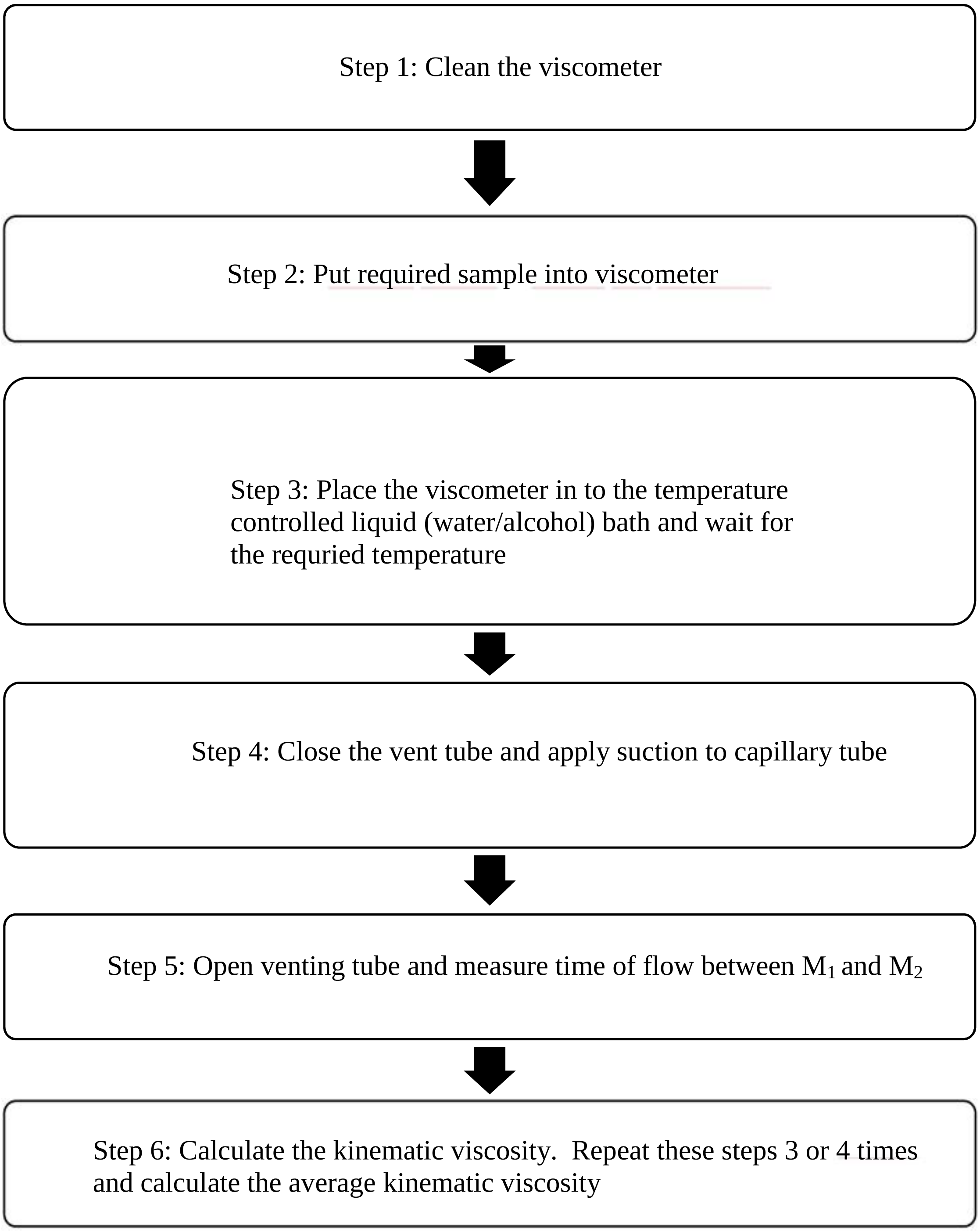
Figure 3.4: Thermostat connected to the cooling bath to measure low temperature.

3.3.3 Accessories

Additional accessories are used to insure proper, accurate and effective readings of the experimental data, and these accessories are listed below:

1. Fiber insulator – This is placed round the cooling bath to minimize the possibility of the interference of environmental relative high temperature when the cooling bath's temperature is relatively low.
2. Beaker insulator – this accessory is used for the purpose to prevent the cooling bath from losing heat to the environment when the system has a relative higher temperature than that of the environment.
3. Glass pippete – This accessory is used to insert the samples of biodiesel into the viscometer.
4. Syringe – This is one of the simple hand accessories that is used for the purpose of suction.
5. Stop watch – This accessory is very important in this work as it is used to measure time, especially during the calculation of the viscosity of the biodiesel.
6. Viscometer holder – The accessory is used to keep the Ubbelohde viscometer in the proper position.

3.3.4 Flow chart on kinematic viscosity



Step 1: Clean the viscometer

Step 2: Put required sample into viscometer

Step 3: Place the viscometer in to the temperature controlled liquid (water/alcohol) bath and wait for the requried temperature

Step 4: Close the vent tube and apply suction to capillary tube

Step 5: Open venting tube and measure time of flow between M_1 and M_2

Step 6: Calculate the kinematic viscosity. Repeat these steps 3 or 4 times and calculate the average kinematic viscosity

3.4 Density Measurment by Using Pycnometer

Pycnometer is has its root from the word puknos, which is a Greek word for density. The pycnometer is also seen as a specific gravity bottle fitted with a glass stopper that has a fine hole drilled through it. This device gives an accurate measurement of the density of a fluid. This procedure for using the pycnometer to measure density is by filling the pycnometer with a sample of the fluid whose density is to be measured and then it is placed on a weighing scale. The difference in weight between the empty pycnometer and the sample loaded pycnometer is calculated and then divided with specific gravity, this gives the accurate density of the fluid.

3.4.1 Standards using the pycnometer

The pycnometer is an expensive piece of equipment that is very delicate and must be handled with care and caution. The following precaution should be taken when using or handling the pycnometer for density measurement.

1. Pay attention to the parts of the pycnometer so that the bulb and the stopper are not interchanged with other lab components because the bulb and the stopper have the same numbers.
2. Prior to the initial measurement of the weight of the empty pycnometer, it is important to ensure that the pycnometer is clean and dry.
3. Pippets must be used to insert sample of the liquids into the bulb of the pycnometer until it is halfway to the neck and care must be taken when inserting the stopper of the capillary.
4. A full glass bulb gives no room for air bubbles in the bulb or in the capillary device likewise in the top.
5. When the filled pycnometer is to be weighed, caution must be observed to ensure that the outside of the pycnometer is dry and clean perfectly.
6. Attention must be given to the temperature readings to ensure that the required temperature is maintained throughout the process.
7. Ensure that the electronic balance is calibrated and set to 0.00 before the filled pycnometer is placed on it.

3.5 Electromagnetic Hot Plates

The electromagnetic hot plate used in this work is the hiedolph mr hei-tec electromagnetic heater which is a device whose top is made of aluminum, to increase the rate of heating up. This apparatus is recommended whenever the kinematic viscosity and the density of a fluid are to be determined at elevated temperatures ranging from 30^{o}C to 90^{o}C. Within this temperature, water may be used as the liquid in the glass beaker. However, silicon oil is used at temperatures beyond this range. The electromagnetic Hot plate used in this work is shown in the diagram of Figure 3.5.

Figure 3.5: Heidolph mr hei-tec. (www.labx.com/item/heidolph-mr-hei)

3.6 Methodology

3.6.1 Procedure I (Kinematic Viscosity)

In this section, the step by step process followed to determine the kinematic viscosity of the blend sample used in this work.

1. The IC viscometer was cleaned with a mixture that contains 70% of unpolluted water, 15% of hydrogen peroxide and 15% of tuz ruhu before usage. Furthermore, the viscometer was rinsed again using acetone and dried to ensure that it is dust free before commencing the experiment.
2. If particles are observed to be in the viscometer, the suction syringe can be used to remove them.
3. Samples of the blend are introduced into the lower reservoir of the viscometer in order to charge it to the upper making line in the lower u-tube.
4. Use the viscometer holder to immerse the viscometer perpendicularly in the cooling bath or the temperature-controlled glass beaker.
5. Leave the sample for some time in order for both the cooling bath and the glass beaker to reach temperature homogeneity.
6. Close the venting tube and start suction till the bigger and smaller bulb are filled with samples, the suction should be stopped when the sample reaches or passes the upper timing mark and then open the venting tube.
7. Measurement of the efflux time t is done. This is the time interval with which the blend moves from the M_1 mark to the M_2 mark.
8. The kinematic viscosity is obtained by multiplication of the efflux time and "υ" which is gotten from equations.
9. In order to reach higher accuracy of the measurement, step 6 to 8 should be repeated about 4 times without recharging the viscometer.
10. In this experiment, for measuring ranges between 6-30 the experimental setup used was Ic while for ranges between 2-10 the I experimental setup was used and for ranges of 0.6-3 the Oc experimental setup was used.
11. All equipment's and apparatus used in this procedure was properly cleaned and stored back in appropriate place.

3.6.2 Procedure II (density)

Step 1: This is the beginning of the experiment in which the weight of the empty pycnometer is recorded. It’s in this stage that the pycnometer is thoroughly cleaned with cleaning materials which include cleaning with acetone and there after it is checked for the presence of any particulate. Before placing the pycnometer on the electronic balance, It is very important to a make sure that the balance is positioned in an area that is vibration free and it is calibrated to 0.00.

Step 2: At this point, the sample of the blend is poured into the pycnometer till it fills it up to the throat level. It is essential that there is no space left in the pycnometer for air bubbles when filling the pycnometer with the sample blend. It is important to observe the level of the sample inside the pycnometer because a slight variation of the sample from the throat level of the pycnometer will affect the measurement of the density.

Step 3: To ensure that the electronic balance is working efficiently and properly, it was calibrated to 0.00 and was observed if this point is altered after placing and removing objects from it. But it was discovered that this level was constant when nothing was placed on it, therefore it is working properly for this purpose.

Step 4: At this point the sample filled pycnometer is immersed in the cold bath that contains alcohol. During the cooling process, there is a tendency for the sample fuel to experience molecular binding or cloting which might reduce the level of the sample below the throat level of the pycnometer due to contraction at low temperatures, when this starts happening, it is important to add more sample to the pycnometer to ensure that the sample remains in the threshold of the throat level of the pycnometer. The homogeneity of the temperature all through the sample is also vital before measurements are done.

Step 5: Once it is observed that the temperature all through the sample is at the desired temperature value, and the sample is at the threshold of the throat level and the electronic balance is observed to be working properly, at that point the measurement is ready to be carried out. It is vital for the electronic balance to be kept close to the pycnometer so as not to have temperature drop or rise when transferring the pycnometer from the cold bath to the electronic balance because the properties to be measured are temperature sensitive. And care must be taken to wipe off excess liquid off the body of the pycnometer prior to placing it on the electronic balance.

Step 6: After taking readings from the electronic balance, it is important that the pycnometer and the electronic balance are kept in their proper place in the lab.

1. Pycnometer of 100 mL

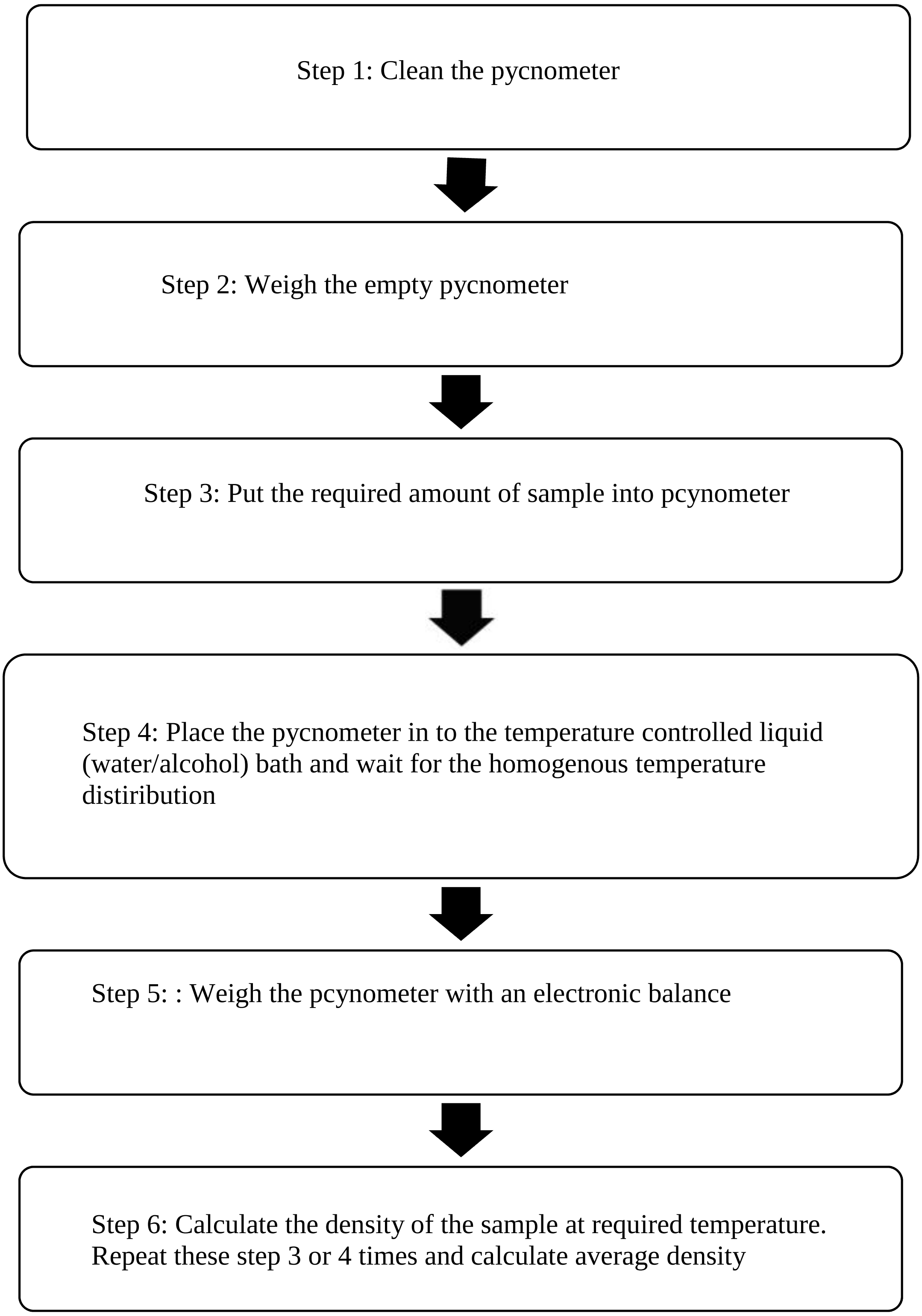
2. Pycnometer of 250 mL

3. Hot Plate

4. Cooling Bath System

Figure 3.6: Pictorial representation of using a pycnometer to measure density.

3.6.3 Flow chart on density



Step 1: Clean the pycnometer

Step 2: Weigh the empty pycnometer

Step 3: Put the required amount of sample into pcynometer

Step 4: Place the pycnometer in to the temperature controlled liquid (water/alcohol) bath and wait for the homogenous temperature distiribution

Step 5: : Weigh the pcynometer with an electronic balance

Step 6: Calculate the density of the sample at required temperature. Repeat these step 3 or 4 times and calculate average density

Example 1:

Following is given an example to determine the density of the sample (20% BD and 80% ED) used for this work at 15°C, the following is done

$$\text{Temperature} = 15O\ ^{\circ}C$$

$$m_E = 42.763\ g$$

$$m_F = 128.082\ g$$

$$m_N = m_F - m_E$$

$$m_N = 128.082g - 42.763g = 85.319\ g$$

$$\rho = m_N / V_p\ , where\ V_p\ is\ the\ volume\ of\ the\ pycnometer$$

$$\rho = 85.319/99.693 = 0.855817 g/mL$$

$$\rho = 0.855817\ x\ 1000 = 855.82k\ g/m^3$$

3.6.4 Procedure III (PP, CP and CFPP)

The procedure undergone to determine the pour point and the cloud point is explained using figure 3.7 and Figure 3.8.

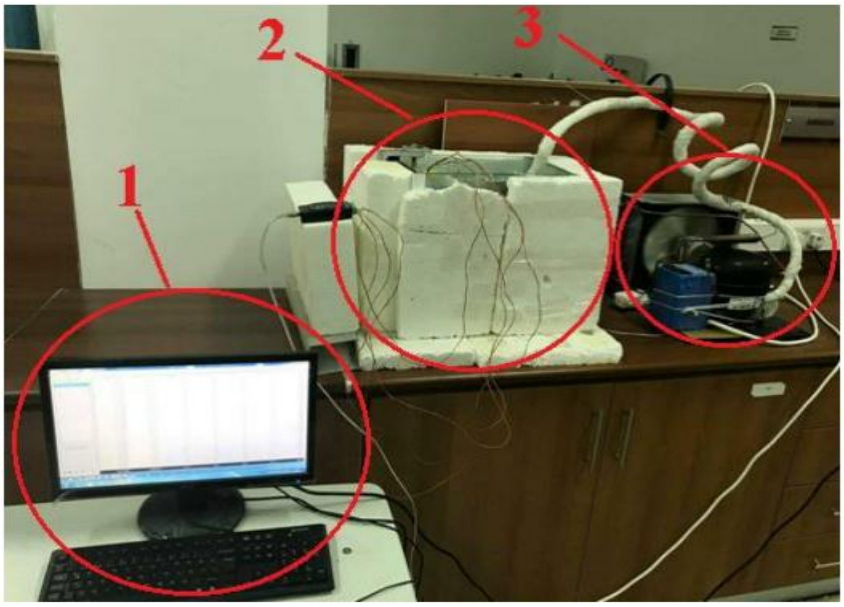


Figure 3.7: Equipment used to measure the pour point and Cloud point.

Points indicated from figure 3.7 above are explained below.

1. Data acquisition and computer
2. Cooling bath
3. Cooling system

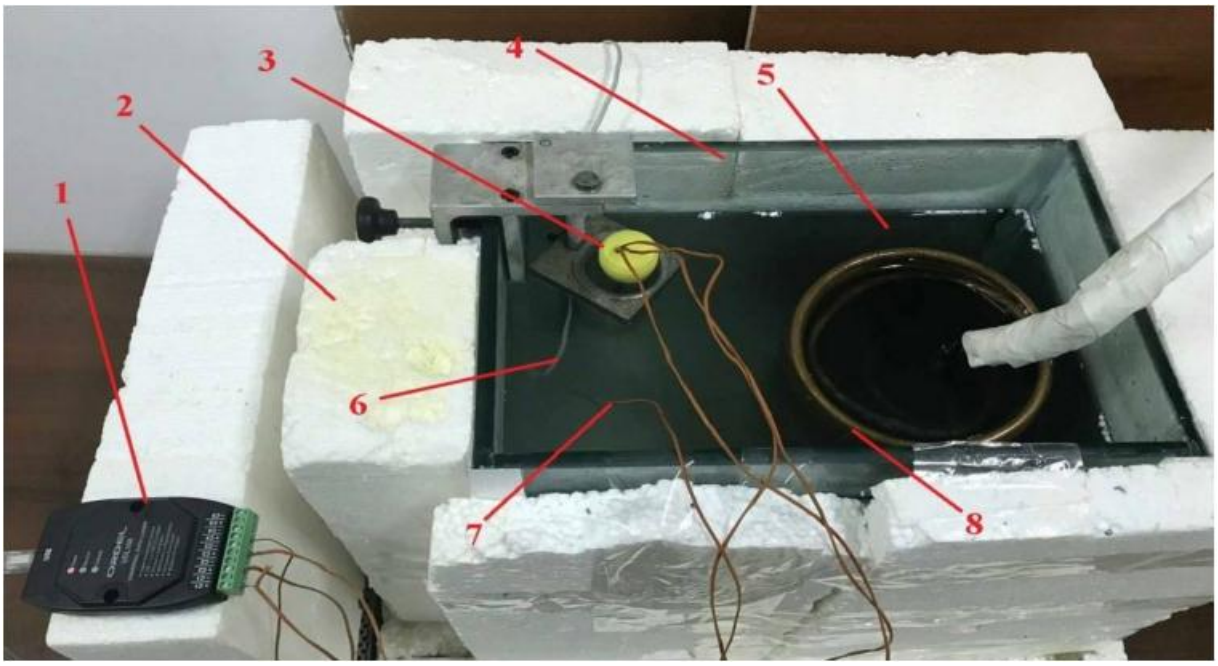


Figure 3.8: Data logger and the thermocouples.

An explanation of the points numbered in Figure 3.8 is given below;

1. Data logger – this is a device that links up the glass jar to a computer using thermocouples where the outputs of the experiment can be read. Thermocouples are used for the connection because of the need to read temperature inside the glass jar. Also to determine the cloud point that is placed inside the glass test jar and for the pour point which is located on top of the inner part of the glass jar.
2. Block of Insulator (Styrofoam): The purpose of this block of insulator is to keep the system at a steady temperature range.

3. Glass test jar: The glass jar contains 45ml of the test sample in which three thermocouples are placed inside as shown in figure 3.9. The three thermocouple serve their distinctive purpose as explained below
   a. The thermocouple sited in the lower portion of the glass jar is used to obtain readings that measure the cloud point of the sample
   b. The thermocouple placed in the middle of the glass jar is used to determine the temperature curve of the cooling system.
   c. The thermocouple sited in the upper portion of the glass jar is for the pour point measurement.
4. Cooling bath: The purpose of the cooling bath is to keep the sample in a steady temperature range and this is achieved by using a thick layer of Styrofoam block with a thickness of 11cm in a wooden box to isolate the system from the surrounding.
5. Alcohol: This is a choice cooling bath material because of its very low freezing point of -114 ^{o}C.
6. Thermocouple of Cooling system: This system is important as such to transmit temperature signals to the compressor.
7. Fourth Thermocouple of data logger: This thermocouple is responsible to determine and transfer the entire readings of the system to the computer's display.
8. Coil of the Cooling System: This coil is used to improve the rate of cooling or the cooling efficiency of the compressor.

In the experimental set up, a glass test jar is retained inside an aluminum cylinder which is enclosed by the cooling bath which contains alcohol. A cork stopper and a ring assembly is used to isolate the glass test jar from the aluminum cylinder. This aluminum cylinder was initially placed in an 8 liter stainless steel cooling bath that contains alcohol at low temperature and the sample was preheated to 65^{o}C before it was poured into the glass jar. The 11cm thick Styrofoam is used to isolate the cooling bath from environmental interference and for vibration damping. The ASTM D445-06 was used to check the determined kinematic viscosity of the sample used in this setup.

In order to assess the the pour point and cloud point, a fresh sample was used and tested using the ASTM D97 and ASTM D2500 American Standard Test Method for pour point and cloud point respectively.

A cloud point test was conducted after the apparatus and the liquid bath was cooled, this test was carried out by cooling the sample placed in the test jar and a stepwise inspection was carried out after every 1°C change until the sample becomes cloudy. At the point where the sample starts being cloudy, the temperature was recorded as the cloud point for the specified sample from the thermocouple placed in the inner lower part of the test jar because it is observed that the temperature value in the lower part of the jar tends to be higher than the temperature in the upper part of the test jar.

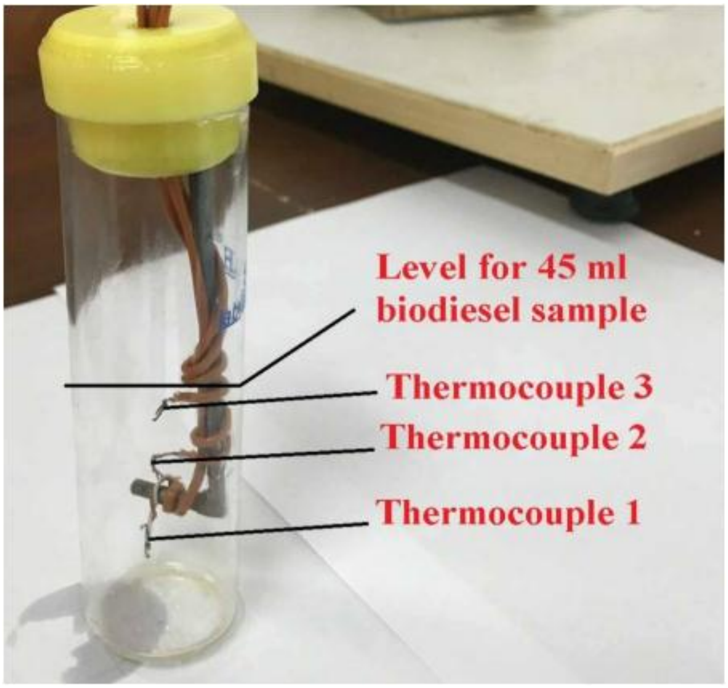


Figure 3.9: Thermocouples placed inside the Glass Jar

In order to determine the pour point, the sample is allowed to achieve temperatures value that is slightly higher than the expected pour point and then an observation is given to the sample at this point. The cooling bath is then allowed to achieve extremely low temperature, then the same sample is immersed into the cooling bath and an inspection at a 1 °C stepwise is carried out until the sample loses its fluidity. The temperature reading of the thermometer is recorded and the temperature reading before the present reading is considered the pour point of the sample, the thermocouple positioned in the upper part of the sample also gives off its reading which is also recorded. To maintain low level of discrepancies of the result, every measurement obtained was done three times for each sample and then averaged and it is recorded that the standard deviation of the test results is a ±2 °C.

3.6.5 Procedure IV (blend temperature stability and storage)

The sample used for this work is a blend of $20\%\ \mathrm{BD} + 80\%\ \mathrm{ED}$ which is stored for long time so as to analyze the flow properties of this blend under extreme temperature and over long period of storage. An oven is used to store and keep the blend at 40 °C for a long period of time using a thermostat to regulate and keep the temperature steady. The thermostat is used to as a temperature monitoring device for the inner temperature of the over. A long copper hollow tube extended from the oven is connected to the thermostat. Heating bulbs are placed inside the oven and whenever the thermostat senses that the inner temperature of the oven has reached the preset temperature of 40 °C, the thermostat cuts off the heat source of the oven and when the temperature drops below this preset temperature, the thermostat kicks off the heating source of the oven so as to keep it steadily at 40 °C.

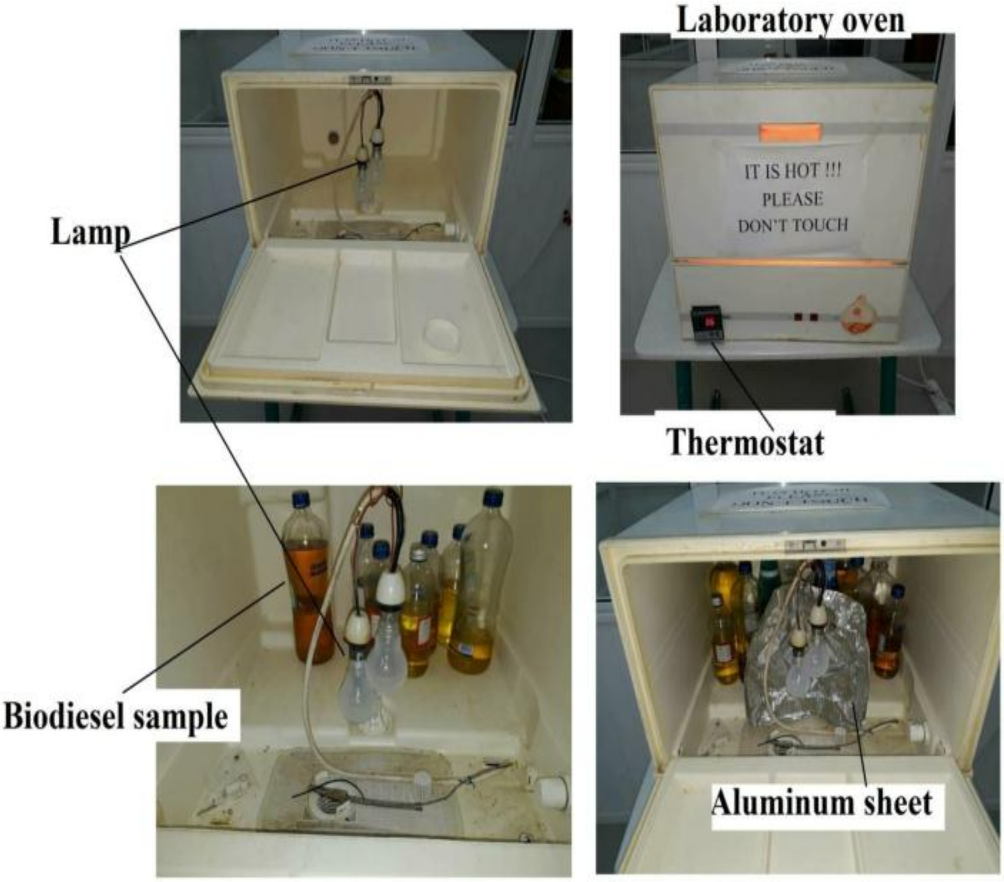
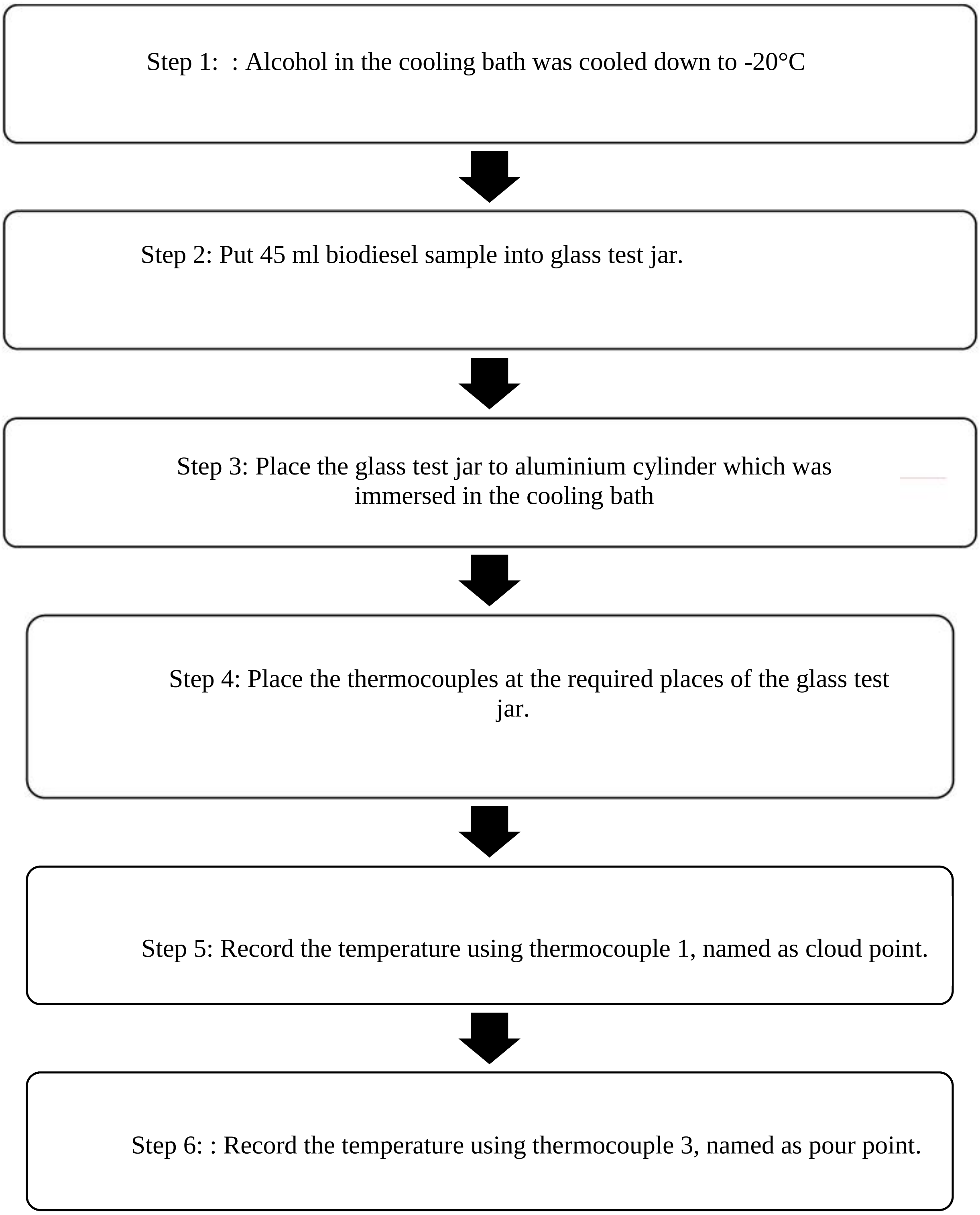


Figure 3.10: The blends of Bio-diesel and Euro-Diesel placed inside the oven.

3.6.6 Flow chart for measuring cloud point and pour point



Step 1: : Alcohol in the cooling bath was cooled down to -20°C

Step 2: Put 45 ml biodiesel sample into glass test jar.

Step 3: Place the glass test jar to aluminium cylinder which was immersed in the cooling bath

Step 4: Place the thermocouples at the required places of the glass test jar.

Step 5: Record the temperature using thermocouple 1, named as cloud point.

Step 6: : Record the temperature using thermocouple 3, named as pour point.

CHAPTER 4

RESULTS AND DISCUSSION

The aim of this work is to find the relationship between the kinematic viscosity and the density and measurement of these properties is done while keeping the blend at a constant temperature of 40 °C over a period of 90 days. The kinematic viscosity of the blend was under study for a period of 12 weeks in varying temperatures from -11 °C to 90 °C. The relationship of the density of the blend was also studied a constant temperature of 15°C for 90 days. Further testing and experimentation was done to determine the behavior of the density of a mixture of 20% bio-diesel and 80% of euro-diesel at a varying temperature range of -11 °C to 90 °C for 12 weeks.

4.1 Kinematic Viscosity Over a Storage of 90 Days at 40 °C

This section is used to explain the results shown in Table 4.1 which is the effect of time on a blend containing 20% Bio-Diesel (BD) and 80% Euro- Diesel (ED) at a constant temperature of 40 °C, which is a temperature that is considered average during summer in Northern Cyprus.

Table 4.1: Kinematic Viscosity (mm^2/s) for a Storage Period of 90 days at 40°C

Days	0	10	20	30	40	50	60	70	80	90
B20	3.247	3.273	3.299	3.370	3.397	3.424	3.500	3.507	3.514	3.636

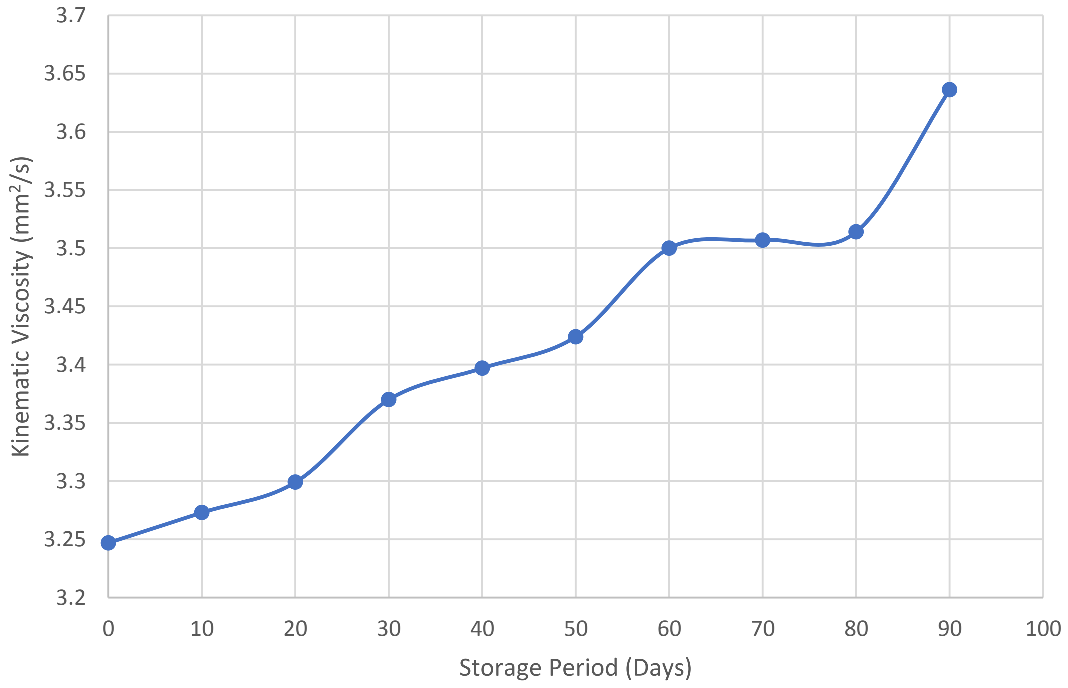


Figure 4.1: Kinematic viscosity (mm^2/s) for a storage period of 90 days at 40 ^{o}C

The graph representation of the relationship between kinematic viscosity and storage periods shown in Figure 4.1 shows that as time increases, the blend becomes more viscos, i.e the viscosity of the blend increased with longer storage period of time. This behavior of the viscosity of the blend is due to the increase of total acidic number in fuels (oxidation of fuels increases with time). The increase in the total acidic number causes more impurities like fatty acid chains and polymers to form in the fuel system.

4.2 Kinematic Viscosity over Testing Temperatures

The behavior of kinematic viscosity of the fuel blend containing 20% of Bio-Diesel and 80% Euro-Diesel over a temperature range of -11 ^{o}C to 90 ^{o}C is studied and tested on weekly intervals. This section discusses the results obtained from the conducted experiments.

Table 4.2: Kinematic Viscosity (mm^2/s) for 12 weeks over Testing Temperatures °C

T(°c)	**0 Week**	**4 Weeks**	**8 Weeks**	**12 Weeks**
-13	-	-	-	-
-11	22.89	-	-	-
-10	18.73	18.80263	-	-
-8	15.33	15.38677	15.95828	17.65
-7	13.39	13.4394	13.93858	15.55
-5	11.56	11.6057	12.03677	12.21
-3	11.18	11.21908	11.63578	13.17
0	9.48	9.514201	9.867586	10.18
2	8.83	8.861503	9.190645	9.78
5	7.98	8.00818	8.305627	8.18
8	7.91	7.936495	8.231279	9.13
10	6.83	6.853623	7.108186	7.81
15	5.97	5.996163	6.218878	6.88
20	5.18	5.198388	5.391471	6.69
30	3.77	3.787421	3.928097	4.37
40	**3.25**	**3.37**	**3.5**	**3.64**
50	2.69	2.702696	2.803082	3.31
60	2.25	2.261996	2.346013	2.73
70	1.93	1.936805	2.008743	2.25
80	1.74	1.743124	1.807869	2.02
90	1.56	1.568812	1.627082	1.82

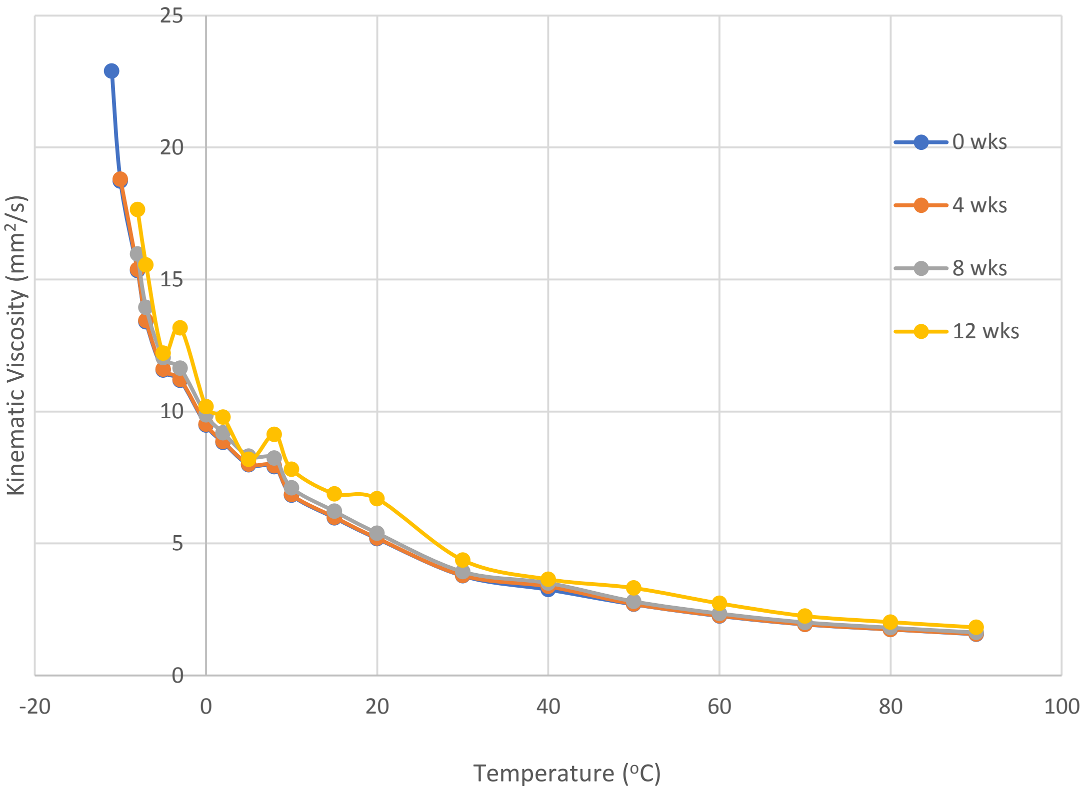


Figure 4.2: Kinematic Viscosity (mm^2/s) for 12 weeks over testing temperatures in ^{o}C.

In the curve represented in Figure 4.2, it is seen that the kinematic viscosity behavior declines as temperature rises. This reduction in viscosity due to high temperature is because of the effect of high temperature on the cohesive molecular forces that exist between the bond and molecules of the fuel, ability of the cohesive force to keep the molecules of the fuel together reduces as the temperature keeps rising.

4.3 Density Over A Storage Period Of 90 Days At Temperature Of 15 °C

In this section, using Table 4.3 an explanation of the effect of keeping the blend of 20% BD+80%ED at 15 °C for 90 days on density. The values tabulated in Table 4.3 are obtained experimentally.

Table 4.3: Density (kg/m^3) for storage period of 90 days at 15 °C

Days	0	10	20	30	40	50	60	70	80	90
B20	855.818	856.931	858.045	861.900	863.020	864.142	866.600	867.727	868.855	870.605

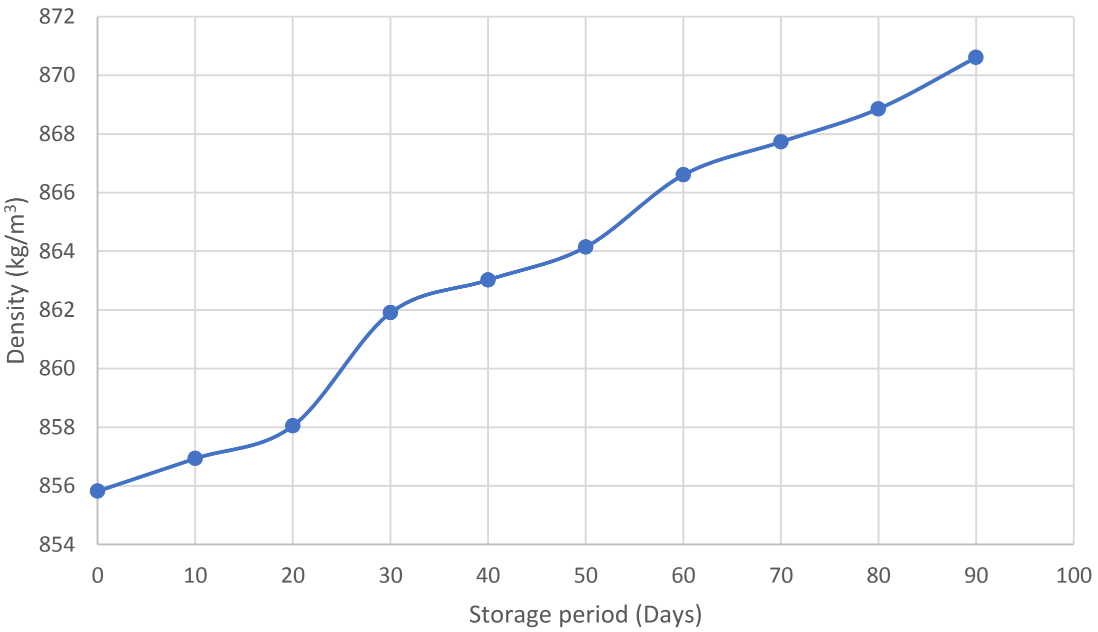


Figure 4.3: Density (kg/m^3) for a storage period of 90 days at 15 °C

Using the graph shown in the Figure 4.3 above, it is evident that the density of the fuel rises as storage time increases also. The increase in density over a long period of time is due to the developed impurities formed in the fuel blend due to oxidation and these impurities therefore make the fuel to be heavier and thicker.

4.4 Density Over Testing Temperatures

In this section the relationship of density of the fuel blends of 20%BD+80%ED and varying temperature ranging from -11 °C to 90 °C will be discussed. The reading and measurement of the density was carried out on a weekly interval.

Table 4.4 Density (kg/m^3) for 12 weeks over a Testing Temperature range °C.

T (°C)	**0 weeks**	**4 weeks**	**8 weeks**	**12 weeks**
-11	947.83	-	-	-
-10	939.46	946.0876	-	-
-8	931.09	937.6564	942.7413	870.60
-7	922.71	929.2252	934.2644	870.60
-5	914.34	920.7941	925.7875	870.60
-3	905.97	912.3629	917.3106	870.60
0	897.60	903.9317	908.8337	870.60
2	889.23	895.5006	900.3569	870.60
5	880.85	887.0694	891.88	870.60
8	872.48	878.6382	883.4031	870.60
10	864.11	870.2071	874.9262	870.60
15	**855.82**	**861.9**	**866.6**	**870.60**
20	847.53	853.5065	858.1351	870.60
30	839.23	845.1563	849.7396	870.60
40	829.32	835.1706	839.6997	870.60
50	827.42	833.2562	837.7749	870.60
60	818.30	824.0786	828.5476	870.60
70	811.52	817.2483	821.6802	870.60
80	798.13	803.7609	808.1197	870.60
90	791.88	797.4693	801.794	870.60

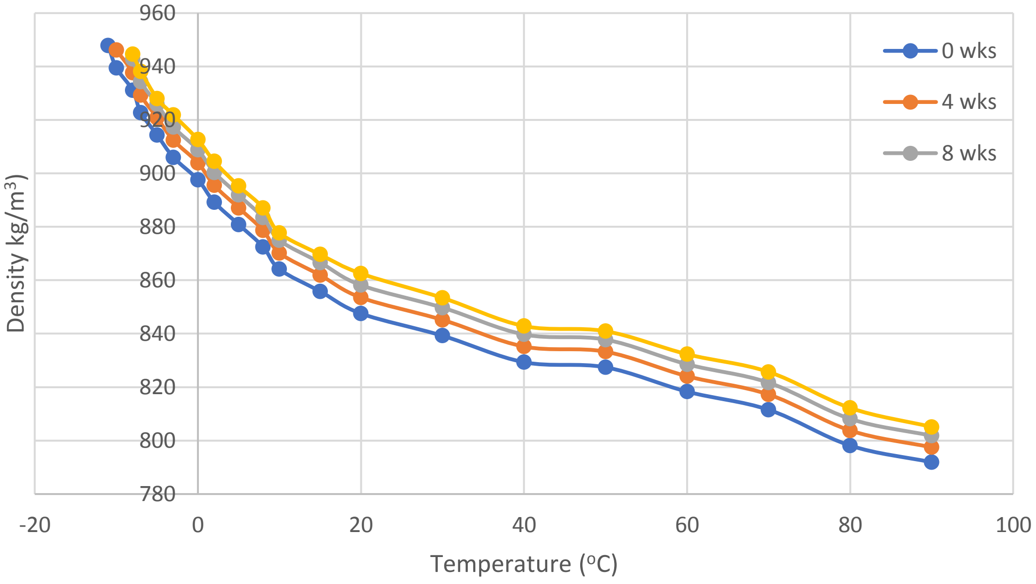


Figure 4.4: Density (kg/m^3) for 12 weeks over testing temperatures

From the graph shown in figure 4.4, it is clear that the density of the fuel blend decreases as the temperature rises. This reduction in density is due to the energy gained by the molecules of the fuel in the form of heat, therefore the molecules are rising in energy and therefore are becoming freer to move without restriction of cohesive forces binding them together.

4.5 Total Acidic Number and Oxidation Stability

The total acidic number is used to determine how acidic is the blend of fuel or it is the quantity of potassium hydroxide in milligrams required to eliminate the acidic nature of 1 gram of a substance. This section is dedicated to discuss the test method used in determining the total acidic value of the biodiesel blend and as well as the result of the test conducted. There were two distinct tests that were done to determine the total acidic number and these two tests were done within 30 days by the Nortest inspection and certification. The specimen used for these experiments were given a satisfactory mark.

Table 4.5: Total Acidic Number (mg KOH, g) and the Oxidation Stability in hours

TEST DESCRIPTION UNITS	TEST METHOD	SPEC LIMIT	TEST RESULTS	
Total Acid Number (mg KOH/g)	D664-04(2017)	-	0.20	0.39
Oxidation Stability (hours)	EN15751:2014	-	3.00	0.30

From the test result, it was observed that the total acidic number increased as the time of storage increases also due to the increase of hydro-peroxide which was produced by the blend in the process of degradation because of the chemical reactions going on inside the blend. These reactions cause more formation of acids by the reason of oxidation and these oxidation causes the acidic number to increase. As the total acidic number of the fuel increases over the time of storage, the oxidation stability of the fuel system decreases alongside.

4.6 Cloud Point, Pour Point and Cold Filter Plugging Point.

The tables included in this section is a representative of the result data that will be used to explain the cloud point, the pour point, the cold filter plugging point.

Table 4.6: Experimental Result of CP, PP and CFPP

Cloud point °C	Pour point °C	Cold filter plugging point °C
-1.5	-7.7	-5.5

A blend of 20% BD + 80% ED is observed to have a cloud point of -1.5 ºC, which is the temperature at which wax begins to precipitate. The pour point is observed to be -7.7 ºC, which is the temperature at which the fuel becomes a gel and does not flow anymore. The cfpp is observed to be -5.5 ºC.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

A high concentration of fatty acid methyl ester in euro-diesel may affect the properties responsible for flow as the fuel gets older in storage. It is already established that the major properties of flow considered in this work is the kinematic viscosity and the density of the fuel. The following conclusion discussed in this section is based on the results gotten from the experimental work of this study.

1. As long as the temperature of the blend increases, the kinematic viscosity of the blend will keep decreasing and temperature drop of the blend will cause a corresponding rise in the viscosity of the blend for all composition and temperature of bio-diesel and euro-diesel.
2. At extreme temperature below -7.7 ^{o}C, the kinematic viscosity could not be determined because of the effect of crystallization of the blend (20% BD+80% ED) at extreme temperature.
3. For all samples and composition of biodiesel, at a level which is slightly higher than the CFPP which is located before the pour point is considered the cloud point.
4. It is not recommended to use the blend used in this study for application in automotive engines in regions where temperature drops to -7.7 ^{o}C.

5.2 Possible Errors

In this experimental study, there are some considerations of the possibilities of uncertainties in the results obtained, and these uncertainties can be traced or link to the following.

1. Knowing that this experiment was conducted over a long period of time, it is possible for human fatigue to cause careless in the conduction of the experiment.
2. In as much as the liquids in the cooling bath were stirred in order to achieve temperature homogeneity all through the cooling bath, there is still a high possibility that there was a temperature variation in the cooling bath which probably wasn't detected by the thermometer used.
3. It is very difficult to completely isolate or insulate the cooling bath from the environment, this difficulty may cause some interference from the environment to the cooling bath in the form of heat loss at elevated temperature or heat gain at low temperature. This could alter the results obtained from the experiments
4. At some point, it was observed that the foam used to damping the effect of vibration on the cooling bath wasn't efficient enough because in some certain time interval the cooling bath vibrates, and this vibration might interfere with the readings on the electronic balance when the density of the blend was to be recorded.
5. Knowing that this experiment was conducted over a long period of time and the samples were usually placed inside the oven for a long period of time, there is a possibility that the oven didn't work properly for some time and it wasn't noticed or the thermostat might have malfunctioned during the course of the steady temperature storage phase. This can alter the results obtained.

5.3 Recommendations

This study primarily focused on the ageing flow properties (Density and Kinematic viscosity) of bio-diesel blend in varying temperature conditions, it is recommended that a further study should be done to investigate other properties such as the heating value of the fuel, the cetane number and the iodine value of the same blend. It is also recommended for a further study to be done that will investigate the effect of additives on this blend (20%BD+80%ED).

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APPENDICES

APPENDIX 1

ASTM D2500-09

STANDARD TEST METHOD FOR CLOUD POINTS OF PETROLEUM PRODUCTS

APPENDIX 2

ASTM D97-05

STANDARD TEST METHOD FOR POUR POINT OF PETROLEUM PRODUCTS

APPENDIX 3

ASTM 6371-05

STANDARD TEST METHOD FOR COLD FILTER PLUGGING POINT OF PETROLEUM PRODUCTS

APPENDIX 4

ASTM D664-04

STANDARD TEST METHOD FOR ACID VALUE OF PETROLEUM PRODUCTS

APPENDIX 5

ASTM D941-88

STANDARD TEST METHOD FOR DENSITY OF PETROLEUM PRODUCTS

APPENDIX 6

ASTM D445-09 STANDARD TEST METHOD FOR VISCOSITY OF PETROLEUM PRODUCTS

APPENDIX 7

KINEMATIC ENERGY CORRECTION UBBELOHDE VISCOMETER, STANDARD FOR FAME AND EURODIESEL

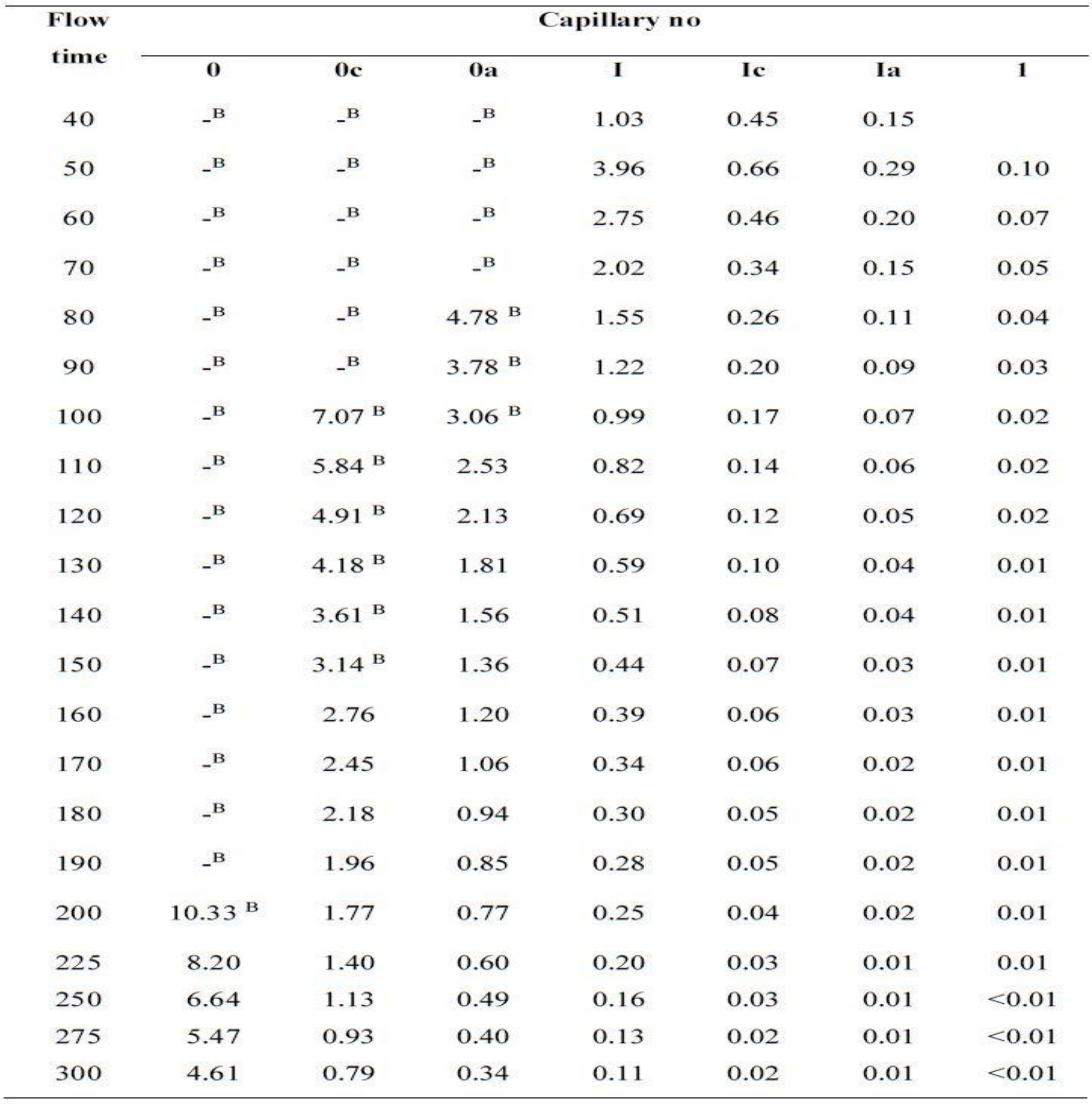
Table 1: Standards for FAME Biodiesel

NAME	**METHOD**	**UNIT**	**SPECS**		**RESULT**
			Mi	**Max**	
FAME content	EN 14103	mass %	96		>99.5
Density at 15°C	ISO 12185	kg/m³	86	900.0	876.4
Kinematic Viscosity at 40°C	EN ISO 3104	mm²/s	3.5	5.000	4.483
Flash point (rapid equilibrium)	ISO 3679	°C	10 1		>140
Cetane Number	EN 15195		51		59.7
Copper Corrosion (3hrs/ 50°C)	EN ISO 2160			Class 1	1A
Oxidation stability (110°C)	EN 14112	hours	8.0		>11
Acid number	EN 14104	mg		0.50	0.31
Iodine value	EN14111	gl2/100		120	74
Linolenic acid methyl ester	EN 14103	mass%		12.0	2.6
Polyunsaturated methyl esters (>=4 double bounds)	EN 15779	mass%		1.0	<0.10
Methanol	EN 14110	mass%		0.20	0.02
Glyceride content	EN 14105				
Mono-glyceride		mass%		0.70	0.21
Di-glyceride		mass%		0.20	0.02
Tri-glyceride		mass%		0.20	<0.03
Free glycerol		mass%		0.02	<0.010
Total glycerol		mass%		0.25	0.065
Water Karl Fischer	EN ISO 12937	mg/kg		300	160
Contamination	EN 12662 98	mg/kg		24	<6
Sulphated ash	ISO 3987	mass%		0.02	<0.005
Sulphur (S)	EN ISO 20846	mg/kg		10.0	9.8
Group i metals (Na+K)	EN 14538	mg/kg		5.0	<2.0
Group ii metals (Ca+Mg)	EN 14538	mg/kg		5.0	<2.0
Phosphorus content	EN 14107	mg/kg		4.0	<4
Kinematic viscosity at 20°C	ASTM D445	mm²/s			7.2

Table 2: Standards for Euro Diesel

PROPERTIES	UNITS	LIMITS		RESULTS	METHOD
		LOW	**HIGH**		
DENSITY 15^{O}C	KG/M^3	820.0	845.0	827.8	ASTM D 4052
CETANE NUMBER		51.5		55.0	ASTM D 613
CETANE INDEX		47.0		54.8	ASTM D 4737
KINEMATIC VISCOSITY 40^{O}C	CST	2.0	4.5	2.8	ASTM D 445
COLD FILTER PLUGGING POINT, CFPP	DEG C		4	-6	IP 309
SULPHUR CONTENT	MG/KG		10.0	5.3	ASTM D 5453
COPPER STRIP CORROSION, 3 HRS 50^{O}C	NO.		1	1	ASTM D 130
OXIDATION STABILITY	MG/L		25	3	ASTM D 2274
CARBON RESIDUE (ON 10 PCT REISDUE)	WT PCT		0.30	0.01	ASTM D 4530
WATER CONTENT	MG/KG		200	39	ASTM D 6304
TOTAL CONTAMINATION	MG/KG		24	2	IP 440
ASH CONTENT	WT PCT		0.010	0.000	ASTM D 482
STRONG ACID NO		NIL		NIL	ASTM D 974
TOTAL ACID NO	MG KOH/GR		0.2	0.1	ASTM D 664
FLASH POINT	DEG C	55		67	ASTM D 93
RECOVERED 250^{O}C	VOL PCT		65	40	ASTM D 86
RECOVERED AT 350 DEG C	VOL PCT	85		92	ASTM D 86
95% RECOVERED	^{O}C		360	360	ASTM D 86
LUBRICITY, WSD 1.4, 60^{O}C	UM		440	385	ISO 12156/1
APPEARANCE		& Bright		Clear & Bright	ASTM D 4176

Table 3.4: Kinematic Energy Correction Ubbelohde Viscometer ISO 3105/DIN51 562/Part1/BS188/NFT 60-100 Ref.No.501…530…532. Correction seconds ^{A}



Flow time	Capillary no					
	0	**0c**	**0a**	**I**	**Ic**	**Ia**	**1**
40	-^{B}	-^{B}	-^{B}	1.03	0.45	0.15	
50	-^{B}	-^{B}	-^{B}	3.96	0.66	0.29	0.10
60	-^{B}	-^{B}	-^{B}	2.75	0.46	0.20	0.07
70	-^{B}	-^{B}	-^{B}	2.02	0.34	0.15	0.05
80	-^{B}	-^{B}	4.78 ^{B}	1.55	0.26	0.11	0.04
90	-^{B}	-^{B}	3.78 ^{B}	1.22	0.20	0.09	0.03
100	-^{B}	7.07 ^{B}	3.06 ^{B}	0.99	0.17	0.07	0.02
110	-^{B}	5.84 ^{B}	2.53	0.82	0.14	0.06	0.02
120	-^{B}	4.91 ^{B}	2.13	0.69	0.12	0.05	0.02
130	-^{B}	4.18 ^{B}	1.81	0.59	0.10	0.04	0.01
140	-^{B}	3.61 ^{B}	1.56	0.51	0.08	0.04	0.01
150	-^{B}	3.14 ^{B}	1.36	0.44	0.07	0.03	0.01
160	-^{B}	2.76	1.20	0.39	0.06	0.03	0.01
170	-^{B}	2.45	1.06	0.34	0.06	0.02	0.01
180	-^{B}	2.18	0.94	0.30	0.05	0.02	0.01
190	-^{B}	1.96	0.85	0.28	0.05	0.02	0.01
200	10.33 ^{B}	1.77	0.77	0.25	0.04	0.02	0.01
225	8.20	1.40	0.60	0.20	0.03	0.01	0.01
250	6.64	1.13	0.49	0.16	0.03	0.01	<0.01
275	5.47	0.93	0.40	0.13	0.02	0.01	<0.01
300	4.61	0.79	0.34	0.11	0.02	0.01	<0.01

Table 3.4: Continued

325	3.90	0.66	0.29	0.09	0.02	0.01
350	3.39	0.58	0.25	0.08	0.01	0.01
375	2.95	0.50	0.22	0.07	0.01	0.01
400	2.59	0.44	0.19	0.06	0.01	<0.01
425	2.30	0.66	0.29	0.09	0.01	<0.01
450	2.05	0.58	0.25	0.08	0.01	<0.01
475	1.84	0.50	0.22	0.07	0.01	
500	1.66	0.44	0.19	0.06	0.01	
550	1.37	0.23	0.1	0.03	0.01	
600	1.15	0.20	0.09	0.03	0.01	
650	0.98	0.17	0.07	0.03	<0.01	
700	0.85	0.14	0.06	0.02	<0.01	
750	0.74	0.13	0.05	0.02	<0.01	
800	0.65	0.11	0.05	0.01		
850	0.57	0.10	0.04	0.01		
900	0.51	0.09	0.04	0.01		
950	0.46	0.08	0.03	0.01		
1000	0.42	0.07	0.03	0.01		

[A] from the above the correction stated are related to the respective theoretical constant.

[B] for a more accurate measurement, the flow time should not be applied. The selection of a smaller sized viscometer of capillary diameter.

APPENDIX 7

LIGHT BULB

An incandescent light bulb, incandescent lamp or incandescent light globe is an electric light with a wire filament heated to such a high temperature that it glows with visible light (incandescence). The filament is protected from oxidation with a glass or fused quartz bulb that is filled with inert gas or a vacuum. In a halogen lamp, filament evaporation is slowed by a chemical process that redeposits metal vapor onto the filament, thereby extending its life.

The light bulb is supplied with electric current by feed-through terminals or wires embedded in the glass. Most bulbs are used in a socket which provides mechanical support and electrical connections.

Incandescent bulbs are manufactured in a wide range of sizes, light output, and voltage ratings, from 1.5 volts to about 300 volts. They require no external regulating equipment, have low manufacturing costs, and work equally well on either alternating current or direct current. As a result, the incandescent bulb is widely used in household and commercial lighting, for portable lighting such as table lamps, car headlamps, and flashlights, and for decorative and advertising lighting.

Incandescent bulbs are much less efficient than other types of electric lighting; incandescent bulbs convert less than 5% of the energy they use into visible light,[1] with standard light bulbs averaging about 2.2%.[2] The remaining energy is converted into heat. The luminous efficacy of a typical incandescent bulb is 16 lumens per watt, compared with 60 lm/W for a compact fluorescent bulb or 150 lm/W for some white LED lamps.[3]

Some applications of the incandescent bulb (such as heat lamps) deliberately use the heat generated by the filament. Such applications include incubators, brooding boxes for poultry,[4] heat lights for reptile tanks,[5] infrared heating for industrial heating and drying processes, lava lamps, and the Easy-Bake Oven toy. Incandescent bulbs typically have short lifetimes compared with other types of lighting; around 1,000 hours for home light bulbs versus typically 10,000 hours for compact fluorescents and 30,000 hours for lighting LEDs.