Palestine Polytechnic University

College of Engineering and Technology

Mechanical Engineering Department

Graduation Project

Biodiesel Production in Hebron District from Waste Cooking Oil

Project Team

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Palestine Polytechnic University
(PPU)

Hebron-Palestine

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According to the project supervisor and according to the agreement of the examination committee members, this project is submitted to the Department of Mechanical Engineering at college of engineering and technology in partial fulfillment of the requirements of the bachelor's degree.

Department Head Signature | Supervisor Signature

Name: ________________ | Name: _______________

June -2008

جـــــــامعة بـــوليتـكـنك فلسطـــــــين

الخليـــــــل- فلسطـــــــين

كلية الـهندسة والتكـــنولوجيا

دائرة الـهندسة الميكانيكية

اسم المشروع

Biodiesel Production from Waste Cooking oil in Hebron District

اسماء الطلبة

مهران شويكي معاوية العويوي

بناء على نظام كلية الهندسة والتكنولوجيا وإشراف ومتابعة المشرف المباشر على المشروع وموافقة أعضاء اللجنة الممتحنة تم تقديم هذا المشروع إلى دائرة الهندســة الميكانيكية وذلك للوفاء بمتطلبات درجة البكالـــوريوس في الهندســـــة تخصص هندســـــة السيارات.

توقيع المشرف

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توقيع اللجنة الممتحة

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توقيع رئيس الدائرة

....

Dedication

To our dear parents and families………………………………………..

To whom who have added anything to the science……………………

To whom who have taught us any letter, word or information………...

To our colleges and instructors……………………………………....

To whom we love………………………………………………….....

We dedicate this project

Project team

Acknowledgment

Here as we finished our graduation project thesis we stop for a moment to thank every body who has helped us to complete this work.

First we want to thank our supervisor Dr. Momen sughayyer who gave us a lot of this time and experience in order to complete the project and gave us the opportunity to start scientific life and methodology in the real life by asking us to do this work.

Specially thanks to the Deanship of Scientific Research and Graduated Studies through the financial support of Palestine polytechnic University Industrial Synergy Center (PPUISC) for financing the building of the project prototype.

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Project prototype

Abstract (English)

Biodiesel Production in Hebron District from Waste Cooking Oil

BY

Mahran Shweiki Moawia Awiwi

This project is oriented toward industrial support and development my means of the availability of a research study capable to be applied within local industrial and economical abilities. Thus; the project is considered to be a feasibility study for the production of a biological fuel obtained from vegetable oil. In Hebron district in Palestine as an example to be expanded later.

This project consists of many stages; it begins with a statistical study for the biological resources available which are used for the production of biodiesel. In this project there will be a study for the biological wastes available from animal fats and vegetable oil in Hebron district with the possibility to be collected and recycled again in order to produce biodiesel fuel. Then possible amounts that should be collected are will be determined, that evaluation of the whole cost due to the process of collection and storage will follow. Then after, the production process should be studied taking into account economical and environmental reflections of this process. In the last stage, there will be a production of a trial amount will be produced using a small plant specially built and financed by Deanship of Scientific Research and Graduated Studies through the financial support of Palestine polytechnic University Industrial Synergy Center (PPUISC). Some basic inspections for the resulted have been done also. The process of all previous stages will proceed idea marketing in the local society.

Abstract (Arabic)

هذا المشروع موجه نحو دعم الصناعة المحلية وتطويرها من خلال اجراء البحوث ودراسة الجدوى الاقتصادية، يعتبر هذا المشروع دراسة اقتصادية لانتاج الوقود الحيوي من المصادر الحيوية.

المشروع اشتمل على عدة مراحل بدأت بدراسة احصائية للموارد الحيوية المتوفرة والتي تستخدم في انتاج الوقود الحيوي في محافظة الخليل. حيث تم دراسة المصادر التوفرة للمخلفات الحيوية من الدهون الحيوانية والزيوت النباتية في منطقة الخليل وامكانية تجميعها لاعادة تصنيعها بغرض انتاج الوقود الحيوي.ثم تم تحديد الكميات الممكن تجميعها وتقييم التكلفة لعملية التجميع والتخزين. بعد ذلك تم دراسة عملية الانتاج والانعكاسات الاقتصادية والبيئية لذلك. في المرحلة النهائية تم انتاج كمية تجريبية واستخدامها بعد عمل الفحوصات الاساسية للوقود الناتج. كما تم بناء نموذج تجريبي لتحويل الزيوت الى وقود حيوي بتمويل من عمادة البحث العلمي والدراسات العليا بالتعاون مع مركز التكامل مع الصناعة في جامعة بوليتكنك فلسطين. وسيتم العمل في المراحل المختلفة على تسويق الفكرة للمصانع المحلية.

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Nomenclature

GHG	Green house gas
PAHs	Polycyclic Aromatic Hydrocarbons
EGR	Exhaust gas recyclation
BXX	Blend with xx% Biodiesel (100-xx)% Petrodiesel
FFA	Free Fatty Acid
VOC	Volatile Organic Compounds
PAH	Polycyclic Aromatic Hydrocarbons
nPAH	Nitrated Polycyclic Aromatic Hydrocarbons
PCB	Poly Chlorinated Bi-phenyl
ASTM	American Society of Testing and Material
SVO	Straight vegetable oil
RME	Rape Methyl Ester
PM	Particulate Matter
HC	Hydrocarbons
CO	Carbon Monoxide
NOx	Nitrogen Oxides
SOx	Sulfur Oxides
CO_2	Carbon Dioxide
VAT	Value Added Taxes
c_p	Specific heat at constant pressure

Q	Added energy
NaOH	Sodium Hydroxide
ICE	Ignition Compression Engine
ULSD	Ultra Low Sulfur Diesel
D6751	Specification for Biodiesel (B100)
ICE	Ignition compression engine
gpm	Gallon per minute
VW	Volkswagen

Chapter One

Introduction

Content:

Chapter One

Introduction

1.1 General Outlook

The need for energy is increasing continuously, because of the increase in industrialization and population. The basic sources of this energy which we need in Hebron district is petroleum products and in addition of electricity; natural gas. All that energy sources are imported at high cost for our economy which slows our economy growth. So through this problem their is another alternative source of energy in Hebron which can be extracted from organic material such as waste vegetable oil and animal fats in order to produce renewable source of energy called biodiesel.

Waste vegetable oils and animal fats can affect human beings health and pollute the environment. The quantity of waste cooking oil generated per year in Hebron district is very huge. For the matter of fact, the disposal of waste cooking oil is problematic, because the disposal methods contaminate the environment and pose risk to public health.

The production of biodiesel from waste cooking oil is one of the best ways to utilize it efficiently and economically. The data on the requirements of diesel fuel and availability of waste biomass sources in Hebron indicates that the biodiesel obtained from waste cooking oil and animal fats may not replace diesel fuel completely. But, a substantial amount of diesel fuel can be obtained from waste cooking oil and animal fats, which would partly reduce the dependence on petroleum-based fuel.

Biomass is one of the best sources of energy. Fuels from renewable biomass have the potential to reduce the amount of green house gases and particulate matter. This is because the carbon contained in biomass derived fuel is biogenic and renewable. Therefore, petroleum based fuels can be complemented by fuels obtained from renewable sources.

1.2 Importance of the Project

1- The evaluation of biological wastes amounts possible to be used for the production of Biodiesel in Hebron district.
2- The evaluation of economical and environmental reflections of the production of diesel from the biological wastes locally.
3- Design and construction a plant for the purpose of production of Biodiesel from biological wastes.
4- The production of Biodiesel from biological wastes locally.
5- Supporting the contribution with local industry.
6- Spread the cultural protection and saving in the local society.

1.3 Connections between the Project and Benefited Parties

This project is oriented basically towards local industry, which gives information about the ability of production of biodiesel from animal fats and waste vegetable oil. This project supports local industry from these sides:

1- Financial benefits from recycling of fats and oils from biological resources resulted from the process of food production instead of disposability which is expensive economically and environmentally.

2- Provide industrial investments chances in the field of collection and recycling of biological wastes locally.

3- The help of public institution to develop policies required for health and environment protection in addition to encouragement and support local industry.

1.4 Literature Review

Biodiesel production and all related issue are well studied internationally. some literature review like [1], [2], [3], [4], [5], provide some studies about producing the alternative fuel (biodiesel) from biomass like vegetable oils and animal fats with a limit study about the quantity of waste oil in small regions, a financial study to produce it.

1. Biodiesel production in USA

This project was done in Carolina city in USA; the farmers organized themselves in a self sufficient system to produce biodiesel from soybeans and canola. They examined the financial consideration to produce biodiesel, and they also determined the model of the processors, and studying the environmental impact. [1]

2. Biodiesel production at MIT, USA

This project was done in MIT University in the mechanical Engineering department. They constructed a processor that would convert waste vegetable oil from campus dining facilities into biodiesel to be mixed with regular diesel fuel. They estimated that the biodiesel could be used to replace 5,000 gallons per year. [2]

3. Chemical process of Biodiesel production

This project was done in Al-Najah National University, chemical department by Mohamed Manasra and Bilal Ash-Shayb, under the supervision of Dr. Husni Odeh.

This project purposes to produce an alternative diesel fuel from used cooking vegetable oil. They made a limit statistics of waste cooking oil in small reign in Nablus, they performed many experiments on the produced biodiesel and they compared many values such as, flash point, viscosity, oxidation stability, with ASTM specifications. [3]

4. Biodiesel Production in UK

This project was done by the Wales environment trust in UK. It was done to produce biodiesel from waste cooking oil; production plant was design and built to produce sufficient biodiesel to eight vehicles.

The plant was designed to be suitably sized for fuel required by waste cooking oil whish was available to collect. The total fuel consumption of the vehicles was approximately 1500 litter per week, about 75 tones per year. [4]

5. Automated biodiesel processor at snuffard fuels

This project was done by Stephen Huffard, Andrew Masters, Mark Simmons and Taylor Williams, the main aim of this project is to design a small continuous plant for biodiesel production, it is full automated uses microprocessor, solenoids, electrical pH meter...etc; to control the flow and the process. [5]

1.5 Project Schedule

Table 1.1 Project time-schedule for first semester

process	Week														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Collecting Data and Literature															
Analyzing of data															
Industrial Plants Survey															
Home Survey															
Conclusion And Suggested Design															
Writing The documentation															

Table 1.2 Project time-schedule for second semester

process	Week														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Building the Plant	■	■	■	■	■	■									
Biodiesel Production							■	■	■	■					
Biodiesel Testing								■	■	■	■				
Running ICE											■	■			
Writing Documentation													■	■	■

Collecting data and literature were the first two stages, which started early and passed within eight weeks. Here, resources literatures, and researchers were carefully studied, discussed and analyzed.

Industrial plant and home survey took place as a third step, and started just after finishing collecting and analyzing data. Our team evenly distributed to cover the amounts of waste cooking oil in Hebron district, while the survey of home done by distributed a questionnaire which is our way to get the needed information.

Home survey and questionnaires results to be analyzed by simple proportional relations.

For the second part of this project our team works on designing and building a plant for biodiesel production, then a samples of biodiesel will be produced and tested.

Finally, writing the documentation research was started after finishing the previous steps.

1.6 Project Budget

The apparatus requirements are chemical materials (methanol, sodium hydroxide...), laboratory instrument, tanks, piping and fittings, heater, valves, pumps, blender…..).

The budget of the project also includes printing costs and local study and survey. The following table shows the estimated cost of each one.

Table 1.3 Project budget

Element	Description	Availability	Students	DSR Grant
Plant	Settling and washing tanks			750
	Supporting stands			350
	Mixing tank		30	
	Valves and fitting			400
	Mixer			150
	Piping			30
	Paint			10
	Electric centrifugal pump			150
	Heater			70
	Machining (Lathe and welding)			100
Experimentation	Diesel engine for testing	M.E department Work shop		
	Methanol and NaOH		100	
	Chemistry Lab tools	Chemistry lab in PPU		
	Testing samples	Petropal Company		
Miscellanies	Printing and preparing documentation		500	
Survey and Local study	Visits to companies, shops, and homes		500	
Total cost (NIS)	3230		1130	2100
Total cost($)	923		323	600

1.7 Report content

This chapter presents the general idea of the project and its importance, in addition the field of application and specialization also, in addition conduct the literature reviews of the previous studies about this project, this chapter also includes the time plan for all over the project, and the tools, equipments, materials that are used in the project, and finally the total cost.

Chapter two presents an introduction about biodiesel, historical perspective, the definition of biodiesel with the advantages of it, and also the disadvantage, then it describes how to overcome the disadvantages, in addition of that the emission of biodiesel and finally the impact of biodiesel on environment and health.

Chapter three present the biomass resources in Hebron district and how it disposed, in addition to that it provide the quantities of waste oil and animal fats, and presents the risks of waste oil on human and environment.

Chapter four discuss the process of biodiesel production including purification, titration, mixing methanol with the catalyst then with waste cooking oil, settling and washing of biodiesel and glycerin.

Chapter five presents the plant design of biodiesel processor and discussed its component in details, then economical study for plant and biodiesel is analyzed in detail and calculating the cost of one liter of biodiesel, its cost is compared with imported petroleum diesel

Chapter six presents the tests that will be done on the produced Biodiesel and its results.

Chapter seven discusses the recommendations and conclusions.

Chapter Two

Biodiesel

Content:

Chapter Two

Biodiesel

2.1 Introduction

The industrial revolution in the recent years with the increase in population increases the demand for energy in a continuous manner, and as it is known, the main source of used energy nowadays in all aspects of daily life is restricted at most within petroleum, natural gas, coal, hydro and nuclear energy.

Petroleum diesel continues to be a major fuel world wide. The most of this is utilized in the transportation sector. The major disadvantage of using petroleum-based fuels is that, day by day, the fossil fuel reserves are decreasing. Another disadvantage is atmospheric pollution created by the use of petroleum diesel. Petroleum diesel combustion is a major source of greenhouse gas. Then many industrial countries began to search about alternatives of petroleum based fuel. They suggest using solar, wind, water, and biomass energy, as a result of several researches it was discovered that the vegetable oil can be used as fuel after converted to alkyl esters compounds by reacting with suitable alcohol mainly methanol and the final product was called Biodiesel.

2.2 Historical Perspective

In 1900, Rudolf Diesel demonstrated his compression ignition engine at the World's Exhibition in Paris. In that prototype engine he used peanut oil, the first biodiesel. Vegetable oils were used until the 1920's when an alteration was made to the engine enabling it to use a residue of petroleum diesel. Although the diesel engine gained worldwide acceptance, biodiesel did not. With superior price, availability, and government subsidies, petroleum diesel quickly became the fuel of choice for the diesel engine.

In the mid 1970s, fuel shortages revived interest in developing biodiesel as an alternative to petroleum diesel. However, as the petroleum market was increasingly subsidized, biodiesel was again relegated to a minority “alternative” status. This political and economic struggle continues to limit the impact of the biodiesel industry today.

Now, increasing concerns about the potential of global climate change, declining air and water quality, and serious human health concerns are inspiring the development of biodiesel, as a renewable, cleaner burning diesel alternative. Biodiesel is made from recycled vegetable oil and various feedstocks (biomass sources). As part of an active carbon cycle biodiesel feedstock production reduces the buildup of greenhouse gases, and in turn, global warming. [6]

2.3 What is Biodiesel?

Biodiesel is defined as the mono-alkyl esters of fatty acids derived from vegetable oils or animal fats. In simple terms, biodiesel is the product obtained when a vegetable oil or animal fat is chemically reacted with an alcohol to produce fatty acid alkyl esters. A catalyst such as sodium or potassium hydroxide is required. Glycerol is produced as a co product.

The approximate proportions of the reaction are

100 g of oil + 10 g of methanol → 100 g of biodiesel + 10 g of glycerol

Glycerin which is the main byproduct has a numerous uses, including many applications as an ingredient or processing aid in cosmetics, toiletries, personal care, drugs, and food products [8].

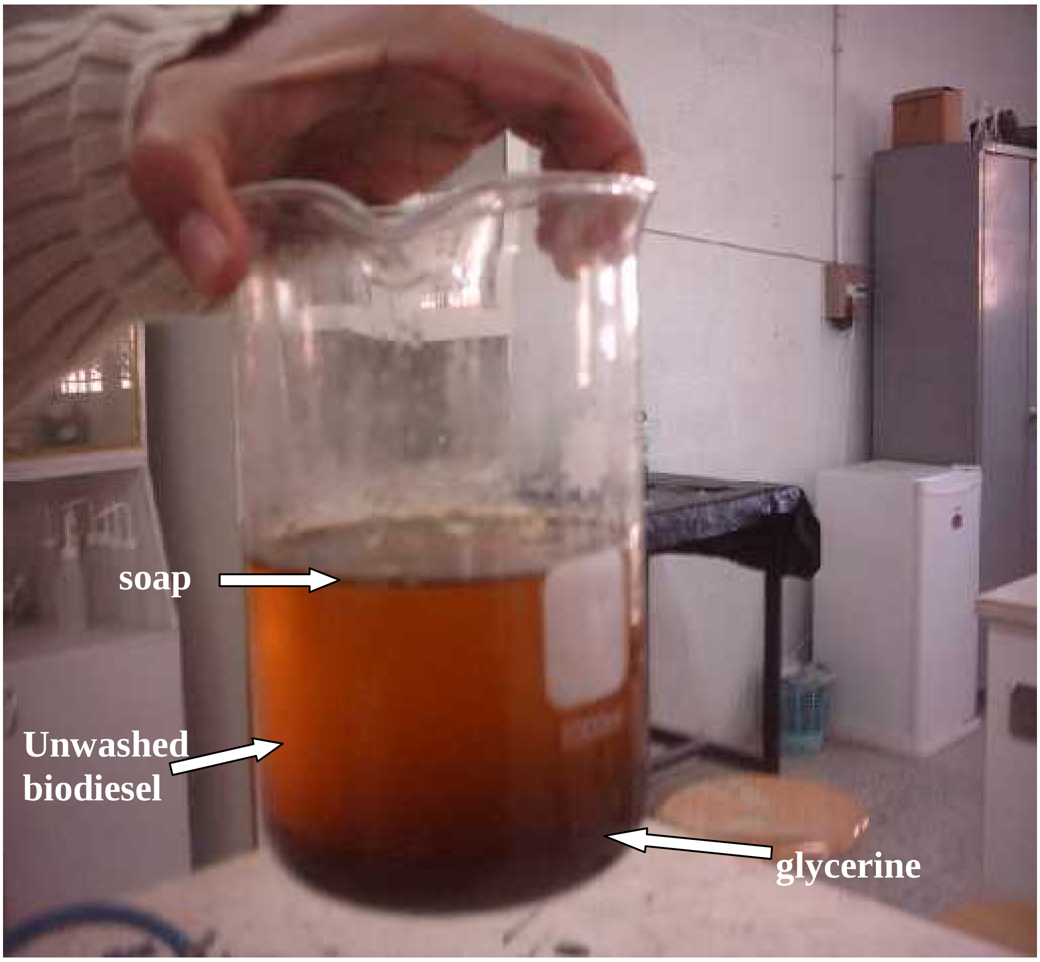


Figure2.1 Biodiesel sample

For figure 2.1 this sample of Biodiesel is produced in PPU by our team.

Biodiesel can also be made from other feedstocks:

1. Other vegetable oils such as corn oil, canola (an edible variety of rapeseed) oil, cottonseed oil, mustard oil, palm oil, etc.
2. Restaurant waste oils such as frying oils
3. Animal fats such as beef tallow or lard
4. Trap grease (from restaurant grease traps), float grease (from waste water treatment Plants), etc. [7]

2.4 Advantages of Biodiesel

Biodiesel can be used in several different ways. one can use 1% to 2% biodiesel as a lubricity additive, which could be especially important for Ultra Low Sulfur Diesel fuels (ULSD, less than 15 ppm sulfur), which may have poor lubricating properties. It can blend by 20% Biodiesel with 80% diesel fuel (B20) for use in most applications that use diesel fuel. Also it can be even use in its pure form (B100) if proper precautions are taken. The word biodiesel in this thesis refers to the pure fuel (B100) that meets the specific biodiesel definition and standards approved by ASTM International. A number following the “B” indicates the percentage of biodiesel in the volume fuel.

Today, B20 is the most common biodiesel blend in the world because it balances property differences with conventional diesel, performance, emission benefits, and costs. Higher blend levels, such as B50 or B100, require special handling and fuel management and may require equipment modifications such as the use of heaters or changing seals and gaskets that come in contact with the fuel to those compatible with high blends of biodiesel. The level of special care needed largely depends on the engine and vehicle manufacturer.

Biodiesel-fueled vehicles are called non-dedicated flexible fuel vehicles because biodiesel use does not require any significant modifications to the engine, so that the engine does not have to be dedicated for biodiesel use only. It is completely soluble in commercial petroleum-based diesel fuel, so **biodiesel can be used as a blend and one fuel tank can be used for storage of both fuels**. This makes the vehicle flexible. This is a unique advantage compared with most other alternative fuels, because this will give users the opportunity to use the alternative fuel where and when it is available without paying any extra money for engine modifications.

Biodiesel is a renewable fuel manufactured from vegetable oils, animal fats, and recycled cooking oils. Biodiesel offers many advantages:

1. It is renewable.
2. It is energy efficient equivalent to petroleum diesel.
3. It potentially replaces petroleum derived diesel fuel.
4. It can be used in most diesel equipment with no or only minor modifications.
5. It can reduce global warming gas emissions because of the plant life cycle.
6. It can reduce tailpipe emissions, including air toxics.
7. It is nontoxic, biodegradable, and suitable for sensitive environments
8. Reduction in emissions of:
    a. Sulfur dioxide by 100%
    b. Soot emissions by 40-60%
    c. Carbon monoxide by 10-50%
    d. Hydrocarbons by 10-50%
    e. Nitrous oxide by 5-10%, depending on engine tuning and the age of the engine. Nitrous oxide emissions may increase in some instances.
9. Readily mixes with petroleum diesel fuel in any ratio
10. It has a higher flash point than petroleum diesel and thus helps prevent damaging fires. [8]
11. Biodiesel (B100) contains 11% oxygen by weight. The presence of fuel oxygen allows the fuel to burn more completely so fewer unburned fuel emissions result. [9]

12. Biodiesel has a higher cetane number than diesel fuel, which is provided easier starting, and quieter operation, better ignition quantity, shorter ignition delay.

Most of the B100 made today that meets D6751 has a cetane number higher than 47. This is compared to the minimum of 40 for highway diesel fuel, whose national average is between 42 and 44. Therefore, biodiesel has a higher cetane number than most U.S. diesel fuel, which is believed to provide easier starting and quieter operation. Highly saturated B100, such as animal fats and used cooking oils, can have a cetane number of 70 or higher. Common polyunsaturated fuels that contain high levels of C18:2 and C18:3 fatty acids include soy, sunflower, corn, and canola (rapeseed) oils. These will be at the lower end of the scale, at 47 or slightly higher. Figure 2.1 shows the cetane number of various biodiesel samples. [8]

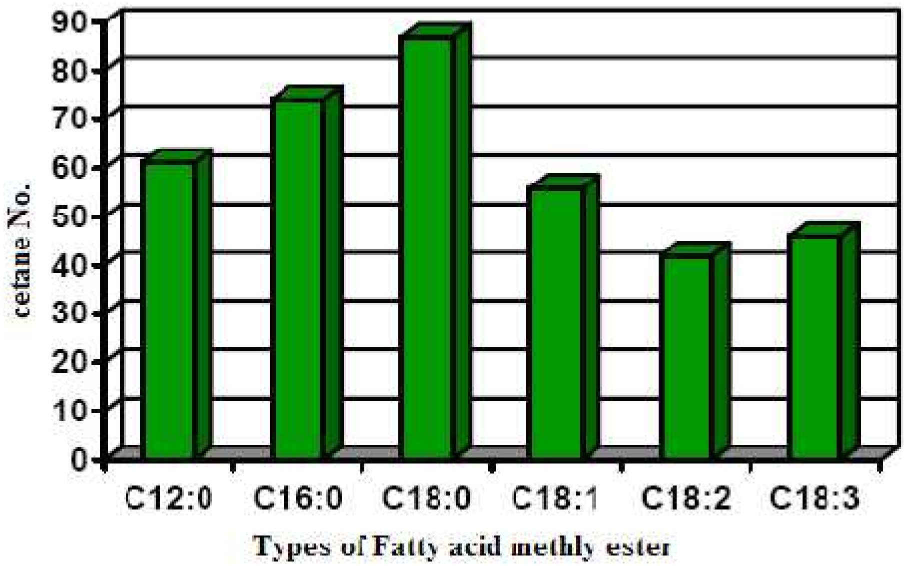


Figure2.2 Cetane number of fuels made from pure fatty acids

Table2.1 Fuel properties as a function of fuel composition in diesel engines

	Saturated	Monounsaturated	Polyunsaturated
Fatty acid	12:0,16:0 18:0,20:0, 22:0	16:1, 18:1, 20:1, 22:1	18:2, 18:3
Cetane Number	High	Medium	Low

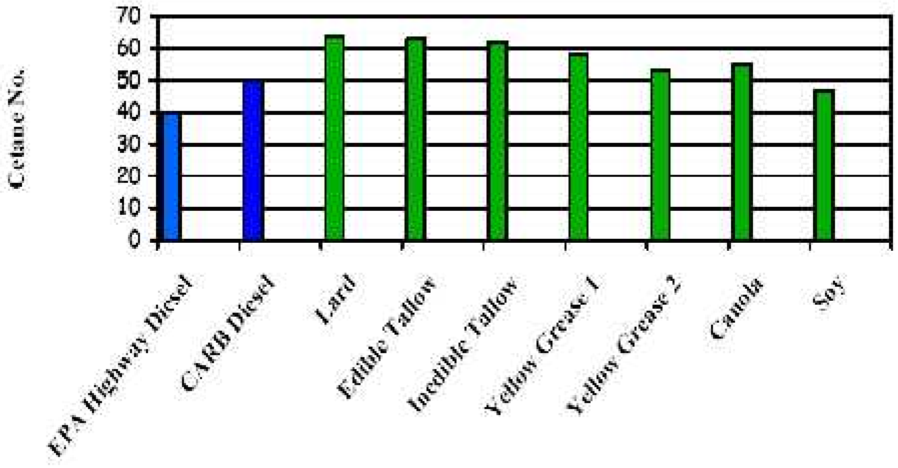


Figure2.3 Cetane number of fatty acid methyl esters, petroleum diesel and various biodiesel fuels

2.5 Biodiesel Disadvantages:

1. Biodiesel is a solvent that can be incompatible with the rubber seals and gaskets in the fuel systems of some types of diesel vehicles. If users have not taken measures to properly adapt their engines to run on biodiesel, dissolution of dirt and rubber can result in clogged engine and fuel lines. As such, pure B100 cannot be safely used as a stand-alone fuel in conventional vehicles.

2. The energy content of biodiesel is lower than that of petroleum diesel. As a result, vehicles running on any blend of biodiesel will experience a small reduction in fuel economy (miles per gallon). [10]

3. The use of biodiesel in cold weather presents certain challenges. All diesel fuel “clouds” at low temperatures. Clouding indicates the formation of wax crystals, which can inhibit proper flow of fuel to the engine and clog fuel lines or filters. Conventional petrodiesel begins to cloud at approximately 0° F, while B100 has a clouding point of about 30° F .The higher clouding temperature is an important consideration for the use of biodiesel during cold winters. [11]

4. Nitrogen oxide emissions are increased for biodiesel combustion versus petrodiesel combustion.

2.6 Overcoming Disadvantages of Biodiesel Blends

Many of the disadvantages associated with neat biodiesel can be overcome by using Biodiesel blends, which consist of petrodiesel mixed with a specified quantity of biodiesel. Biodiesel blends are labeled BX, where X is a number that indicates the percentage of biodiesel in the blend. For example, B20 is a mixture of 80 percent petrodiesel and 20 percent biodiesel. Common blends include: B2, B5, B10, and B20. Biodiesel blends can overcome the inherent disadvantages of B100 in the following ways:

1. Blends up to a B20 (or even B35 in some cases) can be used with no alterations to a standard diesel engine.
2. The use of certain additives can prevent cold-weather clogging issues associated with biodiesel use in the winter months.

3. The addition of varying amounts of kerosene (depending on which biodiesel blend is used) has the ability to reduce nitrogen oxide emission. [12]

2.7 Emissions of Biodiesel

Diesel engines always operate well on the lean side of stoichiometric, which means that CO emissions will be low, and regulations will easily be met. When one considers the chemistry of biodiesel, the CO emissions will be even lower. Because biodiesel is approximately 11% oxygen by weight, there will be extra oxygen to react with during the combustion process, allowing for more complete burning. In addition to reducing the amount of unburned hydrocarbons, this should reduce the emission of CO.

Furthermore, biodiesel has a lower carbon-to-hydrogen ratio than conventional petrodiesel. It was found that biodiesel blends with the lowest carbon content formed the least CO, and all biodiesel emitted less CO than petroleum diesel. This makes intuitive sense, because, with less carbon in the fuel, there is a better chance that each carbon atom will find two oxygen atoms to bind. The decrease in CO emissions that was noticed with an increase in loading can also be simply explained. When the load on the engine is higher, the gas inside the cylinder will naturally be at a higher temperature. This speeds up the conversion rate of CO to CO_2, completing the combustion process and lowering CO emissions.

The oxygen content by weight of the biodiesel as a reason why NOx emissions increase. They reason that because the fuel itself contains oxygen, there will be more oxygen available to react with the nitrogen in the air. However, the increase in NOx is unexpected based on some of the biodiesel fuel properties, since a higher cetane number and lower energy content are usually associated with lower NOx.

Hydrocarbons are also a contributing factor in the creation of smog and ozone. Hydrocarbon emission, also called volatile organic compound (VOC) in atmospheric chemistry, is the main ingredient to the creation of photochemical smog. The oxidation reaction of the VOCs leads to the creation of ozone and aldehydes. The product ozone is also toxic. Ozone has poor solubility properties which, when taken into the lungs, can cause inflammation due to oxidization of lung tissue.

The consequences of local ozone formation also include detrimental effects on crop yields and the faster wearing of tires. When hydrocarbons are combined with NOx emissions, more volatile reactions resulting in ozone formation are possible. NOx emissions are an important emission of automobile exhaust. The reduction of hydrocarbons effectively means a reduction of many harmful consequences of hydrocarbon release into the environment.

The overall ozone (smog) forming potential of Biodiesel is less than Diesel fuel. The ozone forming potential of the speciated hydrocarbon emissions was nearly 50 percent less than that measured for Diesel fuel. Sulphur emissions are essentially eliminated with pure Biodiesel. The exhaust emissions of sulphur oxides and sulfates (major components of acid rain) from Biodiesel were essentially eliminated compared to sulphur oxides and sulphates from Diesel. [13]

Table2.2 provides the percentage changes in various emissions (relative to those from conventional petrodiesel) for various biodiesel blends. Generally, as the percentage of biodiesel blended with diesel increases, there is a concomitant reduction in harmful emissions. A notable exception is NOx emissions, which increase slightly with biodiesel use.[15] (For detail see appendix B)

Overall, however, biodiesel has the potential to reduce harmful emissions from current levels by up to 80 percent. This is equivalent to removing roughly.

Table 2.2 Percentage changes in emissions from various blends of Biodiesel relative to petrodiesel.

% Biodiesel	PM	HC	CO	NOx	SOx	CO_2
1	-0.64	-1.11	-0.65	0.10	-1.00	-0.78
5	-3.14	-5.44	-3.23	0.49	-5.00	-3.92
10	-6.18	-10.59	-6.35	0.98	-10.00	-7.85
20	-11.99	-20.06	-12.30	1.98	-20.00	-15.69
30	-17.43	-28.53	-17.87	2.98	-30.00	-23.54
50	-27.33	-42.86	-27.97	5.02	-50.00	-39.23
80	-39.99	-59.16	-40.84	8.15	-80.00	-62.96
100	-47.19	-67.36	-48.11	10.29	-100.00	-78.45

These data are graphically illustrated in Figure 2.4.

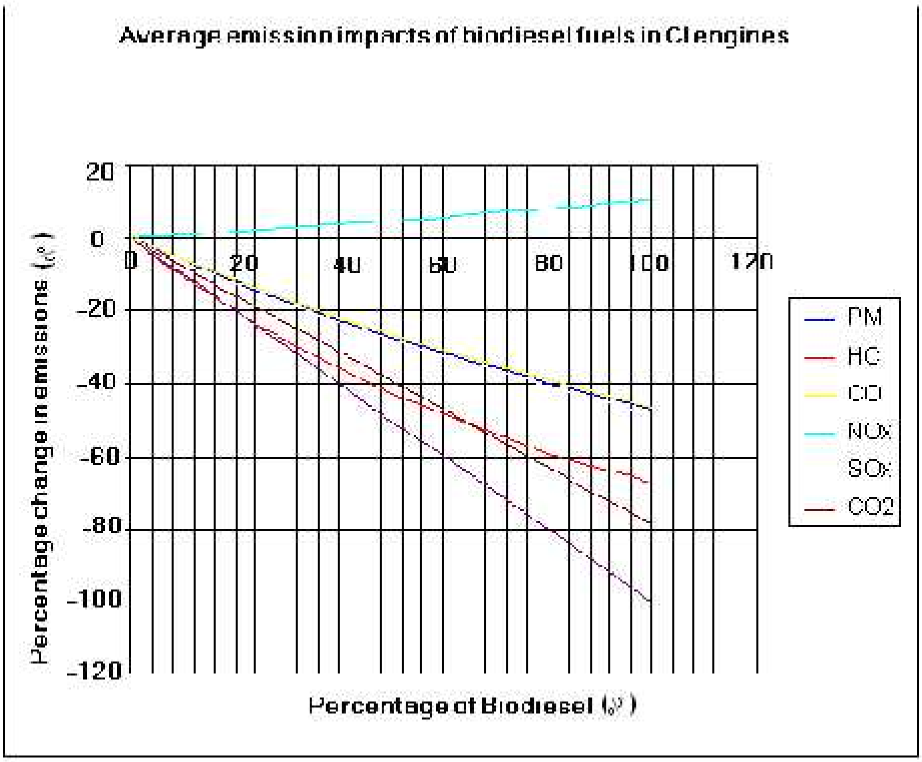


Figure 2.4 Average emission impacts of biodiesel fuels in CI engines

According to the previous figure carbon dioxide is one of the main greenhouse gases contributing to global warming. Neat Biodiesel (100% Biodiesel) reduces carbon dioxide emissions by more than 75% over petroleum Diesel. But using a blend of 20% Biodiesel reduces carbon dioxide emissions by 15%. Biodiesel also produces fewer particulate matter, carbon monoxide, and sulphur dioxide emissions.

The use of Biodiesel has significant benefit when it comes to supporting the environment. Biodiesel is the first and only alternative fuel to have a complete evaluation of emission results and potential health effects.

According to figure2.4 it can make a comparison of emission between diesel and Biodiesel.

1. Carbon Monoxide: The exhaust emissions of carbon monoxide (a poisonous gas) from Biodiesel were 50 percent lower than carbon monoxide emissions from Diesel.

2. Particulate Matter: Breathing particulate has been shown to be a human health hazard. The exhaust emissions of particulate matter from Biodiesel were 30 percent lower than overall particulate matter emissions from Diesel.

3. Hydrocarbons: The exhaust emissions of total hydrocarbons (a contributing factor in the localized formation of smog and ozone) were 93 percent lower for Biodiesel than Diesel fuel.

3. Sulphur oxides: Sulphur emissions are essentially eliminated with pure Biodiesel. The exhaust emissions of sulphur oxides and sulfates (major components of acid rain) from Biodiesel were essentially eliminated compared to sulphur oxides and sulphates from Diesel.

4. Nitrogen Oxides: NOx emissions from (100%) Biodiesel increased in this by 13 percent. However, Biodiesel's lack of sulphur allows the use of NOx control technologies that cannot be used with conventional Diesel. So, Biodiesel NOx emissions can be effectively managed and efficiently eliminated as a concern of the fuel's use.

2.7.1 How to solve the problem of NOx

The high level of NOx emissions is the major obstacle standing in the way of broad support for biodiesel, and much research has been devoted to its reduction, particularly in light of stringent exhaust emission regulations being imposed on diesel engines over the next few years. One popular method of reducing NOx emissions is exhaust gas recirculation (EGR). EGR reduces engine temperature by pumping a portion (10-25%) of exhaust gas back into the intake. Because the exhaust gas is nearly inert, it will not react in the combustion chamber and acts only as a heat sink. A small power loss is associated with EGR systems, but NOx emissions are decreased by up to 80%.

Another option to reduce NOx emissions is to install a catalytic converter. However, they work best at the stoichiometric ratio, so it will not be as effective on a diesel engine. They are also expensive and work better at high temperatures, while diesel exhaust is generally lower than gasoline exhaust. Selective noncatalytic reduction, diesel oxidation catalysts, water-fuel emulsions, and NOx and particulate traps have also been used to reduce NOx emissions on biodiesel engines. All of these methods, however, are only solving the problem of biodiesel NOx emissions indirectly, by removing the NOx after it are created.

Many studies of biodiesel combustion have found that the start of injection timing is advanced. This should result in a higher peak temperature inside the cylinder due to more premixed combustion, which will increase the rate of NOx production. This will also result in a longer residence time, allowing NOx production to continue for more time. In fact, It was found that a linear relationship between NOx emission and injection timing. The retard (delay) of injection timing lowered the NOx emission for all the biodiesel fuel blends. It has been pointed out that there was a NOx emission reduction of 35% to 43% for all biodiesel fuel blends at 3° retarded injection timing relative to the 3° advanced injection timing for the same fuel at the same load and speed condition. [13]

2.8 Impacts of Biodiesel on Health

Biodiesel emissions show decreased levels of Polycyclic Aromatic Hydrocarbons (PAH) and Nitrated Polycyclic Aromatic Hydrocarbons (nPAH), which have been identified as potential cancer causing compounds. In Health Effects testing, PAH compounds were reduced by 75 to 85 percent, with the exception of benzo(a)anthracene, which was reduced by roughly 50 percent. Targeted nPAH compounds were also reduced dramatically with biodiesel, with 2-nitrofluorene and 1- nitropyrene reduced by 90 percent, and the rest of the nPAH compounds reduced to only trace levels. [14]

2.9 Environmental Impacts of Biodiesel

The production and use of biodiesel creates 78% less carbon dioxide emissions than conventional diesel fuel. Carbon dioxide is a greenhouse gas that contributes to global warming by preventing some of the sun's radiation from escaping the Earth see figure 2.5. Burning biodiesel fuel also effectively eliminates sulfur oxide and sulfate emissions, which are major contributors to acid rain. That's because, unlike petroleum-based diesel fuel, biodiesel is free of sulfur impurities. Combustion of biodiesel additionally provides a 56% reduction in hydrocarbon emissions and yields significant reductions in carbon monoxide and soot particles compared to petroleum based diesel fuel. Also, biodiesel can reduce the carcinogenic properties of diesel fuel by 94%. [15]

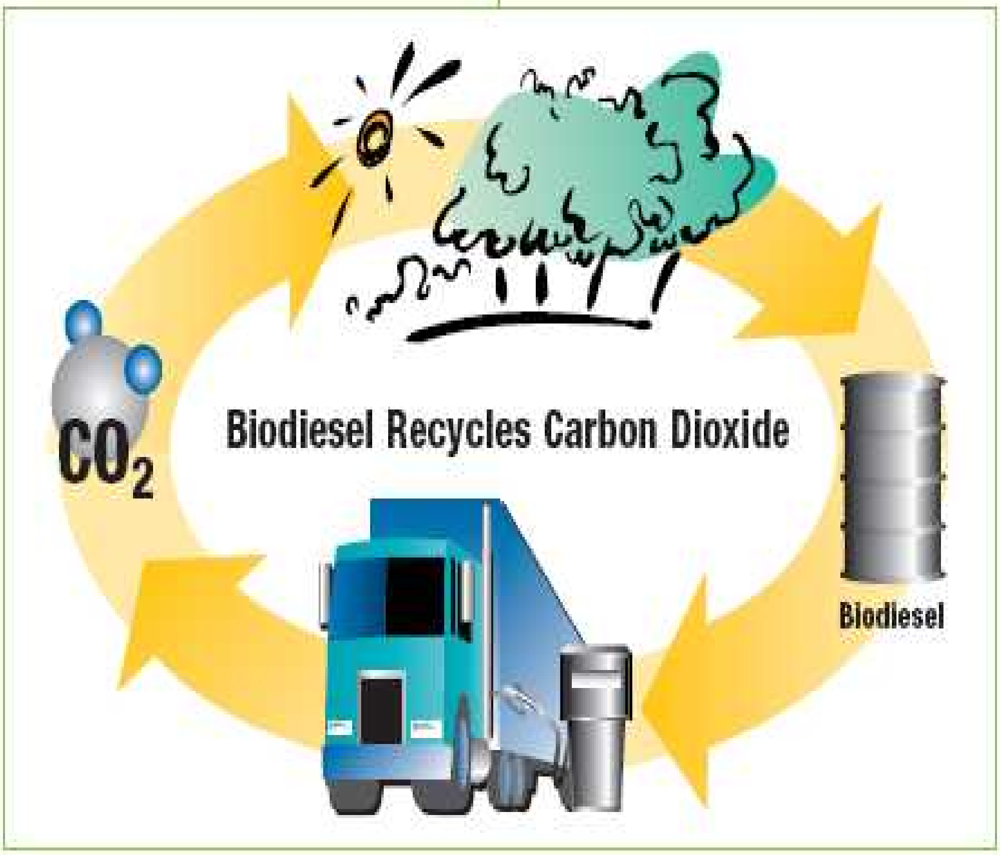


Figure2.5 Biodiesel recycles carbon dioxide

Chapter Three

Biomass Sources for Biodiesel Production; Statistical Study in Hebron District

Content:

Chapter Three

Biomass Sources for Biodiesel Production; Statistical Study in Hebron District

3.1 Introduction

Considering Hebron district can be found that there are many sources for Biodiesel production, whether from restaurants, fast food shops and houses. This shows that the district is heavily dependent on oil frying in the preparation of fast food restaurants, during that must be large quantities of waste oil could be present after use. In addition to that, Hebron district consume a large quantities of meat and livestock, which contains large amounts of fats that can be used in the production of Biodiesel instead of destroying it and cause environmental pollution and negative impact on public health.

Used cooking oils and animal fat can be considered as a waste that is generated from activities in the food sector (industries, restaurants and home use), which has greatly increased in recent years. This requires alternatives for their recycling. The main uses at present are:

1- In animal feed.
2- In the manufacture of soaps.
3- Biodegradable (although not recyclable) lubricants.
4- For combustion (recovery of energy in industrial plants), which may include converting the cooking oils to Biodiesel.

The reason of using waste cooking oil and fats in animal feed is to produce high energy diets for certain intensive livestock enterprises. The use of recycled cooking oils in animal feed needs careful attention from point of view, because in frying cooking oil is heated to a temperature of 170-220 degrees Celsius. Upon heating, cooking oil may undergo chemical reactions, hydrolysis, oxidation and polymerization. Degradation products such as free fatty acids, hydro peroxides and polymerized triglycerides may be formed. Besides, therefore during frying, many harmful compounds are formed and, if the waste cooking oil is used as an additive to feeding mixtures for domestic animals, then it could result in the return of harmful compounds back into the food chain through the animal meat. Hence, the waste cooking oil must be disposed of safely or be used in a way that is not harmful to human beings. [16]

3.1.1 How Waste Oil Disposed

Generally waste cooking oil is poured down drains or sewers. This inevitably leads to blockages and odors or vermin problems and may also pollute watercourses leading to problems for wildlife. Also waste cooking oil may be disposed of with the rest of catering or kitchen waste as it may cause spillages leading to odors or pollution problems.

It is noted that using waste cooking oil in production of Biodiesel fuel is the best way to reduce the risk on the environment and health; so by converting these oil into Biodiesel fuel can partly decrease the dependency on petroleum-based fuel.

3.2 Statistical and Survey Analysis

The work team held many extensive field visits during a period of about five weeks, the surveying process covered whole Hebron district including the city and all other rural areas, and the targeted fields were falafel shops, broasted chicken and ships factories (see appendix A). Hence; there was also a questionnaire that had been distributed to some main areas in the district.

On the other hand, another field visits had targeted meats and chicken shops, and also the project team had concentrated on larger shops such as meats and chicken slaughterhouses to collect the amounts of animals fats and grease that can be obtained from Hebron district.

After the field visits had been finished completely in hand with the questionnaire, there were main concluded information and data that had been studied carefully and analyzed with certain required calculations to attain the final shape of required data available. That is clearly shown in the following table.

Table 3.1 Annual available amounts of waste oil and animal fats in Hebron district

Region	House hold (liter)	Business (liter)	Animal Fats (Ton)
Hebron District	1047000	200400	911

Another thing that should be taken into account that it had been concentrated also on field visits to more formal and governmental associations including ministry of health in Hebron district and general petroleum corporation – Hebron branch, in addition to the Palestinian Centre for census and ministry of environment, also biotechnology center in Palestine polytechnic university – Hebron and college of agriculture in Hebron university – Hebron were also visited to cover all required information for the completion of this project.

3.2.1 Executive Summary

It is estimated that (200400) liters of waste vegetable oil arise from industrial sources annually in Hebron district only by the time of this study. Estimated for Hebron city is 150745 liter and for Hebron villages are 49640 liters respectively. In addition, up to 5 times this amount of waste oil may be available from households. And the amount of animal fats is 911 Ton's annually.

Only a small fraction of this is currently recycled. Currently use to manufacture animal feed or with soap production.

Waste Vegetable oil can be efficiently converted to biodiesel using a simple process. The estimated annual quantities of waste oil produced in Hebron district could produce around 1.085 million liters of Biodiesel fuel. And 0.93 million liter of Biodiesel from animal fats.

A Biodiesel blend provides a cleaner burning, more environmentally friendly substitute to ordinary diesel. No vehicle modifications are necessary.

Collecting waste oil and animal fats could create many jobs in Hebron district. The number of jobs could be increased by increasing of waste oil and animal fats. In addition, it will support Palestinian economy and increase national income.

3.2.2 Survey Results

It is estimated that between 1.1 and 1.2 million liters of waste vegetable oil arise from house hold and industrial sources annually in Hebron district, An even larger amount of household waste oil is available but the quantities involved are more difficult to be collected. Actually, 40% of waste cooking oil from industrial resources is used to make animal feed but thus will shortly be prohibited due to the risk of human health.

Biodiesel is one of the most promising of the alternative fuels. It is produced from vegetable oil or animal fats using fairly simple chemistry .It is non-toxic and rapidly biodegrades. It can be produced from new or waste oil and offers good performance together with a number of environmental benefits compared to ordinary petroleum diesel. If all the estimated quantity of waste vegetable oil and animal fats were collected and converted to biodiesel up to 2.2% of the total 94 million liter of petrodiesel consumed in Hebron district annually could be replaced using the petrodiesel fuel. This is a good and promising stand for reducing petroleum diesel usage. (For detail see appendix A)

3.2.3 Estimated Quantities Available for Producing Biodiesel

Table3.2 shows estimated annual quantities of waste cooking oil available for Recycling in Hebron district. These have been derived from simple proportional calculations for the populations by taking the average estimated Hebron district; the total quantity of house holed is 1047000 liter .and for business sources is 200400 liter. (For detail see appendix A).

Table 3.2 Available waste oil in Hebron district

Region	House hold (liter)	Business(liter)	Total(liter)
Hebron district	1047000	200400	1247400

The total quantity of house hold and industrial waste oil in Hebron district is 1247400 liter. Would be sufficient to produce 1.085 million liters of biodiesel per a year by assuming densities of 0.92 g/cm^3 for the waste oil, 0.88 g/cm^3 for bio-diesel. It is estimated that the amount of animal fats available annually in Hebron district is between 910 and 920ton. Which is sufficient to produce 930,000 liter of biodiesel. by assuming densities of 0.9g/ cm^3 for animal fats, 0.88 g/cm^3 for biodiesel.(for detail see appendix A)

Hence; animals fats has not been taken in consideration in the design due to some main reasons that restrict the main practical operation, because converting animal fats requires additional modifications on the system which are not convenient for the proposed design, due to the use of high concentration acid (Sulfuric Acid) that is not compatible with the material of the tanks used, and this method requires stainless steel tanks which are expensive.

The previous table has the amount of waste cooking oil available in Hebron district, but there is a ratio of that amount is usually used in animal feeding, soap manufacturing and other industrial activities.

Table 3.3 Collectable amounts of waste cooking oil in Hebron district

Field	Original amount (Liter)	Collectable ratio	Annual amount (Liter)
Citizens	1,047,000	0.10	104,700
Shops	200,400	0.30	60,120
total			164,800

The above table shows the practical collectable ratios of waste cooking oil. For example, in the field of citizens, previous studies showed that the international collectable average mean ratios from citizens was about 10%, and so, this ratio will be taken into account when making the final statistical analysis of the proposed design. Hence; this value may increase depending on the cooperation of people and formal associations.

In the field of shops, it has been noticed that the average collectable amount of oil will be about 30% of the total shops collected amount, because there is about 40% of oil is used in animal feeding, 20% in soap manufacturing and 10% for wood painting.

Total amount of collectable waste cooking oil is about 164,000 Liters, this amount is to be divided by 365 days to attain daily collectable amount, which is to be about 450 Liters per day.

The process of producing biodiesel (single batch) requires a time of about 36 hours, thus; the amount of oil is to be calculated in the case of two days, which is double of daily collectable amount, that is equal to about 900 Liters

The design will be for 10 years, taking into account, some main factors, such as incremental population (oil), so the increment of oil year by year may be of about

2%. After 10 years, the amount of oil which is used within two days will be about **1,100** Liters.

3.2.4 Employment Opportunities

Hebron district suffers from unemployment opportunities, because of bad economical and political conditions due to the Israeli occupation and the increment of importation rates from abroad, that resulted in closing many factories and workshops, and so; less number of workers required to be included in industrial plants and establishments.

Collecting waste cooking oil and animal fats to produce Biodiesel aims to create many jobs. This will create investment opportunities.

For a 100% collecting process rate of industrial waste, the amount of oil in Hebron district would be enough to sustain at least 4 Employment Opportunities, each collecting over 50,000 liters of waste cooking oil per year.

The same process above for collecting of animal fats, requires about 8 workers to achieve the aim, each one is responsible for collecting a quantity of about 11 Tons annually.

For household collection, about 10 workers are required; each one for collecting about 120,000 liters annually, but that ratio is difficult to be estimated because not all people may cooperate with this project, due to different variations in cultural backgrounds, and lack of awareness.

Also, another 5 workers are required to control the production process of Biodiesel, taking into account, that the whole process demands about 36 - 48 Hours, such that each 2 workers are responsible for a 8 Hours duty, to operate the machine, filtration, processing, titration, and Biodiesel washing.

3.3 Public Awareness and Difficulties

1. There is a little awareness about the importance of processing or converting waste cooking oil into useful fuel (Biodiesel).
2. There is no enough knowledge about fields where cooking oil is used.
3. The most common problem is using cooking oil for several times that causes a harmful risk for human and environment.
4. High percentage of people deposing waste cooking oil in drains system or in soil; through that, drains system will be clogged and environmental risk.

3.3.1 Home Survey Analysis

1. There are differences in the duration of using cooking oil for the same family members number.
2. It was found that about 58% of families in Hebron district deposed waste oil in drains system, 24% in soil and 18% in rubbish.
3. About 73% of families agree to collect the waste cooking oil to use it in this project,14% of families disagree about this idea and 13% of families didn't give any opinion

3.4 Risks to Environment

Recycled oils used as raw materials in feeds do not constitute consideration as a burden on the environment, with the exception of the change in faucal composition that they may cause. Other uses of these recycled oils (such as lubricants, in the manufacture of soaps, and for the manufacture of biofuels), present more specific characteristics of environmental risk, resulting especially from the semi-volatile nature of dioxins, PCBs and other hazardous substances they may contain. However, in principle, in normal oils a low level of contamination is to be expected.

Cooking oil may also have contaminants such as Polycyclic Aromatic Hydrocarbons (PAHs). These contaminants, if present in cooking oil, may be concentrated upon prolonged heating, or in some cases, present in smoke from the heating process. Some PAHs have been found to be potentially carcinogenic to humans. Furthermore, peanut oil may be contaminated by Aflatoxin, which is a kind of harmful substance in foods.

3.5 Risks to Human Health

Vegetable oils or frying oils are reactive substances that can undergo chemical changes during storage, heating or exposure to light. These chemical changes can create "breakdown products" in the oil, which are potentially harmful substances.

The common obvious changes are a darkening of colour, a thickening, a rancid odour, and sometimes a rancid taste. However, some breakdown products can only be detected by chemical laboratory analysis.

Oxidation is a major reason for the chemical breakdown of oil, but there are several other causes of degradation with potentially toxic effects. When oil contains more than specific levels of breakdown products, it is classified as "abused oil" or "over-used oil".

It is important to note that not all oil breakdown products are potentially harmful. Some products are harmless and are normal products of digestion. The speed of breakdown and level of breakdown products formed depends on the type of oil; as the higher the amount of unsaturated fatty acids (monounsaturates and polyunsaturates) the higher the rate of breakdown. Also, polyunsaturated oils, including soy, sunflower and canola, may have lower stability than monounsaturated oils like olive and palm oils. [18]

Chapter Four

Biodiesel Production

Content:

Chapter Four

Biodiesel Production

4.1 Introduction

In previous chapter light is concentrated on the potential available biomass resources in Hebron district. In this chapter the light is concentrated on the procedure of Biodiesel from the available resources.

Straight vegetable oil (SVO) can be used directly as a fossil diesel substitute however using this fuel can lead to some fairly serious engine problems. Due to its relatively high viscosity SVO leads to poor atomization of the fuel, incomplete combustion, coking of the fuel injectors, ring carbonization, and accumulation of fuel in the lubricating oil. The best method for solving these problems is the transesterification of the oil.

Biodiesel can be produced from straight vegetable oil, animal oil/fats, tallow and waste oils. There are three basic routes to Biodiesel production from oils and fats:

1. Base catalyzed transesterification of the oil.
2. Direct acid catalyzed transesterification of the oil.
3. Conversion of the oil to its fatty acids and then to Biodiesel.

Most of the Biodiesel produced today is done with the base catalyzed reaction for several reasons:

1. It is low temperature and pressure.
2. It yields high conversion (98%) with minimal side reactions and reaction time.

3. It is a direct conversion to Biodiesel with no intermediate compounds.
4. No exotic materials of construction are needed. [19]

For this reason only this process is adapted and explained in this thesis;

The technology of converting vegetable oils and animal fats into Biodiesel is a well established process. The most commonly used and most economical process is called the base catalyzed esterification of the fat with methanol, typically referred to as “the methyl ester process”. Essentially the process involves combining the fat/oil with methanol and sodium or potassium hydroxide. This process creates four main products - methyl ester (Biodiesel), Glycerine, feed quality fat and methanol that are recycled back through the system. The primary product, methyl ester, is better known as Biodiesel. The Glycerine and fats can be sold to generate added income from the process.

There are also many new technologies that are used with base catalyst transesterification of the oil like ultrasonic reactor, Batch process; Ultra- and high shear in-line reactors. These technologies can be run as batch or continuous processes given the limited size of the domestic market for Biodiesel. Continuous processes used in industrial processes (to produce methyl esters for uses other than as fuel) can use raw or may require refined oils. Batch processes provide excellent opportunities for quality control if variations in feedstock quality are common, such as with yellow grease and animal fats. Ultra- and High Shear in-line reactors allow producing bio-diesel continuously, therefore, reduces drastically production time and increases production volume. [20]

The Transesterification process is the reaction of a triglyceride (fat/oil) with an alcohol to form esters and glycerol. A triglyceride has a Glycerine molecule as its base with three long chain fatty acids attached. The characteristics of the fat are determined by the nature of the fatty acids attached to the Glycerine. The nature of the fatty acids can in turn affect the characteristics of the Biodiesel. During the esterification process, the triglyceride is reacted with alcohol in the presence of a catalyst, usually a strong alkaline like sodium hydroxide.

The alcohol reacts with the fatty acids to form the mono-alkyl ester, or Biodiesel and crude glycerol. In most production methanol or ethanol is the alcohol used (methanol produces methyl esters, ethanol produces ethyl esters) and is base catalyzed by either potassium or sodium hydroxide. Potassium hydroxide has been found to be more suitable for the ethyl ester Biodiesel production; either base can be used for the methyl ester. A common product of the transesterification process is Rape Methyl Ester (RME) produced from raw rapeseed oil reacted with methanol.

Figure 4.1 below shows the chemical reaction for methyl ester Biodiesel. The reaction between the fat or oil and the alcohol is a reversible reaction and so the alcohol must be added in excess to drive the reaction towards the right and ensure complete conversion. The products of the reaction are the Biodiesel itself and glycerol.

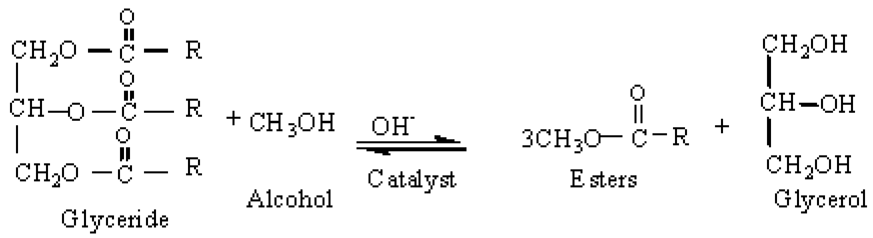


Figure4.1 Chemistry Transesterification Reaction

A successful transesterification reaction is signified by the separation of the ester and glycerol layers after the reaction time. The heavier, co-product, glycerol settles out and may be sold as it is or it may be purified for use in other industries, e.g. the pharmaceutical, cosmetics etc.

The engine combustion benefits of the transesterification of the oil are:

1. Lowered viscosity.
2. Complete removal of the glycerides.
3. Lowered boiling point.
4. Lowered flash point
5. Lowered pour point

4.2 Production Process Scheme

An example of a simple production flow chart is below.

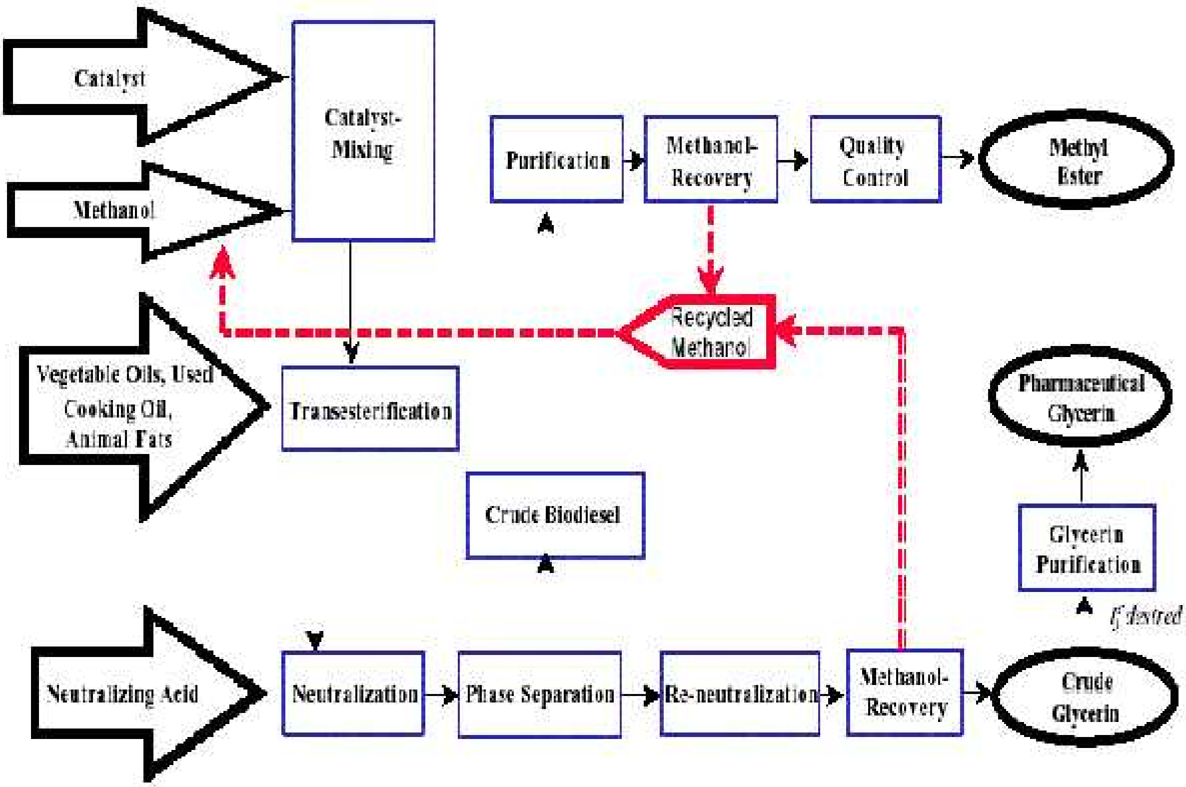


Figure4.2 Based catalyzed transesterfication for Biodiesel production

The following sections explain in detail the process:

4.2.1 Purification

When waste vegetable oil is used, it is filtered to remove dirt, charred food, and other non-oil material often found. Then, Water is removed because its presence causes the triglycerides to hydrolyze to give salts of the fatty acids instead of undergoing transesterification to give Biodiesel.

This is often accomplished by heating the filtered oil to approximately 120 °C. At this point, dissolved or suspended water will boil off. When the water boils, it spatters (chemists refer to it as "bumping"). To prevent injury, this operation should be done in a sufficiently large container (at most two thirds full) which is closed but not sealed.

4.2.2 Titration

For processing used oil, it's essential to titrate the oil to determine the Free Fatty Acid (FFA) content and calculate how much extra lye (NaOH) will be required to neutralize it. An electronic pH meter is best, but you can also use phenolphthalein solution (from a chemicals supplier) or sunflower leaves.

4.2.3 Mixing of Alcohol and Catalyst with Waste Oil

The catalyst is typically sodium hydroxide (caustic soda) or potassium hydroxide (potash). It is dissolved in the alcohol using a standard agitator or mixer Reaction. The alcohol/catalyst mix is then charged into a closed reaction vessel and the oil or fat is added. The system from here on is totally closed to the atmosphere to prevent the loss of alcohol. The reaction mix is kept just below the boiling point of the alcohol (around 71 C °) to speed up the reaction and the reaction takes place. Recommended reaction time varies from 1 to 8 hours, and some systems recommend the reaction take place at room temperature. Excess alcohol is normally used to ensure total conversion of the fat or oil to its esters. Care must be taken to monitor the amount of water and free fatty acids in the incoming oil or fat. If the free fatty acid level or water level is too high it may cause problems with soap formation and the separation of the Glycerine by-product downstream.

4.2.4 Separation

Once the reaction is complete, two major products exist: Glycerine and Biodiesel. Each has a substantial amount of the excess methanol that was used in the reaction. The reacted mixture is sometimes neutralized at this step if needed. The Glycerine phase is much denser than Biodiesel phase and the two can be gravity separated with Glycerine simply drawn off the bottom of the settling vessel. In some cases, a centrifuge is used to separate the two materials faster.

4.2.5 Alcohol Removal

Once the Glycerine and Biodiesel phases have been separated, the excess alcohol in each phase is removed with a flash evaporation process or by distillation. In others systems, the alcohol is removed and the mixture neutralized before the Glycerine and esters have been separated. In either case, the alcohol is recovered using distillation equipment and is re-used. Care must be taken to ensure no water accumulates in the recovered alcohol stream.

4.2.6 Glycerine Neutralization

The Glycerine by-product contains unused catalyst and soaps that are neutralized with an acid and sent to storage as crude Glycerine. In some cases the salt formed during this phase is recovered for use as fertilizer. In most cases the salt is left in the Glycerine. Water and alcohol are removed to produce 80-88% pure Glycerine that is ready to be sold as crude Glycerine. In more sophisticated operations, the Glycerine is distilled to 99% or higher purity and sold into the cosmetic and pharmaceutical markets.

4.2.7 Methyl Ester Wash

Once separated from the Glycerine, the Biodiesel is sometimes purified by washing gently with worm water to remove residual catalyst or soaps, dried and sent to storage. In some processes this step is unnecessary. This is normally the end of the production process resulting in a clear amber-yellow liquid with a viscosity similar to petrodiesel. In some systems the Biodiesel is distilled in an additional step to remove small amounts of colour bodies to produce a colourless Biodiesel.

4.2.8 Product Quality

Prior to use as a commercial fuel, the finished biodiesel must be analyzed using sophisticated analytical equipment to ensure it meets any required specifications. The most important aspects of biodiesel production to ensure trouble free operation in diesel engines are:

1. Complete Reaction.
2. Removal of Glycerine.

3. Removal of Catalyst.

4. Removal of Alcohol.

5. Absence of Free Fatty Acids. [19]

The figure below shows the Biodiesel production process. [21]

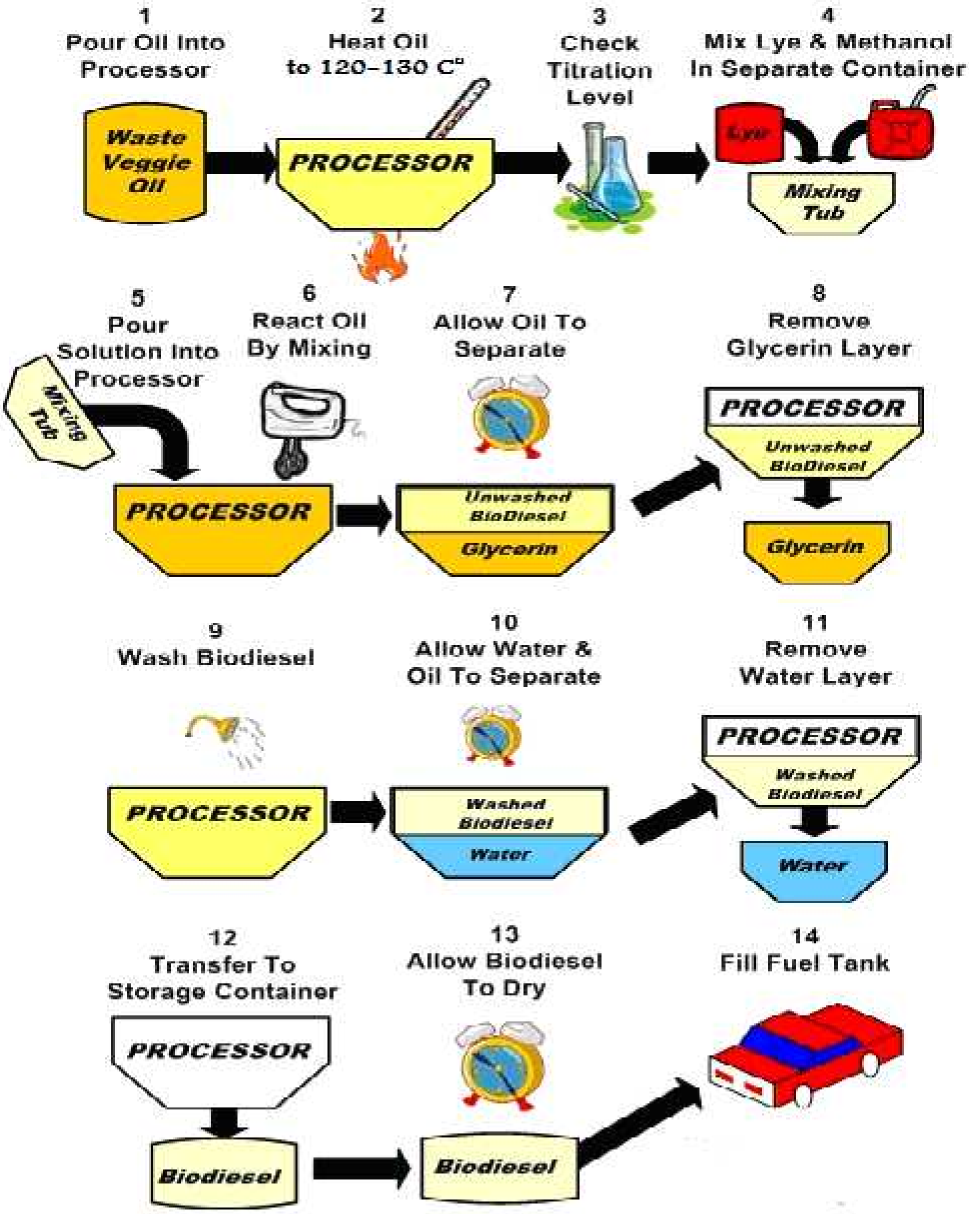


Figure4.3 Biodiesel production process description

Chapter Five

Plant Design and Economical study

Content:

Chapter Five

Plant Design and Economical study

5.1 Biodiesel Overview

With today's increasing demand for fuel and its continually rising cost, Biodiesel is becoming an extremely attractive fuel option. Also, to deal with the problems of pollution, there is a need for alternative fuels in today' society. Biodiesel as an alternative fuel has low emissions during use and manufacturing, and it even reduces the carbon monoxide in the atmosphere. It is also an attractive solution because of the low cost.

The Biodiesel process (see Figure 5.1) consists of mixing methanol and sodium hydroxide to make methoxide. For every liter of waste oil used, 6.5 grams of NaOH and 150 milliliters of methanol are required. The methoxide is added to the oil and mixed for about an hour. It is then left to settle for eight to twelve hours. The result will be a layer of unwashed Biodiesel (on top) and a layer of glycerin (on bottom). The Glycerin is drained off and the Biodiesel is poured into a container already containing water. The Biodiesel is pumped through the water for washing and removing excess lye. Then it should be left to be settled until the liquids have completely separated. Transparent fuel on top and waste water on bottom (about 8 hours). Finally, the top layer can be removed and used in any diesel engine.

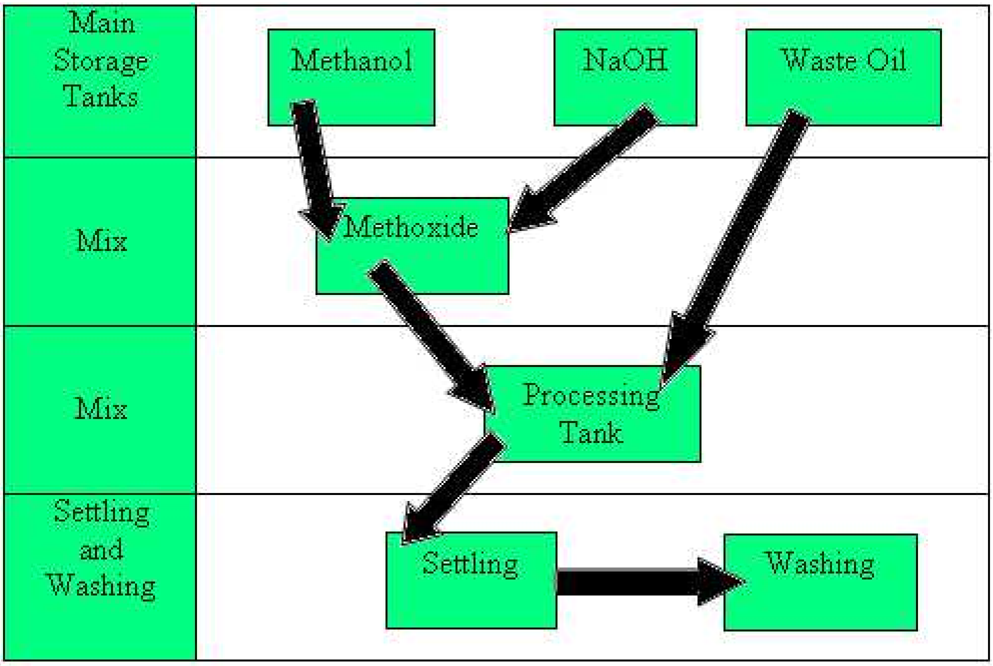


Figure 5.1 Block diagram of Biodiesel process

5.2 Reasons for not including Animal Fats in the Design

It should be recognized that in the case of animal fats, there are two methods of conversion which are super critical methanol at high pressure and temperature, and transesterification at low temperature and pressure.

In the case of super critical method, it operates on high pressure and temperature (80 bar and 240 °C), and it is not commercial. Also it has a high molar ratio, which means that the methanol used should be 42:1 mole ratio. On the other hand, this method has some advantages that it doesn't require a catalyst, and the whole operation is considered fast; that is the reaction time is about 4 min. [22]

Now, in the case of transesterification method, for animal fats, the designed system is slightly modified with the addition of an acid esterification vessel and storage for the acid catalyst. Animal fats is sometimes dried (down to 0.4% water) and filtered before loading the acid esterification tank.

The sulfuric acid and methanol mixture is added and the system is agitated. Similar temperatures to transesterification are used and sometimes the system is pressurized or a co-solvent is added. Glycerol is not produced. If a two-step acid treatment is used, the stirring is suspended until the methanol phase separates and is removed. Fresh methanol and sulfuric acid is added and the stirring resumes.

Once the conversion of the fatty acids to methyl esters has reached equilibrium, the methanol/water/acid mixture is removed by settling or with a centrifuge. The remaining mixture is neutralized or sent straight into transesterification where it will be neutralized using excess base catalysts. Any remaining free fatty acids will be converted into soaps in the transesterification stage. The transesterification batch stage processes as described above. [22]

As mentioned before related to the collectable amount of oil in Hebron district, the plant has been designed, without taking into account the amount of animal fats exist in the district, which covers the biggest amount for biodiesel production, because the methods of converting fats requires additional modifications on the plant, that is; tanks material type (galvanized steel) is not compatible with the added materials (sulfuric acids) for fats conversion process, which basically requires stainless steel tanks, which is very expensive if compared with the galvanized steel.

Collectable amount of oil within 48 hours has been found to be about 1,100 Liter, taking in consideration the incremental population, and the design is for about 10 years. This was discussed in details in chapter 3. So; the tanks design depends heavily on the used oil amount which is 1,100 Liter.

5.3 Considerations of Proposed Practical Design

- This design will be implemented in a flexible way this due the raise of people cooperation, the case of introducing more parts are possible without the change in the main shape and principle of operation of the whole intended design.
- In the first step, the initial phase will be designed using the available collectable quantity from the fields of business and citizens.
- All plant components are available in local market to insure the continuity of the plant operation

In the suggested design, a waste cooking oil storage tank is required, which can handle up to 5,000 Liters, a methoxide tank that can handle up to about 200 Liters (each 1 Liter oil requires 15% methoxide), a mixing tank which can handle up to about 1,400 Liters (1,000 oil + 150 methoxide), 2 settling tanks, each can handle up to about 1,400 Liters, 2 washing tanks, each can handle up to 1,400 Liters and a storage tank for biodiesel that can handle up to 5,000 Liters as shown in the figure

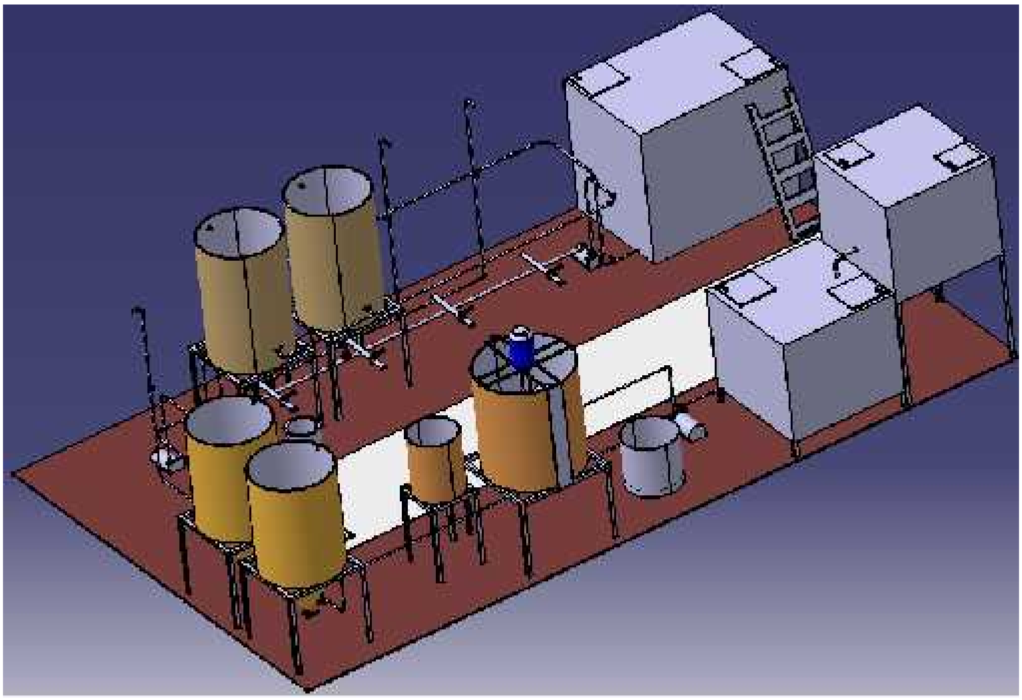


Figure 5.2 3D view for plant

5.4 Individual Component

5.4.1 Choosing Tanks Material Type

Different materials can be used for tanks which are compatible with chemical materials, it is recommended to use stainless steel or carbon steel. [23]

In Hebron district, many various types of material that can be used for making metallic tanks are available; the most available one with low cost is the galvanized steel. Galvanized steel is called so, because it is coated with zinc. This choice is to reduce production costs and to force people use available equipments within the same region.

Thus; this plant is to be designed using galvanized steel tanks. Also, it should be realized that those tanks can be operated within a suitable life time that can last for about 10 years, those tanks can firmly resist corrosion and decay effects in addition to rigidity. The thickness of outer surfaces of tanks is about 2 mm to serve the previous target.

For choosing the thickness of tanks are used:[24]

Sy : for galvanized steel is 334 MPa

$$P = {}^{\circ} \times g \times h; \qquad 5.1$$

Where:

P: pressure on walls (pa).

° : Density of oil (kg/m^3).

g: Gravity acceleration (m/s^2).

H: height of highest tank which is settling tank (m).

$$\pm = P \times \frac{(d_i + t)}{2t} \qquad 5.2$$

Where:

t: thickness of tank(m).

d_i: inside diameter(m).

σ: Tangential stress (Pa).

By taking factor of safety is 2 which is enough to achieve a safe operation for workers around the tanks:

$$\text{F.S} = \frac{\text{Sy}}{\pm_{all.}} \qquad 5.3$$

$$\Rightarrow \pm_{all} = \frac{\text{Sy}}{F.s} = 167\ \text{MPa}$$

To calculate pressure:

$P = 920 \times 9.81 \times 2.02 = 18230.9\text{Pa}$

To find the thickness of the tank:

$$167 = 18230.9 \times \frac{(1.2 + t)}{2t} \Rightarrow t = 6.55 \times 10^{-5} = 0.0000655m.$$

So in order to reserve the rigidity of the tank and to take into account the life surface of these tanks. We choose the thickness 2 mm. In addition to that is available in the market.

5.4.2 Main Storage Tank

There are two storage tanks; upper and lower, oil will be poured in the upper one down to the lower one. The transfer of oil content from the upper and lower tanks will be at a height suitable for transferring oil only and not impurities. Also the lower tank has the same configuration. Both tanks have a certain hole at the bottom for draining and cleaning. This tank can handle up to about 5,000 Liters of waste cooking oil. The two tanks have 1.5 x 1.5x 1.25 m^3.

5.4.3 Mixing Tank

The mixing tank contains main item, which is a blender for mixing tank material contents, and a heater for heating the contents to around 120 C˚ for purification and then it is cooled to 50 C˚ to achieve appropriate reaction environment.

5.4.3.1 Blender Design

Time required to insure a complete mixing process of waste oil with methoxide is about 60 minutes, with a speed of about 500 to 1000 rpm.

In order to choose a blender for the required process, there are some main equations that should be used to determine specifications rpm speed and dimensions of the blender. [25]

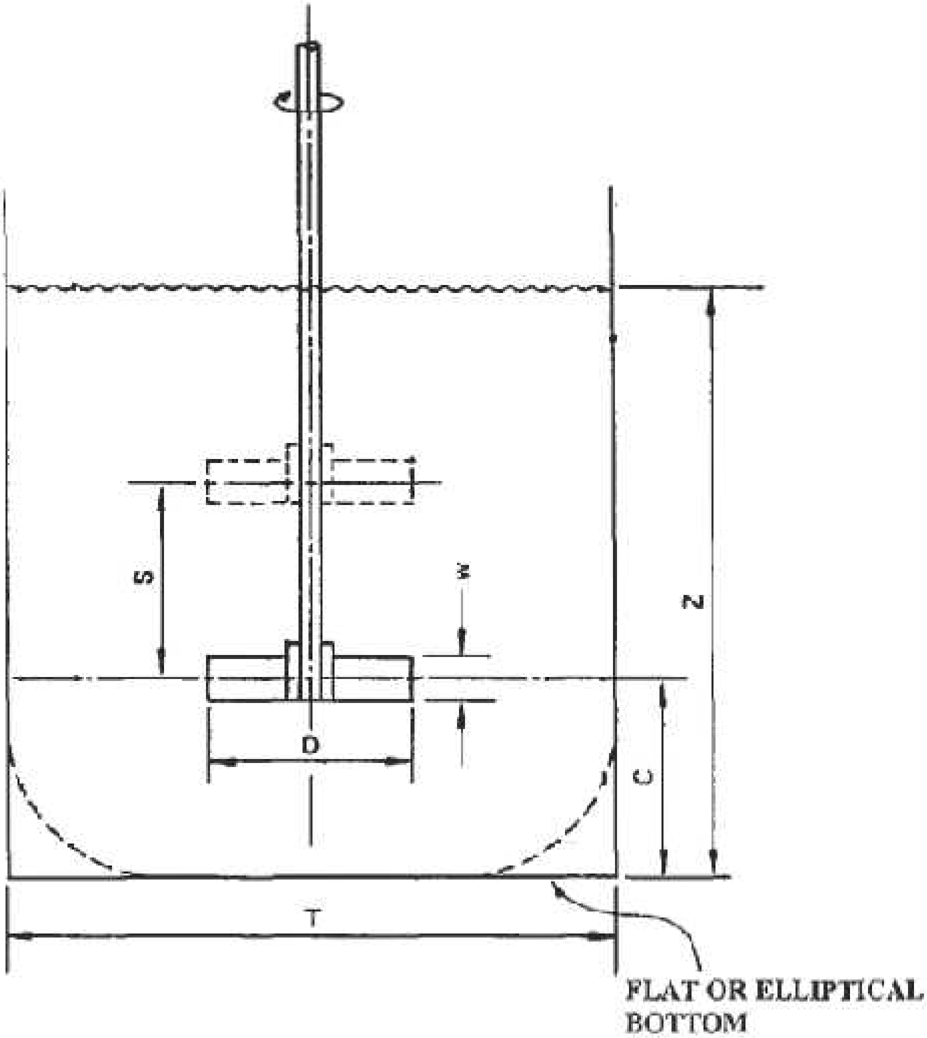


Figure 5.3 Schematic design of a tank provided with a blender

The following figure illustrates the relationship between power number and Reynolds number, each curve has impeller blade width/diameter ratios, the power number can be calculated as being proportional to this ratio.

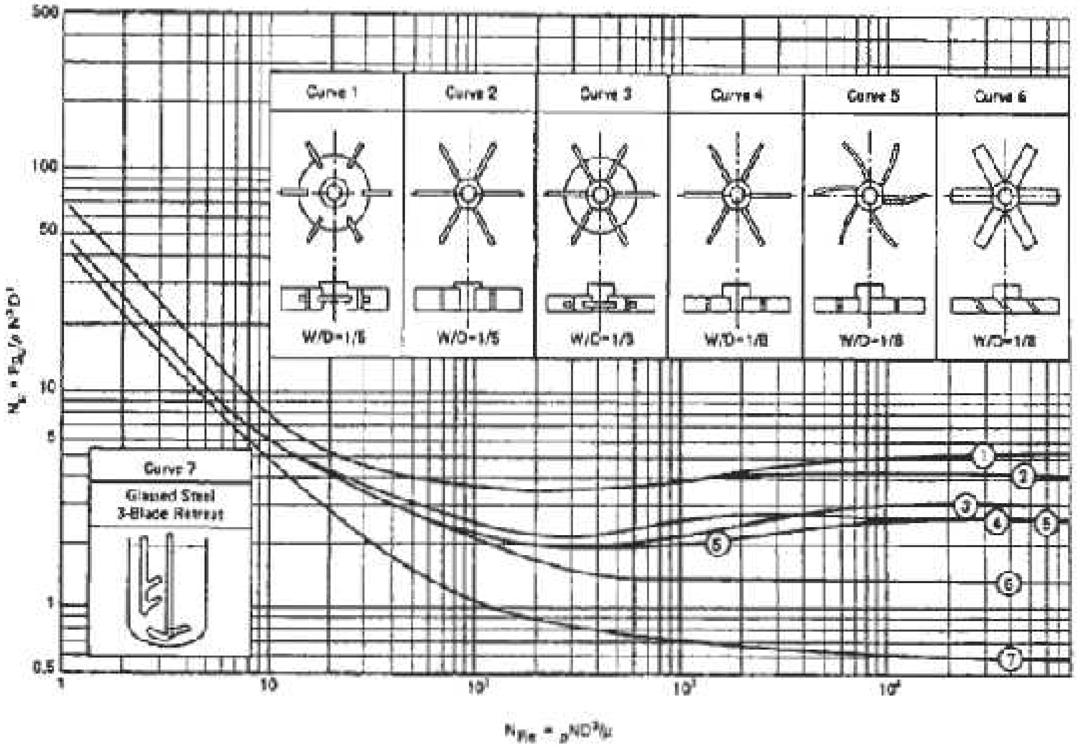


Figure 5.4 Correlations for mixing power number vs. Reynolds number

The following figure shows the relationship between Reynolds number with impeller discharge coefficient, also; each curve appeared on the same graph has a ratio between impeller diameter and tank diameter.

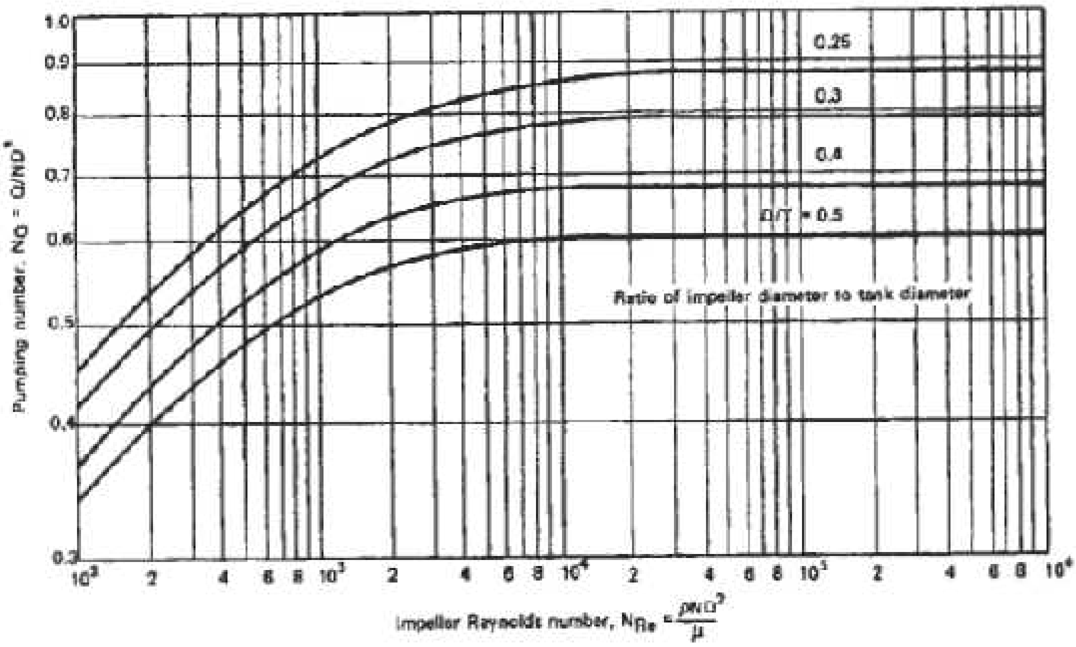


Figure 5.5 Discharge coefficients for 45° pitched blade turbine vs. impeller Reynolds number

Following, the graph shows the relationship between impeller spacing ratio and power number ratio, and each curve depends on blades design. In the plant design, it has been treated with the flat and pitched shape.

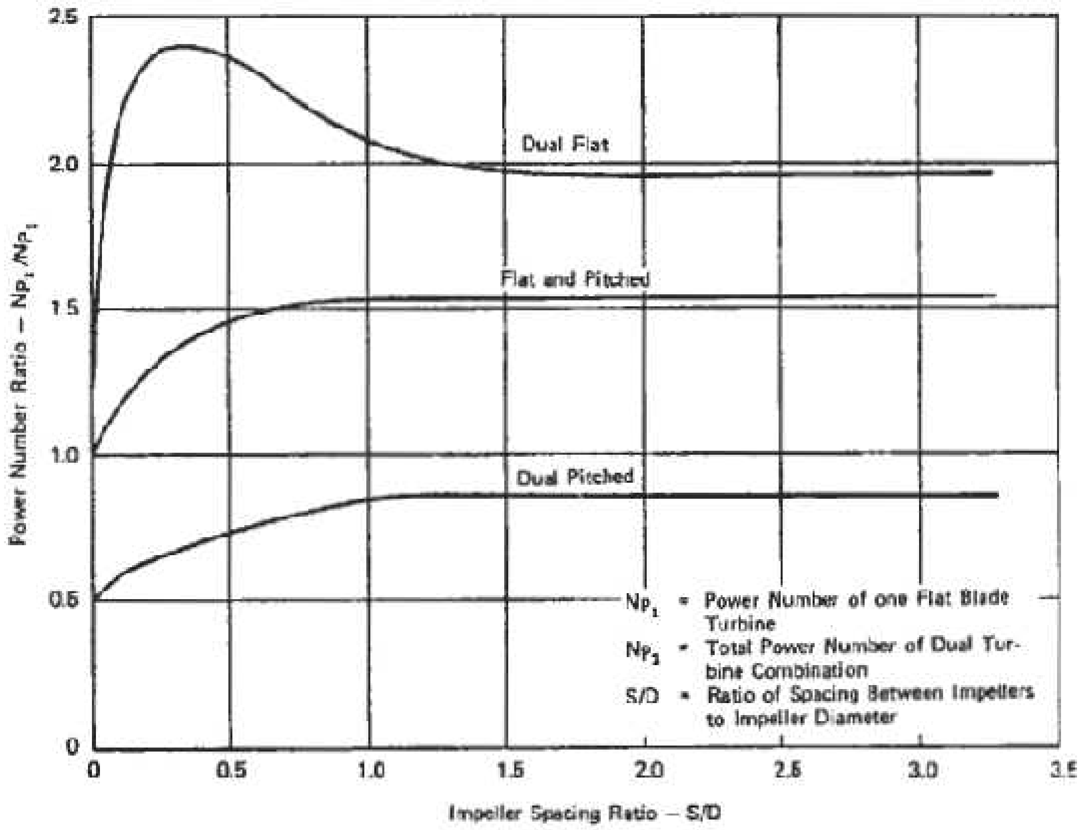


Figure 5.6 Plot shows effect of dual turbine spacing on power

For standard design of blender and its relationship with dimensions of mixing tank:

$$Z = T \qquad 5.4$$

$$D = \frac{T}{3} \qquad 5.5$$

$$W = \left(\frac{D}{8} \text{ to } \frac{D}{5}\right) \qquad 5.6$$

$$T = \left(\frac{4 \times V}{®}\right)^{\frac{1}{3}} \qquad 5.7$$

$T = Z = 1.15$ m.

$$D = \frac{T}{3} = \frac{1.15}{3} = 0.384\ \text{m.}$$

$$W = \frac{D}{8} = \frac{0.384}{8} = 0.047\ \text{m.}$$

Where:

Z: Height of oil level in the tank (m).

T: Diameter of the oil tank (m).

D: Impeller Diameter (m).

W: Impeller thickness (m).

$$S = 2 \times \text{®} \times r \times \tan(\cdot\ ) \qquad 5.8$$

$$r = \frac{D}{2} = 0.19\ \text{m.}$$

$$= 2 \times \text{®} \times 0.19 \times \tan(15^{o}) = 0.32m$$

$$C = \frac{Z - S}{2} = 0.415\ \text{m.}$$

Where:

S: Distance between the two impeller's centroid(m).

C: Distance between the bottom of the tank and the first impeller (m).

· : Blade titling angle (deg).

$$N = \frac{Q}{N_Q \times D^3} \qquad 5.9$$

where:

N: Impeller speed (rev/sec).

Q : Pumping capacity (discharge flow m^3/s).

N_Q : Impeler discharge coeffient.

D : Impeller diameter(m).

Assuming that $Q = 0.2\ m^3/s, \&\ \text{Re} > 4 \times 10^3$

From Figure 5.5 :

$N_Q = 0.75$

$$N = \frac{0.2}{0.75 \times (0.384)^3} = 4.7 \text{ rev/sec}$$

$$D = \sqrt[3]{\frac{Q}{N_Q \times N}} \quad 5.10$$

$$= \sqrt[3]{\frac{0.2}{0.75 \times 4.7}} = 0.384m$$

To check the validity of Reynolds number whether it is right or not:

$$\text{Re} = \frac{° \times N \times D^2}{«} \quad 5.11$$

Where:

« : dynamic viscosity of oil(N.s/m^2).

$$= \frac{920 \times 4.7 \times (0.384)^2}{0.065} = 9.809 \times 10^3$$

And so, it is concluded that Reynolds number holds.

The required power for the blender can be calculated as follow:

$$p = 10^{-3} \times N_p \times ° \times N^3 \times D^5 \quad 5.12$$

$$= 10^{-3} \times 0.937 \times 920 \times 4.7^3 \times 0.384^5 = 747.2 \text{ W} \approx 1\text{hp}$$

Where:

Power dissipation (kW). p :

Dimensionless power number. N_p :

$\circ$: Density of oil (kg/m^3).

N : Impeller speed (rev/s).

D : Impeller diameter(m).

Power number is a result of multiple two factors from figure 5.4 and 5.6

$$N_p = 0.75 \times 1.25 = 0.9375$$

By assuming mechanical losses due to the use of gears :

$$p = 1.25 \times 747.2 = 934W \approx 1.25hp$$

5.4.3.2 Mixing Tank Insulation Design

In order to reduce the rate of heat transfer during heating the oil through tank wall, an insulator must be fitted around the outer surface of the tank, using an air gap as an insulator is the recommended since it is require to cool the oil from 120 c to 50 to a achieve good environment of reaction, water is used to cool it through the air gap. Feeding of water is done by gravity, a flow meter is used to control the flow of water. [26]

To calculate the rate of heat transfer through the air gap, the inner and the outer temperature must be known.

By taking the outer temperature of the air gap is the same for room temperature. And the inner temperature is the same for heated oil.

t_{w2}: the temperature to the external surface for the air gap.($^\circ C$)=20

t_{w1}: the temperature to the internal surface for the air gap.($^\circ C$)= 120

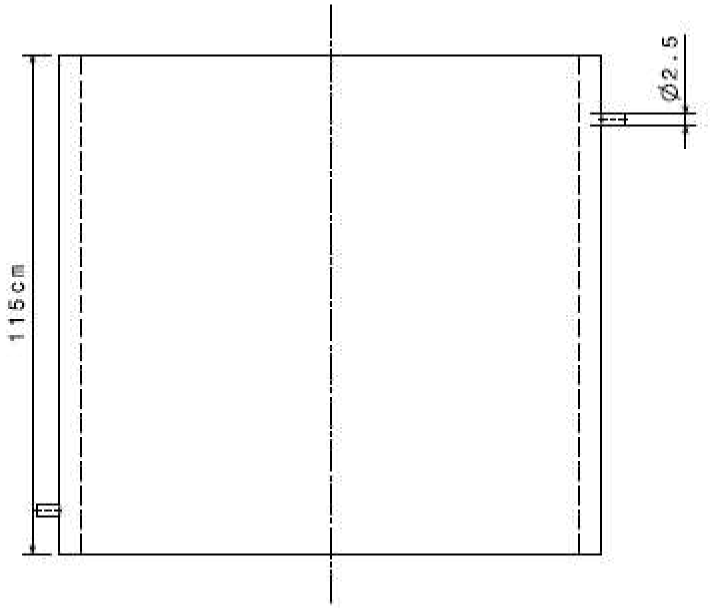


Figure 5.7 Air gap for mixing tank

$$t_{ref} = \frac{t_{W1} + t_{W2}}{2} \qquad 5.13$$

$$= \frac{120+20}{2} = 70^{\circ}C = 70+273 = 343K$$

The properties of the air at the reference temperature from appendix C.

$° = 1.028 (kg/m^3).$

$Cp = 1007\ (J/(kg.C^0)).$

$k = .02881\ (w/(m.C^0)).$

$\sim\ = 2.78*10^{-5} (m^2/s).$

$\neg\ = 1.995*10^{-5} (m^2/s).$

$pr = 0.717.$

Assume Ra = 1000, to insure the air stay stationery in the air gap to prevent convection heat transfer.

$$Ra = Gr * pr = 1000$$

$$Gr * pr = 1000$$

$$Gr = \frac{g \quad (\Delta t)¢^{3}}{v^{2}}$$

$$¢ = \sqrt[3]{\frac{Gr * v^{2}}{g * \quad * \Delta t}}$$

Where is:-

g = the gravitational acceleration (m^2/s)

$=1/T$ =coefficient of volume expansion and equals for gases (1/K) .

Δt =difference temperature between the temperature of the surface &

temperature of the fluid sufficiently far from the surface (°C)

¢ = characteristic length of the geometry (m)

v = kinematics viscosity of the fluid.

Ra =the Raleigh number

$$= \frac{1}{T_{ref}} = \frac{1}{343} = 2.9 \times 10^{-3} K^{-1}$$

$$¢ = \sqrt[3]{\frac{\frac{1000}{0.717} \times (1.995 \times 10^{-5})^{2}}{9.81 \times 2.9 \times 10^{-3} \times (120 - 20)}} = 0.058\ m = 5.8\,cm$$

By adding 5.8 cm to the inner radius of the air gap the outer radius becomes 0.604 m.

To calculate the required amount of water to cool the oil from 120 c to 50, the amount of heat oil has is equal to the amount of heat by water.

$$Q_{oil} = m_{oil} \times Cp_{oil} \times (\Delta T) \qquad 5.14$$

Where

Q: Heat flow in (KJ)

Cp: specific heat at constant pressure.(KJ/kg.c)

ΔT : The temperature difference.

$$Q_{oil} = 920 \times 1.67 \times (120 - 20) = 153.6 KJ.$$

$$Q_{water} = m_{water} \times cp_{water} \times (\Delta T) \qquad 5.15$$

$$153.6 = m_{water} \times 4.18 \times (50 - 20)$$

$$m_{water} = 1224 kg$$

By assuming the cooling time is 1 hour:

$$\dot{m} = \frac{1224}{1} = 1224 kg / h$$

This amount of water is to be used after the process for tanks cleaning and biodiesel washing.

5.4.4 Methoxide Tank Design

This tank can handle up to about 200 Liters of methanol and sodium hydroxide. The process of mixing methanol with NaOH is manually activated. The following graph appears the dimensions of it.

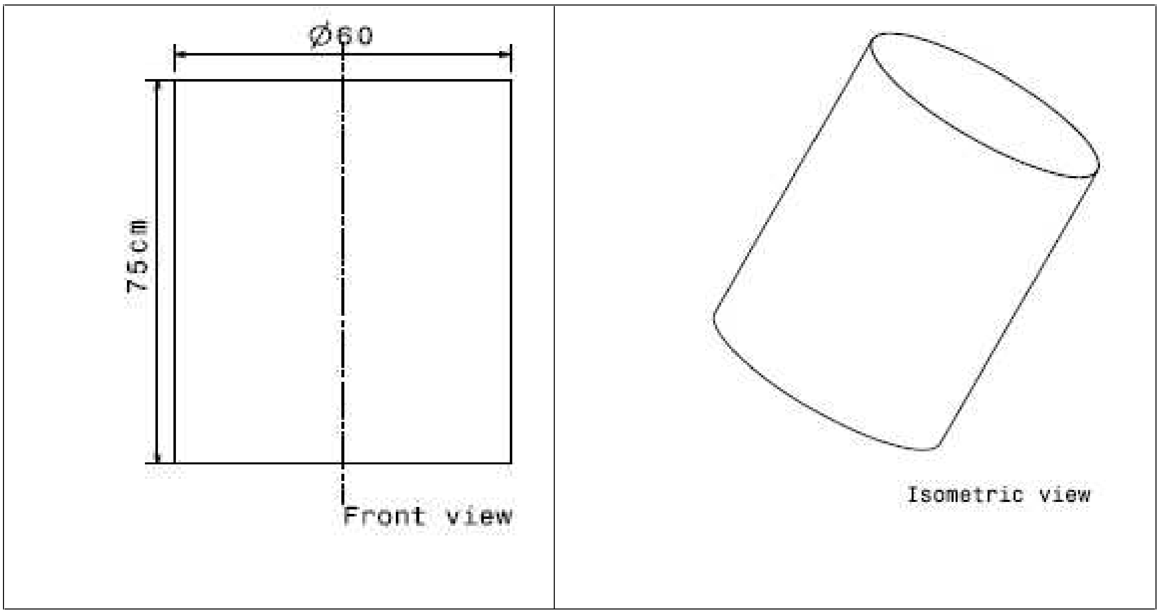


Figure 5.8 Projections of methoxide tank

5.4.5 Settling Tank Design

As before, it's made of a galvanized steel material, this tank is used for separating biodiesel from glycerin. The tank is conic shaped from the bottom side, the conical volume is about 150 Liter which is capable for handling most amount of glycerin. For ideal process, it is recommended that the time of settling operation is to be between 8 and 12 hours.

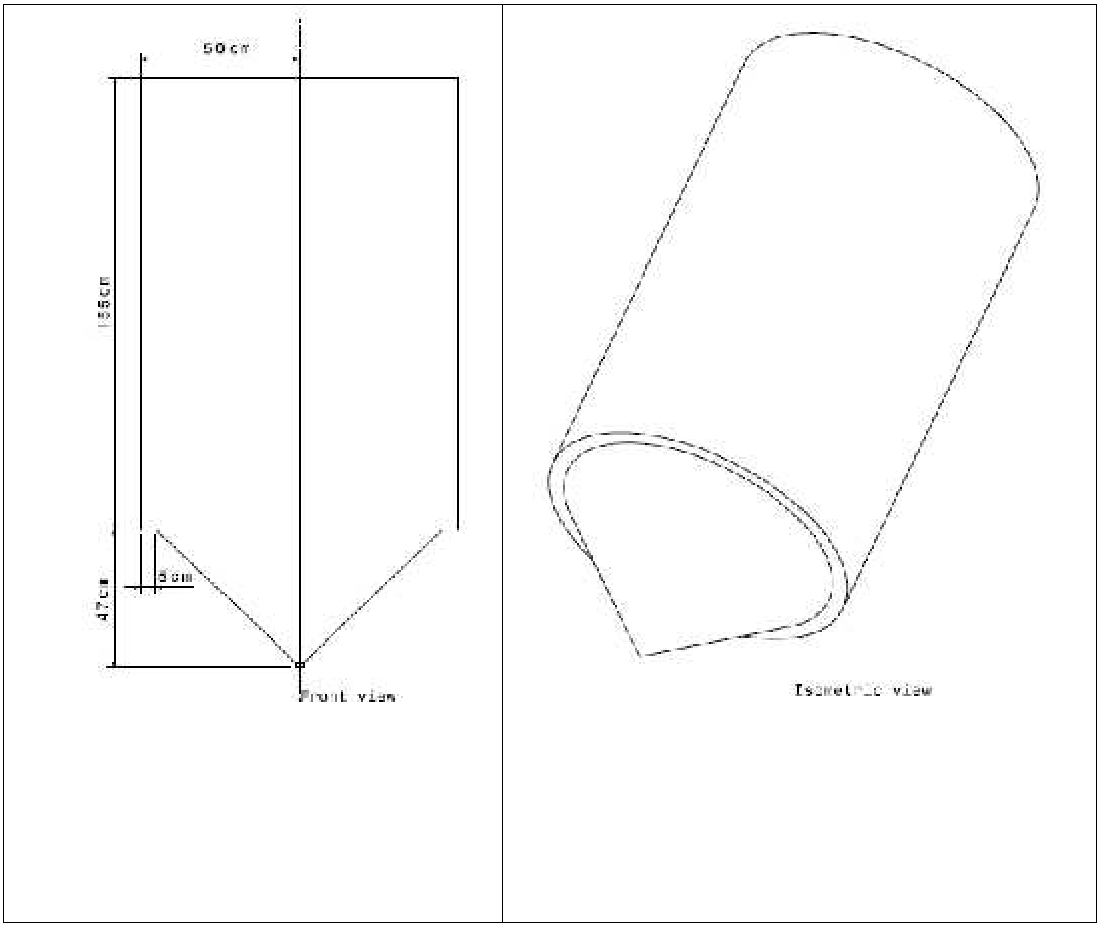


Figure 5.9 Projections of settling tank

The bottom of this tank is provided with a valve for the removal operation of glycerin, also there is another valve located at the top of the conic part of the same tank, which is used for the absorption of biodiesel towards the washing tank.

5.4.6 Washing Tank

Its design has the same designing dimensions of the settling tank, there is a metal pipe which is concentric within the tank, and it is connected to a pump for absorbing water and biodiesel from the opened top of the same pipe.

For ideal process, it is recommended that the time of washing operation is to be between 1 and 1.5 hours, and then, the settling process is to be between 8 and 10 hours.

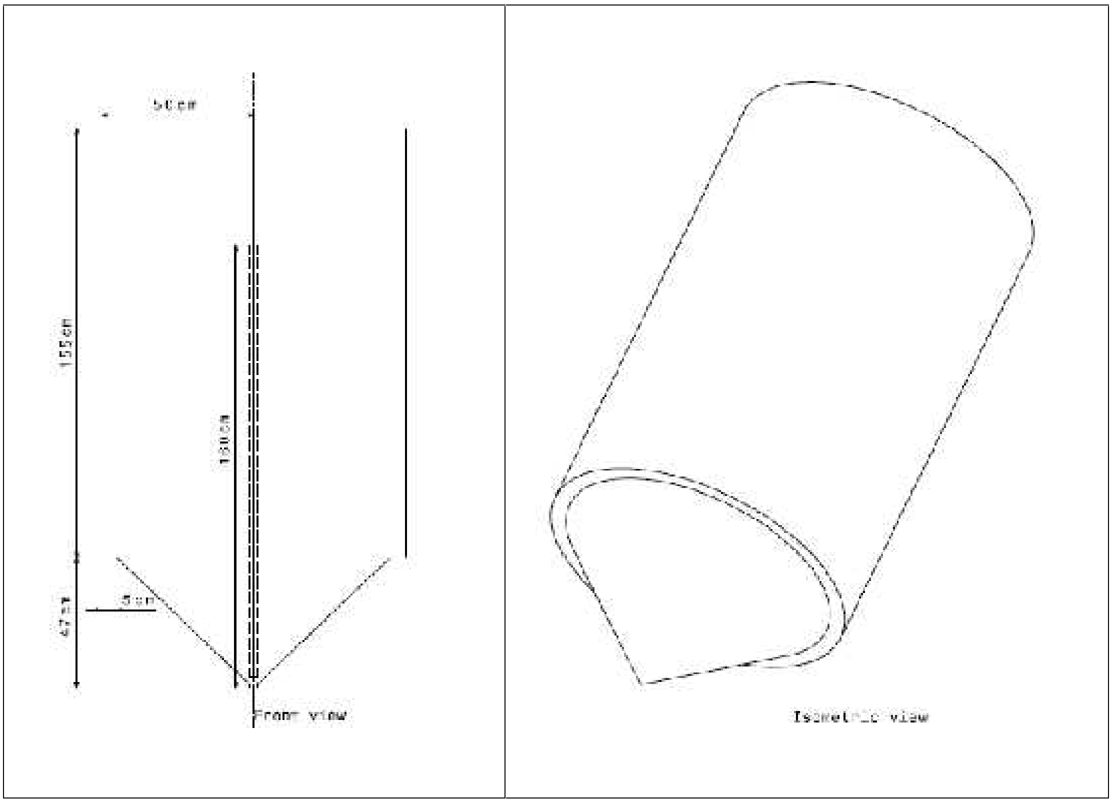


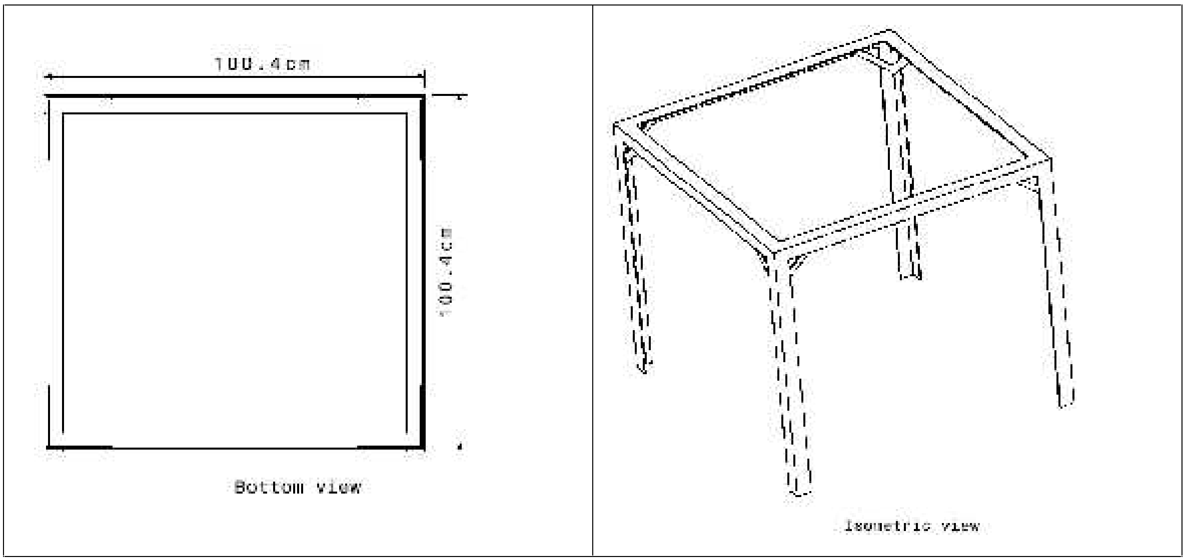
Figure 5.10 Projections of washing tank

The water is added to the tank after the tank is fulfilled with biodiesel. The amount of added water should be within 150 Liter to be suitable for the conic space at the bottom.

The bottom of this tank is provided with a valve for the removal operation of water, also there is another valve located at the top of the conic part of the same tank, which is used for the absorption of biodiesel towards the storage tank.

The washing process implies absorption of biodiesel and water, and then they will return back to the same tank, it is connected after the top valve. Air can be used for the decomposition of bonds and soap. This process lasts until it is assured that the entire amount is mixed very well completely.

5.4.7 Tanks Stands Design



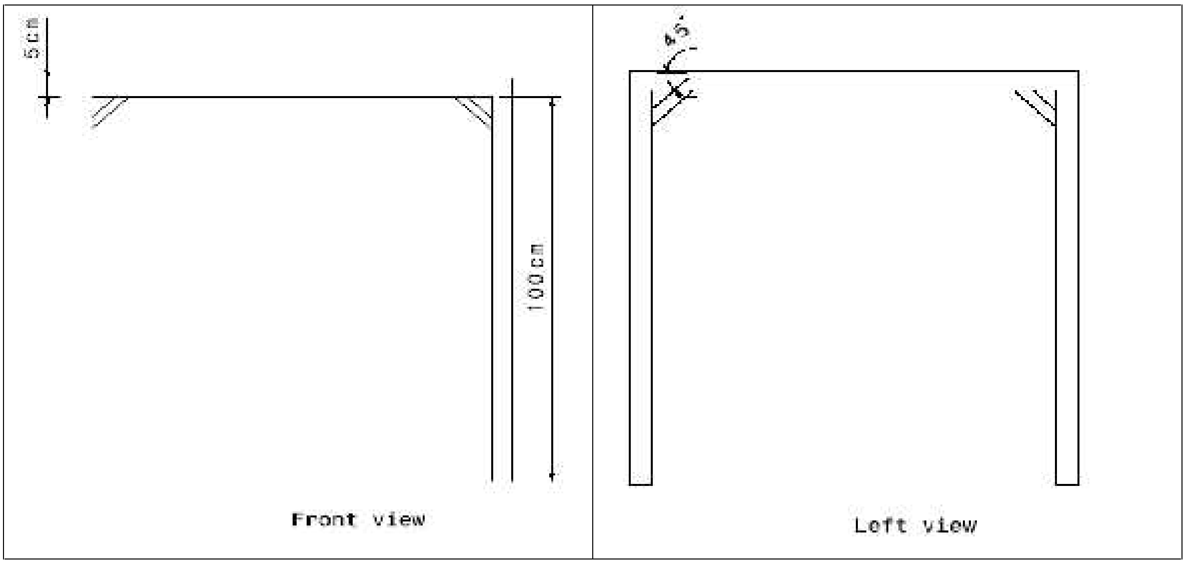
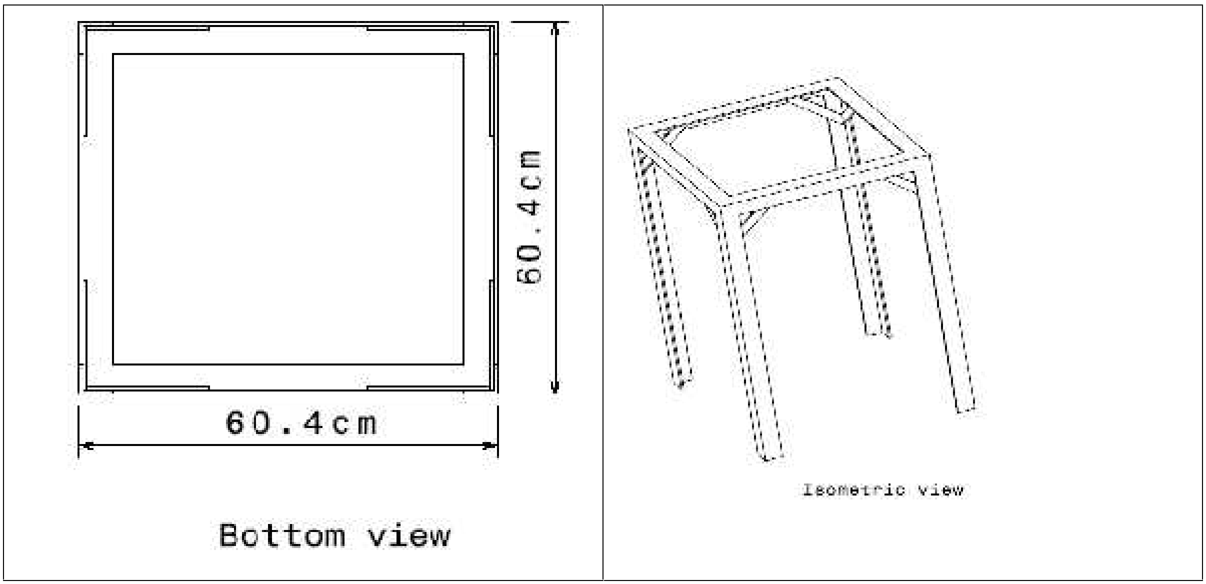


Figure 5.11 Projections of settling & washing tanks' stands



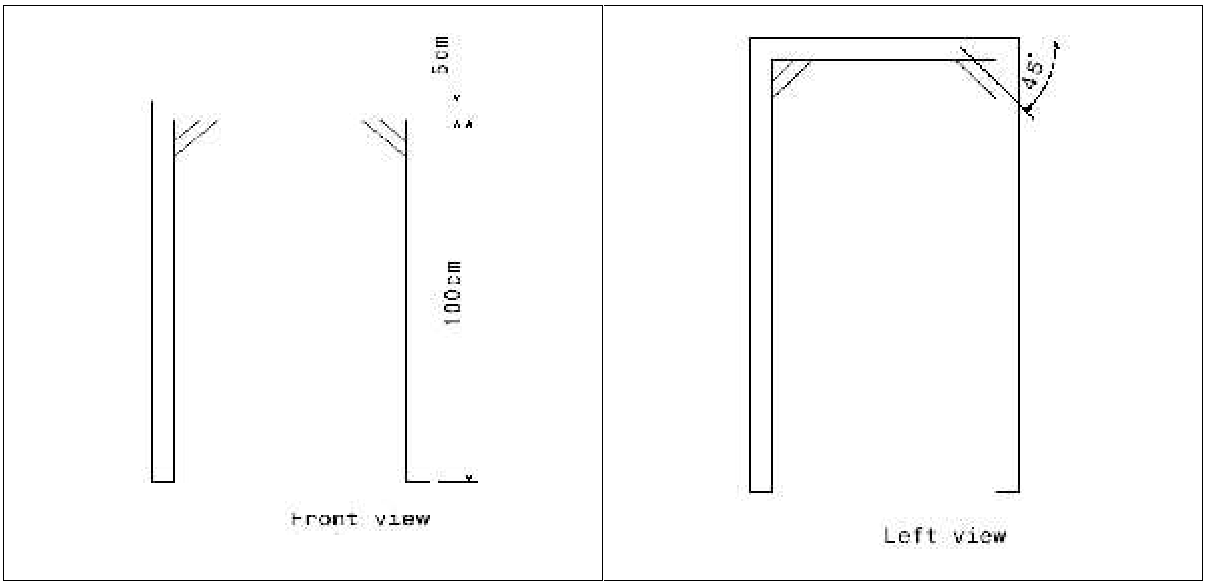


Figure 5.12 Projections of methoxide tanks' stands

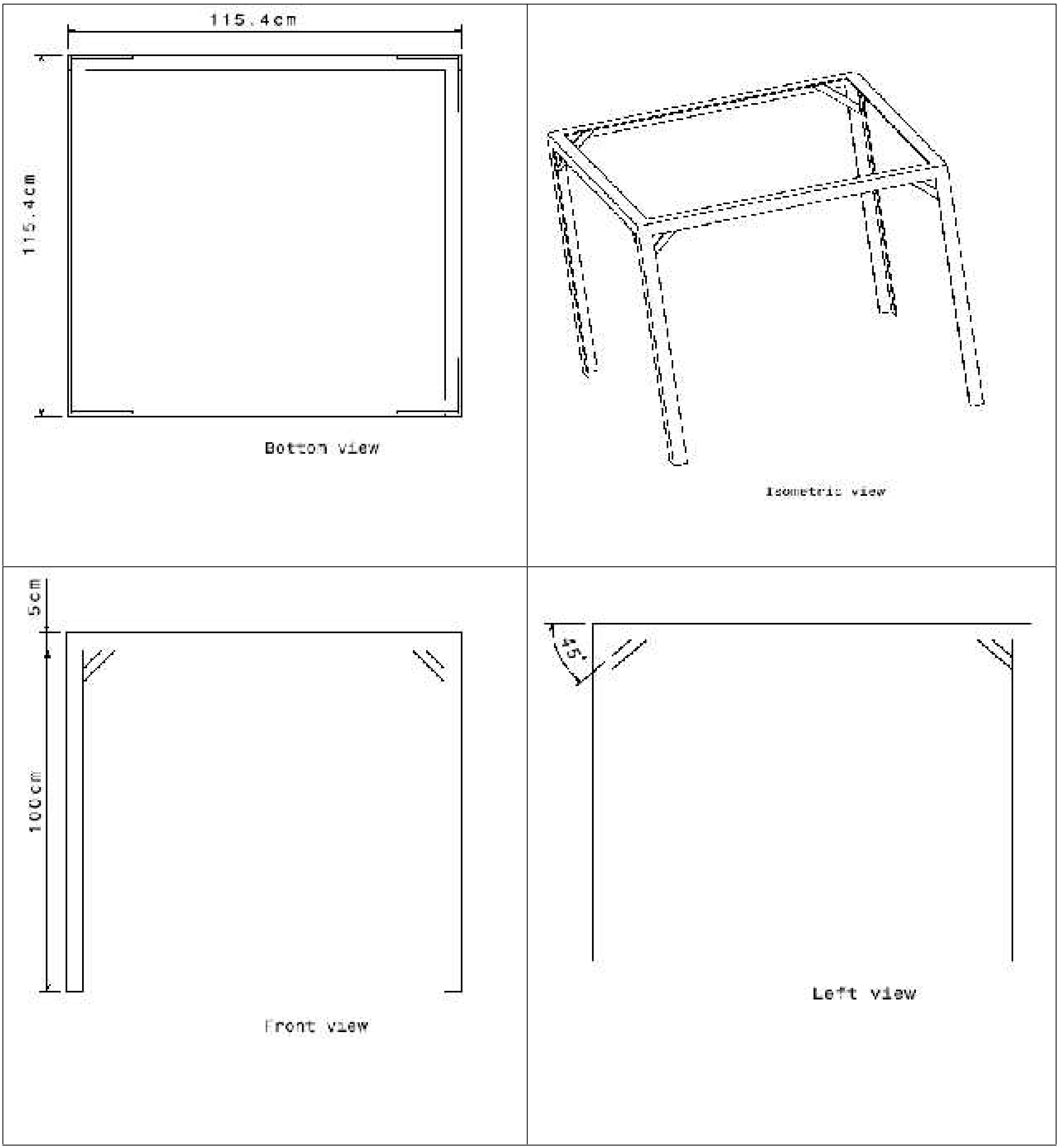


Figure 5.13: Projections of mixing tanks' stands

To calculate for structure: [24]

$$Y_{\max.} = \frac{-F_{leg} \times L^3}{48 \times E \times I} \qquad 5.16$$

where:

$Y_{\max}$: Maximum deflection of beam (m).

F: Applied force (N).

L: Beam length (m)

E: Modulus of elasticity (GPa)

I: Second moment of inertia (m^4)

To calculate the force:

$$m_{biodiesel} = \rho_{biodiesel} \times V_{biodiesel} = 870 \times 1 = 870kg \qquad 5.17$$

$$m_{water} = \rho_{water} \times V_{water} = 1000 \times 0.2 = 200kg$$

$$m_{steel} = \rho_{steel} \times V_{steel}$$

$$V_{steel} = V_{cylinder} + V_{cone}$$

$$= (2 \times \pi \times r \times L_{cylinder} \times t) + ((\frac{1}{3} \times \pi \times r_1{}^2 \times L_1) - (\frac{1}{3} \times \pi \times r_2{}^2 \times L_2)) \qquad 5.18$$

Where:

t: Steel thickness(m).

L: Steel tank height (m).

r: Steel tank radius (m).

r_1: Inner conic radius (m).

r_2: Outer conic radius (m).

$$= (2\times® \times 0.5\times 1.55\times 0.002) + ((\frac{1}{3}\times® \times 0.45^2 \times 0.47) - (\frac{1}{3}\times® \times 0.448^2 \times 0.468)) = 0.01103 m^3$$

$$m_{steel} = 8000\times 0.01103 = 88.272 kg$$

$$m_{total} = m_{biodiesel} + m_{water} + m_{steel} = 1158.3 kg$$

$$F = m_{total}\times g = 1158.3\times 9.81 = 11363 N$$

Where:

g: Acceleration due to gravity (m/s^2).

Since each stand has four legs, thus; force should be divided by four:

$$F_{leg} = \frac{F}{4} = 2840.7 N$$

Let Y_{max} = 0.003 m; and so:

$$Y_{max.} = \frac{-F_{leg}\times L^3}{48\times E\times I} \Leftrightarrow 0.003 = \frac{-2840.7\times 1^3}{48\times 200\times 10^9\times I} \Leftrightarrow I = 9.86 cm^4$$

With a safety factor of 1.2, this implies that:

$$I_{safety} = I\times 1.2 = 11.83 cm^4$$

Referring to table in appendix C, and due to the calculated I, L-shape has almost the same I that of the calculated one.

L-shape dimensions are:

$50\times 50\times 6$

$$± = \frac{M\times c}{I} \quad 5.19$$

Where:

σ: Normal stress(Pa)

M: Moment (N.m).

c: Distance between centroid and upper surface (m).

I: Second moment of inertia (m^4).

$$\pm = \frac{M \times c}{I} = \frac{F_{leg} \times 0.5 \times c}{I} = \frac{2840.7 \times 0.5 \times 1.45}{11.83 \times 10^{-8}} = 147.09 MPa.$$

Normal stress (σ) should always be less than yield strength (Sy).

Sy = 400MPa.

And it is clear that the normal stress is less than the yield strength.

Now, it should be checked whether there will be buckling or not:

$$P_{critical} = \frac{®^2 \times E \times I}{4 \times L^2} \qquad 5.20$$

$$= \frac{®^2 \times 200 \times 10^9 \times 11.83 \times 10^{-8}}{4 \times 1^2} = 58.319 kN$$

Where:

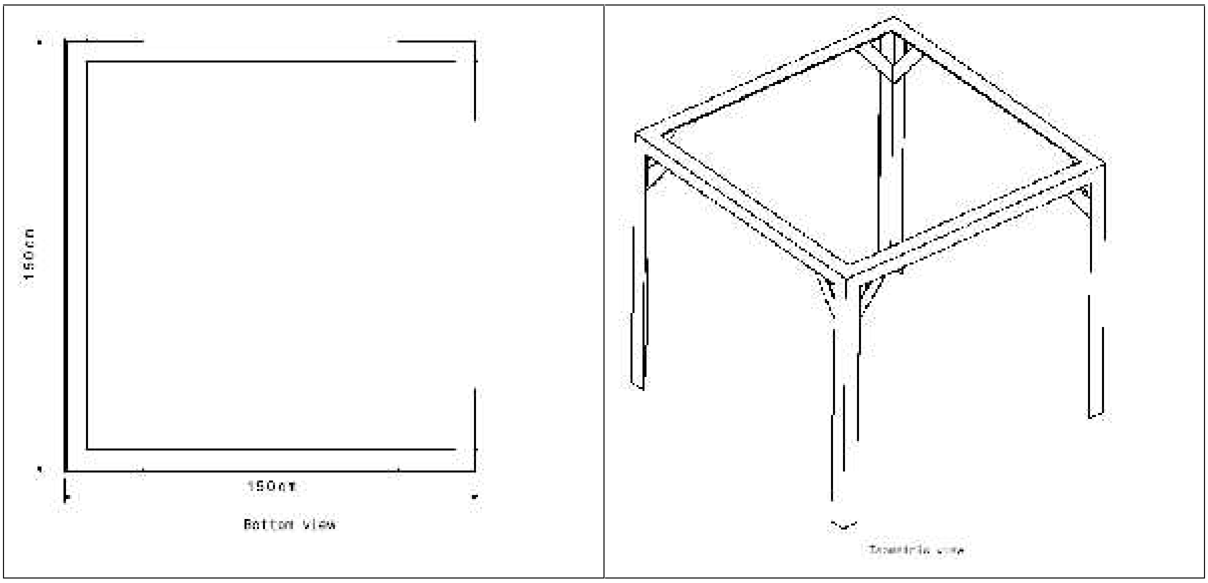
$P_{critical}$: Force where buckling occurs (N)

F_{leg} <<< $P_{critical}$, and so; buckling will not occur.

5.4.8 Biodiesel Storage Tanks

As mentioned previously, the biodiesel storage tank is made of galvanized steel. The dimension of biodiesel storage tank is $2x1.5x1.7m^3$, and it can handle up to about 5,000 Liters.

5.4.9 Storage Tank Stand Design



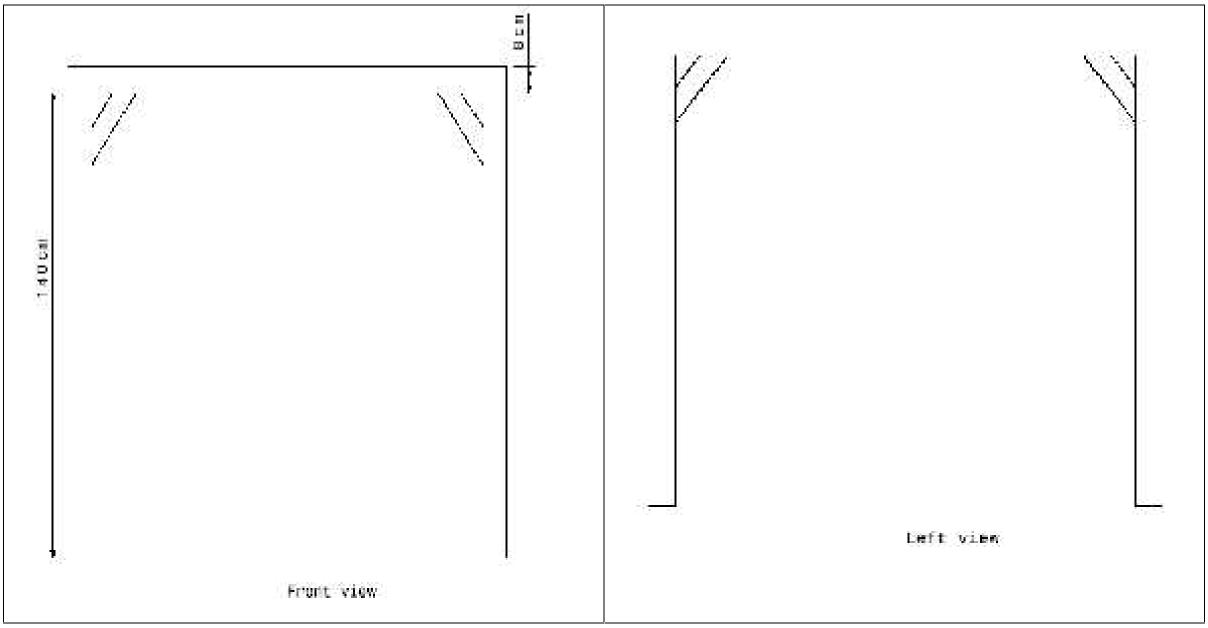
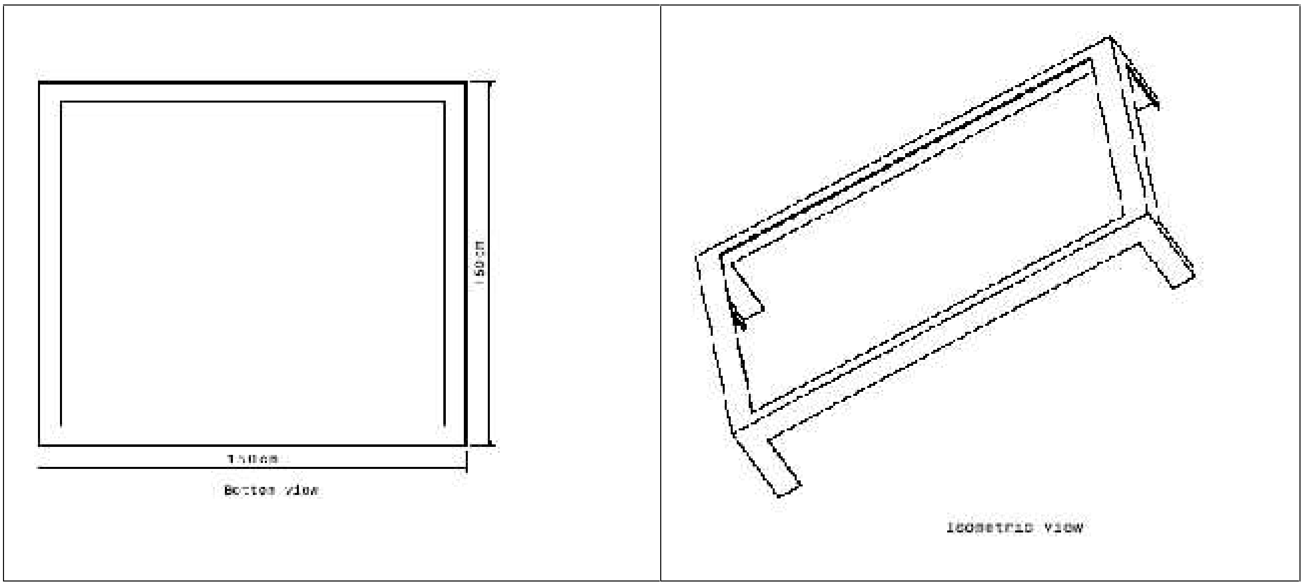


Figure 5.14: Projections of upper storage tanks' stands



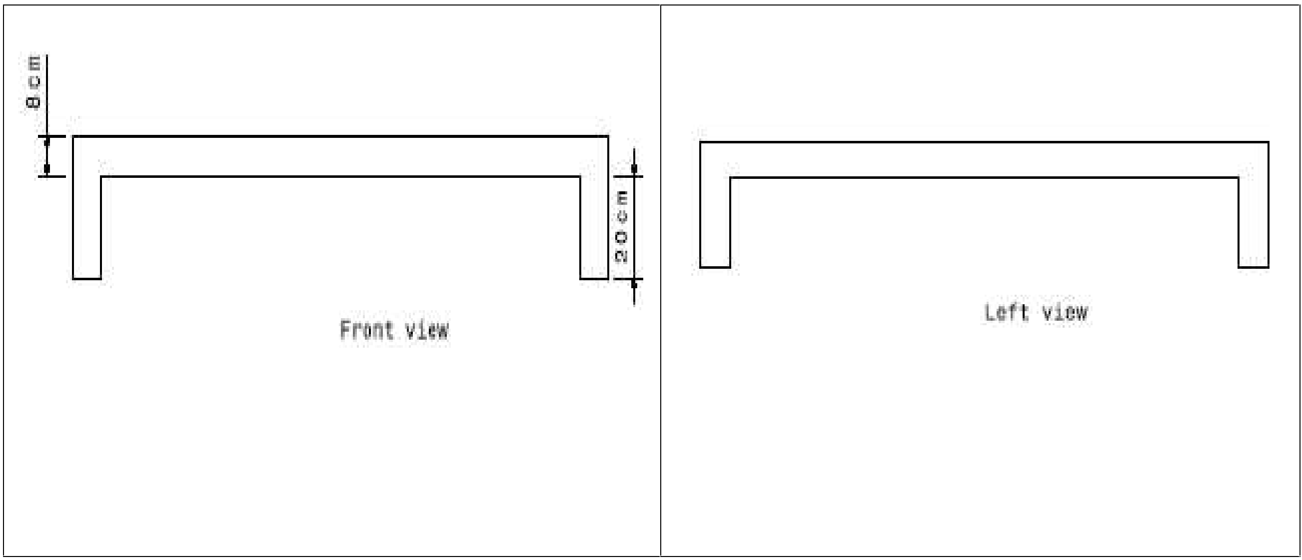


Figure 5.15: Projections of lower storage tanks' stands

To calculate the structure

$$Y_{\max.} = \frac{-F_{leg} \times L^3}{48 \times E \times I} \qquad 5.21$$

where:

F: Applied force (N)

L: Beam length (m)

E: Modulus of elasticity (GPa)

I: Second moment of inertia(m^4)

To calculate the force:

$$m_{oil} = {}^{\circ}{}_{oil} \times V_{oil} = 920 \times 2.8125 = 2587kg$$

$$m_{steel} = {}^{\circ}{}_{steel} \times V_{steel}$$

$$V_{steel} = 1.5\times1.5\times1.25 - 1.498\times1.498\times1.248 = 0.012m^3$$

$$m_{steel} = 8000\times0.012 = 96kg$$

$$m_{total} = m_{oil} + m_{steel} = 2683kg$$

$$F = m_{total}\times a = 2683\times9.81 = 26320N$$

Since each stand has four legs, thus; force should be divided by four:

$$F_{leg} = \frac{F}{4} = 6580N$$

Let Y_{max} = 0.005 m; and so:

$$Y_{max.} = \frac{-F_{leg}\times L^3}{48\times E\times I} \Leftrightarrow 0.005 = \frac{-6580\times1.4^3}{48\times200\times10^9\times I} \Leftrightarrow I = 37.615cm^4$$

With a safety factor of 1.2, this implies that:

$$I_{safety} = I\times1.2 = 45.13cm^4$$

Referring to table in appendix C, and due to the calculated I, L-shape has almost the same I that of the calculated one.

L-shape dimensions are:

$80\times80\times6$

$$\pm = \frac{M\times c}{I} \qquad 5.22$$

Where:

σ: Normal stress (Pa)

M: Moment (N.m).

c: Distance between centroid and upper surface (m).
I: Second moment of inertia (m^4).

$$\pm = \frac{M \times c}{I} = \frac{F_{leg} \times 0.75 \times c}{I} = \frac{6580 \times 0.75 \times 2.17 \times 10^{-2}}{55.83 \times 10^{-8}} = 191.91 MPa.$$

Normal stress (σ) should always be less than yield strength (Sy).

Sy = 400MPa.

And it is clear that the normal stress is less than the yield strength.

Now, it should be checked whether there will be a buckling or not.

$$P_{critical} = \frac{®^2 \times E \times I}{4 \times L^2} = \frac{®^2 \times 200 \times 10^9 \times 55.8 \times 10^{-8}}{4 \times 1.4^2} = 140.34 kN$$

Where:
$P_{critical}$: Force where buckling occurs.

F_{leg} <<< $P_{critical}$, and so; buckling will not occur.

5.4.10 Pump Design

Because the used materials have high viscosity, so it is needed to have a gear pump. That gear pump can be selected due to main parameters that should be calculated first. Such parameters are as follows:

- Flow rate
- Total head
- Power required

There is a simple calculation for computing the total head and the flow rate in order to select the suitable pump for this purpose. [27]

$$\text{Flow rate(Q)} = \frac{V}{t} \qquad 5.23$$

$$= \frac{1200}{15} = 80\ \text{L/min} = 21.13\ \text{gpm}$$

Where:

V: Oil volume (m^3).

t: Time required (s).

$$\text{Total head} = \text{Head loss due to friction} + \text{static head}$$

$$f = \frac{64}{Re} \text{ for laminar flow.} \qquad 5.24$$

Where:

f: Friction factor for laminar flow.

Re: Reynolds number.

$$\text{The velocity of the fluid} = \frac{Q}{A} \qquad 5.25$$

$$= \frac{1.33\times10^{-3}\ (m^3/s)}{(\frac{®D^2}{4})} = \frac{1.33\times10^{-3}}{557.3\times10^{-6}} = 2.4 m/s$$

Where:

Q: Flow (m^3/s).

A: Pipe area (m^2).

$$Re = \frac{V \times D}{v} \qquad 5.26$$

$$= \frac{2.4 \times 26}{34.9} = 1829 \quad Re \langle 2000 \text{ valid.}$$

V: Fluid velocity (m/s).

D: Pipe diameter (m).

v: Kinematics' viscosity of oil(mm^2/s)

$$f = \frac{64}{1829} = 0.035$$

$$Le = \frac{K \times D}{f} \qquad 5.27$$

$$= \frac{0.75 \times 0.026}{0.035} = 0.535m$$

Where:

Le: Equivalent length of fitting (m).

K: Factor of fitting.

$$H_1 = f \times \left(\frac{L}{D}\right) \times \frac{V^2}{2g} \qquad 5.28$$

Where:

H_1: Kinematics' head (m).

The equivelent length

$$L = 15 + (5 \times 0.353) = 16.75m$$

$$H_l = 0.035 \times \left(\frac{16.75}{0.025}\right) \times \frac{2.42^2}{2 \times 9.81} = 6.9m$$

H_{static} = 2.5m (referring to plant design).

Total head $= 6.9 + 2.5 = 9.4$m

A pump is required, having the following characteristics:

H=9.4m, Q=21.13 gpm

$$p(kw) = \frac{p \times Q}{600} \qquad 5.29$$

Where:

P: Power (kW).

p: Pressure (bar).

Q: Flow rate (L/min).

$$p(kw) = \frac{1 \times 80}{600} = 0.133kW.$$

Since the require power to run this pump, a half horse power motor which a standard size and available in local market done the required aim.

From performance data it suitable to choose (sp20b30) at 3000 rpm and max pressure 2500 psi. (for detail see appendix C)

5.4.11 Heater Design

In this proposed design, an electric heater is to be used so as to heat oil to a temperature about 120 C° for purification, and then operated at temperature about 50 C° for reaction and prevent methanol evaporation. This heater is fixed inside the waste oil tank. Heater power is to be determined using the following equations:[105]

$$Q = m \times C_P \times \Delta T \qquad 5.30$$

$$m = \circ \times V \qquad 5.31$$

Where:

Q: Total heat transfer (kW)

m: Oil mass (kg)

C_p: Specific heat at constant pressure(kJ/kg.K°).

Temperature difference. ΔT :

Oil density (g/cm^3). $\circ$:

V: Oil volume (m^3).

Knowing that:

$$C_P(oil) = 1.67\, kJ / kg.K^{-}$$

$$V(oil) = 1000L = 1000 \times 10^3 Cm^3$$

$$\circ(oil) = 0.92 g / Cm^3$$

$$T_1 = 20C^{-}, T_2 = 120C^{-}$$

$$m = \circ \times V = 0.92 \times 1000 \times 10^3 = 920 \times 10^3 g.$$

$$Q(kJ) = m(kg) \times C_P (\frac{kJ}{kg.K^{-}}) \times \Delta T(K^{-}) = 920 \times 1.67 \times 100 = 153640 kJ.$$

This energy required to heat the oil.

To calculate the power of the heater, suppose that time required for heating is about 60 minutes to heat 1,000 liters, referring to the following equation:

$$P(kW) = \frac{Q(kJ)}{t(\text{sec.})} \qquad 5.31$$

$$= \frac{153640}{60 \times 60} = 42.67 kW.$$

In order to heat the oil with 42.67 kW heater it is better to choose 5 heaters with 9kw out put power to distribute the heat through the oil, so from catalog (xps-9-2-21c).(for detail see appendix C)

5.4.12 Piping Selection

In this project, a galvanized steel pipes were used due to low cost, available in local market, 1 inch diameter, with fitting 1 inch diameter also, PVC piping can be used also but for safety and provide higher service life it is better to select galvanized steel pipes.

5.5 Plant Safety

Like any project, safety must be applied to prevent risks for human and environment, since this project uses high flammable materials. Some of the rules that may apply are:

1. Methanol storage containers must be metal, grounded, use supports and must not spill contents if connectors burn through.
2. Space required around tanks for fire fighting access.

3. Explosion proof electrical wiring.
4. No other operations in the room with the equipment.
5. Existence of a fire security system.
6. Ventilation system.

5.6 Project Prototype

A prototype has been implemented to represent the process of biodiesel production, it has three tanks, mixing, settling and washing tanks respectively, in addition to a heater, a blender and a pump. The prototype has a biodiesel production range of about 30 to 60 Liters. The dimensions and the operating manual are mentioned in appendices. (For detail see appendix D).

5.7 Economical Study

By undertaking a detailed feasibility study and financial analysis for producing Biodiesel in Hebron, this can give an impression about the percentage for the success of the project. So the determination of the cost of each element is needed in the process and for making it ready for marketing. In the case of Biodiesel project, the things or issues are to be coasted in details, including:

1. Fixed cost

a. Capital investment.
b. collection vehicle.
c. Operating place and storage.
d. Processing equipment/blender/delivery pump/heaters.
e. VAT's.
f. Salaries.

g. Insurance.

h. Promotion/media/ad's.

2. Variable cost

a. Raw materials (waste oil, fats and reactants).

b. Filtering/processing/blending/quality control.

c. Delivery/transport to market.

d. Energy and electricity.

e. Maintenance.

5.7.1 Analysis and Calculations

Now the variable and fixed cost will be discussed in details:

1. for variable cost:

a. methanol and sodium hydroxide:

Table 5.1 Cost of methanol and sodium hydroxide

Material	Cost (NIS)	Percentage required to produce 1 liter	Cost for 1 liter biodiesel (NIS)
Methanol (each liter)	5	0.150	0.75
Sodium hydroxide (each kg)	4	0.0065	0.02

The above percentages are due to previous studies and calculations that give the best yield of production.

b. waste cooking oil

According to survey result, the average cost of waste cooking oil per 1 liter is 1 NIS.

c. energy for heater, blender and pump

The following table shows the required power for each element.

Table 5.2 Power required for each component for the plant design

	blender	pump	heater
Power(kW)	0.933	0.373	42.67

For blender and pump it is needed 500-1000 rpm for blender and 1 bar for pump respectively.

For heater; according to the operating conditions it needs 42.67 kW; this done by simple calculation.

In order to calculate the energy price for each liter

$$Energy(kW.h) = \frac{Power(kW) \times Operting \text{ time (min)}}{60\text{(min)}} \qquad 5.32$$

$$\text{Price for one liter(NIS)} = \frac{\text{Energy} \times \text{Electrc triff}}{1000 \text{ liter}} \qquad 5.33$$

For blender:

There is a blender in this process for mixing waste cooking oil with methoxide; it takes about 60 minuets.

$$\text{Price for one liter(NIS)} = \frac{0.933 \times 60 \times 0.57}{1000 \times 60} = 0.00053 NIS.$$

For pump:

$$\text{Price for one liter(NIS)} = \frac{0.373 \times 110 \times 0.57}{1000 \times 60} = 0.0004 NIS.$$

For heater:

$$\text{Price for one liter(NIS)} = \frac{42.67 \times 60 \times 0.57}{1000 \times 60} = 0.024 NIS.$$

d. for maintenance

Assuming 0.06 NIS per liter of biodiesel

2. for fixed cost:

a. Depreciation

Cost of plant is mentioned below.

Table 5.3 plant element's cost

material	Cost(NIS)
Waste oil storage tanks	4000
Mixing tank with blender, heater, insulater and stand	8000
Methoxide tank with stand	500
Two settling tank	4000
Two washing tank	4000
Biodiesel storage tank	3000
Piping and fittings	3500
Three pumps	3000
Total	33.000

To calculate the depreciation for the plant for one year .it will take **declining balance method** to calculate it.

Assume the percentage of declining is 15%.

$$D.c(n) = \mathrm{P} \times 15\% \qquad 5.34$$

Where:

D.c: depreciation charger year.

n: actual life.

P: the price of machine.

$$D.c(1) = 33{,}000 \times 15\%$$
$$= 4950 \text{ NIS}$$

b. Operating place and storage

The dimension operation place of the plant requires about $4 \times 10\ m^2$ which costs about 9000 NIS per year. By assuming the shop is two floors, the second floor is used for manager office, maintenance, utilities.

c. Salaries.

The plant requires about 5 workers to control the production process and collection of waste oil, taking into account, each person needs about 1500 NIS per month, so the total of salaries per year is 90,000NIS.

d. collection vehicle.

The collection of waste oil from Hebron district requires two vehicles to collect it. Two vehicles need about 20,000NIS per year to cover the cost of operation (such as fuel, maintenance, etc).

e. Capital investment

By assuming 40,000NIS to operate this project.

5.7.3 Price per Liter of Biodiesel

The price of 1 liter of biodiesel is calculated by the following equation.

$$P = \frac{(F + n \times V)}{n} \qquad 5.35$$

Where;

P: price without profit and VAT.

F: total of fixed cost.

V: total of variable cost.

n: amount of biodiesel in liter.

Then;

F= Depreciation+ Operating place and storage+ Salaries+ collection vehicle+capital ivestment.

= 4950+9000+90,000+20,000+40,000=163,950NIS.

V= methanol and sodium hydroxide +waste cooking oil+ energy for heater, blender, pump+ maintenance .

=0.75+0.002+1+0.025+0.06=1.83NIS.

$$P = \frac{(163950 + 164800 \times 1.83)}{164800}$$

$$= 2.8\text{NIS}$$

The following table indicates how much cost is required per 1 liter of Biodiesel:

Table 5.4 Cost of one liter Biodiesel

Material	Cost(NIS)
1 liter of biodiesel	2.8
Glycerin recovery	-0.15
Total	2.65

According to the previous results showed in the table above, the price of Biodiesel is approximately half the usual petrodiesel fuel; the price of diesel has an international price between world countries, taxes added to the price of diesel is different from country to another, as an example, in Palestine, taxes added is about 1.36 NIS per liter. It is recovered from the Israeli petrol community to the Palestinian authority; this tax is called (blue tax).

Also, profits of Palestinian petroleum authority is about 0.7 NIS; profits of petrol station is 0.25 NIS, however; price of diesel that Palestinian petroleum authority pay for Israeli petroleum authority is about 2.3 NIS and it is not a stable price, it may arise in the future. [17]

Table 5.5 price of one liter Biodiesel with profit and VAT

Element	Price(NIS)
Biodiesel Cost	2.65
Profits	0.5
VAT	0.42
Total price to market	3.1

According to table 5.5 the cost of one liter biodiesel 2.65 without adding tax and profit; so if is taken that the profit is about 0.5 NIS then the total cost to market with added tax (VAT=14.5% of total cost) is 3.1NIS

CHAPTER SIX

Biodiesel Testing

Content:

CHAPTER SIX

Biodiesel Testing

6.1 Introduction

This chapter aims to provide an indication that produced biodiesel can be used an alternative fuel. Thus, it must be passed through several specification tests; these tests are mainly based on ASTM standards, and compared with those for commonly used diesel. In ASTM standards, Physical and chemical properties are measured and compared with reference standards that related to diesel.

The ASTM tests for diesel are several; in this project only basic tests were obtained from Petropal experimental lab. With the help of eng. Motasem Abu Rayyan, the head of lab. Given the lack of the required instruments. Note that all biodiesel samples extracted from waste cooking oil.

6.2 Specification Tests of Biodiesel

The basic tests as follows:

- Flash point test.
- Kinematic viscosity test.
- Density, specific gravity test.
- Water content test.
- Sulfur content test.
- Color test.

6.2.1 Flash Point Test

The flash point of a liquid is the lowest temperature at which it gives off enough vapor to form an ignitable mixture with air, at this point the vapor will burn, but only briefly; inadequate vapor is produced to maintain combustion.

This test aimed to determine the flammability hazards of biodiesel. The apparatus which was used to serve this activity was Glevel Land Open Cup Flash Point Tester.

Figure 6.1 Flash point tester

Apparatus

Normalab analis Open Cup Flash Point Tester

Test Procedure:

1- The biodiesel sample was transferred to flash point apparatus copper open cup.

2- The cup was heated slowly to 100 C, while flame was passed above sample every 1 min
3- The temperature at which an instantaneous flash was observed is the flash point of biodiesel.
4- The heating was continued, while the flame was passed as above.
5- The temperature at which the sample ignited for 5 sec continuously is the flash point of biodiesel.

Results:

Flash point test was performed for four samples, and table (6.2) shows the results

Table 6.1 Flash Point Test Results

Sample	Flash point(°C)
A	164
B	158
C	151

The average flash point = 157.6 °C.

The flash point standard limit is between 100 and 170 °C, so this test result is acceptable. (For detail see appendix B)

6.2.2 Kinematic Viscosity

The Kinematic viscosity of a fluid measures its resistance to flow under gravity, the viscosity of fuel effect the fuel injectors operation, the viscosity of fuel is important for the estimation of optimum storage, handling, and operational conditions.

Apparatus

1- Capillary tube viscometer.
2- Tamson heater.
3- Stopwatch.

Test Procedure:

1- Capillary tube is used to measure the viscosity.
2- 5mL of biodiesel transferred into the viscometer that was put in oven at (40°C), and drawn up about (7mm) above the upper timing mark.
3- The stopwatch was turned on when liquid reached the upper timing viscometer mark.
4- When the liquid reached to lower timing mark the time was taken to be used in Kinematic viscosity calculation.
5- Each tube has factor which is multiple by the time and result is Kinematic viscosity.

Figure 6.2 Kinematic viscosity tester

Results:

Table 6.3 shows the results for kinematic viscosity of biodiesel samples:

Table 6.2 Kinematic Viscosity Test Results

Sample	Viscosity at 40 °C (mm^2/s)
A	3.4
B	3.7
C	3.5

-The average kinematic viscosity for produced biodiesel= 3.53mm^2/s

-The standard range for biodiesel kinematic viscosity is from 1.9-6.5 mm^2/s, so this test satisfies the biodiesel standard limits. (For detail see appendix B)

6.2.3. Density, Specific Gravity

The density of a liquid is the ratio of unit mass to the unit volume, where the specific gravity is the ratio between liquid density and water density.

Apparatus

1- Hydrometer

2- Graduated cylinder

Test Procedure:

1- Suitable volume of biodiesel (about 150mL) was transferred to graduated cylinder

2- Hydrometer with suitable scale was immersed into the biodiesel cylinder and the reading was taken.

Results:

Table 6.3 Density and specific gravity results

Sample	Density at 15 °C (kg/m^3)	Specific gravity
A	883	0.883
B	881	0.881
C	879	0.879

The average density of the three samples at 15 °C = 881 kg/m^3, hence; this result is near to the density of biodiesel which is = 880 kg/m^3. (For detail see appendix B)

6.2.4 Sulfur content

This test appears the amount of sulfur introduced in the produced biodiesel sample. The ratio of sulfur content should be low as possible, according to the formation of acid rain which was introduced in the previous chapters.

Apparatus

1. Graduated flask.
2. Oven.
3. Spectrum tester.

Test procedure

1. A drop of biodiesel is mixed with zincronium oxide powder (ZrO_2).
2. This sample is burned.
3. The burned sample is heated into oven at 700 C˚ for quarter hour, and then leave it to cool until it reach room temperature.
4. Distilled water (8 ml) and (2ml) sulfuric acid (H_2SO_4) is mixed with burned sample.
5. Put the mixture in a flask and add water until the volume become (100ml).
6. A ray is directed to the previous mixture, the reflected ray is proportional to amount of sulfur.

Figure 6.3 Sulfur content oven

Figure 6.4 spectrum sulfur content tester

Results

Table 6.4 sulfur content Test Results

Sample	Wt%
A	0.0016
B	0.0012
C	0.0019

The average of the above results is = 0.00156 Wt%, and so, this result is naturally implied within the acceptable range which is between 0 and 0.0024 Wt%. (for detail see appendix B)

6.2.5 Water content

The water content of fuel is significant because it can cause corrosion of equipment and problems in processing. The presence of water is due to incomplete washing and filtering.

Test procedure

1. Put biodiesel sample in distilled flask.
2. Heat the sample of biodiesel until the dissolved water is fully evaporates.
3. All evaporated amount of water must be cooled until it is condensed.
4. Metering the weight of water relatively to biodiesel

Results

Table 6.5 water content Test Results

Sample	Wt%
A	0.2
B	0.2
C	0.2

The average of the above results is = 0.2 Wt%, and so, this result is naturally implied within the acceptable ratio which is 0.5 Wt%.

A comparison is done between this project and al najah university project

Table 6.6 Tests comparison

Test	Al najah university project	This project
Flash point	110	157.6
Kinematic viscosity	4.02	3.53
Density, specific gravity	880	881

Some variation in the done tests, this related to the operating condition for each test related to reaction temperature, mixing time, amount of methanol and sodium hydroxide, mixer rotational speed, and etc..

6.3 Observations on IC engine

The produced samples of biodiesel (B100, B20) were tested to operate an (VW, 2.15 liter, 85 model) engine available in the mechanical engineering department workshop, and results were as follows:

- The engine was operated efficiently and in an easy manner relatively same as common diesel fuel on a sample of B100.
- When using biodiesel (B100), it has been noticed that the speed of the engine (rpm) was more than that of common diesel fuel, because of higher cetane number than diesel.
- It has been noticed during the test, that there was a white smoke in emission, due to the presence of water which was used for the operation of washing.
- The test resulted in a certain smell as if it was fried oil.
- In the case of biodiesel B20, it has been noticed that speed was less than that of sample B100, comparatively the same as diesel fuel, also white smoke and smell was less.

Figure 6.5 Diesel engine

Chapter Seven

Conclusions and Recommendations

Contents:

Chapter Seven

Conclusions and Recommendations

7.1 conclusions

1. Biodiesel production needs simple raw materials that can be found in large quantities.
2. There are good resources to produce Biodiesel in Hebron district according to quantities that was surveyed; such as animal fats, waste oil.
3. In Hebron district it was found that a high percentage of people using waste oil in animal feeding, the other used it to make soap, which causes human risk.
4. It was found there are differences in the duration of using cooking oil for the same family member's number, Which adds difficulty determine accurately the quantity.
5. The price of biodiesel is approximately half the usual petrodiesel fuel, so this project will get high profits if Biodiesel sold slightly below petroleum diesel.
6. Using Biodiesel fuel (B100) in diesel engine reduces the out put emission like: Sulfur dioxide by 100%, Soot emissions by 40-60%, Carbon monoxide by 10-50% , Hydrocarbons by 10-50%, than diesel engine, but Nitrous oxide increased by 5-10% than diesel engine, so Biodiesel fuel will protect the environment.
7. Using Biodiesel fuel blends does not need any modification on the engine.
8. Biodiesel reduce global warming green house effect.
9.If the estimated quantity of waste vegetable oil and animal fats were collected and converted to biodiesel up to 2.2% of the total 94 million liter of petrodiesel consumed in Hebron district annually could be replaced using the petrodiesel fuel.

7.2 Recommendations

1. Help of formal and local institutions to spread awareness about the best way to dispose waste oil and the duration of using it.
2. Formal and local institutions need to put regulations to prevent disposed waste oil in drain systems and soil.
3. Using Unrefined biodiesel fuel primarily in heating systems.
4. Invite ministry of health in Hebron district to check restaurants and fast food shops because some of them used cooking oil for a long time, and others doesn't change it at all, that will cause a harmful diseases like cancer.

APPINDEX

APPINDEX A

متوسط كمية الزيوت المهدورة من المنازل في محافظة الخليل					
عدد افراد الاسرة	الزمن	الضائع(لتر)	العبوة المستخدمة(لتر)	الضائع/عدد افراد الاسرة	استهلاك الفرد/الزمن
5	5	1	3	0.2	0.040
8	3	2	5	0.25	0.083
9	5	1	5	0.11	0.022
6	2	1	5	0.16	0.083
10	8	2	16	0.2	0.025
5	3	0.5	3	0.1	0.033
2	2	0.25	1	0.125	0.062
5	2	0.5	3	0.1	0.050
8	3	0.25	3	0.031	0.010
5	4	1	3	0.2	0.050
5	3	0.5	5	0.1	0.033
8	2	2	5	0.25	0.125
7	2	0.25	1	0.035	0.017
7	3	0.5	3	0.071	0.023
9	1	0.5	3	0.055	0.055
5	4	2	5	0.4	0.100
8	3	1	3	0.125	0.041
8	3	1	5	0.125	0.041
11	4	0.25	3	0.022	0.005
8	2	0.25	3	0.031	0.015
7	3	0.25	3	0.035	0.011
5	3	0.25	5	0.05	0.016
5	3	0.25	3	0.05	0.016
9	8	1	16	0.11	0.013
7	6	2	16	0.28	0.047
6	4	0.5	3	0.083	0.020
8	3	1	3	0.125	0.041
5	4	0.5	5	0.1	0.025
6	4	1	3	0.16	0.041
6	3	2	5	0.33	0.111
4	4	0.5	3	0.125	0.031
7	4	0.5	3	0.071	0.017
8	5	1	3	0.125	0.025
9	4	2	5	0.22	0.055
5	3	0.5	5	0.1	0.033
3	4	0.25	3	0.083	0.020
9	2	1	5	0.11	0.055
4	2	0.5	3	0.125	0.062
2	4	0.25	1	0.125	0.031
8	3	1	5	0.125	0.041
7	2	0.5	3	0.071	0.035
				المجموع	1.677
				المعدل الفرد لكل اسبوع	**0.040**
				المعدل لجميع السكان اسبوعيا	21812.365
				المعدل سنويا(لتر)	1046993.55
				المعدل يوميا(لتر)	2868.475

مسح لكميات الزيوت في مدينة الخليل من المطاعم ومحلات الوجبات السريعة لكل يوم						
الكمية(لتر)	محلات البروست	الكمية(لتر)	المطاعم الكبيرة	الكمية(لتر)	كفيتريات الجامعات	
50	عين سارة	7	خليل الرحمن	20	البوليتكنك بفروعه	
8	الجامعة	3	القدس	10	الخليل	
17	الحاووز	10	ابو مازن	5	القدس المفتوحة	
2	باب الزاوية	5	لبنان			
2	دوار الرحمة	7	الصباح			
		5	بلودان			
		4	ابو الفتوح			
		3	زيتون			
79		44		35		158
الكمية(لتر)	مصانع الشيبس	الكمية(لتر)	مطاعم صغيرة			
25	القصراوي	14	مطاعم شارع وادي التفاح(7)			
10	صلاح	4	شارع نمرة(2)			
		6	الحاووز(3)			
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20	السلايمة(ملك الفلافل)	8	شارع وادي التفاح(4)	20	محلات متفرقة10	
6	شاور	8	شارع السلام(4)			
7	طهبوب المنارة	8	شارع عين سارة(4)			
4	ابوسرية	12	شارع الحاووز(6)			
9	الفاخوري الثانوية	6	حي الجامعة(3)			
7	الفاخوري باب الزاوية	10	شارع الشلالة(5)			
8	الفاخوري موقف حلحول	8	شارع نمرة(4)			
8	شاورما الريان1	5	الجلدة+عيصى(5)			
8	شاورما الريان2	20	المنطقةالجنوبية(10)			
77		85		20		182
					المجموع الكلي يوميا(لتر)	413
					سنويا(لتر)	150745

كمية الزيوت المهدورة يوميا في قرى الخليل الكبيرة			
القرية	الكمية باللتر		
دورا	20		7300
الظاهرية	21		7665
يطا	22		8030
نوبا	4		1460
خاراس	5		1825
اذنا	5		1825
ترقوميا	7		2555
بيت اولا	7		2555
بيت امر	15		5475
صوريف	6		2190
سعير	5		1825
بني نعيم	10		3650
حلحول	8		2920
تفوح	1		365
المجموع يوميا	136	المجموع سنويا(لتر)	49640

احصائيه الدهون المستخلصه سنويا في محافظه الخليل			
نوع الدهون	العدد	الكميه الضائعه(غم)	الكميه بلكيلو
اغنام	120000	1500	180000
عجول	37000	3000	111000
جمل	10000	2000	20000
لحوم بيضاء	3000000	200	600000
المجموع (سنويا)			911000

بسم الله الرحمن الرحيم

جامعة بوليتكنك فلسطين

كلية الهندسة والتكنولوجيا

دائرة الهندسة الميكانيكية

استبيان خاص لمعرفة كميات الزيوت المهدورة في المنازل

السادة الكرام

السلام عليكم ورحمة الله وبركاته ،،،

نود إعلام حضراتكم أننا الفريق الطلابي من جامعة بوليتكنك فلسطين/مرحلة التخرج، نقوم بدراسة مسحية لكميات الزيوت المستنفذة من الاستخدام المنزلي وتأثيرها على البيئة المحيطة والصحة بالاضافة الى المساعدة في دعم الاقتصاد المحلي من خلال المساهمة باعادة استخدام هذه الزيوت كوقود بديل عن الديزل (الوقود الحيوي).

لذا نرجو من حضراتكم التكرم بالإجابة على الأسئلة المطروحة في هذا الاستبيان بموضوعية ووضوح قدر المستطاع من أجل التوصل إلى الأهداف العلمية المرجوة، علماً بأن هذه الدراسة سوف تستخدم لأغراض البحث العلمي.

شاكرين لكم حسن تعاونكم

الطلبة الباحثون

معاوية العويوي

مهران شويكي

الرجاء وضع إشارة × في مربع الإجابة المناسبة

1. كم عدد أفراد الأسرة لديكم؟

☐ اثنين	☐ ثلاثة	☐ أربعة	☐ خمسة	☐ غير ذلك

2. ماهو حجم عبوة الزيت النباتي المستخدمة لديكم بشكل دوري؟

☐ 1لتر	☐ 3لتر	☐ 5لتر	☐ 16لتر	☐ غير ذلك

3. القترة الزمنية التي تستهلك فيها هذه العبوة:

☐ أسبوع واحد	☐ أسبوعين	☐ ثلاثة أسابيع	☐ أربعة أسابيع	☐ غير ذلك

4. كم كمية الزيت المتلفة بعد الاستعمال من العبوة الواحدة؟

☐ ربع لتر	☐ نصف لتر	☐ لتر	☐ 2لتر	☐ غير ذلك

5. مكان إتلافها؟

☐ الصرف الصحي	☐ التربة	☐ حاويات النفايات	☐ غير ذلك

6. هل ترغب بالتعاون في تجميع الزيوت بعد الاستخدام من اجل حماية البيئة والصحة وتحويلها إلى وقود حيوي؟

☐ نعم	☐ لا	☐ ربما	☐ غير ذلك

مع فائق الاحترام والتقدير

Palestinian National Authority
Ministry Of Finance
General Petroleum Corporation

السلطة الوطنية الفلسطينية
وزارة المالية
الهيئة العامة للبترول

بسم الله الرحمن الرحيم

التاريخ: ٢٠٠٧/١١/١٤م

حضرة السيد م. زهير وزوز المحترم

تحية طيبة وبعد،،

الموضوع: كتابكم رقم 9/2007

رداً على كتابكم رقم 9/2007 بتاريخ ٢٠٠٧/١١/١٢م ، مرفق طيه كشف يوضح مسحوبات محافظة الخليل من مادة السولار خلال سنة 2007 وكذلك سعر اللتر وهامش الربح لمحطات محافظة الخليل وهي على النحو التالي:

الشهر	مسحوبات محافظة الخليل من السولار	سعر اللتر	هامش الربح لكل 1000 لتر
1/2007	5607779 لتر	4.18	220 شيكل
2/2007	7292562 لتر	4.05	220 شيكل
3/2007	7310194 لتر	4.18	220 شيكل
4/2007	7979071 لتر	3.76	220 شيكل
5/2007	8444425 لتر	3.86	220 شيكل
6/2007	8174477 لتر	3.94	220 شيكل
7/2007	8980082 لتر	4.17	230 شيكل
8/2007	8319927 لتر	4.31	250 شيكل
9/2007	8554448 لتر	4.40	250 شيكل
10/2007	8308208 لتر	4.67	250 شيكل

وتفضلوا بقبول فائق الاحترام والتقدير

مدير مكتب الخليل

عريف العجلوني

السلطة الوطنية الفلسطينية
وزارة المالية
الهيئة العامة للبترول

تلفون : ٠٢-٢٤٠٤٩٨٨ فاكس : ٠٢-٢٤٠٤٠٠٣ ص . ب : ٣٧٢٥ البيرة - فلسطين
تلفون : ٠٨-٢٨٢٣٧٤٥ فاكس : ٠٨-٢٨٤٣٤٠٧ ص . ب : ١٤٤٤ الرمال - غزة - فلسطين

APPINDEX B

Comparison Of Biodiesel Specifications and ASTM D 975 Specifications

Fuel Property	**Diesel**	**Biodiesel**
Fuel Standard	ASTM PS 121	ASTM D975
Fuel composition	C10-C21 HC	C12-C22 FAME
Lower Heating Value, kJ/Kg	43,138	37,135
Kin. Viscosity at 40°C ,mm ^{2}/s	1.3-4.1	1.9-6.0
Specific Gravity	0.85	0.87
Density at 15 °C, kg/m^3	850	880
Water content	161ppm	0.05% wt
Carbon, wt %	87	77
Hydrogen, wt %	13	12
Oxygen, wt %	0	11
Sulfur, wt %	0.05 max	0.0 - 0.0024
Boiling Point, °C	188-343	182-338
Flash Point, °C	60-80	100-170
Cloud Point, °C	-15 to 5	-3 to 12
Pour Point, °C	-35 to -15	-15 to 10
Cetane Number	40-55	48-65
Stoichiometric Air/Fuel Ratio wt./wt.	15	13.8

Viscosity of various liquids

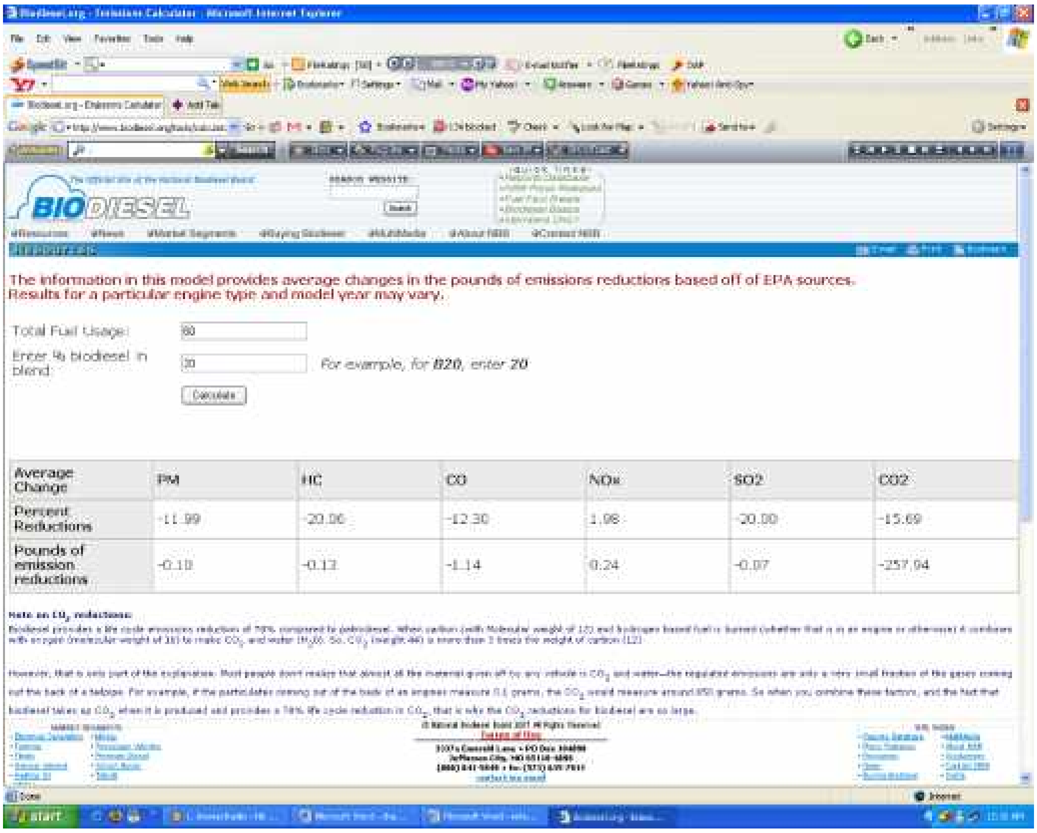
Oil or Fat	*Iodine Value*	*CN*	*HG (kJ/kg)*	*Viscosity (mm^2/s)*	*CP (°C)*	*PP (°C)*	*FP (°C)*
Babassu	10-18	38					
Castor	82-88	?	39500	297 (38°)	---	-31.7	260
Coconut	6-12						
Corn	103-140	37.6	39500	34.9 (38°)	-1.1	-40.0	277
Cottonseed	90-119	41.8	39468	33.5 (38°)	1.7	-15.0	234
Crambe	93	44.6	40482	53.6 (38°)	10.0	-12.2	274
Linseed	168-204	34.6	39307	27.2 (38°)	1.7	-15.0	241
Olive	75-94						
Palm	35-61	42					
Peanut	80-106	41.8	39782	39.6 (38°)	12.8	-6.7	271
Rapeseed	94-120	37.6	39709	37.0 (38°)	-3.9	-31.7	246
Safflower	126-152	41.3	39519	31.3 (38°)	18.3	-6.7	260
High-oleic safflower	90-100	49.1	39516	41.2 (38°)	-12.2	-20.6	293
Sesame	104-120	40.2	39349	35.5 (38°)	-3.9	-9.4	260
Soybean	117-143	37.9	39623	32.6 (38°)	-3.9	-12.2	254
Sunflower	110-143	37.1	39575	37.1 (38°)	7.2	-15.0	274
Tallow	35-48	-	40054	51.15 (40°)	-	-	201
No. 2 DF		47	45343	2.7 (38°)	-15.0	-33.0	52

The specific heat capacity of some common liquids and fluids can be found in the table below:

Product	Specific Heat Capacity - c_p	
	(kJ/kg.K)	(Btu/lb.°F)
Freon R-12 saturated 120°F	1.02	0.244
Fuel Oil min.	1.67	0.4
Fuel Oil max.	2.09	0.5
Gasoline	2.22	0.53
Iodine	2.15	0.51
Kerosene	2.01	0.48
Linseed Oil	1.84	0.44
Mercury	0.14	0.03
Milk	3.93	0.94
Naphthalene	1.72	0.41
Octane	2.15	0.51
Oil, mineral	1.67	0.4
Oil, vegetable	1.67	0.4
Olive oil	1.97	0.47

Table 1		
Oils	**Density (g/cm³)**	**Temp (°C)**
coconut	0.925	15
cotton seed	0.926	16
olive	0.918	15

Table 2	
Cotton Seed oil, U.S.P./N.F. specific gravity @ 25 °C	0.915-0.921
Olive Oil, U.S.P./N.F specific gravity @ 25 °C	0.910-0.915
Peanut Oil, U.S.P./N.F. specific gravity @ 25 °C	0.912-0.920


BIODIESEL

The information in this model provides average changes in the pounds of emissions reductions based off of EPA sources.
Results for a particular engine type and model year may vary.

Total Fuel Usage: 80

Enter % biodiesel in blend: 20 For example, for **B20**, enter **20**

Calculate

Average Change	PM	HC	CO	NOx	SO2	CO2
Percent Reductions	-11.99	-20.06	-12.30	1.98	-20.00	-15.69
Pounds of emission reductions	-0.10	-0.13	-1.14	0.24	-0.07	-257.94

APPINDEX C

WARREN ELECTRIC CORPORATION

ISO 9001 REGISTERED

Warren, Rhode Island

Screw Plug Heaters - Copper Sheathed Elements

2" NPT BRONZE Plug

1.5 to 18 kW
56-67 W/in²

U.L. Listed

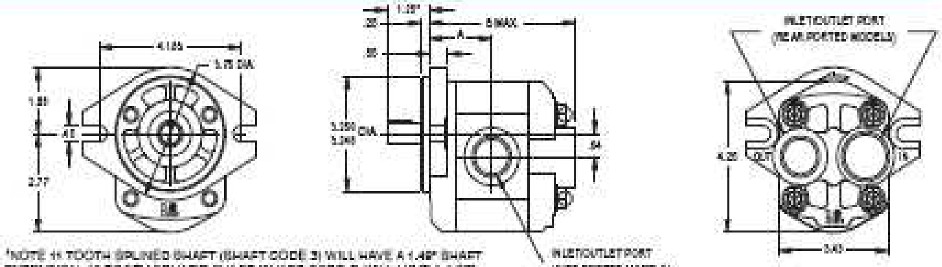
120 Volt, Single Phase & 208 Volt, Single & Three Phase

kW	Immersion in	Immersion (mm)	Watt Density W/in²	Watt Density (W/cm²)	120V 1 Phase	208V 1 Phase	208V 3 Phase	No. Ele	Est Weight lb	Est Weight (kg)
1.5	11	(280)	61	(9.5)	XPS-1.5-1-11C	XPS-1.5-208-11C		1	4	(2)
2	8	(204)	61	(9.5)	XPS-2-1-8C	XPS-2-208-8C		2	4	(2)
2.5	9.5	(242)	58	(9)	XPS-2.5-1-9.5C	XPS-2.5-208-9.5C		2	5	(3)
3	8	(204)	61	(9.5)	XPS-3-1-8C	XPS-3-208-8C	XPS-3-208-8C*3	3	5	(3)
3	11	(280)	61	(9.5)	XPS-3-1-11C	XPS-3-208-11C		2	5	(3)
4	15	(381)	56	(8.7)	XPS-4-1-15C	XPS-4-208-15C		2	5	(3)
4.5	11	(280)	61	(9.5)	XPS-4.5-1-11C	XPS-4.5-208-11C	XPS-4.5-208-11C*3	4	5	(3)
5	18	(458)	57	(8.8)	XPS-5-1-18C	XPS-5-208-18C		2	5	(3)
6	15	(381)	56	(8.7)		XPS-6-208-15C	XPS-6-208-15C*3	3	6	(3)
6	21	(534)	58	(9)		XPS-6-208-21C		2	6	(3)
7	25	(635)	60	(9.3)		XPS 7 208 25C		2	6	(3)
7.5	18	(458)	57	(8.8)		XPS-7.5-208-18C	XPS-7.5-208-18C*3	3	6	(3)
8	27	(686)	61	(9.5)		XPS 8 208 27C		2	6	(3)
9	21	(534)	58	(9)		XPS-9-208-21C	XPS-9-208-21C*3	3	7	(4)
10	32	(813)	61	(9.5)		XPS 10 208 32C		2	7	(4)
12	27	(686)	61	(9.5)			XPS-12-208-27C*3	3	8	(4)
15	32	(813)	61	(9.5)			XPS-15-208-32C*3	3	9	(5)

240 & 480 Volt, Single & Three Phase

kW	Immersion in	Immersion (mm)	Watt Density W/in²	Watt Density (W/cm²)	240V 1 Phase	240V 3 Phase	480V 1 Phase	480V 3 Phase	No. Ele	Est Weight lb	Est Weight (kg)
1.5	11	(280)	61	(9.5)	XPS-1.5-2-11C		XPS-1.5-4-11C		1	4	(2)
2	8	(204)	61	(9.5)	XPS-2-2-8C		XPS-2-4-8C		2	4	(2)
2.5	9.5	(242)	58	(9)	XPS-2.5-2-9.5C		XPS-2.5-4-9.5C		2	5	(3)
3	8	(204)	61	(9.5)	XPS-3-2-8C	XPS-3-2-8C*3	XPS-3-4-8C	XPS-3-4-8C*3	3	5	(3)
3	11	(280)	61	(9.5)	XPS-3-2-11C		XPS-3-4-11C		2	5	(3)
4	15	(381)	56	(8.7)	XPS-4-2-15C		XPS-4-4-15C		2	5	(3)
4.5	11	(280)	61	(9.5)	XPS-4.5-2-11C	XPS-4.5-2-11C*3	XPS-4.5-4-11C	XPS-4.5-4-11C*3	3	5	(3)
5	18	(458)	57	(8.8)	XPS 5 2 18C		XPS 5 4 18C		2	5	(3)
6	15	(381)	56	(8.7)	XPS 6 2 15C	XPS 6 2 15C*3	XPS 6 4 15C	XPS 6 4 15C*3	3	6	(3)
6	21	(534)	58	(9)	XPS 6 2 21C		XPS 6 4 21C		2	6	(3)
7	25	(635)	60	(9.3)	XPS-7-2-25C		XPS-7-4-25C		2	6	(3)
7.5	18	(458)	57	(8.8)	XPS-7.5-2-18C	XPS-7.5-2-18C*3	XPS-7.5-4-18C	XPS-7.5-4-18C*3	3	6	(3)
8	27	(686)	61	(9.5)	XPS-8-2-27C		XPS-8-4-27C		2	6	(3)
9	21	(534)	58	(9)	XPS-9-2-21C	XPS-9-2-21C*3	XPS-9-4-21C	XPS-9-4-21C*3	3	7	(4)
10	32	(813)	61	(9.5)	XPS-10-2-32C		XPS-10-4-32C		2	7	(4)
12	27	(686)	61	(9.5)		XPS-12-2-27C*3	XPS-12-4-27C	XPS-12-4-27C*3	3	8	(4)
12	38	(966)	67	(10.4)	XPS-12-2-38C*2		XPS-12-4-38C		2	7	(4)
15	32	(813)	61	(9.5)		XPS-15-2-32C*3	XPS-15-4-32C	XPS-15-4-32C*3	3	9	(5)
18	38	(966)	67	(10.4)		XPS-18-2-38C*3	XPS-18-4-38C	XPS-18-4-38C*3	3	9	(5)

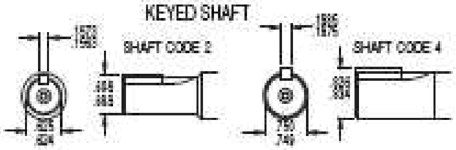
SP20 SERIES DIMENSIONAL DATA



*NOTE 11 TOOTH SPLINED SHAFT (SHAFT CODE 3) WILL HAVE A 1.49" SHAFT EXTENSION. 10 TOOTH SPLINED SHAFT (SHAFT CODE 5) WILL HAVE A 1.37" SHAFT EXTENSION.

INLET/OUTLET PORT (SIDE PORTED MODELS)

KEYED SHAFT



SPLINED SHAFT

SHAFT CODE 9	SHAFT CODE 5	SHAFT CODE 3
9 TOOTH 16/32 DP 30° PA FLAT ROOT SIDE FIT	10 TOOTH 16/32 DP 30° PA FLAT ROOT SIDE FIT	11 TOOTH 16/32 DP 30° PA FLAT ROOT SIDE FIT

TYPICAL PERFORMANCE DATA

		RPM								PRESSURE
MODEL		500	1000	1500	2000	2500	3000	3500	4000	(PSI)
SP20B06	FLOW (GPM)	.78	1.62	2.48	3.35	4.24	5.10	5.96	6.92	3000
	INPUT HORSE POWER	1.85	3.77	5.66	7.57	9.45	11.13	13.06	14.80	
SP20B08	FLOW (GPM)	.88	1.91	2.97	4.04	5.10	6.16	7.27	8.33	
	INPUT HORSE POWER	2.23	4.38	6.53	8.83	11.13	13.57	16.17	18.69	
SP20B09	FLOW (GPM)	1.03	2.30	3.52	4.75	5.97	7.19	8.46	9.74	
	INPUT HORSE POWER	2.81	5.03	7.54	10.14	12.84	15.54	18.43	21.31	
SP20B11	FLOW (GPM)	1.27	2.74	4.16	5.63	7.05	8.51	9.98	11.40	
	INPUT HORSE POWER	2.98	5.77	8.75	11.63	14.80	17.87	21.12	24.38	
SP20B14	FLOW (GPM)	1.61	3.36	5.19	7.01	8.91	10.74	12.56	14.39	
	INPUT HORSE POWER	3.68	7.09	10.51	14.19	18.00	21.68	25.49	29.43	
SP20B16	FLOW (GPM)	1.80	3.82	5.87	7.93	9.98	12.11	14.24	16.22	
	INPUT HORSE POWER	4.01	7.86	11.87	15.87	20.17	24.33	28.78	34.12	
SP20B20	FLOW (GPM)	2.35	4.92	7.49	10.05	12.70	15.26	17.76		
	INPUT HORSE POWER	5.21	9.98	14.69	20.10	25.16	30.52	35.73		
SP20B23	FLOW (GPM)	2.80	5.72	8.73	11.60	14.68	17.61	20.55		2500
	INPUT HORSE POWER	5.06	9.68	14.44	19.21	24.27	29.48	34.54		
SP20B27	FLOW (GPM)	3.30	6.90	10.47	13.90	17.52	20.94	24.46		
	INPUT HORSE POWER	5.98	11.59	17.20	23.00	28.98	34.78	41.13		
SP20B30	FLOW (GPM)	3.85	7.78	11.47	15.36	19.22	23.03	26.88		
	INPUT HORSE POWER	6.40	12.56	18.38	24.64	30.93	37.59	43.80		
SP20B33	FLOW (GPM)	4.13	8.47	12.60	16.86	21.11	25.26	29.52		
	INPUT HORSE POWER	7.14	13.40	19.98	27.04	33.90	41.05	47.89		

Typical Performance Data Based on 140 SUS Oil at 120° F

PUMPS AND MOTORS

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Table A–6

Properties of Structural-Steel Angles*† (Continued)

Size, mm	m	A	I_{1-1}	k_{1-1}	Z_{1-1}	y	k_{3-3}
25 × 25 × 3	1.11	1.42	0.80	0.75	0.45	0.72	0.48
× 4	1.45	1.85	1.01	0.74	0.58	0.76	0.48
× 5	1.77	2.26	1.20	0.73	0.71	0.80	0.48
40 × 40 × 4	2.42	3.08	4.47	1.21	1.55	1.12	0.78
× 5	2.97	3.79	5.43	1.20	1.91	1.16	0.77
× 6	3.52	4.48	6.31	1.19	2.26	1.20	0.77
50 × 50 × 5	3.77	4.80	11.0	1.51	3.05	1.40	0.97
× 6	4.47	5.59	12.8	1.50	3.61	1.45	0.97
× 8	5.82	7.41	16.3	1.48	4.68	1.52	0.96
60 × 60 × 5	4.57	5.82	19.4	1.82	4.45	1.64	1.17
× 6	5.42	6.91	22.8	1.82	5.29	1.69	1.17
× 8	7.09	9.03	29.2	1.80	6.89	1.77	1.16
× 10	8.69	11.1	34.9	1.78	8.41	1.85	1.16
80 × 80 × 6	7.34	9.35	55.8	2.44	9.57	2.17	1.57
× 8	9.63	12.3	72.2	2.43	12.6	2.26	1.56
× 10	11.9	15.1	87.5	2.41	15.4	2.34	1.55
100 × 100 × 8	12.2	15.5	145	3.06	19.9	2.74	1.96
× 12	17.8	22.7	207	3.02	29.1	2.90	1.94
× 15	21.9	27.9	249	2.98	35.6	3.02	1.93
150 × 150 × 10	23.0	29.3	624	4.62	56.9	4.03	2.97
× 12	27.3	34.8	737	4.60	67.7	4.12	2.95
× 15	33.8	43.0	898	4.57	83.5	4.25	2.93
× 18	40.1	51.0	1050	4.54	98.7	4.37	2.92

*Metric sizes also available in sizes of 45, 70, 90, 120, and 200 mm.

†These sizes are also available in aluminum alloy.

TABLE A-15

Properties of air at 1 atm pressure

Temp., T, °C	Density, ρ, kg/m³	Specific Heat, C_p, J/kg · °C	Thermal Conductivity, k, W/m · °C	Thermal Diffusivity, α, m²/s	Dynamic Viscosity, μ, kg/m · s	Kinematic Viscosity, ν, m²/s	Prandtl Number, Pr
−150	2.866	983	0.01171	4.158×10^{-6}	8.636×10^{-6}	3.013×10^{-6}	[illegible]
−100	2.038	966	0.01582	8.036×10^{-6}	1.189×10^{-5}	5.837×10^{-6}	[illegible]
−50	1.582	999	0.01979	1.252×10^{-5}	1.474×10^{-5}	9.319×10^{-6}	[illegible]
−40	1.514	1002	0.02057	1.356×10^{-5}	1.527×10^{-5}	1.008×10^{-5}	[illegible]
−30	1.451	1004	0.02134	1.465×10^{-5}	1.579×10^{-5}	1.087×10^{-5}	[illegible]
−20	1.394	1005	0.02211	1.578×10^{-5}	1.630×10^{-5}	1.169×10^{-5}	[illegible]
−10	1.341	1006	0.02288	1.696×10^{-5}	1.680×10^{-5}	1.252×10^{-5}	[illegible]
0	1.292	1006	0.02364	1.818×10^{-5}	1.729×10^{-5}	1.338×10^{-5}	[illegible]
5	1.269	1006	0.02401	1.880×10^{-5}	1.754×10^{-5}	1.382×10^{-5}	[illegible]
10	1.246	1006	0.02439	1.944×10^{-5}	1.778×10^{-5}	1.426×10^{-5}	[illegible]
15	1.225	1007	0.02476	2.009×10^{-5}	1.802×10^{-5}	1.470×10^{-5}	[illegible]
20	1.204	1007	0.02514	2.074×10^{-5}	1.825×10^{-5}	1.516×10^{-5}	[illegible]
25	1.184	1007	0.02551	2.141×10^{-5}	1.849×10^{-5}	1.562×10^{-5}	[illegible]
30	1.164	1007	0.02588	2.208×10^{-5}	1.872×10^{-5}	1.608×10^{-5}	[illegible]
35	1.145	1007	0.02625	2.277×10^{-5}	1.895×10^{-5}	1.655×10^{-5}	[illegible]
40	1.127	1007	0.02662	2.346×10^{-5}	1.918×10^{-5}	1.702×10^{-5}	[illegible]
45	1.109	1007	0.02699	2.416×10^{-5}	1.941×10^{-5}	1.750×10^{-5}	[illegible]
50	1.092	1007	0.02735	2.487×10^{-5}	1.963×10^{-5}	1.798×10^{-5}	[illegible]
60	1.059	1007	0.02808	2.632×10^{-5}	2.008×10^{-5}	1.896×10^{-5}	[illegible]
70	1.028	1007	0.02881	2.780×10^{-5}	2.052×10^{-5}	1.995×10^{-5}	[illegible]
80	0.9994	1008	0.02953	2.931×10^{-5}	2.096×10^{-5}	2.097×10^{-5}	[illegible]
90	0.9718	1008	0.03024	3.086×10^{-5}	2.139×10^{-5}	2.201×10^{-5}	[illegible]
100	0.9458	1009	0.03095	3.243×10^{-5}	2.181×10^{-5}	2.306×10^{-5}	[illegible]
120	0.8977	1011	0.03235	3.565×10^{-5}	2.264×10^{-5}	2.522×10^{-5}	[illegible]
140	0.8542	1013	0.03374	3.898×10^{-5}	2.345×10^{-5}	2.745×10^{-5}	[illegible]
160	0.8148	1016	0.03511	4.241×10^{-5}	2.420×10^{-5}	2.975×10^{-5}	[illegible]
180	0.7788	1019	0.03646	4.593×10^{-5}	2.504×10^{-5}	3.212×10^{-5}	[illegible]
200	0.7459	1023	0.03779	4.954×10^{-5}	2.577×10^{-5}	3.455×10^{-5}	[illegible]
250	0.6746	1033	0.04104	5.890×10^{-5}	2.760×10^{-5}	4.091×10^{-5}	[illegible]
300	0.6158	1044	0.04418	6.871×10^{-5}	2.934×10^{-5}	4.765×10^{-5}	[illegible]
350	0.5664	1056	0.04721	7.892×10^{-5}	3.101×10^{-5}	5.475×10^{-5}	[illegible]
400	0.5243	1069	0.05015	8.951×10^{-5}	3.261×10^{-5}	6.219×10^{-5}	[illegible]
450	0.4880	1081	0.05298	1.004×10^{-4}	3.415×10^{-5}	6.997×10^{-5}	[illegible]
500	0.4565	1093	0.05572	1.117×10^{-4}	3.563×10^{-5}	7.806×10^{-5}	[illegible]
600	0.4042	1115	0.06093	1.352×10^{-4}	3.846×10^{-5}	9.515×10^{-5}	[illegible]
700	0.3627	1135	0.06581	1.598×10^{-4}	4.111×10^{-5}	1.133×10^{-4}	[illegible]
800	0.3289	1153	0.07037	1.855×10^{-4}	4.362×10^{-5}	1.326×10^{-4}	[illegible]
900	0.3008	1169	0.07465	2.122×10^{-4}	4.600×10^{-5}	1.529×10^{-4}	[illegible]
1000	0.2772	1184	0.07868	2.398×10^{-4}	4.826×10^{-5}	1.741×10^{-4}	[illegible]
1500	0.1990	1234	0.09599	3.908×10^{-4}	5.817×10^{-5}	2.922×10^{-4}	[illegible]
2000	0.1553	1264	0.11113	5.664×10^{-4}	6.630×10^{-5}	4.270×10^{-4}	[illegible]

Note: For ideal gases, the properties C_p, k, μ, and Pr are independent of pressure. The properties ρ, ν, and α at a pressure P (in atm) other than [illegible] determined by multiplying the values of ρ at the given temperature by P and by dividing ν and α by P.

Source: Data generated from the EES software developed by S. A. Klein and F. L. Alvarado. Original sources: Keenan, Chao, Keyes, Gas Tables, [illegible] and Thermophysical Properties of Matter, Vol. 3: Thermal Conductivity, Y. S. Touloukian, P. E. Liley, S. C. Saxena, Vol. 11: Viscosity, Y. S. Touloukian, S. C. Saxena, and P. Hestermans, IFI/Plenum, NY, 1970, ISBN 0-306067020-8.

Appendix B. Typical Properties of Selected Materials Used in Engineering[1,5] (SI Units)

Material	Density kg/m³	Ultimate Strength: Tension, MPa	Ultimate Strength: Compression,[3] MPa	Ultimate Strength: Shear, MPa	Yield Strength[3]: Tension, MPa	Yield Strength[3]: Shear, MPa	Modulus of Elasticity, GPa	Modulus of Rigidity, GPa	Coefficient of Thermal Expansion, $10^{-6}/°C$	Ductility, Percent Elongation in 50 mm
Steel										
Structural (ASTM-A36)	7860	400			250	145	200	77.2	11.7	21
High-strength-low-alloy										
ASTM-A709 Grade 345	7860	450			345		200	77.2	11.7	21
ASTM-A913 Grade 450	7860	550			450		200	77.2	11.7	17
ASTM-A992 Grade 345	7860	450			345		200	77.2	11.7	21
Quenched & tempered										
ASTM-A709 Grade 690	7860	760			690		200	77.2	11.7	18
Stainless, AISI 302										
Cold-rolled	7920	860			520		190	75	17.3	12
Annealed	7920	655			260	150	190	75	17.3	50
Reinforcing Steel										
Medium strength	7860	480			275		200	77	11.7	
High strength	7860	620			415		200	77	11.7	
Cast Iron										
Gray Cast Iron										
4.5% C, ASTM A-48	7200	170	655	240			69	28	12.1	0.5
Malleable Cast Iron										
2% C, 1% Si, ASTM A-47	7300	345	620	330	230		165	65	12.1	10
Aluminum										
Alloy 1100-H14 (99% Al)	2710	110		70	95	55	70	26	23.6	9
Alloy 2014-T6	2800	455		275	400	230	75	27	23.0	13
Alloy-2024-T4	2800	470		280	325		73		23.2	19
Alloy-5456-H116	2630	315		185	230	130	72		23.9	16
Alloy 6061-T6	2710	260		165	240	140	70	26	23.6	17
Alloy 7075-T6	2800	570		330	500		72	28	23.6	11
Copper										
Oxygen-free copper (99.9% Cu)										
Annealed	8910	220		150	70		120	44	16.9	45
Hard-drawn	8910	390		200	265		120	44	16.9	4
Yellow-Brass (65% Cu, 35% Zn)										
Cold-rolled	8470	510		300	410	250	105	39	20.9	8
Annealed	8470	320		220	100	60	105	39	20.9	65
Red Brass (85% Cu, 15% Zn)										
Cold-rolled	8740	585		320	435		120	44	18.7	3
Annealed	8740	270		210	70		120	44	18.7	48
Tin bronze	8800	310			145		95		18.0	30
(88 Cu, 8Sn, 4Zn)										
Manganese bronze	8360	655			330		105		21.6	20
(63 Cu, 25 Zn, 6 Al, 3 Mn, 3 Fe)										
Aluminum bronze	8330	620	900		275		110	42	16.2	6
(81 Cu, 4 Ni, 4 Fe, 11 Al)										

(Table continued on page 74

LAB DEPT

Date :27/4/2008

Sample A bioDiesel

PETROPAL

SPECIFICATIONS

Test Name	unit	typical	NORM
Specific Gravity	-	0.883	ASTM D4052
Dinsety @15c, kg/m³		883	
Colour	-	1.5	ASTM D1500
Viscosity at 40°c	mm² /s	3.4	-
Viscosity at 100°c	mm² /s	-	ASTM D445
Viscosity index	-	-	ASTM D2270
Flash point Clevenad	c°	164	ASTM D92
Pour point	c°	-	ASTM D97
Water contet		0.2%wt	ASTM D2896
Sulfer content	wt%	0.0016	--

Lab manager

1 A 27/4/2008

LAB DEPT

Date :27/4/2008

Sample B bioDiesel

PETROPAL

SPECIFICATIONS

Test Name	unit	typical	NORM
Specific Gravity	-	0.881	ASTM D4052
Dinsety @15c, kg/m³		881	
Colour	-	1.5	ASTM D1500
Viscosity at 40°c	mm²/s	3.7	-
Viscosity at 100°c	mm²/s	-	ASTM D445
Viscosity index	-	-	ASTM D2270
Flash point Clevenad	c°	158	ASTM D92
Pour point	c°	-	ASTM D97
Water contet		0.2%wt	ASTM D2896
Sulfer content	wt%	0.0012	--

Lab manager

27/4/2008

LAB DEPT

Date :27/4/2008

Sample c bioDiesel

PETROPAL

SPECIFICATIONS

Test Name	unit	typical	NORM
Specific Gravity	-	0.879	ASTM D4052
Dinsety @15c, kg/m³		879	
Colour	-	1.5	ASTM D1500
Viscosity at 40°c	mm² /s	3.5	-
Viscosity at 100°c	mm² /s	-	ASTM D445
Viscosity index	-	-	ASTM D2270
Flash point Clevenad	c°	151	ASTM D92
Pour point	c°	-	ASTM D97
Water contet		0.2%wt	ASTM D2896
Sulfer content	wt%	0.0019	--

Lab manager

PETROPAL
Ctrl. No.
Serial No. 3
Date 27/4/2008

Viscosities of Selected Materials (note the different unit prefixes)

simple liquids	T (°C)	η (mPa·s)
alcohol, ethyl (grain)	20	1.1
alcohol, isopropyl	20	2.4
alcohol, methyl (wood)	20	0.59
blood	37	3 - 4
ethylene glycol	25	16.1
ethylene glycol	100	1.98
freon 11 (propellant)	-25	0.74
freon 11 (propellant)	0	0.54
freon 11 (propellant)	+25	0.42
freon 12 (refrigerant)	-15	??
freon 12 (refrigerant)	0	??
freon 12 (refrigerant)	+15	0.20
glycerin	20	1420
glycerin	40	280
mercury	15	1.55
milk	25	3
oil, vegetable, canola	25	57
oil, vegetable, canola	40	33
oil, vegetable, corn	20	65
oil, vegetable, corn	40	31
oil, vegetable, olive	20	84
oil, vegetable, olive	40	??
oil, vegetable, soybean	20	69
oil, vegetable, soybean	40	26
oil, machine, light	20	102
oil, machine, heavy	20	233
oil, motor, SAE 10	20	65
oil, motor, SAE 20	20	125
oil, motor, SAE 30	20	200
oil, motor, SAE 40	20	319

gases	T (°C)	η (μPa·s)
air	15	17.9
hydrogen	0	8.42
helium	0	18.6
nitrogen	0	16.7
oxygen	0	18.1

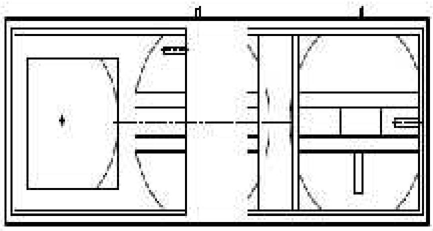
complex materials	T (°C)	η (Pa·s)
caulk	20	1000
glass, room temperature		10^{18} - 10^{21}
glass, strain point		$10^{13.6}$
glass, annealing point		$10^{12.4}$
glass, softening		$10^{6.6}$
glass, working		10^{3}
glass, melting		10^{2}
honey	20	10
ketchup	20	50
lard	20	1000
molasses	20	5
mustard	25	70
peanut butter	20	150 - 250
sour cream	25	100
syrup, chocolate	20	10 - 25
syrup, corn	25	2 - 3
syrup, maple	20	2 - 3
tar	20	30,000
vegetable shortening	20	1200

propylene glycol	25	40.4
propylene glycol	100	2.75
water	0	1.79
water	20	1.00
water	40	0.65
water	100	0.28

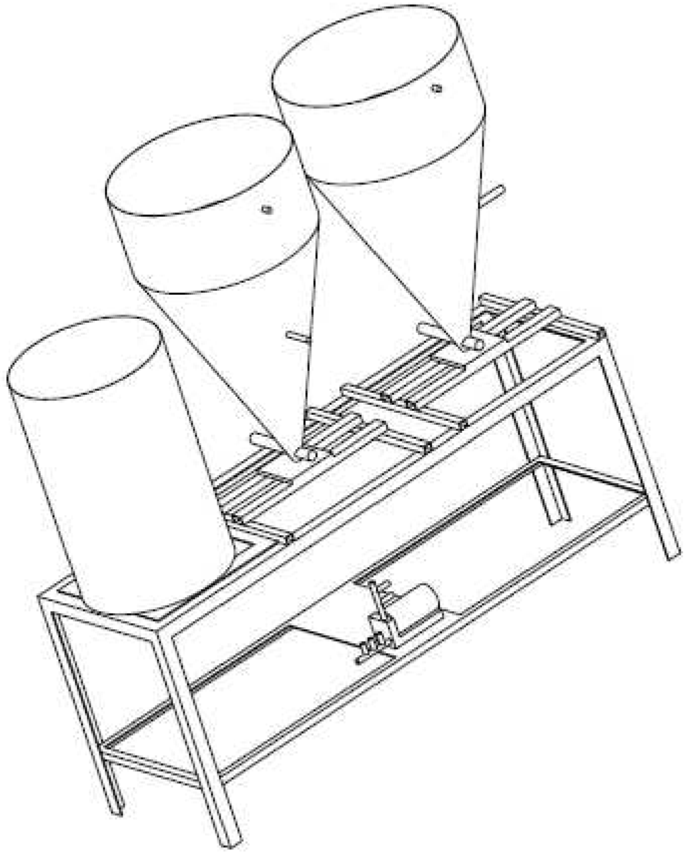
APPINDEX D

Three dimensional view for prototype

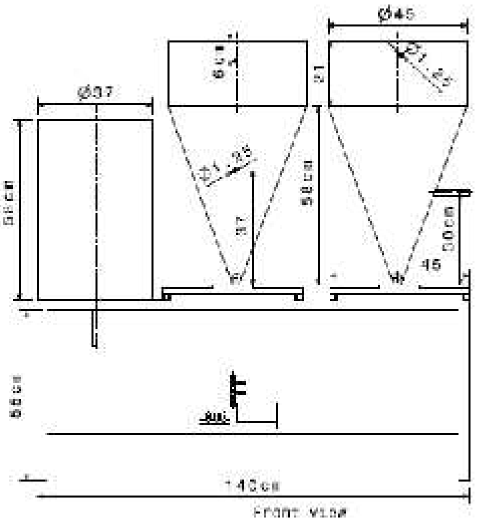
The dimension of this prototype as shown below



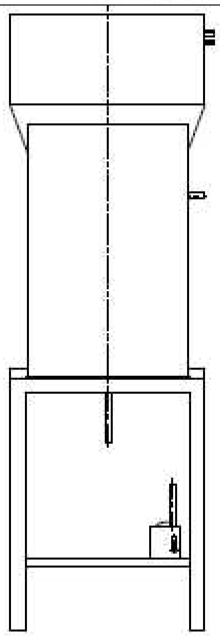
Bottom view



Isometric view



Front view



Left view

Prototype operating manual:

Switches:

1. Heater switch.
2. Blender switch.
3. Pump switch.

Manual valves;

4. Mixing tank output
5. Pump input from mixing tank.
6. Pump input from settling tank.
7. Pump input from washing tank.
8. Pump output to settling tank.
9. Pump output to washing tank.
10. Settling tank output.
11. Washing tank output.
12. Glycerin drain.
13. Waste water drain.
14. Biodiesel output.

Operation procedure:

1. Pour the required amount of waste oil in mixing tank between 30 to 60 litters.
2. Operate switch 1 until temperature reach 120 C˚.
3. Leave the content until temperature drop to 50 C˚.
4. Add the require amount of methanol and sodium hydroxide and then operate switch 2 for half hour.

5. Open valve 4, 5 and 8 then operate switch 3 until all amount transferred to settling tank. When finish closes them and leaves it about 8 to 12 hours.
6. open valve 6,10 and 9 then operate switch 3 until all amount transferred to washing tank, When finish close them.
7. Open valve 12 to drain glycerin.
8. Add about 5 liters of water to washing tank, after that open valve 7 and 11, then operate switch 3 for 10 minutes for washing process, then leave is to settle about 8 hours.
9. Open valve 14 to take biodiesel.
10. Open valve 13 to drain waste water

Note: the time required for each process as discussed in chapter 5.

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