DESIGN OF A BIODIESEL PROCESSOR

BY

OYENIRAN TAUFIQ O.

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A PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG) DEGREE IN AGRICULTURAL AND BIORESOURCE ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY MINNA, NIGER STATE, NIGERIA.

FEBRUARY, 2010.

DECLARATION

I hereby affirm that this project titled "Design of a biodiesel processor" is an original work and has never been submitted anywhere else before, neither has it been wholly or partially presented for any other degree. All sources of information have been duly acknowledged by means of reference.

Oyeniran Taufiq O.

22-02-10

Date

CERTIFICATION

This is to certify that the project titled "Design of a biodiesel processor" under the supervision of Dr. A.A. Balami of Agricultural and Bio-resource Engineering Department, Federal University of Technology, Minna.

____________________ ____________________

Engr. Dr. A.A. Balami — Date

(Project supervisor)

____________________ ____________________

Engr. Dr. A.A. Balami — Date

(Head of Department)

____________________ ____________________

(External Supervisor) — Date

DEDICATION

This Project is solely dedicated to Almighty Allah, who in His mercy I started this project and ended it in His infinite mercy "Say surely my prayer, my sacrifice my living and my death are for Allah, the Lord of the world Q6: 162.

ACKNOWLEDGMENT

I am grateful to the almighty Allah who has provided me with my needs, protection, guidance and sustained my life through my academic pursuit.

Special thanks go to my supervisor Engr. Dr. A.A. Balami, and other academic staff of Agricultural and Bioresources Engineering for their immense contributions and support during the execution of this project.

My sincere and profound gratitude goes to my beloved parents Mr. and Mrs. AbdurRasheed Oyeniran and, for their selfless moral and financial support, may Allah continue to shower his blessings on them and grant them " Aljannatul Firdaus" (Amin),. To my siblings: Jemila, Kareemah, Khalid and Abdussalam I love you all.

Also my friends to numerous to mention, you made my journey worthwhile. May Allah keep us together.

ABSTRACT

This project establishes and describes the design considerations involved in construction of a biodiesel processor for domestic use. A biodiesel processor designed comprises of two units capable of processing 131 litres of feedstock into biodiesel in the presence of the catalyst Potassium hydroxide (KOH). The Processor units are the main processor unit and the sub processor unit which are cylindrical with volume of 150litres and 100litres respectively . The units also comprise a pipe network of ¾inch galvanized iron for material transport, 2 support stands of angular iron of height 0.35m and a maximum load bearing capacity of 665.8kg. Also two electrically operated pumps of approximately 0.5hp an 0.7hp is required for material agitation and transportation but a 1hp pump is recommended. The total height of the Processor is 1.0675m. The design concluded that biodiesel through the transesterication can be processed and recommended the use of conical bottomed tanks for future modifications and an integrated heating system.

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CHAPTER ONE

1.0 INTRODUCTION

Design is a creativity whereby ideas are generated and translated into processes and equipment for producing new materials or significantly upgrading the value of the existing once. In this case, the target of this project is to design a prototype to produce biodiesel fuel.

1.1 Background of study

The definition of biodiesel in general terms for the layman can in some technical cases include a range of other experimental fuel that are not biodiesel and since the technical term can be quite confusing, two definitions will be stated

- General definition: biodiesel is a domestic, renewable fuel for diesel engines derived from natural oils like soybeans oil, olive oils etc.
- Technical definition: biodiesel is a fuel comprised of mono-alkyl esters (methyl ester) of long chain fatty acids derived from vegetable oils or animal fats through transesterification.

Biodiesel is a fuel made from plant or animal feedstocks, and may be used in conventional diesel engines. Biodiesel is comprised of specific chemical components defined by ASTM as "mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats."(U.S.E.P.A. 2007)

Biodiesel refers to a clean burning alternative fuel, produced from domestic, renewable resources (eg. jatropha, corn oil, canola oil, soyabean oil, lard, beef tallow) (Kinast 2003). Biodiesel contains no petroleum, but it can be blended at any level with petroleum diesel to create a biodiesel blend. Biodiesel in its pure or blended form can be used directly in compression ignition engines (diesel engines) with little or no modifications

Biodiesel is typically produced by a transesterification or alcoholysis whereby the glycerin is separated from the fat or vegetable oil in the presence of a catalyst alkali (NaOH, KOH, or Alkoxides). The process leaves behind two products -- methyl esters (the chemical name for biodiesel) and glycerin (a valuable byproduct usually sold to be used in soaps and other cosmetic products) (Kinast 2003)

Biodiesel is manufactured from plant oils, animal fats, and recycled cooking oils. Biodiesel's advantages are as follows:

• It is renewable.

• It is energy efficient.

• It displaces petroleum-derived diesel fuel.

• It can be used as a 20% blend in most diesel equipment with no or only minor modifications.

• It can reduce global warming gas emissions.

• It can reduce tailpipe emissions, including air toxics.

• It is nontoxic, biodegradable, and suitable for sensitive environments (Kinast 2003)

It is to note that the basis of all biodiesel processes involve transesterification and There are several methods for carrying out this transesterification reaction.These methods include the common batch process, supercritical processes, ultrasonic methods, Ultra- and high-shear in-line and batch reactors and even microwave methods (Wikipedia 2009).

Only the common batch process is involved in this project and thereby discussed. Figure 3 shows the stages of the common batch process

2.5 Common batch process

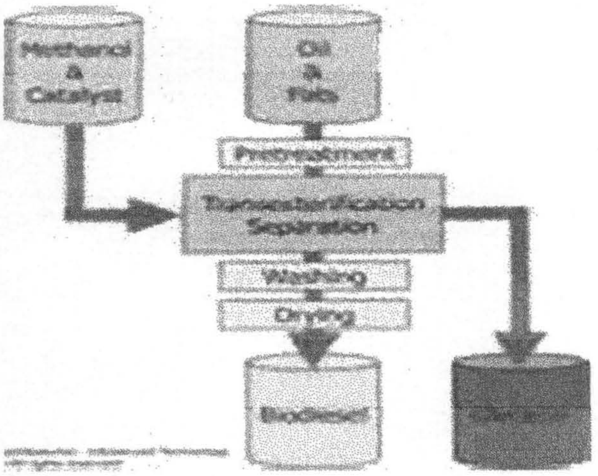

Fig. 3: Diagram showing common batch process stages

This production process involves a straight forward reaction process in the presence of the catalyst. Care must be taken to monitor the amount of water and free fatty acids in the incoming oil. High levels can defect the reaction to towards saponification (soap formation) and hinder the separation of the glycerine by-product downstream. The moisture content can be eliminated by preheating the feedstock to eliminate water while the fatty acid content can be titrated with a standardized base solution in order to determine the concentration of free fatty acids (carboxylic

This project involves the design of a biodiesel processor for the transesterification process of pure vegetable oil using methanol in the presence of potassium hydroxide to produce biodiesel as the main product and glycerin as the byproduct.

1.2 Objectives

The objective of this project is to establish the necessary and needed design considerations and calculations for future construction. Also to highlight the importance of the biodiesel fuel and the need for a potential substitute for fossil diesel oil.

1.3. Problem statement

Fossil fuel are characterized with emission of harmful chemical substances which have proven to be hazardous to health and costly to buy. This has caused an increase in cost in the use of agricultural machines. The search for an alternative that is relatively easy to produce and handle has led to this project.

1.4. Justification

Agriculture is powered by machinery running on fossil fuel which is characterized by health problems, cost transportation and availability. Finding an affordable alternative to fossil fuels, as well as one that offers environmental benefits is incredibly important especially if diesel and other fuels are either not available or priced too high for the economically disadvantaged. However, the impact on the wallet and performance are also an equally important factor to consider when speaking of fuel alternatives. The task is burdened with the current environmental stance on harmful emission from fuel combustion, compatibility with existing infrastructure and the financial implication of production. Therefore with these borne in mind, this project was embarked upon.

1.7. Scope and Limitation

This project involves the design consideration and economics of a Biodiesel Processor which can produce biodiesel from the transesterification process of pure vegetable oil using methanol in the presence of potassium hydroxide (KOH) as the main product and glycerin as the byproduct.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 History

Biodiesel debut entry was recorded on August 31, 1937 by G. Chavanne of the University of Brussels (Belgium) and was granted a patent for a 'Procedure for the transformation of vegetable oils for their uses as fuels' (fr. 'Procédé de Transformation d'Huiles Végétales en Vue de Leur Utilisation comme Carburants') Belgian Patent 422,877 (Knothe 2001). This patent described the alcoholysis (often referred to as transesterification) of vegetable oils using ethanol (and mentions methanol) in order to separate the fatty acids from the glycerol by replacing the glycerol with short linear alcohols. This appears to be the first account of the production of what is known as 'biodiesel' today.

Although earlier records show attempts at converting natural oil into fuels many years before the first diesel engine became functional by scientists E. Duffy and J. Patrick as early as 1853 (Knothe 2001).

Also in 1895, Dr. Rudolf Diesel developed the "diesel" engine with the intention of running it on a variety of fuels, including vegetable oil. In fact, when Diesel demonstrated his engine at the World Exhibition in Paris in 1900, he used peanut oil as fuel. Since that time, however, the diesel engine has been modified to run on petroleum-derived fuel (petrodiesel) because historically

it was the least expensive fuel available.

Biodiesel processing and processors became imminent especially as the recent surge of energy crisis and the search of a new alternative to petroleum based fuels.

In 1977, Brazilian scientist Expedito Parente invented and submitted for patent, the first industrial process for the production of biodiesel (http://www.nist.gov). This process is classified as biodiesel by international norms, conferring a "standardized identity and quality. No other proposed biofuel has been validated by the motor industry."

South African Agricultural Engineers Researched into the use of transesterified sunflower oil, and refining it to diesel fuel standards, in 1979. By 1983, the process for producing fuel-quality, engine-tested biodiesel was completed and published internationally.

This technology has been borrowed by an Austrian company, Gaskoks and they erected the first biodiesel pilot plant in November 1987 and the first industrial-scale plant in April 1989 (with a capacity of 30,000 tons of rapeseed per annum).

In more recent times, local productions have been invented to produce biodiesel. Austrian Biofuels Institute in a survey in 1998 had identified 21 countries with commercial biodiesel projects. Nations in other parts of the world also saw local production of biodiesel starting up. 100% Biodiesel is now available at many normal service stations across Europe (Wikipedia 2009).

2.2 Jatropha oil

Jatropha oil is the most popular feedstock used for biodiesel production due to its high oil content. It is estimated,the oil content in seeds range from 35-40% oil and the kernels 55-60% (http://www.jartropha.org). However, the amount of actual oil produced from seeds and kernels is contingent upon the method of extraction, with hand presses extruding only about 20% and more sophisticated a much higher quantity. One source reports that one ton of nuts yield an estimated 70 kg refined petroleum, 40 kg "gasoil legers" (light fuel oil), 40 kg regular fuel oil, 34 kg dry tar/pitch/rosin, 270 kg coke- like char, and 200 kg ammoniacal water, natural gas, creosote, etc. (Mike, 2006)

Its properties both physical and chemical were assessed and put into consideration during design.

Extraction and use of this oil contributes to its being used for the production of biodiesel. Using the above stated oil content, 20 to 30% oil yield can be realized(1/2 to 3/4ths of the potential oil is extracted) using hand operated ram while 35% can be obtained using a diesel or electrical powered spindle press, and depending on the size of the press (Mike 2006).

The cost of jatropha oil in Nigeria is not certain as research in still going on at the Agricultural Research Institute in A.B.U. Zaria and also the Ministry of Science and Technology Abuja but according to Mike Benge a litre of biodiesel goes for $1.05 for a litre which according to recent conversion rates is N150.

Also survey by the Global Facilitation Unit show that 1kg of jatropha oil will cost $0.10 per kilogram (Reinhard 2006). This is still relatively high but ongoing research promises substantial reduction in cost.

2.3 Biodiesel

Biodiesel is commonly produced by the transesterification of the vegetable oil or animal fat feedstock. Chemically, transesterified biodiesel comprises a mix of mono-alkyl esters of long chain fatty acids. The most common form uses methanol (converted to sodium methoxide) to produce methyl esters (commonly referred to as Fatty Acid Methyl Ester - FAME) as it is the cheapest alcohol available, though ethanol can be used to produce an ethyl ester (commonly referred to as Fatty Acid Ethyl Ester – FAEE) biodiesel. Equation for a tranesterification process is hereby shown in figure 1

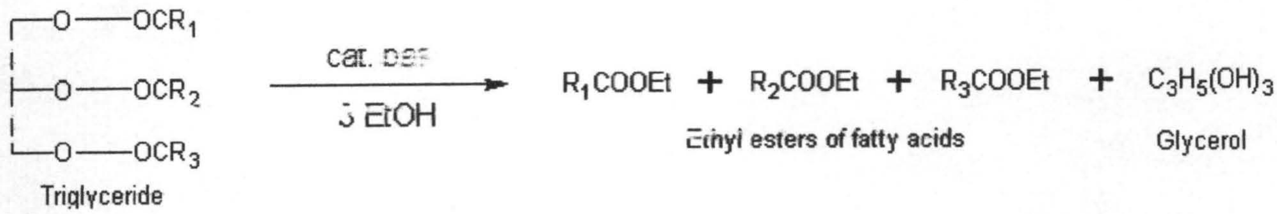

Fig. 1: Equation for a tranesterification process

Animal and plant fats and oils are typically made of triglycerides which are esters of free fatty acids with the trihydric alcohol, glycerol. The Basic Transesterification Process is shown in figure 2.

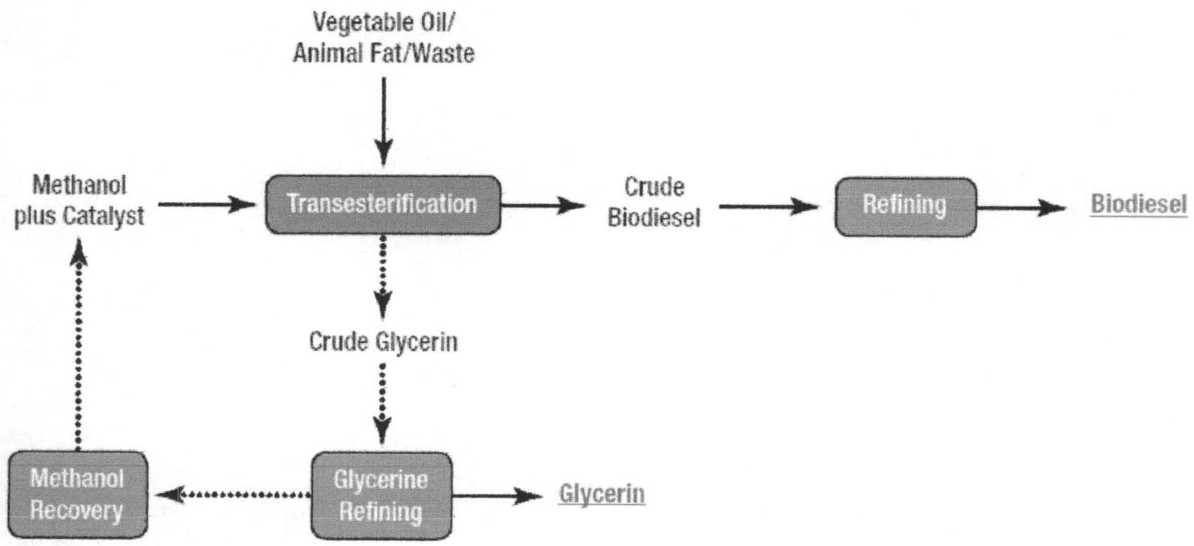

Fig. 2: Basic Transesterification Process

Fig. 2: Basic Transesterification Process

Higher alcohols such as isopropanol and butanol have also been used. Using alcohols of higher molecular weights improves the cold flow properties of the resulting ester, at the cost of a less efficient transesterification reaction.

2.4 Methanol

Methanol is the most common alcohol used for the conversion of fats and oils to biodiesel. Methanol is flammable, as such proper handling is required for safety. Methanol and oil do not mix well, and poor contact between the oil and methanol reactants means the reaction rate will be slow. Vigorous mixing at the beginning of the reaction improves reaction rates. Towards the end of the reaction, reduced mixing helps the separation of glycerine, and the reaction would proceed faster in the top layer, which contains oil and methanol. At ambient temperature (21 ^{0}C or 70 ^{0}F), the reaction takes four to eight hours to complete. The boiling point of methanol is 65 ^{0}C or 148 ^{0}F. The reaction is usually conducted below the boiling point of methanol (60 ^{0}C or 140 ^{0}F). At this temperature, the reaction time may vary between 20 minutes to 1 hour 30 minutes.

Transesterification production process will convert the base oil to the desired esters. Any Free fatty acids (FFAs) in the base oil are either converted to soap or removed from the process, or they are esterified (yielding more biodiesel) using an acidic catalyst. After this processing, unlike straight vegetable oil, biodiesel has combustion properties very similar to those of petroleum diesel, and can replace it in most current uses.

It is to note that the basis of all biodiesel processes involve transesterification and There are several methods for carrying out this transesterification reaction.These methods include the common batch process, supercritical processes, ultrasonic methods, Ultra- and high-shear in-line and batch reactors and even microwave methods (Wikipedia 2009).

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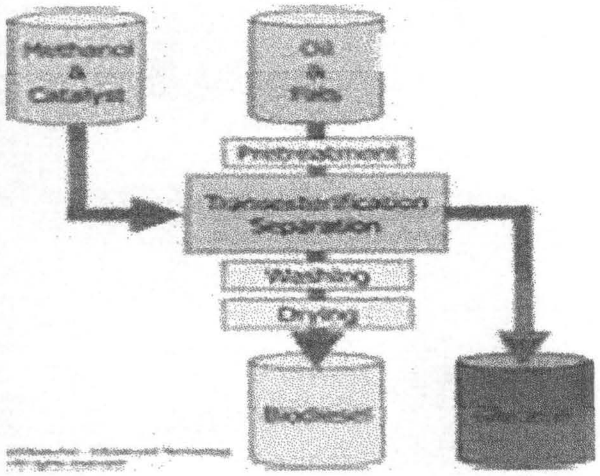

Fig. 3: Diagram showing common batch process stages

This production process involves a straight forward reaction process in the presence of the catalyst. Care must be taken to monitor the amount of water and free fatty acids in the incoming oil. High levels can defect the reaction to towards saponification (soap formation) and hinder the separation of the glycerine by-product downstream. The moisture content can be eliminated by preheating the feedstock to eliminate water while the fatty acid content can be titrated with a standardized base solution in order to determine the concentration of free fatty acids (carboxylic acids) present in the oil sample and can be taken care of by using excess alcohol usually up to six parts alcohol one part oil (Leadbetter and Nicholas (2006).

Common batch production procedures are:

- Catalyst in this case Potassium Hydroxide (KOH) is dissolved in the alcohol (methanol) using a standard agitator or mixer.

- The alcohol/catalyst mixture called methoxide is then charged into a closed reaction vessel and the feedstock oil 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 above the boiling point of the alcohol (around 70 °C, 158 °F) to speed up the reaction though some systems recommend constant application of heat to maintain this temperature.
- The reaction take place anywhere from room temperature to 55 °C (131 °F) for safety reasons. Recommended reaction time varies from 1 to 8 hours; under normal conditions the reaction rate will double with every 10 °C increase in reaction temperature. Excess alcohol is normally used to ensure total conversion of the fat or oil to its esters.
- The reaction produces a mixture with two phases. 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.
- 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. The removal of alcohol can be done before or after the separation stage depending on the system design.

- The biodiesel is purified by washing gently with warm water to remove residual catalyst or soaps, dried, and sent to storage.
- The glycerine by-product is purified by removing unused catalyst and soaps through neutralization with an acid and sent to storage as crude glycerine (water and alcohol are removed later, chiefly using evaporation, to produce 80-88% pure glycerine).
- Following the reaction, the glycerine is removed from the methyl esters. Due to the low solubility of glycerine in the esters, this separation generally occurs quickly and may be accomplished with either a settling tank or a centrifuge.

2.6 Fuel Quality

The primary criterion for biodiesel quality is adherence to the appropriate standard. In the United States, this standard is ASTM D 6751-02 "Standard Specification for Biodiesel Fuel (B100) Blend Stock for Distillate Fuels". Generally, the fuel quality of biodiesel can be influenced by several factors:

- The quality of the feedstock.
- The fatty acid composition of the parent vegetable oil or animal fat.
- The production process and the other materials used in this process.
- Post-production parameters.

Table 1 shows the property values required for a mixture of methyl esters to be considered biodiesel. When these limits are met, the biodiesel can be used in most modern engines without modifications while maintaining the engine's durability and reliability. Even in low level blends with conventional diesel fuel, the biodiesel blending stock is expected to meet the standard before being blended. While some properties in the standard, such as cetane number and density, reflect the properties of the chemical compounds that make up biodiesel, other properties provide indications of the quality of the production process. Generally, the parameters given in ASTM D6751 are defined by other ASTM standards. However, other test methods, such as those developed for the American Oil Chemists' Society, (AOCS) may also be suitable (or even more appropriate as they were developed for fats and oils and not for petroleum-derived materials addressed in the ASTM standards).

Table 2. ASTM D 6751–02 Biodiesel Specifications

Property	Method	Limits	Units
Flash point, closed cup	D93	130 min	°C
Water and sediment	D 2709	0.050 max	% volume
Kinematic viscosity,40°C	D445	1.9-6.0	mm^2/s
Sulfated ash	D874	0.020 max	wt.%
Total sulfur	D5453	0.05 max	wt.%
Copper strip corrosion	D130	No.3 max	
Cetane number	D613	47 min	
Cloud point	D2500	Report to consumer	°C
Carbon residue	D4530	0.05 max	wt.%
Acid number	D664	0.8 max	Mg KOH/g
Free glycerin	D6584	0.02	wt.%
Total glycerin	D6584	0.24	wt.%
Phosphorus	D 4951	10	Ppm
Vacuum distillation end point	D1160	360°C max, at T-90	
Storage stability	To be determined	To be determined	To be determined

2.7 Biodiesel Processors

Biodiesel can be made in anything from a small 2 litre pop bottle to an elaborate processor complete with separate tanks for processing, washing, methoxide mixing, settling, and filtering.

They can be bought, fabricated or assembled as long as it can withstand the demands of the reaction, separation and purification process.

Criteria for local processors are personal preference but some elements are healthy to consider

- Materials used should avoid or exempt copper, natural rubber and plastic. Although some plastics have proven effective e.g. H.D.P.E. (high density polyethene)
- Size and shape of the Processor should be able to contain the whole process with extra room and provide ease and thoroughness of agitation.
- Heat source should not be open-flamed as this can cause ignition of some of the reagents. An internal boiler or heat medium exchange is as advised. Also insulation can be introduced to maintain heat.
- Thermostats are advised but not compulsory as to regulate and maintain temperature of reaction.
- Area around the Processor (footprint) should complement your work space in order to leave enough room to move around.
- Methods of agitation should be sufficient to mix the Processor contents thoroughly.

Common and popular locally made processors include:

- Simple 5-gallon Processor
- Journey to Forever 90-litre Processor
- The 'Deepthort 100B' Batch Reactor
- Ian's vacuum biodiesel Processor

- Chuck Ranum's biodiesel Processor
- Pelly "Model A" Processor
- "Foolproof" method Processors
- The touch-less Processor

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1 Introduction

In the process of machine design, a proper selection of materials is important and the characteristics of the material, both physical and chemical e.g. toughness, hardness, ability to withstand certain chemicals and factors affecting the use of the machine e.g. temperature, weather condition – humidity, etc. are all put into consideration. This chapter includes the materials selected and the calculations involved. Also a detailed description of the design is discussed. The following components are calculated for:

- Length and radius of both processors (main and sub processor).
- Pump Horsepower required for material transport.
- Maximum allowable load on the support stand

3.2 Materials

H.D.P.E. (High density polyethyne) plastic tanks is prefered for the processors instead of metal or steel tanks because biodiesel is a powerful solvent and hot methanol and lye can react with iron which will pose an adverse effect on the reaction and can reduce the efficiency of the processor and also quality of the biodiesel. Also plastic was opted for against steel as steel will rust on the outside (not on the inside). Stainless steel is a very good alternative as it will last much longer but the cost was also put into consideration. The plastic tank should have an H.D.P.E. rating which means it can withstand the chemicals it comes in contact with.

The electrical water pump was a stainless steel impeller centrifuge and explosion-proof. This is to ensure it can withstand the methanol, lye and biodiesel (Leadbetter and Nicholas, 2006).

Pallets and frames used to give support were wooden due to its firmness and strength.

Valves used were stainless steel in order to avoid contamination of product.

The rubber hose used was stiff walled in order to prevent it from collapsing under the pressure of the pump.

Below is a list of the materials for the construction of a Biodiesel Processor

- Two H.D.P.E. plastic tanks - a 150 litre tank for main processor 100 litre tank for sub-processor.
- Support stand for tanks.
- Pallet. 1.83m × 1.83m
- One ¾ inch 2 by 4 plywood.
- Two 1 horsepower explosion resistant pumps with a maximum delivery capacity of 60ltr/min.
- Seven ¾ inch Stainless steel ball valves.
- Three ¾ inch T's.
- Six ¾ inch 90 degree elbow.
- Ten metres ¾ inch galvanized iron pipe.
- Three ¾ inch hub to thread.
- Three nuts for ¾ inch hub.
- Three fender washers.

- Ten hose clamps.
- 7meters ¾ inch transparent hose pipes.

In the selection of material, factors considered included material availability, susceptibility of material to corrosion by solvent (biodiesel and potassium hydroxide are known to corrode certain material) cost, ease of fabrication, strength and serviceability.

3.3 Design consideration

The Biodiesel Processor designed is for domestic use. With that borne in mind, the following was put in design.

- Simplicity- the Processor is simple to assemble and dismantle for maintenance and repair.
- Material availability- all components for the Processor are readily available at plumbing stores. This is important for serviceability.
- Transparent hoses integrated to the system to monitor the processing of biodiesel.
- The total height is moderate at 0.98m. This is to aid accessibility.
- The total work area is optimal at 1.83m × 1.83m. This is for compatibility and also give enough room to operate the Processor.

3.4 Design Calculations

3.4.1 Determination of processor tank diameter and height

The optimum proportions for a cylindrical container is a classical example of the optimization of a simple function the surface area, A of a closed cylinder is:

$$A = \pi \times D \times L + 2\frac{\pi}{4}D^2 \quad (1)$$

Where D = diameter and L = length or height.

For optimization, $\frac{D}{H} = 0.83$

Assuming a value for main processor diameter $D_1 = 0.8$m. Therefore $H_1 = 1.0375$m.

For the sub processor diameter and height, $D_2 = 0.4$m and $H_2 = 0.58$m.

3.4.2 Design of processor support

This consist of a circular seat welded onto 3 angle iron legs. Data of support material are given

Material: low carbon steel (Fe 290)

Ultimate stress= 290Mpa

Yield stress =160Mpa

Allowable stress of the material =47.25Mpa

Young modulus constant = 2×10^5 Mpa

Steel length= 0.35m

Acceleration due to gravity, g= 9.81m/s

3.4.3 Determination of design length

$l_{eff} = \mu L_s$ (2)

$\mu = 1/4$

$l_{eff} = 0.35/4 = 0.0875$m

3.4.4 Determination of moment of inertia, I_p

$I_p = {H4 - h4}/_{12}$ (3)

H= 0.038m

h=0.036m

$I_p = 0.038^4 - 0.036^4/12 = 3.3793m^4$

Where

H= external lenght

h= internal lenght

3.4.5 Determination of cross-section area A_s

$A_s = H^2 - h^2$ (4)

$=0.038^2-0.036^2$

$=1.48m^2$

3.4.5 Determination of radius of gyration, L_s

$L_s = \sqrt{\frac{Ip}{As}} = \sqrt{\frac{3379.3}{148}} = 4.78mm = 0.00478m$ (5)

3.4.6 Determination of slenderness ratio, λ,of the hollow pipe

$\lambda = \frac{Leff}{Ls}$ (6)

$= \frac{0.0875}{0.004785} = 18.286 \simeq 18$

3.4.7 Determination of slenderness ratio, λx, of the material using equation

$$\lambda x = \sqrt{\frac{\pi^2 E}{\delta_x}} \quad (7)$$

$$= \sqrt{\frac{\pi^2 \times 2 \times 10^5}{47.25 \times 10^6}} = 204.39$$

$$\lambda < \lambda_x$$

3.4.8 Determination of reduction factor, U, from table (Kinasoshville, 1972)

$$U = 0.94 + \frac{37-30}{40-30}(0.9 - 0.94) \quad (8)$$

(8)

$$= 0.934$$

3.4.9 Determination of allowable stress, δ_a, on the hollow square pipe

$$\delta a = \delta_{all} \times U \quad (9)$$

$$= 47.25 \times 0.934$$

$$= 44.131500 \text{ N/m}^2$$

3.5.0 Determination of critical load, F_u, on the hollow square pipe

$$F_u = \delta a \times A_s \quad (10)$$

$$= 44.1315 \times 148$$

$$= 6.53146 \text{ KN}$$

This represents maximum load the stand can carry. Therefore maximum weight that it can carry is 6531.46 N/9.81m/s =665.8kg

3.5.1 Design of pump

Two pumps were employed. Pump 1 for main processor and pump 2 for sub processor. Energy, horsepower required are calculated.

- For the sub processor the details are as follows

Flow rate required Q:	72 litre/min	
Fluid specific weight γ:	84.13 kg/m^3	
	Suction	discharge
Elevation E:	0.8636m	1.4732m
Pipe diameter d:	0.019m	0.019m
Pipe length L:	0.9652m	1.6256m
Pipe friction factor f:	0.02	0.01

The Energy equation

$$\frac{V_r^2}{2 \cdot g} + \frac{P_r}{\gamma} + E_r + E_p = \frac{V_s^2}{2 \cdot g} + \frac{P_s}{\gamma} + E_s + h_L \qquad (11)$$

V_r, V_s = velocity

P_r, P_s = pressure

E_r, E_s = elevation

γ = fluid density

E_p = pump energy

h_L = head loss

solving for pump energy

$$E_p = \left(\frac{V_s^2}{2 \cdot g} - \frac{V_r^2}{2 \cdot g}\right) + \left(\frac{p_s}{\gamma} - \frac{p_r}{\gamma}\right) + (E_s - E_r) + h_L \tag{12}$$

Assuming that the velocity and pressure head are negligible.

$$E_p = (E_s - E_r) + h_L \tag{13}$$

The head loss in this equation can be found using the Darcy-Weisbach equation.

$$h_L = f \cdot \frac{L}{d} \cdot \left(\frac{Q}{\pi \cdot \frac{d^2}{4}}\right)^2 \cdot \frac{1}{2 \cdot g} \tag{14}$$

Substituting the Darcy-Weisbach equation into the energy equation for the calculation of pump head

$$E_p := (E_s - E_r) + h_L(f_r, L_r, d_r, Q) + h_L(f_s, L_s, d_s, Q) \tag{15}$$

$E_p = 1.0034$

The horsepower required is the product of the fluid specific weight, flowrate and pump energy.

$hp := \gamma \cdot Q \cdot E_p$ = 0.5064 hp

- For the main processor, the detail are as follows:

Flow rate required Q: 120 litres/minute

Fluid specific weight γ: 84.13kg/m^3

	Suction	discharge
Elevation E:	0.3048m	1.524m
	Suction	Discharge
Pipe diameter d:	0.019m	0.019m
Pipe length L:	1.2192m	1.8288m
Pipe friction factor f:	0.02	0.01

Substituting the values into equation 15,

$E_p = 1.4304$

Also for the horsepower required for sub processor

hp = 0.799hp

3.5.2 Design for pipe network

3.5.3 Pipe network

The pipe network consist of an assembly of galvanized iron, elbow joints and valves. This network serves as a transport path for biodiesel mixture to move under the pressure supplied by the pump. they are:

- Main processor/plumbing 1
- Main processor/plumbing 2
- Sub processor/plumbing 1
- sub processor/plumbing 2

- Pump 1 plumbing
- Pump 2 plumbing

Each group in network is detailed.

All pipes used for design are ¾ inch pipes. The pipes are in four size groups. Table 2 shows the groups

Table 2 size group of galvanized iron

Sizes	Length (m)
Size 1	0.16
Size 2	0.31
Size 3	0.4572
Size 4	0.9144

3.5.3 Main processor/plumbing 1

A 'T' (T 1) is fluxed with three (3) size1 galvanised iron and fitted with two valves V1 and V2. The openings are labelled T 1a T 1b T 1c. A size2 galvanized iron is attached to T 1b. An elbow joint is fitted with a size3 at one end and a size1 at the other end. This end is fitted to T1c. T1b should give an angle of between 90-120 degrees to T1c. This piece of plumbing is called main processor/plumbing 1 as shown in figure 4.

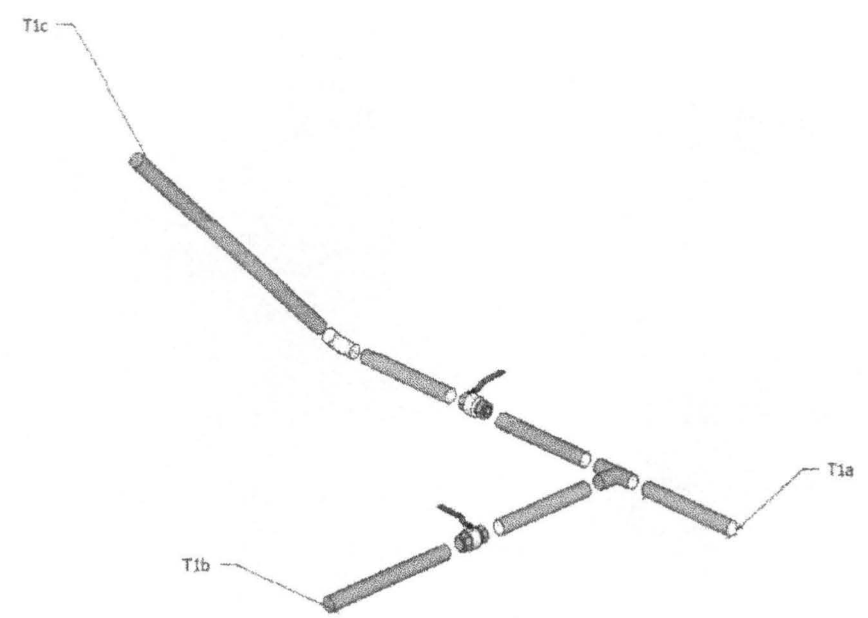

Figure 4: Main processor/plumbing 1

3.5.4 **Main processor/plumbing 2.**

Another 'T' (T 2) is fitted with galvanised iron size 1, 2, 3 and are labelled T2a, T2b, T2c respectively and valves V3 and V4 are attached at T2a and T2b. T2c is fitted to an elbow joint and a size 2 galvanised iron. T2a and T2b are both fitted with size 3 galvanised iron. T2b should give an angle of between 90-120 degrees to T2c. This piece of plumbing as shown below is called main processor/plumbing 2.

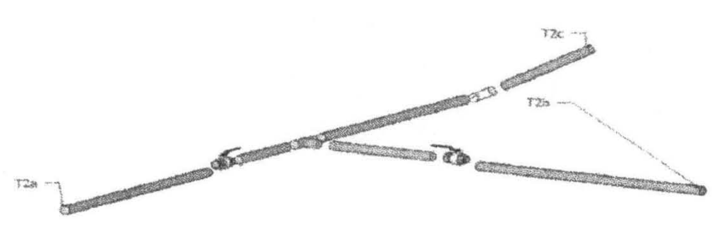

Figure 5: Main processor/plumbing 2

3.5.5 Sub processor/plumbing 1

A valve V5 is fitted with a size2 on one end and a size3 on the other labelled V5a and V5b respectively. V5b is fitted with an elbow joint. This piece of plumbing is called sub processor/plumbing 1.

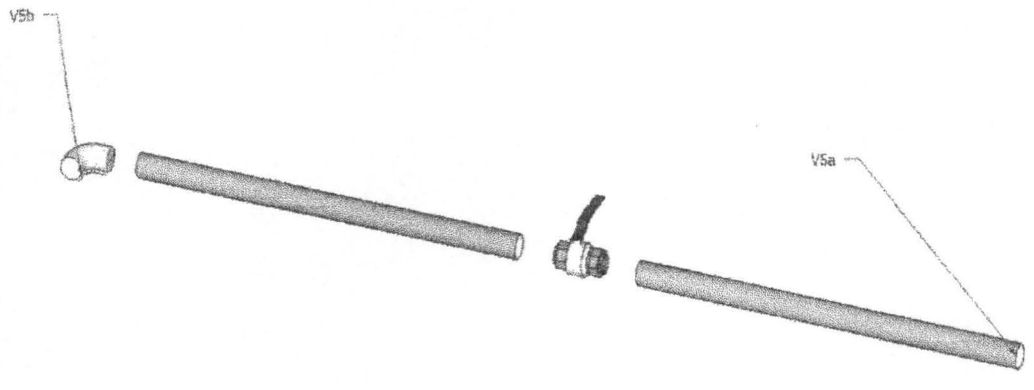

Figure 6: Sub processor/plumbing 1

3.5.6 Sub processor/plumbing 2

A 'T' (T3) is fitted with two (2) galvanised iron size 1 and a size4. T3a is fitted with a valve V6 and a size1 galvanised iron, T3b is fitted with a valve V7, a size3, an elbow then a size 3. T3c is fitted with a size4 then fitted with an elbow joint and a size 2. This piece of plumbing as shown below is called sub processor/plumbing 2.

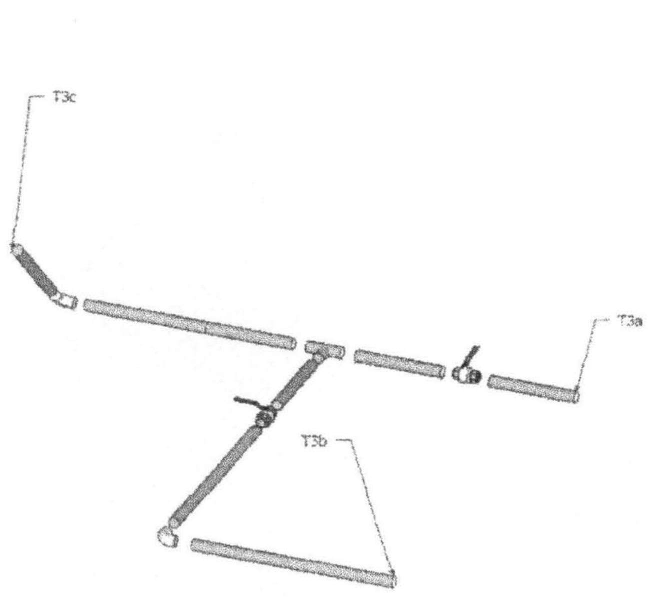

Figure 7: Sub processor/plumbing 2

3.5.7 Pump 1

Pump1 is fitted with an adapter, then a size 2 galvanised iron and an elbow joint at its suction end. This opening is called P1. The opening at the discharge end is fitted with an adaptor and it is labelled P2.

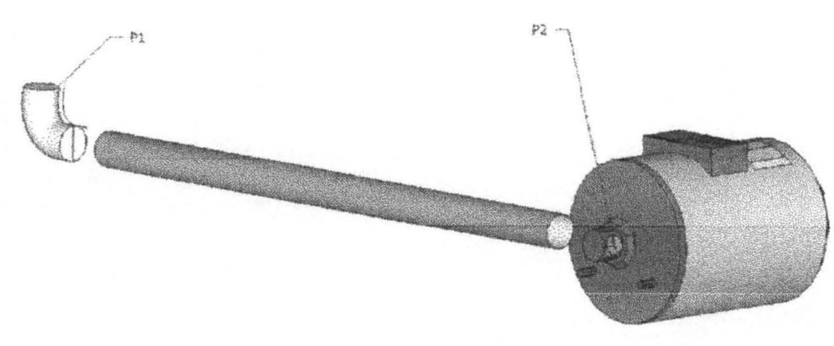

Figure 8: Pump1

3.5.8 **Pump 2**

Pump 2 is fitted with an adapter and a size 3 galvanised iron at the suction end and it is labelled P3 and the discharge end is fitted with adapter and it is labelled P4.

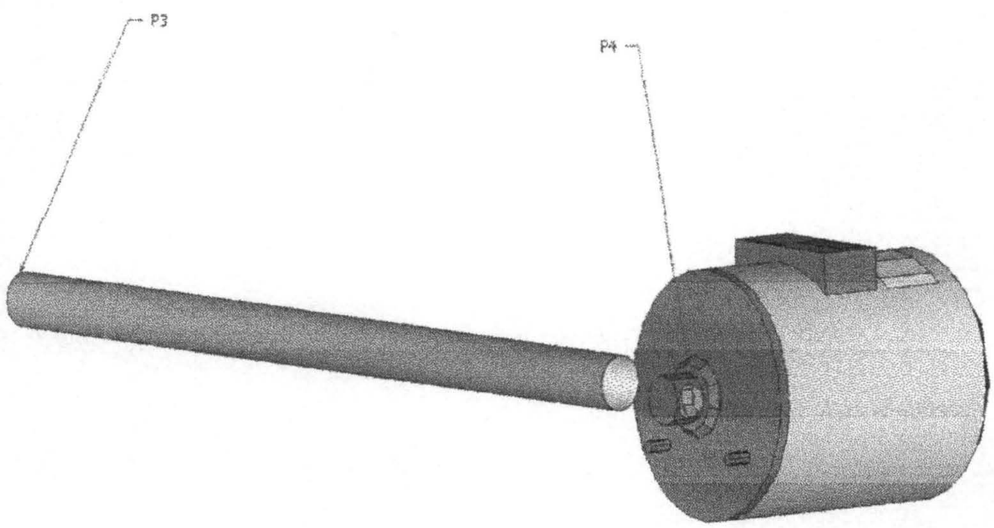

Figure 9: Pump2

3.5.9 Tank inlets

Two holes are drilled on top the main processor tank. Adapters are fitted in the holes and secured with fender, washers and nuts beneath. The hole to the right is labelled O1 and other O2. The bottom is drilled at the center beneath the processor was fitted with an adapter.

A hole is drilled on top the sub-processor. An adapter is fitted in the hole and secured with a fender, washer and nut beneath. The hole was labelled O3. The bottom opening beneath the processor is fitted with an adapter.

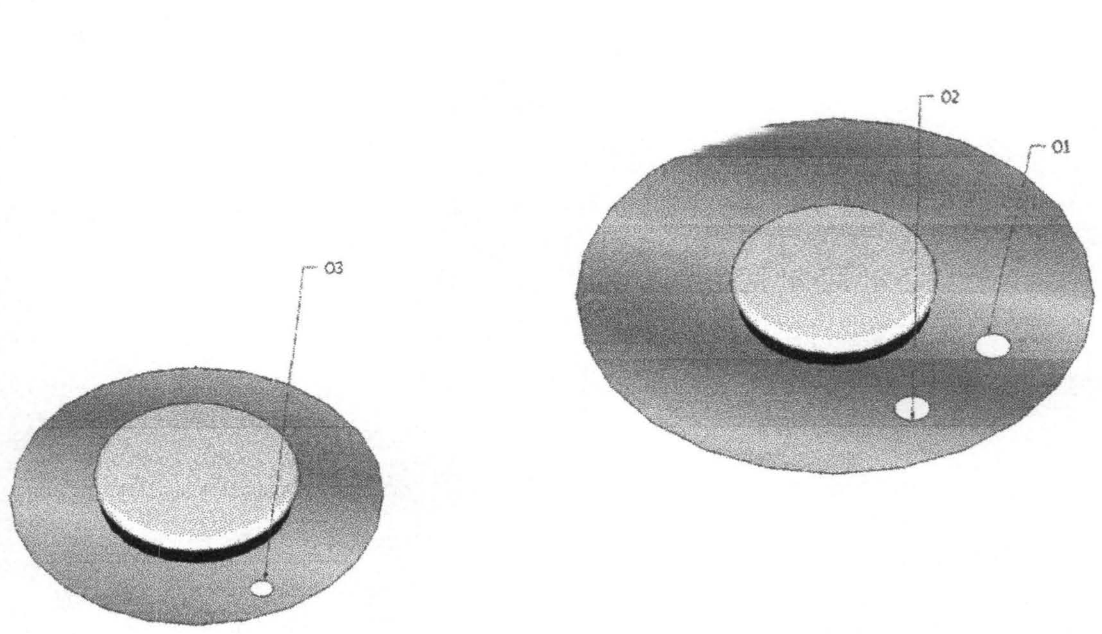

Figure 10: processor hole

3.6 Assembly

The room area for the processor is 1.83m by 1.83m. This is big enough for easy access and compactibility.

The pallet is laid down and the 2 by 4 feet plywood screwed tightly onto it. This provides the foundation.

The stand for the tank processor is screwed tightly to the foundation. The stand for the main processor is placed on the right while the sub-processor's on the left and the tanks is placed upon. The tanks stability was tested to avoid later accidents due to stress or weight imbalance.

Main processor/plumbing 1 is fitted beneath the main processor tank at T1a.

Pump1 is secured to the pallet directly in front of the main processor with its suction and discharge end facing the main processor. Opening P1 is attached to T1a through a size2 hose. Main processor/plumbing 2 is attached to pump1 through P2 at T2c.

Sub-processor /plumbing 1 is attached beneath the sub-processor through V5a. Opening V5b is attached to P3 of Pump2 which is the suction end. The discharge end (P4) is fitted with sub-processor/plumbing2 through T3c.

A hose of 1 meter is fixed and clamped properly using hose clamps at T3a and connected to the opening O3 atop the sub-processor. Another hose 1 meter is fixed and clamped at T3b and connected to the opening O2 on the main processor. Opening T2a is connected to O1 with a hose of length 2meters and clamped properly. T1c is for the discharge of glycerine and wash water. T2b is for the discharge of the finished product biodiesel.

3.7 Mode of operation

For the processing to begin, all valves are shut off. Measure out the correct amount of methanol and lye and place it the sub processor tank. The valve V5 and V6 are opened and pump2 is turned on. This agitates the mixture thoroughly. Next, place your pre-heated, cleaned and de-watered vegetable oil into the main processor tank. Valves V1 and V3 are then opened and pump1 is turned on.

With the vegetable oil mixing, open the valve from the methanol/lye pump to the large reactor tank. Next, turn off the valve that goes from the methanol/lye pump to the top of the small tank.

With both pumps working, open valve V7 first then shut off V6. This will ensure that all the reactants are driven into the main processor. The main processor is allowed to work on for 10 minutes then pump1 is shut off. The mixture is left to stand for 1-2 hours to allow for separation of the biodiesel from the glycerine. This is aided due to the density difference between the two fluids. Hoses can be attached to T1c and T2b for collection into any desirable receptacle.

CHAPTER F0UR

4.0 RESULTS AND DISCUSSION

4.1 Results

The results for the design of a biodiesel processor for domestic use to produce 131litres of biodiesel obtained from calculation made are stated below:

Table 4.1 Processor tank parameters

	Volume(ltr)	Height(m)	Diameter(m)
Main processor tank	120	1.0375	0.8
Sub processor	72	0.58	0.4

Table 4.2 Pump parameters

	Elevation(m)	Power required(hp)
Pump 1	0.3048	0.799
Pump 2	0.8636	0.5064

4.1.1 Economic requirement

This discusses the cost requirement of production and it will include material cost, production cost and overhead cost.

4.1.2 Cost of materials

The table below shows the description, quantity, rate and total amount of the materials considered for construction

Table 4.2: Cost of construction materials

S/No	Description	Quantity	Rate(N)	Amount(N)
1	Large tank 150 litre	1	2000	2000
2	Small tank 100 litre	1	1500	1500
3	Pump for biodiesel pump	1	1500	1500
4	Pump for methanol	1	1500	1500
5	Wooden palette	1	1000	1000
6	Plywood 2 by 4	1	300	300
7	¾ inch ball valves	7	250	1750
8	¾ inch 'T's'	3	70	210
9	¾ inch 90 degrees elbow	6	70	420
10	7 m ¾ inch copper tubing	1	2600	2600
11	¾ inch hub to thread	3	50	150
12	Fender washers	3	50	150
13	Nuts for ¾ inch hubs	3	50	150
14	7m ¾inch transparent rubber hose	1	1200	1200
15	Hose clamps	10	20	200
	Total	-	-	14,630

4.1.3 Labour cost

Labour cost is 25% of material cost.

25/100 × 14,630 = N3657.5

4.1.4 Overhead cost

This is assumed to be 10% of material cost.

10/100 × 14,630 = N1463

Therefore total cost of producing the processor = N19750.50

4.2 Discussion of results

From the results shown in table 4.1, the diameter and height of the processor is optimized to reduce material cost. An allowance for safety should be incorporated into the processors by increasing volume by 10%. A 150litre tank for the main processor and 100litre tank for the sub processor is recommended.

The pump required for the processors are less than 1hp and the elevation is less than 20m. Thus a 240volt powered1hp pump with a flow-rate of 60ltr/min and a maximum elevation of 20meters can be used.

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CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The design of a biodiesel processor for domestic use was carried out and documented in this project. The Processor comprises of two units capable of processing feedstock into biodiesel in the presence of a catalyst KOH. The Processor units are the main processor unit and the sub processor unit which are cylindrical with volume of 150litres and 100litres respectively. The units also comprise a pipe network of ¾inch galvanized iron for material transport, a support stand of hollow square iron of height 0.35m, 1 horsepower pumps for material agitation and transportation. The total height of the Processor is 1.0375m. The overall cost of the processor is N19750.50.

5.2 Safety

Safety is one of the major criteria for the selection of the best alternative along with economic viability; this is due to the value placed on the operating personnel and equipment in designing a processor.

Any person has a legal and moral obligation to safeguard the health and welfare of its employees and the general public. The plant should be sited away from the public to avoid environmental pollution to the host community. For this design, the hazards and some of the actions that could lead to these hazards are identified and safety measures are then recommended to fit into the processor design.

The following may be considered in Safety and loss prevention of a process design:

1. Identification and assessment of the hazards.

2. Control of the hazards: for example, by containment of flammable and toxic materials.

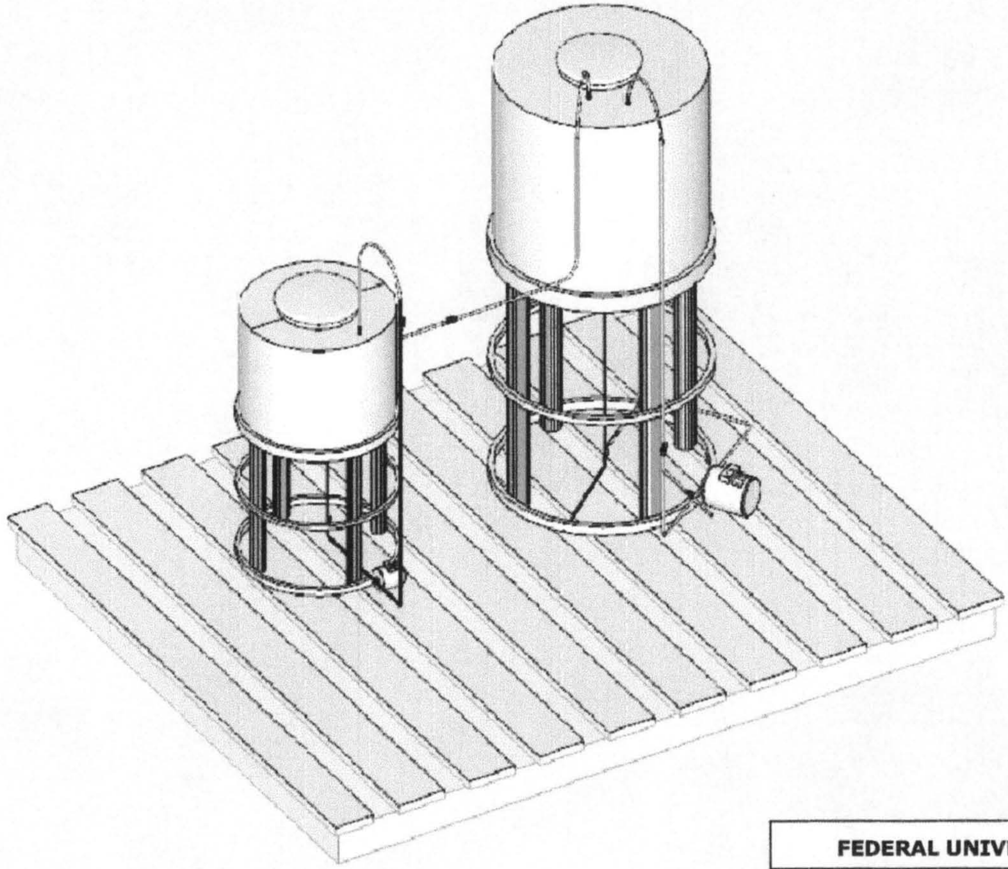
3. Control of the process. Prevention of hazardous deviations in process guideline together with good operating practices and management.

4. Limitation of the loss when damage and injury caused if an incident occurs: pressure relief, provision of fire-fighting equipment.

All production processes are to some extent hazardous, but in chemical processes there are additional, special, hazards associated with the chemicals used and the process conditions. The designer must be aware of these hazards, and ensure, through the application of sound engineering practice, that the risks are reduced to acceptable levels.

5.3 Recommendations

1. It is recommended that conical bottom tanks be used for later improvements for total draining of the reactants and products. Biodiesel is a Newtonian fluid and the conical shaped bottom would increase the flow rate. This would also ensure a total conversion of reactants to products.
2. Future processors should integrate the heating of the pure vegetable oil. This is to ensure safety and reduce tediousness in the processing.



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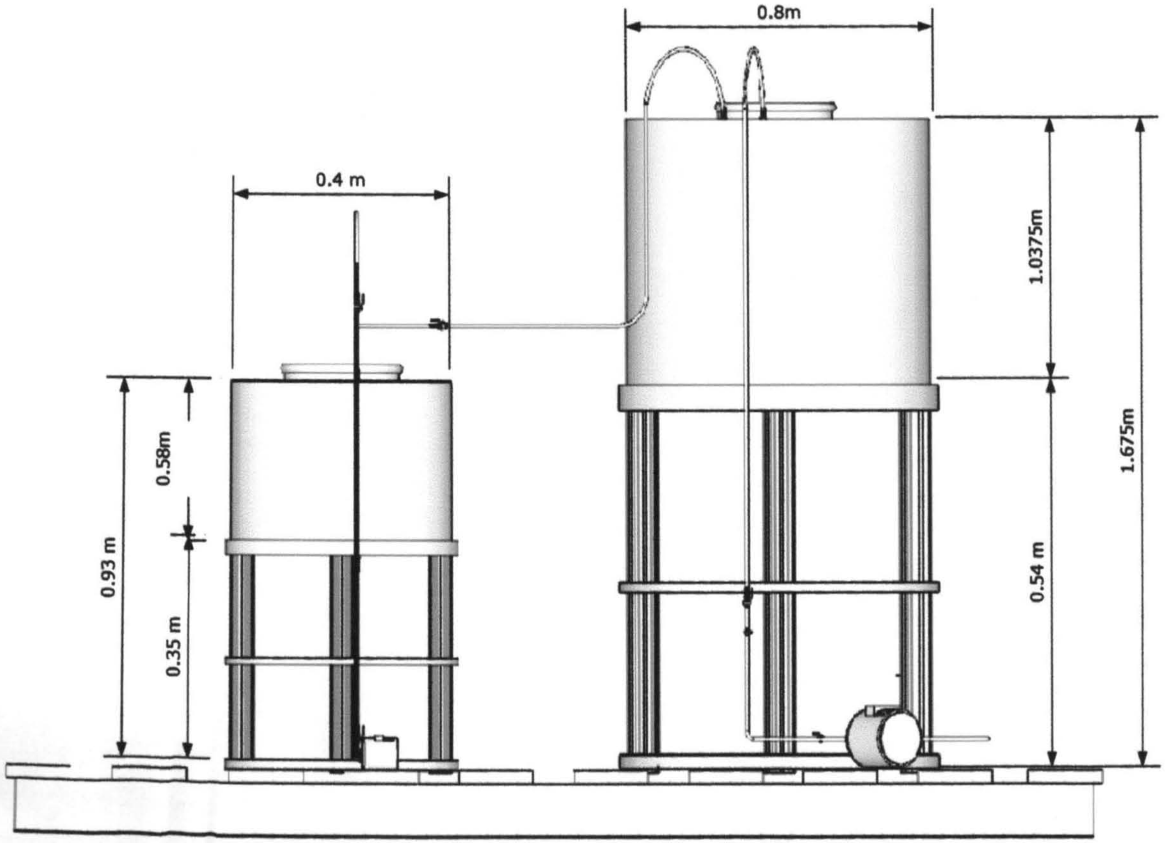
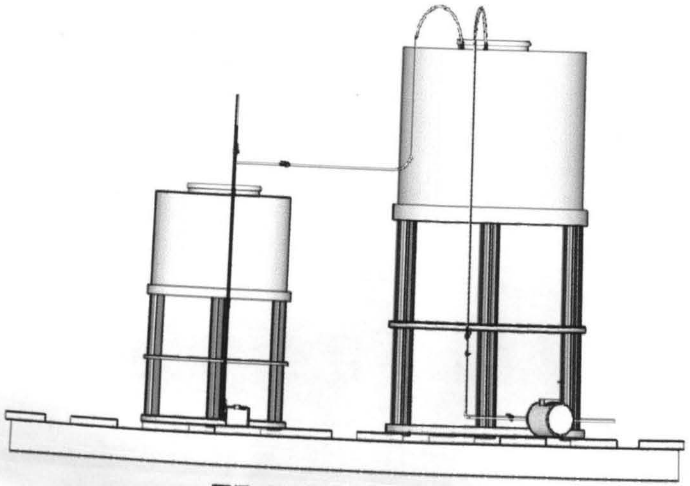
DEPARTMENT OF AGRICULTURAL ENGINEERING AND BIO RESOURCES.			
ISOMETRIC DRAWING			
BIODIESEL PROCESSOR		SCALE	
	NAME	MATRIC NO	DATE
DRAWN BY	OYENIRAN T.O.	2004/18415EA	FEB.2010
DESIGNED BY	OYENIRAN T.O.	2004/18415EA	FEB.2010

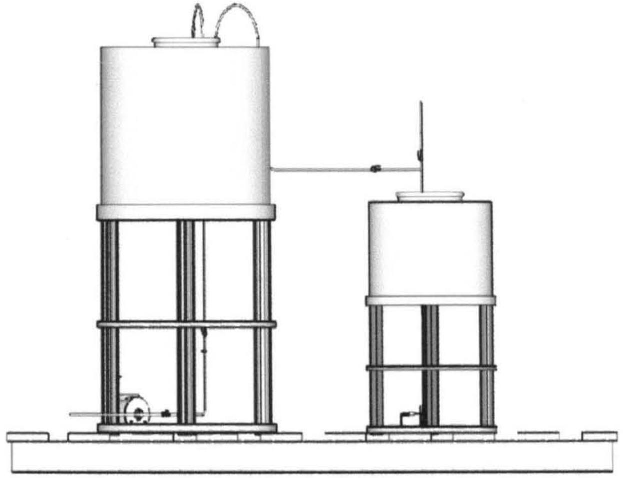


FRONT VIEW

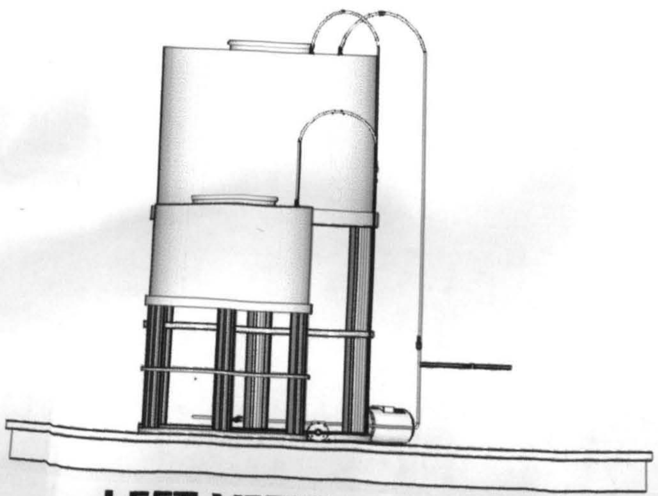
FEDERAL UNIVERSITY OF TECHNOLOGY MINNA			
DEPARTMENT OF AGRICULTURAL ENGINEERING AND BIO RESOURCES.			
WORKING DRAWING			
BIODIESEL PROCESSOR		SCALE	
	NAME	MATRIC NO	DATE
DRAWN BY	OYENIRAN T.O.	2004/18415EA	FEB.2010
DESIGNED BY	OYENIRAN T.O.	2004/18415EA	FEB.2010



FRONT VIEW



REAR VIEW



LEFT VIEW

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DEPARTMENT OF AGRICULTURAL ENGINEERING AND BIO RESOURCES.			
ORTHOGRAPHIC PROJECTION			
BIODIESEL PROCESSOR		**SCALE**	
	NAME	**MATRIC NO**	**DATE**
DRAWN BY	**OYENIRAN T.O.**	**2004/18415EA**	**FEB.2010**
DESIGNED BY	**OYENIRAN T.O.**	**2004/18415EA**	**FEB.2010**