EML 4905 Senior Design Project

A B.S. THESIS

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BACHELOR OF SCIENCE

IN

MECHANICAL ENGINEERING

BIODIESEL FEEDSTOCK PRE-TREATMENT STATION

25% of Final Report

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Sponsorship: Green Bio-fuels

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This B.S. thesis is written in partial fulfillment of the requirements in EML 4905. The contents represent the opinion of the authors and not the Department of Mechanical and Materials Engineering.

Ethics Statement and Signatures

The work submitted in this B.S. thesis is solely prepared by a team consisting of Milton Díaz, Luis A. Pérez-Brugman, and Jimmy A. Fernández and it is original. Excerpts from others' work have been clearly identified, their work acknowledged within the text and listed in the list of references. All of the engineering drawings, computer programs, formulations, design work, prototype development and testing reported in this document are also original and prepared by the same team of students.

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Abstract

The elaborate design of this prototype pre-treatment plant would be planned, analyzed and developed in an orderly fashion by the three members of the team and under the supervision of the advisor. Biodiesel is an advanced biofuel made for diesel engines from agricultural co-products and byproducts such as vegetable oils and animal fats. In order to be considered biodiesel, it must meet strict industry quality standards and specifications of ASTM D 6751. For our customer Green Biofuels LLC, to be able to comply with these specifications and deliver a quality product, a Feedstock Pre-treatment Station needs to be developed. With the Feedstock Pre-treatment Station in place our customer can process any type of waste from agricultural co-products and byproducts it can acquire or collect from outside sources, such as grease trap waste or WVO (waste vegetable oil) from food preparation facilities and local sewer. The process consists of pre-separating liquids and solids out of the grease, leaving a higher percentage of treatable brown and yellow grease. Brown grease is the name given to rendered grease trap waste FOG, (fat, oil and grease) and food solids that builds overtime in any commercial or residential grease waste trap.

Figure 1 A biofuel plant. Source: qcoinc.com

This type of grease commonly referred to as “grease trap waste” or “grease sludge” cannot be used to animal feed and it contaminates land soil when dispersed in landfill. Our team has developed a rough mechanical system design which is potentially the solution for this existing problem. Currently the plant is technically limited to the amount and type of WVO they can process hence purchase. Our design, the Biodiesel Feedstock Pre- Treatment Station is capable of removing the residual water and organic debris from this raw material prior to its delivery into the plant. This preliminary cleaning stage for the existing plant leaves small room for error, as the biodiesel production will not allow for much water or bio-solid contents in its treatment. The end product follows strict quality control tests in order to provide the best results and meet our

sponsor’s conditions. By exploring innovative solutions the team has committed not only to optimize the biodiesel plant production, but to help transform a waste stream into local energy source.

1. Problem Statement

Fossil fuels have become expensive and undesirable pollutants around the world, pushing energy developers to exploit new sources of fuels. Our sponsor, Green Biofuels, specializes in producing Biodiesel from used vegetable oil. They are a South American entity, and have exported their Biodiesel production to South Florida, creating a good use to WVO which would otherwise pollute waters and impair sewers. Our design considerations were prepared following biodiesel composition guidelines set forth in ASTM D 6751 and from agreed conditions from our client. In order to improve ASTM quality of biodiesel production, the pre-treated product has to achieve less than 2% MIU (moisture, insoluble, and unsaponifiables) or less than less than 500 and 5000 ppm purity of brown and yellow grease to be treated for biodiesel production. However, when FOG waste is collected it contains a high percentage of just liquids (usually water) and different types of solids. This not only could cause damage to the plant, it also decreases the quality of the end product and increases the cost of production. The proposed design which would ensure the quality of the feedstock is to be depended on specific mechanical systems. First, upon receiving the saturated fluid at the storage stage of the design, the macro-filtering of the raw material takes place by capturing debris as a fluid flows through a membrane. Once poured into the receiving tanks, these holding tanks serve as a sedimentation juncture and the action of stagnation or sedimentation of the fluid as a whole for a yet undetermined period of time takes place. Once the sedimentation is completed it continues to the congealing and percolating stages, eliminating the stearic phase and solids. The usable oil will be removed leaving behind a great amount of the unwanted water and solids. In the next stage heat is added to remove any gummy residues, this stage is called degumming. At last before becoming the desired pre-treated oil it passes through the drying stage where water residue is evaporated. The end product is then tested on its proposed terms, maintaining a thorough analysis in the design proposition. With a pre-treatment station in place, the production plant can operate at higher efficiency and improve quality production. It could lead to establishing cost standards for grease trap waste industrial pre-treatment processes and become a more cost effective and successful operation. A recent economic study commissioned by the National Biodiesel Board found that biodiesel production of 1 billion gallons supports 39,027 jobs across the country and more than $2.1 billion in household income. An additional 11,698 jobs could be added between 2012 and 2013 alone under continued growth in the Renewable Fuel Standard (RFS) and with an extension of the biodiesel tax incentive. The U.S. biodiesel industry reached a key milestone by producing more than 1 billion gallons of fuel in 2011, according to year-end numbers released by the EPA in January 2012. Biodiesel is an advanced biofuel and the world is in need of greener energy solutions and less pollution.

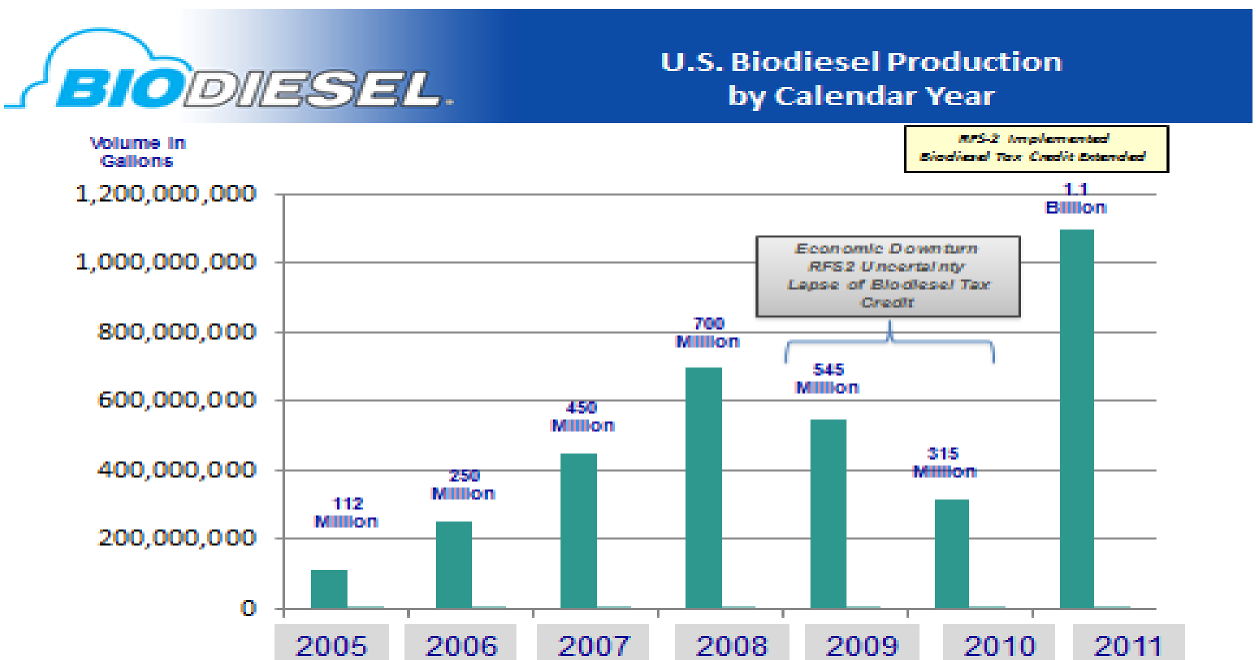


Figure 2 **U.S. Biodiesel Production by Calendar. Source: biodiesel.org**

2. Motivation

The purification of liquids such as fuels and other oils have been significant in the energy producing industry. Many machines filter such fluids from contaminants such as water, other fuels, and undesirable particulates. A couple of these purifiers are so effective when cleaning oils and greases to the point that they can be considered renewed. It is important to be able to effectively clean these discarded oils as it helps reduce pollution, with less and less oil and grease being disposed and more being purified. It also saves companies money when they can opt for used oil that has been refined to become "new" or pure once again than buying more oil from factories, or when energy producing companies reuse these recycled oils in order to create combustible fuels for the motor industry. Most energy producing companies implement a cleaning system to renew their oils rather than spending more money to new oil. This phenomenon of recycling used or burned oils and fuels is becoming more common in the food processing industry, specifically restaurants, cafeterias, places with a high use of cooking oils for deep frying foods. Instead of disposing this oil in city sewage or drainage systems where definite pollution and increase sewage maintenance occurs, more companies are recycling this waste vegetable oil (WVO), as it has been classified, collecting it for other institutions who use it for its combustible properties in order to produce Biodiesel fuel, a source of energy most commonly produced from actual unburned and refined crop oil. The companies interested in these used vegetable oils either collect the undesirable WVO without price or purchase the fluids, they either produce the biodiesel themselves or sell it to energy companies that have developed this technologies.

Some companies are trying to make an effort to produce eco-friendly fuels that can be beneficial during harsh economic times and questionable environmental concerns. Bio-fuels or more specifically biodiesel, produced from vegetable oils has more and more entered our gas station and industrial fuel suppliers markets. For many years, the pollution due to petroleum and fossil fuels used to make gasoline, diesel or fossil oils has increased dramatically and the carbon dioxide emissions have drastically changed global temperatures, ecosystems in addition to our health. Many hot, greenhouse gases have allowed ultraviolent rays and other such radiation to penetrate our biosphere weakening our ecological systems. Emissions for such fuels have contaminated the very air we breathe. However, in recent decades there have been alternatives to the types of fuels that can be used to operate cars and machinery and simultaneously be environmentally friendlier. One of these alternatives is the increasingly popular biodiesel. The use this extremely beneficial fuel can reduce air pollution, by emitting less toxic gases in the air. Several companies and governments around the world (primarily in North America and Europe) are building up resources to increase the availability of biodiesel to the public seeing that it is not as common as gasoline and other petroleum-based fuels but way less damaging.

For the senior design project, our group has been in contact with a company called Green Bio-fuels. This Brazilian based, family owned energy company, has its past in the production of Biodiesel from crop sources like sugar cane, corn etc., a market very competitive and of high importance in the South American nation. Now, here in the United States they see an open opportunity of exploiting this young market of biodiesel production from WVO. They have already started their production of Biodiesel from WVO in a local facility, but just as it was stated in the Problem Statement section of the report, they need our help in the preliminary treatment of the feedstock they collect. Green Bio-fuels buys waste vegetable oil with limited amounts of debris and water to convert it into biodiesel. They are having problems with the waste cooking oil when they buy it from their suppliers. Their suppliers usually add water or other debris to make more volume and earn more money. Currently, Green Bio-fuels cannot treat this oil for biodiesel production. So if there is too much debris and water in the WVO they obtain, they are unable to use it for Biodiesel production. We are assigned to make a design for this company for a preliminary cleaning or filtering system so that Green Bio-fuels can accept any type of waste vegetable oil possible, remove the greatest amounts of water and bio-solid and then process it safely in their plant without damaging their equipment, whilst generating a better quality of biodiesel. In addition, an important byproduct coming from the production of biodiesel is a substance called glycerol. Glycerol is a very important compound for several fields ranging from pharmaceuticals to automotive applications. The significance of developing a bio-fuel feedstock filters to aid the production of biodiesel and have glycerol as a byproduct is compelling reason to work on this project.

3. Literature Survey

3.1 Centrifuge functions

In order to produce biodiesel, the feedstock must be filtered from contaminants and debris. To do so, most oil purifiers are built as centrifuges. The centrifuge consists for a bowl with a shaft that rotates the bowl using power from a motor. The simple idea behind using a centrifuge can be made if one relates to the following example. If there is fuel mixed with water and dirt, the rotation of the centrifuge caused by the shaft will separate the fuel from its contaminants. The rotation causes the dirt and water to be pushed towards the inner walls of the bowl while the fuel remains at the center around the shaft.

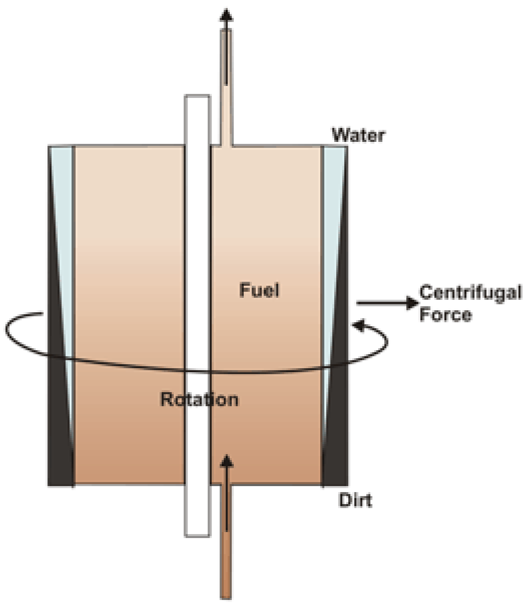


Figure 3 Simple centrifugal separation. Source: marinediesels.info

This separation is due to the lower density of the fuel in comparison to the denser water and dirt. Most oil filters and purifiers use this technology to clean several types of fuels. The fuel will then exit through a pipe which is also how the fuel entered the centrifuge.

3.2 Filtering by osmosis

Several oil purifiers and filters contain a series of filter papers. Filter papers are used to separate liquids such as water from solids. They are widely used in chemical labs to separate a solution from precipitates and other solid residues. A common method to learn about osmosis is using filter papers.

Figure 4 Filter papers. Source: mindfiesta.com

In osmosis, one can assume that two solutions of different concentrations poured in a u-tube separated by a semi-permeable membrane can reach the same concentration of molecules that both solutions shared. The transport of water, or osmosis, can balance the amount of concentrations of a substance on both sides of the u-tube. Filter papers are, to some extent, used to separate oil from fuel from debris due to the semi-permeability that the paper possesses.

3.3 Applications and features of recent oil purifiers and filters

There are several centrifuge-based machines that purify and filter oil. Such oil purifiers are commonly found in the United States, South Korea, Japan, and China. The purifiers help clean the oil from wear components, water, debris, bacteria, and other contaminants of oil. There are several types of purifiers used in these countries and have several features.

Figure 5 30 GPM Vacuum Dehydration Oil Purification System. Source: oilfiltrationsystems.com

According to the system brochure this purifier can be used for oils from turbine lube, paper machine lube, gearboxes (ISO 150 to 680), mineral-based for transformers, silicon, refrigerant, compressor, EHC fluids (Fyrquel), and PAO fluids.

Some of its features include a dry running claw vacuum pump, a permanent dispersion media in vacuum tower, high efficiency particulate remove element, variable frequency drive, and system view windows.

This following NAKIN brand purifier can be applied to several types of oils for switches, mutual inductors, and transformers. This oil purifier series removes trace water, gases, and particles from oil. Some of its features are duplex-stereo film evaporation technology, multi-stage precision filtration system, efficient electric heating system, and double-infrared liquid level sensor. Its main advantages are that it has a working efficiency several times higher than most traditional vacuums and when the purifier is working unattended, it is very reliable and safe.

The Light Fuel Oil Purifier Water Oil Separating Machine (ZJD-F) shown below is used to specifically clean vegetable oil, cooking oil, fuel oil, and lubricating oil. It can also be used to renew cooking oil. This filter has a precision filter system with highly efficient dewatering and demulsifying systems. Its features include the ability to remove small particles and impurities in large quantities as well as water at high speeds without heating, it quickly removes water from oil, it is adequate to work with light oil, it has more than 20 times for efficiency for dewatering when compared other such machines, prevents degradation or deterioration of oils, automatically discharges water online, and has low operation costs.

Figure 6 ZY Single stage vacuum insulating oil purifier. Source: nakinoilpurifier.com

Figure 7 ZJD-F oil purifier machine. Source: chongqingtongrui.en.made-in-china.com

Enervac's High Vacuum Degasifier is used for purifying liquids that insulate electricity. The processes it goes through to accomplish this are dehydration and degasification. These processes can remove particulates, water, and gases such as air.

There are purifiers with High Vacuum (HV) systems that purify insulation oils satisfy operational, economics, and environmental aspects in the oil filtering and purification industry.

Figure 9 **High Vacuum (transformer oil purification) Degasifier. Source: enervac.com**

These HV systems can also remove water to 10 parts per million, gases to 0.25% of total gases, particulate matter to 0.5 microns, etc. They are very practical as they operate easily, require little maintenance, and can be a portable and stationary. These machines are ASME authorized.

Figure 8 **HV-1200-CW-64-B/S 20 GPM. Source: precisionfiltration.com**

3.4 Yellow and brown grease

Figure 10 **A sample of yellow grease. Source: merincorp.com**

Yellow grease is mostly composed of used vegetable oil used for cooking. Their properties are very close to that of WVO. It can be reused and recycled several times. Yellow grease has many applications making it a versatile substance. It is used to make fuels such as biodiesel and usually it is a main component of biodiesel along with brown grease.

Brown grease is collected from waste water from restaurants. While also being WVO, it is much more thick and viscous than yellow grease and it usually cannot be used for anything due to its contaminated nature and containing free fatty acids. However, it is a very significant component in the production of biodiesel.

Figure 11 **Sample brown grease. Source: ncfuturefuels.com**

These waste vegetable greases are collected by the use of grease traps. Both yellow and brown grease cost very little to process as feedstock per pound which is a great way to produce biodiesel inexpensively.

3.5 Biodiesel characteristics

Biodiesel is fuel for a diesel engine. Biodiesel is different from other diesel fuels in that it is produced using renewable sources and other leftover used oils such as cooking oil that is no longer safe to use. Biodiesel can be blended with petroleum as well. Anything that contains an abundant amount of fatty acids such as oils and greases can be made into biodiesel through transesterification, a chemical reaction that occurs between esters and alcohols. Although not as common as the other types of fuels, the way it is produced and the advantages it brings has made biodiesel very popular and it would be beneficial to increase its production and availability to the fuel market.

Figure 12 Soybeam seeds. Source: afdc.energy.gov

Biodiesels have several properties that make them stand out from the different types of fuels that are usually compared. Biodiesels have a higher flash point (temperature of ignition of about 130 °C) than petroleum diesel meaning it is less flammable. It also emits almost no sulfur dioxide and approximately 80 percent less carbon dioxide when compare to other types of fuels. The kinematic viscosity of biodiesels (5 to 6 millimeters per second squared) is higher than their petroleum counterparts which means it has better lubrication properties. With a cetane rating ranging from 55 to 65, the biodiesels combust quicker and start engines faster than other fuels. Biodiesels have a density of 0.88 grams per cubic centimeter and are also denser than petroleum diesel so it gives more energy per liter.

Biodiesels also have several economical and ecological advantages. First of all, it is a nontoxic chemical so it is not threatening to humans. It is produced from renewable sources so it can be produces in sheer amounts and not cause any negative impact to its sources. Due to this reason, it is much more simple and inexpensive to produce. Economically, the production of biodiesel can open up several thousand new jobs to workers.

Figure 13 Biodiesel sample. Source: ccdbiofuels.com

The oils used to produce biodiesel are commonly found and easily obtained. The process of production gives off very little pollution to the environment when compared to petroleum and fossil fuel-based oils. In other words, it is safer to the environment. Biodiesel is biodegradable with means it can be absorbed back to the environment without harming it and it biodegrades faster than other substances.

3.6 Glycerol characteristics


Figure 14 Glycerol sample. Source: projectsday.hci.edu.sg

Glycerol is produced as a byproduct when making biodiesel. This substance is viscous, odorless, and is a widely used compound that has many applications in different fields.

This sugar alcohol is a reactive substance and can be heated without forming acrolein (an unsaturated aldehyde also known as propenal) up to 250 °C. The boiling point of glycerol is 290 °C and its melting point is 18.2 °C. Its density is 1.261 g cm^{-3} and its viscosity is 1.5 Pa·s. These properties and its relationships with other chemicals make it a very valuable substance in the modern world that can be applied to almost every industry.

4. Project Objective

The main objective of this project is to design, develop and test an efficient Biodiesel Feedstock Pre-treatment Station prototype for agricultural co-products and byproducts such as vegetable oils and animal fats resulting in a high composition of yellow and brown grease particles suitable for high quality Biodiesel production in accordance with ASTM standards and regulations. Another objective is to help reduce dependency on fossil fuels and undesirable gas emissions by transforming a waste stream into local energy source.

5. Conceptual Design

There are at least three operations which are indispensable when processing waste vegetable oil in order to convert it into feedstock for the production of Biodiesel. Any waste oil purification will carry some type membrane filtration. It all depends on the specific type's oil being filtered in order to know at what step in the process the filtering membrane will be located or the micron size specifications of the membranes or even how many filters will be needed. Filtration by capturing debris as a fluid flows through a membrane is a very cheap and efficient method of purifying a saturated fluid. In our case, the action of stagnation or sedimentation of the fluid as a whole for some time before the cleaning process saves plenty of work and energy. At times half the battle is won when concerning how much debris and water can be removed from the treated oil when they are collected by way of gravity and density difference at the lowermost part of the storage tank.

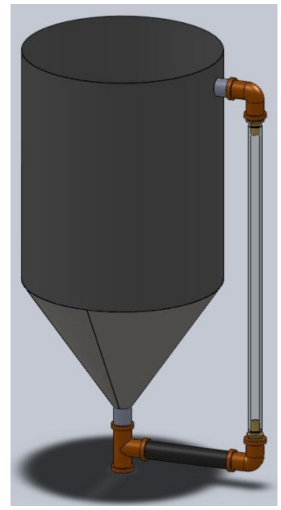


Figure 15 **Storage tank**

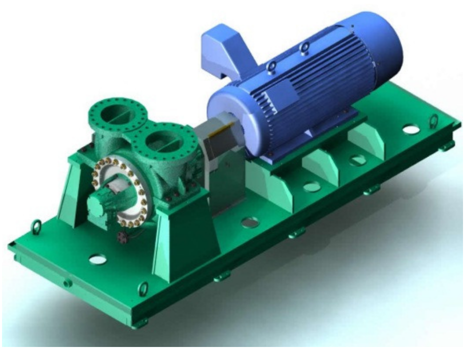


Figure 16 **Pump (javelin-teck.com)**

Something else that is needed for the proper operation of the system is an external force which would create the necessary fluid movement through the already stated filter membranes, a pump. This mechanism would be located right below the storage tank unit, and to be used at beginning of the pre-treatment cycle. It could be similar to a mud-sucking hydraulic pump or a simple industrial impeller pump.

5.1 Transferring heat

When preparing waste vegetable oil for biodiesel feedstock, viscosity of the solutions can be a great factor of how fast and efficient debris is removed and, or humidity is dissipated from the oil. Viscosity as a physical property of fluids decreases when temperature is increased and vice versa. This control on the resistance to flow can be very important. A very common method used to clean highly saturated engine lubricants which can be applied into the production of suitable biodiesel feedstock is to heat or increase somehow the temperatures of these fluids before filtering through membranes or before putting the fluid through industrial centrifuges for a more efficient separation of debris and oil. Organic waste oil could also be positively affected by any increase in heat, specifically in the waste oil most commonly known as brown grease, where viscosity is inconveniently high. A negative aspect of this heat addition into the process of treating waste oil for feedstock is the expense increase; energy would have to be consumed in order to transform new energy. The action of increasing the temperature of the fluid at the receiving storage tanks can be implemented by either an oil resistant electric resistance which would emit heat into the fluid. Another method of significantly increasing the temperature could be by implementing solar cells where the thermal energy of the sun would directly heat the oil at an external loop. These two methods could also work in tandem due to weather conditions.

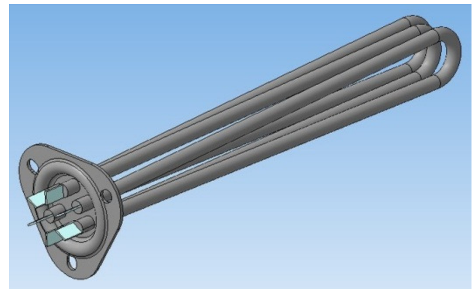


Figure 17 **Electric heater (grabcad.com)**

5.2 Centrifuge dependency

Another alternative design will comprise only the use of an industrial like centrifuge unit. The waste vegetable oil will travel through this as many times as it would be required until the feedstock specifications are met. Knowing that without a filtering membrane available in the system, if very saturated waste oil comes about, then the cycles through the centrifuge could increase significantly. This could very well occur when processing brown grease. A centrifuge would also utilize a significant amount of energy although it would be cost well spent due to its importance and skill in separating water and oil.

5.3 In-line filtering

A very simple and straight forward design would be comprised of several filtering stations placed in line the system loop, this filtering might still need recycling through the in line filters a repeated amount of times. Four or even a set of five filtering membranes could be implemented for debris removal. An oil and water separator filter housing could be very much important to add in these series of filters at the preliminary section when the fluid first leaves the tank. This dependency on filter membranes could leave out the use of the centrifuge and its energy expenditure. Humidity presence in the feedstock could be a negative factor if this alternative design is used due to the lack of a centrifuge presence, which is a devise so proficient in the separation of water and oil, membrane filtering as it is might not be enough if the waste oil encountered is highly emulsified.

6. Proposed Design

Our proposed design begins as the raw material to be processed into biodiesel feed stock is first acquired. This waste vegetable oil we are focusing on could come in any condition possible, any amount of organic debris or any level of emulsification, therefore the preliminary steps of our design has to emphasize on the major debris and humidity removal of the fluid when is first obtained.

Figure 18 **Proposed Pretreatment Plant (www.ageratec.com)**

Biodiesel feedstock has many intricate specifications on its contents. Yellow grease for example, a very common raw material in the production of Biodiesel brings with it high concentrations of burned organic particles and a varied mixture of cooking sauces and condiments. Brown grease on the other hand is the less cooperative of the residual oils in the waste vegetable oil family. By having a much higher density than yellow grease, it is also heavily mixed with great amounts of bio-solids, creating of it a very high viscous fluid, almost sludge like molten grease.

6.1 Macro Filtration

The storage tanks where this yellow and, or brown grease will be received will be adapted with a mesh like filter at the pouring aperture where the major residual solids will be captured before entering the tanks. This removable screen or metal mesh will be subject to periodic cleaning every time a new load of waste vegetable oil is received and dumped into the storage tanks.

6.2 Temperature Increase

The increase in temperature of the raw material before transferring or cleaning saves time and work when obtaining a quality product that is well suited for Biodiesel processing. By implementing an electric heater, more specifically what is commonly called an oil pan heater, which is resistant to oils and immersing this component into the fluid content through the upper aperture of the storage tank, sufficient temperature increase will be available for the WVO to decrease its viscosity. Debris will more rapidly disconnect from the oils and drop to the bottom of the tank facilitating a better sedimentation process. Temperature increase shall be no greater than 120 degrees Fahrenheit; this is because the oil cannot be even more saturated than what it already is. By increasing temperatures in the component we are seeking to just reduce the molecular sizes of the oils for better filtration.

6.3 Stagnation Process

After the oil in the tanks it stays for some hours allowing a stagnation process to occur where most of the solids which are still in the solution accumulate at the very bottom of the tanks together with most of the free water which might be present. The receiving tanks will be segmented on the inside in order to keep turbulent flows in the fluids as the oil are introduced or removed from the tank. The tanks shall have available a drainage valve at the very bottom where excess free water and debris would be removed after the stagnation time is finished. Through this valve, which size has not been determined, but has been chosen as butterfly valve, the solution will be drained while visually inspecting the fluids. At a higher level another drainage valve will have to be adapted. This is where the already heated-sediment free oils will be removed from. These initial storage or stagnation tanks will also have available an access panel at the lower level where scheduled maintenance shall be performed, sort of a periodic clean up inside the floor of the tank.

6.4 Transfer System

The desired WVO is removed from the tank at the level selected via suction. An oil pump transfers the product to the centrifuge. The oil pump specifications depend greatly on the type of centrifuge. Centrifuges are classified as either passive or active. A passive unit requires a higher capacity pump, an active centrifuge would not. The piping and coupling to be used has to be characterized with a low friction coefficient due to the WVO's high viscosity potential.

6.5 Centrifuge filtration

Most of the humidity and the emulsified oils will stay in the general mixture together with the smaller residual organic particles. Using a pumping system, may be a Mud Sucker Diaphragm pump and a piping capacity of 2 inch diameter with distances design upon manufacture, the waste oil will be send into an industrial centrifuge unit where the water and any residual debris will be separated from the waste oil.

1. Housing
2. Center outlet
3. Product
4. Blade Bottom
5. Inlet
6. Blade Top
7. Grabbing Surface
8. Excess
9. Base
10. Main Outlet
11. Vent

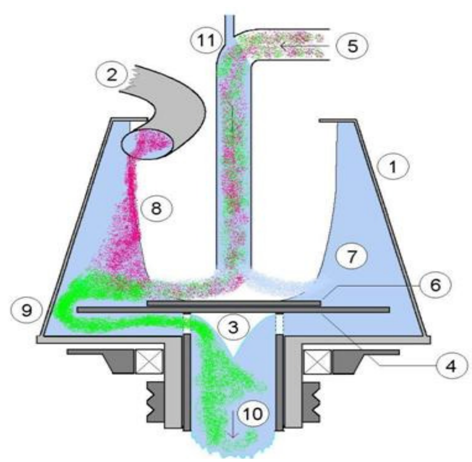


Figure 19 **Centrifuge Principle (www.hsproducts.com)**

A centrifuge removes water and debris from the less dense oil fluid by way centrifugal forces exerted by its mechanical rotary system, sending the unwanted and the wanted in separate directions. These centrifuge units need minimal maintenance which is composed of periodic clean up in order to keep an efficient and proficient rhythm of operation and also prolong the life of the unit.

6.6 Membrane filtration

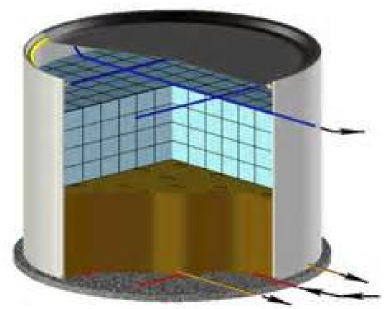


Figure 20 Filter Membrane (adisystemsinc.com)

With an inlet GPM of approximately no more than 20 GPM and a pressure of no more than 60 psig, the oil shall enter the filtration housing equipped with two filters. These hydraulic like functioning filters will remove any last minuscule particles of bio-solids which might have escaped the centrifuge unit. The oil will travel and come in contact with this membrane like shells inside the filtering canisters which will trap most of the bio solid particles. These filters will have life span equivalent to the amount of filtering cycles they are subjected to. This will be the last purification step of the oil before verifying its readiness and sending it to the processing plant.

6.7 Electrical System

The electrical power source is provided by the electrical grid, preferably 120 volts phase. The portable oil pan heater, the transfer pump and the centrifuge unit are to be connected at different locations and each of them shall have a separate circuit breaker for safety precautions. The electrical controls for each of these components are to be intertwined at the control room.

6.8 Testing samples

While obtaining the first amounts of the cleaned oil, samples of the solution will have to be tested for water and debris content. These samples will be collected right away in order to verify if it's ready to become feedstock oil. If the purified oil still does not pass the limits of water content or debris it would have to return to the inlet of the transferring pump and travel through the cleaning process once more. The specifications for a clean oil used as feedstock for biodiesel production is no less than 500 PPM of water content or 0.05 % of water in its solution approximately. Around a bigger content is allowed when testing the solid particles left in the process, a value not greater than 5000 PPM or 0.5 %. Although after traveling through the filter housing very little debris will be left in the solution, the future feedstock will still have to be tested prior entering the processing plant. After the oil has passed its quality control testing, the feedstock is then ready to be supplied into the processing plant for the production of the desired biodiesel product.

6.9 Safety

- Electrical sources connect to a circuit breaker.
- Storage tanks are to be grounded to floor.
- Oil is to be handled with assigned safety equipment: goggles, apron and gloves.
- Each mechanical unit which is to hand oil is to be surrounded by a spill safe platform.
- Laboratory equipment is to be cleaned and identified prior and after testing of oil.

7. Analytical Analysis

7.1 Pretreatment sequence

In this project, the biodiesel feedstock must go through a process to become biodiesel itself.

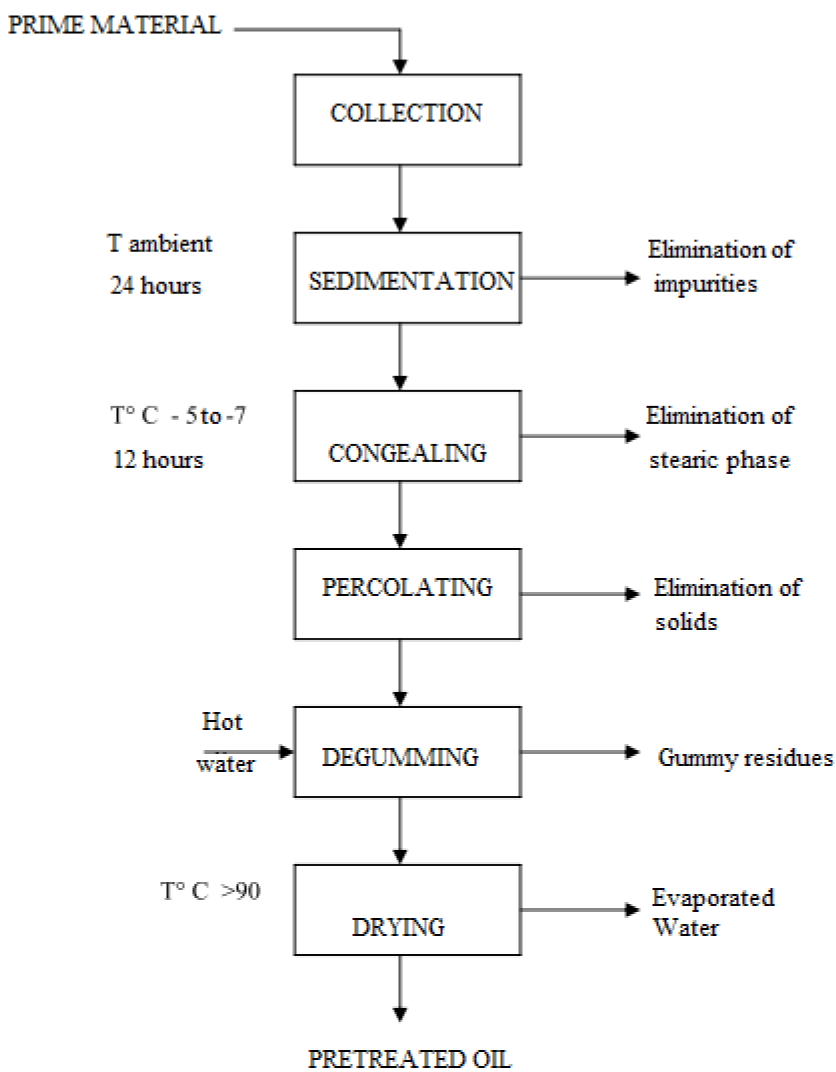


Figure 21 Flow diagram showing the pretreatment of used oils. Source: revistavirtualpro.com

The feedstock, also known as the prime material, must first be collected. It will then be stored in a tank at ambient temperature for 24 hours to allow the contaminants to sediment and settle on the bottom of tank or container. This stage will lead to the elimination of sediment impurities.

Batch	Prime Material Kg	Oil Kg	Solid Residues Kg	Recovered Oil %	Solid Residues %
1	17	13.7	3.3	80.5	19.5
2	12	11.0	1.0	91.7	8.3
3	10	9.1	0.9	91.0	9.0
4	9	8.0	1.0	89.0	11.0
TOTAL	48	41.8	6.2	87.0	13.0

Table 1 Results from sedimentation process. Source: revistavirtualpro.com

After sedimentation, the feedstock will be congealed at a temperature range between -5 and -7 °C for 12 hours. During this stage, any stearic and oleic compounds and properties must also be separated.

Batch	Oil Kg	Oleic phase Kg	Stearic phase Kg	Recovered Oleic phase %	Stearic phase %
1	13.7	10.0	3.7	73	27
2	11.0	10.8	0.2	98	2
3	9.1	8.8	0.3	97	3
4	8.0	7.8	0.2	97.5	2.5
TOTAL	41.8	37.4	4.4	89.5	10.5

Table 2 Results from congealing process. Source: revistavirtualpro.com

Then, the percolation of the feedstock takes places which will facilitate the elimination of the filtered solids from the waste vegetable oil.

Batch	Oleic phase Kg	Filtered oleic phase Kg	Retained Solids Kg	Recovered Oleic phase %
1	10.0	9.65	0.35	96.5
2	10.8	10.45	0.34	96.7
3	8.8	8.52	0.28	96.8
4	7.8	7.55	0.25	96.8
Total	37.4	36.17	1.22	96.7

Table 3 Percolation performance. Source: revistavirtualpro.com

Next, hot water will be added to the WVO to commence the degumming stage where adhesive and sticky properties of the WVO are no longer present. The gummy residues leftover will also be removed from the oil.

Sample	Oil G	Percentage of water %	Gum %
1	300	3	11
2	300	10	15
3	300	15	24
4	300	20	26
5	300	30	27

Table 4 **Optimization of water use in the degumming process. Source: revistavirtualpro.com**

Batch	Percolated Oil Kg	Degummed Oil Kg	Gum Kg	Recovered Oil %
1	9.65	8.88	0.80	92.0
2	10.45	10.00	0.45	95.7
3	8.52	8.37	0.15	98,0
4	7.55	7.41	0.14	98.0
Total	36.17	34.67	1.55	95.8

Table 5 **Performance of degumming process. Source: revistavirtualpro.com**

Finally, the WVO must be exposed to temperatures above 90 °C to it can dry and have the water that was added a couple of stages ago evaporate. Thus, drying the WVO completes the process to pretreat the feedstock. The following diagram shows how much oil was recovered using this process.

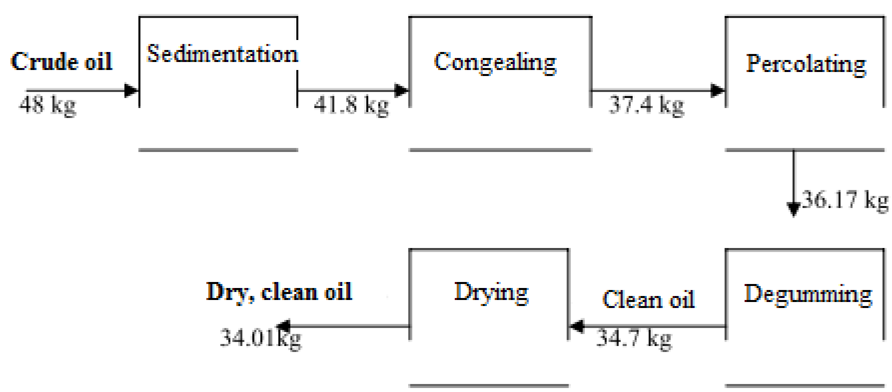


Figure 22 **Results of pretreatment of used oil. Source: revistavirtualpro.com**

In this specific order, 72% of the oil was cleaned and ready for biodiesel production. However, the performance is of 72% is too low. In order to achieve better results, the next flow chart can be followed as an alternative approach.

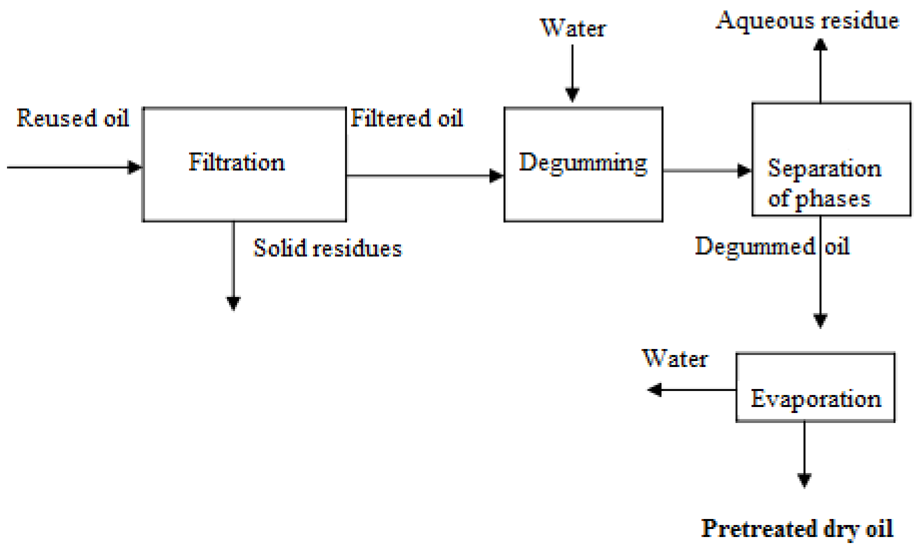


Figure 23 **New pretreament of used oils. Source: revistavirtualpro.com**

With the new set up for the pretreatment of oil, a much higher performance of 89% was obtained, meaning this method is more effective. From then on, the feedstock is ready to undergo transesterification and become biodiesel.

7.2 Basic equations that define filtration

The fundamental purpose of the filtration is to obtain a fluid free from solid or semisolid particles called filtration flow q.

Since the filter flow q depends on the impulsive force in this case, a pressure difference $-\Delta P$ and the existing resistance R from mid filter and the deposited solids oppose the flow; the former can be mathematically expressed as:

$$q \propto \frac{(-\Delta P)}{R} \quad (1)$$

$$q = \frac{K'(-\Delta P)}{R} \quad (2)$$

Where:

K' = constant of proportionality.

During the filtration, the solids are deposited over the mid filter and the thickness of the layer of the cake-like solids is increased. At the same time, channels or capillaries are formed between the solids where the filter flow is laminar. The resistance due to these solids is increased as well while the amount of filter flow decreases.

The equation that allows quantifying the flow velocity in the channels is the Poiseuille equation who published, in 1842, a mathematical relation of liquid flow across a capillary:

$$q = \frac{\pi r^4(-\Delta P)}{8\mu L} \quad (3)$$

Where:

q = fluid flow.

r = capillary radius.

$(-\Delta P)$ = pressure drop across the capillary.

μ = viscosity of the fluid.

L = length of the capillary.

The importance of the Poiseuille equation and its use allows predicting the potential effect of the decreasing size of the capillary over the flow and in the case of the filtration over the resistance of the cake-like solid.

In 1856, d'Arcy described the velocity of the flow of subterranean waters on strata of the ground through the following equation:

$$u = K_1 \frac{-\Delta P}{L} \quad (4)$$

Where:

u = fluid velocity.

K_1 = permeability coefficient of the bed.

ΔP = pressure drop across the bed.

L = thickness of the porous bed.

From the practical point of view, it is more important to determine the filter flow q than the fluid velocity u.

If the volumetric flow of a channel is given by:

$$q = \frac{dV}{dt} = uA \quad (5)$$

Where:

dV/dt = the volume change with respect to time (volumetric flow rate).

A = transversal area of the channel.

Then equation (4) is multiplied by the transversal area and the fluid viscosity is introduced as another resistance at the flow and it is substituted in equation (5) to obtain the modified d'Arcy equation:

$$q = \frac{dV}{dt} = K_1 \frac{-\Delta P}{\mu L} A \quad (6)$$

If the Poiseuille equation (3) is also multiplied by the area, it can be written like this:

$$q = \frac{dV}{dt} = \frac{r^2(-\Delta P)}{8\mu L} \frac{\pi D^2}{4} \quad (7)$$

Grouping the constants can also be written as:

$$q = \frac{dV}{dt} = K \frac{\Delta P}{\mu L} A \quad (8)$$

Then, the modified d'Arcy equation (6) and the Poiseuille equation (8) are equivalent and the permeability coefficient K_1 can be written as K:

$$K = \frac{\mu L}{(-\Delta P) A \frac{dV}{dt}} \quad (9)$$

This is the first contribution of the theory to determine the permeability of the bed and it is measured as the quantity of the fluid that passes in the unit of time. For some materials, the unit of permeability is from d'Arcy.

7.3 Application of filtration equations

7.3.1 Determination of resistances

If the permeability is the ease of the filter flow, the inverse is the resistance of the passing of the filter $K = 1/R$.

The resistance has two components: the deposited solids α and the mid filter *r*.

7.3.2 Resistance of the cake-like solid

Equation (8) can be written as:

$$\frac{dV}{dt} = \frac{1}{\alpha}\frac{(-\Delta P)}{\mu L}A \quad (10)$$

Isolating α:

$$\alpha = \frac{A(-\Delta P)}{\mu L}\frac{dt}{dV} \quad (11)$$

Equation (11) allows determining the permeability across the cake-like solid of the thickness *L* fixed, but this changes continuously; if each layer is supposed to be constant, then, the product of the thickness *L* by the area *A* of the filtration is the volume of the deposited cake-like solid *v* for the units from the corresponding volume of the filter.
If *V* is the total volume of the filter, then the total volume of the deposited cake-like solid is: $AL = Vv$.
Isolating L:

$$L = \frac{V\nu}{A} \quad (12)$$

Equation (12) can be substituted in equation (11):

$$\alpha = \frac{A^2(-\Delta P)}{\mu \nu V}\frac{dt}{dV} \quad (13)$$

7.3.3 Resistance of the mid filter

Sperry was one of the first to establish the filter resistance composed of two resistances in series, the one from the cake-like solid and the mid filter is considered and substituted in equation (13). We have:

$$\frac{dV}{dt} = \frac{-\Delta P A^2}{\mu(\alpha \nu V + rA)} \quad (14)$$

Applying the inverse of equation (14)

$$\frac{dt}{dV} = \frac{\mu\alpha\nu}{-\Delta PA^2 g_c} V + \frac{\mu r}{-\Delta PA g_c} \quad (15)$$

Separating and integrating from $t = 0$ to $t = t$ and $V = 0$ to $V = V$,

$$\int_0^t dt = \frac{\mu\alpha\nu}{-\Delta PA^2 g_c} \int_0^V V dV + \frac{\mu r}{-\Delta PA g_c} \int_0^V dV \quad (16)$$

From the integration of (16), a constant pressure, the time of the filter t can be isolated:

$$t = \frac{\alpha\mu\nu}{-2\Delta PA^2 g_c} V^2 + \frac{\mu r}{-\Delta PA g_c} V \quad (17)$$

Where:

V = volume of the filter in m^3 collected in time t in s.

$-\Delta P$ = pressure drop in kg_f/m^2.

A = filtration are in m^2.

μ = viscosity of the filtered in kg/m·s.

g_c = conversion factor with the value of 9.81 in (kg_m/kg_f) (m/s^2).

If the time when the first drop of the filter is measured until the filtration ends, the filtration is obtained in a series of data that make the following graph of volume versus time. This way, $t = 0$ and $V = 0$.

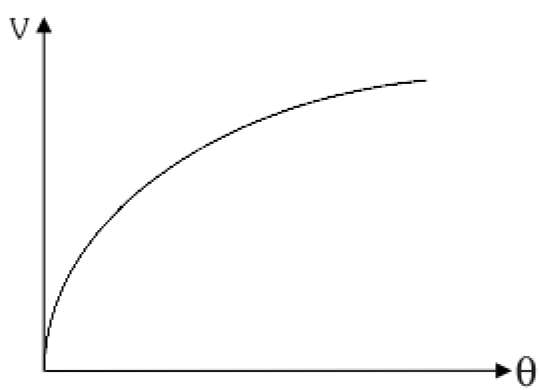


Figure 24 Relationship of the filter V vs time θ. Source: Procesos de Separación I: Prácticas de Laboratorio, Laboratorio de Ingeniería Química UNAM

For a filtration at constant pressure and where the variables of the process do not change, that is, are constant during filtration, equation (15) can be written as:

$$\frac{dt}{dV} = K_1 V + K_2 \quad (18)$$

Where:

$$K_1 = \frac{\alpha\mu\nu}{-\Delta P A^2 g_c} \quad (19)$$

$$K_2 = \frac{\mu r}{-\Delta P A g_c} \quad (20)$$

Supposedly, during experimentation, the determinations of collected volume have been made at different intervals of time, *dt*, when graphing *dt/dV* vs. *V* and a straight line is obtained:

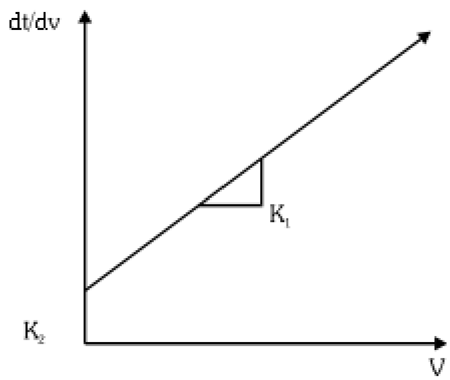


Figure 25 Relationship of the volumetric flow rate vs volume V. Source: Procesos de Separación I: Prácticas de Laboratorio, Laboratorio de Ingeniería Química UNAM

Where:

The pending value of the straight line is K_1 and the origin is K_2 defined previously with equations (19) and (20), respectively.

With the values of K_1 and K_2, α and r can be isolated, which are:

$$\alpha = K_1 \frac{A^2(-\Delta P)g_c}{w\mu} \quad (21)$$

$$r = K_2 \frac{A(-\Delta P)g_c}{\mu} \quad (22)$$

Many determinations can be experimentally done at different pressures; this way, the variation of the resistance with respect to pressure can be calculated.

Another important determination is that of the effects of compression, that is, the effect of pressure in the specific resistance of the cake-like solid. The correlation proposed by Almy and Lewis is the following: $\alpha = \alpha_0(-\Delta P)^s$.

Where: α_0: specific resistance in a pressure of zero, m/kg.

s: compressibility factor (dimensionless).

When the value s is equal to zero, it can be said that the cake-like solid is incompressible; when the value is greater than zero, it can be said that the cake-like solid is compressible.

7.3.4 Basic theory of the centrifuge

For over than a century, centrifuge separation has been one of the most important unitary operations in the key processes of the industries of chemicals, pharmaceuticals, treatment of effluents, purification of combustible oils, lubricants, and suspensions in general.

In the field of technology of separation mechanics, the separators and decanters are installed within the centrifuges are engaged for the concentration of solids, clarification of suspensions, and separation of mixtures of liquids with the simultaneous elimination of solids.

Essentially, the centrifugation is a selective decanting of insoluble components of a mixture under the conditions of the artificial gravity.

A great variety of centrifuges exists in the industry of which can be classified from diverse forms. Next, a classification of a small group of centrifuges known as sedimentaries will be made taking as reference the amount of solids at the inlet of the centrifuge.

Manual discharge, 0-5% of solids.

This type of centrifuge is also known as a massif drum. The solids accumulate in the mud deposits and must be removed manually, stopping the machine and opening the drum.

Automatic intermittent discharge, 0-30% of solids.

These are also known as self de-sludging centrifuges. The solids accumulate in the mud deposits and are expelled intermittently and automatically across the discharge orifices.

Continuous discharge, 0-40% of solids.

Within the chemical industry, they are known as nozzles. The solids accumulate in the mud deposits and are expelled continuously through the nozzles.

Transporting screw, 0-65% of solids.

This type of centrifuge works like a decanter. It has a completely different design from the other centrifuges. They are equipped with a transporting screw that allows them to discharge solids continuously.

The equation for natural sedimentation of a particle is:

$$v_s = \frac{\Delta\rho d^2 g}{18\eta} \quad (23)$$

This equation is known as Stokes' law for natural sedimentation.

To increase the velocity of the sedimentation, the gravitational force g can be substituted by an artificial gravity known as the centrifugal force ωr. We can deduce by analogy from equation (23) that the velocity of sedimentation of a particle in suspension within a fluid that gyrates is:

$$v_g = \frac{\Delta\rho d^2 \omega^2 r}{18\eta} \quad (24)$$

This equation is known as Stokes' law for suspensions in rotation.

If we considered that $v_g = x/t$ where the time t represents the time that the liquid is in the drum and it can be defined as $t = V/Q$ where V is the liquid volume at a determined time and Q is the liquid flow across the drum.

$$x = v_g t = \frac{\Delta\rho d^2 \omega^2 r V}{18\eta Q} \quad (25)$$

If one considers the liquid in the drum as a liquid layer of thickness s and if x is greater than the initial distance of the particle form the wall of the drum, the particle will be separated from the false liquid; from a different manner, it will stay in suspension. In an ideal system $x = s/2$, half of the particles of the diameter d will be separated from the suspension and the other half will not. Therefore, if we rearrange the previous equation:

$$Q = \frac{2\Delta\rho d^2}{18\eta}\frac{\omega^2 r V}{s} \quad (26)$$

Being the first group from the right side of the equation, the parameters from the system that follow Stokes' law $(\Delta\rho d^2/18\eta)$ and the second group $(V\omega^2 r/s)$, the parameters that define the dimensions of the set can also be written in the following manner:

$$Q = 2v_g\Sigma \quad (27)$$

Where:

$v_g = (\Delta\rho d^2/18\eta)g$.

$\Sigma = V\omega^2 r/gs$ and Σ has the dimensions of length.

The equivalent area Σ of a separating centrifuge is defined as the surface that should have a tank of natural sedimentation to give out the clarified flow (m^3/h) equal to the centrifuge in question for any suspension.

It is also possible to obtain the diameter of the particle from the previous equations.

$$d = \sqrt{\frac{18\eta v_g}{\Delta\rho g}} \quad (28)$$

With the prior fundamental, the equivalent area from the two centrifuges is related by the next relation.

$$\frac{Q}{\Sigma} = \frac{Q_1}{\Sigma_1} = \frac{Q_2}{\Sigma_2} = \frac{Q_3}{\Sigma_3} = \cdots = \frac{Q_n}{\Sigma_n} = 2vg \quad (29)$$

Charles M. Amber developed corresponding equations for the different types of drum for the calculations of the equivalent area.

a) Tubular centrifuge

$$\Sigma = \frac{L\omega^2}{g} \frac{r_2^2 - r_1^2}{\ln \frac{2r_2^2}{r_2^2 - r_1^2}} \quad (30)$$

b) Centrifuge of discs and chambers

$$\Sigma = 2\pi\omega^2 N \frac{r_2^2 - r_1^2}{3gC \tan\theta} \quad (31)$$

Where:

r_1 = superior inner radius of the drum.

r_2 = inner radius of the base of the drum.

N = number of discs, for the centrifuge of chambers N = 1.

ω = angular velocity in radians per second.

L = height of the drum.

θ = 45° angle formed between the discs.

C = 1.8, constant of the set.

An empirical correlation that has no exact dimensions and is often utilized in the design of centrifuges of discs is the following.

$$\Sigma = 2\omega^{1.5} N \frac{r_2^{2.75} - r_1^{2.75}}{3gC \tan\theta} \quad (32)$$

8. Major Components

The service we are providing to Green Bio-Fuels is almost in its entirety a macro-mechanical, fluid cleaning station, with of course a combination of simple controls in order to effectively operate the equipment. The components which stand out in the design are important for their indispensability and uniqueness. Below is a description of them.

8.1 Holding Tank

This component could also be termed the storage tank or the receiving tank. These tanks will serve as the receiving containers for all the raw material that is first acquired to the company. These recipients allow a place for the WVO to be slightly heated, and it is used to sediment most of the debris and water. It consists of a high capacity metal cylindrical container, vertically elongated, of a diameter and height of industrial proportions. The tanks themselves have already been attained by Green Bio-Fuels and have been awaiting use.

The tanks are segmented on the inside. Each of its ballast compartments has communicating apertures with each other. Two draining ports have to be adapted into the tanks in order to remove one, the unwanted water and solids accumulated at the bottom and two to collect the usable first stage WVO right above the section with the sediment.

8.2 Oil Pump

This electric motor-driven pump transfers the second stage WVO from the holding tanks towards the centrifuge unit. For the most effective transfer of fluid a diaphragm pump is the best option. Although the common centrifugal type hydraulic pumps are as efficient for this application, just more delicate. Some already exiting types of pumps have come to light, units that are commonly used in similar applications. For example a mud-sucking pump, designed for

Figure 26 Mud-sucking Pump (waste-corp.com)

variable viscosity fluids, is a diaphragm type.

How powerful the pump is depends on the piping distance and the head elevation that follows. It is also depended on if the type of centrifuge being utilized in the loop. This last point will be analyzed in the centrifuge description. In the figure to the right we present a possible unit.

8.3 Centrifuge

This filtration mechanism is our principal method for separating the product from the water and bio solid particles mixed within the oil. A centrifuge unit could be classified in two types, a passive centrifuge or an active centrifuge. The so called passive type depends solely on high flow strength through its cavities, meaning that the flow itself is what produces the centrifugal action which separates heavier matter from lighter ones. For this application of centrifuge the transfer pump has to be of higher potency, because the separation of the debris in the centrifuge is directly related to the output capacity of the oil pump.

An active centrifuge will be assembled with its own rotating motor; giving an extra push to the flow force therefore this design does not require a high potency pump, just enough force to have the fluid reach the centrifuge. An example of an active centrifuge unit very commonly used in biodiesel application is shown in the figure to the right.

Figure 27 Active Centrifuge (kyte-centrifuge.com)

9. Structural Design

9.1 Piping

The big challenge in this WVO pre-treatment station is placing the holding tank and its transfer pump as close as possible to the centrifuge. The tanks themselves, due to their height, do not fit in the building where the centrifuge is certain to go, the same location where the biodiesel processing plant is. Piping and the respective couplings are going to be accommodated between the two important sections of the design. There is also a height lift to be taken into account before the piping reaches the centrifuge.

9.2 Holding Tank Screen

Figure 28 **Screen (wzjdc.com)**

This important component is preferably of soft and light metal which makes it allowable to be easily removed and installed with the upmost simplicity. It also needs continues maintenance hence its simple handling. We show a proposed screen in the figure to the right.

9.3 Electric Heater Element

This is a portable Electric heater or an Oil pan heater which is placed into the oil at the storage tank while sedimentation is occurring. It slightly increases the temperature of the oil, facilitating a more effective sedimentation process. It has to be of easy handling in order to enable its installation and removal from inside the tank.

9.4 Filtering Membrane

This smaller micron-membrane filter catches any small debris which escapes the centrifuge. The higher the quality of the feedstock being delivered to the plant the higher the quality of the biodiesel produced. Fuel varies in prices often due to its refined treatment. A clean biodiesel with no debris is highly regarded in the fuel markets for its high combustibility.

9.5 Control Panel

The transfer pump is operated from a local control panel and from the plant's control station. Its respective electrical circuit and connections work in this process.

10. Prototype System Description

The reduction of the size scale from the plant design to our proposed prototype is significant. Every component reduced is reduced not only in size but also in capabilities.

10.1 Holding Platform

This structure serves as a firm base where the mechanical components are installed on and facilitates the easy transport of the model. It is still uncertain if the platform will have base-wheels or if it will be fixed. A tool cart is thought to work successfully as a platform.

10.2 Holding Tank

The holding tank, receiving tank or storage tank in the prototype serves the same purpose as in the plant design. It facilitates sedimentation and it provides the pump with a constant prime of WVO for proper operation. It also serves as an adequate medium for the electrical heater to be placed into the fluid to help with the sedimentation and to decreases the flow viscosity.

10.3 Transfer Pump

A smaller capacity pump is installed right below the tank. Its location ensures its prime for continuous suction. Considering the small size of the loop, a common centrifugal electric pump is considered sufficient for the application.

10.4 Filtration

A small passive centrifuge is in place right down the flow of the pump in order have better fluid filtration with its centrifugal action. In this case the centrifuge depends only on the flow force produced by the pump for its operation. An example of a possible centrifuge unit for the

Figure 29 Passive Centrifuge (bellflow-systems.com)

prototype is shown in the figure to the right. A filter membrane of smaller scale is available at the outlet of the centrifuge to capture the debris escaping the centrifuge.

10.5 Linkages

Instead of metal piping, the prototype has to be assembled with transparent pipes more specifically plastic tubing which can sustain the flow forces. This allows better analysis while testing prior to industrial scale design.

11. Cost Analysis

The budget for this project has still not come into terms with our sponsor. It is established that after the proposed major components are identified both teams are to proceed upon an estimation of the costs. We have prepared a rough estimate of the component's cost, the man hours which could take to finalize the design and construct an accurate prototype for the pre-treatment station.

#	Components	Status	Quantity	Cost Estimate
1	Tanks	Acquired	2	0
2	Tanks' Base Fixtures	Not Acquired	2	$ 150
3	Filter Screen	Not Acquired	1	$ 200
4	Oil Pan Heater	Not Acquired	1	$ 50 – 250
5	Pump	Not Acquired	1	$ 1300 - 2500
6	Centrifuge	Not Acquired	1	$ 500 -5000
7	Filter Membrane Assembly	Not Acquired	1	$ 80 - 150
8	Filter Elements	Not Acquired	2	$ 30 - 80
9	Electrical Control Panel	Not Acquired	1	$ 200 - 400
10	Wiring	Not Acquired	-----	$ 150
11	Piping	Not Acquired	-----	$ 400
12	Fittings & Couplings	Not Acquired	-----	$ 150
13	Miscellaneous	------	-----	$ 100
14	Total Sum	------	12	$ 9300

Table 6 **Components Cost Estimate**

#	Labor	Status	Hours	Cost Estimate
1	Tanks' Modification	Not Performed	-----	$ 300
2	Electrical Installation	Not Performed	-----	$ 500
3	Graphic Design & Analysis	Not Performed	-----	$ 400
4	System Design	Performed	10	$ 150
5	Structural Design	Not Performed	-----	$ 300
6	Report Preparation	Performed	30	-----
7	Presentation Preparation	Performed	15	-----
8	Components Acquisition	Performed	-----	-----
9	System Installation	Not Performed	-----	$ 2000
10	Total Sum	-----	10	$ 3650

Table 7 **Labor Cost Estimate**

12. Prototype Cost Analysis

In a smaller scale the prototype cost is estimated below. Still plenty of modifications are prone to occur in order to prepare a more detailed analysis of the Pre-treatment station. Most of the assembly of the prototype will be performed by the student team.

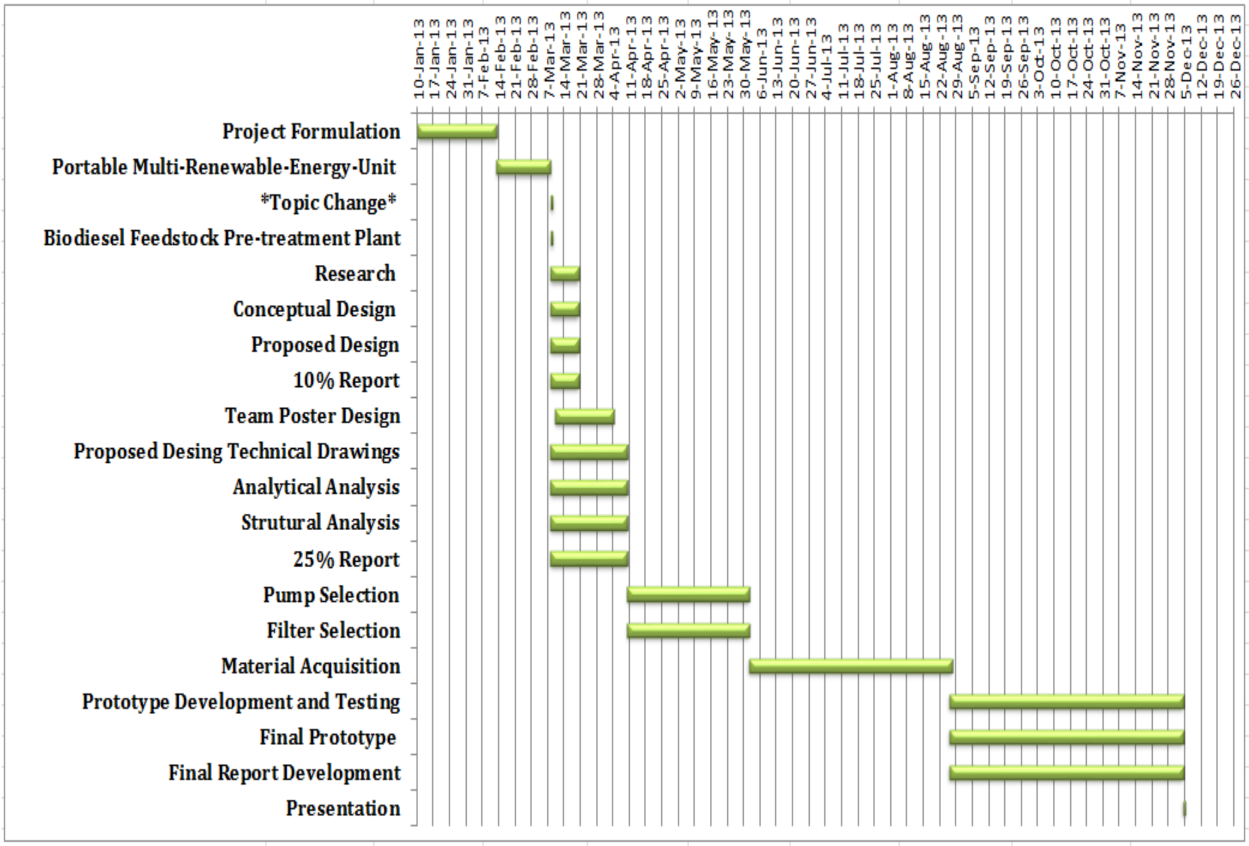
#	Description	Status	Quantity	Cost Estimate
1	Tank	Acquired	1	0
2	Base Platform	Not Acquired	1	$ 60
3	Filter Screen	Not Acquired	1	$ 30
4	Oil Pan Heater	Not Acquired	1	$ 50
5	Pump	Acquired	1	0
6	Centrifuge	Not Acquired	1	$ 150
7	Filter Membrane Assembly & Element	Not Acquired	1	$ 80
9	Electrical Control Panel	Not Acquired	1	$ 100
10	Wiring	Acquired	-----	0
11	Tubing	Not Acquired	-----	$ 50
12	Fittings & Couplings	Acquired	-----	0
13	Assembly Labor	------	-----	$ 200
	Total Sum	------	12	$ 720

Table 8 Prototype Components Cost Estimate

13. Prototype Testing

The model to be built which simulates the Pre-treatment station is to be tested in all aspects of the conditions set forth to the client. The end product should be of the specified water and debris limitations stated in the Testing section 6.8. The prototype shall be shown in its full functionality upon final presentation of the thesis, either directly or via recorded video. All safety procedures are to be seriously followed upon operation of prototype including the oil which shall be handled with caution. Most needed attention to detail is to be given to the end product water and debris content, resulting this in a direct result for the actual Pre-treatment station outcome.

14. Timeline



10-Jan-13
17-Jan-13
24-Jan-13
31-Jan-13
7-Feb-13
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21-Feb-13
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7-Mar-13
14-Mar-13
21-Mar-13
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28-Nov-13
5-Dec-13
12-Dec-13
19-Dec-13
26-Dec-13
Project Formulation
Portable Multi-Renewable-Energy-Unit
Topic Change
Biodiesel Feedstock Pre-treatment Plant
Research
Conceptual Design
Proposed Design
10% Report
Team Poster Design
Proposed Desing Technical Drawings
Analytical Analysis
Strutural Analysis
25% Report
Pump Selection
Filter Selection
Material Acquisition
Prototype Development and Testing
Final Prototype
Final Report Development
Presentation

15. Conclusion

In this report, a design for a pre-treatment station for grease trap waste has been presented. The design incorporates all the necessary steps to comply with the proposed pre-treatment cycle. Beginning with a stagnation process where the first filtration occurs, feed stock sits for a period of time where most of the solids that are still in the solution accumulate at the very bottom of the tanks together with most of the free water which might be present. Then the cycle continues with a centrifuge filtration, where most of the humidity and the emulsified oils that stayed in the general mixture together with the smaller residual organic particles are pumped into an industrial centrifuge unit. The centrifuge unit removes water and debris from the less dense oil fluid by way centrifugal forces exerted by its mechanical rotary system, sending the unwanted and the wanted in separate directions. The oil shall enter the filtration housing equipped with two filters. These hydraulic like functioning filters will remove any last minuscule particles of bio-solids which might have escaped the centrifuge unit. This will be the last purification step of the oil before verifying its readiness and sending it to the processing plant for advance biofuel production, biodiesel. Combining some traditional process with innovative technology and materials should be the key for a successful pre-treatment process to lay the ground for converting a waste stream into a must needed green energy source.

Figure 30 Biodiesel sample. Source: www.permaculture.co.uk

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17. Appendices

Appendix A: Proposed Design Set up

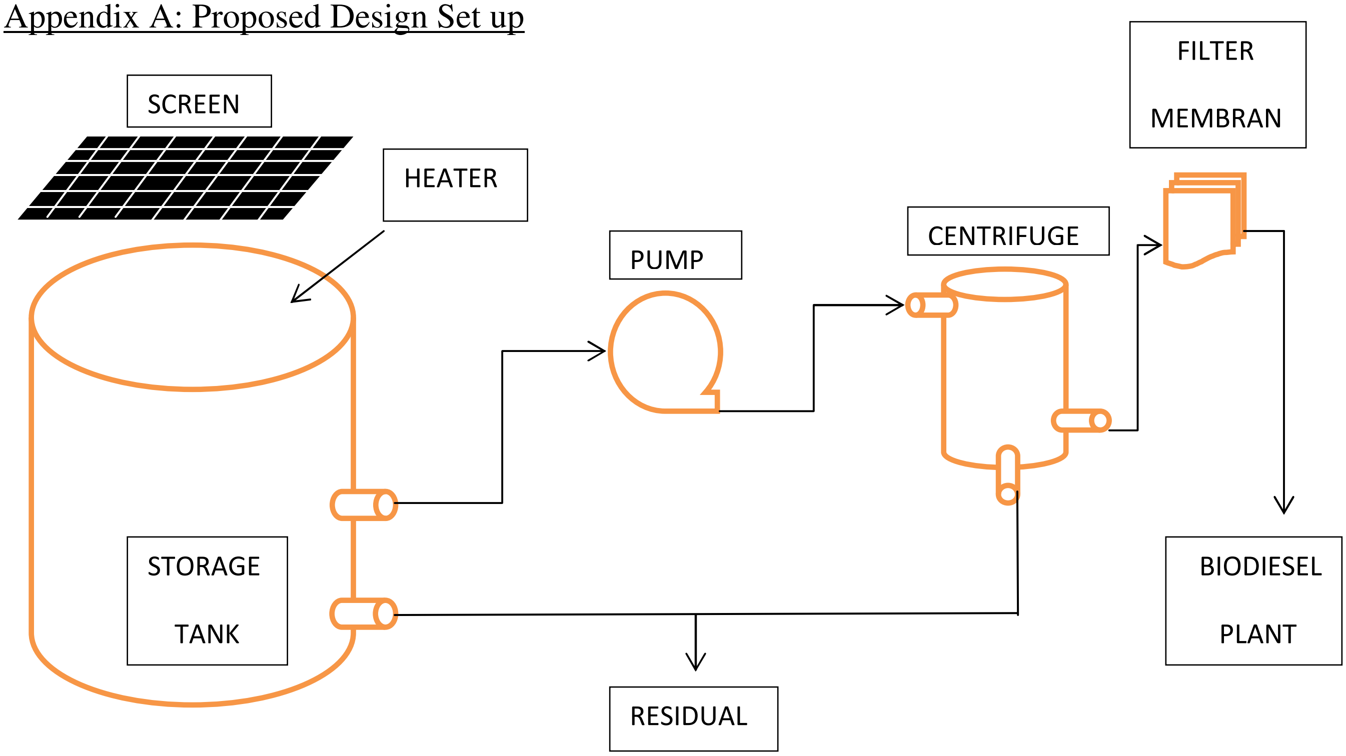
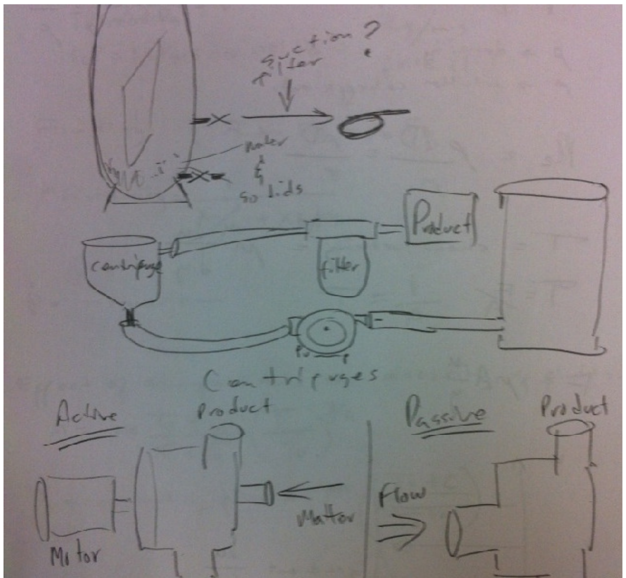
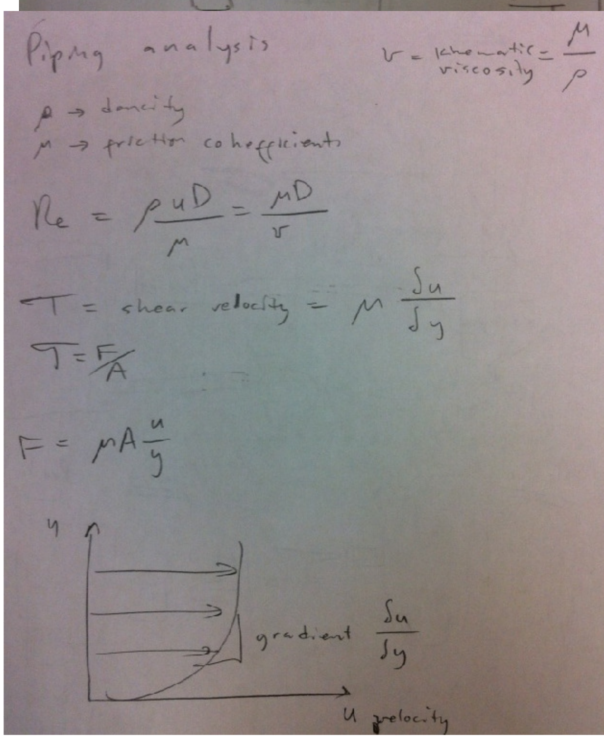


Figure 31 Proposed Design Overview

Appendix B: Planning Sketch





(3)

Dynamic viscosity units

Pa·s

N·s/m²

Kg/m·s

poise (P)

$1P = 0.1\ Pa \cdot s$

$1cP = 1mPa \cdot s = 0.001\ Pa \cdot s$

Fluidity $F \approx x_a F_a + x_b F_b$

$$\mu \approx \text{viscosity} = \frac{1}{x_a/\mu_a + x_b/\mu_b}$$

$\dot{p}$ = momentum $\qquad \tau = \dfrac{\dot{p}}{A}$

Effect of temperature on viscosity of fluids.

$$\mu = \mu_0 \frac{T_0 + C}{T + C} \left(\frac{T}{T_0}\right)^{3/2}$$

$$\lambda = \text{constant of fluid} = \mu_0 \left(\frac{T_0 + C}{T_0^{3/2}}\right)$$