Biodiesel

Final Design Report

Senior Project

ENGR 491

Messiah College

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1 Introduction

1.1 Abstract

The 2006-2007 Biodiesel Senior Project sought to establish a sustainable biodiesel production system on the Messiah College campus using waste vegetable oil (WVO) from Lottie Nelson Dining Hall. Sustainability necessitates proficient documentation of procedures, quality testing, and fuel usage. The team built a successful system in a trailer behind Frey academic building using inherited and purchased components. They proceeded to successfully burn fuel in their Volkswagen and in a home heating system.

1.2 Description

Although the U.S. only contains 4.6% of the world's population, it consumes 25% of the world's oil and 40% of its gasoline. Due to a constant rise in world petroleum consumption, political tensions, and the difficulty of procuring oil from new sources, the United States and other countries faces an impending rise in oil product prices. Biodiesel is not the next petroleum, but it could be a valuable resource if and when oil prices peak. Biodiesel is not a new concept, but its popularity has grown, especially among farmers and the environmentally conscious.

Biodiesel may be useful in developing nations, depending on available resources. For example, the democratic Republic of Congo (DRC) used to be a major exporter or palm oil, but recently has not been able to compete in the world market, so farmers are now unable to sell. Murray Nickel, a missionary in the Congo, has suggested that palm oil could be converted to biodiesel in Congolese communities. Once such systems are established, Congolese farmers would be able to sell palm oil to biodiesel manufacturers at medical clinics in return for health care. The 2006-2007 Messiah College Biodiesel team designed their system with two future goals in mind; to support developing communities with the implementation of biodiesel systems, and to contribute to the biodiesel movement in the United Stated with research performed on campus.

The team inherited a trailer and a small production system from two years previous, which they expanded to approximately three times its original capacity. During this expansion, the team combined two separate processes into one tank for heating and mixing. After system construction, the biodiesel team authored all necessary procedures for oil acquisition and heating, methoxide mixing, biodiesel mixing, water washing, and waste removal. They posted these steps on the trailer walls in laminated single sheets for quick reference. MSDS sheets and hazard warnings were also posted in the trailer for safety awareness.

Before fuel was consumed it had to be quality-ensured. The applicable ASTM standard for biodiesel is found to be D 6751. While the team originally planned to make fuel that was ASTM-qualified, they did not have the necessary laboratory or monetary resources to do so. The tests performed were inspired by ASTM standards.

1.3 Purpose/benefit

The broad purpose of the Messiah College Biodiesel Project is to build relationships and share the Gospel with local and international developing communities by supporting their economic stability with an appropriate, sustainable means of generating income through the use of renewable fuels.

A fully functional Biodiesel processing system can help: to provide fuel for on-campus gators used by the grounds department, to increase the knowledge base of the Messiah College Biodiesel team that will look to future implementation in Africa, to set a positive example for alternative fuels on campus and in the area of south-central PA.

1.4 Objectives

There are two sections of objectives to report on: long-term and annual objectives.

LONG-TERM OBJECTIVES

1) Maintain knowledge of the state of the art of small-scale biodiesel production.
2) Develop a process that converts any location-appropriate feedstock to ASTM-standardized biodiesel fuel in appropriate quantities. Create and maintain a manual that addresses all safety and maintenance concerns, clearly describes systematic procedures, and provides a user-friendly list of input variables with instructions for dealing with them.
3) Consistently produce quality biodiesel fuel on the Messiah College campus for local consumption and research.

4) Develop a business plan for implementation of community biodiesel reaction facilities. Implement biodiesel public relations work; detail the Volkswagen Rabbit and trailer with art that celebrates Messiah College, The Collaboratory for Strategic Partnerships in Applied Research, and biodiesel.
5) Minimize waste by managing Glycerin and other biodiesel side streams.

ANNUAL OBJECTIVES

1) Standardize the production of biodiesel on the Messiah College campus. Design and build a 20-50 gallon processor in a trailer behind Frey academic building. Write clear, concise, step by step procedures for all repeatable processes. Initiate regular production from Lottie Nelson waste vegetable oil.
2) Test the quality of produced Biodiesel, using gas chromatography, cloud point testing, pH and methanol tests.
3) Create documentation for safety and project sustainability. Conform to the Messiah College environmental standards, using stickers and signs for hazardous materials, fire extinguishers, and safety gear requirements such as gloves and splash goggles. Write the second edition of the Messiah College Biodiesel Manual.
4) Develop a clientele of fuel consumers. Use produced biodiesel to fuel the team Volkswagen. Sell fuel to faculty clients and obtain data from Dr. Pratt's combustion analyzer.
5) Perform formal engineering analysis on the biodiesel processor. Statically analyze the load-bearing structure. Investigate the heating of oil and the power loss from the tank. Track the team budget and calculate the price of production.

1.5 Literature Review

The 2006-2007 biodiesel senior project team designed and built a small scale biodiesel conversion system. This system converts waste vegetable oil (WVO) to biodiesel and glycerin waste. This is a technology that has been done before and so we were able to learn from previous work. The processing unit for conversion of waste vegetable oil has many subsystems in the process, and there are variations for each system that we will analyze in the literature review. For this we will follow the form of the design section to cover the information we found and reviewed.

For the waste vegetable oil collection there is a variation in the biodiesel community from people collecting the WVO by using pumps, or pouring to collect the oil. The collection tanks can range in size from 30 gallons to 250 gallons. We have found that barrels sized 55 gallons and larger must be double lined if used for oil collection. This requirement came from Tim Hansen, former head chef of Lottie Nelson Dining Hall.

To establish the state of the art for the heating and mixing units of the processor, we will discuss designs that are currently used. The main variation is whether or not the system is a two step process or a one step process. Some designs pre-heat the oil and then move the oil into another tank for mixing. This is done sometimes to remove water from the WVO, and it also allows for a mixing tank without heating coils inside. The other possible method is for the heating and mixing systems to be combined into one. This combination takes up less space due to fewer tanks.

Other variation we found in our literature review was how to heat the WVO for the reaction. Some people use a hot water heater for the heating tank. Thus, they use electrical heating elements. Due to the work of previous projects; this is the course of action that we are using also. Though we are not using a hot water heater we are using electric heating elements. The other way to heat the WVO is to create a heat exchanger with copper tubing and water flowing through the tubing. This will heat the WVO to the temperature of the water. Thus if a system is created to heat the water in a controlled way then the WVO could also be heated in a controlled way. We have found this system to be used by Keystone Biofuels for their heating and mixing tanks.

Another variation we found in our research for the heating and mixing of the system is the mixing method. Two prominent mixing methods include mixing through a pump or mixing through the use of a stirrer. The use of a pump fits well into a closed system, helping to prevent fluids and vapors from escaping the tanks. The stir-mixing method can have variable mixing speeds and it can do a very good job at agitating the fluid. Our current design utilizes a pump to circulate and mix hot oil and converting biodiesel.

The final variation in design that we researched was that of biodiesel washing technique. The first alternative is to stir water into the fuel, and the other is to mist water through the biodiesel and bubble air up from the bottom to add turbulence. Both systems have the similar effect of mixing the water with the biodiesel to pull out contaminants. The advantage of misting is that it introduces little agitation. Thus, the water is less likely to emulsify with the biodiesel. The lighter agitation of the mister system is less likely to cause the water and the biodiesel to bond, but the contaminants in the biodiesel are still likely to dissolve into the wash water.

Dealing with glycerin and wash water side streams was the next problem that required research. There is not a clear cut answer on the solution for getting rid of the glycerin. Some people have proposed putting it into composting piles, putting it in the woods, throwing it out, and others have avoided the issue by just storing it up waiting for the demand for unrefined glycerin to increase. We found that Keystone Biofuels has a tractor trailer haul their waste glycerin away. This isn't a viable solution for us. We considered making soap out of waste glycerin, but soap-making requires that methanol is removed from the waste, which was not part of the scope of this year's senior project. However, the Collaboratory students have been working on a waste methanol recovery system, so soap-making is a possible option for a future project group. Creating a market for biodiesel byproduct soap may be a difficult undertaking, however. For now, waste glycerin is hauled away by Wes Bower, who charges the senior project to have it hauled away by waste management.

The next side stream we had to deal with was wash water. This waste is chiefly tap water, but also contains traces of glycerin and methanol. When interviewed by our team at the Life After Cheap Oil Conference, many people told us that they simply pour wash water down the drain. Our research of township requirements yielded two important conditions for wash water. There must be no more than 10 parts per 1000 of fatty substances, and the pH must be between 6.5 and 9. Typically the pH of our first wash batch is around 8.5-9. Although this lies within the township requirements, we typically neutralize the pH to just over 7, using vinegar. It is important to note that these requirements vary by location, according to local standards. The other issue we found in our research is that wash water BOD (biological oxidation demand) can be up to 12,000, while sewage water is closer to 5,000. This means that the water lacks oxygen and is likely to form anaerobic reactions, or slime.

Other research that our team gathered in our binder includes Material Safety Data Sheets (MSDS), Biodiesel Handling and Use Guidelines, articles from Penn Future on Biofuels, Messiah College's Hazardous Waste Disposal techniques, and handouts from the Life After Cheap Oil conference. At the conference we were given a quick overview of how biodiesel is made, from web sources including www.biodiesel.infopop.cc , www.biodieselcommunity.org , www.kitchen-biodiesel.com , www.biodiesel.coop , www.utahbiodieselsupply.com , www.b100supply.com , and www.biodiesel.org . We also collected notes that were written during Life After Cheap Oil lectures, a subcontractor's report of Biodiesel Production Technology taken from the National Renewable Energy Laboratory (NREL), information from Murray Nickel about the Congo, and finally a hard copy of the final report of last year's biodiesel senior project team.

From our research, we found that biodiesel kits are readily available on the internet at various websites. These kits vary significantly in size. The main components include a few tanks or drums and piping. Some kits have hand pumps and some have electrical pumps. Internet surfers can also readily find plans for a build-your-own system at http://www.journeytoforever.com and other web locations. Thus, there is not currently a great need for a 20-50 gallon system design in the greater biodiesel community. Our processor design was based more on inherited components and space constraints inside a trailer. We also found that there isn't a clearly agreed-upon method for production at this size. It is this open playing field that has given us liberty to design a system we feel to be a usable system in terms of operation and practicality.

1.6 Solution

The vision of our project is to add to the knowledge of the greater biodiesel community and to help people who are in need of fuel and economic means in developing nations. Much of this effort, however, did not fit within the scope of this year's work. We were more concerned with getting the movement started on campus. The simplest way to get started in biodiesel is probably to research and purchase a system on the internet. However, systems bought on the internet are expensive. Building our own system on campus lent itself easily to the use of inherited and or donated components. It is possible, in hindsight, that purchasing a system would have saved enough time that the price difference would not matter. However, our team ultimately had a limited budget restriction that would simply not allow the necessary expenditure of over $1,000 for a processor kit.

Another option for this year's project was to start producing biodiesel made from palm oil, as this is the feedstock of choice in the Democratic Republic of the Congo. However, Palm oil is expensive in the United States. Using palm oil for the initial phase of processor analysis and quality testing would not be very cost effective, and may not have fit in this year's budget. Waste vegetable oil, on the other hand, is readily available on campus. Our use of WVO even saves the Dining Services money, since they do not have to pay someone to haul it away as waste.

2 Design Process

The design of the '06-'07 25-50 gallon biodiesel system is an integration of the work of the Messiah College biodiesel senior projects of the past two years, with a size upgrade. The team from two years ago developed an automated system that fit in a trailer. However, a few problems in the automation remained unresolved when the students graduated. We have decided to forgo automation this year, because we want to make sure to have a working manual system before we add complication. Another flaw in the system from two years ago was that the heating tank leaked. Last year's team initiated an effort, with the help of the Dokimoi Ergatai biodiesel team, to combine the heating and mixing units into one tank. This will allow heating to take place during the chemical reaction, improving the efficiency of the conversion. When the team began working on the redesign of the tank they also increased its capacity. Since 55-gallon drums are readily available in many African countries, this year's team decided to redesign the trailer system to produce 25-50 gallon batches. This brings us to the point where we designed the current system. The system will be broken into components and addressed on the component level. A process diagram of the whole system can be seen in appendix 8.3.

2.1 Waste Vegetable Oil Collection tank.

The receptacle used to collect waste vegetable oil must be sturdy and rain-proof and it must include a system to filter out large solids before they reach the tank. These needs have driven the design of a 55 gallon drum that has been modified. It first was reduced in size to less then a 55 gallon drum so that proper regulations could be met. It has a screen mesh on the top of the tank that is concave. This allows the large particles to be filtered out of waste vegetable oil before it is added to the heating and mixing tank and it prevents splashing out and down of waste vegetable oil onto the sides of the barrel during filtering. Finally, we designed our tank with a plastic lid for the top, to water proof it when it is not being filled. Plastic will ensure sturdiness and a waterproof design.

2.2 Heating / Mixing Tank

The waste vegetable oil will move from the collection tank to the heating mixing tank by means of the major mixing pump. The heating-mixing tank consists of three heating elements (top and bottom ones are used) mounted to the side, near the bottom, which heat the waste vegetable oil to a temperature of 55°C. This will ultimately be moderated by a thermostat located near the heating elements. The sodium methoxide is then added, and the temperature is maintained at 55°C. In regards to the design of the tank, the conical part of the tank at the bottom has a clear viewing section which allows for the operator to see the distinct line between the glycerin section and the biodiesel section. The heating-mixing tank's conical bottom allows for the glycerin and the biodiesel to flow out of the tank easily without any residue fluid stuck in the barrel. We have decided to use a pump and plumbing to move the methoxide and waste vegetable oil through the tank, so it can mix thoroughly. With the mixing being done by the pump and the heating being done with our two heating elements we have completed designed a tank that will do both of these functions.

2.3 Methoxide Tank

The methoxide tank is the tank that mixes the methanol with the lye catalyst to create sodium methoxide. This tank must be fully closed (airtight), because methanol is very flammable and lye is quite toxic. We decided to pour methanol into the methoxide tank using a hose with male threads on both ends. The first end screws into a five-gallon methanol container, and the other end fits an adapter on top of the methoxide tank. This is how we will prevent significant methanol fumes from escaping into the trailer air. The tank is fitted with a pump that pushes sodium methoxide from the bottom to the top in an outside loop, to make sure that the sodium hydroxide is totally dissolved. The plumbing is designed so that methanol, lye and methoxide all enter the tank through the same hole. The pump loop is permanent, but there is a vertical branch where the methanol tube may be attached and lye may be added with a funnel. Once the methoxide is sufficiently mixed, it is rerouted into the heating and mixing plumbing system, using manual valves.

2.4 Washing Tank

The washing tank is the tank that cleans the residual impurities out of the processed biodiesel. We designed this washing tank to have a bubbling system and a misting system. The misting system is going to be made with 5 misting nozzles connected to a hose. They will add a fine mist of water to the top of the freshly-made biodiesel. This mist of water will fall through the biodiesel due to its greater density, and as it passes through it will attach to impurities, which will then settle to the bottom in a layer of dirty water. We designed the tank to have an aquarium bubbler at the bottom, which increases agitation, pulling more impurities out of the system per wash. The water is drained out of the conical tank through one valve at the bottom. This is designed to be run three to four times per batch to ensure that the product is clean.

Finally, after the cycles are done, the biodiesel is drained through the outlet with the filter before entering a storage container.

2.5 Five Micron Filter

The five micron filter is the final step in the biodiesel converter before it goes into the storage unit. This is to simply ensure that the biodiesel has no particles in it that remain from the waste vegetable oil. See the Biodiesel Manual for the filter specs. In appendix 8.4.

2.6 Plumbing/ Pumping

The design of the plumbing is the critical component that connects all of the stations of the system. The plumbing was upgraded from ½ in. piping to ¾ in. inner diameter piping for a few reasons. Since we increased the size of the processing units, we wanted to allow the fluid to be able to move from one tank to another in a reasonable amount of time. Also, with a larger pipe the biodiesel moves through with less resistance and with greater thermal energy, which is important in the winter months. One feature that we will also employ is piping that is slanted to a slight degree so that a drain valve at the bottom of the system can be utilized. This will allow for the system to be flushed after each use. The system requires two pumps. The major Mixing pump inputs the waste vegetable oil, circulates the waste vegetable oil with the methoxide and pumps the biodiesel to the wash tank. The minor or methoxide pump is required to circulate the sodium methoxide (Lye + Methanol) through the methoxide tank.

3 Implementation

3.1 Construction

Inside the trailer location where our system is located there is limited space to make it hard for many to work at the same time. If construction is to be done during the winter months there needs to is an appropriate temperature maintained inside the trailer to have people able to work and have all materials not in danger of freezing and/or breaking. All framework and supports of the trailer system were secured together and to the trailer. All support framework and chains holding the tanks in place were always secured when any liquid was in the tanks at any time. The assembly of the piping and tanks was completed and the final piping that was glued together had to be maintained at a minimum of 40 degrees Fahrenheit for it to harden. All tanks were tested and cured of leaks during construction and checked with the running of the system. Designated areas for the waste vegetable oil, lye, glycerin, wash water, and final biodiesel product were established near by the system.

Welding was completed in order for the heating/mixing tank to be sealed. Nibbler training was completed so that the waste oil barrel could be appropriately adjusted. Fire extinguisher training was completed in order for effective responses in time of any fire emergency. All tanks that had to be plasma-cut were cleaned prior to doing so in order to prevent fire. Long pants and covered toes were worn at all times when in the shop.

Some things we learned during the construction were that leaks seem to always happen. We did not find a magic bullet that would cure this issue but instead solved the issue with persistence and a fair amount of epoxy. One design change that we have thought of now is the fact that our viewing port has proved to have limited effectiveness. This is because there is little light that goes into the tank to illuminate the tank. This forces us to use the drain hose to determine when all of the glycerin is removed. Another lesson learned in the construction phase is that the heating tank loses a fair amount of heat through the sides of the tank. This forced us to add insulation to the heating tank to minimize heating times and to increase the overall efficiency of the heating tank.

During our construction phase, we completed engineering testing on the overall frame of the system as well as the heat loss. These both can be seen in appendix 8.6. In addition, when constructing and testing the methoxide tank we found that the initial design was flawed. We initially had designed the tank to have the lye drop in and then dissolve with the methanol through the mixing. What we found is that the lye would simply clump and not dissolve into solution. This forced us to add a screen at the bottom of the tank to catch the lye until it dissolved into solution where it could then go through the screen. This design change allowed for the proper mixing of our methoxide.

3.2 Operation

The operation of the biodiesel system is a very loaded word in regards to the biodiesel processing unit. This is because there are a very large number of processes that had to be made for the successful operation of a sustainable biodiesel processing unit. We had to write a procedure for all the steps in our process and they can all been seen in the Biodiesel Manual (appendices 8.4). These operations were laced with other factors, for instance, we had to take into account the safety precautions throughout the whole procedure. We also had to factor in environmental concerns and thus we turned to the aid of Wes Bower and Hillary Surak because they handle the waste management here at Messiah. Determining the proper procedure for dealing with the waste of the process was a large problem but through the aid of Hillary and Wes this was resolved.

Another operation issue that we had to deal with was the fact that we are working in the confined space of the trailer out back. We had limited space to work and operate. To elevate some of this clutter we ended up using a metal cabinet in the trailer to store some of the needed tools in the trailer. This also created a space for a counter in the trailer where we are able to have a workspace to use. Though this actually added more things to the trailer, it made better use of the space we had making the trailer more efficient, safer and overall more cleanly. One of the desires of this year was to streamline the process and this was accomplished partially because of the reorganization of the trailer.

By using the processes that are laid out in the initial paragraph of this section we were able to create almost 100 gallons of biodiesel in total this year. The biodiesel batch size for our first three was: 18, 24 and 30 gallons. The batch size was determined mostly by the amount of the available waste vegetable oil at the starting time of the process. With produced fuel we had to verify that this fuel was good. One thing that we had planned on using was the Gas Chromatograph in the chemistry lab. Upon initial testing of the gas chromatograph, we received inconclusive data. Second, we planned to use our fuel in Dr. Pratt's home heating system to proof that the fuel was sufficient in quality and composition. We had planned to do this with the combustion analyzer that is on his home heating system but the sensors were not working. The actual process of checking our biodiesel was completed at the end of the semester by: 1- Its effectiveness in both Dr. Pratt's home oil furnace and our Volkswagen rabbit diesel car, 2- We did a minimum of four Biodiesel quality tests including: Methanol, Water & Sediment, Cloud point, pH and will include Sulfate ash and Gas chromatograph tests next year.

4 Schedule

It is important for our group to employ careful project planning. Completion of our tasks on schedule will allow us to make the most of our time. Several methods to help our group manage time are as follows: DE work times, weekly meetings, Gantt chart, and advisor meeting report forms.

Our weekly DE work times and weekly meetings consist of a scheduled meetings with all DE biodiesel team members every Monday afternoon while we have addition senior project meeting time Monday night. Addition senior project meetings often occur during the week or on weekends as deemed necessary to address deadlines and completions of certain group or individual tasks.

The advisor meetings allow us to discuss details about our project with Prof. Erikson who offers his experience, direction, and official oversight to our project. In addition to the advisor meetings, our group has meet with Dr. Vader who works with us as a consultant to share his own experience, vision and communications about current issues dealing with our project. The advisor meeting report forms are basically a weekly spin-off of the Gantt chart. This part of the scheduling process helps us communicate with Prof. Erikson what tasks we have accomplished individually and as a whole since the last meeting. In addition, they help us assign tasks to individuals of the group for each upcoming week.

The Gantt chart (see Appendix 8.1 & 8.2) is another tool that helps us to have a clear look at how the project will be divided specifically throughout the year. The Gantt chart would have allowed us to focus on certain parts of the project, and stay with the schedule but due to unforeseen changes our Gantt chart was not used as day to day decision making was required. Reference to a well thought out Gantt chart did give us a clear view of what the important milestones for our project were.

5 Budget

Expenditures this year have been frequent and included many things. At the beginning of the year we were given $500 from the Messiah College Engineering Department as well as $250 from the Collaboratory, giving us a spending limit of $750. We were very close to this limit and just barely stayed under that limit, managing to spend a grand total of $743.30. Expenditures included such things as those which you can find below:

Expenditures	***Cost***
Plumbing (PVC Clear piping, Valves, joints…)	$131.70
110 Volt Diesel Fuel Pump (Major Pump)	$154.01
Additional Framework (Securing Chains...)	$20.58
Adhesives (Leak Control)	$11.71
Methanol	$25.60
Drum Lids	$59.80
Trailer Expenses (Lighting, Padlock, Cleaning supplies…)	$48.52
Ext Cord 12-3 100FT	$49.95
Miscellaneous Car Expenditures (Filters, Engine Oil…)	$89.82
Thermostat	$21.72
Red Diesel Gas Can	$15.99
Marineland AirMaster 2000	$14.99
Arizona Mister	$12.99
Washing Timer	$31.15
Tax & Shipping Total	$54.77
TOTAL	**$743.30**

These detailed list give all exact expenditures for the plumbing, car and all taxes & shipping costs of the project:

Plumbing

NS SH 40 Clear PVC 1/2in	$16.50
NS SH 40 Clear PVC 3/4in	$22.00
PVC BALL VALVE MIP SOC 3/4	$23.10
PVC BALL VALVE MIP SOC 1/2	$2.40
PVC S40 TEE 3/4 S	$1.52
PVC S40 BUSH 3/4 x 1/2 SPGXS	$0.28
PVC S40 90 3/4 S	$2.60
PVC S40 COUP 3/4 S	$0.63
PVC S40 45 3/4 S	$1.20
PVC S40 FE ADPT 2 S X T	$1.06
PVC S40 MIP ADPT 2 S X MT	$1.82
PVC S40 90 1/2 S	$0.72
PVC S40 FE ADPT 3/4 S X T	$0.34
PVC S40 BUSH 2 X 3/4 SPGXS	$0.24
PVC S80 BUSH 2 X 3/4 SPG X S	$9.00
PVC S40 COUP 3/4 S	$0.21
PVC S40 COUP 3/4 X 1/2 SPG X T	$0.39
PVC 2 X 1 inch pump adapter	$4.18
PVC 2 X 1 by 3/4 reducer	$1.04
2 PVC Ball Valve MIP SOC 3/4	$6.60
2 PVC S40 45 3/4 S	$1.20
PVC Conduit 3/4 Female Adpt	$0.23
PVC Conduit term adpt 3/4	$0.30

Miscellaneous Car Expenditures

Fuel Filter	$7.69
Air Filter	$7.45
Oil Filter	$4.79
Valveoline Premium Oil (2)	$22.53
Leak Sealant	$10.24
(screen)	$5.00
B-20	$10.00
B-20	$22.12
Total	$89.82

Tax

TAX	$1.24
TAX	$0.83
Tax	$0.95
TAX	$3.00
Tax	$0.72
Tax	$0.96
Tax	$4.21
Tax	$0.97
Tax	$1.32
Shipping Charge	$10.50
Pump Shipping	$15.00

TBNG Clear Vinyl 3/4ID 10D	$7.76
NS SH 40 Clear PVC Pipe 3/4"	$22.00
GT# / 4X3 / 4Male	$3.99
3PK 1/2"Conduit Locknut	$0.39
Total	$131.70

Shipping for Cover	$7.60
B100 supply LLC shipping	$7.47
Total	$54.77

The lists found on the previous page do not include any of the gifts required to build our system. Thus we came up with a simulated cost of our system. We did a rough estimate of the cost of all the items given to us in order to get an estimate on the cost to reproduce our system. All the highlighted items are gifts in kind and some sections such as Heating/Mixing Tank are shown in detail below the Cost of Our System chart.

Cost of Our System	*Price estimate*
Waste Vegetable Oil	free
55 Gallon Drum	$70.00
Methoxide Tank 15 gallon conical tank	$50.00
Heating/Mixing Tank	$146.00
Wash Tank (70 gallons) conical tank	$100.00
Frame	$50.00
March MDX3 Pump (minor pump)	$122.00
*Piping Cost Total	$110.59
Testing Equipment	$36.00
110 Volt Diesel Fuel Pump (major pump)	$154.01
Mister & Bubbler	$27.98
Buckets & Containers	$97.68
Blue Drum (Glycerin storage)	$40.00
Water Filter (GE Smart Water Household Filtration)	$40.00
Safety Equipment	$50.05
Shipping & Handling	$30.07
System Total:	$1,124

Heating/Mixing Tank	
Item	Price estimate
1 Heating Coil	$12.00
1 Heating Coil	$12.00
1 Heating Coil	$12.00
55 Gallon Drum	$70.00
Insulation	$20.00
Electrical Covers	$20.00
Total	$146.00

Buckets & Containers	
1 5 gallon plastic buckets (white) w/lid	$7.44

1 5 gallon plastic buckets (white)	$7.44
1 5 gallon plastic buckets (white)	$7.44
1 5 gallon plastic buckets (white)	$7.44
1 yellow plastic containers	$15
2 yellow plastic containers	$15
Red Crab Gas Can	$15.99
Sanitary Drum Cover Loose fit	$21.93
Total	$97.68

Safety Equipment		**Shipping & Handling**	
Safety (Glasses)	$1.10	Shipping for Cover	$7.60
Safety Gloves / box	$8.95	B100 supply LLC shipping	$7.47
Safety (Fire Hydrant)	$40.00	Pump Shipping	$15.00
Total	$50.05	**Total**	$30.07

There is a major difference between producing a full-scale product and a prototype. This difference may be found in the comparison between our project and the previous senior project done on Biodiesel. Our finished product is much larger than theirs. To give you an idea, the heating / mixing tank from last year has become our Methoxide tank. Now they spent much more money than we did, and this is because they spent lots of money in preparing test procedures, and practices for future use. Thus much of our saving grace for expenditures this year has come from last year's purchases. Here is the budget from last year's project:

Material	**Cost**
Methanol, Dried, 99.9%	$13.34
4.4 gal Methanol	$10.00
500 g Sodium Hydroxide	$23.28
30 lbs Sodium Hydroxide	$55.02
125 mL Erlenmeyer Flasks	$29.70
Four 500 mL Erlenmeyer Flasks	$17.15
Two 1000 mL Separator Funnels with Ring Stands	$227.56
30 gal Barrel for Oil Collection	$12.00
Three 30 Gallon Metal Trash Cans	$54.00
Sieve	$63.23
GC Column	$322.00
Standards Kit for GC	$356.00
Ferrules for GC	$30.50
MSTFA Reagant	$16.00
Common Supplies from Giant	$15.00
Total	$1,244.78

Components of great importance to us were the Flasks, Barrels for Oil Collection, and Sodium Hydroxide. The Sodium Hydroxide has been huge because we have not needed to go purchase any this year to produce our Biodiesel.

Lastly to give you an idea of what it would cost to make our Biodiesel, we did economic analysis to find out the cost of our Biodiesel per gallon. This price includes all process costs: Methanol, Lye, Electricity, and the cost to remove all of our Waste Glycerin. All this taken into account the price looks something like this:

Process Costs		**Amount for 25 gallons Biodiesel**	**Cost per Batch**
Waste Vegetable Oil	Free	32 gallons	$0.00
Methanol	$3.00 per gallon	7 gallons	$21.00
Lye (Sodium Hydroxide)	$1.83 per lb	2.2 lbs	$4.03
Glycerin Removal	$80 per 55 gal	7 gallons	$11.50
Labor	Voluntary	16 man hours	$0.00
Electricity	$0.07 per kW*h	5.6485 kW * h	$0.40
		Total Cost per Batch	**$36.92**

Price per gallon of Biodiesel
(= $36.92 / 25 gallons)
$1.48

6 Conclusions

The Biodiesel project this year had a goal of making biodiesel that was ASTM tested on a small scale level. We would deem our project a success on the grounds that we have generated multiple batches of fuel from our designed system that has been successfully utilized in our biodiesel car as well as home heating systems of faculty here at campus. The individual fact that we made around 100 gallons would be an accomplishment in itself with the constraints of all the processor issues. We also addressed the wash water and the glycerin side-streams that we had from the conversion process. The removal of these products were removed according to the guidelines established using environmental and safety concerns.

The other accomplishment that the team did was to continually refine the system to the point that we had removed many of the quirks from the system. By having a month to test the processing unit we were able to constantly refine it to the point of a working system. Also, we have trained the underclassmen that will be working on the system next year and we have determined that they are competent enough o continue the process and understand our justification for making the system the way we did. This we felt was crucial because it allowed them to have a working knowledge of the system which would allow them to move forward with other parts of the system and have a good understanding of the parts that were already there.

When looking at our five annual objectives for the year we did not completely meet all five of the objectives, but if not completed the objective was addressed as far as work allowed. The first objective was to design and build a working biodiesel processor. This was accomplished however we needed to change the objective during the year when we knew 500 gallons of biodiesel would not be a manageable goal. The objective was also adjusted to not include the alternative parameters to the system when we needed to focus on the designed inputs. With these designed inputs, we did make close to 80 gallons which certainly verifies our system as a viable system that is able to process quality biodiesel. The second objective to test our biodiesel was done but not every test was available with the time given. The gas chromatograph and sulfate ash tests were left out for future groups to complete. The third objective to address safety and & documentation was completed with the creation of the Biodiesel Manual section edition (see appendix 8.4). The fourth objective was to develop a clientele of fuel consumers and this was completed with the examples of Dr. Pratt's oil furnace and Jonathan Lauer with the first purchase of our Biodiesel. Our final objective was to perform formal engineering analysis of our system and the static, heat transfer and economic analysis was completed to solidify our biodiesel system.

7 Recommendations for Future Work

Our recommendations for future work are extensive. The first recommendation is do not tear apart the system we have. The system we have works and has been tested. When we came to the project, we did not use this discretion and we may have been able to make more progress if we had worked with the current system some. We are very happy with the current setup and the justification for the way that it is can be found in the biodiesel manual.

The second recommendation is to get comfortable with the procedures and making the biodiesel. The bulk of our learning was done once we started making biodiesel. Nothing forces you to learn quicker than an immediate problem with a real batch of biodiesel. The base that we have tried to lay this year entails; a working system, a testing method, a system to get the fuel to the trailer, a system to remove the side streams, a system to run the process and a system to stay safe. **Learn these aspects**

of our project! We learned a lot about the system and we hope that you will be able to utilize this knowledge. The Biodiesel Manual should address these issues well.

As for future work we have a few ideas.

1) Continue to make biodiesel through the year to use in the Rabbit, clients vehicles, and home heating systems. One hurdle that may need to be addressed for this is how people can cover the cost of making the fuel. Also, if full year production is to be accomplished, the trailer has to be warm during the cold weather
2) Buy a small diesel engine that could allow for extensive and prolonged testing of the affects of biodiesel on a diesel engine
3) Do long-term testing of the affect of biodiesel on rubber gaskets versus viton
4) Refine the methanol recover system and integrate it into the system
5) Reestablish touch with a client for an actual application of the project, Matt Walsh has an interest in biodiesel as does Murray Nickel of the Congo. Luke Witmer may have more contact from his trip to the Congo this coming summer
6) Try different feed stocks as well as potassium hydroxide versus sodium hydroxide to determine the affects of changes on the process and product.

8 Appendices

8.0 Appendices Index
8.1 Gantt Chart (Predicted)
8.2 Gantt Chart (Actual)
8.3 Process Diagram
8.4 Biodiesel Manual
Production Procedures…………………… 2
Testing Procedures……………………… 11
Safety Checklist for in trailer work……. 18
Design Justification …………………… 20
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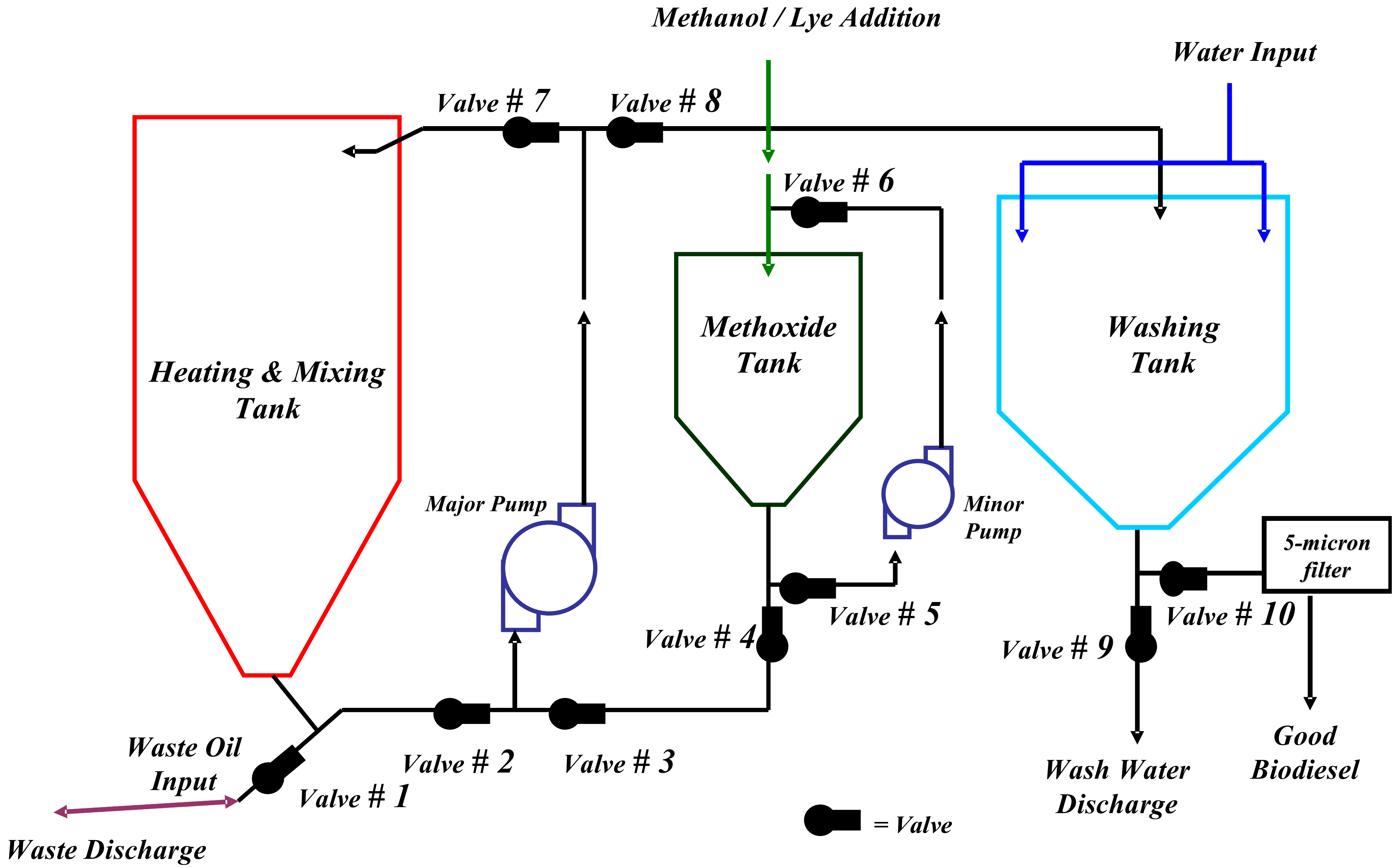
8.5 ASTM D6751
8.6 Engineering Analysis
Static
Heat Transfer
Economic (see Budget)
8.7 Acknowledgments

8.5 ASTM D6751

ASTM D 6751 – 02 Requirements

Property	Method	Limits	Units
Flash point, closed cup	D 93	130 min	°C
Water and sediment	D 2709	0.050 max	% volume
Kinematic viscosity, 40 ° C	D 445	1.9 – 6.0	mm^2/s
Sulfated ash	D 874	0.020 max	wt. %
Total Sulfur	D 5453	0.05 max	wt. %
Copper strip corrosion	D 130	No. 3 max	
Cetane number	D 613	47 min	
Cloud point	D 2500	Report to customer	°C
Carbon residue	D 4530	0.050 max	wt. %
Acid number	D 664	0.80 max	mg KOH/g
Free glycerin	D 6584	0.020	wt. %
Total glycerin	D 6584	0.240	wt. %
Phosphorus	D 4951	0.0010	wt. %
Vacuum distillation end point	D 1160	360 °C max, at 90% distilled	°C
Storage stability	To be determined	To be determined	To be determined

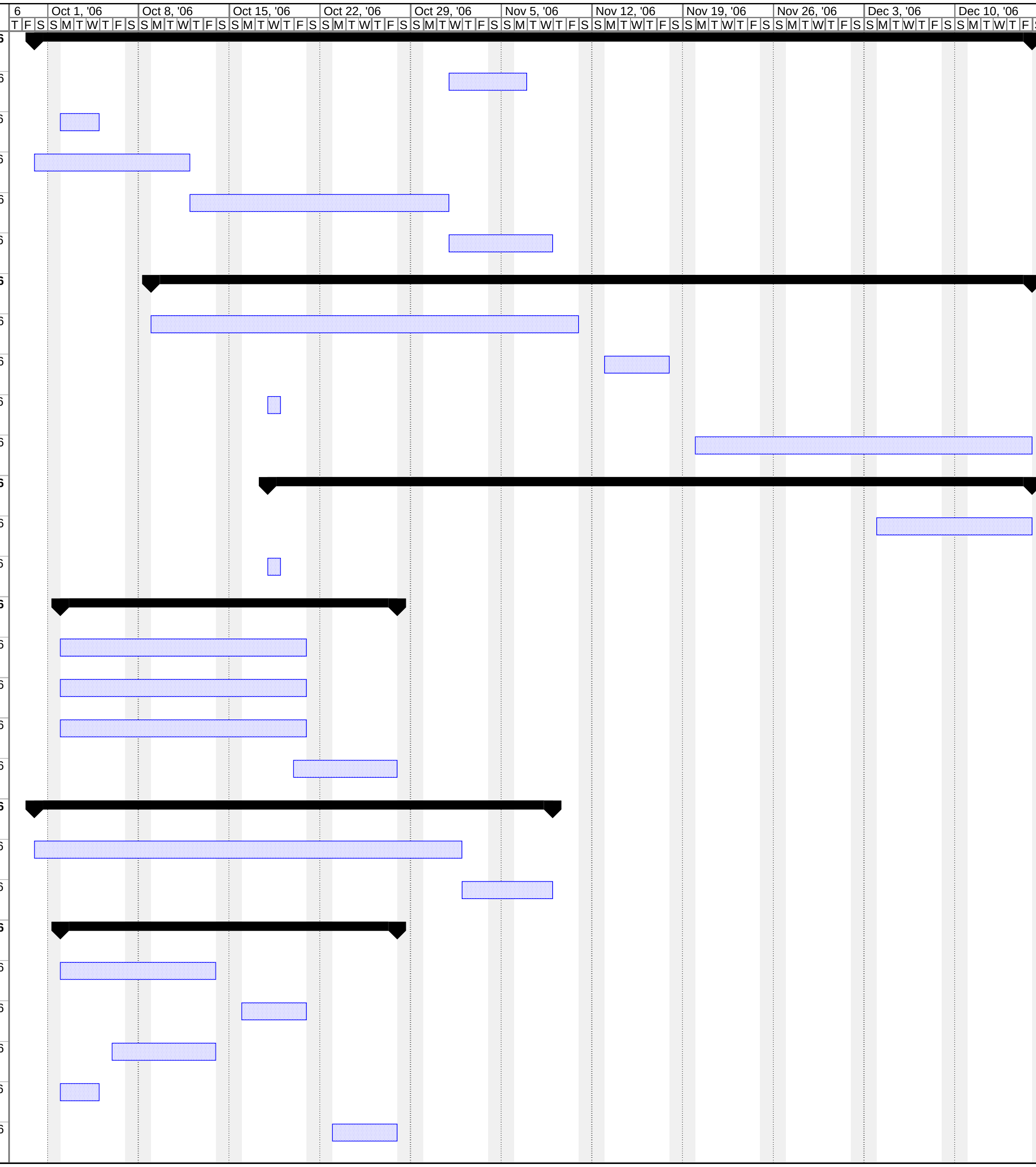
8.3 Process Diagram



8.7 Acknowledgments

- Carl Erikson--- Faculty Advisor
- Donald Pratt--- Senior Project Class Advisor & Home oil furnace client
- Robert Barrett--- Trailer Shelf Construction
- John Meyer--- Engineering Shop Supervisor & Safety Coordinator
- Jay Bennett--- Chemistry Advisor
- Jonathan Lauer--- Biodiesel Client
- Brad Markley & Dan Valencia--- Volkswagen rabbit & Gator supervisors
- Thomas Hanson & Percell Green--- Lottie Nelson contact for waste vegetable oil collection
- Hillary Surak & Wes Bower--- Messiah College Safety Overseers
- Lynda Blaine--- Frey Hall Second shift janitor
- Ken Brown--- Volkswagen rabbit donator
- Keystone Biofuels--- Local Biodiesel producer
- John A. Erikson--- Tour of Keystone Biofuels
- R. F. Fagers--- Construction supplies
- Collaboratory Team--- Construction, car maintenance & testing assistance

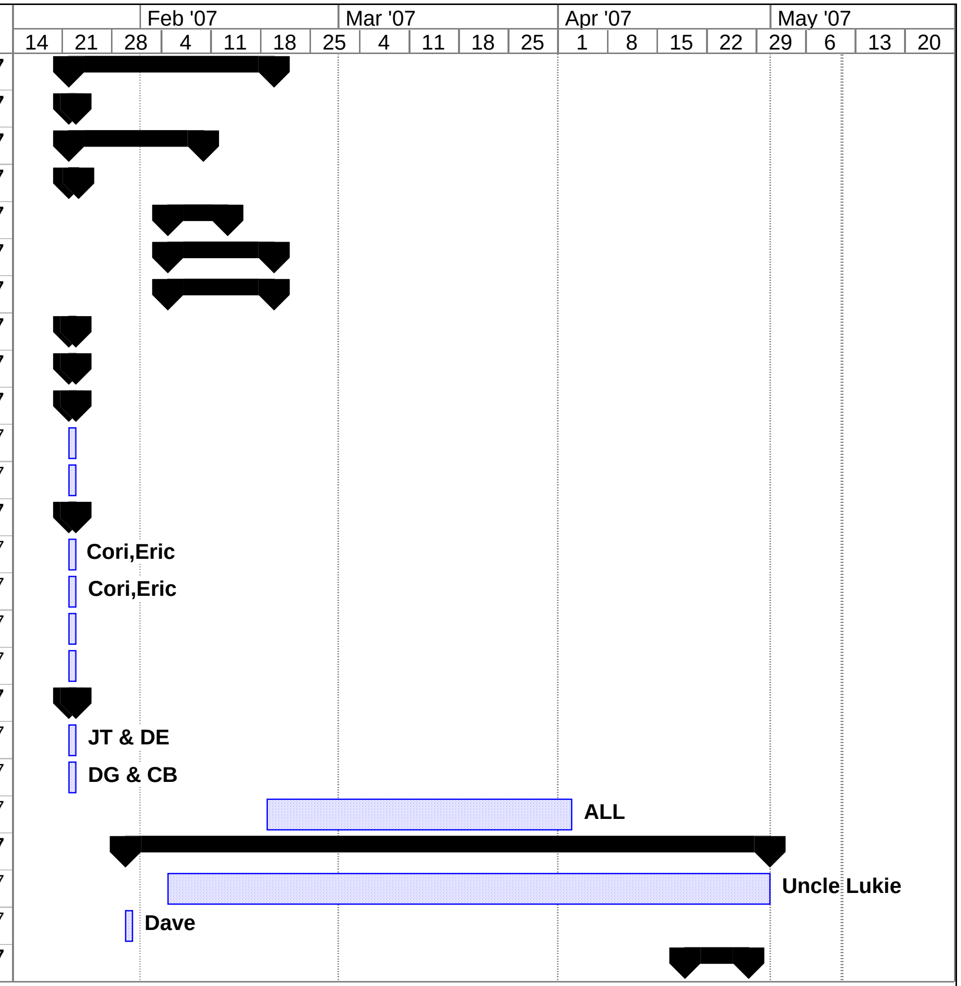
ID		Task Name	Duration	Start	Finish
1		**System Implimentation**	**56 days?**	**Sat 9/30/06**	**Fri 12/15/06**
2		build wash tank	4 days?	Wed 11/1/06	Mon 11/6/06
3		complete heating mixing tank	3 days?	Mon 10/2/06	Wed 10/4/06
4		dismantle old frame design new frame	9 days?	Sat 9/30/06	Wed 10/11/06
5		install frame and drums	14 days?	Thu 10/12/06	Tue 10/31/06
6		complete buiding	6 days?	Wed 11/1/06	Wed 11/8/06
7		**Begin Biodiesel Production**	**50 days?**	**Mon 10/9/06**	**Fri 12/15/06**
8		Collecting Feedstock	25 days?	Mon 10/9/06	Fri 11/10/06
9		Make 10 gal. sample batch	5 days?	Mon 11/13/06	Fri 11/17/06
10		Compare to ASTM	1 day?	Wed 10/18/06	Wed 10/18/06
11		Begin large scale production	20 days?	Mon 11/20/06	Fri 12/15/06
12		**Testing**	**43 days?**	**Wed 10/18/06**	**Fri 12/15/06**
13		Test gas mileage of rabbit with our bios	10 days?	Mon 12/4/06	Fri 12/15/06
14		Compare Biodiesel to ASTM	1 day?	Wed 10/18/06	Wed 10/18/06
15		**Develop Disposal Method/Use for Byproc**	**20 days?**	**Mon 10/2/06**	**Fri 10/27/06**
16		Research uses for byproductses for by	15 days?	Mon 10/2/06	Fri 10/20/06
17		Research disposal options	15 days?	Mon 10/2/06	Fri 10/20/06
18		Research disposal options	15 days?	Mon 10/2/06	Fri 10/20/06
19		Determine whether to dispose or use b	6 days?	Fri 10/20/06	Fri 10/27/06
20		**Safety**	**29 days?**	**Sat 9/30/06**	**Wed 11/8/06**
21		Research all safety needs	24 days?	Sat 9/30/06	Wed 11/1/06
22		Implement safety precautions	5 days?	Thu 11/2/06	Wed 11/8/06
23		**Methanol recovery tank**	**20 days?**	**Mon 10/2/06**	**Fri 10/27/06**
24		Research current methanol recovery	10 days?	Mon 10/2/06	Fri 10/13/06
25		Build methanol recovery	5 days?	Mon 10/16/06	Fri 10/20/06
26		Build methanol tank	6 days?	Fri 10/6/06	Fri 10/13/06
27		Buy filtration system	3 days?	Mon 10/2/06	Wed 10/4/06
28		Design system to fit the trailor and new	5 days?	Mon 10/23/06	Fri 10/27/06



Project: seniorprojectgant06
Date: Fri 5/11/07

Task | Progress | Summary | External Tasks | Deadline
Split | Milestone | Project Summary | External Milestone

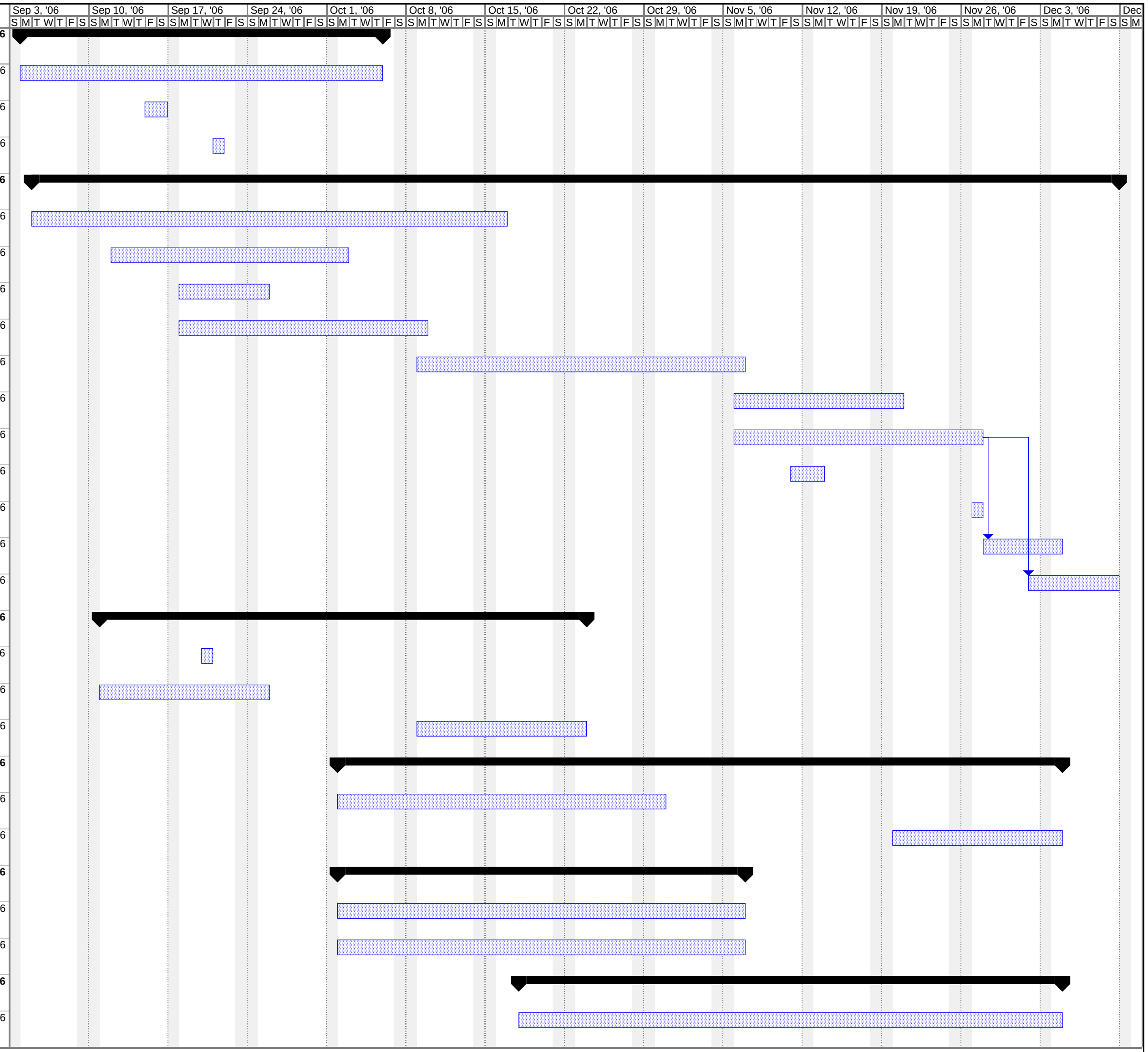
ID		Task Name	Duration	Start
1		**Pre-Operational**	**21 days?**	**Mon 1/22/07**
2		**Operational Procedure**	**1 day?**	**Mon 1/22/07**
5		**Seal Heating Mixing Tank**	**15 days?**	**Mon 1/22/07**
8		**Power Distribution**	**1.13 days?**	**Mon 1/22/07**
15		**Plumbing**	**6.33 days?**	**Mon 2/5/07**
22		**Glycerin Removal**	**11 days?**	**Mon 2/5/07**
27		**Methanol Supply**	**11 days?**	**Mon 2/5/07**
30		**Wash Water Removal**	**1 day?**	**Mon 1/22/07**
34		**Storage**	**1 day?**	**Mon 1/22/07**
39		**Budget**	**1 day?**	**Mon 1/22/07**
40		Collect all Reciepts	1 day?	Mon 1/22/07
41		Get reimbursements	1 day?	Mon 1/22/07
42		**Testing**	**1 day?**	**Mon 1/22/07**
43		Learn GC from Professor Schaeffer	1 day?	Mon 1/22/07
44		Execute GC batch 1	1 day?	Mon 1/22/07
45		In our Rabbit car	1 day?	Mon 1/22/07
46		Dr. Pratt's combustion testing machine	1 day?	Mon 1/22/07
47		**Engineering Analysis**	**1 day?**	**Mon 1/22/07**
48		Heat Transfer	1 day?	Mon 1/22/07
49		Static	1 day?	Mon 1/22/07
50		Production	31 days?	Mon 2/19/07
51		**The Democratic Republic of the Congo**	**65 days?**	**Tue 1/30/07**
52		Potential Trip Planning	61 days?	Mon 2/5/07
53		Find & contact Murray Nickel	1 day?	Tue 1/30/07
54		**Senior Project Presentation**	**7 days?**	**Thu 4/19/07**



Project: Biodiesel Gantt Chart Spring (
Date: Fri 5/11/07

Task	Milestone	External Tasks
Split	Summary	External Milestone
Progress	Project Summary	Deadline

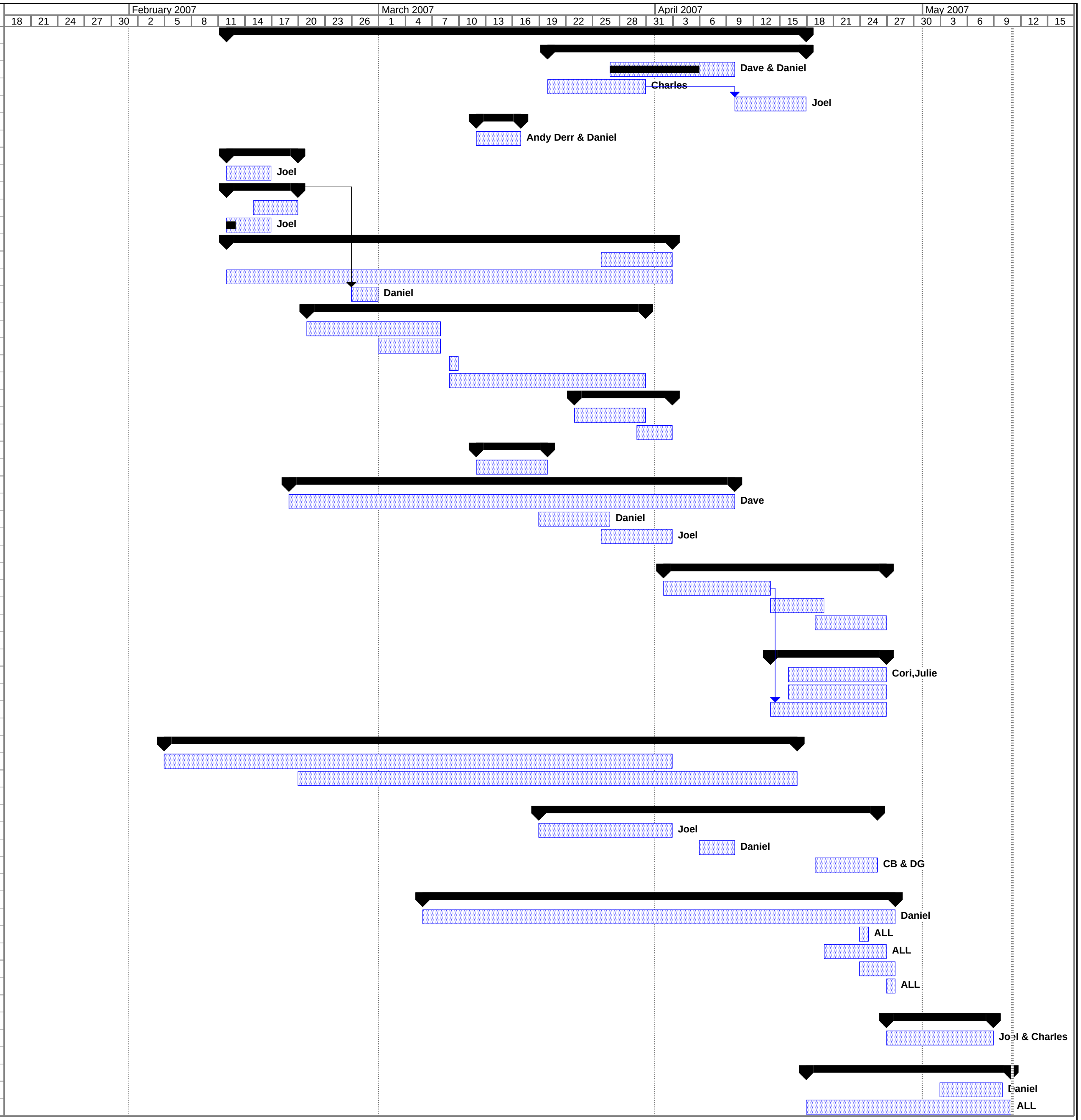
ID	Task Name	Duration	Start	Finish
1	**Biodiesel Research**	**26 days?**	**Mon 9/4/06**	**Thu 10/5/06**
2	Review found Biodiesel handbooks	26 days?	Mon 9/4/06	Thu 10/5/06
3	Biodiesel Conference	2 days?	Fri 9/15/06	Sat 9/16/06
4	Keystone Biofuels visit	1 day?	Thu 9/21/06	Thu 9/21/06
5	**System Implementation**	**74 days?**	**Tue 9/5/06**	**Sat 12/9/06**
6	Fix leaks in Heating / Mixing Tank	32 days?	Tue 9/5/06	Mon 10/16/06
7	Clean Trailer and old tanks, supplies	17 days?	Tue 9/12/06	Mon 10/2/06
8	Move unneeded supplies to Erikson's Farm	6 days?	Mon 9/18/06	Mon 9/25/06
9	Move and Adjust Frame to fix new tanks	17 days?	Mon 9/18/06	Mon 10/9/06
10	Installation of tanks and supports	21 days?	Mon 10/9/06	Mon 11/6/06
11	Install washing systems	12 days?	Mon 11/6/06	Mon 11/20/06
12	Purchase Needed plumbing and pumping products	17 days?	Mon 11/6/06	Mon 11/27/06
13	Remove old system electrical components	2 days?	Sat 11/11/06	Mon 11/13/06
14	Install Lights in Trailer	1 day?	Mon 11/27/06	Mon 11/27/06
15	Install pumps	6 days	Tue 11/28/06	Mon 12/4/06
16	Install all plumbing	7 days?	Sat 12/2/06	Sat 12/9/06
17	**Find contacts for final Biodiesel**	**33 days?**	**Mon 9/11/06**	**Mon 10/23/06**
18	Meeting with John Lauer- purchase	1 day?	Wed 9/20/06	Wed 9/20/06
19	Meet with Dr. Pratt- fuel testing	12 days?	Mon 9/11/06	Mon 9/25/06
20	Meet with Jat Bennett- safety & chemcial tests	11 days?	Mon 10/9/06	Mon 10/23/06
21	**Testing**	**48 days?**	**Mon 10/2/06**	**Mon 12/4/06**
22	Test gas mileage of rabbit with our biosdiesel	21 days?	Mon 10/2/06	Mon 10/30/06
23	Run test batch of Procedure with Lottie Waste oil	12 days?	Mon 11/20/06	Mon 12/4/06
24	**Research Disposal Method/Use for Byproducts**	**26 days?**	**Mon 10/2/06**	**Mon 11/6/06**
25	Research uses for by products for byproduct	26 days?	Mon 10/2/06	Mon 11/6/06
26	Research disposal options	26 days?	Mon 10/2/06	Mon 11/6/06
27	**Safety**	**36 days?**	**Wed 10/18/06**	**Mon 12/4/06**
28	Research all safety needs	36 days?	Wed 10/18/06	Mon 12/4/06



Project: seniorprojectgant06
Date: Fri 5/11/07

Task		Progress		Summary		External Tasks		Deadline
Split		Milestone		Project Summary		External Milestone		

ID		Task Name	Duration	Start	Finish
1		**Pre-Operational**	**49 days?**	**Mon 2/12/07**	**Tue 4/17/07**
2		**Operational Procedure**	**22 days?**	**Tue 3/20/07**	**Tue 4/17/07**
3		Write production procedure	10 days?	Tue 3/27/07	Mon 4/9/07
4		Write / find testing procedures	9 days?	Tue 3/20/07	Fri 3/30/07
5		Fill in procedure gaps	7 days?	Tue 4/10/07	Tue 4/17/07
6		**Seal Heating Mixing Tank**	**5 days?**	**Mon 3/12/07**	**Fri 3/16/07**
7		Sealing lid for Heating Mixing Tank	5 days?	Mon 3/12/07	Fri 3/16/07
8		**Power Distribution**	**7 days?**	**Mon 2/12/07**	**Mon 2/19/07**
9		Arrange Cord to supply, (Air Bubbler, Pump 1, pu	5 days?	Mon 2/12/07	Fri 2/16/07
10		**Temperature Control**	**7 days?**	**Mon 2/12/07**	**Mon 2/19/07**
11		Attach temperature relay to tank.	4 days?	Thu 2/15/07	Mon 2/19/07
12		Wire up power input to relay	5 days?	Mon 2/12/07	Fri 2/16/07
13		**Plumbing**	**37 days?**	**Mon 2/12/07**	**Mon 4/2/07**
14		Design WVO input with stopper	6 days?	Mon 3/26/07	Mon 4/2/07
15		Fix Leaks	37 days?	Mon 2/12/07	Mon 4/2/07
16		Water-test the Heating / Mixing Tank only	3 days	Mon 2/26/07	Wed 2/28/07
17		**Glycerin Removal**	**28 days?**	**Wed 2/21/07**	**Fri 3/30/07**
18		Write glycerin removal procedure	11 days?	Wed 2/21/07	Wed 3/7/07
19		Get hose for glycerin removal and two five gallon	5 days?	Thu 3/1/07	Wed 3/7/07
20		Contact Jay Bennett, Hillary, and Wes Bower to a	1 day?	Fri 3/9/07	Fri 3/9/07
21		Verify Glycerin with Hillary	16 days?	Fri 3/9/07	Fri 3/30/07
22		**Methanol Supply**	**7 days?**	**Fri 3/23/07**	**Mon 4/2/07**
23		Find Methanol Supplier	6 days?	Fri 3/23/07	Fri 3/30/07
24		Buy Two 5 gallon Methanol tanks.	2 days	Fri 3/30/07	Mon 4/2/07
25		**Wash Water Removal**	**6 days?**	**Mon 3/12/07**	**Mon 3/19/07**
26		Learn process to check composition of Wash wat	6 days?	Mon 3/12/07	Mon 3/19/07
27		**Storage**	**36 days?**	**Mon 2/19/07**	**Mon 4/9/07**
28		Label chemicals in trailer	36 days?	Mon 2/19/07	Mon 4/9/07
29		Acquire trailer cabinet with John Meyer's help	6 days?	Mon 3/19/07	Mon 3/26/07
30		Assemble shelves in trailer	6 days?	Mon 3/26/07	Mon 4/2/07
31					
32		**Production**	**20 days?**	**Mon 4/2/07**	**Thu 4/26/07**
33		Batch 1	10 days?	Mon 4/2/07	Fri 4/13/07
34		Batch 2	5 days?	Sat 4/14/07	Thu 4/19/07
35		Batch 3	6 days?	Thu 4/19/07	Thu 4/26/07
36					
37		**Testing**	**10 days?**	**Sat 4/14/07**	**Thu 4/26/07**
38		Run quality testing procedures	9 days?	Mon 4/16/07	Thu 4/26/07
39		In our Rabbit car	9 days?	Mon 4/16/07	Thu 4/26/07
40		Dr. Pratt's combustion testing machine	10 days?	Sat 4/14/07	Thu 4/26/07
41					
42		**Budget**	**53 days?**	**Mon 2/5/07**	**Mon 4/16/07**
43		Collect all Receipts	42 days?	Mon 2/5/07	Mon 4/2/07
44		Get reimbursements	41 days?	Tue 2/20/07	Mon 4/16/07
45					
46		**System Engineering Analysis**	**29 days?**	**Mon 3/19/07**	**Wed 4/25/07**
47		Heat Transfer	11 days	Mon 3/19/07	Mon 4/2/07
48		Static	2 days	Fri 4/6/07	Mon 4/9/07
49		Economic	5 days?	Thu 4/19/07	Wed 4/25/07
50					
51		**Senior Project Presentation**	**40 days?**	**Tue 3/6/07**	**Fri 4/27/07**
52		Create Senior Project PowerPoint	40 days?	Tue 3/6/07	Fri 4/27/07
53		Present to IPC	1 day?	Tue 4/24/07	Tue 4/24/07
54		Practice presentation together	5 days?	Fri 4/20/07	Thu 4/26/07
55		Clean trailer and move	4 days?	Tue 4/24/07	Fri 4/27/07
56		Present at MEB day	1 day	Fri 4/27/07	Fri 4/27/07
57					
58		**Distribution of Biodiesel**	**8 days?**	**Fri 4/27/07**	**Tue 5/8/07**
59		Sell Biodiesel Product to Jonathan Lauer	8 days?	Fri 4/27/07	Tue 5/8/07
60					
61		**Complete Final Design Report**	**17 days?**	**Wed 4/18/07**	**Thu 5/10/07**
62		Compile Biodiesel Manual	5 days?	Thu 5/3/07	Wed 5/9/07
63		Compile FDR	17 days?	Wed 4/18/07	Thu 5/10/07



Project: Biodiesel Gantt Chart Spring 0
Date: Fri 5/11/07

Task		Progress		Summary		External Tasks		Deadline	
Split		Milestone		Project Summary		External Milestone			

Biodiesel Manual

Section Edition

06-07 Senior Project

Charles Brenner, David Enders, Daniel Geeslin, Joel Travis

Production Procedures ………………… 2-10

Testing Procedures ………………………. 11-17

Safety Checklist for in trailer work ……. 18-19

Design Justifications ……………………… 20-26

Contact List ………………………… 27

Biodiesel Production Procedures

06-07 Senior Project

1. **Waste Vegetable Oil Collection**
2. **Titration**
3. **Methoxide Mixing**
4. **Heating & Mixing**
5. **Washing**
6. **Glycerin removal**
7. **Wash Water removal**
8. **Storage & Distribution of Biodiesel**

Notes:

1. Ball valves are Open when parallel with pipe and Closed when perpendicular to pipe
2. All three trailer doors must be open and loading area fire extinguishers must be readily accessible.

1. Waste Vegetable Oil Collection

a. Contact with Percell Green (Head Chief) should be maintained that oil is being poured into our red drum prior to out collection time: pgreen@messiah.edu

i. Note: oil receptacle was reduced by 2in to less than 55 gallons to avoid double-walled rule. Lottie workers should pour oil through the screen lid.

b. Leave oil barrel on wooden flat and borrow hand truck from Lottie Nelson dining hall loading dock. Notify Russ you are using it. (first desk on right upon entering back door of Lottie Nelson dining hall)

c. With the hand truck, tie down the oil barrel to flat and use two to three people to move the hand truck with oil to the Biodiesel trailer behind Frey.

d. Move Biodiesel rabbit vehicle away from trailer to allow for hand truck to be parked on the far side of the trailer compared to Frey Hall.

e. Install the rubber plug to the Heating / Mixing tank

f. Make sure Valve # 3 and Valve # 8 are closed

g. Attach flexible piping to nozzle outside of Valve #1 and on the other end attach the screen with both ends fastened with hose clamps

h. Use gallon stick to measure the initial volume of WVO in barrel

i. Record the number of gallons in the batch in the file ..\Collected Test Data\Batch Data.xls, Open a new tab and record the data into that tab.

i. Open Valves # 1, 2 & 7 and turn on the Major pump for flow of WVO into Heating & Mixing tank.

j. Turn off pump when desired volume of WVO is out of oil barrel- use gallon stick

k. Return hand truck and oil barrel to behind Lottie Nelson dining hall and make sure the oil barrel remains on wooden flat

2. Titration

Goggles and gloves are required for this procedure & whenever handling chemicals

a. Take sample of Waste Vegetable Oil from the WVO as it is drawn into the H /M tank

b. Completely dissolve 1g NaOH in one liter of distilled water (This solution can be used for many titrations). Store it in hazard-labeled bottle in shelving.

c. Mix 10mL of isopropyl alcohol in a small container with 1mL of a sample of Waste Vegetable Oil. (Be exact with these measurements)

d. Add two drops of phenolphthalein.

e. Using an oral syringe drop 0.1mL at a time of the NaOh/water solution into the WVO/isopropyl solution. (A different oral syringe must be used with each liquid to prevent contamination.)

f. Follow each drop with vigorous stirring of the solution. If the solution remains pink for 30 seconds, an endpoint has been reached. (If using a pH meter, it is equivalent to a pH of 8.5)

g. Calculate the required lye input for the biodiesel reaction using the equation:

h. Record the Titration # and the base number of lye used for each batch in the Batch Data file at: ..\Collected Test Data\Batch Data.xls

i. Open a new tab in the file to enter the data in.

ii. If a computer isn't available enter the data into a log book and then add the numbers to the Batch Data file later.

(5 + # *mL solution added*) = (# *grams NaOH added per Liter WVO*)

3. Methoxide Mixing

Splash goggles and gloves are required for this procedure & whenever handling chemicals

a. Measure out necessary amount of Lye:

i. This is done by using the number of (5 + titration number) grams/ liter of waste vegetable oil.

b. Check to see that the proper amount of Methanol is on hand.

i. This is 22% of the waste vegetable oil available. This should be bought at the Exxon in Mechanicsburg the day of use, it is a safety hazard to store methanol in the trailer

c. Place 95 micron filter at the bottom of the Methoxide tank

d. Pour enough Lye onto the filter to cover the filter (approx. 300 grams)

e. Remove the wooden plug from the methoxide tank. Screw the extendable attachment hose to the methanol container, and then push the other end into the methoxide tank opening. Pour approx. 4 gallons into the tank.

f. Replace the methanol attachment with the wooden stopper.

g. Open valve # 5 and # 6 and turn on the minor / methoxide pump briefly to fill the plumbing above with methanol.

h. Valve 4 should still be shut. Valve 5 and valve 6 should still be open. Do the following quickly and be sure to wear gloves and eye protection

i. Remove the wooden stopper from the top of the methanol tank and replace it with a funnel.

j. Pour more lye through the funnel in the top of the tank. Immediately remove the funnel and replace it with the wooden stopper.

k. Quickly turn on the Methoxide / minor pump. (Delaying this step may allow lye to sink into places where it will mix poorly.)

l. If not all the lye is added, repeat steps h – k again until all the lye is added to the Methoxide tank

m. Keep the Methoxide / minor pump for a long time to mix. Watch the clear piping for evidence of mixture. Once the methoxide is finished mixing, (all lye has dissolved into the methanol) you can close valves # 5 & #6 and turn off the pump.

4. <u>Heating & Mixing</u>

a. The heating elements and both pumps are plugged into a power strip attached to the angle iron frame. Make sure these three items are plugged in. To activate the heating elements, flip the switch to "Reset".

i. The oil needs to be heated to 14o degrees Fahrenheit and not exceed 150 deg Fahrenheit.

b. Take temperature measurements as often as practical. It may be a good idea to circulate the oil, using the pump, for 5 minutes every hour. To do this:

i. Close valves # 3 & # 7 and open valve # 2 & # 7, and then turn on the major pump

c. Once the system is ready for the mixing stage (140 F), remove the wooden stopper from the top of the methoxide tank.

d. Make sure Valve # 5, # 6 & # 7 are open while Valve # 8 remains closed

e. Open valve # 4. *It is best to avoid getting waste vegetable oil in the methoxide loop area. The following must be done carefully and quickly*.

f. **Open Valve # 3, turn on the pump, and open Valve # 2**. Balance must be maintained between the pressure heads of oil and methoxide and the pump. If the head of oil mix pushes past valve 3 then reduce the clearance through valve 2.

g. The thermostat mounted to the outside of the heating tank is set to 150 deg.

h. Allow the pump to circulate / mix the heated oil and methoxide mix for a minimum of 5 minutes

i. There will be a point where the only thing going through the pump is glycerin; this is because the glycerin is denser than the biodiesel.

j. Stop the process and drain off the glycerin that has formed already and then return to mixing to guarantee that full mixing has occurred.

k. Settling Time required: 12 hours should be allotted for settling, If left overnight keep trailer locked and make sure upper ventilation is open

5. Glycerin Removal

a. Make sure batch has had proper amount of settling time; minimum 12-18 hours

b. Use flexible piping to attach the nozzle outside of Valve #1 and fasten with hose clamp

c. Have 5 gallon barrel ready to fill with flexible piping

d. Make sure Valve # 2 is closed

e. Open Valve # 1 and empty all glycerin (dark stuff) from the Heating & Mixing tank into the five-gallon bucket. For some instances the bucket may fill and this may need to be done twice (repeat c-e if needed)

f. Take the glycerin and pour it into the tank marked glycerin waste in the trailer.

g. Seal the glycerin tank to prevent exposure to the glycerin.

h. Once the Glycerin tank is full contact Wes Bower (wbower@messiah.edu or x3561) to get a replacement barrel for the extra glycerin.

6. Washing

a. Make sure Valve # 3, 7, 9 & 10 are closed

b. Open Valves # 1, 2 and 8

c. Turn on Major pump and allow the Biodiesel to be pump from the Heating & Mixing Tank and into the Washing Tank

d. Get the Hose wrench from John Meyer, the hose from the Green Shed, and attach the hose to the hose outlet near the garage door.

e. Attach the other end to the hose timer and then into the sprinkler attachment.

f. Set the mechanical hose timer to the appropriate time for filling

   i. The mister has an approximate flow rate of 7 gallons per minute for set the timer according to that flow rate.

g. Turn on water and allow for water to be added to the Washing tank in the amount of 1/3 the volume of the present Biodiesel

h. Turn on the bubbler and keep the bubbler running for at least 5 hours after all the water has been added (the bubbler and the mister can run at the same time.)

i. Return to the trailer at the time that the misting should end to make sure that the hose has turned off. (this is a double precaution but the liability of the shut off failing is great so this is a necessity)

j. After the bubbler has been turned off let the Biodiesel & water settle for approximately 8 hours.

k. After removing the wash water (see below) repeat steps d thru i for two more washes.

   i. There are multiple ways to wash the Biodiesel, a discussion on this topic can be found here.

l. Total allotted time for a complete wash is 39 hours. If scheduling is done well this will take 1 day and 15 hours.

7. Wash Water Removal

Note: This procedure allows Messiah College's Biodiesel team to comply with the Upper Allen Township sanitary disposal regulations 14.7

a. Make sure Valve # 10 is closed and open Valve # 9 to drain wash water into the 5-gallon bucket specified for wash water.

b. Measure the pH of the wash water.

  i. The wash water must have a pH in the range of 6.5 – 9.0

c. Equalize the water by adding vinegar in ½ -cup increments until the 5-gallon bucket is equalized to a pH reading between 6.5 and 9.0.

d. Skim the fat layer off of the wash water to measure the mass of the fat. Compare this mass of fat to the volume of the water.**

  i. The allowable amount of fats in the water is 10 mg/l
  ii. If this value is higher, the water should be flushed with more water as it is put down the drain.

e. After both equalizing the pH and measuring the fat content: Pour the water down the drain and flush if needed.

f. There may be a layer between the Biodiesel and the wash water that is yellow and milky. This is emulsion and can be dealt with in a few ways.

  i. Refer to the following link for more information.

  ii. This hasn't been totally addressed by the current group but adding hat water to the system can break the emulsion and time can too. If another tank is added to the system this can be done simultaneously with another wash.

Reasoning why the other regulation in the code does not affect the wash water is in the above link.

**Step 4 should be done for the first wash until a standard level of fat is established in the wash. Once it can be determined, that the fat content is below 10ml/L of water then the wash water can be put down the drain

8. Storage & Distribution of Biodiesel

Storage

a. Put the hose leaving the five micron filter into one of the 15 gallon barrels for filtered finished Biodiesel.

b. Once the wash water and emulsification has been drained off; close valve 9 and then open valve 10.

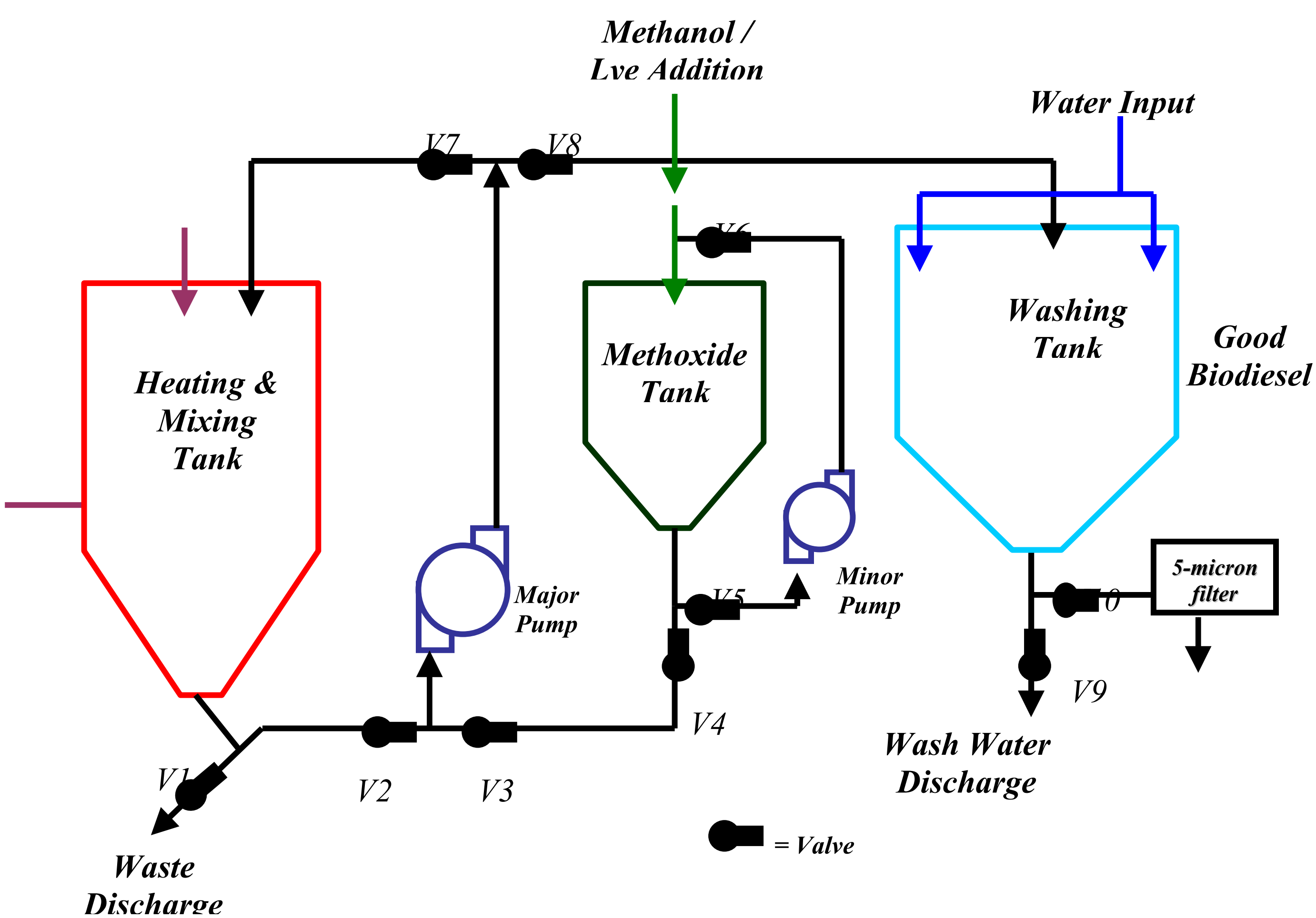
c. The finished biodiesel will go through the filter and into the tank.

d. Record the final amount of Biodiesel in the Batch Data File.

Distribution

*****Distribution of a batch cannot occur until the necessary quality tests have been done on the batch.**

a. Twist the hose onto the 15 gallon tank and pour into 5 gallon jug or into car tank for distribution.



Biodiesel Quality Testing Procedures

06-07 Senior Project

9. **Gas Chromatograph Test**
10. **The Methanol Test (27/3 Test)**
11. **Water and Sediment Testing**
12. **Sulfate Ash Testing**
13. **Cloud Point and Gel Point Test**
14. **pH Test**

Notes:

3. All test data should be recorded in the file Batch Data~.xls which can be found in the Biodiesel folder under collected test data. If you don't have access to this collect the data in a log book and add it to the file later.
4. Splash goggles should be worn for the tests that use toxic materials
5. A compilation of standard tests are at:
   - http://www.b100supply.com/index.cfm?fuseaction=feature.display&feature_id=115

9. Gas Chromatograph Test—Check in library on this.

After searching for the ASTM standard in the library I discovered the library did not have the right volume I needed for standard D6584. The only standard they in Section 5 was Volume 5 of 2004. They also had volumes 1,2,3 and 5 of 1985. We are interested in Vol. 1-5 of Section 5. All of Section 5 has been ordered through Mike Brown of the library.

After doing some research I have discovered some things about testing the total and free glycerol in biodiesel. There are three different analytical methods that can be used for this. They include: chromatographic methods, spectroscopic methods, and physical-property-based methods. Chromatographic and spectroscopic methods can be combined to give what is often termed hyphenated methods.

Chromatographic Methods:

This method is used to separate a mixture of compounds based on their physical properties. The two major methods of this are the gas chromatography (GC) and the liquid chromatography (LC).

To carry out a GS analysis, the sample is usually dissolved in low concentrations in an organic solvent and then injected into the gas chromatograph (the column Dr. Vader described). In the case for biodiesel, the sample needs to be derivatized with a silylating reagent. This is because glycerol and the mono- and diacylglycerols contain free hydroxyl groups which cause them not to perform well in GC. Derivatization improves the performance significantly.

GC forms the basis for ASTM D6584, but I have do not have access to this standard yet. The GC determines the amount of glycerol, mono- and di- and tricylglycerols, and methyl esters in a biodiesel sample. Details on the preparation of the samples and conducting the GC runs are given in the standard.

The LC separates a mixture based on the solubility of its components in a solvent while passing the mixture through a column. LC can be as suitable as GC for determining the contaminants in biodiesel relative to the total amount of methyl esters. The free glycerol can be detected in fatty methyl esters by AOCS (American Oil Chemists' Society) Recommended Practice Ca 14b-96 entitled "Quantification of Free Glycerin in Selected Glycerides and Fatty Acid Methyl Esters by HPLC with Laser Light-Scattering Detection." However, this method is not included in ASTM D6751 (biodiesel). So it could not be used to pass the ASTM standard, but would be ok for our application.

Spectroscopic methods:
Spectroscopic methods are another way we could obtain our result. Spectroscopic methods analyze the intake sample at the same time and the "pure" compounds obtain a unique spectra. This method is not nearly as helpful as chromatographic methods, but is helpful alongside of it giving more detailed information about the product. Stand-alone spectroscopic methods that have been used for biodiesel include nuclear magnetic resonance and near-infrared spectroscopy. In both cases, certain peaks characteristic for triacylglycerols and methyl esters in the spectra indicate how far the conversion has progressed.
After doing research I have found that GC would be our first choice of option, followed by LC. If they aren't available maybe we could try a spectroscopic method. I hope this information helps.

- **Run Gas Chromatograph test if possible.**

10. The Methanol Test (27/3 Test)

Goggles and gloves are required for this procedure & whenever handling chemicals

The purpose of this test is to test for the conversion of the Biodiesel.

Conversion test attributed to Jan Warnqvist (Biodiesel limit – no liquid precipitant)

Scope – This is a quick Pass/Fail conversion test for your Biodiesel and works because Biodiesel will dissolve into methanol while triglycerides do not dissolve in methanol.
It works with washed and dried, or unwashed Biodiesel that is well settled.

Summary of Test Method – A 3 mL sample of Biodiesel is dissolved into 27 mL of methanol to check for conversion of all di and tri glycerides.

Apparatus – Tools needed include 100 mL graduated cylinder for measuring 27 mL of Methanol, 10mL syringe for Biodiesel, and a 125 mL beaker for mixing.

Sampling – This test only needs to be done once per batch.

Procedure – The general steps required to complete this test are:

a. In a 125 mL beaker add 3 mL of Biodiesel and 27 mL of methanol.
b. Swish the beaker until the Biodiesel dissolves into the methanol
c. There should be no Biodiesel left, Triglycerides and Diglycerides will form a precipitant on the bottom. Only a liquid precipitant that collects together to form a bead or bubble that rolls around on the bottom of the test is significant. If you have a liquid precipitant then your Biodiesel is under converted.

Report – Report whether the Biodiesel passed this test or whether it failed do to having to much precipitate.

27/3 Test Online

11. Water and Sediment Testing

ASTM D 2709 Standard Test Method for Water and Sediment in Middle Distillate Fuels by Centrifuge (Biodiesel limit – 0.05 volume %)

Scope – This test method covers the determination of the volume of free water and sediment in middle distillate fuels having viscosities at 40°C in the range of 1.0 to 4.1 mm2/s and densities in the range of 770 to 900 kg/m3. This test is a measure of cleanliness of the fuel. For B100 biodiesel it is particularly important because water can react with the esters to make free fatty acids and can support microbial growth in storage tanks.

Summary of Test Method – A 100 mL sample of undiluted fuel is centrifuged in a tube readable to 0.005 mL. After centrifugation, the volume of water and sediment which has settled into the tip of the centrifuge tube is read to the nearest 0.005 mL and recorded as the volumetric percent water and sediment by centrifuge.

Apparatus – Centrifuge which can be controlled to give a relative centrifugal force (rcf) of 800±60 at the tip of the tubes.

Sampling - It is recommended to follow the sampling instructions in ASTM Standard Practice D4057. The sample for a laboratory test will normally be an aliquot of a much larger sample taken for full or partial specification testing.

Procedure – The general steps required to complete this test are:

a. 100 mL of a well-shaken sample is poured into a centrifuge tube and spun at 800±60 rcf for 10 minutes.

b. The volume of combined water and sediment present at the bottom of the tube is recorded to the nearest 0.005 mL.

Report – Report the volume of the combined water and sediment read from the tube as a percentage of the total sample, since 100 mL of sample was used. Results lower than 0.005% may be reported as either 0 or 0.005 volume%.

12. Sulfate Ash Testing

ASTM D 874 Standard Test Method for Sulfated Ash from Lubricating Oils and Additives (Biodiesel limit – 0.02 mass %)

Scope – This test method determines the amount of mineral ash remaining after a fuel is burned. For biodiesel, this test is an important indicator of the quantity of residual metals in the fuel that could come from the catalyst used in the esterification process. The lower limit of this test is 0.005 mass% sulfated ash.

Terminology – Sulfated ash is the residue remaining after the sample has been carbonized, and the residue subsequently treated with sulfuric acid and heated to constant weight.

Summary of the Test Method – The sample is ignited and burned until only ash and carbon remain. After cooling, the residue is treated with sulfuric acid and heated at 775°C until oxidation of carbon is complete. The ash is then cooled, re-treated with the sulfuric acid, and heated at 775°C to constant weight.

Apparatus – Necessary for the test method are a furnace capable of maintaining 775±25°C and evaporating dishes or crucibles. A 50 or 100 mL crucible is recommended for samples containing more than 0.02 mass% sulfated ash. A 120 or 150 mL crucible is recommended for samples containing less than 0.02 mass% sulfated ash.

Reagents – Required reagents include concentrated sulfuric acid and 50 volume% sulfuric acid in water. Isopropanol and toluene may be needed if the sample contains sufficient moisture to cause foaming and loss of material from the dish/crucible.

Sampling – It is recommended to follow the instructions in ASTM Standard Practice D4057.

Procedure – The general steps required to complete this test are:

a. • Prepare the sample dish by heating at 775 C for at least 10 min, cooling, and weighing;
b. • Weigh in the sample to be determined;
c. • Heat the sample until the contents will sustain a flame and burn the sample until there is no further smoke or fumes;
d. • If the sample has sufficient moisture to foam, discard the sample, and follow procedures given to reduce the moisture content before proceeding;
e. • Cool the sample, add water and sulfuric acid, and heat until no further fumes are evolved;
f. • Place the dish in a furnace and heat at 775 C until oxidation of the carbon is complete. Continue the cooling, acidification and heating process until successive weightings differ by no more than 1.0 mg.

Calculation – Sulfated ash is calculated as a percentage of the original sample.

Sulfated Ash (mass%) = w/W*100

w = mass of sulfated ash (g)
W = mass of sample used in test (g)

Report – Report the result to the nearest 0.001 mass% for samples below 0.02 mass% and to the nearest 0.01 mass% for higher levels.

13. Cloud Point Test / Gel Point Test

a. In this test you place a sample of finished Biodiesel in a freezer and record the temperature at which the Biodiesel starts to gel. This is an important test for winter fuel. Simply put, you don't drive on Biodiesel at temperatures below the gel point.

Rational- Mandatory for winter driving on Biodiesel that is if you don't want to have your car or truck towed to a heated garage to thaw out.

b. This test is performed by placing a sample of finished Biodiesel in the freezer and watching it for cloudiness. The temperature at which the Biodiesel first turns cloudy is the cloud point. This test is important for winter fuel. It is related to the "Gel Point Test". The cloud point is near the temperature at which your filter will clog from frozen Biodiesel.

Rational - Mandatory for Winter Biodiesel that is if you don't want to be changing filters on the side of the road in knee deep snow.

pH Test

1. Test the pH using the pH strips
    a. finished fuel should be 7 (neutral)
    b. high pH = use less lye
    c. This can also be done for washed biodiesel to show that washing is complete.

Rational-This test is for how much catalyst and soaps are left in unwashed Biodiesel.

SAFTEY CHECKLIST FOR TRALER WORK

WHAT TO DO IF….

Methanol

Fire: Use a fire extinguisher to put it out
-watch out for vapors, you may use water spray to cool fire-exposed structures

Spill:
Small- flush with large amounts of waters
Large- absorb spill with non-combustible matter, eliminate ignition sources, do not walk through it, and prevent entry into sewers

First Aid: *Get medical attention immediately
-*Swallowed:* if fully conscious, give two glasses of water to induce vomiting.
-*Inhalation:* Remove to fresh air; give artificial respiration if not breathing
-*Skin Contact:* Wash skin with soap and water for at least 15 minutes
-*Eye Contact:* Flush eyes with water for at least 15 minutes.

Sodium Hydroxide

Fire: not likely, but use a fire extinguisher to put out

Spill: wearing PPE, pick up and place in a suitable container for disposal. Do not flush residue to sewer. Residues from spill can be diluted with water, and neutralized with dilute acid, such as acetic, hydrochloric, or sulfuric.

First Aid: *Get medical attention immediately
-*Swallowed:* DO NOT INDUCE VOMITING! Give large quantities of water or milk, if available.
-*Inhalation:* Remove to fresh air; give artificial respiration if not breathing
-*Skin Contact:* Immediate flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes
-*Eye Contact:* Immediately flush eyes with plenty of water for at least 15 minutes, lifting lower and upper eyelids occasionally

Sodium Methoxide

Fire: Use a fire extinguisher to put it out- DO NOT use water directly on fire!
-watch out for vapors, you may use water spray to cool fire-exposed structures

Spill: Absorb spill with non-combustible matter, eliminate ignition sources, and provide ventilation

First Aid: *Get medical attention immediately
-*Swallowed:* DO NOT INDUCE VOMITING! If victim is conscious and alert, give 2-4 cupfuls of milk or water.
-*Inhalation:* Remove to fresh air; give artificial respiration if not breathing
-*Skin Contact:* Immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes.
-*Eye Contact:* Immediately flush eyes with plenty of water for at least 15 minutes, lifting lower and upper eyelids occasionally

Biodiesel

Fire: Use a fire extinguisher to put it out
-you may use water spray to cool fire-exposed structures

Spill: Absorb spill with non-combustible matter, eliminate ignition sources, and provide ventilation
-if it is a large spill, contact emergency response personnel

First Aid: *Contact medical personnel
-*Swallowing:* Do Not Induce Vomiting. Rinse mouth with water
-*Inhalation:* Remove to fresh air; give artificial respiration if not breathing
-*Skin Contact:* wash contaminated area with soap and water promptly. Remove contaminated clothing.
-*Eye Contact:* Immediately wash eyes with large amounts of water for fifteen minutes, occasionally lifting the lower and upper lids.

Glycerin

Fire: Use a fire extinguisher to put it out
-you may use water spray to cool fire-exposed structures

Spill: Absorb spill with non-combustible matter, and place in suitable container.
-Avoid runoff into sewers.

First Aid: *If irritation persists/develops, get medical aid.
-*Swallowing:* Do Not Induce Vomiting. Rinse mouth and drink 2-4 cups of milk or water.
-*Inhalation:* Remove to fresh air; give artificial respiration if not breathing
-*Skin Contact:* Flush skin with plenty of soap and water for at least 15 minutes while removing contaminated clothing and shoes.
-*Eye Contact:* Flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids.

Justification: ***Heating Mixing Tank***

Our Comments:

The heating-mixing tank was combined together to allow for a smaller processor and to utilize the mixing pump for heating and mixing as well as moving the waste vegetable oil into the tank and the finished product into the wash tank. The design for the cone shaped tank was based on the cone shaped design found at:

http://journeytoforever.org/biodiesel_processor3.html

Features and Reflection:

- The **dimensions** we used for this can be found on the plans that are included into the main Biodiesel Folder.
- Logistically the **welding** of the bottom part of this tank took a very long time. This wasn't time conducive but it did allow us to have a very working heating mixing tank.
- The purpose of having a **cone shaped tank** was to allow for the draining of the glycerin and the biodiesel easily and completely. This is a great feature of our system and has been beneficial in the runs we have done.
- As for the heating part of the tank there are **three heating elements** that are used in the tank. Only two are wired in though because we had to ensure the overall pull of the system is under 15 amps (constraints of using the Frey power supply)
- There was a **viewfinder** that was put into the bottom of the tank. Do to the darkness of the glycerin and waste vegetable oil this viewfinder has proved to be quite ineffective.
  - **<u>A recommendation</u> would be to add a viewing pipe to the outside of the heating mixing tank which could allow the operator to see how well the reaction settled with out interfering with the closed system**
- We added a **sealable lid** to the heating mixing tank to allow for the sealing of the tank as the process is being done. This increases the **safety** of the system.

Justification: ***Main Biodiesel Mixing Pump***

The main biodiesel mixing pump is from Northern Industrial Tools. The link for the latest version of the pump is:

http://www.northerntool.com/webapp/wcs/stores/servlet/product_6970_200201424_200201424

The reason that we went with this pump was for a few reasons.

- It was boidiesel compatible with viton seals.
    - The typical pump used by small scale biodieselers is:
        - http://www.northerntool.com/webapp/wcs/stores/servlet/product_6970_7738_7738
    - This pump doesn't have viton seal so it will degrade over time.
- It had a flow rate of 18 gallons per minute
    - We have checked this and we have gotten 11.6 gpm when moving biodiesel from the heating mixing tank to the washing tank
    - We needed a flow rate in this range because the pump is our primary mixing mechanism for the heating mixing tank
- It was cheaper than many diaphragm style pumps and high end pumps found on pumpbiz.com

Newer version of our current pump:

Reflections:

This pump has served us well so far. We would recommend never putting water in it because that will rust the inside of the pump which is cast iron. It will be hard to remove the pump from the framing so don't put water in it.

We haven't determined if the mixing power of the pump is adequate but if we determine its now a mixer should be added to the heating mixing tank.

Justification: ***Methoxide Tank***

Our Comments:

The methoxide tank is a 15 gallon tank that has a PDF marked below:

http://www.usplastic.com/pdfdatafiles/drawings/8551drawing.pdf

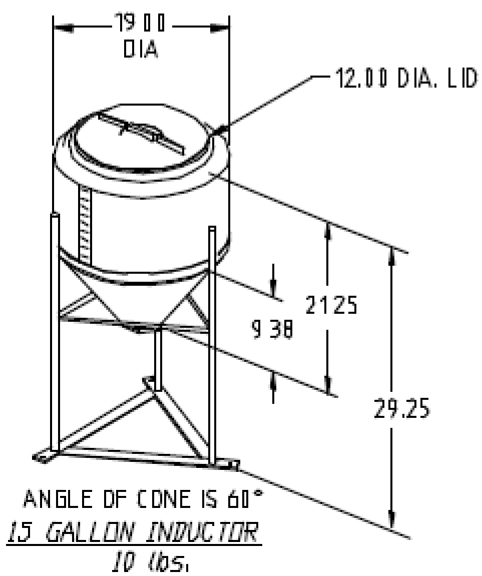
The problem that we have had with both of our cone bottomed plastic tanks is the lip that we have at the bottom, due to the black attachment at the bottom. This allows some of the oil to pool at the bottom which is an issue. We have tried to fix this but currently haven't found a remedy.

Changes that could be done would be to seal the bottom with an epoxy that is biodiesel compliant. This is a hard thing to find and may not be the best option (all of the epoxy we have tried isn't holding up well). **Further research may be needed to verify this.**

Other changes may be to anchor the methoxide tank in better. It is only locked in by the chains but it is still able to spin. This is an issue when opening the top because as you spin the top you may break the pipe fitting at the bottom. **Spin carefully.**

For a great deal check:
http://www.plastic-mart.com/class.php?item=1636

Diagram:



Justification: ***Methoxide Mixing Pump***

Our Comments:

This pump was inherited from the previous teams but it was undersized for the main pump. Thus we moved it to serve the purpose of the methoxide pump on the system. It has a broken piece on the bottom but this was overcome by using epoxy and designing the piece into our system. It has served us well. More information on the MDX MT3 can be found below or at:

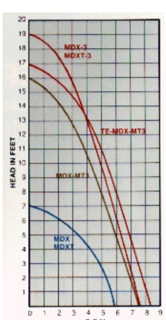
http://www.marchpump.com/series-mdx-info.htm

Reflections:
This pump is a very high quality pump that works well for the purpose of mixing the methanol and the lye. **The problem with the pump is that it is broken. The bottom piece on the pump has an outlet broken off**. This piece can be found at; it is part #16.

http://www.marchpump.com/documents/Part%20Sheets/MDX%20Series/MDX-MT3%20Catalog.pdf

It can be bought for around $13.00 at http://www.depcopump.com/itemlist3.htm. Due to it breaking repeatedly this may need to be replaced. We have tried epoxy and this has worked in the past. This could be tried again but it may be good to buy another piece. Also if flexible tubing were implemented for that loop the stress will be removed from that piece.

Compiled Data:
As indicated in the options and specifications that follow, variations in the MDX Series include: numerous inlet and discharge ports, several motor options and wetted material combinations for total chemical comparability.



The MDX Series can and should be classified as "the granddaddy of them all".

THE SERIES MDX PUMPS INCLUDE MODELS:

MDX	1700 rpm, 1/50 HP
MDXT	1700 rpm, 1/50 HP
MDX-3 ½	3 = High speed, 3500 rpm, 1/25 HP
MDX-3 5/8	
MDXT-3	T= FPT (Female pipe threads)
MDX-MT3	MT = MPT (Male pipe threads)
TE-MDX-MT3	1/15 HP, 3450 rpm, 115/230 Volt
TE-MDK-MT3	K = Kynar

Above models are not self priming pumps.
FLOW AMD HEAD
Flow rates range from 0 to 8.4 GPM maximum. Head of feet range from 0' - 19 max.

INLETS AND OUTLETS

Series MDX pumps are offered in many sizes as shown on page #9, F0960 catalog. Contact the factory for other sizes and types of inlets and outlets. Suffix ½ = suction and discharge sizes. Suffix 5/8 = suction and discharge sizes.

MOTORS

AC type motors in sizes 1/50 HP @ 1700 rpm; 1/25 HP @ 3400 rpm, 115 Volt, single phase or 230 volt single phase 50/60 HZ.
TEFC type motor in 1/15 HP @ 3450 rpm, 115/230 Volt, single phase.
Air motors are available for the MDX series. This can add to overall pump performance.
Air motors indicated by suffix AM

MATERIALS OF CONSTRUCTION

Wetted parts - Glass filled polypropylene, Ryton®, Kynar®, 316 stainless steel, Buna N rubber, ceramic magnet, Viton® O-ring, ceramic shaft.

APPLICATIONS:

Coffee dispensers, aquariums, bio-medical, dryers, ice makers, electrostatic painting, photographic processing, and vending equipment.

MORE INFORMATION

Justification: ***Wash Setup***

 Wash Tank:

The wash tank is an 80 gallon tank with holes drilled into the top to allow space for the mister. This has similar issues as the methoxide tank with having a lip at the bottom to get caught on.

Mister:

Link included here: http://www.b100supply.com/product_p/127.htm

This has an average flow rate of 7 gallons per hour.

Problems:
The problem with the mister is that one of the misters broke and so we had to put that mister into the center to prevent leaking onto the top of the tank.

 Air Mister (Air Pump):

This mister was purchased from b100supply.com but the information on it isn't available. It has served our purposes fine though.

Water Timer:

This timer protects the wash tank from over flowing and it should always be used to guarantee that the mister doesn't overflow the tank.

http://www.lowes.com/lowes/lkn?action=productDetail&productId=97758-306-97758&lpage=none

Justification: ***End of System Filter***

We have a filter at the end of the system to guarantee that the fuel we distribute is free of particulates. **We need to guarantee this by making sure there is little soap particles that make it into the filter.**

The filter that we use at the end of the system is
http://www.geappliances.com/smartwater/model_fs.htm?GXWH04F

The specs are

APPROXIMATE DIMENSIONS (HxDxW)	
13 in x 5 1/2 in x 5 in	
FEATURES	
Max. Filtered Water Flow (gpm)	4-12
Filter Change Indicator	Remote
Feed Water Pressure (psi)	40 Min - 125 Max.
Feed Water Temperature	40-100 F
Plumbing Connections	3/4"
Pressure Relief Valve	Yes
APPEARANCE	
Color Appearance	White on White
Filter Housing	Opaque
Unit Color	White
WEIGHTS & DIMENSIONS	
Overall Depth	5 1/2 in
Overall Height	13 in
Overall Width	5 in
Approximate Shipping Weight	2 lb
ACCESSORIES	
Installation Kit	HDKIT
Mounting Bracket	Included
Wrench	Included
FXUSC (Polyspun)	At Additional Charge
FXWPC (Pleated)	At Additional Charge
FXWSC (String Wound)	At Additional Charge
FXWTC (Carbon Paper Sediment)	At Additional Charge
WARRANTY	
Parts Warranty	Limited 1-year entire appliance
Labor Warranty	Limited 1-year entire appliance
Warranty Notes	For models produced on or after January 1, 2006 See written warranty for full details

Installation instructions can be found at:
http://products.geappliances.com/ApplProducts/images/t07/0000003/r03865v-1.pdf

Contact List

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	R.F.Fager	2058 State Road Camp Hill, PA 17011	(717) 761-0660	www.rffager.com
	Garron Plastics Inc.	7561 Derry St. Suite B Harrisburg, PA 17100	(800) 442-6839	
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