ENGR 491

SENIOR
DESIGN PROJECT

Biodiesel

User's Manual

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TABLE OF CONTENTS

1. Introduction 3
2. Ingredients 3
    2.1 Oil 3
    2.2 Methanol 3
    2.3 Lye 3
3. Adding Oil to the System 4
4. Adding Methanol and Lye 4
5. Operation 5
    5.1 Manual Steps 5
    5.2 Automated Steps 6
6. Cleaning 7
7. Maintenance 7
8. Appendix 8
    8.1 Oil Yields 8
    8.2 Oil and Ester Characteristics 9
    8.3 System Diagram 10
    8.4 Process Diagram 11
    8.4 Control Board 13

1. INTRODUCTION

The Production of Biodiesel senior project team created a versatile system for converting cooking oil into usable fuel for diesel vehicles. The system can accept a variety of vegetable-based oils and can produce a range of batch sizes. With the work in automation of the E-Biodiesel senior project team, the system can produce batches with little user input.

2. INGREDIENTS

2.1 Oil

Biodiesel can be produced out of a variety of natural products. Every oil will require differing amounts of chemicals for reaction and will produce a fuel with slightly differing qualities. ***Section 8.1*** contains information on approximate fuel yields of many agricultural products, and ***Section 8.2*** gives information on the oil and ester characteristics of these products. Virgin oil can be used as well as waste oil. Typically, virgin oils require smaller amounts of the reactants to produce quality fuel. However, the purpose of this project was to enable waste cooking oil to be recycled into usable fuel. This will require a higher cost for the amount of chemicals needed, but will probably result in saving the user money since waste cooking oil is readily available for no cost at many dining facilities.

2.2 Methanol

Methanol, methyl alcohol, is a common fuel used in auto racing. It can be found at many gas stations located near racing tracks, especially tracks where private owners are allowed to race. The methanol must be 99.9% pure for the reaction to be complete. The racing fuel is often not labeled with purity, but rather on a grading system. Grade A, virgin methanol has a high enough purity to ensure the reaction.

2.3 Lye

Lye, also referred to as sodium hydroxide or caustic soda, can be found in reagent grade at chemical stores or more commonly as drain cleaner in grocery stores. The lye should be at least 95% pure. Red Devil brand lye is 99% pure and readily available. In storing and using the lye, air tight containers should be used since lye absorbs humidity in the air.

3. ADDING OIL TO THE SYSTEM

Before the oil can be added to the system, it should be filtered for any large sediment that may be in the oil. If waste cooking oil is being used, often there can be particles of food in the oil that could clog the system or cause damage to the pumps. Our team used a window screen attached to a metal ring could be fitted to 15 gallon steel tanks. While the oil was still warm, we poured the liquid oil through the filter and into a storage/transportation tank. From this tank, the oil could be measured out and poured into the heating tank of our system, after ensuring that the valve on the bottom of the tank is closed.

NOTE: 3 gallons is the minimum batch of oil that can be used to ensure that both immersion heaters are fully covered and that the pump will be primed.

4. ADDING METHANOL AND LYE TO THE SYSTEM

WARNING! Both methanol and lye are potentially harmful substances. Methanol, methyl alcohol, is a skin irritant as well as harmful if swallowed. The fumes from the methanol should not be inhaled, so handle in a well ventilated area. Lye, also called sodium hydroxide or caustic soda, is a caustic base that should not be ingested or come in contact with skin. If contact with skin should occur, vinegar can be used to rinse, neutralizing the base. Once the methanol and lye are mixed, methoxide is produced. This substance is harmful if touched, ingested, inhaled, or if fumes come in contact with eyes. Safety equipment must be used, including appropriate eye wear, gloves, and respiratory mask.

To determine how much lye needs to be used, a titration should be performed on a sample of the oil that is going to be input to the system. The titration determines the fatty free acid content of the oil by indicating its pH. If available, a digital pH meter could eliminate the titration, or litmus paper could be used as well. Below is a set of basic instructions for the titration. If more detailed instructions are needed, visit http://www.journeytoforever.org/biodiesel_mike.html.

Titration Steps (See ***Section 8.3*** for pictures)

1. Weigh out 1 gram of cooking oil into an Erlenmeyer flask.
2. Add 10 mL of Isopropyl Alcohol to the oil sample and mix vigorously.
3. Add one packet of phenolphthalein to the mixture and mix vigorously.
4. Fill buret with 0.1 M Sodium Hydroxide and record initial volume.
5. Titrate the sample with the Sodium Hydroxide until mixture changes color and color remains.
6. Record final volume of Sodium Hydroxide in buret.

Lye Calculation

Add 3.5 to the number of milliliters of sodium hydroxide used to titrate the oil if you are using waste cooking oil. (Do not add the 3.5 if you are using fresh cooking oil.) This is the number of grams of lye needed to be added into the system for every liter of oil added into the system. For example, if the number of milliliters of sodium hydroxide was 2, then 5.5 grams of lye would be needed for every liter of waste cooking oil.

Methanol Calculation

For every gallon of oil added to the system, 1/5 of a gallon of methanol must be added to the system. So for a 3 gallon batch of oil, 3/5 of a gallon of methanol must be used.

Once the amounts of the lye and methanol have been determined, both are ready to be input to the system. Ensuring that valve 5 (see ***Section 8.3***) is closed, the methanol can be poured into the methoxide tank first. Then the lye can be added to the methoxide tank. Once the two are in the tank, the lid should be screwed on.

5. OPERATION

5.1 Manual Steps

NOTE: If the processor is set-up for automated use, skip these manual steps and follow the automated instructions.

Once the raw materials have been added in the appropriate manner, the system is ready to be initiated. Follow the steps below, referencing the diagrams in ***Section 8.3*** and ***Section 8.4***. (All valves are initially closed and heaters and pumps turned off.)

1. Turn on the immersion heaters in the heating tank. The target temperature is between 50 – 60 degrees Celsius. Some stirring of the oil will ensure an even temperature distribution and speed the heating process, but it is not necessary.
2. While the oil is heating, the methanol and lye can begin to circulate. Turn on the methoxide circulation pump. The methanol and lye will circulate with turbulence, creating a methoxide solution. There is no set length of time to circulate the methoxide, but ensure that the lye has been fully dissolved into the methanol.
3. Once the oil is heated and the lye fully dissolved, the circulation pump can be turned off.
4. Valve 1 is opened, draining the oil into the mixing tank. After the oil has fully drained, valve 1 is closed, and valves 2 and 4 are opened. The magnetic drive pump is then initiated, circulating the oil.
5. As the oil circulates, valves 3 and 5 are opened allowing the methoxide to drain into the circulating line, by force of gravity. User should be aware that there is a manual

valve directly beside valve 3 that acts as a flow limiter. The manual valve should be just slightly open, to allow a slow feed of the methoxide into the circulation line.

6. As the methoxide tank and line drain completely, valves 3 and 5 should be shut to stop air from being pulled into the oil circulation line.
7. Once the methoxide is completely drained into the system, the circulation through the magnetic drive pump should be continued for an hour to ensure a thorough mixture.
8. After the mixing, valve 2 is shut and valve 6 opened in rapid succession. As soon as air begins to be sucked into the magnetic drive pump, the pump needs to be shut off. This rapid progression allows the oil that is in the line between valve 2 and the pump to be pulled up to the pump before it is shut off, allowing more oil to be pushed into the mixing tank. Once the pump is turned off, the excess oil in the line is pushed by gravity into the waste discharge container.
9. Valves 4 and 6 can be shut, and the mixture of oil and methoxide allowed to settle for 8 hours. (**NOTE**: User should visually inspect the surface of the fluid in the mixing tank. If there is a foamy, light colored layer on the surface, user should stir to break up the layer. This will ensure complete reaction.)
10. After the settling time, user should be able to see, through the tank wall, a distinct line of separation near the bottom of the tank, where the denser glycerin has settled to the bottom and the Biodiesel is left on top. Valves 2 and 6 are opened to allow only the glycerin to drain into the waste discharge container. Valve 6 should be shut as soon as the glycerin drains out completely and the discharge changes to a noticeably lighter color.
11. Biodiesel then primes the magnetic drive pump. Valve 7 is opened and the pump turned on. This pumps the fuel through the filter and into a storage tank.
12. Once the mixing tank has completely drained, the pump is turned off and the excess fuel in the line drained. All valves are then closed.
13. Biodiesel should be kept in air tight containers in a cool place, and is ready to use.

5.2 Automated Steps

Once the raw materials have been added in the appropriate manner, the system is ready to be initiated. Follow the steps below, referencing the pictures in ***Section 8.5.***

1. **Powering the PLC**
   In order to power the PLC, first plug in the machine and then push the red pushbutton located above the "Emergency Stop" sign. You should hear a "click," from the relay, indicating that power is being supplied to the PLC.
2. **Starting the Process**
   To start the oil heating and methoxide mixing processes, you need to push the "Manual Start" pushbutton. As soon as the pushbutton is pushed the mimic board should look just as it does in the picture. If this does not occur there is something wrong with the wiring. Consult the electrical drawings for further help.

3. **Mixing Cycle**
   The mixing cycle should start immediately after a 15 minute duration. The mimic board should appear as in the picture. If this does not occur there is something wrong with the wiring. Consult the electrical drawings for further help. Also, the LED labeled Valve 1 should stay lit for the rest of the process.
4. **Draining the Glycerin**
   When the Biodiesel has settled for eight hours, the process should automatically alert you to drain the glycerin. When this occurs, you should push in the pushbutton above the alert LED until you are satisfied that all the glycerin is released from the mixing tank. Pushing the button multiple times will not interrupt the sequence, but do not push the button once the switch has been turned to store the Biodiesel.
5. **Storing the Biodiesel**
   As soon as you release the glycerin pushbutton, the LED to alert you to begin storing should come on. To start the storing process, simply turn the switch to the right and the mimic board should appear as in the picture. Valve one should close at this time.
6. **Stopping the Process**
   To stop the process, simply turn the store Biodiesel switch back to the left, and push the mushroom pushbutton in.
7. **Emergency Stop**
   To stop the program in an emergency, push in the mushroom pushbutton. To restart the process, turn the mushroom pushbutton to the right, and pull out. Then push the red pushbutton.

6. CLEANING

1. Allow contents in line to be gravity fed to waste container.
2. If possible, use airline to blow contents in line out into waste container.
3. If the system is going to be unused for awhile, run system with soapy water to clean oil from tanks and lines.
4. Make sure system is fully dry before making next batch of Biodiesel.

7. MAINTENACE

1. The filter will need to be changed if there is not a distinct color change between the incoming and outgoing Biodiesel, or if the pump has difficulty pushing Biodiesel through the filter.
2. Filters can be washed, dried, and reused.
3. Check the seals of the valves and pumps for corrosion.
4. Check holes and seals on tanks for leaks.
5. Check heating tank for rust.
6. Check for kinked hose or blockage of lines.
7. Check electrical wiring for wear or breaks.
8. Check methoxide tank for residual lye.
9. Check bottom of heating tank for sedimentation that needs to be cleaned out.

8. APPENDIX

8.1 Oil Yields

Crop	kg oil/ha	litres oil/ha	lbs oil/acre	US gal/acre
corn (maize)	145	172	129	18
cashew nut	148	176	132	19
oats	183	217	163	23
lupine	195	232	175	25
kenaf	230	273	205	29
calendula	256	305	229	33
cotton	273	325	244	35
hemp	305	363	272	39
soybean	375	446	335	48
coffee	386	459	345	49
linseed (flax)	402	478	359	51
hazelnuts	405	482	362	51
euphorbia	440	524	393	56
pumpkin seed	449	534	401	57
coriander	450	536	402	57
mustard seed	481	572	430	61
camelina	490	583	438	62
sesame	585	696	522	74
safflower	655	779	585	83
rice	696	828	622	88
tung oil tree	790	940	705	100
sunflowers	800	952	714	102
cocoa (cacao)	863	1026	771	110
peanuts	890	1059	795	113
opium poppy	978	1163	873	124
rapeseed	1000	1190	893	127
olives	1019	1212	910	129
castor beans	1188	1413	1061	151
pecan nuts	1505	1791	1344	191
jojoba	1528	1818	1365	194
jatropha	1590	1892	1420	202
macadamia nuts	1887	2246	1685	240
brazil nuts	2010	2392	1795	255
avocado	2217	2638	1980	282
coconut	2260	2689	2018	287
oil palm	5000	5950	4465	635

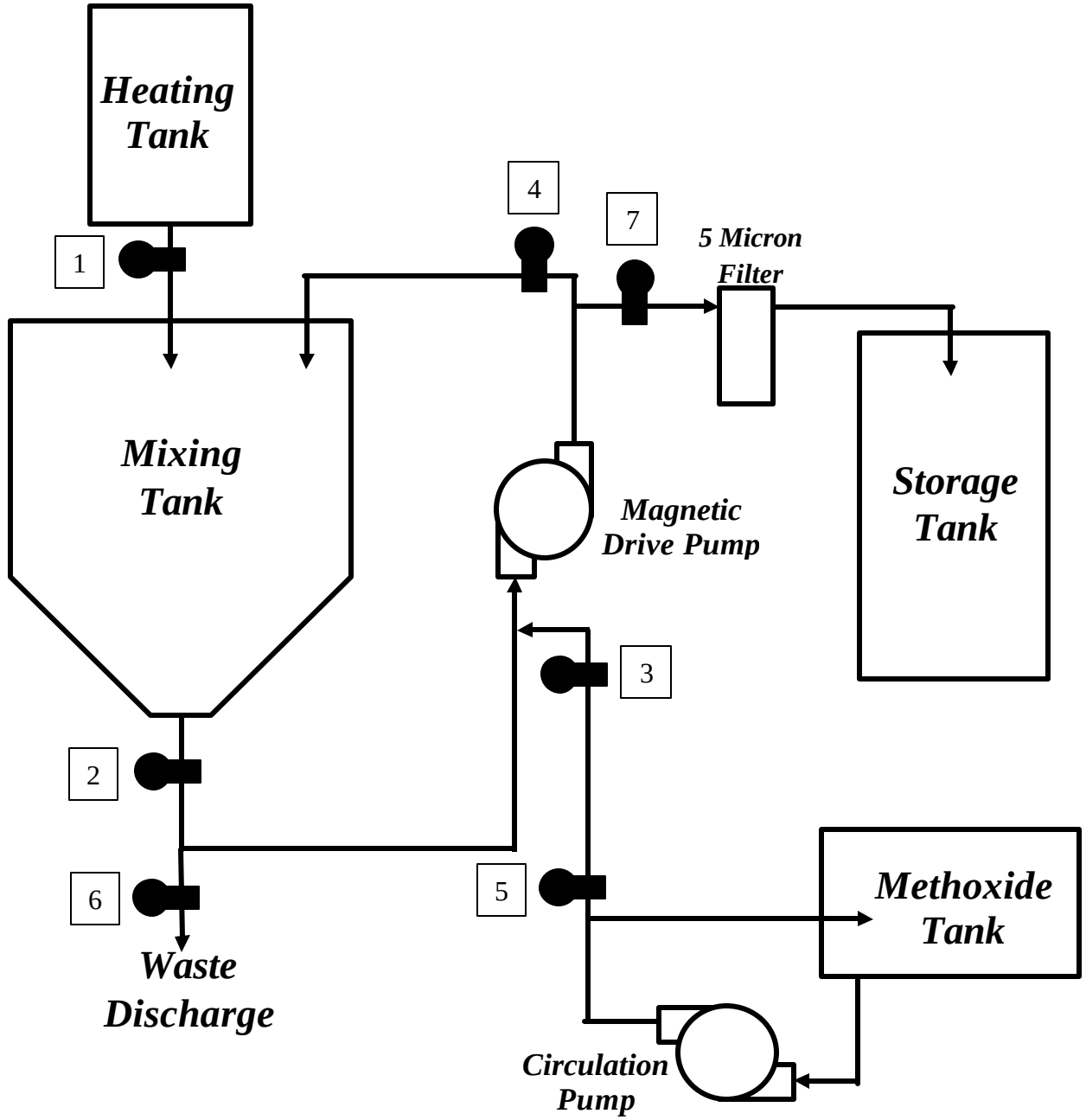
Found at http://www.journeytoforever.org/biodiesel_yield.html

8.2 Oil and Ester Characteristics

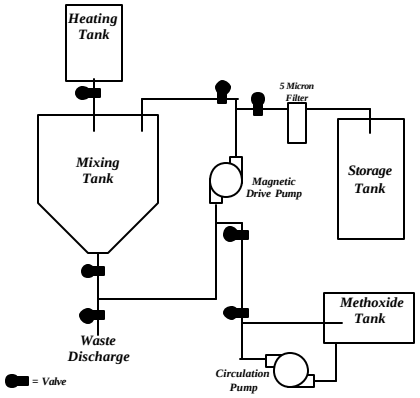
Oils and esters characteristics					
	Melting Range deg C			Iodine number	Cetane number
Type of Oil	Oil / Fat	Methyl Ester	Ethyl Ester		
Rapeseed oil, h. eruc.	5	0	-2	97 to 105	55
Rapeseed oil, i. eruc.	-5	-10	-12	110 to 115	58
Sunflower oil	-18	-12	-14	125 to 135	52
Olive oil	-12	-6	-8	77 to 94	60
Soybean oil	-12	-10	-12	125 to 140	53
Cotton seed oil	0	-5	-8	100 to 115	55
Corn oil	-5	-10	-12	115 to 124	53
Coconut oil	20 to 24	-9	-6	8 to 10	70
Palm kernel oil	20 to 26	-8	-8	12 to 18	70
Palm oil	30 to 38	14	10	44 to 58	65
Palm oleine	20 to 25	5	3	85 to 95	65
Palm stearine	35 to 40	21	18	20 to 45	85
Tallow	35 to 40	16	12	50 to 60	75
Lard	32 to 36	14	10	60 to 70	65

Found at http://www.journeytoforever.org/biodiesel_yield.html

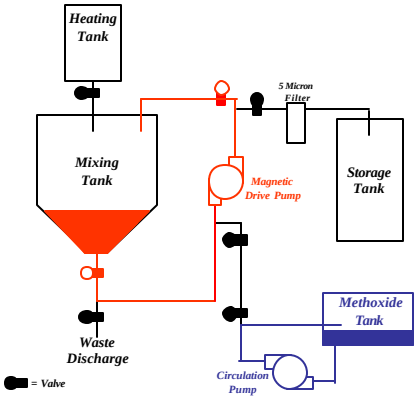
8.3 System Diagram



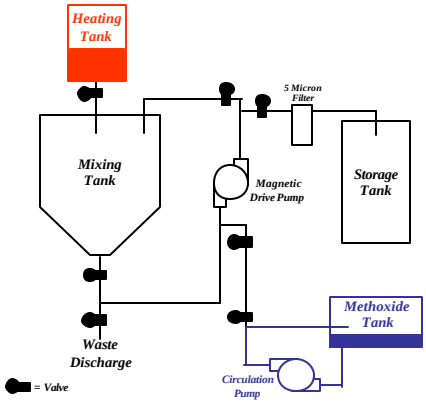
8.4 Process Diagram



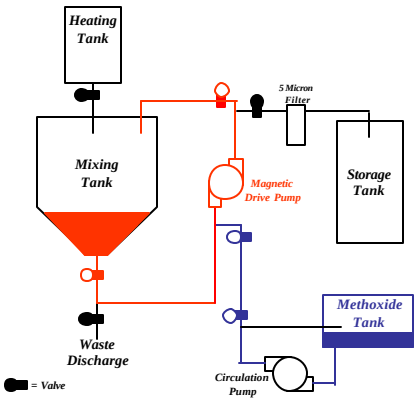
Initial Setup



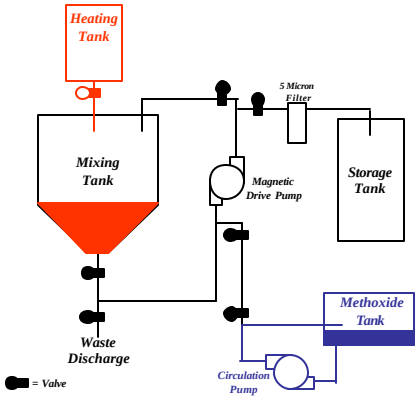
Circulating Heated Oil



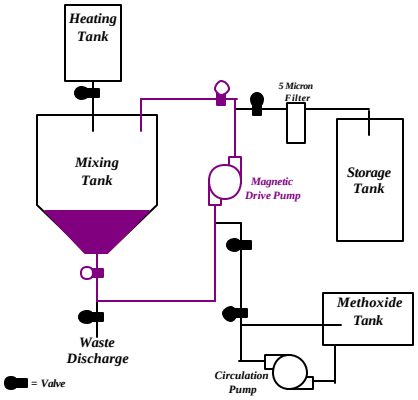
Heating and Methoxide Circulation



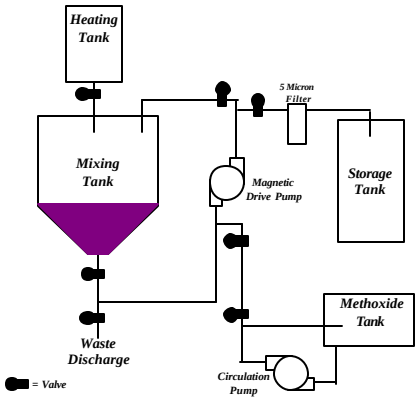
Addition of Methoxide to Circulating Heated Oil



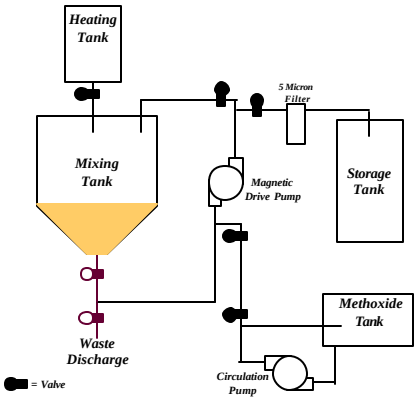
Draining Heated Oil



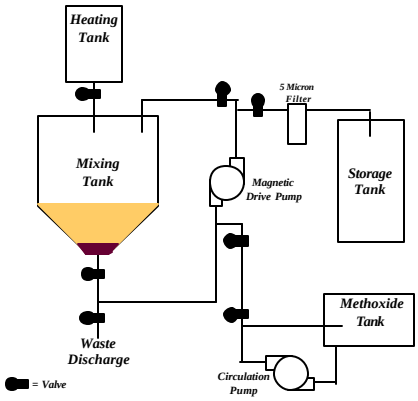
Circulating Oil-Methoxide Mixture



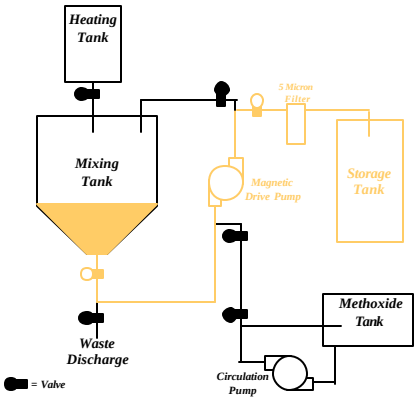
Settling of Oil-Methoxide Mixture



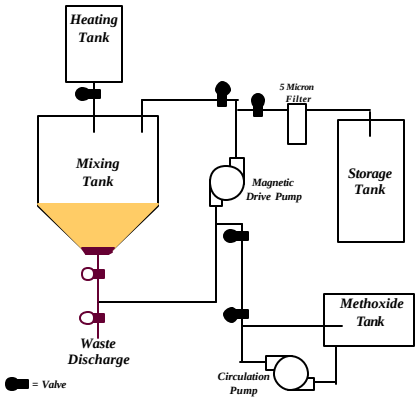
Glycerin Fully Drained



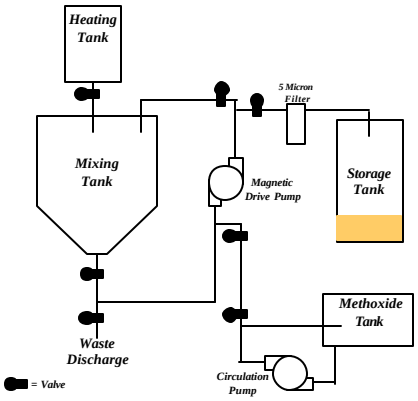
Fully Settled Biodiesel and Glycerin



Pumping Biodiesel to Storage Tank

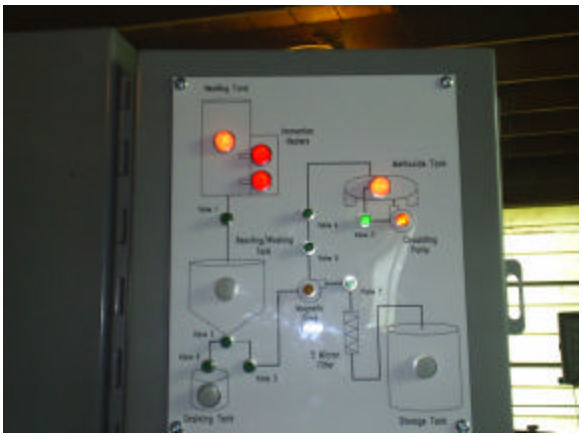


Draining Glycerin

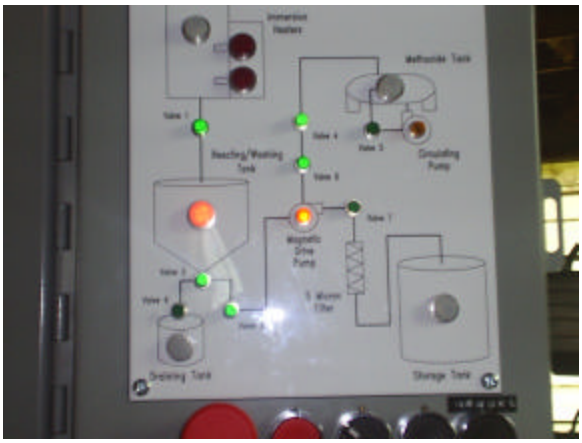


Completed Process

8.5 Control Board



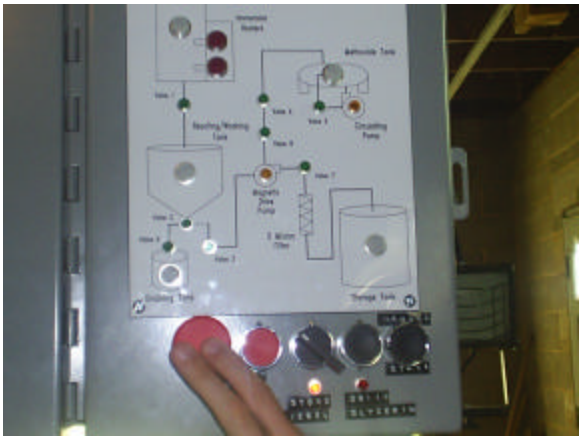
Starting the Process



Mixing Cycle

Draining the Glycerin

Storing the Biodiesel



Stopping the Process