

# **Design Report 1**

**Columbia University  
Mechanical Engineering  
Senior Design**

**Straight Vegetable Oil (SVO) Engine Modification Kit**

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# INTRODUCTION

The technical goal is to isolate the best modification of a single-cylinder Lister diesel engine for increased life and efficiency for straight vegetable oil (SVO) capabilities. While this engine is capable of running on straight vegetable oil, it is known that the engine longevity is seriously compromised. Therefore, we have isolated three areas of concern within the engine: highly viscous fuel, variable load, and the need to flush the engine of vegetable oil so that there is no cold oil present in the combustion chamber at start of subsequent runs. To deal with these issues, we propose the following solutions: a fuel pre-heater, a variable rpm controller, and a duel fuel tank system to allow toggling between diesel and vegetable oil.

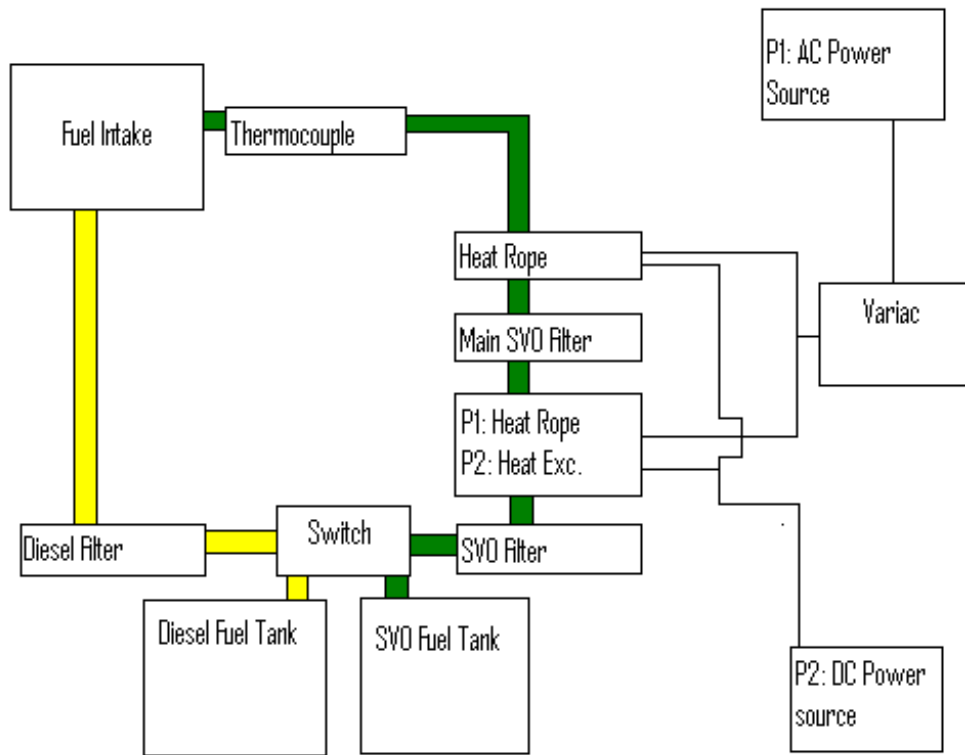
## PRE-HEATER

One of the primary goals of the project is to substantially reduce the amount of diesel fuel used in Lister engine operation. This will be achieved with a dual tank system, one tank supplying diesel fuel, and the other supplying jatropa (SVO).

### **Duel Tank Fuel Supply**

The purpose of the dual tank system is to start and shut down the engine on diesel fuel; once running the engine will have the capability to be run on jatropa (SVO). Diesel start/stop capability accounts for the problems arising due to the viscosity difference of the fuels. Jatropa (SVO) is significantly more viscous than diesel fuel, so viscous that starting the engine with room temperature jatropa is problematic. Therefore the engine

will be primed and flushed with low viscosity diesel fuel, enabling for low to moderate temperature start-up. Once the engine is running the jatropa will be continuously heated, viscosities of the fuels will be comparable, allowing for jatropa run capability.



**Figure 1: Fuel Delivery Diagram**

## **Preheating Project**

### **Phase One:**

A heat rope wrapped around the copper jatropa fuel line will elevate the inlet fuel temperature to 75-140 degrees Celsius. The heat rope requires an AC power source (a simple wall socket), in series with a variac, allowing for a range of temperatures to be

examined. Experiments will be conducted to test for the optimal temperature jatropha SVO should be heated. The rope will be located after the 50 micron filter as well as following the 10 micron filter. A thermocouple is placed before the fuel intake; paired with a control, engaging/disengaging the heat tape according to desired inlet temperature.

### **Phase Two:**

The second phase of the preheating project involves running the heat tape off of a DC car battery in series with a converter in order to supply the heat rope with AC. The battery will be connected to the engine via a belt system so that when the engine is running the battery will charge. The heat rope located after the 50 micron filter in phase one will be replaced with a heat exchanger running off the hot exhaust.

### **Phase Three:**

The third phase does not include the heat tape; rather copper wire (which is connected to the battery) will be wrapped around the copper tubing, preheating the fuel to the ideal temperature. This will lower cost and part count, eliminating the heat rope and converter. More importantly phase three will present a much more feasible approach for potential third world application of the project.

# ENGINE ANALYSIS

## Oil analysis

We plan to use oil analysis in a limited degree to monitor engine performance and degradation. The lubricating oil analysis gives insight into machine components that are wearing and what is occurring inside the engine due to contaminants. In short, three major types of wear occur in an engine: adhesive wear, abrasive wear, and corrosion wear. Correspondingly, the oil (when subjected to high temperatures, oxygen, and combustion) accumulates contaminants that can be measured; thus the wear on the engine can be derived from analysis of the oil contaminants.

Several tests exist with which the oil can be analyzed. Spectrometry measures the quantities and types of metallic elements in the oil. Viscosity tests measure the increase in viscosity due to contaminants. Dilution tests (by gas chromatography) can indicate how much of the fuel is not being combusted and leaking into the lubricating oil. Acid/base tests can indicate how much of the fuel additives are depleting. Finally, microscopy can identify very specific types of particles in the oil (rust, silt, etc.)

The results of the tests (done by a chemist or diagnostician) will give us an estimate of the state of equipment wear, level of contamination, and any recommended corrective measures. For instance, high copper levels indicate bearing wear, and high a high particulate count can indicate unburned fuel, blow-by, or faulty filtration. We will use varying fuels, and use these tests as an indicator of how the engine is performing using these fuels.

## **Exhaust analysis**

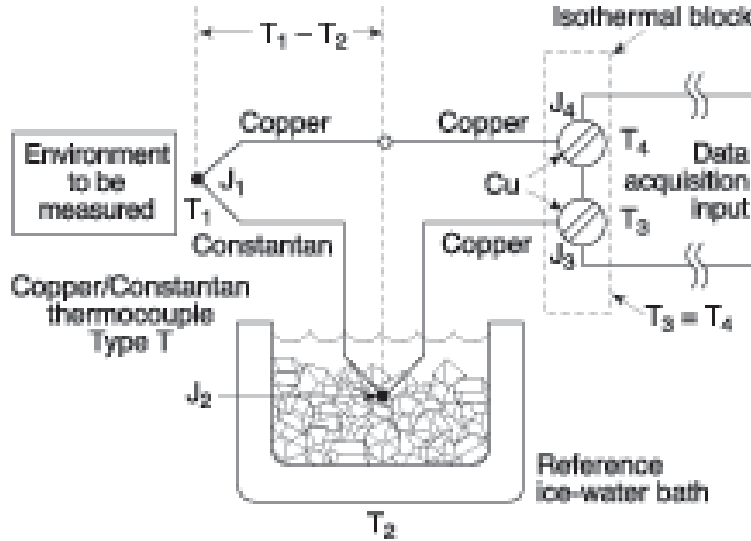
Exhaust analysis will also be performed with the hope of providing information concerning fuel consumption and combustion. Exhaust analyzing capabilities are available to us here at the university. We will measure hydrocarbons, carbon fragments, sulfates, carbon dioxide and carbon monoxide. Hopefully, we will be able to adjust our fuel source (through preheating, etc.) according to the findings from the exhaust analysis and find the optimum load at which emissions are the least for a specified fuel.

## **Thermocouples**

To quantify the efficiency and effectiveness of the Lister engine, we would like to monitor the temperature changes in various locations- the coolant inlet and outlet, the fuel intake, and the exhaust. The coolant analysis will help to verify the effectiveness of the thermal siphon system. Ideally, we would like the engine to run at 190°C while on SVO. The fuel intake temperatures will be varied while we seek the most efficient fuel temperature.

The temperature at these different locations will be measured using thermocouple probes. “When two dissimilar metals are joined at both ends and one end is heated, a current will flow. If the loop is broken at the center, an open circuit voltage (the Seebeck Voltage) is generated and is proportional to the difference in temperature between the two junctions.”<sup>1</sup> In order to retrieve an absolute temperature reading from a thermocouple, a reference temperature must be included in the circuit. While this need can be fulfilled using a signal conditioner, the price of such a device precludes their use

for our purposes. Thus, we will use the functional, though not ideal, ice bath system shown below. The ice bath provides a well-defined reference temperature of 0°C.



**Figure 2: Zeroing Thermocouple**

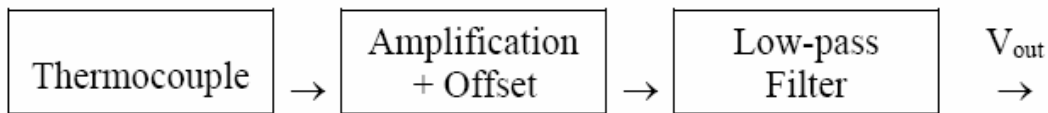
For our purposes, the J-type Iron/Constantine probe will provide the most accurate measurements. The useful temperature range is from 0°C to +750°C. The output of a J-type thermocouple is 8 mV at 210°C and 33 mV at 600°C.

<u>Location</u>	<u>Temperature Estimate</u>
Coolant Inlet	~25°C
Coolant Outlet	~190°C
Fuel Intake	~150°C
Exhaust	~400°C?

**Figure 3: Temperature Estimates**

Because the output of a thermocouple is so small, an amplifier must be devised to increase the voltage output to the useful 0-5V range for the DAQ card. Lastly, due to the distances between the measurement location and the DAQ, excessive noise must be

filtered out of the system. Ideally, these two issues are resolved with the use of a signal conditioner, but again the cost prohibits the purchase. The following block diagram maps out the desired circuit:



**Figure 4: Thermocouple Circuit Diagram**

## **AUTO-THROTTLE**

### **Problem Description**

Lister diesel engines are primarily run at a constant throttle regardless of load. This leads to inefficiencies in the relation between fuel consumption and load requirements. Though a throttle/governor is present on many of these engines, the imprecision of its positioning and effect as well as the lack of knowledge regarding the exact desired throttle position for a desired load makes the current system inadequate. Since most users of these simple diesel engines are third world agricultural and industrial users (and thus know little about their operation), the result is that most users simply keep the engine at full throttle regardless of engine load, thus potentially wasting fuel.

### **Solution/Concept**

The first step in a solution to this problem is to perform engine tests to produce curves relating output load to RPM, fuel efficiency, and exhausts. These tests will be

performed with pure diesel, pure jatropha oil, and mixed blends of the two fuels to compare engine performance and efficiency of the jatropha oil and the diesel fuel. Once proper curves and relations are established, ideal RPM settings for the engine can be determined for each load to optimize power and efficiency. These optimized RPM settings can be programmed into a microprocessor control program that will automatically control the throttle of the engine to produce the optimized RPM according to the output load requirements (this output load will either be automatically detected or manually input). It should be noted that these settings may differ with different fuel mixtures, so this will need to be examined and accounted for in the control program.

### **Specs/Requirements**

In order to perform the analysis output load versus RPM and fuel efficiency, an electrical load board is required. An alternator will be connected directly to the engine to produce DC current like in a car (Prestolite A0014854AA). An inverter (PB13500-12) will then be used to invert the signal to an AC current that will power the load board, which will likely use light bulbs at first. A current transducer (as of yet unknown) will step down the current such that it can be input into the microcomputer for feedback. A rectifier bridge is also needed to switch the current back to DC from AC so it can enter the microcomputer. This setup, shown in figure 5, is ideal for measuring power and efficiency of the motor and feeding that information back to the controller. Using the rated efficiency of the alternator, it is very easy to determine the efficiency of the engine itself, while RPM can be measured via a tachometer. The microcomputer will control either a stepper or servo motor via a PWM signal. This motor will then open or close a

constrictor mounted inline with the fuel line before it enters the pump and is pumped into the injector.

## Conclusions

The goal of the auto throttle system is to take advantage of the variable RPM abilities of the Lister engine to improve performance and efficiency while retaining the simplicity and ease of use of the engine that makes it so popular and affordable today.

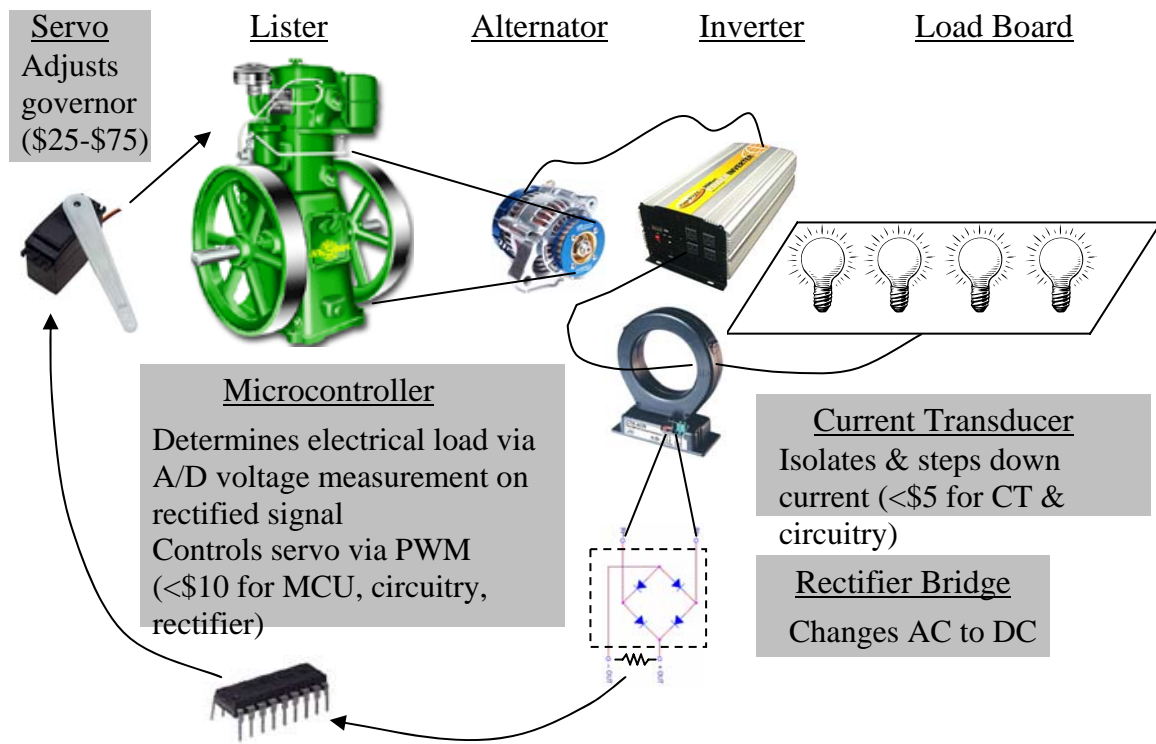


Figure 5: Auto Throttle Diagram

# GANNT CHART

Task	Duration	Who	January		February				March				April				May	
			18	25	1	8	15	22	1	8	15	22	29	5	12	19	26	3
<b>Research</b>																		
oil availability	2	All	█	█														
current research	2	R	█	█														
patent research	1	S		█														
<b>Pre-Heater:</b>																		
<b>Initial Heat Tape</b>																		
concept	1	All	█															
design	2	C,S		█	█													
order parts	2	S,N		█	█													
construction	2	All			█	█												
data analysis	3	All				█	█	█										
<b>DC Heater</b>																		
concept	1	All	█															
design/CAD	2	C,S			█	█												
order parts	1	S,N					█											
curcuit design	2	M,C						█	█									
sensor code	2	M,C							█	█								
construction	3	All						█	█	█								
testing	2	All										█	█					
<b>Heat Exchanger</b>																		
concept	1	All	█															
design/CAD	3	C,S					█	█	█									
order parts	1	S,N						█										
construction	2	All										█	█					
testing	2	All												█	█			
<b>Auto Throttle:</b>																		
<b>Initial Testing</b>																		
design	2	All			█	█												
perform tests	2	All					█	█										
analysis	2	All					█	█										
<b>Circuitry/Control</b>																		
concept circuitry	2	M, N			█	█												
concept control	2	M, N		█	█													
design/diagram	4	M			█	█	█	█										
write code	5	M				█	█	█	█	█								
construction	2	M, N							█	█								
test	3	All								█	█	█						
<b>Mechanical</b>																		
concept	2	All		█	█													

