IPRO 302:
HEAT DRIVEN REFRIGERATION SYSTEM
Midterm Report

Team Members:
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Team Advisor:
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INTRO

The team was broken up into four main groups to tackle the task of completing the mechanical, electrical, and control subsystems of the unit. The team is divided into groups that deal with the following areas: piping, boiler units, electrical system, and data acquisition/controls. Below is a break down of each group along with some objectives.

Boiler Unit: Alex Callow, Dylan Easley, Sean McCann
Finish installation of boilers complete with float sensors, resistor heators, and thermocouples. Validate that the two boilers function correctly independently and in tandem.

Piping: Thomas Alworth, Anna Ryu, Wendell Holmes, Hyang Han
Remove the unsuitable, existing tubing and replace it with new tubing and appropriate insulation. Use proper connections for the junctions and equipment interfaces.

Electrical Systems: Eric Dunaway, Keon Kim, Donghoon Lee
Check all existing, unfinished systems for faulty wiring, and complete them so that the prototype is operable. Develop a control system for the boiler system check valves.

Computer / Data Acquisition: Tony Arkwright, John Brandt
Acquire a computer, then coordinate the acquisition of data from the system, and start a control system that may back up or replace the unfinished, electrical control system.

BOILER SYSTEM:

Currently we have all parts save one needed to complete the boiler section of the refrigerator. The part we need is a new end cap for the pre-boiler because the one currently in use does not allow the float sensors inside the pre-boiler to actuate due to hindrance of their full range of motion. We should have this part acquired by the end of the week and properly drilled by early in the spring break week. If the control circuit is functioning properly, we should be able to test the boiler system independently of the rest of the system next week.

Summary of Project Milestones

- Gained understanding of how boiler system is supposed to work with the rest of the system.
- Found diagrams detailing the operation of the float sensors inside the pre-boiler.
- Brought Eric into our group to design a control circuit for operation of the sensor/solenoid system.
- Devised a system for testing the boiler system independently of the rest of the refrigerator.
- Found all parts necessary for completion of the boiler system.
- Discovered end cap on pre-boiler needs to be replaced and re-drilled

Goals for the Rest of the Semester

- Complete control circuit
    - Approx. completion date: Mar 11
- Obtain ethanol
    - Approx. completion date: Mar 13
- Obtain new end cap and re-drill holes for pre-boiler
    - Approx. completion date: Mar 16
- Install piping between pre-boiler and main boiler
    - Approx. completion date: Mar 18
- Test boilers independently of rest of the system
    - Approx. completion date: Mar 23
- Integrate boiler system with rest of refrigerator
    - Approx. completion date: ???

Diagram of Independent Test Setup for Boiler System

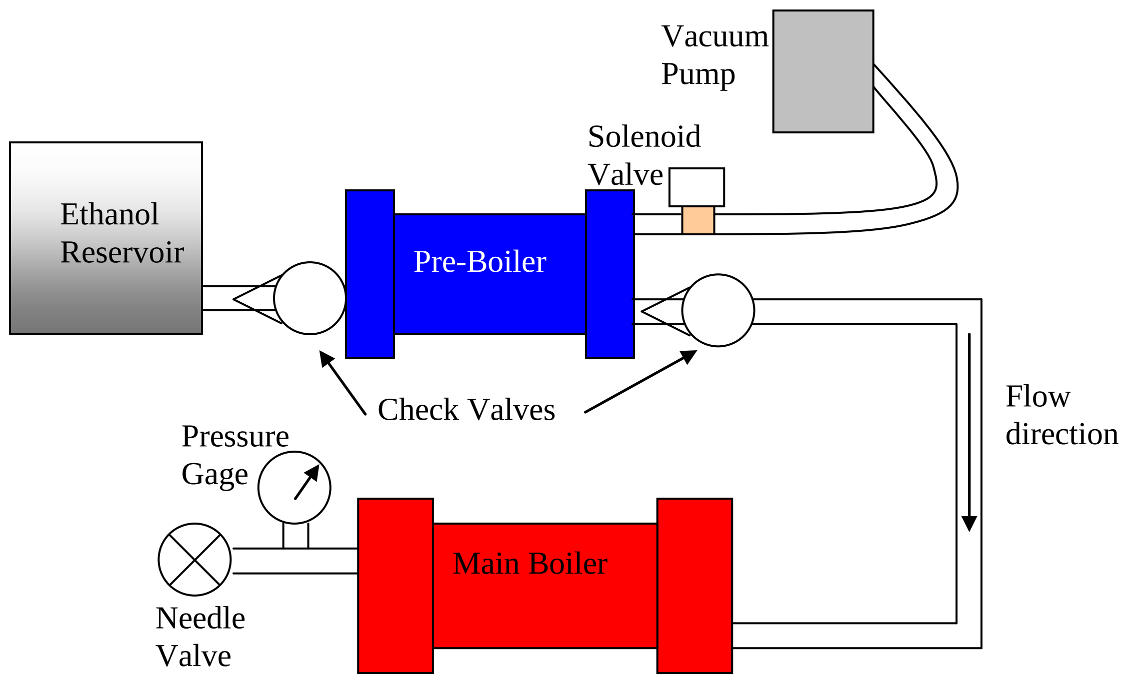

Fig 1 – Independent test setup for boilers

Theory and Test Procedure

We're using ethanol as a test fluid because it takes less energy to boil than water does and is readily available, but won't discharge all over the lab if something isn't sealed properly like R-134a will. Our primary goal with this test setup is to test the mechanical aspects of the boiler system, not to refine the thermodynamic properties. Bottom line: we just want to make sure that it physically works.

We will fill the system with ethanol and turn on the resistance heaters in the boilers. When the pressure in the pre-boiler is greater than the pressure in the main boiler, the preboiler will discharge into the main boiler. When the per-boiler is empty, the float sensors inside will cause the solenoid to actuate, opening the solenoid valve. The vacuum pump on the other end of the solenoid valve will cause a negative pressure to build up in the pre-boiler, drawing in ethanol from the reservoir. When the pre-boiler is full, the float sensors will close the solenoid valve, ending the negative pressure build-up. The cycle then repeats itself.

Diagrams of Main Boiler, Pre-Boiler, and Float Sensor

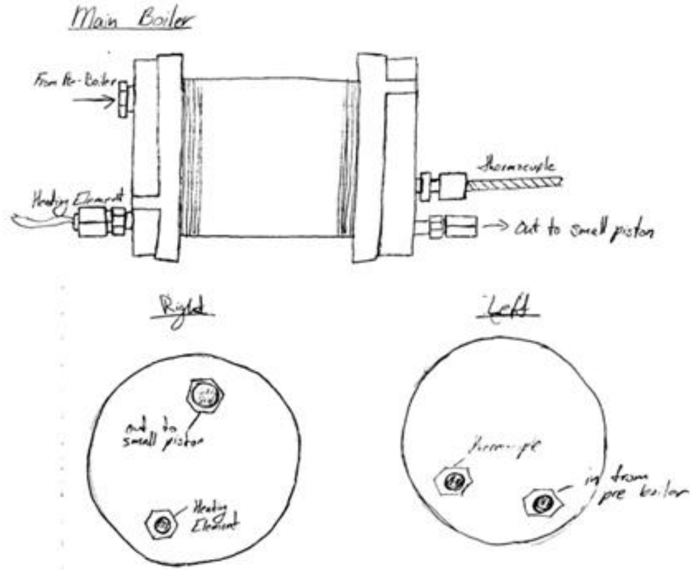

Fig 2 – Main Boiler Diagram

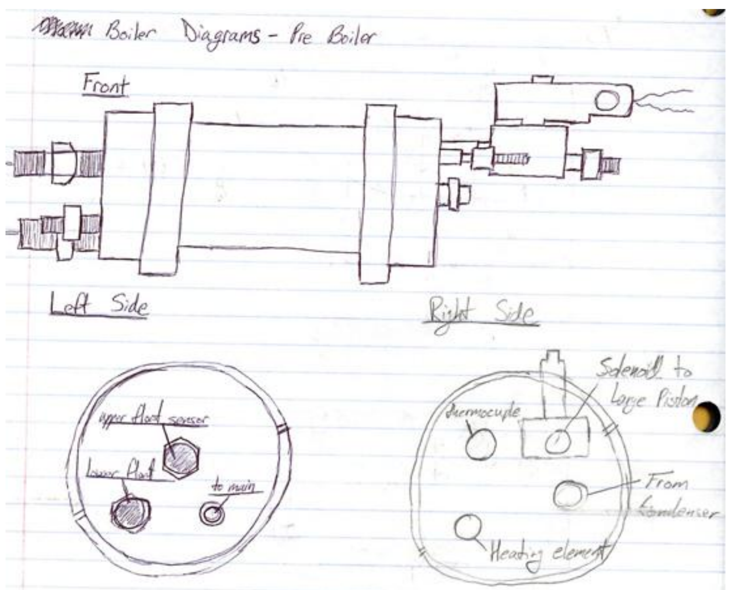

Fig 3 – Pre-Boiler Diagram

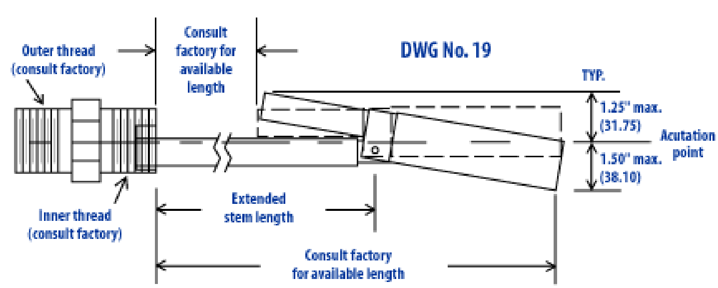

Fig 4 – Float Sensor Diagram

PIPING SYSTEM:

The main goal of this subgroup is to connect the components correctly so that the cycle runs properly. This goal is achieved by first determining how the components ought to be connected (i.e. which component is connected to what other components). Below is the outline of the goals and associated obstacles.

Goal 1: Determine how the cycle components need to be connected.
Goal 2: Determine what is needed to connect the components and obtain these supplies.

Problems:

a) what diameter tubing to use
b) which type of fittings to use
c) where to get the tubing and fittings
d) getting the tubing and fittings (receiving the order)

Goal 3: Connect the cycle components.

Problems:

a) how to connect tubing to mangled condenser outlet (compression fitting, soldering, flanged fitting)

Below are the week-by-week accomplishments of the subgroup.

Week 2-3:

The first activities after being divided into groups was for the Piping Group to understand how the system operates and how the tubing is used to connect the various components together. After analyzing the schematic diagram and the T-s diagram of the cycle we connected the components together using metal wire to visualize how the system operates. From this understanding of the cycle we used AutoCAD to draw up a schematic diagram of the components and all of the tubing connections.

Next, we determined which portions of the cycle would use liquid as the working fluid and which parts would use vapor as the working fluid. From this information we determined that two different diameter tubing sizes would be needed. We chose the vapor tubing diameter to match that of the evaporator outlet tubing and the liquid tubing diameter to match that of the condenser outlet tubing.

Week 4:

We measured all of the inlets and outlets of each of the components and made a list of fittings needed to connect the components. We decided that compression fittings would be the easiest to use, rather than flanged fittings since we do not have a flanging tool readily available to us. We decided to get the materials from McMacter Carr and ordered from them using the IPRO account.

Week 5:

We found that there were some problems with ordering using the IPRO account, so we switched the order to another account to expedite the process. With the fittings and tubing ordered we turned our attention to the mangled condenser outlet and considered how we might attach another length of pipe to it. We decided early on that the most likely solution would be soldering.

Week 6:

As best we could, we straightened the condenser outlet tube and tried to round it out so that the coupling connection used for soldering would fit tightly. We took the entire system over to the Machine Shop to have them solder a piece of tubing onto the condenser outlet. They were uncertain whether soldering would be effective because the condenser outlet tube was malformed. They suggested using a flanged fitting. After finding the appropriate size fitting, it was determined that this would not work because the fitting could not fit over the mangled tube. They then decided that the best course of action would be to solder the piece of tubing onto the condenser outlet and see if it would hold, and if it did not hold to then consider other options. The connection was then successfully soldered.

The following day the connection was pressure checked using compressed air and coating the exterior of the connection with liquid soap to indicate any air leakage. The connection did not indicate any air leakage when tested.

The tubing and fitting order was still not received at this time so we checked on what the delay was, but were not able to learn any reason for the delay. We also started a log of activities (and back dated it to the beginning of the semester) for the Tubing Group to keep track of our activities and make progress reports easier.

Week 7:

We were informed that the McMaster Carr order was not placed until March 1st—two weeks after it was given to the Purchasing Department. Amazingly the order was received the next day, March 2nd, but unfortunately we realized that we had not measured the pipe thread sizes correctly so most of the fittings had to be returned and a second order was placed after going to the Machine Shop and making sure we were measuring the pipe thread size correctly. We worked on bending the 5/16” tubing as much as we could with the limited fittings that we had correctly ordered.

Week 8:

We received the second McMaster Carr order on Tuesday and were able to bend and install all of the tubing that we are able to do at this point. The tubing from to and from the pre-boiler and main boiler is yet to be done. The next step is to pressure check the connections that we have made.

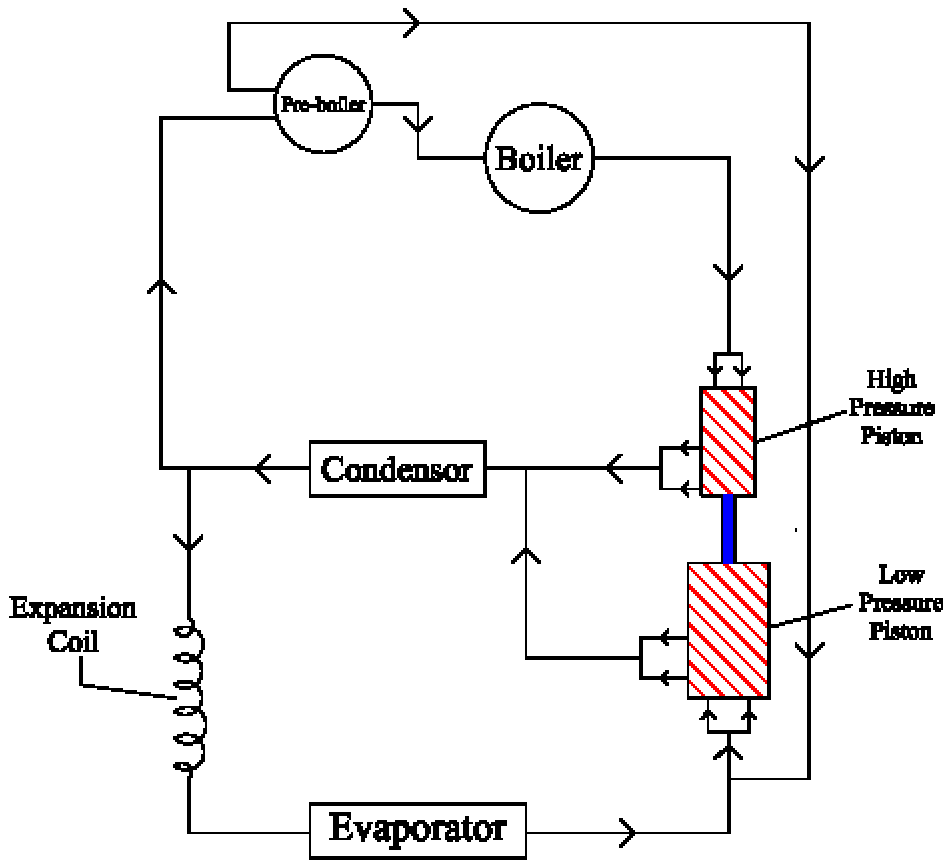

Figure 1 – Diagram of refrigeration process and necessary piping.

ELECTRICAL SYSTEM:

The main objective of the electronic control part is to control the four solenoid valves connected to the boiler in the system. The four solenoid valves in the system are controlled using magnetic sensors and programmable microprocessors. The position of the piston in the system is necessary to control the solenoid valve. Therefore, the four magnetic sensors are used to tell the position of the system. The magnet is attached to the piston and the sensors are fixed to the board just next to the cylinder. The figure below (Figure 1) shows the piston and magnetic sensors in the system

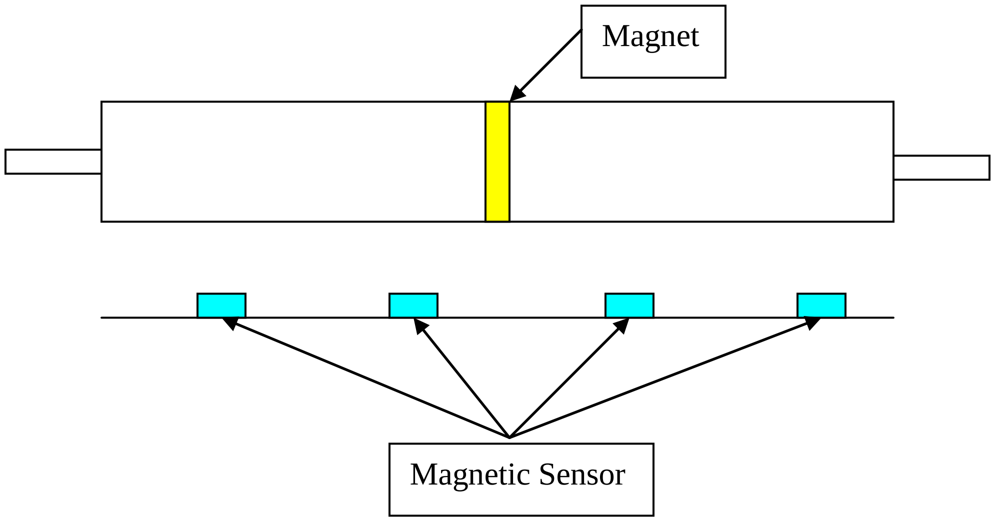

Figure 1 – Diagram of the magnetic sensors

Thus, when the magnet in the cylinder passes the magnetic sensor, it is possible to find the location of the piston. However, the signal from the magnetic sensor is too low, thus it was necessary to use an op-amp LM 324 as a comparator. Then, connecting the output signal from the op-amp to the microprocessor, the signal for controlling the solenoid valve was made for each cylinder position in the system, but the voltage to activate the solenoid valve was 120V(AC). Thus, it was necessary to find the appropriate transistor to control the solenoid valve because the voltage used in microprocessor on the control board is 5V. Because a transistor can be used like a switch, it is possible to control the high voltage(120V AC) for the solenoid valve, using the signal from the microprocessor. The power transistor IRF 510 was tested in the system, but it did not work. One of the reasons for that is assumed to be the lower maximum voltage in IRF 510 transistor. The voltage from the power is 120V, but the maximum voltage rating for the IRF 510 transistor is 100V. So the transistor became saturated, thus it might not work well. So another transistor, the IRF 620 with a higher maximum voltage rating, has been ordered and will be tried if it works or not as soon as possible. Figure 2 indicates the schematic diagram of the present control board.

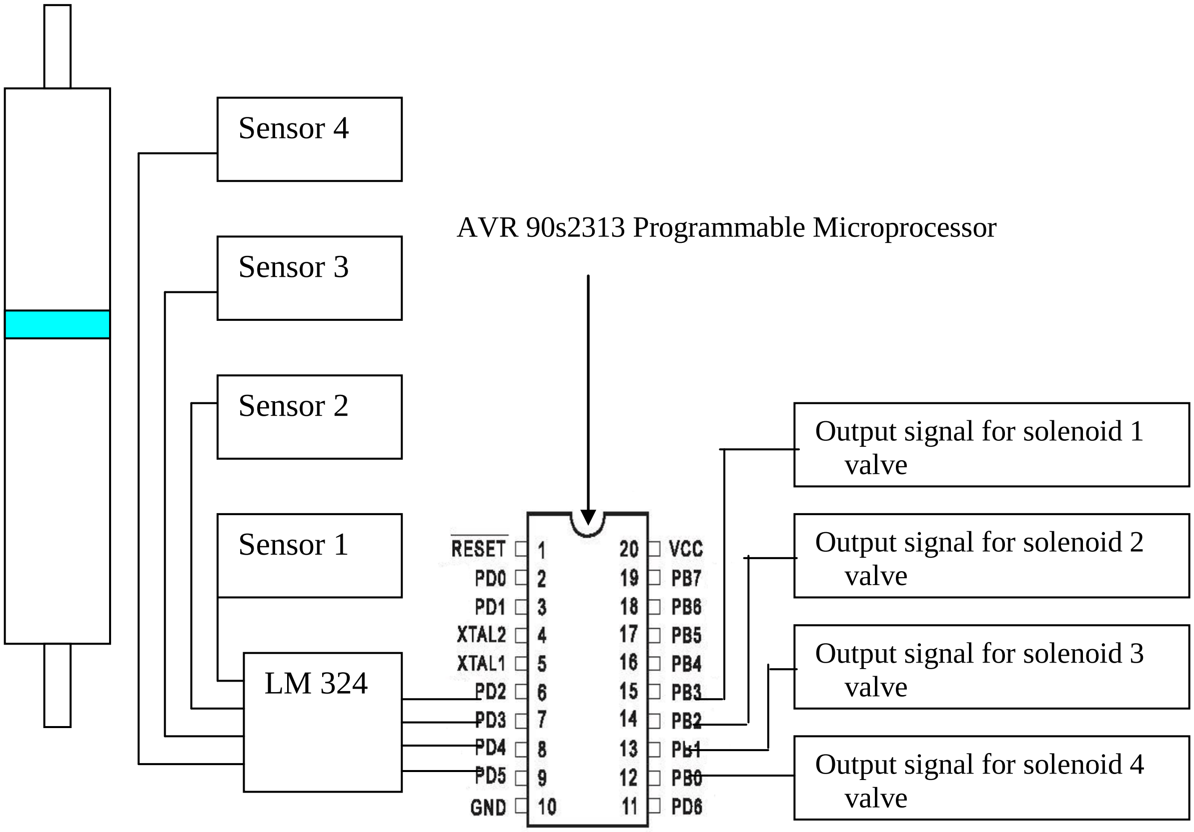

Figure 2 – Schematic of the programmable microprocessor

COMPUTER / DATA AQUISITION SYSTEM:

This subgroup had to acquire a computer, install and verify a data acquisition (DAQ) board, order a terminal board for the DAQ system, and develop a complimentary control system for the refrigeration cycle that can accommodate for optimization.

So far, a computer was assembled from spare computer parts found around the lab in E1 067. However, the only hard drive that was found was too small for the programs and operating systems needed to run the DAQ software (National Instrument's Labview). Therefore, an appropriate hard drive was ordered to fix this dilemma.

The next step has been the most difficult: verifying that our current DAQ board works with Labview. The DAQ board that we have is from a small company, ADAC, which says it is compatible with the Labview software. However, software issues have arisen, and we are currently working with the company to eradicate of this particular issue. Another problem concerning the DAQ system is that the terminal board (the board that is the interface between the computer and the process supplying data) was stolen from the lab. Thus is the reason for the next step of ordering a new terminal board once everything is verified that it works.

In the upcoming weeks, we will be working on developing a program to control and optimize the refrigeration process.