Mechanical Engineering Senior Design

Spring Semester 2013

Team 20: Solar Powered Phase Change Compressor

Restated Scope / Project Plan

Team Members:

Addsion Bender

Jesse Diaz

Emmanuel Ferdinand

Project Sponsor: Grant Peacock

Project Advisor: Dr. Juan Ordonez

Senior Design Coordinators: Dr. Kamal Amin, Dr. Chiang Shih

January 17, 2013

Executive Summary

In the previous semester a design concept was selected to meet the sponsor's need, and the design was developed so that a working prototype can be built by the conclusion of the current semester. The focus of the project is to create a compressor, designed to meet the requirements of a small refrigeration system, which can potentially be powered by solar generated steam.

The compressor which was designed in the fall consists of a pressure vessel with two chambers separated by an elastic membrane. One side will contain a controlled flow of steam that will cause the membrane to expand, thus compressing the refrigerant fluid on the adjacent side. Incorporating an electronically controlled valve to regulate the flow of steam will allow the membrane to reciprocate at the required frequency.

The major components for the project have been ordered, and construction of the prototype will begin as the components arrive. This will allow for time to test and revise the device so that a functioning prototype can be demonstrated at the senior design open house in April.

Project Scope

The focus of the project is to design a refrigerant compressor which is capable of being driven by solar-generated steam. The scope of the project is limited by resources available, a budget of $2,000, and the eight-month time frame. After conferring with the project sponsor, it was decided to focus on the design of a prototype compressor. The compressor is being designed to meet the system requirements of a small window-unit air conditioner. The most modest commercially available air conditioners have a cooling rating of 5,000 btu/hr, which is equivalent to 1465 W.

Since the project is mainly concerned with the compressor, an electrically powered steam supply will be used. This will simulate the best-case operating conditions and will allow for consistent test conditions to refine the prototype once it is constructed. The two major components of the prototype are the two-chamber compressor, and a electronic control circuit to regulate the steam valve.

Goals/Objectives

- Develop a functioning prototype by April 14, 2013.
- Compressor should admit R134a at 4°C, 338kPa and produce 33°C, 771kPa.
- The flow rate of R134a generated by the compressor should be 0.009kg/s.

Technical Plan

Orders have been placed for major components of the prototype, including steel for the compressor vessel, silicone elastomer for the membrane, valves, and a microcontroller to control the steam valve. These major components cost $743; the total project budget is $2000. As soon as the steel arrives, it will be provided to the college of engineering machine shop, along with engineering drawings so that it can be machined into the parts for the compressor.

Our team is working with Dr. Chuy, of the mechanical engineering department, to design a control circuit for the solenoid valve that will regulate the steam flow. This will require some basic programming, which should be within the capabilities of our team members.

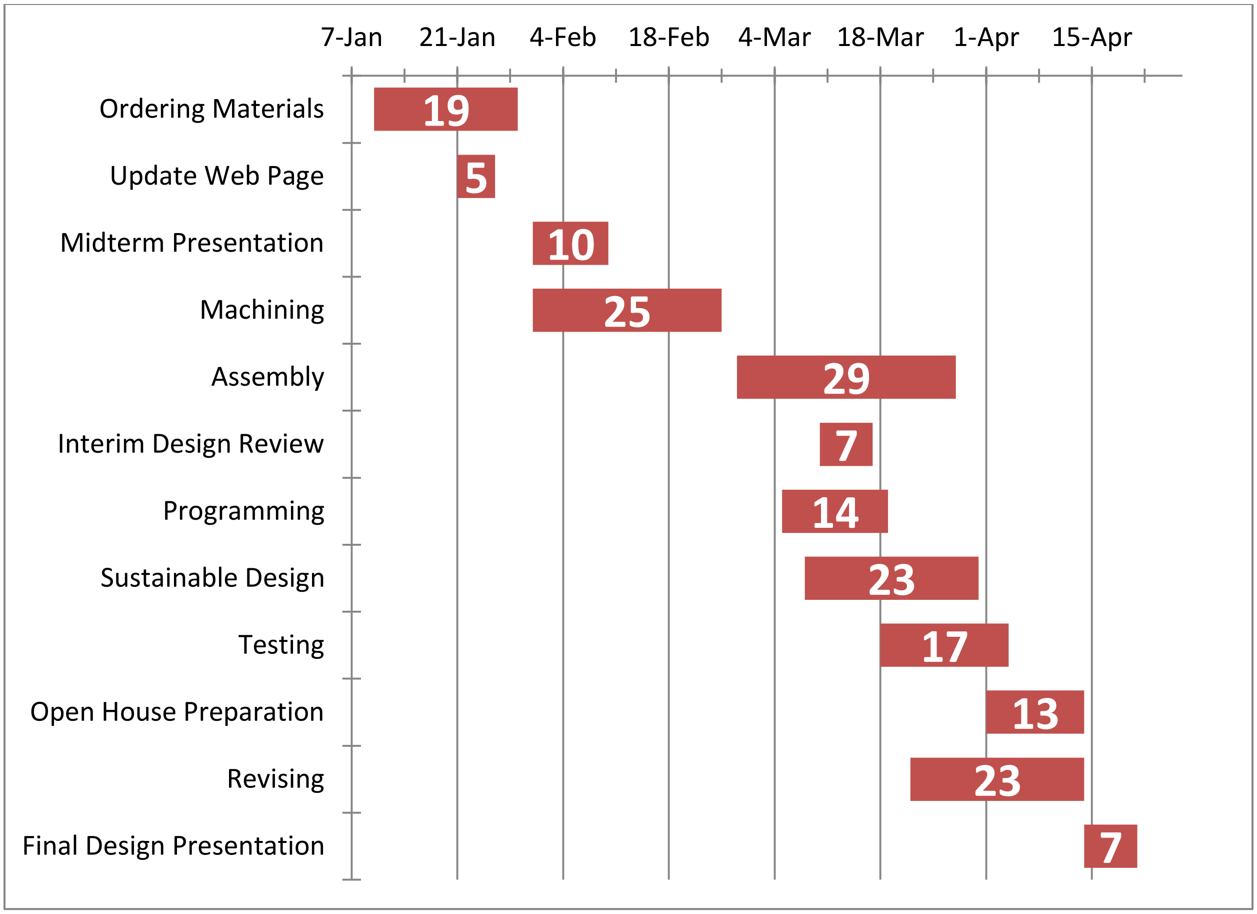
A challenge that remains to be addressed is how the device will be tested. To match the capability of a small air conditioner compressor, the unit must admit refrigerant at 4°C and 338kPa, and reject the fluid at 33°C, 771kPa. One possible option is to obtain a supply of R134a in which the temperature and pressure can be regulated. Another possibility is to connect the compressor to a closed-loop refrigeration cycle.

Spring Schedule

Over the course the of the 2013 spring semester, the team will order the materials, fabricate parts for and assemble the compressor, conduct testing to meet design requirements, and make any necessary revisions in order to affirm the design meets the system specifications. The team will order the main components of the design in the first week of the semester and then continue to order other necessary materials due to unforeseen changes.

All of the machining will take place at the College of Engineering under the supervision of the machine shop. Due to complexity of the solenoid valves, a microcontroller will be implemented. The programming of the valves, to regulate the flow of steam, will be conducted under the guidance of Dr. Chuy. By mid-semester, the team will focus on testing and revising the compressor until it meets the design requirements to power a small window A/C unit.

Tasks	Start Date	Duration (Days)	End Date
Ordering Materials	10-Jan	19	29-Jan
Update Web Page	21-Jan	5	26-Jan
Midterm Presentation	31-Jan	10	10-Feb
Machining	31-Jan	25	25-Feb
Assembly	27-Feb	29	28-Mar
Interim Design Review	10-Mar	7	17-Mar
Programming	5-Mar	14	19-Mar
Sustainable Design	8-Mar	23	31-Mar
Testing	18-Mar	17	4-Apr
Open House Preparation	1-Apr	13	14-Apr
Revising	22-Mar	23	14-Apr
Final Design Presentation	14-Apr	7	21-Apr


7-Jan
21-Jan
4-Feb
18-Feb
4-Mar
18-Mar
1-Apr
15-Apr
Ordering Materials
19
Update Web Page
5
Midterm Presentation
10
Machining
25
Assembly
29
Interim Design Review
7
Programming
14
Sustainable Design
23
Testing
17
Open House Preparation
13
Revising
23
Final Design Presentation
7

Expenditure Report

Purchase Orders Submitted to Mechanical Engineering Department on 1-14-13.

Microcontroller: Arduino Uno R3, **Catalog #:** 276-128

- http://www.radioshack.com/product/index.jsp?productId=12268262

Price	$34.99
Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz

Control Valve: ASCO Solenoid Valve, Steam/Hot Water, 3/4 In, #**4NWZ8**

- http://www.grainger.com/Grainger/wwg/search.shtml?searchQuery=4NWZ8&op=search&Ntt=4NWZ8&N=0&GlobalSearch=true&sst=subset

Price (ea.)	**$312.50**
Brand	ASCO
Mfr. Model #	8220G409
UNSPSC #	40141605

Diaphragm: 3/8” High Temperature Silicone Rubber Sheet

- http://www.rubbersheetroll.com/silicone-rubber-commercial-grade.html
- 12”x12”x0.375”
- $113.56

¼” Ultra-Strength Silicone Rubber

- http://www.mcmaster.com/#standard-rubber-sheets/=l0pcv3
- Temperature Range: -80° to +400° F, Tensile Strength: 1,200 psi
  Rubber only (not adhesive) meets MIL-ZZR-765, Class 2A and 2B. Adhesive is acrylic and has a temperature range of -20° to +180° F. Width and length tolerances are ±1/8" for 6" × 6" and 12" × 12" sheets and ±3/8" for 24" × 24" sheets. Durometer hardness is 50A (medium). Durometer tolerance is ±5.

6”x6”x1/4"	±0.020"	5787T35	$10.18

Steel:

6" Long

Dia.	Dia. Tolerance		Each
6"	-0.005"	7786T78	$155.82

- http://www.mcmaster.com/#standard-steel-rods/=l0pej4

- Yield Strength: 54,000
- Hardness: Not rated
- Can be surface hardened to C60
- Meet ASTM A108
- Material is 1018 carbon steel. Have a length tolerance of ±1/16".

Refrigerant Check Valves

High-Use Bronze Check Valves

- Use with water, oil, inert gas, air, steam, diesel fuel, and gasoline
- Max. Pressure:
  Class 125: Water, Oil, and Inert Gas: 200 psi @ 150° F; Steam: 175psi @ 353° F
  Class 300: Water, Oil, and Inert Gas: 1,000 psi @ 150° F; Steam: 520psi @ 421° F
- Temp. Range:
  Class 125: -20° to +406° F
  Class 300: -20° to +450° F
- Designed to withstand the frequent opening and closing of pulsatingflow. A threaded cap provides easy access for maintenance. Body and seal are bronze, except 4894K47 has a brass seal. At least 2 psi is required to open valves. Install for horizontal or upward flow. Meet MSS-SP-80. Connections are NPT female.

Class 125

Pipe Size	Lg.		Each
1/2	2 3/16"	4894K47	$52.62

Steam shut off valve

- Max. Pressure for Water, Oil, and Inert Gas:
  1/4"-2": 600 psi @ 100° F
  2 1/2"-4": 450 psi @ 100° F
- Max. Pressure for Steam: 150 psi @ 366° F
- Temp. Range: -50° to +400° F
- Vacuum Rating: 29.9" Hg
  1/2" 2 3/4" 47865K43 $11.18

Total Expenditures to date: $743.47
(Does not include shipping cost.)