Mechanical Engineering Senior Design

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Team 20: Solar Powered Phase Change Compressor

Operation Manual

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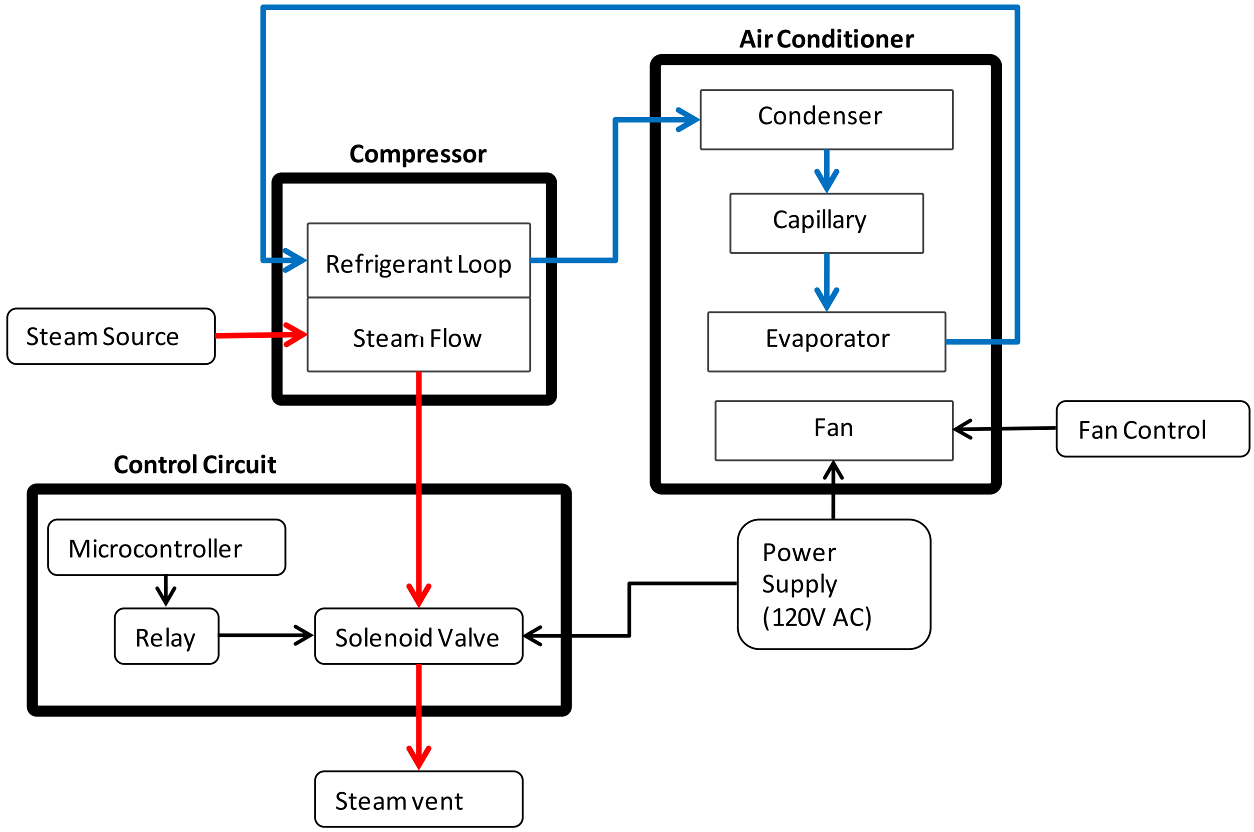
System Overview – Functional Analysis



The prototype steam-driven refrigerant compressor system described in this manual contains three major subsystems (outlined in the bold rectangles): The compressor, air conditioner, and control circuit.

The compressor contains two separate fluid flows, which are mechanically coupled by an elastic membrane. The steam flow (red arrows) is supplied by a source which models a high-pressure solar-generated steam supply. A solenoid valve regulates the flow of steam, allowing pressure to periodically build up in the lower chamber of the compressor then vent to ambient conditions.

The solenoid valve is regulated by the control circuit which contains an Arduino microcontroller, solid-state relay, and the solenoid which actuates the valve. A code is uploaded to the microcontroller which controls the valve duty cycle. Based on the model for the membrane deflection in (Fall Report), the initial period will be 1s: 0.5s closed, 0.5s open.

As the steam causes the membrane to do work on the refrigerant, it will be pumped through the air conditioner (blue arrows). According to the design, the refrigerant should leave the compressor, as a superheated vapor near 800kPa. As it flows through the air conditioner components, with heat transfer enhanced by the fan, it should return to the compressor as a two-phase mixture near 400kPa.

Operating Procedures

The start-up of the compressor will begin with confirming all components are present with a checklist. This is to ensure that all safety parts are properly fitted and a high temperature safety tube releases steam into a safe area. Before testing is conducted, the necessary supervision is recommended in order to operate the electric boiler. The connection between the boiler and the pressure vessel will be coupled with a high-pressure cable supplied by FSU's Energy and Sustainability Center.

To control the flow of steam, a single-board microcontroller will control the frequency at which the steam is cycled. The start-up of the control circuit will consist of a USB cable connecting the Arduino platform to the computer, which contains the program. A jump cable and wires will connect the Arduino to the input side of the solid state relay. The positive side will be connected to pin 9, in order to ensure smooth switching using pulse width modulation and the negative side will be connected to ground. The relay is the intermediate stage between the Arduino and the solenoid valve. The solenoid valve will be connected to the load side of the solid state relay, with the previous positive and negative conditions satisfied. The power of the system will be plugged into the wall and will be connected to the Arduino.

The boiler set-up and start-up will be conducted under the supervision of the ESC. The data acquisition system will consist of a pressure transducer that will generate pressure readings of our refrigerant that is being pumped through the air conditioning unit. The pressure data that is collected will be used to verify whether the compressor is producing the optimal. Since the pressure is the ultimate property in order to sustain a working prototype, it will be monitored and adjustments will be determined with respect to the live readings. The frequency of the steam valve will be controlled through the Arduino and will be increased if the pressure is too low and decreased if the pressure is too high through the program, by altering the delay of the valve between 'open' and 'close'.

To shut down the system after testing has ended, the steam flow must be concluded. Next, the high pressure connection hose between the compressor and the electric boiler will be disconnected. The high pressure safety hose will be removed from the compressor and cleaned out. The control circuit will be disconnected from the solenoid; followed by the breakdown and shutdown of all electrical components.

Product Ratings& Design Conditions

The following operating conditions are based on the design to achieve refrigerant compression of 400kPa (58 psi).

Product Specifications		Operating Conditions
- Dimensions		
o Length	18 in	
o Width	6 in	
o Height	6 in	
o Compressor Thickness	0.35 in	
o Membrane Thickness	0.5 in	
- Pressure Vessel		
o Compressor Chambers	1018 Mild Steel	
▪ Hoop Strength	53600 psi	0 - 116 psi
o Membrane	Silicone rubber	
▪ Temperature range	15 - 273°C	25 - 178°C
- Valves		
o Check Valve(2)		
▪ Temperature range	-6 to 407 °C	4 - 33°C
▪ Max Pressure	200 psi at 65 °C	116 psi
o ASCO Solenoid Valve		
▪ Max Temperature	178 °C	178 °C
▪ Max pressure differential	125 psi	
▪ Power	10.1 W	
o Globe Valve		
▪ Temperature range	10 to 204 °C	
▪ Max Pressure	150 psi at 185 °C	
o Relief Valve(safety)		
▪ Temperature range	-26 to 207 °C	178°C
▪ Set Pressure	150 psi	

Maintenance Concerns

The component which is most likely to fail is the membrane. Further revisions of the prototype will require thorough testing to determine how the membrane material properties are affected by the high-repetition cyclical loading. If the membrane ruptures, refrigerant would be released to the atmosphere, which should be avoided. The membrane must be replaced before this occurs.

The process of preemptively replacing the membrane would involve first evacuating and reclaiming the refrigerant from the system. When this has been done, the bolts that clamp the membrane between the two chambers of the compressor can be removed. A new membrane can then be aligned to the holes and the compressor bolted back together.