Senior Design Team 20
Solar Powered Phase-Change Compressor

Interim Design Review
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Project Definition

- Need Statement: Design a compressor for a refrigeration system that can be powered by solar energy.
- Objective: 5,000 BTU/hr of cooling (1465 W)
- Solar-Thermal Driven
- Project Budget: $2000

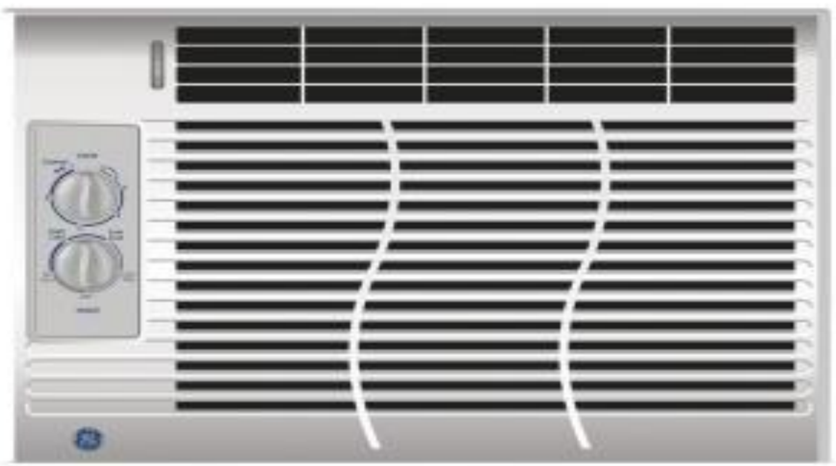
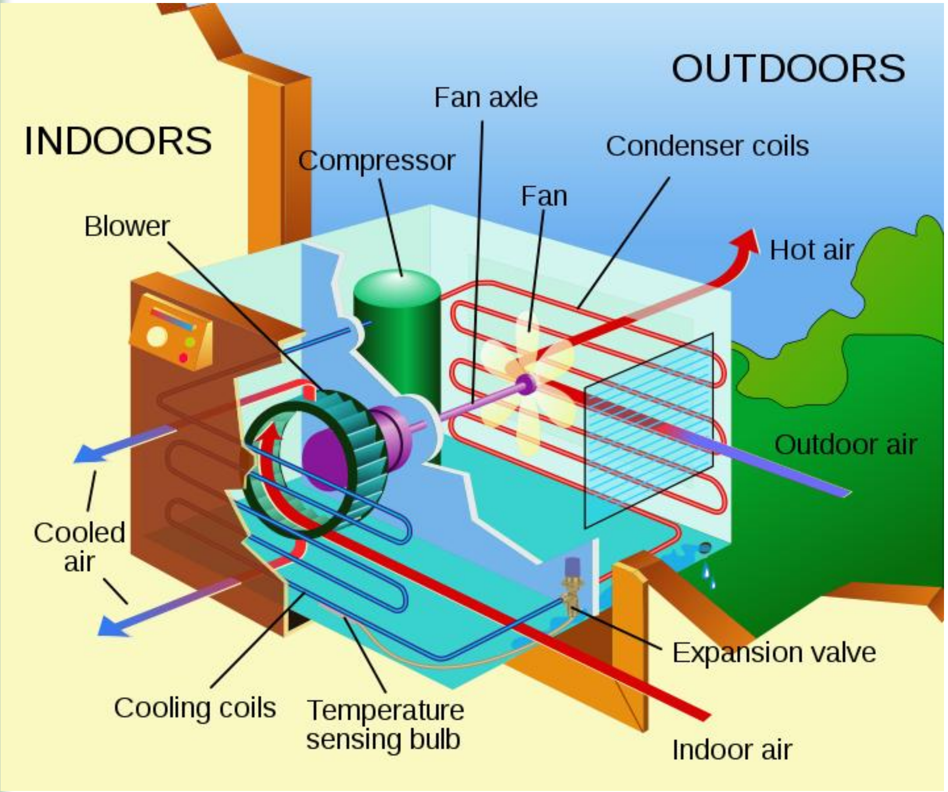
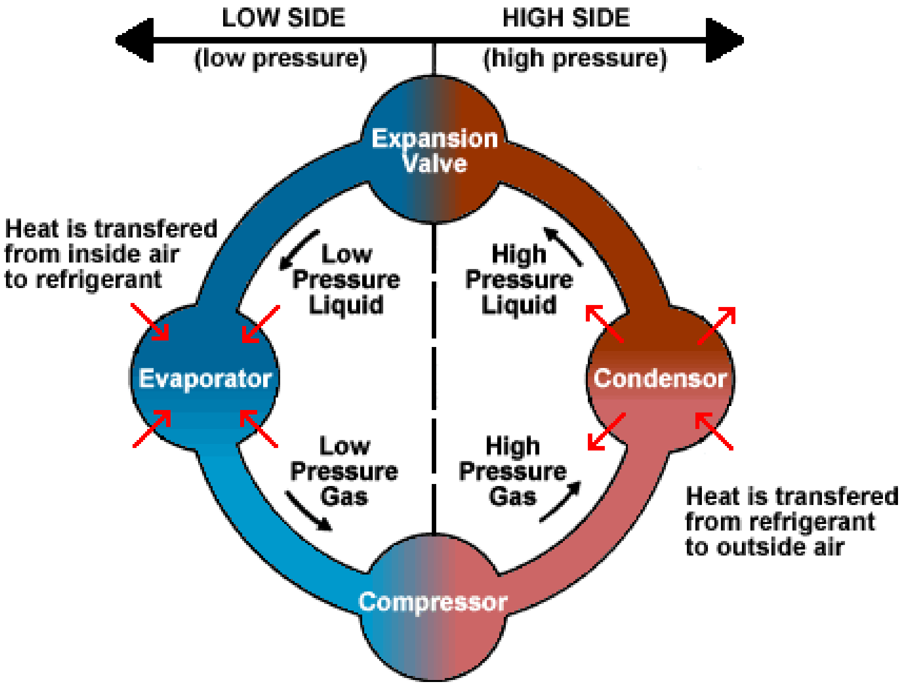


Figure 1: GE 115 Volt 5,000 BTU A/C

A/C Refrigeration Cycle





Refrigeration Selection

- Pressure created by compressor limited by the solar-steam pressure.
  - Not as high as typical electrical compressors.
  - Lower frequency

- Refrigerants used in air Conditioning
  - R22 No longer commercially available
  - R410a Requires High Pressure
  - R134a Low pressure/automobile use (for small spaces)

Refrigeration Selection

- P_H is the pressure on the condenser side and depends on the temperature outside
  - 190 psi < $P_{H\text{-}R22}$ < 250 psi (Cp= 0.65 KJ/Kg*K)
  - 100 °F < $T_{H\text{-}R22}$ < 120 °F (Pressure –Temperature chart)

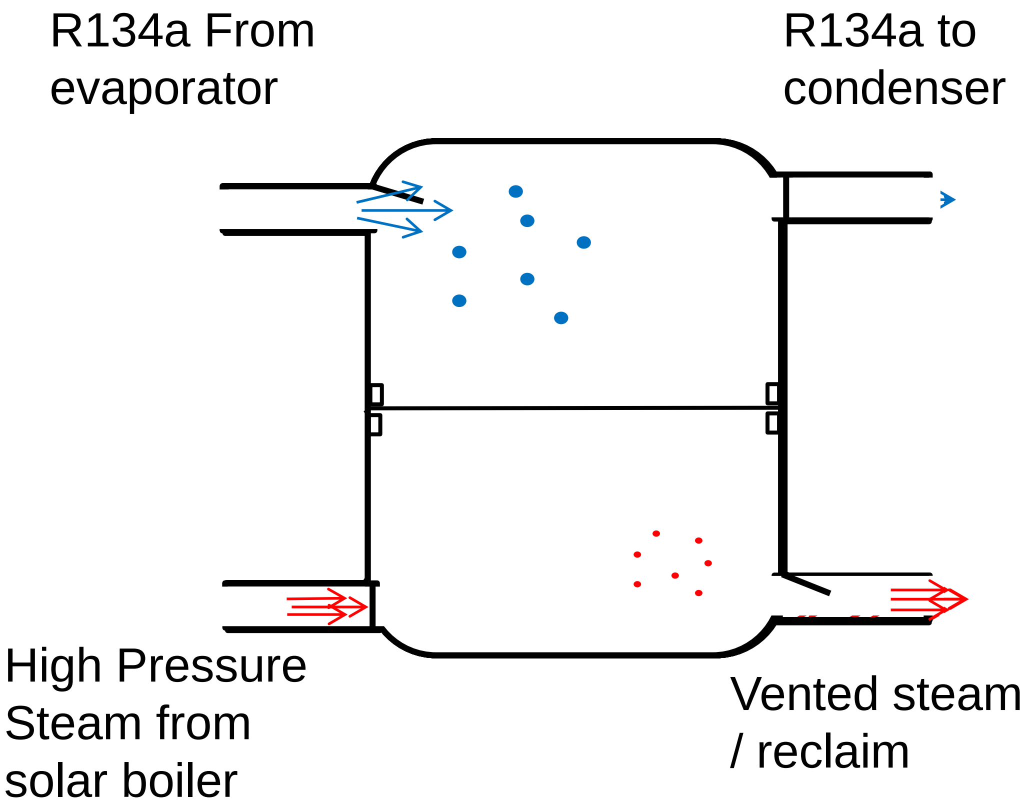
  - $Q=mC_p\Delta T$

  - 75 °F < T < 90 °F (Pressure –Temperature chart)

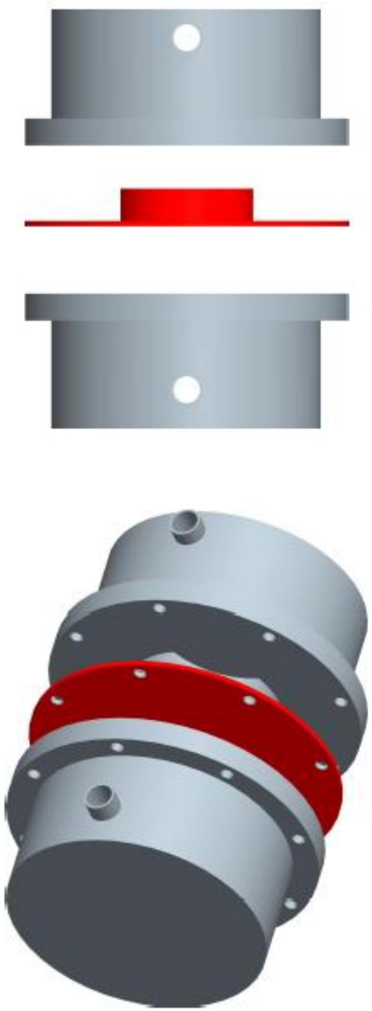
  - 218 psi < $P_{H\text{-}R401a}$ < 274 psi (Cp= 0.87 KJ/Kg*K)
  - 78 psi < $P_{H\text{-}R134a}$ < 104 psi (Cp= 0.84 KJ/Kg*K)
- R134a is best choice because of low vapor pressure

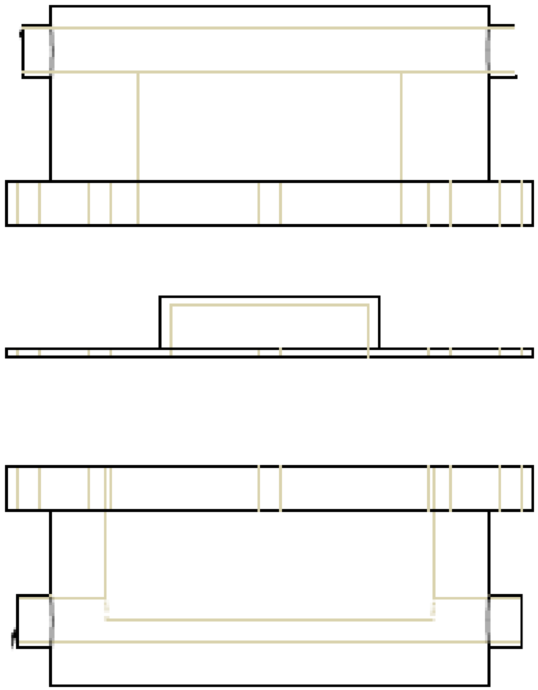
Compressor Concept

- Pressure from boiler raises the membrane and compresses refrigerant.
- Steam is vented and refrigerant is drawn into compressor.
- Vent is closed, cycle repeats.

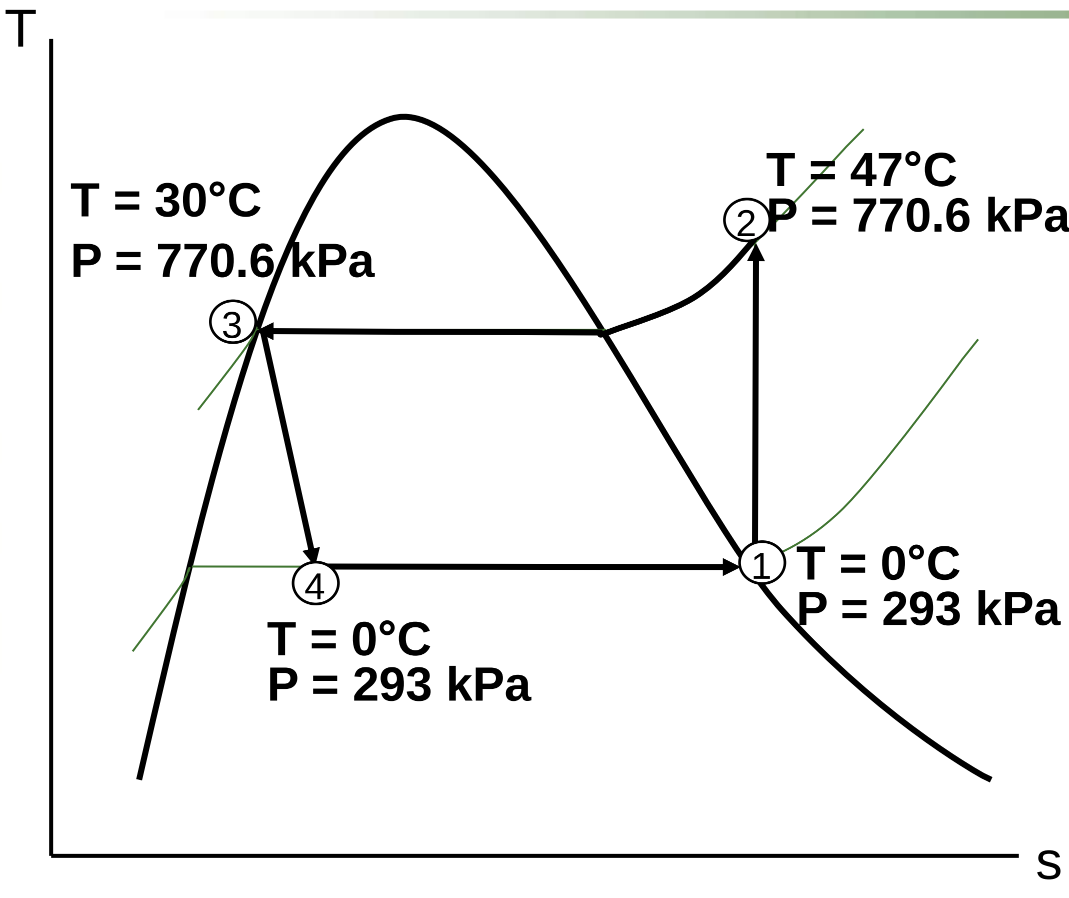


Compressor Concept





Thermodynamic Model: Ideal Vapor-Compression Refrigeration Cycle



- T3 (condenser) is limited by surroundings (86°F)
- Saturated liquid, P3 = 770.6 kPa

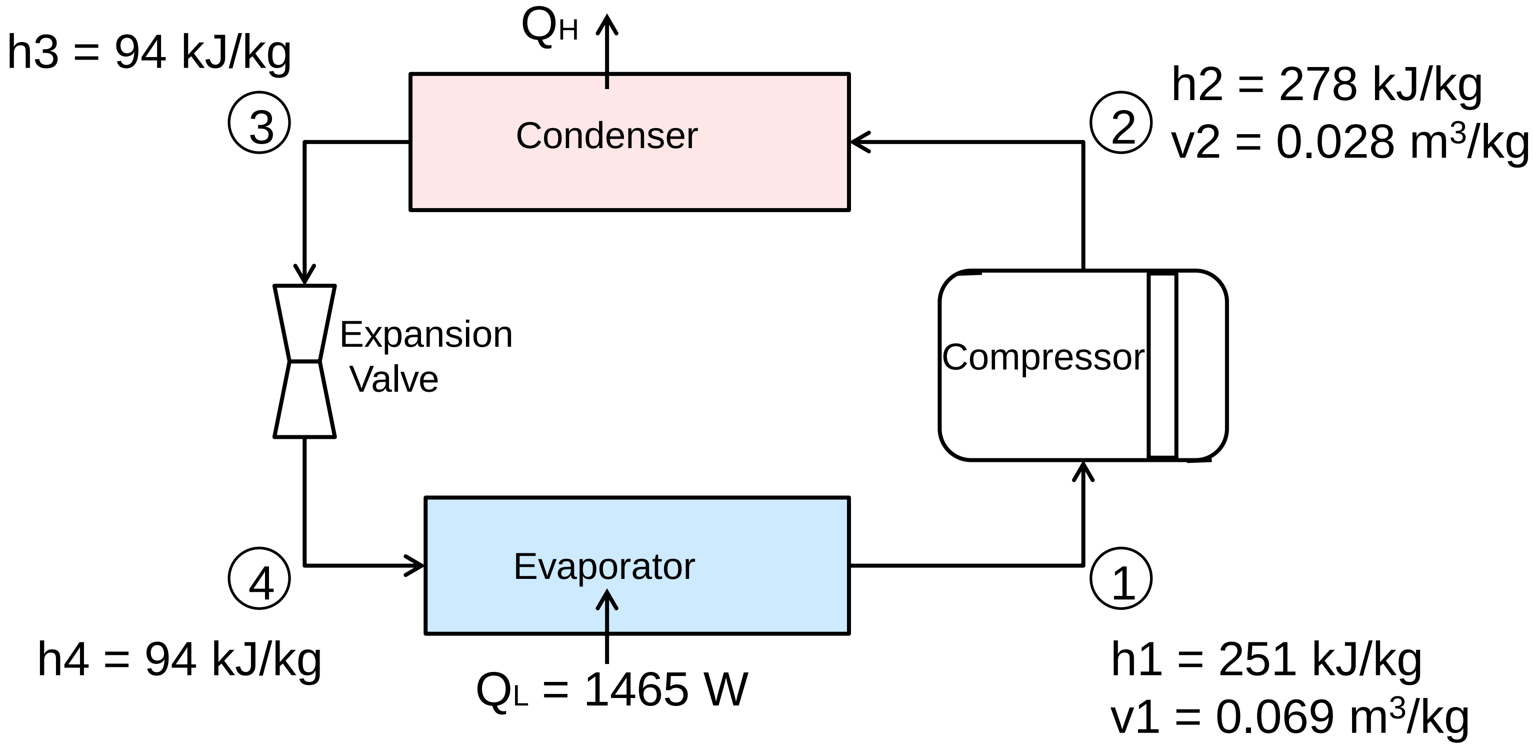
- 2 →3 isobaric, P2 = P3

- Lower T limit, arbitrary. T1 = 0°C
- Saturated vapor, P1 = 293 kPa

- 1 →2 isentropic, T2 = 47°C

- 4 →1 adiabatic.

Thermodynamic Model: Ideal Vapor-Compression Refrigeration Cycle



$Q_L = m(h1 - h4)$

$m = 0.009$ kg/s

Membrane Displacement Calculation

$V = (m \cdot v) / f$

Assume device capability, $f = 1Hz$

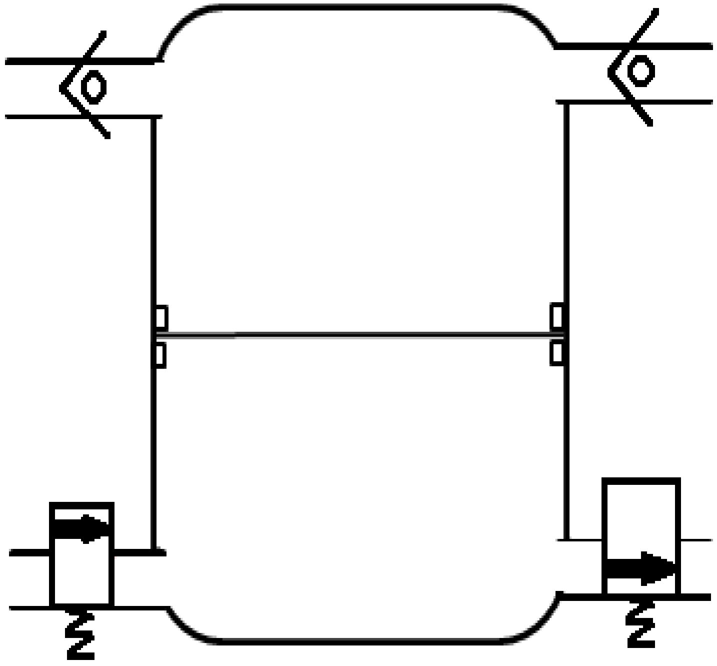
$m = 0.009$ kg/s

$v_{avg} = 0.049$ m^3/kg

$V = 4.41 \times 10^{-4}$ m^3 :Required Displacement

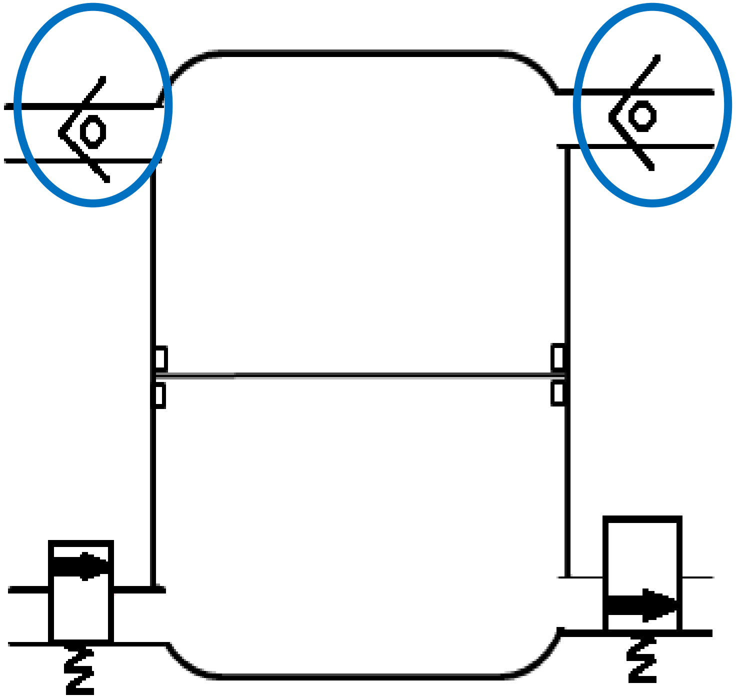
Compressor Valves

- Control flow of fluid
  - Check valves
  - High frequency valves
- Designed for efficiency
  - Minimum pressure loss
  - Maximum reliability



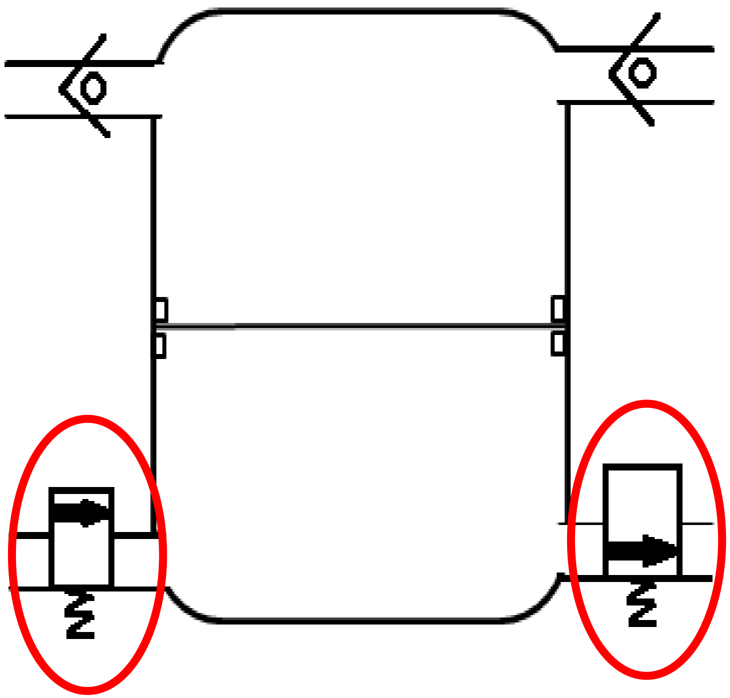
Check Valves

- Fluid only flows in one direction
- Two-port valves
- Operates automatically
  - No need for external control
  - Allows flow once it reaches its “cracking pressure”



High Frequency Valves

- Solenoid valve
  - Electromechanically operated valve
  - Fast and safe switching between “suction” and “discharge”
- Steady Flow
  - High frequency simulates steady flow
  - Necessity for compressing the refrigerant



Electric Steam Boiler

- Simulates solar powered steam generation system
  - Easily controlled
  - Adjusts to multiple fittings
- Produces up 80 kg/hr at 650 C

Challenges / Updates

- Advised not to work with refrigerant fluid – hazards and expense
- Focus on compressor
  - Design for refrigerant conditions
  - Test by compressing air

- Design Tasks
  - Membrane material selection
  - Pressure vessel design
  - Valve selection / control

REFERENCES

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