Senior Design Team 20
Solar Powered Phase-Change Compressor

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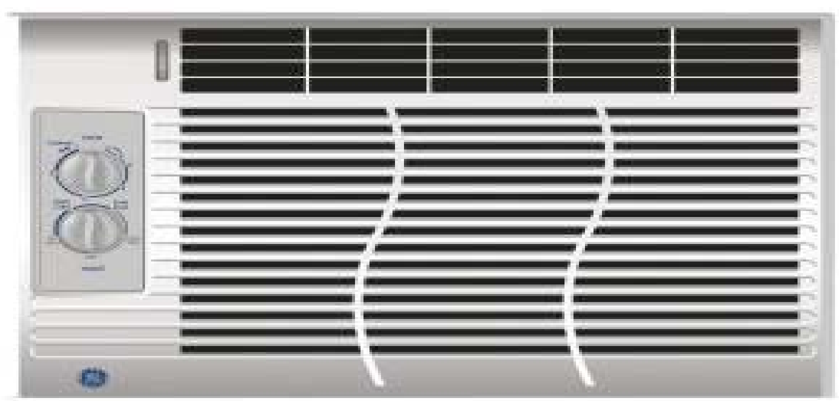
Project Definition

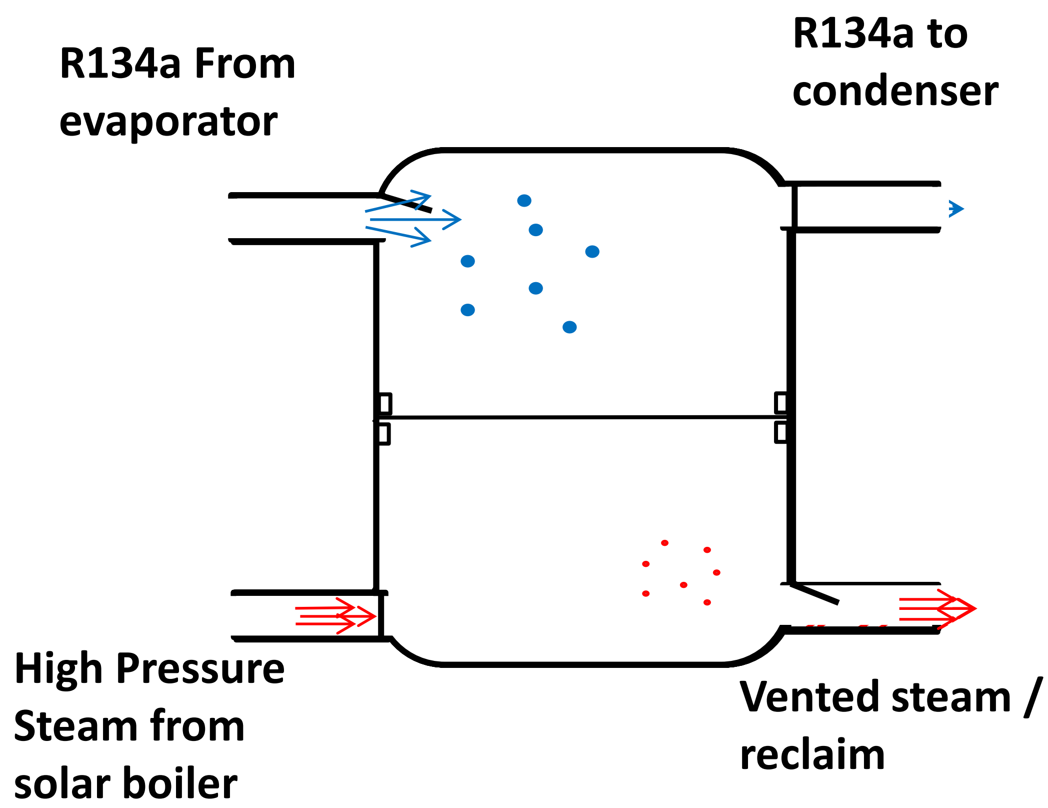
- Need Statement:

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

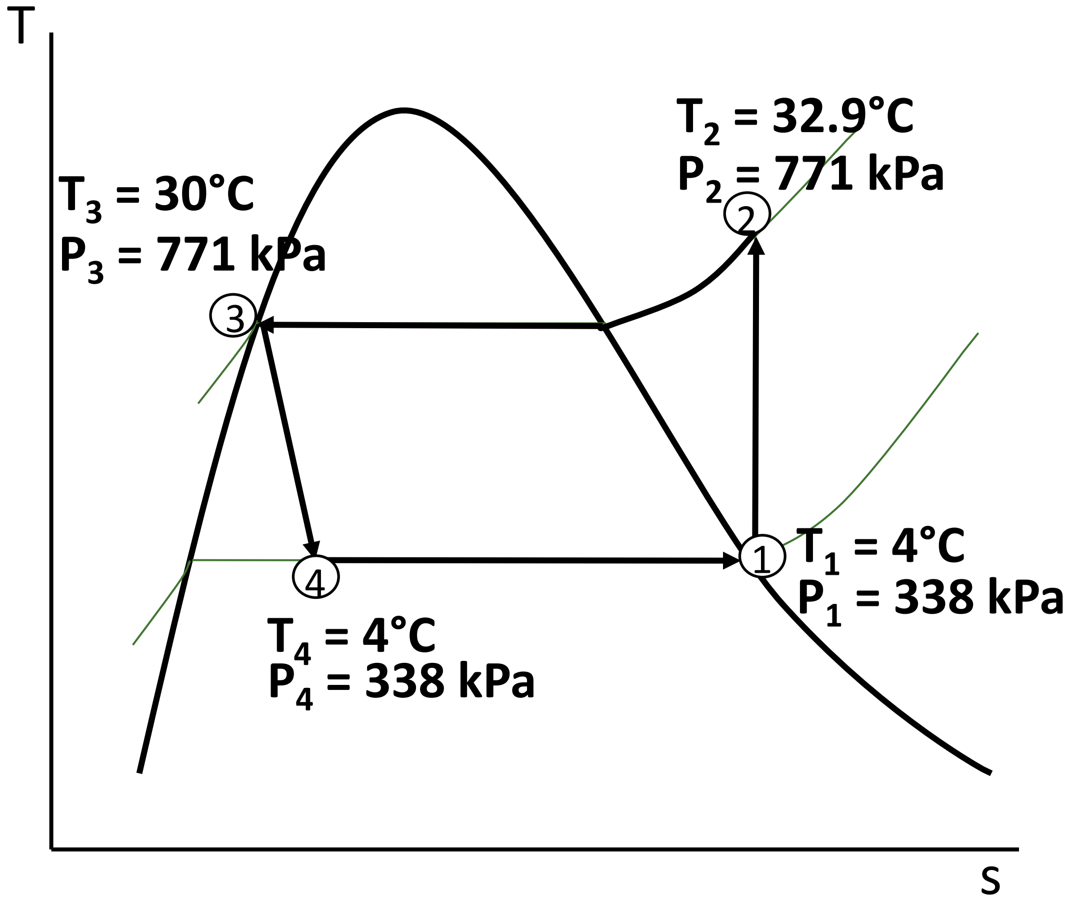


Design Concept

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



Thermodynamic Model: Refrigeration Cycle

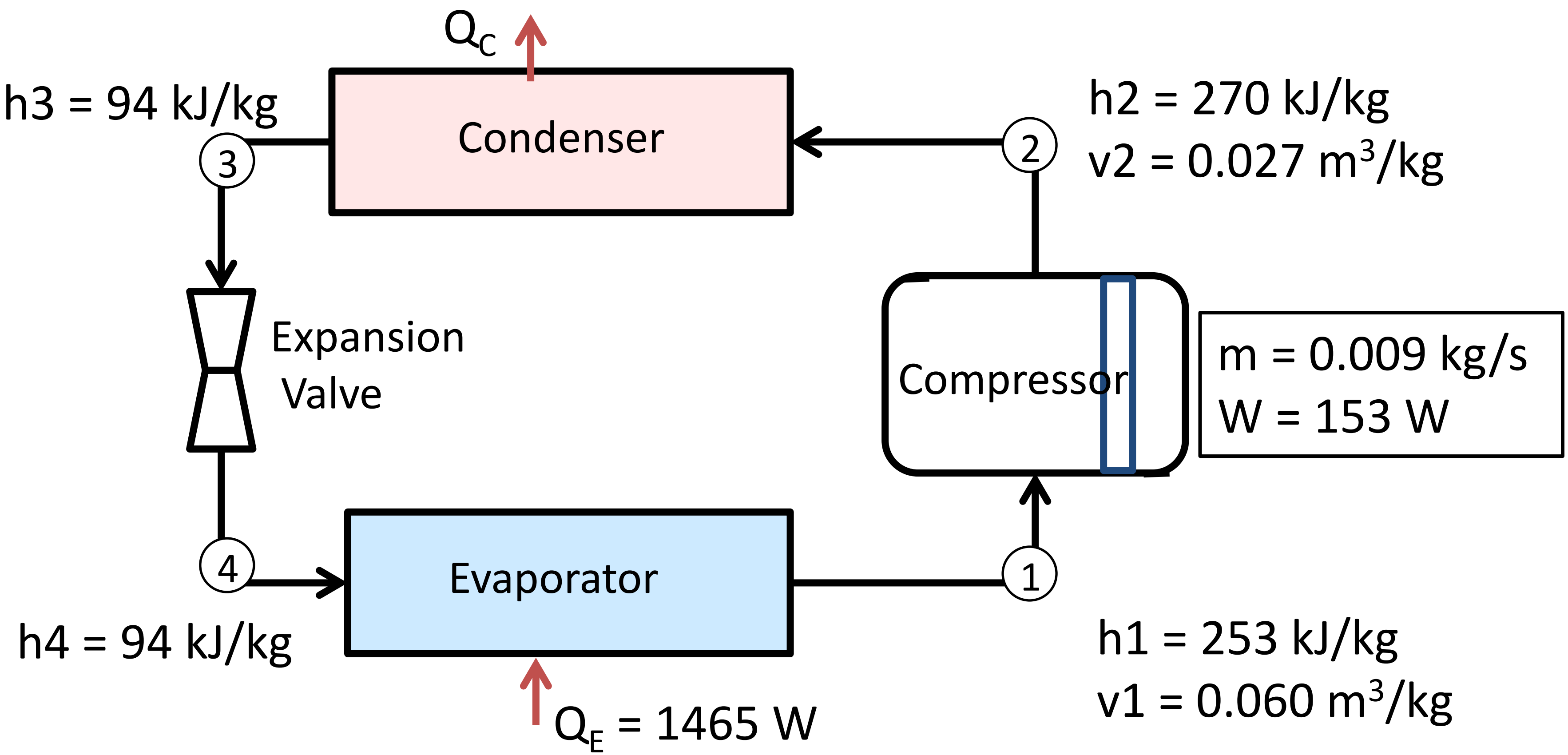


R134a Ideal Vapor-Compression Refrigeration Cycle

- Isentropic compression
- Isobaric heat rejection
- Adiabatic expansion
- Isobaric heat absorption

- Pressures are limited by T of environment
- ΔP = 433 kPa

Thermodynamic Model: Refrigeration Cycle



$$QL = m(h1 - h4)$$

$$m = 0.009 \text{ kg/s}$$

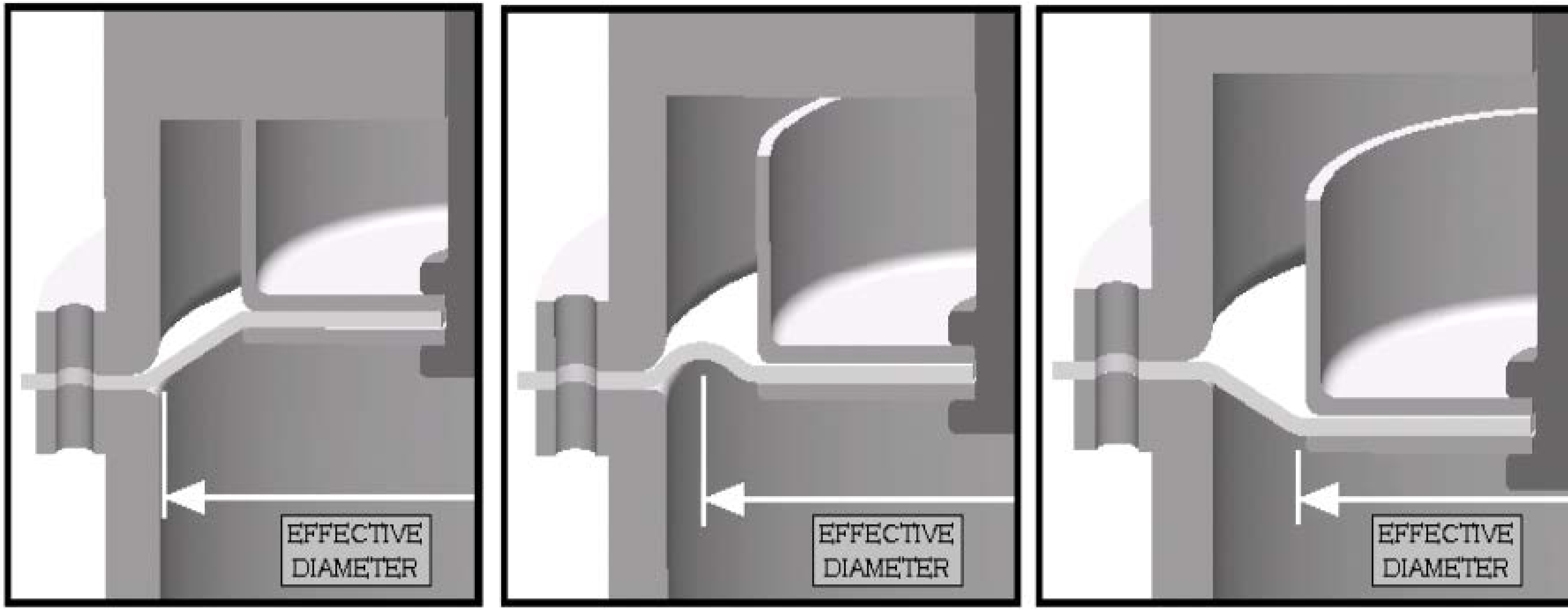
Selecting Diaphragm

- $V = (m \cdot v_{avg}) / f$

- Valve capability: max 200Hz, 500×10^6 cycles
- $f = 2Hz$
- $m = 0.009\ kg/s$
- $v_{avg} = 0.037\ m^3/kg$

- $V = 1.67 \times 10^{-4}\ m^3$:Required Displacement

Selecting Diaphragm



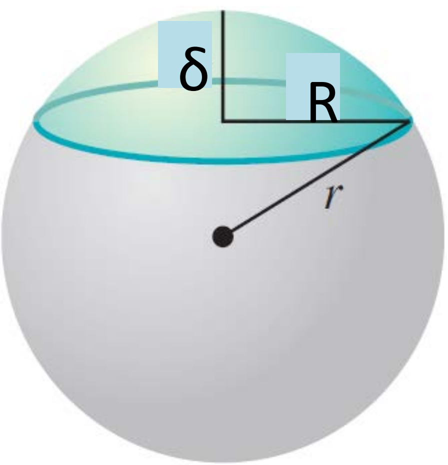
Selecting Diaphragm

- Elasticity of material is used to predict deflection when loaded

$$\delta = \frac{3}{16}(1-\nu^2)\frac{P\ R^4}{E\ t^3}$$

- Silicone elastomer selected for high temperature tolerance
- $\delta/D < 0.25$

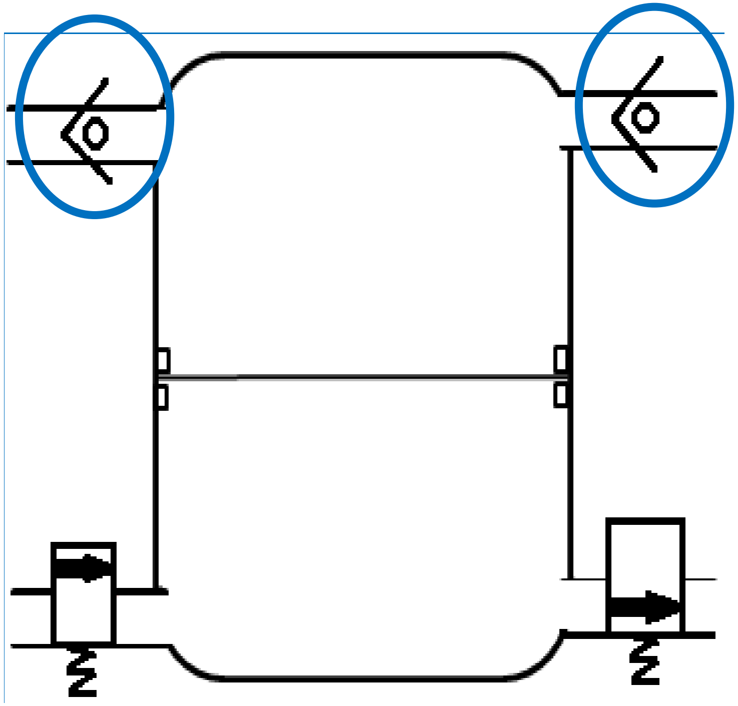
$$V_{cap} = \frac{1}{6}\pi\delta(3R^2+\delta^2)$$



- Result: D = 12cm, δ = 2.7 cm, t = 1.3 cm

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”

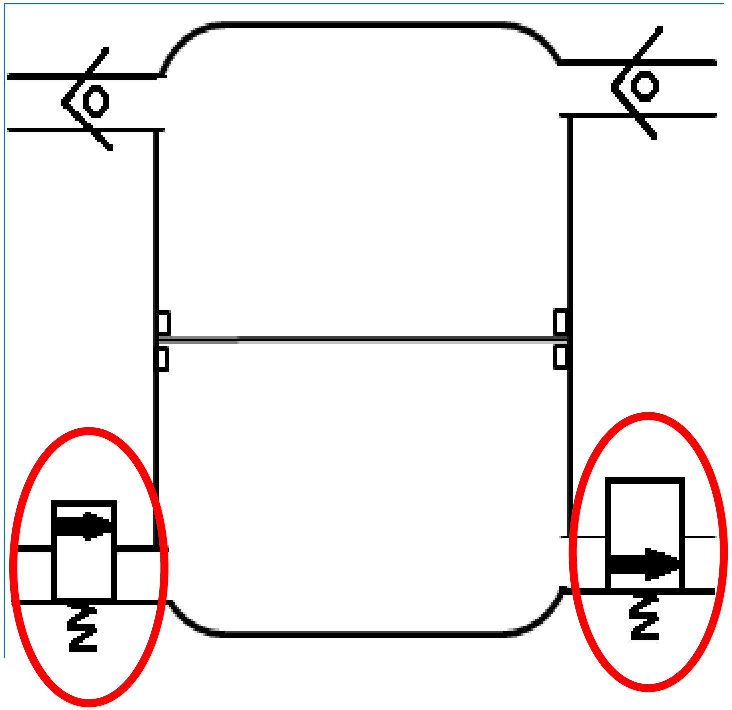


Refrigeration Check Valve

- For use with many refrigerants, including R-134a
- Spring-loaded check ball
- Mounts in any position
- Copper body

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



Solenoid Valve

- Max fluid temp of 82 °C
- Max operating pressure differential of 1,034 kPa
- Power to operate at 2 W
- Constructed of Brass

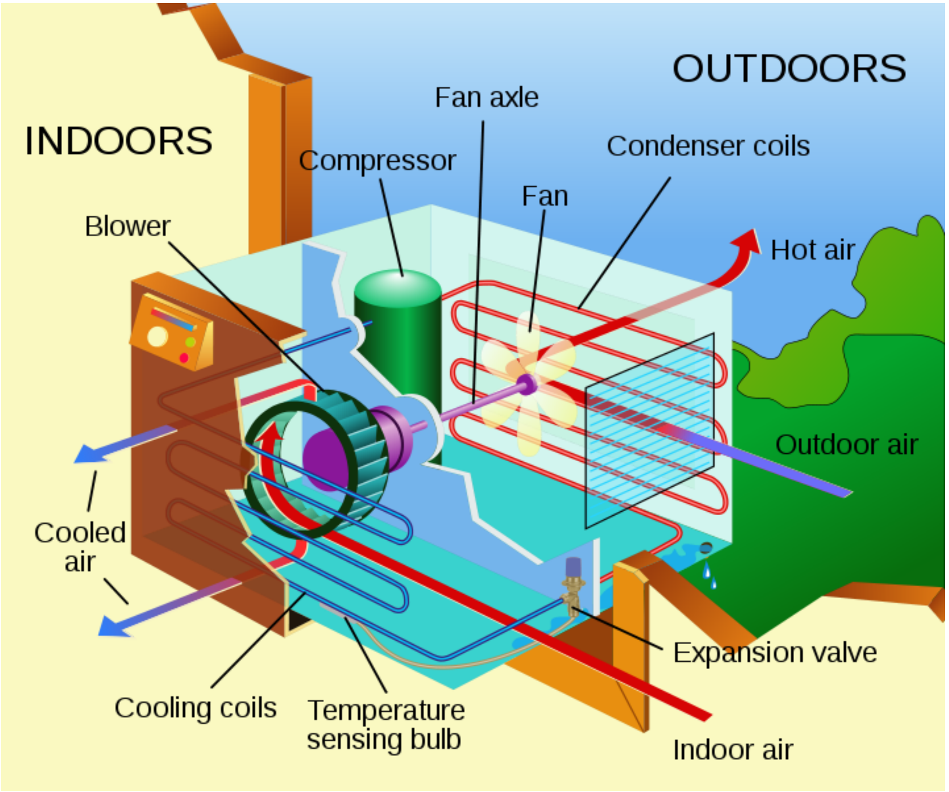
Electric Steam Boiler

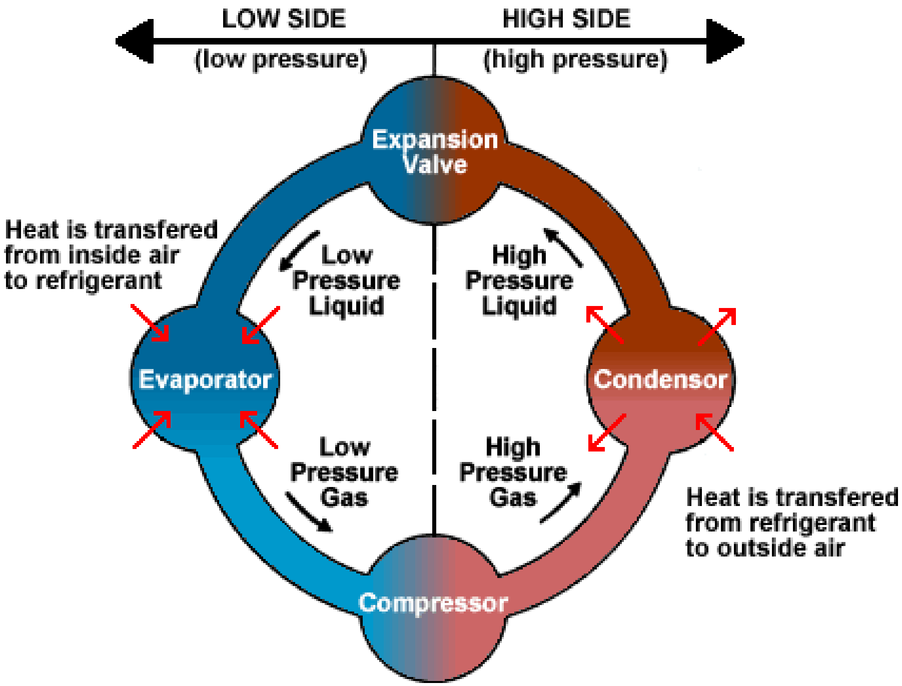
- Simulates solar powered steam generation system
  - Easily controlled
  - Adjusts to multiple fittings
- Produces up 80 kg/hr at 650 C
- Testing will take place at the Florida State University ESC

Steam Generation

- Based on John Dascomb's concentrating solar collector
- Solar collector must have an Area = $17.75m^2$
- System will generate the required 770 kPa

A/C Refrigeration Cycle





Refrigeration Selection

- Pressure created by compressor limited by the solar-steam pressure.
- Inferior compression power to electrical compressors.
- Refrigerants used in air Conditioning
  - R22 No longer commercially available
  - R410a Requires High Pressure
  - R134a Low pressure/automobile use (mostly)

Refrigeration Selection

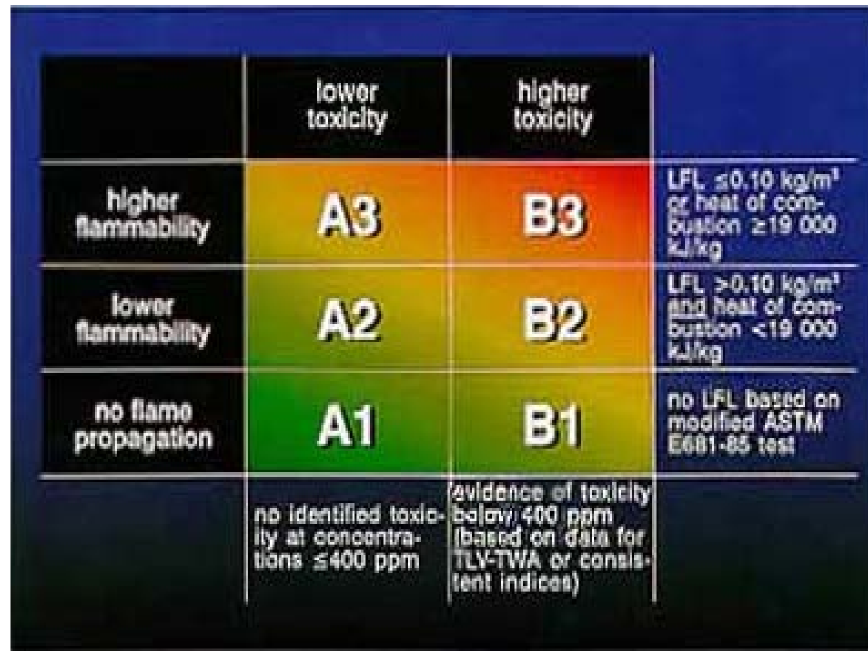
- P_H is the pressure on the condenser side and depends on the temperature outside
  - 190 psi < $P_{H\text{-}R22}$ < 250 psi (Cp= 0.65 kJ/kg*K)
  - 100 ^oF < $T_{H\text{-}R22}$ < 120 ^oF (Pressure –Temperature chart)

  - $Q=mCp\Delta T$
  - 75 ^oF < Ref < 90 ^oF (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)

Safety and Environmental Concerns

- Pressure Vessel
  - High strength material
  - Second casing to contain failure
- Refrigerant
  - A1 safety classification
  - Not corrosive
  - ODP=0
  - GWP=1300



ASHRAE refrigerant safety rating

Bill of Materials

Description	Quantity	Price
Silicone Diaphragm	1	$123.01
1018 Steel Rod	1	$124.12
Solenoid Valve	2	$388.50
Check Valve	2	$76.10
	Total	**$711.73**

Questions?