Request For Action

Team Thermocline

Due 18th November

RFA.1 Full Analysis of Heating and Cooling

$L_{floor} := 13 \ in \quad H_{wall} := 6 \ in$

$A_{internal} := 2 \cdot L_{floor}^2 + 4 \cdot \left(L_{floor} \cdot H_{wall} \right) = 0.4194 \ m^2$

$t_{start} := 20 \ °C \quad t_{end} := (-40) \ °C$

$\Delta_t := t_{end} - t_{start} = -60 \ K$

$$U := 5 \ \frac{W}{m^2 \ K} \qquad \text{Overall heat transfer estimate}$$

$Q_{cond} := U \cdot A_{internal} \cdot \Delta_t = -429.2686 \ \frac{BTU}{hr}$

BTU just to maintain the condition.

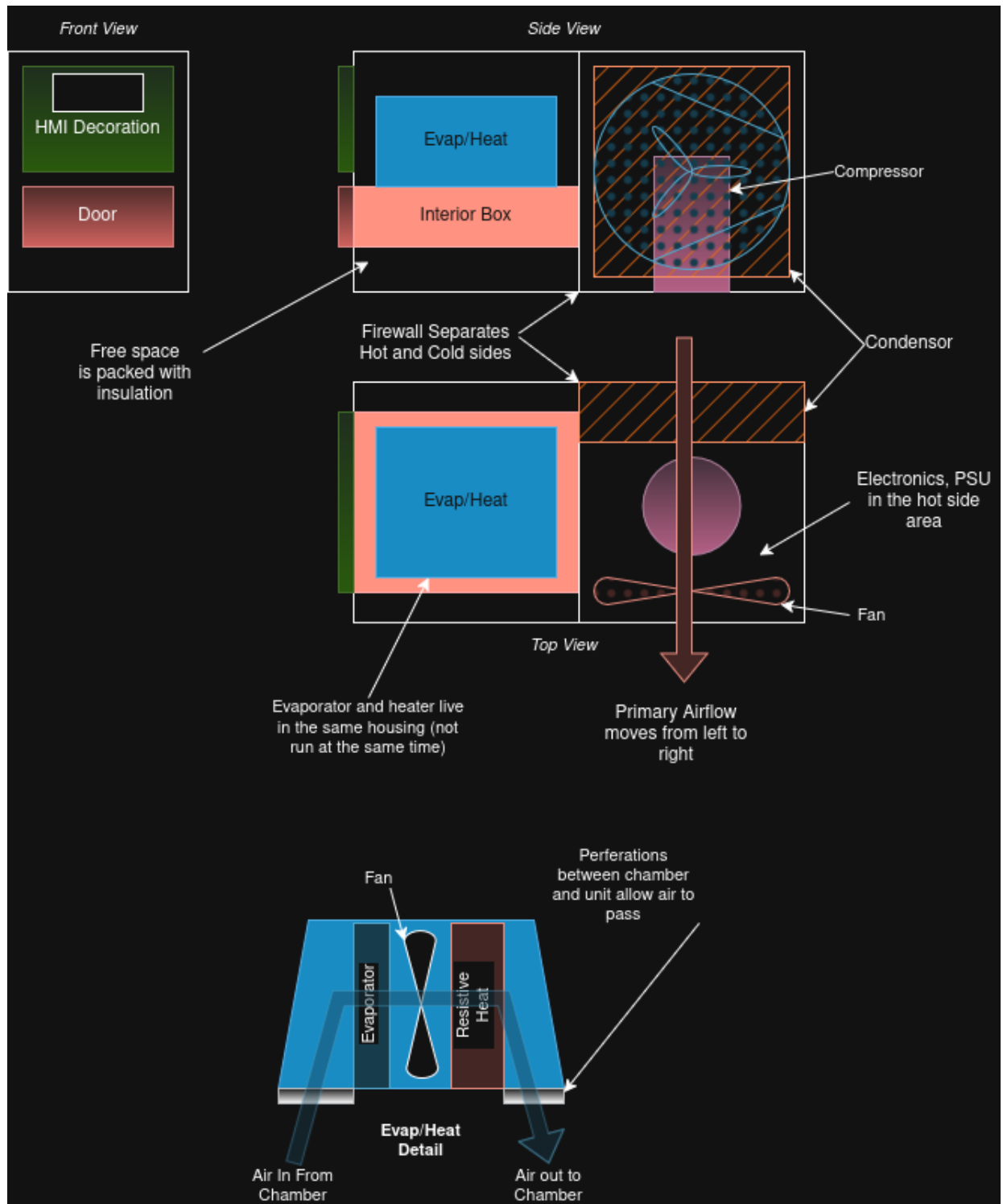Not accounting for the density of air or anything just asuming contents of box and aluminum walls dominate.

$c_{p\_aluminum} := 0.9 \ \frac{kJ}{kg \ K} \qquad m_{aluminum} := 1 \ kg$

$Q_{pull} := m_{aluminum} \cdot c_{p\_aluminum} \cdot \Delta_t = -51.1821 \ BTU$

$t_{time\_to\_cool} := 30 \ min$

$$Q_{total} := Q_{cond} + \frac{Q_{pull}}{t_{time\_to\_cool}} = -531.6328 \ \frac{BTU}{hr}$$

RFA.2 Rough Structure

Front View

HMI Decoration

Door

Side View

Evap/Heat

Interior Box

Compressor

Free space is packed with insulation

Firewall Separates Hot and Cold sides

Condensor

Evap/Heat

Electronics, PSU in the hot side area

Fan

Top View

Evaporator and heater live in the same housing (not run at the same time)

Primary Airflow moves from left to right

Fan

Perforations between chamber and unit allow air to pass

Evaporator

Resistive Heat

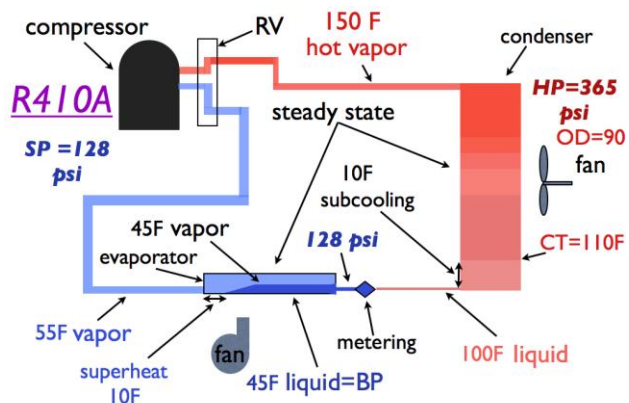Evap/Heat Detail

Air In From Chamber

Air out to Chamber

RFA.3 Exploration of Reversable Heating

Theres two things that got in the way of our reversable heating. We touched briefly on them in the slideshow but they are:

1. Added Complexity in manufacturing
2. The fast-cycle problem

      Firstly and most simply, a heat pump is more joints we have to sweat and solder. More failure points to leak refrigerant, and more control systems to manage. Valve actuation, check valves and extra copper. It also increases the internal volume of our system which increases the price as we need more refrigerant to fill more space. Having a heat pump system simply increases the overall stuff in the machine. And not as important but still worth mentioning, purposefully using the hot side to gather heat is tough on the oil. Most of the units we're using are not actually designed for a sustained hot-side load where the hot side temperature remains at or above the breakdown temperature (around 200-250f). So we'd either have to change the oil (expensive and hard to do) or purchase a pump with the right oil (also very expensive)

Second is a control systems problem. Called the fast-cycle problem. We cannot simply cycle a compressor on and off especially in a high pressure near-cryo system we want to build. The reason is pressure.

The pump can maintain the near 400psi pressure on the hot side just fine. Its built and rated for that and is normal. But what the pumps we have access to, and almost all pumps cannot do is start under a **load.** By allowing the pump to reach high pressure, then shutting it off. There will be a non-significant amount of time where hot vapor at the full pressure is

stuck between the pump and the metering valve. This is a hot-start and attempting to start the pump in this state usually means we stall the motor.

This is a bad enough problem in our single stage system where we need to maintain 3 degrees accuracy but must cycle the pump on and off to meter the cooling. We will be limited by a normal off-time for a single direction system. But in a dual direction system this problem gets not just much worse, but switching between directions especially rapidly could take as long as 4 minutes between when we want to cycle and when the pressure has gone down enough to allow it.

In short, it could lead to efficiency gains within the system. But adds so much complexity, cost, risk and cuts performance. That it isnt hardly a fair comparison at all to the ease of simply just using resistive heat. Which can be cycled as fast as we want, requires almost no wiring and is the cheapest by far.