Request For Action

Team Thermocline

Due 18th November

RFA.1 Full Analysis of Heating and Cooling

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

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

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

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

$U := 5\ \frac{W}{m^{2}\ K}$ 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.

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

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

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

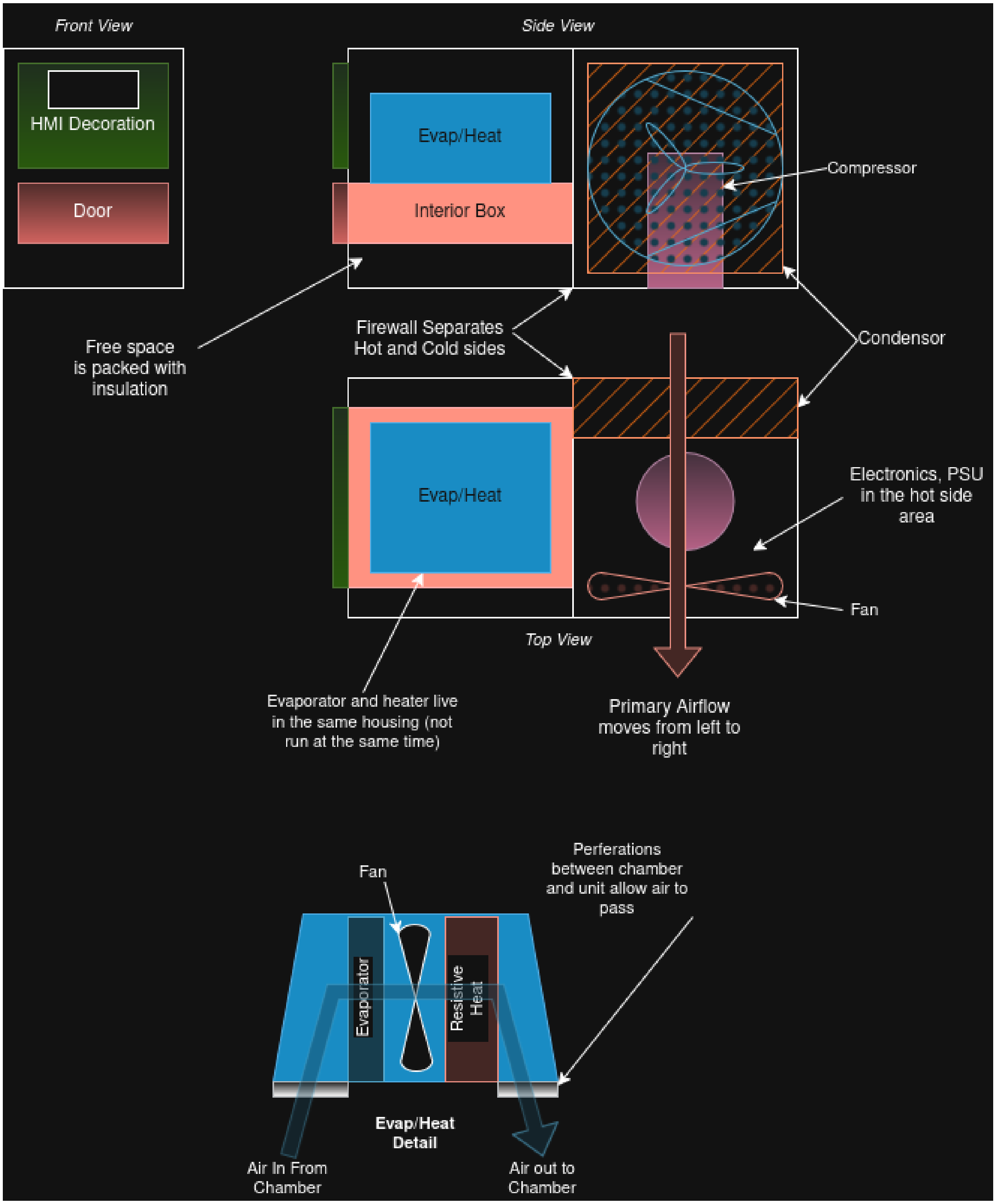
$$\boxed{Q_{total} := Q_{cond} + \frac{Q_{pull}}{t_{time\_to\_cool}} = -531.6328\ \frac{BTU}{hr}}$$

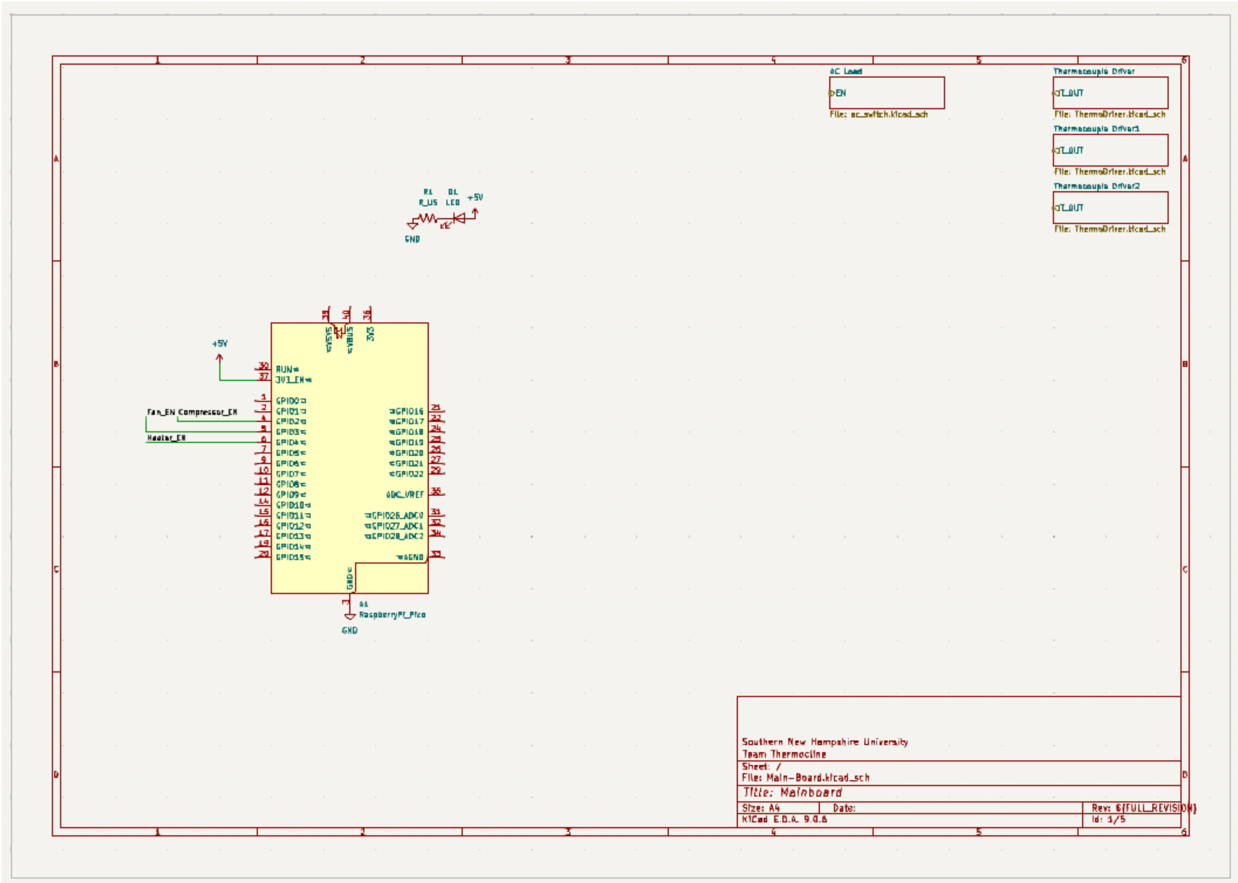
Trade study on ancillary heating of system:

> After using the “refrigeration system” to cool the internals to a certain temperature degree, the compressor produces heat. If immediately requiring to heat the internals, this heat can be recycled into the chamber to assist the resistive heating system. In some cases this can be profitable not only for costs and material usage but overall heating efficiency. However, after performing an analytical trade study to evaluate its effectiveness in the end-design, the group decided to solely use a resistive heating method. Recycling heat would require additional mechanisms and components (fans, valves, ducts) – increasing cost, manufacturing and maintenance complexity, and possibly the requiring a modification of internal design specifications. In addition, this design possibility would demand a more complicated control system; one that can actively monitor the heat transfer rates between the resistive heating and recycled compressor heat to maintain a precise temperature range, along with managing when the vents/fans are operating to ensure the heat is either recycled, insulated, or discarded from the system. Thus, the team has decided to forgo the idea of using recycled compressor heat, using only resistive, in order to keep a simple, cost-efficient, and effective temperature-controlled system.

Ultimately, the team has decided to use resistive heating elements and a refrigeration system to heat and cool the chamber respectively.

RFA.2 Rough Structure





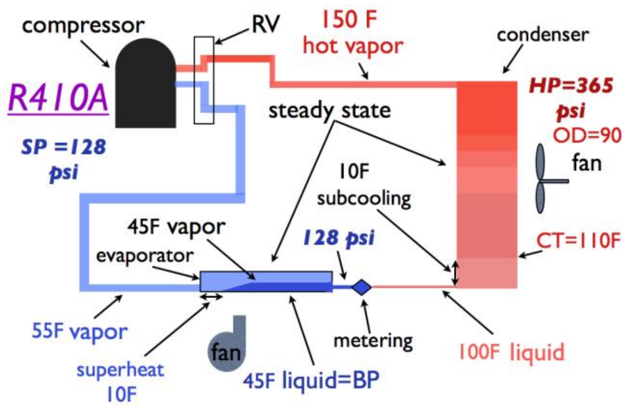
RFA.3 Exploration of Reversable Heating

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.