Vault-0 Thermal Management System

Team Members: Cristina Huerta, Mineh Khodagholian, Nicholas Lee, Luis Paz Tinoco, Francisco Reyes
Faculty Advisor: Dr. Nurullah Arslan
hatchTank Liaison: Matthis Herrera, Ryan Beckmann, Connor Gallagher-Moore
Department of Mechanical Engineering
College of Engineering, Computer Science, and Technology
California State University, Los Angeles

Background

Lithium-Ion batteries have the potential to provide energy for diverse sections of production. They are viewed as a great alternative to fuel for their high energy production and potential to help the environment. hatchTank's EnVault is looking to make an impact by providing clean energy to businesses, government agencies, and community centers. For this to happen, the batteries shall operate at a temperature range of 25 to 65 ˚C, anything above this range can be a potential health hazard to the operator and environment.

Objective

Battery systems can be complex in design and composition. Approaching this problem requires searching for replacement batteries, determining the appropriate method to connect the selected batteries, designing the modules for the batteries, design the cooling system that can keep the batteries at a safe temperature range of 20 to 45˚C

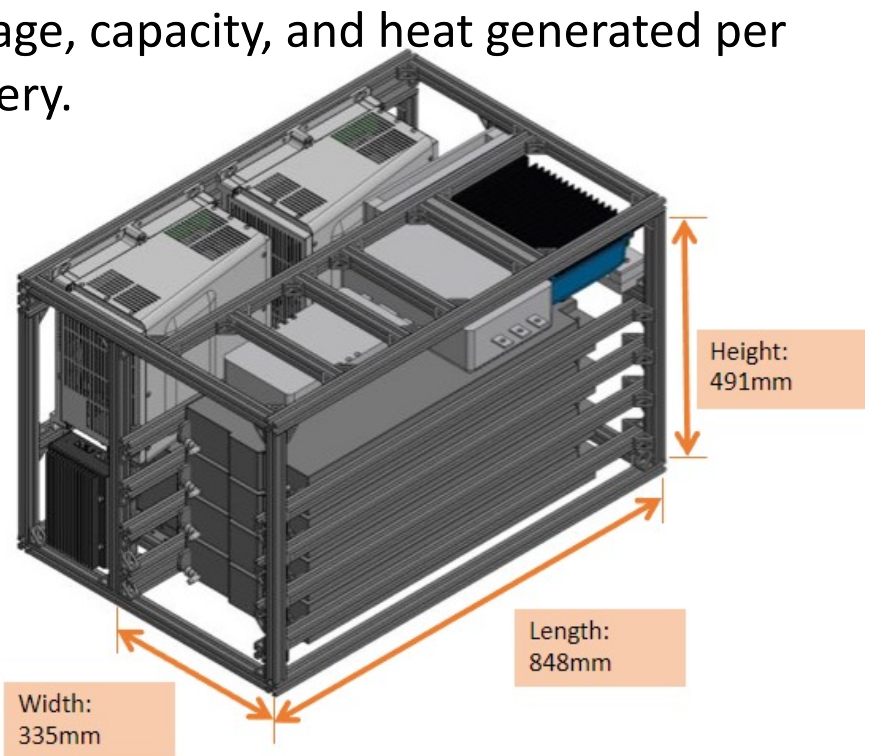
Requirements

No.	Limitations	Value	Units
1	Voltage	24	V
2	Energy	20	kWh
3	Weight	80.49	kg
4	Length	849	mm
5	Height	285	mm
6	Width	405	mm
7	Maximum Temperature	65	˚C
8	Minimum Temperature	25	˚C

Design Approach

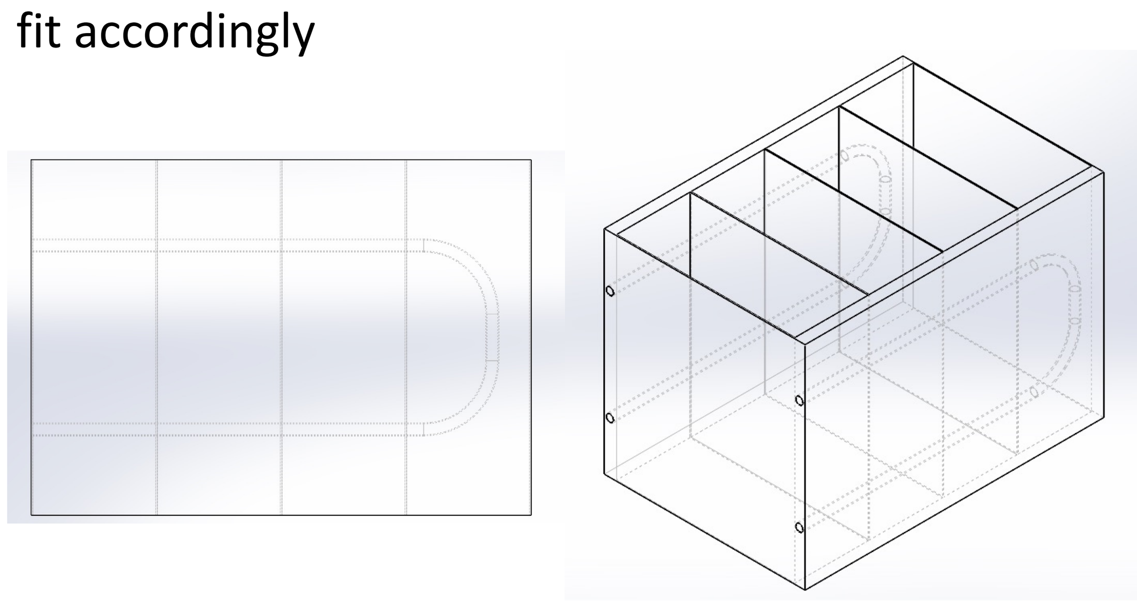
1. Battery Selection

Research different selections of batteries that can meet the required output. Determine the voltage, capacity, and heat generated per battery.



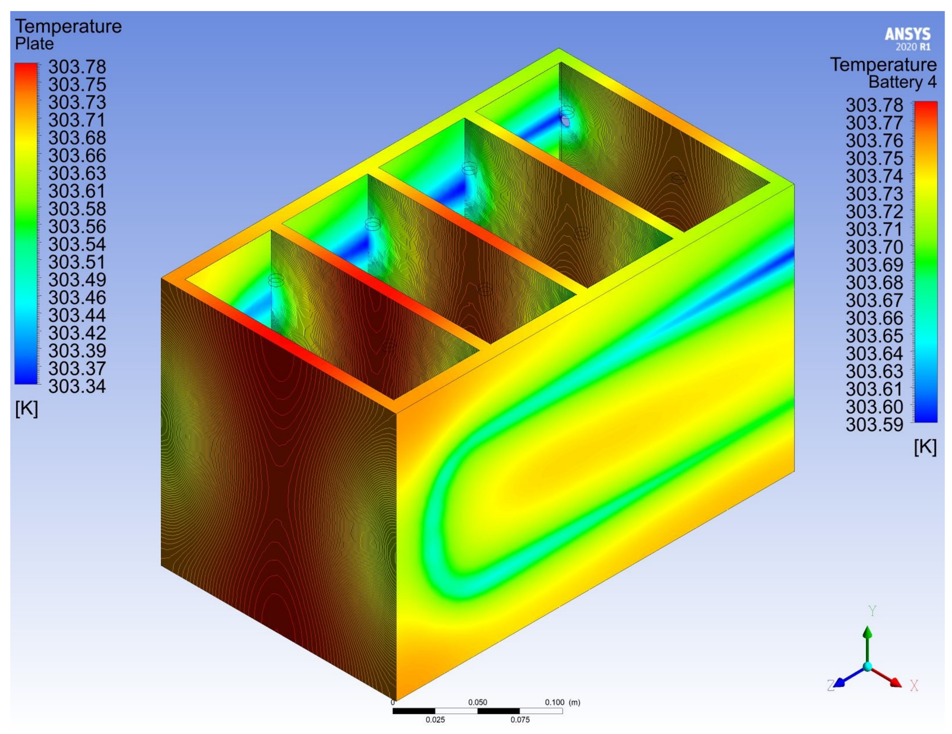
2. Module and Cooling System Design

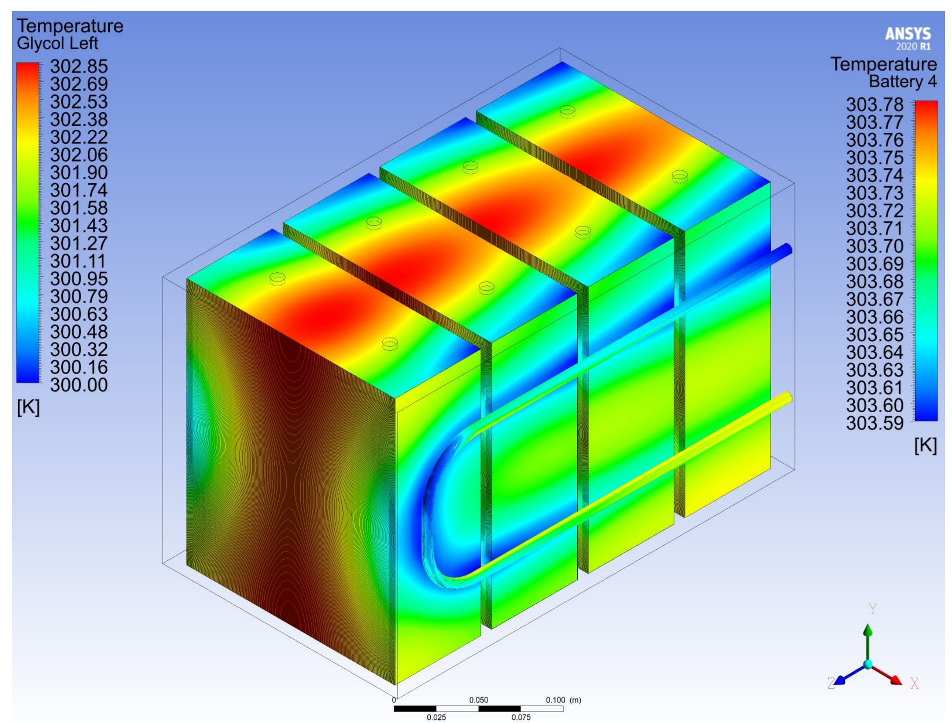
Determine how many batteries are needed and how shall be installed in a module to meet the required output. Estimate the space limitation within the generator and how many modules can fit accordingly

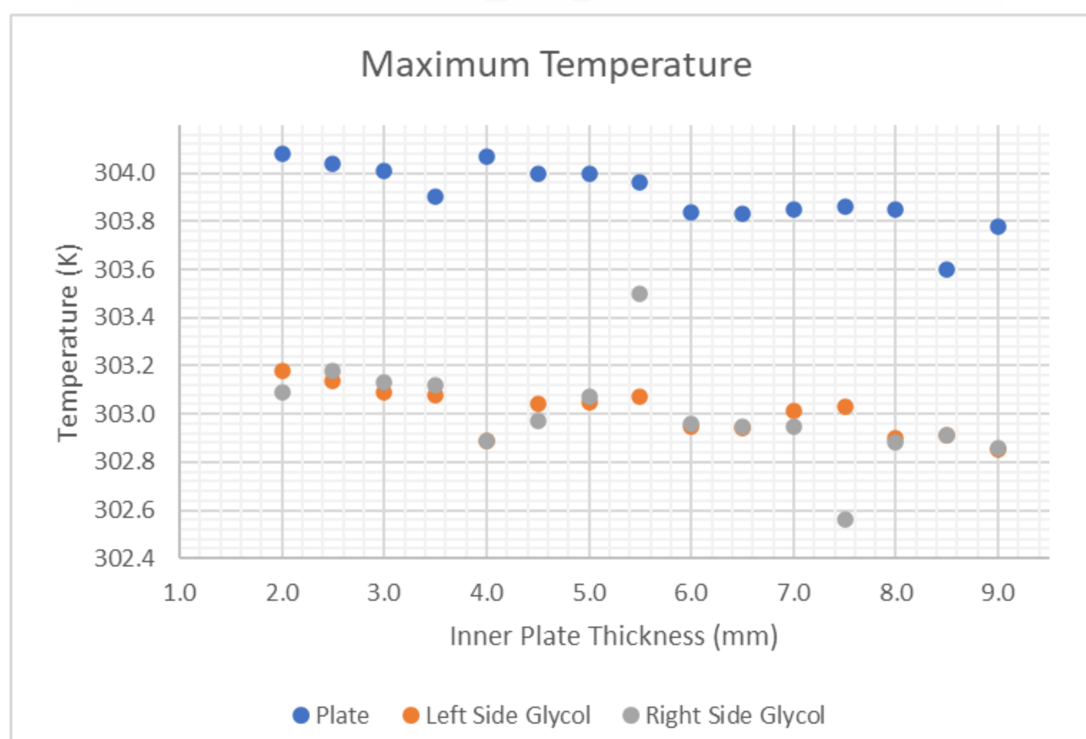


4. Cooling System Optimization

Design a cooling system that can maintain the batteries at a safe and optimal performance. Perform the appropriate simulations to optimize the design and make modifications when necessary.







Boundaries Conditions:

- Models:
  - Energy Equation
  - Laminar
- Fluid: **Glycol 50/50**
  - Density: $1055.5\,\frac{kg}{m^3}$
  - Specific Heat: $3297.1\,\frac{J}{kg{\cdot}K}$
  - Thermal Conductivity: $0.4311\,\frac{W}{m{\cdot}K}$
  - Viscosity: $0.012119\,\frac{kg}{m{\cdot}s}$
- Solid: **6061 Aluminum**
  - Density: $2700\,\frac{kg}{m^3}$
  - Specific Heat: $896\,\frac{J}{kg{\cdot}K}$
  - Thermal Conductivity: $196\,\frac{W}{m{\cdot}K}$
- Inlet:
  - Velocity: $0.271\,\frac{m}{s}$
  - Temperature : 300 K
- Cell Zone Conditions:
  - Heat Gen: $6196.4\,\frac{W}{m^3}$
  - 16W of Heat per Battery

3. Materials

Explore possible materials and their properties for the design. Determine what material can maximize the heat transfer rate.

Fluid Properties

Composition	Density $\rho\left(\frac{kg}{m^3}\right)$	Specific Heat $Cp\left(\frac{J}{kg\cdot K}\right)$	Thermal Conductivity $k\cdot 10^{-3}\left(\frac{W}{m\cdot K}\right)$	Thermal Diffusivity $\alpha\cdot 10^{-7}\left(\frac{m^2}{s}\right)$	Dynamic Viscosity $\mu\cdot 10^{-2}\left(\frac{N\cdot s}{m^2}\right)$
Ethylene Glycol	1114.4	2415	252	0.939	1.57
Refrigenrant R134a	1199.7	1432	80.3	0.468	0.01905
Water	996.6	4179.2	610.2	1.4651	0.8538
50/50 Ethylene Glycol (w.water)	1055.5	3297.1	431.1	1.202	1.2119

Thermophysical Properties of Solids at 300K

Composition	Melting Point Kelvin	Density $\rho\left(\frac{kg}{m^3}\right)$	Specific Heat $Cp\left(\frac{J}{kg\cdot K}\right)$	Thermal Conductivity $K\left(\frac{W}{m\cdot K}\right)$
Aluminum				
Pure	933	2702	903	237
Alloy 2024-T6	775	2790	875	177
Alloy 6061		2700	896	167
Copper				
Pure	1358	8933	385	401
Commercial Bronze	1293	8800	420	52
Cartridge Brass	1188	8530	380	110
Constantan	1493	8920	384	23

Conclusion

The desired output was achieved by having 24 batteries with 320 Ah and 3.2 V each. This would require 6 modules with 4 batteries each that will help us reach an output of 25.6 V and 960 Ah. The final design was set on using cooling plates with coolant as the source of heat absorption The fluid is chosen will be ethylene glycol with 50% of concentration and Aluminum Plates. The final step is to optimize the design chosen by testing the thickness of the inner plates, the flow rate, and the number of channels it should cover per side.

Acknowledgements

The Vault-0 Thermal Management System would like to extend its gratitude to Professors Nurullah Arslan, Mike Thorburn, Chris Bachman, and the hatchTank team for assisting the team and giving us the opportunity to work on this project.