EMBRY-RIDDLE Aeronautical University

Mechanical Engineering

Student Research Symposium

ASHRAE 2022 Applied Engineering Challenge: Project Frozo

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ABSTRACT

Project Frozo has designed an ultra-low temperature portable freezer capable of storing 500 COVID-19 vaccine vials for global distribution. The device does not require external power, and utilizes a combination of vacuum insulation panels, aerogel, and phase change material to maintain a storage volume temperature of -70°C for over 10 days. This duration of time was determined by running a one-dimensional transient heat transfer simulation with a constant ambient temperature of 48.89°C (120°F). Construction of a prototype is underway which will be used to perform physical testing and validate the simulation results. The design will enable cost effective distribution of the COVID-19 vaccine on a global scale. The design follows guidelines set by The Setty Family Foundation: 2022 Applied Engineering Challenge as well as the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) standards. Vaccine storage requirements were determined using public information provided by Pfizer. Project Frozo's design will function as the final storage system for vaccines prior to doses being administered to recipients.

REQUIREMENTS

1. The design shall be capable of being shipped using a standard shipping container.
2. The design shall maintain a vaccine storage temperature of –70°C.
3. The design shall be able to identify if temperature loss occurs.
4. The design shall remain at specified temperature for 10 days.
5. The design shall be capable of containing 1 unit of vaccines.
    - *1 unit is defined as a 10-inch × 10-inch × 10-inch space that holds 500 vaccine vials.*
6. The design shall weigh no greater than 110 pounds.

THE COLD CHAIN

The current vaccine transportation and distribution method is referred to as the cold chain. It is a set of rules and procedures which ensure the proper storage and distribution of vaccines to health services from the national to the local level. Interconnected refrigeration equipment maintains storage temperature of vaccines to ensure the vaccines remain potent. The vaccines are produced in the manufacturing facility and are then transported downstream through the cold chain through different storage and distribution centers. The final stop in the cold chain is the point of contact where the vaccine is administered to the individual. However, these logistics are not accessible in regions that are underdeveloped compared to the United States and similar Western nations. To enable the distribution of vaccines to these regions, an ultra-low temperature (ULT) portable freezer could be used in place of the final distribution center.

INSULATION & PCM DESIGN

The insulation and phase change material (PCM) design consists of three layers: vacuum insulated panel (VIP), aerogel, and a PCM. The VIP is the outermost layer, followed by the aerogel, and then the PCM with the storage volume at the very center. *Figure 1* below is a diagram depicting the thickness and orientation of each layer.

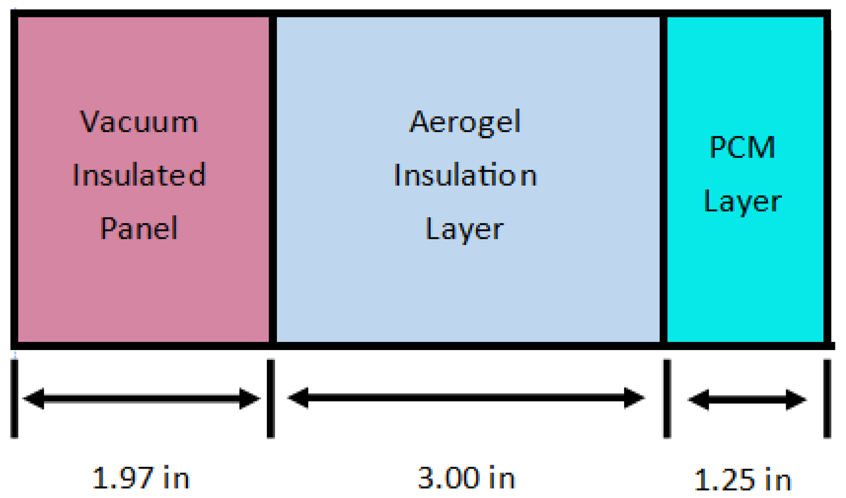

Fig. 1: Layer construction from outside (left) to inside (right).

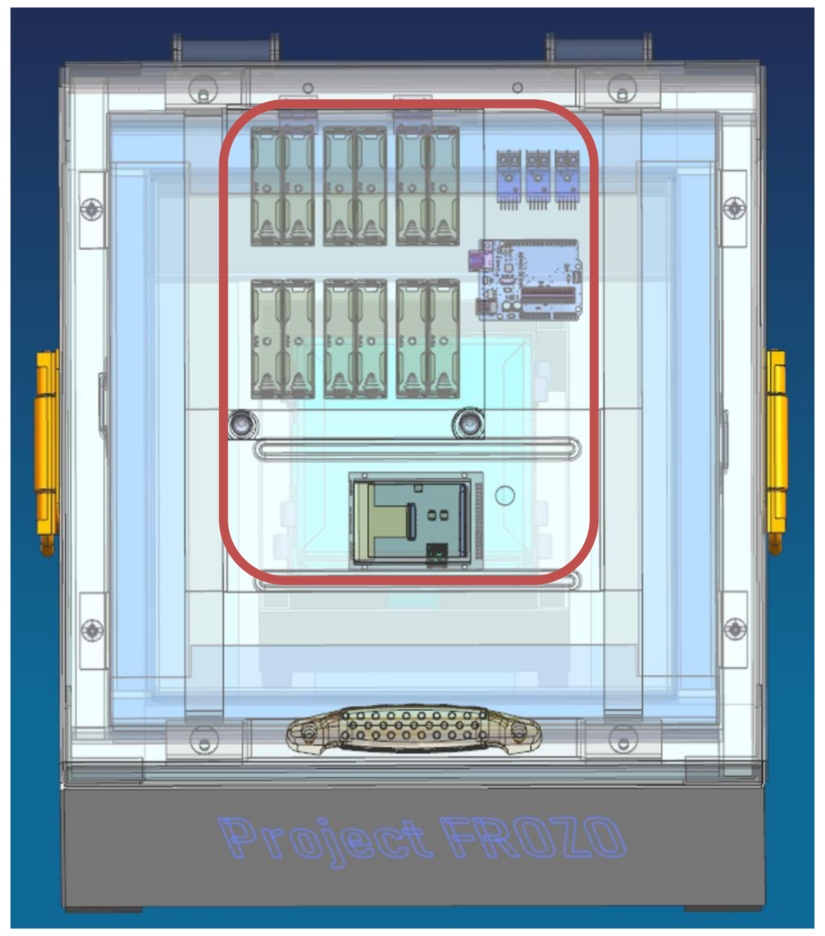

Fig. 2: Device instrumentation location.

INSTRUMENTATION DESIGN

An Arduino REV3 is used as the circuit board to process the thermocouple readings. A thermocouple shield is used to provide a cold junction and a way for the data to reach the circuit board. With a built-in relay switch, multiple readings from different thermocouples can be collected and displayed to the touchscreen display. The power supply is comprised of lithium-ion rechargeable batteries in both series and parallel to meet the required energy capacity of 20.8 Amp-hours and voltage of 7.2 V required to operate. Instrumentation layout is shown in *Figure 2* above in the area outlined in red.

3D-MODEL

Fig. 3: Isometric view of closed freezer.

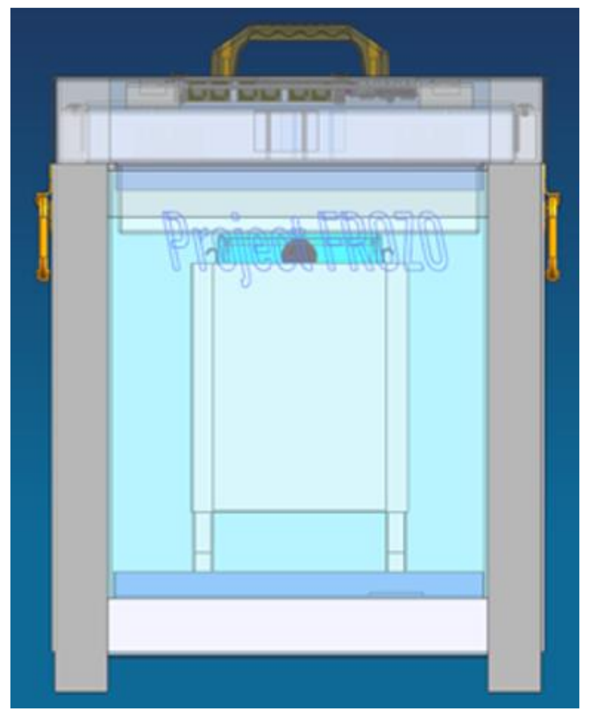

Fig. 4: Side view with transparent outer wall.

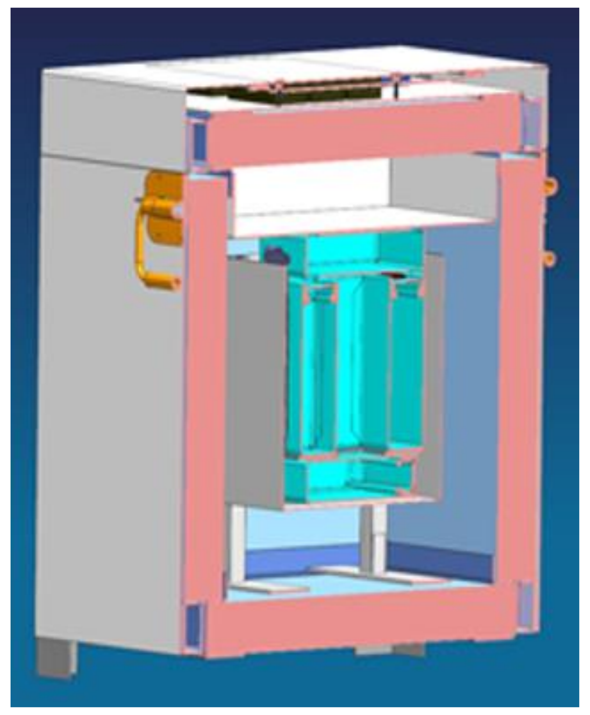

Fig. 5: Isometric cross-section view of layers.

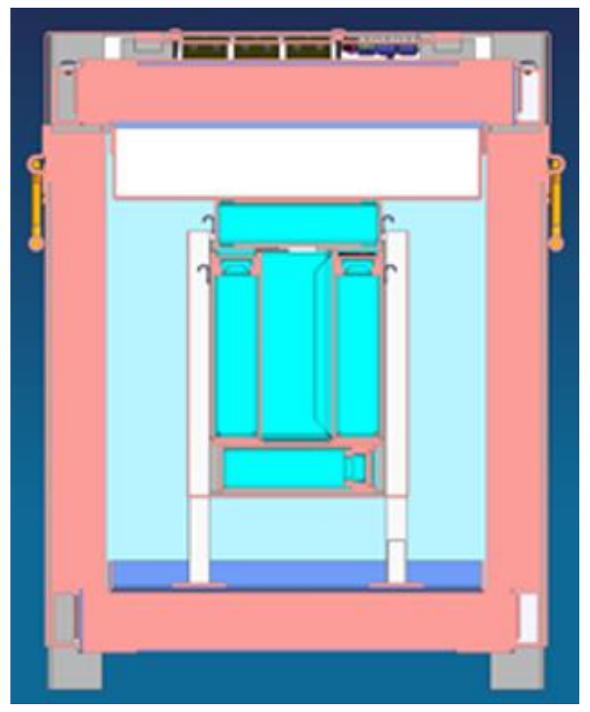

Fig. 6 Side view of layers.

1-D TRANSIENT HEAT TRANSFER ANALYSIS USING ANSYS

Assumptions:
Initial internal temperature of -70°C and external temperature of 48.89°C (120°F)

Purpose:
This analysis was used to determine the thickness needed for each layer of insulation as well as the duration of time the storage volume would remain at acceptable temperature for vaccine storage.

Results:
The analysis determined that the Vacuum Insulation Panel should be 1.97 inches thick, the aerogel should be 3 inches thick, and the PCM layer should be 1.25 inches thick. These values showed that the storage volume temperature would remain cold enough to meet the 10-day requirement and would remain at acceptable temperature for almost 16 days.

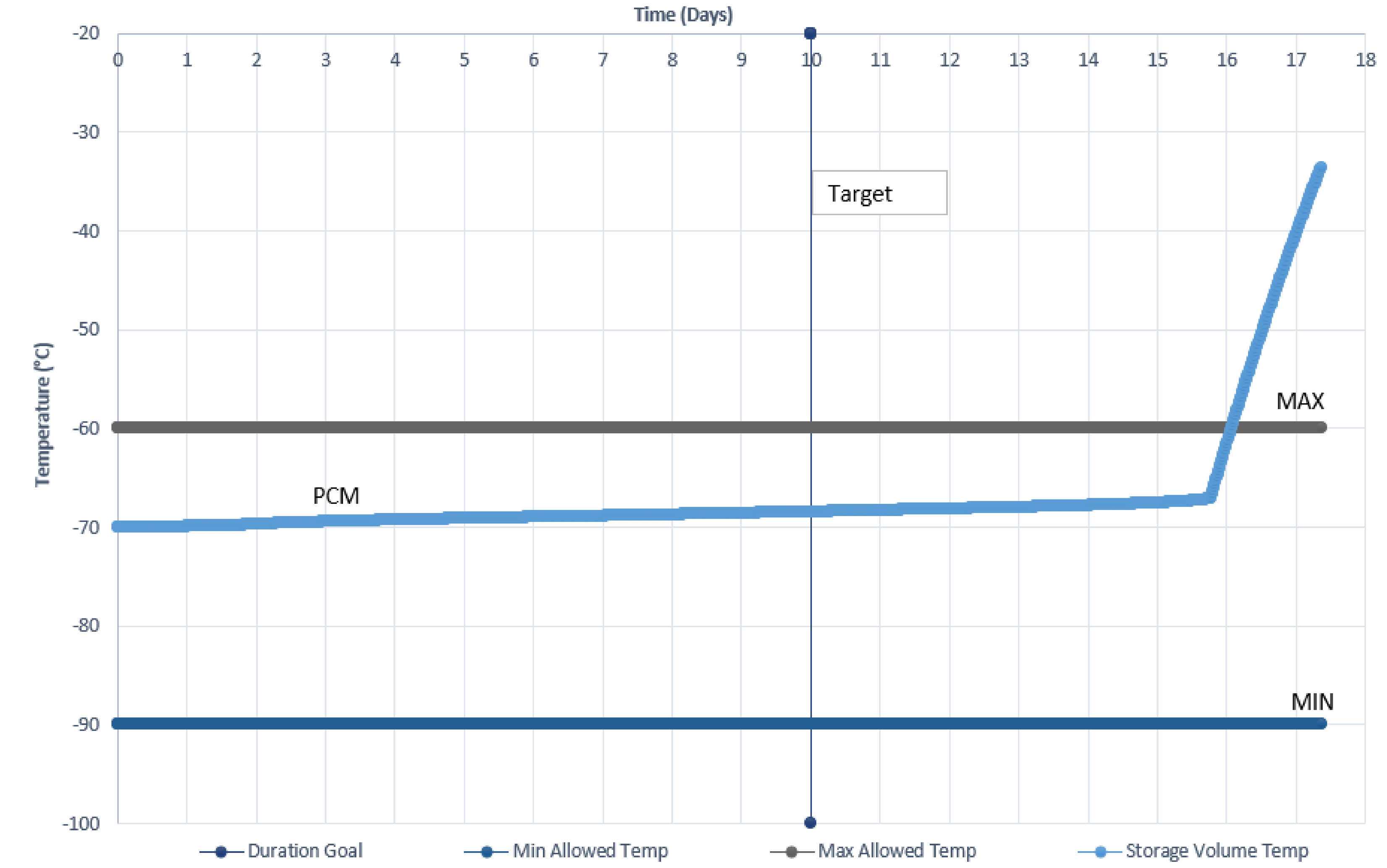

Fig. 7: ANSYS heat transfer simulation results.

CONCLUSIONS

Our team of 5 members plans to finish a fully functioning prototype of the design by the end of the Fall 2022 semester. Project Frozo will be presenting the prototype in the 2023 ASHRAE National Convention in Atlanta, GA. With this design, Project Frozo has utilized new insulation and PCM technology to help transport vaccines to remote areas around the world.

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