

Background

E.W. Grobbel produces high quality fermented pickle products. This fermentation process relies on the activity of naturally occurring lactic acid bacteria in the cucumbers. It can be measured based on the change in pH over time, the salinity of the brine, and the storage temperature. Challenges with consistent temperature control exist at the E.W. Grobbel facility.

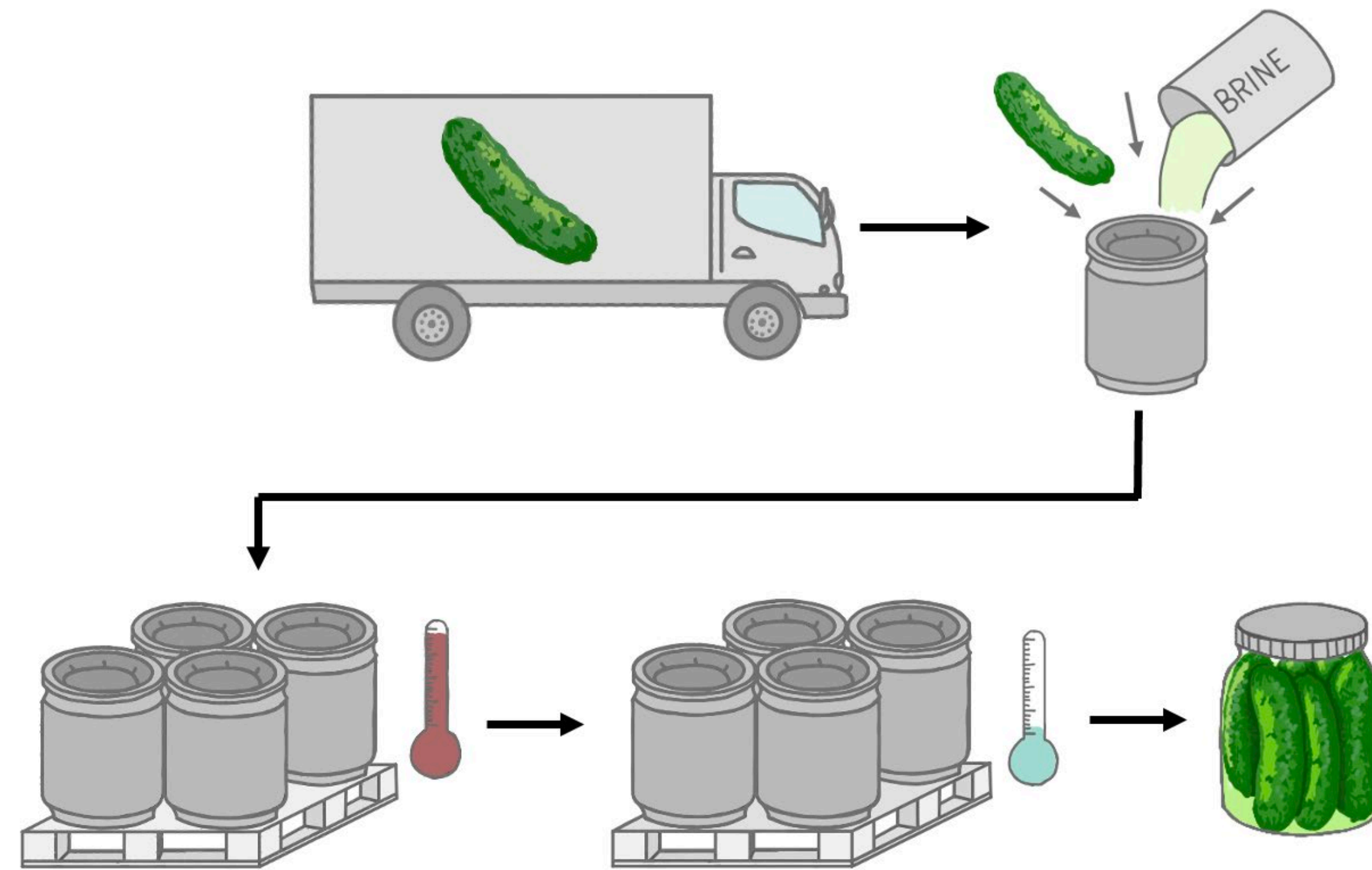


Figure 1. Fermentation process flow

Problem Statement

Design a scalable and modular temperature control chamber within an existing racking system for pickle fermentation to limit temperature fluctuations during the fermentation process

Objectives

- Limit temperature fluctuations to $\pm 2^\circ\text{F}$ of target temperature 68°F
- Determine time required to reduce pH < 4.6
- Determine a heating method that ensures equal temperature distribution, meaning there are no cold spots below 66°F

Constraints

- Solution cannot negatively impact product quality
- pH < 4.6
- Unit cost < \$5000
- Solution must fit in current racking system
- Unit lifespan > 5 years

Design Alternatives

The team considered 5 preliminary design alternatives based on in-depth research and the knowledge gained from a site visit. A decision matrix was used to determine the final design based on 1) ease of use, 2) effectiveness of maintaining temperature, 3) QA feasibility, 4) safety, 5) cost, and 6) durability of the system.

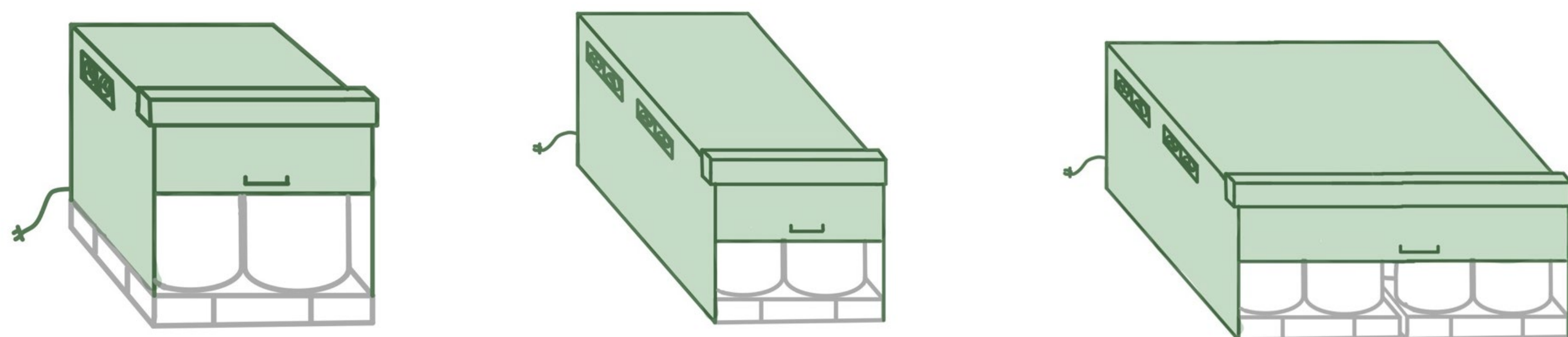


Figure 2. Respective single-pallet, two-pallet, and four-pallet preliminary design sketches

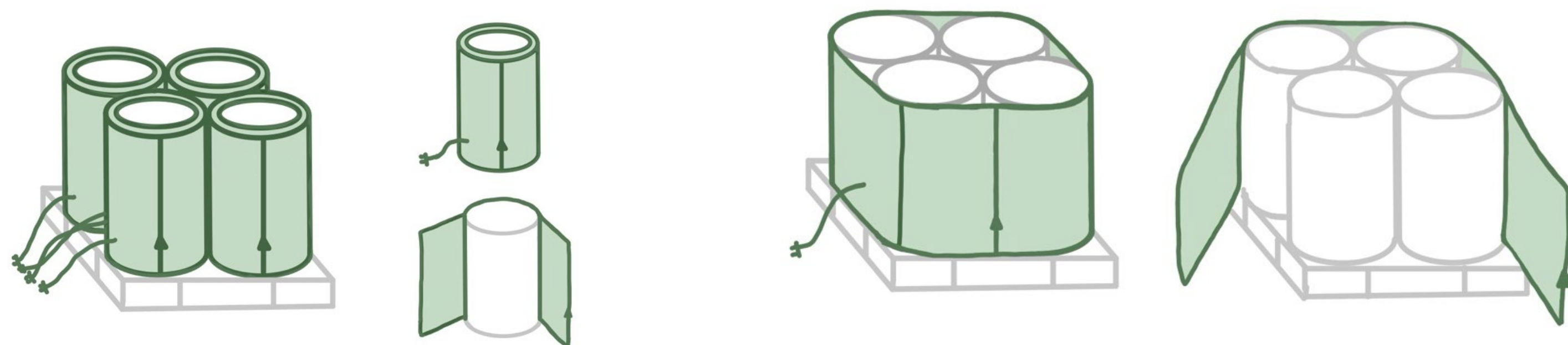


Figure 3. Respective single barrel and four-barrel preliminary design sketches

Selected Design

- Frame:
 - T-slot frames of custom sizes
 - Food safe silicon adhesive to attach insulation boards to the inside of each the T-slot
 - Screws, self-aligning T-nuts, and corner connectors for construction
- Insulation:
 - 1" foam boards
 - Aluminum and heat-reflecting foil fabric for the flooring
- Heating system:
 - Placed on the top of the chamber
 - Built in fan to circulate the air
 - Controlled using a PID-controller
- Door:
 - Insulated sliding curtain that provides easy access to barrels

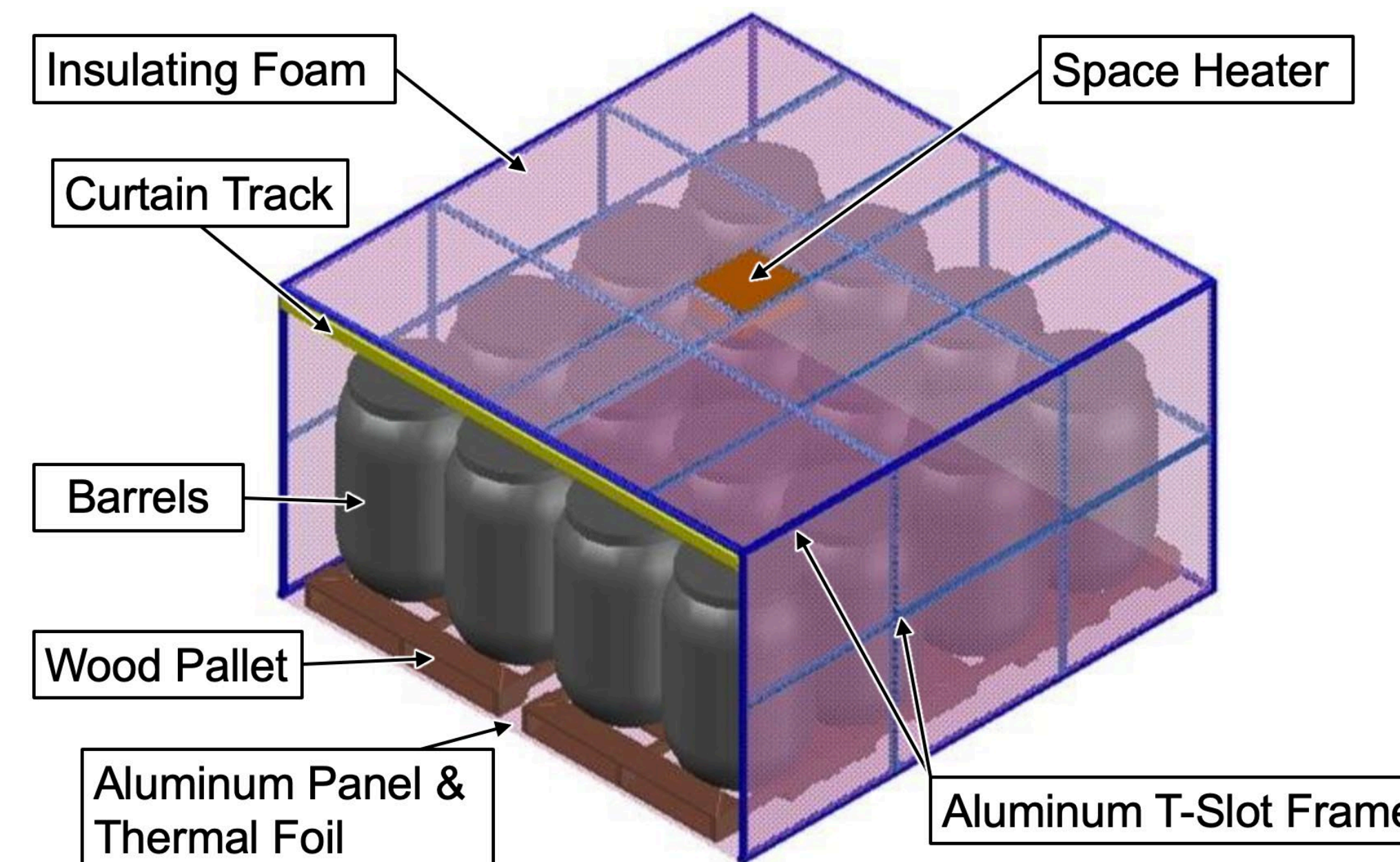


Figure 4. Final design 3D AutoCAD model

Heater Validation

The heater selected for the chamber must be validated to prove that the heater is sufficient to maintain the internal temperature of 68°F . To do so, the system was simplified to a 1D heat transfer problem. The thermal resistance method was used to determine flux and total heat loss using the equations below.

$$q_x'' = \frac{\Delta T}{\Sigma \text{Sum Thermal Resistance}} \quad (1)$$

$$\text{Total Flux Out} = q_x'' * A \quad (2)$$

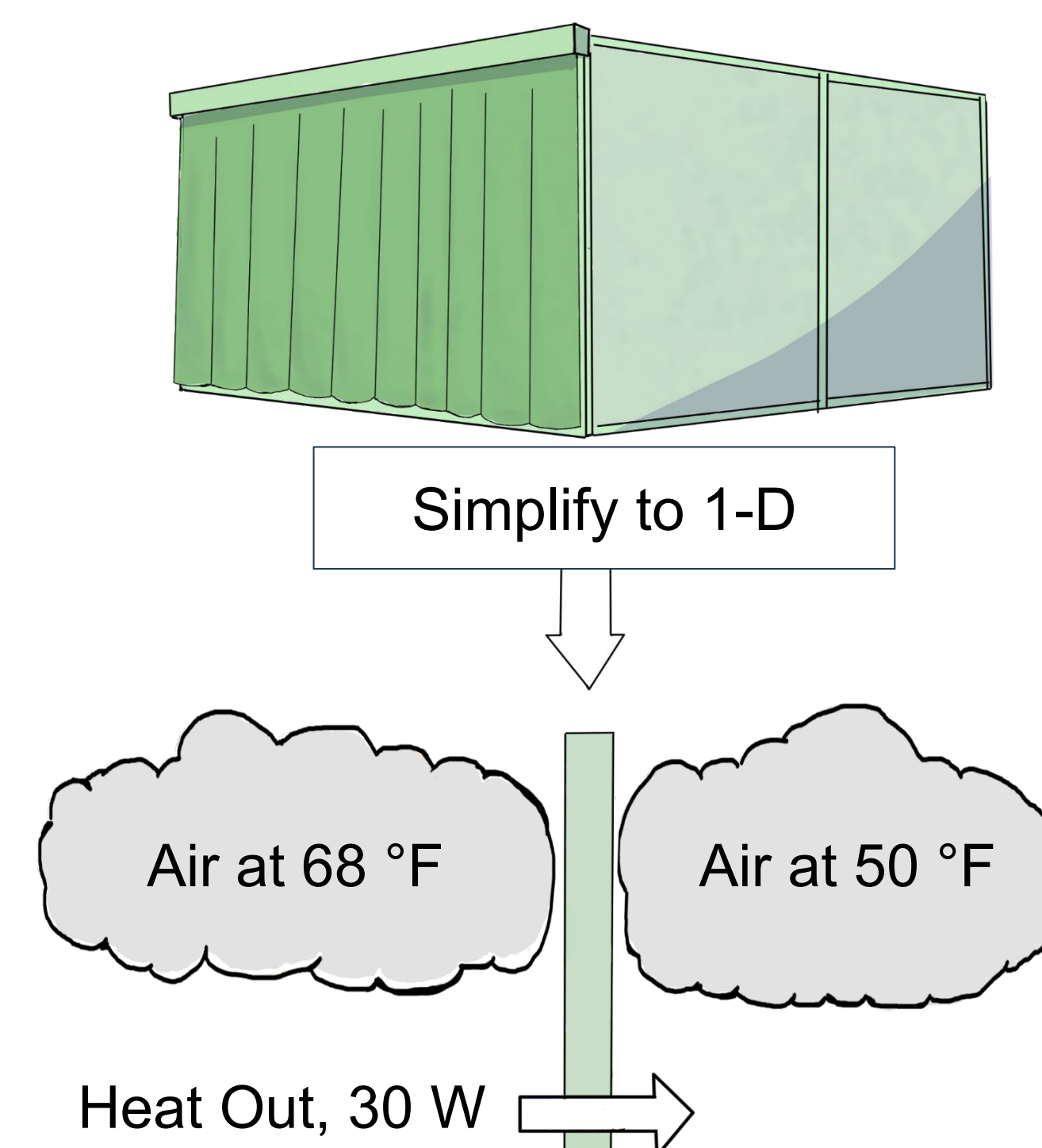


Figure 5. Simplified 1D heat transfer model

Heater Control

- Chamber needs a heater to maintain target temperature and a control system for this heater
- PID controller system:
 - Turns the heater on or off using the solid-state relay
 - Detects whether the chamber needs to be heated using the thermocouple
 - Manual switch in case of emergency
 - Alarm light to alert QA if chamber is out of temperature range

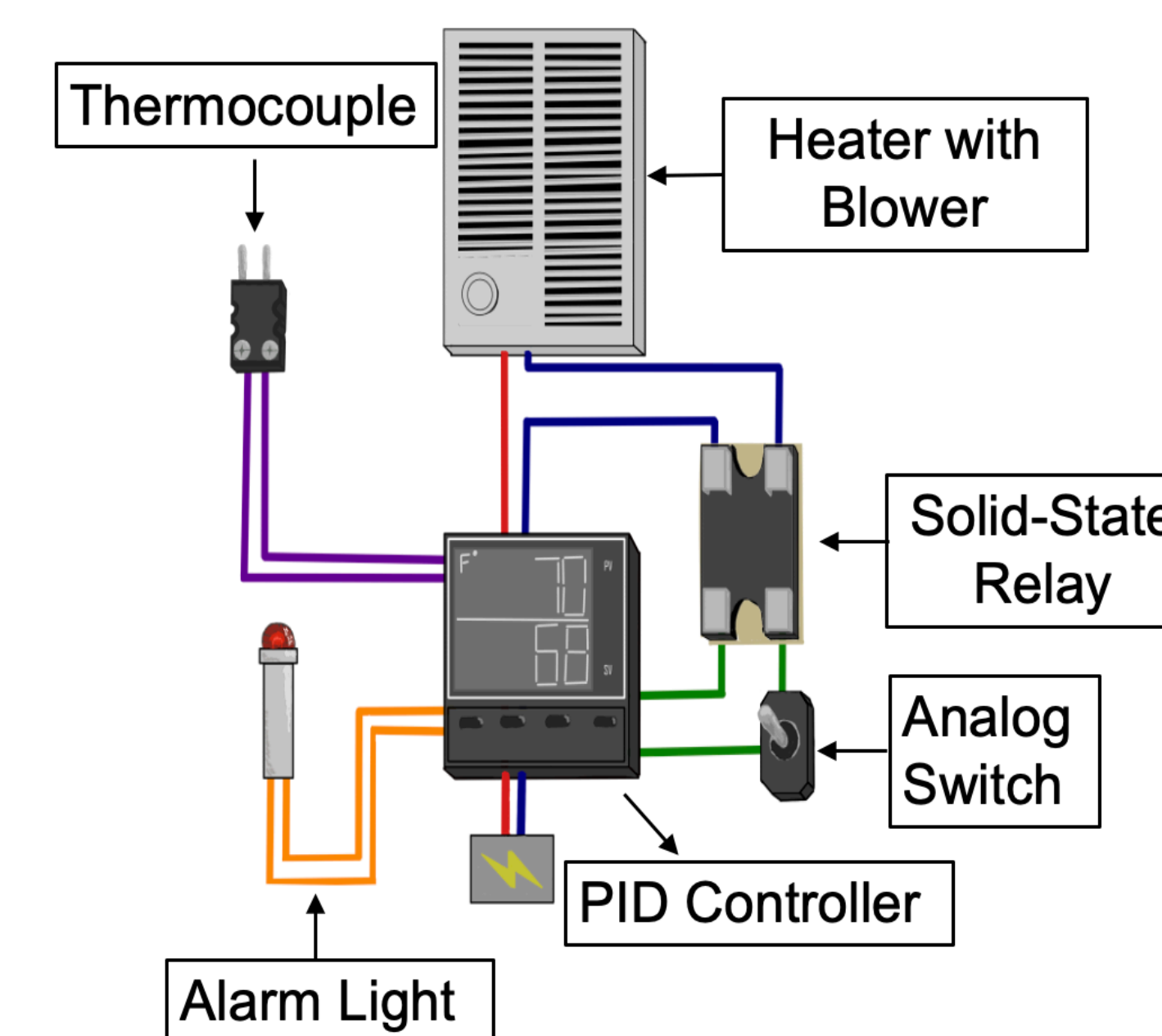


Figure 6. Heater control system

Economics

The total cost breakdown was determined for the final design.

Table 1. Final design cost breakdown

| Category | Price (\$) |
|----------------|------------|
| Frame | 1,859 |
| Flooring | 661 |
| Door | 529 |
| Heating System | 616 |
| Insulation | 295 |
| Total | 3,960 |

Following cost breakdown, economic analysis included calculating the net present value (NPV). This value shows what the price of the chamber would be 5 years from now in today's money, using equation 1 below.

$$NPV = \Sigma \frac{R_t}{(1+i)^t} - C_0 \quad (3)$$

The final calculated value was large and positive; therefore, the system should be implemented as it would be worthwhile investment for the client.

Next Steps

Based on the heater validation and economic analysis, the team recommends that E.W. Grobbel move forward with design implementation of our temperature control system. Future optimization for this project includes conducting a sensitivity analysis of analytical calculations, and a quality improvement study based on chamber implementation, as well as a feasibility study of improved racking system.

Acknowledgements

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