Herbert Wertheim College of Engineering
UNIVERSITY of FLORIDA

The Si-Moo-Lator™

EML4502 Mechanical Engineering Design III, Spring 2024

SiMooLation Gators™

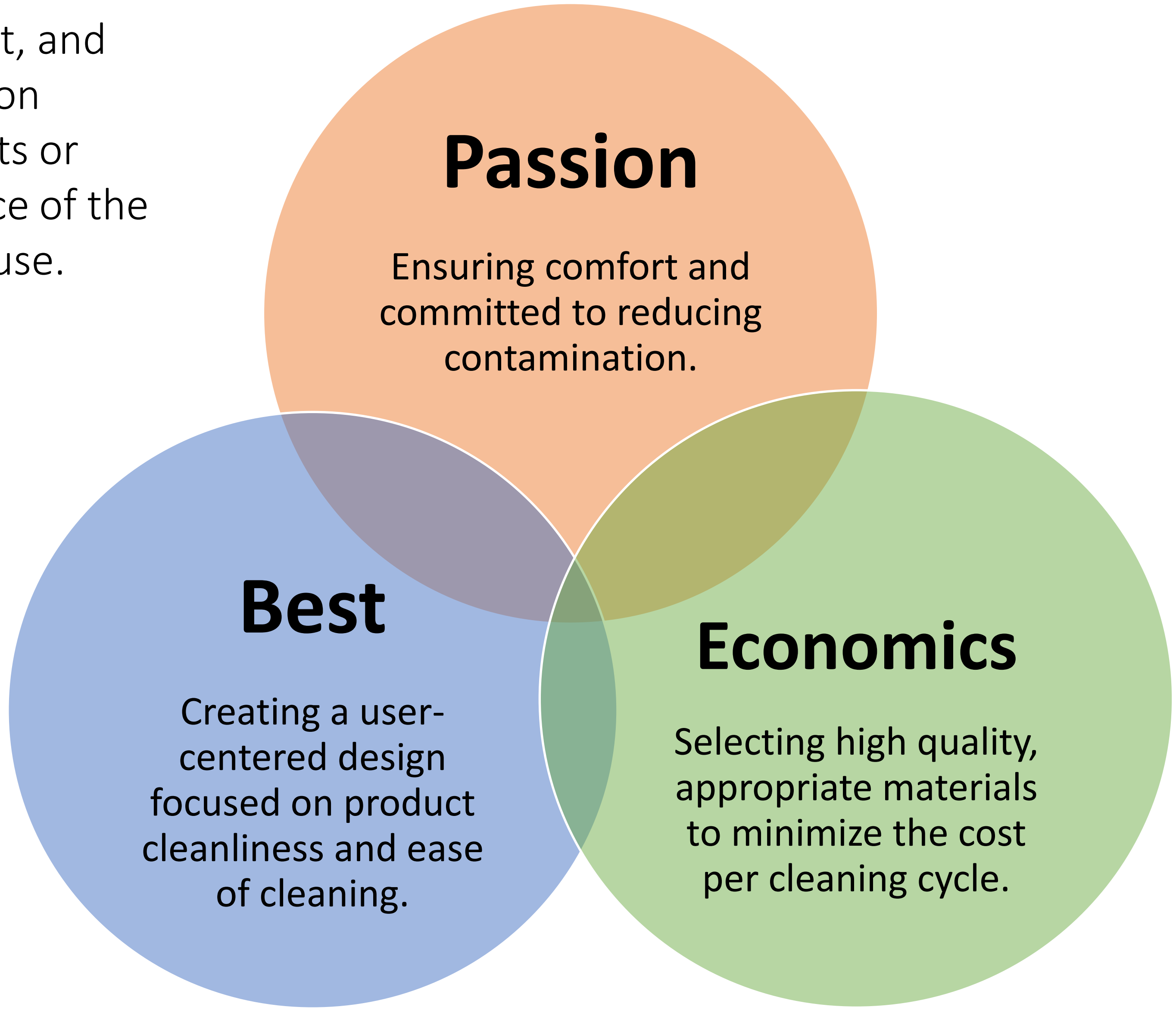
MTOB-1: Louis Bollaerts, Elizabeth Campa, Patrik Raguz, Mahzen Babekir, Andrew Kaye, Andrew Montiegel, David Reyes

POWERING THE NEW ENGINEER TO TRANSFORM THE FUTURE

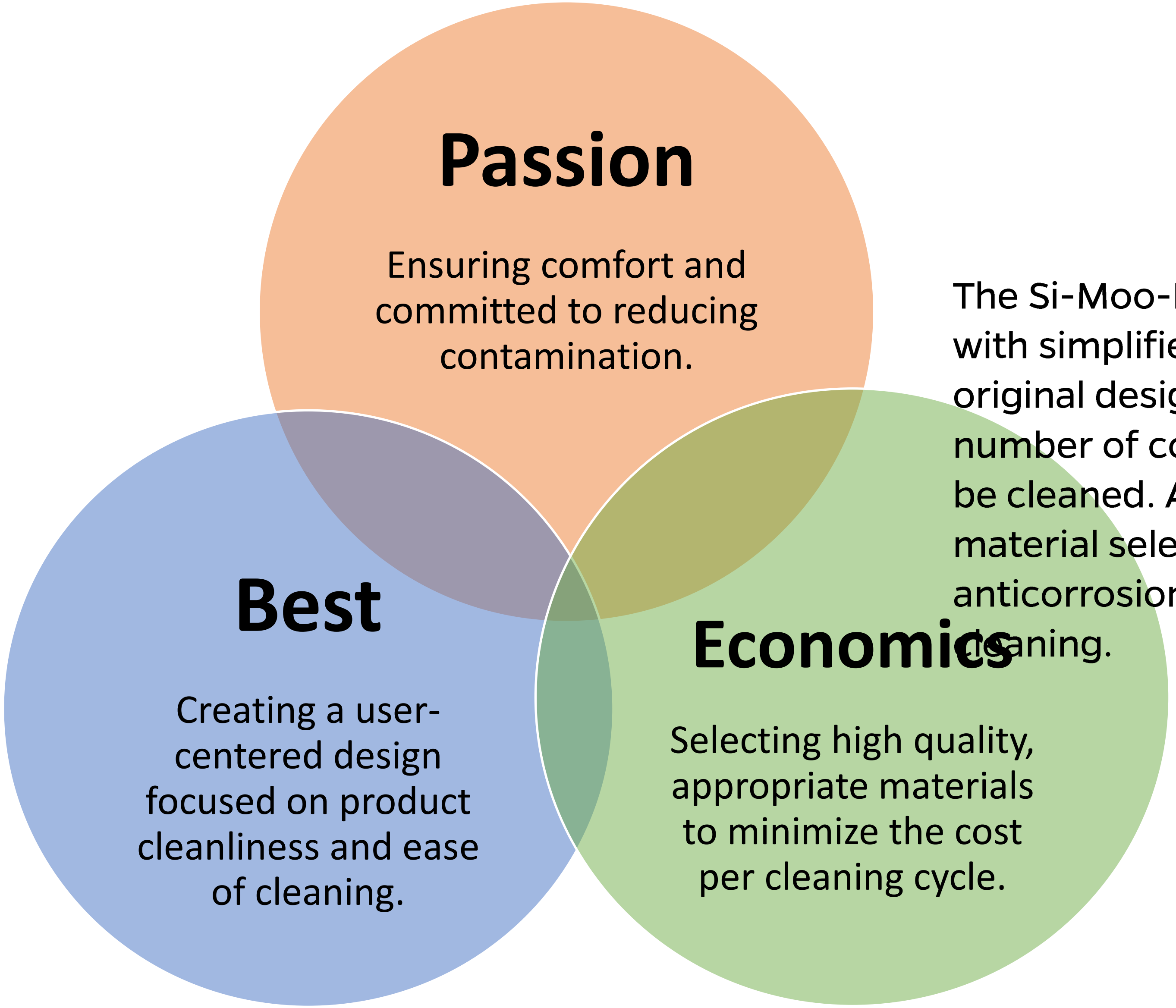
Agenda

Hedgehog Concept

<u>Task:</u> Develop, build, test, and evaluate a cattle digestion simulator unit that meets or exceeds the performance of the legacy unit currently in use.



Hedgehog Concept

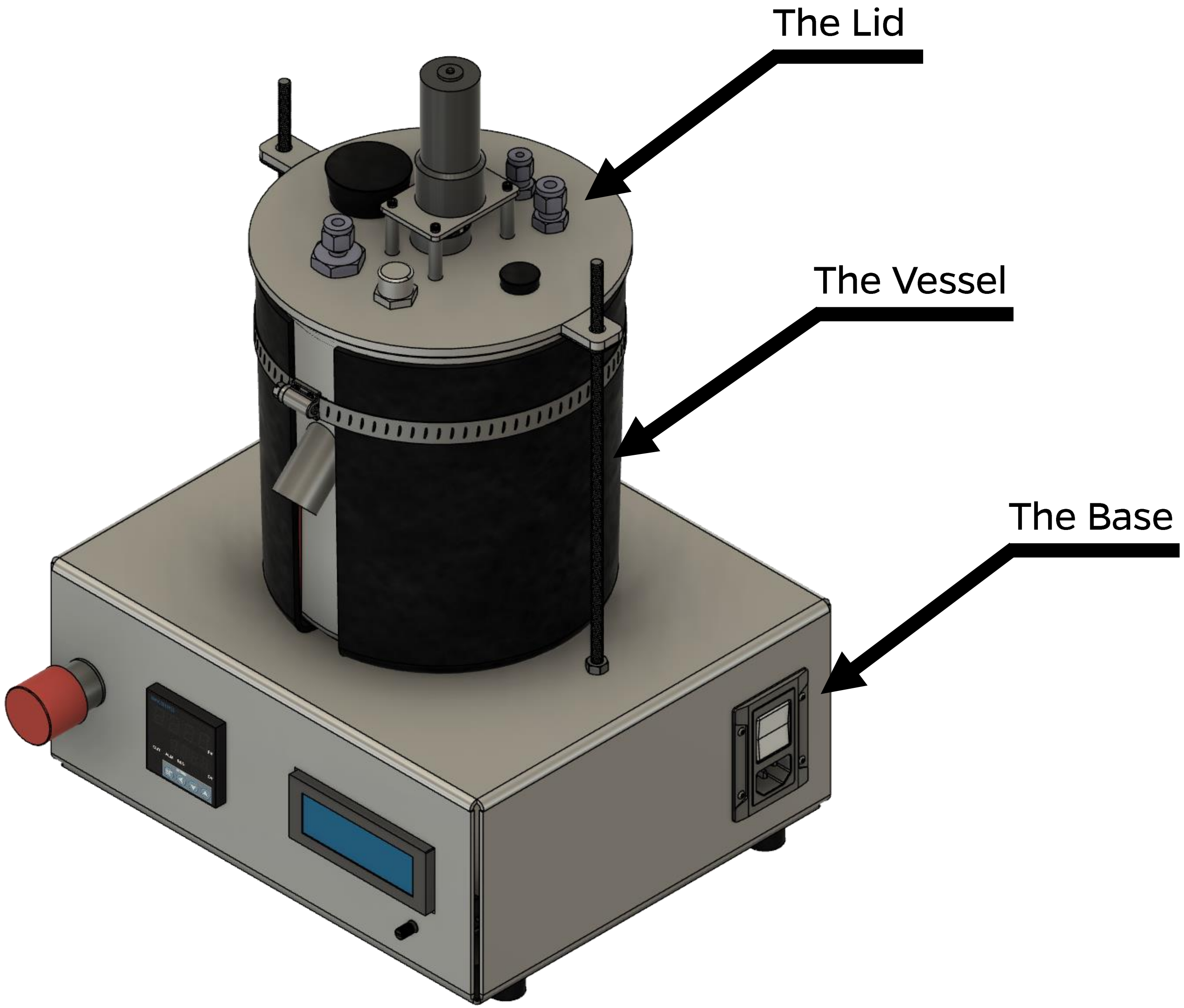


The Si-Moo-Lator was designed with simplified features from the original design to reduce the number of components that must be cleaned. Additionally, all material selection is based around anticorrosion and ease of cleaning.

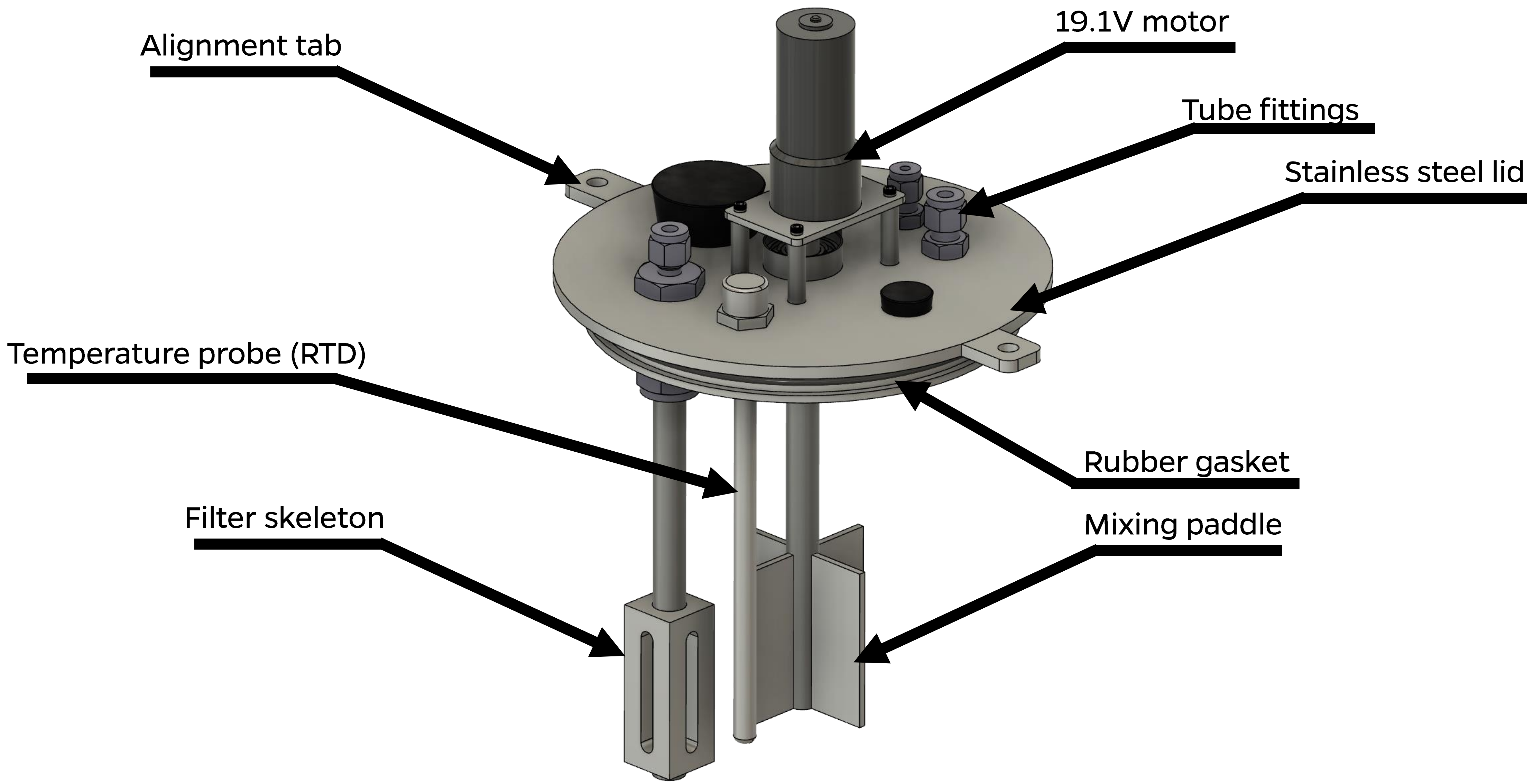
Key Product Specifications

- Lid Design:
  - Motor integration for stirring mechanism
  - O-ring
- Filter System:
  - Replaced zip-tie method with stainless-steel casing
- Heating Mechanism:
  - Replaced submerged heater with flexible heaters for optimized heat distribution
- Base:
  - Removable plate for enhanced accessibility and ease of maintenance
- Material:
  - Stainless-steel for its corrosion resistance and easy cleaning

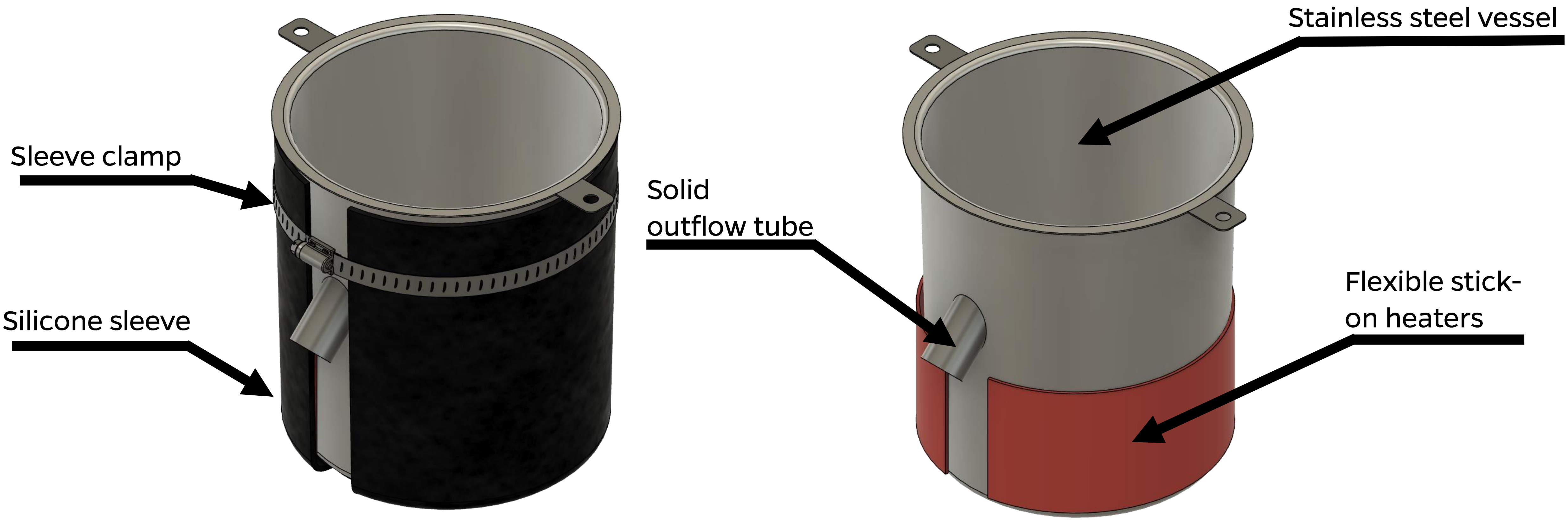
Key Specifications: Overall Unit



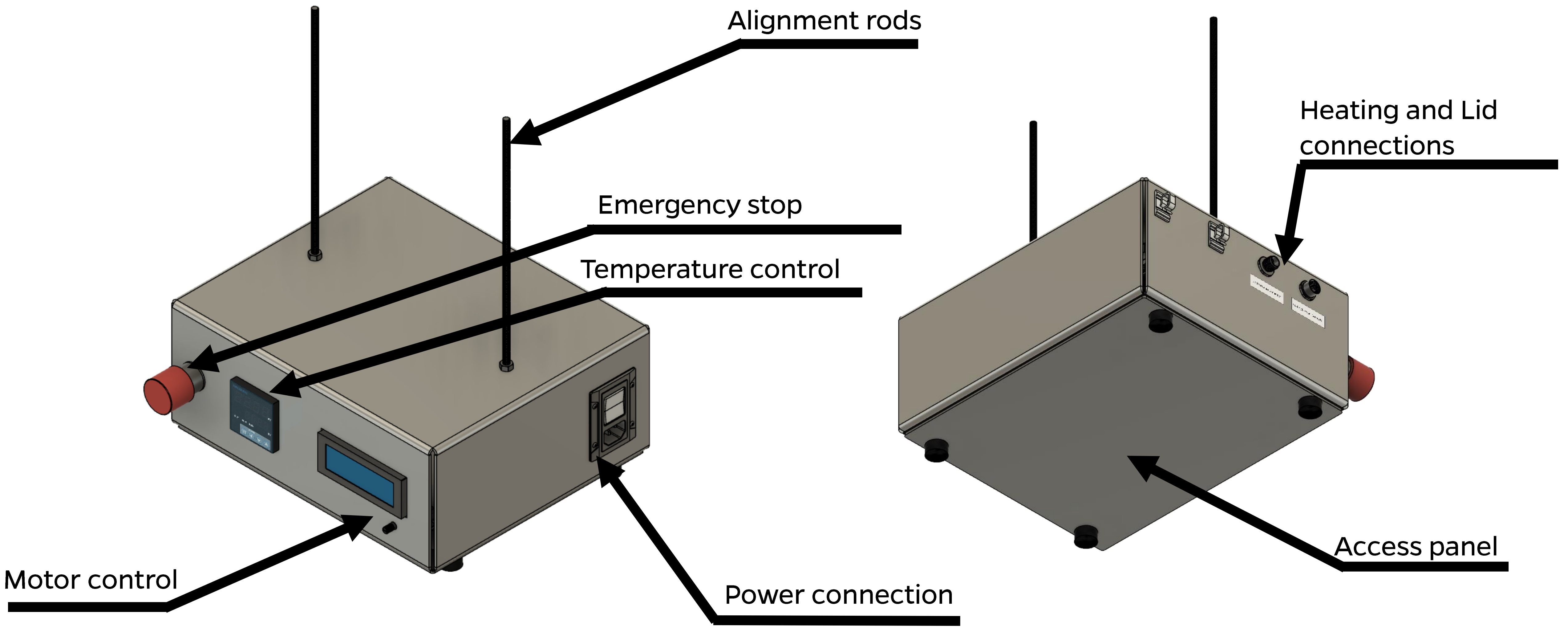
Key Specifications: The Lid



Key Specifications: The Vessel

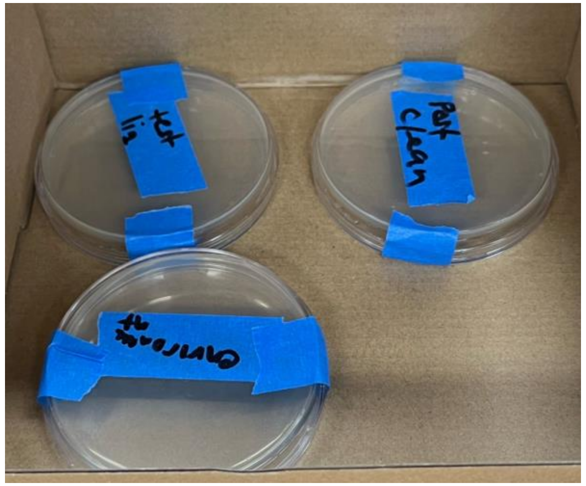


Key Specifications: The Base



Protocol #1: Ease of cleaning

- Measuring: Cleaning efficiency and accuracy.
- Result: Post cleaning swab showed no growth. Cleaning only took 3.5 minutes.

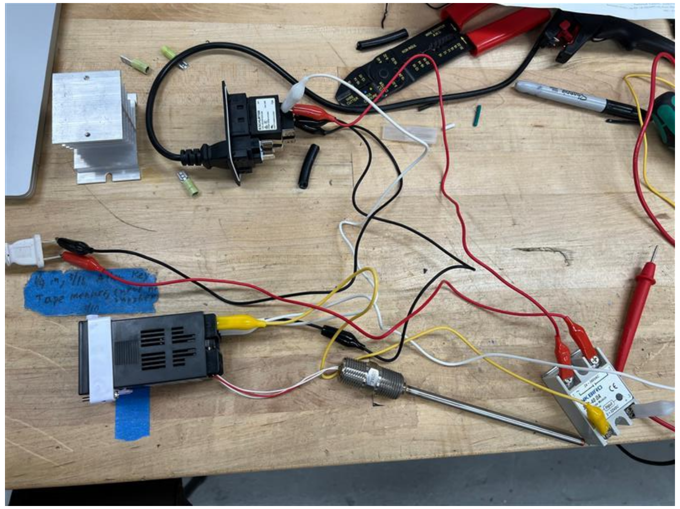


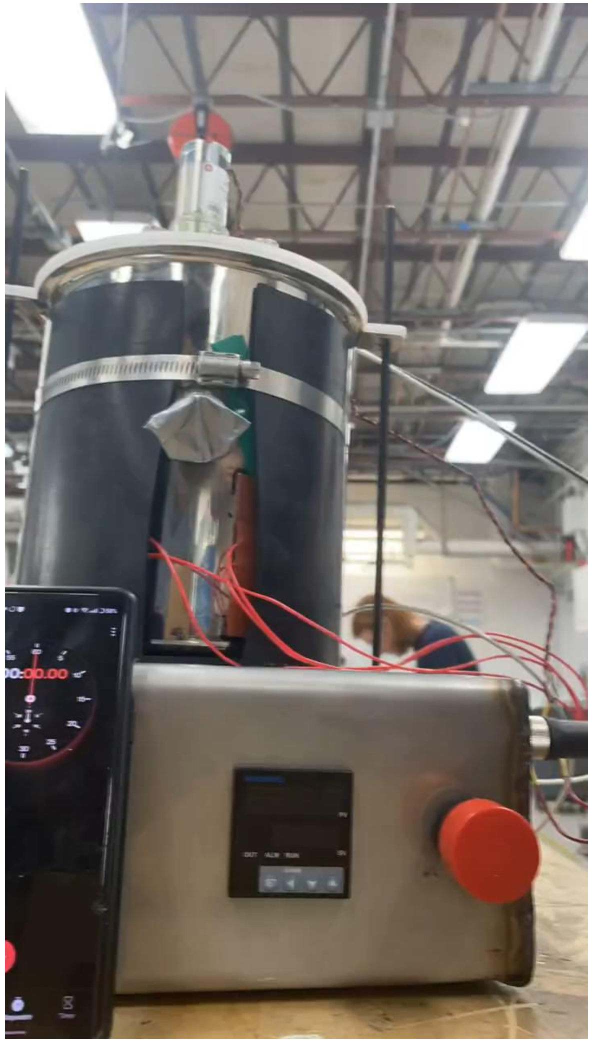
Before growth

Petri dishes showing contamination

Protocol # 2: Temperature control

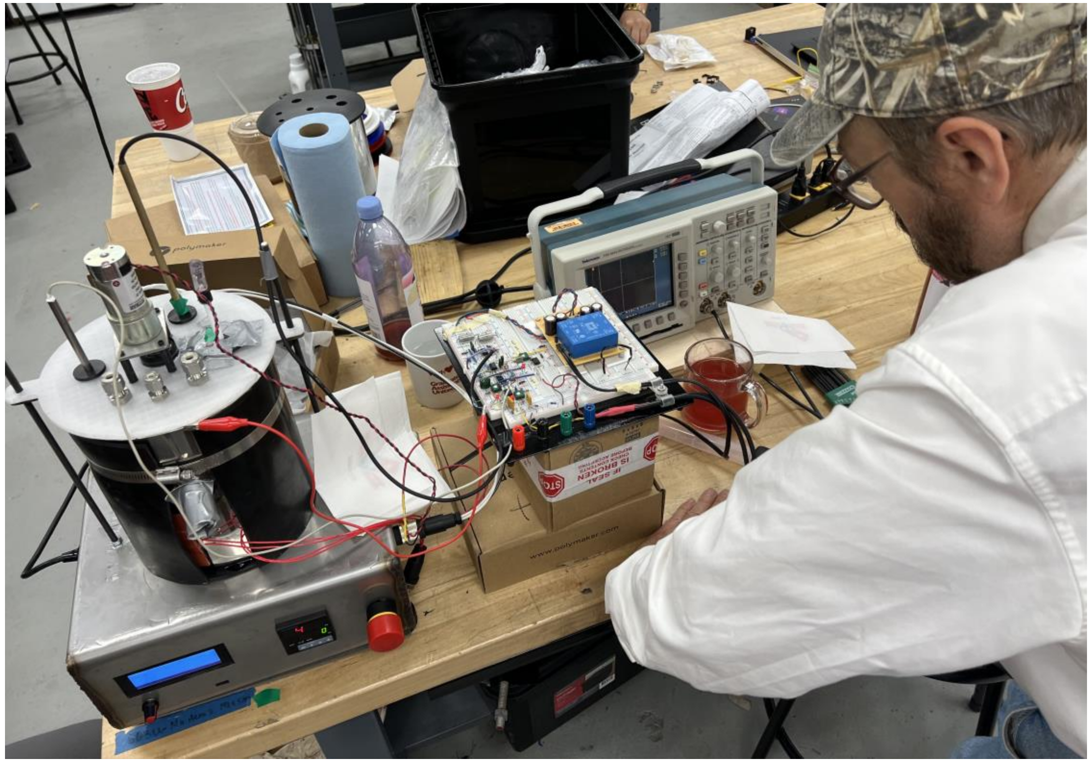
- Measuring: Temperature consistency.
- Results:
  - PID Controller showed success
  - Water temperature remained within acceptable range





Protocol # 3: Mixing ability

- Measuring: How long it took for the solution to fully emulsify
- Result: Passed protocol



Calculation justification: Motor selection

Parameter	Quantity	Unit
Viscosity (μ)	350	cP
	0.35	Pa·s
Density (ρ)	1380	kg/m³
Impeller diameter (D)	0.08	m
Rotational speed (N)	150	RPM
	15.708	Rad/sec
Power number (N_P)	3	
Impeller type	Cross Blade	

$$Re = \frac{\rho N D^2}{\mu}$$

$$Re = \frac{\left(\left(1380\left[\frac{kg}{m^3}\right]\right)\cdot(150[RPM])\cdot(0.08\,m)\right)}{0.35\,[Pa\cdot s]} = 3785.14$$

$$P = N_P \cdot \rho \cdot N^3 \cdot D^5$$

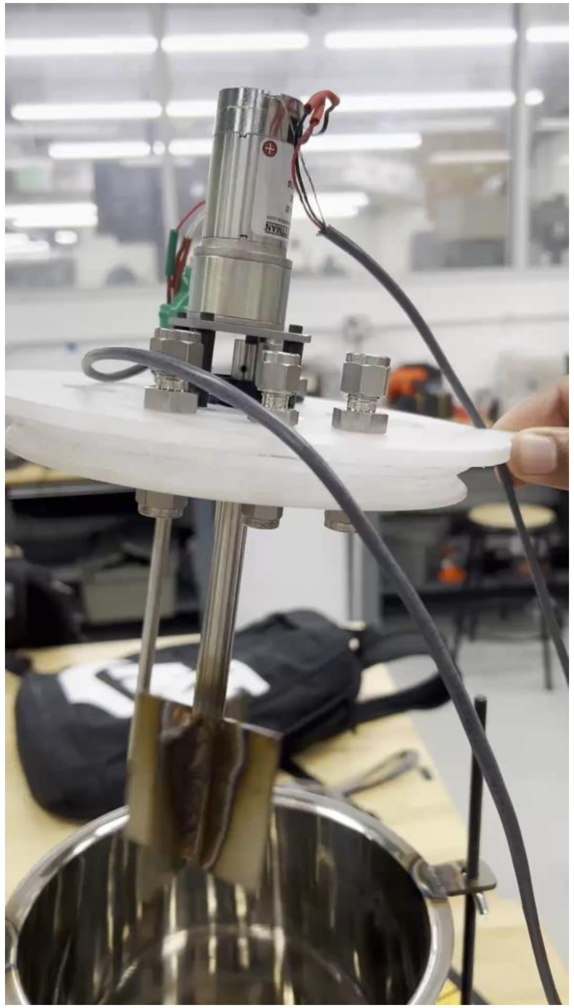
$$P = 3\cdot\left(1380\left[\frac{kg}{m^3}\right]\right)\cdot(15.708\,[Rad/sec])^3\cdot(0.08\,[m])^5 = 52.579\,W$$

$$T = \frac{P}{W} = \frac{P}{\frac{2\cdot\pi\cdot N}{60}} = \frac{30\cdot P}{\pi\cdot N}$$

$$T = \frac{52.579\,[W]}{15.708\,[Rad/sec])} = 3.347\,Nm$$

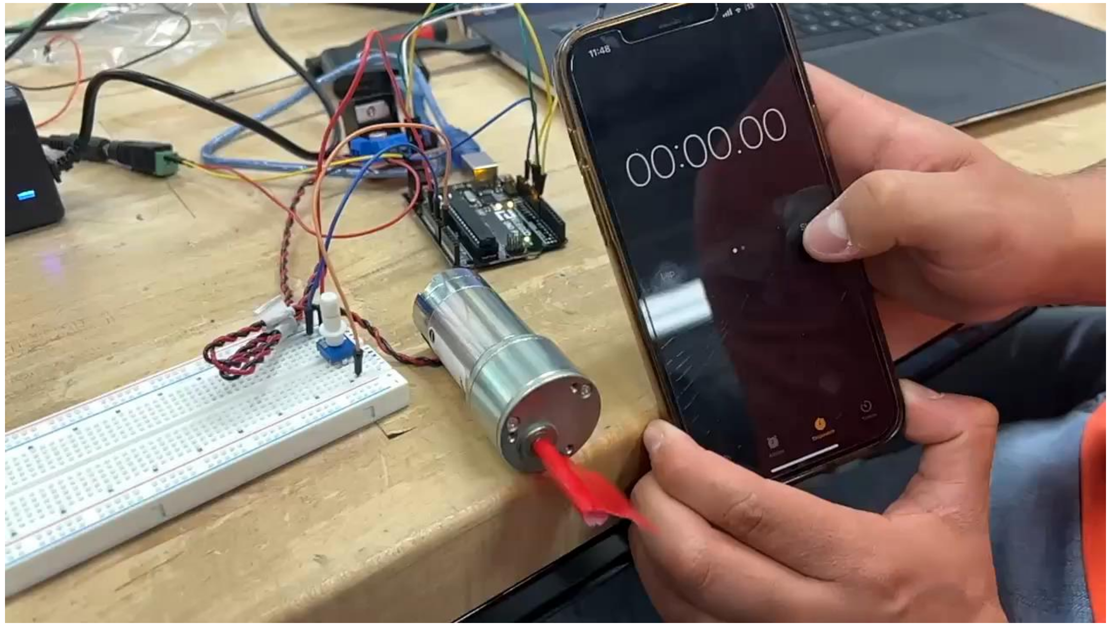
Motor Control

- Potentiometer Input
  - Variable Resistance
- PWM Signal Generation
  - Simulation of Analog Output
- Mapping Analog Input to PWM
  - 10-bit to 8-bit



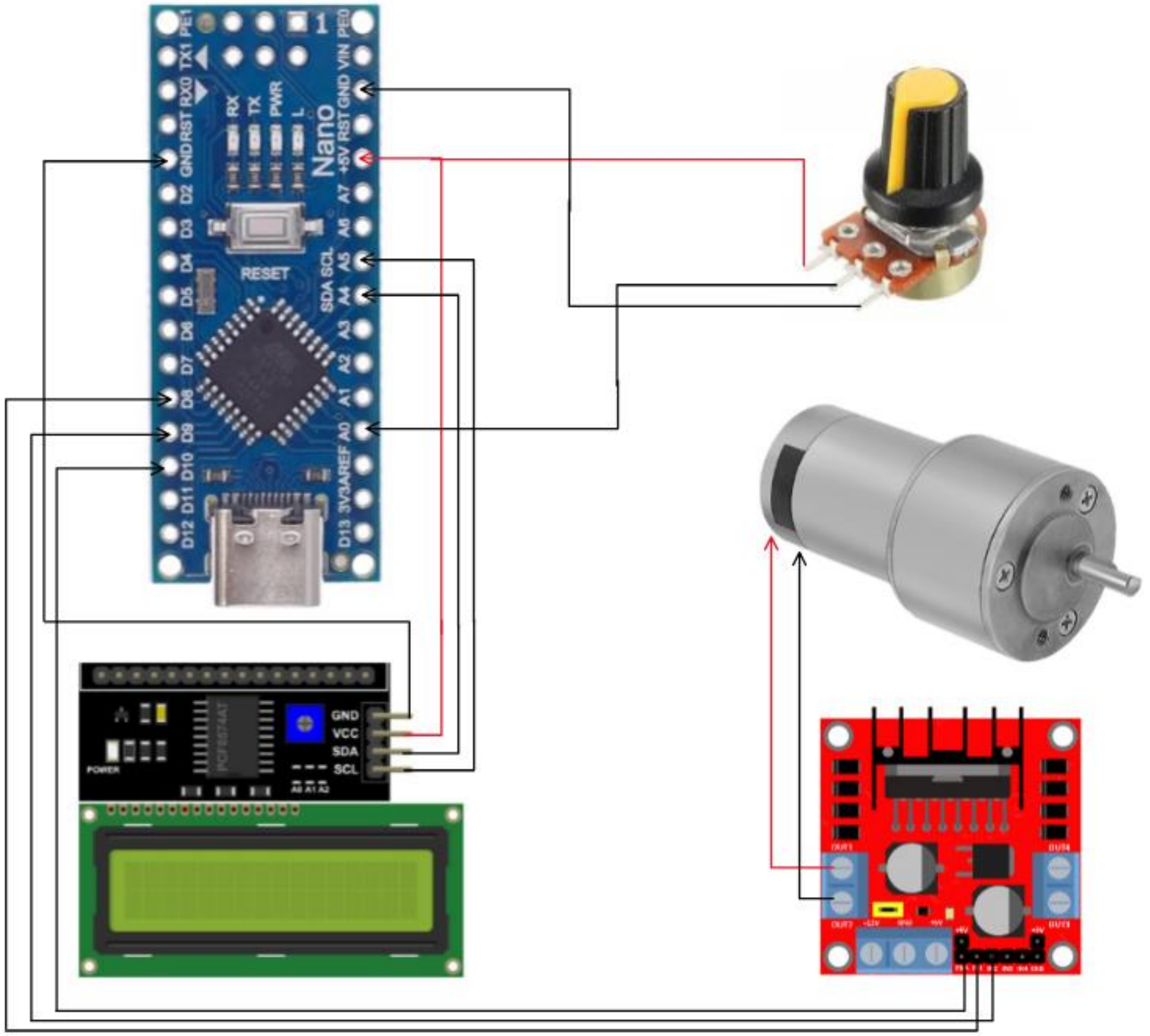
Motor Desired vs Actual RPM

- Stir Speed Customer Need
  - 10-150 RPM
- Setting Desired RPM
- Measuring Actual RPM
- Solution:
  - Mapping maximum motor effort to maximum RPM
- Proposed improvement:
  - Encoder application

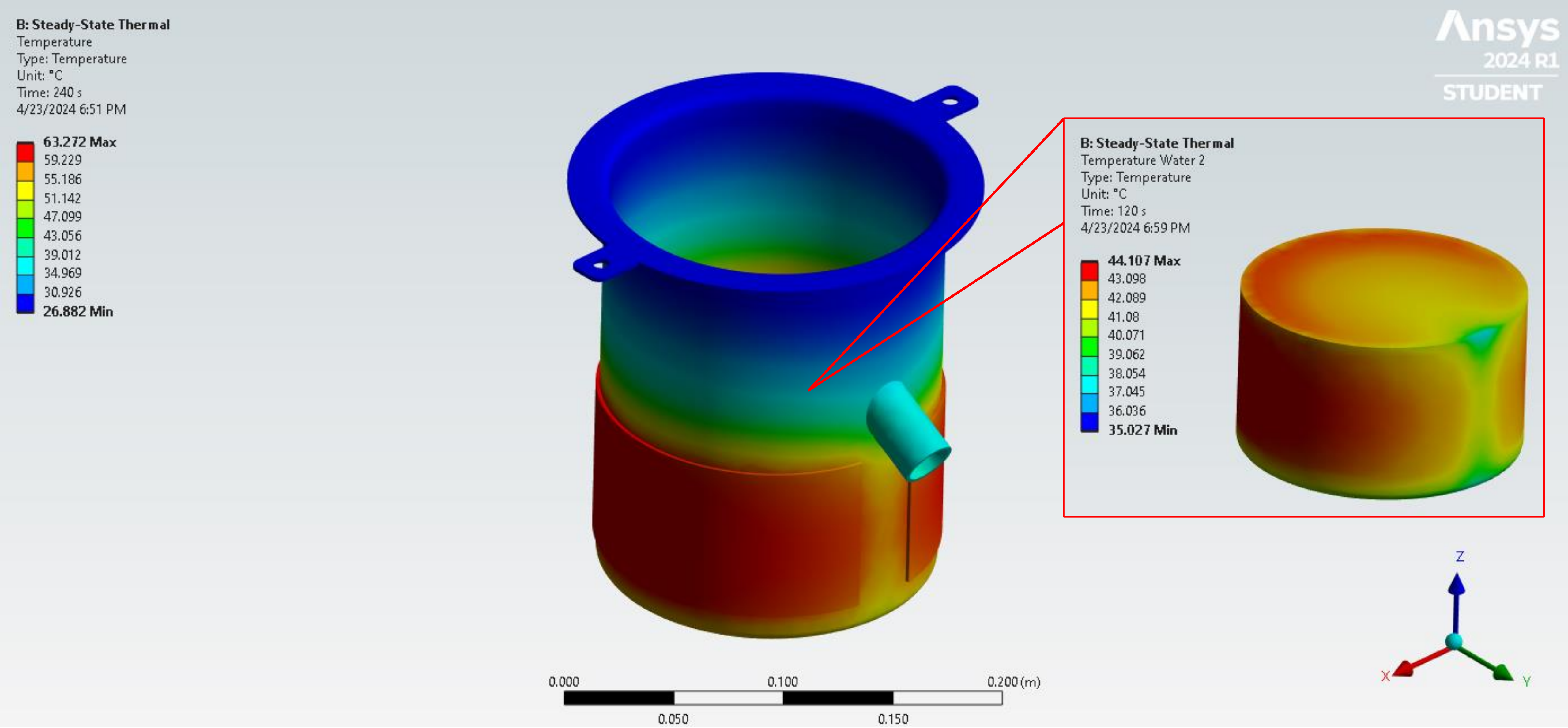


Subsystem 2: Motor

- Arduino Nano
- 10K Ohm Potentiometer
- I2C LCD
- L298N Motor Driver
- 19.1 V Motor



Calculation justification: Stick on heater



Calculation justification: Internal temperatures of control box

- Heat transfer overview:
  - Purpose:
    - Predict temp within base assembly (system) to confirm safe operation of electronics.
    - Maximum Allowable Temp = 55°C (102 °F) (PID Temp Controller)
  - Assumptions:
    - Isolated system with uniform temperature distribution
    - Ideal gas behavior
    - Constant material properties and geometry
    - Heating Pads transfer 100% of heat to top of system
    - Linear interpolation where applicable
    - Worst case values selected from referenced data ranges

Calculation justification: Internal temperatures of control box

- Heat transfer summarized:

$$\dot{W}_{out} - \dot{W}_{in} = \dot{Q}_{in} - \dot{Q}_{out}$$

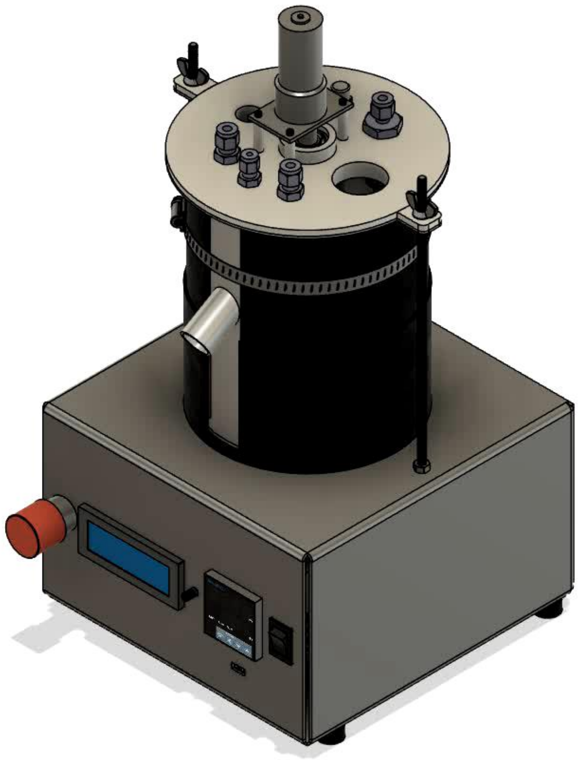
$$(\dot{W}_{out}) - (\dot{W}_{in}) = \left((T_v - T_b)\frac{k\,A_v}{L}\right) - \left(h\,A_T(T_b - T_\infty)\right)$$

$$T_b\left(\frac{k\,A_v}{L} - h\,A_T\right) = \dot{Q}_{out} - \dot{Q}_{in} + T_v\left(\frac{k\,A_v}{L}\right) + T_\infty(h\,A_T)$$

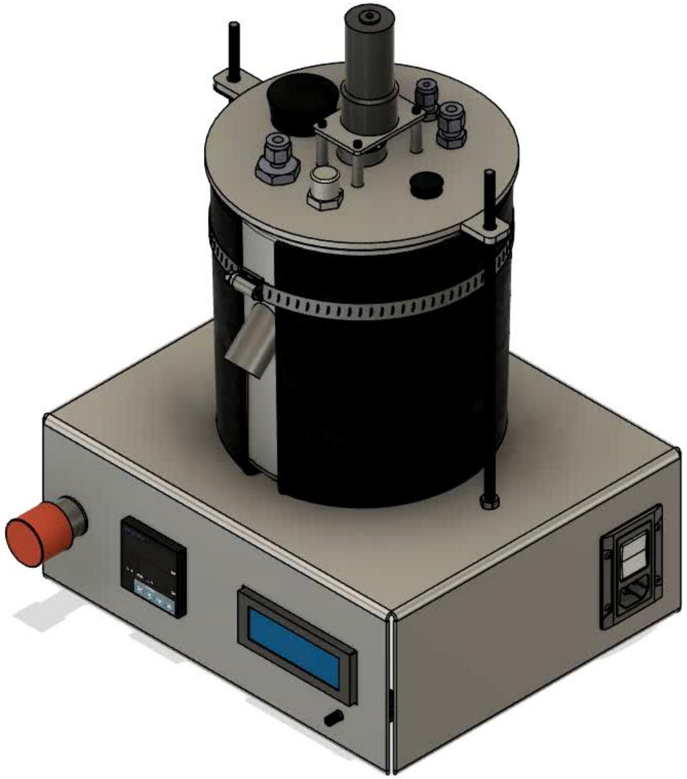
$$\mathbf{T_b \approx 44.08°C\ (111.35°F)}$$

- Notes:
  - $\dot{W}_{out}$ done by motor and 2 heating pads (manufacturer specs)
  - $\dot{W}_{in}$ from standard nominal US voltage (+5%) and current (15A)
  - $\dot{Q}_{in}$ from T_v and T_b junction (vessel base (A_v))
  - $\dot{Q}_{out}$ is the summed convective transfer of boundary walls (A_T)

Evolution of: The overall product



Iteration #1



Final Iteration

Evolution of: The lid

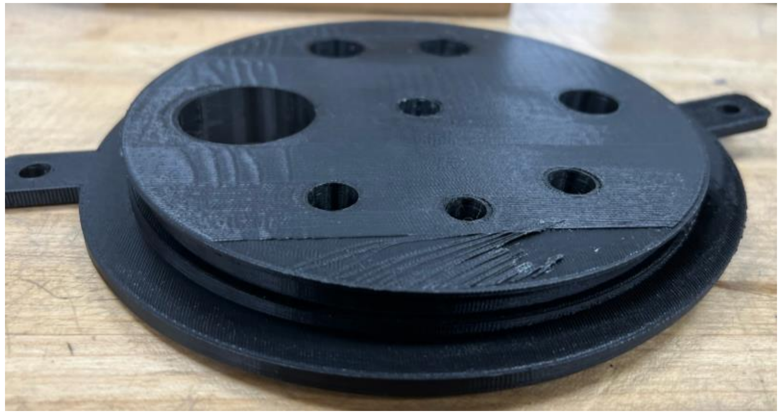

Iteration #1


Iteration #2


Iteration #3


Iteration #4


Iteration #5

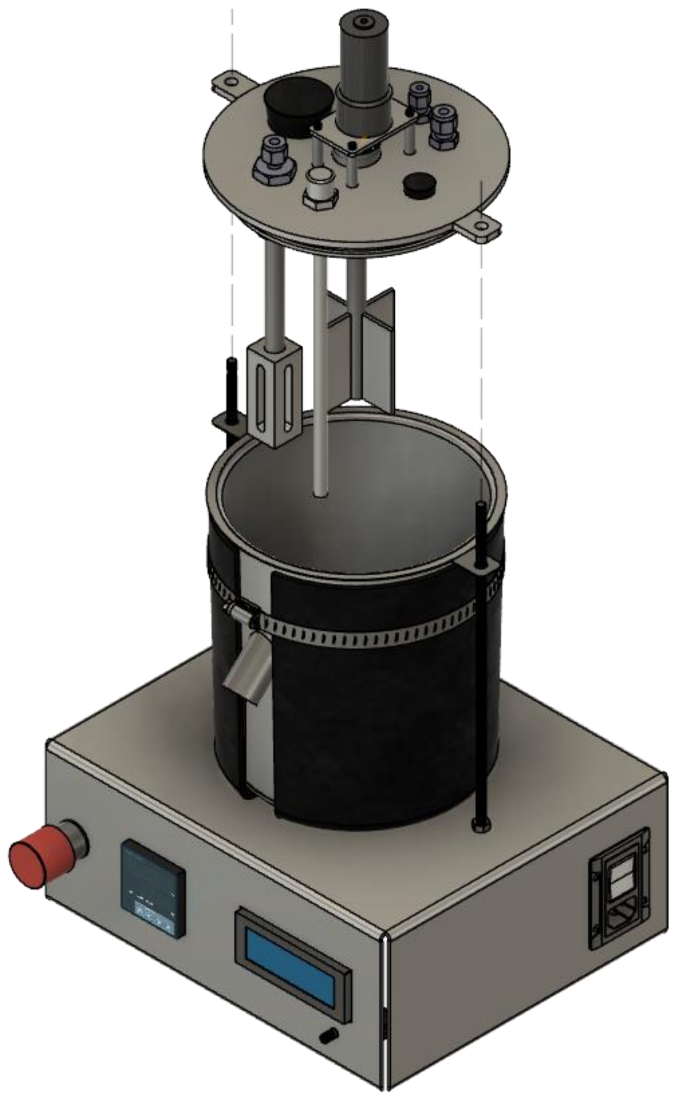

Iteration #6

Evolution of: The filter skeleton

Iteration #1

Final Iteration

CAD Overview



Cost Analysis

- Budget usage for OTS parts: $1301.03 / $1500
- Single prototype vs. Batch Manufacturing Run
- Total Cost

$$C = C_{OTS} + C_{assem} + C_{mfg}$$

- OTS Cost

$$C_{OTS} = C_1 + C_2 + \cdots C_{47}$$

- Manufacturing Cost

$$C_{mfg} = C_1 + C_2 + \cdots C_{11}$$

- Assembly Cost

$$C_{assem} = t_{assem} \times \$19.10/hr$$

Cost Analysis

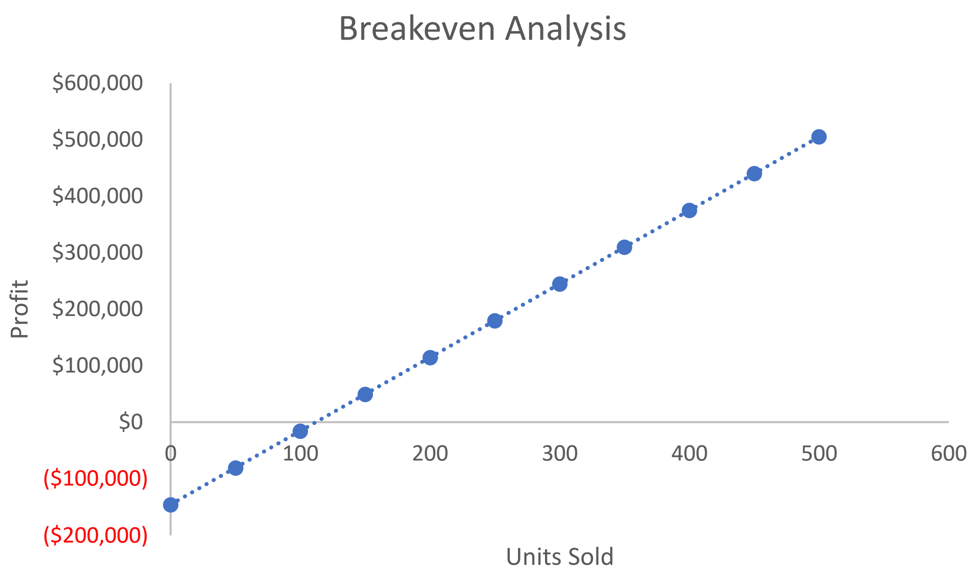
- Single prototype vs. Batch Manufacturing Run

Cost Type	Single Prototype	Batch Manufacturing Run Cost per Unit
OTS Parts	$1,910.25	$1,427.78
Manufacturing	$127.05	$38.89
Assembly	$32.09	$32.09
Total	**$2,069.39**	**$1,498.76**

Cost Analysis

- Product Price Analysis:
  - Overall Cost

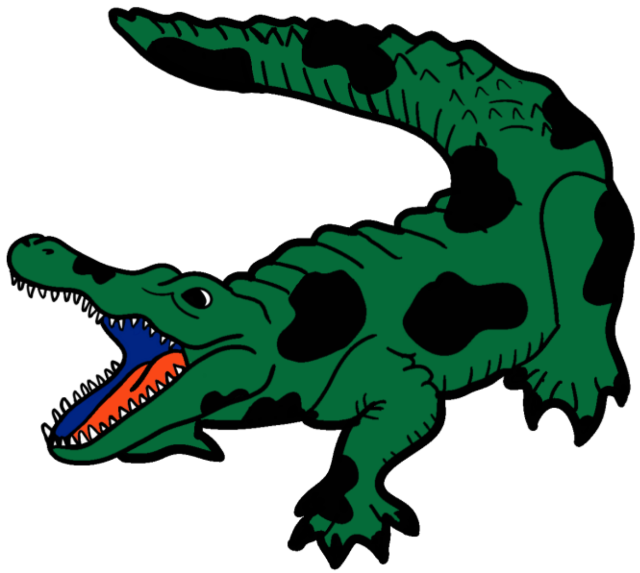
Cost Type	Estimated Amount
Total Product Cost	$1,498.76
Variable Cost (25% T.P.C)	$375
Rent (annual)	$28,000
Business Insurances (annual)	$7,836
Die Cast Machines	$60,000
Additional facility setup costs	$50,000



  - Price set at $2800, for 1000 units, M.o.P is 41.28%

Why choose the SiMooLator™?

LEGACY MODEL	The SiMooLator™
Magnetic stirring mechanism: Unreliable readouts, failed, magnets lost magnetism over time.	**Top loaded stirring mechanism:** Accurately control using the potentiometer, easy to control, easy repairability.
Submerged heating element: dangerous if powered on by accident, unreliable, needed maintenance often.	**Stick on heating element:** safe to handle, low risk of misuse, reliable.
Zip ties for filter mesh: one time use, could contaminate liquid, required more effort.	**Filter skeleton:** reusable and easy to clean, stainless steel, durable.



Herbert Wertheim
College of Engineering
UNIVERSITY *of* FLORIDA

POWERING THE NEW ENGINEER TO TRANSFORM THE FUTURE