# Otter Inspired All-Weather Coat

Department of MECHANICAL ENGINEERING
THE UNIVERSITY OF UTAH

Heather Anderson, Ocean Armstrong, Gabriel Astié, Ashley Howell, Leaticia Mimche, Allie Richards, Catie Ritchie
Advisor: Dr. Cristian Clavijo

## Introduction:

There is a growing demand for an insulating material that retains heat when exposed to cold environments but doesn't overheat in warm air. The objective of this project is to develop a coat sample with a manually changing thermal conductivity based on user input and environment.

## Design:

A bistable, spring-loaded mechanism (see Figure 1) is used to expand and contract an insulated coat sample into an open and closed position. The compression of this sample varies the amount of air and, therefore, the internal conduction and convection of the sample. The insulation type/amount, mechanism dimensions, spring rate, and plate materials are optimized to achieve maximum difference in k value. Desired metrics for the project are shown below in Table 1.

Table 1: The metrics of the project the desired values and the values reached

| Metrics | Units | Value | Reached |
|---|---|---|---|
| Magnitude of Thermal Conductivity Difference (Uncompressed vs Compressed) | - | >10 | 1.33 |
| Compression Ratio | % | >50 | 57 |
| Ease of Use: Compression Force | N | <78 | 47 |

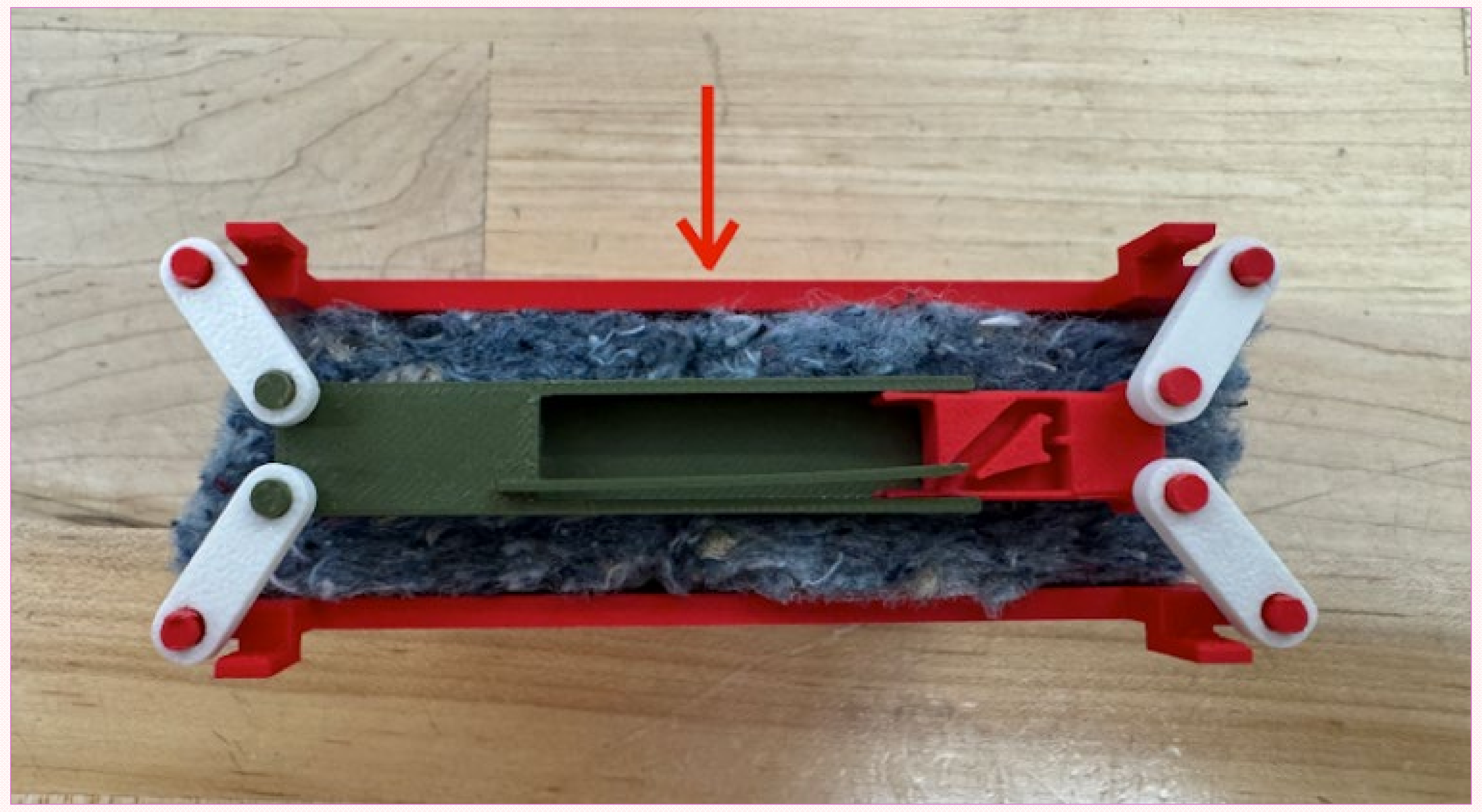

Figure 1: A prototype of our compression mechanism.

## Ease of Use:

Compression force required to close the sample was tested using a dynamometer producing the following results:

Table 2: Dynamometer testing results for multiple insulation levels

| Insulation [g] | Average Force [N] |
|---|---|
| 3.978 | 22.67 |
| 5.304 | 35.33 |
| 6.63 | 47.33 |

## Testing:

Thermal conductivity values of unknown samples were determined in an insulated testing chamber at a temperature of -16° C (see Figure 2) by measuring the temperature difference across the sample using an automated LabVIEW program every 50 seconds for over 3 hours. The heat flux, q", of the heat source was determined with an acrylic sample of a known thermal conductivity value, k, of 0.18 $W/m^2$-K, which was then used to calculate the k value of the unknown sample.

$$k_s = \frac{(T_{c_B} - T_{c_T})L_s k_c}{(T_{s_B} - T_{s_T})L_c}$$

| Sample | | Control | |
|---|---|---|---|
| $k_s$ | - thermal conductivity | $k_C$ | - thermal conductivity |
| $L_s$ | - height | $L_C$ | - height |
| $T_{T_S}$ | - temperature on top | $T_{T_C}$ | - temperature on top |
| $T_{B_S}$ | - temperature beneath | $T_{B_C}$ | - temperature beneath |

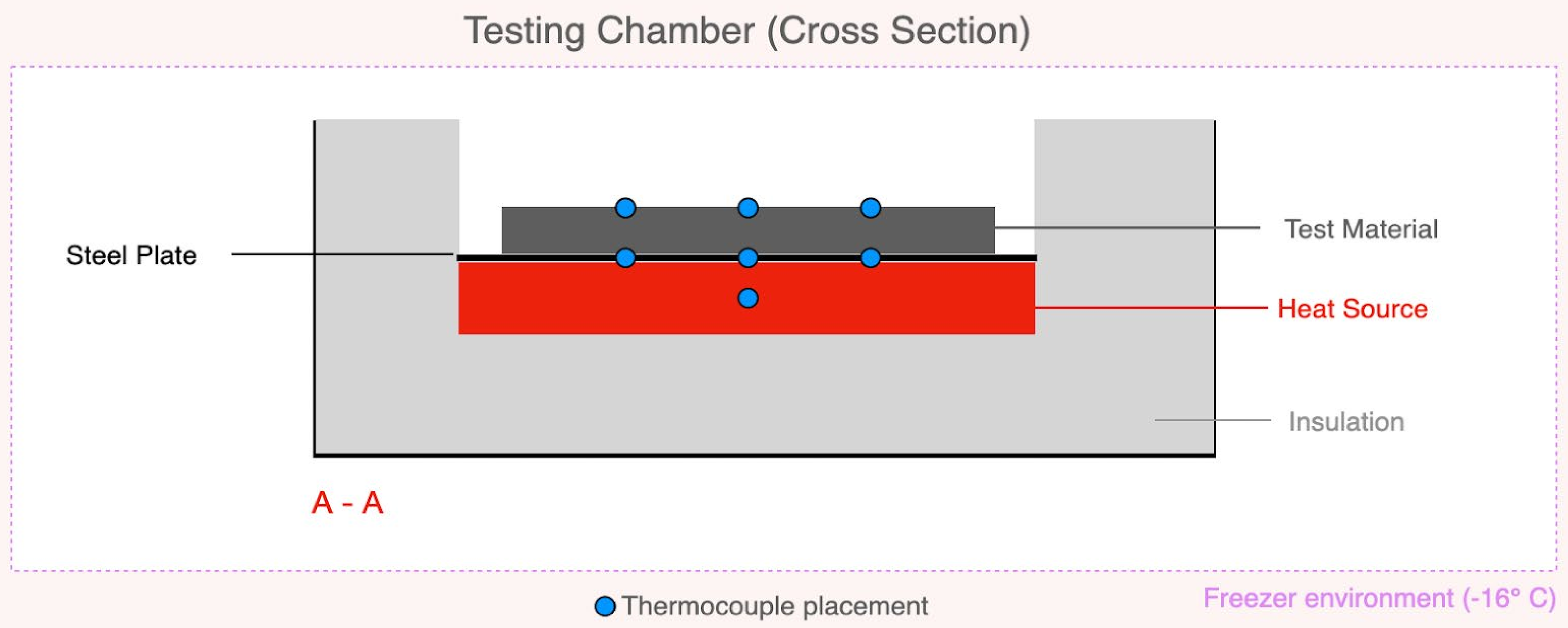


Figure 2: A cross-section diagram of the testing chamber.

## Results:

The prototype with 7g of Climashield APEX insulation was able to achieve a thermal conductivity difference factor of 1.33, as shown in Table 3.

Table 3: The final thermal conductivities of the best test sample, and final prototype.

| Sample | K-value [W/m-K] |
|---|---|
| Final Prototype Compressed | 0.101 |
| Final Prototype Uncompressed | 0.076 |
| Best Test Sample Compressed | 0.23 |
| Best Test Sample Uncompressed | 0.717 |

To explore the concept beyond the mechanism limitations, test samples with variable plate materials, insulation types, and insulation amounts. The optimal sample achieved a difference factor of 3.2 (see Table 3) by using PLA plates, with 15g of Climashield APEX insulation and had a 76% compression ratio. Additional results from these tests can be seen in Figures 3 and 4.


Figure 3: Results from a series of tests done with PLA plates and varying insulation amounts.

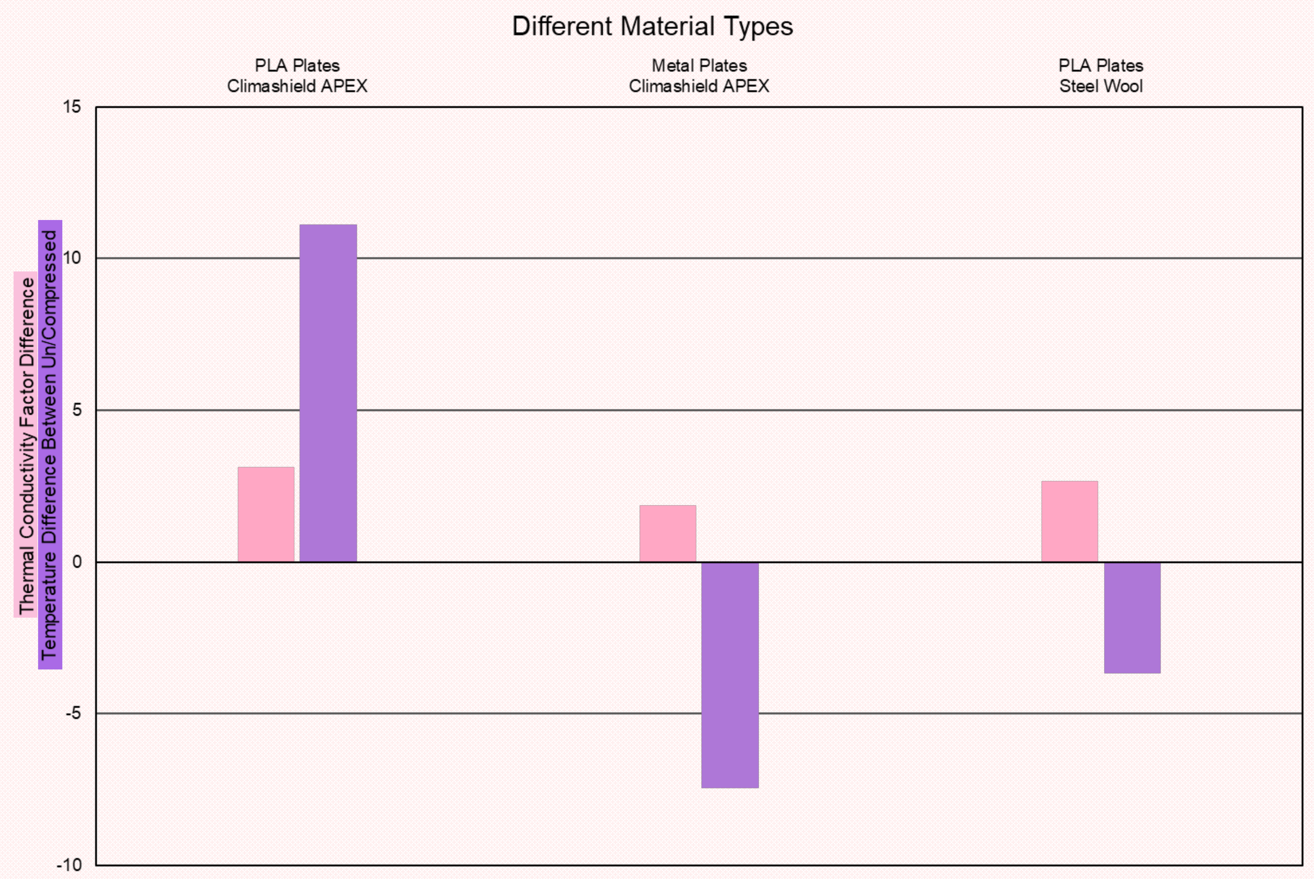


Figure 4: Results from a series of tests done with varying plate materials and insulation types.

## Conclusion:

Our metrics, except for the magnitude of the thermal conductivity difference, were achieved.

- A compression ratio of 57% was achieved, despite an expected 50%.
- The force required to compress the sample was 47 N, which was less than the 78 N needed.
- A thermal conductivity difference of 1.33 was achieved, not a magnitude of 10 difference, but it was still a significant difference.

## Future work:

This project's scope could be continued to include waterproofing to further imitate otters as well as continual development in material optimization to improve thermal conductivity difference.
The sample's wearability could be improved by using better, more flexible materials. With more financial flexibility and time, these goals could likely be achieved by a future senior design team.