40-Quart Cooler Design Team

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Engineering Analysis

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INTRODUCTION

This report addresses the design team's progress over the past few weeks in regards to generating potential design concepts and evaluating the potential performance of each one. During this process it was important to keep in mind the objectives of the project outlined in our problem statement and to refine our direction.

The needs of the client, Jason Costello, are wide and sweeping in nature. There were many possible directions that this capstone project could have focused its attention in. One of our jobs was to listen to his business needs and choose a direction in which we felt we could make the biggest and best impact on the business. Addressing the most pressing issues that are outlined in the quart sized ice chest that yields low uncertainties in the manufacturing process and provides the features and price that appeal to a wide range of customers.

Through thorough consideration of this need the goal of the project was identified and is stated as such. Produce a 40-quart cooler that shares quality and features with the best models in the market but at a reduced price. The challenge that the engineering team faces is to innovate the design of the cooler in such a way that it has minimal impact on the current MSRP of the 40-quart size.

From the beginning of this project the team has been discovering new ways in which we can maximize the efficiency of our designs to best fit Mr. Costello's business needs. Initially he was interested in the implementation of a quick access port for the cooler that would allow the user to access the contents of the chest without opening the entire lid and facilitating heat transfer. After some consideration, the team decided that this feature did not belong on the smaller 40-quart sized cooler. However this feature maintains a position in the design plans, as it will be implemented on 120-quart sizes and up in the future. Another discovery in the design process centers on the latch design. Over the past few weeks the team has developed initial CAD models for the cooler body itself, and for the individual components. Most of these designs seem to meet the favor of the client, Jason Costello, but minor changes are still required and the team members are working on updating the CAD models.

FINAL DESIGN CONCEPTS

These final designs drawings and CAD photos were the exact copies that were presented to the client during our most recent meeting. There was a lot of good conversation and collaboration that came out of the meeting that will assist the team in making changes to these existing designs in order to best satisfy the client. The designs presented here include the gasket, latches, handle, tie downs, floor, and hinge.

Since the client was satisfied with the gasket CAD modeling during the last meeting the changes on this model are going to be small and not change the nature of its design. This gasket layout has two foam seals that are meant to trap air in between. By doing so, we are planning on significantly reduce the rate of heat transfer trough the seals, therefore minimizing the overall rate of heat transfer for the entire assembly. The goal is to offer redundancy features as well, by doing so the entire assembly will not be totally compromised in case of the failure of one of the foam seals. The only change the team might make on the CAD model is the shape and size of the foam seals, since these components are extremely cheap and utilizing better ones would not end up affecting the

cost of the final product significantly. Figure 1 depicts the exploded view of the gasket assembly and Figure 2 shows the design in its compact form.
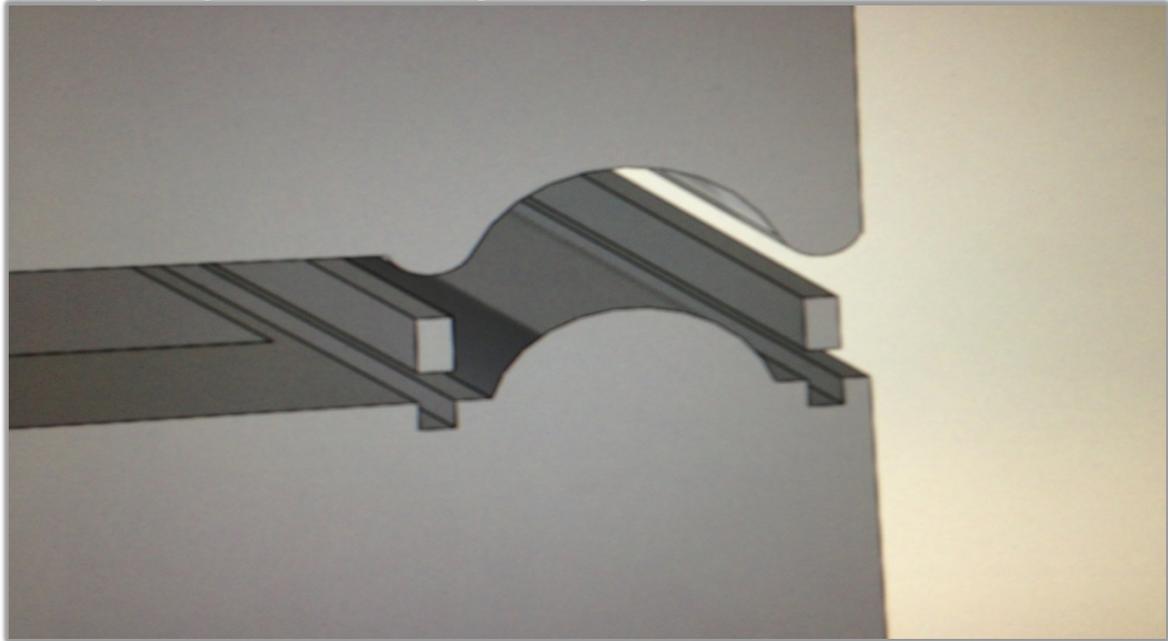
**Figure 1** – Exploded view of gasket assembly

This view looks at a sectional cut of the cooler body and lid. This design will wrap the entire perimeter of the cooler. It can be noticed in Figure 2 below that the design conflicts with itself in the meshing of the top and bottom. The plan is to expand the width of the foam strips to improve the mesh.
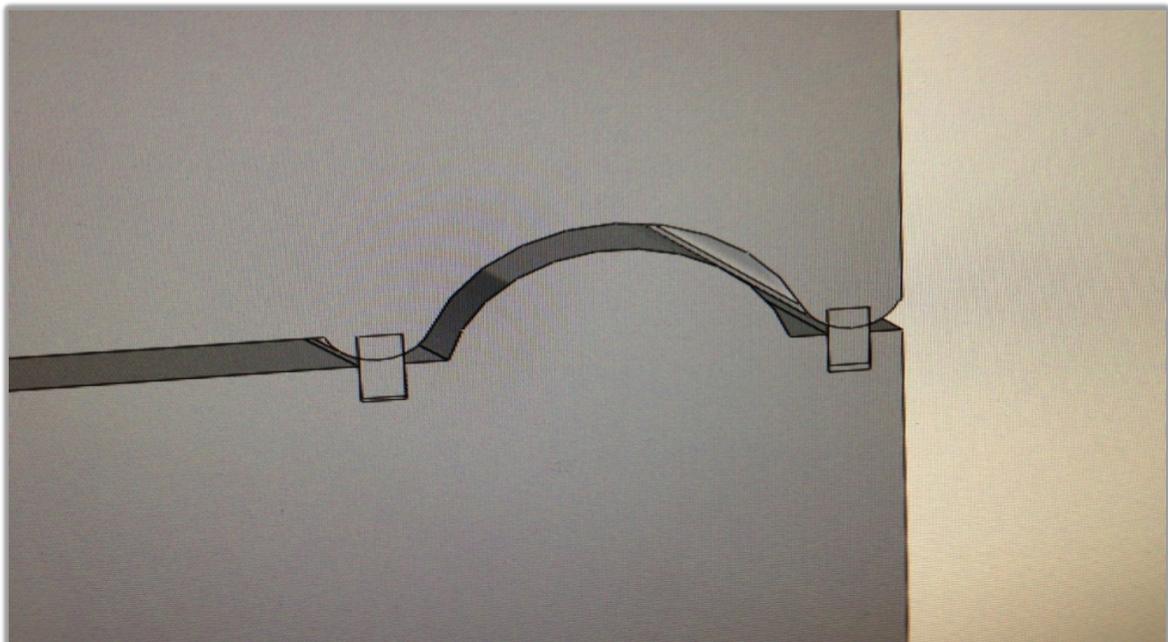
**Figure 2** – Compact view of gasket assembly

The next design concept to discuss is the latch. The main focus in designing this latch was to make it backwards compatible with the existing design. This means our design functions in the same basic way, with a single rivet in the top driving the latch into the cooler lid, and a male knob screwed into the cooler body where the female attachment on the latch secures. The specifics of the design can be seen in Figure 3 below.
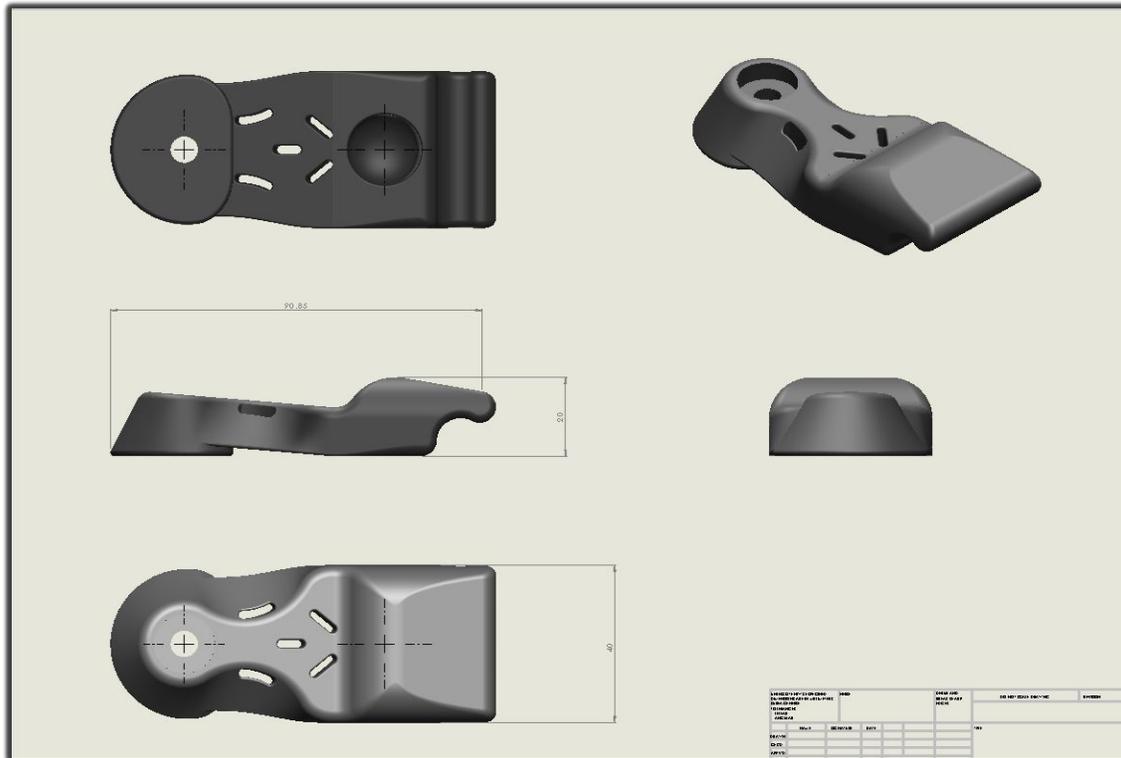
Figure 3 – Solid Works drawing of the "Phantom Latch"

The design features a tapered shape on all sides to help reduce its surface area, which makes the design less prone to catch on other objects when in use. The lower part of the latch was design with the human hand in mind. It is ergonomically shaped to allow the palm to apply downward pressure for latching and to allow the use of a single finger to undo the latch. The cut outs in the design are strategically positioned to allow the latch to stretch and flex without inducing excessive stress concentrations. The group is doing research on various forms of nitrile rubber as the main candidate for the latch material. The stress analysis done on this component can be seen in the experimental portion of this report.

The third design feature is that of the dynamic handle. The handle mechanism itself will be purchased wholesale from an existing distributer. It consists of a strong nylon rope and a cheap plastic handle that is threaded onto the rope. The rope is fixed to the cooler through a system of knots. The part that the team designed was the specifics of this attachment. The design is shown below in Figure 4.
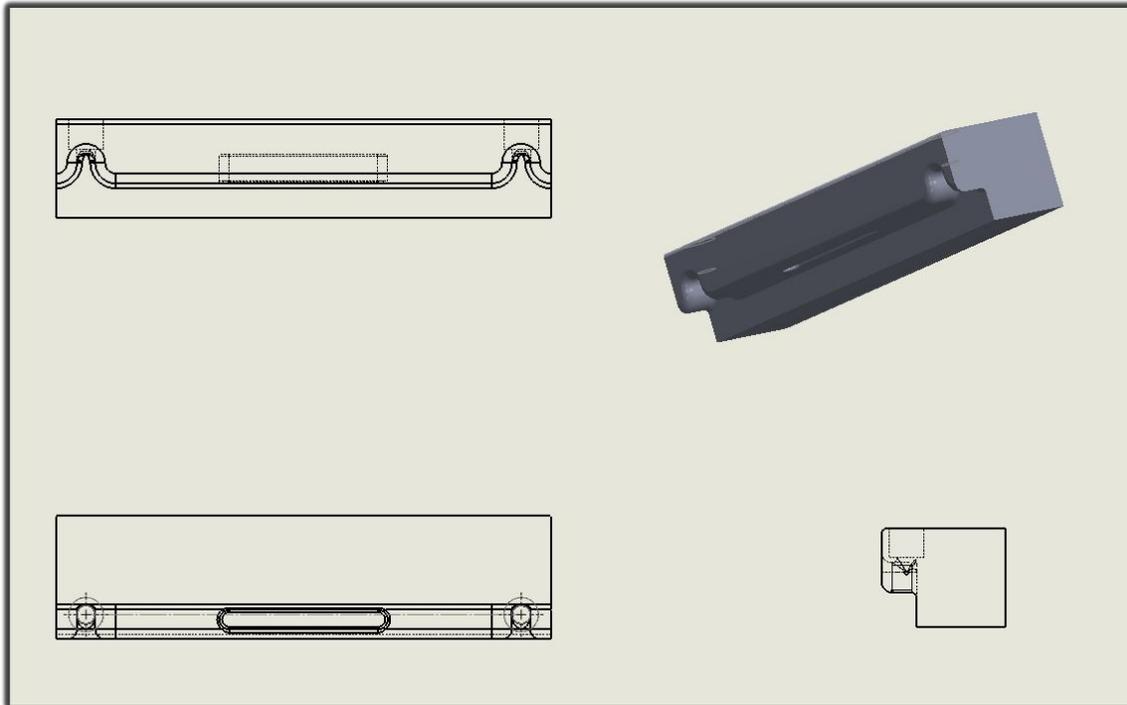
Figure 4 – Solid Works drawing of the dynamic handle fixture

       The top left corner is the front view of the design, bottom left is the bottom, bottom right is the side view, and the top left is the isometric view. This is located on each side of the cooler body on the lower lip. The wide holes on the top of the design will recess the rope knot into the cooler body reducing the overall projected footprint of the cooler. The two channels will guide the rope and secure it into place as the user lifts the ice chest. They will also reduce the overall distance the rope has to travel therefore saving material and reducing cost. The cut out in the center of the design is an additional fixed handle that provides the user with a couple options for transporting the device. One disadvantage of this design is the possibility of the recessed holes collecting debris and facilitating wear on the rope. This problem will be addressed in the future.

       The arrangement and mechanics of the tie downs is another area the group focused design in depth. This feature allows the user to secure the cooler in a wide range of configurations for different purposes. The main advantages of the design are its ability to fix the cooler body to a surface while keeping the lid free to open and close maintaining functionality. The lid can also be fixed in place to improve seal and keep out intruders of the human or animal variety. The design is depicted below in Figure 5.

Figure 5 – Tie down isometric view with additional top down view

The tie downs in this design are placed in each of the corners of the lid, and they extend down through the bottom lip of the cooler body. The shadow in Figure 4 shows that the slot extends through all surfaces. The drawing in the photo shows the top view of the design. The soft lines represent channels that are recessed very shallow into the cooler lid to allow the strap to nest. The client was displeased with the aesthetic aspect of this design and the group was worried about functionality becoming an issue. The advantage to putting the slots in the corners is the added strength that the corners provide in roto-molded products. The disadvantage is that most surfaces that will be used to fix the cooler will be oriented parallel to the cooler sides, which clashes with the angle the current slots are at. This is another problem that will be addressed when the complete CAD design is produced.

The bottom of the cooler has a few features worth mentioning. First of all the roto-molding and insulation injection process calls for four holes along the outside of the cooler and this makes perfect standardized holes for rubber feet and there are already standardized rubber feat available. Around these holes we have recesses so the cooler will slide easily when tilted. Also this protects the rubber feet from high shear stresses when dragged along an irregular surface. The drain plug is a standard 1" inch hole lofted into the inner chamber of the cooler to allow for easy draining. Currently we are conversing with our client and playing with aesthetics of the bottom of the cooler but the basic design we are building off of can be seen in Figure 6.
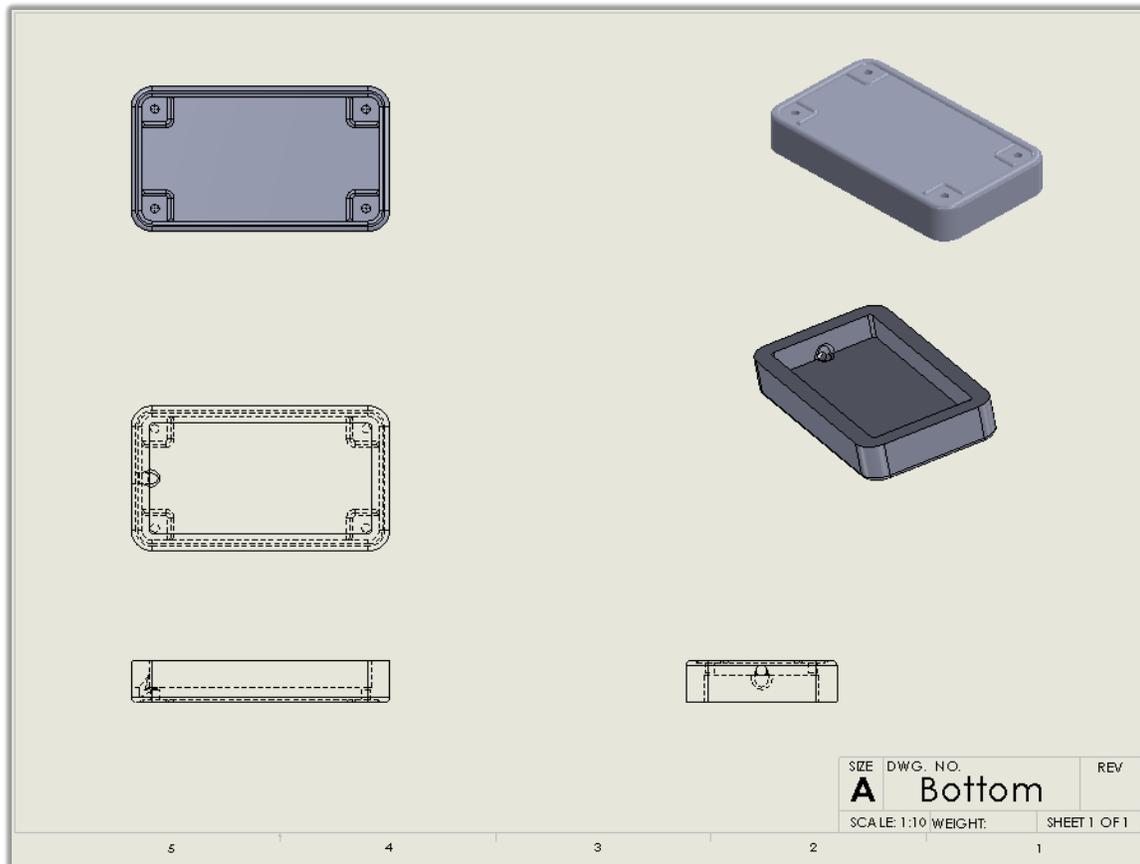
Figure 6 – Solid works drawing of the floor design

The design of the hinge is one of the few components that are still in the stage of design. The requirements of the hinge are that it open and close easily, add durability to the lid of the cooler to prevent warping, create a firm and consistent seal between the lid and the body and open flat against a wall when open. Currently, this last requirement is proving to be the most challenging. The current design allows for this but has very tall hinges on the body, creating stress points and promoting fatigue in the ears on the body. A design is currently being modeled using Solid Works to combat this and is still in progress. Figure 7 below depicts the current design for the hinge. Changes are constantly being made to this design to improve it. The final design will open flat against the back and provide a very tight seal as well as allow for easy opening and closing.
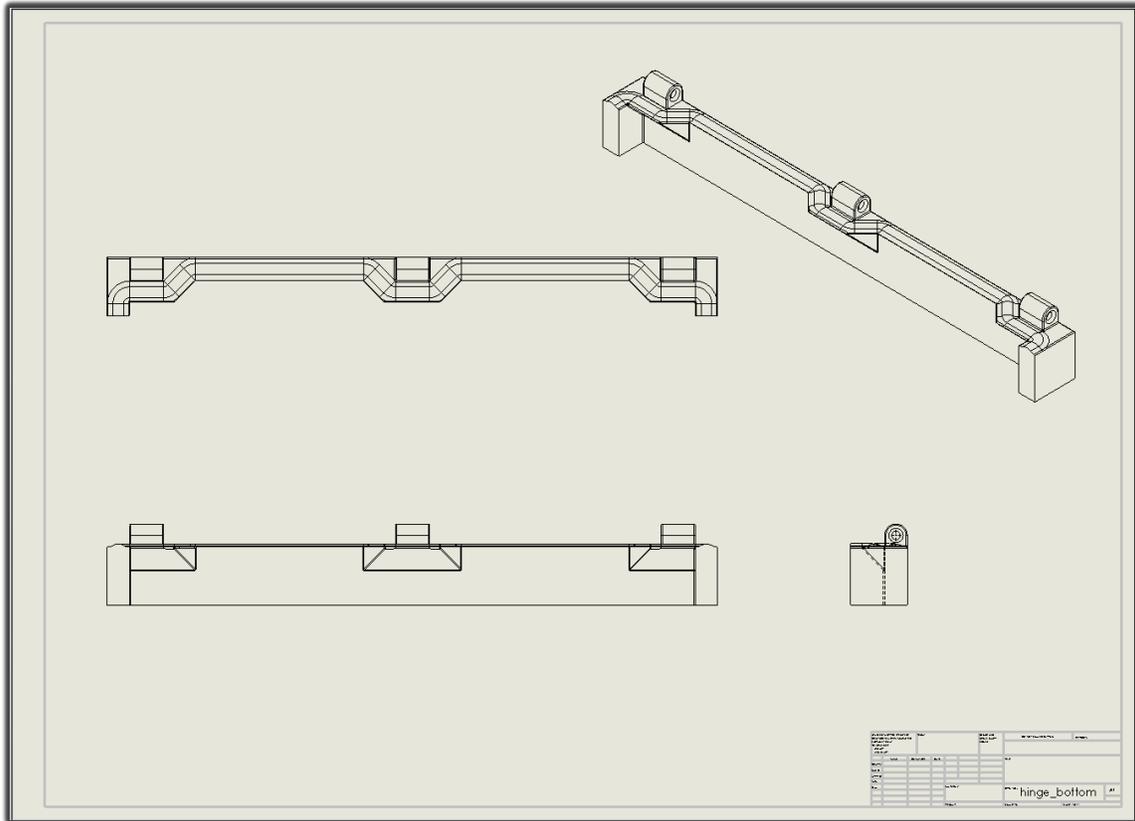
Figure 7 – Solid Works drawing of the proposed hinge design

Figure seven shows the design of the hinge only on the cooler body. The lid will mesh evenly with the ears shown in this design. This ensures that the pin that holds the assembly in place has the majority of its length in the cooler lid, thus preventing warp.

THEORETICAL ENGINEERING ANALYSIS

Preliminary analysis of our cooler consists of a 1-D heat transfer analysis. Some assumptions we made are that the corners of the cooler are negligable due to aspect ratio of the cooler panels. Also we are neglecting discontinuities in the cooler walls. We know this first theoretical calulation will be rough but it will give us good ball park numbers to come back to once we have some experimental data. Below in Figure 8 and Table 1 ithe thermal circuit that was developed and the thermal resistances calculated on the large panel (front) of the cooler are displayed.
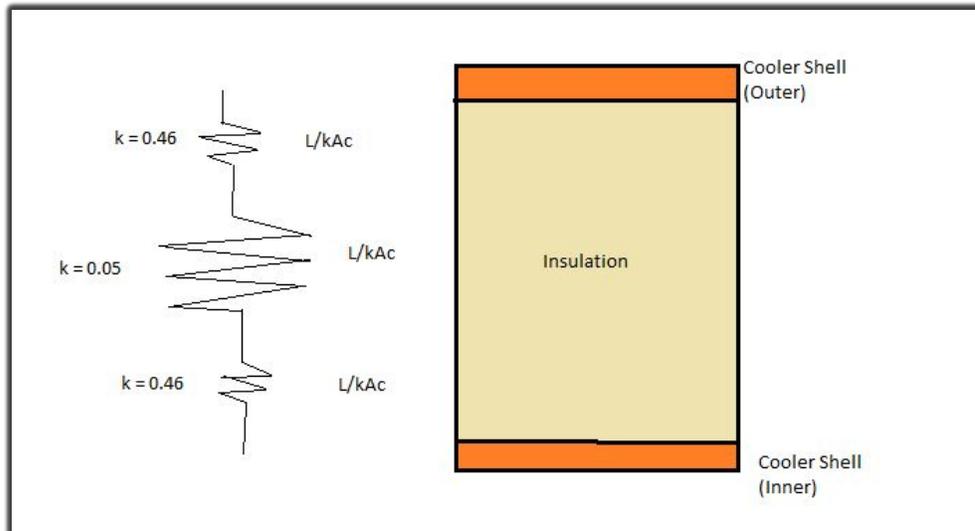
Figure 8 – Diagram and thermal circuit for cooler walls

**Table 1** – Breakdown of variables and resulting thermal resistances

Thermal Resistances			
Component	L (m)	A_c (m^2)	R $(m^2 K)/W$
Cooler Shell (Outer)	0.0036	0.255	0.03
Insulation	0.051	0.255	3.99
Cooler Shell (Inner)	0.0036	0.255	0.03

It is noted that the plastic doesn't play much into the thermal resistance. It is mostly the polyurethane foam that provides the thermal resistance. Later we can use this analysis to calculate how much time it would theoretically take to melt the ice based on the rate of heat loss.

For the stress and durability testing of the components of the cooler we plan to rely on Solid Works Simulation XPress, therefore physical prototypes are not needed to test. The components we plan to test are the latches, hinges, and body of the cooler. The types of tests we are going to perform are the deformation analysis, stress analysis, deflections analysis, and the thermal expansion properties. Solid Works Simulation XPress puts all the data into easily readable maps and reports. We are aware of mesh

dependency issues concerning simulation software and we plan on minimizing error to within 5% for all node analysis simulations.

One such test performed by this software involved the latch design discussed in the design concept section of this report. The significant results from the test can be seen in Figures 9 & 10 below.
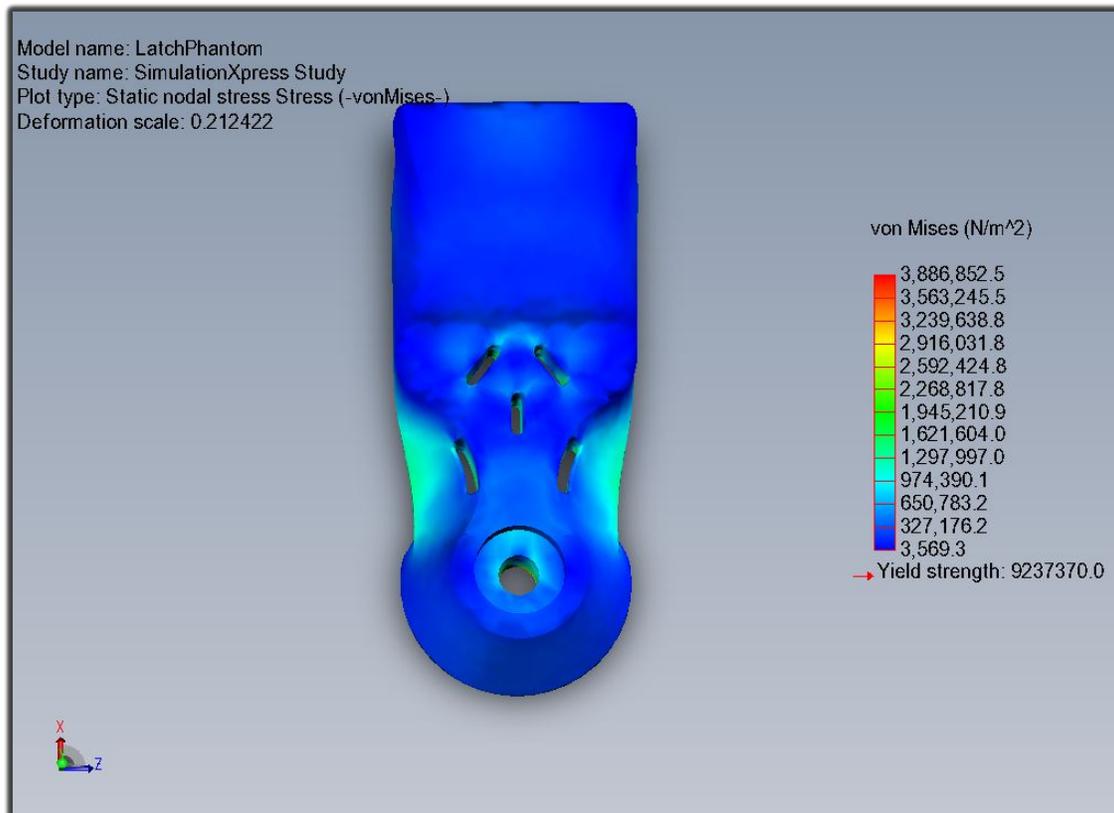
Figure 9 – Top view of stress map performed on the Phantom Latch

The parameters of this test were those associated with a standard latching condition. The fixed point was the rivet at the hole, and the force of 200 N was applied at the mating location that can be seen in Figure 10. These two figures represent the stress on the latch. The scale of stress is on the left with the highest stress in the system at 3.9 MPa. Note that the yield strength of the rubber in this case is about 9.2 MPa. Figure 10 contains the areas of high stress concentration.
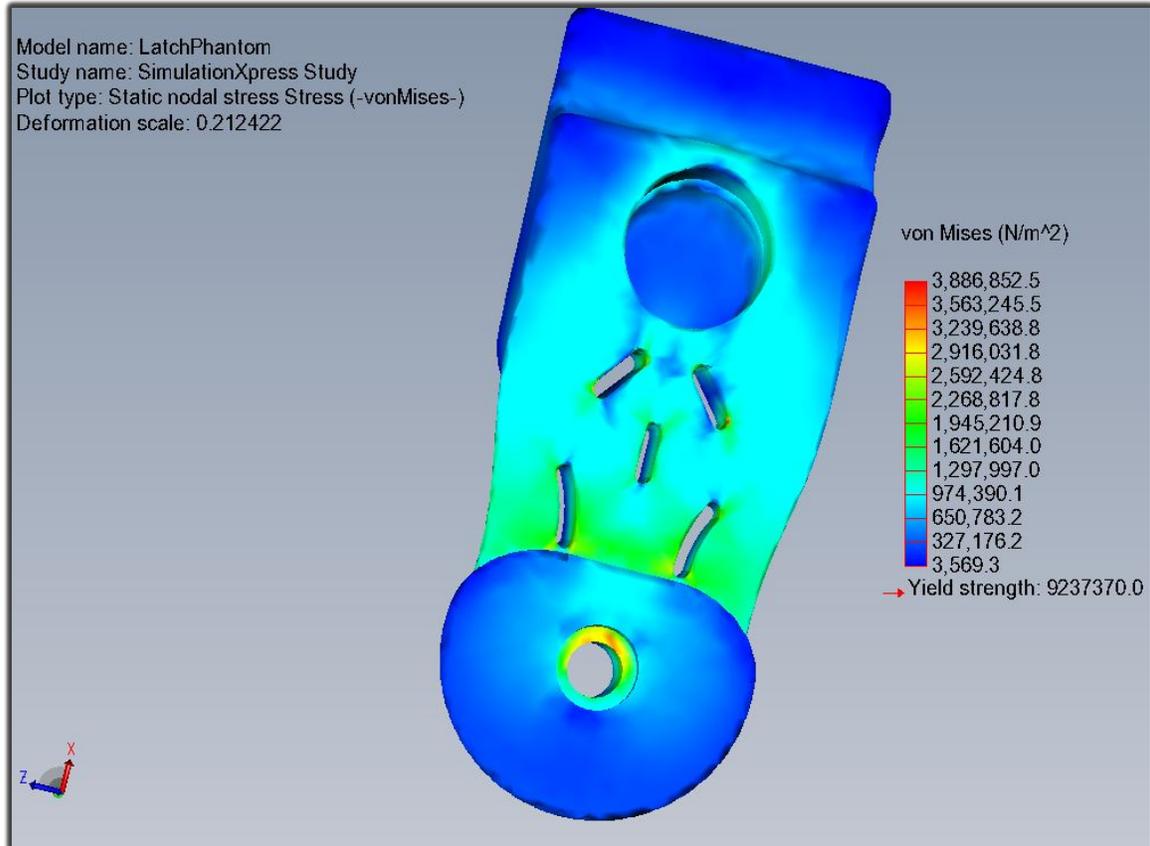
Figure 10 – Bottom view of stress map performed on the Phantom Latch

The highest stresses in the system are located just below the rivet, at the corners of the cut outs, and the change in geometry from the head of the latch to the body. This stress configuration yields a safety factor of about 2.5, which is more than adequate. Further testing will include common impact scenarios on the latch and some extreme cases of stress.

EXPERIMENTAL ANALYSIS

The team decided to implement a few experiments on existing coolers in order to establish a proof of quality and assurance to guarantee a client satisfaction. The experiments are:

1. Temperature test

Using a temperature data logger (Figure 11) to record a temperature for 2 other competitive coolers along with a similar product from Canyon Coolers.

Figure 11 - Temperature data logger from Lascar Electronics [2]

Procedure:

    I.   Place the three coolers outdoors (Coleman, Yeti, and Canyon Coolers).
   II.   Put a temperature data logger into each cooler.
 III.   Put a block of ice into each cooler at the exact same time.
 IV.   The data logger will record temperature reading every 5 minutes for the period of one week.
   V.   Coolers will be exposed to external factors such as space heaters.
 VI.   Melted water will be emptied twice a day. And each cooler will be opened four times a day for 1 minute at the exact same time.
VII.   The test concludes a full 12 hours after ice melting completes.
VIII.   Finally transfer temperature date to an excel spreadsheet, plot and analyze results.

Results:

      The results will be analyzed using Excel to produce a chart of temperature vs. time for each cooler. The sponsor will receive the data to make further discussions about the results.

2. Vacuum test

      This test will be used to check the gasket seal and drain plug for air leaks as well as measuring air leak rate. This test is in high demand from the client due to existing issues.

Procedure:

The vacuum pump comes with several different fittings and some vacuum connections (Figure 2). To test if the drainage plug will hold vacuum, the device will be pumped up and the vacuum will build on the gauge. If no vacuum is showing on the gauge after pumping a few times, there is a leak.

Figure 12 - Mityvac vacuum pump [3]

Results:

        If there is a leak in the system, the team will use a time-watch to measure the vacuum reading on the gauge vs. time to estimate the leak rate. The results will be set to the sponsor to make further discussions and modifications. This test could become a major part of quality assurance at Canyon Coolers.

3. Temperature profile test

        This test will be used to get temperature data at key points of the system. The results of this test will provide the team with insight on the temperature map experienced by the cooler. This information will be essential in developing heat transfer models for the cooler.

Procedure:

        Place a cooler manufactured by the sponsor in a controlled temperature room. Thermocouples will be placed on each wall, external and internal, of the cooler (Figure 13). Then one block of ice will be placed into the cooler. The device has wires that will be connected to a computer to record readings. Since the wires are very small, the

performance of the gaskets will not be affected. The test duration will last until a steady state condition is established.
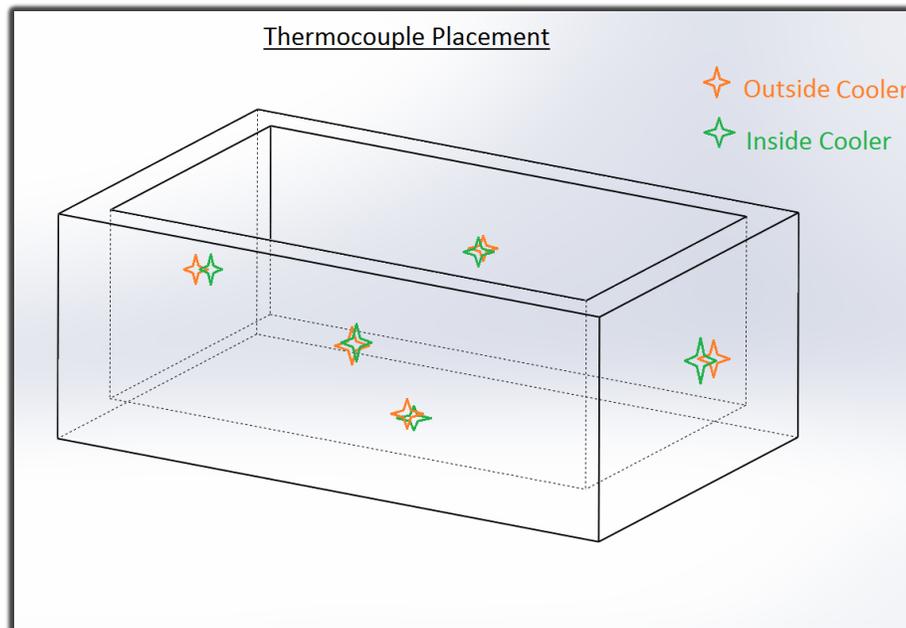
Figure 13 – Thermocouple placement for the temperature profile test

Results:

The test will produce temperature boundary conditions for each wall. A transient 1-D analysis will be conducted with the results of this experiment. This calculation will most likely be coded using Matlab so variables can be easily adjusted if necessary. The details of this analysis can be seen in the following section of the report. The results of the analysis will be provided to the client for advertising purposes.

THEORETICAL & NUMERICAL ANALYSIS

Once testing on the coolers is in progress, theoretical and numerical analysis on the coolers will be conducted. During a meeting with Dr. Nelson, the best method of conducting these calculations was determined to be purely analytical, in a one dimensional setting. Each wall of the cooler will be treated as a one dimensional heat transfer problem over a step change setting. Temperature will be read in large intervals over the testing period and these values will be used to conduct a semi-transient solution to the total heat transfer in the testing coolers. These values will then be compared and used to determine the final thickness of the walls of the cooler. More calculations may be necessary later in the experiment stage.

TEAM PROGRESS

      The Gantt chart, shown in figure 14 below, shows the team progress so far throughout the fall semester. The red bar indicates the completion progress.

Figure 14 – Gantt chart representing the 40 qt design team's project progress

      As of now the team is right on schedule with planned progress. Currently all the designs are being edited to client specifications, and are being complied into a comprehensive CAD model. Theoretical calculations are underway and the code is currently in progress. The team is in conversations with supporters willing lend some data logging equipment as well as some competing cooler models. Once this equipment is gathered the experimental testing will commence.

REFERENCES

[1] www.canyoncoolers.com

[2] http://www.lascarelectronics.com

[3] http://www.mityvac.com/