40-Quart Cooler Design

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1. PROBLEM STATEMENT

1.1 INTRODUCTION

This report addresses progress over the past few months in regards to the client's needs, the background research in existing products and generating potential design concepts and evaluating the potential performance of each one. During these processes a key factor was to bear in mind the objectives of the project outlined in the problem statement as well as continuously refining the direction of design.

This report will cover the latest results in theoretical analysis regarding single and multi-dimensional heat transfer analysis as well as software simulations to evaluate stresses in the design and their concentration factors. Also, the details of the design of the components will be discussed in relation to the roto-molding process as well as injection molding processes.

1.2 BACKGROUND RESEARCH

The needs of the client, Jason Costello, are wide and sweeping in nature. There are many possible directions that the design focus can follow. One important consideration is the client's business needs and wants then to choose a direction for the design in which the biggest and best impact on the business can be made.

From the beginning of this project new mays were discovered in which efficiency of the designs can be maximized to best fit Mr. Costello's needs. Initially the client 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, it was 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 initial CAD models for the cooler body and for the individual components were developed. Most of these designs seem to meet the favor of the client, but minor changes will be made to create a fully dimensioned, manufacture-able, SolidWorks CAD file.

Major time has been allotted for coming up with an alternative design for a new latch. This research is due to the fact that the client is not happy with the current latch system that is equipped on the vast majority of Canyon Coolers products that are being sold presently. Since there are several issues with the current latch design, an alternative design for the latch is being created for the 40 quart cooler that can also be retro-fitted on the current models in production and sale without any modifications on the cooler itself.

1.3 NEEDS IDENTIFICATION

There are several issues with the current 40-quart cooler produced by Canyon Coolers. These issues include inconsistent product quality as it is shipped from Thailand. This issue leads to some of the coolers being shipped back to Canyon Coolers that have major quality issues. This translates to unnecessary returns that the client has to pay for, that end up hurting the success of the business.

Another huge issue is that the client is not satisfied with the current latches equipped because they are difficult to operate under specific conditions and have fairly high failure rates. One of the main issues that afflict the current cooler is that the gaskets are not up to quality and standards and this issue negatively affects the global ice retention performance. The current cooler lineup is not oriented towards the casual cooler user, and this need to be changed in order for the cooler to succeed on the market.

1.4 PROJECT GOAL & SCOPE OF PROJECT

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 faced is to improve the design of the cooler in such a way that it has minimal impact on the current MSRP of the 40-quart size. The MSRP is set to be $ 189.99.

The cooler designed needs to offer ice retention of at least 72 hours, and be resistant enough to withstand stresses and impacts caused by normal operating conditions and be equipped with the Phantom latch.

1.5 OBJECTIVES

Following the goal of the design, a cooler that satisfies specific objectives and guidelines will be created. Part of these of these objectives (Table 1) are the cooler must have an ice retention of at least 72 hours, and the cooler body and lid have to be able to withstand impacts and falls due to normal usage without being indented because this would cause delamination of polyethylene and polyurethane foam. The fixed MSRP is $ 189.99. The final product must weight no more than seven kilograms when empty so that it can be easily carried. One of the main objectives are the dimensions; these must be designed so the outer dimensions allow for nested shipping and the inside allows the cooler to fit common items. The cooler must require little to no maintenance as well, reducing costs.

TABLE 1: *Objectives and basis for measurements with associated units*

Objective	Basis for Measurement	Units
Well Insulated	Significant ice retention	Watts & t
Sturdy	No major dents upon impact	m
Inexpensive	Low MSRP	$
Light Weight	Easily carried by one person	kg
Dimensions	Nests into other coolers (shipping), and compatible with common sources of use	m
Maintains Shape	No warp from temperature changes	Degrees
Low Maintenance	Costly for distributer to fix	$

1.6 CONSTRAINTS

There are five main constraints to be dealt with for designing the cooler. They consist of dimensions, weight, durability, cost and function. Each must be thoroughly explored and considered in the final design in order to meet the specific needs of the customer.

When evaluating the criteria for the dimensions there are a few aspects to consider. One of the key aspects of the dimensions is to ensure that the cooler nests side by side top and bottom with other coolers as well as inside of the larger coolers. This is to ensure a maximum number of coolers can be shipped in order to save money on shipping costs. This constraint is extremely important to the customer, since shipping about 400 coolers costs about $8000 and a nested solution would allow it cut down the shipping costs. This also includes constructing all of the features on the cooler to be flush with the base structure, such as handles, locks, latches or wheels. The cooler must also be able to fit standard items.

The weight of the cooler must not exceed 7 kg when it is empty. This is a customer requirement and is to ensure that the cooler is easy to maneuver and can easily be lifted by one person.

The cooler also needs to be durable. The design must stand up to typical use. The latches must withstand high stresses and hold an airtight seal. The body and lid must be well integrated and impervious to small stresses. Some typical examples would be sitting or standing on the cooler, dropping it as well as not warping under heat or use. It is critical for the product to perform well under normal conditions because otherwise it could suffer delamination problems that could later on lead to customers being unsatisfied and returning their product.

The cost of the cooler is one of the main concerns. The customer is looking to manufacture the product in the United States instead of the current manufacturer, located in Thailand. Currently, the cost to produce coolers in the U.S. is very expensive compared to overseas. The goal for the MSRP is to be lower than that of the current cooler as well as surpassing its current performance.

Lastly, the function of the cooler is extremely important. The design must hold ice for at least one week with a goal time period of three weeks. In order to do this the cooler will be designed with an air and watertight apparatus. The insulation design and dimensions will be improved as well as a few small improvements such as feet, a porthole and inner compartments.

All of these constraints are labeled in Table 2 on the following page.

TABLE 2: *Constraints and scales*

Constraint	Units	Scale
Weight	kg	<7.0 kg
Durability	Cycles	>100,000 Cycles
Cost	(US) $	< 189.99 $
Function	36 hours	Ice Retention >36 hours
Volume	quarts	40

1.8 CRITERIA TREE

Displayed below is the criteria tree for the production of the 40 quart cooler. As it possible to observe, cost is one of the main factors that come into play. The other two extremely important factors are build quality and global performance of the product.

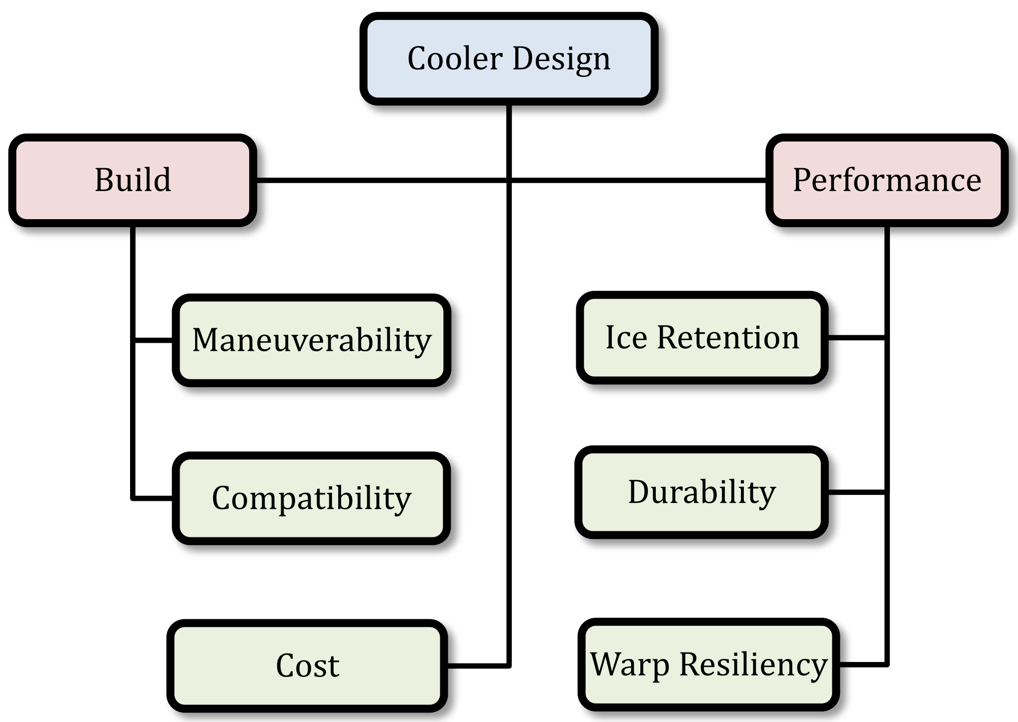

FIGURE 2: *Breakdown of criteria in relation to the cooler design.*

1.9 QUALITY FUNCITON DEPLOYMENT

Another design tool that used to determine how to relate engineering requirements to each other is the house of quality (Figure 3). The house of quality takes the engineering requirements and maps them against each other. Where the requirements intersect in the top region a "+" or "-" correlation is placed; i.e. modulus of elasticity and density are positively correlated therefore when one increases, the other increases. A "-" signifies an inverse relationship, where as one increases, the other decreases.

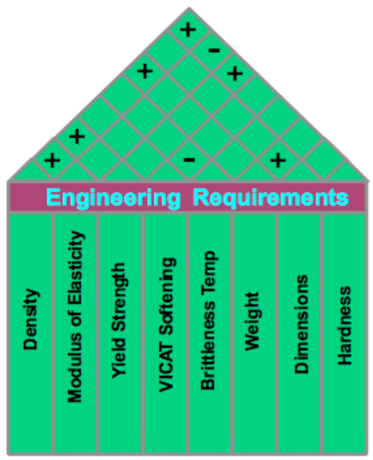

FIGURE 3: *House of Quality*

2. CONCEPT GENERATION

2.1 OVERVIEW

The first stage of design process was to draft multiple ideas created from brainstorming. Many ideas and concepts were generated and were all used to narrow down the design into three main concepts. The three main concepts consist of various smaller concepts that are integrated into the separate coolers. One aspect of these smaller integrated parts is that the designs for each component can be interchanged if desired with another full concept. This was expected and did occur frequently. Each original concept will be discussed individually in detail in this section.

2.2 CONCEPT A

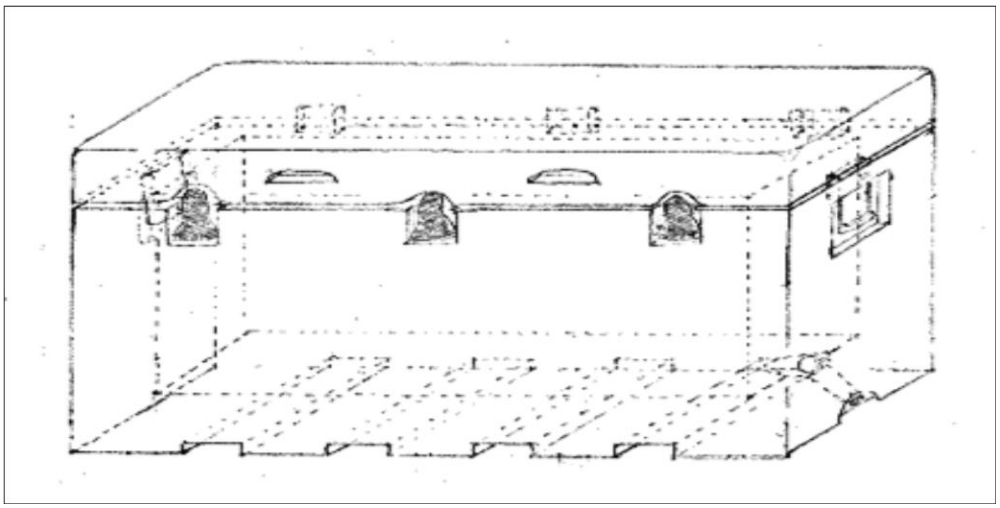

FIGURE 4: *Concept A*

The design for this cooler consists of very simple elements and standard geometry as displayed in Figure 4. The purpose of this is to have a basis to build a more refined design around. Should this be the chosen design, the dimensions can be easily changed as the design changes. The main hull of the cooler is designed to be near rectangular. This is to ensure maximum volume of the inside of the cooler as well as to promote ideal meshing and nesting with other coolers.

The handles of the cooler are consistent for all three designs and consist of a rope-handle design. A nylon rope with a plastic handle threaded onto it ties into the top of the hull. The handle also falls flat and flush against the hull. The benefit of this handle design is that it is cheap, lightweight, strong, easily installed and easily replaceable.

The latch system consists of a rubber pull-down hook that affixes to the lid and pulls down onto a male joiner of the hull (Figure 5). This creates a tension in the latch and thus a force on the lid and causes the foam in the seal to flatten down and create a strong seal. The latches fit flush into the cooler and are cheap and reliable.

Affixed to the outside of the body is the drain plug, which is a standardized part. The drain plug will screw into a sleeve bolted to the outside of the body that leads to the inside of the body (Figure 5). There is a small scooped section on the floor of the inside of the body in place to guide water to the drain with ease.

As for the seal between the hull and the lid, the design consists of a protruded, curved radius on the base that fits flush with a recessed radius on the lid. A piece of waterproof foam insulation covers the length of the ridge and runs around the perimeter of the space between the hull and the lid (Figure 5). This design ensures a near airtight seal, added cross sectional area to reduce heat transfer and possess no harsh edges.

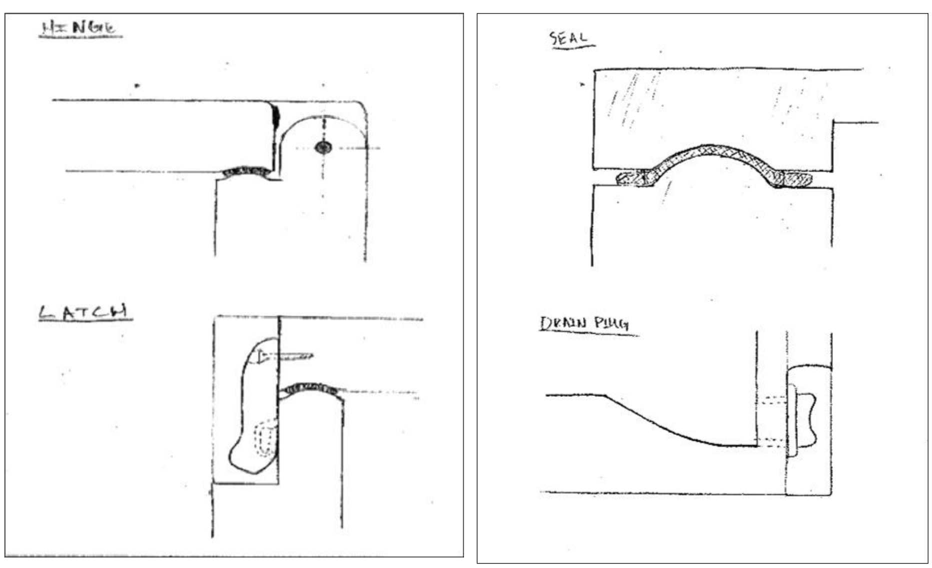

FIGURE 5: *Latch and hinge design (left), seal and drain plug design (right)*

2.3 CONCEPT B

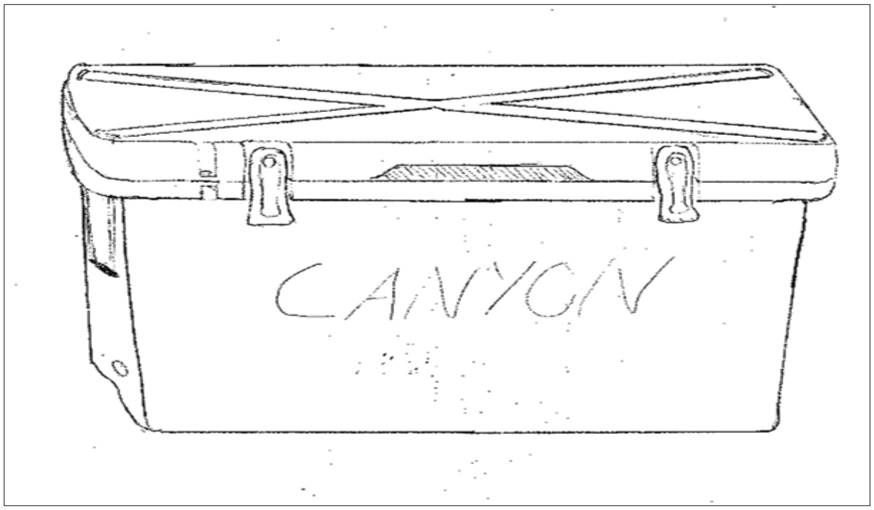

FIGURE 6: *Concept B*

This concept follows a different shape than the other two designs, displayed in Figure 6. It has sides that draft down towards the bottom. There is a lip around the top of the cooler. This is where the latches, handles, lock-slot and hinges would fit flush.

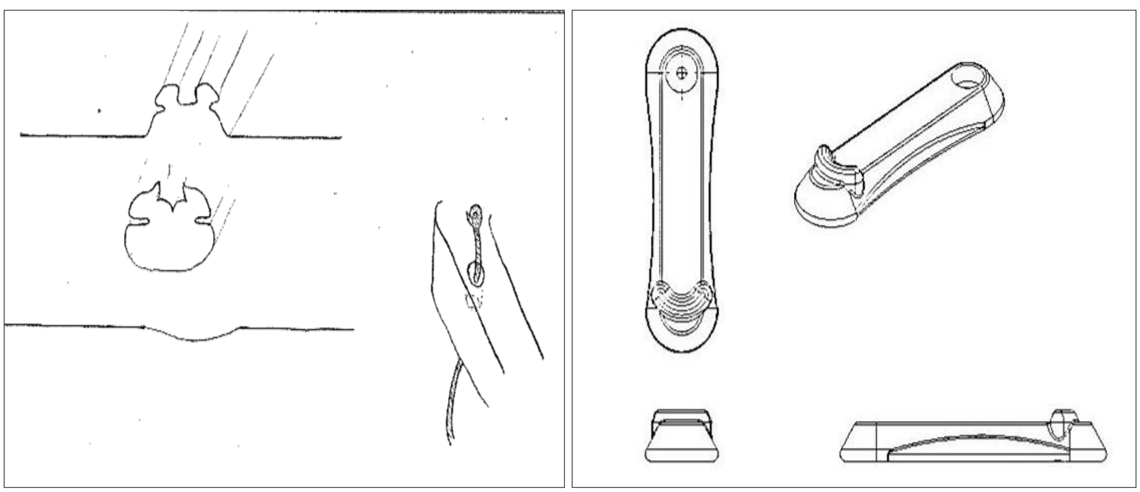

FIGURE 7: *Seal Design (left); Latch Design (right)*

The latch and handle system for this cooler is the same as Concept A. One small difference is that the handles do not fall flush next to the hull; instead they hang down to the side of the hull (Figure 7). This concept also consists of a different seal design which includes a rubber insert as opposed to a foam seal. The rubber insert would fit into a slot which would be molded into the lid and push flush up against a groove in the body.

2.4 CONCEPT C

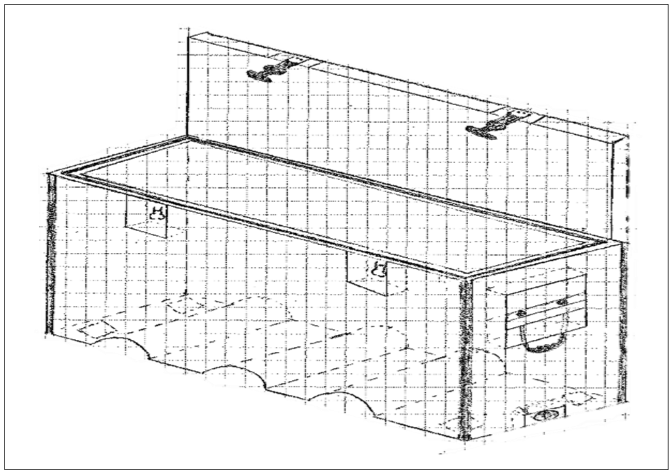

FIGURE 8: *Concept C*

The third concept is very similar to Concept A with a few exceptions of a different latch system as well as a different number of latches (Figure 8).

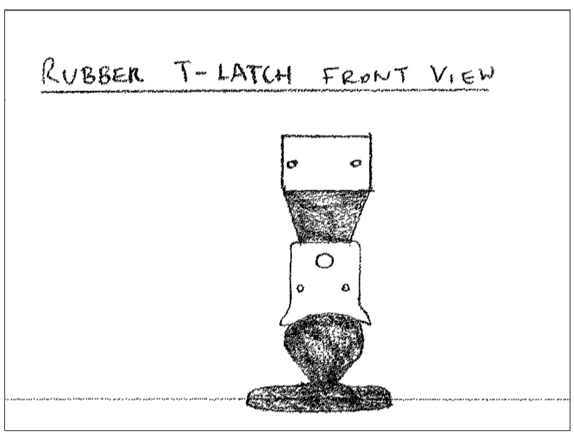

FIGURE 9: *Latch Design*

This latch is comprised of a metal fixture on the body and a rubber piece that pulls down and hooks onto the metal fixture. This concept has the same designs for the handles, hinges, and drain as Concept A.

3. CONCEPT SELECTION

To determine which features are more important than others a pairwise comparison must be performed (Table 3). In the pairwise comparison each feature is matched against all of the other features. The ones that are more important receive a '1' in the corresponding row. For example if the cost row is examined we can see that the cost is more important (receiving a '1') then everything other than the ice retention and durability (receiving a '0'). After each feature is compared pairwise, the totals of the rows are taken from left to right then normalized to display the more important features.

TABLE 3: *Pairwise Comparison of Design Criteria*

	Cost	Ergonomics	Ice retention	Durability	Latches	Lock slot	Tie downs	Drain Plug	Aesthetics	Dynamic Handle	Total	Normalized Total
Cost	NA	1	0	0	1	1	1	1	1	1	7	**0.155**
Ergonomics	0	NA	0	0	1	1	1	1	1	1	6	**0.133**
Ice retention	1	1	NA	1	1	1	1	1	1	1	9	**0.2**
Durability	0	1	0	NA	1	1	1	1	1	1	7	**0.155**
Latches	0	0	0	0	NA	1	1	0	1	1	4	0.0888
Lock slot	0	0	0	0	0	NA	0	0	1	0	1	0.0222
Tie downs	0	0	0	0	0	1	NA	0	0	0	1	0.0222
Drain Plug	0	1	0	0	0	1	1	NA	1	1	5	0.111
Aesthetics	0	0	0	0	0	1	1	0	NA	0	2	0.0444
Dynamic Handle	0	0	0	0	0	1	1	0	1	NA	3	0.0666

Table 1 above shows the criteria that will dictate the performance rank of the chosen designs. These criteria are ice retention, durability, cost, and ergonomic. In order to standardize the comparison between the different features, everything needs to be organized on the same scale. The multiple criteria scale presented in Table 4 does just that. Some features are well defined like cost and the corresponding price points. Other features take a more subjective form rating from poor to excellent. On the far left the ratings of each feature are corresponded to a number from zero to five, zero being the worst rating and five being the best.

TABLE 4: *Multi-Criteria Scale for Elements of Design*

Value	Cost ($)	Ergonomics	Ice retention (Hrs)	Durability (Cycles)	Latches	Lock slot	Tie downs	Drain Plug	Asthetics	Dynamic Handle
5	179.99	Excellent	240	100000	Excellent	Excellent	Excellent	Excellent	Excellent	Excellent
4	184.99	Good	192	50000	Good	Good	Good	Good	Good	Good
3	189.99	Satisfactory	144	10000	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory
2	194.99	Adiquate	96	1000	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate
1	199.99	Tolerable	48	500	Tolerable	Tolerable	Tolerable	Tolerable	Tolerable	Tolerable
0	200+	Poor	24	100	Poor	Poor	Poor	Poor	Poor	Poor

The two different types of analyses were performed to provide the client with different choices: a weighted analysis and a non-weighted analysis (Table 5). Both of the decision matrices are based on the multi-criteria scale but the weighted matrix is intended to better compare the three designs. Concept B is the most favorable numerically.

TABLE 5: *Non-Weighted (left) and Weighted (right) Analyses*

Design Option	Cooler A	Cooler B	Cooler C
Cost	2.8	3	3
Ergonomics	3	4	2.5
Ice retention	4	3.5	4.5
Durability	5	4	5
Latches	5	4	4
Lock slot	0	4	3
Tie downs	2	4	2
Drain Plug	3	3	3
Asthetics	3.5	4.5	3
Dynamic Handle	4	4.5	2

Design Option	Weight	Cooler A	Cooler B	Cooler C
Cost	0.156	0.436	0.467	0.467
Ergonomics	0.133	0.4	0.533	0.333
Ice retention	0.2	0.8	0.7	0.9
Durability	0.156	0.778	0.622	0.778
Latches	0.089	0.444	0.356	0.356
Lock slot	0.022	0	0.089	0.067
Tie downs	0.022	0.044	0.089	0.044
Drain Plug	0.111	0.333	0.333	0.333
Asthetics	0.044	0.156	0.2	0.133
Dynamic Handle	0.067	0.267	0.3	0.133
Totals	1	3.658	3.689	3.544

4. ENGINEERING ANALYSIS

4.1 1D THEORETICAL ANALYSIS

Preliminary analysis of the cooler consists of a 1-D heat transfer analysis. Some assumptions that were made are that the corners of the cooler are negligable due to aspect ratio of the cooler panels, the entire cooler is isothermal, and we are neglecting discontinuities in the cooler walls. It is know this first theoretical calulation will be rough but it will give some good ball park numbers to come back to once there is some experimental data. Below in Figure 8 the thermal circuit that was developed and the thermal resistances calculated. Once the resistances are calculated the wall thickness can very and it can be see how this affects performance and cost.

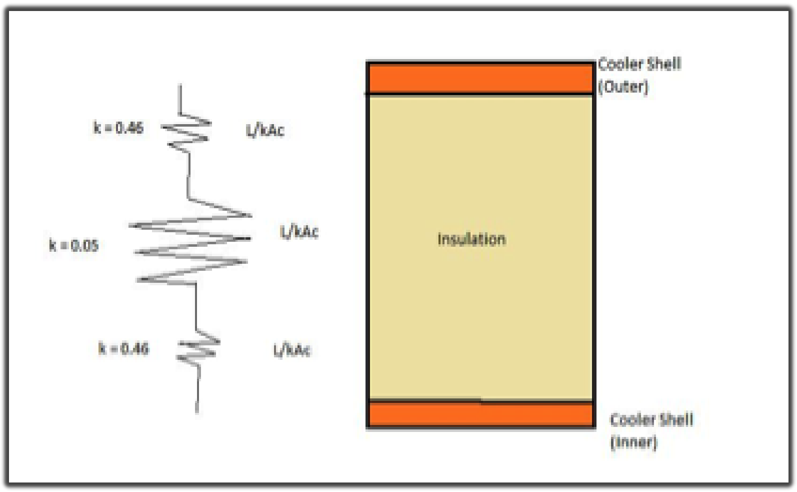

FIGURE 10 – *Diagram and thermal circuit for cooler wall*

In the analysis that was developed a MatLab code was generated that plots the cost and ice retention against wall thickness. This will give a general idea of how the two are related, and what the rate of change is of each function. To determine ice retention and cost a few assumptions had to be made. Latent heat of ice is 334 kJ per kg, there is 5.2 kg of ice in the cooler, and the ambient temperature (outside cooler) is 20° C. Figure 11 is the plot that the code generated. Also please refer to the appendix for a copy of the MatLab Script.

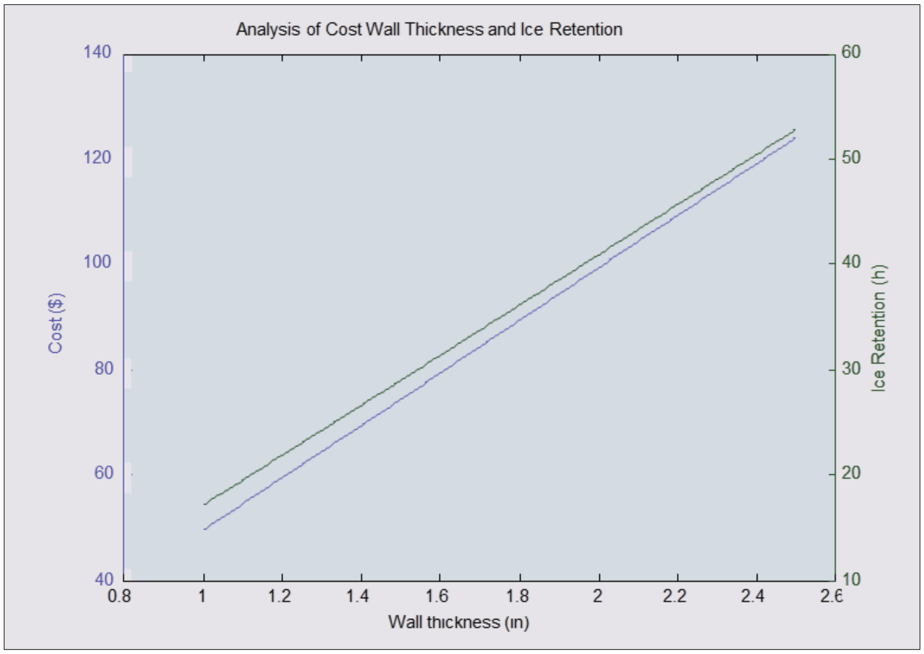

FIGURE 11: *Results of Wall Thickness vs. Cost and Ice Retention*

In Table 6 there are tabulated important numbers and price points from the code. Industry standards in width are going to be used, and those range from 1.25”-2.25”. This is where competitors and current Canyon Coolers have found the optimum tradeoff between cost and ice retention.

TABLE 6: *Wall Thickness vs. Cost and Ice Retention*

Wall thickness (in)	Cost ($)	Ice Retention (h)
1.25	63.41	24.0
1.50	75.83	31.53
1.75	88.25	39.06
2.00	100.67	46.59
2.25	113.09	54.12

There were a lot of assumptions made and these numbers are not exact by any means. The cost is a little higher then the actual cost of manufactured coolers, but this does give an educated idea on how cost and ice retention is related. These numbers give a pretty good idea of the rate of change of each parameter with the wall thickness variable.

4.2 3D THEORHTICAL HEAT TRANSFER ANALYSIS

Next semester there will be performed a 3D transient analysis of the cooler with the help of Dr. Nelson and the experimental data that we collect. This will be transient and will be a much more accurate representation of what is actually happening throughout the cooler. This analysis will be used to further refine the design of the next Canyon cooler.

4.3 THEORHETICAL STRESS ANALYSIS

For the stress and durability testing of the components of the cooler Solid Works Simulation Xpress will be relied on, therefore physical prototypes are not needed to test. The components tested are going to be the latches, hinges, and body of the cooler. The types of tests that are going to be performed are the deformation analysis, stress analysis, deflections analysis, and the thermal expansion properties. Mesh dependency issues concerning simulation software are known. The mesh dependencies will be reduced to less than 5%.

One such test performed by this software involved the latch design. The significant results from the test can be seen in Figures 12 & 13 below.

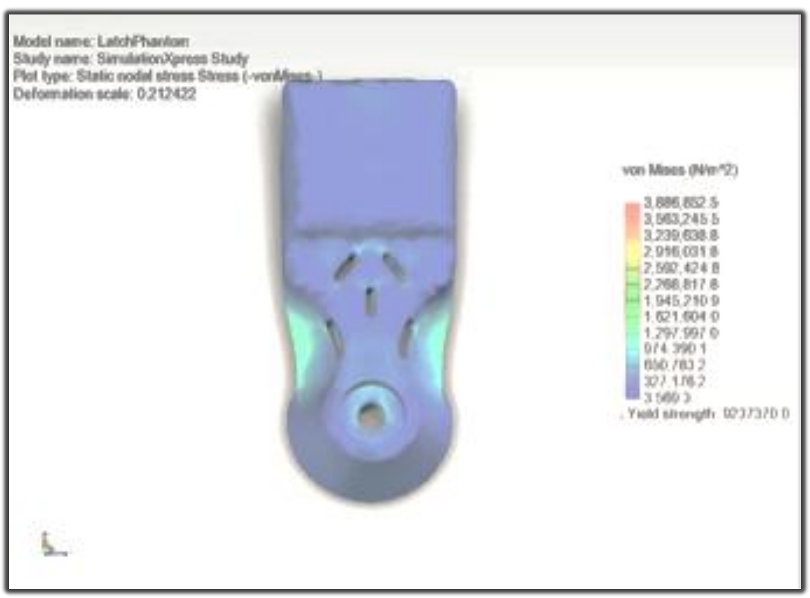

FIGURE 12 – *Top view of stress map performed on the Phantom Latch*

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 13. 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 13 contains the areas of high stress concentration.

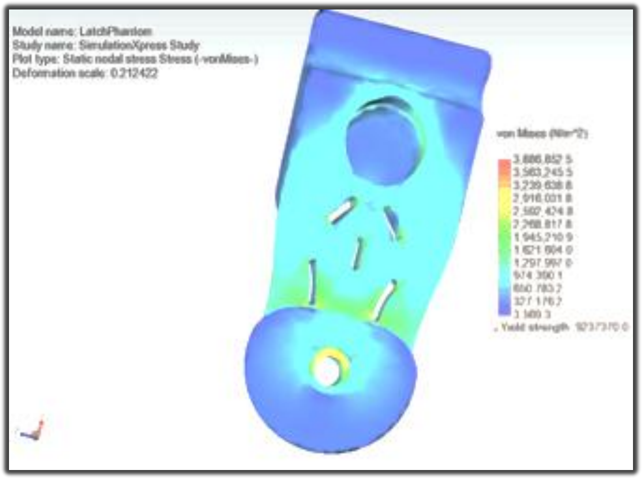

FIGURE 13 – *Bottom view of stress map performed on the Phantom Latch*

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.

It was 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:

4.4 TEMPERATURE TEST

Using a temperature data logger (Figure 14) to record a temperature for 2 other competitive coolers along with a similar product from Canyon Coolers.

FIGURE 14 - *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.

4.5 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 15). 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 15 - *Mityvac vacuum pump*

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.

4.4 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 16). 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.

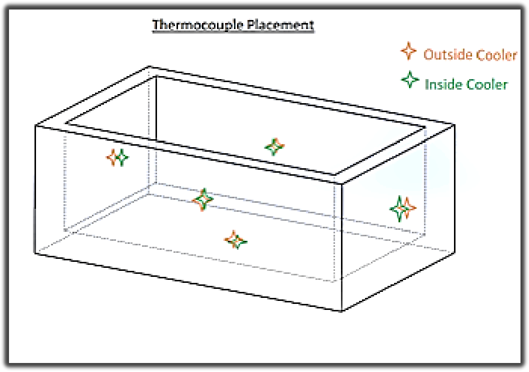

FIGURE 16 – *Thermocouple placement for the temperature profile test*

RESULTS:

The test will produce temperature boundary conditions for each wall. A transient 3-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 are previously mentioned above see: 3D Theoretical Engineering Analysis.

5. FINAL DESIGNS

At this stage in the project the proposed designs have reached, or are fast approaching, their final configuration. The cooler body and cooler lid assemblies are still be modeled in CAD software. There are many stipulations and rigorous guidelines pertaining to rotational molding that require careful attention during the modeling of these two designs. Draft angles, inside & outside radii, uniform wall thickness, and dimensions are a few components of design that have roto-molding specific constraints. The third and final design is production is the latch system. This component is in the form and fit prototyping phase and is being analyzed by a few companies for price estimation, material selection, and the possibility of a function prototype. The first company with the design is AAAcme rubber co. They specialize in all things rubber and are conveniently located in the Phoenix area. The second organization, Roto Dynamics Inc., based in Portland, Oregon, is also considering the design for manufacturing. The design for the cooler body and lid are currently in the modeling stage. Their complexity is on an order of magnitude higher than that of the latch. The design for the cooler body is depicted below in Figure 17.

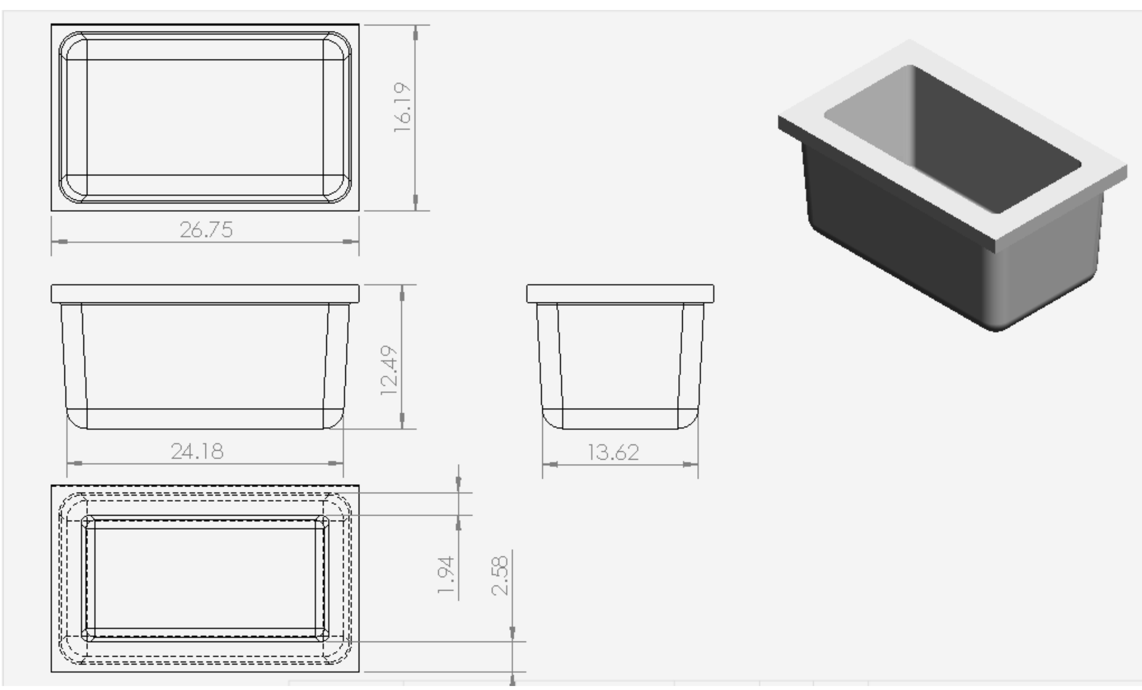

FIGURE 17 - *Design drawing for cooler body*

The above drawing shows the rough outline of the cooler body design in production. The current configuration is in the middle of design and this version gives good details on dimensioning. One of the main considerations, aside from roto-molding specifications, was to make the entire design dependent on global variables. This allows the design to be scaled up rather easily so larger sister models can be created with the change of only a few variables. The dimensions in this image are in inches. At the moment the team is working with a wall thickness of 1.94 inches all around the design. This was determined from some the heat transfer analysis performed. The shell of the body and lid will be manufactured out of a high density polyethylene, and the insulation will be polyurethane foam.

The design for the lid centers on the hinge design which is currently underway. Once this is completed the lid design can be modeled. The next design is that of the latch. The specifics of the latest prototype can be seen below in Figure 18.

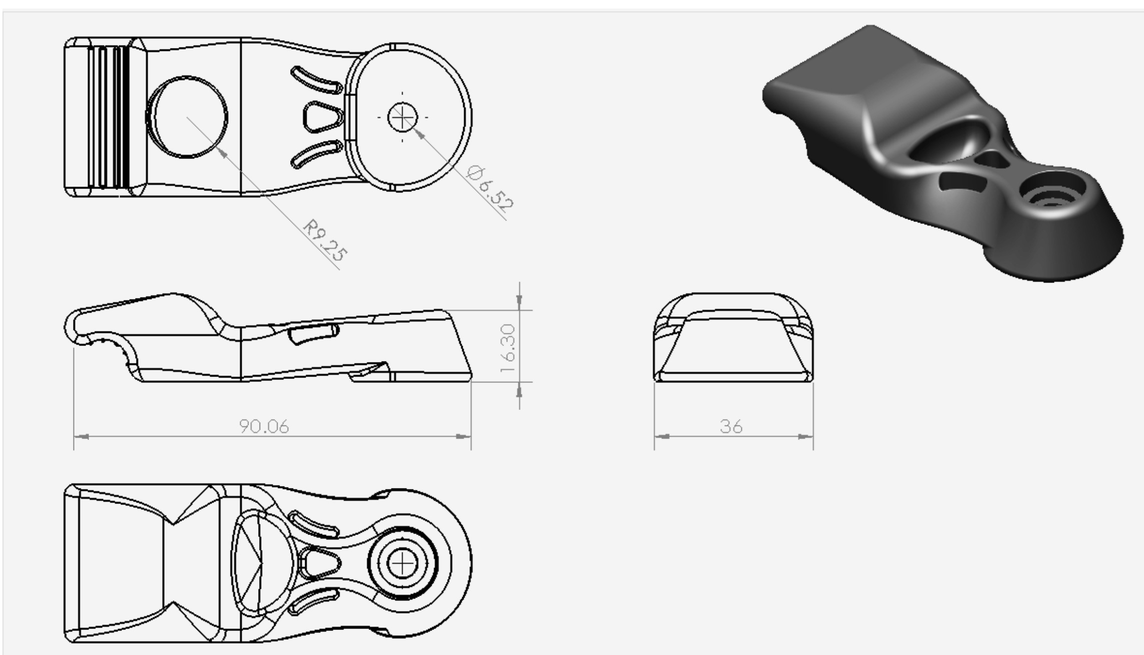

FIGURE 18 - *Design drawing for the Phantom Latch*

This latch represents the second iteration of the design. Some key changes that have been made include the width of the design, from 38 to 36 mm, the size of some key fillets have been increased to reduce stress, ribs have been added to the underside of the back end (depicted in the bottom view of Figure 18), and a large thumb hole was recessed into the design to improve the amount of force that can be applied to the latch. All the dimensions in this drawing are in mm. The specifics on the material type of this latch are being considered at the moment. The group is unsure as to the material types in use by industry because these details are coveted by those who make them. Our sponsor has offered to send the rubber facility in phoenix a sample of some of his latches so material properties can be analyzed. The team would also like to hear form this organization what type of prototyping techniques are available for injection molding. For now simulations are being run to test the latches theoretical durability. The analysis for stresses during a common latching situation is shown in Figure 19.

Name	Type	Min	Max
Stress	VON: von Mises Stress	778.846 N/m^2 Node: 54469	5.74005e+006 N/m^2 Node: 2651

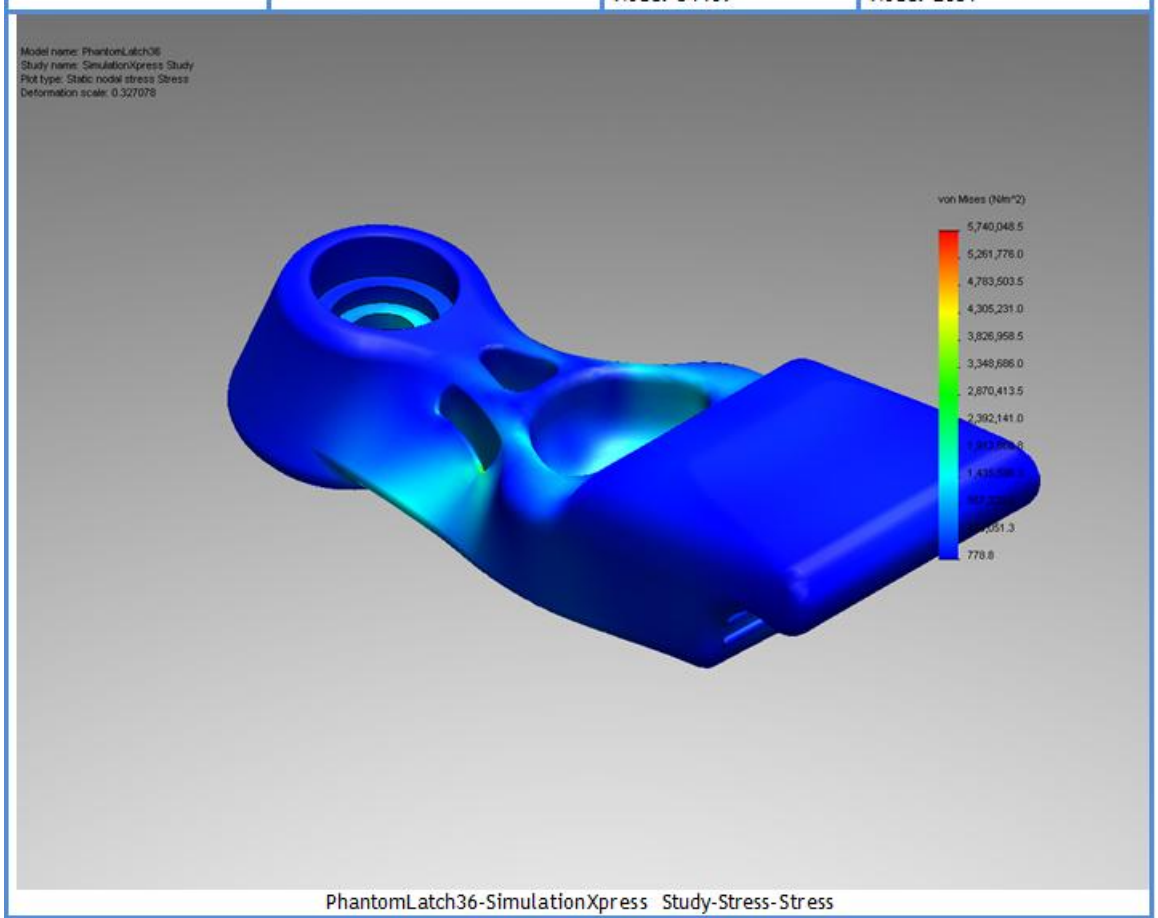

FIGURE 19 - *Stresses observed in the Phantom Latch under a 30 lb. load.*

The purpose of this stress analysis is to observe the theoretical stresses that would be seen in the most common use of the latch, to establish a firm seal from body to lid. The stress has been overestimated to bring possible stress concentrations to the surface. The fixture in this test was placed at the top hole where the latch would be fixed to the cooler lid. The force was applied where the latch mates with the cooler body. This puts the latch in an axial tension load with a small moment caused by the geometry of the latch. A standard rubber was used for the test, and a very fine mesh density was employed to bring the deviation of results to a minimum. The minimum and maximum stresses in the system are displayed above the stress map. The smallest factor of safety in the system was about 1.6 which is sufficient for this situation.

As the project approaches production serious cost analysis must be performed. The team was able to gather a significant amount of information from our client and the partners were both collaborating with. Table 7 below shows the breakdown on the cost analysis.

TABLE 7 - *Detailed cost analysis*

Component	Quantity	Individual Cost ($)	Cost ($)
Rubber Foot	4	0.85	3.38
Drain Plug	1	1	1
Plastic Handle	2	0.49	0.98
Rope	4 ft	0.34	1.36
Rubber Latch	2	3	6
Latch Screw	2	0.1	0.2
Latch Rivet	2	0.16	0.32
Plastic Knob	2	0.1	0.2
Gasket	14 ft	0.25/ft	3.5
Nylon Bushing	2	0.08	0.16
Total = $17.10			

Everything on the above list consists of parts that will be ordered wholesale from existing distributers aside from the rubber latch. The price estimate for the latch was derived from existing designs and was estimated by the client. The components missing from this list are the production costs for the lid and the body. An MSRP of $189.99, noting that business usually desires a 3.0 multiplier of profit, gives the design team a target goal of $50 to produce both the lid and the body of the cooler. Note that this price estimate is on a per unit base, so this estimate is the cost to produce a single cooler. Cost estimates for molds are forth coming.

A quick comparison of current progress with project objectives reveals that the design team is meeting all the important marks thus far. Table 8 below is the verification of the objectives and any important notes that accompany.

TABLE 8 - *Project objectives compared with current progress*

Objective	Completed(o)/Incomplete(x)	Notes
Well Insulated	o	Theoretical heat transfer verification
Sturdy	o	Simulation testing
Inexpensive	o	On target for cost
Light Weight	x	Cannot be determined
Dimensions	o	On target thus far
Maintains Shape	x	Cannot be determined
Low Maintenance	x	Cannot be determined

Close attention is being directed toward these objectives because each and every one needs to be met for the project to be successful. Some of the objectives won't get a true test until units are pulled from their prospective molds and assembled for use. However, the team is obtaining theoretical information for these objectives from theoretical and numerical approximations.

6. FUTURE TASKS

The team has several tasks to accomplish during the spring semester. The tasks are

I. Complete experimental analysis:

As described in the analysis section above, this task is extremely important to the project. The analyses that need to be accomplished are the temperature test, the vacuum test, and the temperature profile test.

II. Conduct 3D heat transfer analysis:

For this task, the team will investigate methods to solve the 3D heat transfer problem. The methods that the team will look into using are finite volume method and the tri-diagonal matrix iterative solver method. The software the time will use for the analysis is MATLAB and other software that might deem useful.

III. Investigate rotational-molding for making the cooler body, and injection molding for making the parts:

The client desires to make coolers to be manufactured in country rather than in Thailand. Hence the team decided to investigate cheap and efficient methods in making the cooler body by roto-molding, and parts by injection molding. There will be a scheduled trip to a manufacturer in Prescott, AZ specialized in molding processing. The trip will discuss costs associated in manufacturing 40QT cooler along will all parts that come with it.
Iterations on existing designs

The team will keep improving designs throughout the spring semester. The parts that that needed to be improved specifically are hinges and latches. This task is an ongoing task and has no deadline. The will hope that they come up with a state of an art design and a breakthrough design with maximum durability and life-span.

IV. Get in touch with Thailand and get rough estimate in operational/manufacturing costs:

The sponsor has a contract with a molding manufacturer in Thailand, and the team will get in touch with the VP of the company. The task will take place using Skype or conference room. The team will ask few questions and request costs associated with operation and manufacturing. The main purpose of this task is to find solutions and alternatives to shifting the manufacturing of the coolers to be made into the United States.

7. PROJECT PLAN

7.1 FALL SEMESTER

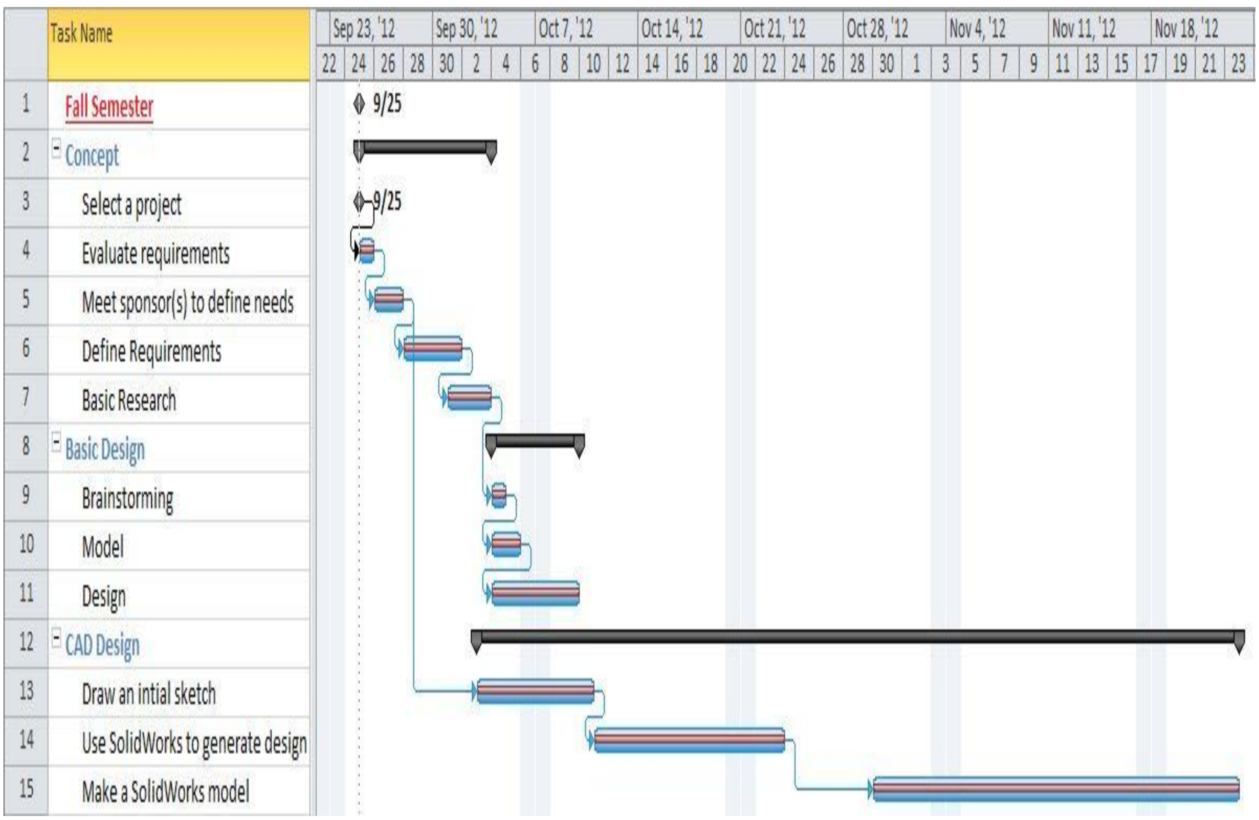

FIGURE 20 – *Gannet chart for the fall semester*

The team was able to achieve all different tasks that were assigned in the fall semester. By dividing work equally between each team member and clear communications, the tasks were done efficiently and on time.

7.2 SPRING SEMESTER

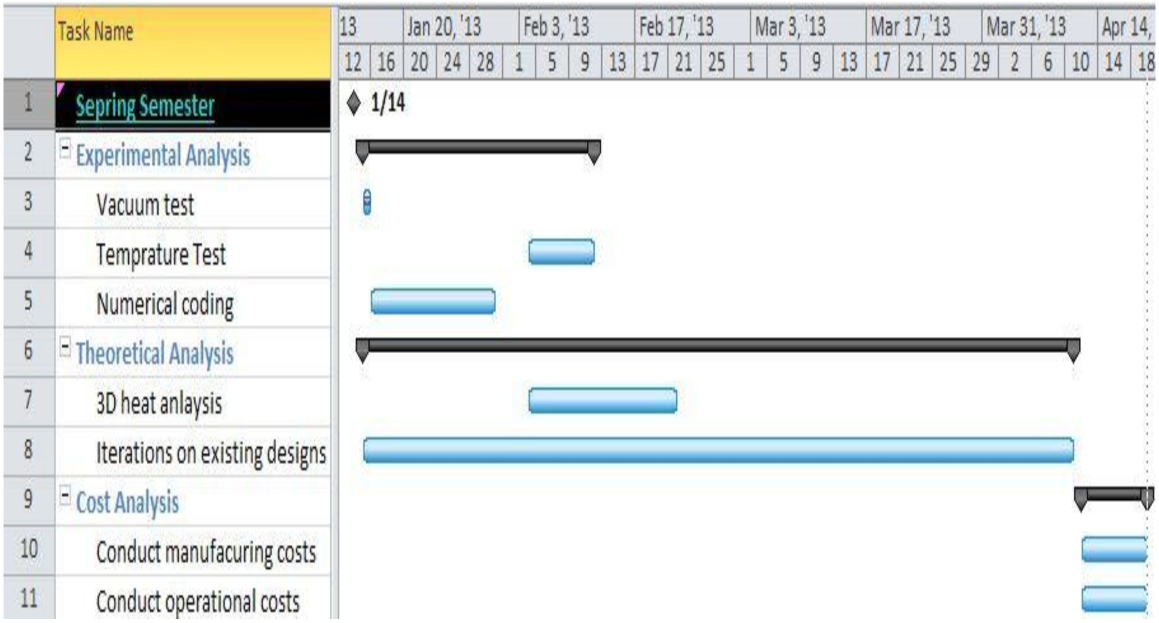

FIGURE 21 – *Gannet chart for the spring semester*

The team will continue working on the project during winter break. Also, the team will try to get all testing equipment needed to do all testing requirements.

8. CONCLUSION

The 40qt design project has been ever evolving in nature. The needs of the client were not explicitly described so there has been much collaboration between the team and the client as to how best accomplish the task of designing a superior cooler. The nature of the business drives the variability of the project. This is because Canyon Coolers is a small business on the upswing frequently encountering different clients and different avenues of expansion. Communication has been imperative during the process.

Through an examination of the nature of the business and concerns of the client the direction of a 40qt model was established. During a meeting with the client the constraints on design were carefully chosen. Those constraints helped form a list of objectives to aid in design. Each design objective/constraint must be met in order to produce a successful product. When decisions are being made, or designs are being considered the list of objectives and constraints are at the foundation. This ensures that steps are being taken in the right direction and time isn't being wasted on something that falls outside acceptable bounds.

With the details of the project well developed the design stage began. There were many different designs in consideration encompassing the wide array of features that could potentially be available on an ice chest. The best of these designs were carefully chosen for further development through a process of design selection. Following this, the designs were presented to the client. This particular meeting was extremely effective in refining design and producing an even clearer direction for the proposed designs. The job of the design team is now to compile the various features and components of design into a single cohesive design. This undertaking is the where the project currently stands. However, one feature stands apart from the rest for its versatility and its backwards compatibility with existing coolers in the Canyon fleet.

The prototyping process has accelerated the motion of the project. Once the client was able to physically hold the design, which was a perfect physical representation of the form and fit of the latch, he was able to visualize how it would behave on the cooler. Adjustments were made to the design and another prototype was produced. Being confident in the performance of this second iteration, the design was sent to a couple companies that deal with rubber and injection molding. Their experience will help guide the design team in the proper direction to get the latch officially tested and subsequently produced.

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APPENDIX

```
% Code to compute thermal resistances
% Dirk Prather and Federico Martolini
% 1D heat transfer analysis
%
% in order to change geometry comment out  L W H values

clear all
wtmin=1*.0253999;
wtmax=2.5*.0253999;
witer=wtmin:.0001:wtmax;
n=size(witer,2);
%%price_pu=
%%price_pe=1.10/lb

for i=1:n

Kpe=.46;
Kpu=.0352;
Mice=5.2;%input('Enter mass of ice in Kg:90.7800');

Tinf=20; %input('Enter an ambient air temp (outside cooler):');

L= 0.5334;%input('Enter internal length in m:');
W= 0.2794;%input('Enter internal width in m:');
H= 0.2667;%input('Enter internal height in m:');
wt=witer(i);%input('enter wall thickness:');
latent=334;
qice=latent*Mice;

% calulate resistances
r_fb=(2*.00381)/(Kpe*L*H)+(wt-(2*.00381))/(Kpu*L*H);
r_tb=(2*.00381)/(Kpe*W*L)+(wt-(2*.00381))/(Kpu*W*L);
r_sides=(2*.00381)/(Kpe*W*H)+(wt-(2*.00381))/(Kpu*W*H);

% calculate heat flow
q_fb=2*(0-Tinf/r_fb);
q_tb=2*(0-Tinf)/r_tb;
q_sides=2*(0-Tinf)/r_sides;
q_total=q_fb+q_tb+q_sides;
q_losskjs=-q_total/1000;

% Time based on heatflow and latenet heat of ice
time=qice/q_losskjs;
time=time/3600;
Time(i)=time

% Calculate volume and cost of materials
PU_VOL(i)=2*((wt-(2*.00381))*H*W+(wt-(2*.00381))*W*L+(wt-
(2*.00381)*H*L));
PE_VOL(i)=2*((2*.00381)*H*W+(2*.00381)*W*L+(2*.00381)*H*L);
VOL_TOT(i)=PU_VOL(i)+PE_VOL(i);
COST(i)=VOL_TOT(i)*800
```

```
end


% Create some data for the two curves to be plotted
x  = witer*39.37;
y1 = COST;
y2 = Time;

% Create a plot with 2 y axes using the plotyy function
figure;
[ax, h1, h2] = plotyy(x, y1, x, y2, 'plot');

% Add title and x axis label
xlabel('Wall thickness (in)');
title('Analysis of Cost Wall Thickness and Ice Retention');

% Use the axis handles to set the labels of the y axes
set(get(ax(1), 'Ylabel'), 'String', 'Cost ($)');
set(get(ax(2), 'Ylabel'), 'String', 'Ice Retention (h)');
```