Design of A Queen Bee Shipping Container

BEE RIGHT THERE

ALBERTA BEEKEEPERS COMMISSION

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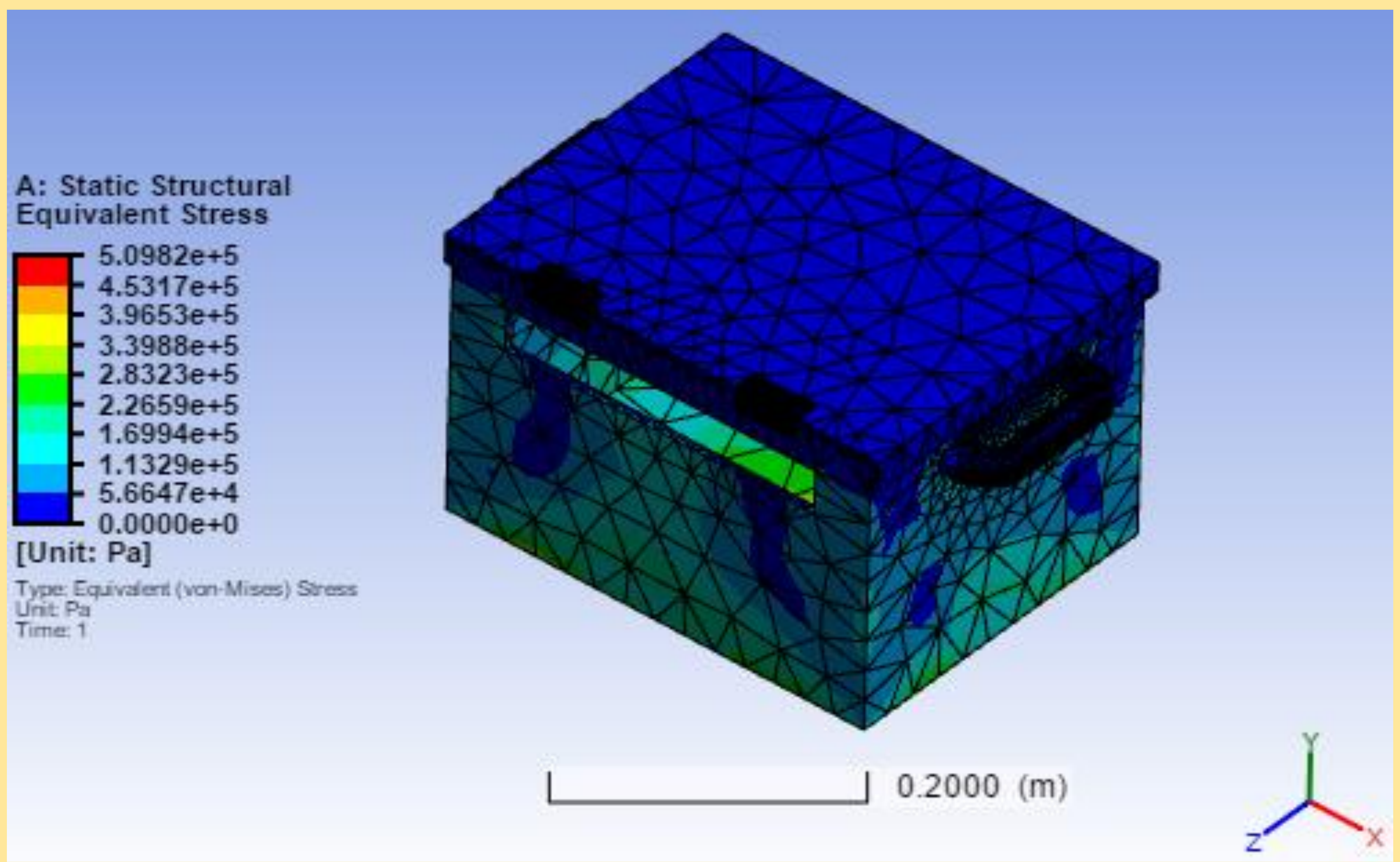
Objective

To design a shipping container which regulates temperature in order to maintain the viability of stored sperm in queen bees. The ideal temperature range is 30 (±5) °C, for a total transportation period of 32 hours.

Structural Analysis

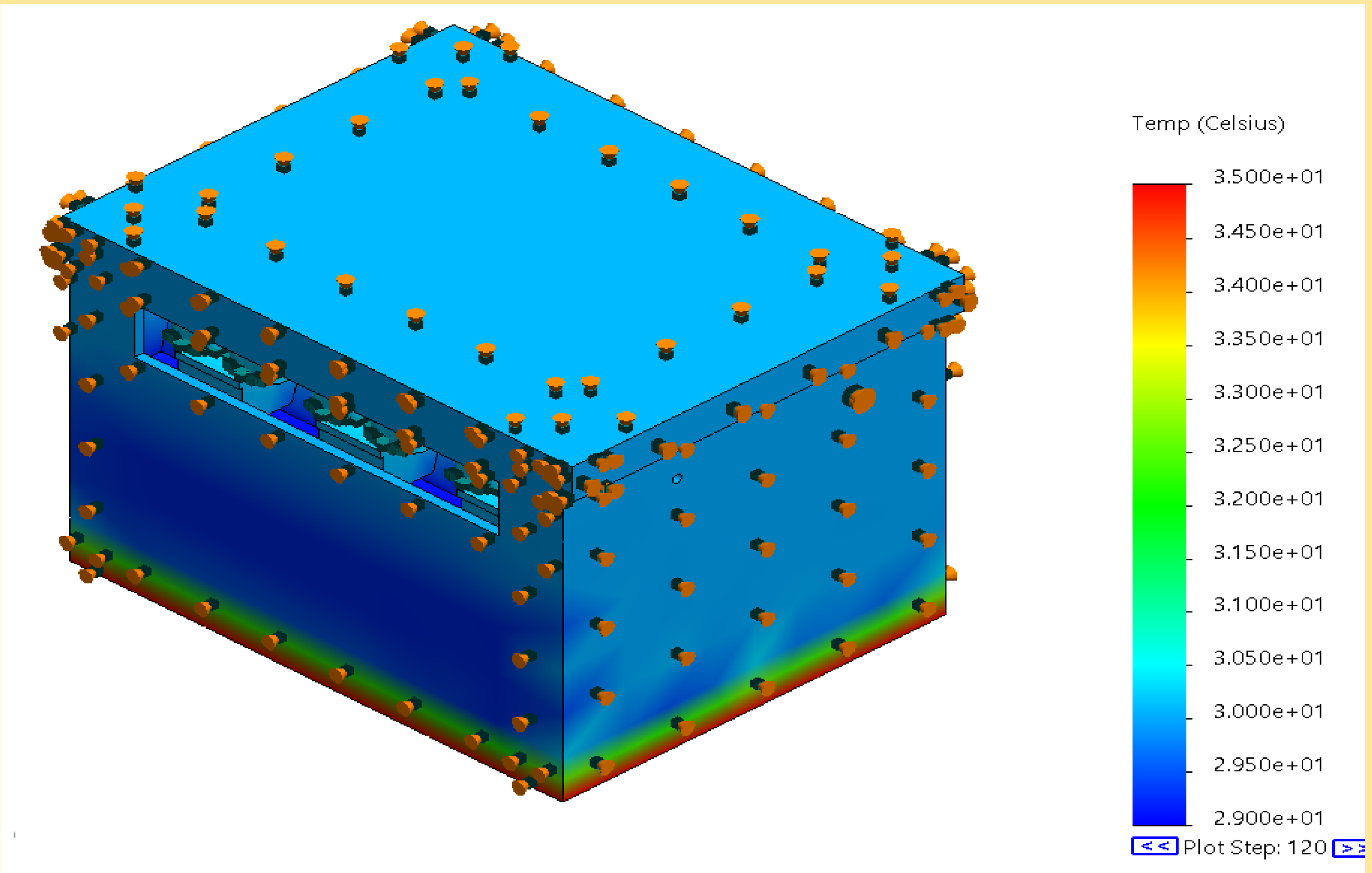
- Different loading cases were examined in ANSYS FEA [1]
- Stress, strain, shear, and deformation were examined
- Lowest factor of safety determined was 13 and occurred in the stacking loading case



[1] – ANSYS FEA Analysis

Thermal Analysis

- Validated that container design will keep queen bees in the ideal temperature range for stored sperm viability
- Used simulation to ensure there is enough heat capacity for multiple stages of queen bee transport [2]



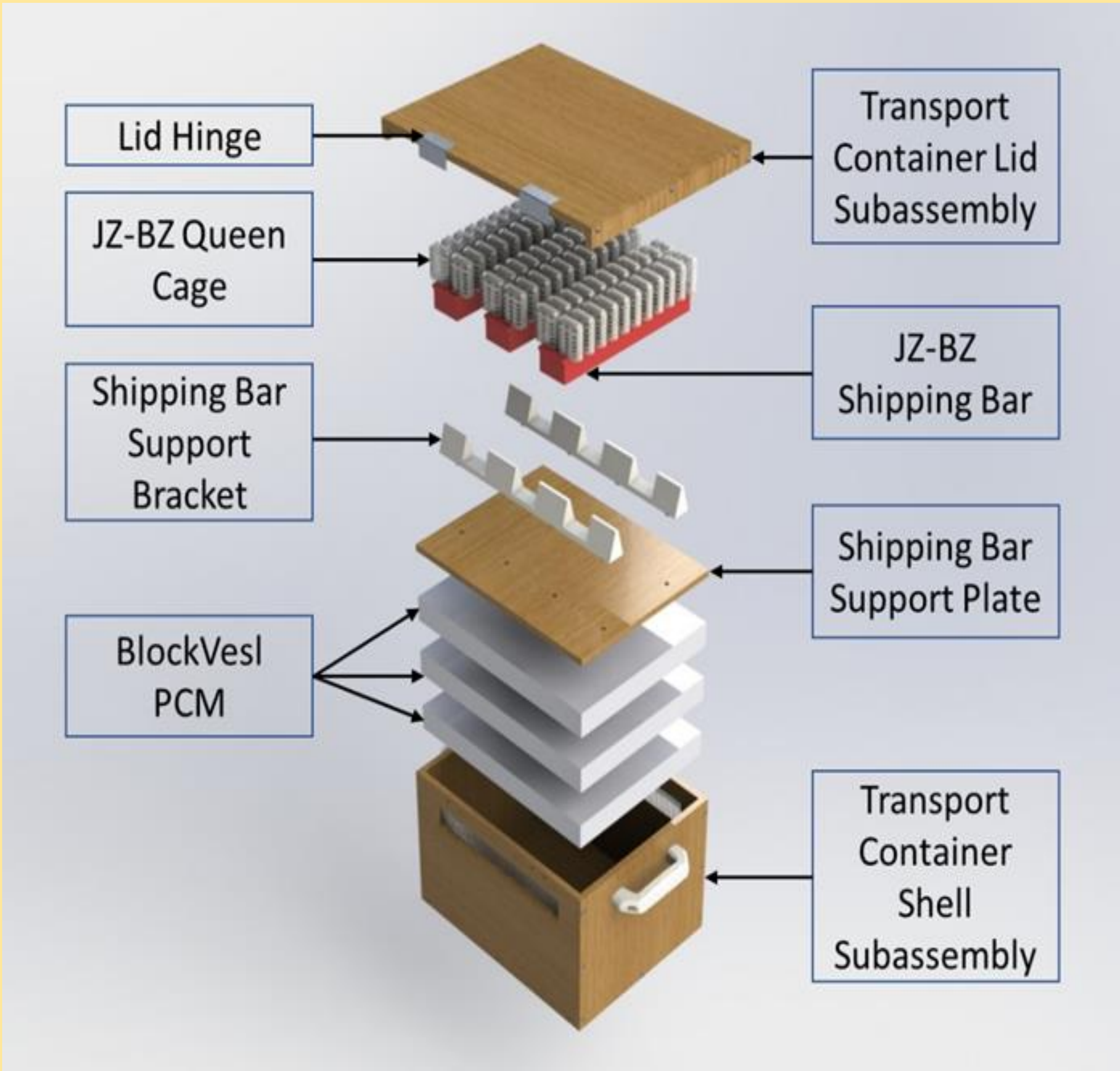
[2] – SolidWorks® Thermal Analysis

Pure Phase Change Design (PPCD)

[3] – SolidWorks® CAD Model of PPCD

Innovation of PPCD

- Final Design [3] utilizes PureTemp® BlockVesl phase change material
- Provides thermal control at an accurate specified temperature (29 °C)
- Stores 5-14X more heat than ice packs [4]
- Vegetable based biodegradable material



[4] – Exploded View of PPCD in SolidWorks®

Manufacturing Cost

- The total cost to build a prototype is $869 which includes material, labor and equipment purchasing
- The total cost to mass manufacture for 1000 units is $131 per unit.

UNIVERSITY OF ALBERTA

Department of Mechanical Engineering

12/02/2019

Phase III Report

Design of a Shipping Container for Queen Bees

BEE RIGHT THERE

Executive Summary

Bee Right There Engineering was hired to design a temperature-controlled queen bee shipping container. The main design constraints presented by the client include maintaining the temperature range of 30 ± 5°C for 33 hours, while minimizing cost, size and weight.

Bee Right There Engineering conducted a feasibility analysis on three conceptual designs and selected the Pure Phase Change Design to develop further. The design consists of a custom plywood box filled with three PureTemp BlockVesl phase change material packages. These packages are located at the bottom of the shipping container with three rows of queen bee cages resting on top of this portion of the container. The phase change material will be selected to change from solid to liquid phase at 29 °C effectively controlling the temperature of the interior of the box until the phase change has been completed. The design specifications provided by the client were supplemented by taking into consideration the return on investment, impact on the environment, safety and manufacturing considerations.

Detailed analysis for this design includes finite element analysis, thermal analysis, detailed costing and manufacturing analysis and an optimization study. These have been completed to ensure the design would satisfy the design constraints as well as the functionality of the design.

Bee Right There Engineering has invested 243 hours into Phase III including the design conference presentation items. The engineering team was under budget in Phase III including presentation preparation by 17 hours which brings the total engineering hours close to the initial estimate. Overall the entire project was over budget by 7 hours which is attributed to the extra hours invested into the Phase II deliverables. This has resulted in a total project cost of $51,780. This value is $630 off the estimated cost for the entirety of the project and still within the 20% contingency cost set at the beginning of the project.

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1. Introduction

Queen bees are imported from around the United States, Oceania and South America to support the agricultural and honey production industries in Canada. Studies have shown that queen bees can be safely shipped at a temperature range of 13°C - 39°C [1], however using stipulations provided by the client's advisory board, a range of 30 ± 5°C was accepted as an ideal range as seen in Appendix A. When the temperature deviates from this range it can reduce the viability of the queen's stored sperm and results in a significant economic impact on both the agricultural and honey producing industries [2].

As mentioned in the previous phases of the design process, Canada must import a large quantity of queen bees from around the United States, Oceania and South America to support the agricultural and honey production industries. During importation of queen bees, the shipping containers see spikes in ambient temperature that can raise the queen bee temperatures above this range and effect their viability.

Bee Right There Engineering (BRTE) was tasked with the design creation of a temperature-controlled queen bee shipping container. Pure Phase Change Design (PPCD) was selected for further development in Phase II. Figure 1 shows an overview of the PPCD design. BRTE has provided a detailed analysis to prove the feasibility of this design in the following report.

Figure 1: An Overview of PPC Design with Lid Closed (437mm x 284mm x 246mm)

2. Design Summary

The PPCD consists of custom plywood box filled with phase change material (PCM) packages in order to control the internal ambient temperature. Rows of JZ-BZ queen bee cages are held in the box above the PCM packages by a custom support tray. The box is opened from the top and the lid is secured with a pair of hinges. Figure 2 shows a render of the final designs solid model.

Figure 2: PPC Design with Lid Open with Right Panel Removed (437mm x 284mm x 246mm)

2.1 Incremental Design Description

The design consists of a custom-made plywood container that was designed to be light weight, durable and cost effective. The container is designed to hold three PCM packages under a small shelf which supports the queen bee shipping bars. The lid of the box is secured by two metal hinges. The sides of the box have handles and two mesh screens to ensure that the CO_2 generated from the bees does not accumulate to dangerous levels. Figure 3 shows an exploded view of the components that make up the container. Box markings were added to the shipping container to ensure the container stays upright during shipping as well as live animal air requirement markings found in Figure 4.

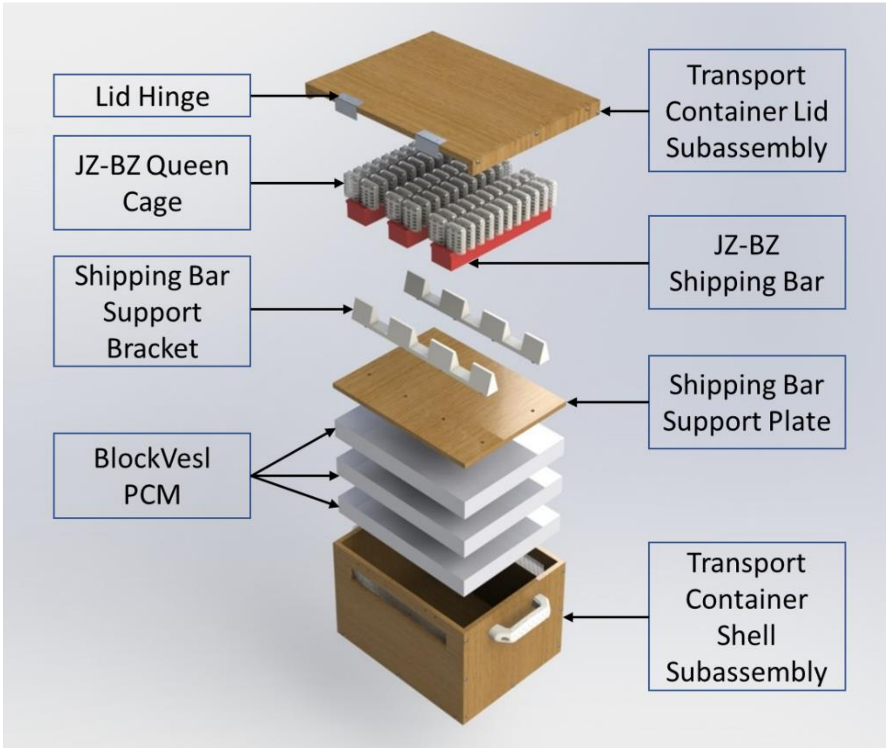


Figure 3: Exploded View of PPC Design (437mm x 284mm x 246mm)

Figure 4: Shipping Container Box Markings

The PureTemp BlockVesl PCM packages in Figure 5, are designed to change phase at various temperatures by either absorbing or releasing thermal energy or heat. For this application the PCM was set at 29°C as this was closest available to 30°C. Preliminary calculations in Phase II showed that this design will maintain the proper temperature range during transit and further thermal analysis have been conducted to ensure the design is viable as seen in Appendix B.

Figure 5:BlockVesl (330mm x 254mm x 38mm)

The JZ-BZ Shipping Bar is used along with JZ-BZ Queen Cages as seen in Figure 6 and Figure 7 respectively.

Figure 6: JZ-BZ Shipping Bar (238mm x 44mm x 33mm)

Figure 7: JZ-BZ Queen Cage (75mm x 36mm x 16mm)

2.2 Design Innovation Highlights

The current method of shipping queen bees is in inexpensive single use cardboard boxes that are filled with queen cages. The most notable innovation in terms of the components of this design is the use of PCM. As mentioned above PCM’s function similar to that of an ice package with a melting point set at a specified temperature. This allows for a very simple solution to a complex problem.

3. Summary of Detailed Analysis

The design was modeled using SolidWorks® and then analyzed using finite element analysis (FEA) to validate the design. An optimization study was then conducted on the design to ensure that the final design is ready for production. A summary of analytical and computational analysis is shown below.

3.1 Finite Element Analysis

Calculations in finite element were performed to prove the functionality of the design. The main analysis on the shipping container was done on the custom box assembly as most of the remaining parts are off the shelf and are already designed to industry standards. The shipping container was made of oriented strand board (OSB) and must support different stress scenarios throughout the shipping process. All values obtained from this analysis were compared to the mechanical properties of OSB and are summarized in Table 1 below.

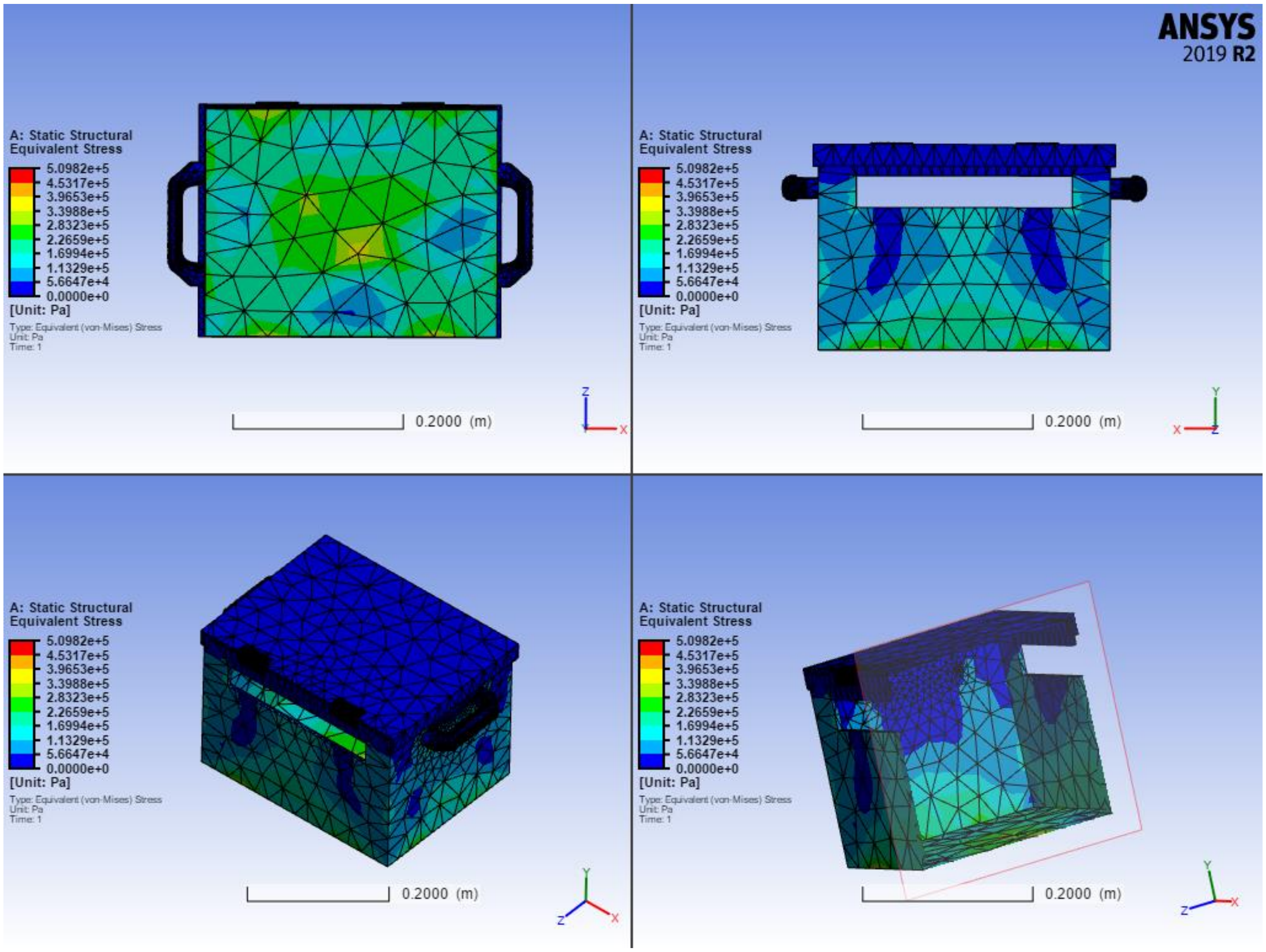
Table 1: OSB Mechanical Properties [3]

Mechanical Properties	Value
Ultimate Tensile Strength	31 MPa
Flexural Modulus	9.3 MPa
Yield Strength	31-41 MPa
Shear Modulus	0.17-0.7 GPa
Shear Strength	1.9-6.2 MPa

The most relevant case analyzed was the internal weight (lifting by the handles) loading scenario. Two other cases were explored, lifting by the lid and stacking the boxes, and the individual analysis for these cases can be found in Appendix D.

3.1.1 Effect of Internal Weight (Lifting by the Handles)

The effect of the internal weight on the box was analyzed by applying the total mass of the internals and converting this value to a pressure being applied on the bottom of the box. The handles of the box were assumed fixed within ANSYS to simulate lifting by the handles. The mass was calculated by SolidWorks® to be 14.2 kg. In order to validate this number, the total mass of the box was calculated in Appendix C to be 13.52 kg. The 14.2 kg was used in this analysis having an associated pressure being 1448 Pa as seen in Appendix D. BRTE decided to use 31 MPa as an initial failure criterion of the box which is the lowest end of the plywood yield strength [3]. Figure 8 below shows the Von Mises Stress distribution of the internal weight load.



*Top Left: Bottom View, Top Right: Front View, Bottom Left: Isometric, Bottom Right: Section View

Figure 8: Internal Weight FEA Equivalent Stress Analysis

The maximum stress on the box was found to be 0.510 MPa. This is well below the yield strength of plywood by a factor of 60. Therefore, BRTE can confidently say under this loading scenario the box will not yield. Having a such a high safety factor brought up the question on whether a cheaper material should be considered. However, the material selected is already one of the cheapest and is an appropriate thickness for fasteners.

For this loading scenario BRTE also analyzed deflection, shear stress and strain as well. The maximum results for each case are summarized below in Table 2 with the figures being found in Appendix D.

Table 2: Summary of Internal Weight FEA Calculation

Von Mises Stress	0.51	MPa
Total Deformation	8.81E-05	m
Total Shear Stress	0.128	MPa
Equivalent Elastic Strain	6.10E-05	m/m

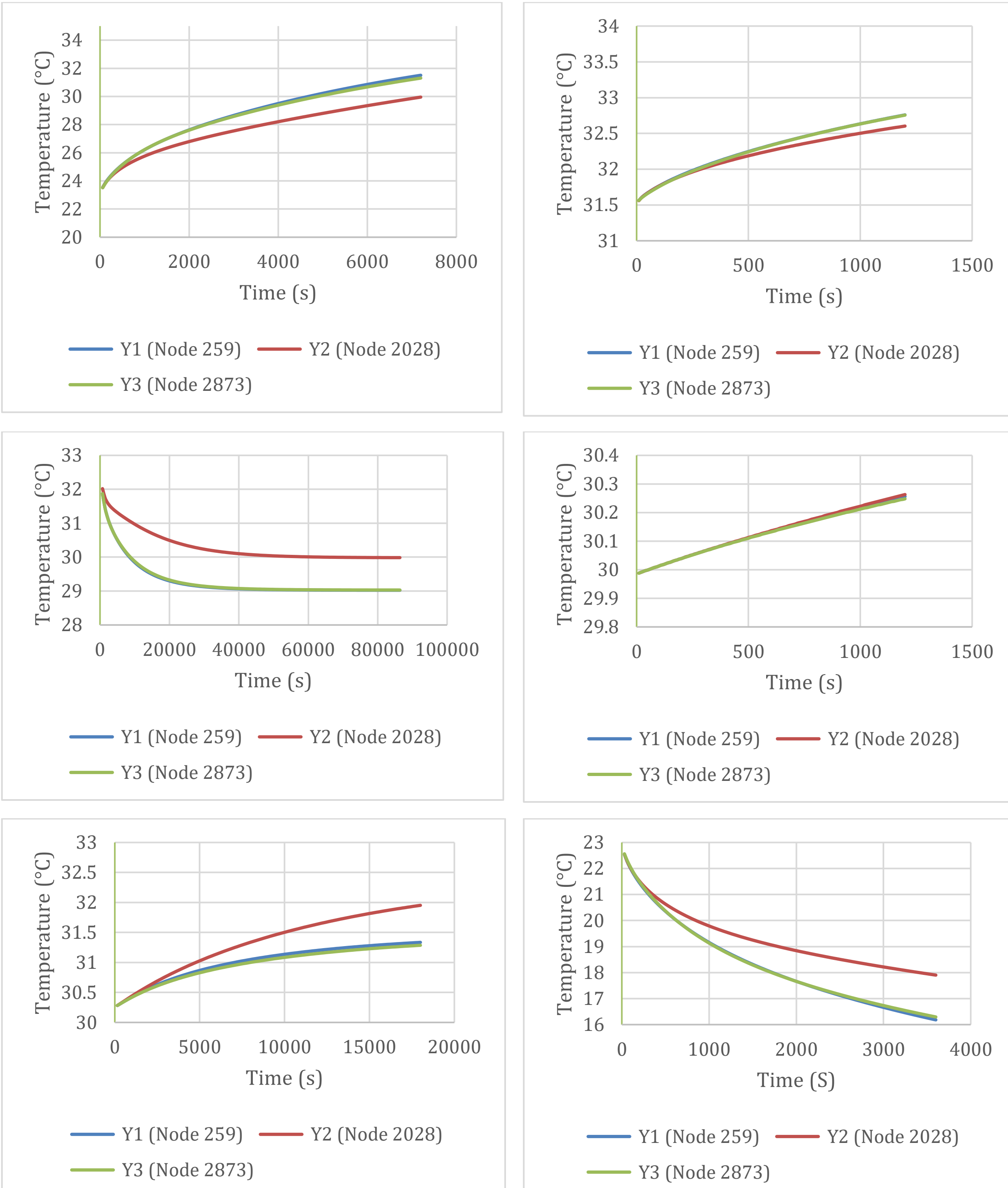
3.2 Thermal Analysis

Thermal analysis was conducted in SolidWorks® to confirm the assumptions and hand calculations performed in the conceptual design phase. The primary objective of these simulations was to determine the temperatures inhibited by the queen bees, and the amount of heat that is absorbed by each BlockVesl during the five stages of air transport seen in Figure 9. The thermal properties of the BlockVesl filled with PureTemp 29 were collected from their datasheet shown in Appendix F, and inputted as a function in SolidWorks® assuming that the properties transfer from a solid to a liquid state exactly at 29°C.

3.2.1 Temperature Distribution of Queen Bees

In order to accurately assess the effect of the thermal simulation conducted on the queen bees in each stage of transport, the temperature distribution of three queen bee cages during the study were collected and plotted in Figure 9. At the end of each stage of transport, the highest queen bee temperature value was taken to be the starting temperature of the queen bees, transport box, lid, shipping trays, and supports for the next stage of transport, see Appendix G for more details. This was done to provide an accurate and conservative boundary condition for consecutive stages of transport.

It should be noted that Y1, Y2, and Y3 (node 259, 2028, and 2873) are the temperatures recorded on a queen cage located in the front, middle, and back with the results being shown in Figure 9. The distribution of these temperatures was chosen to get an overall idea of the distribution of heat during the 5 stages of transport.



**Top Left: Stage 1, Top Right: Stage 2, Middle Left: Stage 3, Middle Right: Stage 4, Bottom Left: Stage 5, Bottom Right: Stage C*

Figure 9: Queen Bee Temperatures for Stages 1-5 and Stage C of Transport

For the main 5 stages of transport, there is no time where the temperature of the bees falls out of the ideal range of 30 ± 5°C except for the assumption that they start at room temperature of 23°C. The cold loading case which was brought up late in Phase III could be examined further as it results in the bees being maintained outside of the ideal range, but not falling out of the damaging range to queen bees stored sperm viability of 13°C - 39°C. See Appendix H for the client's future work request. The total heat absorbed by the BlockVesl packages can be seen in Appendix G with a summary of the results below in Table 3.

Table 3: Summary of Heat Absorbed by System in 5-Stages of Transport

	Heat Absorbed by system (kJ)
Stage 1	136.4
Stage 2	33.04
Stage 3	-81.66
Stage 4	14.09
Stage 5	207.8
Net	309.7
Net w/o Stage 3	391.3

The safety factor of the final iteration of the design was calculated to be 2.08, which is in the ideal range of values shown in Appendix G. This confirms that our design meets the thermal criteria of the project and will perform its function of maintaining queen bee stored sperm viability in a safe and effective manner.

3.3 Optimization Study

The client has made it clear that the cost of the final design must be minimized. The calculations initially conducted in Phase II found in Appendix B, show that the number of packages of PCM have been reduced to 3 packages.

The client has also made it clear that the footprint and the height of the shipping container must be minimized. After changing how the shipping bars are mounted in the main assembly, the overall height of the shipping container was reduced by approximately 20 mm. Both have been taken into consideration see drawing package in Appendix J.

4. Product Analysis

The following section includes a summary of the cost and return on investment analysis, a summary of the industrial design analysis and how societal factors impacted this final design and finally a sustainability analysis.

4.1 Cost and Return on Investment Analysis

BRTE has determined the costs associated with producing a single prototype along with mass producing 1000 of these shipping containers. The operating costs of each task is calculated by approximating the time required to complete work and multiplying this value by the hourly rate of hiring a carpenter, which for this project is approximated at $37 [5]. The detailed costs and quotations for all materials and tools purchased are seen in Appendix K.

4.1.1 Materials and Manufacturing Cost

The cost to manufacture a single prototype unit is $868.96 including all the labour, set-up and material costs. The cost to manufacture 1000 units is estimated at $130,763.30 or $130.76 per unit which is under the client requirement of $150.

4.1.2 Return on Investment:

In order to calculate the return on investment, 10 years worth of cost savings have been evaluated. This time frame is chosen as it is the estimated lifespan of the PPCD shipping container. The total number of bees imported to Canada is 225,000 [1]. As Appendix K.7 illustrates over a ten-year period this design will cost $408,635.21 while the savings are $3,605,760.00 in terms of viable product compared to $1,205,537.10 for the existing design.

4.2 Industrial Design Considerations

In order to ensure that BRTE's design is usable and provides ergonomic function for the client, industrial design factors have been considered. One improvement over existing queen bee transport container is the addition of robust carrying handles, which can reduce stresses on a worker caused by lifting [6]. They have been sized to leave adequate space for workers wearing gloves which is a likely scenario in industry. BRTE implemented a loading system in which the mounting plate, shipping bar supports, and shipping bars are all connected and can be loaded as one subassembly. The queen cages can be inserted before placing this subassembly in the container or loaded individually after the subassembly has been set in the container for flexible loading options shown in Appendix J.

4.3 Societal Factors

Bee populations have been declining in most areas of the world due to loss of habitat and the use of pesticides. A study conducted by the United Nations in 2011 [2] stated that society has fabricated the illusion that the human race no longer requires nature to thrive. The same report also stated that of the 100 crop species that are used to feed most of the world 70 of these species are threatened by the global decline in the population of bees. This project is heavily influenced by this environmental crisis and provides both an economical and ethical solution to the decline of bee populations in Canada.

In legal terms Canada has a short list of locations in which bees can be imported from New Zealand being the furthest considered.

4.4 Sustainability

This design is made mostly out of off the shelf items, except for the OSB components and the plastic shipping bar support. Even though the production of OSB generates 18.4 kg of C_xO_y for every thousand square feet, it is produced from small farmed trees which allows it to have a lower carbon footprint than other building materials such as cardboard and aluminum [7]. The waxes and resin binders are also cured to be less toxic than MDF, Plywood and particleboards, this ensures that less harmful gasses are released compared to other products [8]. The production process of OSB uses 2.11 kg of nonrenewable resources and 611.47 kg of renewable resources [9].

During the design process market sustainability was also researched. Canada cannot rear enough viable queen bees due to the issues presented Figure 10 [10]. The importation of bees from around the world is therefore growing as the agricultural industry grows and the market for this design is expected to continue to increase in size.

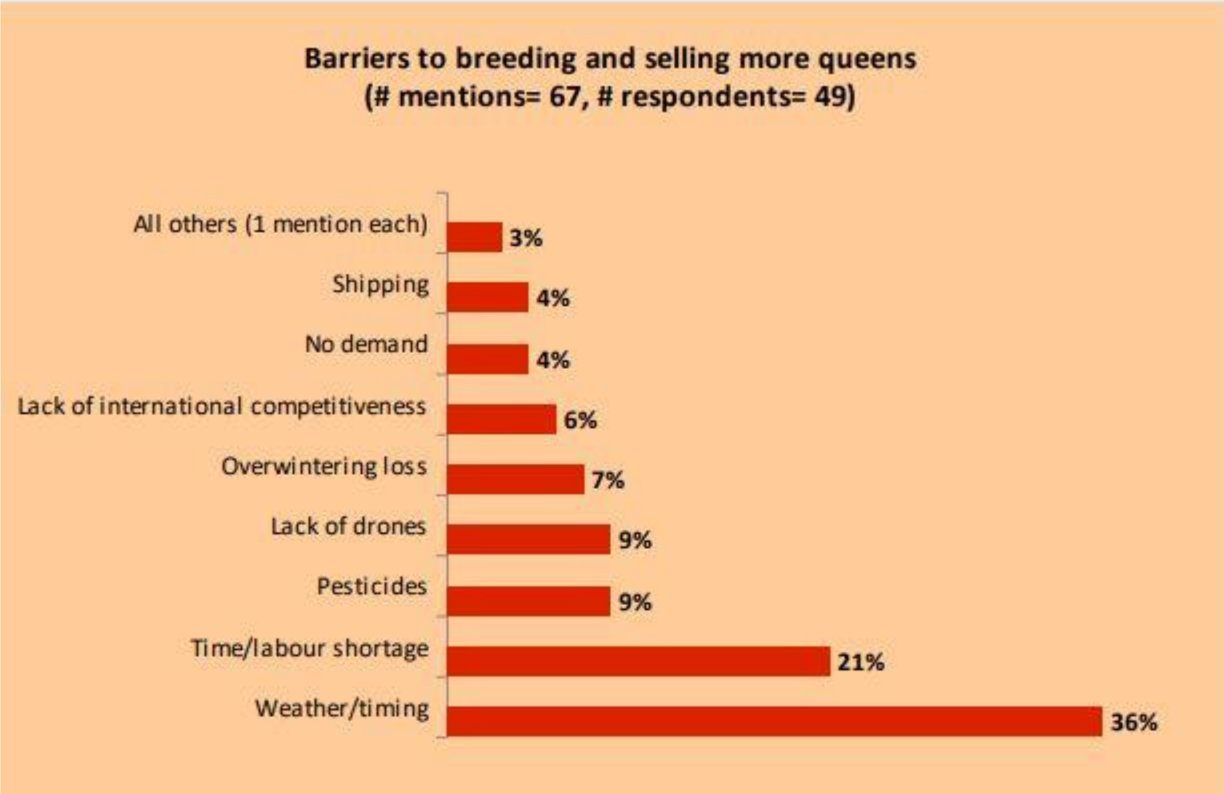


Figure 10:Barriers to Breeding Queens in Canada [10]

4.5 Environmental Impact of Design

The PPCD is expected to last more than 10 years which gives a distinct advantage over current shipping methods in terms of environmental impact. The PCM packages are made of biodegradable materials meaning that near their end of life they can be replaced with little to no environmental consequences. The plastic shipping bars, queen cages, shipping bar support, and the handles are the only plastic parts and are expected to remain in useable condition far past 10 years due to the durability of the plywood shipping container. In addition, OSB is certified by the Forest Stewardship Council which ensures that the wood is harvested is a way that is both environmentally responsible and socially beneficial [11].

5. Design Compliance Matrix

During the design process several of the original design specifications were changed. These changes were made by the client's advisory council consisting of Dr. Renata Borba and Mr. Jim Valian.

5.1 Updated Design Specifications

Feedback from the Alberta Beekeepers Commission has altered the design specification matrix as shown in Table 4 and Table 5.

Table 4: Design Importance Rating

Importance	Description
1	Crucial (Must Have)
2	Important
3	Nice to Have
4	Optional Design Additions

Table 5: Design Specification Matrix

Item	Description	Specification	Revised Specification	Importance (1-4)
1.0	Temperature Control Range			
1.1	Temperature Range	- Must maintain a temperature range of 28 °C minus 15°C and plus 11°C in order to ensure the queen bees arrive in healthy condition.	- The client's advisory council has changed the requirement to 30 ± 5°C.	1
1.2	Temperature Sensor and Recording System	- If chosen in the final design the temperature sensor must accurately record temperature to ± 2°C - If chosen in the final design, ensure that a recording system is accurate to ± 2°C	- The client's advisory council has changed this importance score to a level 3.	3

1.3	Air circulating System	- If chosen in the final design the circulating system must dissipate the required heat produced by the bees and absorbed from the external environment. - Must be sized in order to maintain operation for 72 hours on the battery that supplies the entire system	- The client's advisory council has changed this importance score to a level 4. - The final design did not utilize this specification.	4
2.0	Air Composition System			
2.1	Air sensory system	- A system to accurately measure the composition of air including carbon dioxide and oxygen. - If chosen for the final design this would need to be paired with an air circulatory system.	- The client's advisory council has changed this importance score to a level 4.	4
3.0	Bee Container			
3.2	Queen Cell material	- Cardboard is used in the current design with no significant issues.	- The clients advisory council has changed the queen cells to JZ-BZ cages made of plastic	2
4.0	Transportation Container			
4.2	Box Size	- The box will be 10” X 10” X 5” (254mm x 254mm x 127mm)	- The client's advisory council has changed this importance score to a level 3.	3
6.0	Ergonomics			
6.2	Human Interface	- If a temperature sensor and recording system is included in the final design, ensure that the data recorded is easily accessible.	- The client's advisory council has changed this importance score to a level 4.	4

5.2 Design Compliance Matrix

Table 6 below summarizes which design specifications have been satisfied by the final design.

Table 6: Design Compliance Matrix

Item	Description	Specification	Design Authority	Design Compliances	Importance (1-4)
1.0	Temperature Control Range				
1.1	Temperature Range	- Clients advisory counsel has changed the requirement to 30 ± 5°C.	Client	Complies: The final design maintains this range throughout the entire timespan.	1
1.2	Temperature Sensor and Recording System	- If chosen in the final design the temperature sensor must accurately record temperature to ± 2°C - If chosen in the final design, ensure that a recording system is accurate to ± 2°C	Team	Does not comply: The final approved design does not include this specification.	3
1.3	Air circulating System	- If chosen in the final design the circulating system must dissipate the required heat produced by the bees and absorbed	Client	Does not comply: The final approved design does not include this specification.	4

		from the external environment. - Must be sized in order to maintain operation for 72 hours on the battery that supplies the entire system			
1.4	Battery	- If chosen in the final design the battery must be sized in order to power all other systems for 72 hours.	Client	Does not comply: The final approved design does not include this specification.	4
1.5	Air Condition System	- If chosen in the final design size the air conditioning system in order to maintain the ideal shipping temperature.	Team	Does not comply: The final approved design does not include this specification.	4
1.6	Phase change material temperature control system	- If chosen in the final design size phase change materials in order to maintain the ideal shipping temperature range.	Client	Complies: The final design includes phase change materials as its temperature	4

2.0	Air Composition System				
2.1	Air sensory system	- A system to accurately measure the composition of air including carbon dioxide and oxygen. - If chosen for the final design this would need to be paired with an air circulatory system.	Team	Does not comply: The final approved design does not include this specification.	4
3.0	Bee Container				
3.1	Queen Cell dimension	- 2 ¾ x 1 x ¾ in - Dimensions subjects to minor changes	Current design	Complies	1
3.2	Queen Cell material	- The clients advisory council has changed the queen cells to JZ-BZ cages made of plastic	Current design	Complies	2
3.3	Sugar container fit	- DIA 15/32 in	Current design	Complies	1
4.0	Transportation Container				
4.1	Box material	- Wood or cardboard or metal that is	Team	Complies: The final design container is made out of OSB	2

			durable enough to withstand 10 years of use.		plywood with sufficiently large safety factors that indicate that it should last 10 or more years.	
4.2	Box Size	-	The box will be 10” X 10” X 5”	Team	Does not comply: The final approved design has larger dimensions however the client deemed the changes acceptable.	3
4.3	Wire mesh	-	Mesh size varies from 8 to 20 mesh	Current design	Complies	2
4.4	Wire mesh material	-	For safety reasons the current metal mesh material will be reused	Current design	Complies	3
5.0	Sugar Container					
5.1	Dimension	-	Cylinder with base diameter 15/32 in, 1in height	Current design	Complies	2
5.2	Material	-	The current plastic material will be reused.	Team	Complies	3
6.0	Ergonomics					
6.1	Weight of Product	-	The weight should be less the 25 kg to ensure people can carry it without severe risk of injury.	Team	Complies: The final design is 14.2 kg.	3

6.2	Human Interface	- If a temperature sensor and recording system is included in the final design, ensure that the data recorded is easily accessible.	Team	Does not comply: The final approved design does not include this specification.	4
7.0	Cost				
7.1	Overall Cost	- The overall costs of manufacturing this design should not exceed $150	Team	Complies: Mass produced at roughly $130	3
8.0	Environmental Concerns				
8.1	Manufacturing / End of Life Waste	- Ensure that at end of life all materials used are either biodegradable or recyclable.	Team	Does not comply: The final approved design is sourced mostly from biodegradable or recyclable components however the client has asked that the plastic JZ-BZ queen cages and shipping bars be used which are not biodegradable. A shipping bar, and handle is also made out of plastic.	3
9.0	Safety				
9.1	Bee Enclosures	- Queens are shipped in separately packed	Team	Complies	2

			cells within the shipping container, ensure that the risk of the bees escaping their individual cells and the container are mitigated			
10.0	Maintenance					
9.1	Accessibility of components	-	Ensure that all components are accessible and can be sourced and received with lead times of less then 10 weeks	Team	Complies	2
11.0	Miscellaneous					
11.1	Load Requirements	-	These boxes are not designed as stackable and therefore it will only need to support the load of the final design components and the minimal weight of the bees. This value will be determined at the	Team	Complies: The final design loads have been modeled and presented in Section 3.1.	1

		end of the Phase Two report.			
	Box Markings	- The boxes will require right side up markings - The boxes will require live animal air requirement markings near the mesh screens	Team	Complies	1

6. Drawing Package

The drawing tree can be seen in the Figure 11 below which outlines the relationships between the main assembly, subassemblies, and individual parts which can be seen in Appendix J.

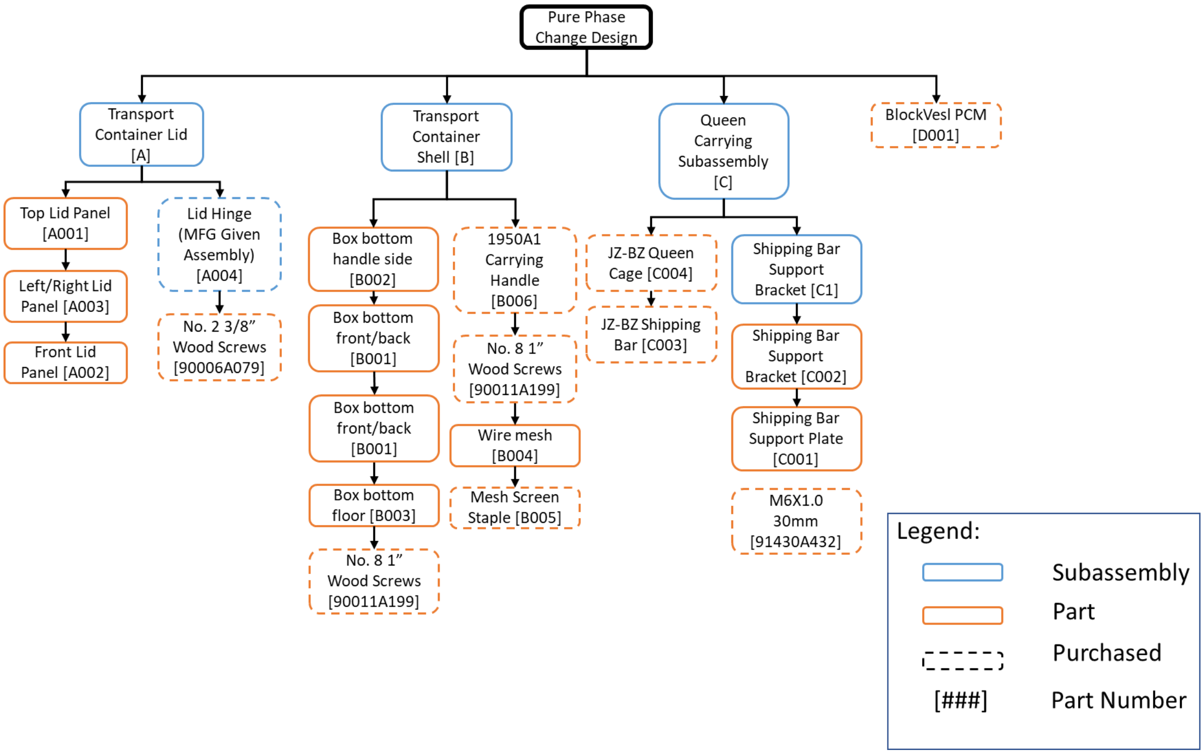


Figure 11: Drawing Tree

7. Future Considerations

BRTE's design is compliant with the crucial specifications, however there are still improvements or adjustments that can be made. The client has suggested including a temperature recording device and interface in a prototype model to better understand the internal temperatures.

8. Project Management

The following section outlines BRTE's project management strategy. This also includes the engineering hours required to complete this project.

8.1 Time Management

BRTE scheduled and tracked tasks by using a custom-made Gantt chart in excel. The project schedule was updated on a weekly basis to allow the engineering team to make important decisions on priority ranking to ensure that the important milestones are delivered on time. A detailed schedule can be found in Appendix L. It is important to note that in Phase II BRTE was over budget on the engineering hours spent, however these were recovered by less time being invested into Phase III and the presentation preparation.

8.2 Actual Hours for Phase II

The actual junior engineering hours invested into Phase III and presentation preparation was calculated to be 243 as seen in Appendix L. This was 17 hours off the estimate given in the updated schedule presented in Phase II report which can be attributed to the extra work done in Phase II. Overall BRTE invested 557 hours into the project along with 11 Senior engineering hours. The comparison between the initial estimated engineering hours and costs, and the actual engineering hours and costs invested into the project were graphically developed in Figure 12 and Figure 13. BRTE produced the final deliverable at a total cost of $51,780. The total engineering costs for the project differed by $630 compared to the estimate due to extra hours spent in the conceptual design stage. The entirety of the cost breakdown can be found in Appendix L.

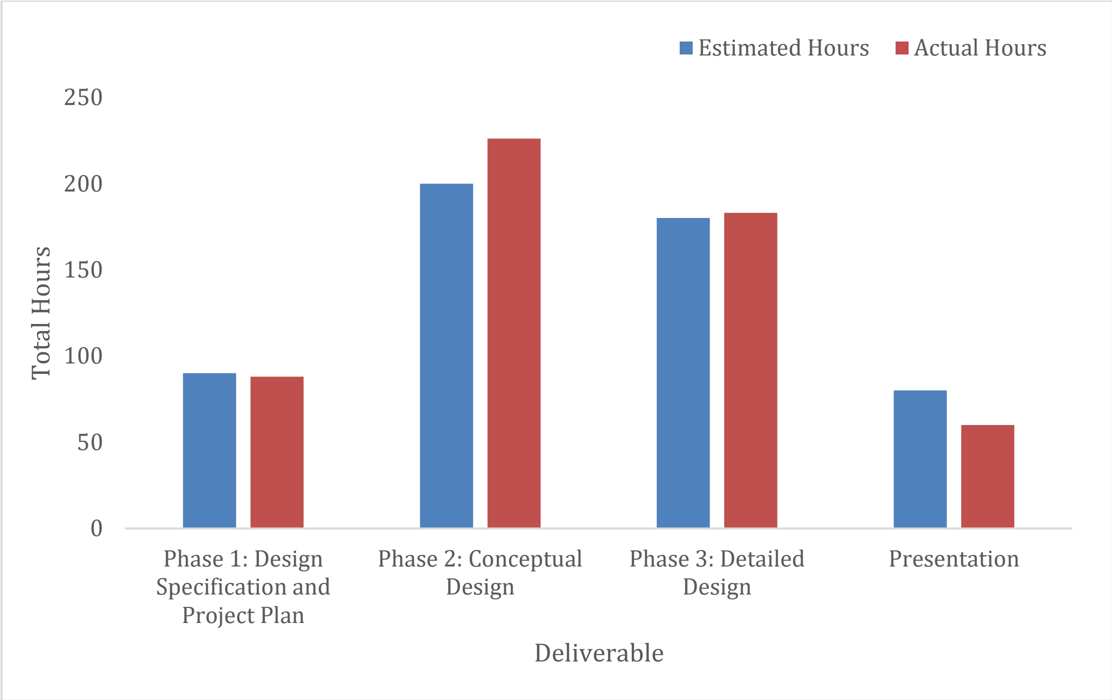


Figure 12: Estimated and Actual Engineering Hours

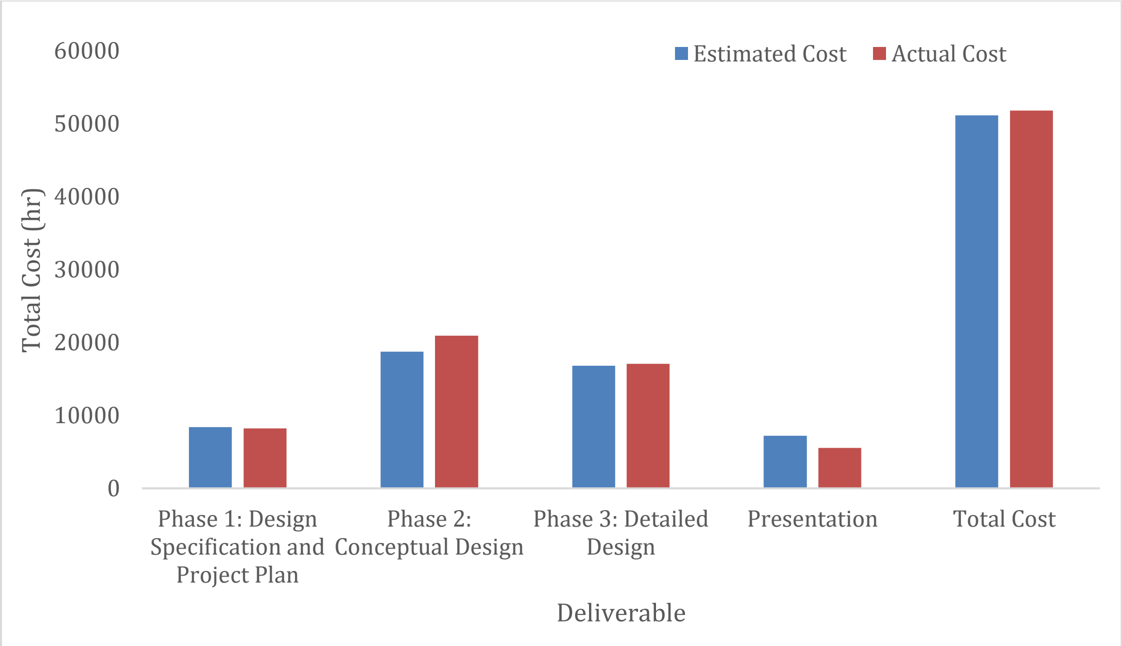


Figure 13: Estimated and Actual Engineering Costs

9. Conclusion

BRTE has produced a detailed design of a temperature-controlled queen bee shipping container. The total mass of the container is 14.2 kg which is light enough to be handled by a single laborer or farmer. The dimensions is 284 mm by 437 mm by 246 mm which has been deemed small enough by the client.

Finite Element Analysis and SolidWorks® thermal simulation have been performed on the design. The FEA results show that the box will be durable enough to withstand all of the expected stresses and has a safety factor of 13. The SolidWorks® analysis results show that the clients specified temperature range was maintained through all steps of the importation process.

The final design is easily assembled with most of the components being readily available stock items. The only custom-made components are the OSB container and the queen shipping bar support piece. The design and all associated research, calculations and models will be transferred to the Alberta Beekeepers Commission at the conclusion of the 2019 Fall Academic term.

References

[1] "Spermatogenesis: Definition of Spermatogenesis by Lexico." *Lexico Dictionaries | English*, Lexico Dictionaries, https://www.lexico.com/en/definition/spermatogenesis.

[2] UN Report "Humans must change behaviour to save bees, vital for food production" Retrieved December 1, 2019 from https://news.un.org/en/story/2011/03/368622-humans-must-change-behaviour-save-bees-vital-food-production-un-report

[3] Mechanical Properties of OSB Retrieved December 1, 2019 from http://edge.rit.edu/edge/P14418/public/4-Subsystems%20Design/Plywood%20Materials.pdf

[4] United Performance Metals – Stainless 316, 316L, 317, 317L. Retrieved November 26, 2019 from https://www.upmet.com/

[5] Average hourly rate for a carpenter – Average Cost To Hire a Carpenter. (n.d.). Retrieved from https://www.networx.com/cost-guide/hire-a-carpenter

[6] UNC-Lifting and Material Handling. Retrieved November 20, 2019 from https://ehs.unc.edu/workplace-safety/ergonomics/lifting/

[7] "Sustainability and OSB." The Upstyle Wood Guide, 2AD. Retrieved November 28, 2019 from www.woodguide.org/guide/osb/

[8] Chan, George. Sustainability Assessment of OSB and Softwood Plywood Manufacturing in North America. 2012, pp. 7–47, Sustainability Assessment of OSB and Softwood Plywood Manufacturing in North America.

[9] "Oriented Strand Board (OSB)." PJ Fitzpatrick, 2AD, Retrieved November 27, 2019 from www.pjfitz.com/roofing/oriented-strand-board/.

[10] M. Bixby, M. M. Guarna, S. E. Hoover, and S. F. Pernal, "Canadian Honey Bee Queen Bee Breeders ' Reference Guide."

[11] "North American Oriented Strand Board." American Wood Council, 2013.

[12] "PureTemp 29 Technical Data Sheet" https://www.puretemp.com/stories/puretemp-29-tds

Appendix A: Client Suggested Temperature

The client advisory board consist of Renata Borba, Jim Valant, Connie Phillips. Below is an email sent on behalf of the client advisory board with key design information that was not included in the original project proposal.

Renata Borba Wed, Oct 30, 9:36 AM (4 days ago)

to me

Hi Cole,

The temperature I suggested is based on many research that have studied the brood nest optimal temperature, which is between 30-35 °C. Mark L. Winston's book " The biology of the honey bee" is a good reference because it compiles the findings of many of these studies. When the question is specifically about queens, 'what is the queen optimal temperature?', we don 't know the answer. A couple recent studies have suggested that the **safe** temperature for queens is from 13°C to 39°C. Temperature above and below those numbers can cause some negative effects on her sperm viability and count (McAfee A, Higo H, Underwood R, Milone J, Foster LJ, Guarna MM, Tarpy DR, Pettis JS. (2019) Queen honey bees combat heat stress-induced loss of stored sperm viability with ATP-independent heat shock proteins. BioRxiv 2019, 627729. doi: https://doi.org/10.1101/627729 ; Pettis JS, Rice N, Joselow K, vanEngelsdorp D, Chaimanee V. (2016). Colony Failure Linked to Low Sperm Viability in Honey Bee (Apis mellifera) Queens and an Exploration of Potential Causative Factors. PLoS One 11. https://**doi**.org/10.1371/journal.pone.0147220). My suggestion of 32 °C is completely based on the brood nest optimal temperate, which is where the queen is often located in the hive. But for a short period of time, as for shipment, she will most likely be safe if the shipping box temperature range is 30 °C +/- 5 °C.

I hope this helps.

Best,
Renata

Appendix B: Heat Transfer Manual Calculations

Document Author: Michael Primrose Date Written:October 17 2019

Peer Reviewed By: Cole Masse Date Checked: October 22 2019

Revision Number: 3 Date Revision: October 25 2019

Objective:The following calculations will describe the various heat transfers for every stage of the shipping process. This first iteration will use the furthest trip for the bees which is when they are imported from New Zealand.

Known Data and Assumptions:

Iteration 1

The following known parameters and assumptions will be used throughout the following calculations

- The carrying box is likely to be made out of wood, cardboard or some other cheap material however the heat transfer coefficients used will reflect that of plywood
-The box dimensions will be 10"X13"X10"
-When reasonable the worst case scenario will calculated.
-Two sides of the box will include two small mesh screens each for airflow. For the surface area calculation the mesh screens will be ignored.
-The box will have an assumed emissivity of 0.83
-The box will hold 72 bees with an approximate heat generation of 0.0037 Watts/bee
-The box will remain at a constant temperature which is 29 degrees celsius which is the highest temperature that the block vessel can be set at.
-Three Blockvesl packs will be used.
-The specific heat of PURETEMP 29 block vessel is 1.94 J/g˚C
-The thickness of the box is 1/4 inch or 0.0064m
-All heat calculations have been made assuming the box does not change temperature.

The surface area used throughout the calculations is calculated below, please note that the outer surface area is used in the radiation heat calcs and the convective surface area also includes the surface area of three BlockVesl packages.

$$c_{bv29} := \frac{1.94\ J}{g\ °C}$$

$$A_{surface} := ((10 \cdot 13) \cdot 1)\ in^2 + (10 \cdot 10 \cdot 2)\ in^2 + (10 \cdot 13 \cdot 2)\ in^2 = 0.3806\ m^2$$

$$A_{bottom} := 10 \cdot 13\ in^2 = 0.0839\ m^2$$

$$A_{blockvesl} := 3277\ cm^2 = 0.3277\ m^2$$

$$A_{conv} := 3 \cdot A_{blockvesl} + A_{surface} = 1.3637\ m^2$$

$$K := 0.13\ \frac{W}{m\ K}$$

$$\varepsilon := 0.83$$

$$\sigma := 5.6703 \cdot 10^{-8}\ \frac{W}{m^2\ K^4}$$

$d := \frac{3}{8}\ \text{in} = 0.0095\ \text{m}$

$q_{bee} := 0.0037 \cdot 72\ \text{W} = 0.2664\ \text{W}$

Analysis :

Stage 1: Exporting Country Farm to airport

The majority of the locations that Canada imports queen bees from are relatively hot climates such as California and New Zealand. The bees are typically shipped in the box of trucks with tarps covering them or in closed vans. The worst case scenario here would in a covered truck box. The following calculations will be using this assumption in a hot New Zealand climate as this is assumed to be the worst case scenario.
It is also assumed that in the covered truck there is no direct sunlight hitting the box and that the air is close to stagnant under the tarp so that convection is not forced.

Heat Transfer due to radiation, note that the truck is assumed to be at 35 degrees celsius which is a high assumption based on the climate. The box is assumed to be at 29 degrees Celsius which is as close to the ideal shipping temperature of 32 degrees celsius that BlockVesl can be set at.

$T_{box} := (29 + 273.15)\ \text{K}$

$T_{truck} := (35 + 273.15)\ \text{K}$

$q_{rad1} := \left(-A_{surface} \cdot s \cdot \sigma\right) \cdot \left(T_{box}^{\ 4} - T_{truck}^{\ 4}\right) = 12.2179\ \text{W}$

Heat transfer due to conduction, note that the materials are assumed to be plywood.

$q_{cond1} := \left(\frac{K \cdot A_{bottom}}{d}\right) \cdot \left(T_{truck} - T_{box}\right) = 6.8682\ \text{W}$

Heat transferred due to convection, note that the surface area used in this calculation includes the surface area of 3 blockvesl packages as well as the outside of the box. A value for low speed flow of air over a flat surface was used for a convective heat transfer coefficient.

$T_{air1} := (35 + 273)\ \text{K} = 308\ \text{K}$

$h := 5\ \frac{\text{W}}{\text{m}^2\ \text{K}}$

$q_{conv1} := h \cdot A_{conv} \cdot \left(T_{air1} - T_{box}\right) = 39.8895\ \text{W}$

The total time for the transportation of stage one is estimated to be less then 2 hours however however 2 hours will be used as a worst case scenario.

$Q_{stage1} := \left(q_{conv1} + q_{cond1} + q_{rad1} + q_{bee}\right) \cdot 2\ \text{hr} = 4.2654 \cdot 10^{5}\ \text{J}$

Stage 2: Foreign Airport

It is assumed that the box will be sitting in the sun on the tarmac of the airport for a maximum of 20 min the sun. The following calculations use this assumption.

Heat Transfer due to radiation, note that in this scenario it is assumed that the box is sitting out on a tarmac in full sunlight. According to the university of Tennessee one square meter of flat earth in the sun absorbs approximately 1000 W. This value will be used to calculate the heat transfer due to radiation in this scenario.

$$q_{sun} := 1000 \frac{W}{m^2}$$

$$q_{rad2} := q_{sun} \cdot A_{surface} \cdot s = 315.9349\ W$$

Heat transfer due to conduction, note that the materials are assumed to be plywood, and are almost identical to the calculations of the first stage. The New Zealand Tarmac is estimated to be at 40 degrees Celsius.

$$T_{tarmac} := (40 + 273)\ K$$

$$q_{cond2} := \left(\frac{K \cdot A_{bottom}}{d}\right) \cdot \left(T_{tarmac} - T_{box}\right) = 12.4199\ W$$

Heat transferred due to convection, note that the surface area used in this calculation includes the surface area of 3 blockvesl packages as well as the outside of the box. A value for low speed flow of air over a flat surface was used for a convective heat transfer coefficient.

$$q_{conv2} := h \cdot A_{conv} \cdot \left(T_{air1} - T_{box}\right) = 39.8895\ W$$

The total time to be on the tarmac is expected to be less then 20 minutes however twenty minutes will be used as a worst case scenario.

$$Q_{stage2} := \left(q_{conv2} + q_{cond2} + q_{rad2} + q_{bee}\right) \cdot 20\ min = 4.4221 \cdot 10^5\ J$$

Stage 3: Airport cargo

The airport cargo hold is estimated to be at 27 degrees Celsius for shipping live animals. This value will be used to determine all the heat transfers for the following calculations. The time in the cargo hold was estimated using the flight times from New Zealand to Edmonton Alberta Canada.

Heat Transfer due to radiation. The box is still assumed to be at 29 degrees celsius.

$$T_{cargo} := (27 + 273)\ K$$

$$q_{rad3} := \left(-A_{surface} \cdot s \cdot \sigma\right) \cdot \left(T_{box}^{\ 4} - T_{cargo}^{\ 4}\right) = -4.2047\ W$$

Heat transfer due to conduction, note that the materials are assumed to be aluminum.

$$q_{cond3} := \left(\frac{K \cdot A_{bottom}}{d}\right) \cdot \left(T_{cargo} - T_{box}\right) = -2.4611\ W$$

Heat transferred due to convection, note that the surface area used in this calculation includes the surface area of 3 blockvesl packages as well as the outside of the box. A value for low speed flow of air over a flat surface was used for a convective heat transfer coefficient.

$$q_{conv3} := h \cdot A_{conv} \cdot \left(T_{cargo} - T_{box}\right) = -14.6603 \text{ W}$$

The time in the cargo hold was estimated using the flight times from New Zealand to Edmonton Alberta Canada which the longest flight are in the range of 24 hours. These are the longest flights from countries that Canada imports bees from and will be used as a worst case scenario

$$Q_{stage3} := \left(q_{conv3} + q_{cond3} + q_{rad3} + q_{bee}\right) \cdot 24 \text{ hr} = -1.8196 \cdot 10^{6} \text{ J}$$

Stage 4: Canadian Airport

The airport in Canada will be a similar calculation to that of the exporting country, with the exception that temperature has been adjusted for Canada's climate. Please see below for the calucations.

$$q_{sun} := 1000 \frac{\text{W}}{\text{m}^2}$$

$$q_{rad4} := q_{sun} \cdot A_{surface} \cdot s = 315.9349 \text{ W}$$

Heat transfer due to conduction, note that the materials are assumed to be plywood and are almost identical to the calculations of the second stage however the tarmac is assumed to be 30 degrees celsius.

$$T_{tarmac4} := (30 + 273) \text{ K}$$

$$q_{cond4} := \left(\frac{K \cdot A_{bottom}}{d}\right) \cdot \left(T_{tarmac4} - T_{box}\right) = 0.973 \text{ W}$$

Heat transferred due to convection, note that the surface area used in this calculation includes the surface area of 3 blockvesl packages as well as the outside of the box. A value for low speed flow of air over a flat surface was used for a convective heat transfer coefficient.

$$T_{air4} := (30 + 273) \text{ K} = 303 \text{ K}$$

$$q_{conv4} := h \cdot A_{conv} \cdot \left(T_{air4} - T_{box}\right) = 5.7959 \text{ W}$$

The total time to be on the tarmac is expected to be less then 20 minutes however a half an hour has been selected.

$$Q_{stage4} := \left(q_{conv4} + q_{cond4} + q_{rad4} + q_{bee}\right) \cdot 20 \text{ min} = 3.8756 \cdot 10^{5} \text{ J}$$

Stage 5: Transporation to an Alberta Farm

The last stage of the shipping will be from the airport to a Albertan Bee Farm. The town of Falher is roughly a five hours away from Edmonton and that value will be used becuase it has a large number of honey producing farms located there.

Heat Transfer due to radiation. The box is assumed to be at 29 degrees Celsius which is the ideal shipping temperature.

$$T_{truck} := (30 + 273)\ K = 303\ K$$

$$q_{rad5} := \left(-A_{surface} \cdot s \cdot \sigma\right) \cdot \left(T_{box}^{\ 4} - T_{truck}^{\ 4}\right) = 1.6873\ W$$

Heat transfer due to conduction, note that the materials are assumed to be plywood.

$$q_{cond5} := \left(\frac{K \cdot A_{bottom}}{d}\right) \cdot \left(T_{truck} - T_{box}\right) = 0.973\ W$$

Heat transferred due to convection, note that the surface area used in this calculation includes the surface area of 3 blockvesl packages as well as the outside of the box. A value for low speed flow of air over a flat surface was used for a convective heat transfer coefficient.

$$T_{air4} := (30 + 273)\ K$$

$$q_{conv5} := h \cdot A_{conv} \cdot \left(T_{air4} - T_{box}\right) = 5.7959\ W$$

$$Q_{stage5} := \left(q_{conv5} + q_{cond5} + q_{rad5} + q_{bee}\right) \cdot 5\ hr = 1.5701 \cdot 10^{5}\ J$$

The following calculations will be done to see how many blockvesl packages are required to absorb the total heat of each stage. The first guess above shows a value of 3 Block vessels maintaining a constant temperature for the 34 hours jounry that has been estimated. Firstly the heat absorbed by a single Block vessel will be calculated below.

Knowns:
Heat storage is roughly 200 J/g for these phase change materials
The specific gravity varies from 0.75 - 1.5 with the higher values used for higher temperatures.
The volume of the phase change material will be 908 ml +- 5%

$$SG_{PCM} := 1.5$$

$$rho := 1.5 \cdot 0.9962\ \frac{g}{mL} = 1494.3\ \frac{kg}{m^{3}}$$

$$e_{bv} := 200\ \frac{J}{g}$$

$$V_{bv} := 908\ mL = 0.0009\ m^{3}$$

$$E_{bv} := rho \cdot V_{bv} \cdot e_{bv} = 2.7136 \cdot 10^{5}\ J$$

The above value is for a single blockVesl

Stage 1 will require the below number of BV

$$BV_1 := \frac{Q_{stage1}}{E_{bv}} = 1.5718$$

Stage 2 will require the below number of BV.

$$BV_2 := \frac{Q_{stage2}}{E_{bv}} = 1.6296$$

Stage 3 will require the below number of BV.

$$BV_3 := \frac{Q_{stage3}}{E_{bv}} = -6.7052$$

Stage 3 will actually result in heat transfer into the plains cargo hold so no additional block vessels will be require for this section. This negative value will be taken into account at the end of the iteration.

Stage 4 will require the below number of BV.

$$BV_4 := \frac{Q_{stage4}}{E_{bv}} = 1.4282$$

Stage 5 will require the below number of BV.

$$BV_5 := \frac{Q_{stage5}}{E_{bv}} = 0.5786$$

The net BV is shown below.

$$BV_{total} := BV_1 + BV_2 + BV_3 + BV_4 + BV_5 = -1.497$$

To ensure that the temperature does not start to rise in the first two steps the number of BV needed is shown below.

$$BV_{net12} := BV_1 + BV_2 = 3.2014$$

To ensure that the temperature does not start to rise in the last two steps the number of BV needed is shown below.

$$BV_{net45} := BV_4 + BV_5 = 2.0068$$

For finaicial reason more then 3 BV per box is not feasable. Therefore it needs to be shown that the temperature does not leave the prevoisly determined safe shipping range.

In the above calcs it was shown that more then 3 blockVesl packs would be required to keep the box at a constant temperature during stages 1 and 2. In stage 3 the box would lose heat to the enviroment in the cargo hold however it will never go below the miniumum temperature range. By some time during the flight the blockvesl's would refreeze and would be able to absorb their full heat capacity once more. For stages 4 and 5 slightly more then 3 blockVesl would be required. The next step in the proccess is to see if the temperature would increase past the acceptable shipping range and to see how long the bees would be subject to that temperature. Stage 1 and 2 combined will be used to determine this.

The following known parameters and assumptions will be used throughout the following calculations
-The safe temperature range is 13 - 39 °C[1] using 3 block vessels we know the temperature will remain constant until some time during stage 2. The queens sperm count is also 60% viable after 4 hours at 42 degrees celsius so the following calcs will ensure that the time span is far lower than that length and that the temperature is not 42 degrees celsius.

After stage one there is the following amount of energy left to be absorbed by the block vessels.

$$E_{bvremain} := \left(3 - BV_1\right) \cdot E_{bv} = 3.8755 \cdot 10^5 \text{ J}$$

From stage 2's calculations the temperature of the box will start to increase after the above value is reached. Please see below for the time calculation.

$$t_{expended} := \frac{E_{bvremain}}{\left(q_{conv2} + q_{cond2} + q_{rad2} + q_{bee}\right)} = 1051.6717 \text{ s}$$

That means that after the above time has expired in stage two the temperature of the box will start to rise.

$$t_{remaining} := 20 \text{ min} - t_{expended} = 148.3283 \text{ s}$$

Conclusion 1 :

That means that the temperature of the box will begin to rise after sitting on the tarmac for roughly 17 minutes. This leaves 3 minutes in which the temperature will begin to increase. This is below the 4 hour time frame and starting at a lower temperature then 42 degrees celsius. This design is therefore feasable. Stage 3 will reduce the temperature at most to 27 degrees celsuis which is within the range. The temperature will raise back to 29 degrees celsius for stages 4 and 5 and remain constant.

Becuase the temperature is no longer constant the equations begin to change with respect to temperature. These more advanced thermo calculations will be completed should this design be selected for phase three.

Appendix C: Manual Mass Calculation

Weight Calculation

Document Author: Cole Hancheryk
Date Initiated: October 24, 2019

Peer Reviewed By: Michael Primrose
Date Checked: October 29, 2019

Revision Number: 4
Date Revised: October 29, 2019

Objective : The objective of the following calculations is to determine the entire weight of the proposed design of the Simple Phase Change Design. The purpose of determining the weight is to aid in the designs team selection of the most adequate design. This will also assist in the selection of appropriate materials for the casing of the shipping container.

Known Data: The references below are where the values of individual components were obtained. These values were verfied through multiple websites to make sure the weight reported for the component could be trusted.

- OSB (https://www.hardwoodstore.com/hardwood-plywood) https://www.prosalesmagazine.com/products/lumber/plywood-vs-osb-which-is-better_o
- Phase Change Material Guidelines http://www.pcmproducts.net/files/design_manual.pdf
-Weight of Queens https://bioone.org/journals/Journal-of-the-Kansas-Entomological-Society/volume-81/issue-2/JKES-705.13.1/Live-Weight-of-Queen-Honey-Bees-span-classgenus-speciesApis-Mellifera/10.2317/JKES-705.13.1.short
- BlockVesl https://www.environmental-expert.com/products/blockvesl-precisely-engineered-duct-plate-535122
- Weight of Plastic https://www.acplasticsinc.com/informationcenter/r/guide-to-plastic-weights
- Queen Cages Weight http://www.beemaidbeestore.com/product.php?txtCatID=0&txtProdID=193
- Queen Cages Cost https://ripplefarm.com.au/product/queen-cage-jzs-bzs-style/
- Battery Box Weight http://www.beemaidbeestore.com/product.php?txtCatID=104&txtProdID=191
- Battery Box Dimensions and Cost https://ripplefarm.com.au/product/jz-bz-battery-box/
- Plywood weight https://www.performancepanels.com/lightness-in-weight
- Hinge Weight http://lockwood1878.com/wp-content/uploads/2016/10/LW-HingesWEB.pdf
- Hinge Price https://www.leevalley.com/en-us/shop/hardware/hinges/small-box/45242-small-box-hinges
- Latch Cost and weight https://www.protex.com/18-613SS-non-adjustable-toggle-latch-light-duty-stainless-steel-natural
- Fasteners Cost and Weight https://www.homedepot.ca/product/paulin--8-x-1-1-2-inch-flat-head-square-drive-phosphate-high-performance-floor-screws-500pcs/1000152692

Assumptions :

1. BlockVesl is made of 1/8" thick plastic. This will be an over estimate on the thickness of the component however it is the more conservative approach therefor the design team was confident in this assumption.
2. The BlockVesl is filled with the highest specific gravity material. This assumption was also a conservative assumption made by the design team as it was not specified what phase change material there plastic housing was filled with to satisfy each design. After attempts to reach out to the maufacture with no response the specific gravity range from the website was used and the worst case senario was considered which was the heaviest product .
3. The material of the plastic housing of the BlockVesl is ABS plastic. This assumption was made as there is no reference anywhere to what the material of the housing is along with the supplier not responding to emails on clarification. ABS plastic was chosen as it is a common plastic used in the refrigeration industry and is highly durable. This fit the description of the BlockVesl's intended purpose the best so it was selected.

Analysis :

The Simple Phase Change Design concept will be designed to fit the following off the shelf components. The design weight will also have to incorporate the assemply of the shell and the weight of the shell material. Below is a summary of all the components that needed to have the weight calculated to come up with a final weight of the design.

1. BlockVesl Phase Change Material filled with product
2. JZ/BZ Queen Cages
3. JZ/BZ Queen Cage Shipping Bar
4. Queen Bees
5. OSB Plywood for the Casing

Component 1:BlockVesl

For ease of manufacturing the Bee Right There Engineering design team has chose to use the standard off the shelf BlockVesl. This is the largest component of the design, therefor the size of the casing was designed base on this component. It is essential for cost as an off the shelf BlockVesl only costs $20 where as a custom made one carries a shipping cost of approximately $400 per unit once manufactured. Assumption 1. was made to account for an easy analysis of the BlockVesl weight as no value was provided.

The surface area was found based on the dimension of the off the shelf product found which was a 13"x 10"x 1.5" container.

$SA_{BV} := 3277\ cm^2$

The thickness, as stated in Assumption 1 was taken as 1/8"

$t_{BV} := 0.125\ in$

Next Assumption 3 had to be used as the material of the plastic housing for the phase change material was not specified by the supplier. ABS plastic weight is defined as :

$w_{ABS} := 1.03\ \frac{g}{cm^3}$

Therefore after all the assumptions were made the following calculation could be completed for the weight of the Dry BlockVesl component.

$w_{BVD} := SA_{BV} \cdot t_{BV} \cdot w_{ABS} = 1.0717\ kg$

BlockVesl's are filled with biofuel products with different specific gravities to allow for phase change heat absorbtion. A specific gravity range was reported by the vendor to be from 0.75-1.5 but was not specified which product would be in the BlockVesl we will be ordering. Therefore using Assumption 2. and knowing the a BlockVesl of this size holds 908mL the following calculation was done for the added weight of the liquid.

Volume of Liquid for 1 BlockVesl

$V_{liq} := 908\ mL$

Specific Gravity

$SG_{BIO} := 1.5$

Density of Water

$\rho_{H2O} := 1000\ \frac{kg}{m^3}$

Using the above values the desnisty of the biofuel product added was calculated

$$\rho_{BIO} := \rho_{H2O} \cdot SG_{BIO} = 1500 \frac{kg}{m^3}$$

And finally the weight of the biofuel alone added to one BlockVesl was calculated.

$$w_{BIO} := \rho_{BIO} \cdot V_{liq} = 1.362\ kg$$

There for the total weight of one complete BlockVesl in the worst case scenario is

$$w_{BVW} := w_{BIO} + w_{BVD} = 2.4337\ kg$$

Component 2: Queen Cages

As found in the references shown in the Known Values Section the weight of the queen cages were found to be

$$w_{100CAGE} := 0.907\ kg$$

However for this design each shpping tray contains a slot for 24 queen cages and this design contains 3 of these trays leaving 72 cages being required. Below is the calculation done to determine the amount of weight of 72 queen cages.

The weight of one cage was first calculated.

$$w_{1CAGE} := \frac{w_{100CAGE}}{100} = 0.0091\ kg$$

Then multiplying that by 72, the desired weight of 72 cages was found.

$$w_{72CAGE} := w_{1CAGE} \cdot 72 = 0.653\ kg$$

Component 3: Queen Cage Shipping Bar

As found in the Known Values Section the Queen be shipping bar was another weight contributing to the overall weight of the concept.Below is the weight of one shipping bar.

$$w_{SBAR} := 0.014\ kg$$

However in the Simple Phase Change Design it requires 3 shipping bars. Therefor the weight is adjusted to.

$$w_{SBAR3} := w_{SBAR} \cdot 3 = 0.042\ kg$$

Component 4: Queen Bees

The design will have the most weight in the stage when it is filled with queen bees. This is an important step to analyse because it will give us a conservative total weight estimate for the heaviest case of loading. As found in the known values section the approximate weight of one queen bee is:

$w_{queen} := 207.63\ \text{mg}$

Since the Simple Phase Change Design transports 72 bees the weight of 72 bees was then calculated.

$w_{72queen} := w_{queen} \cdot 72 = 0.0149\ \text{kg}$

Component 5: Weight of the Shell of the Box

The shell of the box was chosen to be made out OSB plywood due to its durability, price, and constant material properties.Based on the box make up 4 walls were made at 13 x 10 inches and 2 walls were made at 10 x 10 inches. Below is the Surface Area calculation for the OBS walls

$SA_{OSB} := (13\ \text{in} \cdot 10\ \text{in} \cdot 4) + (10\ \text{in} \cdot 10\ \text{in} \cdot 2) = 0.4645\ \text{m}^2$

The weight of OSB was found in the known values section to be the following value

$w_{OSB} := 1.2\ \frac{\text{lb}}{\text{ft}^2}$

The total weight of the OSB shell was then calculated to be

$w_{shell} := w_{OSB} \cdot SA_{OSB} = 2.7216\ \text{kg}$

Conclusion :
The calculations completed above were needed to be able to quantify values for some components of the Simple Phase Change Design. A summary of the results can be found in Appendix B.1. Other components were not included in this calculation sheet as the values did not have to be manipulated to our design. The values researched for those components were satisfactory to be used as an estimate and no calculation was *needed*

Appendix D: Finite Element Analysis

D.1: Internal Weight Load

For the internal weight load it was assumed that the weight acts only on the bottom of the box. Refer to Appendix C for the weight calculations of this design. A simple calculation was completed to transition the force into a pressure acting over the entire area of the bottom of the box.

$$Mass = 14.2\ kg$$

$$g = 9.81 \frac{m}{s^2}$$

$$Mass * g = Force$$

$$Force = 9.81 * 14.2 = 139.3\ N$$

To convert this force into a pressure it was divided by the area of the bottom of the box which the force acts on. This area is equal to 0.274 m x 0.351 m.

$$Pressure = \frac{Force}{Area}$$

$$Pressure = \frac{139.3}{0.274 * 0.351} = 1448\ Pa$$

To set–up the model the first constraint had to be determined. For this loading case it is assumed that the consumer is lifting the model using both handles.

In order to refine the mesh of this model a few components of the design were omitted. These omissions were deemed acceptable by BRTE as they are not affecting the integrity of the design. The omission for the FEA model were:

- Aluminum mesh screens (added for air flow)
- Queen bee Cages (do not support weight)
- Queen Cage Shipping bar (Designed to support queen cages)
- Support Tray (Designed by BRTE to hold the shipping bars in place)
    - This was omitted from FEA as it is not an integrity piece
- BlockVesl (Designed by BlockVesl and can be stacked)

To refine the mesh for the shipping container five meshes were tested. Convergence was observed when the number of elements increased. Therefore, at roughly 56000 elements convergence was observed and is the mesh sized used going forward. Figure 14 shows the graph of the stress convergence.

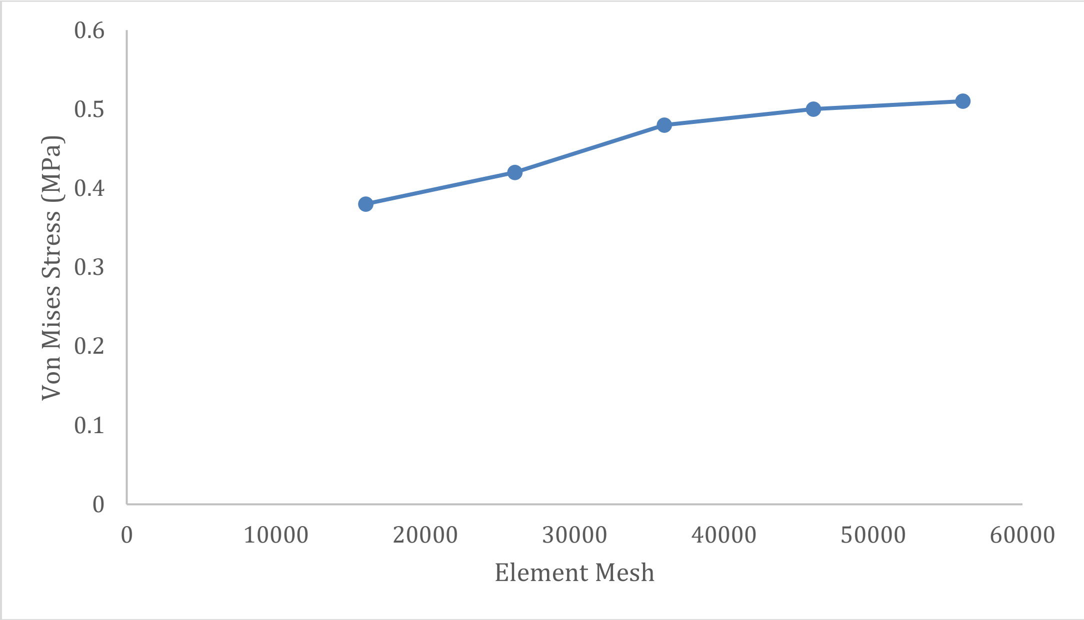
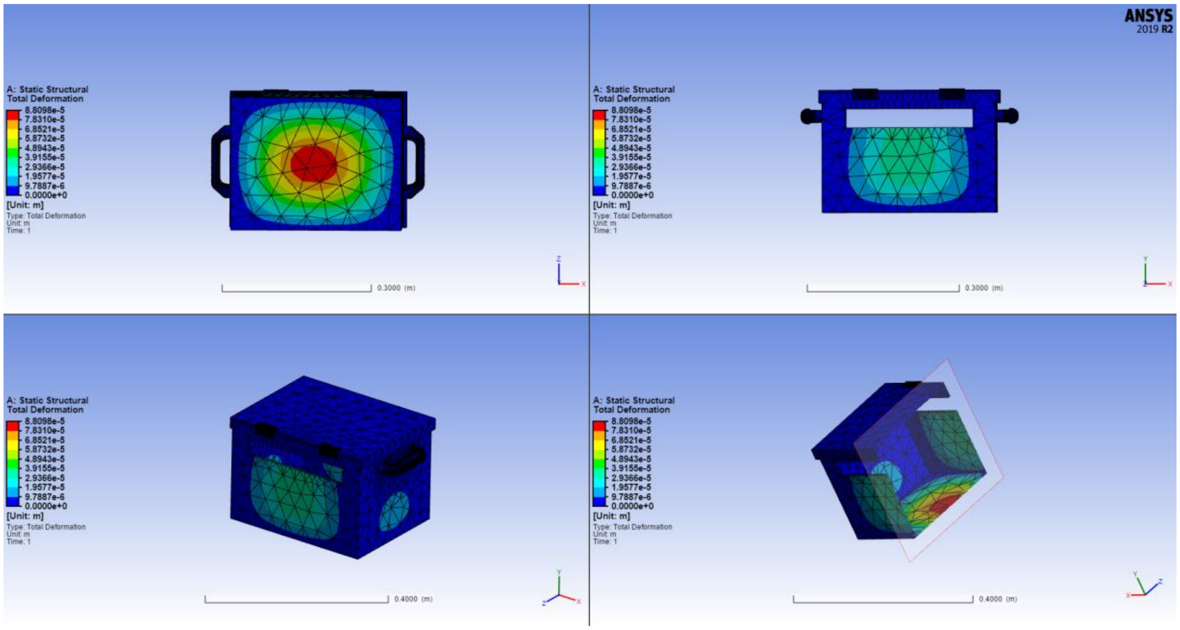


Figure 14: Stress Convergence of Internal Weight FEA Analysis

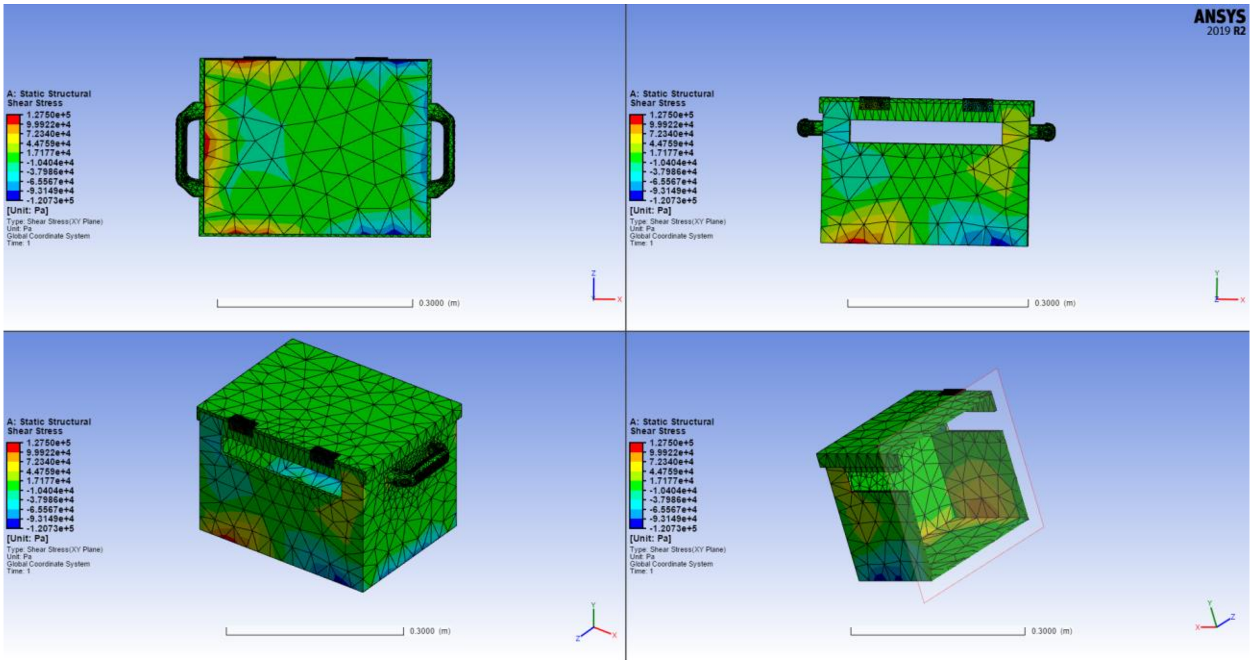
The total deformation cause by the internal weight load is modeled in Figure 15 below. It is seen that the maximum deformation occures at the bottom of the box and is 0.088 mm. This is the expected loaction and result of this deformation as the center of that face will be the most suseptible to bending. The failure criteria for deflection was defined in Section D.4 and was set at 0.0024 m which is much greated then the deflection seen in this loading scenario.



*Top Left: Bottom, Top Right: Front, Bottom Left: Isometric, Bottom Right: Section View

Figure 15: Total Deformation Caused by Internal Weight Load

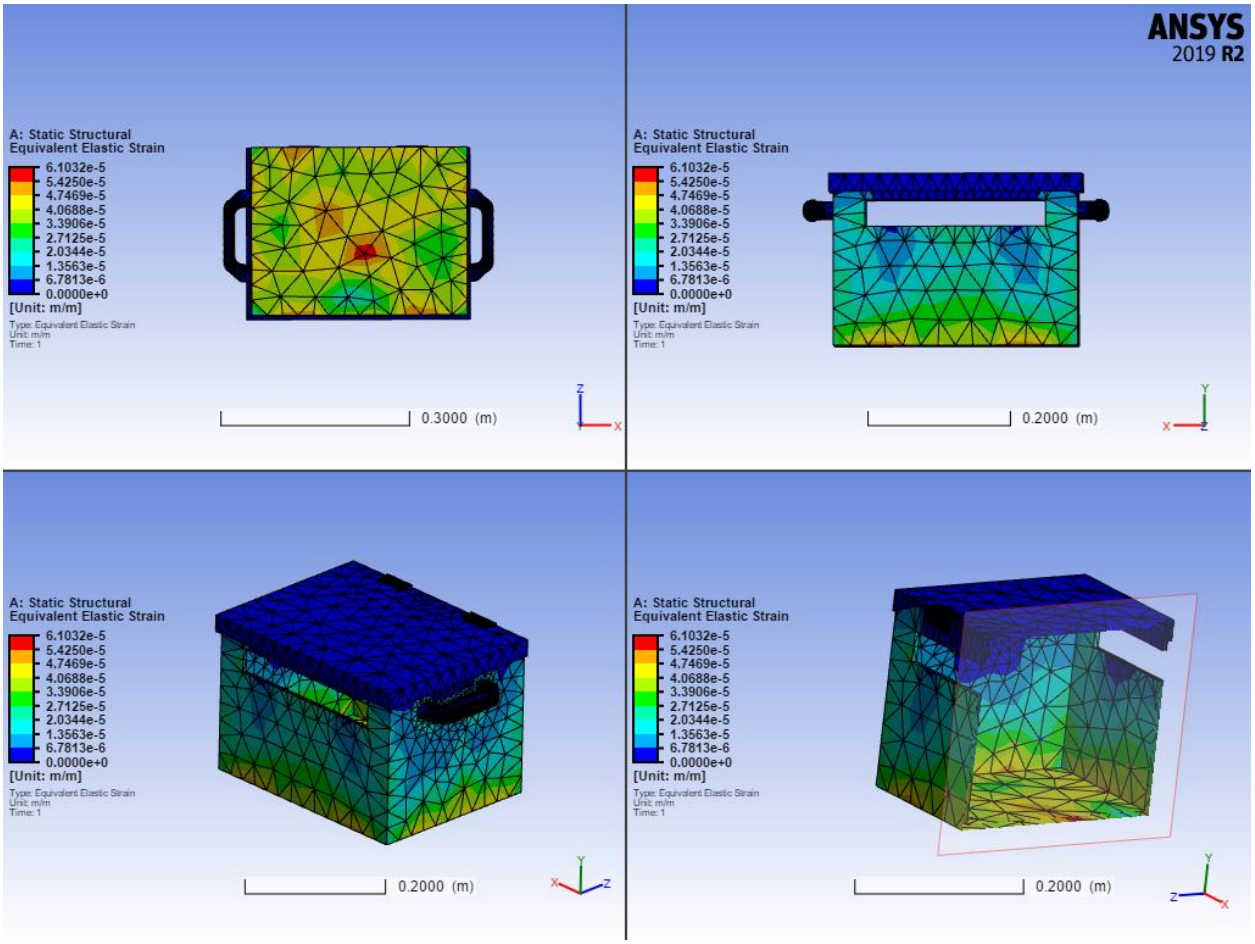
BRTE also analyzed the shear stress generated by the internal load force as seen in Figure 16. This force was compared to the minimum shear strength of that material found in Table 1 to be 1.9 MPa. The maximum shear stress found was 0.127 MPa. Compared to the allowable shear stress the safety factor is at 14.



*Top Left: Bottom, Top Right: Front, Bottom Left: Isometric, Bottom Right: Section View

Figure 16: Shear Stress Caused by Internal Weight Load

Strain was also modeled to see where the high areas of strain were within the box. Figure 17 below shows the FEA model for equivalent strain. These values are expected in the locations they are shown in as those are the high deformation areas are found in the aforementioned deformation model.



*Top Left: Bottom, Top Right: Front, Bottom Left: Isometric, Bottom Right: Section View

Figure 17: Elastic Strain Caused by Internal Weight Load

D.2. Lifting by Lid Load

For the lid load it was assumed that the customer will be attempting to lift the box by the sides of the lid instead of the handles. The mass of the box was then converted into a force and the force was evenly distributed between the two sides of the lid to simulated two hands picking it up. Refer to Appendix C for the mass calculations of this design. A simple calculation was completed to transition the mass of the box into a force that will lift the box.

$$Mass = 14.2\ kg$$

$$g = 9.81 \frac{m}{s^2}$$

$$Mass * g = Force$$

$$Force = 9.81 * 14.2 = 139.3\ N$$

To set–up the model the first constraint had to be determined. For this loading case it is assumed that the consumer is lifting the model using both sides of the lid. It was challenging to determine which part of the box to fix for this scenario therefor the front edge was fixed as it would be the last piece touching the ground before it is fully lifted.

In order to refine the mesh of this model a few components of the design were omitted. These omissions were deemed acceptable by BRTE as they are not affecting the integrity of the design. The omission for the FEA model were:

- Aluminum mesh screens (added for air flow)
- Queen bee Cages (do not support weight)
- Queen Cage Shipping bar (Designed to support queen cages)
- Support Tray (Designed by BRTE to hold the shipping bars in place)
    - This was omitted from FEA as it is not an integrity piece
- BlockVesl (Designed by BlockVesl and can be stacked)

To refine the mesh for the shipping container five meshes were tested. Convergence was observed when the number of elements increased. Therefore, at roughly 56000 elements convergence was observed and is the mesh sized used going forward. Figure 18 shows the graph of the stress convergence.

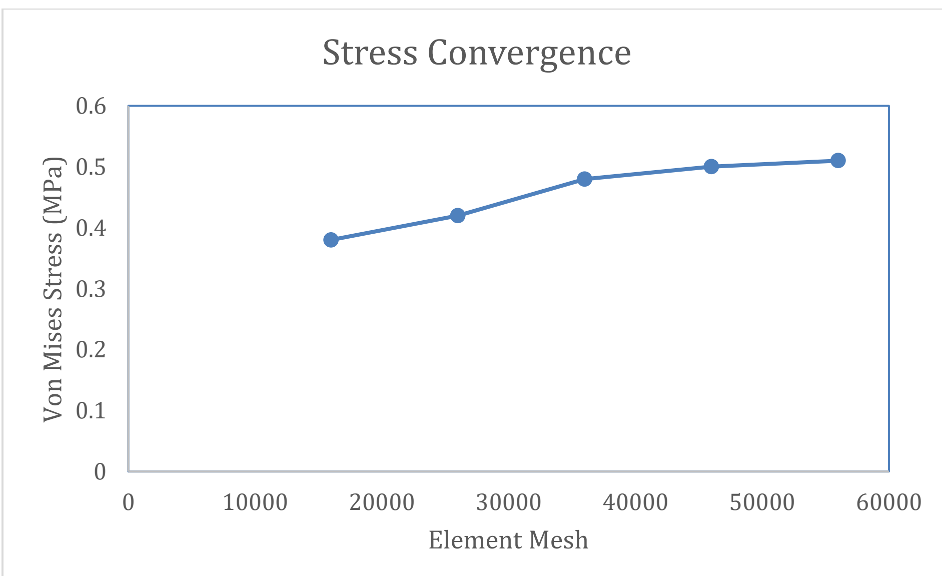
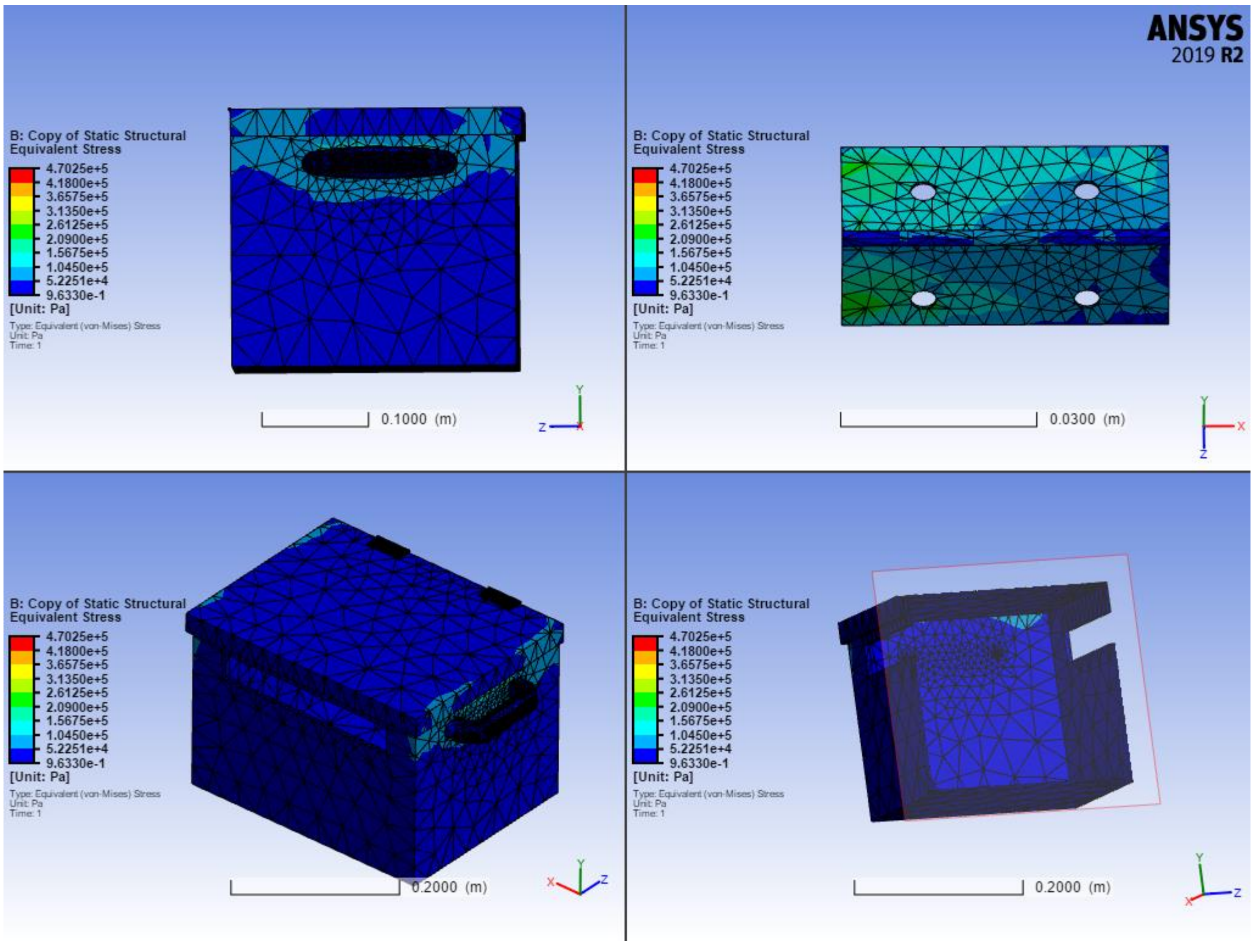


Figure 18: Stress Convergence of Lifting by Lid FEA Analysis

The effect of lifting by the lid was analyzed by applying the total mass of the internals and converting to a force being applied across two hinges. The front edge of the box was fixed in this scenario assuming that the customer will be lifting and moving the box by the lid leaving this edge to be the last contact point with the ground. The total force applied to the lid of the box is 139.3 N. The most important factor analyzed was Von Mises Equivalent Stress. BRTE decided to use 31 MPa as an initial failure criterion of the box which is the lowest end of the plywood yield strength [3]. Figure 19 below shows the Von Mises Stress distribution of the internal weight load.

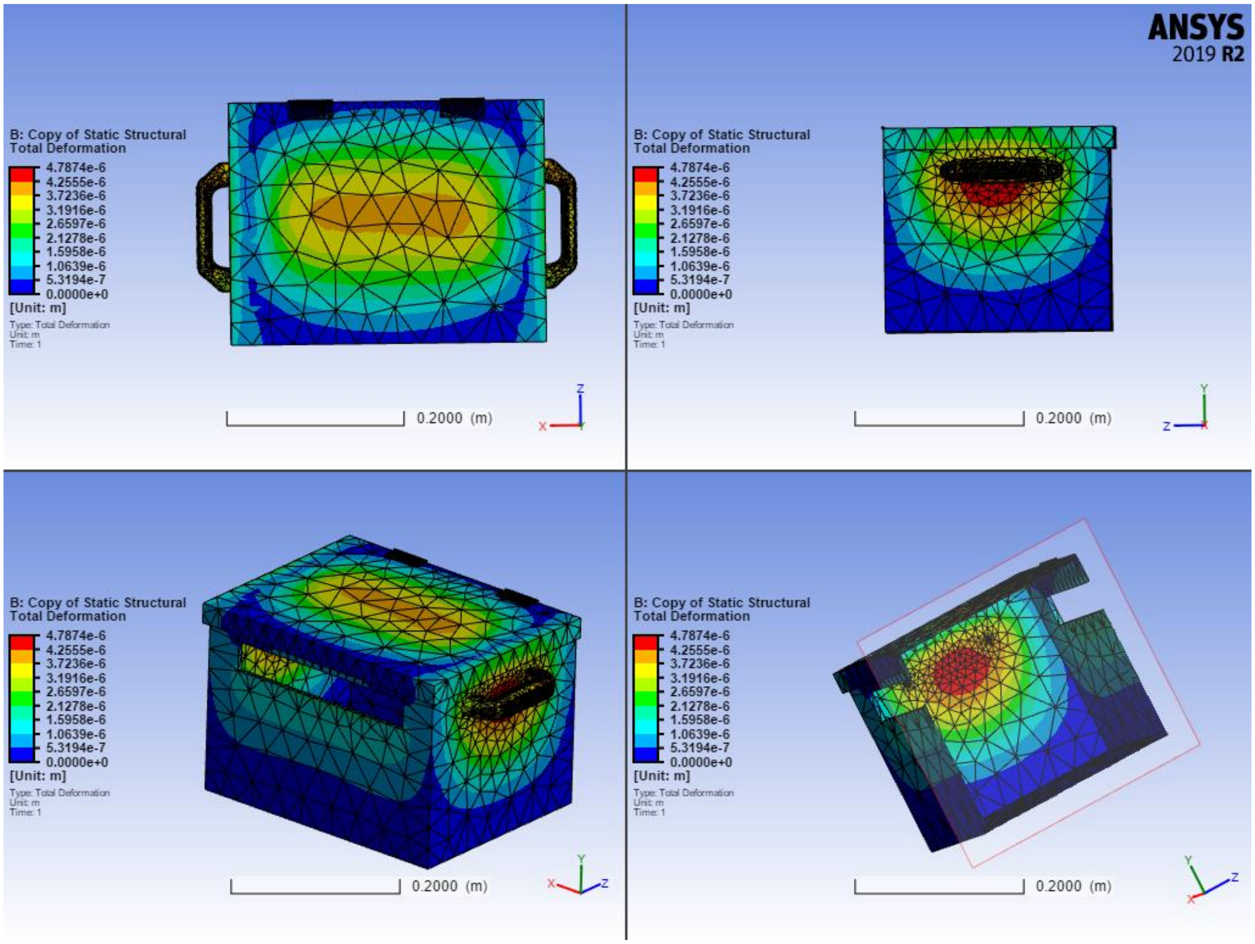


*Top Left: Right View, Top Right: Hinge, Bottom Left: Isometric, Bottom Right: Section View

Figure 19: Effect of Lifting by Lid FEA Equivalent Stress Analysis

The maximum stress on the box was found to be 0.470 MPa. However, the maximum stress occurred on the hinges which is not made of OSB, they're made of stainless steel. Stainless steel has a yield strength of 205 MPa which is well above the stress endured during this lifting scenario [4]. This is over 200 times below the yield strength of aluminum. Therefore, BRTE can confidently say under this loading scenario the box or the hinges will not yield.

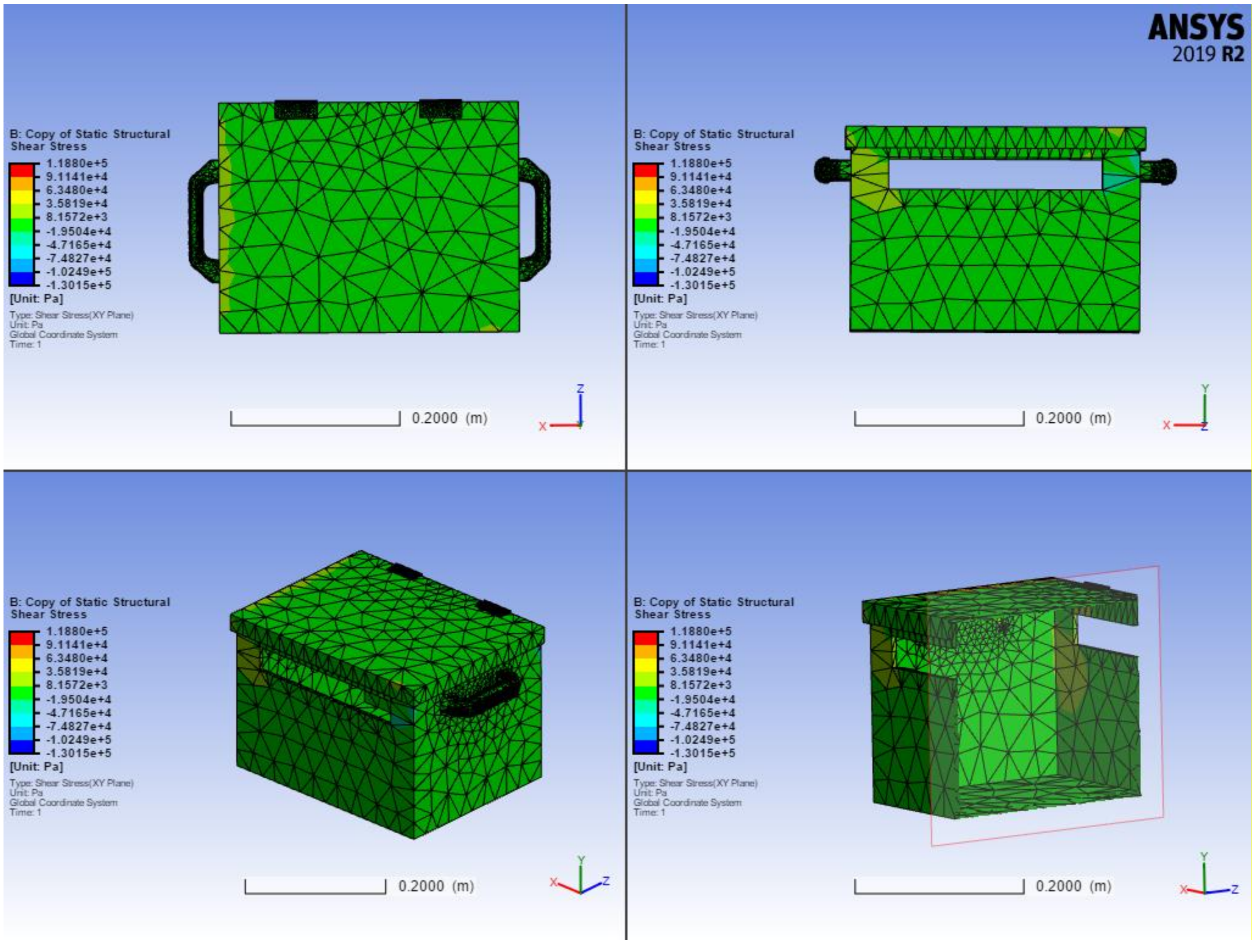
The total deformation cause by the lifting by the lid load is modeled in Figure 20 below. It is seen that the maximum deformation occures at the bottom of the box and is 0.0048 mm. This is the expected location and result of this deformation as the center of that face will be the most suseptible to bending. The failure criteria for deflection was defined in Section D.4 and was set at 0.0024 m which is much greated then the deflection seen in this loading scenario.



*Top Left: Bottom, Top Right: Right, Bottom Left: Isometric, Bottom Right: Section View

Figure 20: Total Deformation Caused by Lifting by the Lid Load

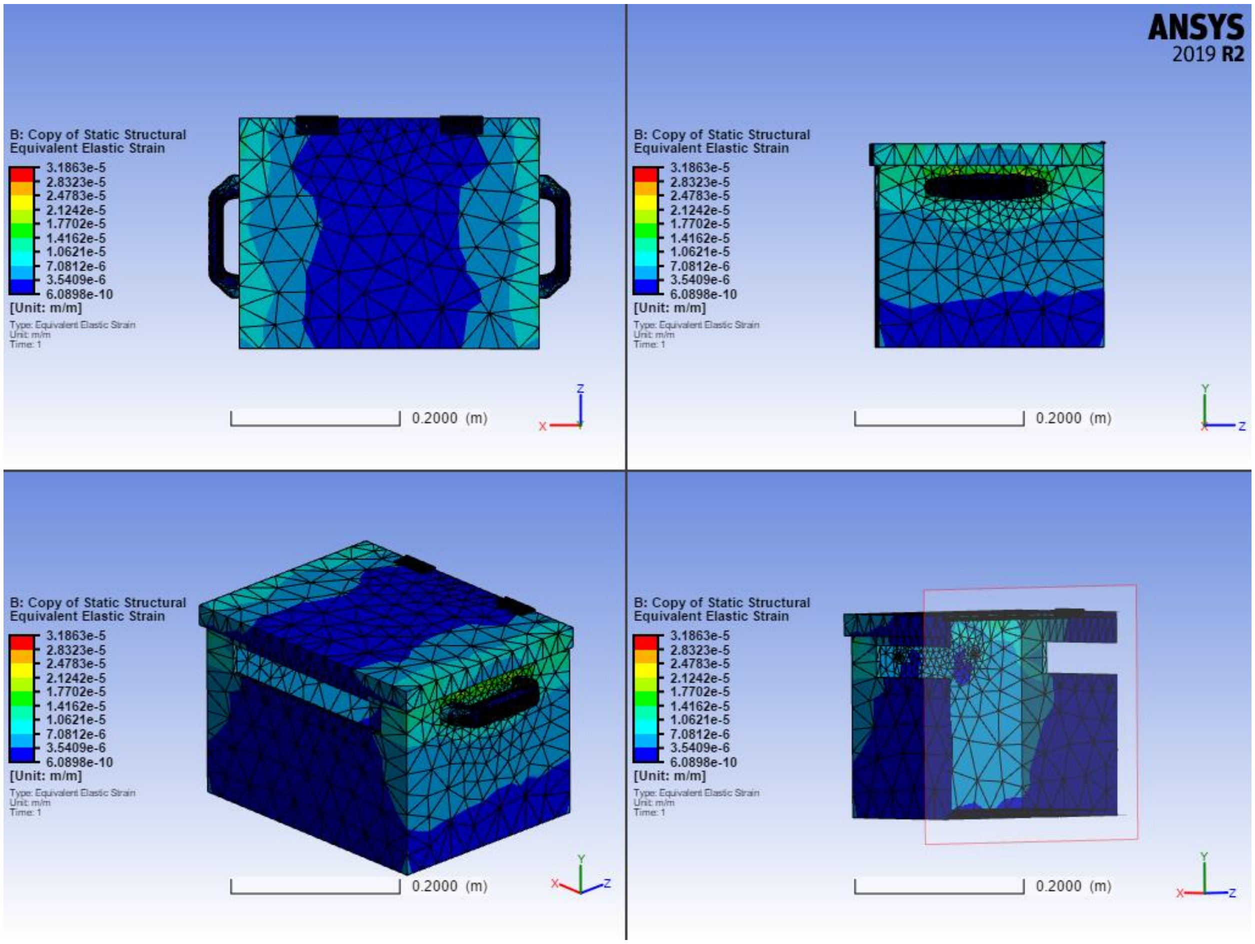
BRTE also analyzed the shear stress generated by the lifting by the lid force as seen in Figure 21. This force was compared to the minimum shear strength of that material found in Table 1 to be 1.9 MPa. The maximum shear stress found was 0.119 MPa. Compared to the allowable shear stress the safety factor is at 15.



*Top Left: Bottom, Top Right: Front, Bottom Left: Isometric, Bottom Right: Section View

Figure 21: Shear Stress Caused by Lifting by the Load

Strain was also modeled to see where the high areas of strain were within the box. Figure 22 below shows the FEA model for equivalent strain. These values are expected in the locations they are shown in as that is where the high deformation areas are found in the aforementioned deformation model.



*Top Left: Bottom, Top Right: Right, Bottom Left: Isometric, Bottom Right: Section View

Figure 22: Elastic Strain Caused by Lifting by the Lid Load

The maximum results for each case are summarized below in Table 7.

Table 7: Summary of Lifting by Lid FEA Calculation

Von Mises Stress	0.470	MPa
Total Deformation	4.79E-06	m
Total Shear Stress	0.119	MPa
Equivalent Elastic Strain	3.18E-05	m/m

D.3 Stacking Load

For the stacking load it was assumed that the customer will be attempting to stack the boxes up to 3 boxes on top of the base box. The weight of the top three boxes was calculated and then converted into a pressure acting on the lid of the bottom box. Refer to Appendix C for the mass calculations of this design. A simple calculation was completed to transition the mass of the 3 boxes into a pressure acting on the lid of the bottom box.

$$Mass = 14.2\ kg$$

$$g = 9.81\frac{m}{s^2}$$

$$Mass * g = Force$$

$$3 * Force = 3 * 9.81 * 14.2 = 417.9\ N$$

To convert this force into a pressure it was divided by the area of the bottom of the box which the force acts on. This area is equal to 0.274 m x 0.351 m.

$$Pressure = \frac{Force}{Area}$$

$$Pressure = \frac{417.9\ N}{0.274 * 0.351} = 4345\ Pa$$

To set–up the model the first constraint had to be determined. For this loading case it is assumed that the bottom box will not being moving so the bottom face to the ground.

In order to refine the mesh of this model a few components of the design were omitted. These omissions were deemed acceptable by BRTE as they are not affecting the integrity of the design. The omission for the FEA model were:

- Aluminum mesh screens (added for air flow)
- Queen bee Cages (do not support weight)
- Queen Cage Shipping bar (Designed to support queen cages)
- Support Tray (Designed by BRTE to hold the shipping bars in place)
    - This was omitted from FEA as it is not an integrity piece
- BlockVesl (Designed by BlockVesl and can be stacked)

To refine the mesh for the shipping container five meshes were tested. Convergence was observed when the number of elements increased. Therefore, at roughly 56000 elements convergence was observed and is the mesh sized used going forward. Figure 23 shows the graph of the stress convergence.

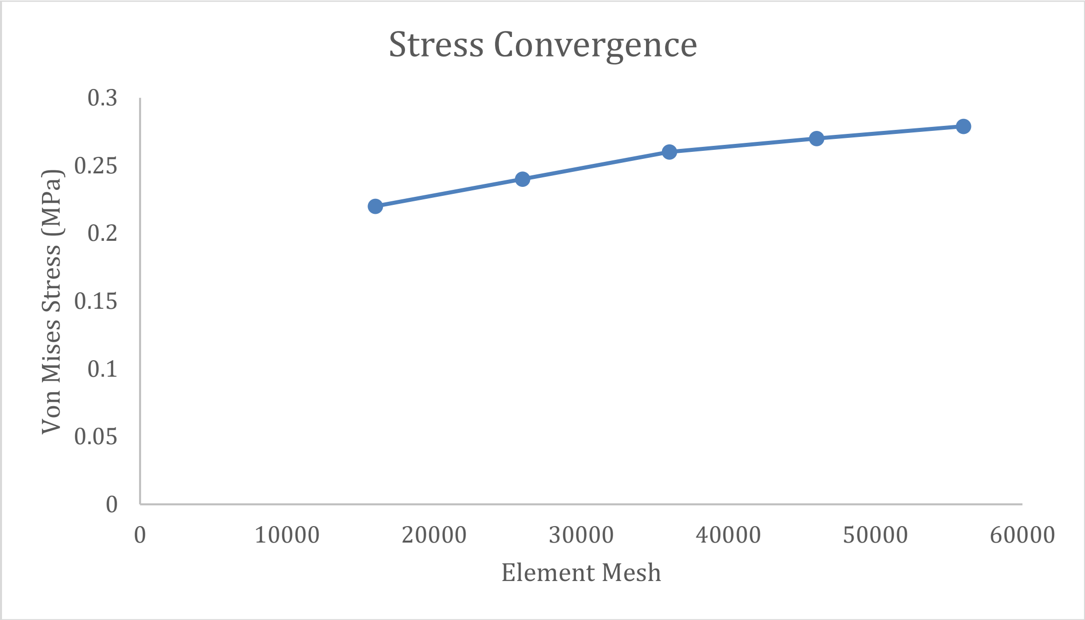
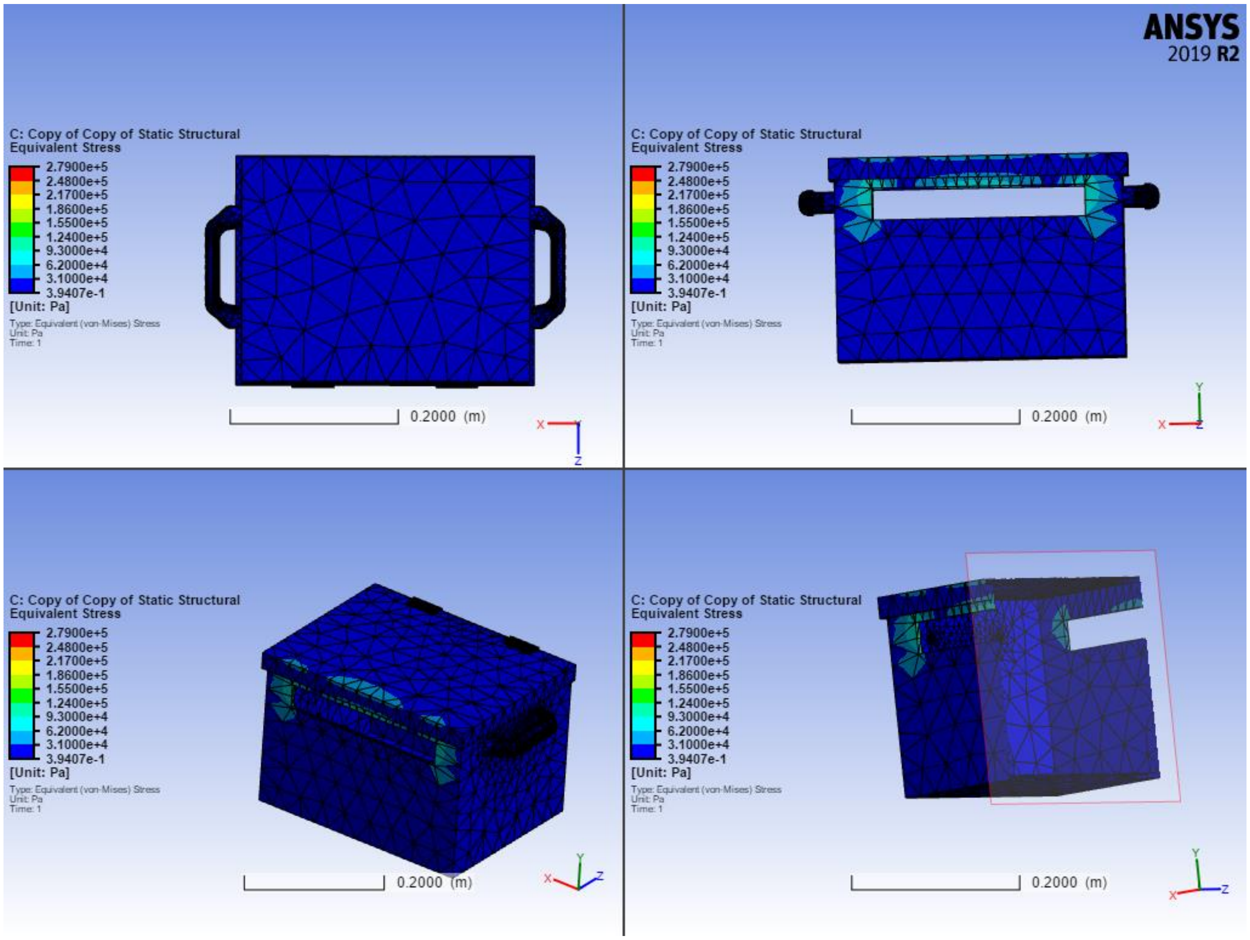


Figure 23: Stress Convergence of Stacking FEA Analysis

The effect of stacking boxes on top of one another was analyzed by applying the total mass of three boxes and converting to a pressure being applied to the top of the bottom box. The base of the bottom box was fixed in this scenario assuming that the customer will be stacking on the ground. The total pressure exerted on the bottom box is 4345 Pa. The most important factor analyzed was Von Mises Equivalent Stress. BRTE decided to use 31 MPa as an initial failure criterion of the box which is the lowest end of the plywood yield strength [3]. Figure 24 below shows the Von Mises Stress distribution of the internal weight load.

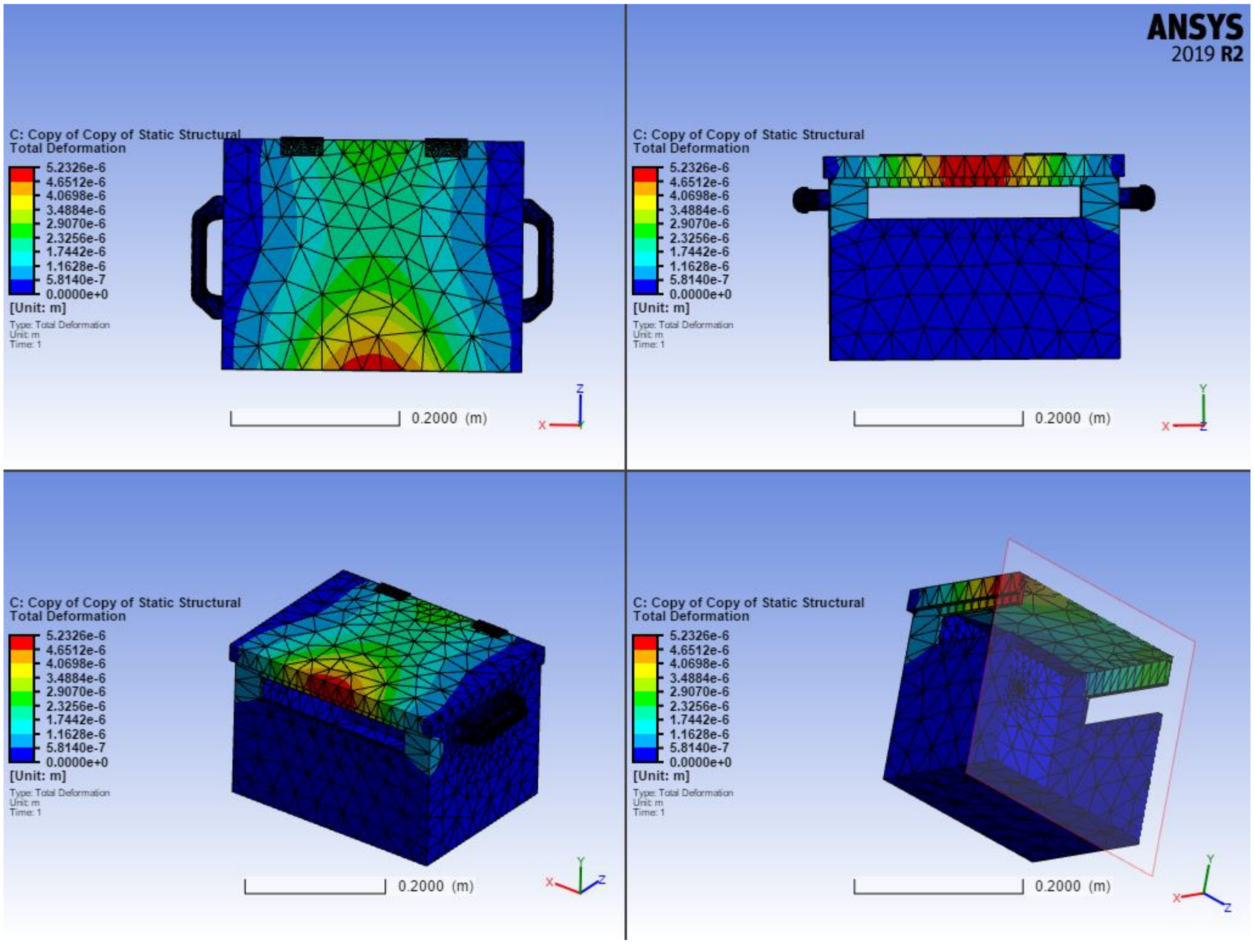


*Top Left: Bottom View, Top Right: Front View, Bottom Left: Isometric, Bottom Right: Section View

Figure 24: Effect of Stacking FEA Equivalent Stress Analysis

It is important to note that for the analysis it was assumed the box will be stacked to a maximum of 4 boxes. The maximum stress on the box was found to be 0.279 MPa. This is well below the yield strength of plywood by a factor of 111. Therefore, BRTE can confidently say under this loading scenario the box will not yield

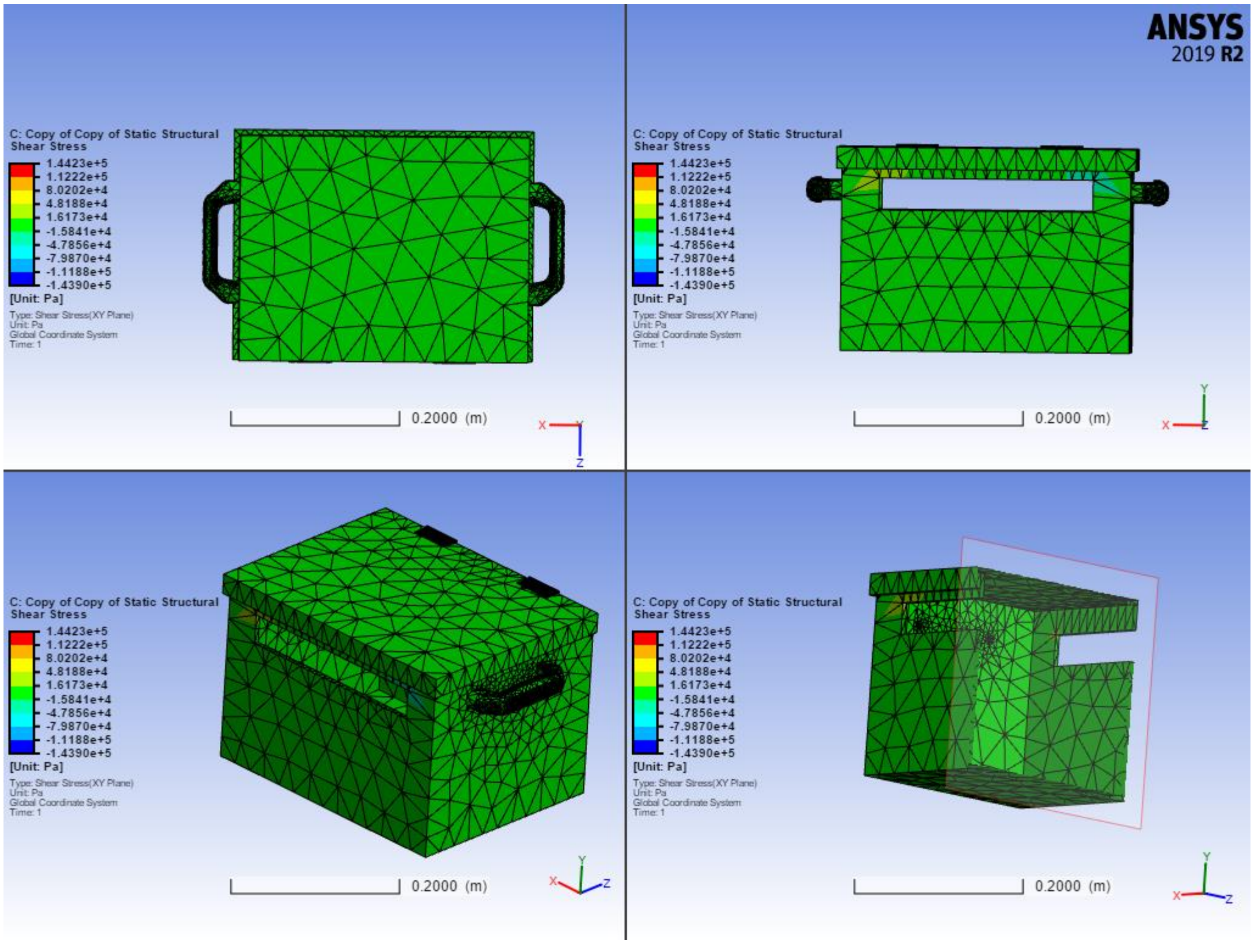
The total deformation cause by the stacking load is modeled is shown in Figure 25 below. It is seen that the maximum deformation occures at the bottom of the box and is 0.005 mm. This is the expected location and result of this deformation as the center air vent having the largest bending. The failure criteria for deflection was defined in Section D.4 and was set at 0.0024 m which is much greated then the deflection seen in this loading scenario.



*Top Left: Bottom, Top Right: Front, Bottom Left: Isometric, Bottom Right: Section View

Figure 25: Total Deformation Caused by Stacking Load

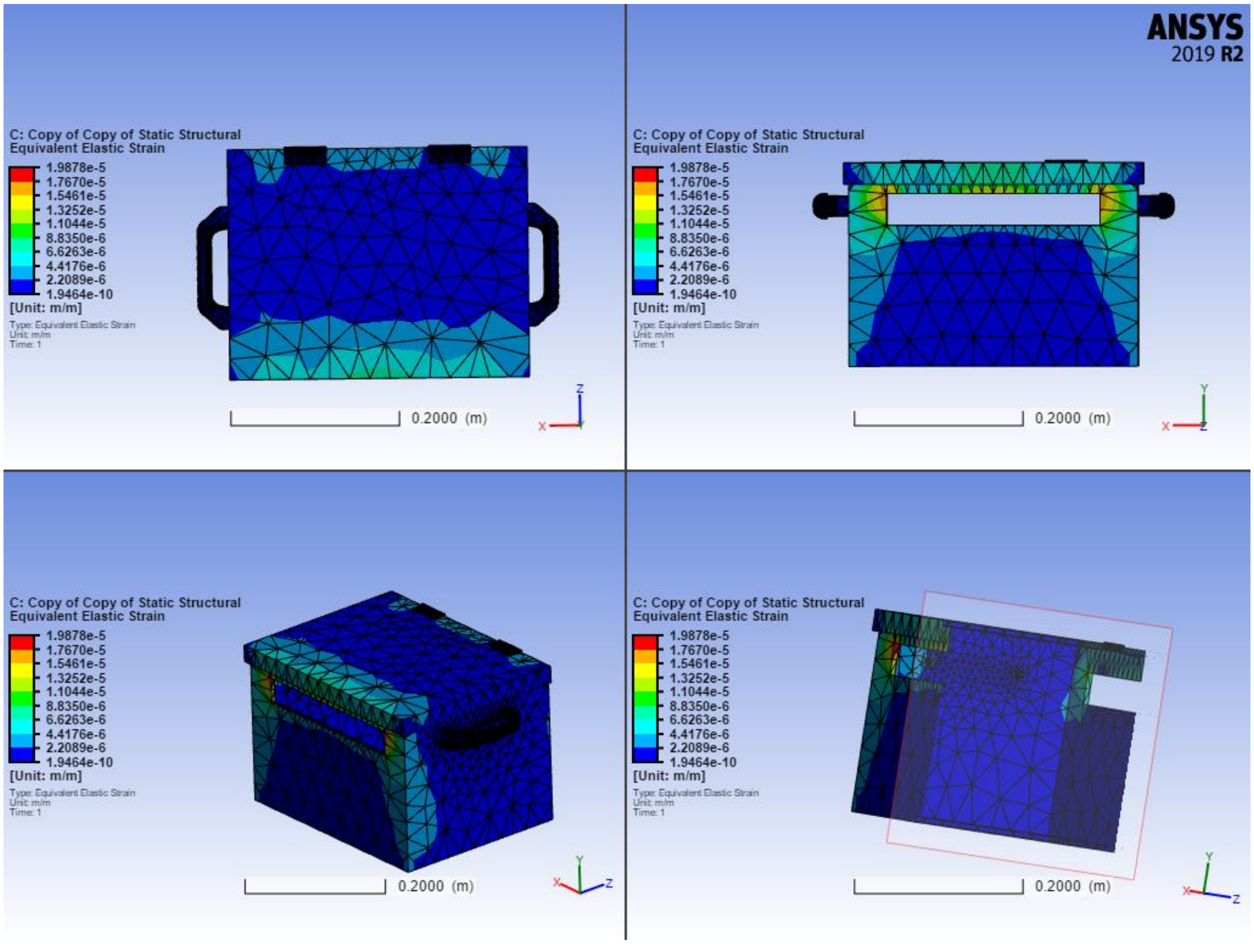
BRTE also analyzed the shear stress generated by the stacking force and is shown in Figure 26. This force was compared to the minimum shear strength of that material found in Table 1 to be 1.9 MPa. The maximum shear stress found was 0.144 MPa. Compared to the allowable shear stress the safety factor is at 13.



*Top Left: Bottom, Top Right: Front, Bottom Left: Isometric, Bottom Right: Section View

Figure 26: Shear Stress Caused by Stacking Load

Strain was also modeled to see where the high areas of strain were within the box. Figure 27 below shows the FEA model for equivalent strain. These values are expected in the locations they are shown in as that is where the high deformation areas are found in the aforementioned deformation model.



*Top Left: Bottom, Top Right: Front, Bottom Left: Isometric, Bottom Right: Section View

Figure 27: Elastic Strain Caused by Stacking Load

The maximum results for each case are summarized below in Table 8.

Table 8: Summary of Stacking FEA Calculation

Von Mises Stress	0.279	MPa
Total Deformation	5.23E-06	m
Total Shear Stress	0.144	MPa
Equivalent Elastic Strain	1.99E-05	m/m

D.4 Maximum Deflection Calculation

Document Author: Cole Hancheryk

Date Written: November 28, 2019

Peer Reviewed By: Michael Primrose

Date Checked: November 29, 2019

Revision Number:

Date Revision:

Objective : Calculate the maximum allowed deflection of OSB plywood. This will allow BRTE to set a failure criteria when running finite element analysis on the shipping container

Known Data:

Mechanical Properties
Ultimate Tensile Strength: 31 MPa
Yield Strength: 31-41 MPa
Shear Modulus: 0.17-0.7 GPa
Shear Strength: 1.9-6.2 MPa
Youngs Modulus: 4.41-6.28 GPa

Retreived from:

http://edge.rit.edu/edge/P14418/public/4-Subsystems%20Design/Plywood%20Materials.pdf
https://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr190/chapter_12.pdf

Assumptions:
OSB plywood has a linear youngs modulus

Analysis :

$Length := 0.343\ m$

Stress = E*Strain

Use Yield stress to find the maximum strain

$Stress := 31\ MPa$

$E := 4.41\ GPa$

Rearrange the stress equation to solve for strain at the yield strength

$$Strain := \frac{Stress}{E} = 0.007$$

$$Deflection := Strain \cdot Length = 0.0024\ m$$

Conclusion : The maximum deflection before rupture is 0.0024 m. This value will be used as a failure criteria in the finite element analysis. The maximum equivelant strain was determined to be 0.007 which will also be used in the finite element analysis as a failure criteria

Appendix E: Bee Heat Production

Based off the research paper *Colony Defense Strategies of the Honeybees in Thailand* from Thomas Seeley in 1982 the metabolic the metabolic rate of bees is estimated to be between 4 watts and 16 watts per kg of bees. A single bee weighs 0.0025 pounds which is 0.00113 kg. The low-end assumption is that 20% of a bee's energy is used for heat production. With this information we can do an estimate calculation of the heat produced by a single bee which is shown below.

$$Watts\ per\ bee = \left(16\frac{watts}{kg}\right) * (0.0011339\ kg) * (20\%)$$

$$Watts\ per\ bee = 0.0037\ Watts/bee$$

The box we intend to design has 150 queens and each queen is shipped with 8 attendants leaving a total of 1350 bees per shipping container. That total heat produced is shown below.

$$Total\ Watts = 1350\ bees * 0.003628\frac{Watts}{bee} = 4.90\ Watts\ per\ container$$

The final design will have to dissipate this amount of heat with a safety factor for a time period of 72 hours. The final design report will include the instruments and the battery calculations.

Appendix F: PureTemp Datasheet

PureTemp 29 Technical Information

PureTemp 29 is a USDA Certified Biobased product

Appearance	Clear liquid, waxy solid
Melting point	29 °C
Heat storage capacity	202 J/g
Thermal conductivity (liquid)	0.15 W/m°C
Thermal conductivity (solid)	0.25 W/m°C
Density (liquid)	0.85 g/ml
Density (solid)	0.94 g/ml
Specific heat (liquid)	1.94 J/g˚C
Specific heat (solid)	1.77 J/g˚C

Typical physical properties are listed in the table above.

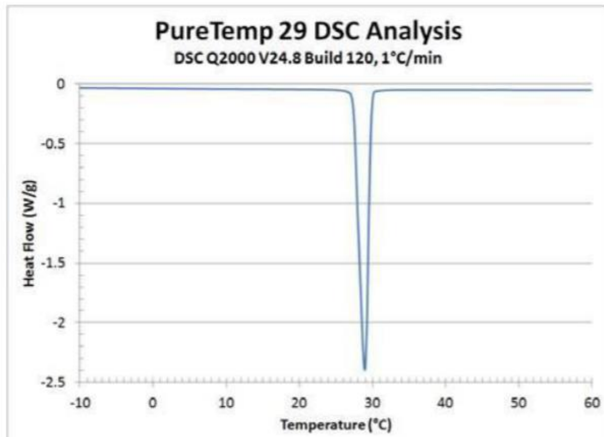


Figure 28: Technical Information of PureTemp 29 PCM [12]

Appendix G: Thermal Heat Simulations

The SolidWorks assembly was simplified to reduce the computation time and remove components that were nonessential to the study of heat transfer. This simplification included the following components:

- Both mesh screens
- Simplifying the queen cages to solid abs pieces, and setting a boundary condition to be constant heat dissipation from each cage equivalent to that of three bees
- Both lid hinges
- Both carrying handles
- Addition of bottom plate to provide the effects of conduction from the loading surface in each scenario (truck bed e.g.)

The resulting assembly is an accurate representation of the container from a heat transfer perspective as seen in Figure 29, Figure 30 and Figure 31.

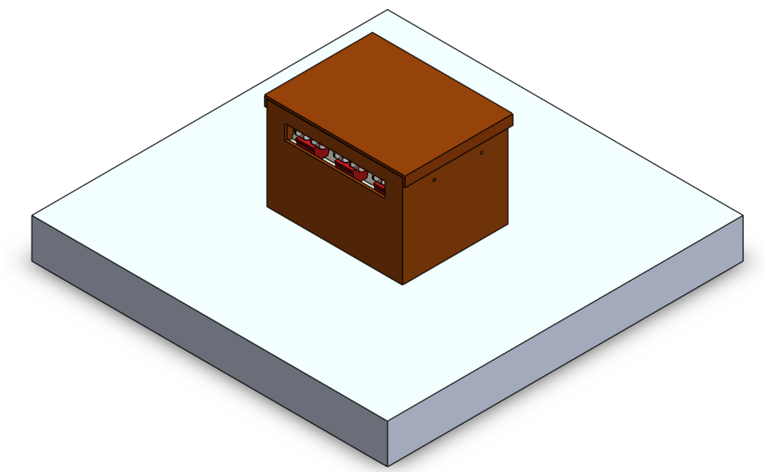


Figure 29: SolidWorks Setup for Thermal Analysis

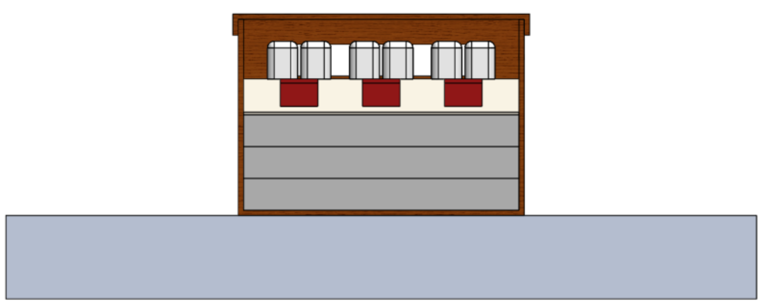


Figure 30: Cross-Section View

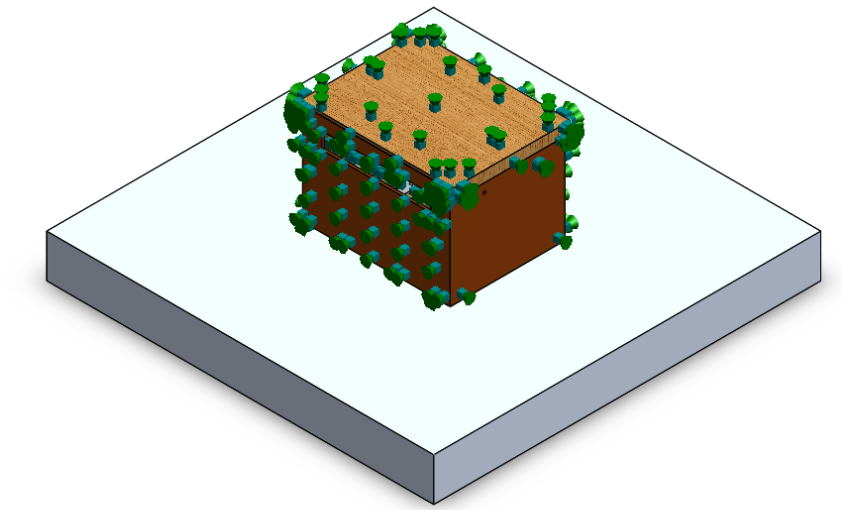
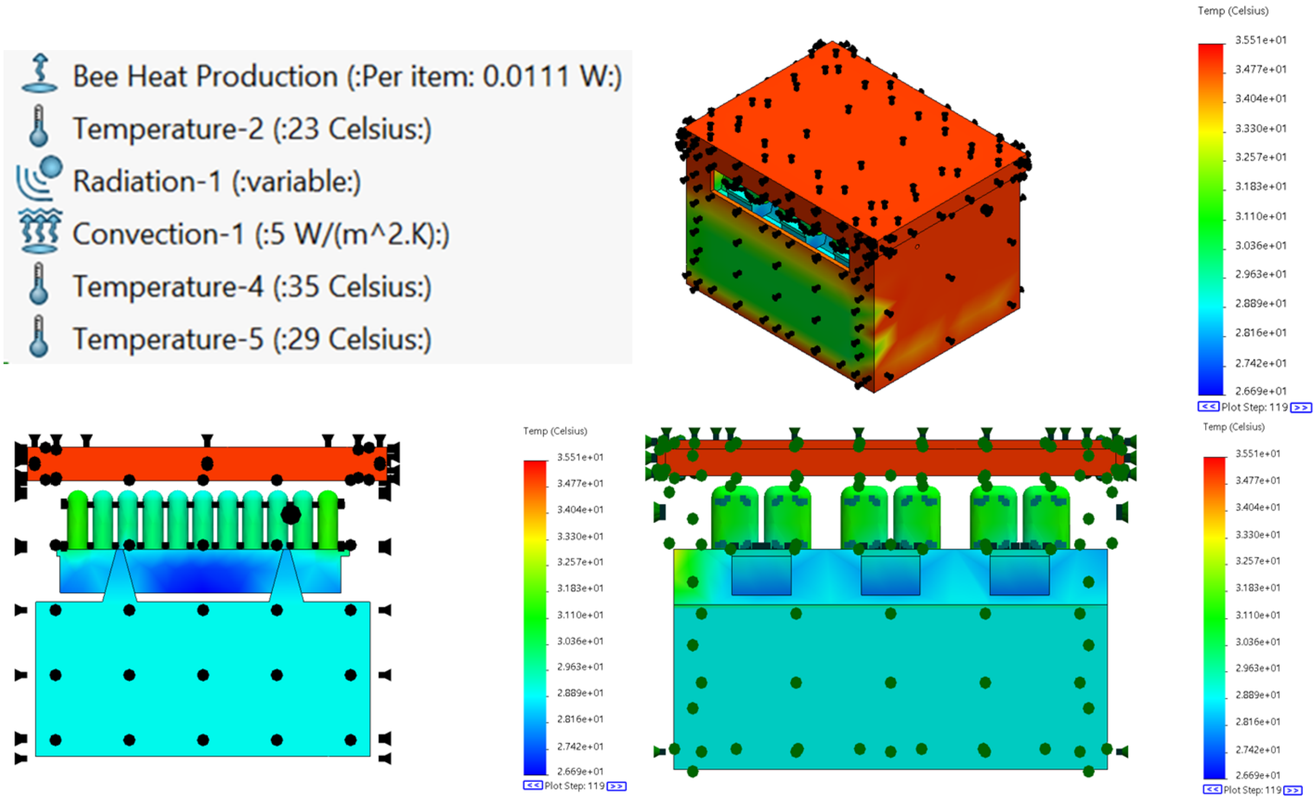


Figure 31:SolidWorks Thermal Loads for Thermal Analysis

In order to create an accurate scenario of queen bee transport and ensure that the PPCD is robust enough to accommodate most loading scenarios, a long-haul flight from New Zealand to Canada was explored. This was the longest flight available and was broken up into 5 stages of transport with higher ranges of temperatures to ensure on the conservative side of calculations. It should also be noted that the colour coded thermal analysis results have the containers body, and bottom plate hidden for visibility purposes only seen in Figure 32, Figure 33, Figure 34, Figure 35, Figure 36, and Figure 37. It should also be noted that the ambient temperature used in stage 3 (27°C), is on the higher range of airplane cargo storage to try and help mitigate the effects of BlockVesl units refreezing as a conservative approach.

Stage 1 - Covered land transport from New Zealand farm to airport

- Base surface (aluminum alloy truck bed) temperature - 35°C
- Ambient temperature - 35°C

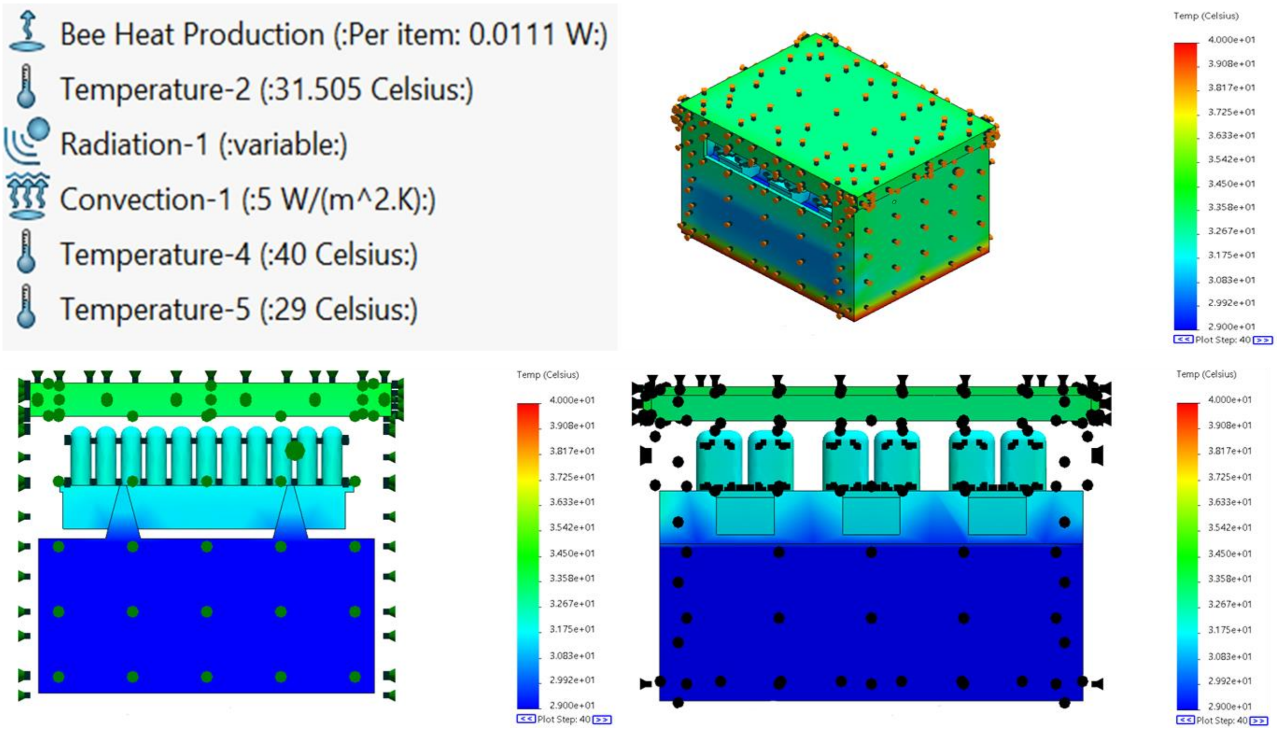


*Top Left: Boundary Conditions, Top Right: Isometric, Bottom Left: Right View, Bottom Right: Front View

Figure 32: Stage 1 SolidWorks Thermal Analysis Boundary Conditions and Results

Stage 2 - Sitting on the open tarmac at the New Zealand airport

- Base surface (aluminum alloy tug trailer) temperature - 40°C
- Ambient temperature - 35°C

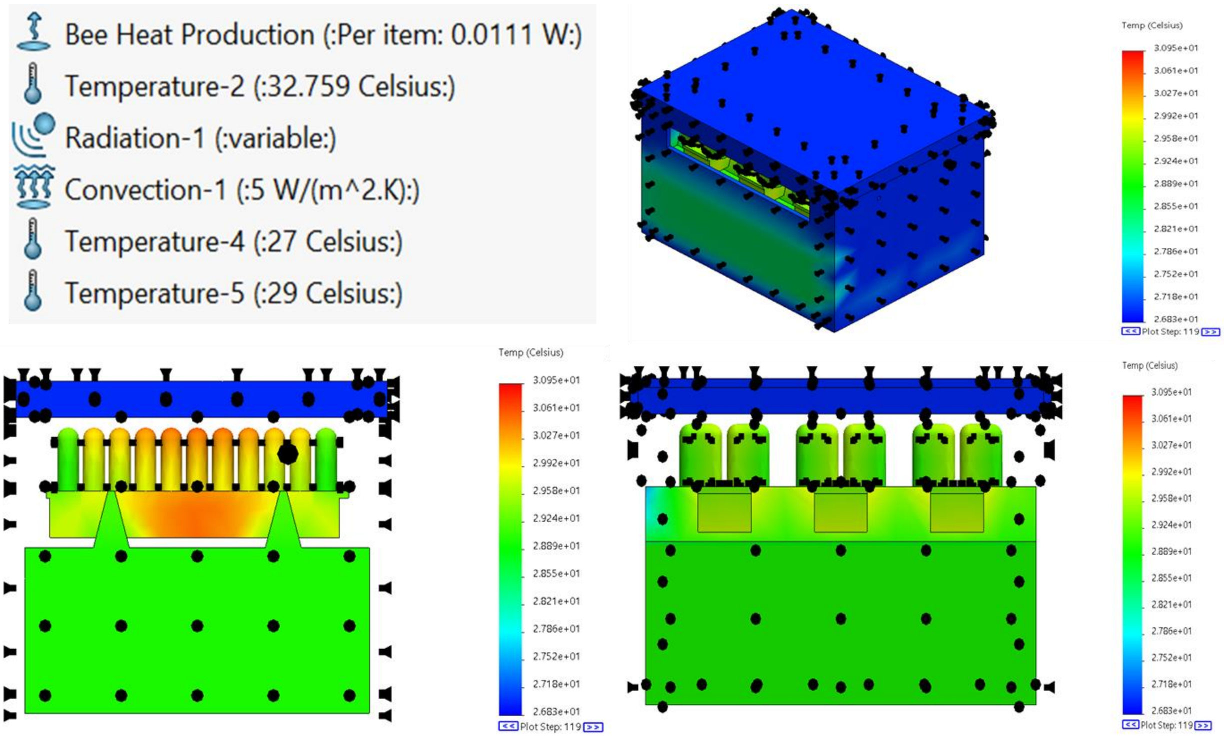


*Top Left: Boundary Conditions, Top Right: Isometric, Bottom Left: Right View, Bottom Right: Front View

Figure 33: Stage 2 SolidWorks Thermal Analysis Boundary Conditions and Results

Stage 3 - Flying from a New Zealand to Canadian airport (note: high temperature assumptions to remain conservative due to BlockVesl's refreezing)

- Base surface (bed of airplane cargo area) temperature - 27°C
- Ambient temperature - 27°C

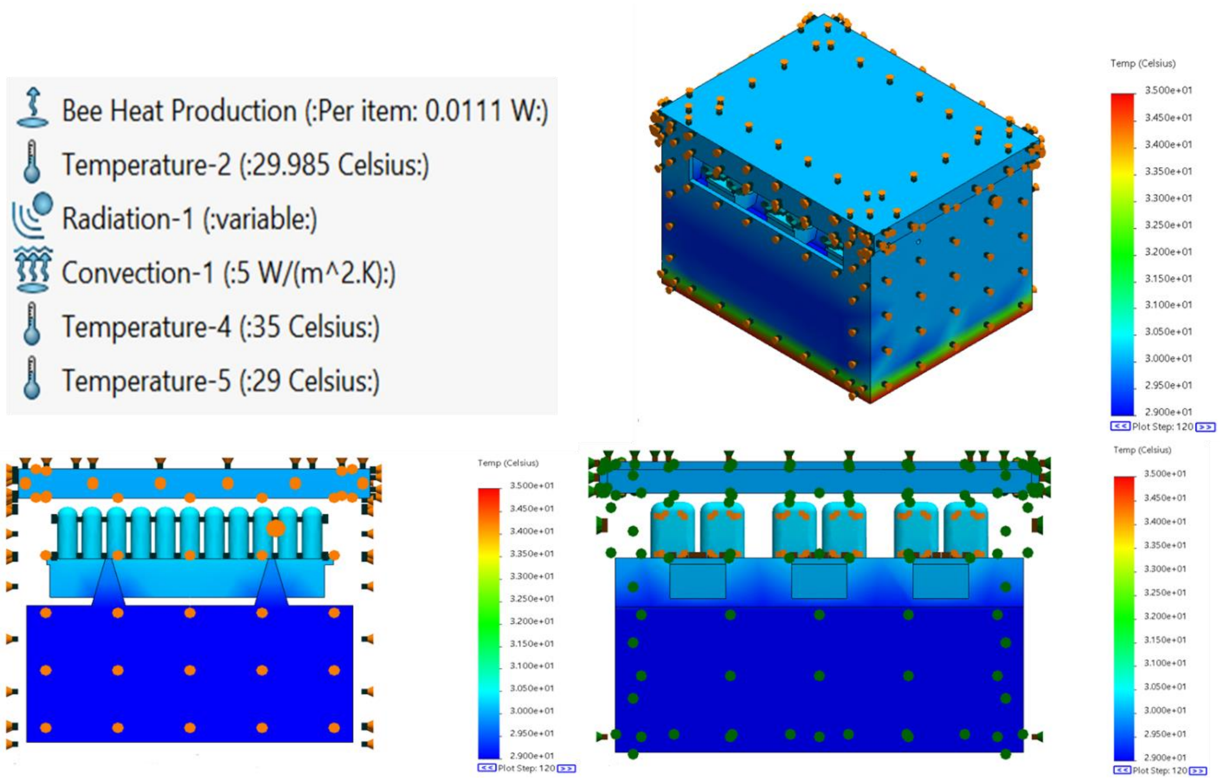


*Top Left: Boundary Conditions, Top Right: Isometric, Bottom Left: Right View, Bottom Right: Front View

Figure 34: Stage 3 SolidWorks Thermal Analysis Boundary Conditions and Results

Stage 4 - Sitting on the open tarmac at the Canadian airport

- Base surface (aluminum alloy tug trailer) temperature - 35°C
- Ambient temperature - 30°C

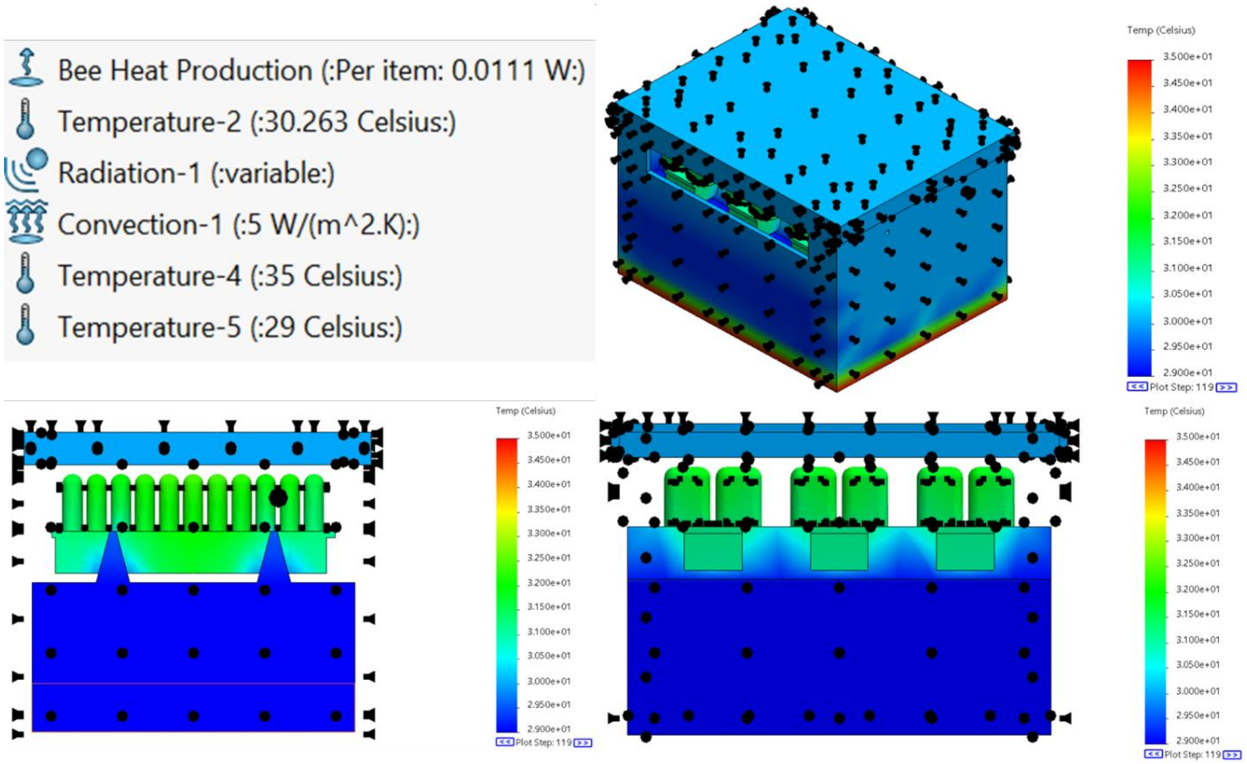


*Top Left: Boundary Conditions, Top Right: Isometric, Bottom Left: Right View, Bottom Right: Front View

Figure 35: Stage 4 SolidWorks Thermal Analysis Boundary Conditions and Results

Stage 5 - Land transport from Canadian airport to farm

- Base surface (aluminum alloy truck bed) temperature - 35°C
- Ambient temperature - 30°C

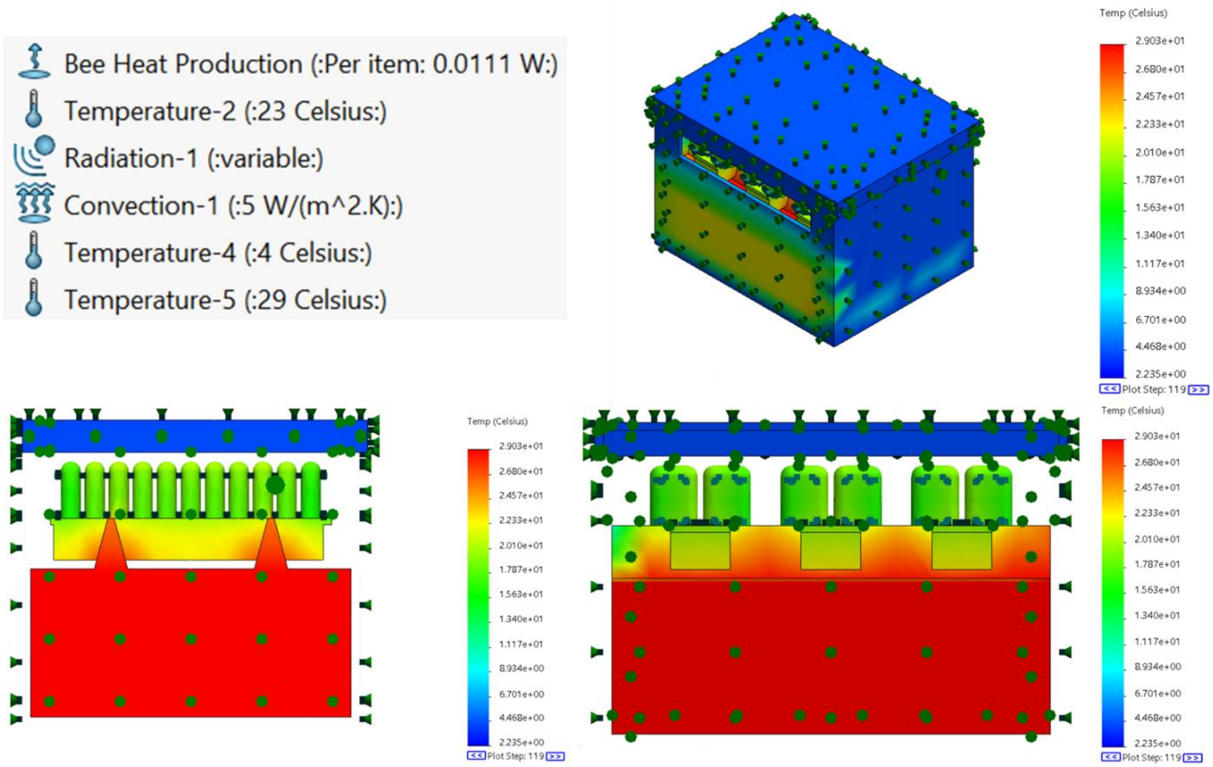


*Top Left: Boundary Conditions, Top Right: Isometric, Bottom Left: Right View, Bottom Right: Front View

Figure 36: Stage 5 SolidWorks Thermal Analysis Boundary Conditions and Results

Stage C – Separate Cold Loading Case in Canadian Shipping Yard

- Base surface (aluminum alloy truck bed) temperature - 4°C
- Ambient temperature - 4°C



*Top Left: Boundary Conditions, Top Right: Isometric, Bottom Left: Right View, Bottom Right: Front View

Figure 37: Stage C SolidWorks Thermal Analysis Boundary Conditions and Results

G.1 Heat Absorbed by BlockVesl Packages

The temperature controlling system consists of three BlockVesl packages that are used to absorb heat produced by the bees and ambient environment during transport. In order to ensure that the capacity of heat absorbed for the BlockVesl packages is sufficient, the number of packages required is compared with the existing design calculations in Phase II and can be found in Appendix B. A safety factor of was utilized in the thermal analysis and will be the threshold for a "successful" design to account for thermal variances and deviations from simulation assumptions. The three units are stacked on top of each other, so they are treated as one heat sink so the heat absorbed by the entire system can be compared. Table 3 has a summary of heat absorbed by the system in each stage of transport.

It should also be noted that the value for the net heat absorbed not including stage 3 (391.3 kJ) will be used to calculate the safety factor. This was done because cargo areas on airplanes are always kept at a temperature below 29°C, which results in the BlockVesl packages effectively refreezing during this stage of transport. Not including this section in safety factor calculations is a conservative approach and ensures that if a much shorter flight was experienced the design would still be sufficient.

G.2 BlockVesl Thermal Energy Absorption Calculations

The amount of energy absorbed by the BlockVesls present in the queen bee transport container were calculated to ensure that the design was viable for the full 5 stage transport scenario. First the amount of heat storage in the three BlockVesl's was calculated as follows:

$$E_{BV} = 3 * \rho * V_{BV} * e_{BV} = 3 * \left(1494.3\frac{kg}{m^3}\right) * (0.000908m^3) * \left(200\frac{kJ}{kg}\right) = 814.1kJ$$

Where E_{BV} is the heat storage of the three BlockVesl units, ρ is the density of the PureTemp 29 PCM, V_{BV} is the volume of PureTemp 29 PCM in each BlockVesl unit, and e_{BV} is the specific heat storage of the PureTemp 29 PCM.

Similarly, the safety factor provided by the three BlockVesl units is calculated using the heat absorption data (E_{in}) collected from the SolidWorks thermal analysis, and neglecting the heat emitted by the packages during phase 3 of the process as a conservative precaution as seen in Table 3.

$$n = \frac{E_{BV}}{E_{in}} = \frac{814.1kJ}{391.3\text{kJ}} = 2.081$$

This surpasses the requirement of a thermal safety factor of 2 and validates the PPC Design for thermal transfer into the BlockVesl units.

Appendix H: Future Considerations from Client

Hi Cole,

Thank you for the Phase II report.

I have a couple of questions/points

First I agree with the decision to use one of the phase change designs

After a quick read-through, here are my thoughts...

The crate design concepts appear to be based on an assumption that the crates require cooling to prevent overheating as they will be exposed to 40degC temperature outside the crate (Appendix L, pg85, "T(ambient)"). This is also an assumption that the crates require cooling, and do not require heating to prevent the bees from getting too cold. However, transportation across the ocean from New Zealand involves much cooler ambient temperatures outside the crate than 40degC. Talking with Shelley Hoover yesterday she mentioned a queen crating example where the bees got too cold to maintain fertility, so those crates needed heating, not cooling. I wonder if the shipping environments might require both heating and cooling for the crate, in which case two different phase change materials could be integrated into the crate to help regulate both heating and cooling.

Best

Connie

Connie Phillips

Executive Director

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11434-168 Street #102, Edmonton, AB T5M 3T9

albertabeekeepers.ca

Appendix J: Drawing Package

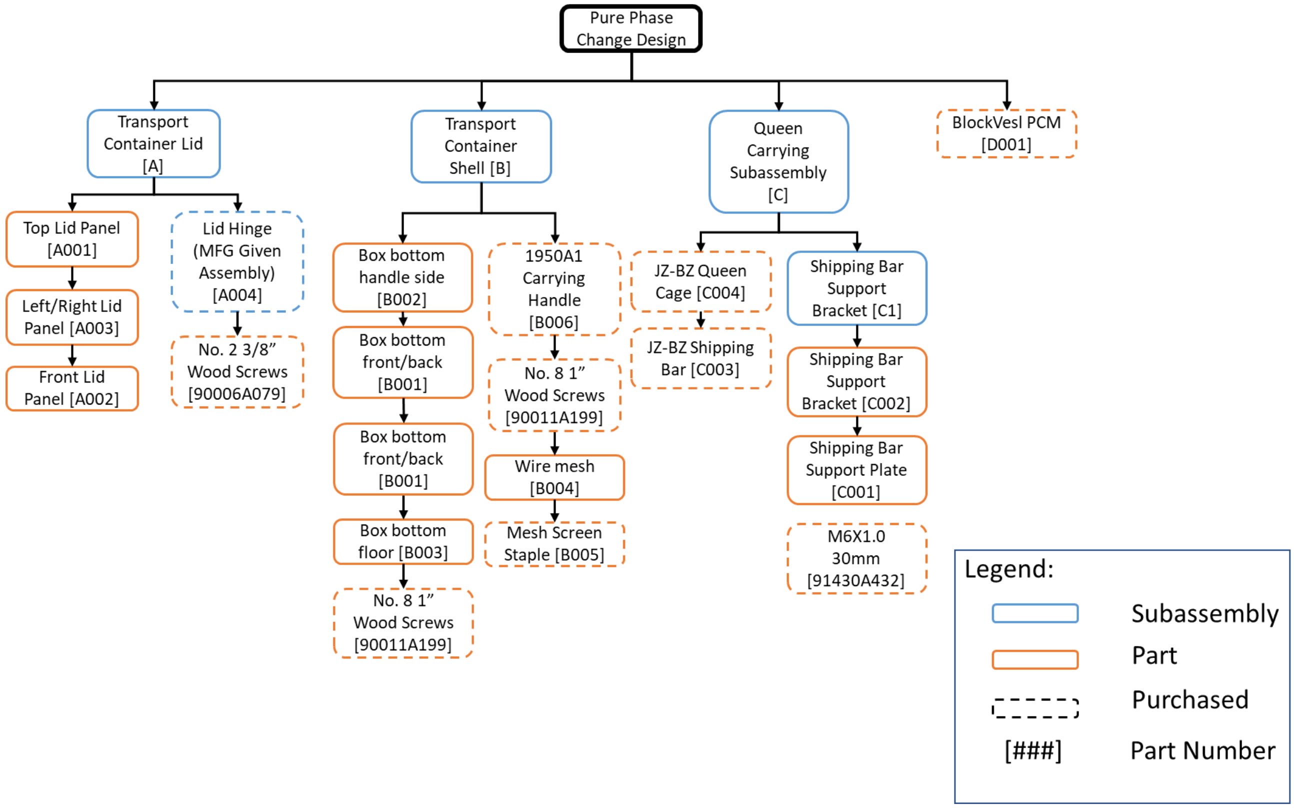
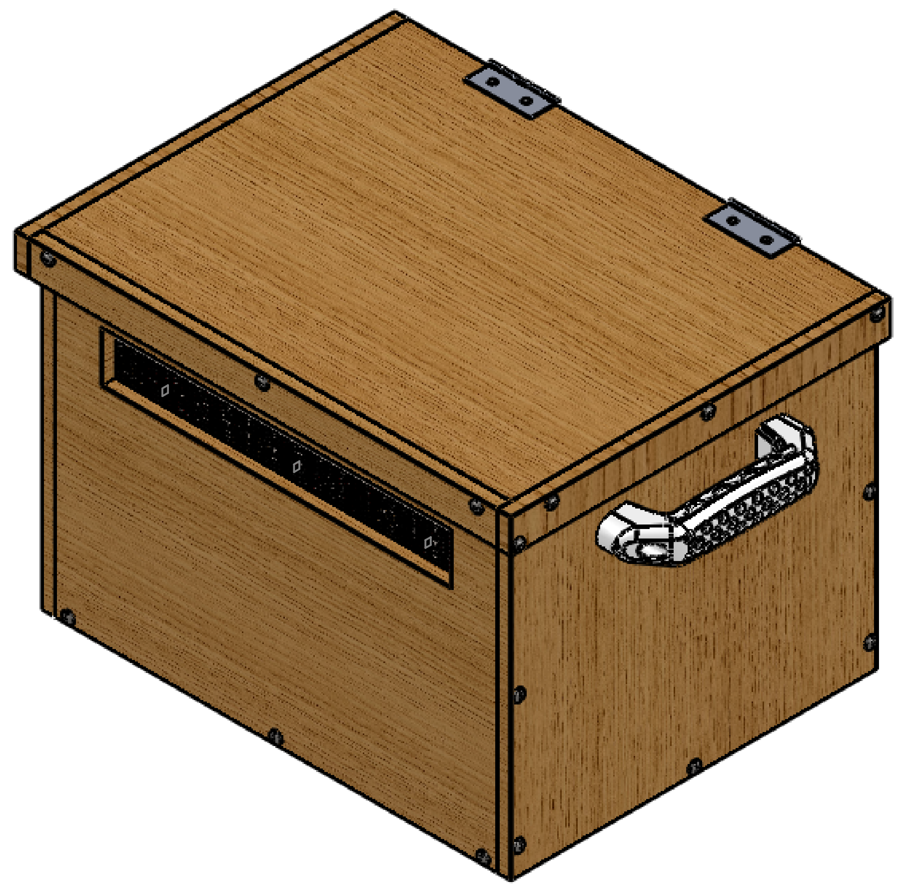
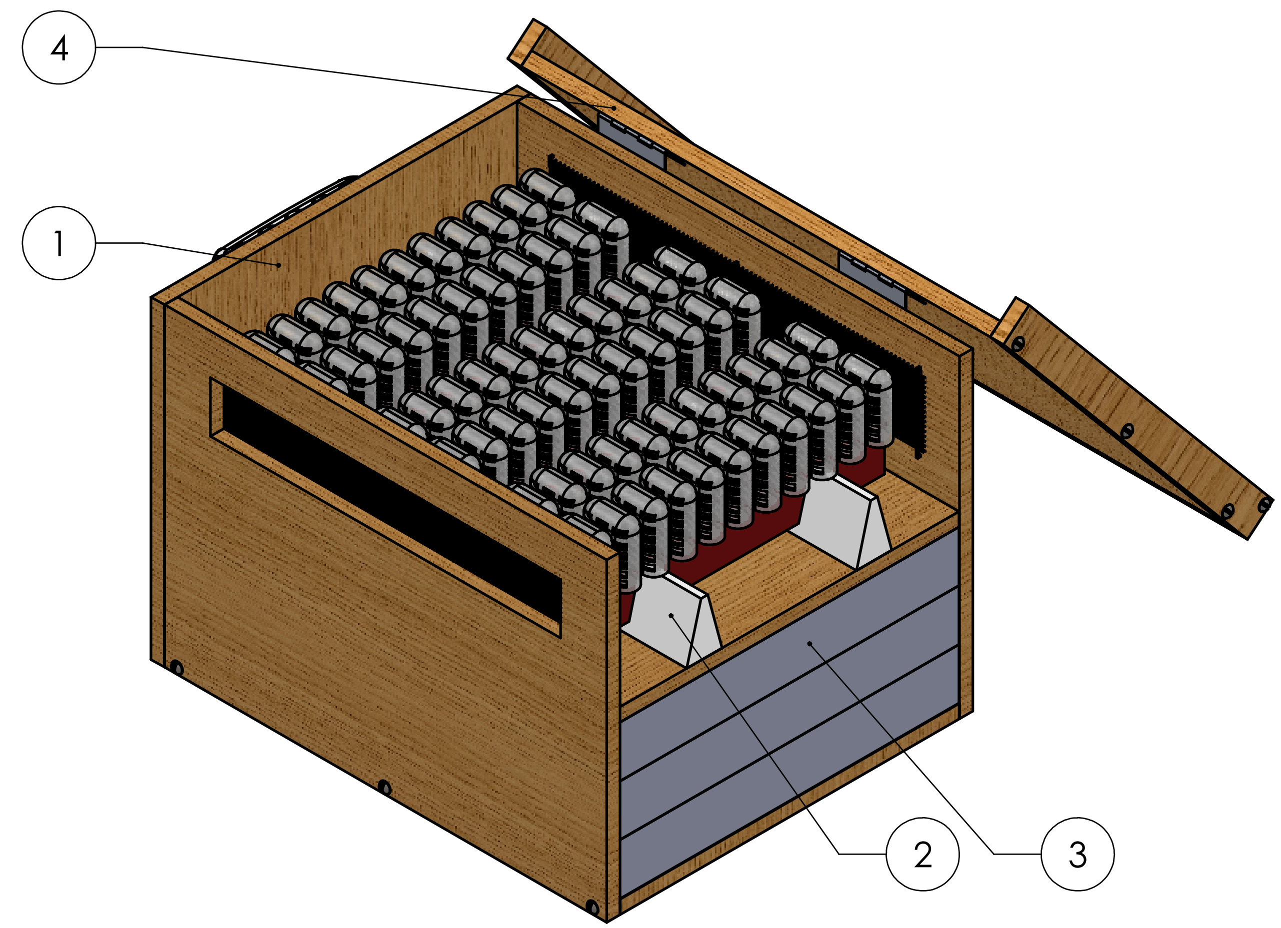


Figure 38: PPCD Design Tree

ITEM NO.	Assembly Name	Part No.	Material	SW-Author(Author)	
1	Transport container shell	B	Various	CCX/CM	1
2	Queen carrying subassembly	C	Various	CCX	1
3	Phase Change Material	D001	BlockVesl	CCX	3
4	Transportation Container lid	A	Various	CCX/CM	1





MecE 460
Instructor: Dr. K Duke
Fall 2019
Comments:

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MM
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025
SURFACE FINISH µm 0.6
DO NOT SCALE DRAWING

MATERIAL: Various
FILE NAME: PPCD(final assembly)

DRAWN BY: CCX/CM
Student
Lab Day
SM By: Chuanchen Xiao/Cole Masse
Checked By: Cole Masse
December 1, 2019 4:56:14 PM
November 25, 2019 2:13:15 PM

The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

TITLE: Pure Phase Change design

SIZE	Part No.	REV
B	PPCD	1

SCALE: 1:4 | Mass: 14223.13 | SHEET 1 OF 16

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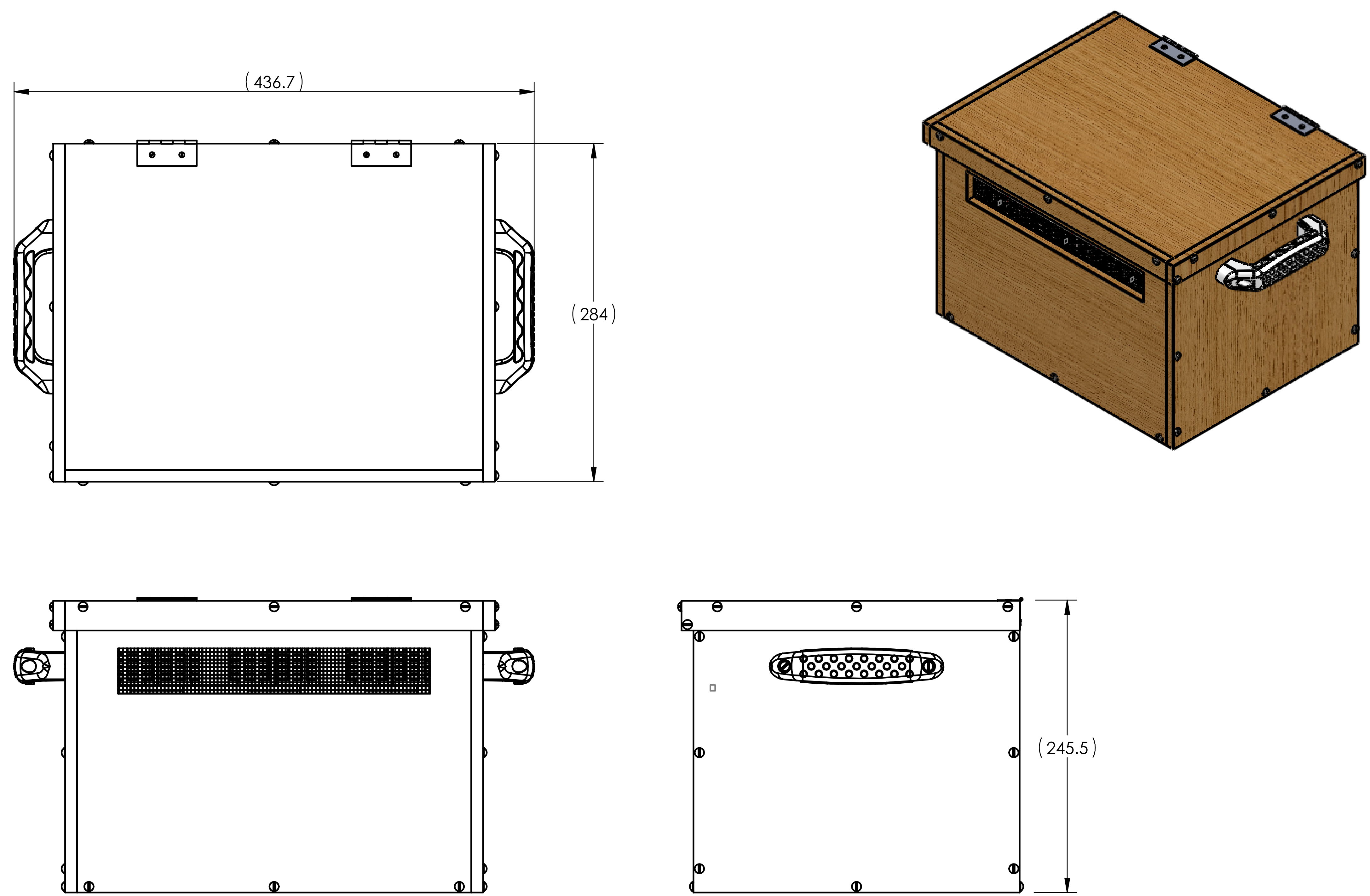

MecE 460
Instructor:
Dr. K Duke
Fall 2019
Comments:

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MM
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025
SURFACE FINISH µm 0.6
DO NOT SCALE DRAWING

MATERIAL:
Various
FILE NAME:
PPCD(final assembly)

DRAWN BY:
CCX/CM
Student
Lab Day
SM By Chuanchen Xiao/Cole Masse
Checked By Cole Masse
December 1, 2019 4:56:14 PM
November 25, 2019 2:13:15 PM

The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA
TITLE:
Pure Phase Change design

SIZE	Part No.	REV
B	PPCD	1

SCALE: 1:4 Mass: 14223.13 SHEET 2 OF 16

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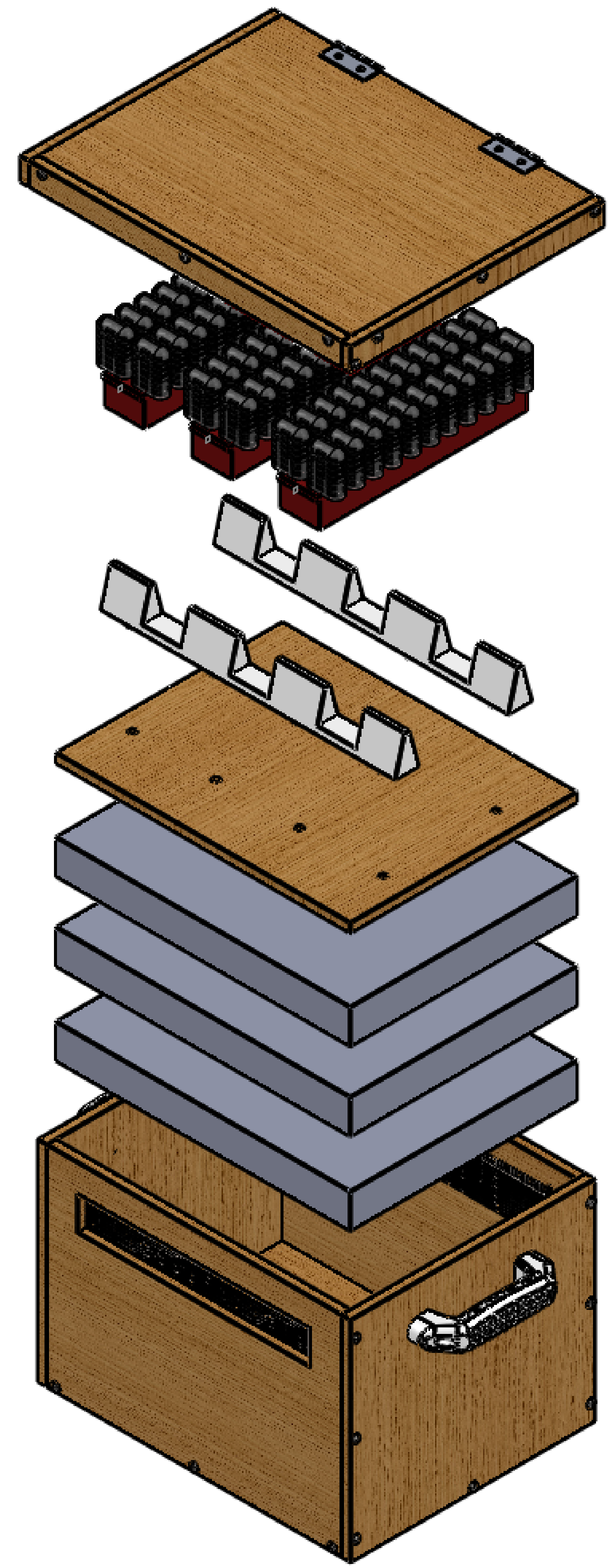

MecE 460
Instructor:
Dr. K Duke
Fall 2019
Comments:

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MM
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025
SURFACE FINISH µm 0.6
DO NOT SCALE DRAWING

MATERIAL:
Various
FILE NAME:
PPCD(final assembly)

DRAWN BY:
CCX/CM
Student #
Lab Day
SM By: Chuanchen Xiao/Cole Masse
Checked By: Cole Masse
December 1, 2019 4:56:14 PM
November 25, 2019 2:13:15 PM

The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA
TITLE:
Pure Phase Change design

SIZE	Part No.	REV
B	PPCD	1

SCALE: 1:6 Mass: 14223.13 SHEET 3 OF 16

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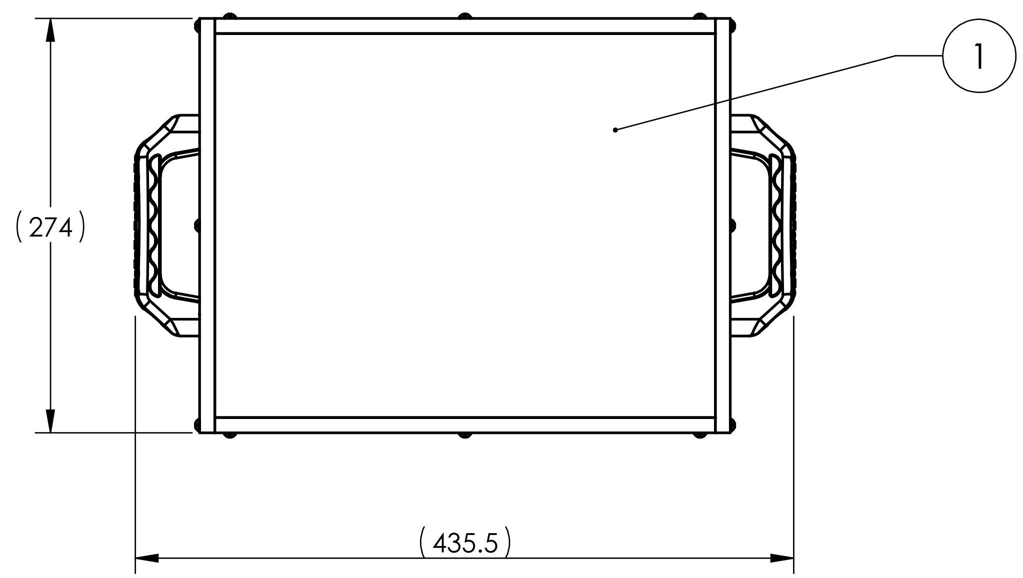
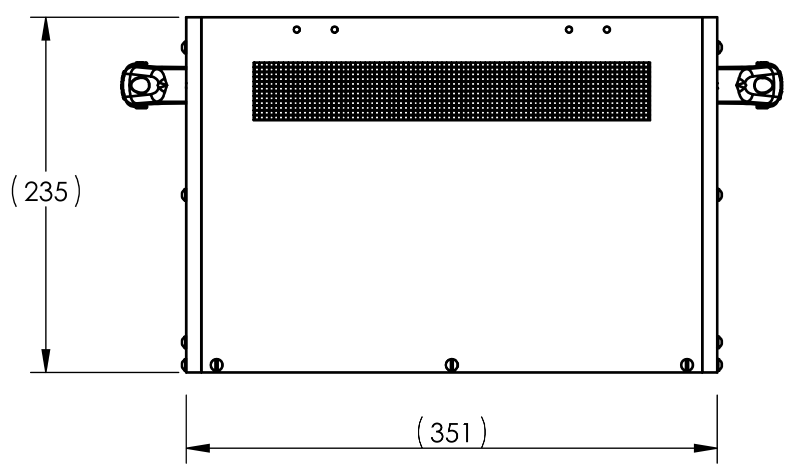
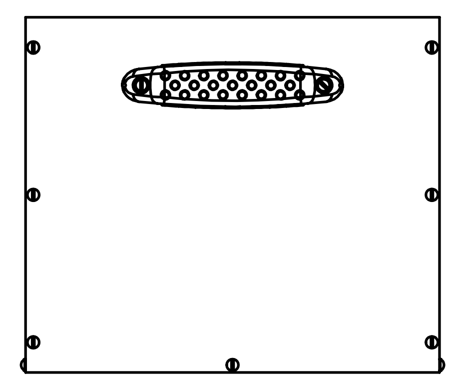
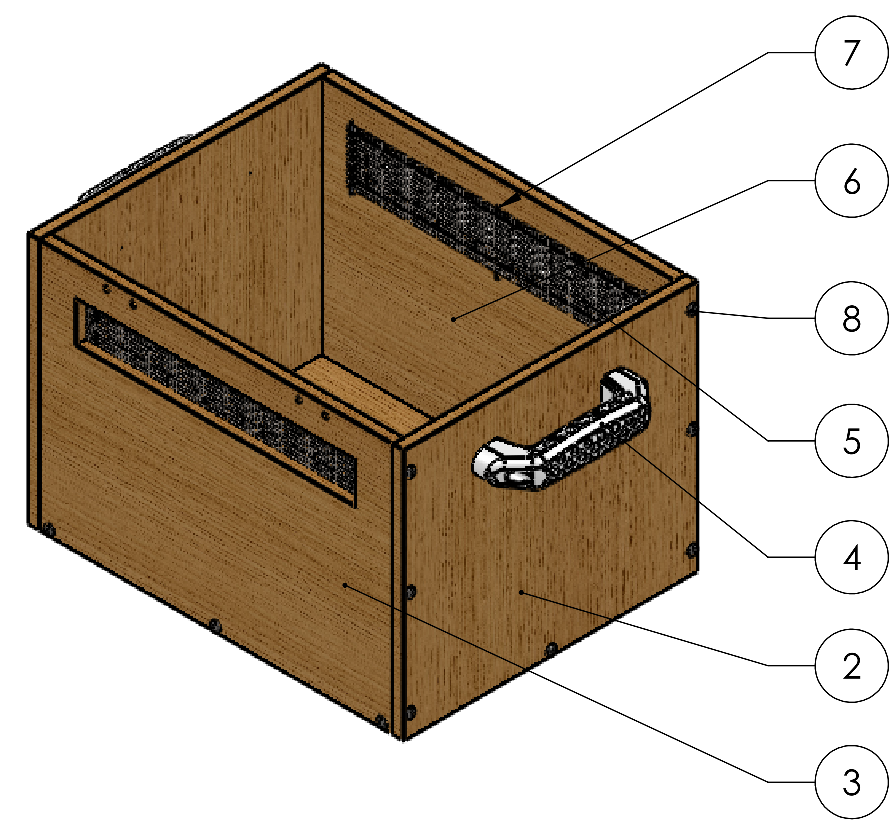
ITEM NO.	Part Name	Part No.	Material	QTY.
1	Box bottom floor	B003	Oak	1
2	Box bottom handle side	B002	Oak	2
3	Box bottom back side	B001	Oak	1
4	1950A1	B006	ABS	2
5	Wire mesh	B004	Alloy Steel	2
6	Box bottom front side	B001	Oak	1
7	Screen Staple	B005	1060 Alloy	12
8	90011A199	90011A199	AISI 304	24









MecE 460

Instructor: Dr. K Duke
Fall 2019
Comments:

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MM
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025
SURFACE FINISH µm 0.6
DO NOT SCALE DRAWING

MATERIAL: Various
FILE NAME: Transport container shell

DRAWN BY: CCX/CM
Student
Lab Day
SM By: CCX/CM
Checked By: Cole Masse
November 30, 2019 5:56:40 PM
November 25, 2019 12:42:38 PM

The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

TITLE: Transportation Container Shell

SIZE: B | Part No.: B | REV: 1

SCALE: 1:5 | Mass: 2202.60 | SHEET 4 OF 16

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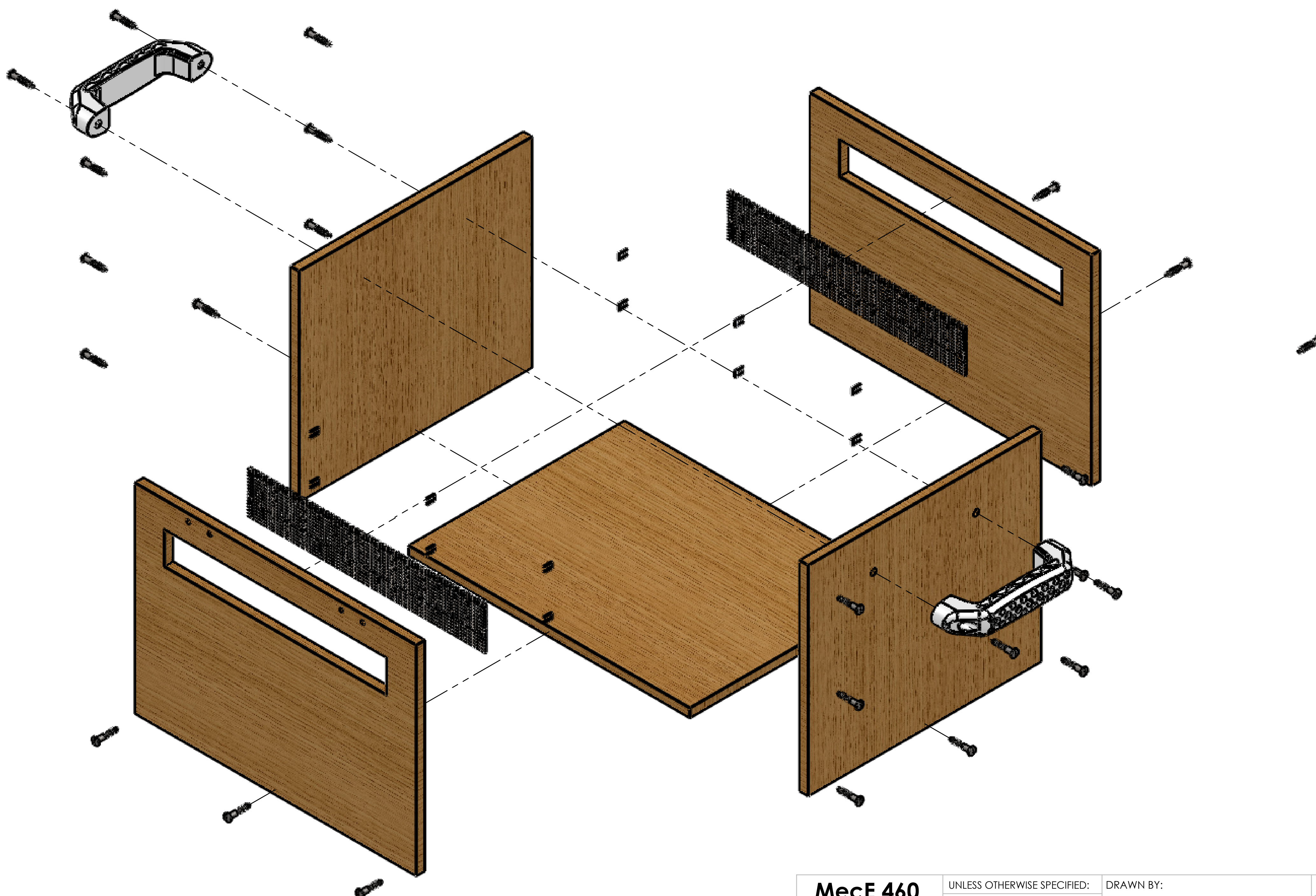


MecE 460
Instructor:
Dr. K Duke
Fall 2019
Comments:

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MM
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025
SURFACE FINISH µm 0.6
DO NOT SCALE DRAWING

MATERIAL:
Various
FILE NAME:
Transport container shell

DRAWN BY:	CCX/CM
Student	
Lab Day	
SM By	CCX/CM
Checked By	Cole Masse

November 30, 2019 5:56:40 PM
November 25, 2019 12:42:38 PM

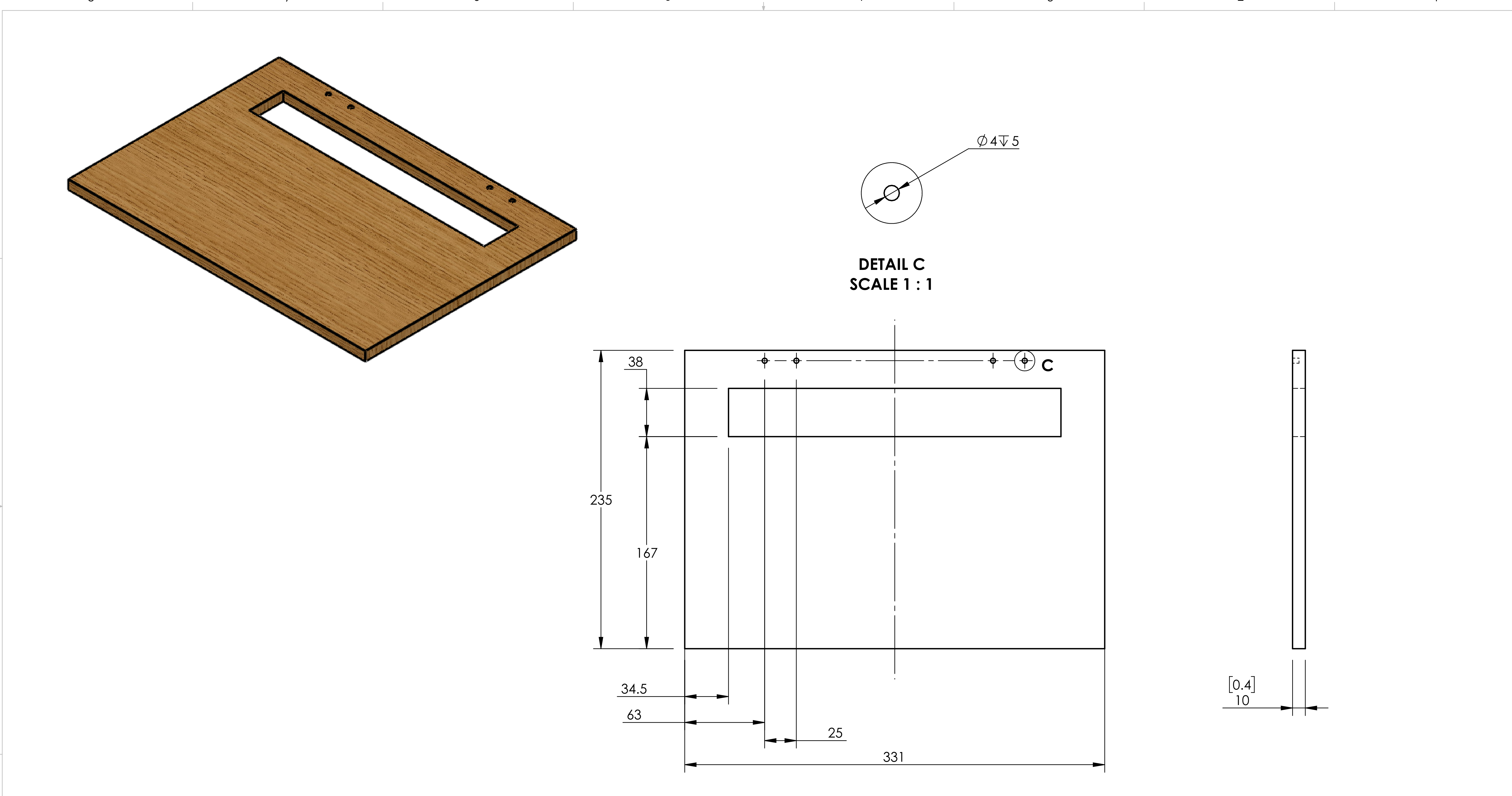
The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

TITLE:
Transportation Container Shell

SIZE	Part No.	REV
B	B	1

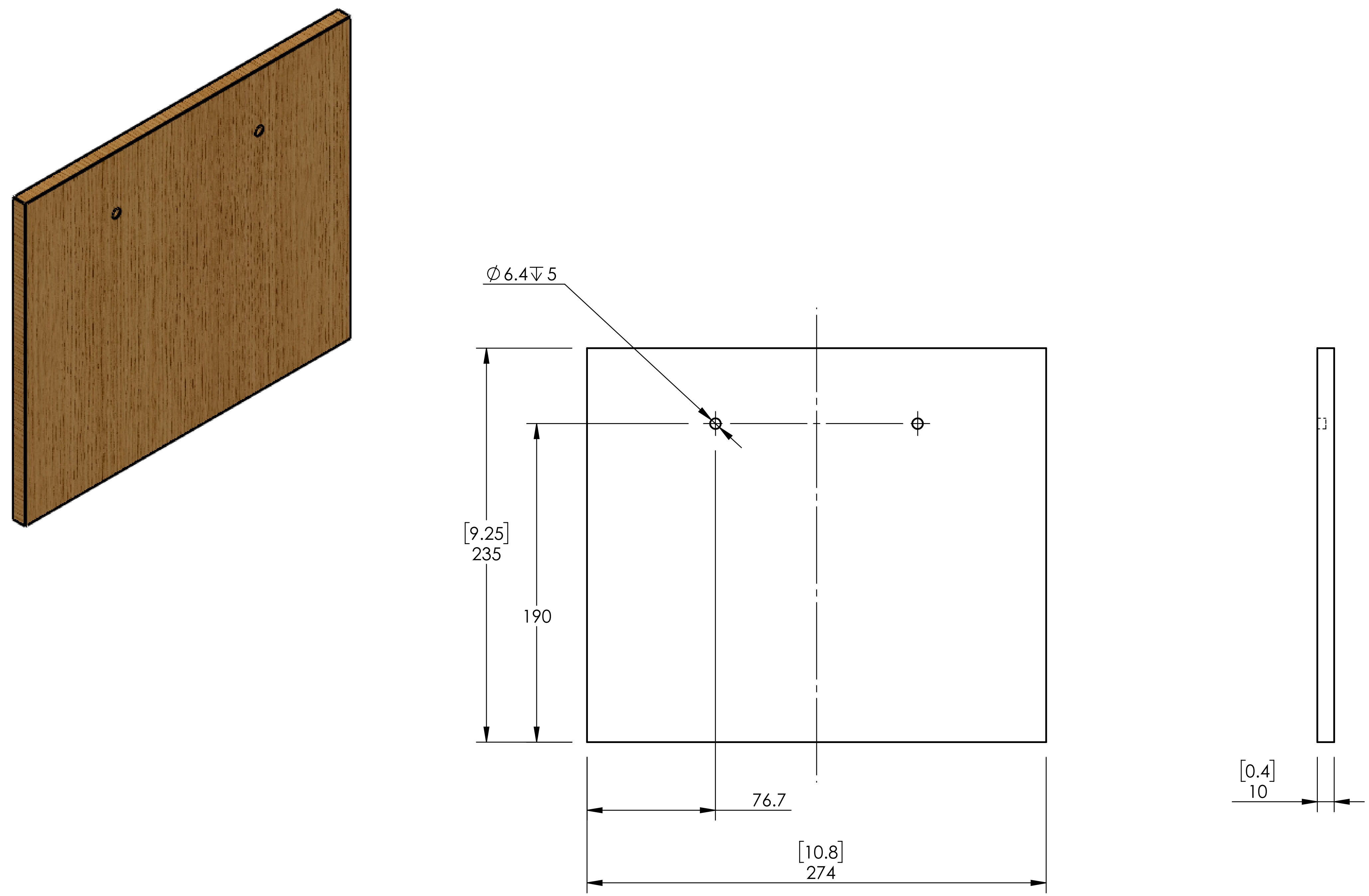
SCALE: 1:4 | Mass: 2202.60 | SHEET 5 OF 16

SOLIDWORKS Educational Product. For Instructional Use Only.



MecE 460	UNLESS OTHERWISE SPECIFIED:	DRAWN BY:	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA
Instructor: Dr. K Duke Fall 2019	DIMENSIONS ARE IN MM TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025	CCX/CM	TITLE: Box bottom back side
Comments:	SURFACE FINISH µm 0.6	Student	
		Lab Day	
	DO NOT SCALE DRAWING	SM By: CCX	SIZE B / Part No. B001 / REV 1
MATERIAL: Oak		Checked By: MP	
FILE NAME: Box bottom mesh side		November 30, 2019 5:56:40 PM November 25, 2019 12:23:29 PM	SCALE: 1:3 / Mass: 379.70 / SHEET 6 OF 16

SOLIDWORKS Educational Product. For Instructional Use Only.



MecE 460

Instructor:
Dr. K Duke
Fall 2019

Comments:

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MM
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025

SURFACE FINISH µm 0.6

DO NOT SCALE DRAWING

DRAWN BY: CCX/CM

Student	
Lab Day	
SM By	CCX
Checked By	MP

November 30, 2019 5:56:40 PM
November 25, 2019 12:32:10 PM

MATERIAL: Oak

FILE NAME: Box bottom handle side

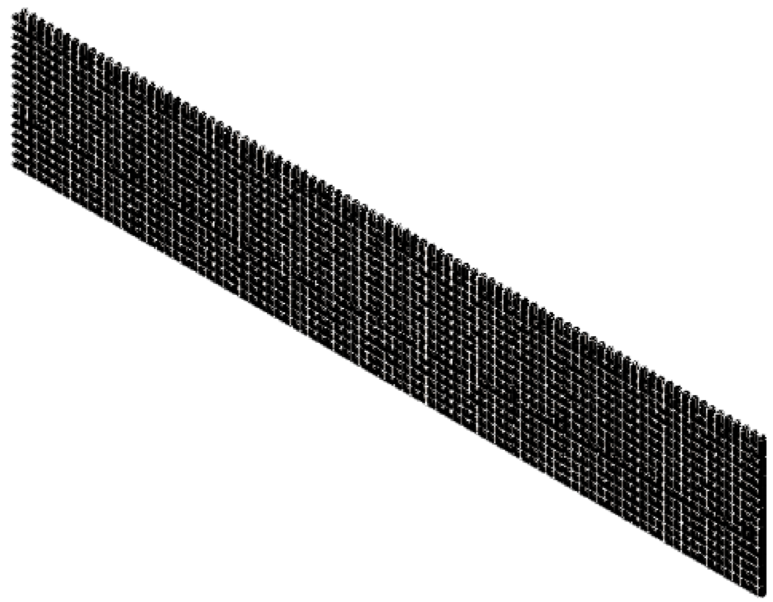
The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

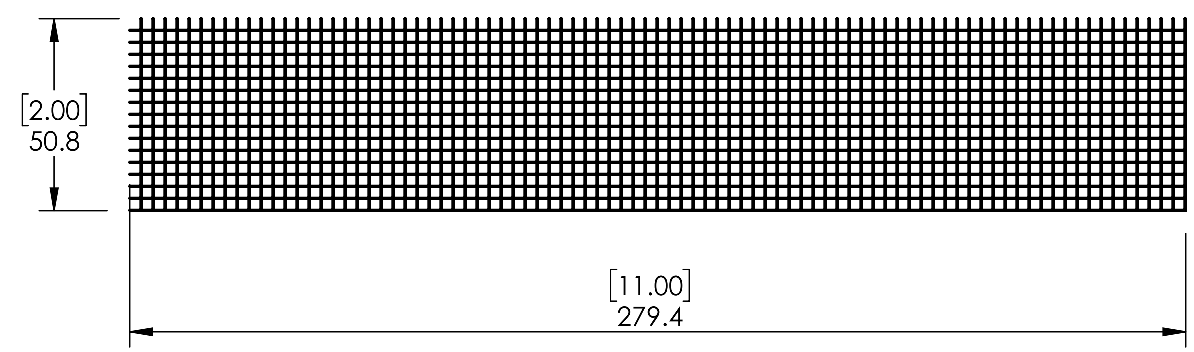
TITLE: Box bottom handle side

SIZE	Part No.	REV
B	B002	1

SCALE: 1:3 | Mass: 360.41 | SHEET 7 OF 16

SOLIDWORKS Educational Product. For Instructional Use Only.

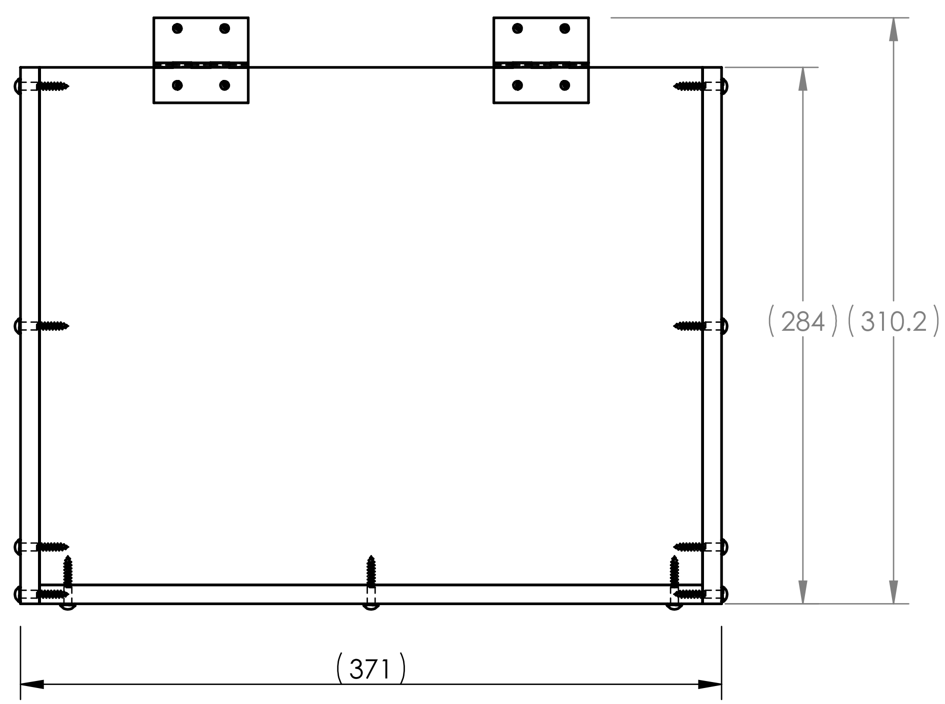


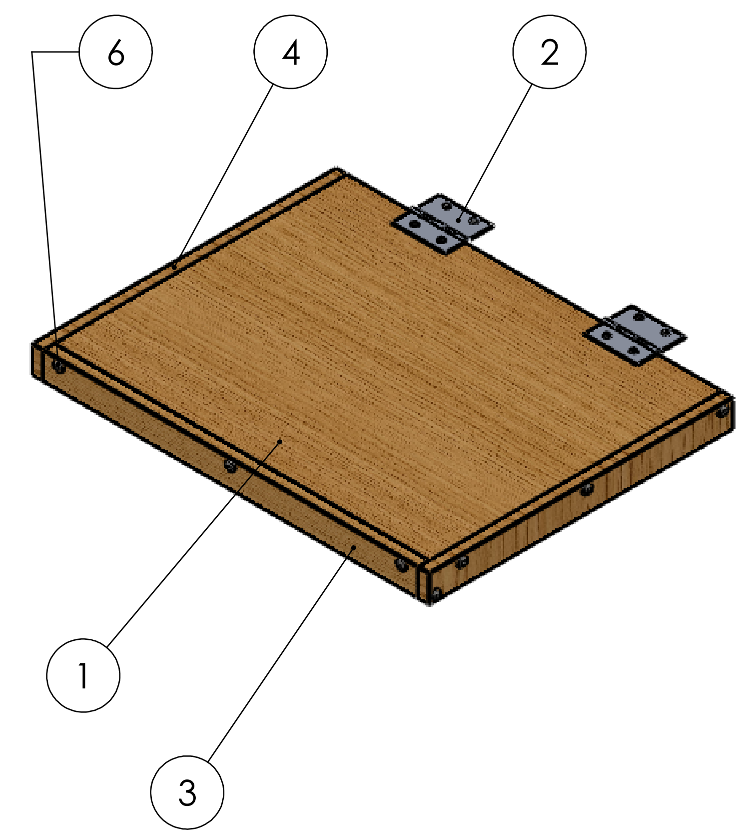


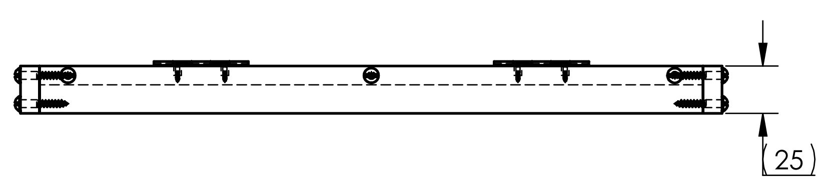
Instructor:	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MM TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025 SURFACE FINISH µm 0.6 DO NOT SCALE DRAWING	DRAWN BY: CCX/CM	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA
Comments:		Student	TITLE: Wire mesh
		Lab Day	
		SM By: CCX	
		Checked By	SIZE B / Part No. B004 / REV
MATERIAL: Alloy Steel		November 30, 2019 4:33:42 PM / October 27, 2019 11:57:32 AM	SCALE: 1:2 / Mass: / SHEET 8 OF 16
FILE NAME: Wire mesh			

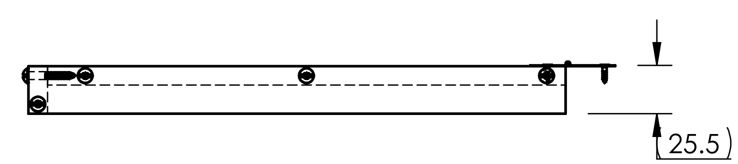
SOLIDWORKS Educational Product. For Instructional Use Only.

ITEM NO.	Part Name	Part No.	Material	
1	Lid top	A001	Oak	1
2	Hinge Assembly	A004	1060 Alloy	2
3	Lid front	A002	Oak	1
4	Lid side	A003	Oak	1
5	Lid side	A003	Oak	1
6	90011A199	90011A199	AISI 304	11



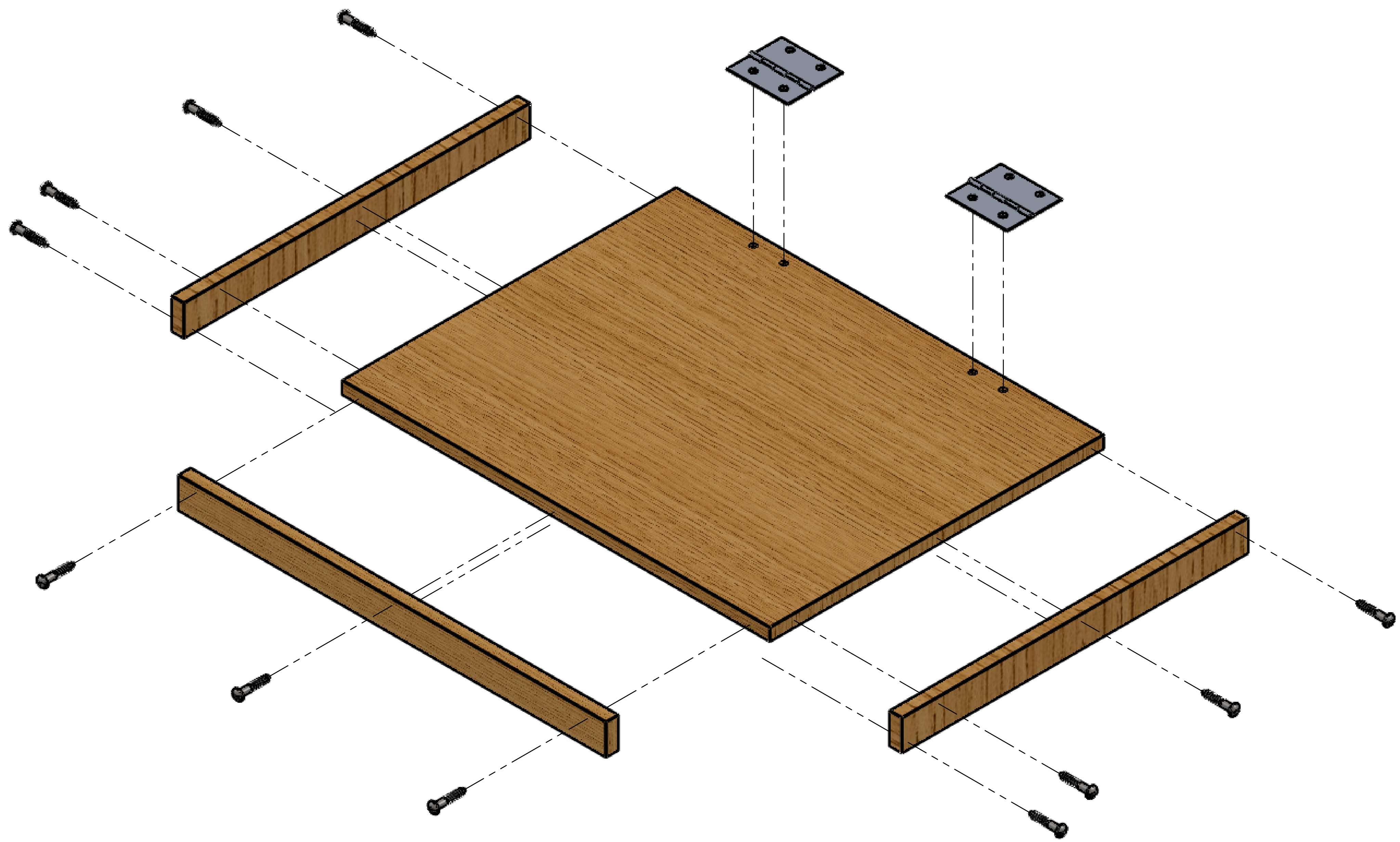






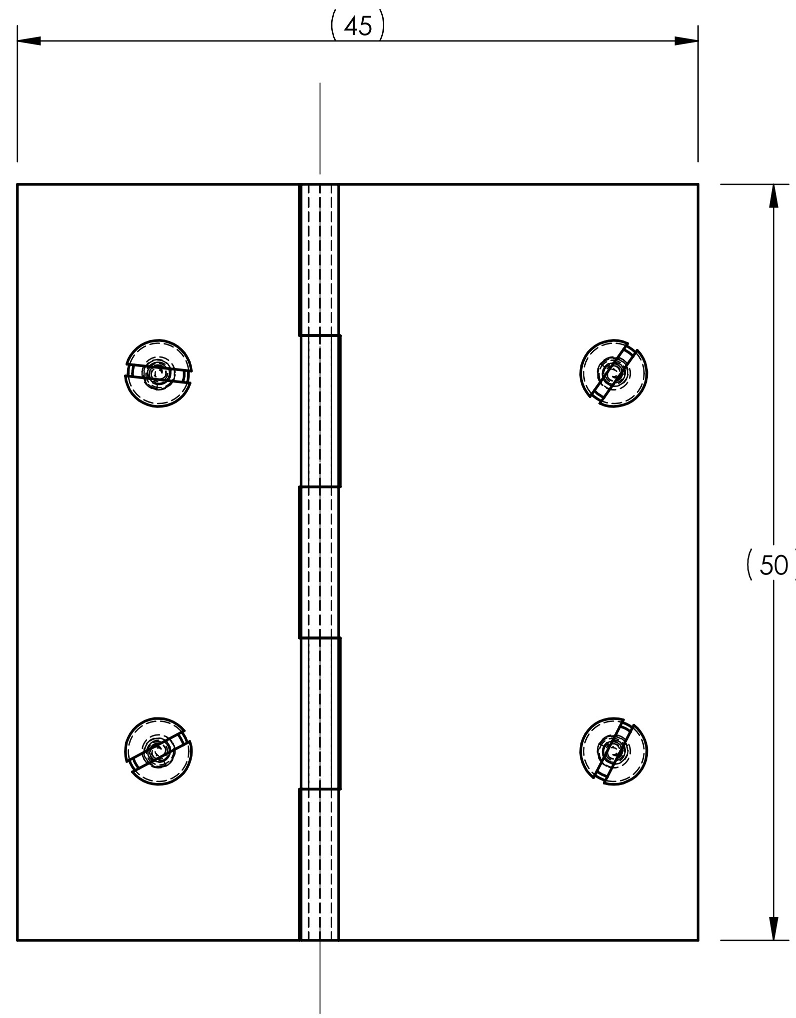
MecE 460 Instructor: Dr. K Duke Fall 2019 Comments: Thickness 10mm	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MM TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025 SURFACE FINISH µm 0.6 DO NOT SCALE DRAWING	DRAWN BY: CCX/CM Student Lab Day SM By CCX/CM Checked By CH	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA TITLE: Transportation container lid
MATERIAL: Various FILE NAME: Transportation Container lid		November 30, 2019 6:01:42 PM November 25, 2019 1:43:41 PM	SIZE B · Part No. A · REV 1 SCALE: 1:4 · Mass: 703.33 · SHEET 9 OF 16

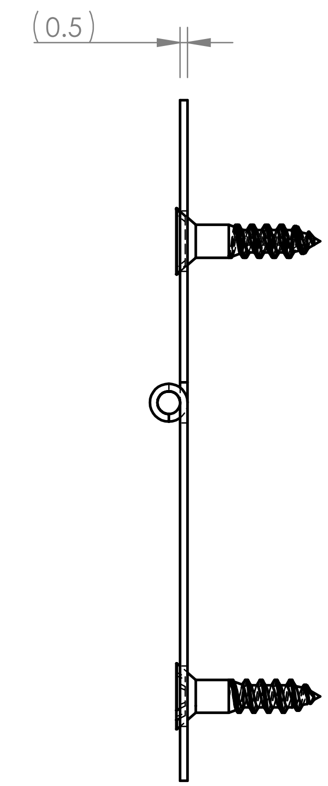
SOLIDWORKS Educational Product. For Instructional Use Only.



MecE 460 Instructor: Dr. K Duke Fall 2019 Comments: Thickness 10mm	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MM TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025 SURFACE FINISH µm 0.6 DO NOT SCALE DRAWING	DRAWN BY: CCX/CM	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA
		Student	TITLE: Transportation container lid
		Lab Day	
		SM By: CCX/CM	SIZE B; Part No. A; REV 1
MATERIAL: Various		Checked By: CH	
FILE NAME: Transportation Container lid		November 30, 2019 6:01:42 PM November 25, 2019 1:43:41 PM	SCALE: 1:3; Mass: 703.33; SHEET 10 OF 16

SOLIDWORKS Educational Product. For Instructional Use Only.





MecE 265
Instructor:
Dr. AJ Qureshi
Fall 2019
Comments:

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MM
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025
SURFACE FINISH µm 0.6
DO NOT SCALE DRAWING

DRAWN BY:
CCX/CM

Student	
Lab Day	
SM By	Cole Masse
Checked By	CH

November 30, 2019 6:01:46 PM
November 19, 2019 3:36:05 PM

MATERIAL:
1060 Alloy
FILE NAME:
Hinge Assembly

The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

TITLE:
Hinge Assembly

SIZE	Part No.	REV
B	A004	1

SCALE: 2:1 | Mass: 3.56 | SHEET 11 OF 16

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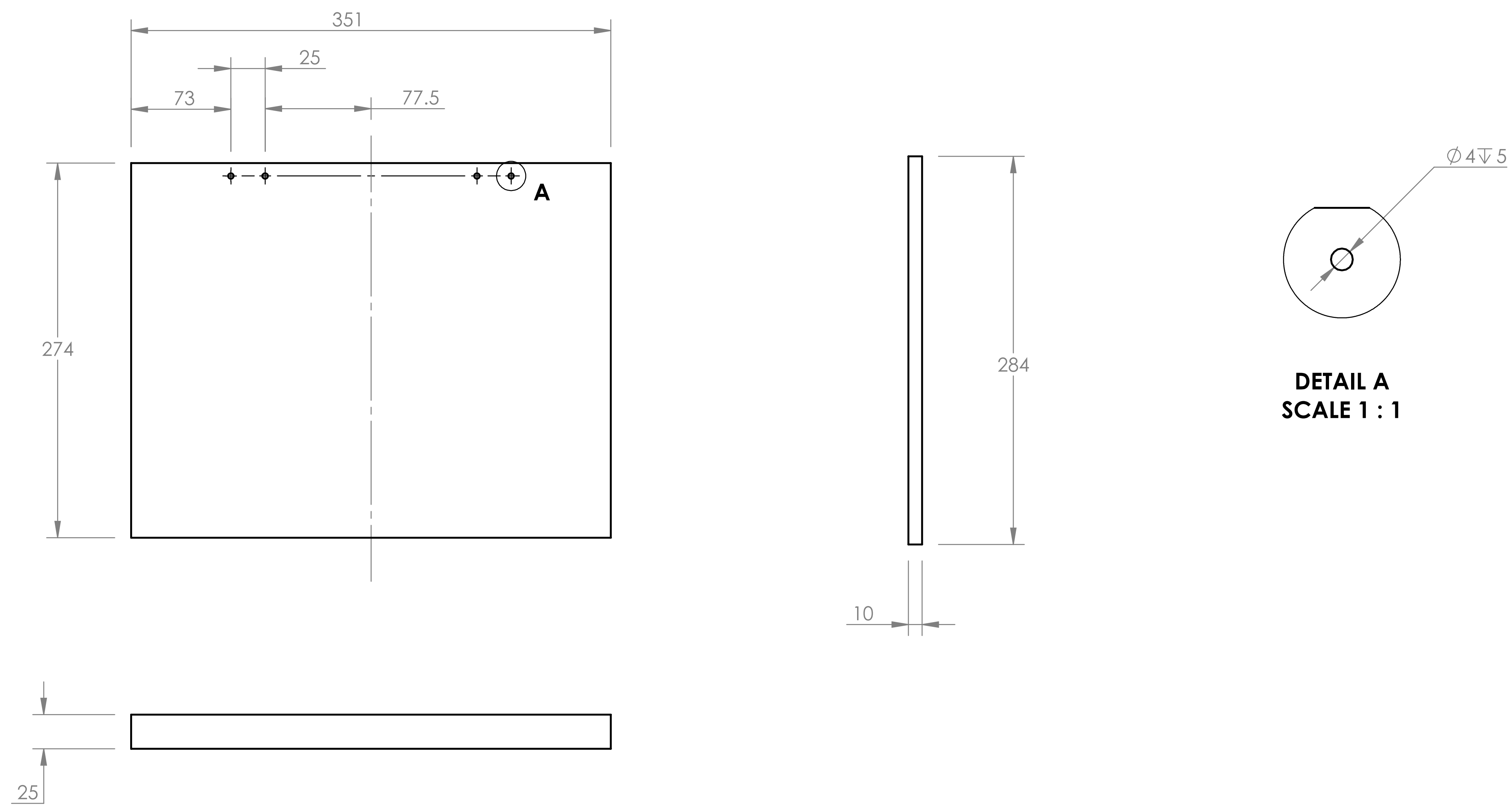
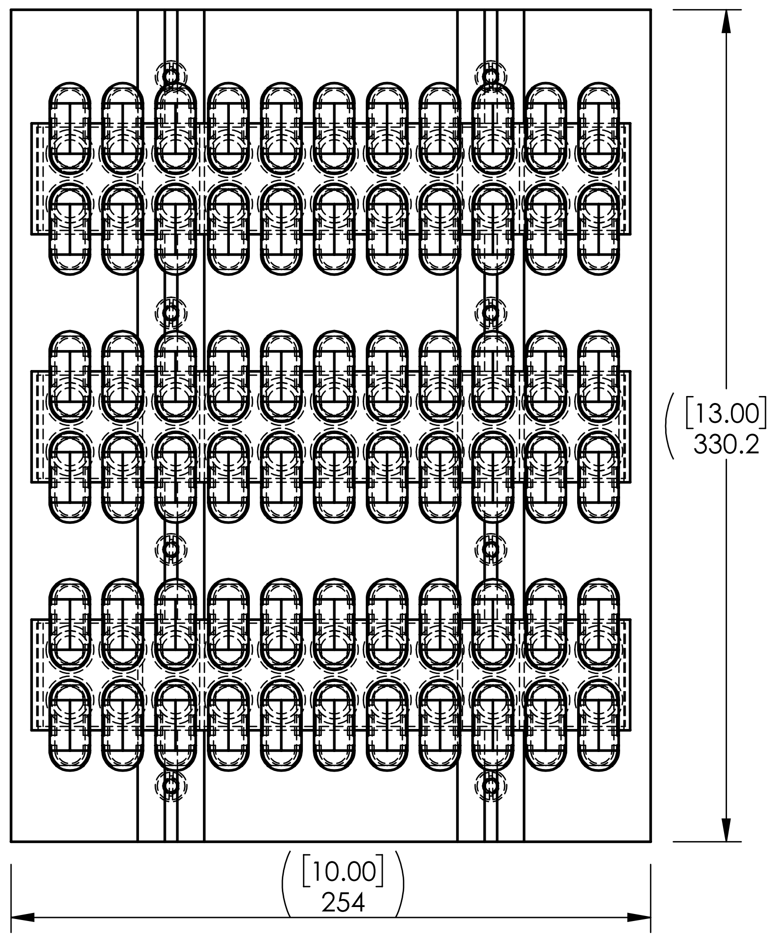
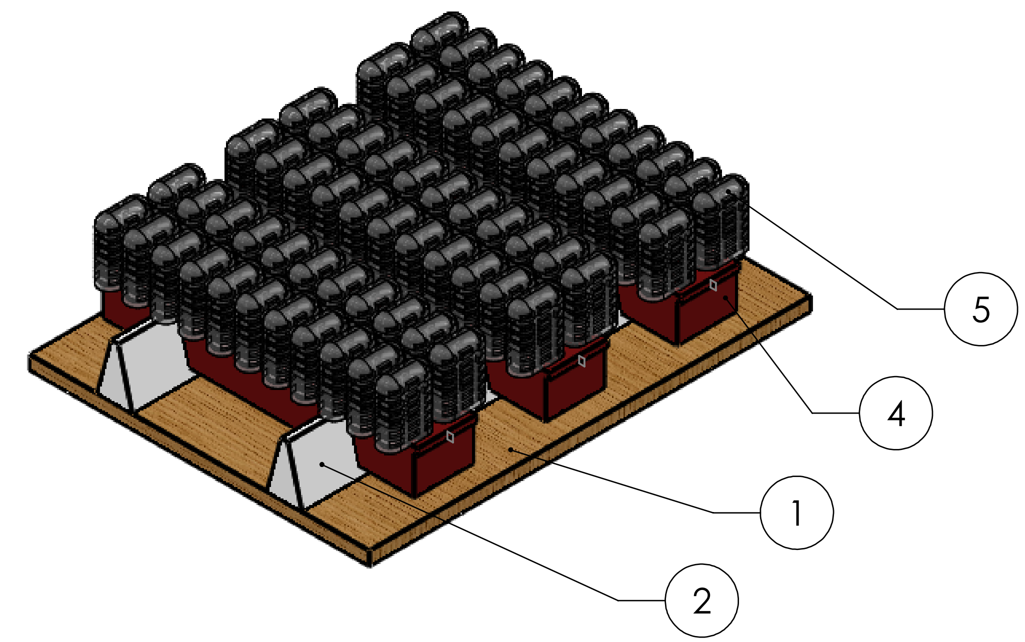


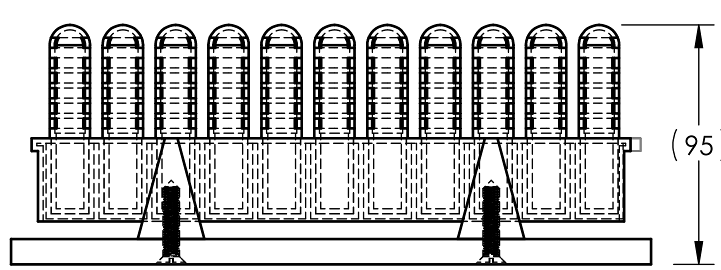
MecE 460 Instructor: Dr. K Duke Fall 2019 Comments: All thickness 10mm	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MM TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025 SURFACE FINISH µm 0.6 DO NOT SCALE DRAWING	DRAWN BY: CCX/CM	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA
		Student	TITLE: Lid
		Lab Day	
		SM By: CCX	SIZE B
MATERIAL: Oak		Checked By: CH	Part No. A001 - 003
FILE NAME: Lid top		November 30, 2019 6:01:46 PM November 25, 2019 1:29:43 PM	REV 1
			SCALE: 1:4 · Mass: 538.43 · SHEET 12 OF 16

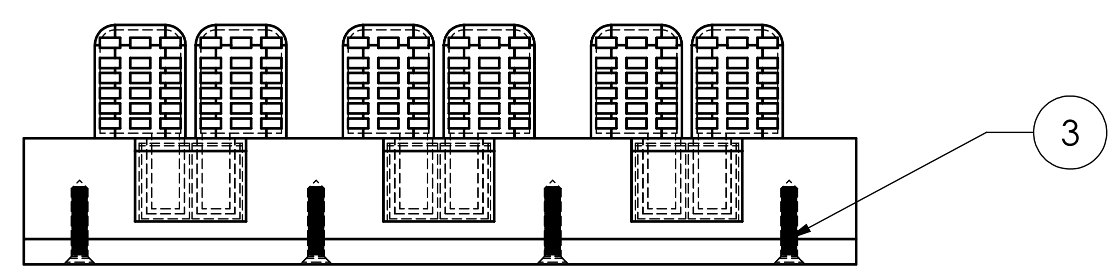
SOLIDWORKS Educational Product. For Instructional Use Only.

ITEM NO.	Part Name	Part No.	Material	QTY.
1	Shipping Bar Support Plate	C001	Oak	1
2	Shipping bar support bracket	C002	ABS	2
3	91430A432	M6 x 1 mm	AISI 304	8
4	Shipping bar	C003	ABS	3
5	JZ BZ queen cage model	C004	ABS	66









MecE 460

Instructor:
Dr. K Duke
Fall 2019

Comments:
All Parts are available in market.
The dimensions of the model are measured/estimated from existing product

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MM
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025

SURFACE FINISH 0.6 µm

DO NOT SCALE DRAWING

MATERIAL:
Various

FILE NAME:
Queen carrying subassembly

DRAWN BY:
CCX/CM

Student
Lab Day
SM By CCX
Checked By NC

November 30, 2019 6:01:44 PM
November 25, 2019 1:08:06 PM

The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

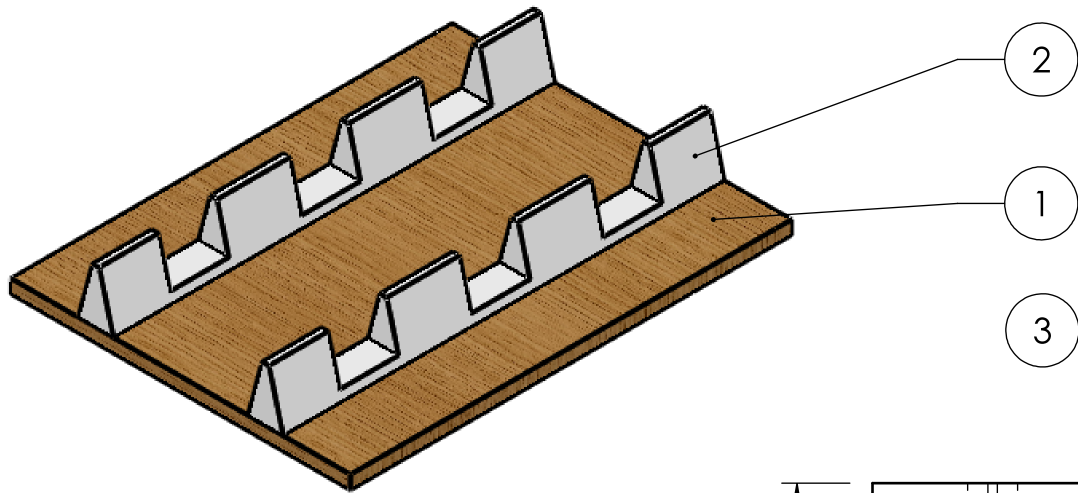
TITLE:
Queen Carrying Assembly

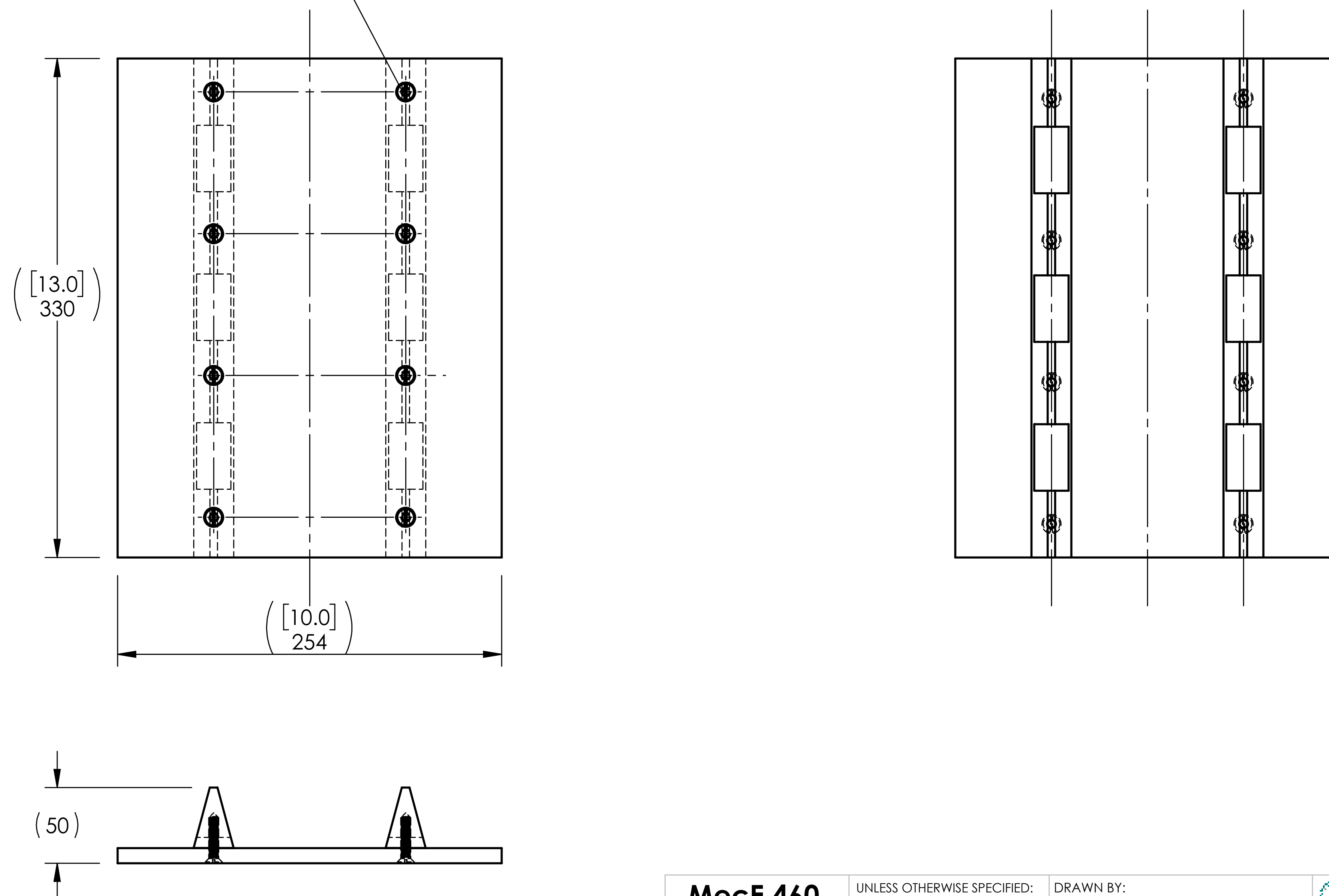
SIZE B | Part No. C | REV 1

SCALE: 1:3 | Mass: 1730.77 | SHEET 13 OF 16

SOLIDWORKS Educational Product. For Instructional Use Only.

ITEM NO.	Part Name	Part No.	Material	QTY.
1	Shipping Bar Support Plate	C001	Oak	1
2	Shipping bar support bracket	C002	ABS	2
3	91430A432	M6 x 1 mm	AISI 304	8





MecE 460
Instructor: Dr. K Duke
Fall 2019
Comments:

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MM
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025
SURFACE FINISH µm 0.6
DO NOT SCALE DRAWING

MATERIAL: ABS
FILE NAME: Shipping bar support

DRAWN BY: CCX/CM
Student
Lab Day
SM By: CCX
Checked By: NC
November 30, 2019 6:01:42 PM
November 25, 2019 1:02:58 PM

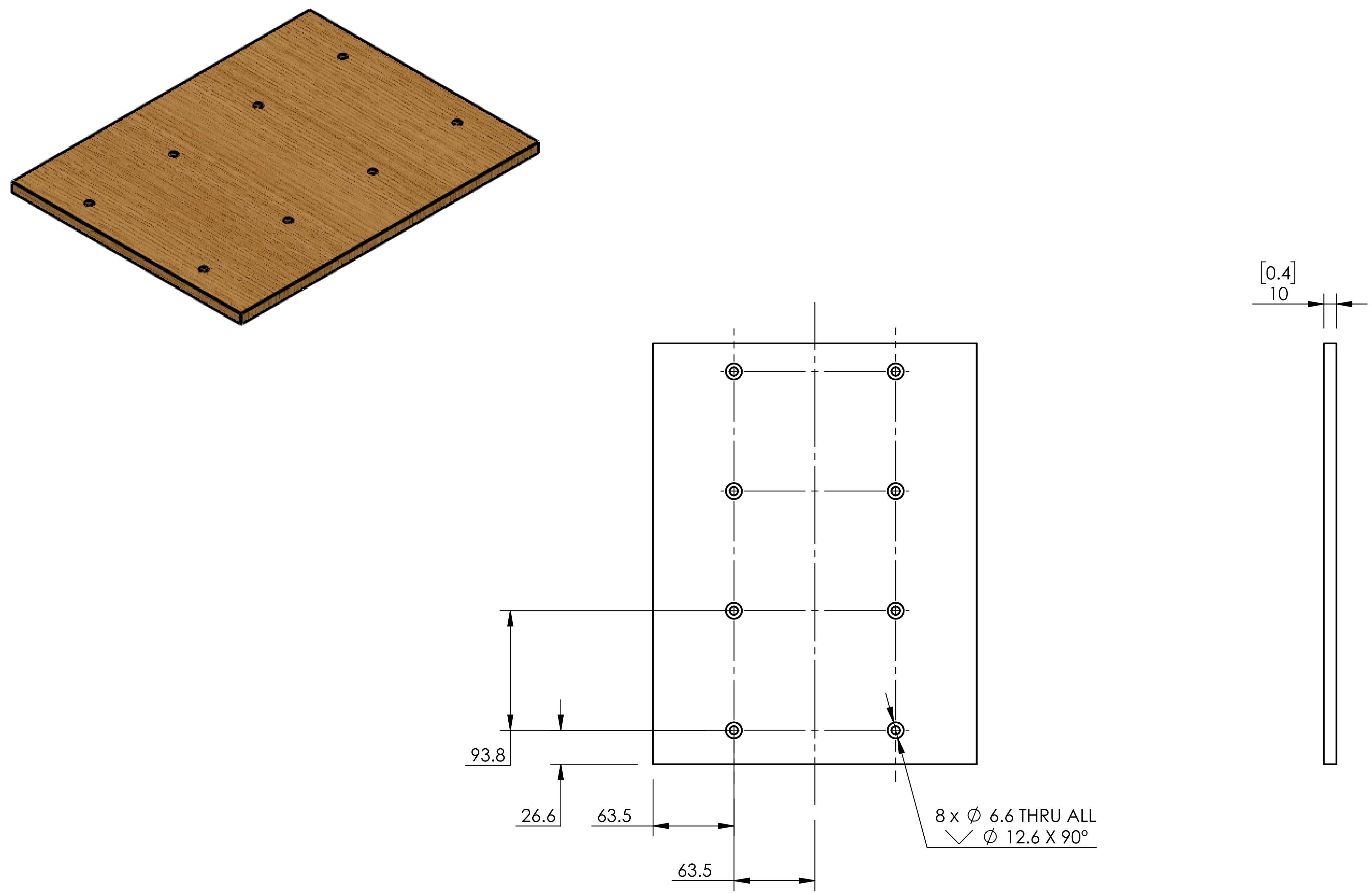
The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

TITLE: Shipping Bar Support

SIZE: B
Part No.: C001 - 002
REV: 1

SCALE: 1:4 | Mass: 809.95 | SHEET 14 OF 16

SOLIDWORKS Educational Product. For Instructional Use Only.



MecE 460

Instructor:
Dr. K Duke
Fall 2019

Comments:

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN MM
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025

SURFACE FINISH µm 0.6

DO NOT SCALE DRAWING

MATERIAL:
Oak

FILE NAME:
Shipping Bar Support Plate

DRAWN BY:
CCX/CM

Student	
Lab Day	
SM By	CCX
Checked By	NC

November 30, 2019 6:01:44 PM
November 19, 2019 2:34:38 PM

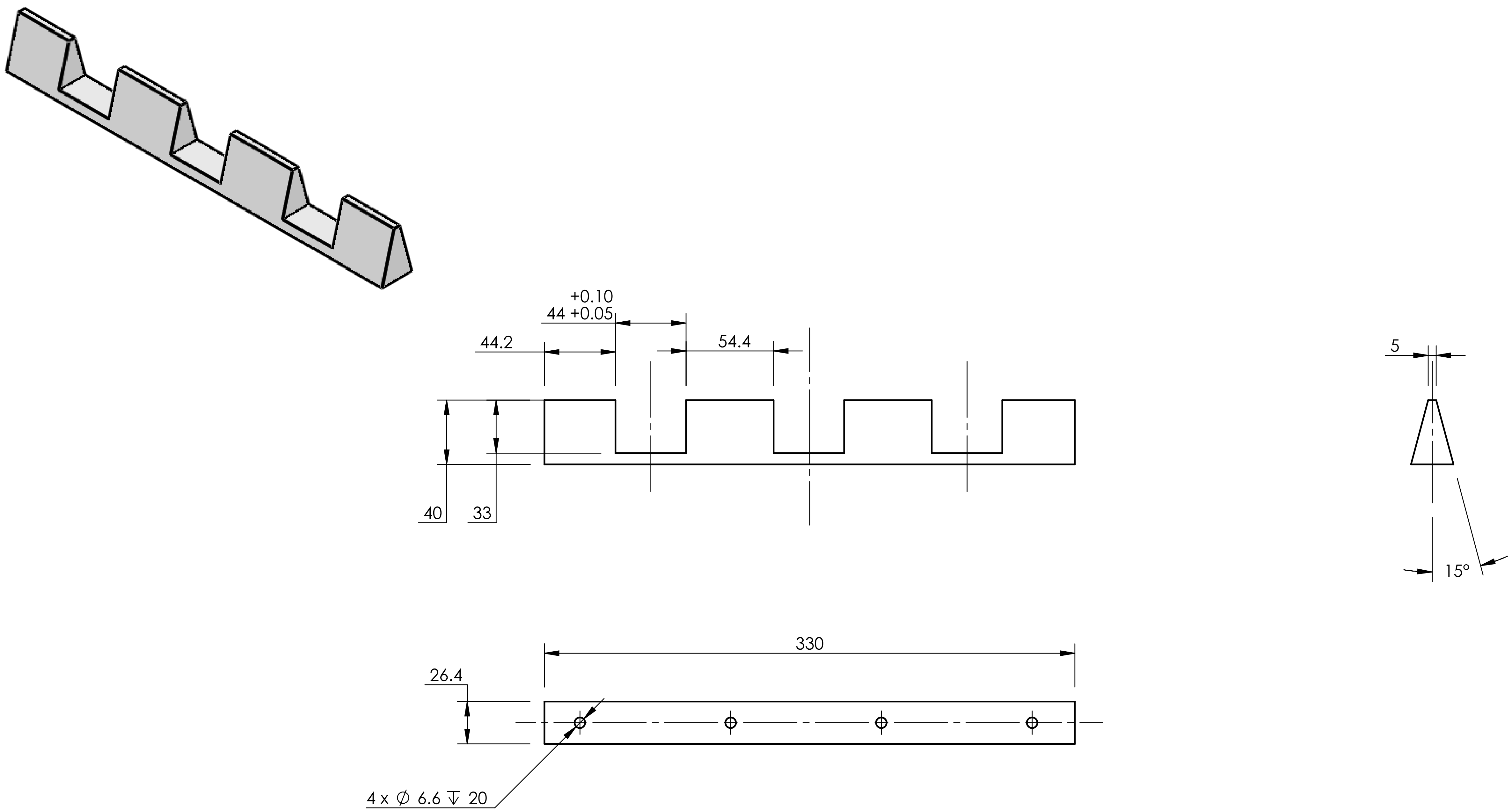
The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

TITLE:
Shipping Bar Support Plate

SIZE	Part No.	REV
B	C001	1

SCALE: 1:4 | Mass: 467.60 | SHEET 15 OF 16

SOLIDWORKS Educational Product. For Instructional Use Only.



MecE 460

Instructor:
Dr. K Duke
Fall 2019

Comments:

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN MM
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025

SURFACE FINISH µm 0.6

DO NOT SCALE DRAWING

MATERIAL:
ABS

FILE NAME:
Shipping bar support bracket

DRAWN BY:
CCX/CM

Student	
Lab Day	
SM By	CCX
Checked By	ME

November 30, 2019 6:01:43 PM
November 19, 2019 2:20:02 PM

The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

TITLE:
Shipping bar support bracket

SIZE	Part No.	REV
B	C002	1

SCALE: 1:3 | Mass: 147.31 | SHEET 16 OF 16

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Appendix K: Manufacturing and Material Costing

This appendix includes a detailed analysis on the manufacturing costs associated with creating a single unit and also the costs associated with creating 1000 units. The cost to create a single unit was estimated to be $868.96 while the cost to create 1000 units was estimated to be $130,763.30 or $130.76 per unit.

K.1: Manufacturing Time and Labour Costs

The total cost of building a single unit or a prototype unit for testing purposes is $868.96. This cost includes purchasing the machines, paying the wage of a carpenter and the total cost of the materials. This cost does not include the personal protective equipment costs that have been added as supplemental information later on in this Appendix. Table 9 summarizes the labor costs and times estimated for a single carpenter to make a single unit. Please note that the average wage of a carpenter is 37.00 per hour.

Table 9: Manufacturing Time and Labor Costs

Cutting Plywood		
Tasks Completed	Time (minutes)	Cost ($)
Long cuts of plywood	10.00	6.17
Cutting Vents	3.00	1.85
Total Cost		8.02
Assembling Plywood		
Securing Panels	7.00	4.32
Attaching the bottom and 3 side panels using wood screws	24.00	14.80
Total Cost		19.12
Installing Hinges and Handles		
Screwing Hinges and Handles	7.00	4.32
Stapling Wire Mesh		
Securing and stapling	2	1.23
Inserting Components		
Inserting PCM, Shipping bar & supports, queen cages)	7.00	4.32
Total Estimated Time to Build Prototype	**60.00**	
Total Labor Cost to Build Prototype:		**37.00**

In order to estimate the benefit of mass manufacturing these units it was assumed that 1000 units would be produced. A single carpenter is estimated to take 1000 hours to complete an order of this size. If five carpenters are hired to create this order it would be assumed that each carpenter spends roughly 200 hours making roughly 200 units if all five of them were working on this project independent of one another. Studies show that compartmentalizing work or creating specialized workstations can increase productivity. It is therefore assumed that five stations could be set up, this would include one station for the table saw, one station for the jigsaw, two stations for the OSB assembly and one station for the combined tasks of stapling the mesh screens over the vents and inserting the remaining components. BRTE believes that this system minimizes the additional tools needed and will save 15 minutes per unit of time, reducing the total time for order to be completed at 750 billable hours. Table 10 summarizes the relevant labor cost information.

Table 10: Task and Total Cost of Labor Workers

	Time (hours)	Labor Cost ($)
One Carpenter	1000	37,000.00
Five Carpenters	750	27,750.00

K.2 Material Costs

Table 11 specifies the cost of the materials used to build the shipping container for both a single unit and 1000 units. Please note that in the column “Number of parts per unit” if the value is fractional it indicates that the smallest quantity available can create more than a single unit.

Table 11: Material Cost Detail for Building Prototype and for Mass Manufacturing

Product Description	Material	Dimensions	Number of parts per unit	Cost per part	Cost per unit	Number of parts per 1000 units	Cost per 1000 units
Plywood	OSB	4’x8’x0.375"	1/5	$12.20	$12.20	200	$1,996.00
BlockVesl	Phase Change Material	9.93" x 12.97"	3	$20.00	$60.00	3000	$60,000.00
ABS Filament	ABS	1.75 mm (DIA)	2/13	$25.99	$25.99	154	$4,002.46
Bee Cages (100 pack)	JZ-BZ Plastic	8.75" x 5.5" x 1.75"	72/100	$19.95	$19.95	720	$14,364.00
24 Bee Shipping Bar	JZ-BZ Plastic	238mm x 44mm x 33mm	3	$1.35	$4.05	3000	$4,050.00
Hinges	Satin Nickel	2"	2	$2.77	$5.54	2000	$5,540.00
Screws (100 pack)	Satin Nickel	#9X1”	36/100	$6.28	$6.28	360	$2260.80
Side Handles	Iron Chroming	3-3/4 “	2	$4.98	$9.96	200	$9,960.00
Staples (1250 pack)	Stainless Steel	1/2"	6/1250	$4.27	$4.27	4.8	$20.50
Total Cost to Build Prototype:						**$ 148.24**	
Total Cost for Mass Manufacturing:						**$ 102,193.76 (102.19)**	

Table 12 provides a cost specification of the tools purchased to build a single unit or to produce 1000 units.

Table 12: Cost Specification of Tools

Tools	Cost per Unit	Cost for Prototype	Cost for Mass Manufacturing
Table Saw	$449.00	$449.00	$449.00
Staple Gun	$44.98	$44.98	$44.98
Jigsaw	$84.98	$84.98	$84.98
Saw Replacements	$21.24	$0	$21.24 (spare blade)
Drill	$99.89	$99.89	$199.78 (two drills)
Drill bits	$4.89	$4.89 (one spare bit)	$19.56 (2 drills, two spare drill bits)
Total Machine Costs for Prototype:			**$ 683.72**
Total Cost for Mass Manufacturing:			**$ 819.54**

K.4 Personal Protective Equipment Costs

The purchasing of personal protective equipment (PPE) to build a prototype and for mass manufacturing will be a onetime cost. Table 14, shown below, describes the cost description of the PPE required for this project, please note that the cost for creating 1000 units is assuming that all 5 carpenters are hired.

Table 13: Cost Specification of Personal Protective Equipment

PPE	Unit Price	Cost for Building Prototype	Cost for Mass Manufacturing
Coveralls	$ 33.50	$ 33.50	$ 167.50
Safety Googles	$ 25.20	$ 25.20	$ 126.00
Hearing Protection	$ 22.00	$ 22.00	$ 110.00
Hard Hats	$ 13.00	$ 13.00	$ 65.00
Gloves	$ 23.00	$ 23.00	$ 115.00
Dust Mask	$ 12.00	$ 12.00	$ 60.00
Steel Toed Boots	$ 89.99	$ 89.99	$ 449.95
Total Cost to Build Prototype:			**$ 218.69**
Total Cost to Mass Manufacture:			**$ 1,093.45**

K.5 Quotes & Price Comparison

Superior Lumber – OSB Plywood

DATE 11/26/19

SUPERIOR LUMBER LTD.1972
7040-71ST
EDMONTON AB T6B2M4
780-468-3222 FX 468-3297

PAGE 1

ACCOUNT: A41-00 LOCATION 01 -
PHONE NO (780) 735-0506

A/R ADDRESS
ALBERTA HEALTH SERVICES
ACCTS. PAYABLE 10TH FLR N.
10030 - 107 STREET
EDMONTON AB T5J 3E4

DELIVERY INSTRUCTIONS
NO DELIVERIES BEFORE 8:30,
@9:30, NOON OR 2:30 PM

ORDER # 321842-00
ORD DATE 11/26/19
INVOICE#
INV DATE
DEL DATE 11/26/19
SALES ID 004
PO QUOTE
STATUS QUOTE

Total Weight: 9750.00

Product	U/M	Qty Ord	Qty Del	Description	Price U/M	Unit Price	Total Price	Loc
4838OSB	EA *	250		4X8-3/8" OSB SQ EDGE TO BE CUT TO 1000 PCS 2' X 4'	EA	12.200	3050.00	01
CUT		1		CUTTING FEE INCLUDES PALLETIZING		2000.000	2000.00	

ALLOW 1 WEEK FOR DELIVERY

INCLUDES DELIVERY ANY-
WHERE IN CITY OF EDMONTON
AND IMMEDIATE SURROUNDING
AREAS OF LEDUC, BEAUMONT,
NISKU, SHERWOOD PARK,
ST.ALBERT AND ACHESON

PRICE ON OSB IS BASED
UPON THE CURRENT MILL
COST AND MAY FLUCTUATE;
PLEASE CONFIRM PRICING AT
THE TIME OF ORDER

NET BALANCE	5050.00
TOTAL GST/HST	.00
TOTAL PST	.00
TOTAL	5050.00

Glenora Lumber – OSB Plywood

Peter Rudanec prudanec@glenoralumber.ca via megamailservers.com
to me, Kerry
Tue, Nov 26, 9:49 AM (2 days ago)

Good Morning,

Pricing as follows –

250 sheets 4 X 8 X 3/8 OSB – 13.10 each

Labour to cut 1000 pcs to 24" X 48" – $ 600.00

Thank you for the opportunity to quote.

BeeMaid Bee Supplies – Bee Cages and Cell Bars

Christie Martens
to me, Divina, Lisa
1:07 PM (27 minutes ago)

Hi Mickyas,

I was given the message that you are looking for 66,000 queen cages and 3,000 shipping bars. At that larger quantity the price for the queen cages will drop to $0.28 each from the regular $0.35 each. As for the shipping bars we could offer them to you for $2.65 each in comparison to the regular price of $2.95 each. Please note that the only cell bars available to us hold 46 queen cages per bar.

As per our previous email exchange the quantities of cages and cell bars that you are looking for will have to be special ordered as we do not have such large quantities on hand. Because of the large quantities you are needing please allow some extra lead time when you order as these items will have to be shipped from our supplier.

Please let me know if you have any other questions or would like us to place this order for you.

Thank you,

Christie Martens
Beekeeping Coordinator

BeeMaid
BEE SUPPLIES

Direct Line: (780) 960-8005
Toll Free: (800) 213-6131
Email: cmartens@beemaid.com

beemaid.com

Blue Sky Bee Supply – Cell Bars

Erin Minnier
to me
Nov 22, 2019, 12:02 PM (7 days ago)

Just to clarify, we are discussing the orange shipping bars attached, correct?

We can accommodate an order for these. For such a large order, we would require 100% pre-payment up front via wire transfer. I can imagine that there would be a bit of lead time as well.

Also, for this quantity, we would be able to offer them at $2.25 each + truck freight charges.

The challenge will be that a shipment of this size would be sent via freight so you would need to provide us with an address for them to be delivered in the U.S. as we do not have a way of brokering truck freight in to Canada. Do you have a location on the States' side where they could be delivered?

Please let me know. 😊

Thank you again,
Erin

Dancing Bee Honey – Bee Cages and Cell Bars

Todd Kalisz Dancing Bee
to me

7:40 AM (54 minutes ago)

Hello Mickyas,
Sorry for the delay I have been at the Saskatoon bee meeting.
We can do the queen cages for .20 and the cell bars for $155 for a box of 100.
Let me know if you would like to order.
My cell is 289-771-2623 if you have any questions.
Where are you located ? With that volume order I think there are other items you might need from us that I can do much better pricing on.
Thanks

...

Todd

Cryopak - Gel Packs (Phase Change Material)

FGIC74086
16 OZ
24 UNITS/ CASE
60 CASES/ PALLET
Cost: 15.20$/case

SHIPPING:
If you are not picking up the shipment, there will also be freight cost. We will look into the least expensive option for you. Freight cost depends on a few factors, distance, weight and if there is a loading dock or any challenges a driver may face.

Let me know what you think.

...

Cynthia Baldassarre
Inside Sales Representative/Customer Service
Représentante aux ventes interne/Service à la clientèle
cbaldassarre@cryopak.com
Cryopak Industries (2007) ULC
11 000 Boul, Parkway
Montréal, QC H1J 1R6
tel:514-324-4720 ext: 322/fax:514-324-9623
Cryopak

VWR Avantor Sciences – Gel Packs (Phase Change Material)

vwr
part of avantor

2360 Argentia Road
Mississauga ON L5N 5Z7

To Place an Order / Pour Commander	
Phone / Tél. :	1-800-932-5000
Fax / Téléc. :	1-800-668-6348
Web :	https://ca.vwr.com
Email / Courriel :	Canada_Orders@vwr.com

When placing your order, please include your quotation number and account number to ensure you receive the correct price.
Fournir numéro de client VWR et référence de soumission lors de vos commandes.

THANK YOU FOR THE OPPORTUNITY TO EARN YOUR BUSINESS.
MERCI DE FAIRE CONFIANCE A VWR.

QUOTE / SOUMISSION

Quote / Soumission	Valid From / En vigueur	Valid To / Jusqu'au	Page
8602535008	11/29/2019	12/29/2019	1 of 2

Currency / Devise	Sales Rep / Représentant	Reference / Référence
CAD	Peter Lavallie	Cold Packs

Prepared For/Soumission à l'attention de	Phone(Tél)/Fax(Téléc)/Mail(Courriel)
Mickyas Etana	etana@ualberta.ca

Ship To / Livraison : 86022516	Sold To / Facturation : 86022413
AB UNIV OF SUPPLY NET ORDERS CENTRAL RECEIVING 116STREET & 85AVE EDMONTON AB T6G 2R3 CANADA	AB UNIV OF SMS SUPPLYNET COUPA POFLIP WEB BILLING CENTRAL RECEIVING 116 ST 85TH AVE EDMONTON AB T6G 2R3 CANADA

Item / Article	VWR Catalog No. / No. cat. VWR	Description	Qty / Qté	UOM / Unité	Unit Net Price / Prix Unitaire	Ext Net Price/ Prix total
10	33500-356	GEL PACK KOOLIT CMC 8.8X5.5X1.5 CS24	125	CS	29.95	3,743.75
		List Price / Liste des Prix : [illegible] Koolit® Gel Packs, Gel Pack Refrigerants, Cold Chain Product Link : https://ca.vwr.com/store/catalog/product.jsp?catalog_number=33500-356 Shipping Dimensions Weight / Size (L*W*H) per UOM : 37.000 LB / 13.500*10.500*15.000 IN UOM Component Info : CS(24/case) Availability : Ordered Upon Request				
20	75845-342	FOAM BRICK POLAR 20 OZ CS24	125	CS	43.23	5,403.75
		List Price / Liste des Prix : [illegible] PolarPack® Foam Brick, Ice Pack Refrigerant Ice Bricks, Sonoco ThermoSafe Product Link : https://ca.vwr.com/store/catalog/product.jsp?catalog_number=75845-342 Shipping Dimensions Weight / Size (L*W*H) per UOM : 39.000 LB / 13.000*13.000*6.880 IN UOM Component Info : CS(24/case) Availability : Product on Order. Estimated delivery date will be provided after order is placed				

Quote Total / Valeur Totale : 9,147.50

VWR TRADE SECRET/CONFIDENTIAL/PROPRIETARY INFORMATION (SECRET COMMERCIAL/CONFIDENTIELLE/TERME PRIVILÉGIÉ VWR)

BEE RIGHT THERE

vwr part of avantor

QUOTE / SOUMISSION			
Quote / Soumission	Valid From / En vigueur	Valid To / Jusqu'au	Page
8602535008	11/29/2019	12/29/2019	2 of 2
Currency / Devise	Sales Rep / Représentant	Reference / Référence	
CAD	Peter Lavallo	Cold Packs	

2360 Argentia Road
Mississauga ON L5N 5Z7

Financing Available. Contact your VWR Representative for details about flexible financing programs.

PRICES SUBJECT TO CHANGE DUE TO CURRENCY FLUCTUATIONS

Transport fees as per standard terms and conditions unless indicated otherwise in this quotation. Taxes not included.

VWR International's Terms and Conditions of Sale apply. A copy is available on our website ([illegible]), or by request. Customer represents that it has read and agrees to VWR International's Terms and Conditions of Sale.

Identified stock status is based on product availability at time of the quote and may change at time of order. Delivery dates are based on standard lead times from suppliers.

Any images used are not necessarily representative of any product offering from VWR International and do not constitute the basis for purchase decisions.

Customer is responsible for unloading and providing standard receiving facilities for large and/or heavy shipments. Special unloading or delivery can be arranged, provided VWR International is notified at the time of order placement. For such arrangements, please contact VWR International for a quotation. All quotes for installation assume that services related to the equipment are in place at the Customer site (including, but not limited to, gas, plumbing, electrical and ventilation) as per the equipment manufacturer's specifications prior to the installation of the equipment. Installation or other services are not included in this quotation, unless otherwise noted on the quotation.

Customer has a limited amount of time to document and report any shipping damage. Please inspect all shipments upon receipt and refer to Section 4 of VWR International's Terms and Conditions of Sale for additional information.

Items prefixed with "MISC-" are subject to regulatory approval once VWR International receives acceptance from the customer. They are special order, and as such may not be returnable. Please allow 6-8 weeks delivery from the time of your first order or acceptance of this quotation.

Financement disponible. Veuillez contacter votre représentant pour plus détails à propos de nos programmes flexibles.

VWR SE RESERVE LE DROIT DE REVISER LES PRIX DU A LA FLUCTUATION DU TAUX DE CHANGE.

Frais de transport selon les termes et conditions standard, sauf sur indication contraire plus bas. Taxes en sus.

LES TERMES ET CONDITIONS DE VENTES STANDARD DE VWR S'APPPLIQUENT SAUF SI INDIQUÉS. Les termes sont disponibles sur le site internet [illegible] ou sur demande. Les parties déclarent par les présentes qu'ils exigent que cette entente et tous les documents y afférents, soit pour le présent ou l'avenir, soient rédigés en langue anglaise seulement.

La disponibilité d'inventaire au moment de la soumission peut changer à tout moment avant la commande. Les délais de livraison sont basés sur les délais standards des fournisseurs de VWR.

Les images représentées peuvent différer des articles de la soumission et ne constituent pas une base pour une décision d'achat.

Installation non incluse, sauf si indiquée dans la soumission. Le client est responsable de fournir les installations adéquates pour la réception de gros équipements. Si un camion avec plateforme est nécessaire, un surplus sera chargé. Pour livraison autre qu'au quai de réception, svp nous contacter pour les coûts supplémentaires.

L'installation, qu'elle soit incluse ou non, n'inclut pas les entrées de gaz, de plomberie, de ventilation, l'alimentation électrique ou autres. Le client est responsable de fournir les installations conformes aux spécifications du fabricant pour le bon fonctionnement des appareils.

Le client est responsable d'inspecter la livraison dès sa réception. Si un dommage externe est décelé et avant d'accepter la marchandise, il doit immédiatement aviser le transporteur et réclamer une inspection sur place de ce transporteur. Si la marchandise reçue comporte des dommages internes ou cachés, le client doit contacter VWR dans les 24 heures afin de procéder à une réclamation pour "dommages cachés".

Le client doit documenter et signaler tout dommage dû au transport dans les délais établis. Veuillez contrôler tous vos colis lors de leur réception et vous référer à la section 4 des Conditions Générales de Ventes de VWR International pour plus d'informations.

Les articles codés avec préfixe " MISC " sont en commande spéciale et ne peuvent être annulés ou remboursés. Veuillez allouer 6 à 8 semaines de livraison à partir de votre première commande. Les articles codés avec préfixe MISC sont sujets aux approbations réglementaires. VWR International ne pourra fournir un produit qui ne rencontre pas les critères des normes et lois canadiennes et sera dans l'obligation d'annuler la commande sans aucune pénalité pour VWR.

VWR TRADE SECRET/CONFIDENTIAL/PROPRIETARY INFORMATION (SECRET COMMERCIAL/CONFIDENTIELLE/TERME PRIVILÉGIÉ VWR)

Phase Change Material Products Ltd. – Gel Packs

---------- Forwarded message ---------
From: <info@pcmproducts.net>
Date: Tue, Oct 22, 2019 at 12:57 AM
Subject: RE: PCM/19/10/020/ZU, RE: PCM for Bee Shipping
To: Cole Hancheryk <hanchery@ualberta.ca>
Cc: Michael Primrose <msprimro@ualberta.ca>, <adam.dicken@pcmproducts.net>, Hayley Beasley <hayley.beasley@pcmproducts.net>

Sounds like you may be able to use medium size ice packs and normally cost could be around US$ 6.00~10.00 / ice pack depending on order volume.

As the range is very big we do not keep any ready made samples. We can treat this small amount as sample. All samples are made to order. Although we have the raw materials in stock but we do not keep any ready made PCM in stock and all samples are made to order. Regarding samples, we can not use our automated reactor vessels for any small scale PCM production less than 1 Ton which has to be manufactured by hand. This process takes 1 ½ ~ 2 days to prepare the sample and carry out the essential quality freeze and melt cycles / tests before shipment and therefore unfortunately any sample order will be subject to minimum handling charges of **£(GBP) 250.00** (for each temperature range) plus export packaging & documentation charges.

The above cost applied to each and every temperature range samples so multiply then above by three if you wish to try S27/S30/S32 versions.

Regards

Zafer

Table 14: Price Comparison between Various Companies Costs for Products

OSB (Oriented Strand Board) Plywood 4'x8'x3/8"	Superior Lumber	$12.20	**$ 12.20**
	Glenora Lumber	$13.10	
	Home Depot	$12.75	
Phase change Material	Cryopak Industries	$22.00	**$ 20.00**
	VWR	$29.95	
	BlockVesl	$20.00	
Shipping Bars	BeeMaid Bee Supplies	$2.65	**$ 1.35**
	Blue Sky Bee Supply	$2.25	
	JZ-BZ	$1.35	
ABS Filament Spool	Rep Rap Warehouse	$ 32.59	**$ 15.95**
	iPrint 3D Inc.	$ 30.99	
	Amazon	$ 25.99	
Bee Cages	BeeMaid Bee Supplies	$ 0.28	**$ 0.19**
	Dancing Bee Honey	$ 0.20	
	JZ-BZ	0.19	
Utility Hinges	Home Depot	$ 2.68	**$ 2.68**
	Global Industrial	$ 10.00	
	Hinge Outlet	$ 7.33	
Side Handles	Etsy	$ 12.50	**$ 2.00**
	Alibaba	$ 2.00	

	Grainger	$ 3.15	
Staples (staple gun)	Amazon	$ 13.99	**$ 4.79**
	Home Depot	$ 14.97	
	Lowes	$ 4.79	
	Lowes	$ 7.39	
	Amazon	$ 3.25	

K.6 Cost References

[1] Butt Hinges Cost - 2 Inch Zinc Narrow Hinge Fixed Pin (2-Pack). (.n.d.). Retrieved from https://www.google.com/shopping/product/5091999375781189194?lsf=seller:6472097,store:17413161453037518061&prds=oid:11053087074132375049&q=butt+hinges+2+holes&hl=en&ei=bxPYXaCCOOPY9AOT9aNw&lsft=gclid:EAIaIQobChMIteDh9KT-5QIVEh6tBh1G-gLaEAYYBCABEgLQv_D_BwE,gclsrc:aw.ds

[2] Wood Screws Cost - Slotted Hinge Screws for Doors - Satin Nickel - Flat Head. (n.d.). Retrieved from https://www.hingeoutlet.com/collections/wood-screws/products/slotted-hinge-screws-for-doors-satin-nickel-flat-head-9-x-3-4-inch

[3] Metal Handles Cost - Metal Handles For Service Tool Box. (n.d.). https://www.alibaba.com/product-detail/Metal-Handles-for-Service-Tools-Box_60830118939.html?spm=a2700.7724857.normalList.131.6db9403edXNhnz

[4] PLA 3D Printing Spool Cost - White - 1.75mm Value PLA Filament - 1 kg. (n.d.). Retrieved from https://3dprintingcanada.com/products/white-1-75mm-value-pla-filament-1-kg?utm_medium=cpc&utm_source=google&utm_campaign=Google%20Shopping&gclid=EAIaIQobChMIv62tzdqE5gIVmB-tBh3MrA7hEAQYASABEgIxePD_BwE

[5] Stainless Steel Staple Cost - Arrow Fastener 508SS1 1/2-Inch Genuine T50 Stainless Staples. (September 15, 2011). Retrieved from https://www.amazon.ca/Arrow-Fastener-508SS1-Stainless-000-

Pack/dp/B000OMJWNA/ref=sr_1_7?keywords=stainless+steel+staples+for+staple+gun&qid=1574667306&sr=8-7

[6] Corded Screwdriver Cost - 5.5 Amp Corded 3/8 in. Variable Speed Compact Drill/Driver with Bag. (n.d.). Retrieved from https://www.homedepot.com/p/RYOBI-5-5-Amp-Corded-3-8-in-Variable-Speed-Compact-Drill-Driver-with-Bag-D43K/205216326

[7] Staple Gun Cost - T50 Heavy Duty Staple Gun. (n.d.). Retrieved from https://www.homedepot.com/p/Arrow-Fastener-T50-Heavy-Duty-Staple-Gun-T50/100021099

[8] Router Bit Cost - T50 Heavy Duty Staple Gun. (n.d.). Retrieved from https://www.homedepot.com/p/Diablo-1-2-in-x-1-in-Carbide-Flush-Trimming-Router-Bit-DR42104/100660716

[9] Sand Paper Cost - Pro Grade Precision 9 in. x 11 in. 80 Grit Coarse Advanced Sanding Sheets (4-Pack). (n.d.). https://www.homedepot.com/p/3M-Pro-Grade-Precision-9-in-x-11-in-80-Grit-Coarse-Advanced-Sanding-Sheets-4-Pack-26080PGP-4/205415911

[10] Varnish Coating and Brush Cost - 1 qt. Clear Gloss Spar Varnish Coatings (6-Pack). (n.d.). Retrieved from https://www.homedepot.com/p/Rust-Oleum-Marine-1-qt-Clear-Gloss-Spar-Varnish-Coatings-6-Pack-207008/202558038?keyword=varnish+coating&semanticToken=20310000111_2019112503202128888_r6q0+20310000111+%3E++cnn%3A%7B0%3A0%7D+cnr%3A%7B7%3A1%7D+cnd%3A%7B4%3A0%7D+cne%3A%7B8%3A0%7D+cnb%3A%7B9%3A0%7D+cns%3A%7B5%3A0%7D+cnx%3A%7B3%3A0%7D+st%3A%7Bvarnish+coating%7D%3Ast+oos%3A%7B0%3A1%7D+pt%3A%7Bvarnish+coating%7D%3Apt+dln%3A%7B584834%7D+qu%3A%7Bvarnish+coating%7D%3Aqu

[11] Coveralls Cost - Big Al Coverall. (n.d.). Retrieved from https://www.gostwear.com/coverall-promotion-p-226.html?currency=CAD&gclid=EAIaIQobChMI9eqHpf6E5gIVkx6tBh2khwaSEAYYBSABEgJD1fD_BwE

[12] Safety Goggles Cost - Everest Safety Glasses. (n.d.). Retrieved from https://www.uline.ca/Product/Detail/S-5685/Safety-Glasses/Everest-Safety-Glasses?pricode=YF342&gadtype=pla&id=S-5685&gclid=EAIaIQobChMI5rP80_6E5gIVKSCtBh0irwXuEAQYAiABEgIOZPD_BwE&gclsrc=aw.ds

[13] Hearing protection Cost - Uline Earmuffs - Lime. (n.d.). Retrieved from https://www.uline.ca/Product/Detail/S-20706LIME/Hearing-Protection/Uline-Earmuffs-Lime?pricode=YF268&gadtype=pla&id=S-20706LIME&gclid=EAIaIQobChMI3bmC8v6E5gIV1RZ9Ch0gxA9QEAQYASABEgILOPD_BwE&gclsrc=aw.ds

[14] Hard Hat Cost - Hard Hat White. (n.d.). Retrieved from https://www.uline.ca/Product/Detail/S-10512W/Hard-Hats/Hard-Hat-White?pricode=YF236&gadtype=pla&id=S-10512W&gclid=EAIaIQobChMI7tKHnfGB5gIVER6tBh06_gESEAYYASABEgLbo_D_BwE&gclsrc=aw.ds

[15] Gloves Cost - Uline Gription Gloves - Black. (n.d.). Retrieved from https://www.uline.ca/Product/Detail/S-12553BL-X/Performance-Gloves/Uline-Gription-Gloves-Black-XL?pricode=YE333&gadtype=pla&id=S-12553BL-X&gclid=EAIaIQobChMIq-yh1_GB5gIV4SCtBh354gOjEAQYAyABEgL5yvD_BwE&gclsrc=aw.ds

[16] Dust Mask Cost - Uline Standard Dust Mask. (n.d.). Retrieved from https://www.uline.ca/Product/Detail/S-5687/Disposable-Respirators/Uline-Standard-Dust-Mask?pricode=YF193&gadtype=pla&id=S-5687&gclid=EAIaIQobChMI7J28_PGB5gIVRCCtBh1NiQQkEAQYAiABEgJuPPD_BwE&gclsrc=aw.ds

[17] Steel Toe Boots Cost - Men's 6" Lynx II Steel Toe Steel Plate Work Boots. (n.d.). Retrieved from https://www.marks.com/en/aggressor-mens-6-lynx-ii-steel-toe-steel-plate-work-boots-29785.html?cid=DRMKT&gclid=EAIaIQobChMIw5uhz_-E5gIVYh6tBh2LnQtqEAQYASABEgJuhPD_BwE&gclsrc=aw.ds#29785%5Bcolor%5D=TAN&29785%5Bsize%5D=7%201%2F2&29785%5Bwidth%5D=WID&fo_c=1301&fo_k=6893223559603445d53c704174723f48&fo_s=gplaca

[18] Router Table Cost – SKIL RAS900 Router Table. (October 11, 2013). Retrieved from https://www.amazon.ca/Skil-RAS900-SKIL-Router-Table/dp/B002G9UG0C/ref=pd_sbs_469_3/131-0965097-2012442?_encoding=UTF8&pd_rd_i=B002G9UG0C&pd_rd_r=370fccbb-65f2-4480-bfb9-5bdbdc89557f&pd_rd_w=cZAic&pd_rd_wg=eE3CJ&pf_rd_p=c7838c3c-6de6-

46ad-946c-b7318af714fb&pf_rd_r=KFSR9WYXSTDVQWJ5PNCX&psc=1&refRID=KFSR9WYXSTDVQWJ5PNCX

[19] Drill Bits Cost - Shockwave Impact Duty Titanium Drill Bit Set (15 Piece). (n.d.). Retrieved from https://www.homedepot.com/p/Milwaukee-SHOCKWAVE-IMPACT-DUTY-Titanium-Drill-Bit-Set-15-Piece-48-89-4630/205879023

[20] Drill Press Cost - 10 in. Drill Press with EXACTLINE Laser Alignment System. (n.d.). Retrieved from https://www.homedepot.com/p/RYOBI-10-in-Drill-Press-with-EXACTLINE-Laser-Alignment-System-DP103L/205503636

[21] Power Tools, Saws, and Table Saws (n.d.). Retrieved November 26, 2019 from https://www.homedepot.com/b/Tools-Power-Tools-Saws-Table-Saws/N-5yc1vZ2fkokih

[22] Calculating Shop Rate - How to calculate your shop rate. (September 2, 2016). Retrieved from https://www.creativebloq.com/business/how-calculate-your-shop-rate-71621306

K.7 Return on Investment

3125 containers will be needed to import the current number of queens into Canada. A single healthy queen bee is expected to maintain a hive for 5 years in Canada. When a queen's sperm is damaged from heat spikes this viability can be reduced significantly as pointed out in Phase II. In phase II it was assumed that if the queens are assumed to be consistently damaged during the importation process then the total revenue added would be $1,152.00 per box per trip. This is a high estimation because it assumes that every single shipment of imported bees prior to the implementation of this design would be damaged. There is not currently enough accessible data that indicates the actual number of viable bee shipments, so a conservative estimate of 10 percent was selected for shipments that have been compromised by heat spikes. Now if this design is implemented it is assumed that the 10% that would have been compromised will now be healthy meaning that of the 3125 containers used 313 more containers full of bees will be viable. Each queen bee is worth $40 when imported. Table 15 displays a summary of the update on the return on investment calculations.

Table 15: Return on Investment Phase II Revision

Phase II Estimation of Return on Investment per Container	Increased number of viable queen containers.	Total increase in value per year.
$1,152.00	313	$360,576.00

It should also be noted that this design is intended to last 10 years versus the current importation method that is a single use cardboard container that costs approximately $15 and can import 28 bees. Because this design can be mass produced at $130.76 per unit the customer will begin saving additional money in year four even if the increased viability is ignored. Please see the summarized savings below.

Table 16: Year by Year Cost Savings

Year	Cost Using Current Method to import 225,000 bees ($)	Cost Using PPCD design to import 225,000 bees	Money saved due to increased queen viability
1	120,535.71	408,635.21	(360,576.00)
2	120,535.71	0	(360,576.00)
3	120,535.71	0	(360,576.00)
4	120,535.71	0	(360,576.00)
5	120,535.71	0	(360,576.00)
6	120,535.71	0	(360,576.00)
7	120,535.71	0	(360,576.00)
8	120,535.71	0	(360,576.00)
9	120,535.71	0	(360,576.00)
10	120,535.71	0	(360,576.00)
Total	1,205,357.10	408,635.21	(3,605,760.00)

Table 16 above shows over a ten-year period this design is will cost $408,635.21 while the saving $3,605,760.00 in terms of viable product compared to the current method that will cost $1,205,537.10 during the 10 year period.

Appendix L: Project Management

L.1: Gantt Chart Phase 1

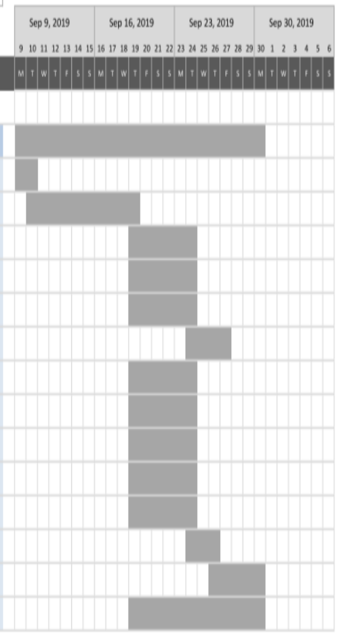
Design Shipping Container for Queen Bees

Bee Right There Engineering
Project Lead: Cole Hancheryk

SIMPLE GANTT CHART by Vertex42.com
https://www.vertex42.com/ExcelTemplates/simple-gantt-chart.html

Project Start: 2019-09-09
Display Week: 1

TASK	ASSIGNED TO	COMPLETE BY	ESTIMATED EFFORT (HRS)	ACTUAL EFFORT (HRS)	PROGRESS	START	END
Phase 1: Design Specification and Project Plan			90	88	100%	9-Sep-2019	30-Sep-2019
Letter of Intent	Cole Hancheryk	Cole Hancheryk	3	3	100%	9-Sep-2019	10-Sep-2019
Background Research	Team 10	Team 10	20	18	100%	10-Sep-2019	19-Sep-2019
Design Specification Matrix	Michael Primrose/Chuanchen Xiao	Michael Primrose/Chuanchen Xiao	15	15	100%	19-Sep-2019	24-Sep-2019
Design Objective	Mickyas Etana	Mickyas Etana	4	4	100%	19-Sep-2019	24-Sep-2019
Design Constraints and Customer Requirements	Mickyas Etana	Mickyas Etana	2	2	100%	19-Sep-2019	24-Sep-2019
Manufacturing Considerations	Chuanchen Xiao	Chuanchen Xiao	4	4	100%	24-Sep-2019	27-Sep-2019
IP Ownership Agreement	Cole Hancheryk	Cole Hancheryk	2	2	100%	19-Sep-2019	24-Sep-2019
Design Standards and Regulations	Neelanjana Chatterjee	Neelanjana Chatterjee	4	4	100%	19-Sep-2019	24-Sep-2019
Marketing and Sales Information	Cole Masse	Cole Masse	8	8	100%	19-Sep-2019	24-Sep-2019
Project Schedule	Cole Hancheryk/Michael Primrose	Cole Hancheryk/Michael Primrose	14	14	100%	19-Sep-2019	24-Sep-2019
Cost Analysis	Cole Hancheryk	Cole Hancheryk	2	2	100%	19-Sep-2019	24-Sep-2019
Compile Phase 1 Report	Neelanjana Chatterjee, Cole Hancheryk	Neelanjana Chatterjee, Cole Hancheryk	4	4	100%	24-Sep-2019	26-Sep-2019
Phase 1 Report Review	Team 10	Team 10	8	8	100%	26-Sep-2019	30-Sep-2019
Phase 1 Report	Team 10	Team 10			100%	19-Sep-2019	30-Sep-2019



L.2 Gantt Chart Phase II

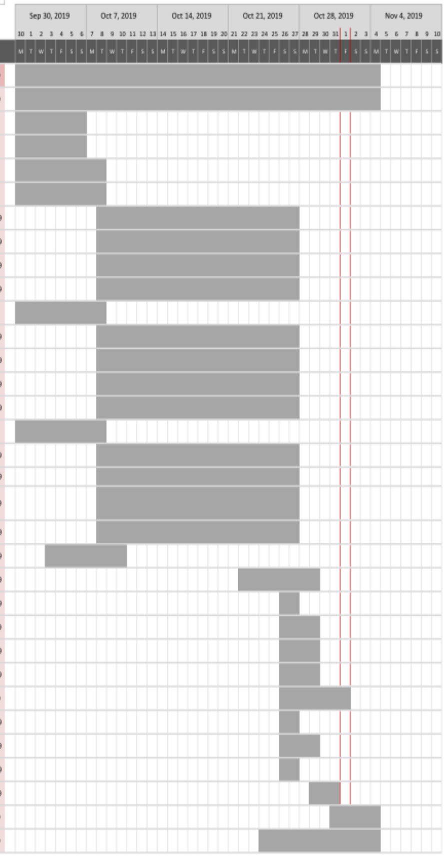
Design Shipping Container for Queen Bees

Bee Right There Engineering
Project Lead: Cole Hancheryk

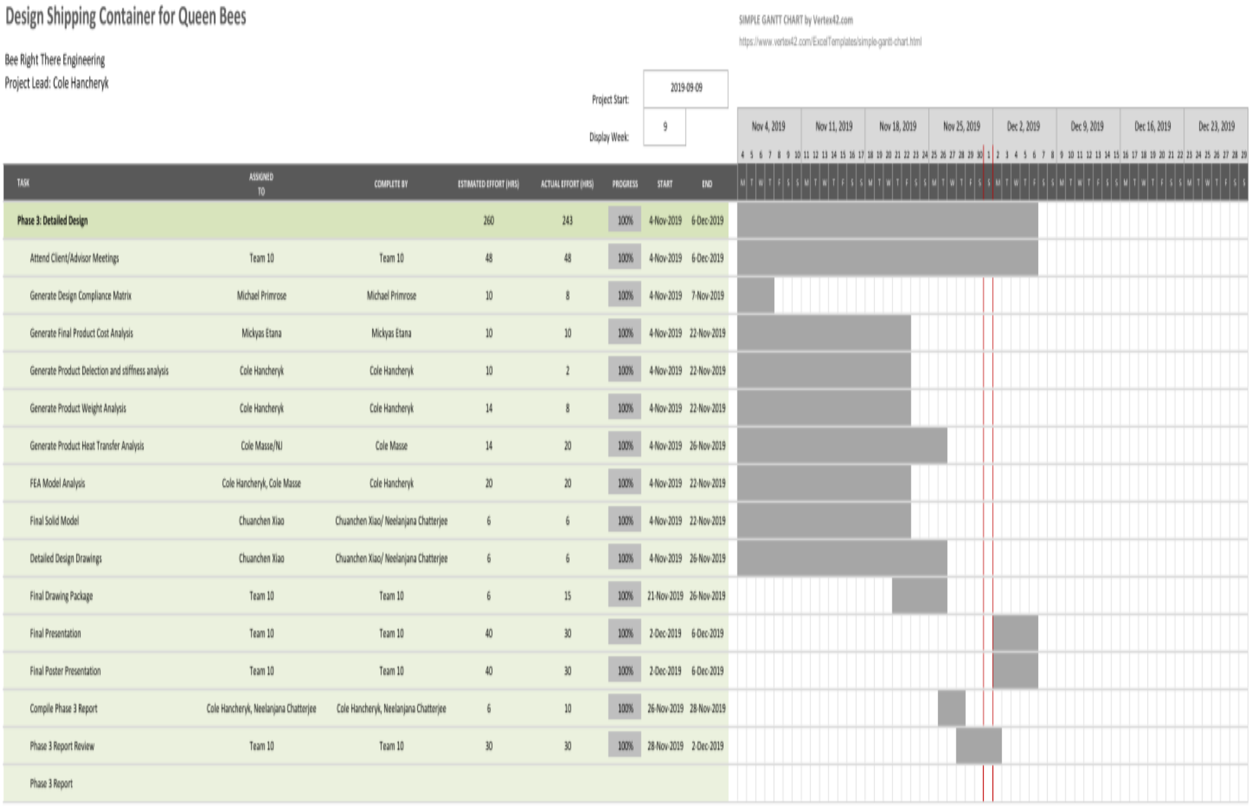
SIMPLE GANTT CHART by Vertex42.com
https://www.vertex42.com/ExcelTemplates/simple-gantt-chart.html

Project Start: 2019-09-09
Display Week: 4

TASK	ASSIGNED TO	COMPLETE BY	ESTIMATED EFFORT (HRS)	ACTUAL EFFORT (HRS)	PROGRESS	START	END
Phase 2: Conceptual Design			200	226	100.0%	30-Sep-2019	4-Nov-2019
Attend Client/Advisor Meetings	Team 10	Team 10	42	34	100%	30-Sep-2019	4-Nov-2019
Research Existing Products	Team 10	Team 10	18	18	100%	30-Sep-2019	6-Oct-2019
Brainstorm Conceptual Design	Team 10	Team 10	15	17	100%	30-Sep-2019	6-Oct-2019
Three Conceptual Designs Selection	Team 10	Team 10	2	1	100%	30-Sep-2019	8-Oct-2019
Concept 1 Design Drawing	Michael Primrose	Michael Primrose	1	1	100%	30-Sep-2019	8-Oct-2019
Concept 1 Cost Estimate	Cole Hancheryk	Cole Hancheryk	5	5	100%	8-Oct-2019	27-Oct-2019
Concept 1 Solid Models	Chuanchen Xiao	Chuanchen Xiao	3	4	100%	8-Oct-2019	27-Oct-2019
Concept 1 Design Heat Calculations	Michael Primrose	Michael Primrose	10	14	100%	8-Oct-2019	27-Oct-2019
Concept 1 Design Weight Calculation	Cole Hancheryk	Cole Hancheryk	6	10	100%	8-Oct-2019	27-Oct-2019
Concept 2 Design Drawing	Chuanchen Xiao	Chuanchen Xiao	1	1	100%	30-Sep-2019	8-Oct-2019
Concept 2 Cost Estimate	Chuanchen Xiao	Chuanchen Xiao, Cole Hancheryk	4	4	100%	8-Oct-2019	27-Oct-2019
Concept 2 Solid Models	Chuanchen Xiao	Chuanchen Xiao	3	3	100%	8-Oct-2019	27-Oct-2019
Concept 2 Design Heat Calculations	Cole Masse	Cole Masse, Michael Primrose	10	10	100%	8-Oct-2019	27-Oct-2019
Concept 2 Design Weight Calculation	Cole Masse	Cole Masse, Cole Hancheryk	4	6	100%	8-Oct-2019	27-Oct-2019
Concept 3 Design Drawing	Mickyas Etana	Neelanjana Chatterjee	1	1	100%	30-Sep-2019	8-Oct-2019
Concept 3 Cost Estimate	Mickyas Etana	Neelanjana Chatterjee	2	1	100%	8-Oct-2019	27-Oct-2019
Concept 3 Solid Models	Chuanchen Xiao	Chuanchen Xiao	3	6	100%	8-Oct-2019	27-Oct-2019
Concept 3 Design Heat Calculations	Mickyas Etana	Mickyas Etana, Michael Primrose,Neelanjana Chatterjee, Cole Masse	8	13	100%	8-Oct-2019	27-Oct-2019
Concept 3 Design Weight Calculation	Mickyas Etana	Neelanjana Chatterjee	4	4	100%	8-Oct-2019	27-Oct-2019
Set-up Evaluation Matrix For Proposed Designs	Michael Primrose	Michael Primrose	2	4	100%	3-Oct-2019	10-Oct-2019
Final Design Selection	Team 10	Team 10	2	2	100%	22-Oct-2019	29-Oct-2019
Write Summary of Concept Generation	Chuanchen Xiao	Cole Hancheryk	2	2	100%	26-Oct-2019	27-Oct-2019
Write Description of Three Design Concepts	Cole Hancheryk, Cole Masse, Mickyas Etana	Cole Hancheryk, Cole Masse, Neelanjana Chatterjee	4	3	100%	26-Oct-2019	29-Oct-2019
Write Summary of Key Design Analysis	Mickyas Etana	Cole Masse	2	2	100%	26-Oct-2019	29-Oct-2019
Write Common Design Features and Guidelines Section	Chuanchen Xiao	Cole Hancheryk	2	2	100%	26-Oct-2019	29-Oct-2019
Project Management	Cole Hancheryk	Cole Hancheryk	12	20	100%	26-Oct-2019	1-Nov-2019
Write Cover Letter	Cole Hancheryk	Cole Hancheryk	2	2	100%	26-Oct-2019	27-Oct-2019
Write Excutive Summary	Neelanjana Chatterjee	Neelanjana Chatterjee	2	2	100%	26-Oct-2019	29-Oct-2019
Write Introduction and Conclusion	Michael Primrose	Michael Primrose	2	2	100%	26-Oct-2019	27-Oct-2019
Compile Phase 2 Report	Team 10	Team 10	6	8	100%	29-Oct-2019	31-Oct-2019
Phase 2 Report Review	Team 10	Team 10	20	24	100%	31-Oct-2019	4-Nov-2019
Phase 2 Report					100%	24-Oct-2019	4-Nov-2019



L.3 Gantt Chart Phase III



Design Shipping Container for Queen Bees

Bee Right There Engineering
Project Lead: Cole Hancheryk

Project Start: 2019-09-09
Display Week: 9

TASK	ASSIGNED TO	COMPLETE BY	ESTIMATED EFFORT (HRS)	ACTUAL EFFORT (HRS)	PROGRESS	START	END
Phase 3: Detailed Design			260	243	100%	4-Nov-2019	6-Dec-2019
Attend Client/Advisor Meetings	Team 10	Team 10	48	48	100%	4-Nov-2019	6-Dec-2019
Generate Design Compliance Matrix	Michael Primrose	Michael Primrose	10	8	100%	4-Nov-2019	7-Nov-2019
Generate Final Product Cost Analysis	Mickyas Etana	Mickyas Etana	10	10	100%	4-Nov-2019	22-Nov-2019
Generate Product Delection and stiffness analysis	Cole Hancheryk	Cole Hancheryk	10	2	100%	4-Nov-2019	22-Nov-2019
Generate Product Weight Analysis	Cole Hancheryk	Cole Hancheryk	14	8	100%	4-Nov-2019	22-Nov-2019
Generate Product Heat Transfer Analysis	Cole Masse/NJ	Cole Masse	14	20	100%	4-Nov-2019	26-Nov-2019
FEA Model Analysis	Cole Hancheryk, Cole Masse	Cole Hancheryk	20	20	100%	4-Nov-2019	22-Nov-2019
Final Solid Model	Chuanchen Xiao	Chuanchen Xiao/ Neelanjana Chatterjee	6	6	100%	4-Nov-2019	22-Nov-2019
Detailed Design Drawings	Chuanchen Xiao	Chuanchen Xiao/ Neelanjana Chatterjee	6	6	100%	4-Nov-2019	26-Nov-2019
Final Drawing Package	Team 10	Team 10	6	15	100%	21-Nov-2019	26-Nov-2019
Final Presentation	Team 10	Team 10	40	30	100%	2-Dec-2019	6-Dec-2019
Final Poster Presentation	Team 10	Team 10	40	30	100%	2-Dec-2019	6-Dec-2019
Compile Phase 3 Report	Cole Hancheryk, Neelanjana Chatterjee	Cole Hancheryk, Neelanjana Chatterjee	6	10	100%	26-Nov-2019	28-Nov-2019
Phase 3 Report Review	Team 10	Team 10	30	30	100%	28-Nov-2019	2-Dec-2019
Phase 3 Report							

L.4 Actual Hours Logged by Team in Phase III

Team Member	Hours	Relative Percentage
Cole Hancheryk	45	**18.52%**
Cole Masse	55	**22.63%**
Mickyas Etana	35	**14.40%**
Michael Primrose	45	**18.52%**
Chuanchen Xiao	33	**13.58%**
Neelanjana Chatterjee	30	**12.35%**
	243.00	

L.5 Actual Hours Logged by Team for Project

Team Member	Hours	RELATIVE PERCENT
Cole Hancheryk	115	**20.65%**
Cole Masse	119	**21.36%**
Mickyas Etana	69	**12.39%**
Michael Primrose	111	**19.93%**
Chuanchen Xiao	65	**11.67%**
Neelanjana Chatterjee	78	**14.00%**
	557.00	