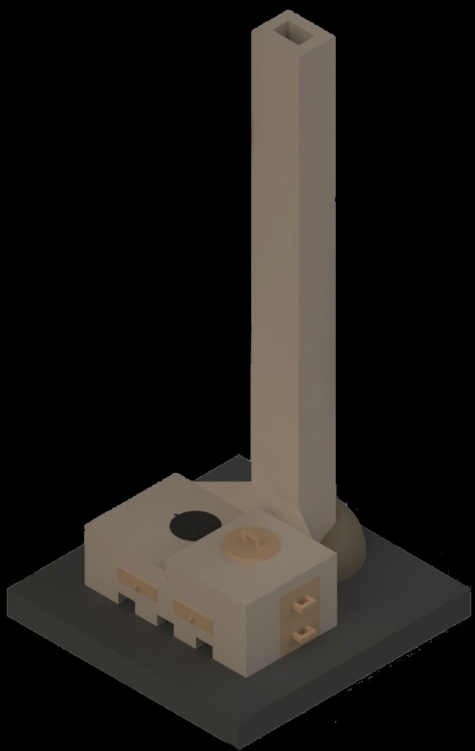
KNACK'D CORPORATION

PHASE 3 REPORT

August 9, 2021



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August 9, 2021

Connor Speer
Project Engineer
Mountains of Relief
PO Box 121
Jasper, AB T0E 1E0

Dear Mr. Speer,

RE: Mountains of Relief Nepal Stove - Phase 3: Design Submission

KNACK'D Corporation is pleased to present the *Phase 3: Design Submission* report for the Mountains of Relief Nepal Stove project. The report outlines the following items below:

- Description of final design
- Design analysis
- Design Compliance Matrix
- SolidWorks CAD assembly and part drawings
- Manufacturing and cost estimates
- Assembly Instructions

A total of 519.5 hours were logged by the team from the beginning of the project which results in a total cost of $47,025. The cost to construct the prototype was $40 CAD and the estimated cost to manufacture the designed stove is 479 NPR or approximately $4.90 CAD per unit.

It was a pleasure working with you on this exciting project and we will patiently wait to see what lies ahead for the stove project and Mountains of Relief organization.

Sincerely,

CC: KNACK'D Corporation team
Ehsan Hashemi, ehashemi@ualberta.ca (Project Advisor)
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Executive Summary

The primary objective of KNACK'D Corporation and Mountains of Relief for this project is to increase the quality of life of rural Nepalese people. This goal is to be achieved by designing an improved biomass cookstove which will decrease harmful smoke emissions and increase fuel burning efficiency compared to existing stoves being used by these people.

To effectively theorize an advanced biomass cookstove, KNACK'D developed three conceptual designs which tackled the design problem in a unique manner. Calculations were performed to determine their behaviour regarding heat transfer, and SolidWorks (CAD) simulations were performed to determine fluid flows. These concepts were then evaluated with the following criteria: necessary physical dimensions, necessary functionality, safety, and manufacturability. After the concepts were considered, the decision was made to move forward with the conventional stove.

The conventional stove follows a more basic design in terms of it shape and function. It features two cooking burner locations and an angular chimney which aids airflow. This stove is designed to be simplistic, yet effectively meet the design goals specified by the client, which are: improved efficiency, reduced smoke exposure to the user, can be easily constructed out of freely available materials, and be maintained easily, while the costing below 500 Nepalese rupees (NPR) per unit (or approximately $5 CAD).

A prototype of the conventional stove was constructed using brick and clay mixtures; real-world testing was performed on this stove. A water boiling test was performed using 1 litre of water and 1 kg of firewood as fuel. It took 14 minutes to bring the water temperature to 100°C. Temperatures were recorded for exterior surface, combustion chamber, air inlet, and chimney outlet using thermocouples. The target exterior surface temperature was 48°C beyond which users can experience first degree burns and the experiment showed that the stove exceeded that by 7°C but could be improved by using thicker bricks. Smoke emissions could not be reasonably quantified during testing due to the inherent difficulty of this procedure and our limited capabilities.

The overall project time logged was 519.5 hours for a final cost of $47,025 CAD. Junior engineer hours totalled 515 hours for a cost of $46,350 CAD and senior advisor hours totalled 4.5 hours for a cost of $675 CAD

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Introduction

Mountains of Relief has contracted KNACK'D Corporation to develop a fuel-efficient, low smoke producing stove for rural Nepalese communities with limited access to electricity and natural gas/propane. This report includes the final design concept for the stove, along with the CAD drawing package and total project cost.

Final Design

Design Revisions

Additional research and meetings with the client have resulted in certain design specifications being changed. The final design compliance matrix can be found in Table 6, which contains further details on the compliance of each specification. The matrix changes are listed below.

1. "Firewood Storage" removed due to the inconvenience to the user; having this installed exceeds the benefits acquired. A storage system takes up additional space, and poses a fire hazard no matter how many precautions are taken, due to its proximity to the fire. Firewood should be stored away from the stove.
2. "Energy Production" value of 2450 kcal changed to 102 kcal. Previous value was from assumptions that all water is vaporized from a starting temperature of 0°C; changed calculations to use a starting water temperature of 5°C and to evaporate 5% of water in under 30 min.
3. "Stove Surface Temperature" maximum temperature changed from 40°C to 48°C, which better reflects the guidelines of the American Burns Association, as this is the temperature where adult skin requires five minutes of exposure for a full thickness burn to occur. Priority level changed from 3 to 5.
4. "Carbon Monoxide Emissions" and "PM10 Concentration" combined into "Emissions." Testing for CO emissions and the PM10 concentrations requires specialized equipment unavailable to the team and is very resource intensive, therefore the two sections have been combined into emissions. Simulations and prototyping will be done to fulfill this section.

Design Features

The finalized conventional stove design is shown in Figure 1 and 2. The stove uses a simple, yet effective method of getting heat to the cooking surface, while simultaneously taking smoke from the combustion chamber and optimizing its flow out through the chimney. The components used to construct this stove are listed in Table 1.

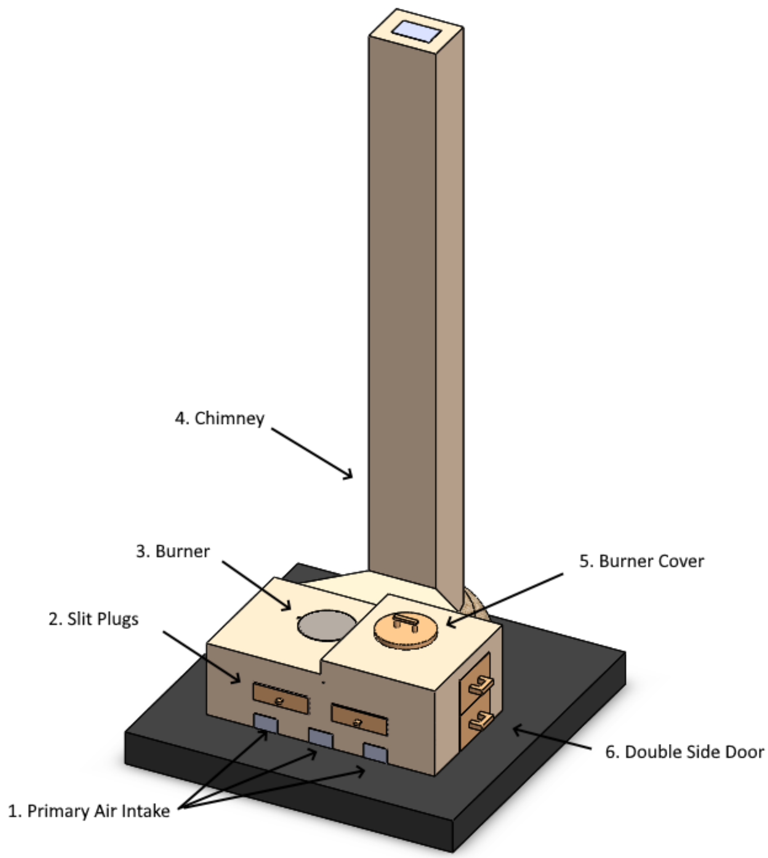

Figure 1: Conventional stove design isometric view

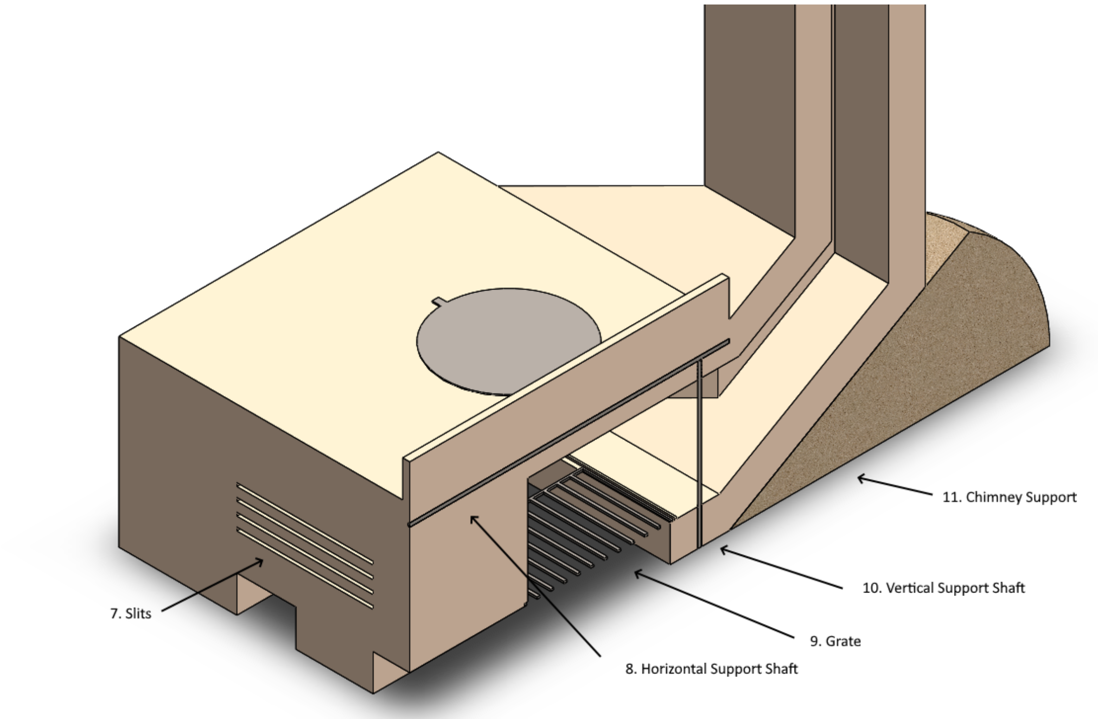

Figure 2: Conventional stove design section view

Table 1: Stove components

Part Number	Part Name	Description
1	Primary Air Intake	Large holes open on the bottom of the stove to provide enough air for combustion
2	Slit Plugs	Plugs to block the slits on the side of the stove, to stop smoke emission or release less heat to the environment
3	Burner	A thin steel plate used to cook food in a flat pot or pan
4	Chimney	Excess smoke and heat are led out of the house through the chimney.
5	Burner Cover	A clay cover for the open burner hole while it is not being used
6	Double Side Door	Double door to allow user to restock fire, move grate, or remove completely to clean out oven
7	Slits	Slits on the side of the oven to provide more heat and light to the home of the user, while also supplying more intake air to the fire
8	Horizontal Support Shaft	A circular beam of metal embedded horizontally in the stove body to support the structure
9	Grate	Steel grate, about half the size of the combustion chamber to set fire on. Can be moved underneath either burner or in the middle of the combustion chamber. Can also be removed if the user wants to build a fire bigger than the grate
10	Vertical Support Shaft	A circular beam of metal embedded vertically in the stove body to support the structure

Design Usability

To make the stove most ergonomic and accessible to the user, several design components were optimized. The first design factor considered which aids in usability is the actual dimensions of the stove itself. As is relevant to cooking practices in Nepal, the stove is 2ft by 2ft in size. This is necessary for the Nepalese, as they prefer to kneel in front of their stove's whilst cooking and the more compact size of the stove allows for it to fit well in their homes. The stovetop has the provisions for two burners. One of these burners is a steel plate, which allows for a normal saucepan style of pot to be cooked with, the other burner is an open hole, which allows for a traditional Nepalese "Kadai" cookpot to be placed in the burner and used as such. The stovetop also has two different heights, one for each burner, which enhances usability and optimizes heat concentration on either burner. Another feature which enhances usability is the door system. The stove has two doors on the side which allows for only the top to be opened when fuel needs to be added, but then both doors can be opened/removed to aid in cleaning and maintenance capabilities. Another user-friendly feature is the grate's sliding groove, which allows for the fire source to be moved under the necessary burner to increase the amount of heat getting to a burner. Another feature is the slits in the front side of the stove. These slits allow for light and heat radiation when the stove is fully heated up, but when the stove is first heating up, or this feature is not in use, there are slit plugs which cover up the holes.

Design Analysis

Prototyping

The prototype built for this project was based around the final digital design, and the scale was made to match as closely as possible. The client was able to provide a budget of $100 CAD, and a large collection of bricks from a previous attempt. The final structure was built out of bricks, stone slabs, and a mud-clay mixture. The bricks were staggered in a 2 x 3.5 brick layout for the main body. Three inlet holes were implemented by leaving a half brick gap, one brick tall. The dirt-clay-water mixture was used to patch holes within the structure and help hold bricks together. The fire sat on top of a grill grate, to allow air flow from the bottom. This elevated grated is shown in Figure 3.


Figure 3: Grill grate inside prototype

The prototype went through two iterations, where the slope towards the chimney was altered and the behaviour of smoke emission was noted. A flat incline towards the stove resulted in smoke blowback up the burner, while the angled approach significantly reduced this. These designs are shown below in Figure 4 and Figure 5, which are the sloped and flat designs respectively.


Figure 4: Sloped preliminary prototype

Figure 5: Flat preliminary prototype

After this testing, a proper burner top was made using a clay mould shown in Figure 6 and a wooden frame to support it on the body of the stove. This final prototype design is shown in Figure 7 and was used for the calculations.

Figure 6: Clay mould


Figure 7: Final prototype design

Other factors recorded was the amount of time for 1kg of water to boil, and how much fuel was required to keep the stove running. These calculations are shown in Appendix A.1: Prototype Calculation Analysis. These results were compared with the digital model. A thermal efficiency was found to be around 2.76%. This low efficiency could be due to failure to measure the exact amount of fuel required to boil 1kg of water, and assuming all the fuel was used. From the transducers, an average surface temperature ranged from around 45-55°C was found. The recorded surface temperature from the thermocouple is shown in Appendix A.3 The results of the water boiling test, fuel consumption, mass flow rate, and smoke emissions are shown below.

Water Boiling Test

Once the prototype was constructed, a water boiling test was conducted using a Kadai shaped pot. One litre of water was measured using a kitchen scale and placed in the pot and fire was lit underneath. Time taken to bring the water to boiling was noted. It took approximately 12 minutes to boil water. When the team spoke to the client's partners in Nepal, they mentioned that they wanted the stove to be able to boil water in around 10 minutes. Although this goal was not met due to imperfect prototype construction, it was very close and could easily be met if the final stove is perfectly moulded with all gaps sealed and with the use of smaller sized pot

Fuel Consumption Test

Fuel consumption testing was performed on the prototype to understand the performance of the stove. Initially, a kilogram of firewood was burned in the stove and the time taken to completely burn the wood was recorded using a stopwatch. More wood was added later, between 1-2.5 kgs of wood was burned and the fire lasted about one hour. Fuel consumption of this stove can be estimated between 0.33 to 0.83 kg/hour. Fuel consumption of the Nepalese stove is estimated to be between 6.67 to 13.33 kg/hour as shown in Appendix A.1

Mass Flow Rate Calculation

Mass flow rate was estimated by using a 25-litre garbage bag and placing it over the chimney outlet and recording the time it took to fill up the bag. It took 27 seconds to completely fill the bag, resulting in a volumetric flow rate of 0.0204 m^3/s, as calculated in Appendix A.2 Density of air was found in the textbook, using that value, mass flow rate was estimated to be 0.0250 kg/s.

Smoke Emissions Testing

The smoke produced by the stove should not be directed towards the user and should only exit out of the chimney. This was validated on both the CAD model and on the prototype, the team found that patching holes with cob mixture prevented any smoke from leaking out.

Carbon monoxide and particulate matter emission testing could not be performed due to complicated nature of the procedure and our inexperience in this field.

SolidWorks Simulations

To optimize the performance of our stove design, a SolidWorks fluid simulation was performed to analyze the fluid flow and heat transfer throughout the stove body. Three parameters on the chimney were selected to be altered iteratively, while recording and comparing the theoretical burner surface temperature and mass flow rate out of the chimney for each iteration. The wall thickness was also altered to decrease the surface temperature of the stove exposed to the user. A detailed breakdown of the set-up, process, and results of these fluid simulations can be found in Appendix B.

Design Optimization

The three chimney parameters selected for optimization were the chimney slope angle, divergence angle, and chimney height. These parameters are shown in Figure 8, Figure 9 and Figure 10.

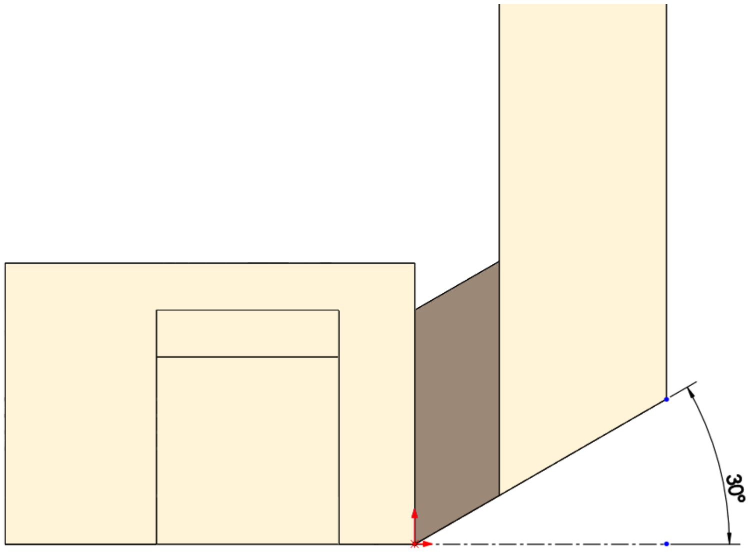

Figure 8: Side view of stove body indicating slope angle

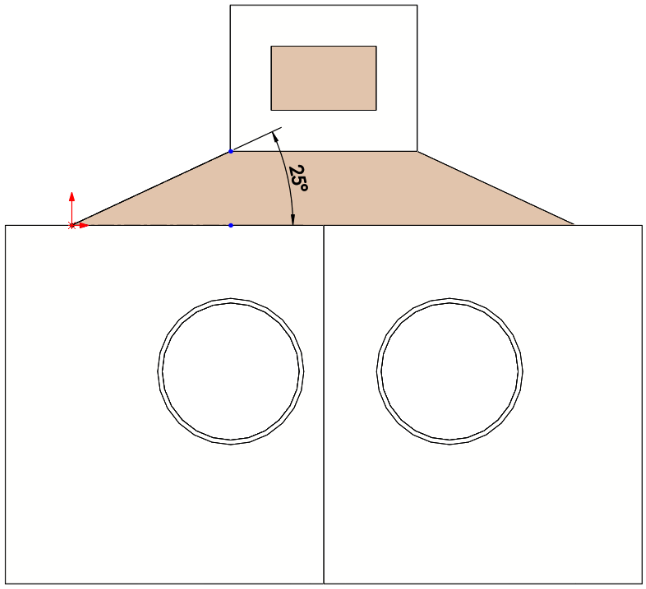

Figure 9: Top view of stove body indicating divergence angle

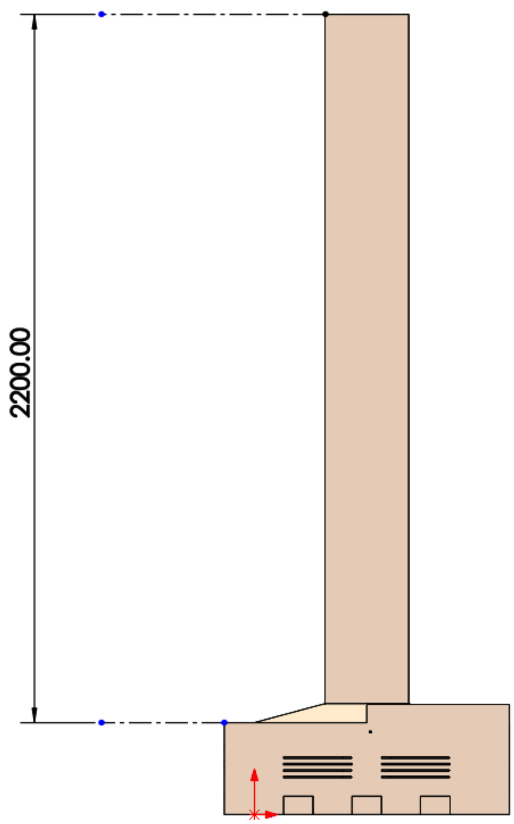

Figure 10: Front view of stove body indicating chimney height

For the chimney slope angle and divergence angle, the optimal angles were determined to be 30˚ and 25˚ respectively. For the chimney height, the optimal height was determined to be between a range of 2.2m to 2.8m meters tall, measured from the lower stove top. The wall thickness was also doubled to 184mm from the previous iteration, as this maintained the ability to build the stove out of bricks if available and substantially reduced the surface temperatures exposed to the user. A surface temperature contour of the stove after increasing the wall thickness can be seen in Figure 11.

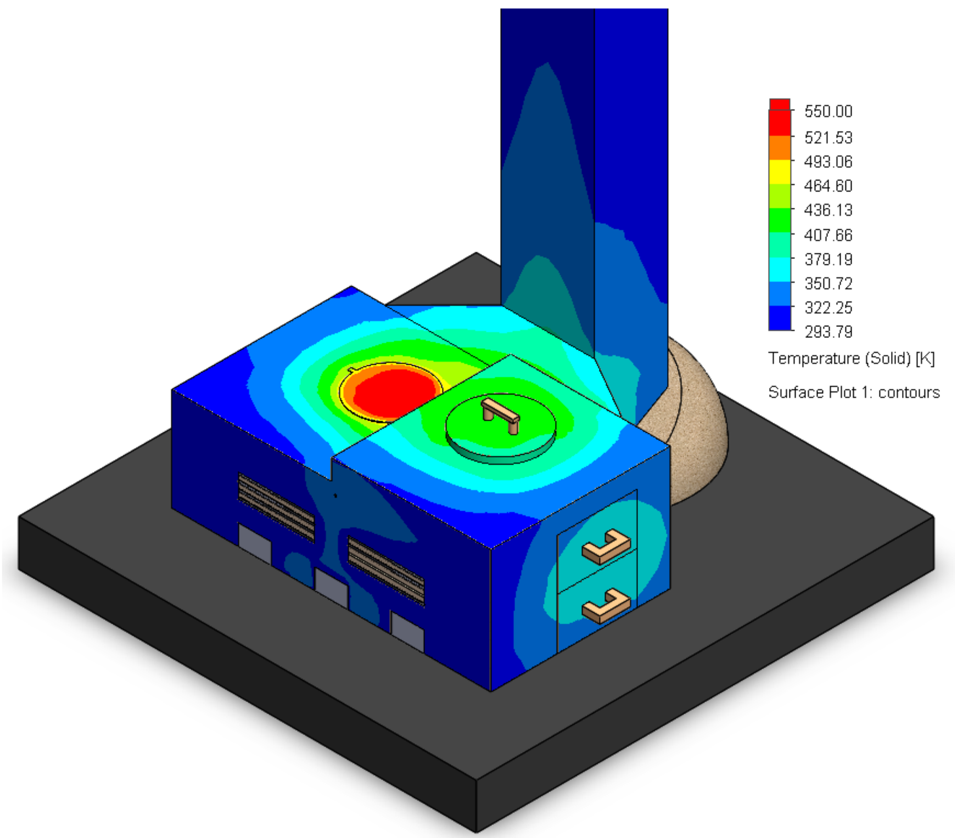

Figure 11: Surface temperature contour of final stove design

Final Fluid Flow and Heat Transfer Analysis

After implementing the changes to optimize the stove design, a final fluid simulation was conducted to study the flow throughout the system which can be seen in Figure 12, Figure 13, and Figure 14.

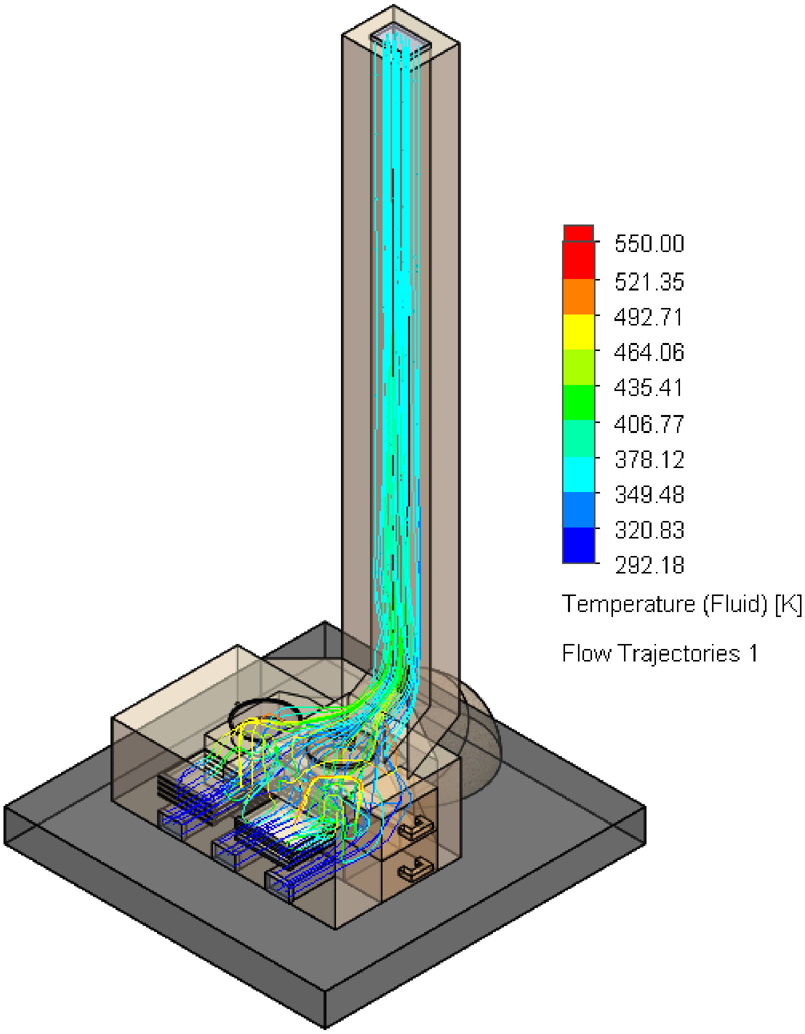

Figure 12: Isometric overview of final fluid simulation

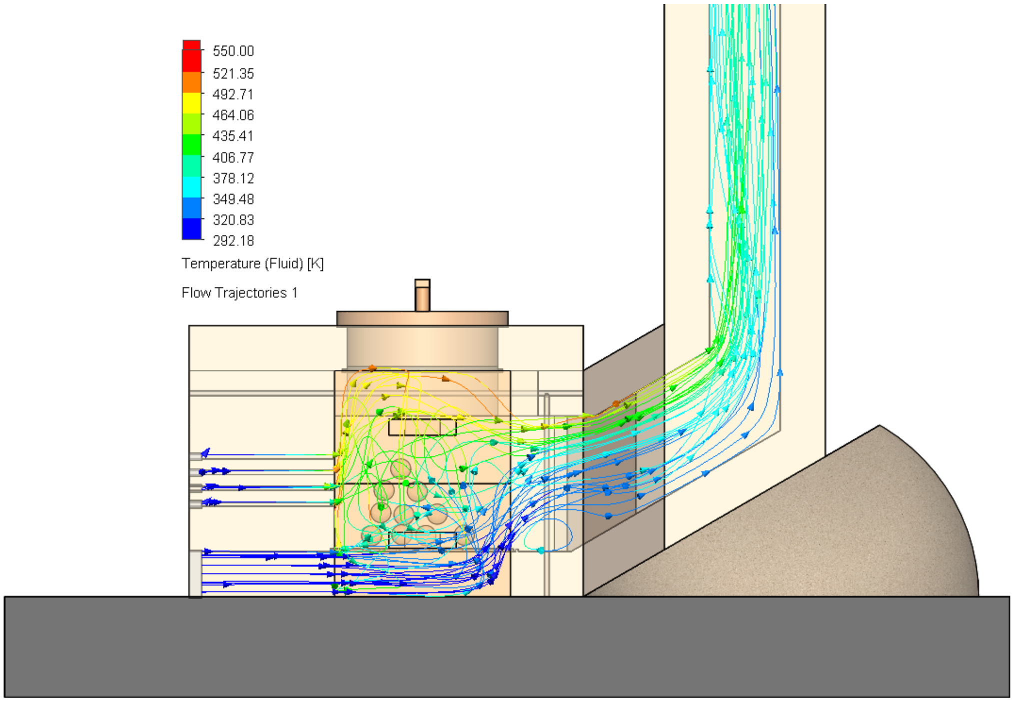

Figure 13: Side view of final fluid simulation

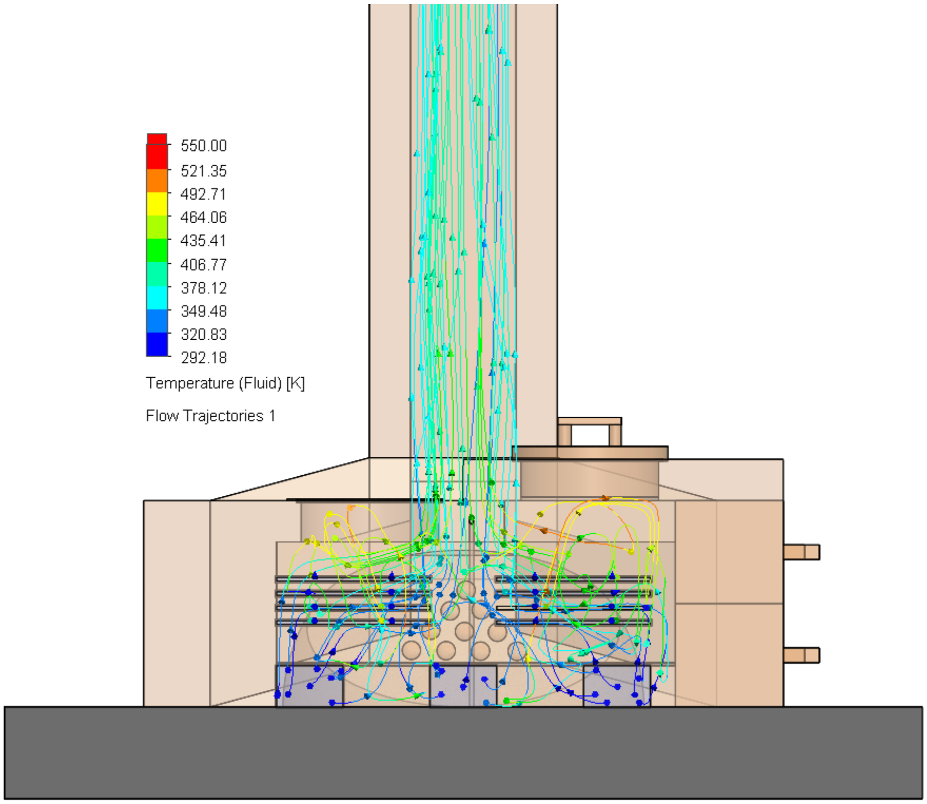

Figure 14: Front view of final fluid simulation

In analyzing the fluid flow, the air successfully flows in through the inlets, circulates underneath both burners, and flows out of the chimney without recirculating out the inlets. Thus, the flow circulation within the stove should theoretically prevent the user from being exposed to any combustion products while wood is burning within the stove and both burner holes are covered. The final measured burner temperature was recorded to be 525 K, around 252 ˚C, and the final mass flow rate out of the chimney was recorded to be 0.0240 kg/s.

Safety Analysis

The oven effectively lessens smoke outflow to the user as the majority of the unused smoke is depleted through the chimney. The user is also protected from the fire through utilizing a two-entryway door system. The oven surface temperature was likewise intended to not surpass 48 °C to dispose of the danger of burns. However, that standard was not particularly fulfilled as the recorded surface temperature was found to be slightly higher at between 45 °C and 50 °C. Furthermore, the design also introduces some underlying risks like sharp corners and possibly unstable stove structure, chimney, and door. Such dangers can be relieved as found in Table 3 underneath.

Table 2: Risk matrix

		Severity		
		Low (Little to no harm)	Moderate (Harmful)	High (Life Threatening)
Probability	Rarely (Occur less than once a year)		• Burns from operation • Cut from sharp corners • Chimney Falling	• House fire • User exposure to fire • Structure collapsing
	Possible (occur once a month)	• Pinching fingers in door • Door tipping	• Emission Leak	
	Certain (Occur daily)			

Table 3: Risk mitigation

Scenario	Solution
Risk of emission leakage	Ensure all gaps are fully sealed with cob or mud
Risk of user exposure to fire	Two-door design gives user flexibility to avoid contact with fire
Risk of burn due to high surface temperature	Practice caution while stove is hot or line the walls with another layer of bricks
Risk of cuts due to sharp corners	Practice caution while around stove
Risk of chimney collapsing	Reinforce chimney with extra bricks and cob
Risk of structure collapsing	Reinforce structure with extra bricks and cob
Risk of door tipping	Increase the width of the door or support it using bricks from the outside

Cost Analysis

Detailed cost analysis has revealed that the total cost for the parts, manufacturing, assembly is 479 NPR. This cost is lower than the Phase 2 estimate of 584 NPR and complies with the maximum cost of 500 NPR in the design specification. A breakdown of the different types of costs can be seen in Table 4. The entirety of the material cost derives from the AISI 1018 carbon steel used, as the cob used for the rest of the stove is assumed to be free and obtained by the user building the stove. This is a fair assumption to make, as the materials that make up cob are extremely plentiful and can be easily obtained in rural Nepal. Firebricks may also be utilized as a replacement for cob, but this is solely up to the discretion of the builder and will not be accounted for in manufacturing calculations. Labor and transportation costs are not included due to the assumption that they will be covered by the builder of the stove. Detailed material and manufacturing calculations can be seen in *Appendix C*.

Table 4: Total costs

Category	Name	Description	Unit Cost (NPR)	Quantity	Total Cost (NPR)
Materials	Metal Burner Plate	0.004 m x 0.2032 m x 0.2032 m AISI 1018 steel plate	265	1	265
Materials	Grate Support Rods	0.006 m diameter x 1 m length AISI 1018 steel rod	45	1	45
Materials	Grate Surface Rods	0.003 m diameter x 1.5 m length AISI 1018 steel rod	17	3	51
Manufacturing	Weld	⅛ in mitre fillet welds for 0.003 m diameter rod	1.5	21	31
Manufacturing	Bend	0.003 m diameter rod bends	26	3	79
Manufacturing	Cut	0.003 m and 0.006 m rods cut cycles	1.5	2	3
Manufacturing	Mill	0.004 m x 0.2032 m x 0.2032 m plate milling	5	1	5
Total					479

Due to the lack of information on the machining industry of Nepal, an average American rate of $50 USD/hr is utilized as the basis of the manufacturing cost calculations [1]. Using an American rate provides extra utility for Mountains of Relief, average Canadian rates are very similar [2].

Materials

The types of materials chosen for the design will have a big impact on the deployment and usage of the biofuel stove. Apart from the functionality being heavily affected, the overall cost and ease of construction will be influenced. Due to the severe cost restrictions imposed, and the lack of material availability in Nepal, the team narrowed down material selection to three materials: cob, carbon steel, and firebrick. Using only these three commonly obtainable materials will aid the project in staying on budget and ensure that procurement of these materials will not hinder the manufacturing of these stoves.

Extensive research has been done into each material to ensure that they are durable, and suitable for high temperatures, while also being easily obtainable and transportable to the rural, hilly regions of Nepal. Cob will be the primary material used to build the stoves, since cob is already commonly used to build stoves in the region and has minimal cost. Selected material properties can be seen in Table 5 below.

Table 5: Material properties for stoves

Material	Thermal Conductivity (W/mK)	Specific Heat Capacity (J/kgK)	Density (kg/m^3)
Cob [3] [4]	0.6	891	1700
AISI 1018 Steel [5]	51.9	472	7870

Design Compliance Matrix

The Design Compliance Matrix, as shown in Table 6, acts as a solitary source outlining all the prerequisites relating to the four subcategories that make up the stove design. It was developed to gauge the design requirements for the stove and was later utilized in administering the design compliance to the requirements. The matrix spans the stove's safety, functionality, manufacturing, and physical specifications. The stove design satisfies all requirements apart from the 48°C top surface temperature and the 75% efficiency score. The maximum surface temperature recorded is 45-55°C and the efficiency is found to be 2.76%, however the stove consumes less wood than Nepalese stoves per hour currently in use.

Table 6: Design compliance matrix

#	Item	Notes / Details	Design Authority	Priority	Design Compliance
PHYSICAL					
1.1	Stove Materials	The material used to construct the stove must be easily obtainable in Nepal	Client	5	Complies
1.2	Maximum Height	The stove shall have a maximum height of 60 cm, not including the chimney	Physical Constraint	5	Complies, height is 34.44 cm
1.3	Maximum Width and Length	Stove should have a maximum length of 150 cm and a maximum width of 100 cm	KNACK'D	4	Complies, dimensions are 49.8 cm x88.5 cm
1.4	Useful Life	The stove should be fully functional for a minimum of 10 years	Client	5	Complies, if regular maintenance is done
FUNCTIONALITY					
2.1	Burners	The stove shall have 1 burner designed for frying and 1 burner designed for boiling; each burner should be 0.203 m in diameter	Client	5	Complies
2.2	Ignition Time	Fire should be stable within 3 minutes of ignition	Client	4	Complies, determined through testing
2.3	Heat Control and Regulation	Should be able to control and regulate the heat produced by the stove for purposes of adjusting heat while cooking and using heat for indoor heating	Client	4	Complies
2.4	Illumination	The stove should be able to emit light while food is being cooked to illuminate the room	Client	2	Complies
2.5	Stove Efficiency	Fuel-to-burner efficiency should be 75% or higher to minimize the wood required to produce energy [6]	Client	5	Does not comply at 2.76%, however the stove consumes less wood than Nepalese stoves per hour currently in use
2.6	Energy Production	Each burner should be able to transfer 102 kcal of energy to the pot in under 30 minutes [7]	Client	5	Complies, prototype produced heat energy at rate of 312.98 kcal in 30 minutes
2.7	Cleaning and Maintenance	Stove interior should be reachable for cleaning and maintenance	Client	3	Complies
SAFETY					
3.1	Stove Surface Temperature	The temperature of the horizontal stove outer surface should not exceed 48°C to eliminate risk of burns [8]	Client	5	Does not comply, maximum surface temperature is 45-55°C
3.2	Emissions	Minimizes emission to the user by ejecting a minimum amount of smoke to stove vicinity	Client	5	Complies through simulations and prototype testing
3.3	Fire Exposure	Design should minimize the fire exposure that the user faces when adding fuel to the stove	KNACK'D	4	Complies
MANUFACTURING					
4.1	Design Cost Estimate	Maximum cost per unit should be 500 NPR	Client	5	Complies, estimated total cost = 479 NPR
4.2	Assembly	Should be assembled with tools commonly available in Nepal including by hand, screwdrivers, pliers, etc.	Client	5	Complies, can be assembled by hand and simple tools
4.3	Ease of Repair	Stove should be repaired with locally available tools and materials at little to no cost	KNACK'D	3	Complies
4.4	Prototype Stove	The working prototype of the stove has a cost limit $100; a lower cost is preferable	Client	5	Complies, total prototype cost = $40 CAD
4.5	Stove Standards	Ensure the biofuel stove follows the Nepalese standard NICB 2016	Client / KNACK'D	5	Complies

Priority	Description
5	A must have; key feature required by the client
3-4	A should have; feature highly desired but not mandatory for function
1-2	A nice to have; bonus feature that is not required or desired but adds value to the design

Client Approval	Not Available
Client Sign Off:	---
Date:	---
Comments:	The team last communicated with the client on July 28. Although our client was not available to review our final report and compliance matrix due to him being on a trip with no access to internet, his colleague Michael Nicol-Seto visited the project poster at the Zoom Capstone conference and provided positive feedback.

Project Management

For Phase 3, 168.5 hours were spent on the project, which is slightly higher than the Phase 1 estimate of 166 hours and significantly higher than the Phase 2 revised estimate of 139 hours. Reasons behind the underestimation of hours include the prototype taking longer than projected to build and underestimation of the time required to organize different sections of the report. An additional factor is the inexperience of the team in terms of managing projects and estimating time.

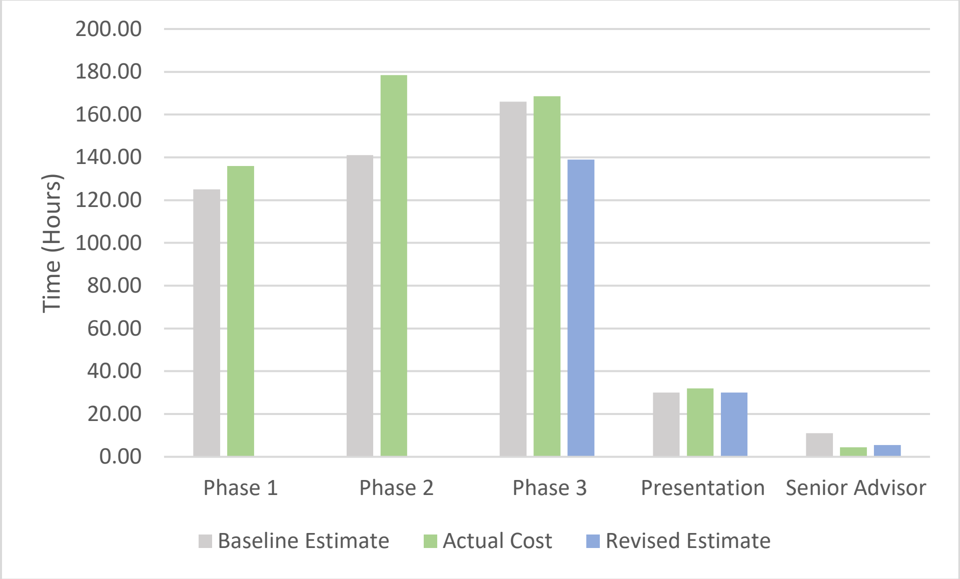

Figure 15: Baseline, actual and revised project hours

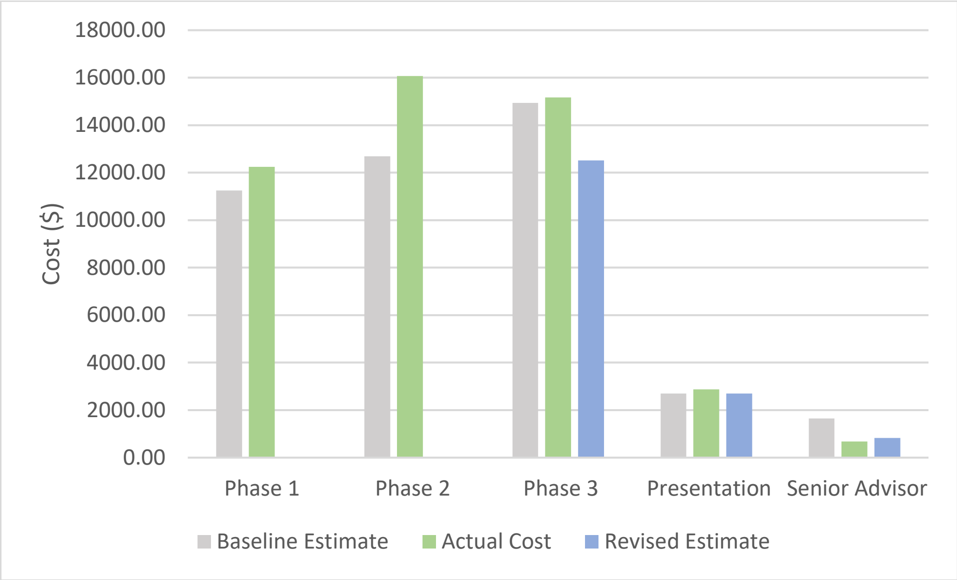

Figure 16: Baseline, actual and revised project costs

The breakdown of hours and costs can be seen in Figure 15 and Figure 16, respectively. The initial estimate projected the total hours to be 473 and the total cost to be $43230. Phase 2 revisions decreased the total hours to 440.5 and total cost to $39975. With a 10% contingency applied, the cost of the Phase 1 and 2 estimates are $47553 and $43972.5, respectively. The final cost of the project is $47025, which is significantly higher than both the estimated total costs. It exceeds the contingency cost of the Phase 2 revised estimate but stays within the contingency cost of the Phase 1 estimate. KNACK'D Inc realizes that the actual cost has unfortunately exceeded the Phase 2 estimate by $7050, but acknowledges that as the cost is not real, and will receive this as a learning opportunity to estimate better in the future. Breakdown of total project costs is shown in Table 7 below.

Table 7: Project costs

Item	Actual Hours	Cost / Hour ($)	Subtotal ($)
Phase 1	136	90	12240
Phase 2	178.5	90	16065
Phase 3	168.5	90	15165
Presentation	32	90	2880
Senior Advisor Fees	4.5	150	675
Total	519.5	-	47025

Future Considerations

The chimney is vertical, and rainwater can go down the chute, to prevent this from happening a 90-degree elbow can be placed on the opening to let the exhaust out or the chimney can be designed with a horizontal exit. If the budget were to be increased, some additional features such as preheating incoming air to the burner using hot exhaust gases in the chimney could be incorporated. The door can be made of fire-resistant glass, so the user can view the fire instead of opening the doors which in turn causes emissions to enter the house.

Conclusion

In the KNACKD Wood Burning Stove project, a cost-effective, low-emission, and safe stove was designed and tested for Mountains of Relief. Features include a sloping chimney design that allows for smoke to escape effectively, and two burners at different heights to provide control over cooking temperatures. Detailed design calculations, cost analyses, and prototype testing was conducted to determine the stove compliance with the required specifications. It was seen that the KNACKD Wood Burning Stove complies with all but two specifications. Due to extenuating circumstances, KNACK'D Corporation has not been able to reach the client since July 28, 2021 and has thus not been able to obtain client sign off. However, another member of Mountains of Relief has provided positive project feedback at the Zoom Capstone Conference.

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Appendices

Appendix A: Prototype analysis

Appendix A.1: Prototype Calculation Analysis

Assumptions made during the progress of this analysis:

- Fluid flow through the stove is in steady state
- Heat transfer into the ground is ignored
- Surface Temperature of clay and steel is homogenously spread

The energy analysis of flow through the stove can be represented in the Figure A 1.

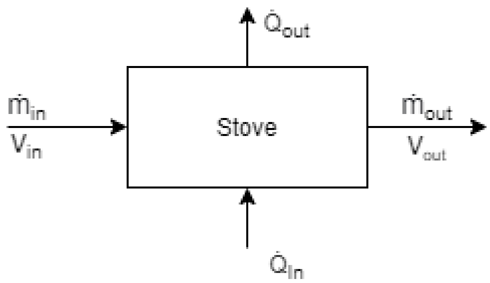


Figure A 1: Energy flow of stove

The energy flow of a system can be written in the mathematical form shown in Equation A-1.

$$\dot{Q}_{in} + \dot{W}_{in} + \sum_{in} \dot{m}\left(h + \frac{V^2}{2} + gz\right) = \dot{Q}_{out} + \dot{W}_{out} + \sum_{out} \dot{m}\left(h + \frac{\dot{V}^2}{2} + gz\right) \qquad \text{(A-1)}$$

To calculate the efficiency of this system, the following equation can be used is shown in equation (A-2).

$$\eta = \frac{Heat\ Used}{Input\ Heat} \qquad \text{(A-2)}$$

The equation A-1 can be used to determine the energy radiating out of the stove, and conduction analysis can be done to determine the energy used to heat up the water. Equation A-1 Can be simplified into A-3. This is because there is no physical work being put in or out of the system, and the elevation of the air intake can be assumed 0. The assumption of steady state dictates that $\dot{m}_{in} = \dot{m}_{out}$.

$$\dot{Q}_{in} + \dot{m}\left(h_{in} - h_{out} + \frac{V_{in}{}^2 - V_{out}{}^2}{2} + gz_{out}\right) \qquad \text{(A-3)}$$

The enthalpy difference can be converted into

$$h_{in} - h_{out} = c_v(T_1 - T_2) \quad \text{(A-4)}$$

Where c_v is the specific heat capacity of air, and T_1 and T_2 is the air temperature of the inlet and outlet respectively. A-3 is further changed into equation A-5 to represent this conversion.

$$\dot{Q}_{in} + \dot{m}\left(c_v(T_1 - T_2) + \frac{V_{in}^2 - V_{out}^2}{2} + gz_{out}\right) = \dot{Q}_{out} \quad \text{(A-5)}$$

On the day of testing the prototype, the atmospheric air temperature was measured to be 28°C. This was set to be the inlet temperature. The acceleration due to gravity is assumed to be $9.81\ m/s^2$.

The team had borrowed temperature thermocouple to measure the surface and air temperatures. The exit chimney temperature was found to be around 200°C.

The measured surface temperature of the prototype was measured to be around 40-45°C, and water within the wok was able to come to a boil. Using a textbook [1], the heat capacity of air was found to be $c_v = 0.718\ kJ/kgK$. The top of the chimney was 5ft above the air, or 1.524 m.

The mass flow rate was found by measuring the volumetric flow rate of air out the chimney. This was done by measuring the amount of time it took to fill a 25L garbage bag with air. This was measured to be around 1.23 seconds. This resulted in a volumetric flow rate of:

$$25L = 0.025\ m^3$$

$$\dot{v} = \frac{0.025m^3}{1.23s} = 0.0204\frac{m^3}{s}$$

Dividing this by the cross-sectional area of the chimney, the velocity can be found. Multiplying the volumetric flow rate by the density will result in the mass flow rate. The density of air is given in the textbook [A1] as $\rho = 1.225\ kg/m^3$. The cross-sectional area of the chimney top was measured to be around $15\ cm\ x\ 7\ cm = 0.0105m^2$. The following calculations were done to obtain the mass flow rate and velocity of the exit.

$$\dot{m} = 1.225 * 0.0204 = 0.0250\ kg/s$$

$$V_{out} = \frac{0.0204}{0.0105} = 2.38\ m/s$$

The volumetric flow rate could not be measured for the inlets, so it was assumed that the three inlet ports have the same volumetric flow rate as the exit. The ports had the same cross-sectional area as the inlets. The total cross-sectional area of the inlet was calculated to be $0.0105 * 3 = 0.0315m^2$. The inlet velocity was found to be:

$$V_{in} = \frac{0.000925}{0.0315} = 0.0648\ m/s$$

A research paper gave the energy output of air-dried wood to be around $18.99\ MJ/kg$. In this experiment, 1 kg of wood was burned, resulting in $\dot{Q}_{in} = 18990kJ$. The time it took for the wood to burn was 12 minutes. This results in a final $\dot{Q}_{in} = 26.5kW$ Solving equation A-5 to find $\dot{Q}_{out}$ is shown below.

$$0.718\frac{kJ}{kgK} * (28 - 200)K = -123.496\ kJ/kg$$

$$\frac{(0.02939)^2 - (0.0882)^2 m^2/s^2}{2} = -3.4577 * 10^{-3} J/kg = -3.4577 * 10^{-6}\ kJ/kg$$

$$9.81 * 1.524 = 14.95\frac{m^2}{s^2} = 0.01495\frac{kJ}{kg}$$

$$26.5 + 0.001134 * \left(-123.496\ - 3.4577 * 10^{-6} - 0.01495\frac{kJ}{kg}\right) = \dot{Q}_{out}$$

$$\dot{Q}_{out} = 26.36\ kW$$

Next, the heat required to boil 1 kg of water will be analyzed. This heat will be used in calculating the efficiency of the stove.

The energy required can be found using the following formula:

$$E = c * m * (100 - T) + \Delta h_{vap} * m_{vap} \qquad \text{(A-6)}$$

$$Q = E/t \qquad \text{(A-7)}$$

By dividing this energy by the time recorded to get the water to boil, the rate of energy can be found. Here, c is the specific heat of water, m is the mass of water being boiled, T is the initial temperature of the water, and Δh_{vap} is the specific enthalpy of vaporization of water. m_{vap} is the mass of the water that evaporated.

From the prototype the water began to boil after 12 minutes of exposure. The water within the wok was weighed first, with a total mass of 1kg and an initial temperature of 24℃. The specific enthalpy of vaporization has a value of $2.260\frac{kJ}{g}$ and the specific heat of water is $4.186\frac{J}{g}$℃. After boiling, the mass of the water was weighed again. The amount of water remaining was around 964g. This resulted in $m_{vap} = 36\ g$. The resulting energy requirement for water to boil is shown:

$$E = \frac{4.186}{1000} * 1000 * (120 - 24) + 2.26644 * 50$$

$$E = 515.178\ kJ$$

$$Q = \frac{515.178}{12 * 60} = 0.7155kW$$

Using this amount of energy, the resulting efficiency is found to be:

$$\eta = \frac{0.728kW}{26.375kW} * 120 = 2.76\%$$

This method was also used in the research paper [A2]. This small efficiency calculation could be due to the high temperatures already present in the

The fuel efficiency was calculated as well and compared to interview results done with members of the Mountains of Relief program. They have stated that a typical Nepalese home will use around 20-40 kg of firewood per day, with a total use of around 3 hours a day. During multiple testing sessions, the stove was able to boil water in a wok in around 10-12 minutes and kept burning for around an hour. During these sessions, around 1-2.5kg of wood was used.

The Nepalese fuel consumption per hour can be rounded to 6.67-13.33 kg/hour. The KNACK'D prototype stove top has a resulting fuel consumption of 0.33-0.83 kg/hour.

One of the tech specs was to determine the amount of kcal per burner. This value can be determined by using the rate of energy that was able to heat the 1 kg of fuel. This conversion can be found in [A3].

$$0.728kw = 625.97\ kcal/hr$$

This value within 30 minutes is shown as:

$$625.97kcal/hr * (\frac{1hr}{60min}) * (30min) = 312.98kcal$$

Overall, the prototype design did not meet heat efficiency standards, but surpassed the fuel efficiency standards.

Analysis Summary:

Mass flow rate for entire system: 0.0250 kg/s

<u>Inlet:</u>

Temperature: 28°C

Velocity: $0.648\ m/s$

<u>Outlet:</u>

Temperature: ~120°C

Velocity: $2.38\ m/s$

<u>Heat Transfer Efficiency:</u>

2.76%

Fuel Efficiency:

Our stove consumes around 0.33-0.83kg/hour, compared to the Nepalese 6.67-13.33kg/hour

Burner Heat Transfer

0.728kw to boil water, or

312.98kcal per 30 minutes

[A1] Y.A.Cengel, M.A. Boles, and M.Kanoglu, *Thermodynamics An Engineering Approach, 9th edition,McGraw Hill Education, 2019, New York*

[A2] S. C. Bhattacharya, Albina, and M. Khaing, "Effects of selected parameters on performance and emission of biomass-fired cookstoves," vol. 23. p. 387, 2002.

[A3] *Convert Kilowatt to Kilocalorie,* [online]. Accessed: https://www.unitconverters.net/power/kilowatt-to-kilocalorie-it-hour.htm [2021-07-30]

Appendix A.2: Prototype Smoke Emission Analysis

Introduction

The purpose of this study is to determine if the overall design of the prototype match the emission expectations of the project. The goal is to reduce user contact with smoke and other emissions. The largest health issue faced by the people in Nepal originate from exposure to smoke. This analysis will be done by a series of tests on the prototype, noting any spots of emission leaks and how these were fixed.

Materials:

The materials used within this analysis consist of:

- Prototype: The system being analyzed. It was constructed out of brick, clay and a steel grill.
- Pre-made clay: A wet mix of water and dirt. Used to hold bricks together and patch holes.
- White Cardboard: Used to gain a higher contrast of the smoke quality as it leaves the system.
- High smoke yielding materials: This consisted of leaves, grass, and wet sticks. Will create more smoke than is typical, allowing for a greater analysis of smoke exiting.
- Camera: Used to record the smoke quality.

Procedure:

After consulting Dr. Olfert, a professor that specializes emission analysis, a procedure for comparing emissions was brainstormed. Materials were gathered and burned within the stove, for the sole purpose of creating as much smoke as possible. Spots of emission release were recorded and fixed with the clay mixture. The process was repeated until as little to no smoke was released in inappropriate areas. The only exit for the emissions was the chimney, or when the burner was left uncovered. Figure A 2 shows one case where smoke was escaping from the design.

Figure A 2: Smoke being released from the stove corner before being patched

Figure A 3 shows the resulting smoke emissions being released from the chimney.

Figure A 3: Smoke released from the stove chimney

Results:

The prototype design ensured that no smoke would exit the inappropriately, resulting in smoke inhalation. This confirms that our final digital design will have the same results. Smoke that exits the burner when the wok is removed can easily be covered up with a lid as shown in the final design.

Appendix A.3: Thermocouple Surface Temperatures

The data recorded using Type J thermocouple is shown below in Table A1 using an OM-DAQPRO-5300 transducer. This transducer is shown in Figure A 4. After a period of around 8 minutes, it can be noted that the temperature of the right wall (without the door) hovered around a 50-55°C. The front wall had surface temperatures of around 49-54°C, and the left wall (with the door) 35-40°C. Overall, it was agreed that the average wall temperature for the overall system can be assumed to be around 45-55°C. The thermocouple measuring the inlet was placed outside the middle of the three inlet holes. This can be compared with the weather of the day, around 28°C. The internal temperature and the chimney temperature readings can be seen to vary greatly over time. These measurements were not taken into consideration. This error of these temperatures could be due to the machine itself, or the use of the thermocouples inappropriately.

However, for calculative purposes, the exiting temperature of the chimney can be assumed to be around 120°C. This assumption was taken from the last recorded value at the end of the recording period. This is because this value seemed to fall in line with the simulated results. It should also be noted that the recording of these measurements was started after the fire reached a stable burn after the starting period (around 2 minutes).

Figure A 4: Picture of OM-DAQPRO-5300 transducer

Table A 1: Data recorded from stove prototype using Type J thermocouple

Time (s)	Temperature Right [°C]	Temperature Inlet [°C]	Temperature Front [°C]	Temperature Left [°C]	Temperature Internal [°C]	Temperature Exhaust [°C]
0	30	26	35	34	-281	-93
10	30	26	35	34	-281	-93
20	30	25	35	34	-281	-112
30	30	25	35	34	-281	-108
40	38	26	35	34	-78	-108
50	34	26	35	34	-78	-113
60	32	25	35	34	752	-111
70	32	26	35	33	752	-111
80	32	25	35	33	605	-108
90	32	26	35	33	605	-108
100	33	26	36	34	505	-105
110	33	25	36	34	505	-105
120	34	27	36	34	431	-114
130	34	26	36	34	431	-117
140	34	26	36	34	209	-109
150	35	26	38	34	209	-111
160	36	26	38	34	23	-106
170	36	26	38	34	23	-106
180	37	27	39	34	-49	-106
190	37	26	39	34	-35	-106
200	38	26	39	34	-35	-121
210	38	25	40	34	-77	-117
220	39	27	40	34	-77	-117
230	39	27	40	34	-86	-120
240	40	26	41	34	-91	-120
250	41	27	41	34	-91	-93
260	41	27	42	34	-69	-89
270	42	26	42	34	-69	-85
280	42	27	42	34	79	-78
290	43	26	43	34	79	-74
300	43	26	44	34	396	-66
310	43	30	45	34	395	-60
320	44	31	45	34	96	-59
330	44	31	46	34	96	-59
340	45	32	46	35	-31	-39
350	45	32	47	35	-31	-40
360	46	31	47	35	40	-40
370	46	31	47	35	40	-19
380	46	32	48	35	63	-12
390	47	32	48	35	63	-9
400	47	32	48	35	63	-4
410	47	32	49	35	573	3
420	50	32	49	35	573	5
430	50	33	49	35	-101	13
440	53	33	49	35	-32	16
450	53	33	49	35	-32	16
460	55	33	49	36	-86	-8
470	55	34	49	36	-86	-8
480	56	34	49	36	-84	-8
490	56	33	50	36	-84	-15
500	56	34	50	36	-84	-16
510	56	33	50	36	-52	-10
520	57	34	50	36	-43	-7
530	56	33	50	36	-43	-2
540	56	33	51	37	18	-1
550	55	34	51	37	18	-1
560	56	33	51	37	-19	-7
570	56	33	51	37	-19	0
580	55	34	51	37	41	0
590	55	33	52	37	41	13
600	55	34	52	38	104	15
610	55	33	52	38	104	17
620	55	33	52	38	104	22
630	54	33	52	38	267	20
640	54	33	52	38	267	28
650	54	34	53	38	284	29
660	54	34	53	38	284	29
670	54	34	53	39	245	27
680	54	34	53	39	245	29
690	54	33	53	39	254	29
700	53	33	54	39	254	29
710	53	33	54	39	-31	50
720	54	32	54	40	-31	50
730	53	31	54	40	592	118
740	53	30	54	40	592	119

Appendix B: Optimization and recorded results using simulation analysis

To optimize the performance of our stove design, a Solidworks fluid simulation was set up to monitor the theoretical surface temperature of the steel burner T, as well as the outlet mass flow rate $\dot{m}$ through the chimney. Three parameters were then selected to be altered consecutively, recording the simulation results for each to find the optimal value or values for each parameter. The thickness of the stove walls was also increased to reduce the surface temperature of the stove. The set-up of this fluid simulation, as well as each parameter and their results will be discussed in this section.

Appendix B.1: Setting up the fluid simulation

The first step in setting up the SolidWorks fluid simulation was setting up a way of simulating fire within the stove. As SolidWorks does not have a dedicated fire simulation program, a method was devised for approximating the effect a fire would have on the system after some internal brainstorming and discussion with our advisor Dr. Ehsan Hashemi. To simulate the fire, 10 small wooden balls were placed in a pyramid shape over the grate centered in the stove, with enough space in between them for air to flow through them. They were also placed in random locations horizontally to imitate the randomness of a burning wood fire. The set up can be seen in Figure B 1 and Figure B 2.

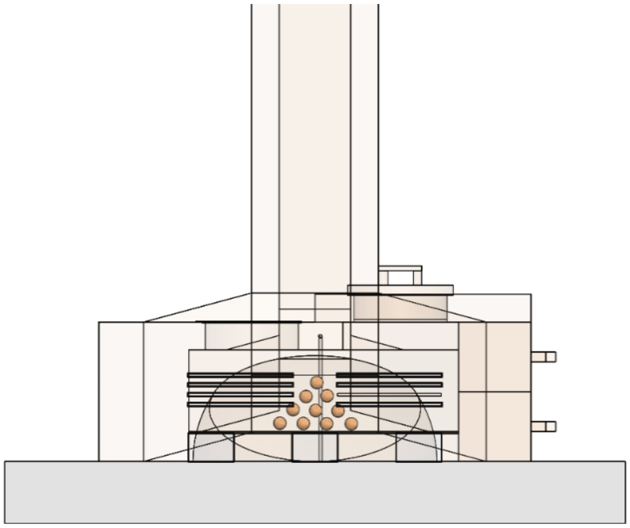


Figure B 1: Front view of wooden ball set up

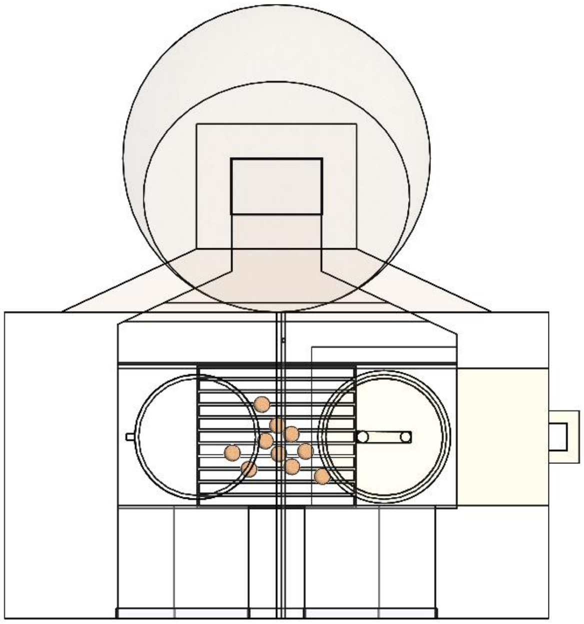


Figure B 2: Top view of wooden ball set up

The three most central balls were then set to a heat volume source of 1500 W, the four most intermediary balls were set to 1000 W, and the 3 outside balls were set to 500W. The sum of their energy outputs is totaled to 10 kW (around 24000Btu/hr.), based on the energy release of a typical small wood fire [B1].

The next step in setting up the fluid simulation was setting up the appropriate initial conditions of the stove inlets and outlets. As the fluid should only be moving using the heat produced from the fire within the stove, the initial conditions for all inlets and outlets were set to an atmospheric pressure of 101 kPa. Using the same initial condition for each stove opening allows the simulation to properly predict if the any air recirculates out of the stove inlets towards the user. If no inlet air recirculates back towards the user of the stove, the results of the simulation show that the user is theoretically exposed to none of the stove emissions, with all the combustion products being ejected out of the chimney outlet.

The last step in setting up the simulation was selecting values to be recorded to compare between simulation results. The values selected were the final surface temperature of the steel burner on the lower stove top, as well as the mass flow rate out of the chimney. These values provide an easy way of comparing the performance and circulation of the stove between iterations.

Appendix B.2: Optimizing Design Parameters

Optimization 1: Chimney slope angle

The first stove parameter that was altered iteratively was the slope of the chimney θ. This angle is depicted in Figure B 3. Simulations were performed for an angle of 50˚ to 5˚ in iterations of 5˚. The max value of 50˚ was used as the geometry of the stove breaks down at 55˚. The results from this simulation can be seen in Figure B 4 and Figure B 5 and are tabulated in Table B 1.

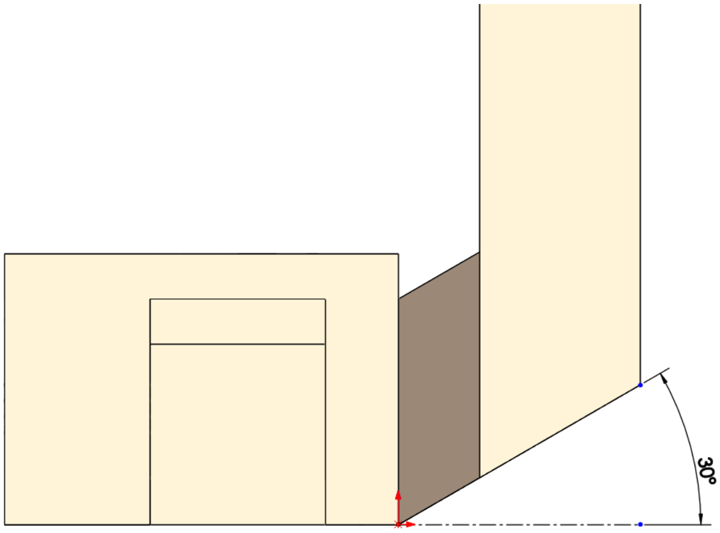


Figure B 3: Side view of stove body indicating slope angle θ

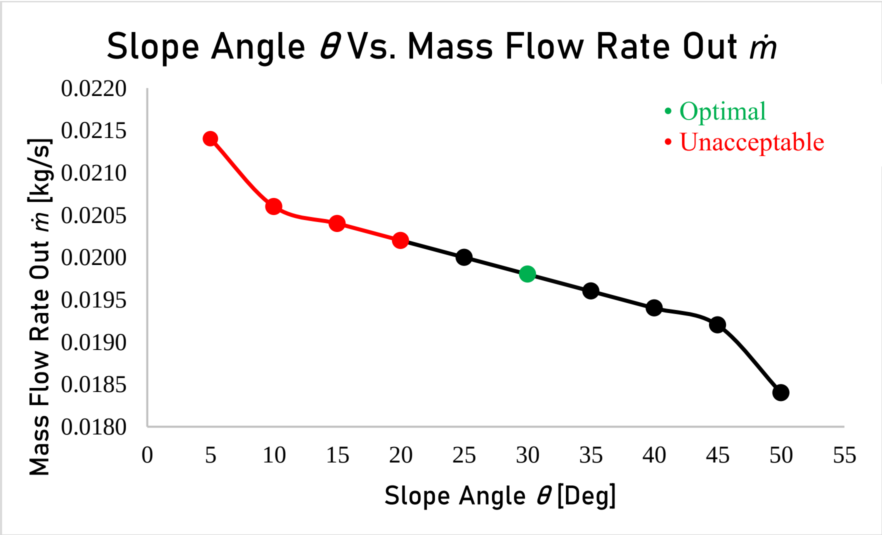


Figure B 4: Graph of slope angle vs. mass flow rate out of the chimney

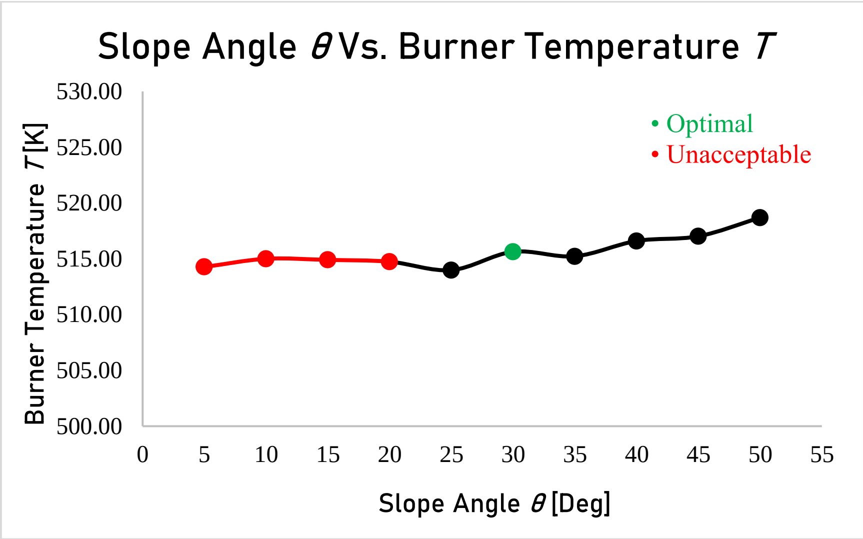


Figure B 5: Graph of slope angle vs. burner temperature

Table B 1: Simulation results for various slope angles

θ [Deg]	ṁ [kg/s]	T [K]
50	0.0184	518.69
45	0.0192	517.02
40	0.0194	516.60
35	0.0196	515.23
30	0.0198	515.63
25	0.0200	513.99
20	0.0202	514.74
15	0.0204	514.90
10	0.0206	515.00
5	0.0214	514.27

In reviewing the results, it was found that changing the slope angle had little effect on the burner temperature, only varying by 4˚C over an angle change of 45˚. The focus for optimizing this parameter was then shifted towards maximizing the airflow rate out of the chimney. However, upon analyzing the simulation flow results, at every angle below 20˚, air started recirculating back out of the inlets. Since this would mean subjecting the user to the combustion products of the fire, the slope angle needs to be kept above 20˚. The optimal slope angle was then determined to be 30˚, as it has a slightly higher burner temperature compared to 25˚, as well as provides a further gap between the angle at which the fluid starts to flow out of the inlets.

Optimization 2: Chimney divergence angle

The second stove parameter that was altered iteratively was the divergence angle of the chimney *α*. This angle is depicted in Figure B 6. Simulations were performed for an angle of 65˚ to 15˚ in iterations of 5˚. The max value of 65˚ was used as the geometry of the stove breaks down at 65˚. The results from this simulation can be seen in Figure B 7 and Figure B 8 and are tabulated in Table B 2.

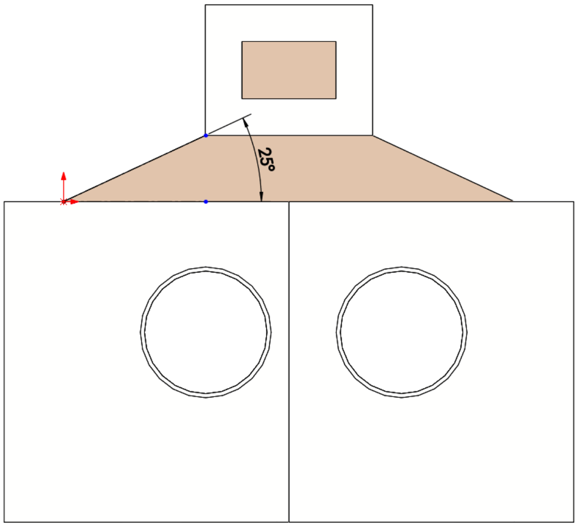


Figure B 6: Top view of stove body indicating divergence angle α

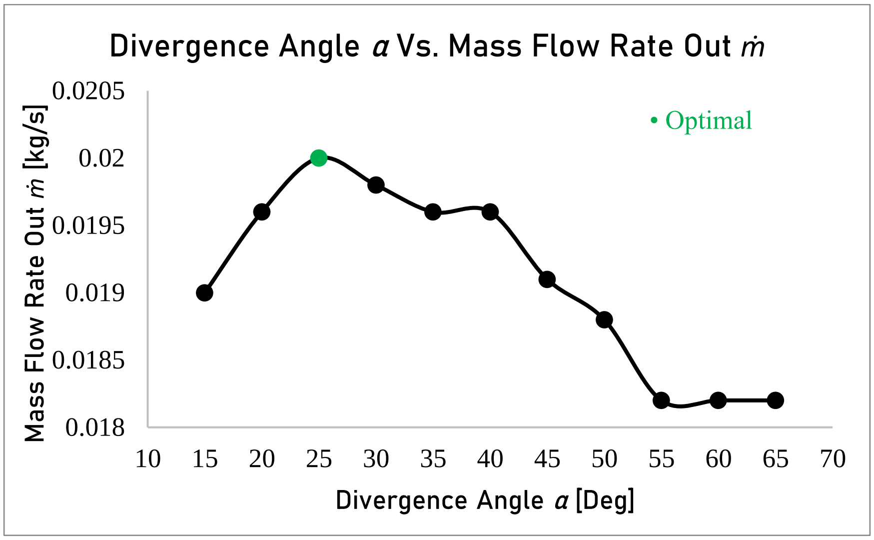


Figure B 7: Graph of divergence angle vs. mass flow rate out of the chimney

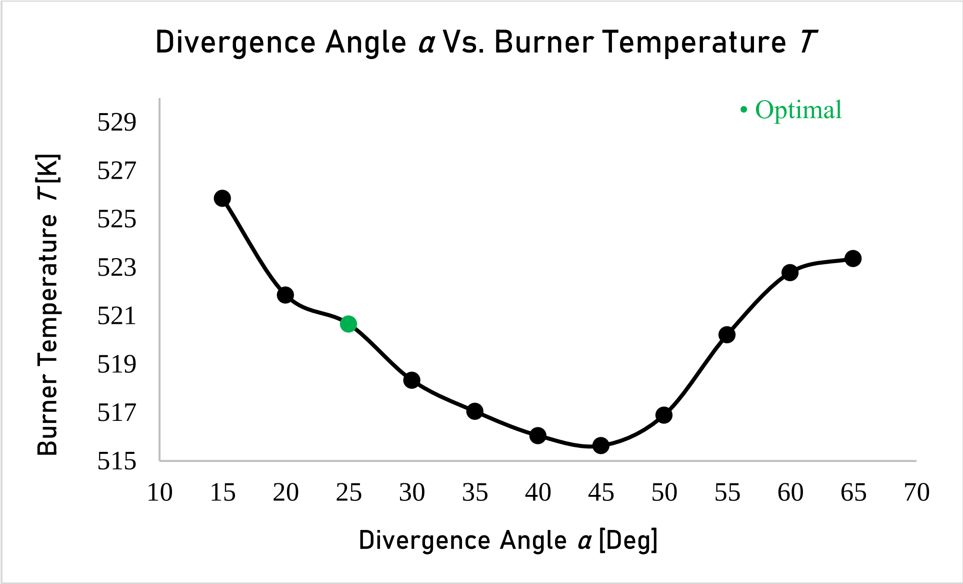


Figure B 8: Graph of divergence angle vs. burner temperature

Table B 2: Simulation results for various divergence angles

α [Deg]	ṁ [kg/s]	T [K]
65	0.0182	523.37
60	0.0182	522.79
55	0.0182	520.22
50	0.0188	516.90
45	0.0191	515.63
40	0.0196	516.05
35	0.0196	517.05
30	0.0198	518.34
25	0.0200	520.66
20	0.0196	521.86
15	0.0190	525.85

For this parameter, the temperature of the burner seems to act parabolic in relation to the divergence angle of the chimney. However, there is a maximum value for the mass flow rate out of the chimney at 25˚. Since the burner temperature is also recorded to be on the higher end of the simulated results, 25˚ was selected as the optimal chimney convergence angle.

Optimization 3: Chimney Height

The third and final stove parameter that was altered iteratively was the height of the chimney *H*. This height is depicted in Figure B 9, measured from the lower stove top. Simulations were performed for a height of 1m to 3m in iterations of 0.2m. The max value of 3m was used as this would be an adequate height to escape any room in the homes built in rural Nepal. The results from this simulation can be seen in Figure B 10 and Figure B 11 and are tabulated in Table B 3.

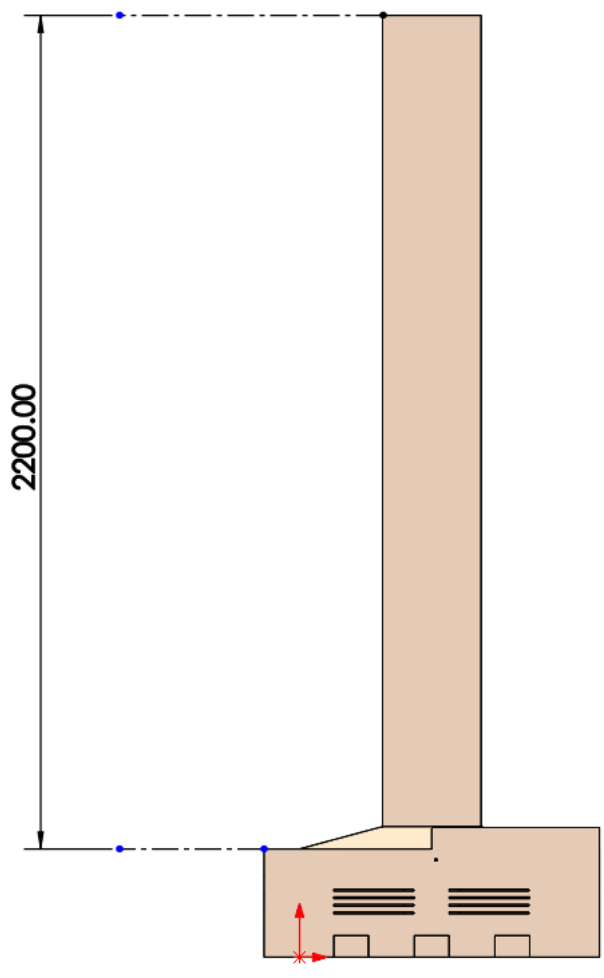


Figure B 9: Front view of stove body indicating chimney height H

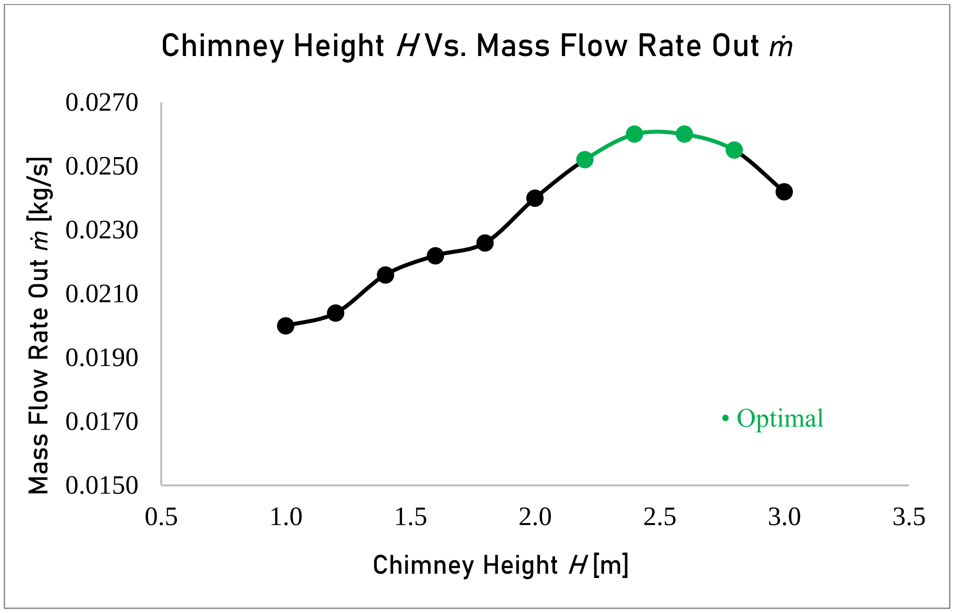


Figure B 10: Graph of chimney height vs. mass flow rate out of the chimney

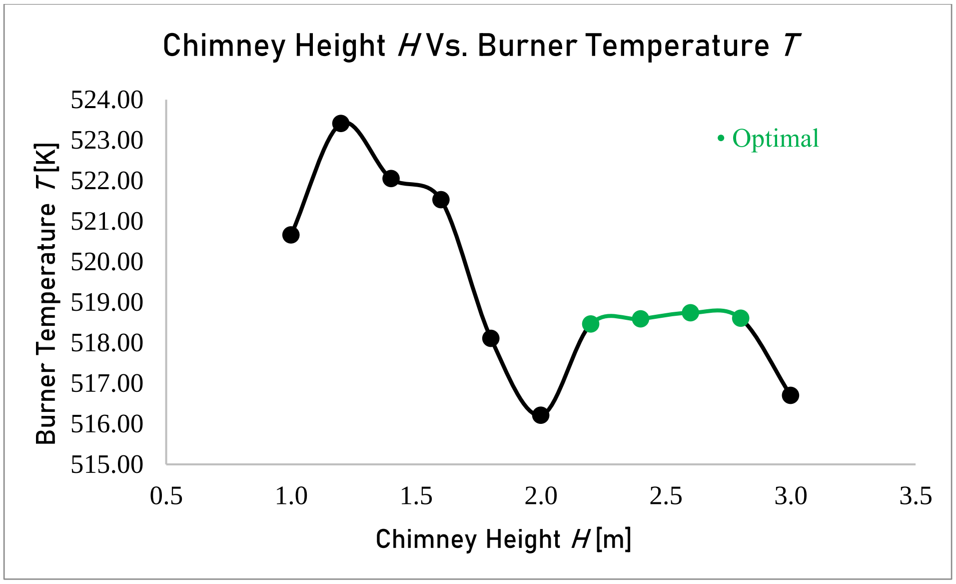


Figure B 11: Graph of chimney height vs. burner temperature

Table B 3: Simulation results for various chimney heights

H [m]	ṁ [kg/s]	T [K]
1.0	0.0200	520.66
1.2	0.0204	523.41
1.4	0.0216	522.05
1.6	0.0222	521.53
1.8	0.0226	518.11
2.0	0.0240	516.21
2.2	0.0252	518.46
2.4	0.0260	518.59
2.6	0.0260	518.74
2.8	0.0255	518.60
3.0	0.0242	516.70

In analyzing the simulation results, it's apparent that increasing the chimney height rapidly increases the mass flow rate out the chimney. Although the burner temperature decreases until a steady temperature of around 518 K, increasing the mass flow rate out of the chimney decreases the chance of the user being exposed to emissions released by the combustion products in the stove. As the mass flow rate out of the chimney remains relatively similar between the ranges of 2.2m to 2.8m, the optimal chimney height was determined to be anywhere between these values. This provides some flexibility for the user, as they can select a height depending on the height of their home, while maintaining an adequate stove performance.

<u>Altering wall thickness to decrease body surface temperature</u>

In the previous iteration of the wood burning stove design, most of the stove body reached unsafe surface temperature levels, well above the surface temperature target of 48 °C. This surface plot can be seen in Figure B 12.

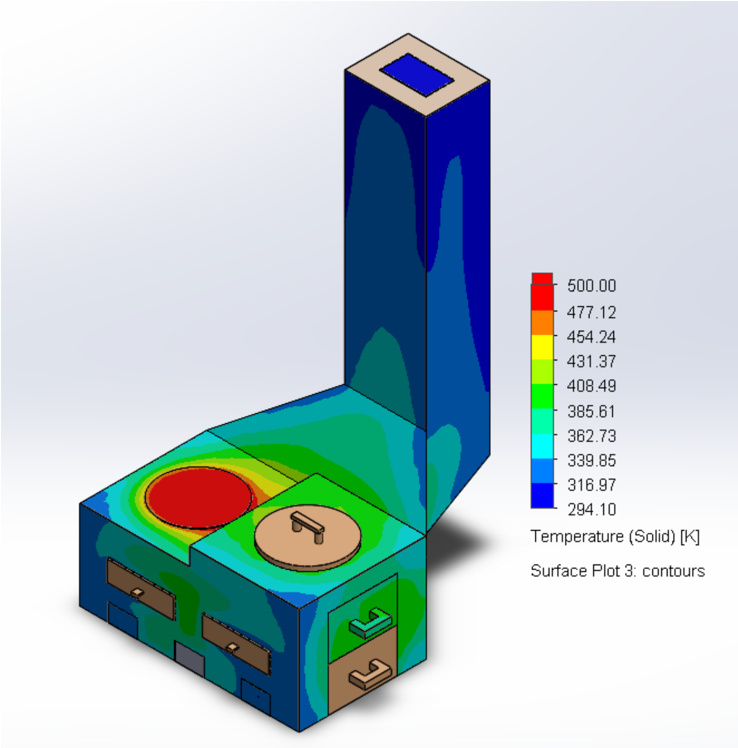


Figure B 12: Surface temperature contour of previous stove design iteration

To reduce the temperature of the surfaces that may come in contact with the user, the thickness of the front and side walls were doubled to 184mm. This increase was also done to maintain the ability for the stove to be built out of bricks if the user desires, as one would simply add another layer of bricks to these outside walls. The effect that this increase has on the surface temperatures of the stove, as well as the changes made in the previous optimizations, can be seen in Figure B 13.

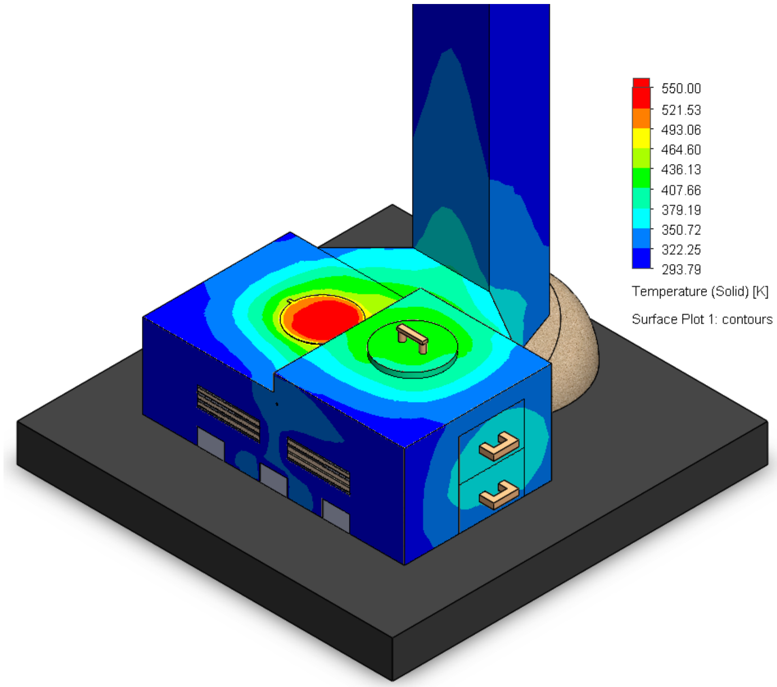


Figure B 13: Surface temperature contour of final stove design

Upon reviewing the results from the final surface temperature contour plot, the increase in thickness reduced the surface temperature exposed to the user substantially. The front walls in which the user would have the most contact with stay at mostly room temperature, reducing the risk of burns. Although a small portion of the front surface is shown to be slightly above the 48 ˚C, it should be noted that these results are recorded once the system reaches steady state. Therefore, as the bulk of the time the user will spent cooking the stove will not be at steady state, we can assume that the actual surface temperatures of the stove subjected to the user will be reduced for most of the stove's usage. To demonstrate this, temperature values were recorded using thermocouples on the stove's external surfaces using the constructed prototype, which can be seen in Appendix A.3. If further insolation is required, an extra layer of Cob can be added at the user's discretion. An extra layer of bricks was not added to the stove top however, as this extra weight may contribute to a potential collapse of the stove top. Caution should therefore be used when placing hands around the stove top. It should also be noted that there was an issue producing a surface contour on the surfaces of the handles of the stove components. These were therefore manually recorded, in which all three were recorded below 48 ˚C.

Summary

After analyzing and comparing the results on the effect that the chimney slope angle, divergence angle, and height had on the stove performance, the optimal parameters were determined to be a slope angle of 30˚, a convergence angle of 25˚, and a chimney height of 2.2m to 2.8m. Although both mass flow rate out of the chimney and burner temperature were meant to be compared to determine the optimal parameters, the decisions we're mainly determined by the mass flow rate out, as every burner temperature recorded were high enough to use for cooking. The wall thickness of the stove was also double to 184mm to improve the safety of the stove by reducing the risk of burns subjected to the user. To continue with the final analysis, a chimney height of 2.2m was selected to examine the stove performance at the lowest end of the optimal height range as it produced the lowest temperature and mass flow rate values across the range.

Appendix B.3: Final Simulation and results

After altering the stove design using the chosen optimal parameters, a final fluid simulation was performed to determine the flow rate inside the stove. Heat transfer analysis was also used to determine the final theoretical burner temperature and mass flow rate out of the stove. An overview of the final fluid flow simulations can be seen in Figure B 14, B 15, and B 16.

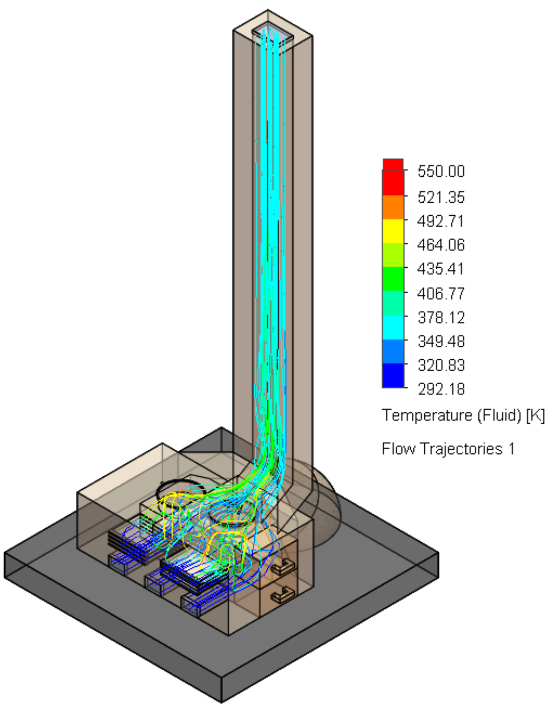


Figure B 14: Isometric overview of final fluid simulation

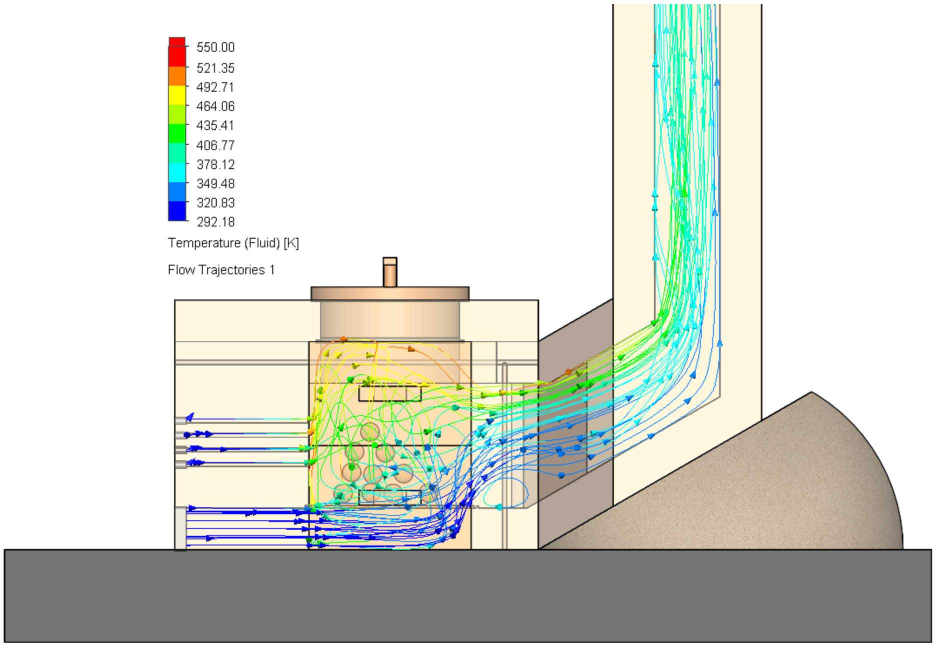


Figure B 15: Side view of final fluid simulation

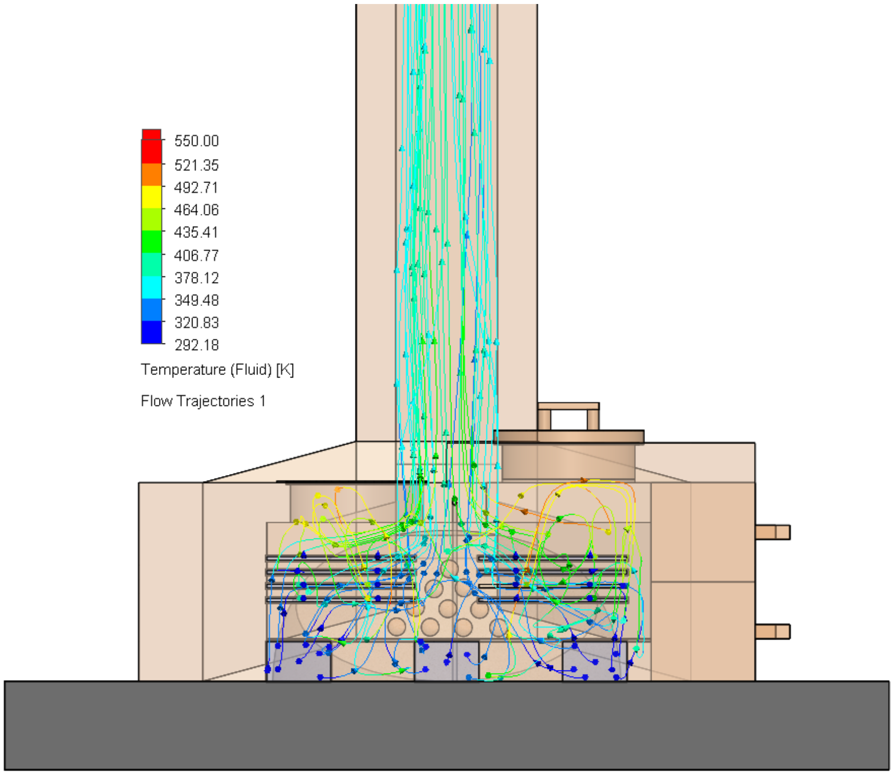


Figure B 16: Front view of final fluid simulation

Upon analyzing the flow results in Figure B 15 and B 16, the air successfully flows in through the inlets, circulates underneath both burners, and flows out of the chimney without recirculating out the inlets. Thus, the flow circulation within the stove should theoretically prevent the user from being exposed to any combustion products while wood is burning within the stove, and both burner holes are covered. The final measured burner temperature was recorded to be 525 K, around 252 °C, and the final mass flow rate out of the chimney was recorded to be 0.0240 kg/s.

[B1] "The Fire Place Place" [Online] Available: https://www.fireplaceofatlanta.com/blog/gas-vs-wood-fireplace-heat-output-which-is-superior#:~:text=The%20number%20of%20BTUs%20a,range%20from%2020%2C000%2D40%2C000%20BTUs [Accessed: 08-June-2021]

Appendix C: Cost Estimate

The total cost of each biofuel stove is split into two parts, materials costs, and manufacturing costs. Cob and AISI 1018 carbon steel were selected as the two materials to be used in order to reduce complexity and stay within the 500 NPR budget. Cob is assumed to be free, while the cost of the AISI 1018 carbon steel is based on the quantities of steel required to be machined into the final product, as well as the current cost of steel. The manufacturing cost only includes the machining cost required to machine the metal part utilized in the stoves. The labor cost involved in assembling the stove is not included, as it will be done by the villagers who will use the stove at no cost. The transportation cost required to transport the materials to the rural mountainous regions of Nepal is also excluded from the cost estimate calculations.

Materials Cost Estimate

The material costs cover the cost of the raw materials that will be required to build the stove. The components selected are of sizes that are commonly found to ensure ease of obtainability. Due to the low budget limit of 500 NPR, quotes were not established due the high prices encountered when ordering individual pieces; instead, the international price of the item is utilized [C1], which better simulates the cost when ordering at very high quantities. Please see Appendix A for calculations. The price of cob used is neglected, due to the high availability of the materials used to make it in the countryside of Nepal.

Cob

Cob is defined as a mixture of clay, sand, water, and straw that is all manually mixed together to form building material [C2]. Cob will be the primary material used to build the stoves, due to it being abundant in the region. Sand provides the mixture strength, straw provides tensile strength, clay binds the materials together, and water activates the clay to help keep the mixture together while building [C3].

AISI 1018 Carbon Steel

There are many different types of steel, each with varying properties. One type of steel that works very well for the construction of biofuel stoves is carbon steel. Carbon steel is lightweight yet strong, and further possesses excellent heat transfer properties, which makes it an ideal choice for a biofuel stove. Carbon steel is also more durable than cast iron, which tends to crack at high temperatures due to its brittle nature [C4]. Furthermore, carbon steel heats up rapidly thanks to its unique properties.

Parts Cost Calculations:

0.004 m x 0.2032 m x 0.2032 m AISI 1018 Steel Plate (1)

$$C = \text{Volume} * \text{Density} * 2.20462\ \text{lb/kg} * 0.78\ \text{USD/lb} * 118.55\ \text{NPR/USD}$$

$$C = (0.004\ \text{m} * 0.2032\ \text{m} * 0.2032\ \text{m}) * 7870\ \text{kg/m3} * 2.20462\ \text{lb/kg} * 0.78\ \text{USD/lb} * 118.55\ \text{NPR/USD}$$

$$C = 265\ NPR$$

$$Total\ Cost = 1 * 265\ NPR = 265\ NPR$$

0.006 m Diameter x 1 m Length AISI 1018 Steel Rod (1)

$$C = Volume * 2.20462\ lb/kg * 0.78\ USD/lb * 118.55\ NPR/USD$$

$$C = (\pi * (0.006\ m)^2 * 1\ m/4) * 7870\ kg/m3 * 2.20462\ lb/kg * 0.78\ USD/lb * 118.55\ NPR/USD$$

$$C = 45\ NPR$$

$$Total\ Cost = 1 * 45\ NPR = 45\ NPR$$

0.003 m Diameter x 1.5 m Length AISI 1018 Steel Rod (1)

$$C = Volume * 2.20462\ lb/kg * 0.78\ USD/lb * 118.55\ NPR/USD$$

$$C = (\pi * (0.003\ \text{m})^2 * 1.5\ \text{m}/4) * 7870\ \text{kg/m3} * 2.20462\ \text{lb/kg} * 0.78\ \text{USD/lb} * 118.55\ \text{NPR/USD}$$

$$C = 17\ NPR$$

$$Total\ Cost = 3 * 17\ NPR = 51\ NPR$$

Table C 1: Material costs

Item	Quantity	Unit Volume (m3)	Total Volume (m3)	Unit Cost (NPR)	Total Cost (NPR)
0.004 m x 0.2032 m x 0.2032 m AISI 1018 steel plate	1	1.65*10^-4	1.65*10^-4	265	265
0.006 m diameter x 1 m length AISI 1018 steel rod	1	2.83*10^-4	2.83*10^-4	45	45
0.003 m diameter x 1.5 m length AISI 1018 steel rod	3	1.06*10^-4	3.18*10^-4	17	17
				Total Cost:	361

Manufacturing Cost Estimate

Welds:

Assume ⅛ in mitre fillet welds are to be utilized for 21 3 mm rod welds. Assuming that the cost per pound of weld metal at a machining rate of $50 USD per hour is $29.91, it is possible to calculate the cost of each individual weld [C5]. Assume that the weld metal used is tungsten carbide filled electrode with a density of 12500 kg/cm3 [C6].

$$C = 29.91 \text{ USD/lb} * 1 \text{ lb}/0.453592 \text{ kg} * \text{Density} * \text{Area} * \text{Length} * 118.55 \text{ NPR/USD}$$

$$C = 29.91 \frac{\text{USD}}{\text{lb}} * 1 \frac{\text{lb}}{0.453592} \text{kg} * \ 12500 \frac{\text{kg}}{\text{cm}^3} * \frac{(0.003175 \text{ m})^2}{2} * 0.003 \text{ m} * 118.55 \text{ NPR/USD}$$

$$C = 1.5\ NPR$$

$$Total\ Cost = 21 * 1.5\ NPR = 31\ NPR$$

Bends:

Three bends are required per stove for the 3 mm rods. [C7] states that the cycle time per bend for a simple tube is 16 seconds, using a dedicated bending machine. The machine is capable of conducting multiple bends at the same time, thus only three cycles are required to complete all the bends for one stove. Assume a machining rate of $50 USD per hour.

$$C = \text{Rate} * \text{Time} * 118.55\ \text{NPR/USD}$$
$$C = 50\ \text{USD/hr} * 1\ \text{hr/3600 s} * 16\ \text{s} * 118.55\ \text{NPR/USD}$$
$$C = 26\ NPR$$
$$Total\ Cost = 3 * 26\ NPR = 79\ NPR$$

Cuts:

Two 6 mm support rods will be cut per stove, requiring 2 cuts. Eleven short 3 mm rods will also be cut per stove, along with two long 3 mm rods, together requiring a total of 12 cuts. In total, 14 cuts will be made. The recommended cutting rate for a maximum material size of 1 inch is 8-10 SIPM (square inches per minute) for AISI 1018 carbon steel. The total square area of the cuts will be determined and used to determine the total cost required for the cuts, assuming a machining rate of $50 USD per hour and average cutting rate of 9 SIPM [C8].

$$Total\ Cost = \text{Area} * \text{Rate} * 118.55\ \text{NPR/USD}$$
$$Total\ Cost = (2 * \pi * (0.006\ m)^2/4 + 12 * \pi * (0.003\ m)^2/4) * 1550\ in^2/m^2 * \ 1\ min/9\ in^2 * 1\ hr/60\ min$$
$$Total\ Cost = 3\ NPR$$

Mills:

An 8 in metal burner is to be machined using a milling machine. The cutting speed must first be determined, which requires the cutter diameter and spindle speed to be known; the milling time is then calculated [C9]. The optimum cutter diameter is 1.5 times the diameter of the item to be machined [C10], while the optimum spindle speed is approximately 15,000 rpm [C11]. Cutting speed can be determined by dividing the length to be cut by the cutting speed. The length to be cut in this case is the circumference of the circular burner. Assume a machining rate of $50 USD per hour.

$$Cutting\ Speed = [\pi * \text{Cutter Diameter} * \text{Spindle Speed}]/1000$$

$$Cutting\ Speed = [\pi * (1.5 * 8\ \text{in} * 1\ \text{m}/39.37\ \text{in}) * (15000\ \text{rpm} * 1/60\ \text{rpm s} * 60\ \text{s/min}]/1000$$

$$Cutting\ Speed = 14.36\ \text{m/min}$$

$$Milling\ Time = \pi * \text{Diameter}/\text{Cutting Speed}$$

$$Milling\ Time = [\pi * 8\ \text{in} * 1\ \text{m}/39.37\ \text{in}]/[14.36 \frac{\text{m}}{\text{min}} * 1\ \text{min}/60\ \text{s}]$$

$$Milling\ Time = 3\ \text{s}$$

$$Total\ Cost = 50\ \text{USD/ hr} * 1\ \text{hr}/60\ \text{min} * 1\ \text{min}/60\ \text{s} * 3\ \text{s} * 118.55\ \text{NPR/USD} = 5\ \text{NPR}$$

References:

[C1] Carbon Steel, [Online] Available: https://agmetalminer.com/metal-prices/carbon-steel/ [Accessed: 18-July-2021]

[C2] Natural Building Techniques, [Online] Available: https://greenbuildingcanada.ca/green-building-guide/natural-building-techniques/ [Accessed: 08-June-2021]

[C3] How to Build With Cob, [Online] Available: http://www.earthbench.org/how-to-cob.html [Accessed: 08-June-2021]

[C4] Which Is Better, A Steel or Cast Iron Stove?, [Online] Available: https://www.thestoveyard.com/pages/which-is-better-a-steel-or-cast-iron-stove [Accessed: 09-June-2021]

[C5] Estimating Total Welding Costs, [Online] Available: https://www.fabricatingandmetalworking.com/2012/04/estimating-total-welding-costs/ [Accessed: 18-July-2021]

[C6] Material Product Data Sheet, Dip Coated Tungsten, [Online] Available: https://www.oerlikon.com/ecoma/files/DSMW-0011.5_WokaDur_E_Electrode.pdf?download=true [Accessed: 18-July-2021]

[C7] Bending and Handling tube, [Online] Available: https://www.thefabricator.com/tubepipejournal/article/tubepipefabrication/bending-and-handling-tube [Accessed: 18-July-2021]

[C8] Band Saw Blade Speed and Feed Chart, [Online] Available: https://www.sawblade.com/band-saw-blade-speed-and-feed-chart.cfm [Accessed: 20-July-2021]

[C9] Face Milling Formulas, [Online] Available: https://www.keyence.com/ss/products/measure-sys/machining/formula/milling.jsp [Accessed: 20-July-2021]

[C10] A New Milling 101: Cutter Design and Application Considerations, [Online] Available: https://www.mmsonline.com/articles/a-new-milling-101-cutter-design-and-application-considerations#:~:text=For%20standard%20face%2Dmilling%20operations,inch%2Ddiameter%20cutter%20is%20recommended. [Accessed: 21-July-2021]

[C11] Maximum Aluminum: Optimizing Metal Removal Rate in Aluminum with a High Speed Spindle, [Online] Available: https://www.mmsonline.com/articles/maximum-aluminum [Accessed: 21-July-2021]

Appendix D: Assembly Instructions

Shop Assembly Instructions

1. Cut out a 978 mm length of 0.003 m steel rod. Conduct 3 bends to transform the rod into a rectangular shape with side lengths of 252.5 mm.
2. Cut the rest of the 0.003 m steel rods into 10 252.5 mm lengths.
3. Perform ⅛ in mitre fillets welds to attach the 10 252.5 mm rods to the inside of the rectangular shape at both ends. Ensure regular spacing between the rods. Weld the ends of the 978 bent steel rod to close the rectangle.
4. Cut the 0.006 m steel rod into 1 498 mm length rod and 1 252.5 mm length rod.
5. Mill the 0.004 m x 0.2032 m x 0.2032 m steel plate into 0.203 m diameter, 0.004 m thick steel round plate.

Stove User Assembly Instructions

1. Prepare cob mixture for construction of the stove.
2. Mold the small door, large door, and burner out of cob; set out to dry.
3. Mold the main body of the stove using cob, excluding the chimney; and wait for it to dry
4. Once the main stove body has dried, carefully mold out the chimney; minor adjustments can be made to the chimney to direct airflow in different directions. This is dependent on user preference and room layout.
5. Insert the steel grate and supports inside the stove.
6. Put the steel burner on the stove.

Appendix E: Safety Analysis

The stove successfully reduces emissions to the user as most of the unused smoke is exhausted through the chimney. This was confirmed through testing the prototype as well as through conducting SolidWorks simulations as seen in Figures B13 and B14. The design also minimizes the exposure of the user to the fire while adjusting the burning wood. This is achieved through incorporating a two-door design that gives the user flexible accessibility to the underneath of the burning wood without exposure to the fire. Similarly, the long narrow design of the interior allows the user to refuel the hot stove while maintaining a safe horizontal distance from the fire. The stove surface temperature is also designed to not exceed 48 °C in order to eliminate the risk of burns to the user. This temperature was tested and a maximum surface temperature of 45 °C to 55 °C was expected as per the SolidWorks simulation seen in B12. A thermocouple was then used to measure the surface temperature of the stove prototype and a similar value was obtained as seen in Table A1. This proves that although the surface temperature criteria is not satisfied, a burn due to a high surface temperature is less likely when combined with an individual's ability to react to and prevent a burn. Such a burn would occur under prolonged exposure, yet there would be sufficient time for an individual to react to prevent the burn. Additionally, the stove imposes some structural safety risks such as sharp corners, unstable chimney, structural un-rigidity, and unsteady stove door. Such risks can be mitigated as seen in Table 3.

Appendix F: Project Management

Gantt charts were created to estimate project time expenditure for all three phases. The Phase 3 Gantt chart was updated during Phase 2 in an attempt to obtain a more accurate estimate for Phase 3; Appendix F.1 displays the Phase 1, Phase 2, and updated Phase 3 Gantt charts. Individual hours were logged into an activity time log, which can be found in Appendix F.2. Meeting minutes were also kept and logged for each meeting; the Phase 3 meetings minutes can be found in Appendix F.3. The activity time log and meeting minutes form the basis of the actual hours worked on the project.

Appendix F.1 Gantt Charts

Mountains of Relief Nepal Stove

KNACK'D Corporation (Team 1)

Project Start Date: 10-May

Project Manager: Hardik Nijhawan

Phase	WBS	Task	Resources Allocated	Start	End	Percent Complete	Total Hours	Work Days
		Phase 1						
1	**1**	**Project Initiation**	**-**	**14-May**	**17-May**	**100%**	**14**	**4**
1	1.1	Letter of Intent	Team	14-May	14-May	100%	6	1
1	1.2	Team Charter	Han	15-May	16-May	100%	2	2
1	1.3	Preliminary Scope Research	Team	17-May	17-May	100%	6	1
1	**2**	**Cover Letter**	**Han**	**19-May**	**20-May**	**100%**	**2**	**2**
1	**3**	**Design Specification Report**	**-**	**23-May**	**01-Jun**	**100%**	**30**	**10**
1	3.1	Design Objective	Cole	23-May	26-May	100%	4	4
1	3.2	Key Design Specifications	Nicholas, Mohamad	27-May	30-May	100%	8	4
1	3.3	Business Specifications	Brock	28-May	29-May	100%	2	2
1	3.4	Material Research	Mohamad, Cole	28-May	29-May	100%	4	2
1	3.5	Manufacturing and Cost Estimate	Mohamad, Brock	28-May	29-May	100%	4	2
1	3.6	Codes, Standards, Patents Investigation	Hardik, Cole	28-May	30-May	100%	6	3
1	3.7	Report Compiling	Hardik, Brock	01-Jun	01-Jun	100%	2	1
1	**4**	**Design Specifications Matrix**	**-**	**24-May**	**31-May**	**100%**	**18**	**8**
1	4.1	Setting Specifications	Han, Mohamad	24-May	29-May	100%	12	6
1	4.2	Review	Team	31-May	31-May	100%	6	1
1	**5**	**Project Management**	**-**	**19-May**	**01-Jun**	**100%**	**16**	**14**
1	5.1	Create TimeSheet	Nicholas	19-May	20-May	100%	2	2
1	5.2	Gantt Chart	Han	23-May	28-May	100%	6	6
1	5.3	Time Estimates	Han	28-May	30-May	100%	3	3
1	5.4	Review	Team	01-Jun	01-Jun	100%	6	1
1		**Pre-Submission Team Review**	**Team**					
1		**Submission**	**Team**	**02-Jun**	**02-Jun**			
1	**6**	**Self Assessment**	**Team**	**05-Jun**	**05-Jun**	**100%**	**6**	**1**

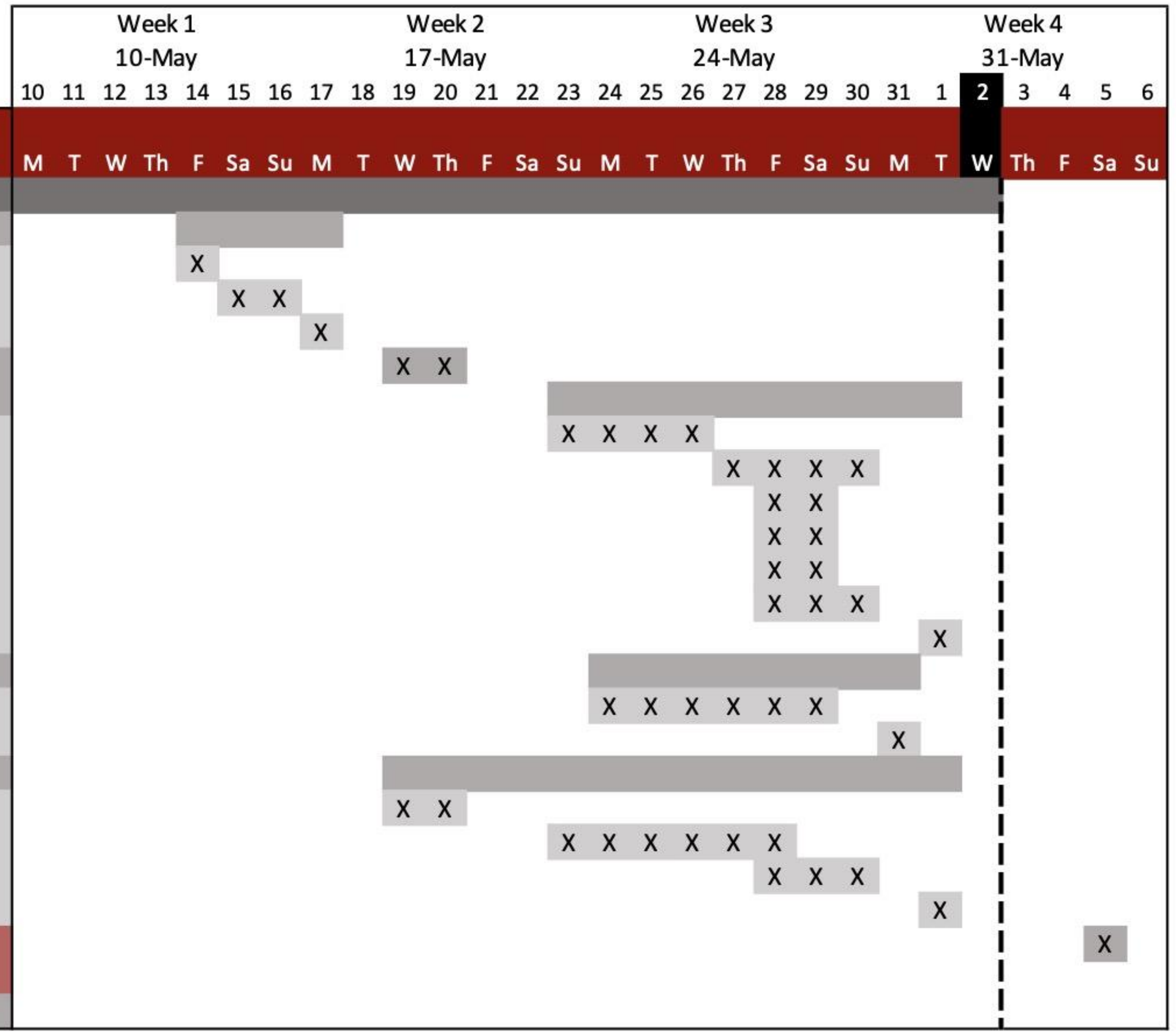


Figure F 1: Phase 1 Gantt Chart

Mountains of Relief Nepal Stove

KNACK'D Corporation (Team 1)

Project Start Date: 10-May

Project Manager: Hardik Nijhawan

*assume 1 hr worked per day multiplied by number of people working on it

Phase	WBS	Task	Resources Allocated	Start	End	Percent Complete	Total Hours*	Work Days
		Phase 2						
2	**7**	**Scope Research**	**-**	**03-Jun**	**06-Jun**	**100%**	**16**	**4**
2	7.1	Stove Standards	Hardik, Mohamad	03-Jun	06-Jun	100%	8	4
2	7.3	Materials	Cole, Mohamad	03-Jun	06-Jun	100%	8	4
2	**8**	**Executive Summary**	**Team**	**04-Jun**	**05-Jun**	**100%**	**12**	**2**
2	**9**	**Conceptual Design Report**	**-**	**04-Jun**	**14-Jun**	**100%**	**53**	**11**
2	9.1	Design Problem Summary	Brock	07-Jun	08-Jun	100%	2	2
2	9.2	Conceptual Designs	-	04-Jun	13-Jun	100%	45	10
2	9.2.1	Concept Brainstorming	Team	04-Jun	04-Jun	100%	6	1
2	9.2.2	Concept 1	-	05-Jun	13-Jun	100%	13	9
2	9.2.2.1	Concept 1 Description	Brock	05-Jun	06-Jun	100%	2	2
2	9.2.2.2	Concept 1 Model	Cole	07-Jun	11-Jun	100%	5	5
2	9.2.2.3	Concept 1 Simulations/Analysis	Cole	09-Jun	12-Jun	100%	4	4
2	9.2.2.4	Concept 1 Cost Analysis	Brock	12-Jun	13-Jun	100%	2	2
2	9.2.3	Concept 2	-	05-Jun	13-Jun	100%	13	9
2	9.2.3.1	Concept 2 Description	Mohamad	05-Jun	06-Jun	100%	2	2
2	9.2.3.2	Concept 2 Model	Hardik	07-Jun	11-Jun	100%	5	5
2	9.2.3.3	Concept 2 Simulations/Analysis	Hardik	09-Jun	12-Jun	100%	4	4
2	9.2.3.4	Concept 2 Cost Analysis	Mohamad	12-Jun	13-Jun	100%	2	2
2	9.2.4	Concept 3	-	05-Jun	13-Jun	100%	13	9
2	9.2.4.1	Concept 3 Description	Han	05-Jun	06-Jun	100%	2	2
2	9.2.4.2	Concept 3 Model	Nicholas	07-Jun	11-Jun	100%	5	5
2	9.2.4.3	Concept 3 Simulations/Analysis	Nicholas	09-Jun	12-Jun	100%	4	4
2	9.2.4.4	Concept 3 Cost Analysis	Han	12-Jun	13-Jun	100%	2	2
2	9.3	Review Conceptual Designs	Team	14-Jun	14-Jun	100%	6	1
2	**10**	**Conceptual Design Calculations**	**Team**	**07-Jun**	**11-Jun**	**100%**	**30**	**5**
2	**11**	**Design Evaluation Matrix**	**-**	**19-Jun**	**23-Jun**	**100%**	**21**	**5**
2	11.1	Update Specification Matrix	Han	19-Jun	21-Jun	100%	3	3
2	11.2	Update Scope	Team	20-Jun	20-Jun	100%	6	1
2	11.3	Concept Decision Matrix	Team	22-Jun	23-Jun	100%	12	2
2	**12**	**Project Management**	**-**	**23-Jun**	**26-Jun**	**100%**	**9**	**4**
2	12.1	Update TimeSheet & Time Estimates	Han	23-Jun	24-Jun	100%	2	2
2	12.2	Update Gantt Chart	Han	24-Jun	25-Jan	100%	2	2
2	12.3	Hours/Cost Graphical Analysis	Mohamad	24-Jun	26-Jun	100%	3	3
2	12.4	Refine P3 Estimates	Brock	25-Jun	26-Jun	100%	2	2
2		**Pre-Submission Team Review**	**Team**					
2		**Submission**	**Team**	**30-Jun**	**30-Jun**			
2	**13**	**Self Assessment**	**Team**	**03-Jul**	**03-Jul**	**100%**	**1**	**1**
					Total Hours:		**141**	

Figure F 2: Phase 2 Gantt Chart

Mountains of Relief Nepal Stove

KNACK'D Corporation (Team 1)

Project Start Date: 10-May

Project Manager: Hardik Nijhawan

*assume 1 hr worked per day multiplied by number of people working on it

Phase	WBS	Task	Resources Allocated	Start	End	Percent Complete	Total Hours	Work Days
		Phase 3						
3	**14**	**Detailed Design Report**	-	**05-Jul**	**03-Aug**	**100%**	**41**	**30**
3	14.1	Description of Final Design	Brock, Nicholas	05-Jul	06-Jul	100%	4	2
3	14.2	Design Innovation	Hardik, Brock	05-Jul	07-Jul	100%	6	3
3	14.3	Design Analysis Summary	Cole	07-Jul	09-Jul	100%	3	3
3	14.4	Cost Analysis Summary	Han, Nicholas	07-Jul	10-Jul	100%	8	4
3	14.5	Design Cost/Schedule Summary	Brock, Mohamad	08-Jul	10-Jul	100%	6	3
3	14.6	Manufacturing Schematics	Brock, Mohamad	09-Jul	10-Jul	100%	4	2
3	14.7	Design Considerations	Brock, Hardik	10-Jul	11-Jul	100%	4	2
3	14.8	Future Work	Brock, Mohamad	01-Aug	02-Aug	100%	4	2
3	14.9	Design Influences	Mohamad	01-Aug	02-Aug	100%	2	2
3	**15**	**Detailed Design Schematics**	-	**03-Jul**	**11-Jul**	**100%**	**23**	**9**
3	15.1	Detailed Manufacturing Part Drawings	Nicholas	03-Jul	06-Jul	100%	4	4
3	15.2	Subassembly Drawings	Nicholas	04-Jul	06-Jul	100%	3	3
3	15.3	Overall Assembly Drawing	Nicholas	08-Jul	11-Jul	100%	4	4
3	15.4	Technical/Process Schematics	Cole, Hardik	05-Jul	07-Jul	100%	6	3
3	15.5	Block Process Diagrams	Cole, Hardik	05-Jul	07-Jul	100%	6	3
3	**16**	**Detailed Design Calculations**	-	**06-Jul**	**08-Jul**	**100%**	**4**	**3**
3	16.1	Heat Calculations (Safety, Functionality)	Brock	06-Jul	08-Jul	100%	2	2
3	16.2	Updated Conceptual Design Calculations	Brock	08-Jul	08-Jul	100%	1	1
3	16.3	System/Sub-System Design Calculations	Cole	08-Jul	08-Jul	100%	1	1
3	**17**	**Design Compliance Matrix**	-	**08-Jul**	**10-Jul**	**100%**	**9**	**3**
3	17.1	Update Design Specification Matrix	Han	08-Jul	09-Jul	100%	2	2
3	17.2	Update Conceptual Design Columns	Team	08-Jul	08-Jul	100%	6	1
3	17.3	Obtain Client Approval of Final Design	Hardik	10-Jul	10-Jul	100%	1	1
3	**18**	**Project Management**	-	**18-Jul**	**22-Jul**	**100%**	**11**	**5**
3	18.1	Update Gantt Chart	Han	18-Jul	19-Jul	100%	2	2
3	18.2	Time Sheets	Team	20-Jul	20-Jul	100%	6	1
3	18.3	Design Cost Analysis	Han	20-Jul	22-Jul	100%	3	3
3	**19**	**Prototype**	-	**17-Jul**	**19-Jul**	**100%**	**20**	**3**
3	19.1	Prototype Construction	Team	17-Jul	19-Jul	100%	18	3
3	19.2	Ignition, Emission and Efficiency Tests	Brock, Hardik	19-Jul	19-Jul	100%	2	1
3	**20**	**Phase 3 Report Finalization**	-	**12-Jul**	**13-Jul**	**100%**	**13**	**2**
3	20.1	Cover Letter	Brock	12-Jul	12-Jul	100%	1	1
3	20.2	Executive Summary	Team	12-Jul	13-Jul	100%	12	2
3	**21**	**Final Design Poster / Brochure**	-	**10-Jul**	**02-Aug**	**100%**	**12**	**24**
3	21.1	Schematics	Hardik	10-Jul	12-Jul	100%	3	3
3	21.2	Design Summary	Mohamad	12-Jul	13-Jul	100%	2	2
3	21.3	Poster Creation	Hardik, Brock	15-Jul	17-Jul	100%	6	3
3	21.4	Submit Poster	Brock	02-Aug	02-Aug	100%	1	1
3	**22**	**Final Design Conference**	-	**12-Jul**	**02-Aug**	**100%**	**30**	**22**
3	22.1	Video Shooting	Mohamad	12-Jul	14-Jul	100%	3	3
3	22.2	Video Editing	Mohamad	15-Jul	16-Jul	100%	2	2
3	22.3	Presentation Editing	Team	15-Jul	17-Jul	100%	18	3
3	22.4	Submission	Brock	02-Aug	02-Aug	100%	1	1
3	22.5	Presentation	Team	11-Aug	11-Aug	100%	6	1
		Pre-Submission Team Review	**Team**					
		Submission	**Team**	**06-Aug**	**06-Aug**			
3	**23**	**Self Assessment**	**Team**	**10-Aug**	**10-Aug**	**0%**	**6**	**1**
					Total Hours:		**166**	

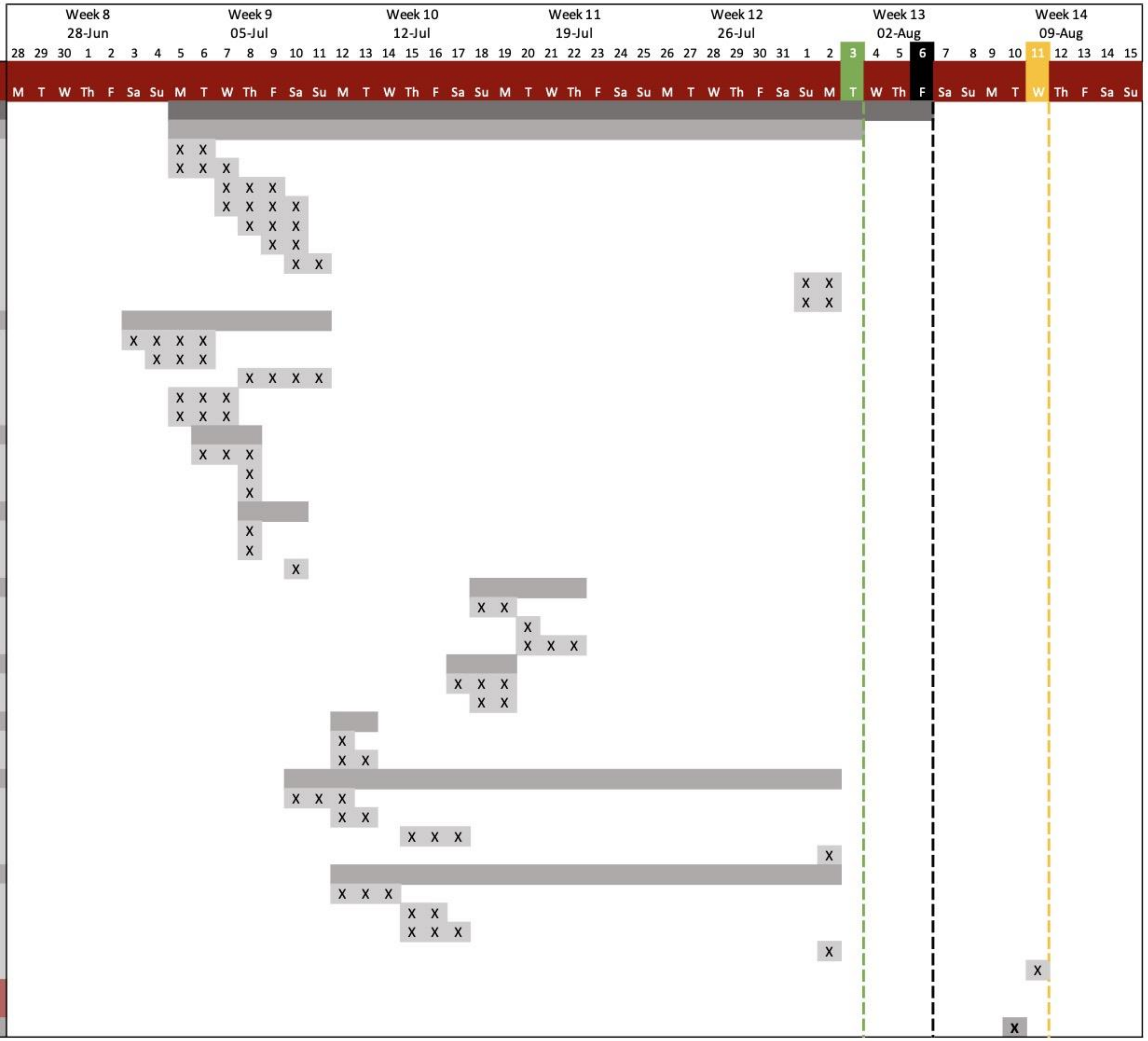


Figure F 3: Phase 3 Gantt Chart

Appendix F.2 Group Hours

Table D 1: Individual activity time log

Week of	Member Name:	Hardik Nijhawan	Mohamad Abdulla	Nicholas Dittaro	Matthew Kirkland	Han King	Cole Clarke	Total Team Hours
May 16 - 22	*activities*	Logo design and cover letter editing	Research client and relevant codes and standards for project	Research client and relevant codes and standards for project	Research related info / misc. research	Worked on LOI, created cover letter, created Team Charter	Research: Patent / old examples	
	active hrs:	1	0.5	0.5	0.5	3	0.5	6
May 23 - 29	*activities*	Presentation + report formatting	Prepare meeting minutes template + Refine team meeting minutes + Prepare meeting agenda for 3 team meetings & 2 client meetings & advisor meeting + Key Design Specifications + Material Research + Manufacturing and Cost Estimate + Setting Specifications	Preparing set up for key design specifications as well as grasping a general idea for the section based on other class examples, writing rough draft of key design specs section, finish key specs section and add info	Begin work on report writing and write on the business model for this project	Created Gantt Chart, created/edited Design Spec. Matrix, client email communications	Research for patents, codes, and standards. Write related sections in report. Help add info to materials (textbook information). Wrote introduction, design objective. General Editing within report.	
	active hrs:	8	4	5	4	13	8	42
May 30 - June 05	*activities*	Report editing	Report formatting + editing/ reference update	References, Report clean up, report finalization, fetching materials	Report editing and formatting. Clean-up so that we have technical writing style and fall within the accepted word count	Finalized design matrix, finalized time estimates, finalized gantt chart	General editing within report. Edited References. Creating tables for patent examples / accepted designs.	
	active hrs:	2.5	3	3.5	3.5	3.5	2	18
June 06 - 12	*activities*	Brainstorming	Brainstorming	Brainstorming	Brainstorming, Preliminary design discussions	Brainstorming	Created Basic Solidworks model for brainstorming	
	active hrs:	1	2	1.5	1.5	1.5	1	8.5
June 13 - 19	*activities*	Modelling and meeting and research	Solid modelling and simulation + Calculation/ Literature	Learning simulations and modeling	materials and manufacturing research	Editing gantt chart, researched manufacturing details, researched materials	Learning Simulation Process and implementing simulation progress	
	active hrs:	5.5	8.5	7	3.5	3.5	7	35
June 20 - 30	*activities*	Report writing, design and modelling	Solid modelling and simulation + Report	Modelling, simulation, report writing	heat transfer, begin report writing	Updated design spec matrix, created evaluation matrix, research materials, PM duties	Solid Modelling and Simulation. Concept Design + Writing in Report	
	active hrs:	19	18	20	16	16	20	109

Week of	Member Name:	Hardik Nijhawan	Mohamad Abdulla	Nicholas Dittaro	Matthew Kirkland	Han King	Cole Clarke	Total Team Hours
Jul 1 - 4	*activities*		Presentation		work on presentation for professor			
	active hrs:		1.5		1.5			3
Jul 5-11	*activities*				Miscellaneous		Prototyping	
	active hrs:				1		3	4
jul 12-18	*activities*	Prototyping	Prototyping	Prototyping	Prototyping	Prototyping		
	active hrs:	3	3	3	3	2		14
jul 19-25	*activities*	Prototyping, Design for poster,	Poster	Optimizing Design using Solidworks, Prototyping, Finalizing design, Photos, Drawings	Presentation	Prototyping, presentation	Ansys Research. Phone Call with Dr.Olfert about emission Calculations	35
	active hrs:	16	2	8	2.5	4	2.5	
Jul 26-31	*activities*	Prototyping, report writing, poster	Prototyping	Prototyping, Finalizing design, Photos, Drawings	presentation, power point	Prototyping, manufacturing, procurement, presentation	Solidworks Drawings. Efficiency research. Prototyping	
	active hrs:	10	5	16	4	8.5	8	51.5
Aug 1-6	*activities*	Presentation, Poster, Report	Presentation, Poster	Finalizing prototype, Report writing, presentation	Presentation formatting and finalizing, submitting and formatting documents	Updating spec matrix, presentation, manufacturing, cost analysis, assembly instructions	Efficiency calculations and research. Writing emission analysis, and prototype process/Calculations. Writing Report.	
	active hrs:	4	4	7	4	8.5	19	46.5
Aug 7-13	*activities*	Report writing	Update meeting minutes + Report	Report Writing and Formatting	Report writing, editing, formatting	Report writing, time estimation, formatting	Report Writing	
	active hrs:	4	6	5	3	2	2	22
	Total Work, hrs	74	57.5	76.5	48	65.5	73	
	Total Work, %	19%	15%	19%	12%	17%	19%	394.5

Appendix F.3 Meeting Minutes

July. 04, 2021 - Meeting Minutes
Team Advisor meeting

Mohamad Abdulla	Hardik Nijhawan	Cole Clarke	Han King	Nicholas Dittaro	Matthew Kirkland
mwabdull@ualberta.ca	nijhawan@ualberta.ca	cnclarke@ualberta.ca	linhan3@ualberta.ca	dittaro@ualberta.ca	mbkirkla@ualberta.ca
Y	**Y**	**Y**	**Y**	**Y**	**Y**

Meeting Agenda:

Review requirements for Phase 3
Review Gantt chart and deliverables
Discuss what to improve on Chosen Design

Meeting commenced: 20:03

Deliverables & Remarks:

N/A

Next Meeting:

July 06

Meeting adjourned: 20:38

July. 06, 2021 - Meeting Minutes

Client meeting

Mohamad Abdulla	Hardik Nijhawan	Cole Clarke	Han King	Nicholas Dittaro	Matthew Kirkland
mwabdull@ualberta.ca	nijhawan@ualberta.ca	cnclarke@ualberta.ca	linhan3@ualberta.ca	dittaro@ualberta.ca	mbkirkla@ualberta.ca
Y	**Y**	**Y**	**Y**	**Y**	**Y**

Meeting Agenda:

Update Connor: discuss design concepts and the selected design

---

Meeting commenced: 14:30

Deliverables & Remarks:

N/A

Next Meeting:

July 06 18:00

Meeting adjourned: 15:12

July. 06, 2021 - Meeting Minutes

Team meeting

Mohamad Abdulla	Hardik Nijhawan	Cole Clarke	Han King	Nicholas Dittaro	Matthew Kirkland
mwabdull@ualberta.ca	nijhawan@ualberta.ca	cnclarke@ualberta.ca	linhan3@ualberta.ca	dittaro@ualberta.ca	mbkirkla@ualberta.ca
Y	**Y**	**Y**	**Y**	**Y**	**Y**

Meeting Agenda:

Review advisor meeting and refine final design

Meeting commenced: 18:00

Deliverables & Remarks:

Next Meeting:

July 20 - 16:30

Meeting adjourned: 18:30

July. 17, 2021 - Meeting Minutes

Team/ Client/ Advisor meeting

Mohamad Abdulla	Hardik Nijhawan	Cole Clarke	Han King	Nicholas Dittaro	Matthew Kirkland
mwabdull@ualberta.ca	nijhawan@ualberta.ca	cnclarke@ualberta.ca	linhan3@ualberta.ca	dittaro@ualberta.ca	mbkirkla@ualberta.ca
Y	**Y**	**Y**	**Y**	**Y**	**Y**

Meeting Agenda:

Keeping Connor Updated
Plans for Prototype Discussion

Meeting commenced:

Deliverables & Remarks:

...

Next Meeting:

July 24th

Meeting adjourned:

...

July. 19, 2021 - Meeting Minutes

July 19th 2021 - Advising with Dr.Olfert about Emission Analysis

Mohamad Abdulla	Hardik Nijhawan	Cole Clarke	Han King	Nicholas Dittaro	Matthew Kirkland
mwabdull@ualberta.ca	nijhawan@ualberta.ca	cnclarke@ualberta.ca	linhan3@ualberta.ca	dittaro@ualberta.ca	mbkirkla@ualberta.ca
N	**N**	**Y**	**N**	**Y**	**N**

Meeting Agenda:

Talk to Dr.Olfert about the process of analyzing emission analysis both digitally and physically

---

Meeting commenced: 10:00

Software to digitally simulate emissions is expensive, difficult to use, and takes a lot of time to process.
Adiabatic Flame Temperature to analyze the amount of energy wood produces, make assumptions.
"Better to show experimental results rather than theoretical calculations"
Ask mece labs for a temperature transducer.

Deliverables & Remarks:

Discuss with Kajsa about experimental Results
Contact MecE labs

Next Meeting:

Allowed to call Mr.Olfert whenever we need help again.

Meeting adjourned:

10:40

July. 20, 2021 - Meeting Minutes

Team meeting

Mohamad Abdulla	Hardik Nijhawan	Cole Clarke	Han King	Nicholas Dittaro	Matthew Kirkland
mwabdull@ualberta.ca	nijhawan@ualberta.ca	cnclarke@ualberta.ca	linhan3@ualberta.ca	dittaro@ualberta.ca	mbkirkla@ualberta.ca
Y	**Y**	**Y**	**Y**	**Y**	**Y**

Meeting Agenda:

Discuss updates
Refine design

Meeting commenced: 16:30

Deliverables & Remarks:

N/A

Next Meeting:

Meeting adjourned: 17:00

July. 27, 2021 - Meeting Minutes
Advisor meeting

Mohamad Abdulla	Hardik Nijhawan	Cole Clarke	Han King	Nicholas Dittaro	Matthew Kirkland
mwabdull@ualberta.ca	nijhawan@ualberta.ca	cnclarke@ualberta.ca	linhan3@ualberta.ca	dittaro@ualberta.ca	mbkirkla@ualberta.ca
Y	**N**	**Y**	**N**	**N**	**N**

Meeting Agenda:

Share updates with Ehsan

Meeting commenced: 17:07

Deliverables & Remarks:

N/A

Next Meeting:

Meeting adjourned: 17:34

Aug. 02, 2021 - Meeting Minutes

Team/ Client/ Advisor meeting

Mohamad Abdulla	Hardik Nijhawan	Cole Clarke	Han King	Nicholas Dittaro	Matthew Kirkland
mwabdull@ualberta.ca	nijhawan@ualberta.ca	cnclarke@ualberta.ca	linhan3@ualberta.ca	dittaro@ualberta.ca	mbkirkla@ualberta.ca
N	**Y**	**Y**	**Y**	**Y**	**Y**

Meeting Agenda:

Discuss presentation

Meeting commenced: 20:30

Deliverables & Remarks:

N/A

Next Meeting:

Meeting adjourned: 21:00

Aug. 03, 2021 - Meeting Minutes

Team/ Client/ Advisor meeting

Mohamad Abdulla	Hardik Nijhawan	Cole Clarke	Han King	Nicholas Dittaro	Matthew Kirkland
mwabdull@ualberta.ca	nijhawan@ualberta.ca	cnclarke@ualberta.ca	linhan3@ualberta.ca	dittaro@ualberta.ca	mbkirkla@ualberta.ca
Y	**Y**	**Y**	**Y**	**Y**	**Y**

Meeting Agenda:

Presentation review

Meeting commenced: 16:00

Deliverables & Remarks:

N/A

Next Meeting:

Meeting adjourned: 16:10

AUG. 07, 2021 - Meeting Minutes

Team meeting

Mohamad Abdulla	Hardik Nijhawan	Cole Clarke	Han King	Nicholas Dittaro	Matthew Kirkland
mwabdull@ualberta.ca	nijhawan@ualberta.ca	cnclarke@ualberta.ca	linhan3@ualberta.ca	dittaro@ualberta.ca	mbkirkla@ualberta.ca
Y	**Y**	**Y**	**Y**	**Y**	**Y**

Meeting Agenda:

Phase 3 report review

Meeting commenced: 18:00

Deliverables & Remarks:

...

Next Meeting:

...

Meeting adjourned:

19:00

Appendix G: Team Charter

MEC E 460 Team Charter
Summer 2021

Team Name: KNACK'D Corporation

As a team we have agreed to the following rules, roles, responsibilities, and expectations (see the document "MEC E 460 Team Charter Guide" for assistance in creating this document):

Roles & Responsibilities

Each group member is responsible for fulfilling the duties associated with their role in addition to general group contributions. Roles may be revised between team members as needed to ensure effective group operation.

- Project Manager – Hardik Nijhawan - Ensures all team members (including themselves) adhere to the team charter; monitors project progress while ensuring team members remain accountable for their duties.
- Sponsor Liaison – Han King - Primary contact between team and Project Sponsor; responsible for managing communications and resolving any questions or concerns between the two parties.
- Group Coordinator – Mohamad Wael - Develops meeting agenda as per team members' suggestions, sends out meeting reminders to participants and records minutes during meetings.
- Assignment Coordinator - Matthew Kirkland - Compiles completed work, assembles the final product, and submits product on time. Also responsible for ensuring files on the Drive remain organized.
- Design Coordinators - Cole Clarke & Nicholas Dittaro - Responsible for CAD modeling and drawings; responsible for developing a modelling plan and overseeing performance simulations required.

General Member Expectations

- All group members will actively contribute to the completion of all assignments; all contributing team members will have their names included on the assignment. An uncooperative or non-performing team member may have their name(s) excluded from the submitted assignment.
- After each assignment, the team will meet to discuss why marks were lost and how the submission could have been improved. The performance of each group member will be assessed according to assigned task(s).
- Meeting schedule will be determined by the team. If a team member is unable to attend a scheduled meeting, they will inform the rest of the team or suggest an alternative time ASAP. Team members are expected to complete individual preparation for team meetings.
- For legitimate absences from group meetings, the team will make sure that the absent member gets caught up on missed material or information.
- Team members, when given a task, should report back to the group in a timely manner as per deadlines discussed in team meetings.
- Team members will support each other in accomplishing individual tasks offering encouragement, resources, and assistance when necessary. Team members will encourage participation of each other during meetings.
- No member will intimidate another member. Shouting, shaming, manipulating, excessive swearing, or any other aggressive behaviors will NOT be tolerated.

Communications

- Communication within the group shall primarily occur via WhatsApp messaging, and University email.
- Project files and information will be shared on the team's Google Drive.
- Email correspondence will include all team members, via CC or BCC, as appropriate. All team members will respond to emails via the "Reply to all" option as appropriate.
- Members shall respond within 3 hours ("Expected Timeframe") of receiving any group-related communication sent between 8 am and 6 pm on Weekdays, or within 8 hours on Weekends and Statutory Holidays.

- Group members are expected to communicate in a professional and respectful manner both within the group and with external parties.

Team Meetings

- Team meetings will be scheduled based on group discussions and the open time slots shown on CATME; invitations will be sent via Google Calendar.
- If a team member is unable to attend a scheduled meeting, they will inform the rest of the team or suggest an alternative time ASAP
- Each group member is expected to be involved in group discussion by providing ideas and constructive feedback and by accepting a suitable amount of action items. If the group is discussing topics outside of a member's role it is expected that the member will still contribute to the group discussion.
- Team members are expected to attend all team meetings. Meeting minutes will be recorded and posted on the team's Shared Drive.

Conflict Resolution

- To prevent conflicts from arising, team members must treat each other with respect. Care must be taken to direct criticism of ideas toward the idea instead itself, and not toward the person.
- The team will first use a consensus-based strategy to solve conflicts. If required, a vote will be held; the majority vote will dictate the course of action.
- If the actions above fail to resolve the conflict, the team will follow the Mec E 460 conflict resolution process and seek advice from an advisor who will have been briefed with full conflict information and then take action.
- If a group member has been repeatedly warned, and attempts to remedy their behaviour have failed, they may be "fired"; likewise, an individual can "fire" their team.

Decision Making

- Active participation at meetings by all members is required. At times, members may be called upon to verbalize (or make explicit) opinions, support, acceptance, rejection, understanding, elaboration, justification, etc.
- All decisions are made with the input of all attending team members. If a team member has a strong opinion about a decision, the decision will be put to a vote.
- Inputs from all team members will be considered via a rating and ranking system. All options will be reviewed and rated by all team members. The final decision will be made according to the cumulative results of the rating and ranking points.
- If the rating and ranking system does not yield a clear decision, the process will be repeated after team discussion and/or with the addition of new information. If the choice is still unclear, the Project Sponsor, Client, or other person/party mutually agreed upon by a majority of the group members, will have ruling authority in a final decision.

Stress Management

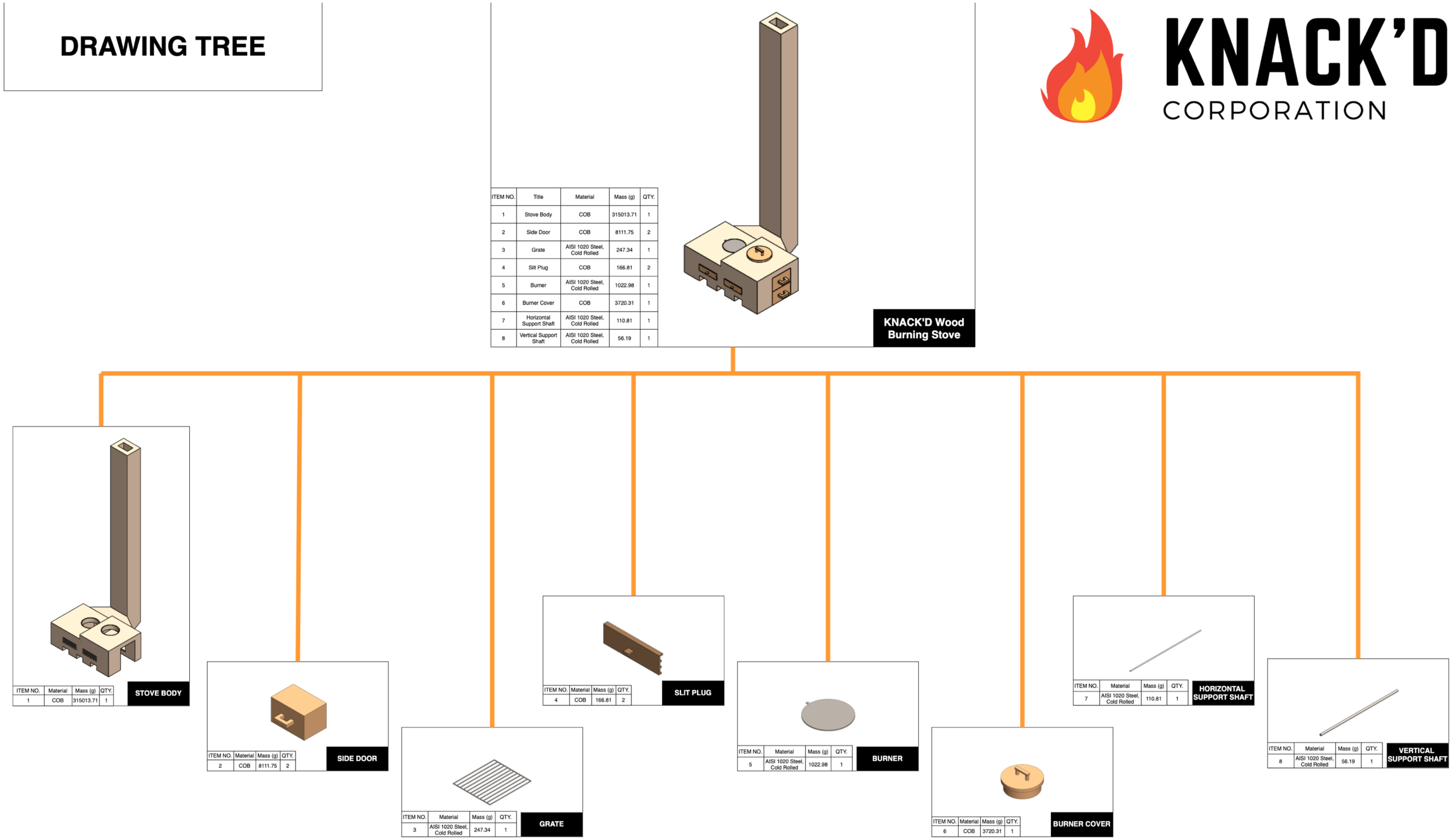
- Meetings may include a discussion regarding the workload of each of the group members, how each of the group members are handling their work, and if any reallocation of the workload is necessary.
- Group members are encouraged to reach out to fellow team members if they are experiencing too much stress or are overwhelmed by their workload for the project.
- Group members may access the University of Alberta's Health and Wellness Support resources for additional support.
  https://www.ualberta.ca/currentstudents/wellness/index.html

The undersigned group members have contributed to the creation of the above agreement and accept to work under its guidance.

Group Member: Han King Date: May 24, 2021
Group Member: Cole Clarke Date: May 24, 2021
Group Member: Hardik Nijhawan Date: May 24, 2021
Group Member: Mohamad Abdulla Date: May 24, 2021
Group Member: Brock Kirkland Date: May 24, 2021
Group Member: Nicholas Dittaro Date: May 24, 2021

Appendix H: Drawing Package

The part and assembly drawings for the stove design are shown below starting with the drawing tree shown in Figure H1

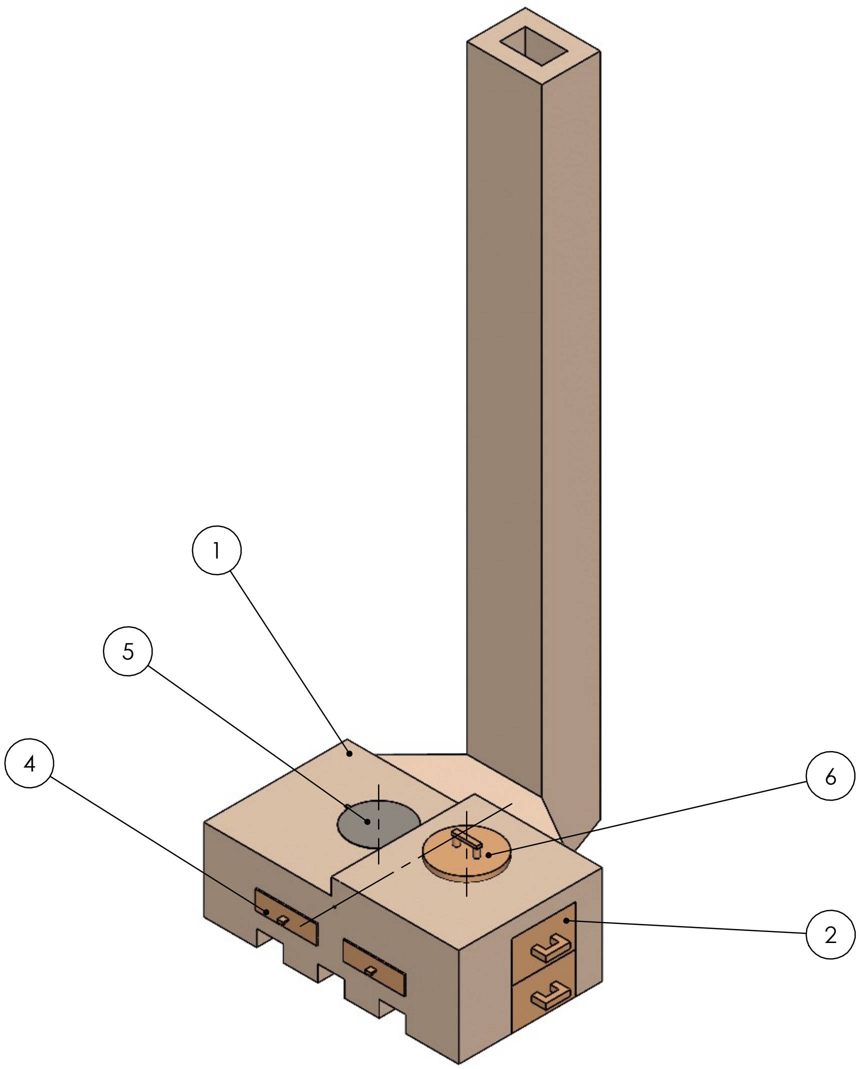


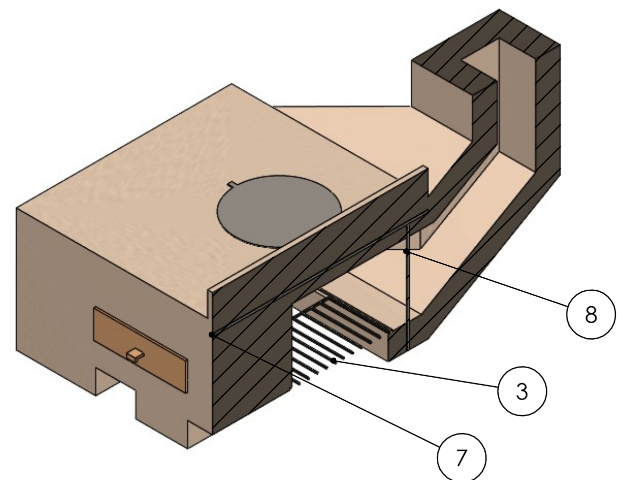
ITEM NO.	Title	Material	Mass (g)	QTY.
1	Stove Body	COB	315013.71	1
2	Side Door	COB	8111.75	2
3	Grate	AISI 1020 Steel, Cold Rolled	247.34	1
4	Slit Plug	COB	166.81	2
5	Burner	AISI 1020 Steel, Cold Rolled	1022.98	1
6	Burner Cover	COB	3720.31	1
7	Horizontal Support Shaft	AISI 1020 Steel, Cold Rolled	110.81	1
8	Vertical Support Shaft	AISI 1020 Steel, Cold Rolled	56.19	1

Notes:
1. All parts made from COB material will be formed manually by the user, as this is a common building material used in Nepal
2. All parts made from AISI 1020 Steel will be manufactured locally in Nepal
3. Drawings for all are available in the attached drawing package

Figure H 1: Drawing tree

ITEM NO.	SW-Title(Title)	Material	Mass (g)	QTY.
1	Stove Body	COB	315013.71	1
2	Side Door	COB	8111.75	2
3	Grate	AISI 1020 Steel, Cold Rolled	247.34	1
4	Slit Plug	COB	166.81	2
5	Burner	AISI 1020 Steel, Cold Rolled	1022.98	1
6	Burner Cover	COB	3720.31	1
7	Horizontal Support Shaft	AISI 1020 Steel, Cold Rolled	110.81	1
8	Vertical Support Shaft	AISI 1020 Steel, Cold Rolled	56.19	1

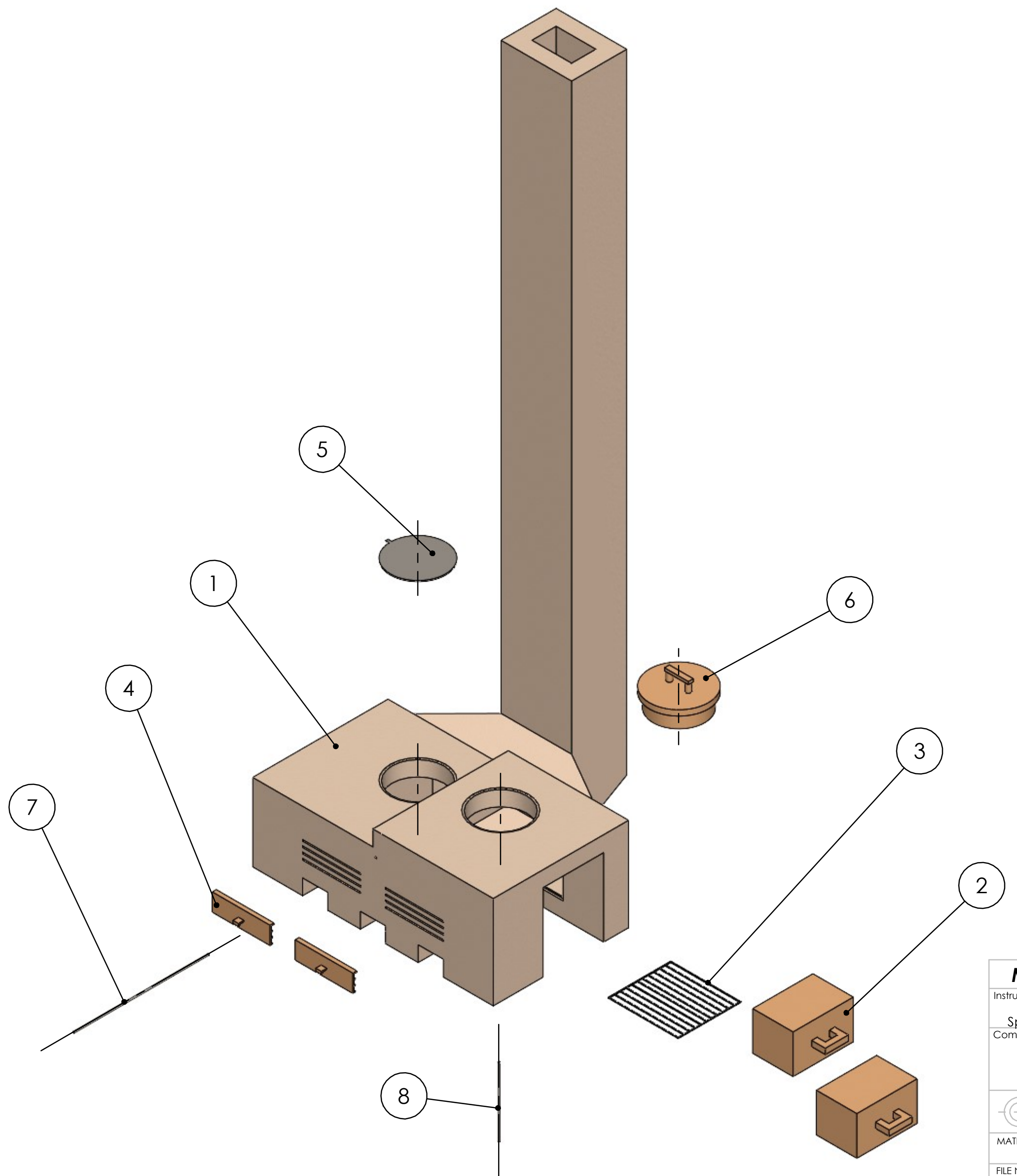




Note: Broken view will not display centerlines

Mec E 460	UNLESS OTHERWISE SPECIFIED:	DRAWN BY: **Nicholas Dittaro**	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA
Instructors: Dr. Duke Spr/Sum 2021	DIMENSIONS ARE IN MM TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025	Group name	TITLE: KNACK'D Wood Burning Stove
Comments:	SURFACE FINISH µm 0.6	Group number	
	DO NOT SCALE DRAWING	SM By: Nicholas Dittaro	SIZE B / Part supplier/manufacturer / REV
MATERIAL:		Reviewed by	
FILE NAME: KNACK'D Wood Burning Stove		Saturday, July 31, 2021 2:10:58 PM Tuesday, June 22, 2021 9:51:38 PM	SCALE: 1:50 / Mass: 336728.45 / SHEET 1 OF 14

ITEM NO.	SW-Title(Title)	Material	Mass (g)	QTY.
1	Stove Body	COB	315013.71	1
2	Side Door	COB	8111.75	2
3	Grate	AISI 1020 Steel, Cold Rolled	247.34	1
4	Slit Plug	COB	166.81	2
5	Burner	AISI 1020 Steel, Cold Rolled	1022.98	1
6	Burner Cover	COB	3720.31	1
7	Horizontal Support Shaft	AISI 1020 Steel, Cold Rolled	110.81	1
8	Vertical Support Shaft	AISI 1020 Steel, Cold Rolled	56.19	1



Mec E 460

Instructors:
Dr. Duke
Spr/Sum 2021
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:

FILE NAME:
KNACK'D Wood Burning Stove

DRAWN BY:
Nicholas Dittaro

Group name

Group number

SM By: Nicholas Dittaro

Reviewed by

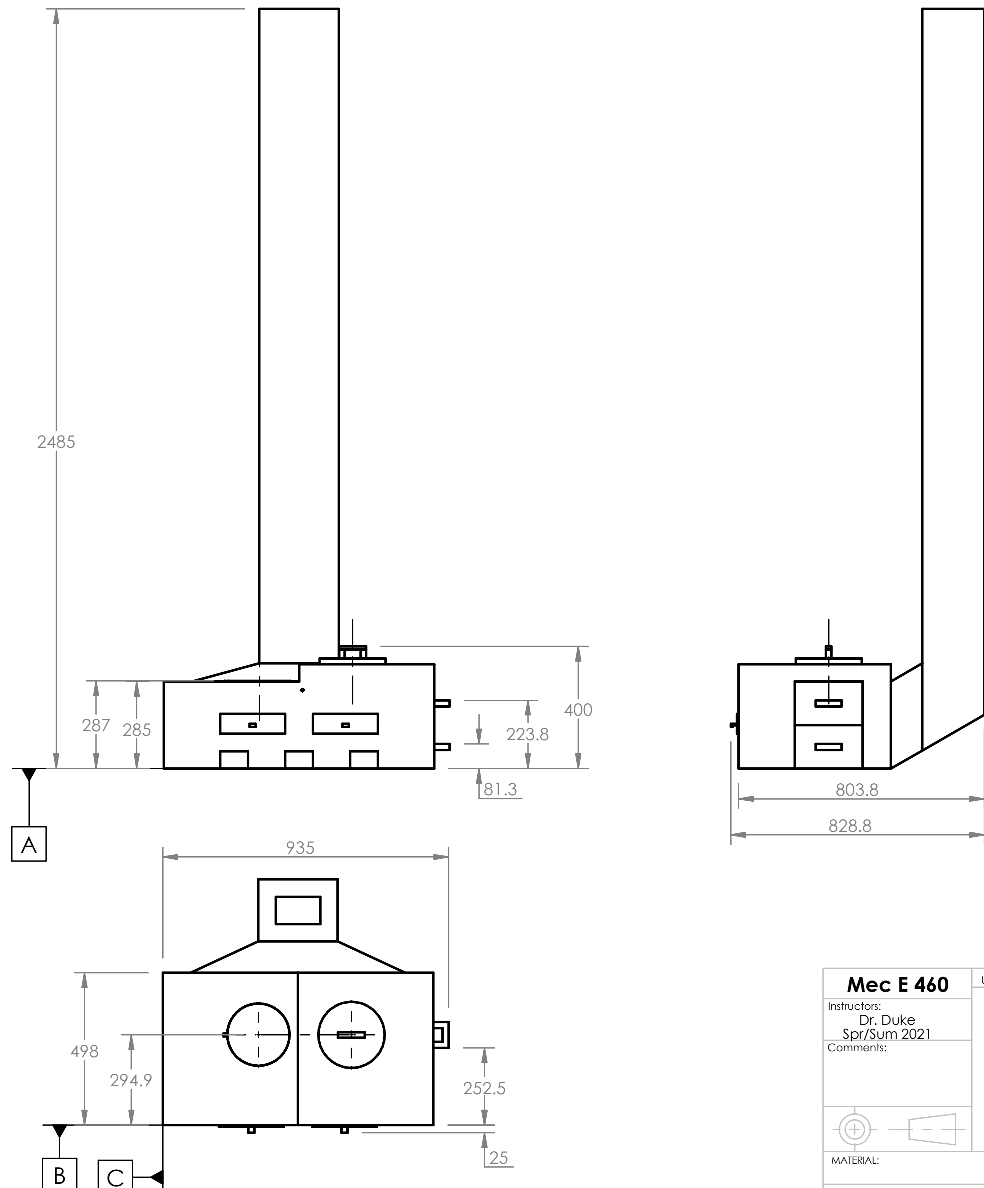
Saturday, July 31, 2021 2:10:58 PM
Tuesday, June 22, 2021 9:51:38 PM

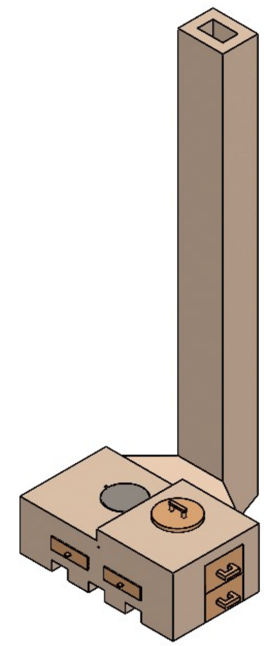
The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

TITLE:
KNACK'D Wood Burning Stove

SIZE **B** | Part supplier/manufacturer | REV

SCALE: 1:50 | Mass: 336728.45 | SHEET 2 OF 14





Mec E 460

Instructors:
Dr. Duke
Spr/Sum 2021

Comments:

MATERIAL:

FILE NAME:
KNACK'D Wood Burning Stove

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:	Nicholas Dittaro
Group name	
Group number	
SM By	Nicholas Dittaro
Reviewed by	

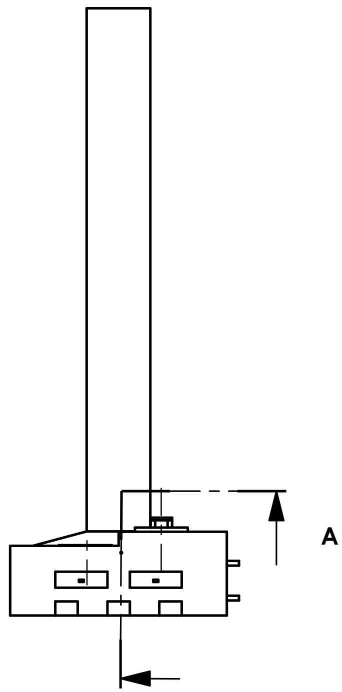
Saturday, July 31, 2021 2:10:58 PM
Tuesday, June 22, 2021 9:51:38 PM

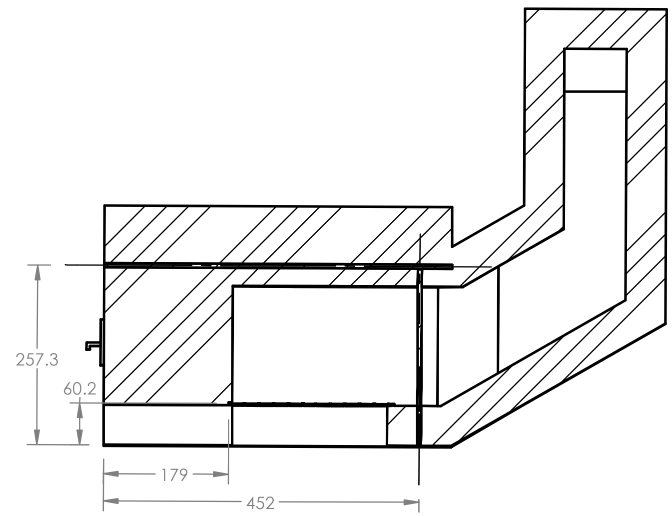
The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

TITLE:
KNACK'D Wood Burning Stove

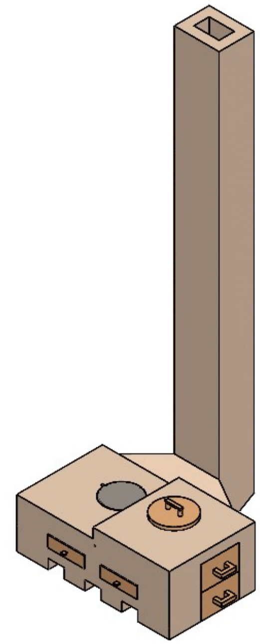
SIZE	Part supplier/manufacturer	REV
B		

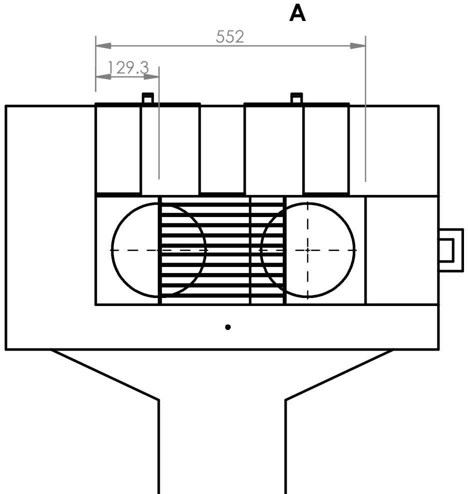
SCALE: 1:20 | Mass: 336728.45 | SHEET 3 OF 14





SECTION A-A
SCALE 1 : 7

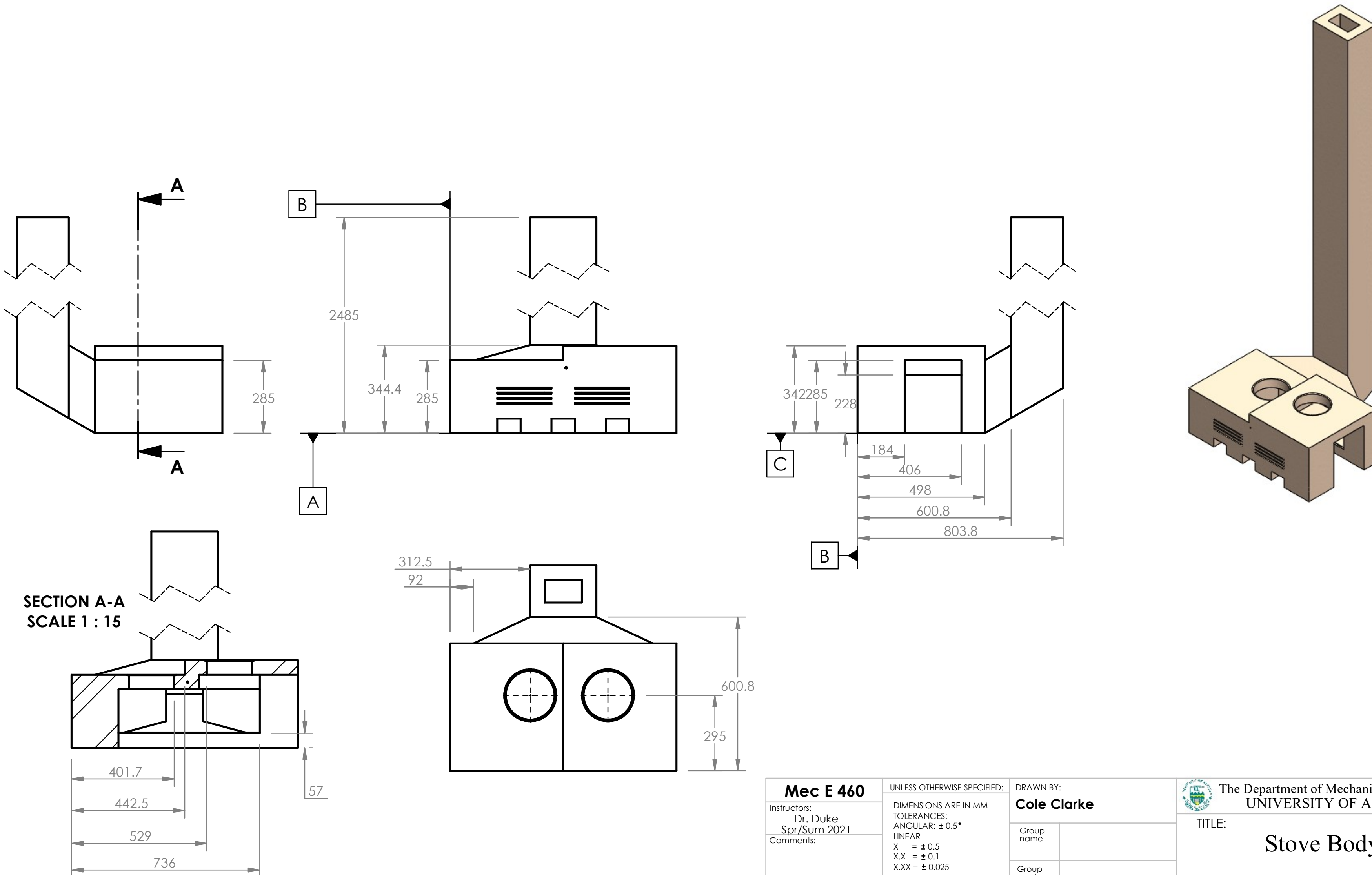




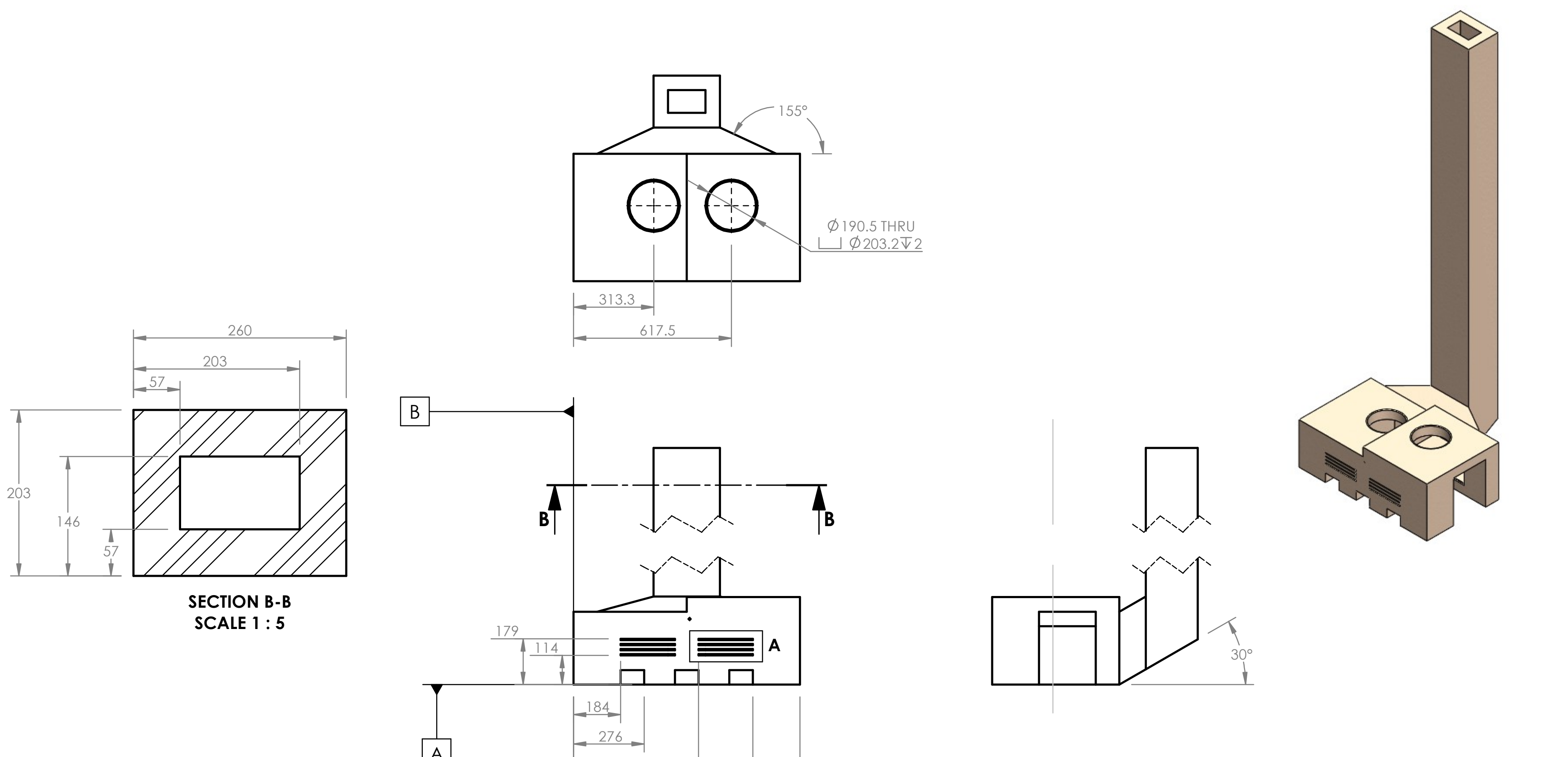
Bottom View

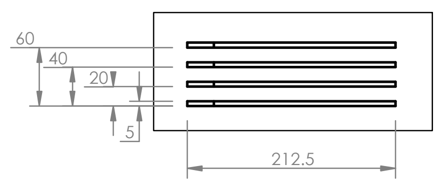
Note: The grate can slide anywhere within the combustion chamber

Mec E 460 Instructors: Dr. Duke Spr/Sum 2021 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: **Nicholas Dittaro** Group name Group number SM By: Nicholas Dittaro Reviewed by	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA TITLE: KNACK'D Wood Burning Stove
MATERIAL:		Saturday, July 31, 2021 2:10:58 PM Tuesday, June 22, 2021 9:51:38 PM	SIZE **B** Part supplier/manufacturer REV
FILE NAME: KNACK'D Wood Burning Stove			SCALE: 1:20 Mass: 336728.45 SHEET 4 OF 14



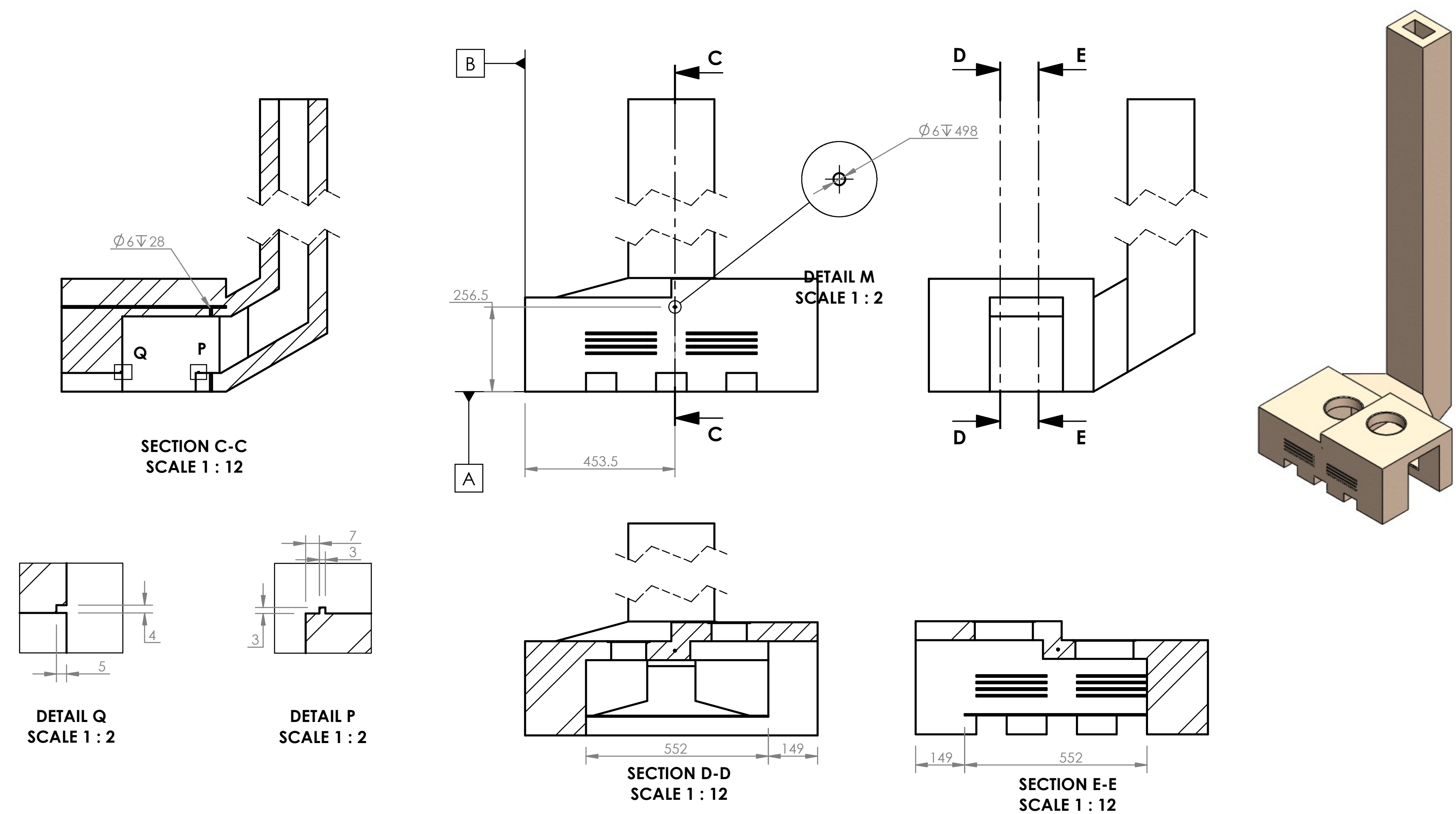
Mec E 460 Instructors: Dr. Duke Spr/Sum 2021 Comments:	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MM TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025 SURFACE FINISH µm 0.6 DO NOT SCALE DRAWING	DRAWN BY: **Cole Clarke** Group name Group number SM By: Nicholas DItTaro Reviewed by Saturday, July 31, 2021 2:10:59 PM Tuesday, June 22, 2021 8:27:56 PM	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA TITLE: Stove Body
MATERIAL:			SIZE **B** | Part supplier/manufacturer | REV
FILE NAME: Stove Body			SCALE: 1:20 | Mass: | SHEET 5 OF 14





DETAIL A
SCALE 1 : 5

Mec E 460 Instructors: Dr. Duke Spr/Sum 2021 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: **Cole Clarke** Group name Group number SM By: Nicholas DIttaro Reviewed by Saturday, July 31, 2021 2:10:59 PM Tuesday, June 22, 2021 8:27:56 PM	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA TITLE: Stove Body SIZE **B** | Part supplier/manufacturer | REV SCALE: 1:20 | Mass: | SHEET 6 OF 14
MATERIAL:			
FILE NAME: Stove Body			



Mec E 460

Instructors:
Dr. Duke
Spr/Sum 2021

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:

FILE NAME:
Stove Body

DRAWN BY:
Cole Clarke

Group name

Group number

SM By Nicholas DiItaro

Reviewed by

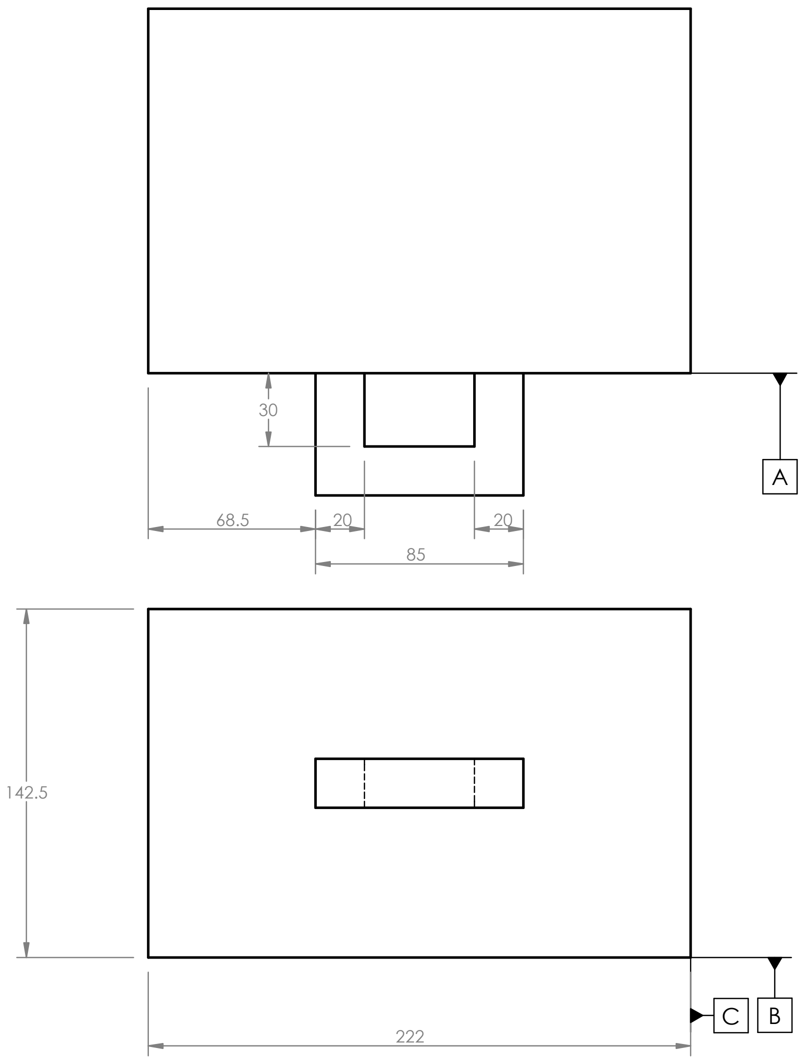
Saturday, July 31, 2021 2:10:59 PM
Tuesday, June 22, 2021 8:27:56 PM

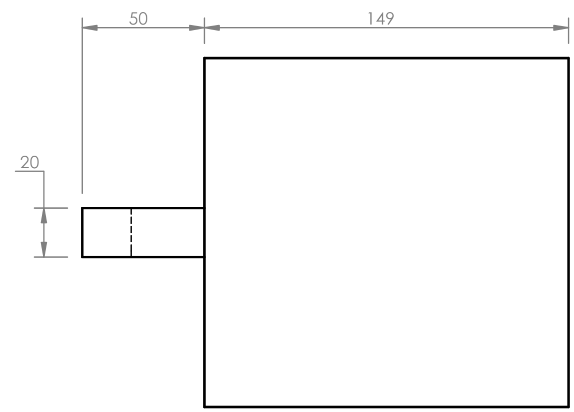
The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

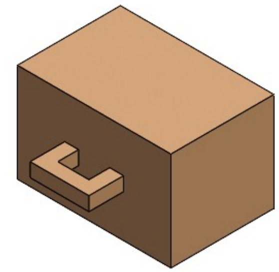
TITLE:
Stove Body

SIZE **B** | Part supplier/manufacturer | REV

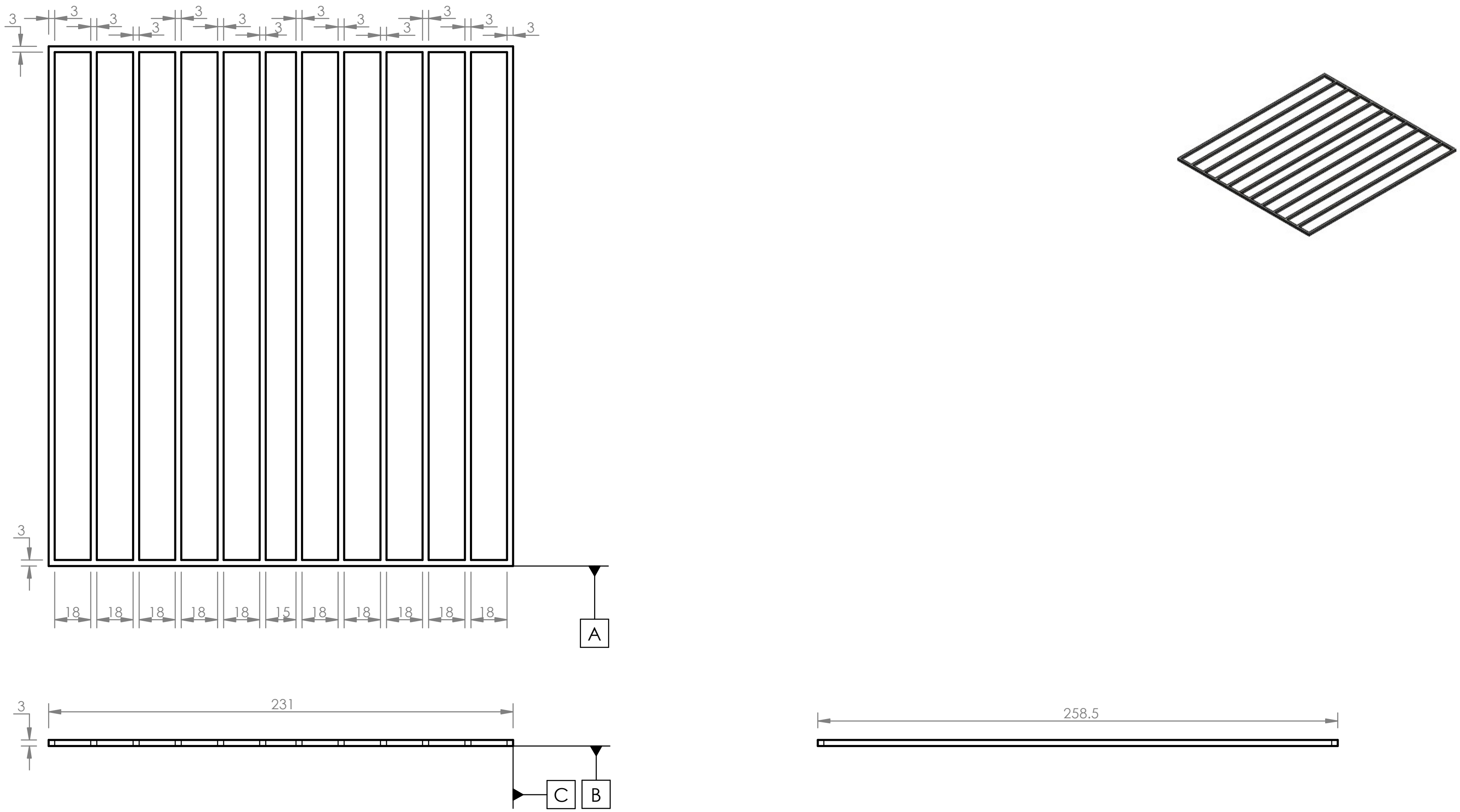
SCALE: 1:20 | Mass: | SHEET 7 OF 14



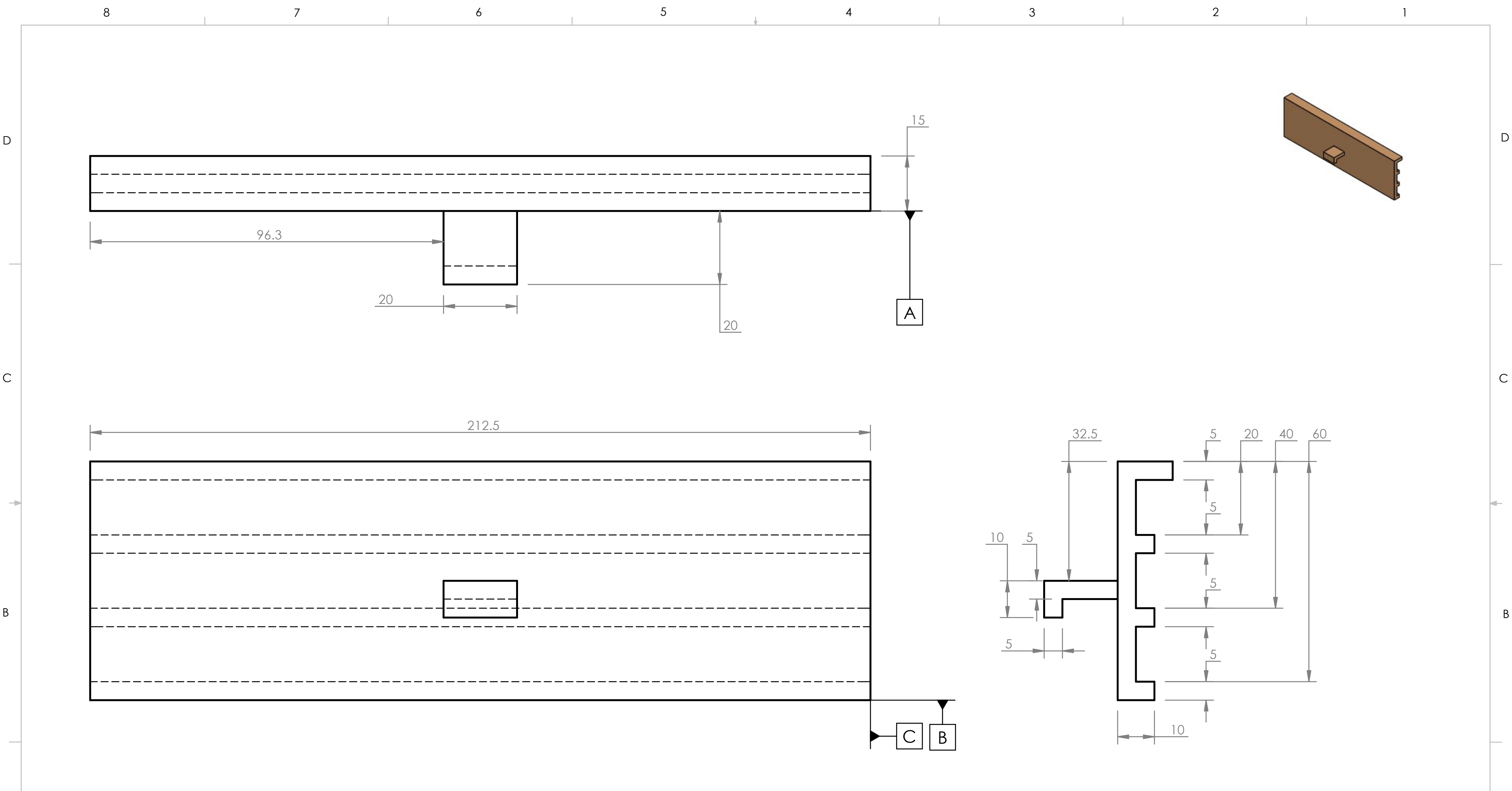




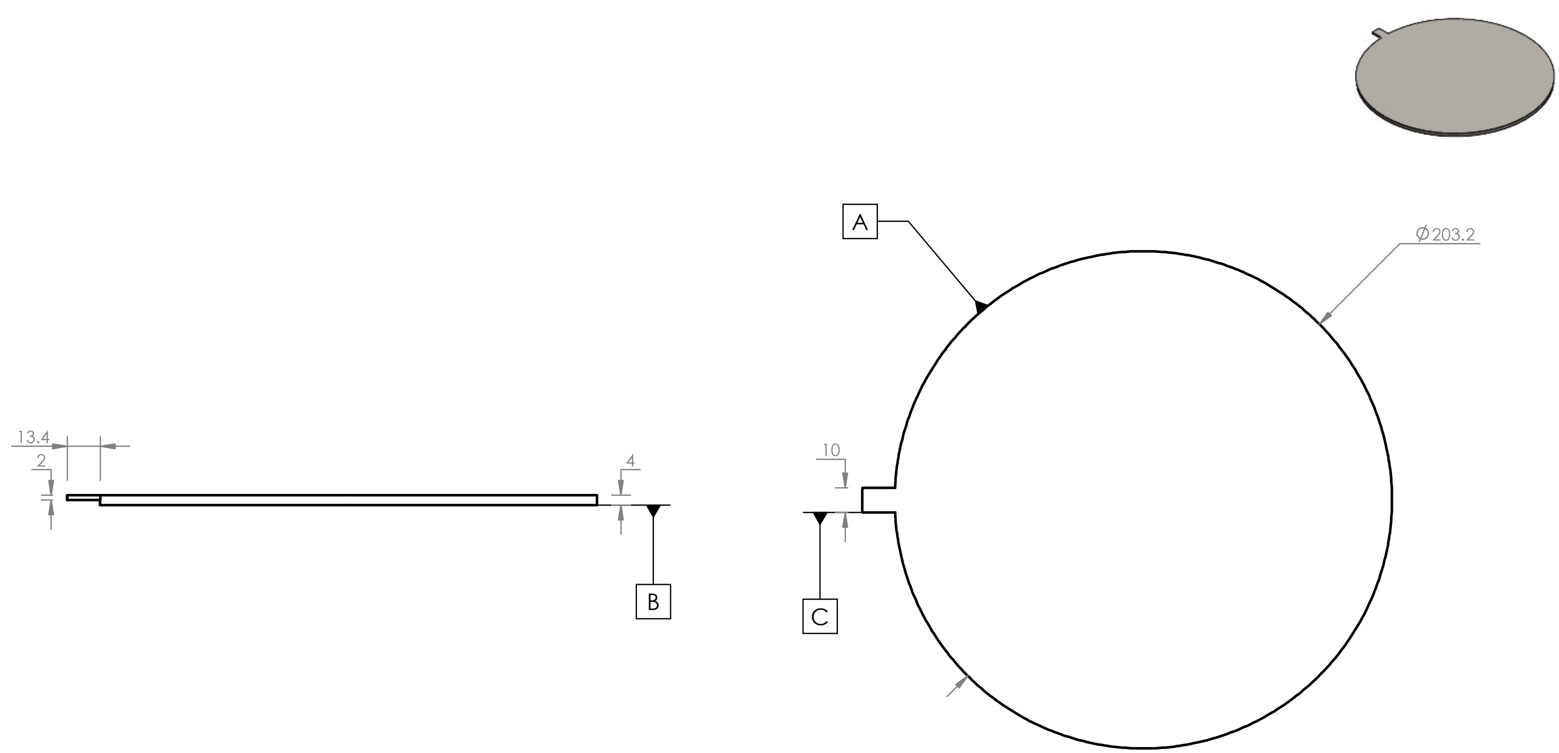
Mec E 460 Instructors: Dr. Duke Spr/Sum 2021 Comments:	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MM TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025 SURFACE FINISH µm 0.6 DO NOT SCALE DRAWING	DRAWN BY: **Nicholas Dittaro** Group name Group number SM By: Nicholas Dittaro Reviewed by Saturday, July 31, 2021 2:10:59 PM Sunday, June 20, 2021 11:10:59 PM	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA TITLE: Side Door
MATERIAL:			SIZE **B**	Part supplier/manufacturer	REV
FILE NAME: Side Door			SCALE: 1:5	Mass:	SHEET 8 OF 14



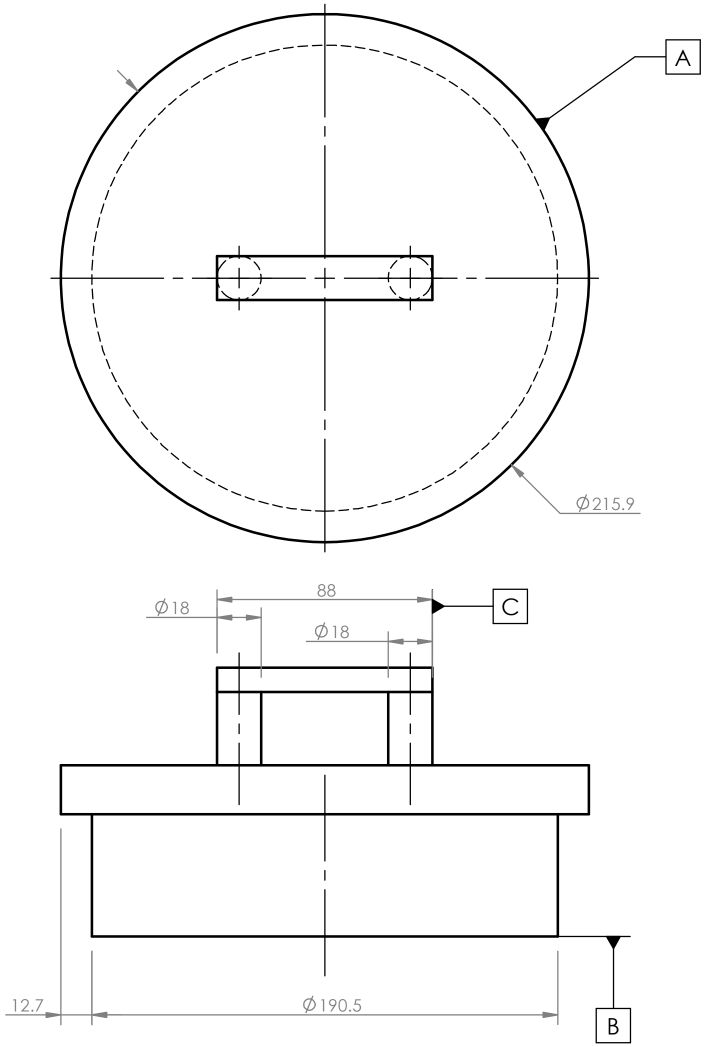
Mec E 460 Instructors: Dr. Duke Spr/Sum 2021 Comments:	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MM TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025 SURFACE FINISH µm 0.6 DO NOT SCALE DRAWING	DRAWN BY: **Nicholas Dittaro** Group name Group number SM By: Nicholas Dittaro Reviewed by Saturday, July 31, 2021 2:10:59 PM Sunday, June 20, 2021 11:10:33 PM	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA TITLE: Grate
MATERIAL:			SIZE **B** · Part supplier/manufacturer · REV
FILE NAME: Grate			SCALE: 1:5 · Mass: · SHEET 9 OF 14

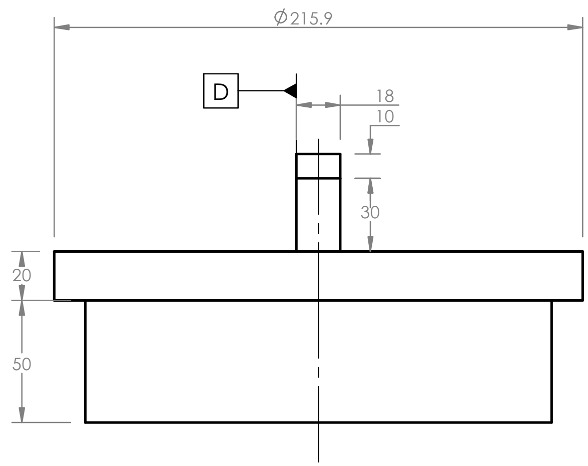


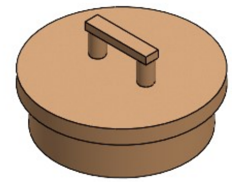
Mec E 460 Instructors: Dr. Duke Spr/Sum 2021 Comments:	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MM TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025 SURFACE FINISH µm 0.6 DO NOT SCALE DRAWING	DRAWN BY: **Nicholas Dittaro** Group name Group number SM By: Nicholas Dittaro Reviewed by Saturday, July 31, 2021 2:10:59 PM Tuesday, June 22, 2021 9:42:55 PM	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA TITLE: Slit Plug
MATERIAL:			SIZE **B** — Part supplier/manufacturer — REV
FILE NAME: Plug			SCALE: 1:5 — Mass: — SHEET 10 OF 14



Mec E 460	UNLESS OTHERWISE SPECIFIED:	DRAWN BY: Nicholas Dittaro	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA
Instructors: Dr. Duke Spr/Sum 2021	DIMENSIONS ARE IN MM TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025	Group name	TITLE: Burner
Comments:	SURFACE FINISH µm 0.6	Group number	
	DO NOT SCALE DRAWING	SM By: Nicholas Dittaro	SIZE B / Part supplier/manufacturer / REV
MATERIAL:		Reviewed by	
FILE NAME: Burner		Saturday, July 31, 2021 2:10:59 PM Sunday, June 20, 2021 10:57:46 PM	SCALE: 1:5 / Mass: / SHEET 11 OF 14







Mec E 460

Instructors:
Dr. Duke
Spr/Sum 2021
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:

FILE NAME: Burner Cover

DRAWN BY: **Nicholas Dittaro**

Group name	
Group number	
SM By	Nicholas Dittaro
Reviewed by	

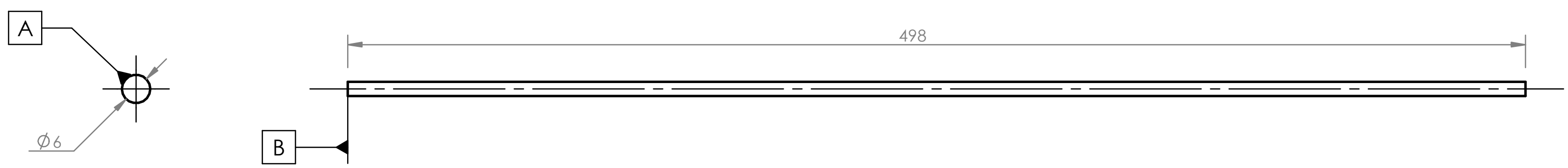
Saturday, July 31, 2021 2:10:58 PM
Sunday, June 27, 2021 1:26:42 PM

The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

TITLE:
Burner Cover

SIZE	Part supplier/manufacturer	REV
B		

SCALE: 1:5 | Mass: | SHEET 12 OF 14



Mec E 460

Instructors:
Dr. Duke
Spr/Sum 2021
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:

FILE NAME: Horizontal Support Shaft

DRAWN BY: **Nicholas Dittaro**

Group name	
Group number	
SM By	Nicholas Dittaro
Reviewed by	

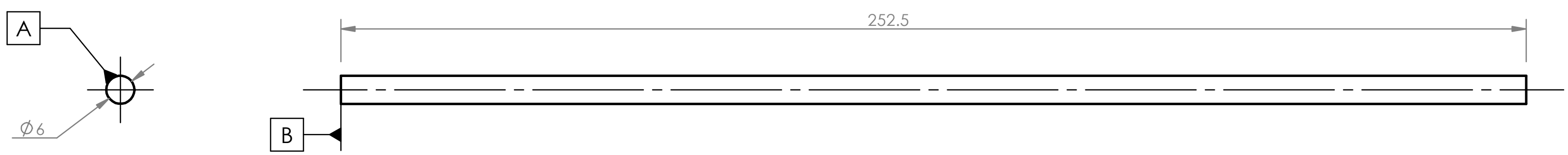
Saturday, July 31, 2021 2:10:59 PM
Friday, July 23, 2021 9:41:10 PM

The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

TITLE:
Horizontal Support Shaft

SIZE	Part supplier/manufacturer	REV
B		

SCALE: 1:2	Mass:	SHEET 13 OF 14



Mec E 460

Instructors:
Dr. Duke
Spr/Sum 2021
Comments:

MATERIAL:

FILE NAME:
Support rod 2

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:
Nicholas Dittaro

Group name

Group number

SM By Nicholas Dittaro

Reviewed by

Saturday, July 31, 2021 2:10:58 PM
Friday, July 23, 2021 9:43:30 PM

The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

TITLE:
Vertical Support Shaft

SIZE **B** | Part supplier/manufacturer | REV

SCALE: 1:2 | Mass: | SHEET 14 OF 14