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Central Washington University C-Clamp Matchplate

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By

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ABSTRACT

The goal was to design and manufacture a matchplate to be used by the Central Washington University (CWU) Engineering Department to cast C-clamps. These castings are produced in the University's foundry and would be prepared as a secondary project for the department's basic machining course. The design produced allows the C-clamps to be molded in a single pour for a full class of students, which is approximately sixteen (16). The desire was to achieve a design that was functional, yet allowed room and/or means to be easily modified or repaired, if needed. This was achieved through designing the C-clamps in a computer based model in the program Solidworks. By using Solidworks it allowed the imprints to be repeatedly modified and improved throughout the design process. This also allows future modifications to be easily made by subsequent students. This model was then converted into imprints for the matchplate and printed via a rapid prototyping system of a 3D printer. The results of these efforts yielded a functioning matchplate for testing. The results of the tests proved that it is capable of producing C-clamps effectively in enough quantity to supply the engineering department for the class project.

INTRODUCTION

Description:

At Central Washington University, the Mechanical Engineering Technologies program has expressed a desire to revive an old project for students. This being an alternative to switch or rotate between the current project of the basic machining class taken in the Mechanical Engineering Technologies program at the University. A hole punch has been the topic of a class project in the class. By developing a C-clamp casting form a student will be able to cast their C-clamp in the foundry class and then complete their C-clamp in the machining class. This portion of the curriculum is developing the mold for the students to use in the foundry to cast the basic shape of the C-clamp.

Motivation:

The MET department wishes to diversify the projects to reflect more balanced depiction of the engineering field. Where some are engineers are, in offices doing design and desk work, and would benefit from timing and taking the basic machining class, others are on the shop-floor or involved with prototyping and would be involved in both the design and building of their work. By reviving the C-clamp project students would be exposed to both types of engineer jobs. When timing allows, the students complete both the casting and the finishing work in the machine shop.

Function Statement:

A device is needed to cast an impression in a green sand casting system so that multiple C-clamps can be cast at a single production line in the foundry at the University.

Requirements:

Since these are to be produced for possible use and machining, the requirements are as follows:

- The design must successfully cast 4 C-clamps.
- Must be able to successfully cast in aluminum.
- Design needs reference-able datum(s) for later work in machining shop.
- The matchplate must be easily repairable.

Success Criteria:

Success depends on the matchplate being properly designed and constructed so that it imparts a proper pattern into the green sand. If it does not impart a proper pattern or the pattern is improperly designed there is a slew of issues that could arise. From the metal not cooling properly, developing air pockets, or even getting metal to flow where it is needed quickly enough.

- Does the matchplate allow a successful casting of the C-clamps in green sand.
- If successful in casting, what is the amount of supplies in green sand and aluminum to produce sixteen to twenty C-clamps.

Scope of Effort:

In this endeavor, the parts in focus are the production of a matchplate that can produce four cast aluminum C-clamps. However, in conjuncture with the campus machine shop datum points are being established on the clamps. This is for designing a jig to machine the clamps after casting.

This project's efforts do not include the production of any jigging or mounting to finish work. Focus is on the production of a matchplate that produces four aluminum C-clamps with effect datums for later finish machining.

DESIGN & ANALYSIS

Proposed Solution:
The design had multiple phases of project analysis to determine the solutions viable to apply. This took place in the processes of determining the mean to cast the clamps. Another issue was, if the means had to be designed and fabricated, how would and could this be done. From the analysis of both the casting means on campus and referring to, Technology of Metalcasting (Schleg, 2015), the best two solutions were to develop a matchplate design or taking a C-clamp and using it as a mold.

Since the goal of the C-clamp itself is to bring a greater focus and aspects of manufacturing and the processes, the matchplate was chosen. This was due to the matchplate's ability to imprint the pattern successfully and quickly if the sand is prepared and packed properly and if time allowed students could improve their foundry skills by packing the matchplate themselves.

Design Description:
It was determined that a Matchplate would be designed that used the output of a C-clamp from the 3D printing lab and all risers, gates, and sprue would be made of wood which would allow the matchplate to be repaired with minimal effort in the future.

With the solution of a matchplate being selected analysis of how to create a pattern that could be split in two and be adhered to both sides of the matchplate needed to be determined. After consulting with Engineering Department Staff, it was determined that the Solidworks 3D printing lab on campus within the Engineering Department would be the best means. This required that a new version of the clamp be designed in the 3D CAD software program Solidworks. This design then had to be split and modified into two half-shell imprints. One with indented holes to accept the other imprints dowels and glue them together with proper datums.

The second challenge in the design analysis, is how the matchplate going to be produced. It was determined that gates, risers, and sprue base could simply be made of dowels, and shaped wooden bars of some dimension. Also, the base of the matchplate could be a simple one-inch thick piece of plywood board. The board would be cut to the proper dimensions to fit the largest flask. The pieces would be attached by drilling holes and aligning the dowel pins which will secure each piece in from both sides with epoxy.

As seen in Figures 1 and 9 in Appendix B the C-clamp itself went through three key levels in design. First in Figure 1 is the first rough draft of what were the optimal features to a design concept. In Figure 9, the finalized design is shown that the imprints were derived from.

Design Parameters
Parameter Values:

- Functional matchplate the produces two C-clamps with each 12.x14 flask which can be reused to produce additional 12x14 flasks for a total 16 C-clamps in a single pour.

Calculated Values:

- Calculate the amount of aluminum needed to produce 16 C-clamps in a single pour
- Calculate the amount of green sand needed to produce 16 C-clamps in a single pour.

Success criteria values:

- Produce two (2) C-clamps, which will allow the foundry to produce 16 C-clamps in one run.

Performance Predictions:

It is expected that the matchplate will perform as expected because of experience with building matchplates and the specialists mentoring me on this project.

METHODS & CONSTRUCTION

Method:

The project was conceived amongst the Engineering Department at Central Washington University as a pedagogical improvement to introduce more manufacturing aspects into the basic machining class in the program. To produce the imprints, the additive manufacturing means of the Solidworks printing lab at Central Washington University will be utilized. Within the Solidworks lab, the designing of any parts requiring specialized geometry and dimensions were produced. From these designs, a 3D printed model of these parts were then produced. Inside of the foundry, the matchplate will be assembled and tested.

Construction: Figures 16 and 17 Appendix B

To construct the device, first the body of the C-clamp imprint for both sides of the match plate needed to be designed. This took several attempts and refereeing with experts to obtain a design in Solidworks that would produce the design needed. From this, five printings of the C-clamp were made in total to achieve the final two successful and complete imprints. This was then converted into a file printable for the Catalyst software which prints the design in a 3D printer. Shown in Figures

Upon design completion, the imprints were to be lined up and assembled on a three-quarters inch thick piece of particleboard resourced by Matt Burvee. The particleboard was drilled with holes that line up two halves of each clamp. From there the gates and runners were crafted and aligned in an array, Figure 16. The outline of these parts was marked in pencil to assist in the layout formation of the matchplate. The parts were then lifted and holes drill through the board.

After the holes were drilled the dowels would align the two halves of the runners in place, the gate or runner were placed into the board. A drill bit was used, equipped into a hand-drill and run through the hole and into the part. This was repeated on all sides to align the runners and gates properly with their dowels, Figures 16 and 17 of Appendix B. After proper alignment of all the impressions were confirmed, the imprints were epoxied into place. Once the epoxy had set, the same was done with the gates and risers to allow proper flow of molten metal in the casting.

The design is based upon a combination of square and cylindrical components. Most were either bought or donated scrap of specific dimensions of three-quarters of an inch by three-quarters of an inch blanks with a five-inch length. To make the top of the well in which the sprue will connect, a piece of two by two by seven-inch-long walnut blank was turned on a mini lathe and carved by hand to achieve a uniform shape, Center part in Figure 17 Appendix B. To achieve cylindrical runners a piece of one inch dowel was rip cut on a bandsaw in half and sanded. These lengths were then shortened and shaped to fit into their designated spots in Figures 16 and 17 of Appendix B.

Operation:

The operation of the device requires that it can impart a proper impression into the green sand to allow for effective casting. The first goal of the operation is to produce the designed C-clamp for the casting process. This will be done by making two “halves” of the C-clamp. After the designs are complete these will be introduced into the 3D printing system and a minimum of four copies will be formed to complete one matchplate. Next comes the assembly of the matchplate. The C-clamp impressions will be epoxied in place. However, the gates and risers will be bound with weaker glue to begin will in case they do not provide an adequate flow of liquid metal.

Benchmark Comparison:
For a benchmark, there is the past two cast examples one what was produced by the University foundry when this was a functional project. As a comparison, we can compare mass of the first clamps to the newly cast ones. As well as compare failure loads.

Performance Predictions:
It is expected that the matchplate will have the strength to endure the production of 16 to 20 C-clamps in one pouring without losing its functionality.

Based on prior matchplates available in the CWU foundry for C-clamps it was predicted that this proposal would be effective. Since the University had an existing broken C-clamp matchplate in the foundry little analyses was needed to determine the reasonableness of duplicating the effort.

It was decided that to improve on the matchplate multiple C-clamps would be formed in one matchplate and associated runners, necks, gates, and sprue wells would be developed in a fashion so that if one broke it could be replaced without junking the rest of the matchplate. Once the matchplate has been built sample C-clamps will be molded in the foundry to determine the efficacy of the C-clamp.

TESTING METHOD

For the matchplate to function and perform the task, it is needs to be able to reliably produce a set quantity of C-clamps. These C-clamps are to be cast with the intent of them being machined by students for the basic machining class. This means that to not waste time and materials, the matchplate needs to be able to produce complete and reliable C-clamps at a set quantity for a certain number of students who will be taking the class. To induce these results a proper system of gates and risers will be needed to ensure a proper solid casting. One method in which allows troubleshooting in the pretesting phase is to use a software program which allows one to simulate the casting. This can be used as a benchmark to do a Go-No-Go system check. This software is only a benchmark for which designs are promising; the true test will come with an empirical pouring of the metal.

Test Plan:
The goal of the project is the produce a device to successfully press an imprint in green sand, and there is a previously made benchmark model to improve upon or meet. The test is simple and direct. For preliminary stages, all that is needed is several test castings until it is clear a proper matchplate capable of imparting an appropriate set of imprints to produce sixteen fully set clamps from four separate pours. The clamps can be cut in sections and inspected. If air bubbles are in excess, the design will need modification. After this mark has been met, a production test will be done. This is where four to five molds will be made with the matchplate to be poured in unison at one setting.

Test Procedure:
The requirements of the build are to produce a functioning matchplate that can produce 2 C-clamps per flask and eight (8) flasks per production run. This means that sixteen (16) clamps are produced in one pouring of molten aluminum. The parameters of interest are the needed amounts of sand, aluminum and walnut shell shavings needed to accomplish the sixteen (16) clamps and testing of the matchplate to produce quality C-clamps.

The testing procedures are broken down into two phases. The first test is testing the matchplate to confirm that it will produce two (2) acceptable C-clamps in the 12x14 inch flask. After proving functionality, a sum of aluminum can be weighed, melted and calculated via a pour to determine how much is needed for a full production run.

Below is the Steps used for Phase 1 of Testing:

1. Aluminum was added to the crucible and placed in the induction furnace
2. Aluminum was melted
3. Matchplate was place in the flash and coated with crushed walnut media
4. Once sand was formed removed the matchplate from the flask
5. The flask was rammed with green sand.
6. Cut out the necessary sprue and vent holes in the sand mold
7. Reassembled flask.
8. Placed mold onto the pour line
9. Removed the crucible with the molten aluminum from the induction furnace.
10. Locked the crucible into the pouring mechanism

11. Using two crane operators poured the metal into the mold(s)
12. Poured excess aluminum into the billet molds for reuse.
13. Let the flask cool
14. Removed the C-clamps from the mold and examined for defects.

Steps to be added after Step 3 of Phase 1 testing for Phase 2 of testing:

1. Weight of the flask and matchplate was recorded on scale
2. Flask was rammed with green sand
3. Weight of rammed flask with matchplate was recorded.

The second test will determine that the foundry has adequate space and supplies to successfully to produce a full production run of sixteen (16) C-clamps. As well, the needed amount of green sand and aluminum needed would be calculated by measuring its weight. The C-clamp castings will then be prepared by cleaning, removing the excess aluminum and presented for machining of the base of the cast C-clamp.

At all times during the testing phases proper eyewear, apron, chaps/shin leg guards, and gloves will be worn, that follow flame/cutting/welding safety grade requirements. Dr. Craig Johnson was on hand to oversee and direct the testing operation. During the pour a third (3^{rd}) person in heat resistant attire was ready with excess sand to throw on any spilled molten metal to remove any threat of fire.

Testing Documentation

Time limitations did not allow me to use the Go-No-Go software solution to review the pour capabilities of the design and construction. Instead after building the matchplate the design was reviewed by a professional pattern maker and advice was given to improve the outcome of the casting with and without causing permanent design changes. The recommendations included adding fillet radiuses in key locations on the sprue and runners.

It was decided to complete phase 1 of testing the matchplate, as currently developed, before any recommended improvements in the design would be implemented.

Phase 1 of the testing was completed on April 4, 2017 from 1pm to 5pm in the afternoon at the Central Washington University (CWU) foundry during a Metal Casting/Foundry class. All resources and required personnel to operate the furnace, pouring crane, and sand mixer were on hand and all required protective clothing was worn. The test steps listed above were followed during this testing.

Phase 1 initial testing resulted in some service defects in the C-clamps these flaws were believed to be operator error by not packing the green sand with enough crushed walnut shells to create a smooth surface. However, these C-clamps will be handed off to the machine shop to complete the C-clamps to functioning tools. It is the responsibility of the Machine Shop to report back any flaws or deficiencies not visible by the foundry. After communication from the machine shop, phase 2 will be scheduled with the following steps conducted at Step 3 of the previous and the final weights of the castings recorded.

Phase 2 had the intent of determining the amount of sand and aluminum required in order to cast a production run of C-clamps. Ideal conditions were determined to ram a number of flasks and weigh them with and without the sand with the matchplate set inside. From these values an average was calculated and recorded. After the melting and pouring of the aluminum, the castings would be left to cool. Then weighed and recorded. From these weights an average was also calculated. These values we then applied in the calculations for the average amount of sand needed to ram eight flasks for sixteen C-clamps. The amount of aluminum need to be melted is 42.4 pounds.

Casting Number	Weight of casting (lbs)
1	5.10
2	5.50
Avg.	5.30

Setup Item	Weight (lbs)
Flask #1	33.00
Flask#1 w/matchplate	39.30
Flask #1 w/sand+plate	117.50
Flask #2	33.00
Flask #2 w/matchplate	39.30
Flask#2 w/sand+palte	114.50

Weight of Flask	33.00	lbs
Weight of matchplate	6.30	lbs
Sand in Flask #1	78.20	lbs
Sand in Flask#2	75.20	lbs

76.70	Average weight of Sand in pounds needed per flask
	8 flasks per production run
613.6	Pounds of sand per run.

Testing Method Gantt Chart				
Stage #1				
Step	Action	Est. Time (hrs)	Act. Time (hrs)	
1	Turn on induction furnace	0.25	0.25	
2	Melt Aluminum in crucible	1.5	2	
3	assemble flask w/matchplate	0.5	0.125	
4	Coat with walnut shell media	0.25	0.125	
5	Pack with sand	0.25	0.25	
6	Repeat 1-3 on other side of flask	0.5	0.25	
7	Cut sprue hole	0.125	0.125	
8	Poke vent holes	0.125	0.125	
9	Remove matchplate	0.25	0.25	
10	Add to pour line and pour	0.25	0.125	
11	Let cool	2	1.5	
	Totals	**6**	**5.125**	**hrs**
Stage #2				
Step	Action	Est. Time (hrs)	Act. Time (hrs)	
1	Ram two flasks with matchplate	0.75	0.5	
2	Turn on induction furnace	0.25	0.5	
3	Melt metal	0.5	0.75	
4	Pour into molds, excess into ingot mold	0.25	0.15	
5	Let cool	2	2	
6	Weigh weigh excess	0.25	0.2	
	Total	**4**	**4.1**	**hrs**

Deliverables:
Parameter Values:

- Functional matchplate the produces two C-clamps with each 12.x14 flask which can be reused to produce additional 12x14 flasks for a total 16 C-clamps in a single pour.

Calculated Values:

- Calculate the amount of aluminum needed to produce 16 C-clamps in a single pour
- Calculate the amount of green sand needed to produce 16 C-clamps in a single pour.

Success criteria values:

- Produce two (2) C-clamps, which will allow the foundry to produce 16 C-clamps in one run.
- Calculated amount of aluminum required to produce 16 C-clamps 42.4 pounds.
- Calculated sums of sand required to produce 16 C-clamps is 613.6 pounds.

BUDGET/SCHEDULE/PROJECT MANAGEMENT

This project will be managed by using Gantt charts along with weekly status reports to the professors.

The project itself has low risk. The main issues that will arise will be in the timeline of printing and completing the C-clamp imprints through additive manufacturing. This is a time-consuming process and only a certain surface area and volume can be printed in the confined space. Thus, if the printer can only print one set of imprints and it takes eight hours to produce. The result is thirty-two hours is needed to produce the imprints. Since most of the tools needed to produce the risers, gates and sprue for the matchplate is owned by the student and the University will be contributing the imprints, and plywood for the matchplate cost is the least concerning risk. If the projects pieces that are the most time consuming are not laid out properly, or if the timeline and any issues that arise will need to be executed and dealt with quickly. If these two main issues encountered for this project the success of the project will be at risk. This is primarily because the clamps being produced by said matchplate are needed for another pairing project to perform the finish machining work on the C-clamps. Thus, they need to be produced timely for the other party's purposes.

Cost and Budget:
A parts list is shown in Appendix D. The parts list details their identification, description (specifications), sources and cost as shown in Appendix C. Relatively low-cost parts like hand tools, power tools, and epoxy will be donated by the student.

Most the components are going to be easy to acquire, they consist of wooden dowels, wooden blanks, and other rectangular wood blocks for the gates, risers and sprue. Fortunately, these scraps may already be obtainable via donation. The parts that are to be fabricated are the imprint plates. These are the parts that will take up the most time and cost in the budget. The final part vitally needed is a three-quarter inch to one inch plywood board cut to twelve and a half inches by eighteen and a half inches estimates for a board from major hardware and lumber stores places the prices around thirty-two dollars for a rough estimate. Dowels needed to anchor the gates estimate at four dollars for seventy-two which should be sufficient.

The cost of the plywood and dowels is supported by HomeDepot.com. The cost of the imprints was totaled at the end of the printing process by Matt Burvee.

Labor costs are being determined with the assistance of Matt Burvee at the end of the production process. This was due to the parts donated by CWU having cost to their department. These amounts were in the entirety of the cost of the printings and the MDF board as follows. $10.00 for two MDF boards useable for a matchplate and $480 for the five 3D printings of parts.

The total cost of this project was $490. However, a budget of $350 is the goal. Appendix C.

Schedule:
Over the course of September, October, November, and December the following topics were addressed. During these months, the proposal was refined. This is displayed in Appendix E

Figure 1 and 2. This process included finding an engineering problem to approach. This was achieved during the later days of September. The analysis and design of the matchplate components was completed from the end of November and the by December 3rd as in Appendix E Figure 2. The analysis and design of how to adapt an engineering a solution to the problem lasted from October until the middle of December Appendix E Figure 2. This was because until the problem had been fully defined more issues were discovered

Milestones:
Milestones were set for each of the quarterly time periods and the list of each milestone component is listed in Appendix E Figures 1 through 7. Below is a list of the quarterly milestones.

Fall:

- Proposal
- Solidworks Design

Winter:

- Matchplate
- Parts Construction
- Device Construction

Spring:

- Device Evaluation
- Proposal Mods
- 495 Deliverables

Project Management:
For this project, there are only a few items of high risks to deal with. This is because the resources and funding are the minor issues of the project, Since the project is being funded, and produced for the Mechanical Engineering Technologies department. That being stated, the project's major realm of risk is possible time limitations with the Professors in the Engineering Department and the adherence to the safety protocol of both the University and comparable industry standards, i.e., the safety protocols being done during the printing, the entire assembly, and the testing in the foundry.

This project will succeed due the technical expertise of the principal engineer, the expertise and insight of the Mechanical Engineering Department staff, as well as the Department's ability to provide the needed funding and resources to complete.

The principal engineer will provide designing, fabricating, and testing the matchplate.

The project sponsor, the Mechanical Engineering Department, is committed to providing resource and monetary based support for the entire length of the project. This will also include equipment and facilities.

DISCUSSION

Most of this process was straight forward and direct. The project's main issue was adhering to the timing constraint for the project, with the funding and resources to build and formulate a way to cast the C-clamp were being handled and provided by the Engineering Department of Central Washington University.

However, that does not mean that there were not problems throughout the designing and building process. During the designing process issues arose in succession. Most were fine detailed work. The imprints were not an issue but once a design was conceived the imprints were saved and converted into a file that would allow them to be 3D-printed. However, once converted into the file and loaded into Catalyst, the 3D printing software, it was clear that the design would not work. This was due to the imprint not fitting in the allowable space for the 3D printer.

The first modification consisted of changing the initial design based on a twelve by eighteen-inch flask that was going to be used to cast four C-clamps in total. However, after several printings of the imprints of the clamps were made, it was clear that the initial calculated space that was assumed was not there. Thus, the design was then modified to produce two clamps in a twelve by fourteen-inch flask. This meant that a full production run of the C-clamps would double from 4 matchplate pours to 8 matchplate pours.

Upon modifying the design, it was also noted that the bottom extrusion that was a datum pin for a machining reference was not going to work. This Datum was one of three intended for a machining system to clean and prepare the clamps for the basic machining course. To allow the imprints to be printed in the axis, the extrusion's maximum length could be 0.10 inches. This would not allow it to be a sufficient datum As shown in Figure 1 Appendix B. This pin at the bottom was required to be removed, illustrated change in Figure 6 Appendix B. Thus, the datum had to be removed. This fixed the issue to allow the printing of the clamps. While it did not affect this project any further, it does for what would be the next step in the manufacturing process. The machinist or worker who is now charged with cleaning and machining the casted clamp has greater work in designing or using a jig to speed up this process, which is not a part of this project.

Another requirement is not to waste materials or time. To do so, the consensus was to use the program in Solidworks called Solidcast. This program would require an entire model of the casting in Solidworks. Once the model is in Solidworks, it would be transferred into Solidcast. Solidcast tests the model to test if there are any flaws in the matchplate. Solidcast shows if the gates, runners, risers, and/or riser necks fail to allow a proper casting. This process will identify major design failures. If that happens then the entire matchplate layout for the gates, runners, and risers must be recalculated, redesigned, and repositioned on the matchplate board.

However, because of timing constraint and issues, an assembly of the final matchplate design was not able to be produced on time. This caused the plan of using Solidcast to simulate the pour and test the hypothetical effectiveness of the matchplate was not completed. In its place two different review methods were initiated.

The first review method consisted of sending pictures of the completed matchplate design to Mr. James Justin, a professional pattern maker in the molding industry, and currently works with Puget Sound Pattern Works. His suggestions included adding fillet radiuses in key locations on the sprue and runners.

After receiving the suggestions from Mr. Justin, it was decided that an empirical test would be done in the place of Solidcast, before implementing his recommendations.

After the empirical testing, the matchplate was found to be successful in casting two C-clamps. From there the second test was done and the needed amount of supplies to cast sixteen to twenty C-clamps were tabulated.

Phase two of testing was done the following Thursday of the week of Test 1. The matchplate was set in flasks, weighed, rammed with sand, and weighed again. This was done with two flasks to find an average amount of sand through weight in pounds was needed per flask. Next after the castings were poured and cooled, the castings could be weighed for how much aluminum would be needed to pour a set number of matchplate molds in a production run.

During the testing a vital operator induced error was noted. If a proper datum system is not setup in advance before ramming with sand, errors in sprue hole placement cause defects. The defect noted was turbulence caused by the widening of the sprue hole. The issue occurred when the sprue hole was punched only connecting with an eighth to a quarter of the sprue well. This caused air to be forced into the molten metal causing it to froth and trap air bubbles. To avoid this problem a means of marked datum lines with straight edges on the flasks to line up the sprue hole punching would be beneficial.

CONCLUSION

The matchplate has been conceive, analyzed and designed and it meets the functional requirements presented. Parts have been specified, sourced, and a budget for acquisitions has been set. Upon solidification of this information, a matchplate to cast C-clamps is ready to be fabricated.

This project meets the requirements for a successful senior project, including:

1. Having substantive engineering merit metal casting, additive manufacturing, and CAD software.
2. Introduces a greater aspect of manufacturing for Engineering Department.
3. Being of great interest to the principal investigator for aspects of prototyping.

The new matchplate was successful in providing a set of molded C-clamps for the Basic Machining Class to finish during the Fall Quarter of 2017. The new matchplate doubled the number of C-clamps formed with each pour because the prior C-clamp only had one C-clamp on the matchplate. This means the number of pours were reduced by one half and increased the number of C-clamps that can be produced doubled. With the risers, gates, and sprue well all being made of wooden parts and easily removed and replaced should they fail the matchplate can be a viable unit for many years in the future.

ACKNOWLEDGEMENTS

Mentor - Dr. Craig Johnson, Professor CWU Mechanical Engineering Department

Design Specialist – Ted Bramble, Instructor CWU Mechanical Engineering Department

Supplies Acquisition Specialist – Matt Burvee, CWU Mechanical Engineering Department

Matchplate Specialist – Mr. James Justin, Professional Pattern Maker, Puget Sound Pattern Works

Part Intent	Part Description	Disposition
Matchplate	3/4 x 12.5" x 18.5" plywood/MDF	Donated by CWU
Adhesives	5-minute Epoxy	Donated by Student
Gates, runners, etc.	Wood scraps and Dowels	Donated by Student
Imprints	3D printed Imprints of C-Clamp	Fabricated by CWU

REFERENCES

Schleg, F. P. (2015). *Technology of Metalcasting.* Schaumburg: American Foundry Society.

APPENDIX A – Analyses

Riser Analysis

Ryan Berghoff MET 495 12/1/2016 1/3

Riser calculations: Modulus method

$$\text{Modulus} = \frac{\text{Volume}}{S.A.} = \frac{19.47 in^3}{67.65 in^2} = 0.2878 \approx 0.29$$

10% of 0.29 = 0.029
+ 0.29
0.319 = Neck modulus

From solidworks model

Volume: $19.47 in^3$

Surface area = $67.65 in^2$

20% of 0.29 = 0.058
+0.290
0.348

0.348 = Riser modulus

r = 0.625 or w = 1in

height to try, 3-6in

Cylinder style riser calculations

$S.A_{h3} = 14.24 in^2$ $V_{h3} = 3.68 in^3$

$SA_{h4} = 18.16 in^2$ $V_{h4} = 4.91 in^3$

$S.A._{h5} = 22.09 in^2$ $V_{h5} = 6.14 in^3$

$S.A._{h6} = 26.02 in^2$ $V_{h6} = 7.36 in^3$

Not working

Retangle prism riser

Surface Area of rectangle: $2(wl + hl + hw)$

L = 3in
w = 1.5in
h range = 1-6in

$S.A_{h2} = 27 in^2$ $V_{h2} = 9 in^3$

$S.A._{h3} = 36 in^2$ $V_{h3} = 13.5 in^3$

$S.A._{h4} = 45 in^2$ $V_{h4} = 18 in^3$

$S.A._{h5} = 54 in^2$ $V_{h5} = 22.5 in^3$

$S.A._{h6} = 63 in^2$ $V_{h6} = 27 in^3$

$S.A._{h1} = 18 in^2$ $V_{h1} = 4.5 in^3$

$S.A._{h2.5} = 31.5 in^2$ $V_{h2.5} = 11.25 in^3$

$S.A._{h2.4} = 30.6 in^2$ $V_{h2.4} = 10.8 in^3$

$M_{h1} = 0.25$
$M_{h2} = 0.333$ > in between
$M_{h3} = 0.375$
$M_{h2.5} = 0.36$
$M_{h2.4} = 0.353$

riser dimensions; 3in x 1.5in x 2.4in X

↳ but causes neck issues

Ryan Berghoff MET 495 12/1/2016 2/3

riser neck dimensions

Modulus to meet = 0.319

Modulus = $\frac{Volume}{Surface\ area}$

width = 1.00 in or 0.75 in

length = 0.75 in

height range: 0 - 1.999 in

too low of ratios.

$S.A._{h0.25}$ = 2.38

$S.A._{h0.5}$ = 3.25

$S.A._{h0.75}$ =

$S.A._{h1}$ =

$S.A._{h1.25}$ =

$S.A._{h1.5}$ =

$S.A._{h1.75}$ =

$V_{h0.25} = 0.19\ in^3$

$V_{h0.5} = 0.38\ in^3$

$V_{h0.75} = 0.56\ in^3$

$V_{h1} = 0.75\ in^3$

$V_{h1.25} = 0.94\ in^3$

$V_{h1.5} = 1.13\ in^3$

$V_{h1.75} = 1.31\ in^3$

L_{riser} = 2.25 in width = 2 in

L_{neck} = 2 in width = 1.5 in

rectangular prism riser & neck calculations 2.0

riser height = 2.1 in

h_{riser}	S.A. (in^2)	V (in^3)	M
1 in	17.5 in^2	4.5	0.257
2 in	26 in^2	9	0.34615
3 in	34.5 in^2	13.5	0.391304
4 in	43 in^2	18	0.4186
2.3 in	28.55	10.35	0.3625
2.25	28.13	10.13	0.3601
2.2	27.7	4.9	0.3574
2.15	27.27	9.67	0.3546
2.1	26.85	9.45	0.3519 ✓

neck

gate height = 2.5 in

h	S.A.	V	M
1	13 in^2	3 in^3	0.2308
1.25	14.75	3.75	0.2542
1.5	16.5	4.5	0.2727
1.75	18.25	5.25	0.2876
2.00	20	6	0.3
2.05	20.35	6.15	0.3022
2.10	20.7	6.3	0.304
2.15	21.05	6.45	0.3064
2.2	21.4	6.6	0.3084
2.3	22.1	6.9	0.3122
✓ 2.5	23.5	7.5	0.3191

Final riser dimensions via Modulus method

riser: (L x w x h) in = 2.25 in x 2 in x 2.1 in
gates: (L x w x h) in = 2 in x 1.5 in x 2.5 in

Gating Analysis

Ryan Berghoff MET 425 12/1/2016 1/1

Gating system calculations:

*Given: previous C-clamp design relied on 1" diameter circular gating from cast. Old design was Non-pressurized

*Find: Size & dimensions of gating with circular gates and 1in×1in runners

*Pressurized Gate system:

→ Well diameter = 1.5(Sprue diameter) = 1.5(1.5in) = 2.25in

→ well thickness: • in cope = 1.5(thickness of runner) = 1.5(1in) = 1.5in in cope

• in drag = 0.5(Thickness of runner) = 0.5(1in) = 0.5in in drag

*Non-Pressurized Gate system:

→ Well diameter = 2(Width of runner) = 2(1in) = 2in

– Well thickness = 1.5–2(thickness of runner) = 1.5(1in) = 1.5in
2(1in) = 2in

*Previous design used a non-pressurized system. The Pressurized system has greater issues fitting effectively as well since being larger on the matchplate surface.

Non-Pressurized gates with a diameter of 2in and well thickness between from 1.5in to 2in.

Volume Analysis

Ryan Berghoff | MET 495 | 12/2/2016

Volume calculations

- Volume of clamp via solid works = $19.47 in^3$
- Volume of 4x C-Clamps = $77.88 in^3$
- Volume of gates = $\pi r^2 h = (\pi)(1^2)(2) in^3 = 6.283 in^3$
- Volume of 2 gates = $12.566 in^3$
- riser Volume
  - riser = 2.25 in x 2 in x 2.1 in = $9.45 in^3$
  - neck = 2 in x 1.5 in x 2.5 in = $7.5 in^3$

4x risers = $37.8 in^3$

8x necks = $60 in^3$

runners 1"x1"; lengths 1" & 3.75" roughly, 2x 3.75" Length, 4x 1" length

- rough total Volume

+ $77.88 in^3$ → 4x C-Clamps
+ $12.566 in^3$ → 2 gates
+ $37.8 in^3$ → 4x risers
+ $60.0 in^3$ → 8x necks
+ $7.5 in^3$ → 2x 3.75 in length runners
+ $4.0 in^3$ → 4x 1"x1"x1" runners

$199.746 in^3$ = rough total volume

APPENDIX B – Sketches, Assembly drawings, Sub-assembly drawings, Part drawings

Figure 1 – C-Clamp Rough Sketch #1

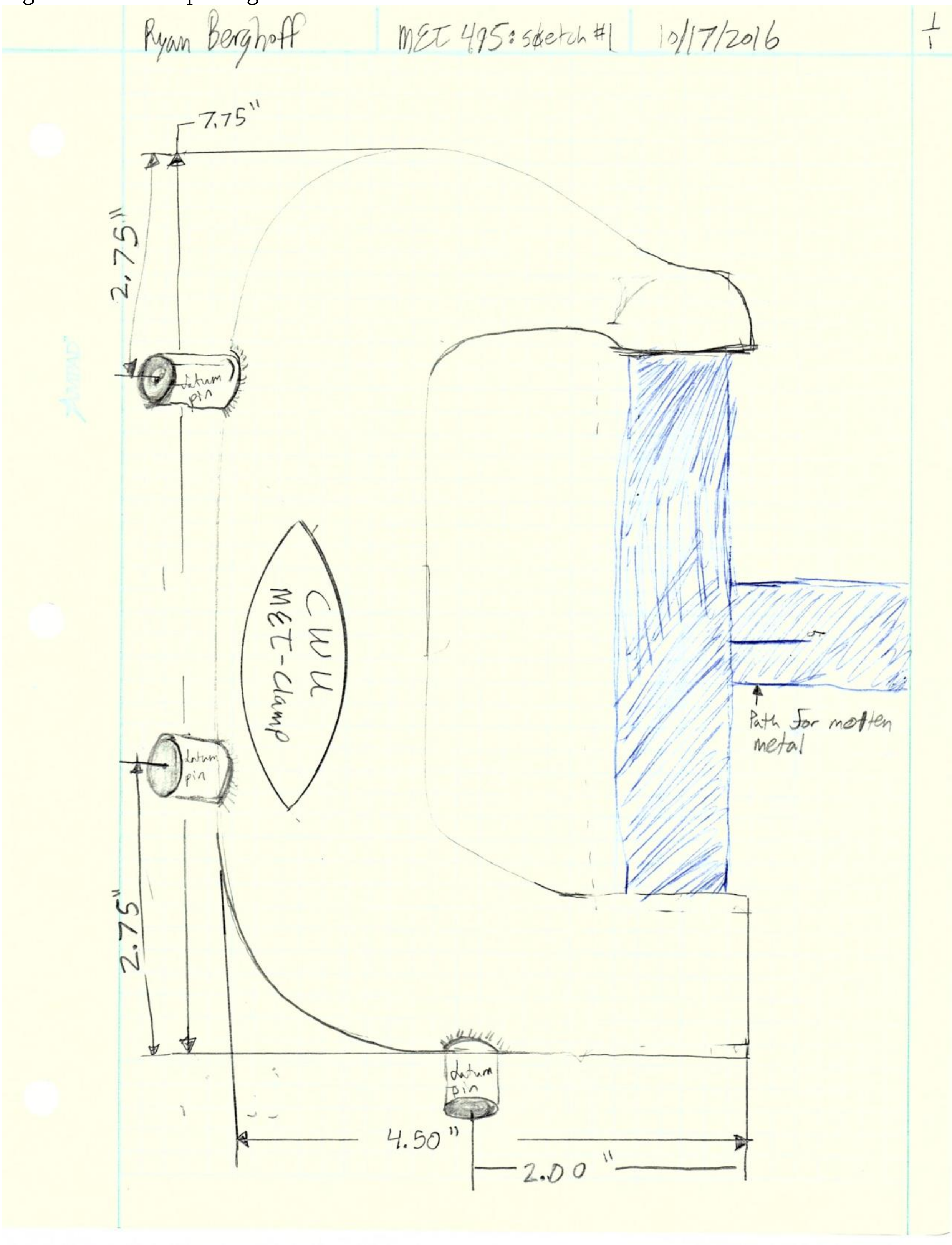


Figure 2 – Matchplate Layout Sketch #1

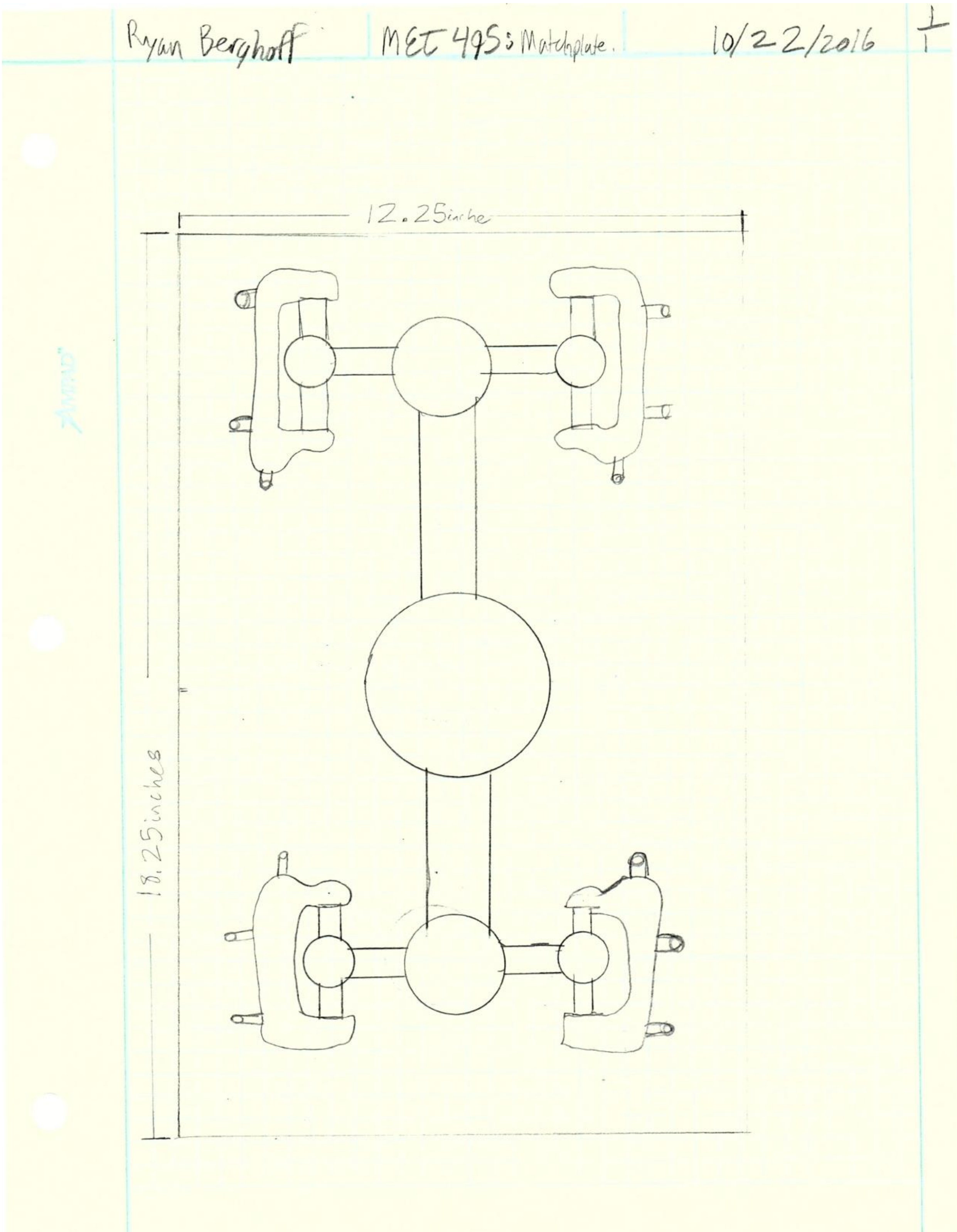


Figure 3 – C-Clamp Rough Sketch #2

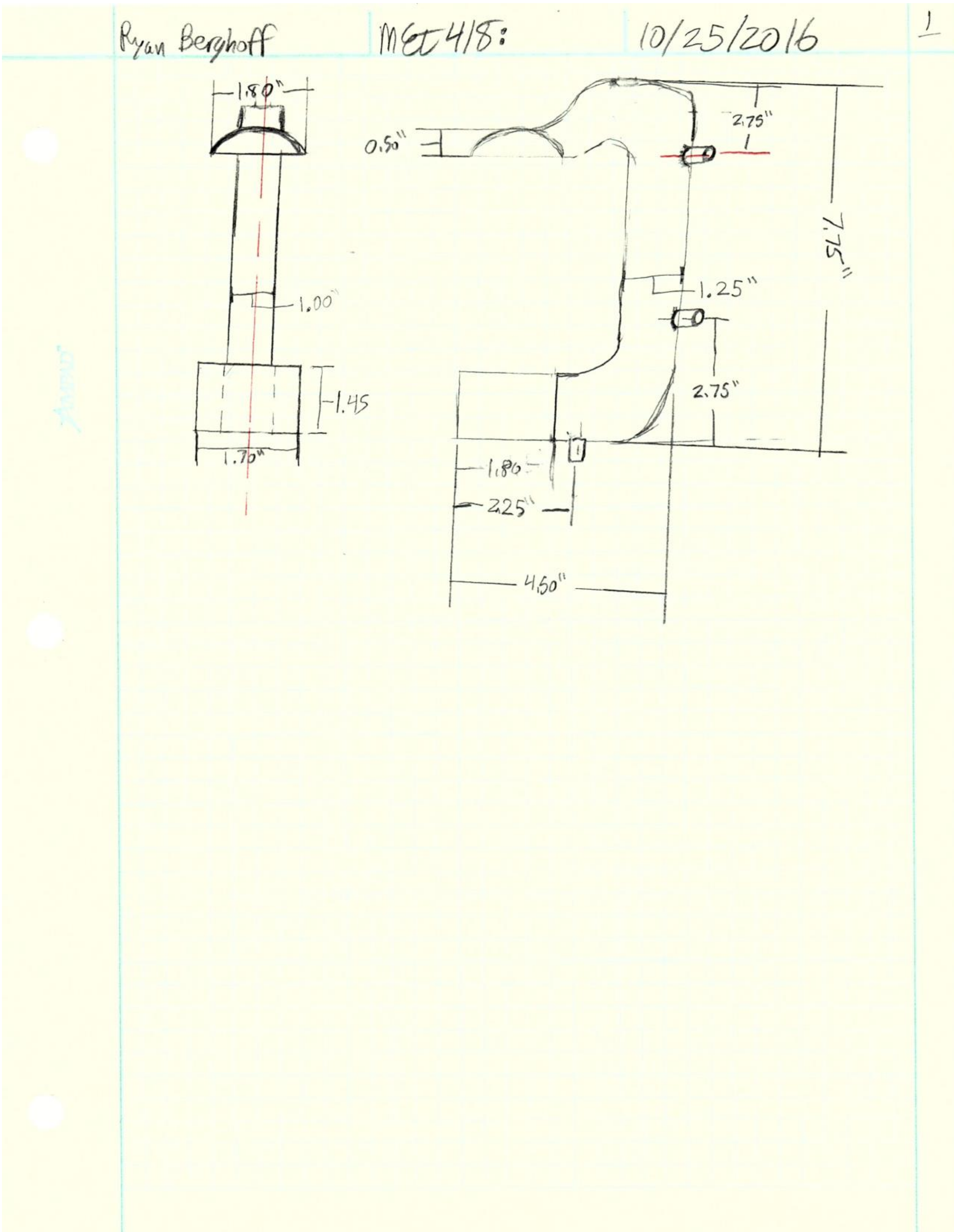


Figure 4 – Imprint Sketch #1

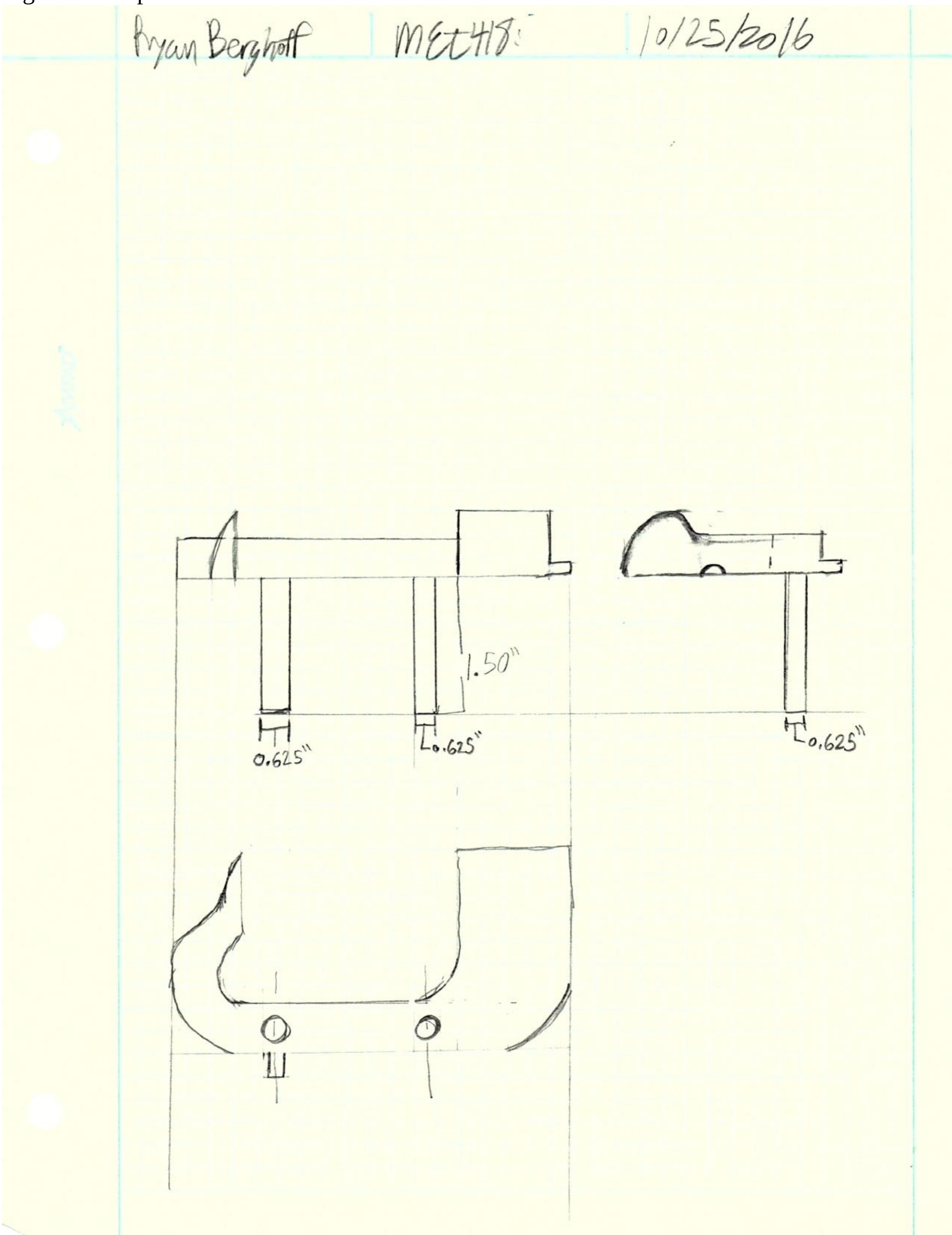


Figure 5 – Previous Model of C-clamp Casting

Figure 6 – Imprint #1 Design 1.0

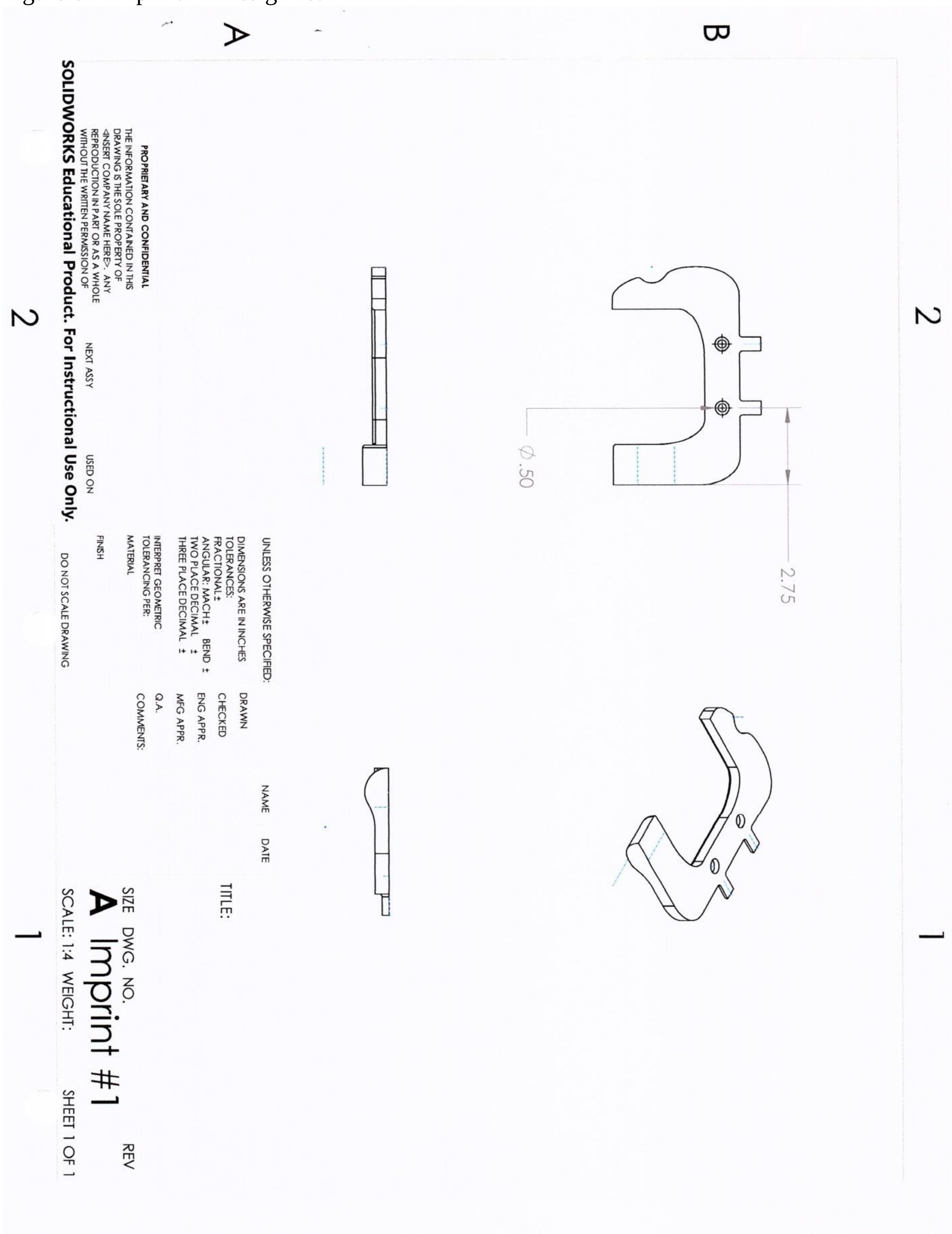


Figure 7 – Imprint #2 Design 1.0

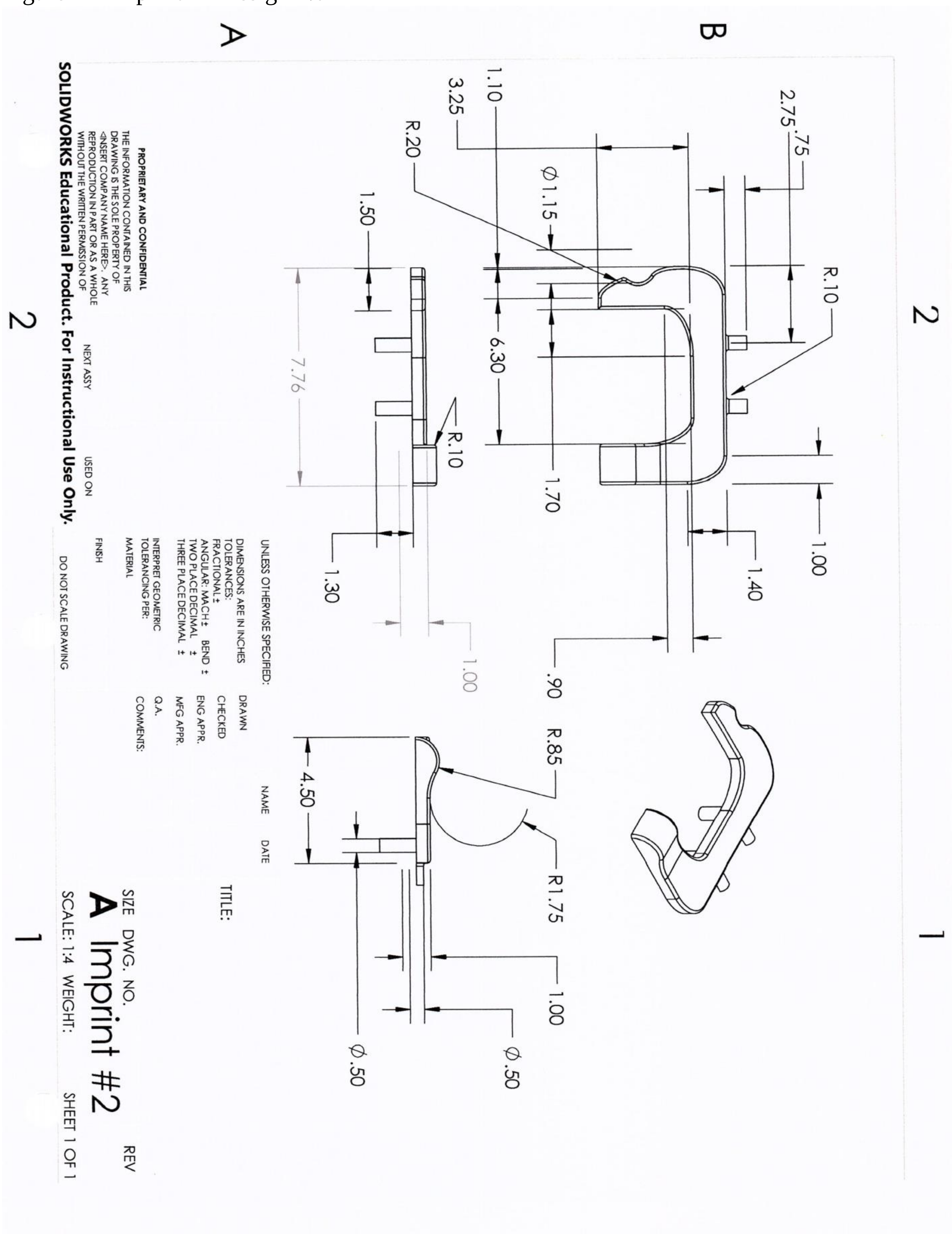


Figure 8 – Matchplate Assembly Model 1

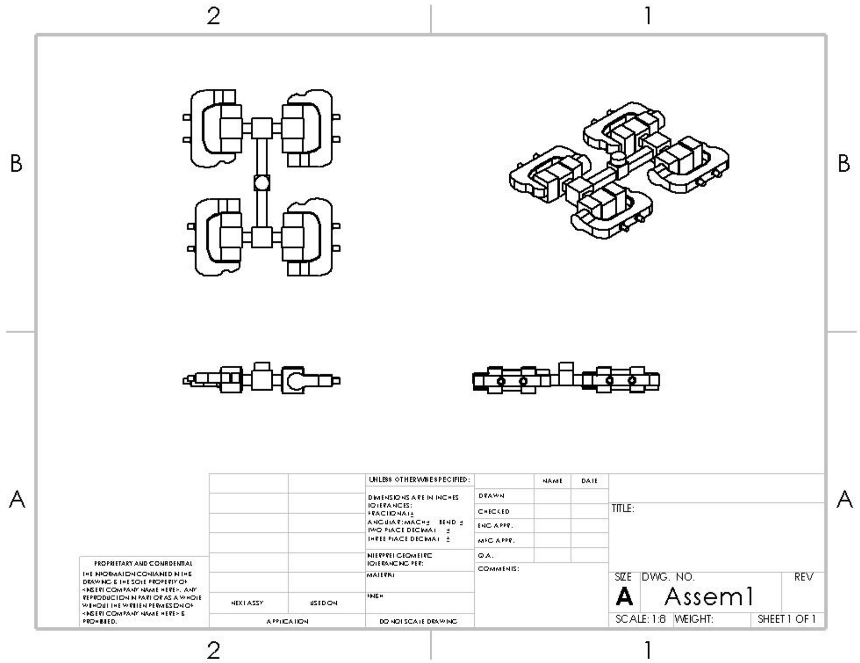


Figure 9 – Clamp Design 2.0

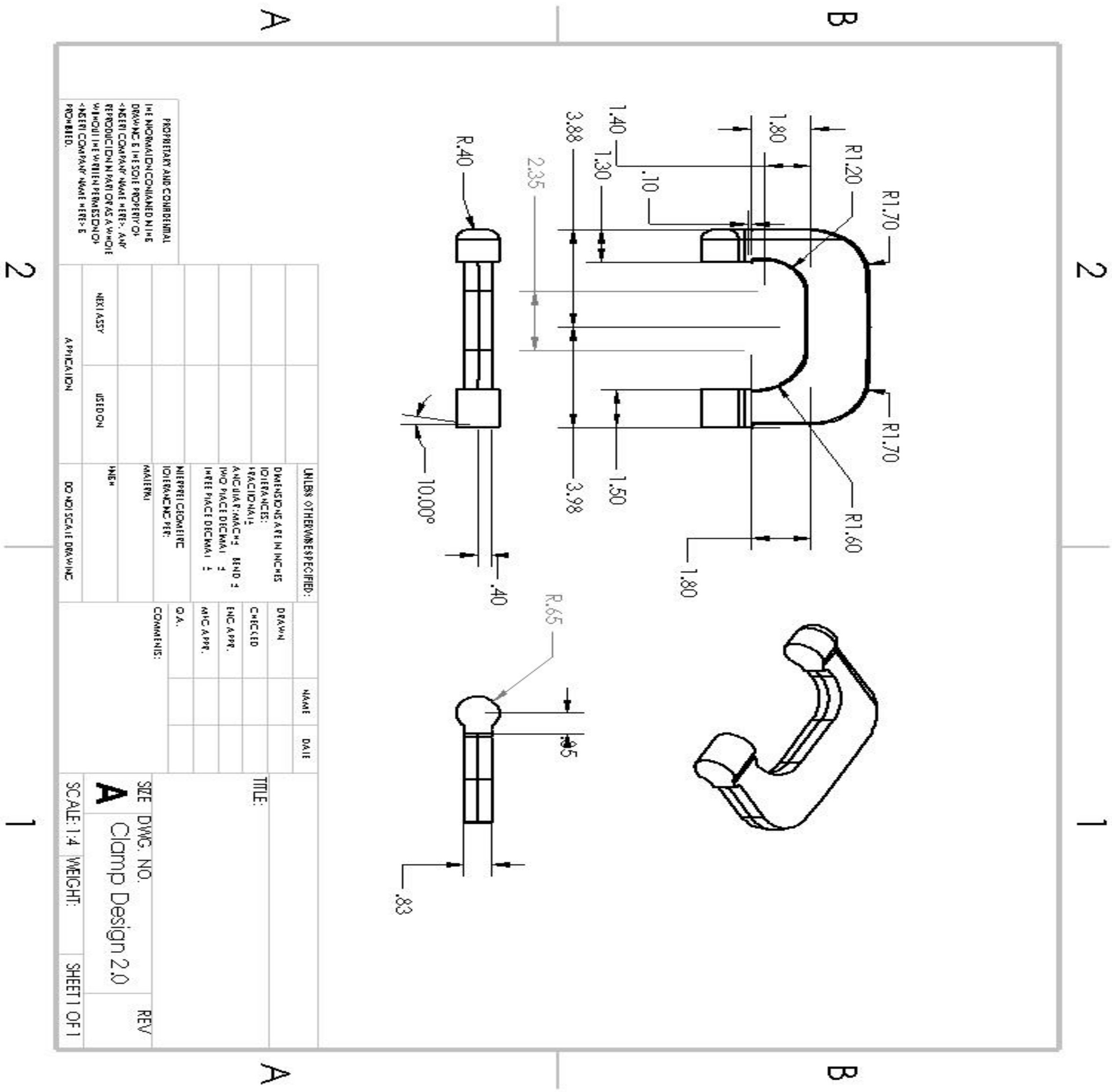


Figure 10– Imprint #1 Design 2.0

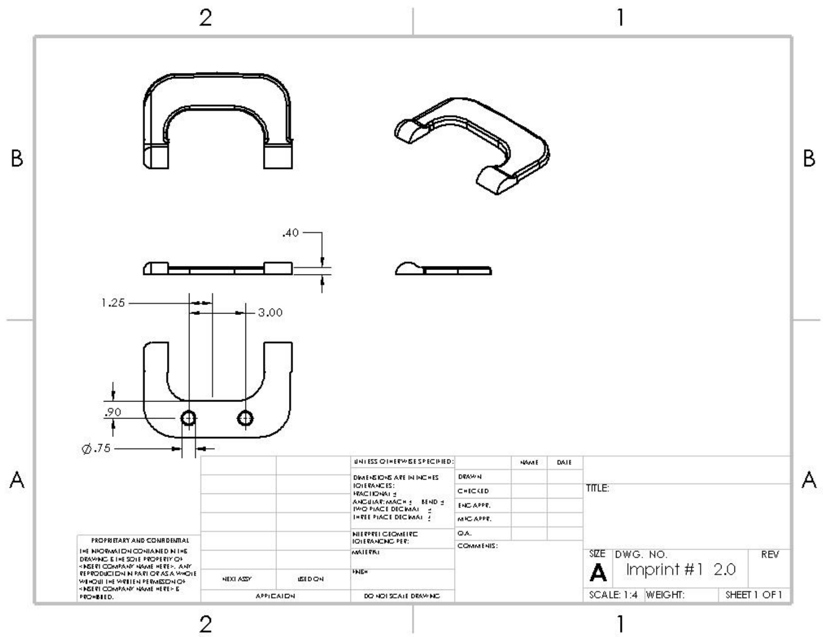


Figure 11 – Imprint #2 Design 2.0

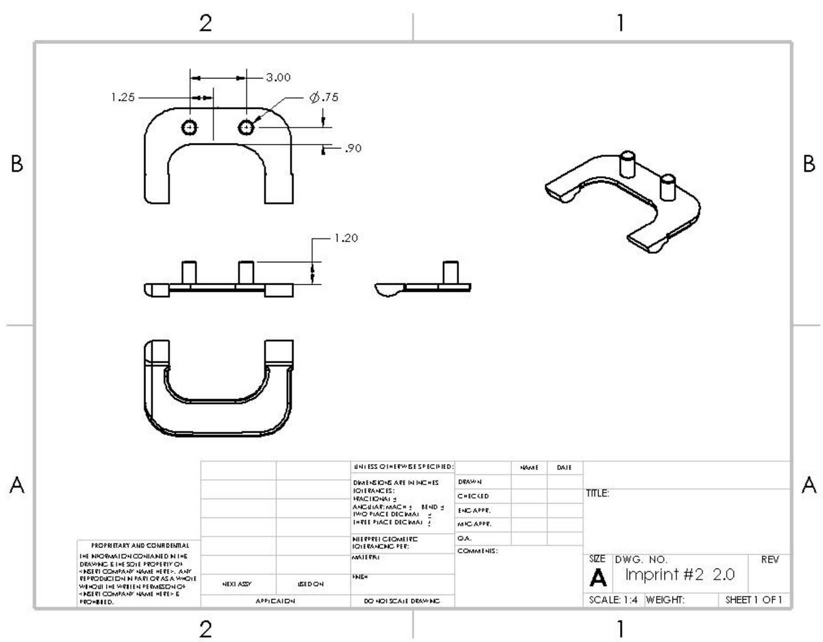


Figure 12 – Imprint 2.0 Test Print: Error Recorded, Failed to print continued drafted edge of Fillet

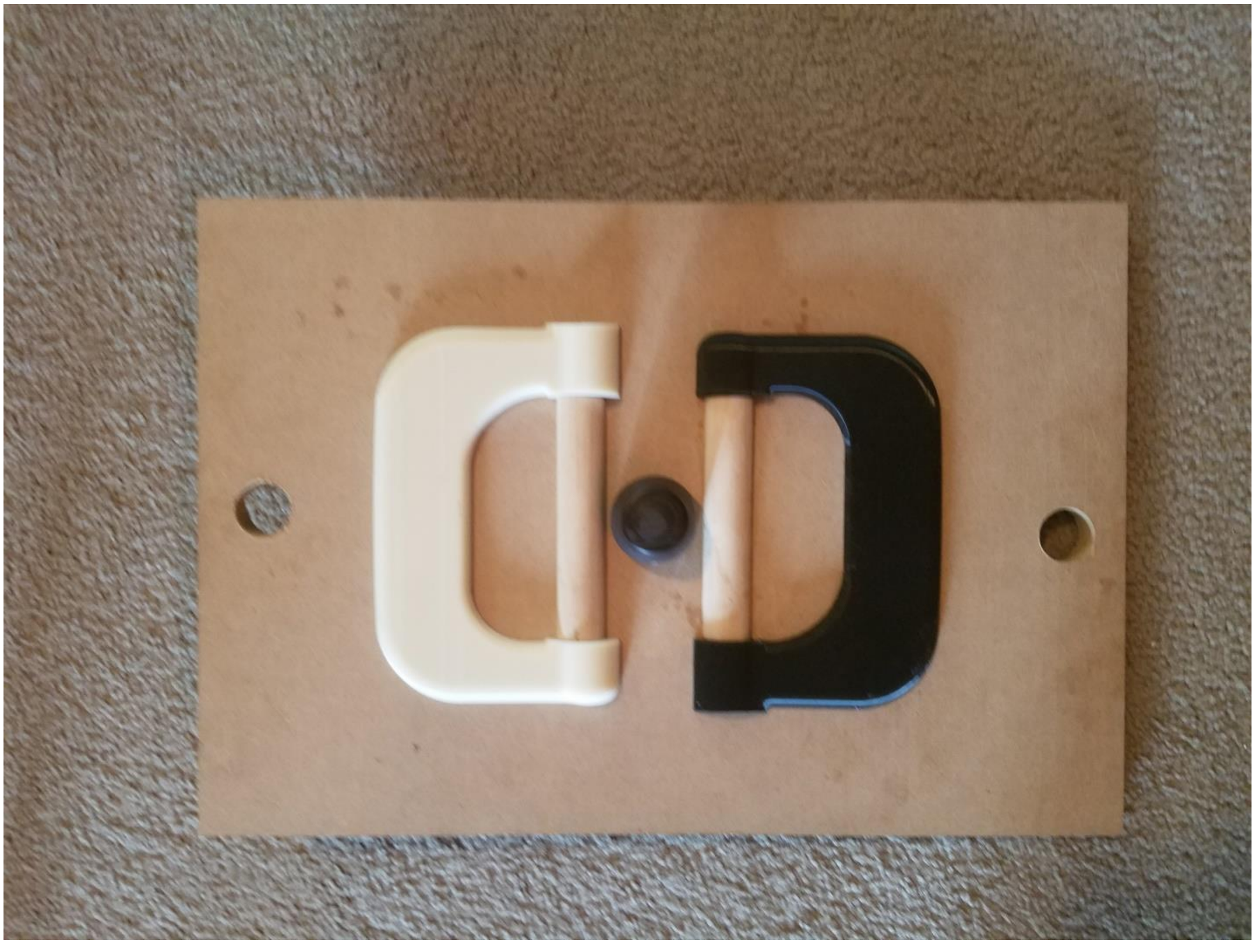
Figure 13 – Imprint 2.0 Test Print: Error Recorded, Required Ten degree draft angle

Figure 14 – Imprint #1 Design 2.0 Test Print Success

Figure 15 – Imprint #2 Design 2.0 Test Print Success

Figure 16 – Matchplate Cope(Bottom) Assembly

Figure 17 – Matchplate Drag(Top) Assembly



APPENDIX C – Parts List and Costs

Part Intent	Part Description	Source	Estimated Cost	Cost	Disposition
Matchplate	3/4 x 12.5" x 18.5" plywood/MDF	Home Depot	$32.00	$10.00	Donated by CWU
Adhesives	5-minute Epoxy	Student	$20.00	$0.00	Donated by Student
Gates, runners, etc.	Wood scraps and Dowels	Student	$16.00	$0.00	Donated by Student
Imprints	3D printed Imprints of C-Clamp	CWU - 3D Print Lab	$200.00	$480.00	Fabricated by CWU
		Total:	**$268.00**	**$490.00**	

APPENDIX D – Budget

Ryan Berghoff | MET 495: Budget | 10/31/2016

Item	Quantity	Price
Plywood Board 12.5" x 18.5" x 3/4"	1	32.00 / Free
C-Clamp Impression	4	TBD w/ Ted Bramble / Matt Burvee
Expoxy / Hotglue / wood glue	1	20.00
Drill	1	own
Drill Bits	1	own
Wooden dowel rod and posts for gates & risers	18	Free / obtainable through School
Aluminum	N/A	Free / Donated by MET department

APPENDIX E – Schedule

Figure 1

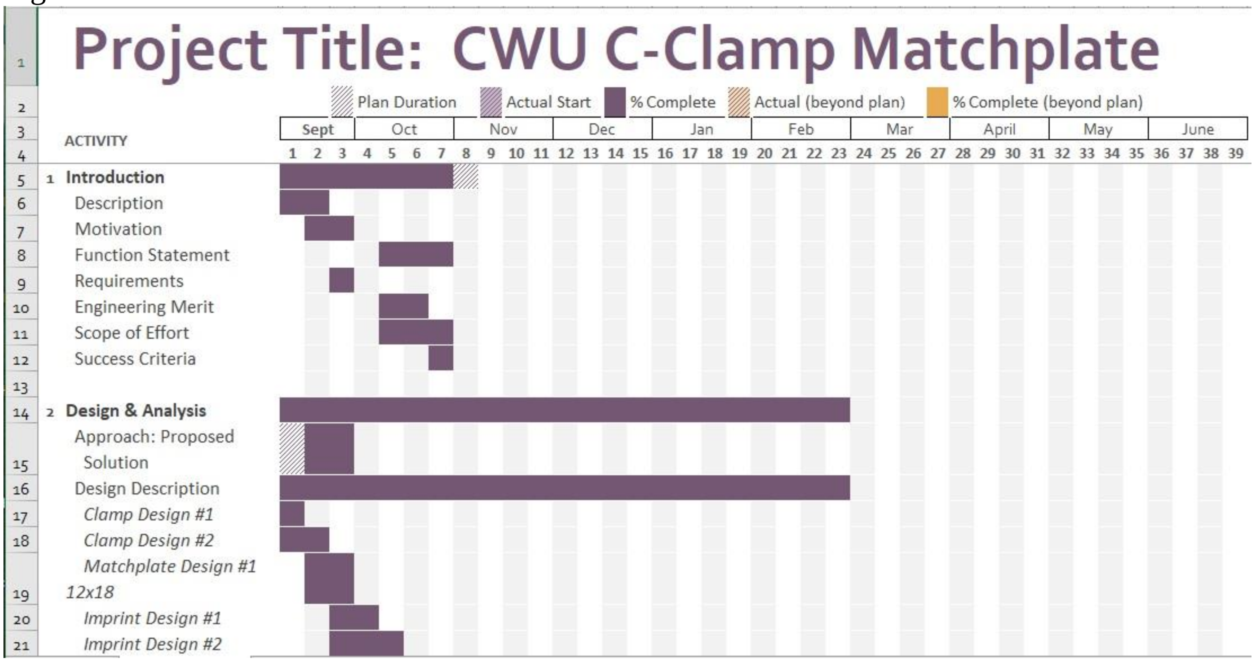


Figure 2

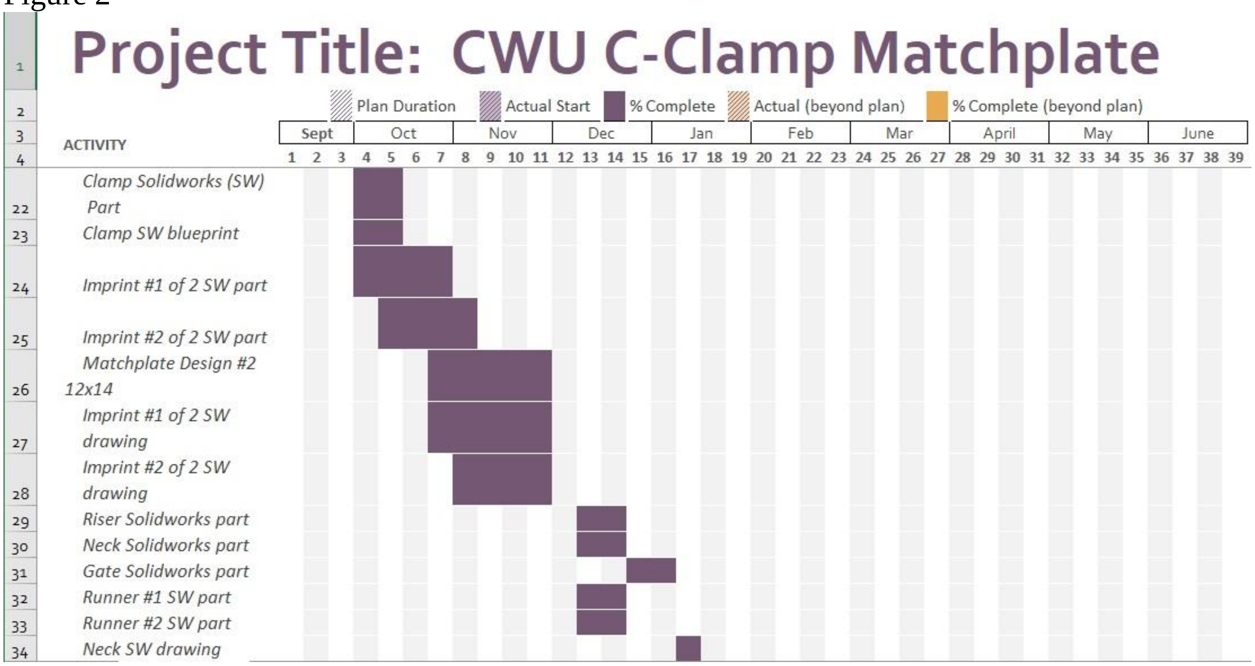


Figure 3

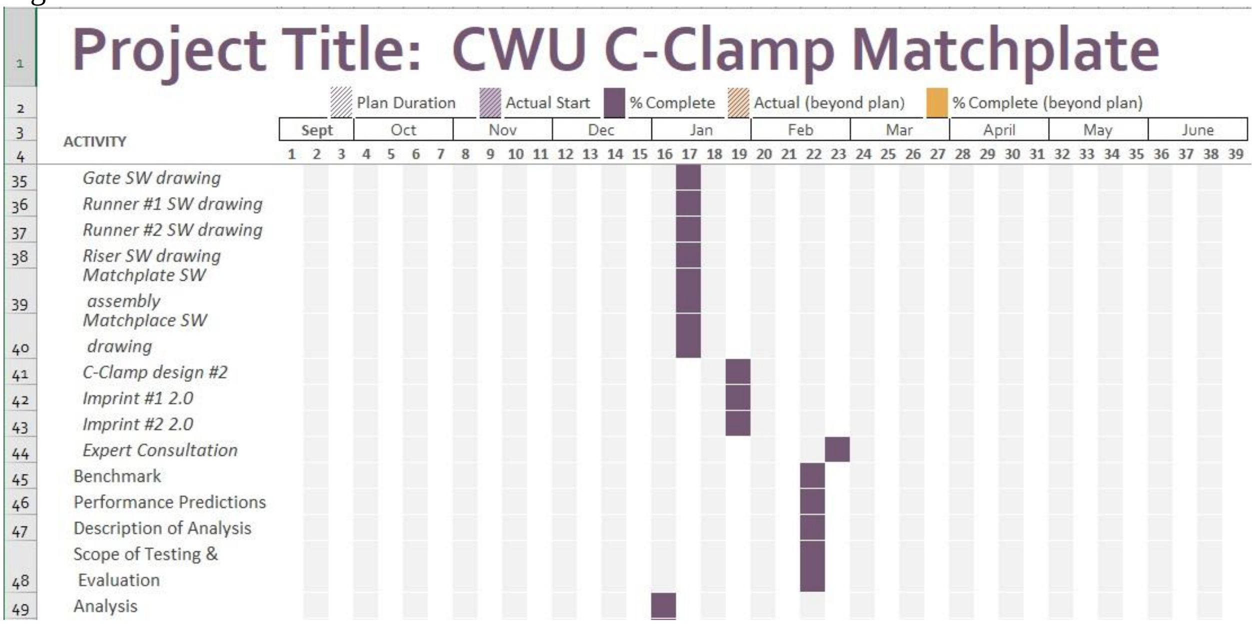


Figure 4

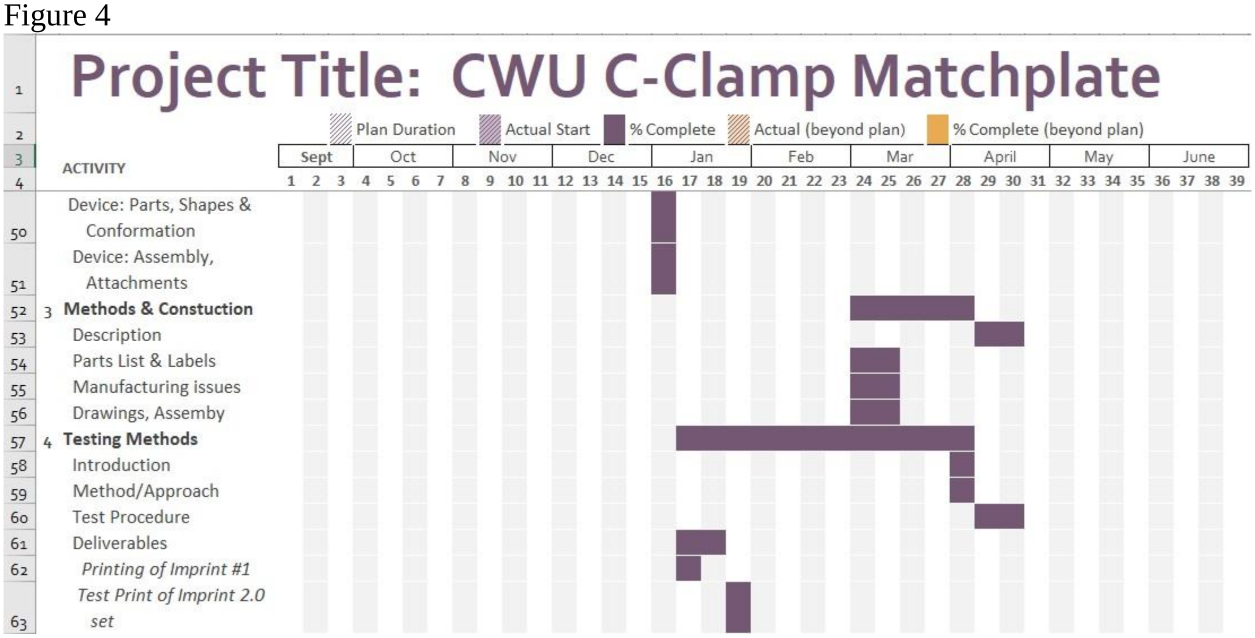


Figure 5

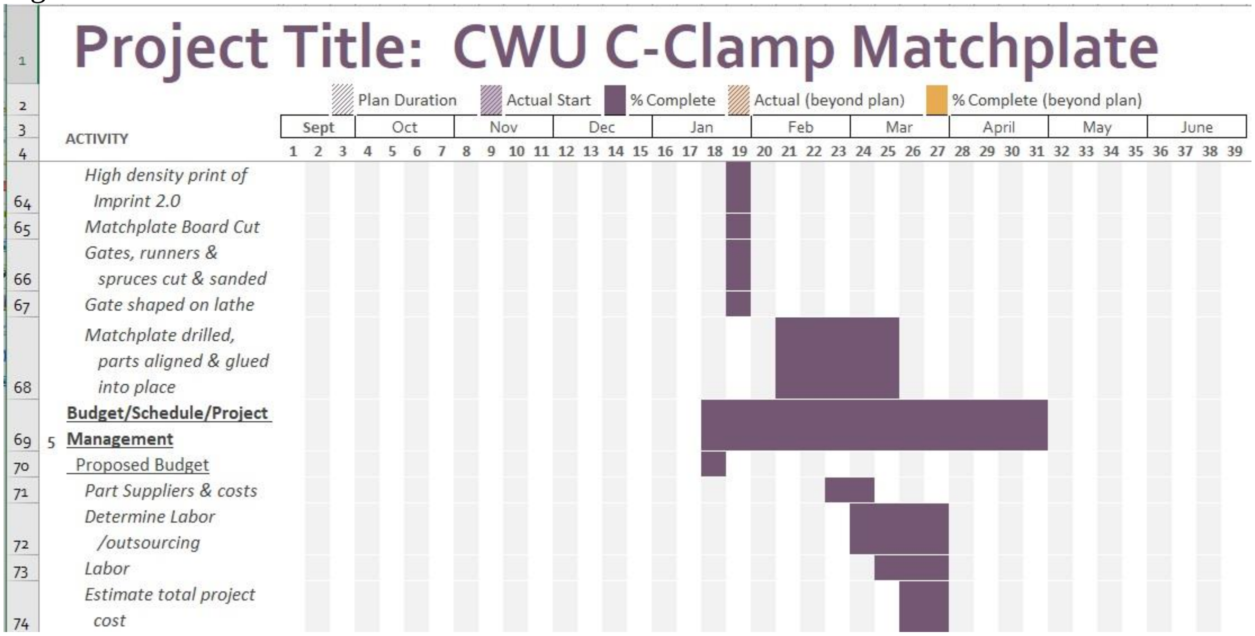


Figure 6

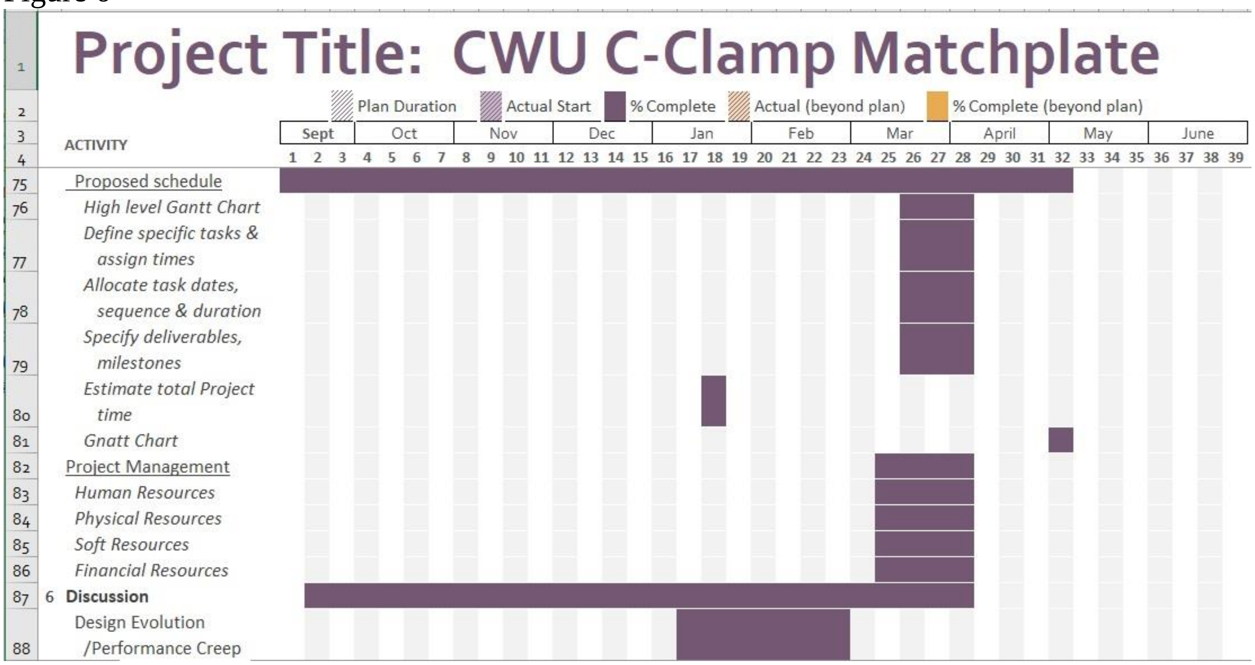


Figure 7

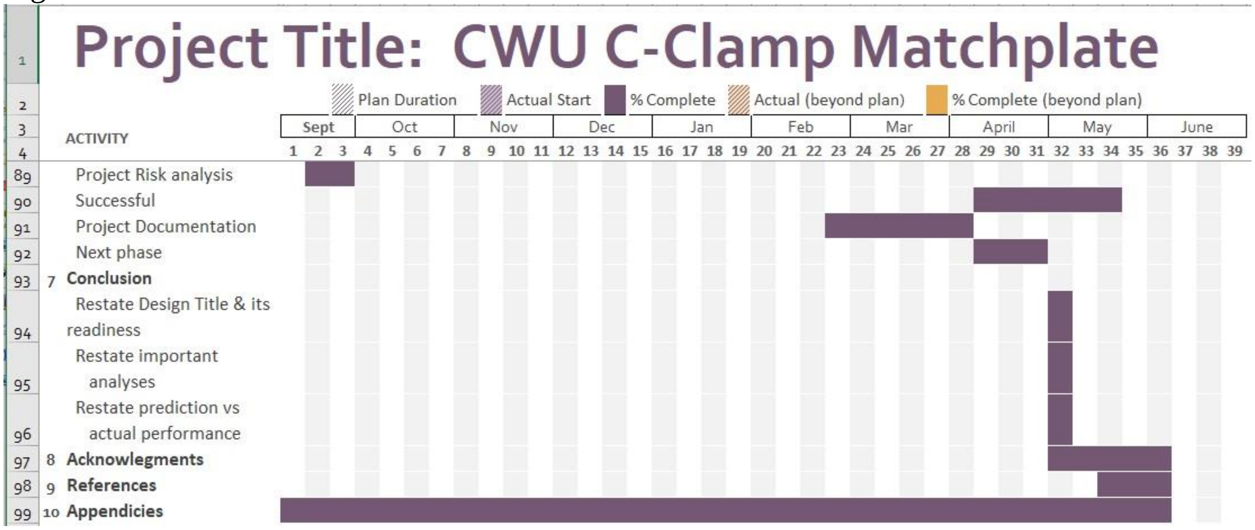
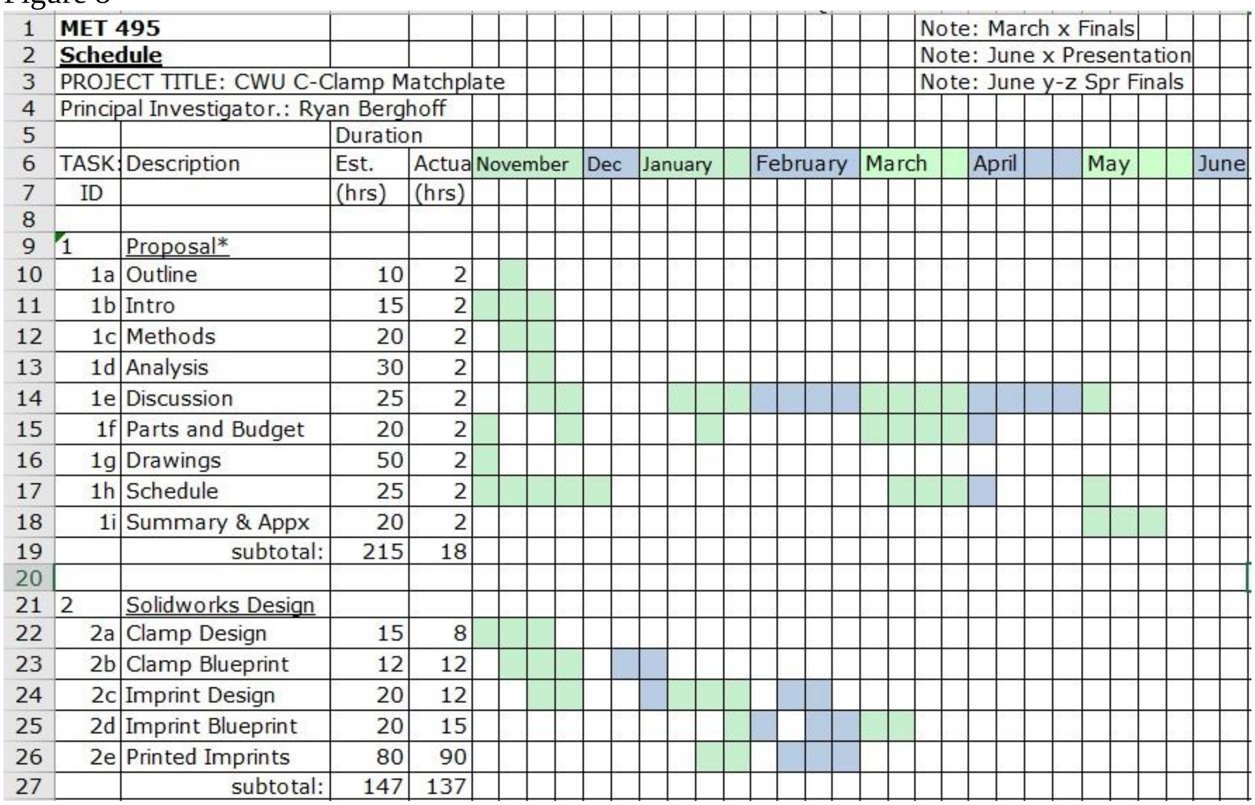


Figure 8



1	**MET 495**			
2	**Schedule**			
3	PROJECT TITLE: CWU C-Clamp Matchplate			
4	Principal Investigator.: Ryan Berghoff			
5			Duration	
6	TASK:	Description	Est.	Actua
7	ID		(hrs)	(hrs)
8				
9	1	Proposal*		
10	1a	Outline	10	2
11	1b	Intro	15	2
12	1c	Methods	20	2
13	1d	Analysis	30	2
14	1e	Discussion	25	2
15	1f	Parts and Budget	20	2
16	1g	Drawings	50	2
17	1h	Schedule	25	2
18	1i	Summary & Appx	20	2
19		subtotal:	215	18
20				
21	2	Solidworks Design		
22	2a	Clamp Design	15	8
23	2b	Clamp Blueprint	12	12
24	2c	Imprint Design	20	12
25	2d	Imprint Blueprint	20	15
26	2e	Printed Imprints	80	90
27		subtotal:	147	137

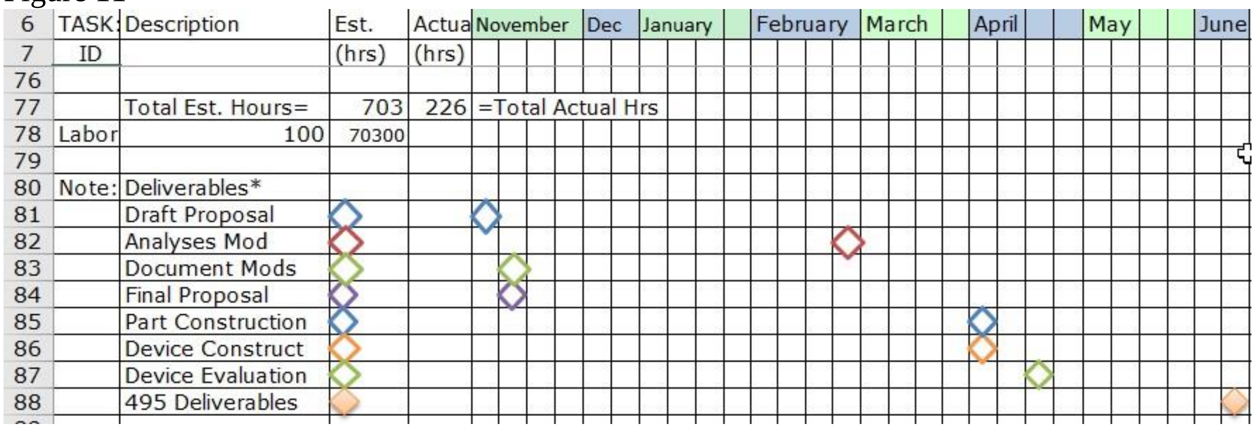
Figure 9

6	TASK	Description	Est.	Actua	November	Dec	January		February	March		April			May		June
7	ID		(hrs)	(hrs)													
28																	
29	3	Matchplate															
30	3a	Plywood backboard	1	0.5													
31	3b	Gates and Risers	1	0.8													
32	3c	Imprints (2x)	3	1													
33	3d	Sprue Base and Top	2	1													
34	3e	Runners	2	1.5													
35		subtotal:	9	4.8													
36																	
37	4	Proposal Mods															
38	4a	Addtion of Test info	2	5													
39	4b	Update Report Components															
40		subtotal:	2	5													
41																	
42	7	Part Construction															
43	7a	Part s cut to length	2	1													
44	7b	Sprue top turned	2	0.5													
45	7c	Datum establishment	5	3													
46		subtotal:	9	4.5													
47																	
48	9	Device Construct															
49	9a	Drilling holes	1	0													
50	9b	Alignment and gluing	48	0													
51		subtotal:	49	0													

Figure 10

6	TASK	Description	Est.	Actua	November	Dec	January		February	March		April			May		June
7	ID		(hrs)	(hrs)													
52																	
53	10	Device Evaluation															
54	10a	List Parameters	5	4													
55	10b	Design Test&Scope	8	2													
56	10c	Obtain resources	1	1													
57	10d	Make test sheets	3	2													
58	10e	Plan analyses	5	2													
59	10f	Test Plan*	36	8													
60	10g	Perform Evaluation	12	0													
61	10h	Take Testing Pics	6	2													
62	10i	Update Website	40	0													
63		subtotal:	116	21													
64																	
65	11	495 Deliverables															
66	11a	Get Report Guide	2	1													
67	11b	Make Rep Outline	20	15													
68	11c	Write Report	25	20													
69	11d	Make Slide Outline	15	0													
70	11e	Create Presentatior	12	0													
71	11f	Make CD Deliv. List	10	0													
72	11e	Write 495 CD parts	15	0													
73	11f	Update Website	45	0													
74	11g	Project CD*	12	0													
75		subtotal:	156	36													

Figure 11


6 TASK Description Est. Actua November Dec January February March April May June
7 ID (hrs) (hrs)
76
77 Total Est. Hours= 703 226 =Total Actual Hrs
78 Labor 100 70300
79
80 Note: Deliverables*
81 Draft Proposal
82 Analyses Mod
83 Document Mods
84 Final Proposal
85 Part Construction
86 Device Construct
87 Device Evaluation
88 495 Deliverables

APPENDIX F – Expertise and Resources

Mentor - Dr. Craig Johnson, Professor CWU Mechanical Engineering Department

Design Specialist – Ted Bramble, Instructor CWU Mechanical Engineering Department

Supplies Acquisition Specialist – Matt Burvee, CWU Mechanical Engineering Department

Matchplate Specialist – Mr. James Justin, Professional Pattern Maker, Puget Sound Pattern Works

APPENDIX G – Test Data

Casting Number	Weight of casting (lbs)
1	5.10
2	5.50
Avg.	5.30

Setup Item	Weight (lbs)
Flask #1	33.00
Flask#1 w/matchplate	39.30
Flask #1 w/sand+plate	117.50
Flask #2	33.00
Flask #2 w/matchplate	39.30
Flask#2 w/sand+palte	114.50

Weight of Flask	33.00	lbs
Weight of matchplate	6.30	lbs
Sand in Flask #1	78.20	lbs
Sand in Flask#2	75.20	lbs

APPENDIX H – Testing Report

76.70	Average weight of Sand in pounds needed per flask
	8 flasks per production run
613.6	Pounds of sand per run.

APPENDIX I - Resume

Ryan Berghoff - 717 East Countryside Ave l Ellensburg, WA 98926 l 509 961-8986 l
berghoffr@cwu.edu l

OBJECTIVE

To acquire a job.

EDUCATION

Bachelor of Science in Mechanical Engineering Technology Expected June 2017
Central Washington University, Ellensburg, WA

Associated of Arts Sept. 2010 – June 2014
Yakima Valley Community College, Yakima, WA

Relevant Coursework
Statics, Thermodynamics, Fluid Mechanics, Basic Machining, AutoCAD, Solidworks, Basic Electricity, Metallurgy, Business and Professional Speaking, Technical Writing Strengths and Materials, Dynamics, Quality Control (spring quarter 2016)

Leadership/Activities
Recorder, Yakima Valley Community College Engineering Club Jan 2012 – June 2014

- Took club meetings minutes Sept. 2013 to June 2014
- Judged and supervised two Science Olympiad events at YVC
- Instructed participants at Science Fair - YVC.

SKILLS

Computer: Microsoft Word, Excel, PowerPoint
Tools: Metal Lathe, Wood Lathe, Vertical Milling Machine, Drill Press, and CNC Milling Machine & CNC Lathe
Hand reload my own ammunition for fourteen caliber munitions.

WORK EXPERIENCE

Tutor, Yakima Valley Community College Tutoring Center,
Yakima WA. Jan. 2013 - June 2014

- Helped students with remedial math up through pre-calculus.
- Worked on the front desk assisting students in scheduling appointments and tutors

Crew Member, Quiznos, Yakima, WA Dec. 2007 - June 2014

- Preformed cashier duties, food preparation, stocked and closed the store

Vector Marketing, Yakima, WA Dec. 2007 - June 2014

- Sold $10,000 worth of products in a summer to win a free trip to a company conference in Las Vegas, NV.

VOLUNTEER EXPERIENCE

Redeemer Lutheran Church, Yakima, WA Nov. 2001 – Present

- Helped coordinate, setup, and cook for events