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Conversion Casting From A36 Steel to Grey Iron

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2015

Conversion Casting From A36 Steel to Grey Iron

Christopher Nichols

Central Washington University

Senior Project Proposal

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ABSTRACT

Conversion castings are used in manufacturing to reduce time and costs of the production of machined parts. This project incorporated a machined production component from a local manufacturer and designed and produced an equivalent component using the casting process. The casting material chosen needed to be able to withstand all tension and compression forces when the component is used in service along with locations and dimensions of holes needed to be in accordance with all specified tolerances. The casting design process had to account for draft issues, shrinkage during material solidification, porosity and internal cavities formed during solidification, and overall optimization of material used for the casting process. The use of computer simulated solidification software aided in the design of runner and gating dimensions as well as predetermining significant problem areas for porosity and internal cavities within the castings. The manufacture of the mold pattern and core boxes was completed using the additive manufacturing process of three dimensional printing. Using this process eliminates the use of any machining processes for the manufacture of the casting along with significantly reducing the amount of man hours for fabrication. The patterns were made as well as the castings poured at Central Washington University using the 3-D printers and the foundry located in the engineering building. Success of this project will be determined through comparison of all dimensions to the current machined components and performance testing when put into service.

INTRODUCTION

Engineering Problem

This project was motivated by the desire to find alternate ways of production for specific parts in order to reduce overall fabrication time and costs. Harvestco Fabricators is a small company (5 full-time employees) that design and fabricate hay squeezes for the agricultural industry. All parts that make up these units are fit, welded, and machined; no castings have ever been used. These types of fabrication processes can be time consuming and, in turn, cost much more. Many of the parts to these units need to be machined, but there are some parts that can be produced in greater numbers through a casting process that will yield equivalent parts at a much cheaper price. This proposal investigates the option of substituting a class of cast grey iron for the currently used machined material, A36 steel. The casting would optimize the fabrication process by eliminating the majority of machining and have the ability to cast multiple parts in one setting.

Function Statement

The function of this project is to produce an equivalent part from a cheaper material and process. Use a casting process to convert from a more costly machining process that is currently in use.

Design Requirements

The following requirements are necessary for the conversion casting to succeed:

- Casting process must prove to be a sufficient substitution for the parts in question and must overall optimize the manufacturing process.
- All final dimensions of the cast part need to be no less than design dimensions and no greater than 0.125."
- Cast material will need to withstand a maximum distributed load of 25,000 lb/in^2.
- Cast parts must withstand a maximum load of 7500 lb. with a safety factor of 1.5 included.
- Casting will need to be solid throughout the area of a threaded hole.
- Any draft considerations must maintain the workability of the final product.
- Hole locations must be +/- 0.0625" of drawing dimensions.
- Finished casting must be accepted by customer for production.

Engineering Merit

The final cast parts must pass all the requirements listed and visual quality accepted that will be evaluated by Harvestco Fabricators. In determining that the castings are sound and solid they are inspected to be free of any significant internal voids or defects. Workability from any added draft for casting will consist that no draft will be integrated on any mating surface of the cast part. Optimization of the current manufacturing process results from the ability to produce equivalent castings that reduce the current machining time by half, therefore, producing a more efficient part.

Scope of this effort

The scope of this project is to provide an alternative way to manufacturing the top and bottom C900 Class III clamp clips for Harvestco Fabricators. By converting these currently machined parts to a cast part the company should be able to significantly reduce the current cost of fabrication by reducing the amount of hours of machining that is involved. The ¾" – 16 threaded hole will still need to be machined post-casting, but all other aspects of machining on the part will be eliminated.

Success Criteria

In order for the conversion to be successful the cast part will meet all the requirements and also prove that the conversion to a casting instead of a machined part will be significantly cost effective.

The cast clips bolting onto the clamp successfully and in working fashion. The cast parts will hold the maximum intended load when put into service.

DESIGN & ANALYSIS

The idea of this design, or conversion, came from the manufacturers, Harvestco Fabricators, in the beginning of 2014 when they were at a trade show in California. A salesperson for an investment casting company approached them on the ability to make castings out of some of the components on their hay clamps. This idea was brought back to their facility, pursued, but never was followed up by the said metal caster.

The clamp clips that were proposed for the conversion casting are the components that connect and hold the C950 hay clamp (Figure 1) to the apron of a forklift.

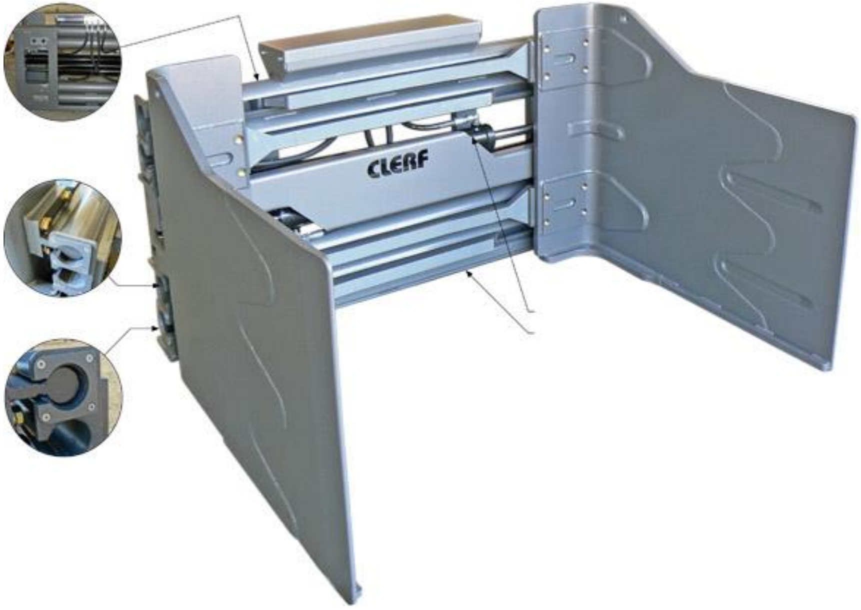


Figure 1. Clerf C950 hay clamp manufactured by Harvestco Fabricators.

These clamps are a heavily used tool in the hay industry. They are specifically manufactured for the use in warehouses and for loading semi-truck trailers and shipping containers. The abuse that these units are put through and withstand is phenomenal. This was primarily taken into consideration when the requirements for these castings were made and their mechanical properties were tested to prove the ability to withstand the rigorous work setting.

The clips that were cast are shown below (figure 2). The hole locations and their specific geometry made core and pattern design challenging. The top clip consists of two counter-bore holes going horizontally through the part and also a threaded hole that is normal to and between the counter-bore holes. It was determined that it would not be attempted to cast the threads for the threaded hole because they are fine threads and it would be too difficult to cast complete threads throughout the hole. Instead, a through-hole would be cast in the part in the location of the hole and a post-machining process would be used to perform the threading operation.

The bottom clip holes also had irregular geometric features where both holes were oblong. This feature was taken into consideration during the core making process.

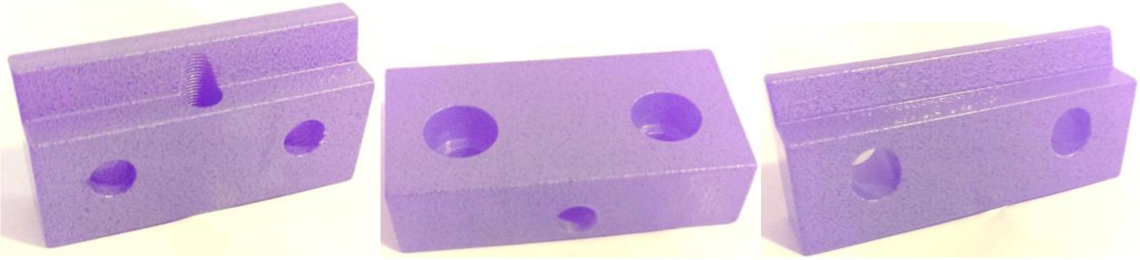


Figure 2. Top Clip vertical, Top clip horizontal, and bottom clip.

The design and manufacturing of prototype components will be completely done at CWU using computer simulation software with CFD capabilities, rapid prototyping for core and pattern casting components, and the foundry for final production of the clamp clips.

First, the clips will be constructed in Solidworks along with multiple gating and runner design ideas. The method for runner and gating design will be a 4-8-3 pressurized gating method (Appendix B-3).

This gating design ratio sets up the choke point at the gates where the liquid iron enters the casting. This process is predominately used in industry when in-line filters are not in use. The liquid iron feeds from the bottom of the runner instead of the top where slag and dross collects and is essentially sprayed into the casting maintaining a constant pressurized flow. Calculations for this method will be done with a spreadsheet and the formulas are listed below:

$$\text{Pour Time} = \sqrt{Pour\ weight}$$

$$\text{Pour Time x .063 = In-gate Area}$$

$$\text{Runner Area} = \frac{In\!-\!gate\ Area\ x\ 8}{3}$$

$$\text{Downsprue Area} = \frac{In\!-\!gate\ Area\ x\ 4}{3}$$

Figure 3. 4-8-3 gating formulas.

This process uses the gross weight of the casting in order to obtain dimensions for the sprue, runner, and gates for the casting mold. The combined casting weight for both clips along with the runner and gating is 15.0 lb. The following table lists dimensions used for the gating system. Design calculations are shown in appendix A-3.

Table 1. 4-8-3 gating design calculations results.

Pour Weight	Pour Time	Runner Dimensions	Gating Dimensions	Sprue Diameter
15 lb.	4 sec.	.70” x .96”	.672” x .1875”	.6875”

Another step of the gating design was the orientation of the cast parts. For the prototype casting it was chosen to run one of each the top and bottom clips. In a production setting more parts would be added to the mold in order to increase overall yield and cost effectiveness. The initial orientation was to insert the gating into the thicker long side of the part (see Appendix A-5), but this would not work due to the location of the threaded hole in the top clip. The first alternate option was to rotate both parts 90 degrees and feed from the sides where there would be no core interference. Figure 2 and 3 below show the first option for orientation of the parts for the casting.

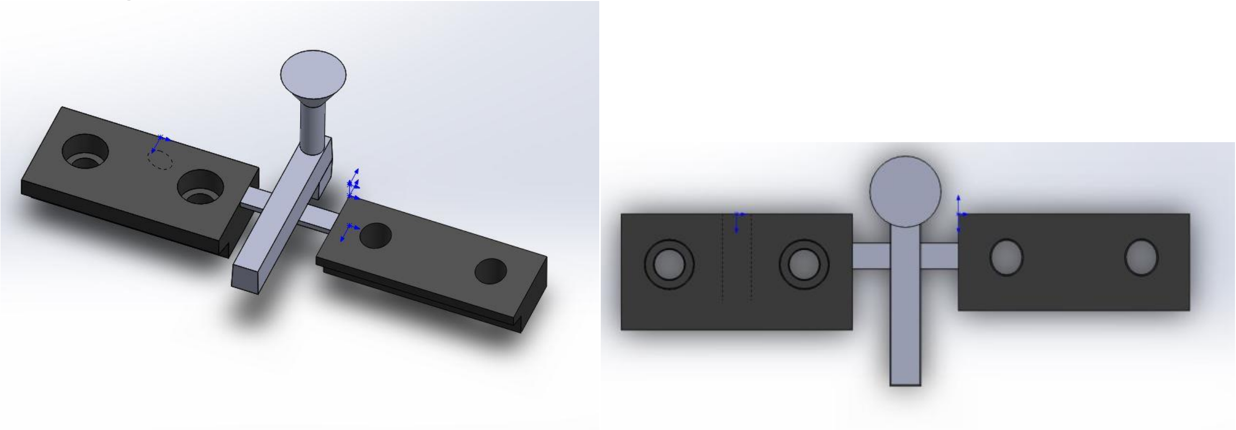


Figure 4. Prototype casting full assembly model (4-8-3 method) in orthogonal and top views.

A second alternative orientation for the cast parts was to have the gates flow into the thinner lip portion of the clips. This orientation would compact the overall casting reducing sand use and also possibly allow better solidification properties to the casting. Generally, it is desired to have thicker portions of castings solidify faster in order to inhibit shrink and other defects. By having in-gates flow into these areas it will maintain a constant flow of hot material keeping the thick areas hot and slowing the solidification [1]. Figures 4 and 5 show the second alternative and preferred orientation.

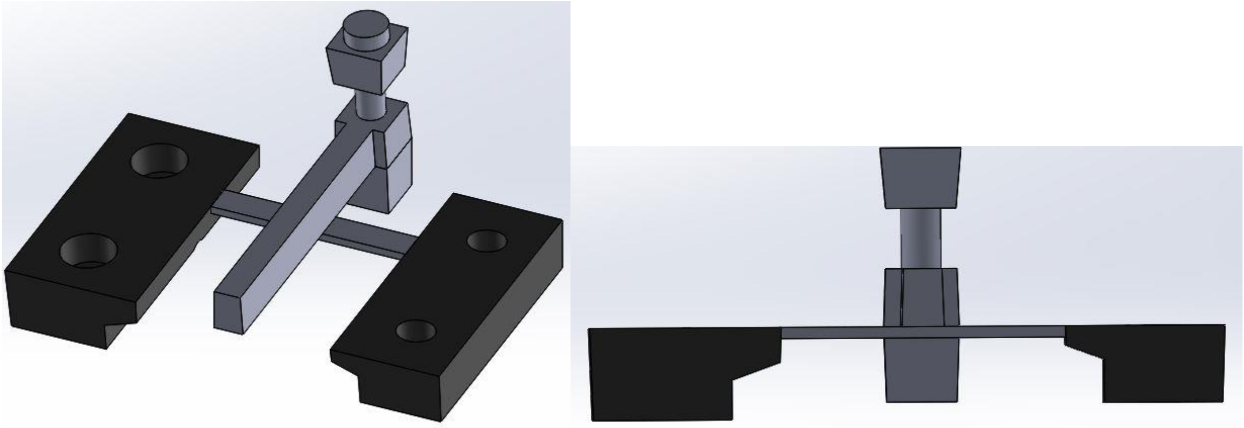


Figure 5. 2nd alternative casting assembly in orthogonal and front views.

Two other factors that were taken into consideration are draft and overall shrinkage during solidification.

- Draft had to be added to most all surfaces in order to get the pattern out of the sand mold. The two main mating surfaces were saved from draft due to one surface being in the bottom of the drag and the other surface because the three other vertical sides were able to accept draft.
- Shrinkage always must be taken into consideration with castings. The percent shrinkage varies with each type of material. Through experience it was determined that the initial percent increase in the overall size of the parts would be 2%. Once the initial prototype casting has been poured it will then be known if the 2% increase was sufficient.

Both gating design solid models were imported into the CFD software, SOLIDCast, for flow and solidification analysis. Multiple parameters were analyzed with the main focus on component density and formation of internal micro-porosity. These two parameters specifically show whether or not the use of risers and/or chills within the mold are necessary. The main intention of this part of the design process is to eliminate most any design flaws before the actual casting is poured and completed. All of the analysis is documented in the appendix of the report.

FEA will be performed on the model to simulate the loading scenarios based off of force calculations documented in appendix A. This analysis will help specify the proper class of grey iron that is necessary for the components.

The major forces on the clip components are in compression. This is what makes these parts excellent candidates for a grey iron casting. A class 30 grade iron is the initial selection for material because it has ultimate compression strength of 109 ksi which exceeds the required compression strength by 12%. Class 30 grey iron is also a more standard material that is easier and cheaper to produce.

Benchmark

This is a custom made part designed and currently machined by Harvestco Fabricators. The conversion casting from A36 hot-rolled steel to grey cast iron will need to withstand all applicable forces and stresses that the current part in use undergoes and is effective.

Technical Risk Analysis and Safety Factor

The safety factor for this design was calculated based on the rated load that is given from the forklift manufacturer. The rated load for the standard forklift that operates the C900 hay clamp is 9000 lbs. This load is based off a safety factor set by the manufacturer. Because of this knowledge of the already rated load the safety factor of 1.5 was chosen as an added buffer to a design load.

Performance Predictions

It is predicted that the cast material will withstand and exceed the required load of 25,000 psi. The prototype parts will fit with ease onto the clamp assembly and be able to withstand any and all scenarios equivalently to what the current steel clips withstand.

The increase in casting size by 2% will be enough to hold to the overall dimension limits of no greater than .125" and will shrink no less than any dimension included on the provided prints (Appendix B-1, B-2). Hole locations will not differ by .0625" and hole sizes will be large enough for bolts to pass through with ease.

Draft that has been added to the parts will not interfere with any connecting piece or fastener used when the cast clip is assembled.

METHODS & CONSTRUCTION

Current Machining Process

As previously stated the current fabrication process for the clips is all done by machining. This process takes four separate tooling and clamping positions (figure 6). Each set up completes once process in the machining. For one part to go through all the steps it takes about 20 minutes. This casting conversion will optimize this process to only one step and a time of less than 5 minutes.

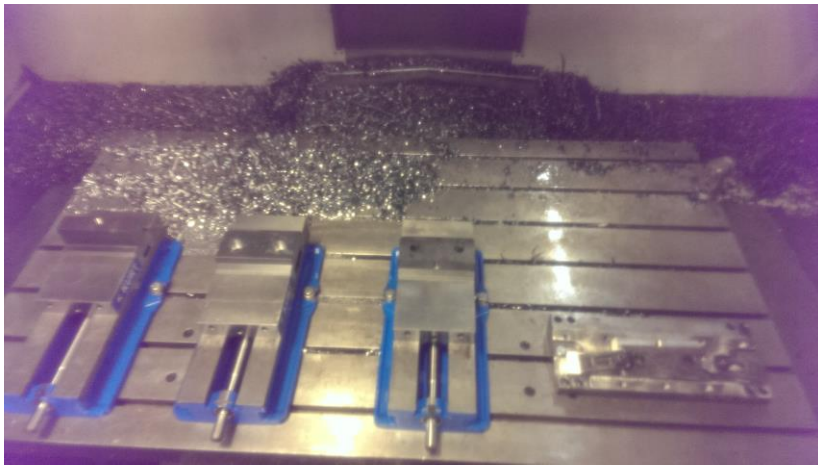


Figure 6. Current 4 step machining process.

The construction of these castings will come in three main stages: pattern and core fabrication, mold manufacture, and pouring of the casting. Each of these stages will take a considerable amount of time and investment with pattern and core fabrication taking up most of that time. All three of these stages will be performed using the resources available at CWU. Cores will be made using a no-bake sand process using the fabricated core boxes. Metal for the pouring process will come from materials stored in the CWU foundry.

Pattern and Core Box Construction

The pattern and core fabrication will all be done using the 3D rapid prototype printing process. This method was chosen in order to use the most modern engineering processing capabilities that is available. The printed parts for the pattern will contain drill holes and locator pins to ensure accurate pattern assembly. The pattern will be produced to work as a match-plate for the molding process. This seems to be the best and most efficient way to make the mold within the capabilities of the CWU foundry. The printed nylon components will be glued and screwed to MDF board in precise locations to complete a finished match-plate pattern.

Three core boxes will be made for the three different sized holes in the castings. The core boxes will be composed of two halves which will negate the necessity of draft for the cores. The following figures show representations of the patterns that will be made.

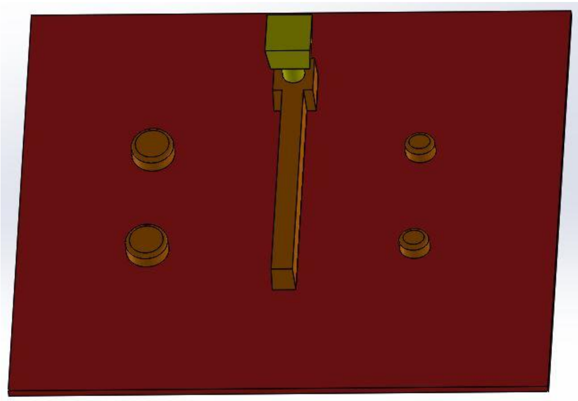


Figure 7. Cope pattern.

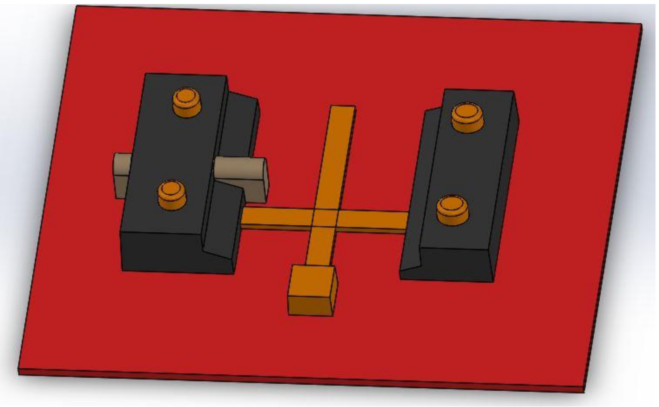


Figure 8. Drag pattern.

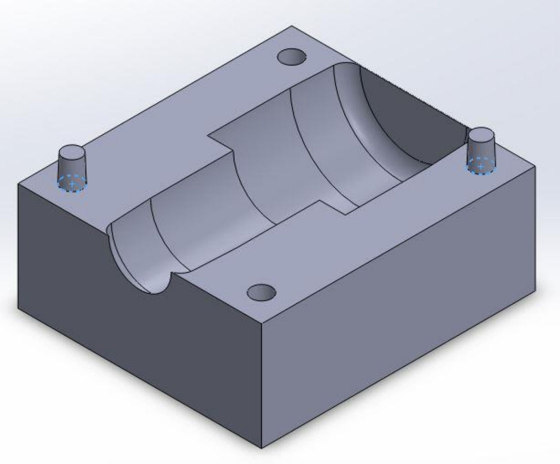


Figure 9. Counter-Bore Core-box

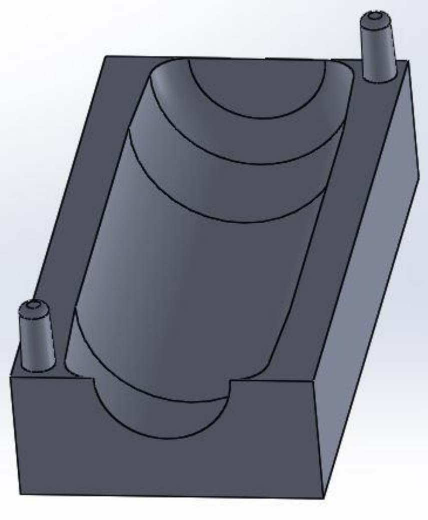


Figure 10. Oblong hole Core-box

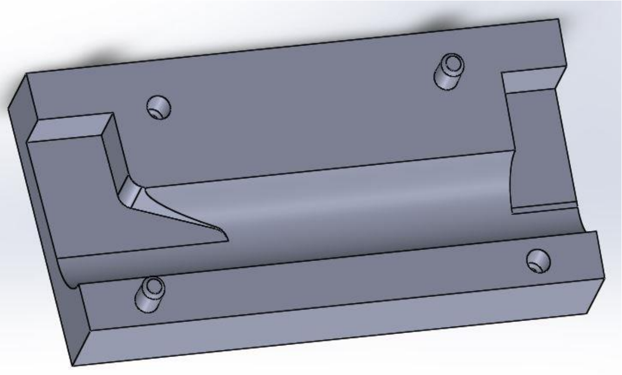


Figure 11. Threaded hole Core-box

Mold and Core Construction

Mold manufacturing takes on two different processes. The first process is using a no-bake sand for the manufacture of cores for the entire mold. Silica sand is mixed together with a binding agent that will flash and solidify after 3-5 minutes of being combined. This process works best for the cores because rigidity of the cores in the mold is very important in order to hold dimensional tolerances within the cast part. Figures 9, 10, and 11 are representations of the three cores used in the mold.

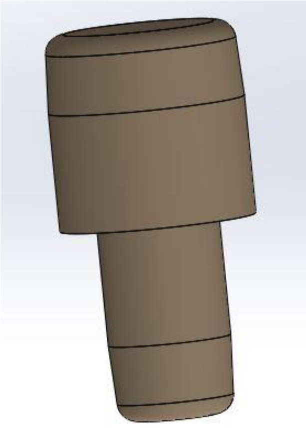


Figure 12. Counter-bore hole core.

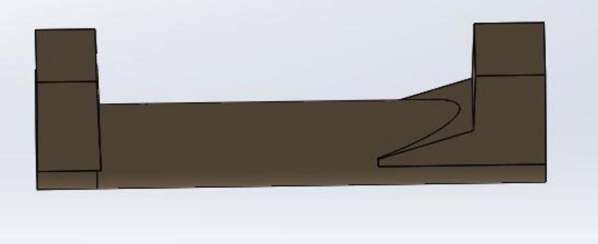


Figure 13. Threaded hole core.

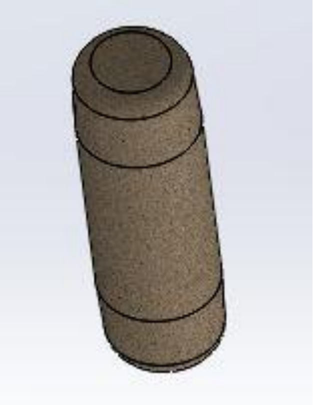


Figure 14. Oblong hole core.

The second molding process is done with green sand. This is a water-based process and makes up the entire casting mold less the cores. The green sand is held within a flask. The cope and drag patterns are aligned on a match plate that is located between the cope and drag parts of the flask. The sand is added and packed into the cope of the flask until completely filled. The mold is then carefully flipped over and the same is done for the drag. The pattern is then taken out of the mold and the cores are inserted into the drag. Figure 14 and 15 show the cast parts with gating, runner, and sand cores all in one piece. This should give a good representation of what the cast parts will look like in the mold.

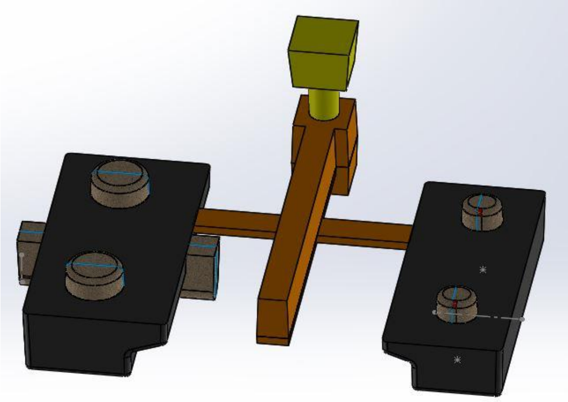


Figure 15. Bottom of complete casting.

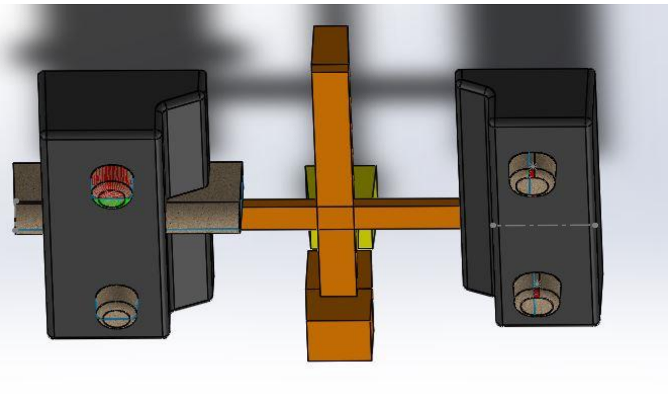


Figure 16. Top side of complete casting assembly.

Drawing Tree

The following drawing tree shows the flow of drawings necessary for this project. The drawings lists are found in appendix B.

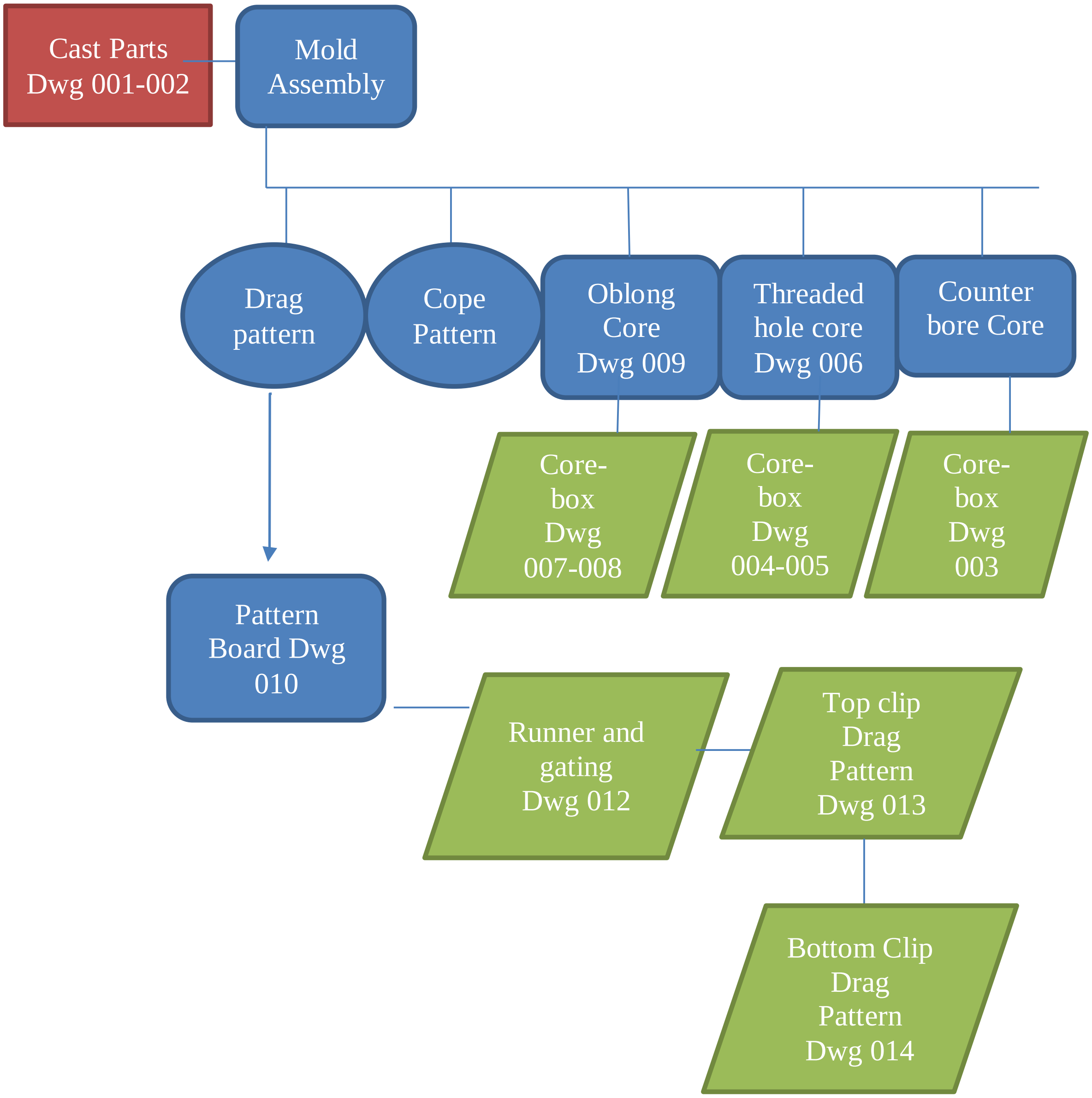


Figure 17. Drawing tree

SOLIDCast Data/Analysis

The use of SolidCast in this project will greatly aid is generating a first pour sound casting. The model in figure 14 and 15 was imported into SolidCast and solidification simulations were performed. The below images show detailed sections of possible micro-porosity within the casting [2]. The areas of yellow within the casting indicate the areas.

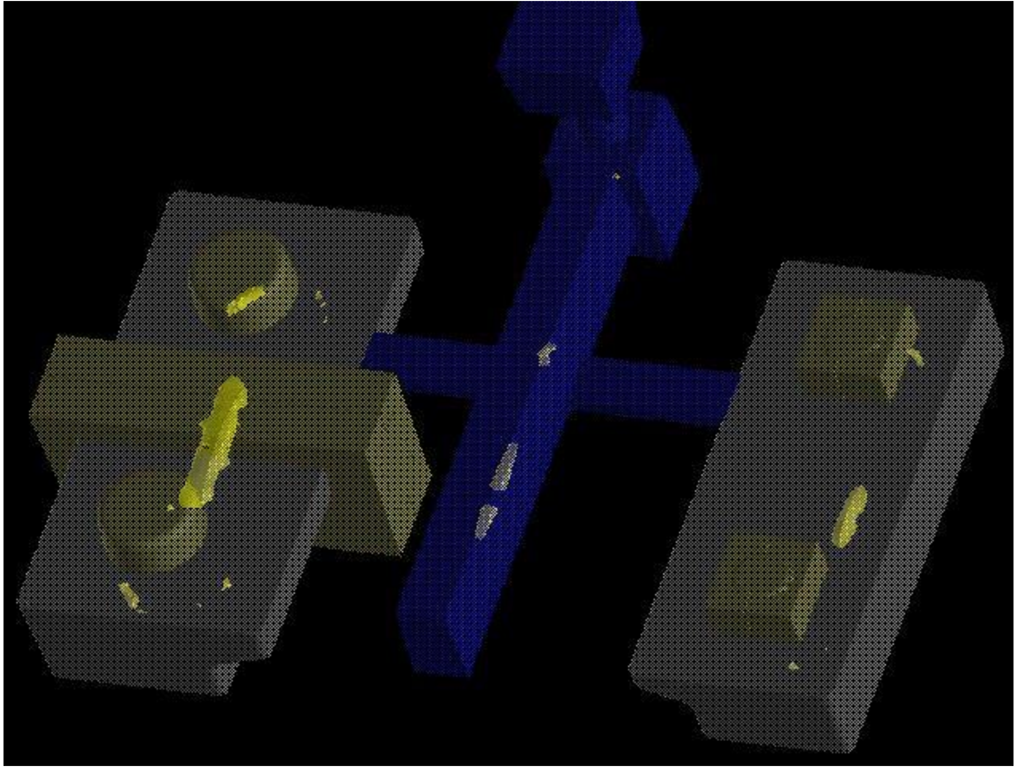


Figure 18. Micro-Shrink Analysis with SolidCast.

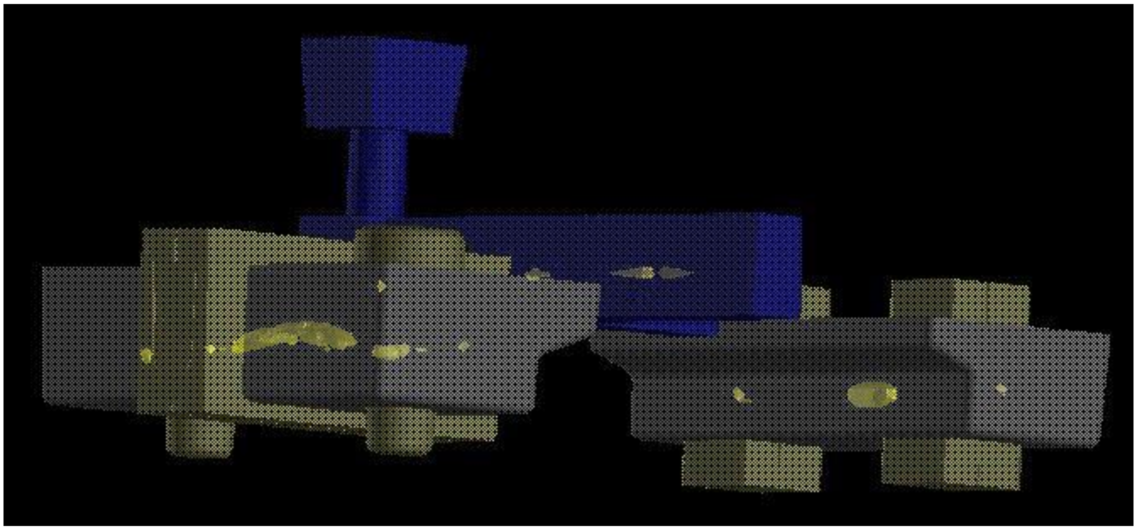


Figure 19. Micro-Shrink analysis using SolidCast.

The micro-shrink data showed a significant area in the center of both castings. This was to be expected due to the nature of the solidification process. The liquid iron will solidify from the outside in. This direction of solidification will pull material from the middle of the part in order to compensate for the shrink areas towards the outer surface of the casting. The shrink in the casting without the horizontal through hole is not very detrimental to the part, so no modifications need be done to the part. The casting with the through hole will need to be modified, but that will be a simple process. Form the available riser sleeves for use a 1 inch diameter riser will be added to the top center of the casting. This riser will feed the middle of the casting as it solidifies and will move the shrink out of the casting and into the riser. Another solidification analysis will be run on the casting with the added riser in order to assure that the 1 inch riser will be sufficient.

TESTING METHOD

A testing method was established in order to prove the quality of the prototype castings. These tests will ensure the requirements of the casting material meets or exceeds all the requirements listed for an acceptable part. The initial testing will show any possible trouble areas in the casting with the use of the solidification software. This software will essentially eliminate the trial and error method more often used in the casting process.

Test Plan

In order to assure a sound and equivalent cast part the following tests will be performed and documented:

1. Solidification software will be used to analyze best gating and possible riser or chill locations. This will also help predict any areas of internal porosity or low density before the actual casting process.
2. Tensile and compression testing will be performed on material specimens taken from the casting and data will be compared to current ASTM standards for grey iron.
3. Load testing will be performed on the cast part to a maximum load of 7500 lbs. in the location that the casting would carry that load while in service. This test will be performed using the Tinius-Olson machine. A jig will need to be made for the load to be properly placed on the part.
4. NDE methods, such as ultrasonic, eddy current, or x-ray will be performed, if possible, to ensure an internal sound structure of the cast part. If this is not possible a prototype part will be drilled in the location of the threaded hole.
5. The cast parts will be bolted to the clamp assembly to insure proper fit and performance.

Test Documentation and Deliverables

Test documentation will be reported using the evaluation and test report sheets listed in appendix G and H. The data from these sheets will be added to appendix I after the castings have been poured and testing has been performed.

Items 2, 3, and 4 of the test plan were discarded due to time constraints and availability of instruments for specific tests. Iron quality was determined by testing the % Carbon of the liquid material before pouring the castings. It was determined that the quality of the material was within the specifications for Class 35 grey iron. Measured value was 3.30% Carbon and the required minimum is 3.25%. This data was sufficient to assume material equivalent to class 35 grey iron.

Dimensional testing was added to the test plan in order to confirm that the castings were within all tolerances listed within the requirements of the project. All vital dimensions were within the required tolerances when compared to the currently machined part. Specific dimensions that were checked are listed in Appendix H of this report.

The final test for this project was the workability of the clips. Both cast clips were taken to Harvestco Fabricators and fit tested to the C950 clamp body. The results are shown below in figure 20.

Figure 20. Cast clips are test fit to body of C950 Clamp.

The schedule for the testing was delayed by one month due to the delay in getting new material for the melting process. All tests prove that the cast parts are sufficient replacements to the currently machined parts.

BUDGET/SCHEDULE/PROJECT MANAGEMENT

Schedule

This project will be managed by following a strict schedule and time management allocated by the MET 495 course. The mentioned schedule is detailed in Appendix E. The schedule is broken down to the month from mid-November 2014 to June 2015 with specific deliverable timestamps included for draft proposal, analysis modifications, document modifications, final proposal, and parts construction, pour schedule, and casting evaluation.

The estimated total hours for this project are 360 hours. This is a base amount and total hours for the project are expected to exceed the estimated amount.

Cost and Budget

Cost for this project will be less due to the available materials at CWU. Major costs will come from the 3-D printing process for the necessary core boxes and pattern.

Part Suppliers

Materials for the project are located in the Hogue building at CWU. The melt material to be used is donated material for D & L Foundry. The rapid prototyping process was done using the printers in Hogue Technology building.

Cost

The estimated total cost of this project is $380.58. The estimated cost does not include the use of donated materials. The major expense for the project will be with the 3-D printing process with an estimated cost of $380.58. This cost may be reduced due to the ability to make portions of the core-box materials out of honeycomb lattice during the printing process. Costs for all materials and parts list are located in Appendix C. No additional costs will come from machining due to all parts being made by rapid prototyping.

Funding Source

Funding for the project will come from personal expense and project funding from Harvestco fabricators.

DISCUSSION

This project came to be more or less by chance. The owners of Harvestco, Inc. were at a trade show in California where a guy came by their booth, looked at their hay squeeze units, and told them that he could make castings out of some of their parts and save them some money. When they returned I was asked about the ability to cast certain parts where, at the time, I still had not gained too much experience with the casting world, but definitely could see how it could be possible. They moved forward, contacted the gentlemen, sent him the necessary information, and then never heard from him. Due to a poor business sense of a salesman in the casting industry, I was able to offer my ability to make castings of their currently machined parts for little to no cost and provide them with data for all aspects via testing and production.

The original idea was to cast these parts with class 30 grey iron (UTS 30 ksi, CS 109 ksi), but it was of concern that the stresses found when put into service come rather close to the calculated critical stress of 25 ksi. The next option in classes of gray iron would be to produce and cast the parts with class 40 gray iron (UTS 42 ksi, CS 140 ksi). By casting this class of gray iron any safety factor would be sufficiently exceeded and ultimately produce a better part for the customer.

Two challenges that still loom over this project are the ability to produce the proper material selected and also the pattern making process for the cope and drag. The biggest challenge will be to effectively produce a class 40 grey iron during the casting process. I know that this will be possible, but also that I expect it to take a few tries to get it right. The second challenge will be the patterns mainly due to my lack of knowledge with the CNC process. This should not be too much of a hurdle as I do have the right connections and help to get me through the process. Also, with the help of Mr. Burvee, I now have a game plan on an efficient way to make the patterns.

CONCLUSION

The process of a conversion casting very easily meets all of the requirements and engineering merit necessary for a senior project. This project takes a currently machined part from steel that takes multiple tool holding set-ups and hours to produce and through casting accomplishes over 90% of the machining through one process. When the casting is finished the only step will be threading of one hole in the part. These parts will be produced more efficiently, effectively and reduce machine and manpower.

This project falls in direct interest with the path that I am on for a career after I graduate. I believe that by doing this project and having the documentation of the process will greatly benefit me when talking and interviewing with casting companies.

ACKNOWLEDGEMENTS

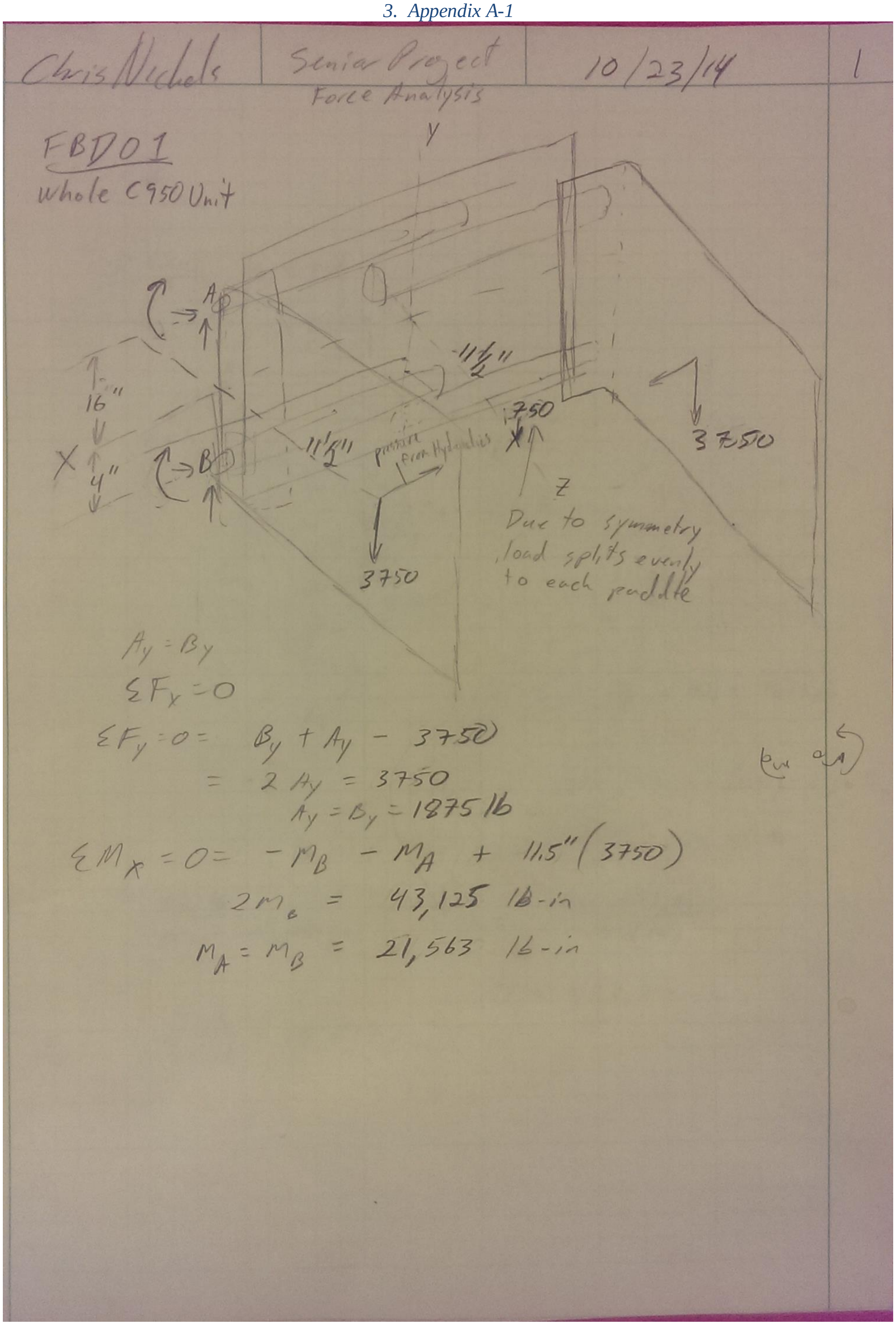
I would like to acknowledge Galen Flory at Harvestco, Inc. for giving me the opportunity to use their parts and design for this project

Personal Acknowledgements

- Prof. Pringle for his assistance and expertise with the structural analysis at the beginning of the project.
- Dr. Johnson for his assistance and expertise with the casting and materials aspect of the project.
- Mr. Burvee for his assistance and machining knowledge with helping me work through and figure out the pattern making process.

APPENDIX A – Analyses

3. Appendix A-1



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Force Analysis

FBD01

whole C950 Unit

Due to symmetry, load splits evenly to each paddle

$A_y = B_y$

$\Sigma F_x = 0$

$\Sigma F_y = 0 = B_y + A_y - 3750$

$= 2A_y = 3750$

$A_y = B_y = 1875$ lb

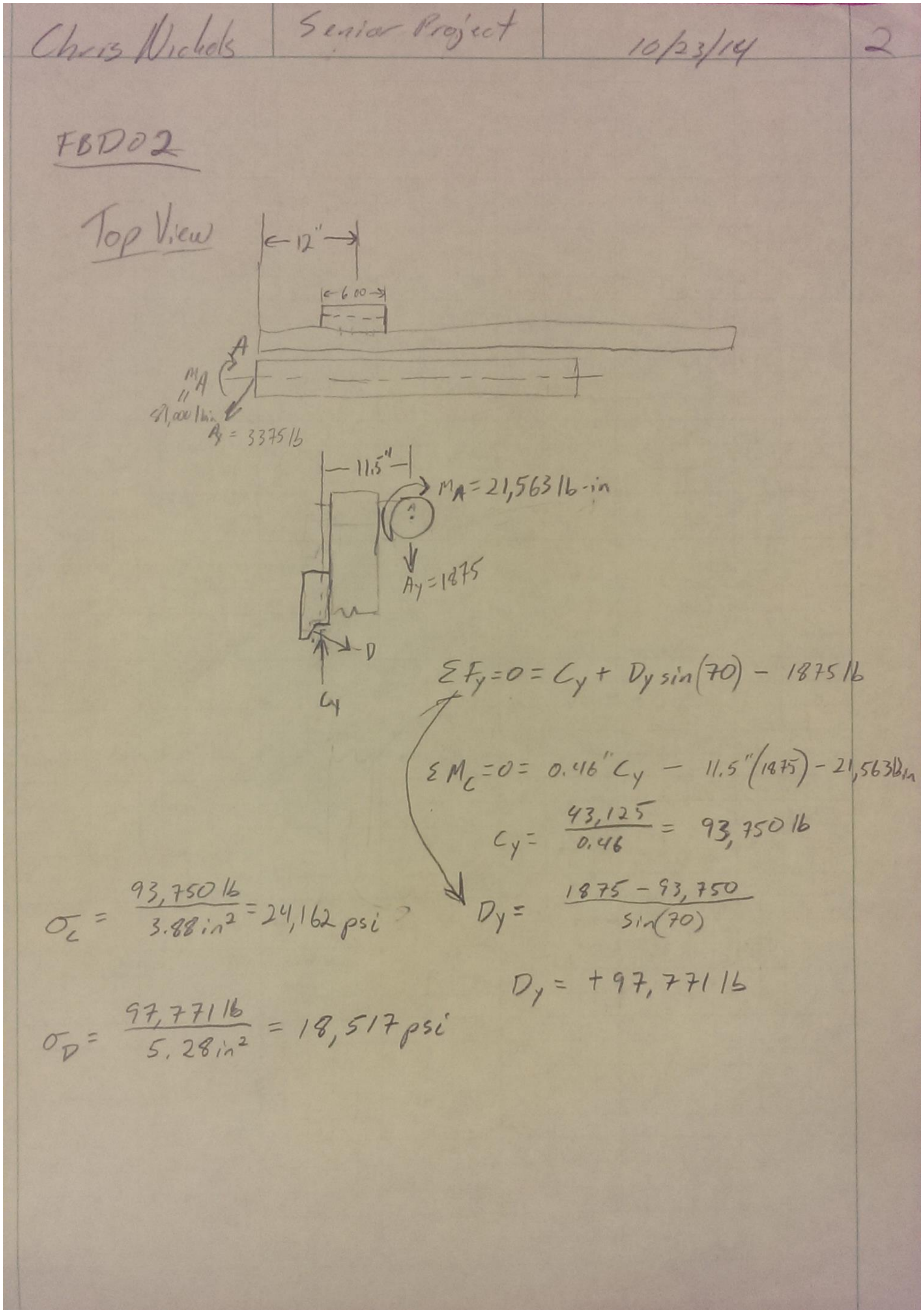
$\Sigma M_x = 0 = -M_B - M_A + 11.5"(3750)$

$2M_B = 43,125$ lb-in

$M_A = M_B = 21,563$ lb-in

ccw @A

4. A-2



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FBD 02

Top View

$\Sigma F_y = 0 = C_y + D_y \sin(70) - 1875\text{ lb}$

$\Sigma M_C = 0 = 0.46'' C_y - 11.5''(1875) - 21{,}563\text{ lb-in}$

$C_y = \frac{43{,}125}{0.46} = 93{,}750\text{ lb}$

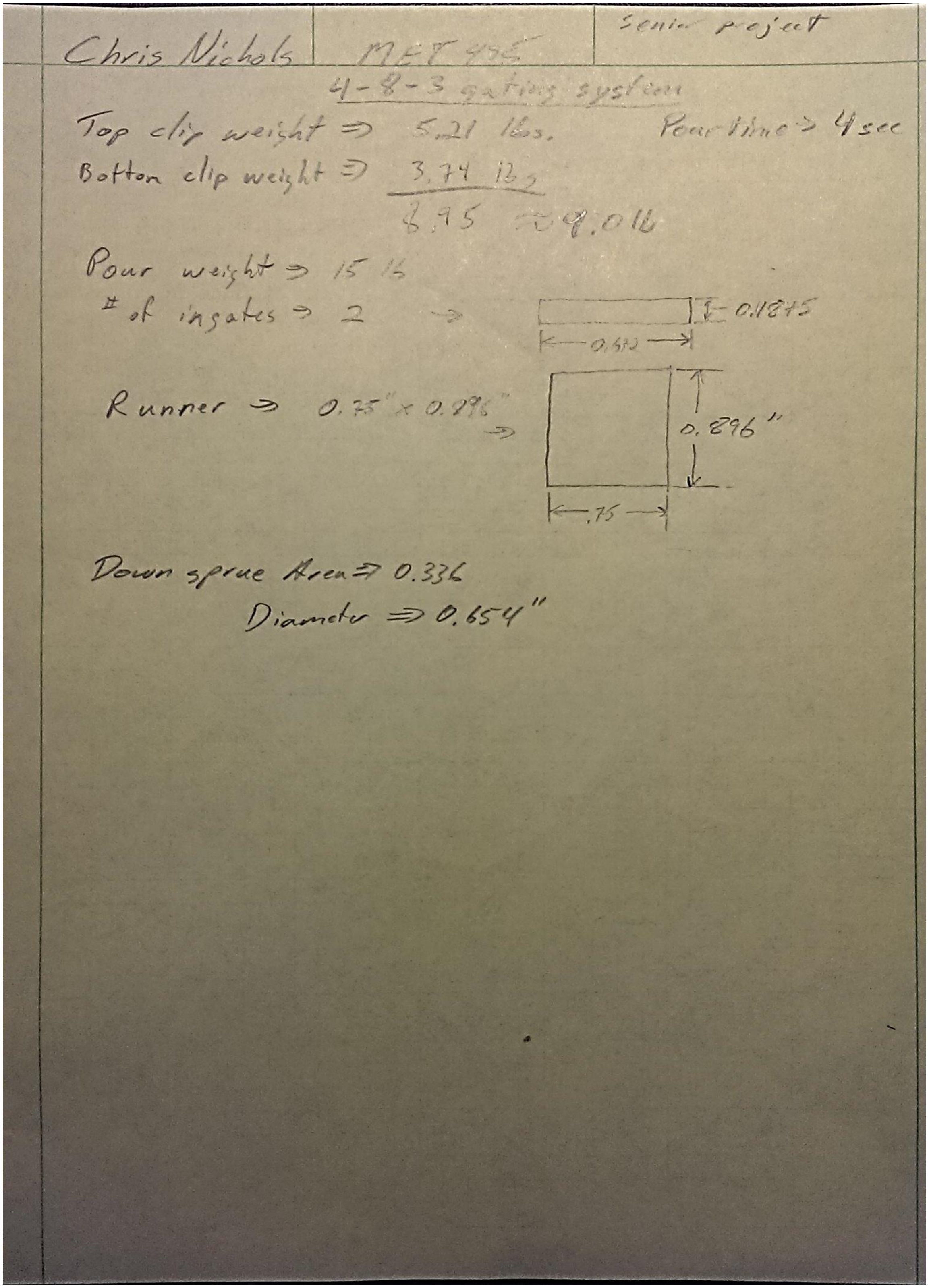
$D_y = \frac{1875 - 93{,}750}{\sin(70)}$

$D_y = +97{,}771\text{ lb}$

$\sigma_C = \frac{93{,}750\text{ lb}}{3.88\text{ in}^2} = 24{,}162\text{ psi}$?

$\sigma_D = \frac{97{,}771\text{ lb}}{5.28\text{ in}^2} = 18{,}517\text{ psi}$

5. A-3



Chris Nichols | MET 495 | Senior project

4-8-3 gating system

Top clip weight ⇒ 5.21 lbs.

Pour time ⇒ 4 sec

Botton clip weight ⇒ 3.74 lbs

8.95 ≈ 9.0 lb

Pour weight ⇒ 15 lb

# of ingates ⇒ 2 →

0.1875

0.632

Runner ⇒ 0.75" × 0.896" →

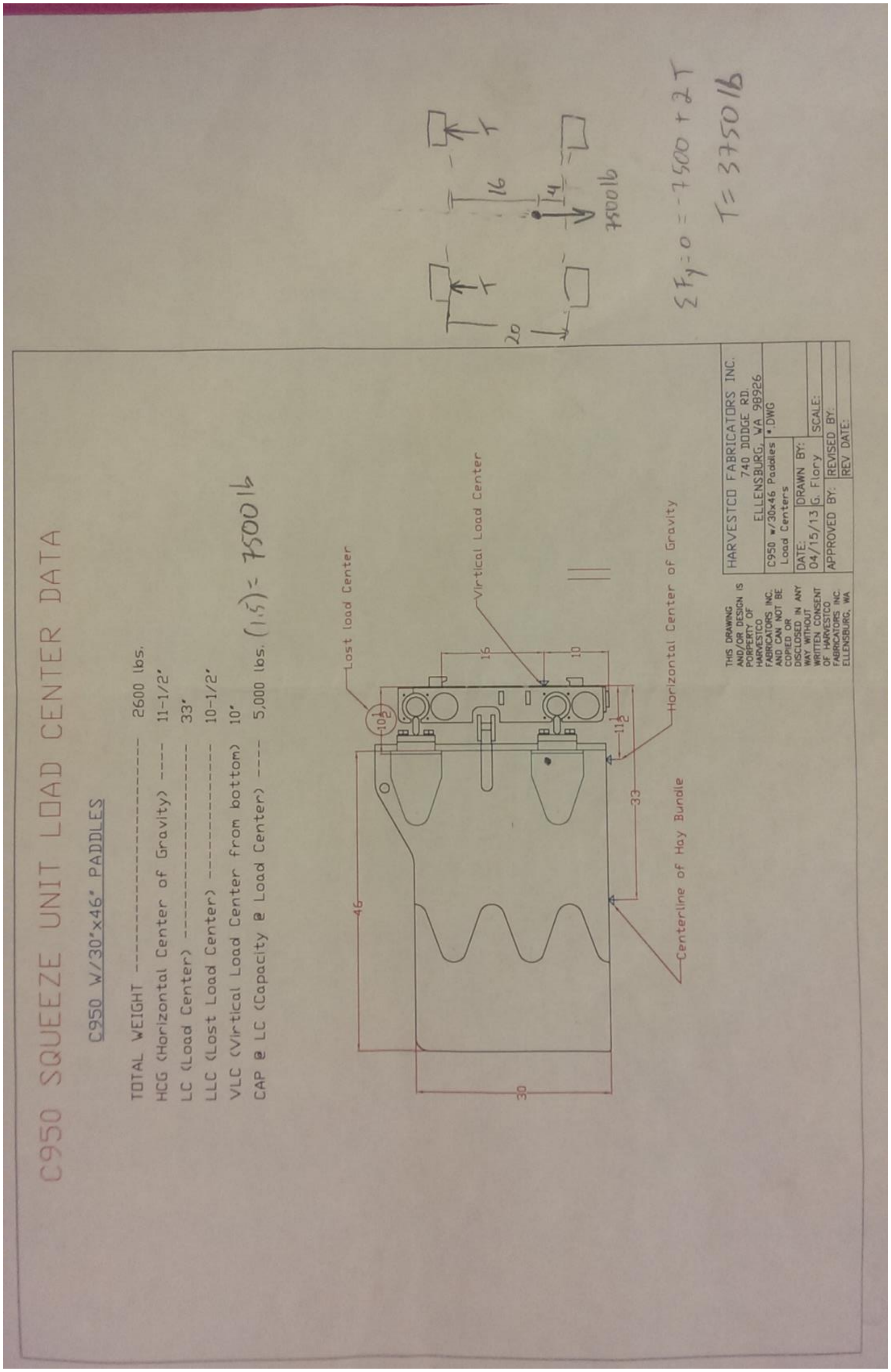
0.896"

.75

Down sprue Area ⇒ 0.336

Diameter ⇒ 0.654"

6. A-4



C950 SQUEEZE UNIT LOAD CENTER DATA

C950 W/30"x46" PADDLES

TOTAL WEIGHT -------------------- 2600 lbs.
HCG (Horizontal Center of Gravity) ---- 11-1/2"
LC (Load Center) ------------------- 33"
LLC (Lost Load Center) -------------- 10-1/2"
VLC (Virtical Load Center from bottom) 10"
CAP @ LC (Capacity @ Load Center) ---- 5,000 lbs. (1.5) = 7500 lb

$\Sigma F_y = 0 = -7500 + 2T$

$T = 3750\,lb$

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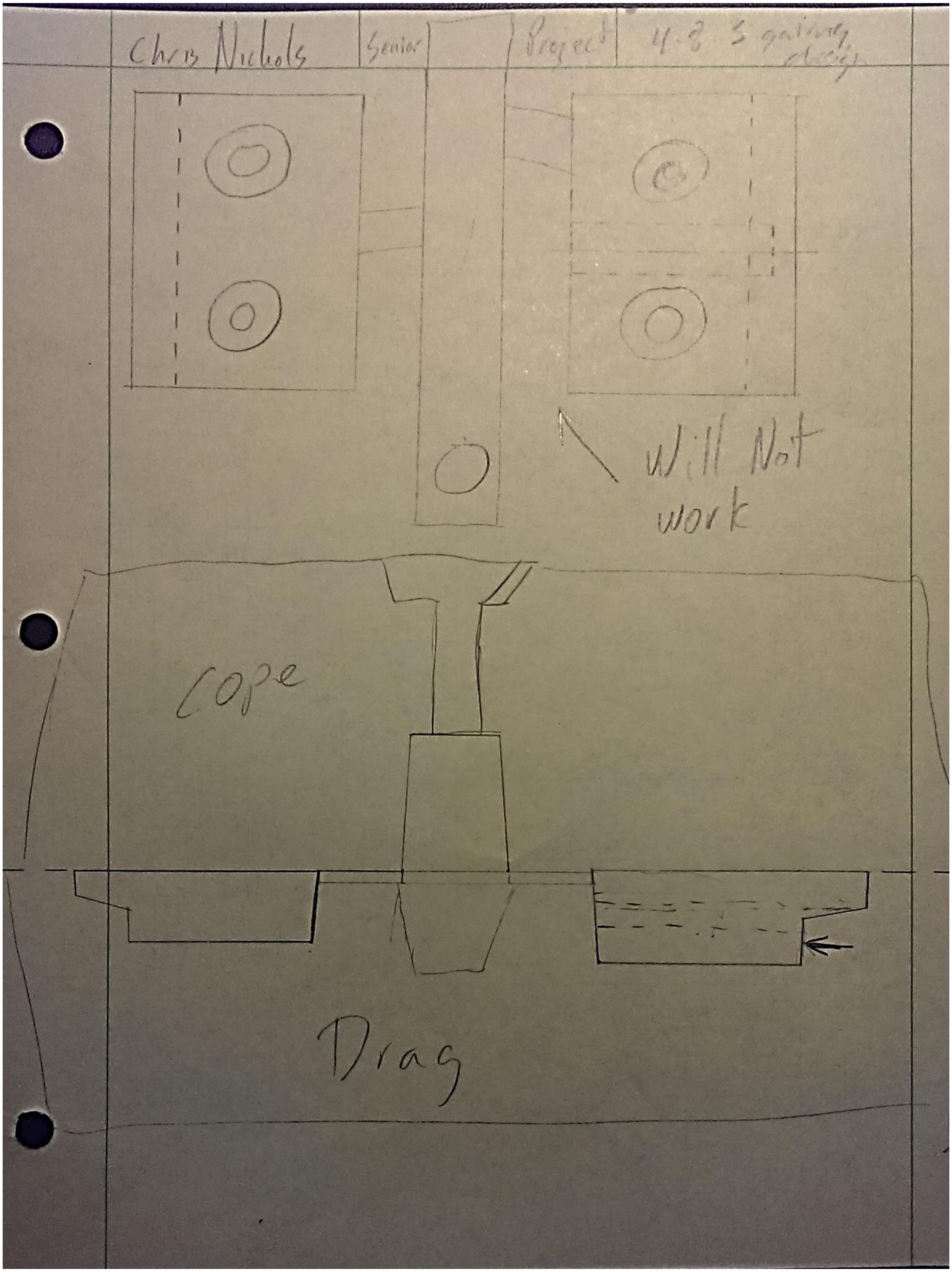
HARVESTCO FABRICATORS INC.
740 DODGE RD.
ELLENSBURG, WA 98926

C950 w/30x46 Paddles Load Centers
*.DWG

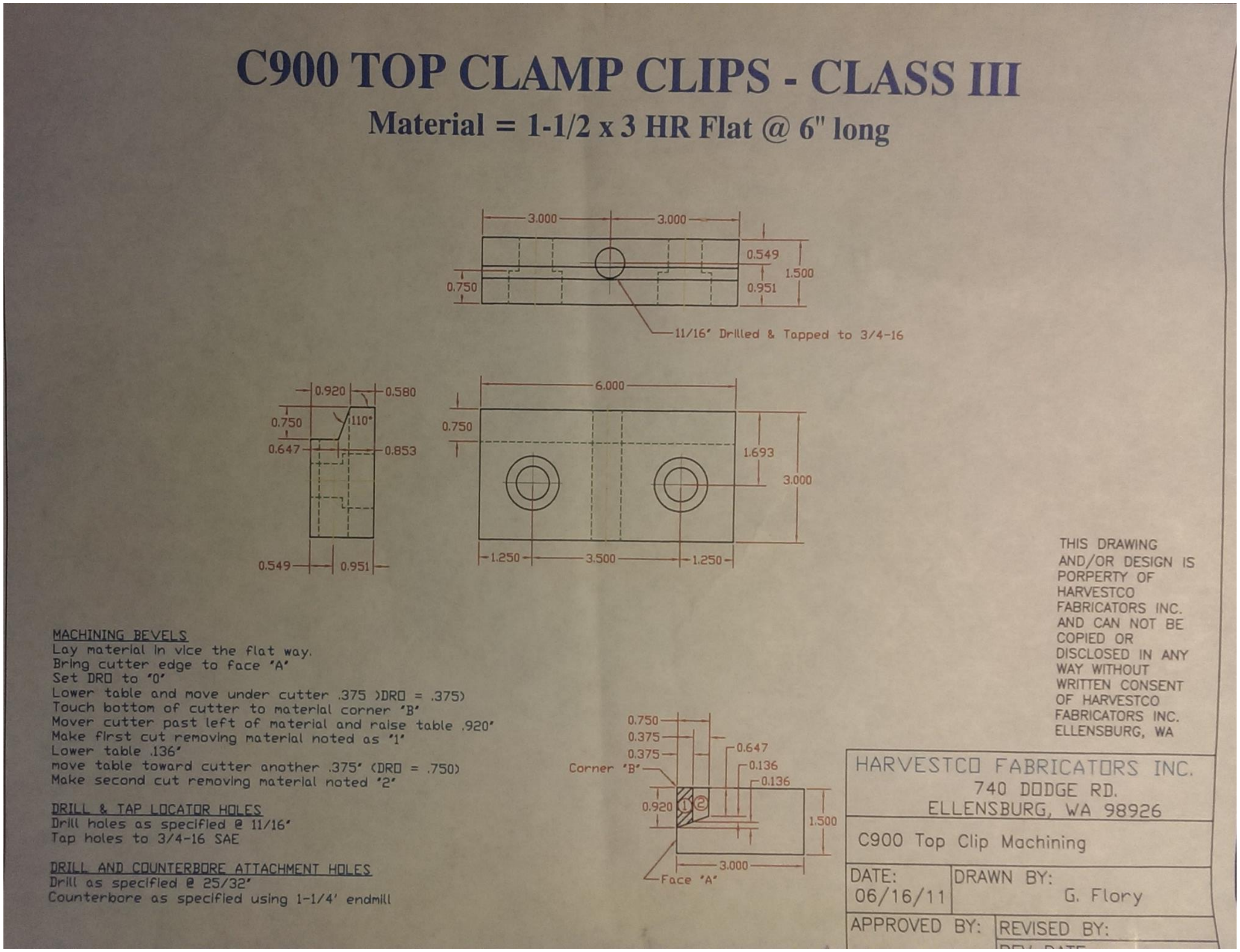
DATE: 04/15/13
DRAWN BY: G. Flory
SCALE:
APPROVED BY:
REVISED BY:
REV DATE:

7. A-5


Chris Nichols
Senior
Project
4-8 5 gating design
Will Not work
Cope
Drag

APPENDIX B – Sketches, Assembly drawings, Part drawings

B - 1. Harvestco part drawings



C900 TOP CLAMP CLIPS - CLASS III

Material = 1-1/2 x 3 HR Flat @ 6" long

MACHINING BEVELS
Lay material in vice the flat way.
Bring cutter edge to face 'A'
Set DRO to '0'
Lower table and move under cutter .375)DRO = .375)
Touch bottom of cutter to material corner 'B'
Mover cutter past left of material and raise table .920'
Make first cut removing material noted as '1'
Lower table .136'
move table toward cutter another .375' (DRO = .750)
Make second cut removing material noted '2'

DRILL & TAP LOCATOR HOLES
Drill holes as specified @ 11/16'
Tap holes to 3/4-16 SAE

DRILL AND COUNTERBORE ATTACHMENT HOLES
Drill as specified @ 25/32'
Counterbore as specified using 1-1/4' endmill

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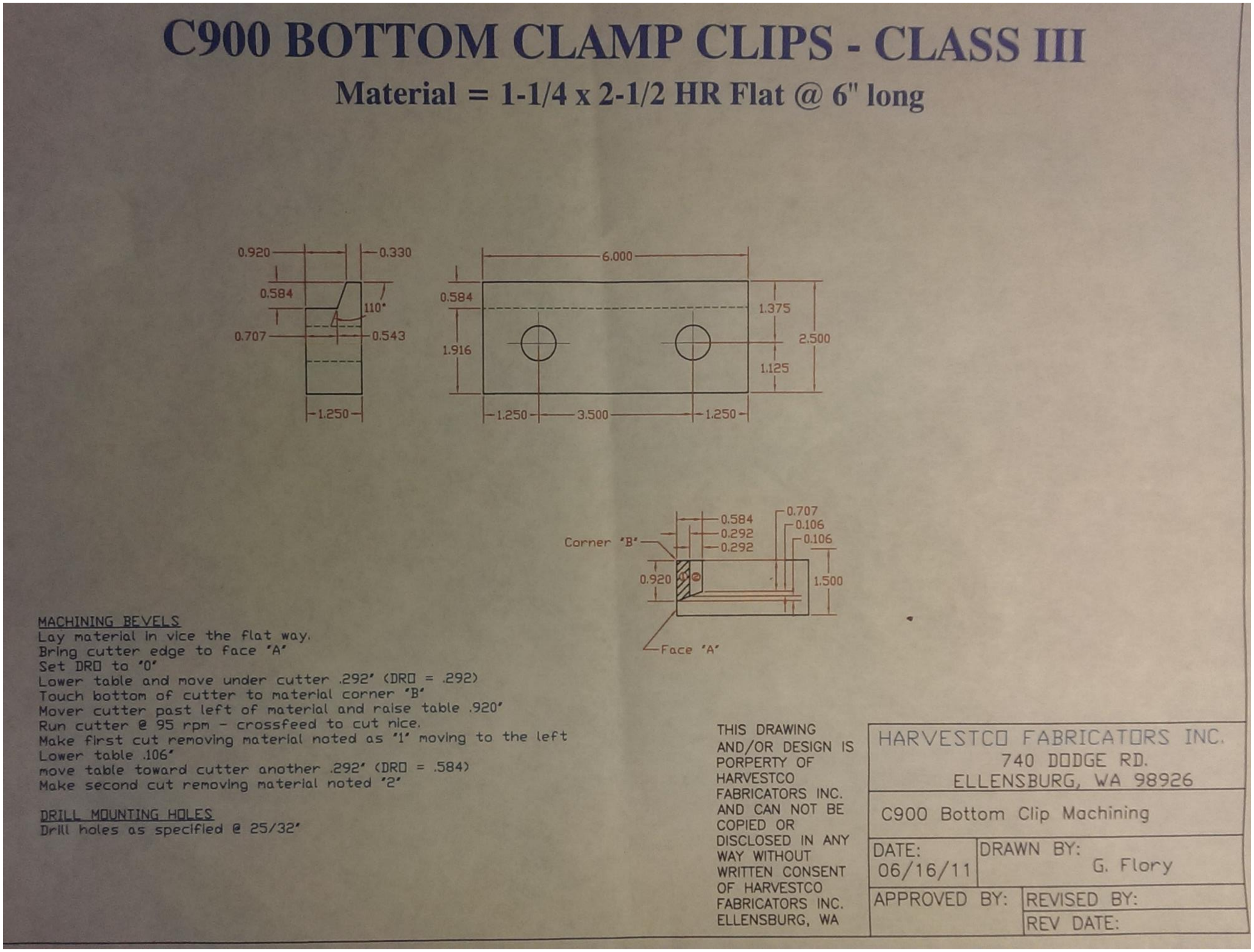
ELLENSBURG, WA

HARVESTCO FABRICATORS INC.
740 DODGE RD.
ELLENSBURG, WA 98926

C900 Top Clip Machining

DATE: 06/16/11
DRAWN BY: G. Flory
APPROVED BY:
REVISED BY:

B - 2 Harvestco part drawings



C900 BOTTOM CLAMP CLIPS - CLASS III

Material = 1-1/4 x 2-1/2 HR Flat @ 6" long

MACHINING BEVELS
Lay material in vice the flat way.
Bring cutter edge to face 'A'
Set DRO to '0'
Lower table and move under cutter .292' (DRO = .292)
Touch bottom of cutter to material corner 'B'
Mover cutter past left of material and raise table .920'
Run cutter @ 95 rpm - crossfeed to cut nice.
Make first cut removing material noted as '1' moving to the left
Lower table .106'
move table toward cutter another .292' (DRO = .584)
Make second cut removing material noted '2'

DRILL MOUNTING HOLES
Drill holes as specified @ 25/32'

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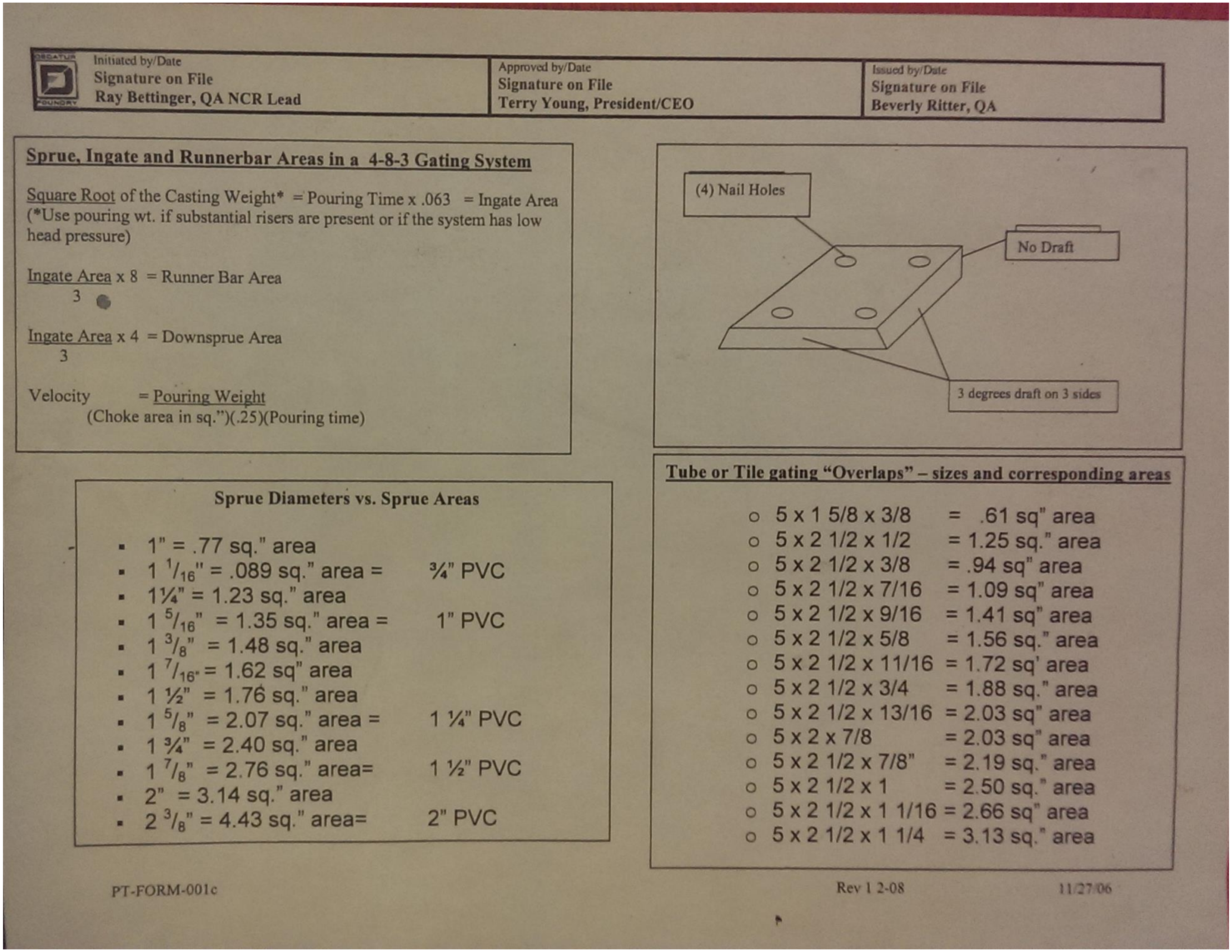
HARVESTCO FABRICATORS INC.
740 DODGE RD.
ELLENSBURG, WA 98926

C900 Bottom Clip Machining

DATE: 06/16/11
DRAWN BY: G. Flory
APPROVED BY:
REVISED BY:
REV DATE:

B - 3 4-8-3 Formula Sheet



Initiated by/Date	Approved by/Date	Issued by/Date
Signature on File **Ray Bettinger, QA NCR Lead**	**Signature on File** **Terry Young, President/CEO**	**Signature on File** **Beverly Ritter, QA**

Sprue, Ingate and Runnerbar Areas in a 4-8-3 Gating System

Square Root of the Casting Weight* = Pouring Time x .063 = Ingate Area
(*Use pouring wt. if substantial risers are present or if the system has low head pressure)

$\frac{\text{Ingate Area}}{3} \times 8$ = Runner Bar Area

$\frac{\text{Ingate Area}}{3} \times 4$ = Downsprue Area

Velocity $= \frac{\text{Pouring Weight}}{(\text{Choke area in sq.''})(.25)(\text{Pouring time})}$

Sprue Diameters vs. Sprue Areas

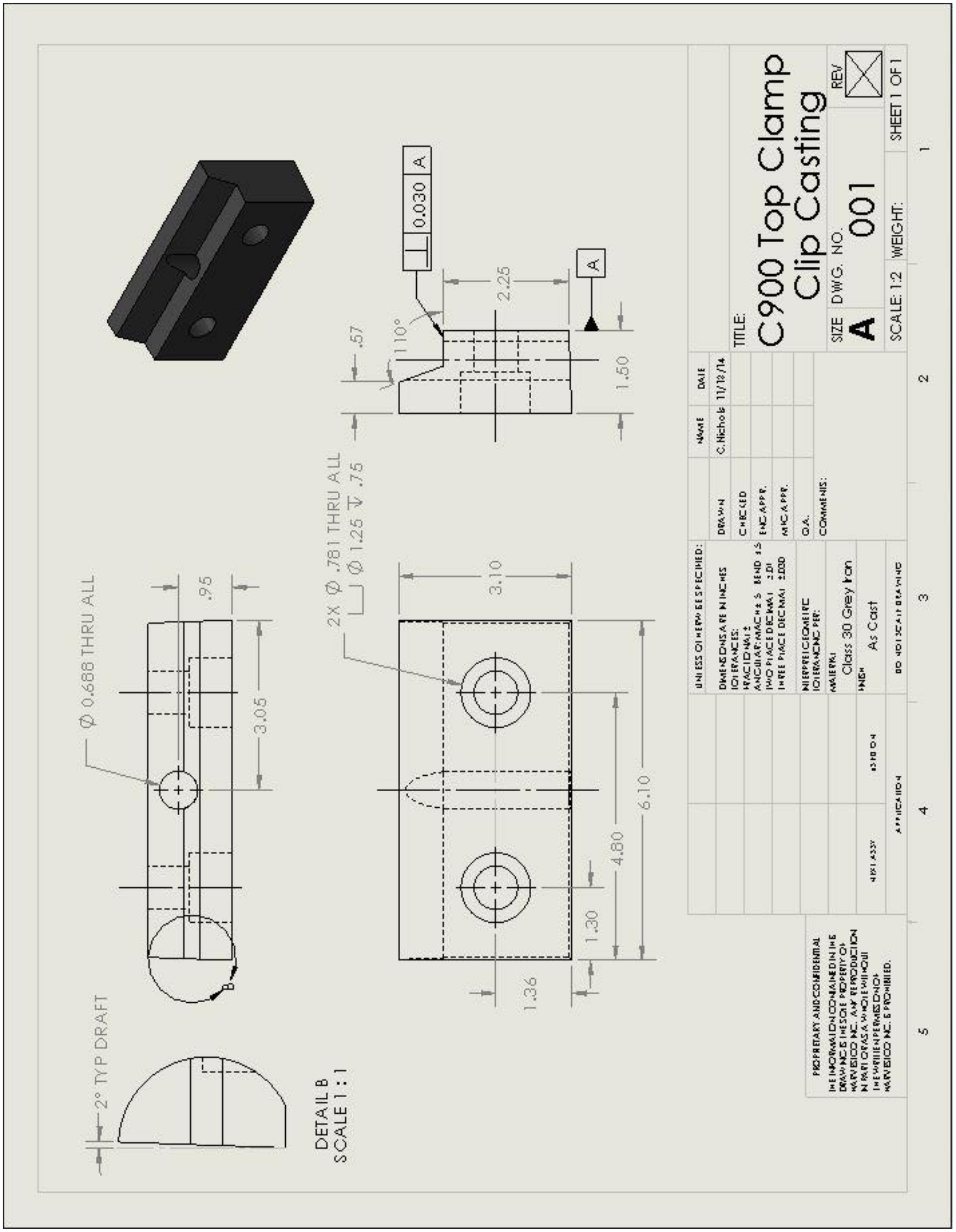
- 1" = .77 sq." area
- 1 $^{1}/_{16}$" = .089 sq." area = ¾" PVC
- 1¼" = 1.23 sq." area
- 1 $^{5}/_{16}$" = 1.35 sq." area = 1" PVC
- 1 $^{3}/_{8}$" = 1.48 sq." area
- 1 $^{7}/_{16}$" = 1.62 sq" area
- 1 ½" = 1.76 sq." area
- 1 $^{5}/_{8}$" = 2.07 sq." area = 1 ¼" PVC
- 1 ¾" = 2.40 sq." area
- 1 $^{7}/_{8}$" = 2.76 sq." area= 1 ½" PVC
- 2" = 3.14 sq." area
- 2 $^{3}/_{8}$" = 4.43 sq." area= 2" PVC

Tube or Tile gating "Overlaps" – sizes and corresponding areas

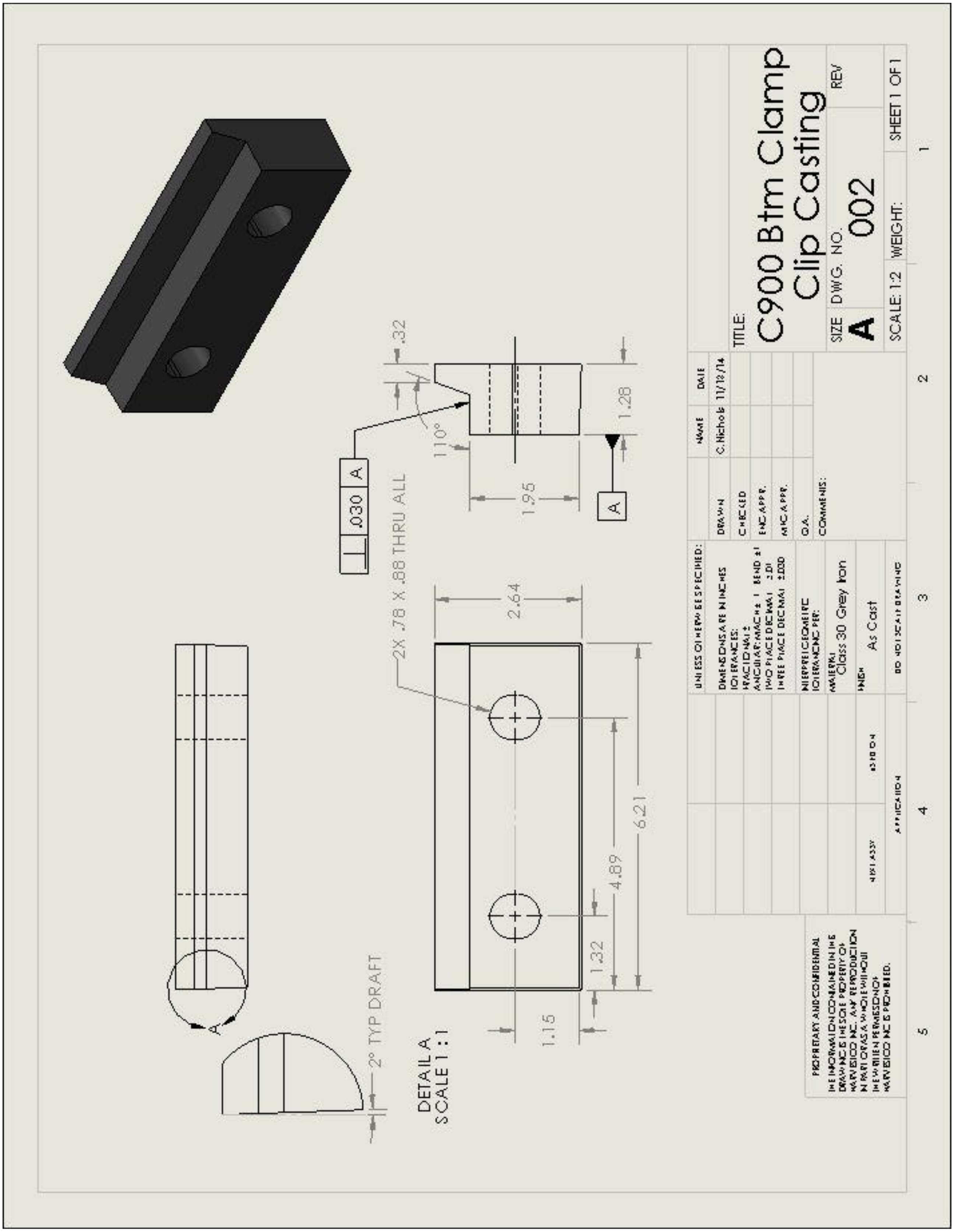
- 5 x 1 5/8 x 3/8 = .61 sq" area
- 5 x 2 1/2 x 1/2 = 1.25 sq." area
- 5 x 2 1/2 x 3/8 = .94 sq" area
- 5 x 2 1/2 x 7/16 = 1.09 sq" area
- 5 x 2 1/2 x 9/16 = 1.41 sq" area
- 5 x 2 1/2 x 5/8 = 1.56 sq." area
- 5 x 2 1/2 x 11/16 = 1.72 sq' area
- 5 x 2 1/2 x 3/4 = 1.88 sq." area
- 5 x 2 1/2 x 13/16 = 2.03 sq" area
- 5 x 2 x 7/8 = 2.03 sq" area
- 5 x 2 1/2 x 7/8" = 2.19 sq." area
- 5 x 2 1/2 x 1 = 2.50 sq." area
- 5 x 2 1/2 x 1 1/16 = 2.66 sq" area
- 5 x 2 1/2 x 1 1/4 = 3.13 sq." area

PT-FORM-001c Rev 1 2-08 11/27/06

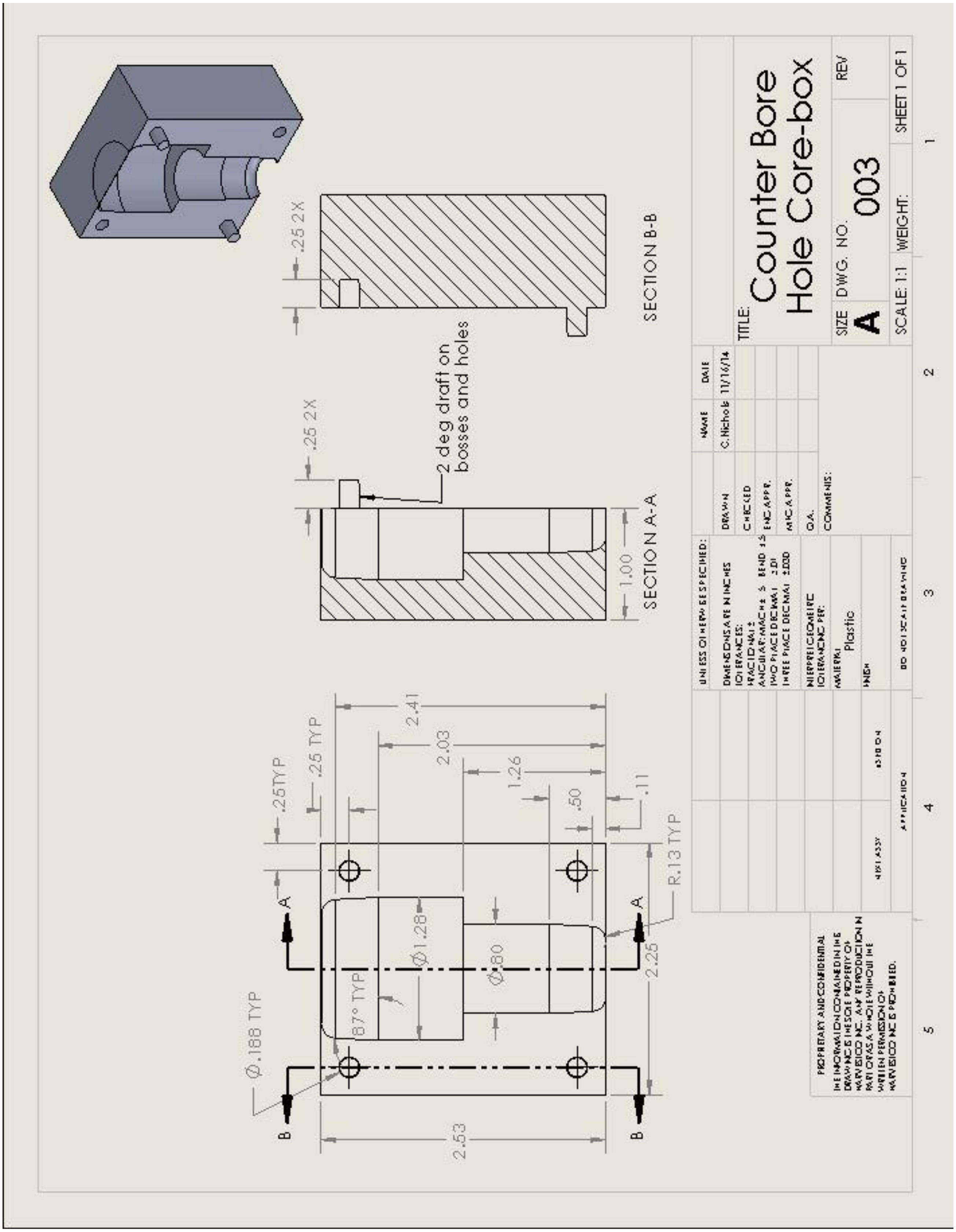
B - 4 Top Clip As Cast final dimensions



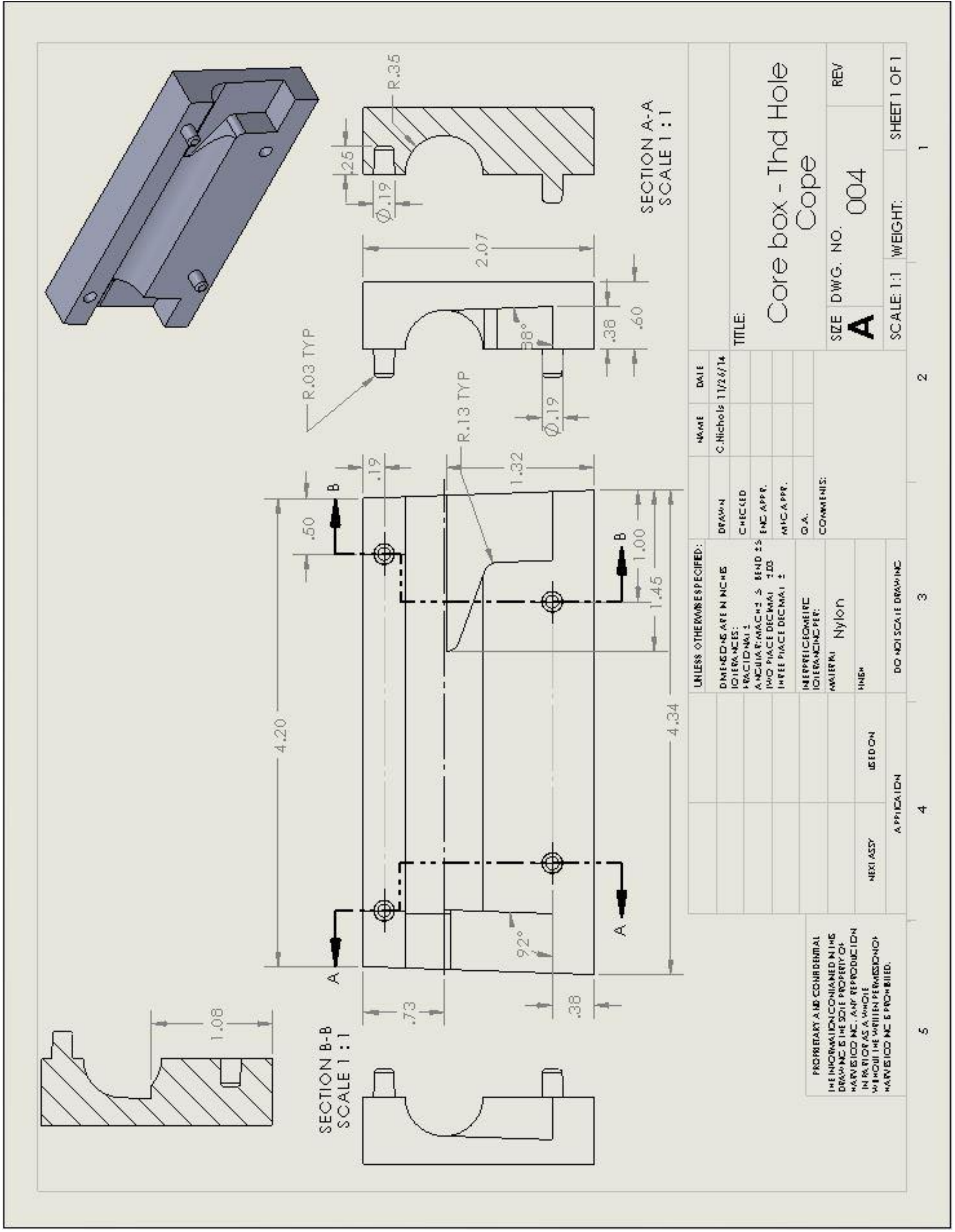
B - 5 Bottom Clip As Cast final dimensions



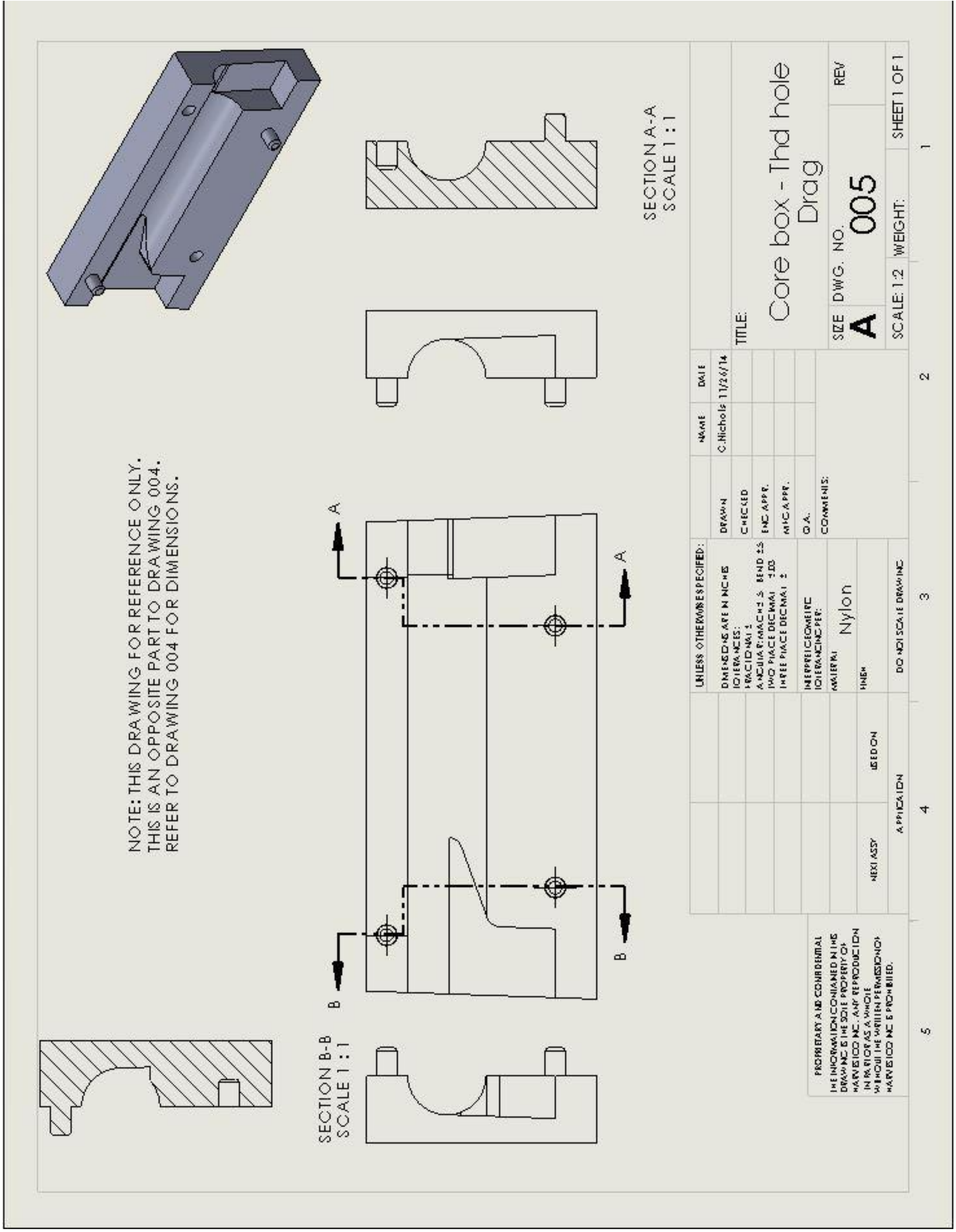
B - 6 Counter bore hole Core box dimensions



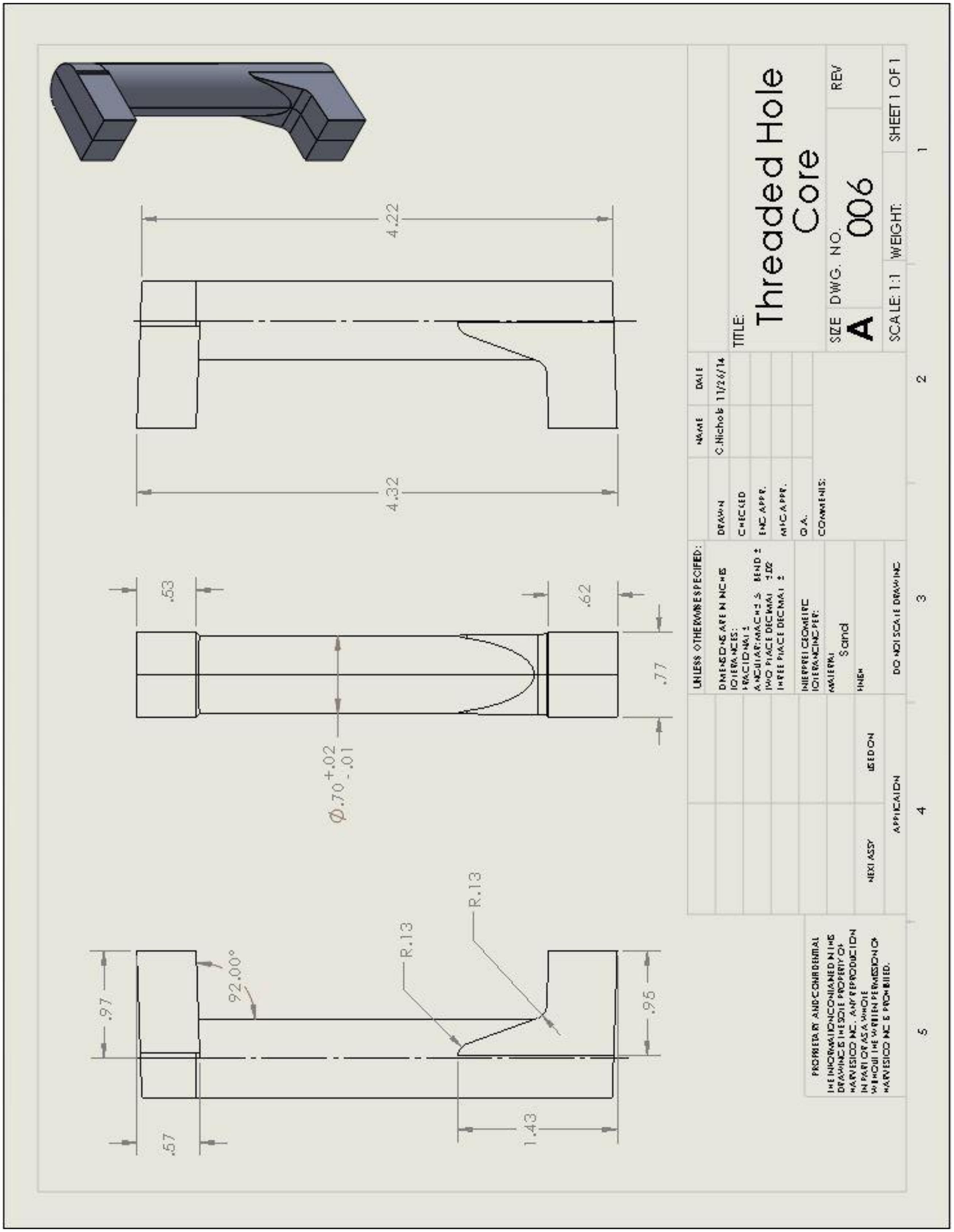
B - 7 Threaded Hole Core box Cope



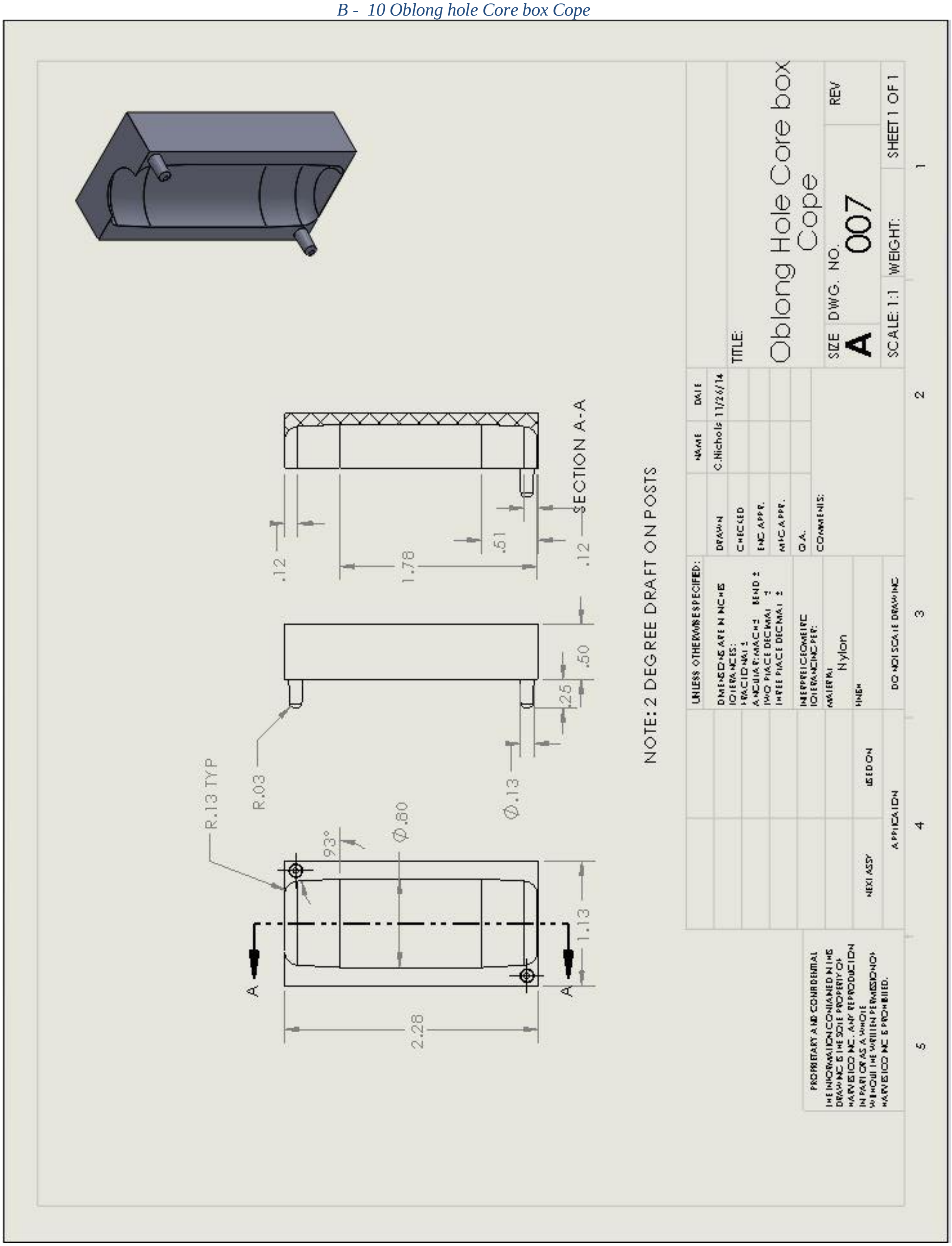
B - 8 Threaded hole Core box Drag



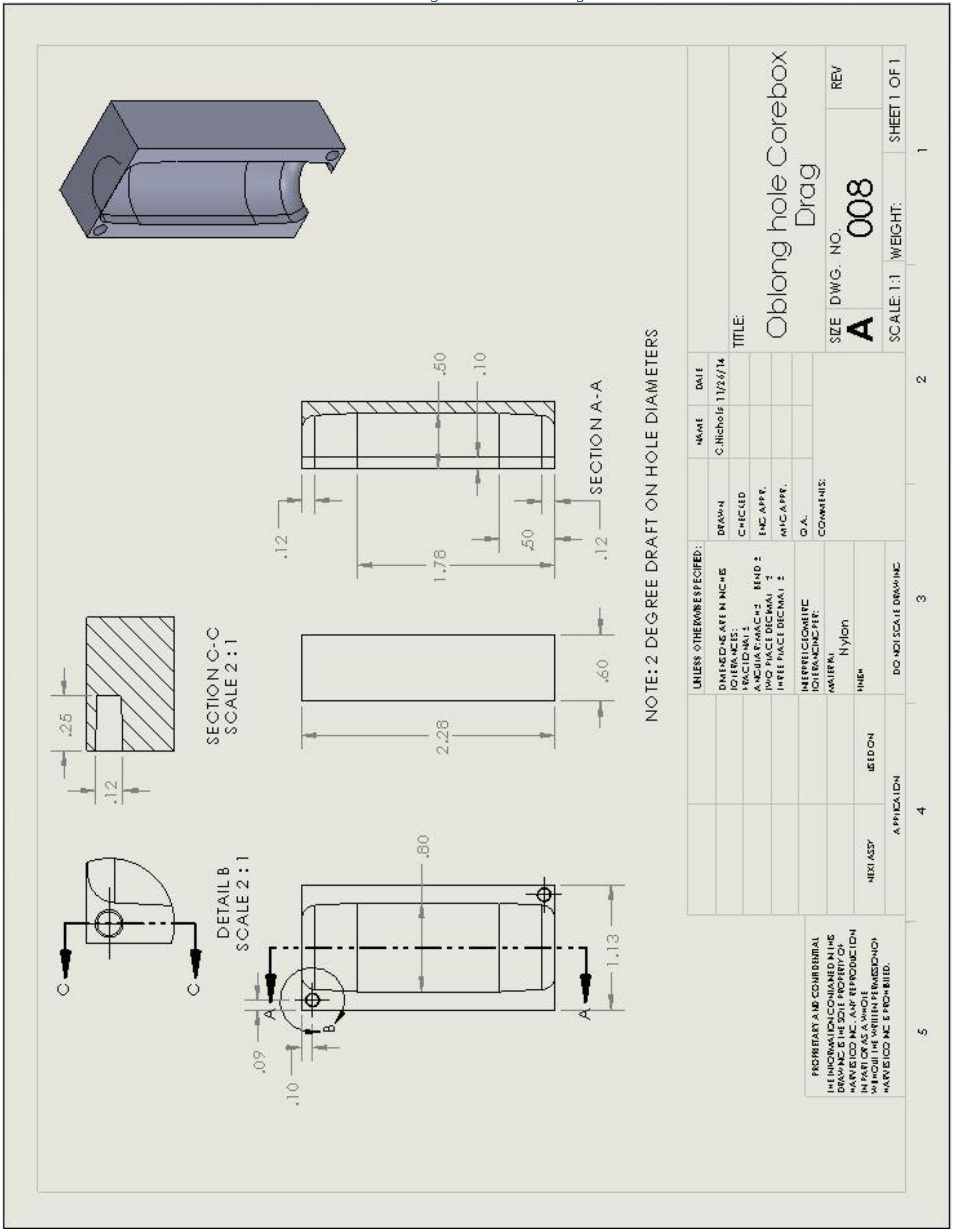
B - 9 Threaded Hole Core



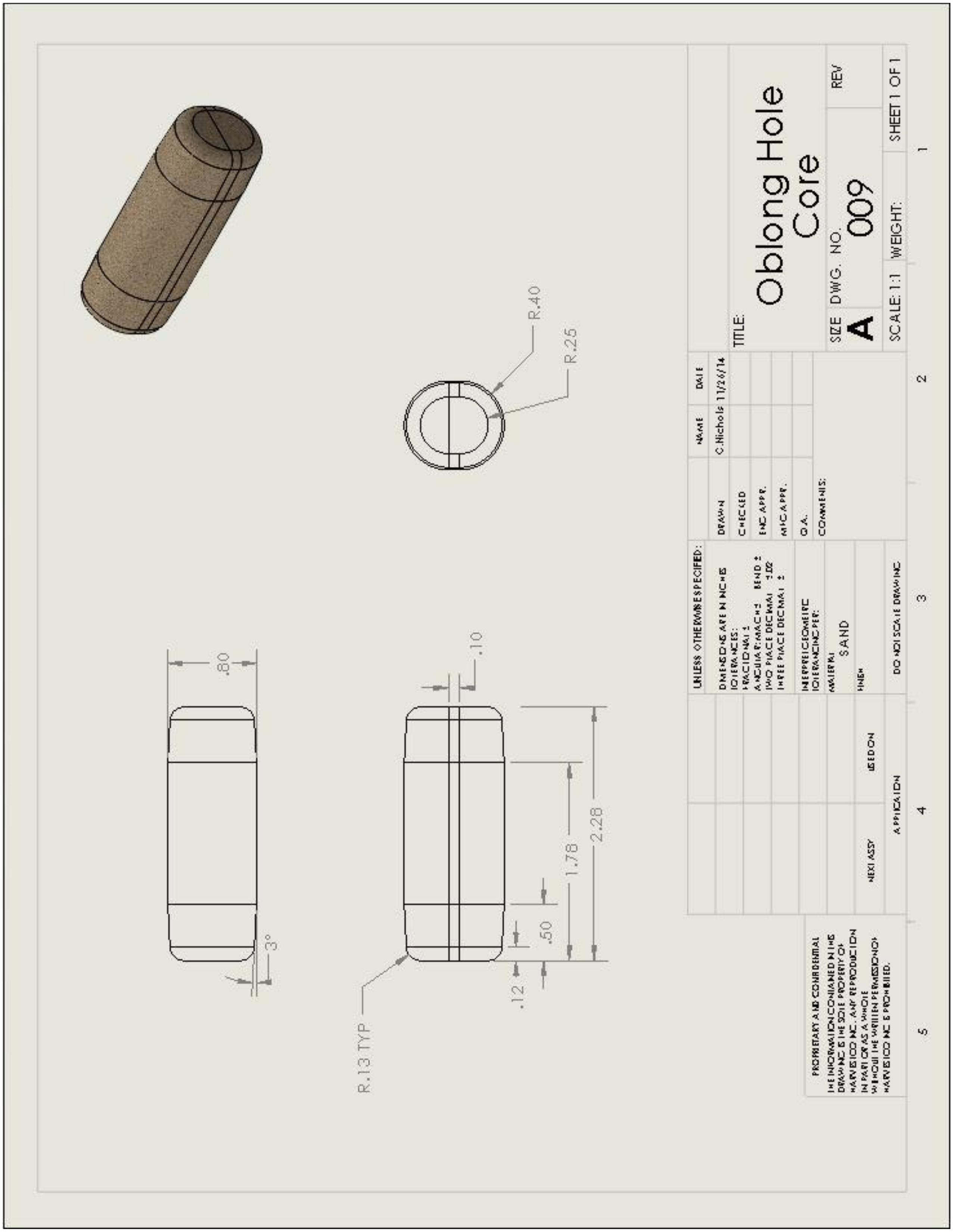
B - 10 Oblong hole Core box Cope



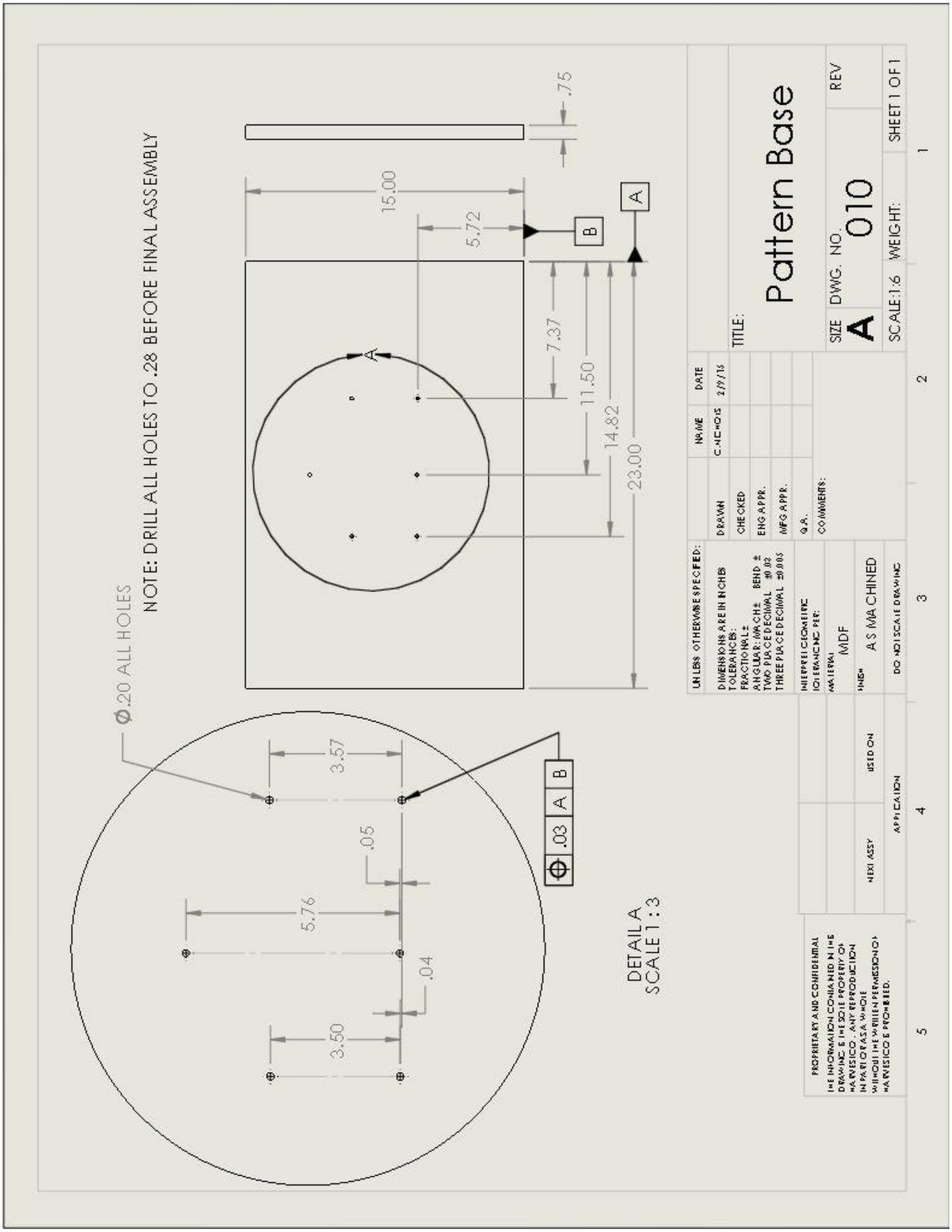
B - 11 Oblong hole Core box Drag



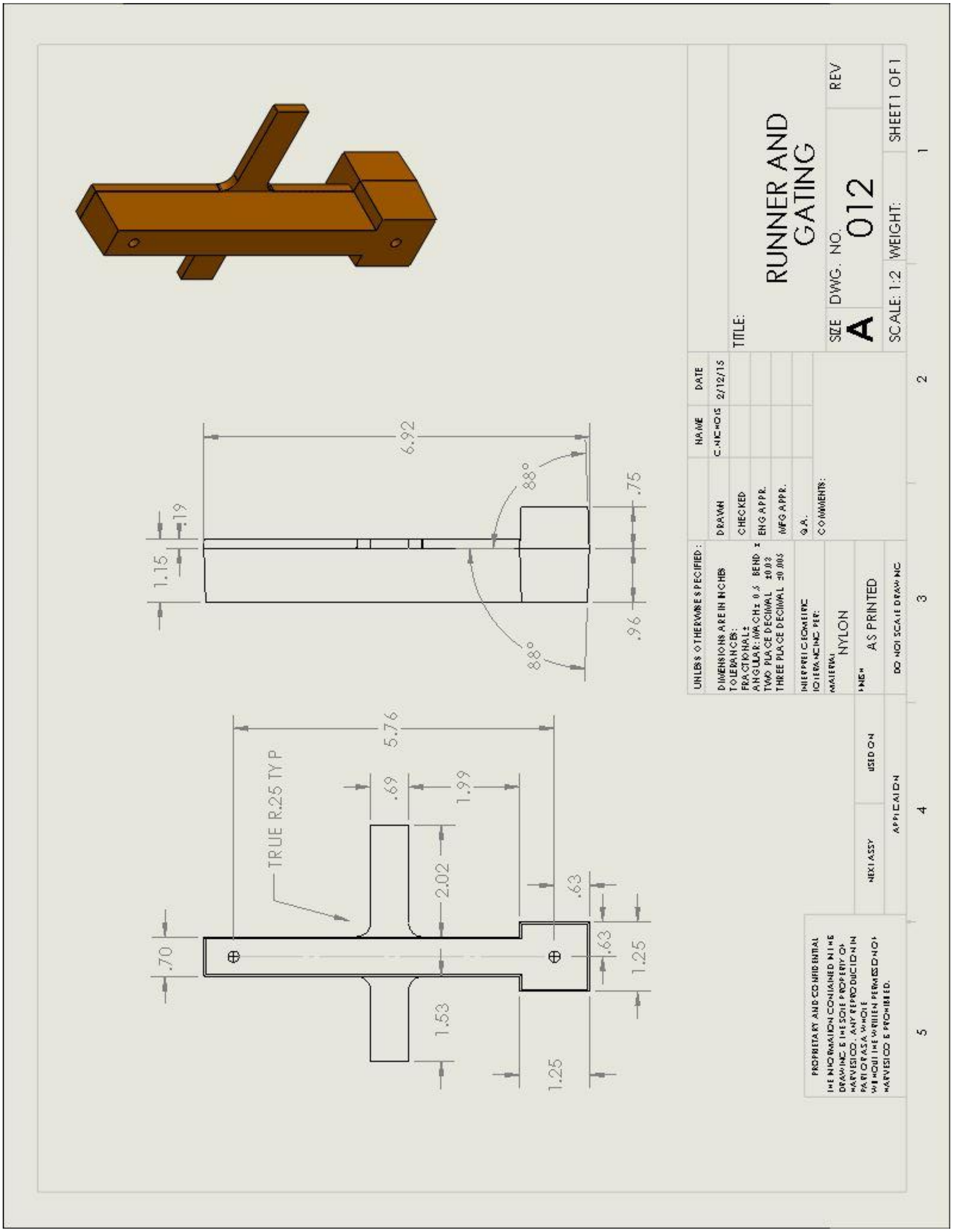
B - 12 Oblong Hole Core



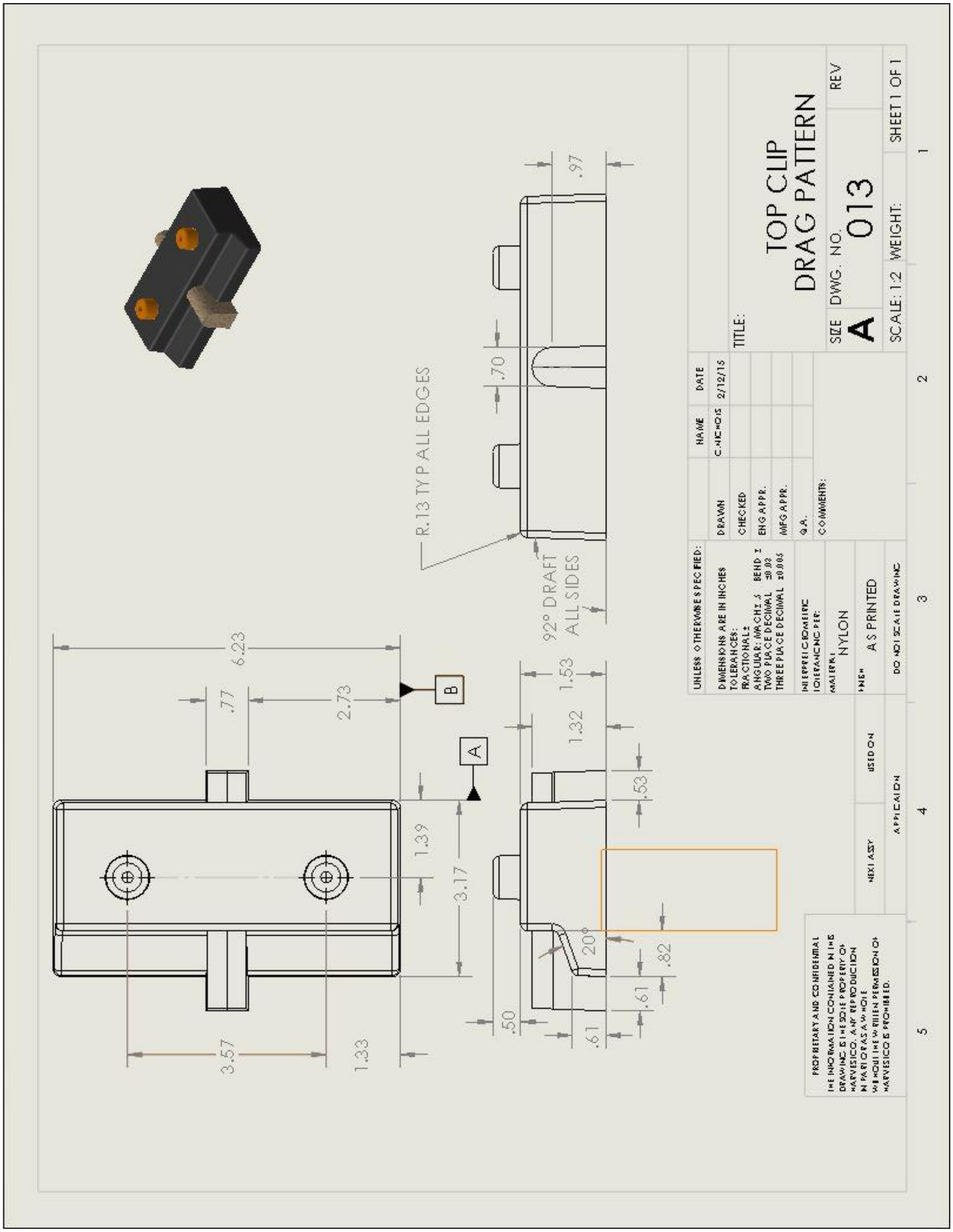
B i. 13 Pattern Base



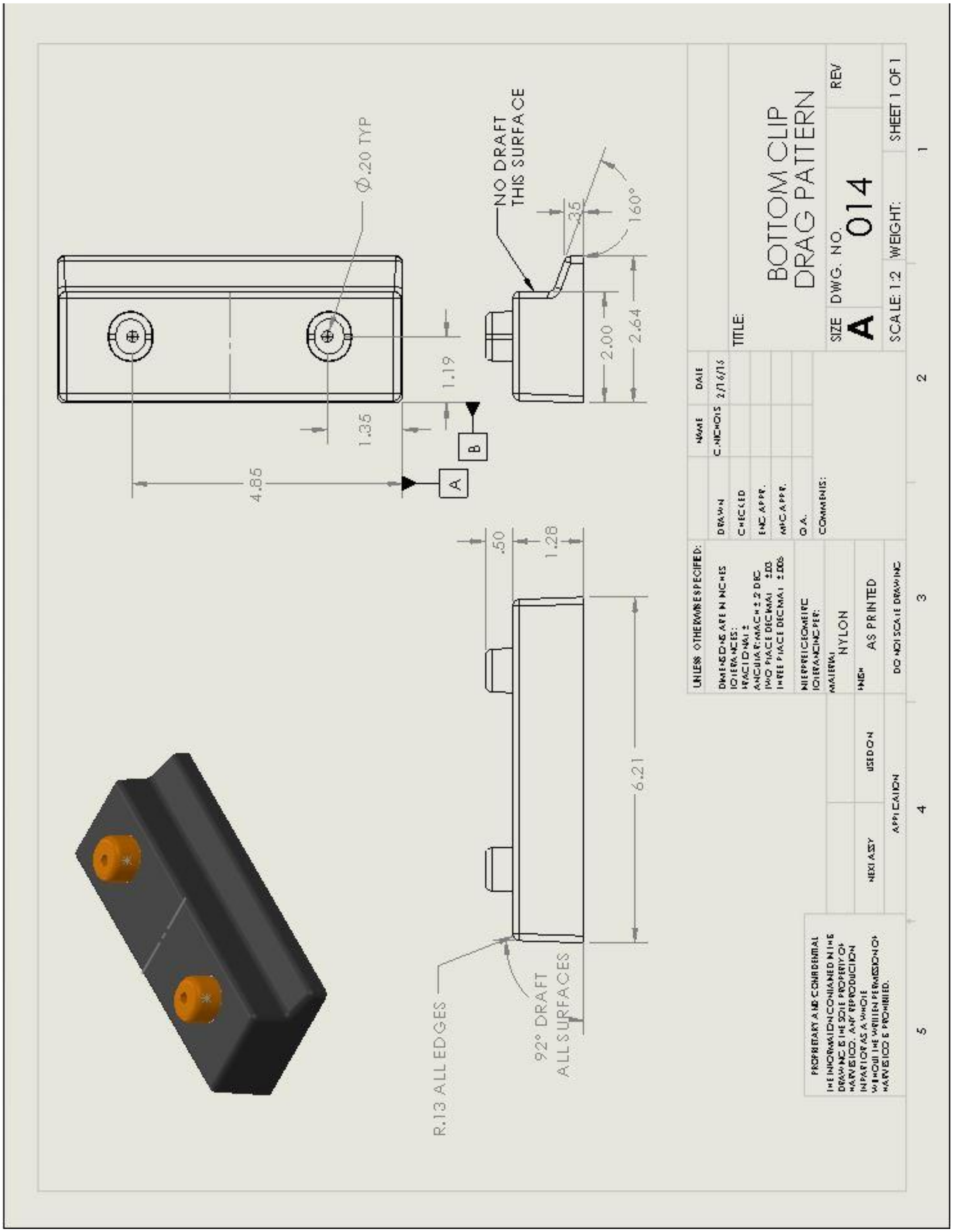
B ii 14. Runner and Gating



B iii 15 Top Clip Drag pattern



B iv 16 Bottom Clip Drag Pattern



APPENDIX C – Parts List and Budget

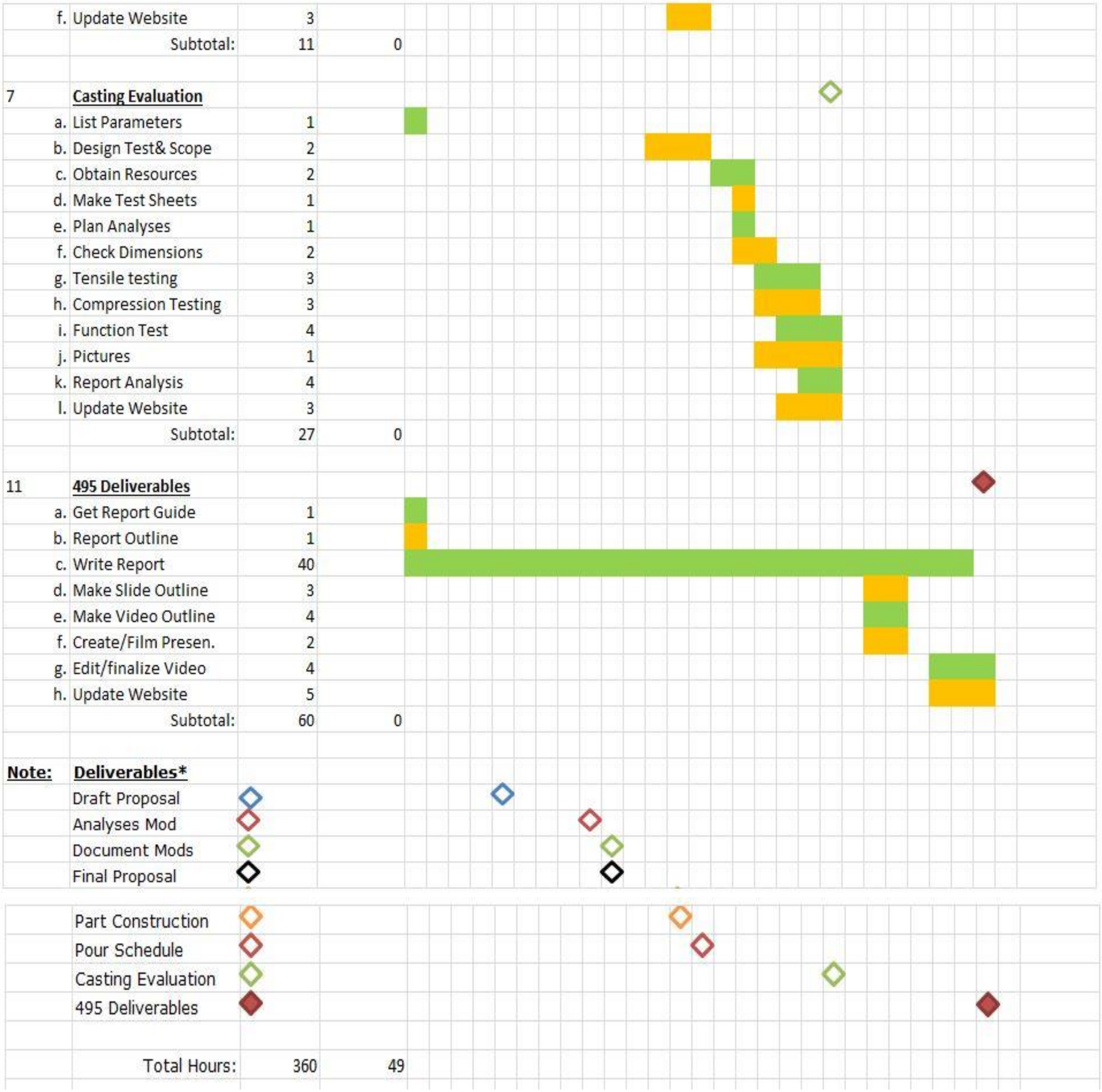
Item ID	Item Description	Item Source	Material	Price/Cost	Unit	Quantity	Unit	Subtotals
	Core Boxes							
1	Counter Bore Cope	CWU	3D Print Nylon	$ 6.00	per in^3	4.6	in^3	$ 27.60
2	Counter Bore Drag	CWU	3D Print Nylon	$ 6.00	per in^3	4.6	in^3	$ 27.60
3	Oblong Hole Cope	CWU	3D Print Nylon	$ 6.00	per in^3	0.81	in^3	$ 4.86
4	Oblong Hole Drag	CWU	3D Print Nylon	$ 6.00	per in^3	0.74	in^3	$ 4.44
5	Thread Hole Cope	CWU	3D Print Nylon	$ 6.00	per in^3	4.18	in^3	$ 25.08
6	Thread Hole Drag	CWU	3D Print Nylon	$ 6.00	per in^3	4.18	in^3	$ 25.08
7	No bake Sand	CWU	Silica Sand		per lb			
8	Binder for Sand	CWU	Adhesive		per oz			
	Patterns							
9	Pattern Cope	CWU	3D Print Nylon	$ 6.00	per lb	24.0	in^3	$ 144.00
10	Pattern Drag	CWU	3D Print Nylon	$ 6.00	per lb	20.32	in^3	$ 121.92
	Pouring							
11	Melt Material	CWU	Grey Iron		per lb			
							Est. Cost =	**$ 380.58**

APPENDIX E – Schedule

Senior Project Schedule
PROJECT TITLE: Conversion Casting from A36 Steel to Class 30 Gray Iron
Principal Investigator: Chris Nichols

TASK ID:	Description	Est. (hrs)	Actual (hrs)	November	Dec	January	February	March	April	May	June
1	**Proposal**				◇						
a.	Outline	2	2	🟩							
b.	Intro	3	2	🟨							
c.	Methods	4	5	🟩							
e.	Analysis	20	20	🟨							
f.	Discussion	5		🟩							
g.	Parts and Budget	8		🟨							
h.	Drawings	50		🟩	🟩						
i.	Schedule	20		🟨	🟨						
j.	Summary & Appx			🟩	🟩						
	Subtotal:	112	29								
2	**Analysis**					◇					
a.	Material Specs	1	1	🟩							
b.	CAD dwgs	70		🟨	🟨	🟨					
c.	FEA	2			🟩						
d.	SOLIDCast	5				🟨🟩					
e.	Gating Design	1	1	🟩							
f.	Kinematic	3	2	🟨							
g.	Tolerance	1	1	🟩							
	Subtotal:	83	5								
3	**Documentation**					◇					
a.	Top clamp dwg	1	1	🟩							
b.	Bottom clamp dwg	1	1	🟨							
c.	CB hole Corebox dwg	1	1		🟩						
d.	Oblong Corebox dwg	1	1		🟨						
e.	Thrd hole c-box dwg	2	4		🟩						

f.	Cope pattern dwg	3	3
g.	Drag pattern dwg	3	3
h.	ANSIY 14.5 Compl	1	
i.	Update Website	3	
	Subtotal:	16	14
4	**Proposal Mods**		
a.	Pattern Prod. Sched.	1	
b.	Pouring Schedule	1	
c.	Critical Des Review	1	
	subtotal:	3	0
5	**Part Construction**		
a.	Corebox - Thd hole	4	
b.	Corebox - CB hole	4	
c.	Corebox - Oblong hole	4	
d.	Pattern - Cope	6	
e.	Pattern - Drag	10	
f.	Core - Thd hole	2	
g.	Core - CB hole	2	
h.	Core - Obl hole	2	
i.	Mold - Cope	3	
j.	Mold - Drag	3	
k.	Pictures of Processes	1	
l.	Update Website	5	
m.	Manufacture Plan	2	
	Subtotal:	48	0
6	**Pour Schedule**		
a.	Melt Time	2	
b.	Pour time	1	
c.	Solidification Time	1	
d.	Shakeout/Clean up	3	
e.	Pictures	1	



	f.	Update Website	3	
		Subtotal:	11	0
7		**Casting Evaluation**		
	a.	List Parameters	1	
	b.	Design Test& Scope	2	
	c.	Obtain Resources	2	
	d.	Make Test Sheets	1	
	e.	Plan Analyses	1	
	f.	Check Dimensions	2	
	g.	Tensile testing	3	
	h.	Compression Testing	3	
	i.	Function Test	4	
	j.	Pictures	1	
	k.	Report Analysis	4	
	l.	Update Website	3	
		Subtotal:	27	0
11		**495 Deliverables**		
	a.	Get Report Guide	1	
	b.	Report Outline	1	
	c.	Write Report	40	
	d.	Make Slide Outline	3	
	e.	Make Video Outline	4	
	f.	Create/Film Presen.	2	
	g.	Edit/finalize Video	4	
	h.	Update Website	5	
		Subtotal:	60	0
Note:		**Deliverables***		
		Draft Proposal	◇	
		Analyses Mod	◇	
		Document Mods	◇	
		Final Proposal	◇	
		Part Construction	◇	
		Pour Schedule	◇	
		Casting Evaluation	◇	
		495 Deliverables	◆	
		Total Hours:	360	49

APPENDIX F – Expertise and Resources

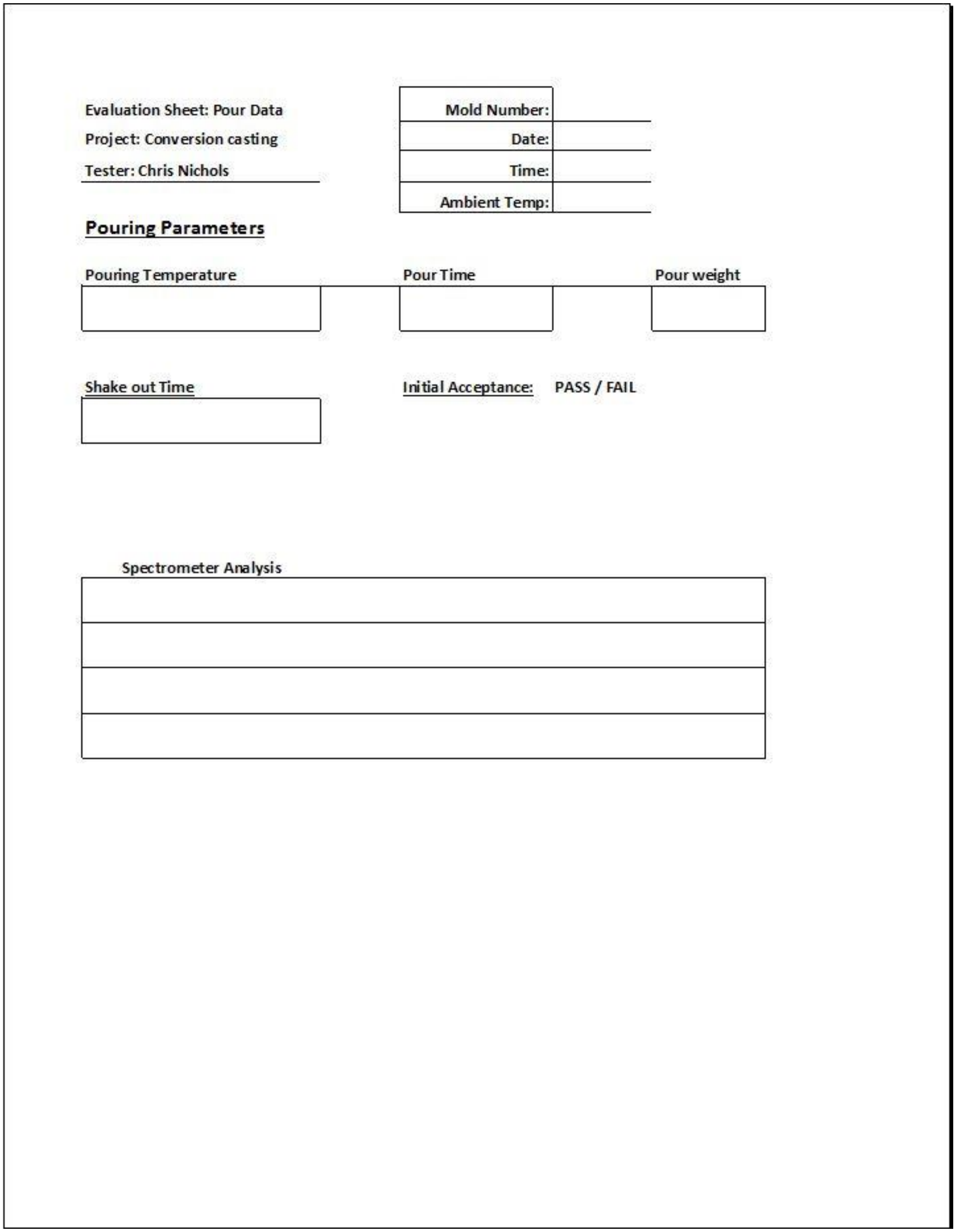
[1] Champan, Cordy. "Practical tips on gating iron castings.." The Free Library. 2005 American Foundry Society, Inc. 29 Oct. 2014. http://www.thefreelibrary.com/Practical+tips+on+gating+iron+castings.-a0134675481.

[2] Finite Solutions, Inc. Solidcast Technical Workbook. 2014.   http://www.finitesolutions.com.

Flory, Galen. Multiple conversations in regards to part outcomes. September 2014 – January 2015.

McGowan, Jason. Email Correspondence. D&L Foundry, January 2015.

APPENDIX G – Evaluation sheet (Testing)



Evaluation Sheet: Pour Data

Project: Conversion casting

Tester: Chris Nichols

Mold Number:	
Date:	
Time:	
Ambient Temp:	

Pouring Parameters

Pouring Temperature	Pour Time	Pour weight

Shake out Time

Initial Acceptance: PASS / FAIL

Spectrometer Analysis

APPENDIX H – Testing Report

Dimension Quality Worksheet

Checked by: Chris Nichols

Date: 6/03/2015

All Dimensions are in Inches

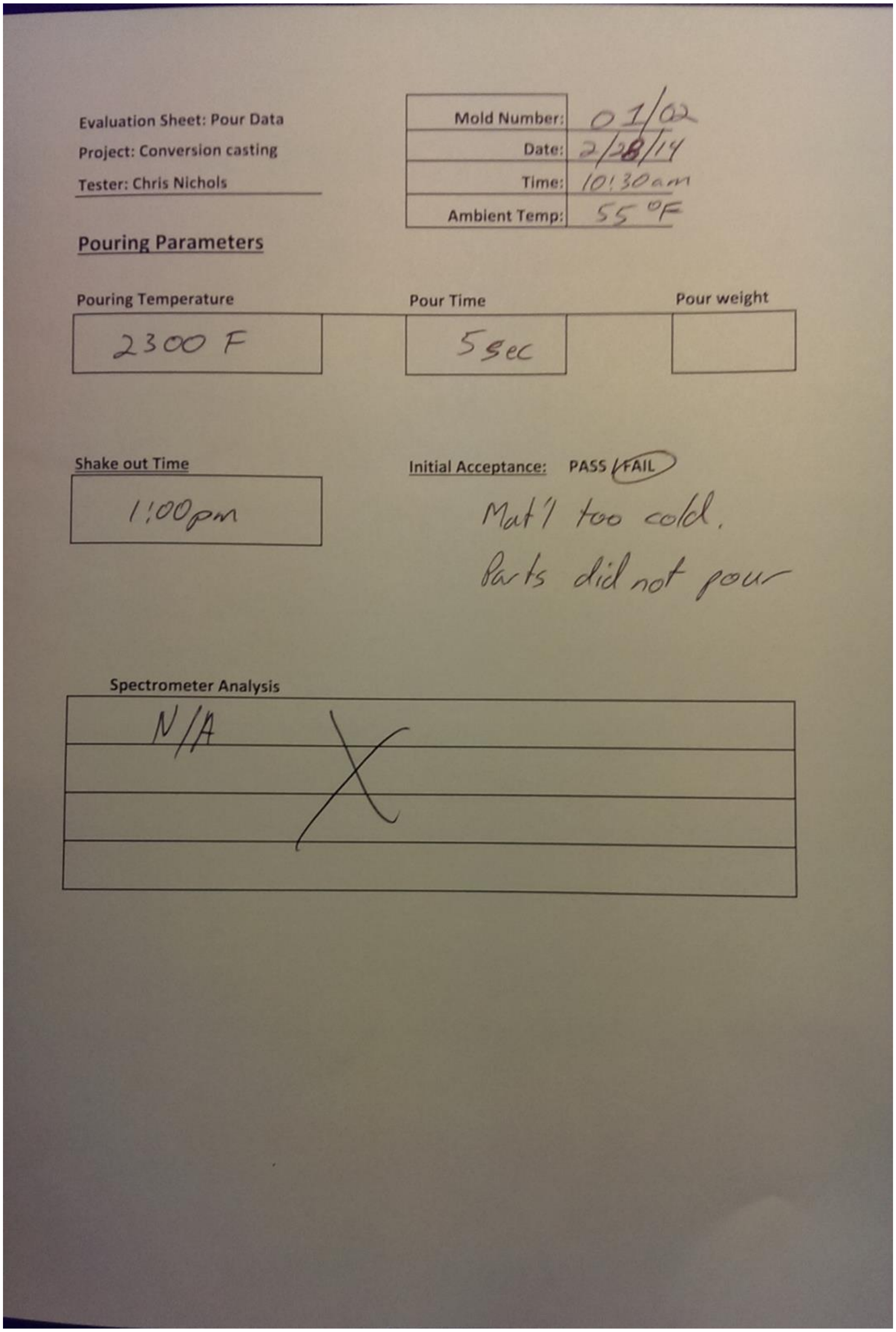
Top Clip Dimensions

	Print Dim.	Tolerance (+/-)	Actual	Pass/Fail
Overall Length	6.000	0.125	6.063	Pass
Overall Width	3.000	0.125	3.063	Pass
Step	0.750	0.125	0.750	Pass
Height	1.500	0.125	1.500	Pass
Counterbore01	1.250	0.063	1.255	Pass
Counterbore02	1.250	0.063	1.286	Pass
Through hole01	0.781	0.063	0.791	Pass
Through hole02	0.781	0.063	0.810	Pass
Threaded Hole	0.688	0.063	0.712	Pass
Center to Center	3.500	0.063	3.500	Pass

Bottom Clip Dimensions

	Print Dim.	Tolerance (+/-)	Actual	Pass/Fail
Overall Length	6.000	0.125	6.063	Pass
Overall Width	2.500	0.125	2.563	Pass
Step	0.584	0.125	0.625	Pass
Height	1.250	0.125	1.250	Pass
Oblong Hole 01	.78 x .88	0.063	.788 x .860	Pass
Oblong Hole 01	.78 x .88	0.063	.780 x .900	Pass
Center to Center	3.500	0.125	3.500	Pass

APPENDIX I – Testing Data



Evaluation Sheet: Pour Data
Project: Conversion casting
Tester: Chris Nichols

Mold Number: 01/02
Date: 2/28/14
Time: 10:30am
Ambient Temp: 55 °F

Pouring Parameters

Pouring Temperature: 2300 F
Pour Time: 5 sec
Pour weight:

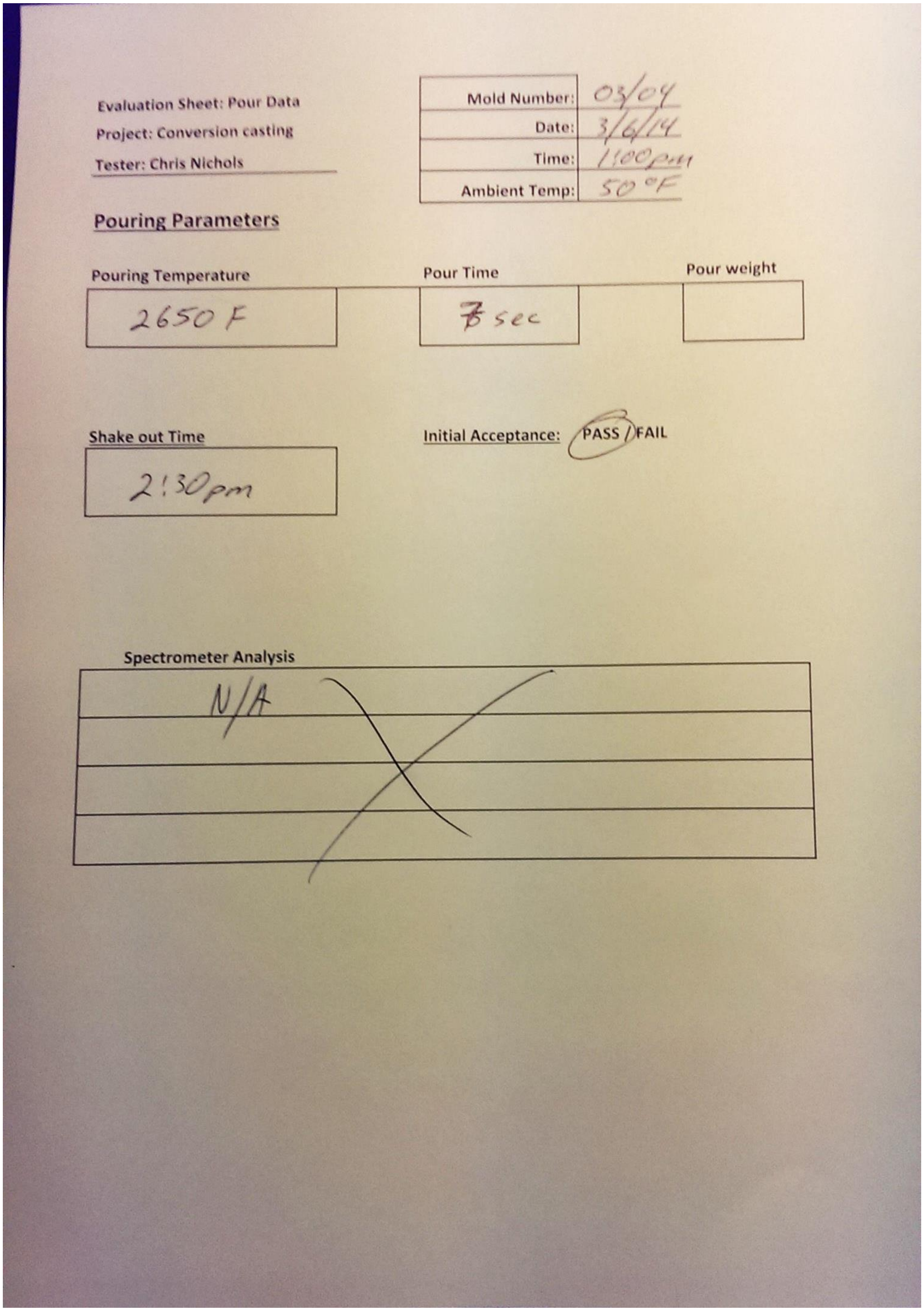
Shake out Time: 1:00pm

Initial Acceptance: PASS / [✓ FAIL]

Mat'l too cold.
Parts did not pour

Spectrometer Analysis

N/A



Evaluation Sheet: Pour Data
Project: Conversion casting
Tester: Chris Nichols

Mold Number: 03/04
Date: 3/6/14
Time: 1:00pm
Ambient Temp: 50 °F

Pouring Parameters

Pouring Temperature: 2650 F

Pour Time: 7 sec

Pour weight:

Shake out Time: 2:30pm

Initial Acceptance: [✓ PASS] / FAIL

Spectrometer Analysis

N/A

APPENDIX J – Resume

501 E. 18th Ave.
Apt. # 112
Ellensburg, WA
Portfolio Website: **http://nicholsdrums.wix.com/cnichols2014**

Phone: 206-914-0128
E-mail: nicholsdrums@gmail.com

Christopher R. Nichols

Objective

To harness my seven years of shop fabrication and manufacturing experience in order to apply that knowledge with my academic engineering knowledge and become a unique, indispensable, and distinguished mechanical design engineer.

Education

2013-Present Central Washington University Ellensburg, WA

Bachelor of Science degree in Mechanical Engineering and Technology, June 2015
Minor in Mathematics including differential equations, linear algebra, and statistics.
Specific Coursework including Applications of Strengths of Materials, Ceramics and Composites, FEA, Casting, Machining, Thermodynamics, Heat Transfer, FE exam.

2010-2012 University of Washington Seattle, WA

Mathematics, pre-engineering and physics classes.

2008-2010 Bellevue College Bellevue, WA

Associate in Arts and Sciences Transfer Degree.
College level courses. Prerequisites for engineering.

2007-2008 Highline Community College Des Moines, WA

College level courses. Prerequisites for engineering.

Work experience

Welder/Fitter **October 2013 – Present**

Harvestco Fabricators www.clerfhayclamp.com
Ellensburg, WA

- Part time work fabricating Clerf Hay Squeezes and Equipment.
- Performed casting conversion design for various machined parts in order to optimize the manufacturing process.

Mechanical Engineer (Intern) **June 2014 – September 2014**

Decatur Foundry, Inc. www.decaturfoundry.com
Decatur, IL

- Ductile and grey iron casting facility.
- Assisted with production and design of runners, gating, and risers for new and problematic castings.
- Incorporated the use of casting simulation software. Developed and established a training protocol and trained employees on the use of the software, SolidCast.
- Used Solidworks and SolidCast to build, simulate, and analyze solidification to ensure casting design.

Supervisor, Lead fitter/Welder **November 2006 – September 2013**

S&S Welding, Inc. www.ssweld.com

Kent, WA

Structural steel and aluminum custom fabrication shop.

- Swing shift Supervisor from May 2010 to October 2011.
- Facilitated multiple employees and projects simultaneously with set deadlines.
- Designed jigs and fabricated large and small difficult, intricate structures.
- Controlled process and flow of large jobs and promoted lean manufacturing techniques.
- Gained a strong ability to interpret structural and Boeing Tooling blueprints and GD&T.
- Provided Quality Assurance to AISC, AWS D1.1, and Boeing D32028-1,-2,-3 standards.
- Performed weld testing and qualified welders to specific welding procedures.
- Performed in process and post non-destructive testing on structural components.

Welder/Fitter **January 2013 – June 2013**

Haytools, Inc.

Ellensburg, WA

Part time work fabricating Haytools and Freeman hay bailers.

Welder/Fitter **January 2010 - March 2010**

Kvichack Industries www.kvichak.com

Kent, WA

- Fabricated and welded sections of the Coast Guard's Response Boat Medium.
- Performed jobs in accordance to 5S lean manufacturing standards.
- Performed work in accordance to ISO: 9001 and Coast Guard Standards.

Supervisor, Welder/Fitter **June 1998 to November 2006**

Pacific Coatings, Inc.

Seattle, WA

- Performed design and fabrication of asphalt sealant tanks from 150 to 6000 gallon in size.
- Facilitated employees in the process and manufacture of a specialized product.
- Worked daily with a large professional customer base ensuring product performance and satisfaction.
- Performed maintenance on delivery vehicles and various industrial type machinery.

Summary of Qualifications

- **Computer:** SolidWorks, AutoCAD, SOLIDCast, FEA and CFD Analysis, Microsoft Word, Excel, and Powerpoint.
- **Leadership:** Team oriented, confident, ability to see strengths of team members and utilize them to the best of their capabilities, time management, and ability to quickly and efficiently solve problems.
- **Quality Assurance:** Knowledge of multiple manufacturing standards, level 2 magnetic particle and dye penetrant certified, former AWS Certified Welding Inspector.
- **Manufacturing:** Experience with 5S lean manufacturing, WABO certification in SMAW, GMAW, and FCAW welding processes, shop certified in GTAW and GMAW Aluminum and GTAW Stainless steel welding. Experience with various machining practices.
- **Clubs/Organizations:** AFS student chapter Past President, SME student chapter Treasurer, ASME student member, Electric Vehicle Club.

References

Available upon request.