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Conversion Casting: Adapter Hub

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Senior Project

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Abstract

The concept of conversion casting makes manufacturing major components much more efficient with regards to time and cost. The conversion cast of the adapter hub used in the Victair Mistifier is a major component that requires 8 hours to machine. The existing hub starts from steel stock and then that block of steel is placed into a CNC machine and coded in to create the adapter hub. The manufacturing method changes to a casting for the adapter hub will create a replicated part that requires 1.5 hours of post machining. The intricate design makes a conversion to casting more effective in reducing time and costs, because the cast part will be near-net shape. The original design was redesigned to be castable with the addition of casting components onto a pattern bed to create a match plate. In order to make this project economical and the final product as close to the net design of the adapter hub, shrinkage of the material was placed into consideration and casting formulas were used to create the smallest gating system as possible. Draft angles were added to all faces of the adapter hub design and filleted edges around the overall design were added for easy removal from the casting flask. This process reduces time and costs by $157 while also providing H.F. Hauff, manufacturer of the Victair Mistifier, the ability the mass produce a critical component of their most sold product. This in turn should lead to reduced costs for their customers.

Introduction

Motivation

H.F. Hauff Co. Inc. is a leading provider for agricultural equipment to provide farmlands the ultimate outcome for each season's harvest. Based out of Yakima, the company is committed to provide local and global farms with equipment to protect crop from frost damage and increase yield.

The current Victair Mistifier is one of the finest sprayers on the market. Directly connected to any tractor ranging from a low 35 hp up to 70 hp, keeps the farmer's resources in mind. This product increases the spraying radius for farmland and reduces chemical usage at the same time.

Although a premium product, manufacturing costs must be reduced to make the Victair Mistifier more feasible for any farm across the globe. To decrease manufacturing costs, an adapter hub that houses two Timken bearings needs to be manufactured using a different method. Using the conversion cast method will provide the same general shape of the product and maintain a uniform material structure. This method reduces the use of machining and reduces the cost of material. From an engineering perspective, this manufacturing process is primitive, yet effective in reducing costs.

Function Statement

Design a devise used to cast an adapter hub designed by H.F. Hauff Co.

Requirements

Neil Hauff has simple requests for this project but casting techniques provide a larger challenge.

- The pattern must be dimensioned within 5% of adapter hub dimensions
- Customer requires the pattern to be made from hard wood
- Match plate must be strong enough to be used in a jolt squeeze; 30psi
- Match plate must fit snug in a 12X14 or 12X18 flask
- Cost of pattern must be under $100
- Devise must reduce manufacturing time by 10%

Engineering Merit

It is critical for the pattern to be as closely dimensioned to the pre-designed adapter hub as possible. The hub provided has already been engineered to fit a gear box on the Victair Mistifier, so dimensions are crucial. Housing two Timken bearings provide the challenge of maintaining a concentric finish and even wall thickness. Using casting techniques provide H.F. Hauff Co. the ability to mass produce a critical component in one of their best selling products while also reducing material costs, machining time, and labor.

Scope of Effort

The design focus simply directs towards the reduction of manufacturing costs and giving the capability of mass production. It is the upmost importance that this pattern is the highest of quality and accurate as possible; not only testing but also used for production.

Success Criteria

The success of this project is based on the performance of the pattern devise or also known as a match plate. If the match plate is designed with all the right components at all the right dimensions, the pattern devise should be able to replicate the adapter hub designed by Neil Hauff while also meeting all the requirements listed above. With the reduction of material usage in comparison to raw stock which is how H.F. Hauff manufactures the adapter hub, not only is money saved but time. The pattern for the adapter hub is close enough to the actual dimensions of the original that minimal machining is required which is the general goal; reduce manufacturing time. Once removed from the sand, only

Design and Analysis

Proposed Solutions/Descriptions

The design process for the adapter hub is quite simple. The adapter hub is already standardized and dimensioned to fit the Victair Mistifier so the challenge is to work around the machine. The adapter hub already has a drawing so the devise will be dimensioned to those same dimensions but larger to accommodate for shrinkage during the solidification process. So, we start with figure a-1 which is the outline of the designing process.

1.) The first approach for this devise is to put the most basic necessities into a match plate. A match plate or a pattern devise consists of a pattern bed, the pattern (part being made), risers, runners, and gates. The pattern bed is what houses all the components of the match plate, pattern, runners, gates and risers. Although typically made from wood, plastic and metal is still a material option. The pattern itself will be the adapter hub. Fortunately the adapter hub has already been dimensioned by the customer so the pattern will fit those requirements but include characteristics that will make the pattern suitable for casting. This includes increased dimensions for shrinkage and a taper to create easy removal from the casting flask. The calculations for these changes can be found in appendix A figure 2 to see the proposed solution. The risers, runners, and gates will be the final portion of this devise. These will be the most intricate components on the pattern bed. This will be researched using SOLIDCast because they must be dimensioned properly for the use of sand being used, material of the adapter hub, and temperature. These must first be thoroughly researched before approaching the design process.

2.) With the original design based off of what was given by the customer H.F. Hauff Co, adding a positive draft on all edges, the addition and subtraction of material based on the direction of shrinkage, and the proper sand core to reduce material use was applied to the new design. The recommended by (casting practice by John Campbell) that a draft angle for patterns is between 2-3 degrees. For this design, 3 degrees was used to make for easy removal as well as any misalignment with the sand core that may occur during the pour. This gives a small addition of material which can easily be removed. Although a solid design, human error can occur and taking all precautions into consideration increases the overall quality of the design and performance. Adding a stub on both the base plate and cylindrical housing sections will help keep the sand core from moving once the cope and drag are locked in.

The customer requests for the adapter hub to be made from steel so the dimensions were changed based off of the shrinkage for steel. Steel has a shrinkage value of approximately 2 percent. For this project, all dimensions could have easily been changed to an increase or decrease based on the direction of shrinkage. Rule of thumb was that inner dimensions shrink outward and outer dimensions shrink inward as seen in figures a-3 and a-4. That being said, the inner diameter was the only dimension with a reduced value and the rest had added material. For extra precautions, the use of 5 percent was used to accommodate for failures that can't be seen. For example, imperfections in the material being used can cause a rough finish on one of the faces, air pockets within the cast causes "bubbles" on the surface, and misalignment.

The cast will be machined to have a smooth finish as the customer requested. There is no real telling as to where an air pocket or an alignment issues may occur because ones the flask is closed, the answer isn't there until after it solidifies. Although the added 3 percent may seem much, it makes for a decent form of insurance. If there is a problem, just machine it off instead of pouring another one.

With the pattern complete, the next step is the design of the components; these being the risers, runners, and gates for the pattern. Following the design tree, the pattern comes first so all other components revolve around the adapter hub.

3.) The risers and runners are a challenge because they must be designed by scratch until going through simulation which will be tested during the winter. During design, they can be designed simply to fit the flask with tapers or designed around the pattern while also fitting the flask. Knowing the dimensions of the flask to fit the requirements, 12X14, utilizing standard design of patternmaking from book *Casting Practice the 10 Rules of Castings* by John Campbell, the best way is to start with an outline then add required characteristics, this outline can be found in appendix A figure a-5. It's said to "don't be afraid to make changes down the road" which is what is going to occur through the manufacturing process.

The outline gives a general perspective on what needs to be made in order to make this pattern devise successful. Alignment is key because the risers on the cope need to match the runners on the drag as well as the sprue well or "choke". Having a general outline makes further modifications easier as well as gives a pictorial representation of what the cope and drag will look like once assembled.

4.) Finally, the core box needs to be designed. Following the project requirements, minimizing material usage minimizes cost and time. Because the core box will be 3D printed, the more the material, the longer it will take to print. Based off of the design of the base plate and hub housing, from stub to stub gives the total length of the core and the stub's diameter gives the core's diameter. Wrapping this section around that idea will make the design quite simple. Knowing that both ends of the core box will need to be packed with sand, having one end open and the other not makes for easy sand packing. The purpose of that is to reduce the pockets within the core and maintain a concentric core from to bottom. Figure 1-6 starts with a general shape then moves to a more intricate design that includes one wall closed and the other open. Adding the alignment holes make for adding the top and bottom sections stay in place. The binding takes about 5-10 minutes to solidify so adding alignment holes on one section and pegs on the other half will keep the core box in place.

Figure a-7 shows the general shape of the sand core as well as the chemical reaction. Adding sodium silicate to sand is like adding glue to sand. With exposure to air or CO_2 is the catalyst. This process is quick, simple, and cheap.

5.) Knowing what sand will be used is not only for the operator's sake because sand is quite heavy. The rough estimate for the total weight without the pattern cavity is 100 pounds; this includes the flask of course.

The flask is made of steel so that doesn't help. Normally this process requires two people because moving the flask from the jolt squeeze to the pouring platform is quite a distance. With constant raddling as well as quick movements can disrupt the loose sand in the cavity. This normally isn't seen because the exterior is packed fairly well but the interior always seems to be more sensitive. If this is the case, the cast will not be complete and the process will have to be repeated.

Benchmark

A direct comparison for this devise would be a similar match plate in the Central Washington University foundry with a different pattern. The match plate is designed to make two tortilla presses. The pattern is good because it fits the design of what is to be made but the components are not. The pattern devise has the same components as any regular match plate but has a flaw in the design. The match plate seizes in the runners. There is not enough information to define the exact reasons for the runners to seize because there are a variety of variables that could cause this to happen; such as poorly packed sand, material temperature, and flow. However, if research was done to accommodate for a temperature tolerance, material and sand, the match plate would provide a complete part after every pour.

Performance Predictions

After careful design and research, the pattern devise has some very touchy requirements that not only the customer requests but is necessary for consistent flow; always keeping in mind that this devise is not a machine but a design. The performance of the pattern devise is based on whether or not the adapter hub can be made based on the design. Dimensions are critical and require an accommodation for shrinkage. By also meeting the requirement of reducing machine time, features on the design were made. A cylindrical sand core was designed to reduce the machine time of the bearing housing but also designed for a positive tolerance so the customer can have a concentric and smooth core for housing the bearings after the excess is machined off. Minimizing machine time meant minimizing material. Although having a positive draft for flask removal, having the smallest angle possible reduces material usage and machine time. Based off of calculations from SolidCast, the pattern itself will have a total of 4 cubic inches material used and 0.28 cubic inches of material that will need to be machined off to meet the customer's requirements of reducing machine time by at least 10%. It is predicted that the pattern devise will create the adapter hub after the solidification process. However, the core of the adapter hub is still undefined. This cannot be confirmed until after a few trial runs.

Description of Analyses

The backbone for this project is simply functionality. The question has to constantly be asked "can the devise produce the adapter hub while maintaining all the design requirements?" Although a simple list, the parameters of casting make the project more intricate. Maintaining a project that is within budget, time, and producing a quality product is key. Starting this project required an imagination towards what exactly is being built as well as a basic outline so a sense of direction and decisions can be made. This can be found in appendix A Figure 1.

The pattern devise has a simple list of parts that will all be manufactured from quality material and still under budget. To allow the pattern devise to perform, the pattern and all components must be designed correctly and cut precisely. Fortunately for this project, a professional CNC operator will be doing the coding for the pattern and components so the risk of failure in that regards is much dampened. However, it's the designer that has to design all components that allow simple cutting and minimal machine time. So, each stock of mahogany wood is to be cut to the minimal volume of each component and then coded into the CNC machine. This will reduce costs and time if done properly. This will provide for extra money to be invested into potential improvements on the pattern bed.

Time is money, everyone knows that. Because this project is under a strict schedule and deadlines that must be met, every step of this project is to be accounted for and monitored. The ultimate goal is to have a perfect design that will take less than a day to machine and a week for total assembly. The assembly will in fact be the most difficult task. All components must align and mirror the cope and drag faces of the pattern bed. The design is completely wrapped around the customer's design and the idea is simply to replicate it using a different form of manufacturing. For the sake of time and money, simulations will be done to account for any flaws in the final design. The project was initially thought upon as the adapter hub with tapered edges and small runners and risers has blossomed into something much bigger. The project now includes a core box for the center cylindrical housing, round runners, two gates instead of one, and rounded risers. The first idea seemed concrete until remembering that the pattern still needs to be pulled out of the sand. This is why the use of simulation software is so critical for the project. It doesn't give a concrete representation of what's actually going on inside the flask, buts it's very accurate.

The thought of producing a fine product is in every engineer's mind when dealing with a project like this; especially if it's for a customer. The only key element with this is based on the performance of the pattern devise. Sure it can be made out of the best material in the world. Sure it can be designed down to the thousandths of an inch. However, if it doesn't actually make the adapter hub, then it's not a fine product. The design has to have tolerances that require a temperature tolerance for the solidification process, it needs decent sized runners to reduce the chances of seizing, and it needs risers that will actually use gravitational force to fill up any loose ends of the adapter hub pattern. All of which must be accounted for or the pattern devise will not meet every requirement and ultimately be a failure.

Scope of Testing and Evaluation

Testing of the design will be analyzed through SolidCast. With the design of the adapter hub already completed and the components identified, simulations must be run to through the software to show the solidification process of the adapter hub. The software will identify flaws in the design of the pattern, the runners, the gates and the risers. The design is made but not complete until the simulations have a 100% success rate after each pour. The simulations will be done using two materials, gray iron and steel. Making a design that has a success rate with both materials will ensure the design is finally complete and the pattern device can move to step 2 which will be the actual manufacturing of the components and pattern.

During step 2, the components will be manufactured and assembled onto the pattern bed. The core box for the bearing housing will also be manufactured and test sand cores will be made with the core box. First testing will be done at the Central Washington University Foundry using green sand a gray iron. If successful, testing will then be moved to a separate foundry using steel.

Testing must be done in steps towards the final material, steel, because this kind of testing can't be done at the Central Washington University Foundry. Doing so will provide time management, material management, and maximize resources.

Analyses

The pattern for the adapter hub is has been designed around the actual drawing; appendix B figures 1. The new design can be seen in appendix B, figure 3. The first approach was dealing with the shrinkage of the pattern. For internal characteristics, such as the internal cylindrical housing, the diameter needed to be reduced because during solidification, it will shrink from the inside out. However, for the external dimensions, material was added because the direction of shrinkage is opposite. It will be shrinking from the outside in. To keep even consistency as well as the listed requirement, 5% was used to accommodate for shrinkage. The customer wants the adapter hub to be made from steel, which has a shrinkage value of approximately 2% so with the added 3%, human error as well as imperfections in material used and possible misalignment, or just giving extra material to be machined off to ensure a smooth finish all around. The equation used was simply $X = l * (percentage)$; percentage either being 1.05 for addition or 0.95 for reduction. For this project, this was the only real hand calculation needed.

A major cast characteristic required in any match plate is a draft angle. The draft angle makes for easy removal as well as laminate flow into the pattern cavity. When it comes to "easy removal" this is directed towards the ability for the pattern to be removed from the sand after being packed. With all patterns, while sand is being packed into the flask, there is a suction or vacuum being produced between the pattern devise and the sand because there is moisture in the sand. With continuous packing, the water in the sand creates a barrier and removes as much air from the flask as possible. In order to break the vacuum, a positive draft angle is placed on all deep components of the pattern devise. While a vertical force is being applied to remove the pattern from the cope or drag, the positive draft angle allows air to come in between the pattern and sand to break the vacuum.

While material is being poured into the pattern cavity, the flow of the material actually makes a difference during solidification. Take for example; if there is a rapid flow into the flask, the material is filling the cavity at a rapid velocity and increases the probability for air pockets within the pattern. This would occur if there is a turbulent flow and the air doesn't have enough time to be removed from that empty space. So, the material stacks above it and begins to solidify. With a positive draft, the material flows evenly into the cavity instead of "dropping" into it.

The added components to the pattern devise are not only simple requirements, but also provide for a better product. With risers, gravitational force is used to push material into the gates and into the pattern. After the pour, all components and sections of the pattern within the cope section solidify last. After the pour, any air in the pattern gets trapped. This is where the calculations for the dimensions of the gates, risers, and runners come in. These components are to overcome that empty space within the pattern. Because this project has a flat surface, its crucial for that space to be filled or the connection of the flange to the gear box will not line up properly or the gasket between the adapter hub and gearbox won't work.

Technical Risk

For this project, one must first analyze the purpose as well as the bigger picture. The bigger picture would be recognizing that this component is part of a larger system. Although the purpose of the project is to conversion cast, looking at this project at a boarder approach gives this project more technicalities in the sense that the adapter hub is an extremely important component. The adapter hub is specifically dimensioned to fit the Victair Mistifier and all changes have to work around that machine. The only real changes that will be made through the project are dimensions and characteristics; dimensions to accommodate for shrinkage and characteristics to allow the pattern to be placed into a flask full of sand and then easily be pulled out.

Risk is mainly wrapped around the imperfections in material. The pattern itself should have no problems replicating the adapter hub but having control of the material that's going into the flask is a risk. If there is an imperfection in the material being poured into the flask, there is a potential for internal failures that can't be seen on the outside. Having a crack in the adapter hub after being machined is an instant failure. Then a new flask will have to be pack and pour again. Preventing this is simply trial and error with the resources available and packing the flask using a jolt squeeze. Using a jolt squeeze is more effective than hand packing and creates a uniform cope and drag; there are no "pockets" in the sand.

Another risk in this project includes alignment. If the cylindrical housing isn't perpendicular to the base plate, the adapter hub will not fit in the Victair Mistifier or wont function properly. Because the adapter hub houses bearings and a shaft, there needs to be a smooth inner diameter and needs to remain concentric. Although this problem is being solved with the use of a core box, if the core box doesn't sit properly in the flask, there can be inconsistencies that can't be seen until the assembly process of the Victair Mistifier.

Failure Analysis

If the pattern devise is to fail, the only indication will be based off of what comes out of the flask after the metal solidifies. The main cause of failure will be the metal seizing within the flask and not completely filling the pattern cavity. In this situation, there can be a variety of reasons as to why. The first possibility would be the devise itself. If there is a flaw in the design that wasn't caught through simulation or a misalignment causing an uneven flow during the casting process, then reconstruction or modifications would have to be made. Second possibility would have to be temperature of the gray iron. There is a change in density due to temperature and although quite minimal, it can easily throw off the flow of the metal and therefore not have laminar flow within the cast. The ultimate goal is to have laminar flow so the cavity will fill evenly. This reduces air pockets within the cast and gives the sides of the cast a smoother finish. Despite the fact that not all faces of the design will be machined, having a uniform look increases the quality of the component and more appealing to the customer.

During the manufacturing process, having any of the components of the pattern bed crack or chip can cause problems. Due to the tight budget, reconstruction of a riser, sprue well, or the pattern will be very expensive and cause the project to go over budget. All components are going to be made of mahogany and that is not a cheap material. It's the best material for the job except for ABS plastic but that is an even pricier material. Having to replace the material and machine a new component will throw this project off schedule.

During the assembly process, there is a high demand of finesse for alignment. All components have been analyzed and tested through simulation but human error does occur. Because the pattern bed has two faces, misalignment with any component on the cope or drag face can lead to failure. In this situation, the component would need to be removed then realigned. This is why the assembly is not completely permanent. Placing all the components onto the pattern bed with epoxy gives the ability for reconstruction or easy realignment. Once the epoxy cures, the pattern devise will be permanent.

Critical Failure Modes

Critical failure will ultimately come from human error. Assuming that the machining process goes smoothly and no components need to be remade, the pattern bed fits the assigned 12x14 flask, the assembly has perfect alignment, if the pattern devise isn't handled with care or the core boxes are abused, parts can easily fracture or crack. That is a large fear for this project due to the fact that the opportunity for total failure will occur after assembly. The core boxes will be 3D printed out of nylon which is tough but if the added nubs on the walls break, alignment becomes an issue when packing it full of sand and binding; this is also a very expensive repair or replacement. The pattern devise will be fairly solid but during the packing processes does create a bit of hesitation. The pattern devise will be used with a jolt squeeze which will be running at roughly 30 psi. The calculations have been made for the pattern bed to support that level of force but while using an older machine, the squeezing process can be more than expected.

Methods and Construction

Description

The pattern and components are all manufactured from red board high density plastic. The plastic will be cut to pattern at H.F. Hauff using a CNC program made from Neil Hauff's lead machine operator Jesús. All final designs are located in Appendix B. The pattern bed will be made from plywood with a laminate layer on the top and bottom. Because both materials will be cured, moisture in the green sand will not be an issue for potential damage or dimension changes within the pattern.

Pattern devise assembly will simply consist of the application of the pattern and design components to the pattern bed using an epoxy; the final assembly can be seen in figure b-9. This allows a perfectly parallel application. Using an epoxy puts a thin cured resin between the pattern bed and designed components that will only add approximately 0.002 inches to the total height of the adapter hub. Wood glue is optional but doesn't provide the same strength as an epoxy.

For this project, a core box will need to be made in order to make a sand core to fill the center of the hub. Placing this sand core into the pattern greatly reduces the post machining process and use of material. The core box will be constructed using the 3D printer available on the Central Washington University campus. The sand core made from the core box fill the cavity in the center of the pattern. So, the core box will be designed based around the size of the cylindrical housing. The core will be made using a no-bake sand process using the designed core box.

Each sand core for the adapter hub core will be made using a sodium silicate as a binder and silica sand from the CWU foundry. The sodium silicate activates when in contact with CO_2. The binder then begins to solidify within 5 minutes. Thus, each core must be made in small batches because only one core box will be made for this project. Although a tedious task, prototyping takes time and costs money. The idea is the minimize costs and save time.

The pattern for the adapter hub will now be manufactured of out red board high density plastic instead of mahogany wood. The material has been donated from the CWU machining lab. The components such as the gating system will still be made from wood. Wood can easily be manipulated as well as allows for easy material addition and subtraction. For example, if the metal freezes at the gate and doesn't fill the pattern cavity, then the gate needs to be larger. Wood can then be sanded to fit then glued on. This is an easy process and can be done within a day.

No modifications were done post assembly. The base plate and cylinder housing are perfectly aligned and the sand core fits perfectly in the pattern cavity.

Drawing Tree

The drawing tree can be found in Appendix B. The diagram shows the beginning of the project. Starting with the adapter hub drawing provided by H.F. Hauff in Appendix B, the design process works its way up into the adapter hub pattern. This is the same design but with added features to allow the part to be manufactured through casting. Once the design is finished, components are designed around the pattern for cast performance; this includes the runners, riser, and gate designs. These designs are critical for the pattern itself to maximize the pattern devise's performance, reduce material usage, reduce the chances of seizing, and to ensure even liquid metal flow into the flask. The pattern bed is basically the final step because it requires the least design and all other components must be designed prior to the pattern bed because the pattern bed simply needs to be dimensioned around the overall dimensions of the pattern and components. Once the components and pattern bed are assembled together, the pattern device is complete.

Parts List

Parts list can view in Appendix C. Parts include quantity, cost, source, and manufacture. This provides insight of project cost. Majority of costs comes from wood stock needed for pattern and components.

Discussion of Assembly

The assembly for the pattern devise is quite simple yet requires some serious precision that could make or break the devise. The pattern devise is broken up into a variety of parts that all come together onto the pattern bed. The components of the devise include two risers, two runners, two gates, and the pattern of the adapter hub. All components designed using SolidCast to ensure all material fills the pattern during the solidification process. If not properly dimensioned, the adapter hub will have air pockets, jagged edges, and could potentially seize during the pour. This is why all major components are designed around the adapter hub. It doesn't matter if the risers don't fill all the way or one of the gates froze, as long as the adapter hub is full and can be removed from the flask, the pattern devise will be successful.

The components will all be machined in house at H.F. Hauff co. in house using hardwood. This was a very easy decision because using the resources available; H.F. Hauff has a master machinist available. This ensures that each program to cut each component will be done properly and in a timely manner. The pattern bed is a simple piece of hardwood/laminated wood. The dimensions based off of the size of flask being used. Because the adapter hub is a fairly small part, it can be done in a 12X12 inch flask but, it will be designed for at 12X14; using a larger than necessary flask size gives more room for play with the components. Reducing costs is critical but having more room for the runners will make for a smooth pour once completed.

Assembly will be done using an epoxy and some set screws. Because dimensions are critical, using an epoxy for the component assembly on the pattern bed instead of screws, nuts and bolts will reduce material space. Adding anything to the pattern has to be machined off. The objective is to reduce machining so epoxy is most suitable. The screws will be used for the flanges that will guide the flask posts. The flask is made of steel and the pattern devise is all wood so it can easily be damaged. Adding the flanges for the guide holes simply reinforces that area to ultimately increase the lifespan of the devise as well as make for easy removal from the cope and drag.

Assembly was completed through epoxy and wood glue. Epoxy was used to make the final connection between the components to the pattern bed. Wood glue was used to add fillets on all sharp corners between the pattern bed and components. This process is very simple and almost necessary. The larger the draft angles and the lesser sharper edges on the pattern devise reduces the suction effect when the devise is being used in the sand. This was proven effective due to a recent test on March 9th, 2016. The epoxy and wood glue cured so the devise was tested in the sand. After packing the cope and drag, the pattern devise came out of the sand quite easily and minimal damage was done to the pattern mould.

Manufacturing Issues

Because the pattern devise is completely made of wood, the greatest fear is having a portion of the pattern or components crack during manufacturing or assembly. Once it's cracked, it will either have to be replaced or sanded down. Sanding down material seems like a simple solution but depending on the depth of the crack will determine if it needs to be replaced. If the crack is substantial, more raw materials will need to be purchased and machined to fit. A small crack isn't as intimidating but can easily cause problems in this project. For a small crack, that section of the pattern or components will be sanded for a smooth finish. Then, that particular component or section will have to be measured again and the changes in dimensions will have to be placed in the casting software to simulate the solidification process. If the simulation doesn't have at least a 90% success rate, that section or component will have to be remade.

Another major issue with this particular assembly is alignment. Every component needs to be assembled onto the pattern bed being either parallel or perpendicular to it. The slightest angle can compromise the devise. This is because this design is to reduce material usage as much as possible but still make the adapter hub. With the sand core in the middle, it also produces another problem. The cylindrical core is critical because it needs to produce an even wall thickness to house the bearings. Misalignment with the core will make machining very difficult.

In order to save money, red board high density plastic was donated from the CWU lab. This material works much better than wood because of its machinability as well as its life span. Limited to sizes, one 3x3x21 inch rectangle was sectioned into four smaller rectangles. These rectangles were then glued together to create a large base rectangle. The new material stock is dimensioned at 6x6x5.25 inches. This piece of plastic will be used for the cylinder housing and a piece of 6x6x3 inch stock will be used for the base plate. Only downside to using the glued stock is the possibility of the epoxy breaking during the machining process. The glued parts are not exactly square but that doesn't minimize its purpose. H.F. Hauff will simply mill some jaw sections on one face and then place it into their 3 jaw chuck CNC machine. Having extra material for both parts was crucial to give extra room for potential machining problems. Although H.F. Hauff now has to machine off more material to make the parts, this doesn't affect the machine time at all. H.F. Hauff can make large cuts with the ABS plastic but will have to stay within reason due to the fact that one part of stock is epoxied together. They will need to take their time with the cylinder housing. If a section of the material comes off, the excess epoxy will need to be sanded off then re-epoxied onto the 3 other sections. This takes time because epoxy takes about 3 days to cure due to the surface area of the stock.

Curing time was accelerated due to lack of time to meet deadlines. The pattern device was placed into an oven at 150F over a period of 20 hours. This process was effective but left a small crack in the base plate pattern. This did not become an issue because the crack was filled with epoxy and the dimensions of all components, including the pattern are still within my design tolerance of 5%.

Testing Method

Introduction

Testing of the pattern devise will mainly be held at the CWU foundry. The tests for the project will determine the quality of the pattern devise as well as the quality of the cast. These tests will ensure the requirements for this project are met and show where error has occurred and see if there is room for improvement. The primary testing will indicate the troubled areas of the design; this being where the pattern may seize or if there is uniform solidification. This testing will be done using trial and error. Due to lack of experience with solidification software, trial and error is the only approach to test where the match plate requires attention. Once the match plate has consistency and fills properly, we move to secondary testing. The secondary testing will be the comparison of the actual design to see if all project requirements are met. Some examples include machining time reduced, and dimensional tolerance in comparison to the original adapter hub designed by H.F. Hauff Co.

Methods

In order to assure a solid and equivalent cast part is made, these tests will be performed and documented throughout the project.

1. Using trial and error, I will be looking to see where the match plate needs improvement. Such improvements include the addition or reduction of material in the runners, gates, sprue well, or the risers. Modifications may be necessary for this process such as an open risers to ensure the pattern is filled completely.
2. Test specimens will be made with each "batch" to compare the quality of material being used. The material of choice is gray iron so the material properties that are found from each batch will be compared to MatWeb to see if there are any flaws in the material being poured. The idea is to get as close to the standardized properties or within tolerance because the solidification software runs on certain material standards; so while testing, certain flaws and conclusions can easily be made.
3. Final test method will include nondestructive testing methods. If the cast fits all dimensions, imperfections within the part need to be made to ensure safety and quality. Methods including liquid penetrant and ultrasonic testing.

Test Procedure

Test procedure follows as scheduled. First the design requires simulation and analysis to show if the design is acceptable. Simulations will be done with solidification software Solidcast and if possible, Magma. Once the final design passes simulation, physical testing will be done. This will be run through a series of temperature changes and pour times. This process will be held at the CWU foundry and if possible, monitored by members of AFS for extra guidance. For each batch of gray iron, tensile test specimens will also be poured to be tested through ASTM E8 standards. This will show material properties and show if the material being used is suitable to justify the outcome of each pour. This being if the pattern freezes or the cope isn't completed filled. Finally, the adapter hub will be machined then go through some non-destructive testing to find any imperfections within the cast that can't be seen from the naked eye. The idea of this is to check the quality of the cast as well as give a sense of direction for potential changes in design.

Last requested test procedure is to test a project requirement, the machine time. The removal of material must reduce manufacturing time by 10%.

Budget/Schedule

Cost

Due to the readily available resources at Central Washington University, costs for this project are relatively low. Located in Appendix C will show the parts used for the pattern bed as well as a rough estimate on prices. The cost for the core box is to be determined based on which resource that will actually be used. Due to the generous donations as well as the resources from AFS, the project costs $52.68.

Budget

The budget for the project also remains a requirement. The budget is to be under $100 not including donations. Much of this project includes "free" resources as well as donated material. Out of pocket should always be under $100 which gives a little bit of wiggle room for any failures or bumps that occur during the manufacturing process. Any extra gives breathing room for any failed part during machining.

Because machining wood is quite a delicate process and a normal CNC machine normally machines metal which requires oil or a lubricant for smooth cuts, there is a slight issue with the manufacturing process. Although not determined, material of choice for the pattern may actually be switched to ABS plastic which is popular in many foundries. With the possibility of material change, costs may or may not go up depending on the resource it comes from. During the manufacturing process, a donation from a local foundry is highly possible which replaces the cost for pattern material. However, if not donated, the project may go above the $100 budget.

Due to a recent donation, the project's cost has slightly gone down. Thanks to the CWU machining lab, the pattern for the adapter hub will be made from red board high density plastic. The components will still be made from wood except for the core box. Using wood for the gating system is a smart move because wood can easily have additions and subtractions of material. If more material is needed, more can be added because with the donations from CWU machine lab and AFS, the project costs are substantially

Schedule

The project will be managed by a strict schedule and time management assigned by the MET 495 course. The schedule for the proposal itself and the project as a whole are located in Appendix D. The project as a whole is broken down into three sections which represents the three quarters in the school year. This starting from September 2015 and ending in June 2016. The schedule includes specific marks that indicate a deadline or checkpoint; this includes draft proposal, analysis modifications, document modifications, final proposal, etc.

The estimated time dedicated to this project is approximately 240.5 hours. This of course is an estimation of time and the final duration can't be determined until the project is complete in June.

Benchmarks have been labeled and marked. An (**X**) indicates that that section of the project is completed. As the project progresses, deadlines will be met and will be clearly marked with the identified symbols on the schedule. Once the project is compete, all benchmark will be marked with a (**X**).

Discussion

This project was presented in MET 495A class and the sponsor for the project was ready to see what a MET senior could do. H.F. Hauff Co. was ready to come on board and give the students any in-house resources they had to complete this project. Although not financially supported, the project itself requires little material and but a lot of work; work being design, analyses, and the manufacturing process. The manufacturing process itself is labor intensive and requires a skill that most students do not have. Now, the idea is for H.F. Hauff Co. to save money by letting a student try and conversion cast the adapter hub that is currently machined from raw stock.

The primary idea is to create a match plate that replicates the adapter hub presented by H.F. Hauff and add the required properties to the original design to make the component cast ready. Neil Hauff of Hauff Co. wants this adapter hub made from steel but this project will mainly be wrapped around the use of gray iron. The current prototype for the adapter hub is made of AISI 1000 series steel with a density tolerance of 0.283 – 0.284 lb/in^3 and gray cast iron has a density tolerance of 0.246 – 0.265 lb/in^3. The density of both materials are not far off but still effect the outcome of the cast. Flow of material remains an issue but with proper runners, risers, and gating system, it can easily be neglected. As long the cast has a laminar flow, which will be human controlled, the outcome should be successful.

One primary issue with this project is giving the pattern devise the ability to be used with not only gray iron, but steel as well. Gray iron has shrinkage of approximately 1.00% while steel on the other hand has a shrinkage value of 2.00%. This is a big difference and if two patterns were made, the new volume would be different. However, a huge benefit to the difference in shrinkage is the reduced machine time. If dimensioned properly to accommodate a tolerance between the two materials, the machine time will still be reduced by at least 10%.

Now, one corner can be skipped and just go straight to a shrinkage value of 2.00% because ultimately when the pattern devise is complete, the goal is for the pattern devise to create the adapter hub. The majority of testing will be done using gray iron to utilize the resources available at CWU. Final testing will be done at a local foundry in Washington using steel.

Conclusion

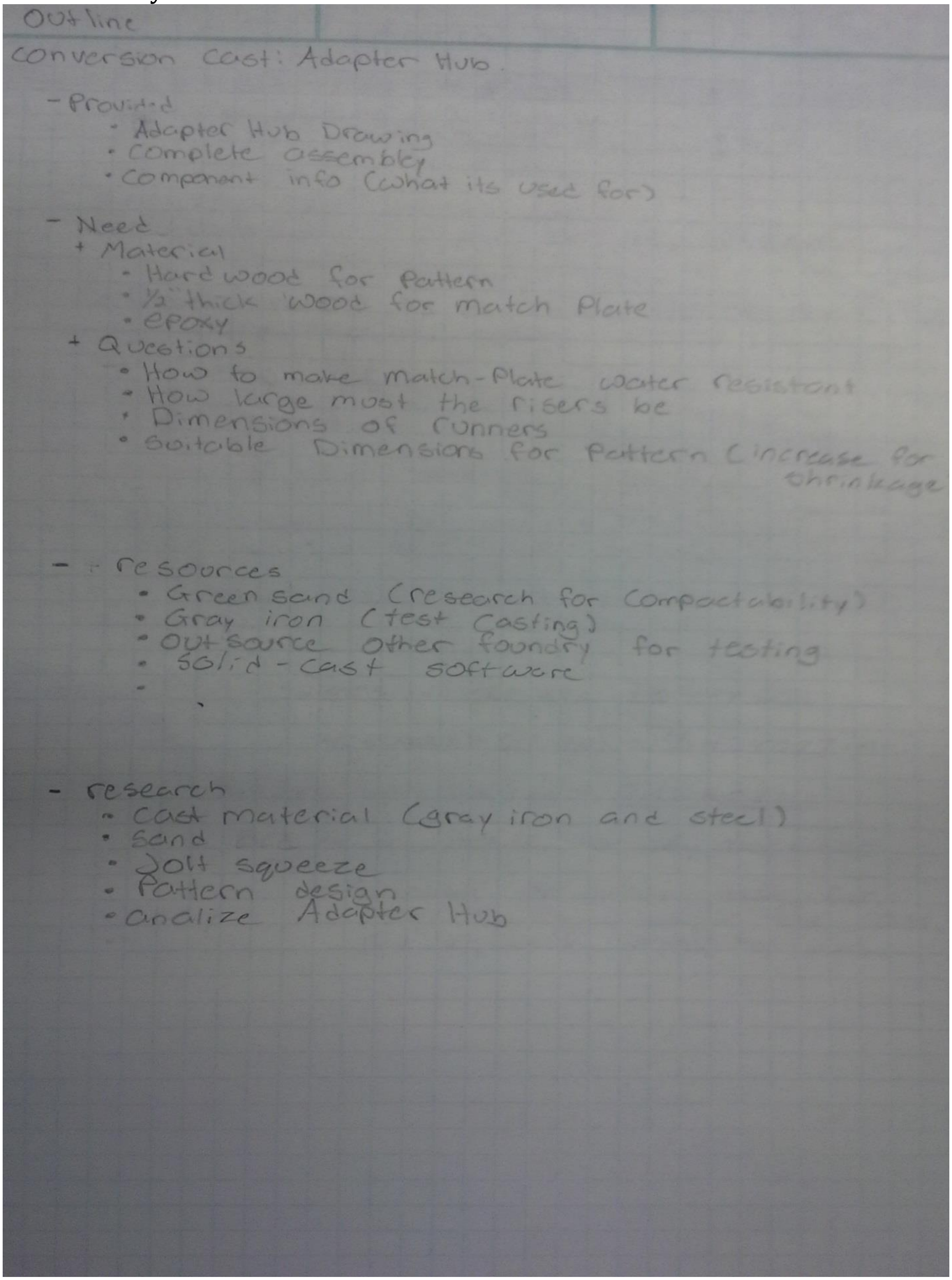
Utilizing what has been taught in the classroom, experience with pattern making, and the vast resources readily available make this project completely doable. Having access to Neil Hauff's manufacturing equipment, a full machine shop at CWU, and support from all that AFS has to offer makes this project feasible. The primary object is to save time and money; this pattern devise will do that for H.F. Hauff. Making the dimensions of the pattern within tolerance that accommodates for material shrinkage and easy post machining reduces the time and work required while minimizing material usage; all key aspects in manufacturing that save money. The general idea is for the design to be well enough where the liquid metal does all the work. It is still undefined as to what post machining will actually be done once the pattern is removed from the flask so this devise as the potential to exceed the required reduced manufacturing time of 10%.

Acknowledgements

This list is in alphabetical order and does not represent that magnitude of support throughout this project.

- AFS and their members for their support and expertise in all foundry related work.
- Casey Mcfarlen of H.F. Hauff Co. for support throughout the proposal.
- Central Washington University for the use of their foundry and material used for testing.
- D&L Foundry for their donation of material used in this project.
- Dr. Johnson of CWU for his assistance and experience with the casting and materials aspect of the project.
- H.F. Hauff Co. for presenting this project and use of machining resources.

Appendix A – Analyses

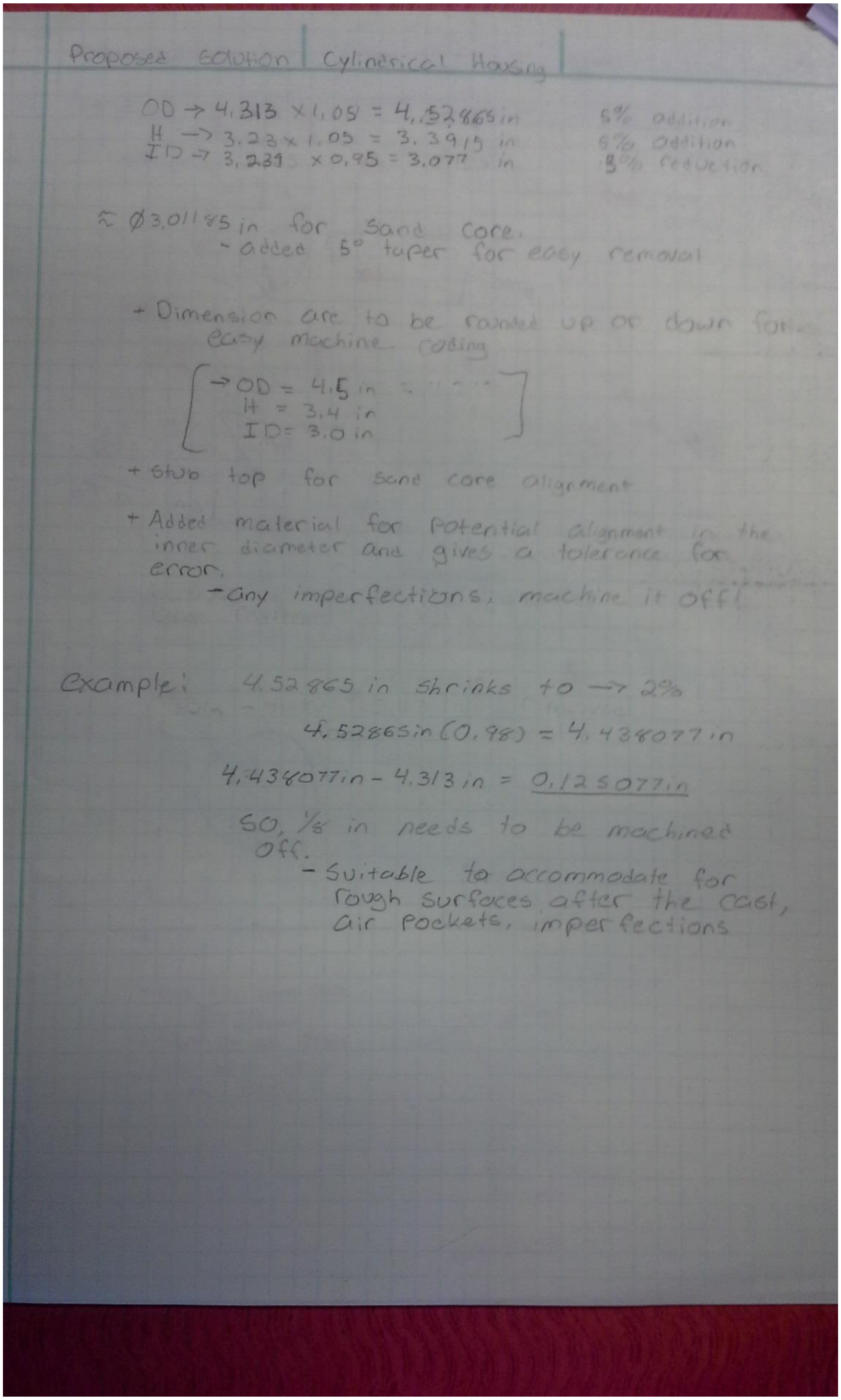


Outline

Conversion cast: Adapter Hub.

- Provided
  - Adapter Hub Drawing
  - Complete assembly
  - Component info (what its used for)
- Need
  - Material
    - Hardwood for pattern
    - ½" thick wood for match plate
    - epoxy
  - Questions
    - How to make match-plate water resistant
    - How large must the risers be
    - Dimensions of runners
    - Suitable Dimensions for Pattern (increase for shrinkage)
- resources
  - Green sand (research for compactability)
  - Gray iron (test casting)
  - Outsource other foundry for testing
  - Solid-cast software
- research
  - cast material (gray iron and steel)
  - sand
  - Jolt squeeze
  - Pattern design
  - analize Adapter Hub

Figure a-1: Outline


Proposed solution | Cylindrical Housing

OD → 4.313 × 1.05 = 4.52865 in — 5% addition
H → 3.23 × 1.05 = 3.3915 in — 5% addition
ID → 3.239 × 0.95 = 3.077 in — 5% reduction

≈ Ø3.01185 in for sand core.
- added 5° taper for easy removal

+ Dimension are to be rounded up or down for easy machine coding

→ OD = 4.5 in
H = 3.4 in
ID = 3.0 in

+ Stub top for sand core alignment

+ Added material for potential alignment in the inner diameter and gives a tolerance for error.
- any imperfections, machine it off!

Example: 4.52865 in shrinks to → 2%

4.52865 in (0.98) = 4.438077 in

4.438077 in − 4.313 in = 0.125077 in

So, 1/8 in needs to be machined off.
- Suitable to accommodate for rough surfaces after the cast, air pockets, imperfections

Figure a-2: Proposed solution –dimensional change

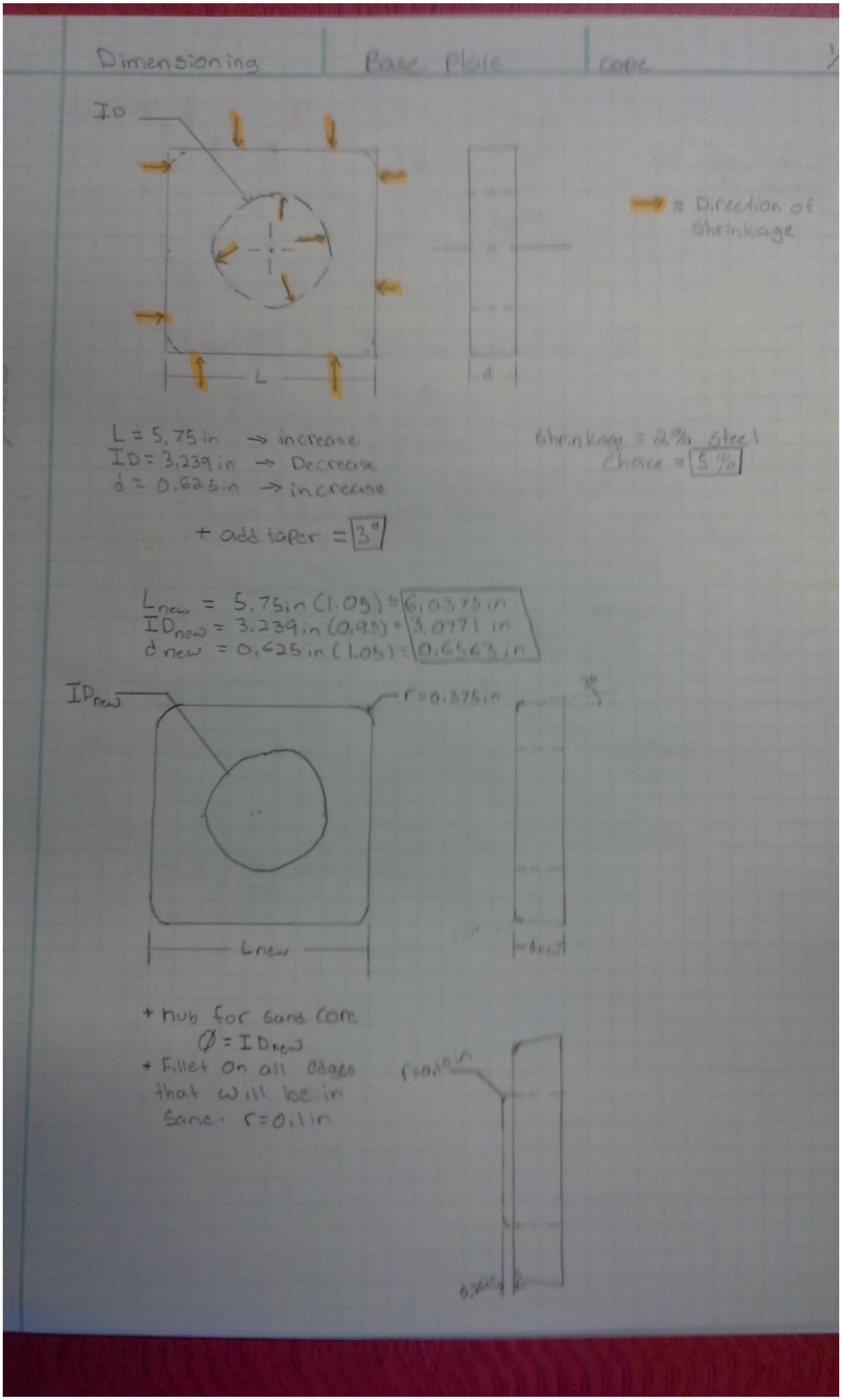


Figure a-3: Base Plate dimensioning

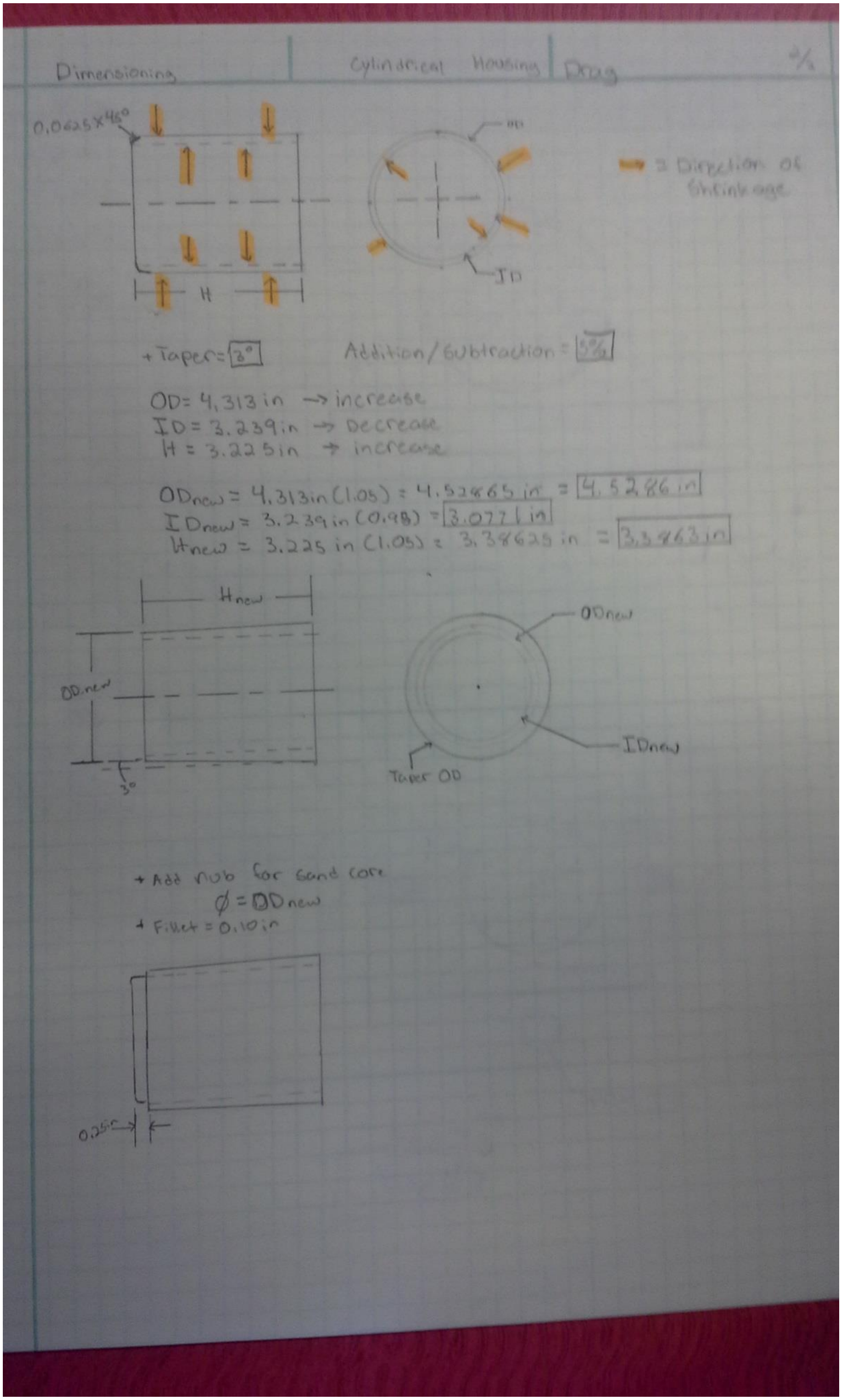


Figure a-4: Hub Housing Dimensioning

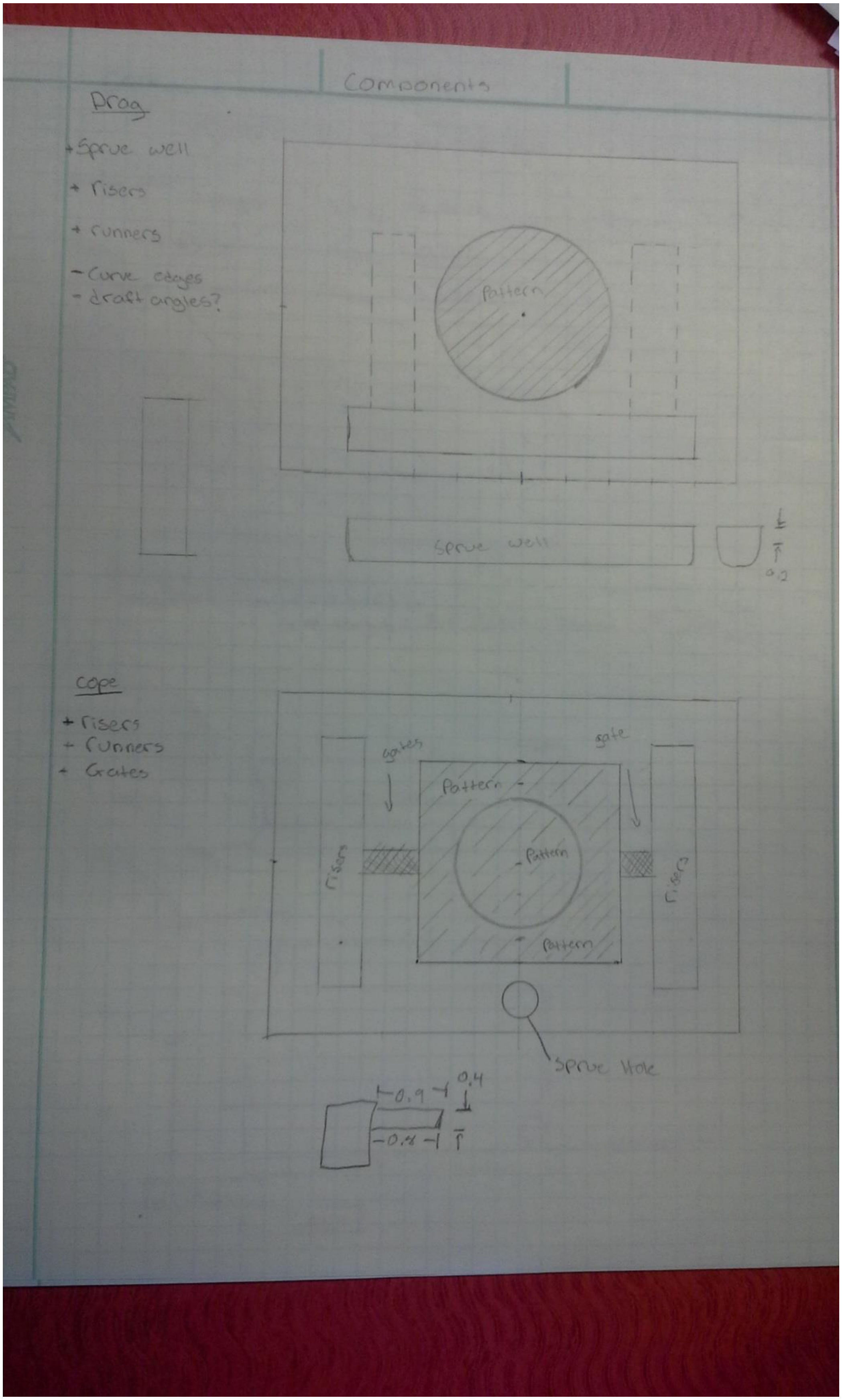


Figure a-5: Components –gating system and risers

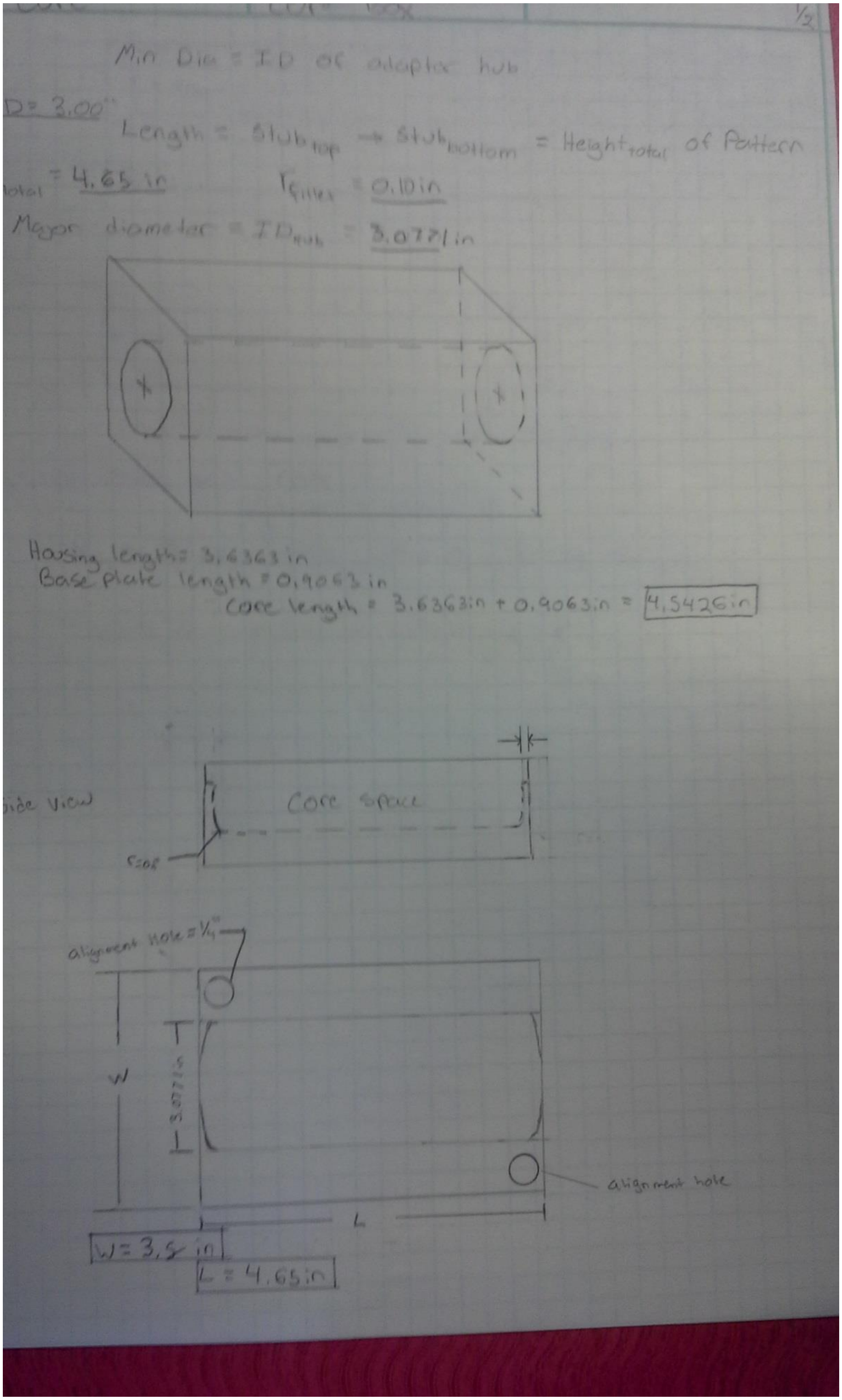


Figure a-6: Core box

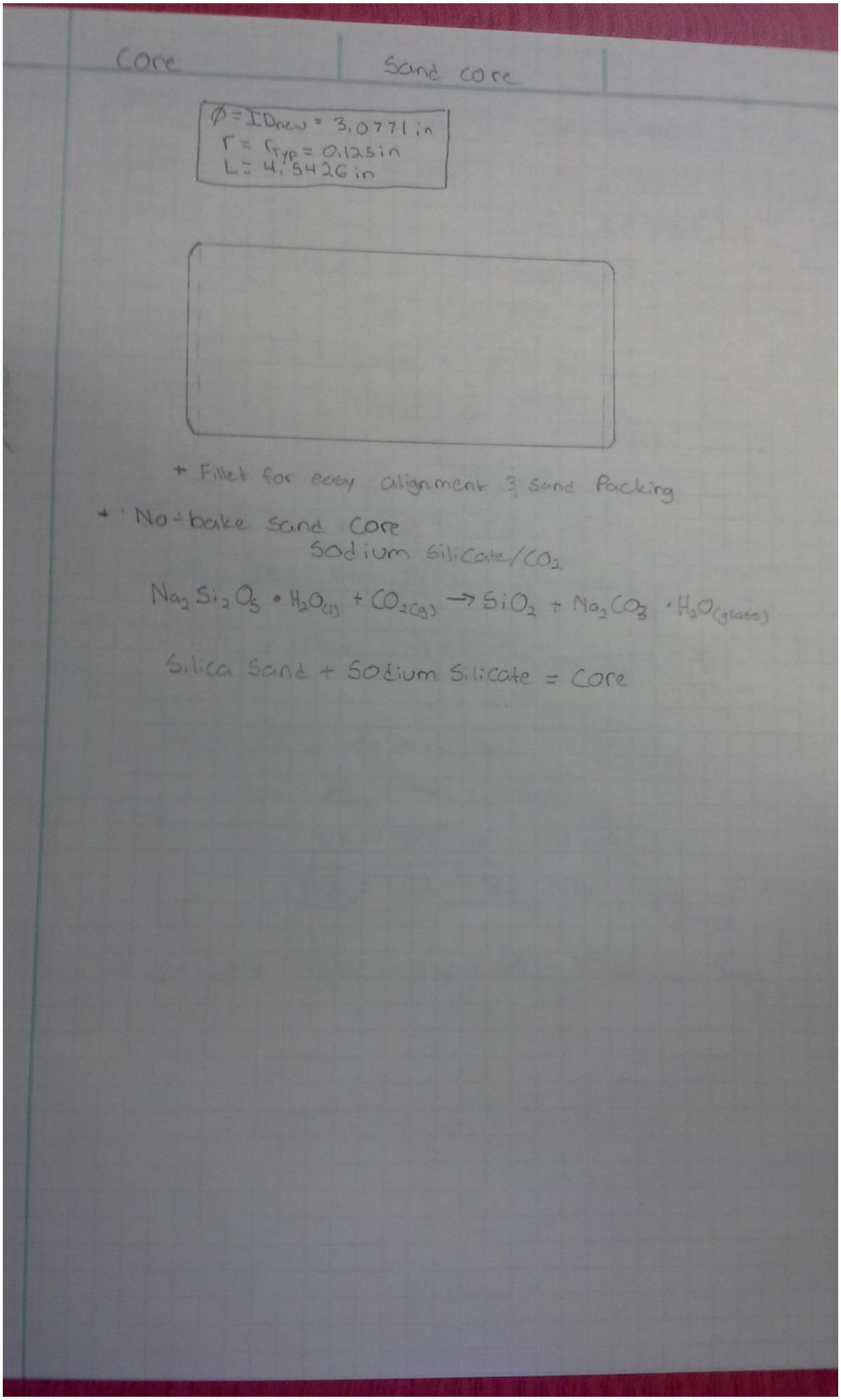
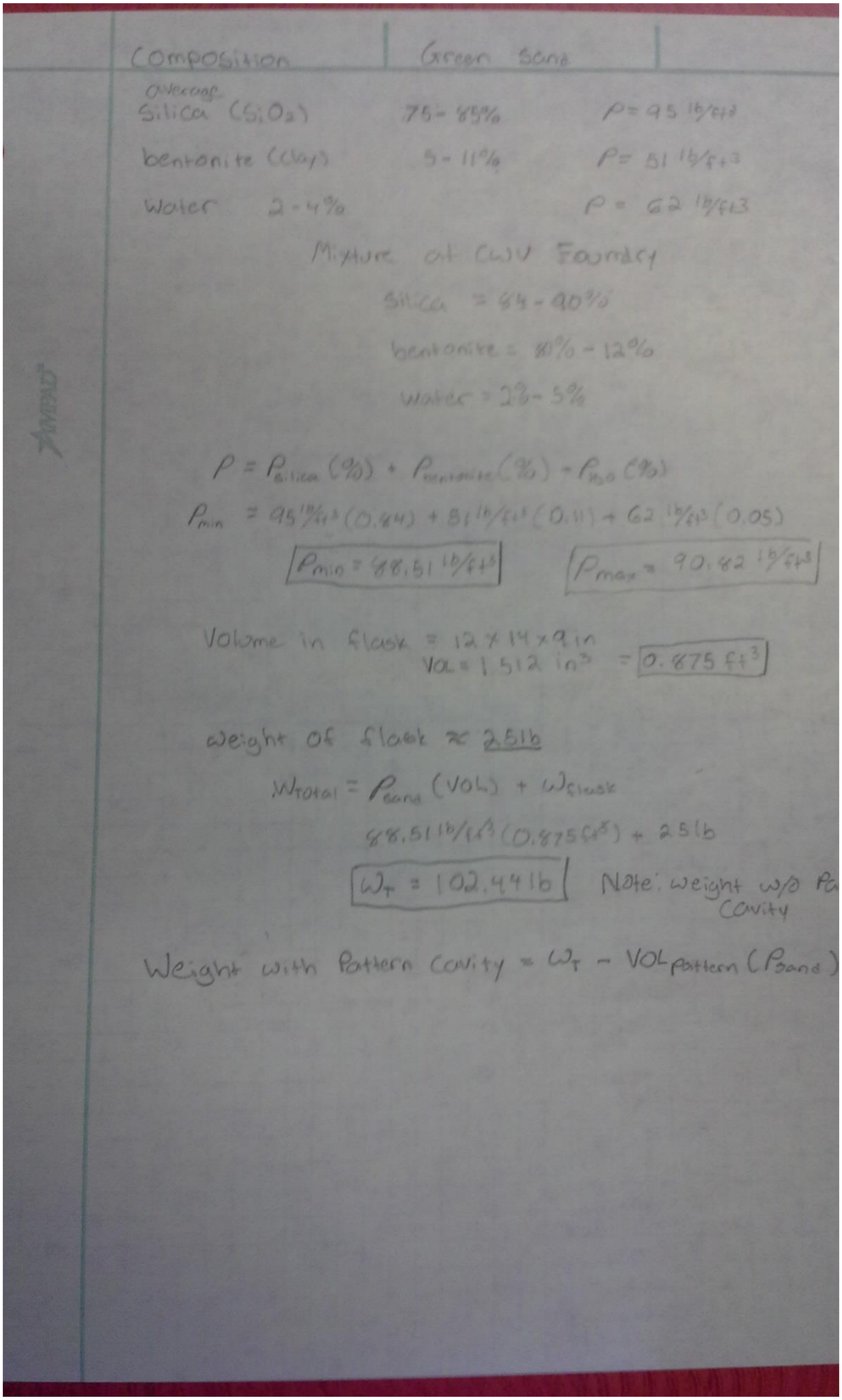


Figure a-7: Sand core and composition



Composition	Green sand	
average Silica (SiO_2)	75 - 85%	ρ = 95 lb/ft³
bentonite (clay)	5 - 11%	ρ = 51 lb/ft³
Water 2 - 4%		ρ = 62 lb/ft³

Mixture at CWU Foundry

Silica = 84 - 90%

bentonite = 8% - 12%

water = 2% - 5%

$\rho = \rho_{silica}(\%) + \rho_{bentonite}(\%) + \rho_{H_2O}(\%)$

$\rho_{min} = 95\,lb/ft^3(0.84) + 51\,lb/ft^3(0.11) + 62\,lb/ft^3(0.05)$

$\boxed{\rho_{min} = 88.51\,lb/ft^3}$ $\boxed{\rho_{max} = 90.82\,lb/ft^3}$

Volume in flask = 12 x 14 x 9 in

Vol = 1,512 in³ = $\boxed{0.875\,ft^3}$

weight of flask ≈ 25 lb

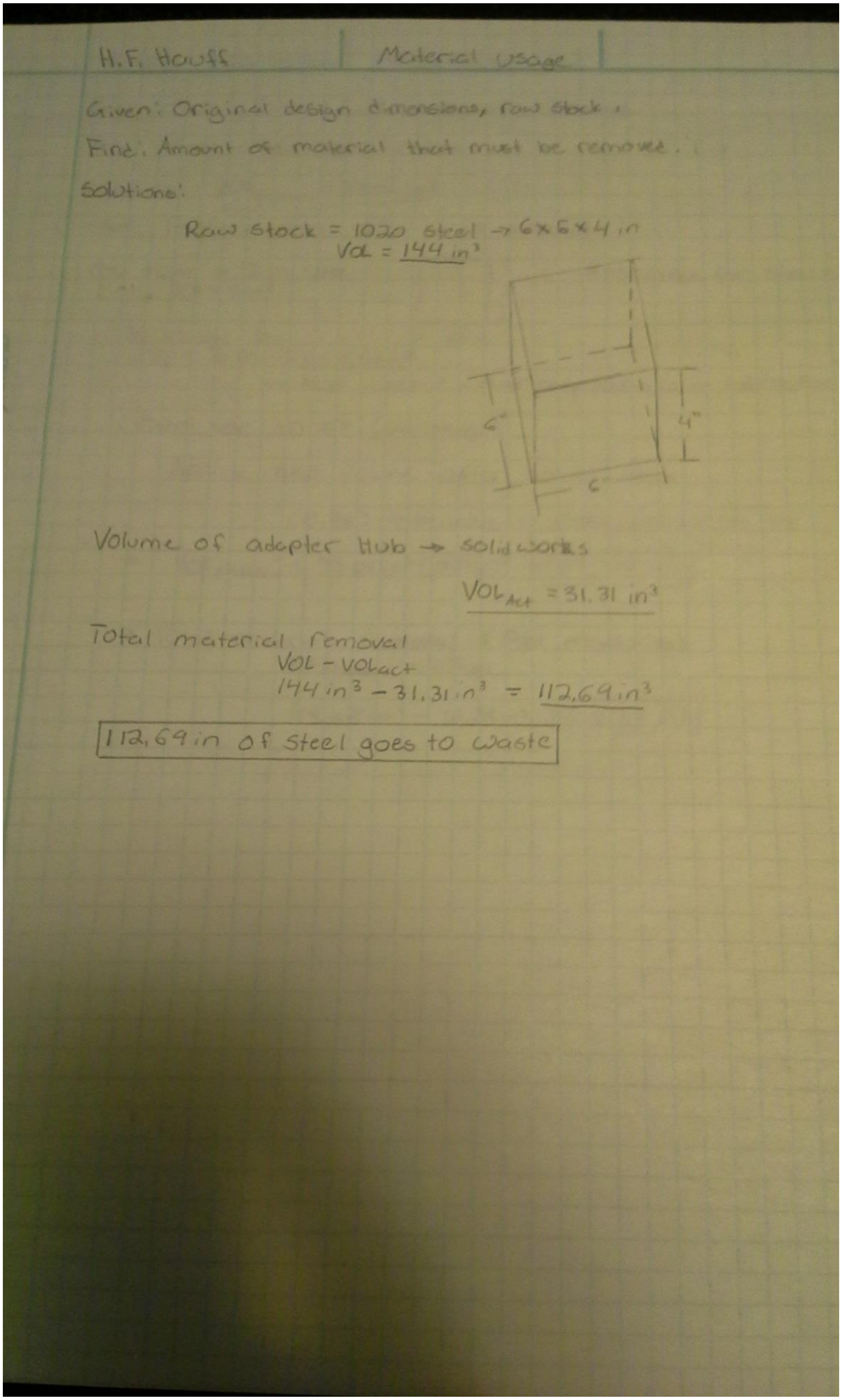
$W_{total} = \rho_{sand}(VOL) + W_{flask}$

$88.51\,lb/ft^3(0.875\,ft^3) + 25\,lb$

$\boxed{W_T = 102.44\,lb}$ Note: weight w/o Pa[ttern] Cavity

Weight with Pattern Cavity = $W_T - VOL_{pattern}(\rho_{sand})$

Figure a-8: Green sand composition



H.F. Hauff | Material usage

Given: Original design dimensions, raw stock.

Find: Amount of material that must be remove.

Solutions:

Raw stock = 1020 steel → 6x6x4 in

Vol = 144 in^3

6" 4" 6"

Volume of adapter Hub → solidworks

$VOL_{Act} = 31.31\ in^3$

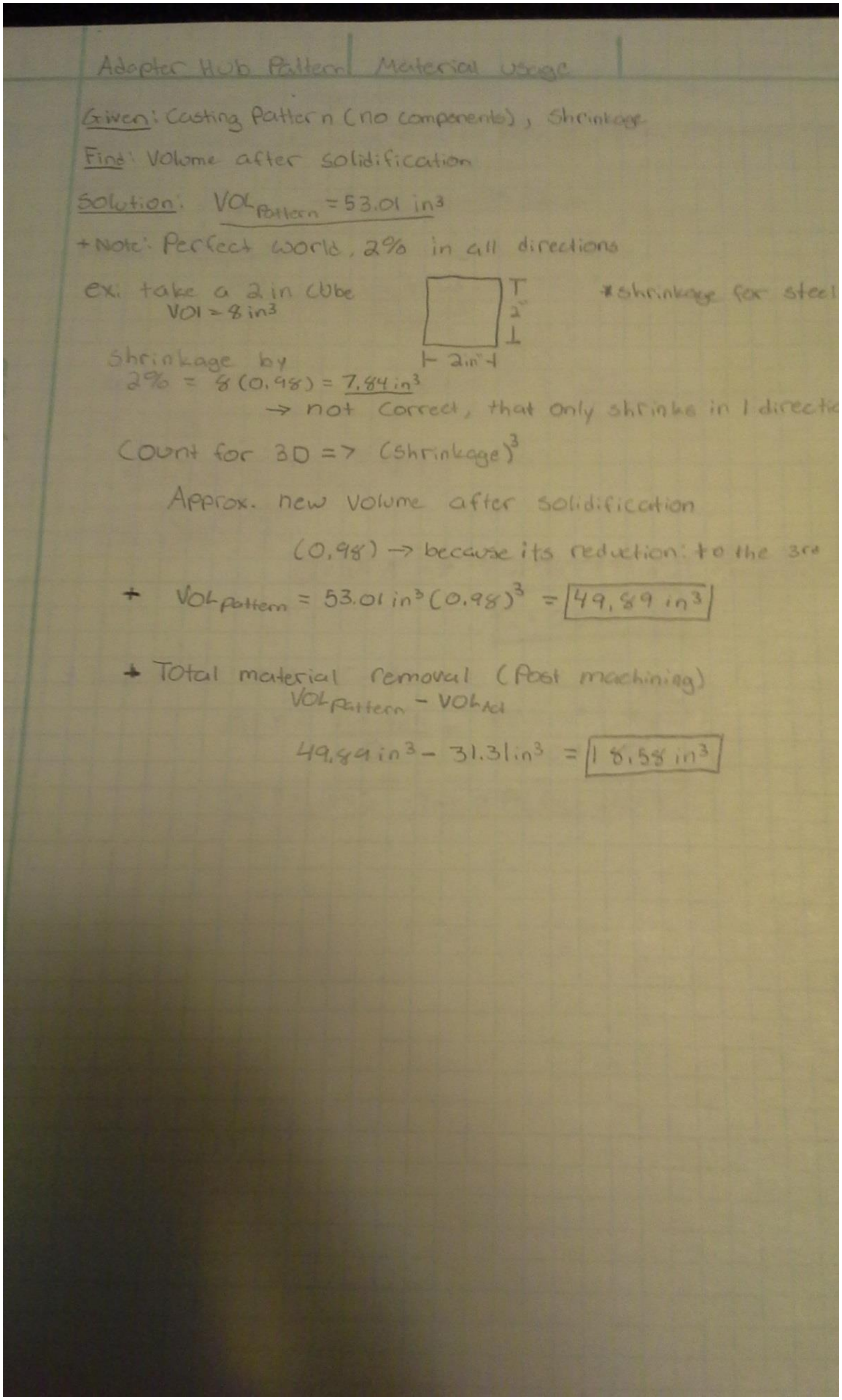
Total material removal

$VOL - VOL_{act}$

$144\ in^3 - 31.31\ in^3 = 112.69\ in^3$

112.69 in of steel goes to waste

Figure a-9: H.F. Hauff material usage



Adopter Hub Pattern | Material usage

Given: Casting Pattern (no components), Shrinkage

Find: Volume after solidification

Solution: $VOL_{Pattern} = 53.01 \text{ in}^3$

+ Note: Perfect world, 2% in all directions

ex. take a 2 in cube
$Vol = 8 \text{ in}^3$

*shrinkage for steel

2"

2in"

Shrinkage by
$2\% = 8(0.98) = 7.84 \text{ in}^3$
→ not correct, that only shrinks in 1 directio

Count for 3D => $(\text{Shrinkage})^3$

Approx. new volume after solidification

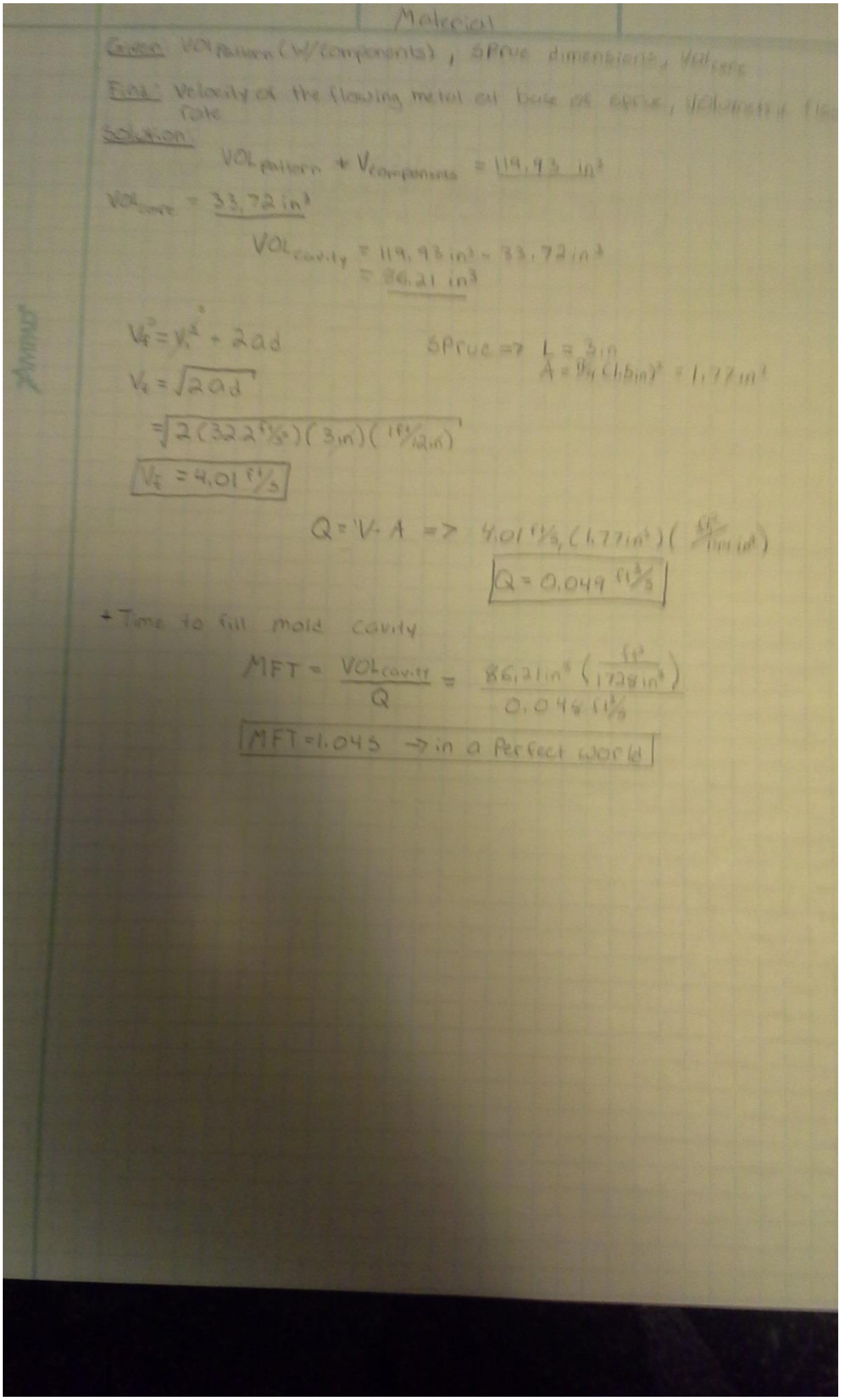
(0.98) → because its reduction: to the 3rd

+ $VOL_{pattern} = 53.01 \text{ in}^3 (0.98)^3 = \boxed{49.89 \text{ in}^3}$

+ Total material removal (Post machining)
$VOL_{Pattern} - VOL_{Act}$

$49.89 \text{ in}^3 - 31.31 \text{ in}^3 = \boxed{18.58 \text{ in}^3}$

Figure: a-10: Cast material usage & Post machining



Material

Given: $VOL_{pattern}$ (w/components), sprue dimensions, VOL_{core}

Find: Velocity of the flowing metal at base of sprue, volumetric flow rate

Solution:

$$VOL_{pattern} + V_{components} = 119.93\ in^3$$

$$VOL_{core} = 33.72\ in^3$$

$$VOL_{cavity} = 119.93\ in^3 - 33.72\ in^3 = 86.21\ in^3$$

$$V_f^2 = V_i^2 + 2ad$$

Sprue => $L = 3\ in$, $A = \frac{\pi}{4}(1.5\ in)^2 = 1.77\ in^2$

$$V_f = \sqrt{2ad}$$

$$= \sqrt{2(32.2\ ft/s^2)(3\ in)(1\ ft/12\ in)}$$

$$V_f = 4.01\ ft/s$$

$$Q = V \cdot A \Rightarrow 4.01\ ft/s\ (1.77\ in^2)\left(\frac{ft^2}{144\ in^2}\right)$$

$$Q = 0.049\ ft^3/s$$

+ Time to fill mold cavity

$$MFT = \frac{VOL_{cavity}}{Q} = \frac{86.21\ in^3\left(\frac{ft^3}{1728\ in^3}\right)}{0.048\ ft^3/s}$$

MFT = 1.04 s → in a perfect world

Figure a-11: Metal velocity and calculated pour time

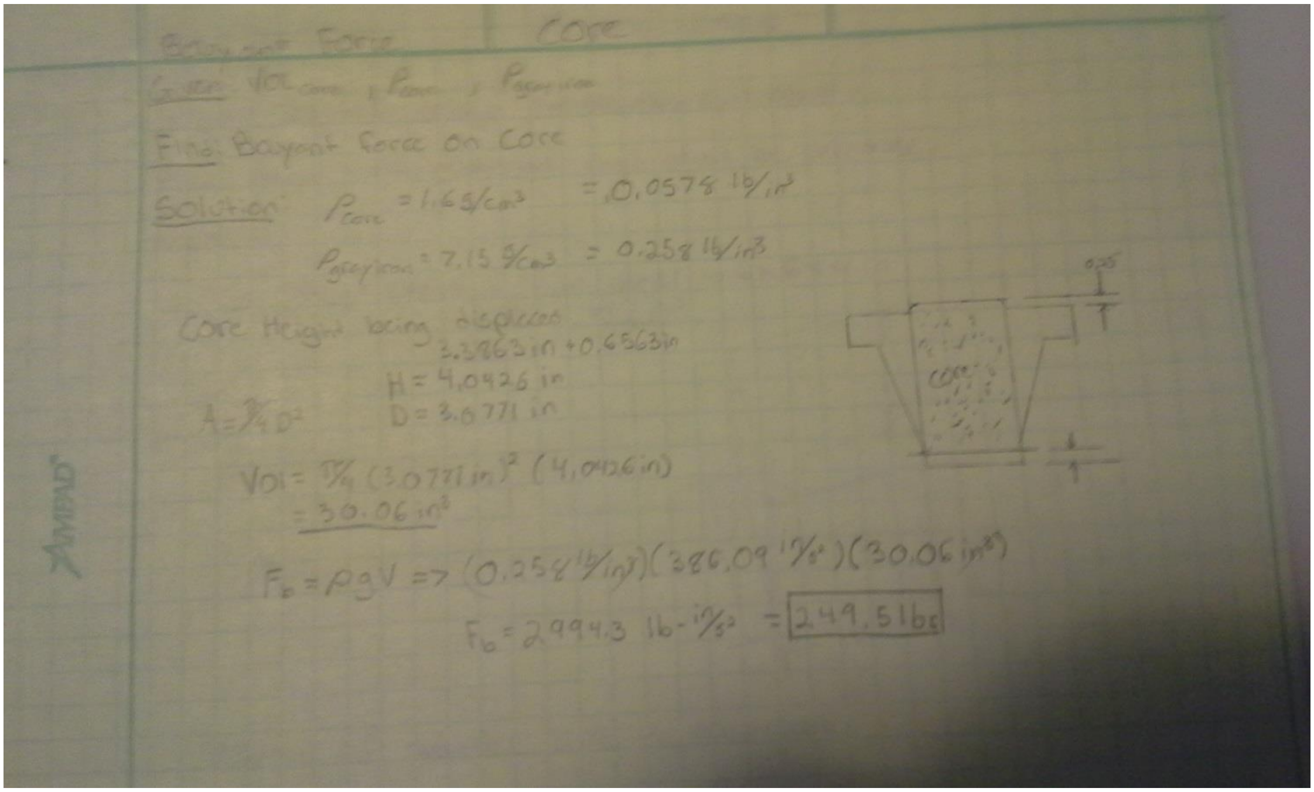


Figure a-12: Buoyant force acting on core

Appendix B – Sketches, Assembly Drawings, Part Drawings

Removed due to company disclosure contract

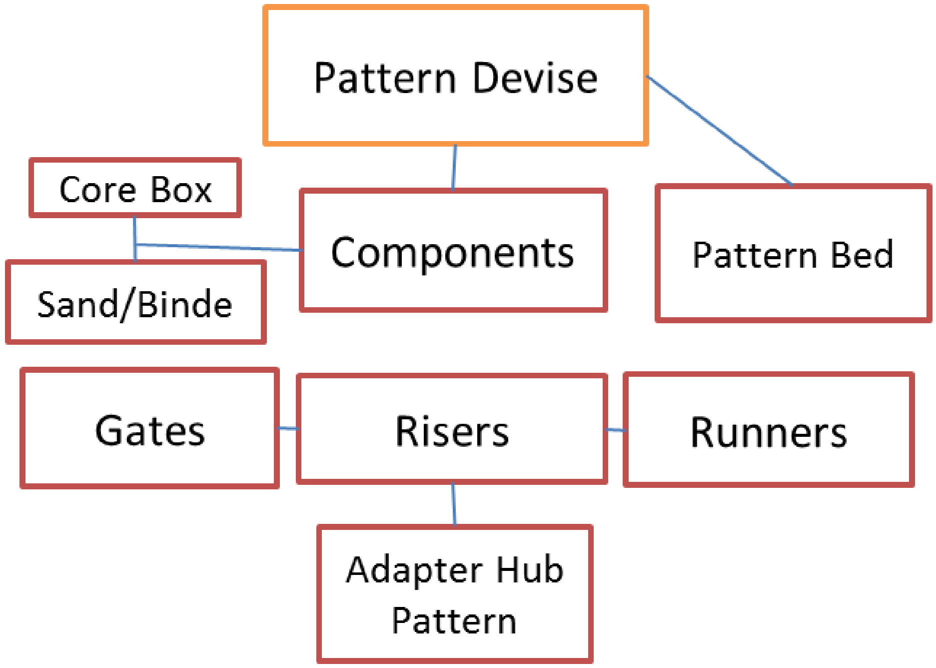


Figure b-12: Drawing Tree

Appendix C – Parts List and Budget

Parts List								
	Resource Provider	Source	Size	Material	Part Number	Quantity	Cost	Total Cost
Adapter Hub Pattern	CWU machine lab	machine lab	6x6x5.25 &6x6x3	Redboard	1-001	1	$ -	$ -
Gates	Lumber Store	In-house manufacture	Ref. Drawing	Mahogany	1-002	2	$ 2.50	$ 5.00
Runners	Lumber Store	In-house manufacture	Ref. Drawing	Mahogany	1-003	2	$ 5.00	$ 10.00
Risers	Lumber Store	In-house manufacture	Ref. Drawing	Mahogany	1-004	2	$ 7.00	$ 14.00
Pattern Bed	Lumber Store	In-house manufacture	Ref. Drawing	Wood Laminate	1-005	1	$ 10.00	$ 10.00
Flask Guide Flange	Lowes	Out-source part	1" Ø	Glavanized Iron	511-603HN	2	$ 6.84	$ 13.68
Core Box	CWU	AFS Donation	8.0 in^3	ABS Plastic	2-001	1	$ -	$ -
No-Bake Sand	CWU	CWU Foundry		Silica Sand	2-002		$ -	0
Core Binder	CWU	CWU Foundry		Sodium Silicate	2-003		$ -	0
Metal	CWU	CWU Foundry	Pattern Size	Gray Iron	2-004		$ -	0
							Material Cost =	$ 52.68

Figure c-1: Parts list for pattern devise

Appendix D – Schedule

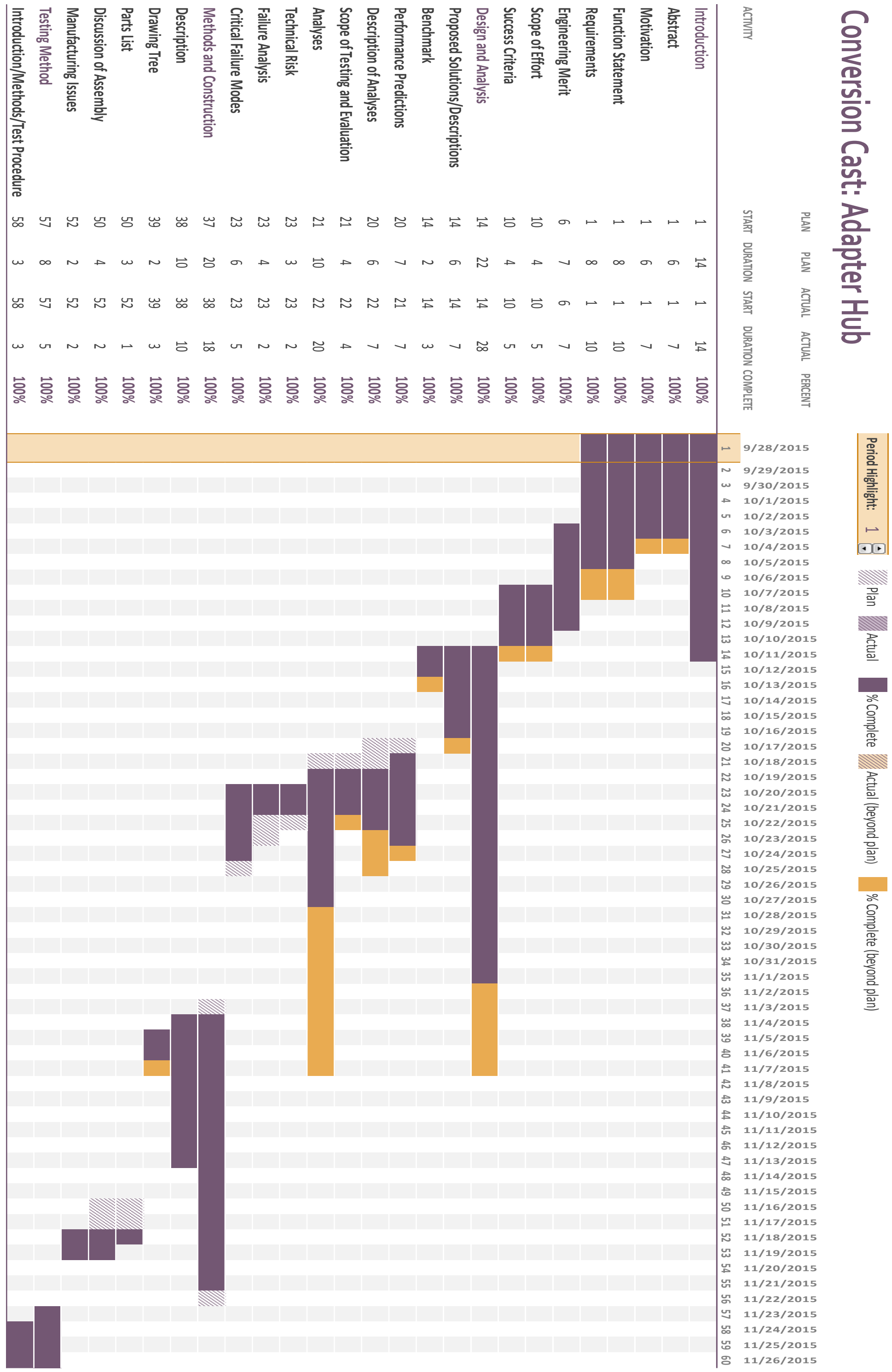
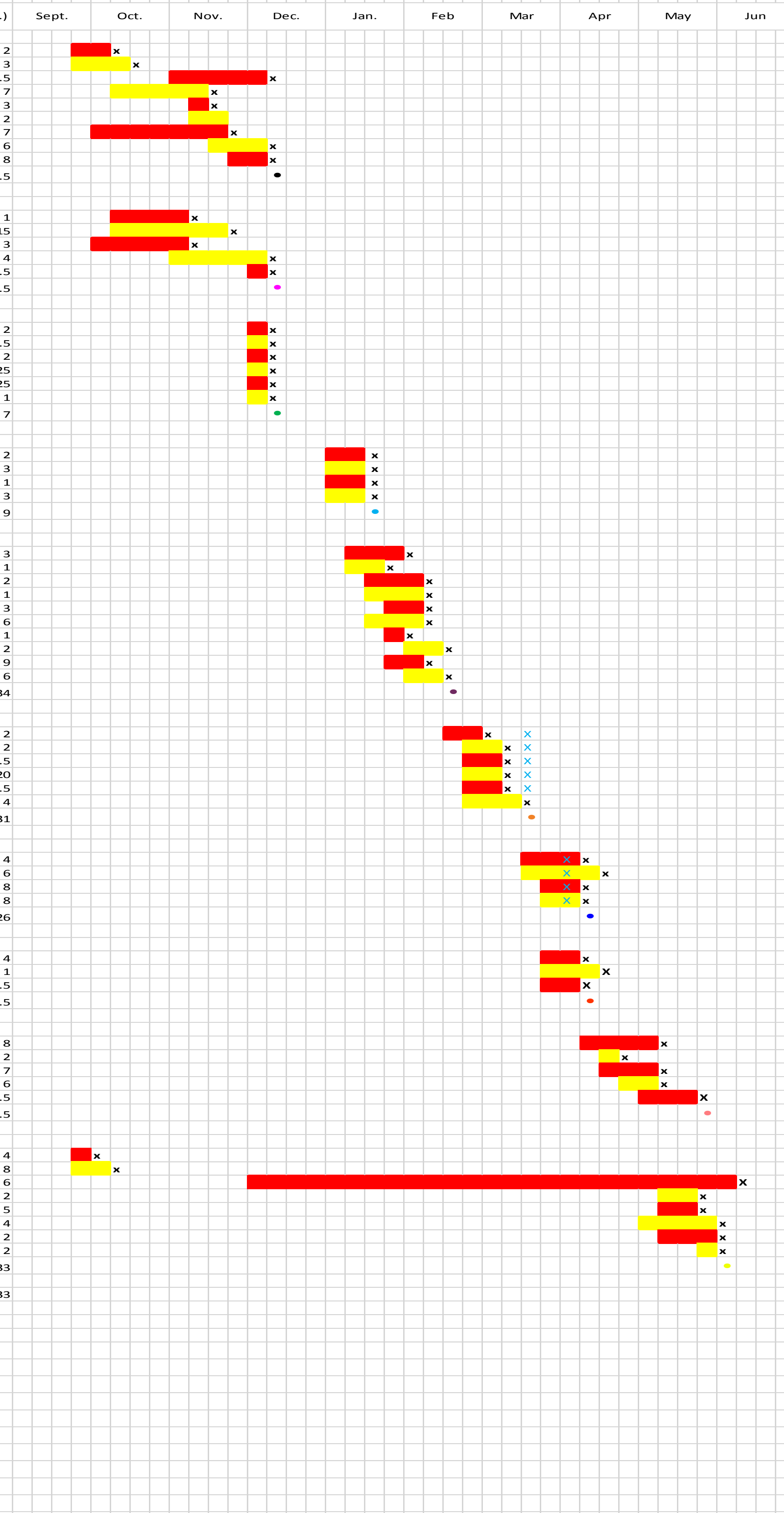


Figure d-1: Proposal Schedule

Senior Project Full Schedule
Conversion Cast Adapter Hub
ENG. TECH. : Joseph M. Coup

Task: ID		Description	Est. (hrs.)	Act. (hrs.)
1		**Proposal**		
	a.	Outline	2	2
	b.	Introduction	4	3
	c.	Methods	5	2.5
	d.	Analysis	5	7
	e.	Discussion	2	3
	f.	Parts & Budget	5	2
	g.	Drawings	10	7
	h.	Schedule	8	6
	i.	Summary & Appendix	10	8
		Total:	51	40.5
2		**Project Analysis**		
	a.	Material Research	2	1
	b.	Casting Research	10	15
	c.	Concept Sketch	4	3
	d.	CAD Drawings	5	4
	e.	Tolerance	0.5	0.5
		Total:	21.5	23.5
3		**Documentation**		
	a.	Drag Pattern	1	2
	b.	Cope Pattern	1	1.5
	c.	Gate System	1	2
	d.	Risers	1	0.25
	e.	Sprue Well	1	0.25
	f.	Core box	1	1
		Total:	6	7
4		**Proposal Modifications**		
	a.	Pattern Design	1	2
	b.	Component Design	1	3
	c.	Cost/Budget Changes	1	1
	d.	Construction Changes	1.5	3
		Total:	4.5	9
5		**Construction**		
	a.	Gather Material	2	3
	b.	Gather Assembly Equipment	1	1
	c.	Cope Pattern - Base plate	4	2
	d.	Drag Pattern - Housing	1	1
	e.	Risers	1	3
	f.	Gate System	2	6
	g.	Sprue Well	1	1
	h.	Pattern Bed	0.5	2
	i.	Core Box	10	9
	j.	Assembly	5	6
		Total:	27.5	34
6		**Pour Schedule**		
	a.	Prep Sand & Fill Flask	1	2
	b.	Melt Time	2	2
	c.	Pour Time	1	1.5
	d.	Solidification	24	20
	e.	Shake/Clean	2	1.5
	f.	Document & Photo	1	4
		Total:	31	31
7		**Casting Evaluation**		
	a.	Visual Inspections	2	4
	b.	Analyze Finish	3	6
	c.	Dimension and Tolerance	1	8
	d.	Modifications/Repair	4	8
		Total:	10	26
8		**Testing**		
	a.	Test Material	4	4
	b.	NDT Adapter Hub	4	1
	c.	Record/Spreadsheet Data	6	0.5
		Total:	14	5.5
9		**Website**		
	a.	Learn WIX	10	8
	b.	About Me	2	2
	c.	The Project	5	7
	d.	Results	5	6
	e.	Final Outcome	8	0.5
		Total:	30	23.5
10		**495 Deliverables**		
	a.	Get Report Guide	1	4
	b.	Report Outline	2	8
	c.	Write Report	30	6
	d.	Make Slide Outline	5	2
	e.	Make Video Outline	5	5
	f.	Create Film Presentation	3	4
	g.	Edit Film	2	2
	h.	Finalize Website	1	2
		Total:	49	33
		Total Project Time:	244.5	233



Deliverables

- Draft Proposal
- Analyses Modifications
- Document Modifications
- Final Proposal
- Part Construction & Assembly
- Pour Schedule
- Casting Evaluation
- Testing
- Website
- 495 Deliverables
- Completed ×

Figure d-2: Project Schedule

Appendix E – Expertise and Resources

Campbell, John. *Castings Practice the 10 Rules of Castings.* Amsterdam: Elsevier/Butterworth-Heinemann, 2004. Print.

Krulikowski, Alex, and Inc Training. *The Ultimate GD & T Pocket Guide: A Companion to the ASME Y14.5-2009 Dimensioning & Tolerancing Standard.* 2nd ed. Westland, MI: Effective Training, 2009. Print.

Schleg, Frederick P., and Frederick H. Kohloff. *Technology of Metalcasting.* Des Plaines, Ill.: American Foundry Society, 2003. Print.

"Search Results-Conversion Cast." AFS. Web. 1 Dec. 2015. <http://www.afsinc.org/search/categorizedsearchresults.cfm?keywords=conversion cast>.

Appendix F – Evaluation Sheet (Testing)

Test #1: Dimensional Analysis			
Location: CWU Mat. Lab		Time:	
Base = 5.75 inch		Height = 0.625 inch	
Avg =		Avg =	
off by =		off by =	
Pass/Fail		Pass/Fail	
Barrel H = 3.225		Barrel Dia. = 3.239	
Avg =		Avg =	
off by =		off by =	
Pass/Fail		Pass/Fail	

Figure f-1: Test spreadsheet for dimension analysis

Test #2: Temperature Tolerance Test		
Location: CWU Foundry	Time:	
Test Temp.	°F	°F
Base Plate Filled		
Base Plate flat Surface		
Barrel Empty		
Barrel Concentric		
Barrel Walls Uniform		

Figure f-2: Test spreadsheet for temperature tolerance

Appendix G – Testing Report

Introduction

The overall design of this project was to be as near net shape as possible of the adapter hub designed by H.F. Hauff Co. in Yakima Washington. The method of conversion casting is a process that should lead to reduced costs during manufacturing, reduced time required to make the component, and reduce post machining. Certain aspects of this project were required in the design of the match plate to make this project cost effective. Certain requirements had to be followed and are listed as such; final dimensions must be within 5% of adapter hub dimensions, match plate must fit in a 12X14 flask, cost of pattern must be under $100, and the devise must reduce manufacturing time by 10%. Some of these requirements were followed during the manufacturing process such as the overall cost and the size of the match plate. Dimensional analysis had to be determined after the patterned was used. Material properties vary due to the resources within the CWU foundry. There is no standard alloy that's being placed into the crucible and for that, dimensions can change due to material shrinkage. This was tested after each pour and tested with different temperatures. Metal viscosity changes due to temperature. The viscosity affects the flow of the material and can cause sand erosion or the gates can seize. This had to be tested to check the tolerance in temperature in which the match plate can operate.

Following the set schedule, the first pour was schedule for the last week of February. Due to unexpected delays, the first test pour was performed on Wednesday March 9th, the day the devise was due. Dimensional analysis was performed April 12th, which is right around it scheduled time. Temperature tolerance testing was an unexpected testing procedure that was performed on April 27th. This test actually gave the match plate a larger tolerance towards its set usage. What was actually set to be used at only 2300F now has a larger tolerance.

Method

The testing methods are quite simple. For dimensional analysis, the pattern devise must first be used. This requires using a flask and actually pouring metal. Once the mould has solidified, the gates are removed and major dimensions are tested. The tools used during this test include a caliper and a 1-2 micrometer. To increase the accuracy of the data, the burrs and edges were all wire brushed or sanded because when using iron, sand has a tendency to stick to the surface of the iron and increase dimensions. Although not substantial, it is highly recommended. Process included testing the dimensions at different locations to check consistency. Major dimensions of interests include; length, width, diameter of barrel, height of base, and total height. The recorded dimensions were averaged and compared to targeted dimension.

Temperature tolerance is a tricky procedure that is very hard to "standardize". Due to the ambient temperature of the foundry, a lot of heat transfer is occurring during each pouring cycle. With a hot crucible, the temperature is checked before the pour to get an idea of how hot the metal is while it's being poured into the flask. The temperature gets recorded and then the metal has to solidify. Because dimensions haven't changed on the match plate, the expected results are whether or not the cavity gets filled. It has already been tested that the pattern devise works and the dimensions are within specification, this test is mainly prioritized based on when can the pattern devise be in use. After solidification, the pattern gets removed from the flask and goes through a visual inspection to check if there are voids, splash, or if the metal seized. The goal is to get the adapter hub cavity completely filled.

Test Procedure

For dimensional analysis, the test procedure is as followed bellow. The location will be in the CWU foundry or CWU materials lab and the duration of time is 12 hours of heating and solidification and 1 hour of dimensional analysis.

Procedure:

1. Use the muller in the CWU foundry and mix dry green sand with approximately 6% water.
2. Grab a 12x14 flask and place match plate between the cope and drag. (drag is facing up)
3. “Dust” the drag face with walnut powder.
4. Sift sand from muller and compact repeatedly with a ram.
5. Once the drag is completely full and compacted, take scraper and remove excess sand to have a leveled face.
6. Flip the flask over so that the drag is now on the bottom and the cope is on the top.
7. Repeat steps 3-5 with the cope.
8. Pull the cope section vertically to remove the match plate.
9. Remove the match plate from the drag.
10. Look for any sand erosion on the cope and drag faces of the pattern. If sand erosion is noticeable, compact those locations with your fingers gently.
11. Once both pattern faces seem clean, start up the furnace.
12. Start the furnace by first engaging power the induction furnace and then power to the pumps.
13. Locate the vent power buttons in the foundry and engage the power.
14. Turn the glycol pumps on.
15. Place iron crucible in the induction furnace.
16. Add a few iron ingots or scrap cast iron into the crucible.
17. Turn the power gage to 15% and wait 10 minutes to warm up the furnace.
18. The foundry has a large “garage” door. Open the door to keep the foundry cool and maintain air flow.
19. While the furnace is heating up, mix approximately 3 cups of washed silica sand with 10% sodium silicate binder in the Kitchen aid located on the mixing table.
20. Once fully mixed, compact the core box with the sand.
21. The core box must be fully compacted in order to create a uniform sand core. The core should take about 5 minutes to cure.
22. Remove the sand core and place the sand core in the center of the pattern cavity of the drag section of the flask.
23. Using a piece of pipe, dig into the cope section to create a sprue. Using a casting spoon, add a taper to the top face of the cope.
24. Place the cope of the flask on top of the drag. This process requires steady hands and strength. The cope will be heavy. Alignment must be perfect so the sand core is secured between the cope and drag.
25. Turn the furnace power dial to 50%. The iron will begin to liquefy shortly.
26. Place the flask on the pouring table with a piece of wood underneath the flask to keep it level. Add weights to the top of the flask. This is to keep the molten iron from pushing the cope section up due to buoyant force.
27. Once the iron is completely molten, turn the power dial to 0% and check the temperature with the furnace thermal probe. Temperature should range between 2250°F-2400°F to pour the iron. If the temperature is closer the 2400°F, get ready to pour.
28. The pouring process takes three people so this part of the test requires two other members. Two people to pour the crucible and one person on fire watch with a shovel filled with sand.

29. Both people that will be doing the pour are required to wear a silver suite. The silver suits are extremely heat resistant and for safety purposes. Total PPE include a silver suit coat, gloves, shin guards, and a face mask.
30. Each person who is pouring has one specific task. The “dumb ends” operates the chain hoist and keeps the pouring ladle stable. The “smart end” turns the ladle to be poured. This operator will tell the chain hoist operator to change elevation of the crucible and tilt the ladle for the pouring process.
31. Once everyone is ready to pour and are wearing the proper PPE, the power of the crucible will be turned to 0%. The furnace must be lifted to expose the crucible to be linked to the chain hoist. The furnace has a built in hydraulic cylinder that lifts the furnace and can be swiveled to the side. One person that is wearing full PPE will take a scraper and remove any slag on the top of the molten iron. We don’t want any slag to be poured into the flask.
32. Once the crucible is exposed, the crucible must quickly be connected to the chain hoist and moved to the pouring table. Both people that are doing the pouring must work together and move the chain hoist connection to the crucible. Once the connection is complete, the crucible is moved to the pouring table.
33. Fire watch will stand near the pouring table while the two people controlling the crucible begin the pour. These people will continue pouring until the sprue begins to fill. This is a sign that indicates that the cavity has filled completely. Fire watch will extinguish any fires that are produced during the pour.
34. Excess metal in the crucible will be poured into a pig. Once the crucible is empty, someone must take a scraper and remove any slag that is stuck to the walls of the crucible.
35. The crucible is then placed on the furnace platform to cool. The glycol pump must remain on to cool the coils in the furnace.
36. After approximately 45 minutes, the glycol pump is then turned off and all the power is removed from the furnace.
37. Solidification and cooling takes about 10 hours. During that time, do whatever to pass the time.
38. After solidification, the cast part is removed from the flask and sand. This is done by moving the flask to the sand return and then “picked” at with any tools necessary to remove the compacted sand from the flask. Once all the sand is removed, the cast pattern should be revealed. If the adapter hub or center portion of the pattern isn’t completely filled, repeat steps 1-37 until a complete part comes out.
39. Cut the gates off of the adapter hub and place the scrap material into the iron scrap bin.
40. Take a wire brush and remove as much of the sand as possible. Some sand will stick to the casting surface so this process may take some time.
41. After most of the sand is removed, take a 6” caliper and record measurements. Critical measurements include the height of the base plate, diameter of inner barrel, total height, and diameter of the bottom cylinder (largest end of cylinder). These measurements will then be compared to the original drawings. Shrinkage of grey iron is approximately 2% depending on total material composition. Because of my design, I added 5% in case of misalignment. After a perfect pour, only 3% of the cast part must be removed from post machining. These dimensions are compared to the “general” shape of the design and see if 3% is truly the amount of material that must be removed. The required drawings will be provided for this test.

Notes: It is absolutely critical that all appropriate PPE is worn while working in the foundry, especially when operating the furnace. Neglecting the risks can result in serious injury from liquid metal. Absolutely no water is near the furnace while in operation. Water and liquid metal do not mix and can lead to explosions.

Recording dimensions is simple but test multiple locations for the same dimension to check for consistency. Do note that the surface of the cast part will be rough, so do your best to get the best measurements as possible. Try sanding some of the rough surfaces if necessary.

This test may require other precision measurement tools, so talk to Ted or Mr. Burvee for other tools. It should only require a caliper but using other tools can be used to get a more accurate measurement.
The procedure for temperature tolerance is identical to dimensional analysis. Follow steps 1-38. Time for this test takes 12 hours for heating and solidification and half hour for visual inspection. Visual inspection is a simple process that requires little to no experience. With a completed adapter hub, it's a simple comparison as to whether or not the adapter hub cavity filled all the way. A second method for a more accurate inspection is to take a caliper and record measurements

Appendix H – Testing Data

Location: CWU Mat. Lab			Time: 1.3 Hours		
Dimension Test					
Base	Req.	5.75 inch	**Height**	Req.	0.625 inch
5.826	5.827		0.751	0.785	
5.825	5.826		0.761	0.761	
5.825	5.827		0.762	0.759	
5.833	5.828		0.759	0.76	
5.832	5.830		0.753	0.818	
5.830	5.829		0.754	0.804	
5.832	5.820		0.757	0.812	
5.826	5.813		0.759	0.821	
Avg	5.827		Avg	0.7735	
off by	1.34%	**PASS**	off by	19.20%	**FAIL**
Barrel H	Req.	3.225 inch	**Barrel Ø**	Req.	3.239
3.365	3.373		2.957	2.958	
3.374	3.354		2.933	2.951	
Avg	3.3665		Avg	2.94975	
off by	4.20%	**PASS**	off by	8.93%	**PASS**

Figure h-1: Test #1 Dimensional analysis test

Location: CWU Foundry		Time: 1.5 Hours
Test Temp	2350F	2250F
Base Plate filled	pass	pass
Base plate flat surface	pass	pass
Barrel empty	Pass	Pass
Barrel concentric	pass	pass
Barrel walls filled	pass	pass

Figure h-2: Test #2 Temperature tolerance test

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Skills

- Organized and detail oriented
- Ability to work with a team
- High levels of communication
- Leadership skills
- Project management

Technical Skills

- AutoCAD, CATIA, Rhinoceros 3D, Microsoft Office, Microsoft Visio
- SOLIDWORKS certified
- Machining experience including Lathe, Milling, Drill press, and abrasive grinding
- Precision measuring
- Fabrication including Mig Welding, Plasma Cutting, Acetylene Torch Work
- Foundry work with green sand, match plates, patterns, aluminum and iron casts

Education

Olympic College *Associate in Arts, June 2011* Bremerton, WA

- 3.1 GPA

Central Washington University *BS in Mechanical Engineering Technology* Ellensburg, WA

- Scheduled to graduate June 2016
- Science Talent Expansion Program. Research on biodiesel
- ASME club member
- 3.67 GPA
- Honor Roll

Work Experience

Pabco Roofing Products, summer 2015 internship Tacoma, WA

- Machine maintenance
- Design, fabrication, and installation
- Purchasing orders
- Project manager
- Full production line layout with all major components labeled and hyperlinked

Family Pancake House, March 2011-September 2014 Bremerton, WA

- Line cook and customer service

Knights of Columbus, 2002-2012
Port Orchard, WA

- Church services, Sunday breakfast, food drives, fundraisers

Affiliations

- CWU STEP
- CWU ASME
- AFS Vice President Central Washington University Chapter