Portable Bathroom Sink Knob Turner

by

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Informative Abstract

The design of a new piece of adaptive equipment to turn round faucet knobs is necessary to help ensure that the elderly and developmentally disabled have the ability to remain as independent as possible. This piece of equipment must be portable and useful to people who have limited range of motion in their wrists, who lack fine motor skills, or who lack the strength to turn the knob.

Through interviews as well as surveys a quantified list of goals was defined. These goals included such things as limited weight, size and corrosion resistance. These goals set the parameters for the design of the piece of adaptive equipment. These goals were then added to a QFD (Quality Function Deployment) Matrix and analyzed to determine the three most important customer requirements. These requirements were: the prototype must be small and lightweight to maximize its portability, and the prototype must be able to turn knobs of various sizes and shapes.

This report details the entire design process from initial research to the detail design, the prototype fabrication and the prototype testing. During the entire process the size, weight and the types of knobs that the prototype could function with are stressed.

In order to develop the best possible knob turner several concepts were weighed objectively and the concept with the best chance of success was detailed. This concept consisted of 2 fixed grip pads with a handle attached. This concept was than analyzed for the amount of wrist motion required to use it as well as the potential weight of the prototype. This analysis proved that the prototype had the potential to be successful and a prototype was subsequently constructed of 6061-T6 aluminum and sorbothane.

The prototype was then tested to determine how much torque could be applied to a knob over a number of cycles as well as the amount of force that was necessary to turn on and off the water of a bathroom faucet.

All together the design is 6.25 inches long, 3 inches tall and 0.75 inches wide. It has a weight of .3375 pounds and can provide a torque of more than 5.5 inch-pounds. The average amount of force necessary to turn on and off the water was found to be approximately 1 pound. This design also eliminates over 20 degrees of wrist rotation necessary to turn a round knob. The cost to manufacture a prototype of this design is only $11.72.

While the analysis and testing of the prototype proved successful there were areas that could be improved on. The weight of the product could be lowered using a different material such as polycarbonate and the stability of the product could be improved with a slight reconfiguration of the grip pads.

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Introduction

Background and Research

In the experience of Liz Gerke [1], an Occupational Therapy student with two years of experience dealing with disabled patients, there are many patients who struggle with motions that most of us take for granted. These motions are those required to turn the round knobs of a conventional bathroom sink in order to wash their hands or perform any of the other tasks that require water. In order for this clientele to remain as independent as possible it is necessary to provide them with a means to turn these faucet knobs. The clientele could be anyone from an elderly person whom lacks the range of motion due to arthritis in either their hand or wrist that is required to turn the knob to persons whom have tremors due to a number of conditions. The conditions that lead to tremors also have a wide range. The most common members of this group suffer from either debilitating diseases such as Parkinson Disease, Muscular Dystrophy, Multiple Sclerosis, or Cerebral Palsy or they have suffered a traumatic brain injury, a stroke or are suffering from arthritis. A small portion of these potential clients are confined to a wheelchair, but not all of them. According to the information gathered from Occupational and Physical Therapists (Appendix A: p 23) 30% of their patients lack the ability to turn their hand, 52% of their patients lack motion in their fingers and/or thumb, and 72% of their patients are lacking in hand grip strength. Any one of these deficiencies makes it difficult for the person to turn the knob of a conventional bathroom sink.

Fig. 1: Conventional Bathroom Sink with Round Knobs

There are currently accessories which can be installed on an existing faucet to facilitate the turning of faucet knobs by a patient as described above. These are produced by a variety of accessory companies such as Able Home Aids [2] and Advance Tabco [3]. There are also some portable models from companies such as Westons [4] and Comfort House [5]. However the portable models have been discontinued. In addition to the status of their production the tap turner by Westons requires the patient to apply downward pressure in order to depress steel pins to provide grip on the faucet knob. Comfort House produces the other portable solution. This tap turner does not require strength to push it onto the tap, however this product has a short, thin handle and protrusions on the back that would make it difficult for a patient to use. Because of the differences in shape between outdoor and indoor knobs this solution is not feasible for use on indoor faucet knobs. There are other solutions that are in use in some facilities. One is the infrared technology in which the flow of water is activated by placing the patient's hands under the faucet. This technology is not yet advanced enough to control the flow of both the hot and cold water. Consequently water from a faucet with infrared technology is always cold water. Another solution used in some facilities is the "L" shaped handle. This handle eliminates the turning motion, thus reducing the motion to a simple push/pull.

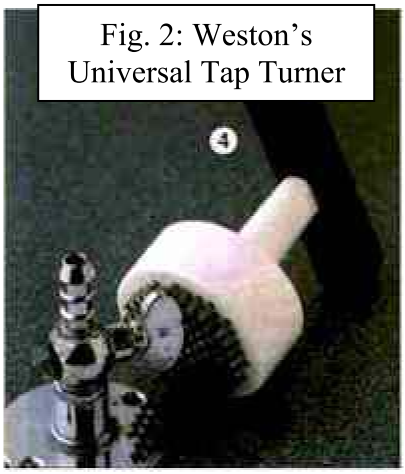


Fig. 2: Weston's Universal Tap Turner

The Americans With Disabilities Act (ADA) requires that facilities make an effort to ensure that they are accessible to those with disabilities [6], however all of the Occupational Therapists that provided information ranked public bathroom facility accessibility as poor. Most of the adaptations that the majority of facilities make focus on getting in and out of the facility itself as well as installing handicap accessible bathroom stalls. However, the faucets are usually overlooked in the refitting of a facility. The addition of any of the technology discussed above would be better than nothing; however, some public facilities are not using any of this technology. The lack of portable devices makes the use of public facilities that are not equipped with facilitating technology difficult or even impossible for this clientele. The clients can deal with this problem in a number of different ways ranging from complete avoidance of public facilities to not washing their hands in public facilities. The complete avoidance of public facilities severely limits their capacity for social interaction and this is not beneficial for their mental health. Not washing their hands in public facilities seems harmless, however it leads to an unsanitary condition. Therefore it is necessary to help this clientele utilize the sinks in public facilities.

In order to ease the suffering of this clientele certain primary objectives must be met. These objectives include the minimization of size and weight so as to make the knob turner portable in a small bag, the reduction of the amount of turning of the wrist necessary to operate a conventional bathroom sink knob, and a design so that it can accommodate a large variety of sizes and shapes in the knobs. All of these objectives, as well as others that are secondary to the success of the design are further discussed later in a section entitled *Project Objectives.*

The remainder of this report will discuss the entire design sequence beginning with the evaluation of several conceptual designs, progressing through the design selection and detail design as well as testing and manufacture and ending with recommendations. The recommendations pertain to further development of the product in order to correct any weaknesses in the overall design.

Design Solution

Design Process

The setup of a schedule (Appendix B: pp 24-27) ensures that the entire design process is proceeding in a timely manner. This schedule includes all of the steps necessary to complete the design as well as the project milestones. These necessary steps include the detail design of the handle, joint and head. In relation to these detail designs there was also analysis associated with them. This analysis included motion design as well as finite element analysis. All of these steps were required to be completed in a timely fashion before March 12, 2002. The fabrication and testing of the prototype were to be completed in a timely fashion with the goal of having a fully functional prototype as well as any applicable test data prior to Tech Expo, which occurred on the 17^{th} and 18^{th} of May, 2002.

Possible Solutions

The design solution began with brainstorming sessions define various types of possible solutions. The ideas were then sketched by hand to give a better understanding of the potential solutions. The best of the potential solutions were then drawn on AutoCAD.

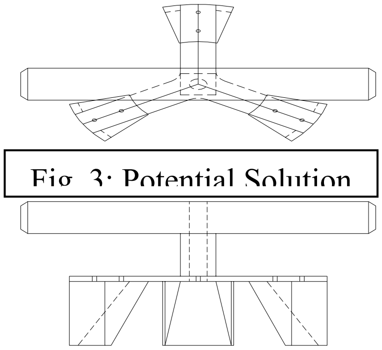


Fig. 3: Potential Solution

The first possible solution is based on an antique jar opener. The opener is designed so that as the handle is rotated the jaws on the ends close and apply the necessary force to grip the jar lid and allow the lid to be removed. The jar opener does not allow for the putting the lid back on the jar. The solution for the previously defined problem would involve 3 jaws equally spaced on a circle. The jaws would open and close via a mechanism that operates with the turning of the handle. This solution would not allow for a definite change of hand motion and it would not lessen the force required to turn the know. This solution would alleviate the problem with hand strength.

The second possible solution consists of a conical section that fits over the knob and a long handle to turn it with. This is the simplest solution. The conical section would have to have a contour on the inside of the conical section to afford it the proper amount of grip to turn the knob. This solution would require force to keep it from coming off of the knob, however it does change the required hand motion and would lessen the amount of force required to turn the knob.

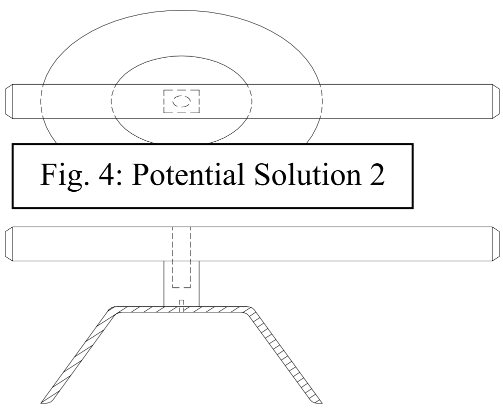


Fig. 4: Potential Solution 2

The third possible solution works on the same basis as the first solution, however it incorporates a longer handle. The longer handle would reduce the amount of force required to turn the handle as well as change the required hand motion. The drawback is that the longer handle would increase the size of the prototype and introduce a moment that

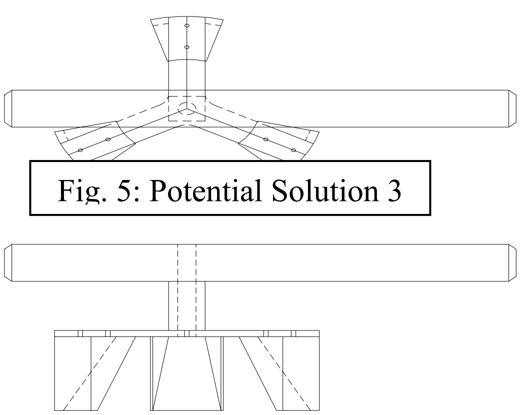


Fig. 5: Potential Solution 3

would require some extra force by the user to maintain the contact with the knob.

The fourth possible solution is similar to solutions one and three, however there are only two jaws located 180 degrees from each other and the motion required to actuate the jaws was changed from rotation to a linear motion. This solution has a slimmer

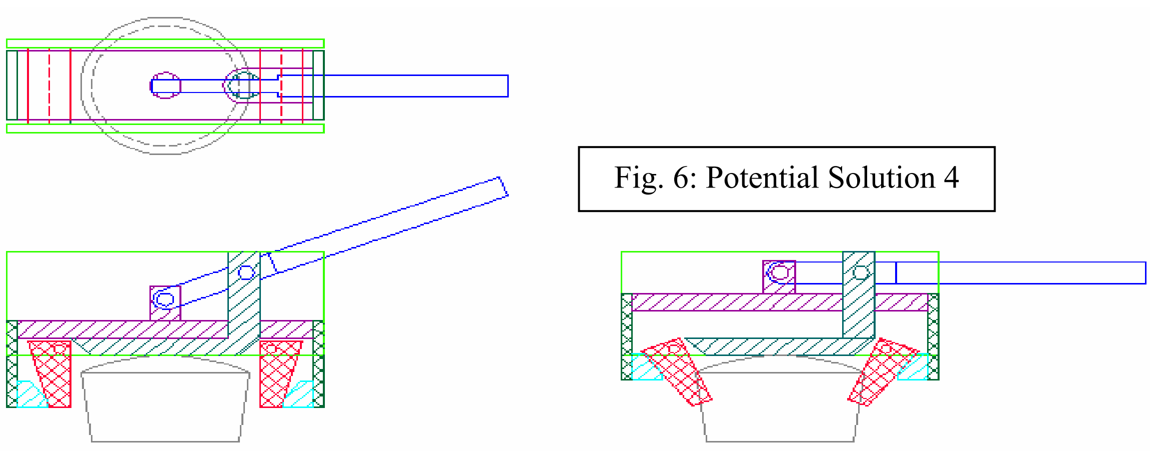


Fig. 6: Potential Solution 4

profile than the rest of solutions, however the moment that would be generated during the turning of the knob might be enough to cause the device to slip off of the knob. In addition to this the linear actuation of the mechanism could cause some problems with pinch points.

The fifth possible works on a principle similar to a product called the "Gator Grip". The pins that are in contact with the knob depress, leaving those in contact with the outside surface extended. The extended pins are in contact with the contours of the knob, thus creating a potential for turning force to be

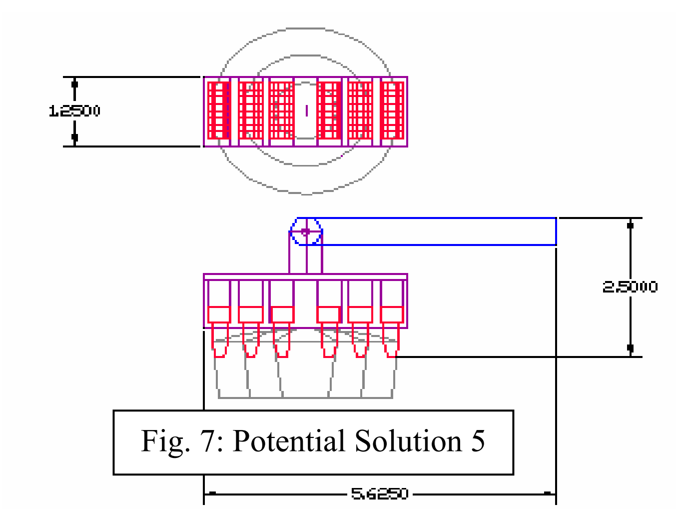


Fig. 7: Potential Solution 5

applied. This design is slightly smaller than the previous designs, however the matrix of pins would add weight and bulk to the head assembly.

The sixth possible design is similar in principle to solution number 4. The difference is that the moving parts have been eliminated, thus placing the force to place it on the person using it. This design is smaller than the previous designs, but no

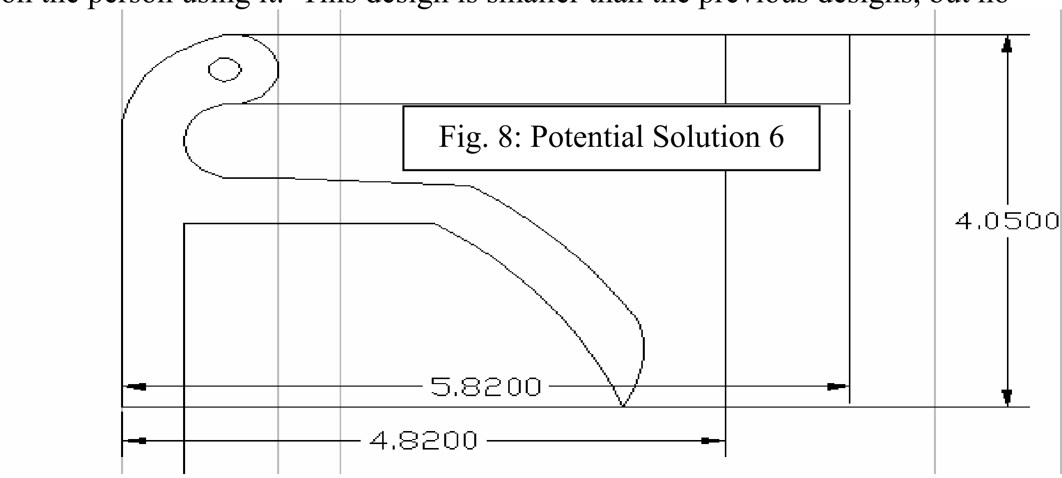
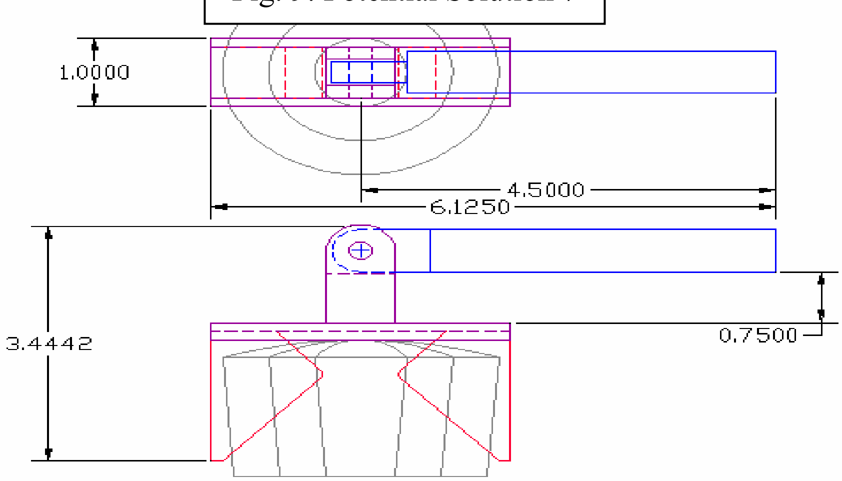


Fig. 8: Potential Solution 6

appreciable gains have been made in any characteristic other than size.

The seventh possible design is similar in principle to solution number 4. The size is similar, however the moving parts have been eliminated. The solution is similar to design 6,

Fig. 9: Potential Solution 7



however the shape of the head and grip pads has been modified to provide an easier and ore sure grip on the knob. This solution is also capable of performing on any knob that falls within the size range of 3.5 inches down to 2 inches, regardless of the contour of the knob.

Desirable Features

In order to select the best design it was necessary to determine what features are the most important on the prototype. This was accomplished using the House of Quality (Appendix C: p 28). These most important design characteristics are as follows: Mechanism Design, Handle Length, Design for Assembly, and Head Design. These correspond to the desire of the customer to have a small, lightweight prototype that is portable and facilitates the turning of a faucet knob.

Project Objectives

Based on the House of Quality analysis there were several factors that were determined to be key to the success of the design. These factors include weight and size as well as maintenance, force necessary for operation, safety and durability. Through further discussions with Liz Gerke the numeric values for the design characteristics were found. Through these discussions it was determined that the weight of the design should be less than 2 pounds and it should be no larger than 8 inches long by 5 inches tall by 2 inches wide. These values constitute the limit of what was determined to be portable. The maintenance objective was designed so that an Occupational Therapist could perform the maintenance with household tools. The force necessary for the operation of the knob is desired to be less than three pounds. This was defined by the amount of force that the patients can successfully work with. The safety was defined as the elimination of all possible pinch points. The durability was defined as being functional for use through

5000 cycles without a 20% decrease in the potential gripping force. These values as well as the characteristics from the House of Quality make up the Proof of Design Statement (Appendix D: p 29). This statement is all of the information that will be used to determine if the design is a success.

Weighted Objective Selection Method

All of the sketches of the possible solutions were submitted to Liz Gerke for analysis. She gave each a score based in all of the required criteria. She was only asked to score the possible solutions based on the weight, size, handle size, turning force, placement, security on the knob, interference, pinch points, maintenance, cleaning, portability, and appearance. In this case solution number 7 is the best solution. This was determined based on the summation of all of the weighted scores that each design received. Solution number 7 was determined to be the best because the total score for the design was the highest. This design scored the highest because of the scores that it received in the categories of weight, size, pinch point elimination, portability and universal fit. Solution 7 did not score the highest in all of those categories but when combined they produced the highest score out of the potential designs. The entire solution matrix is shown in Appendix E on page 30.

Detail Design

Handle

The design of the handle began be specifying a minimum length for gripping. This length was found to be 4 inches through interviews with Liz Gerke. As seen in the Assembly Drawing in Appendix F, the handle for solution 7 has a 0.69 inch clearance between itself and the body of the solution. The handle itself (Appendix F: pp 31-36) was designed to be manufactured of 0.75 inch diameter 6061-T6 aluminum. This aluminum alloy has high strength as well as corrosion resistance. The portion of the handle that was designed for the patient to grip was designed to be coated with a rubberizing compound. The addition of the rubberizing compound creates a softer finish and allow for a better grip using less force. The joint where the handle comes into contact with the body there is a built in stop which was designed to prevent the handle from collapsing down and creating a potential pinch point. In addition to this the end of the handle was designed to rest inside body and the end will be rounded to eliminate the other potential pinch points.

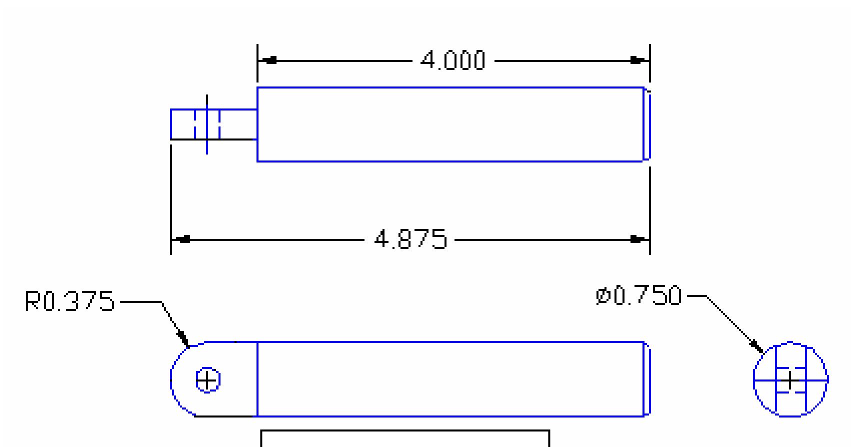


Fig. 10: Handle

Joint

The top portion of the joint was designed to complement the handle so as to eliminate any possible pinch points. The rounded top, when combined with the rounded end of the handle eliminates the pinch point that was possible during the rotation of the handle. The joint also mates with the handle in a fashion such as to provide a stop. This stop prevents the handle from going down into a position less than horizontal, in relation to the head of the design, thus

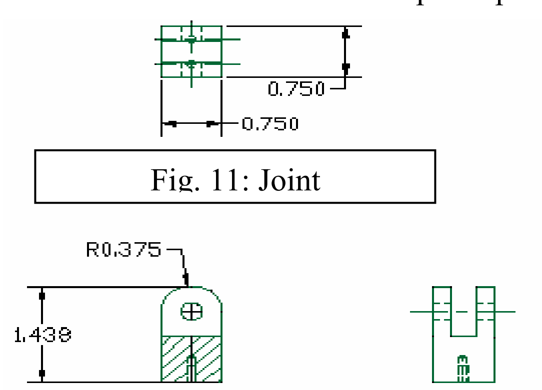


Fig. 11: Joint

eliminating the pinch point there as well. The joint design is shown in Appendix F.

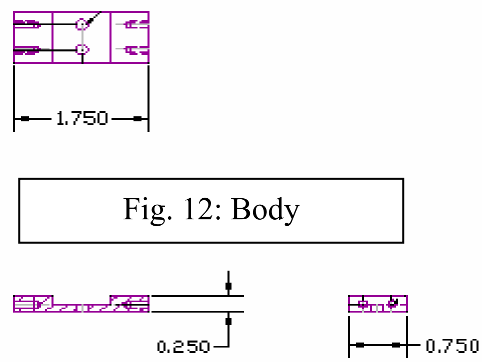


Fig. 12: Body

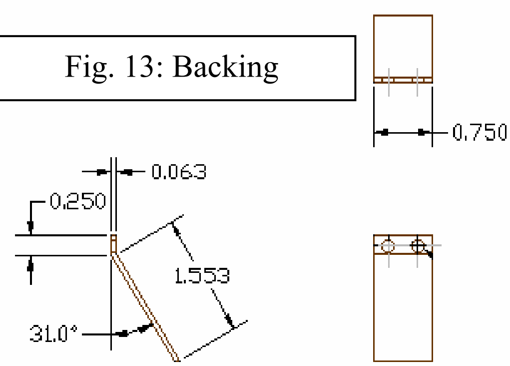
The body the joint was designed to bring together the top of the joint and hold it steady as well as provide an attachment point for the heads. The attachments were designed to be accomplished using #4-40 ¼ long zinc platted screws.

The joint was divided into two different sections to limit the amount of machining as well as to limit the cost of the material.

Head

The head was designed to consist of two identical grip pads. The grip pads were designed to be fabricated from sheets of polyurethane. These pads are then stuck to a 1/16 piece of aluminum (Appendix F: pp 31-36) that is bent so as to accommodate the range of knobs required. The polyurethane durometer was a major consideration during the design. The hardness of the polyurethane, known as the durometer, was a major consideration during the design. The polyurethane that was chosen had a durometer reading of 50 on the Shore Oo scale. This scale is the softest durometer scale that houses materials that are as soft as a piece of chewing gum. This material has the ability to conform to nearly any contour, is extremely abrasion resistant, repels water, and can be cut using such tools as a scissors or it can be wire-cut. The ability to cut the

Fig. 13: Backing



material using a scissors will be important because the material is sold in 4 inch square sheets that are 3/8 of an inch thick. In order use this material it will be necessary to adhere the pad to the backing. This necessitated the use of a special adhesive known as "Pliobond". This adhesive is specially formulated for polyurethane and will also adhere to the aluminum of the backing.

The connection of the pads to the joint was designed to be accomplished using screws that run through the aluminum backing and into the joint.

Assembly

The handle connection to the joint was designed to be accomplished with a spring pin. Spring pins are hollow pins that have a groove cut into them. This groove allows them to be inserted into a nominal hole and form a press fit. Because of the design the removal and re-use of the pins is possible. The pins are constructed of zinc-platted steel for their strength and corrosion resistance.

All of the other connections requiring fasteners were designed to be connected using #4-40 ¼ long screws. These screws will be constructed of the same material as the spring pins.

Analysis

Finite Element Analysis

In order to prove the design of the grip pads a Finite Element Analysis (Appendix G: pp 37-40) was performed. This analysis was performed on the aluminum backing. The purpose of the analysis was to show the amount of bending in the aluminum that would take place during a normal operation as well as an impact loading.

The loading conditions for the normal loading consisted of a two pound force into the .75 inch face of the part and a twelve pound force into the .0625 inch edge of the part trying to twist it. The two pound force is the result of the patient pushing the device onto the knob. Two pounds is the maximum that they can work with. The twelve pound load is 4.25 times the maximum twisting load that the patient can apply using the device. The analysis showed that the stress in the aluminum of 34,200 psi does not exceed the yield strength of 40,000 psi for 6061-T6 Aluminum [7] during normal operation.

The impact loading conditions consisted of five pounds into the .75 inch face of the part. This condition represents the amount of force generated on the edge if the device was dropped from a height of approximately 12.5 feet. The resulting stress and deformation of 32,000 psi is less than the yield strength of the material.

Weight Analysis

In order to qualify 6061-T6 Aluminum as a good choice for the joint and the handle a weight analysis was performed. This consisted of determining the total volume of metal in the design and then determining the weight from the density. The volume was determined by dividing the parts into small, logic geometries and then summing the volumes of the geometries. This volume was then multiplied by the density of the aluminum. The density of the aluminum is 0.098 lb/in^3 [7]. Through these calculations it was determined that the aluminum weighs .32 pounds. The grip pad weight analysis was then performed in the same manner. The density of the polyurethane is 0.033 lb/in^3. With the addition of the weight of the grip pads the total weight is only .3375 pounds. This weight is small enough to be easily transported and it not cause any problems.

Motion Analysis

The motion analysis that was performed was composed of analyzing the range of motion that a human wrist rotates through in the process of turning on a faucet using a round knob and a using a 4.5 inch lever. The results of the testing were then broken down into male and female categories for further investigation. It was determined that the use of a lever clearly changes the range of motion necessary.

	3 Inch Diameter Round Knob		4.5 Inch Lever	
Gender	Beginning Pos.	End Pos.	Beginning Pos.	End Pos.
Male	-15 deg.	30 deg.	0 deg.	20 deg.
Female	-15 deg.	20 deg.	0 deg.	15 deg.
Total Avg.	40 deg.		17.5 deg.	

The chart shows that the amount of rotation necessary decreases significantly when a 4.5 inch lever is used. This decrease in the necessary range of motion quantifies the fact that using a lever makes turning a knob easier for those who have limited range of motion in their wrist or a decreased fine motor control ability.

Parts List & Budget

The prototype was designed to be manufactured using various materials. These materials include 6061-T6 Aluminum, durometer 50 (Shore Oo) polyurethane, and zinc-platted steel. All of these materials provide the required strengths to perform as well as high corrosion resistance. In addition to the materials it was also necessary to comprise a budget for the prototype (Appendix H: p 41) as well as the proposed budget. These budgets both reflect the cost of the raw materials and the labor that are required to produce one part. The total cost of the prototype is $11.87. When the prototype is approved and production begins the materials will shift from aluminum to polycarbonate. The total cost of the polycarbonate parts including the mold and the material totals $0.50

per part. This drops the cost of the production unit to $3.73. Both the prototype and production part manufacturing budgets fall well under the proposed budget of $20.00.

Fabrication and Testing

Outsource Fabrication

Three of the components (Handle, Joint and Body) necessary for the construction of a functional prototype were submitted to RB Tooling and Manufacturing for manufacture. These components were selected for outsourcing because of the complexity of portions of the components. The largest considerations in the decision to outsourcing were the manufacture of accurate rounds on the Handle and the Joint and the deep slot on the Joint. The Body was submitted in order to assure an accurate slot which is required for a solid assembly.

Contact was made with RB Tooling and Manufacture on the 1st of April and a quote was received on the 3rd. The quote was for 1 each of the required components as discussed above. The price for the three components was $225.00. This price was due to the single run nature of the quote. For this price it is possible to produce 24 of each part. The set-up time for the components was quoted as 1.5 hours for the parts with the run time being negligible. The parts were available for pick up within the 1-2 week lead time specified in the quote.

In-house Fabrication

The remainder of the necessary components were manufactured in a small machine shop at home. In order to accurately bend the sheet metal to the desired angle it was necessary to design a simple bending fixture (Appendix I: pp 42-49). This bending fixture consisted of 6061-T6 aluminum bar with the bend being accomplished using a simple hammer and anvil setup with the bend location determined using the distance from the base to the bottom of the hammer and anvil set.

The 50 durometer polyurethane, marketed under the name of sorbothane, necessary to create the grip on a knob was ordered in 4 inch square sheet. The sheet was wider and longer than necessary. This material was cut with a scissors to the required shape and size.

Prototype Assembly

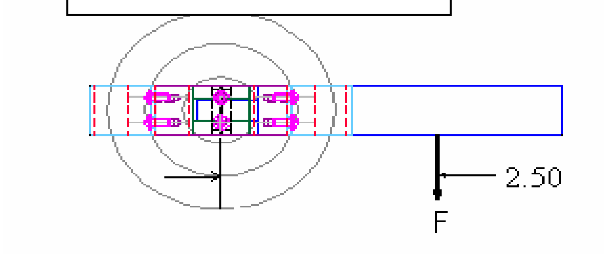
The majority of the prototype assembly was accomplished using a small claw hammer and a standard head screwdriver. The grip pads were attached to the backing using a special adhesive known as "Pliobond". The entire assembly, including the adhesion of the grip pads to the backing took approximately ¼ of an hour. In order for the grip pads to securely adhere to the backing they were left undisturbed for a full day.

Testing

In accordance with the Proof of Design Criteria that the design should be functional over 5,000 uses with less than a 20% loss in the gripping force the design was tested.

In order to determine if the prototype of the Portable Knob Turner was a success testing the prototype was necessary. The testing consisted of a fixed knob, the prototype, a digital scale and a 2 pound weight. The digital scale was fixed in a position 2.5 inches from the pivot point of the handle and force will be applied to the knob. The amount of force that can be applied in a horizontal direction

Fig. 14: Testing Diagram



before the prototype begins to slip will then be recorded and the testing will begin again. For a detailed description of the testing process see Appendix J on page 50. This cycle will be repeated for 5000 cycles. A single cycle will consist of placing the prototype, applying force and removing the prototype.

Testing Results

The results of the testing (Appendix K: p 51) showed that the amount of force exerted by the knob during the testing actually increased from 5.47 in-lbs of torque to a maximum of 6.25 in-lbs then gradually decreased until near the end of the testing where the force dropped off sharply to 5.55 in-lbs.

The increase exhibited as the prototype was used was desirable and beneficial to the function of the prototype. This increase was not permanent. As the testing continued the pads began to show a slight decline in the amount of force. This decline eventually reached a plateau where it held until a sharp decrease in the force was measured. This sharp decrease occurred near the end of the testing showing that the grip pad was reaching the end of its useful life.

During the sharp decrease the prototype became wet. This wetting led to a sharp, but not permanent decrease in the functional force that could be applied. The duration of the decrease was approximately 3 cycles. After the three cycles the force had returned to the level where it was prior to the wetting of the prototype.

This results of this test shows that the prototype exceeds the mandatory levels as given by the Proof of Design Agreement as the comparison of the initial torque (5.47 in-lbs) and the final torque (5.55 in-lbs) demonstrates a 1.4% increase in the amount of torque.

In addition to this testing the amount of force necessary to operate a knob. The results of this testing show that the average amount of force required to turn on a faucet was approximately 3.23 in-lbs of torque and the force to turn off the faucet was approximately 2.19 in-lbs of torque.

This testing demonstrates that the prototype was capable of turning a faucet knob with a factor of safety of approximately 2.

Prototype Wear

At the end of the testing the pads were examined and checked for wear. The wear that was observable consisted of a slight discoloration due to minor marring on the surface of the grip pads where the pad contacted the knob.

Therapist Input

The prototype was submitted to Liz Gerke for her consideration. Her comments were sought specifically in the areas of size, function and maintenance ease.

Her comments included that the size and weight were appropriate to ensure the portability of the product and not hinder the function of the client in any way. The function was good with the exception of slight wobbling on the knob during operation. The maintenance of the prototype was rated as excellent with the time to perform the annual maintenance as less than 2 minutes.

Prototype Results and Recommendations

Proof of Design Results

The results of both the design and the testing were compared to the required prototype characteristics that were set forth in the *Project Objectives* section. During this comparison the prototype met or exceeded all of the characteristic requirements. The characteristics that performed the best when compared to the *Proof of Design Statement* (Appendix D: p 29) were the weight, size and the durability. The *Proof of Design Statement* specified that the prototype weigh less than 2 pounds, be less than 8 inches long, 5 inches tall and 2 inches wide and be functional over 5000 uses with a decline in gripping force of less than 20%. According to the *Proof of Design Solution* (Appendix L: pp 52-53) the prototype weighs .34 pounds, is 6.25 inches long, 3 inches tall and 0.75 inches wide. In addition the prototype is functional over 5000 uses and exhibited a gain in the gripping force of 1.4%. Also included in the *Proof of Design Solution* are instructions for the assembly and maintenance of the prototype.

Recommendations

While the prototype is functional there are a three areas in which the prototype can be improved upon if this concept is to be produced for distribution. The first area that should be explored is the material which composes the handle, body, joint and grip pad backings. Currently these parts are fabricated of aluminum which lends itself to the prototype well because it is machinable, corrosion resistant and lightweight. Construction of these parts of a different material such as injection molded polycarbonate would decrease the weight of the product and would not have a detrimental effect on the rest of the properties. In addition a material change would lower the cost to manufacture the product, thus lowering the price that consumers would pay.

The second area which might be improved is grip pad material. While the sorbothane is able to conform to the contours of the knob and provide gripping force to turn a faucet knob the material is only sold in sheet form and is not adhesive backed. A change of material may provide easier fabrication of the grip pads while not impeding the functionality of the grip pads.

The final area that could be improved upon is the design of the grip pads and/or the shape of the body. A change in this area would be necessary to provide a more stable product when applied to the handle. A change in this area would increase the size, but would provide an easier turning solution to those who need it.

Works Cited

1. Gerke, Liz. 2nd Year Cincinnati State OTA Student . Personal Interview. 19 Sept. 2001.
2. "Home Aides," Able Home Aides Online Catalog, September 2001 October 9, 2001 http://www.universalc.com/hlm.htm
3. "New Products," Advance Tabco Online Catalog, September 2001 October 9, 2001 http://www.advancetabco.com/newproducts.htm
4. "Kitchen: Tap Turners," Westons Internet Catalog, September 2001 October 16, 2001 http://www.westons.com/hh98 12 1.htm
5. "Tap Turner," Comfort House Online Catalog, September 2001 October 16, 2001 http://www.comforthouse.com/comfort/taptur.html
6. "ADA Statute" Americans With Disabilities Act Statute, August 1998 November 5, 2001 http://janweb.icdi.wvi.edu/kinder/pages/ada_statute.htm
7. ASM Handbook Committee, eds. ASM Handbook: Material Selection and Design. Vol. 20. Materials Park, OH: ASM, 1997.

Bibliography

1. "Home Aides," Able Home Aides Online Catalog, September 2001
   October 9, 2001 http://www.universalc.com/hlm.htm
2. "New Products," Advance Tabco Online Catalog, September 2001
   October 9, 2001 http://www.advancetabco.com/newproducts.htm
3. "Kitchen: Tap Turners," Westons Internet Catalog, September 2001
   October 16, 2001 http://www.westons.com/hh98 12 1.htm
4. "Tap Turner," Comfort House Online Catalog, September 2001
   October 16, 2001 http://www.comforthouse.com/comfort/taptur.html
5. "ADA Statute" Americans With Disabilities Act Statute, August 1998
   November 5, 2001 http://janweb.icdi.wvi.edu/kinder/pages/ada_statute.htm
6. Gerke, Liz. Personal Interview. 19 Sept. 2001.
7. Gerke, Liz. Personal Interview. 24 Oct. 2001.
8. Gerke, Susan. Personal Interview. 25 Sept. 2001.
9. Askeland, Donald R., The Science and Engineering of Materials. 3rd ed.
   Boston: PWS Publishing Co., 1994.
10. ASM Handbook Committee, eds. ASM Handbook: Material Selection and Design. Vol. 20. Materials Park, OH: ASM, 1997.
11. Oberg, Erik, et al. Machinery's Handbook. 26th ed.
    New York: Industrial Press Inc., 2000
12. Dieter, George E. Engineering Design: A Materials and Processing Approach.
    3rd ed. Boston: McGraw-Hill Higher Education, 2000

Appendix A
Survey Form and Results

Occupation: 2 PT and 4 OT

1. What percentage of your patients have problems with radial/ulna deviation? 30%

2. What percentage of your patients have problems with hand strength? 72%

3. What percentage of your patients lack hand ROM? 52%

4. How many times per month do your patients go on fieldtrips? 0

5. How would you rate current public bathroom facilities, specifically the faucets, with regard to handicap accessibility?

Excellent	Good	Satisfactory	Poor	Undecided
1	0	1	4	0

6. How much would you be willing to spend on a product to make using public sinks easier?

   0 – 10 dollars 2   20 – 30 dollars 3

   10 - 20 dollars 0   30 + dollars 1

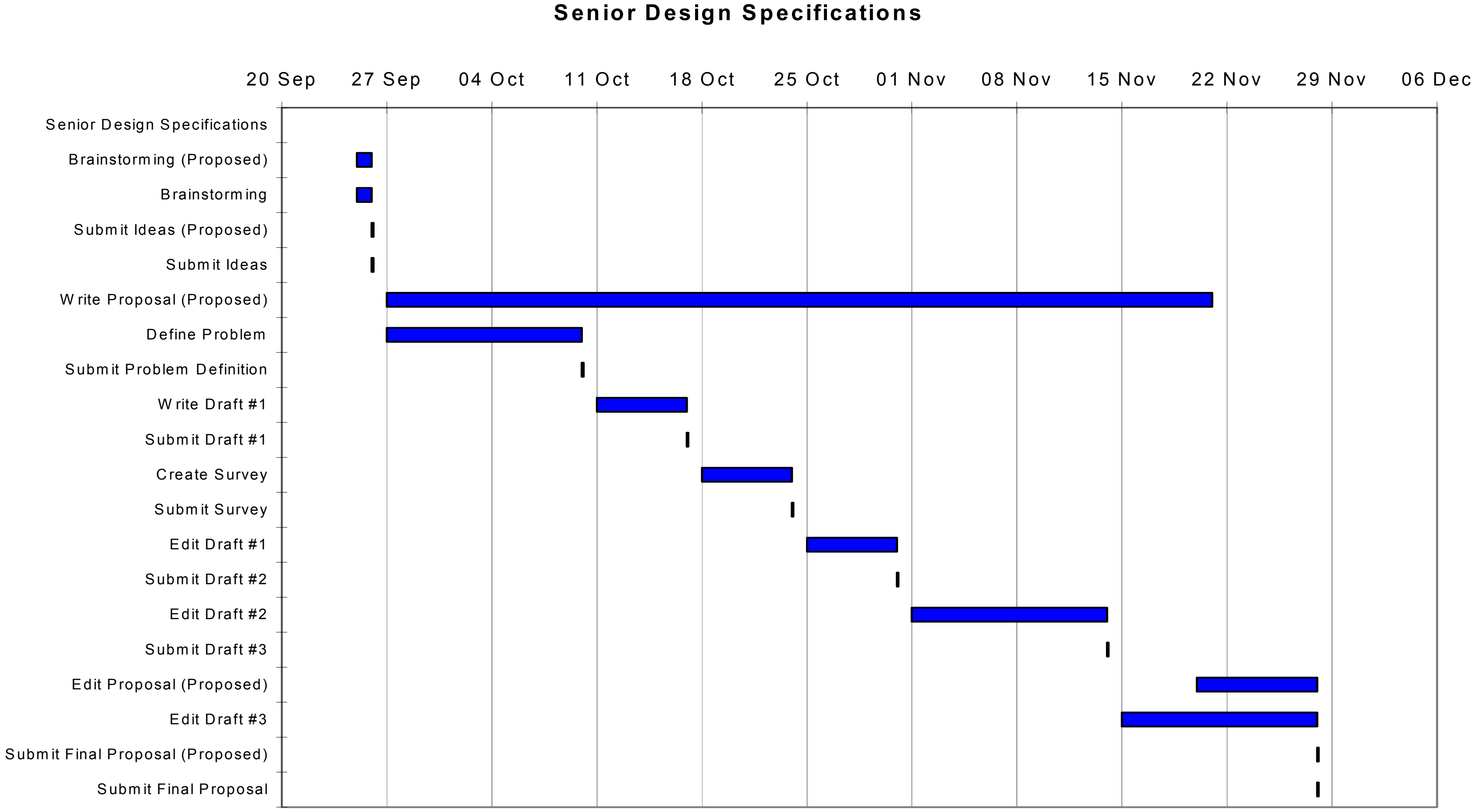
7. Please rate the following based on the order of importance in a product to make using public sinks easier.

	1's	2's	3's	4's	5's	AVG
____Appearance	0	3	0	1	2	4
____Comfort while using	4	1	1	0	0	1.8
____Product Weight	0	1	0	3	2	4.8
____Ease of Transportation	1	1	1	1	2	4
____Price	1	0	4	1	0	3.4

8. Comments?

None Received

Appendix B
Schedule



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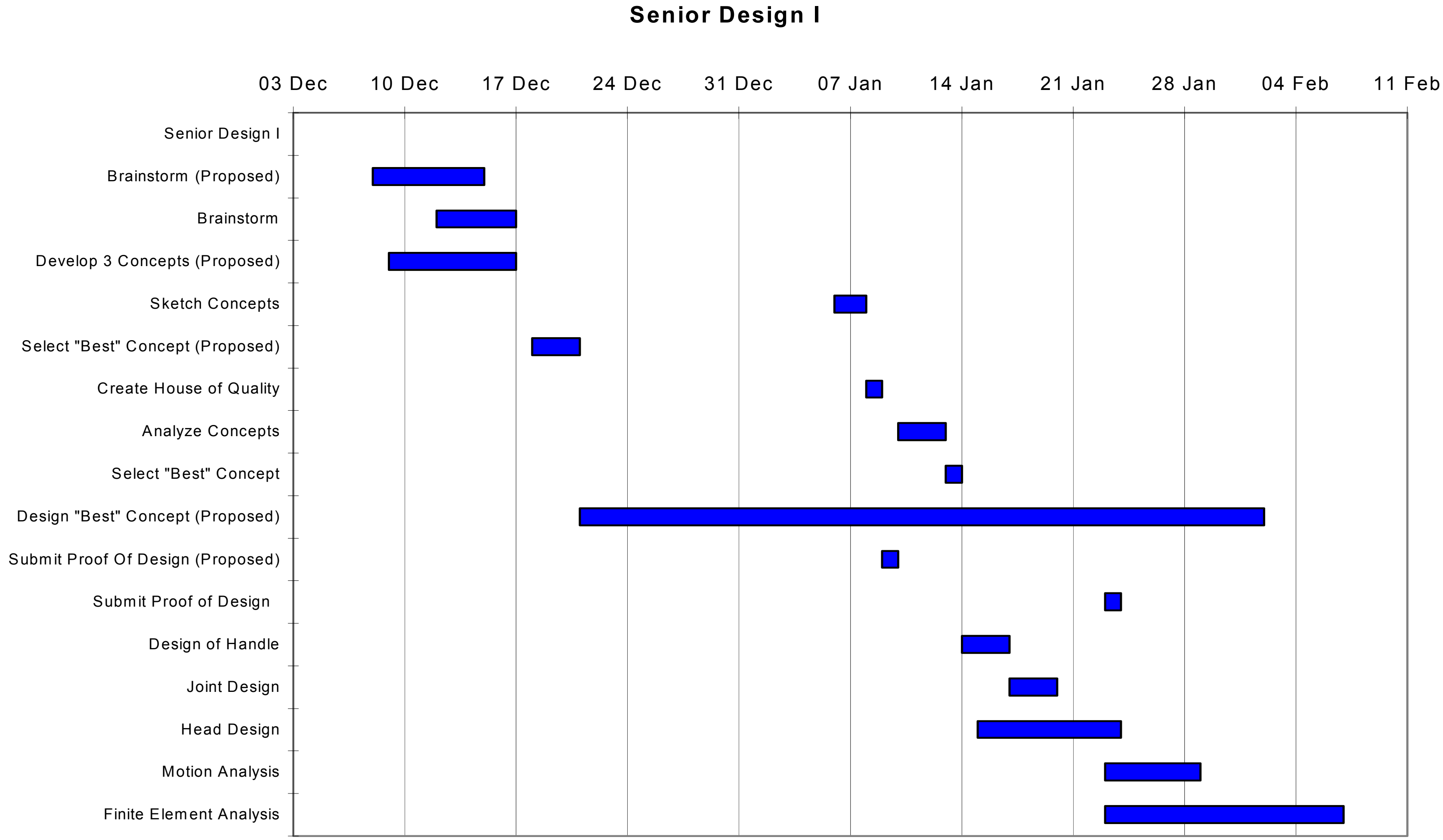
Schedule



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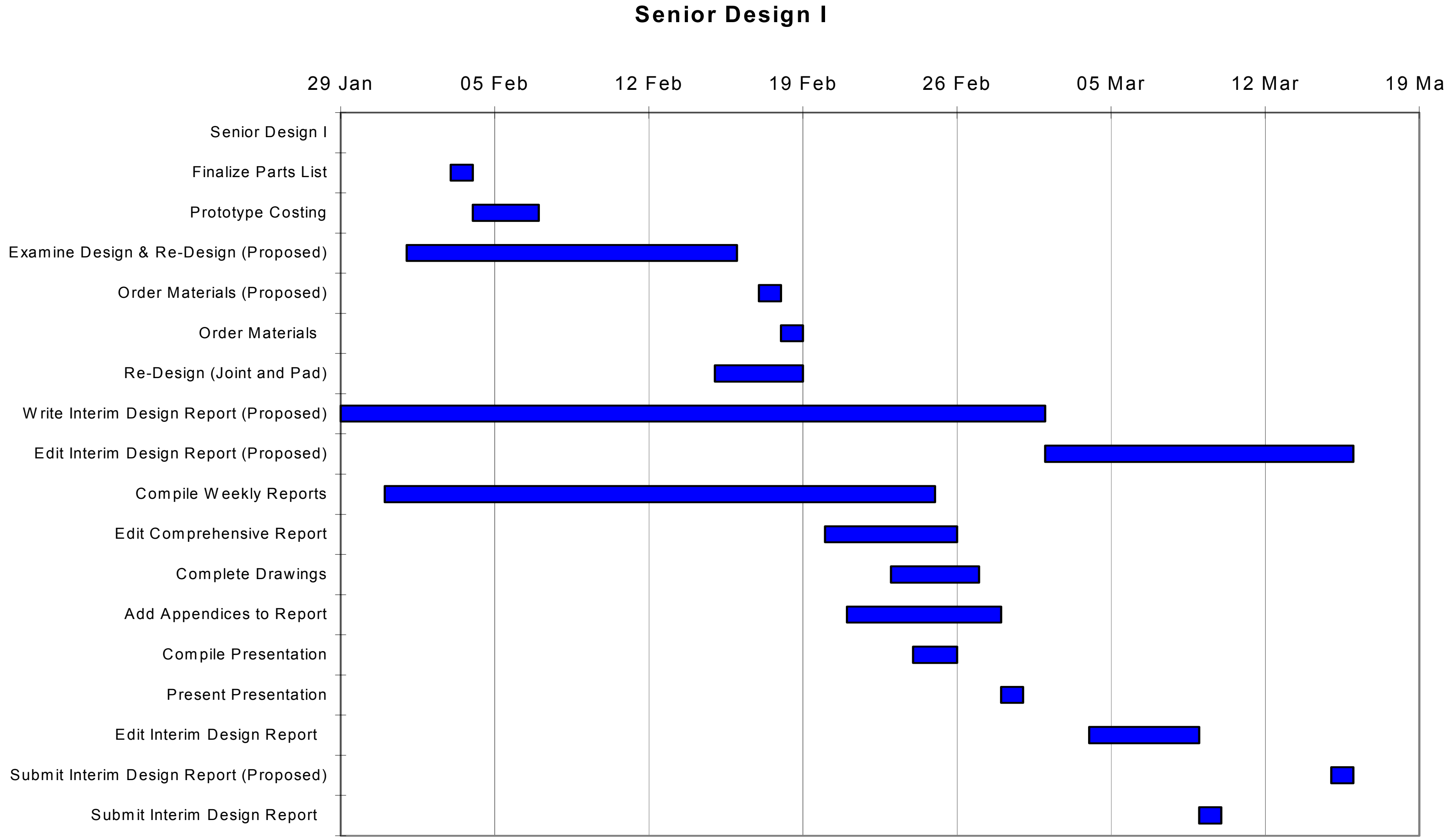

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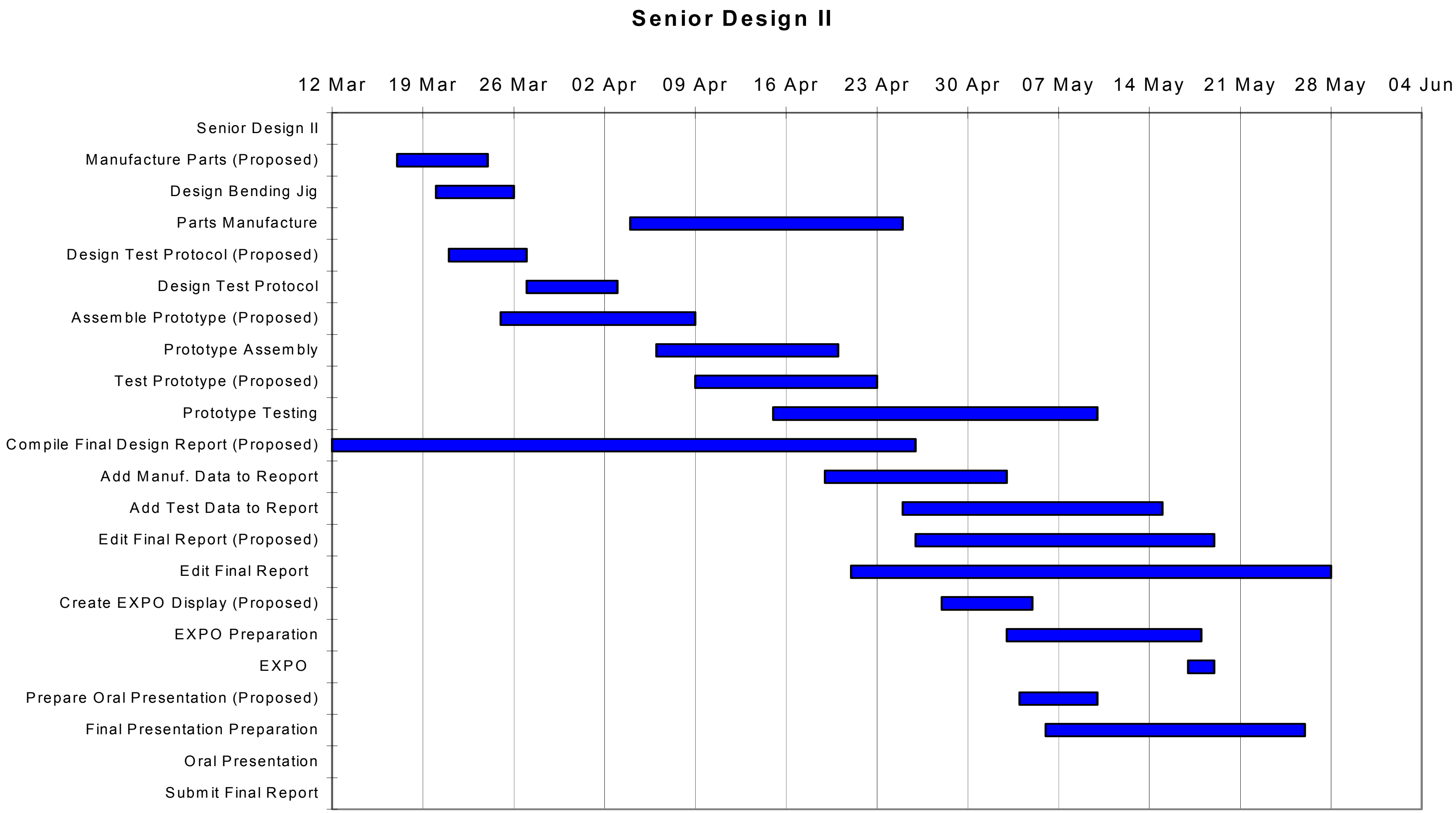


Appendix C
House of Quality

	Material Toughness	Design for Assembly	Force Required to Turn	Material Cost	Manufacture Cost	Material Corrosion Rating	Mechanism Design	Factor of Safety	Head Design	Handle Length	Design for Safety	Surface Finish	Material Density	Placement Time	Handle Diameter	Customer Importance	Current Solution	Planned Solution	Improvement Ratio	Sales Point	Improvement Ratio
Light Weight	3	0	0	3	0	0	9	0	3	0	0	0	9	3	0	5	3	5	1.67	1.5	12.50
Small Size	0	9	0	3	0	0	9	0	3	9	0	0	3	3	0	5	2	5	2.50	1.5	18.75
Large Handle	0	0	9	0	0	0	9	0	0	9	0	0	0	0	9	4	4	4	1.00	1.0	4.00
Turning Ease	0	0	9	0	0	0	9	0	0	9	0	0	0	0	0	5	4	5	1.25	1.0	6.25
Easy Placement	0	0	0	0	0	0	3	0	9	0	0	0	0	9	3	5	3	5	1.67	1.0	8.33
Durability	9	3	1	3	0	0	1	9	1	0	0	0	1	0	0	3	2	4	2.00	1.0	6.00
Corrosion Resistance	1	0	0	3	0	9	0	0	0	0	0	3	0	0	0	1	1	4	4.00	1.0	4.00
Cost	1	9	0	9	9	0	3	3	0	0	3	0	0	0	0	3	1	3	3.00	1.3	11.70
Secure on Knob	0	0	3	0	0	0	9	0	9	0	3	0	0	0	0	4	5	5	1.00	1.0	4.00
No Interference	0	3	0	0	0	0	9	0	1	9	1	0	0	9	0	5	3	5	1.67	1.5	12.50
No Pinch Points	0	0	0	0	3	0	9	1	0	0	9	0	0	0	0	4	4	4	1.00	1.0	4.00
Easy Maintenance	3	3	0	3	0	9	3	0	0	0	0	0	0	0	0	2	2	3	1.50	1.3	3.90
Easy Cleaning	0	3	0	3	0	9	9	0	0	0	0	3	0	0	0	3	3	3	1.00	1.3	3.90
Portable	0	1	0	0	0	0	9	0	1	3	0	0	0	0	0	5	1	5	5.00	1.5	37.50
Appearance	0	0	0	3	0	9	1	0	3	0	0	9	0	0	0	3	2	3	1.50	1.0	4.50
Assembly Ease	0	9	0	3	0	0	3	0	0	0	0	0	0	0	0	1	2	2	1.00	1.0	1.00
Universal Fit	0	0	0	0	0	0	9	0	9	0	0	0	0	0	0	5	4	5	1.25	1.5	9.38
Absolute Importance	0.78	2.62	0.72	1.77	0.77	0.96	7.23	0.61	2.36	3.19	0.63	0.42	1.15	1.85	0.40	25.47				SUM	152.21
Relative Importance	0.0307	0.103	0.0284	0.0694	0.0303	0.0378	0.2838	0.024	0.0925	0.1254	0.0247	0.0166	0.0451	0.0726	0.0157	1					
Target Values	>3000		0.5	25	0	>500		3		8		16	>.2	30	0.75	SUM					
Units	$psi*in^{-1}$		lbs	$	$			unitless		inch		microinches	lb/in^3	sec	inch						

Appendix D
Proof of Design Statement

The design for the portable faucet knob turner for disabled persons will perform the following:

1. It will weigh less than 2 pounds.
2. It will be less than 8 inches long, 5 inches tall and 2 inches wide.
3. It will require less than 3 pounds of force to turn the knob.
4. It will cost less than $20.00 to manufacture.
5. The design will fit all round faucet knobs between 2 and 3.5 inches in diameter.
6. The materials will be corrosion resistant so as not to effect the appearance.
7. The handle will be larger than ½ inch in diameter, but smaller than an inch.
8. The design will eliminate all possible pinch points.
9. The maintenance of the design will be simple enough so that an Occupational Therapist can perform it. Can perform it using 3 or fewer common tools and knowledge of the use of those common tools. Will be fewer than 10 parts and the assembly will have instructions.
10. The design will be functional over 5,000 uses with less than a 20% loss in gripping force so as to limit the amount of maintenance necessary.

Advisor Signature date Student Signature date

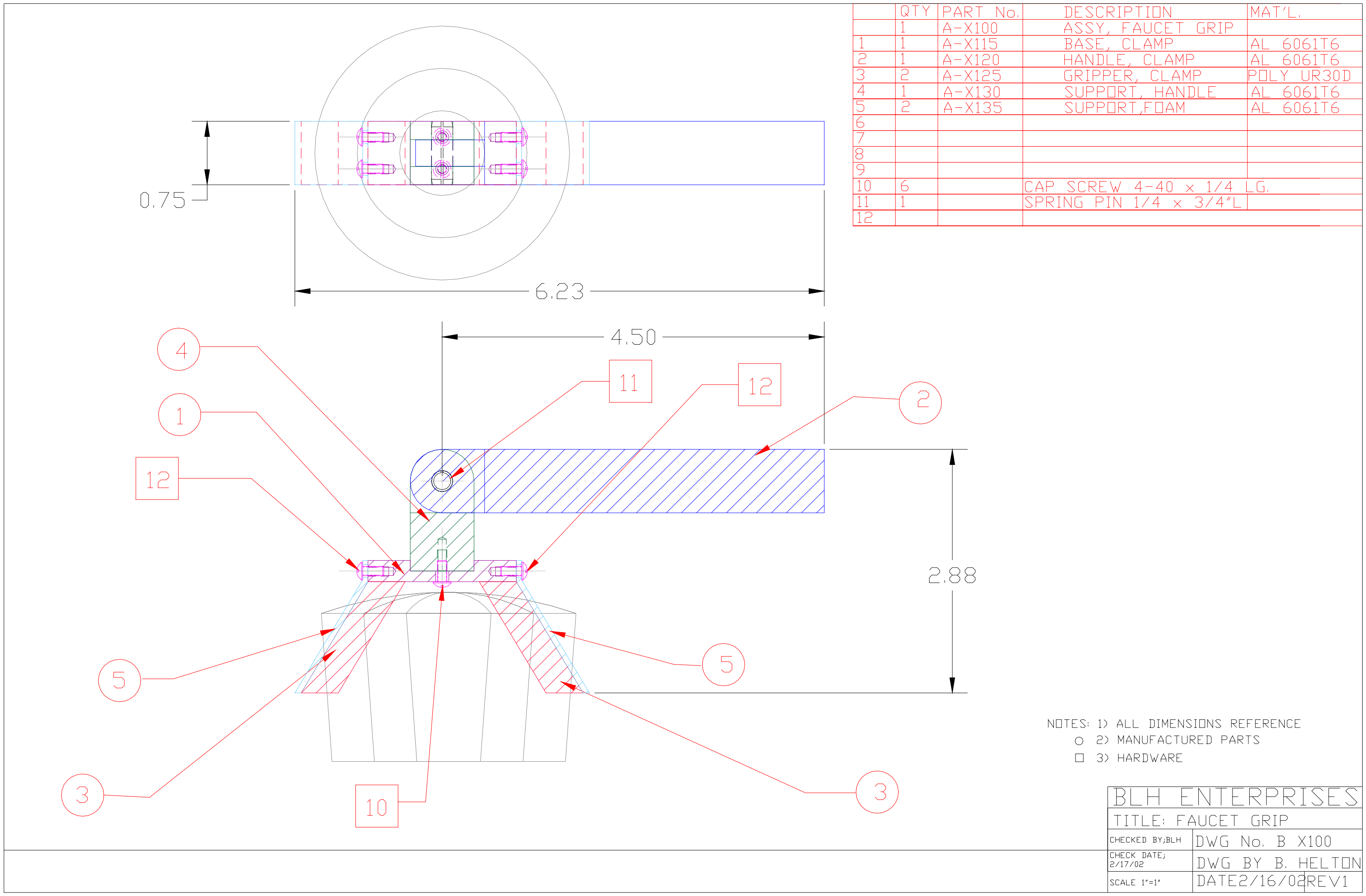
______________________________ ______________________________

Appendix E

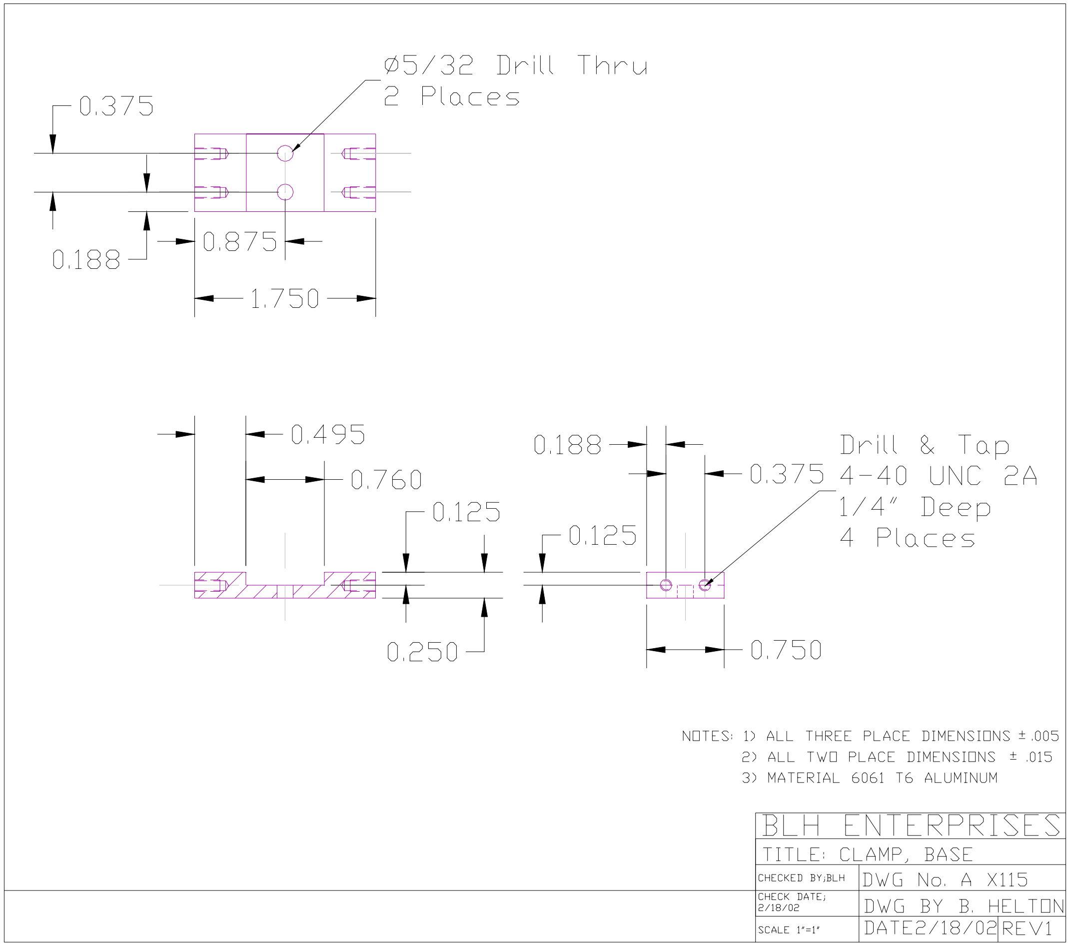
Weighted Objectives Selection Matrix

	Possible Solutions															
	#1		#2		#3		#4		#5		#6		#7			
	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted	Customer Importance	Relative Weight
Weight	2	0.159	3	0.238	2	0.159	1	0.079	2	0.159	4	0.317	5	0.397	5	0.079
Size	5	0.397	3	0.238	3	0.238	2	0.159	3	0.238	3	0.238	4	0.317	5	0.079
Handle Size	2	0.127	5	0.317	3	0.19	4	0.254	4	0.254	4	0.254	4	0.254	4	0.063
Turning force	3	0.238	5	0.397	5	0.397	5	0.397	5	0.397	5	0.397	5	0.397	5	0.079
Placement	3	0.238	3	0.238	2	0.159	1	0.079	4	0.317	2	0.159	3	0.238	5	0.079
Durability	3	0.143	4	0.19	3	0.143	3	0.143	4	0.19	3	0.143	3	0.143	3	0.048
Corrosion Resistance	4	0.063	4	0.063	4	0.063	3	0.048	3	0.048	3	0.048	4	0.063	1	0.016
Cost	4	0.19	4	0.19	4	0.19	3	0.143	3	0.143	3	0.143	3	0.143	3	0.048
Secure on Knob	5	0.317	4	0.254	4	0.254	3	0.19	3	0.19	3	0.19	4	0.254	4	0.063
Interference	5	0.397	1	0.079	2	0.159	3	0.238	4	0.317	3	0.238	3	0.238	5	0.079
Pinch Points	4	0.254	2	0.127	3	0.19	4	0.254	3	0.19	5	0.317	5	0.317	4	0.063
Maintenance	2	0.063	2	0.063	2	0.063	2	0.063	2	0.063	2	0.063	3	0.095	2	0.032
Cleaning	1	0.048	1	0.048	1	0.048	1	0.048	1	0.048	2	0.095	3	0.143	3	0.048
Portable	2	0.159	1	0.079	2	0.159	3	0.238	3	0.238	2	0.159	4	0.317	5	0.079
Appearance	3	0.143	3	0.143	3	0.143	3	0.143	3	0.143	3	0.143	3	0.143	3	0.048
Assembly	1	0.016	3	0.048	2	0.032	2	0.032	2	0.032	4	0.063	3	0.048	1	0.016
Universal Fit	4	0.317	4	0.317	4	0.317	5	0.397	5	0.397	4	0.317	5	0.397	5	0.079
Total	53	3.27	52	3.032	49	2.905	48	2.905	54	3.365	55	3.286	64	3.905	63	1.000

Appendix F
Prototype Drawings



Appendix F (cont'd)
Prototype Drawings



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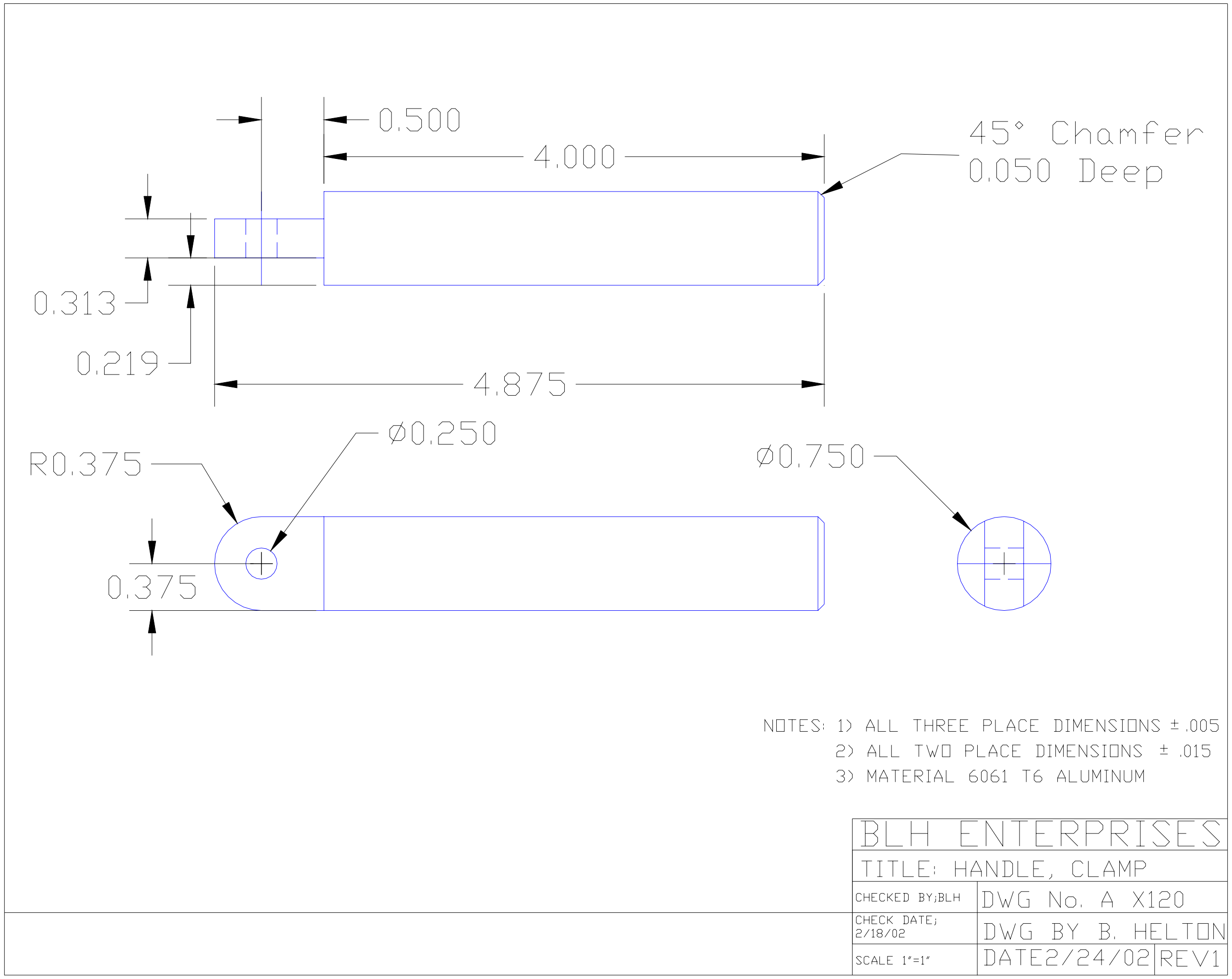
Prototype Drawings



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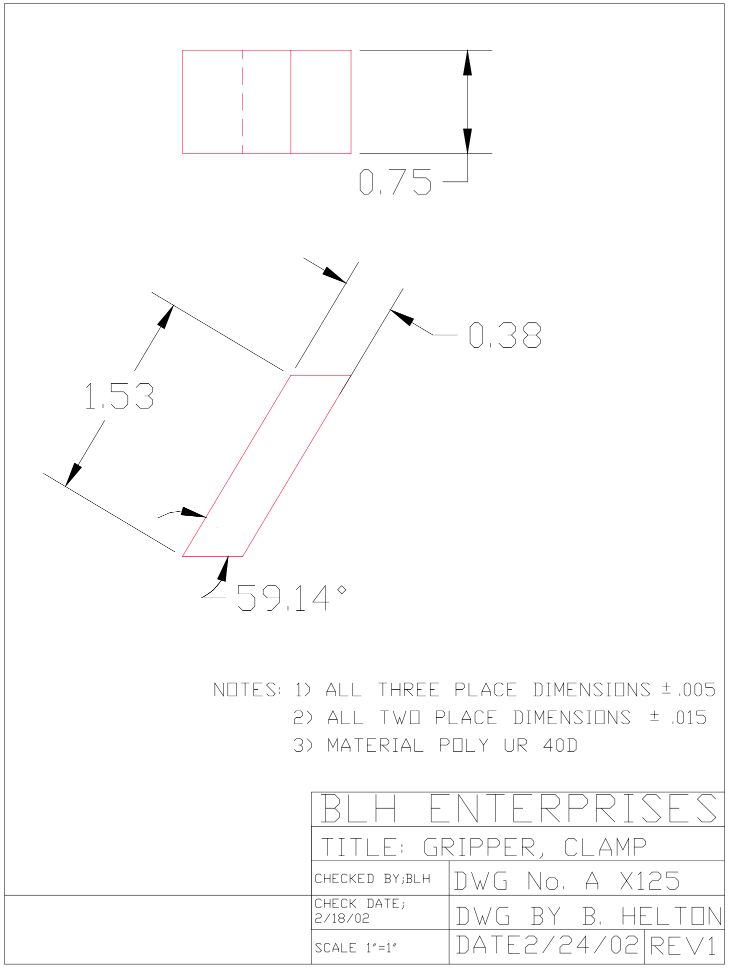
Prototype Drawings



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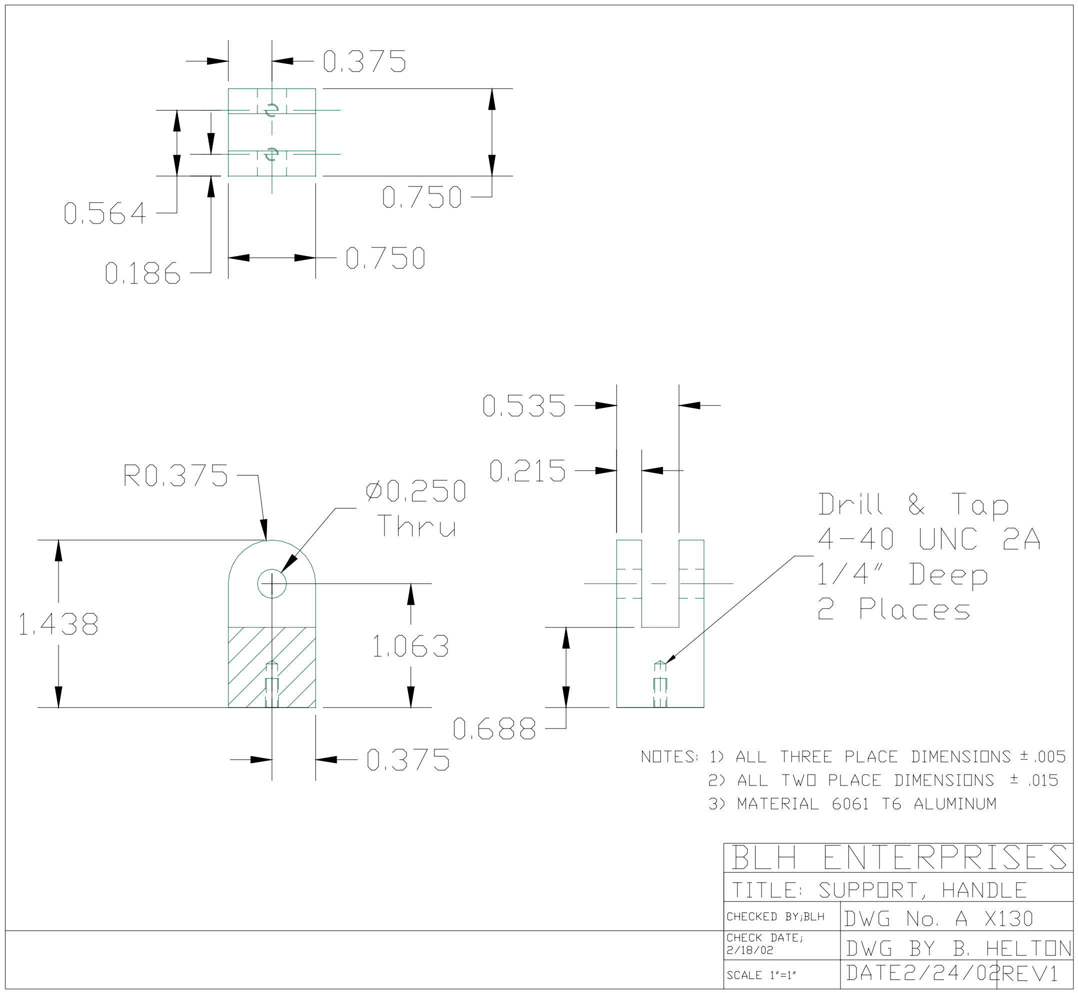
Prototype Drawings



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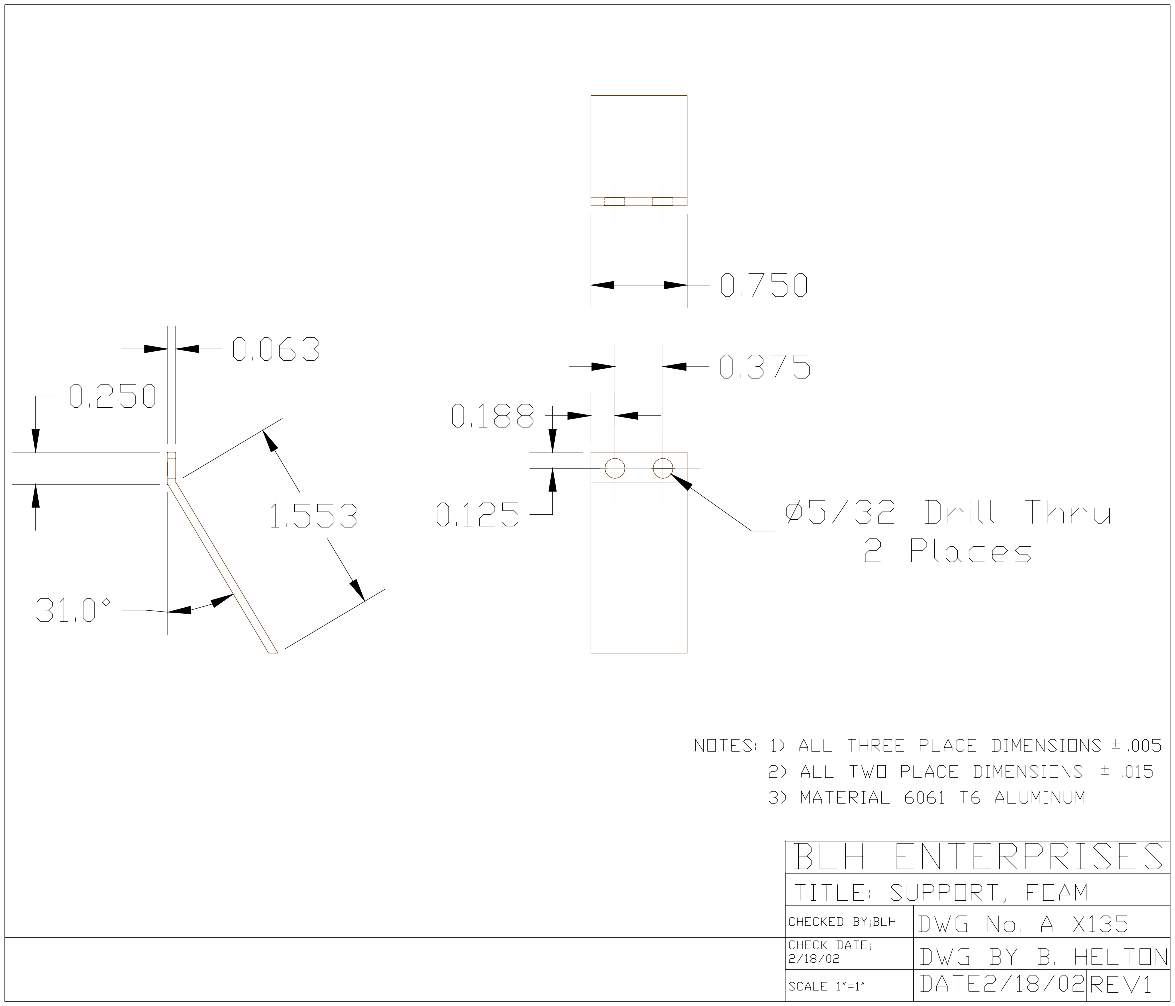
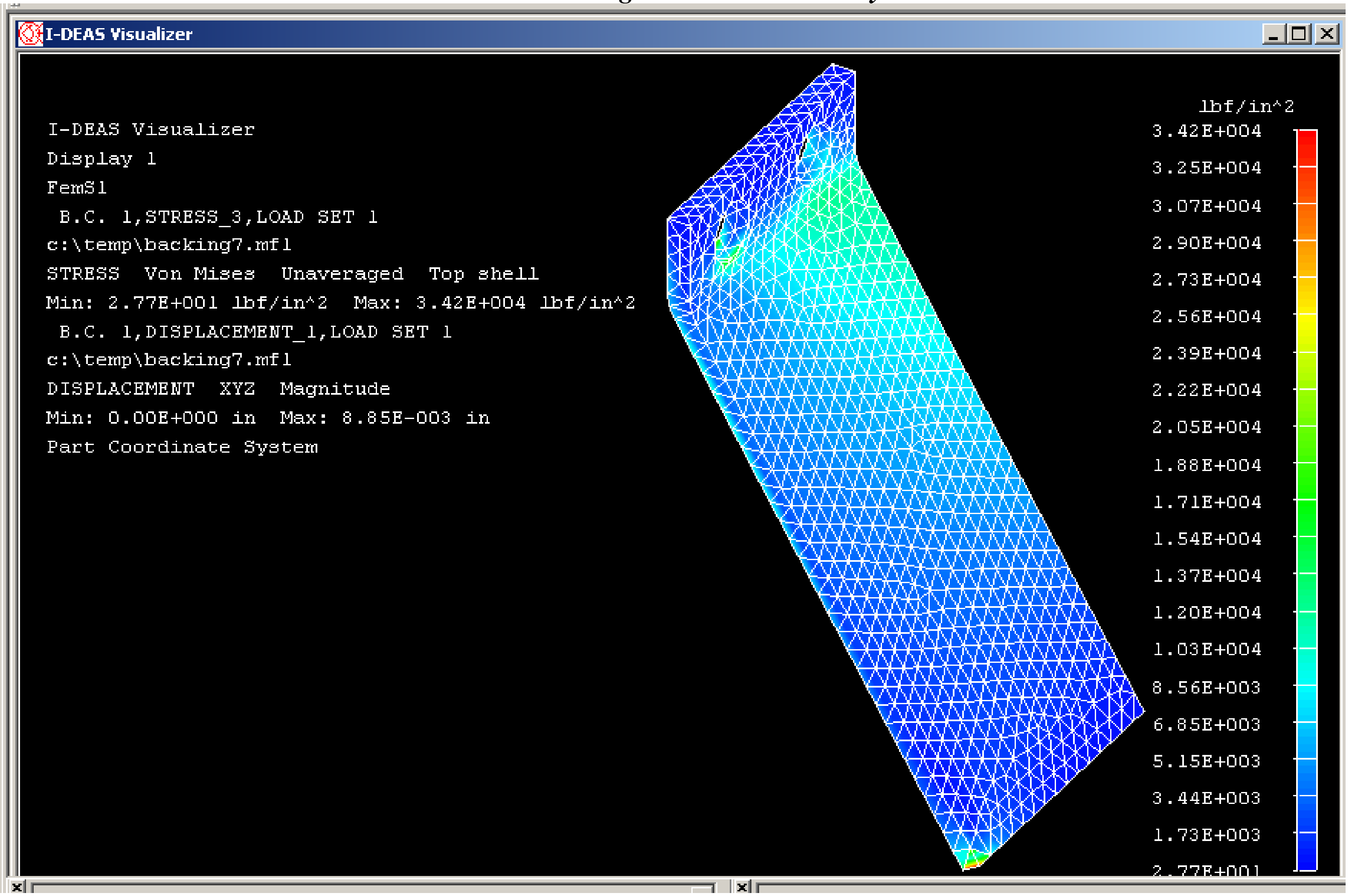
Prototype Drawings



Appendix G
Combined Loading Finite Element Analysis



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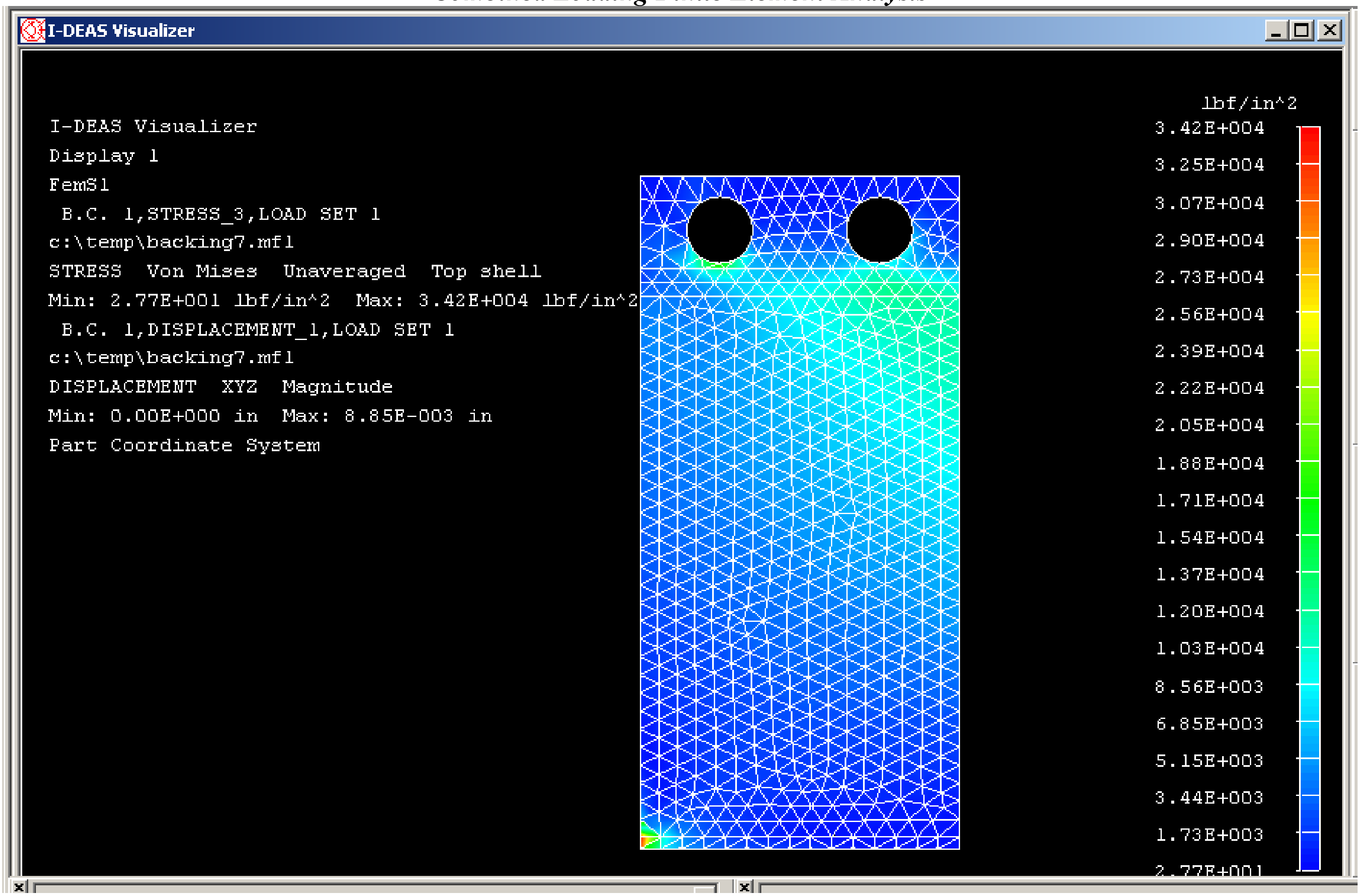

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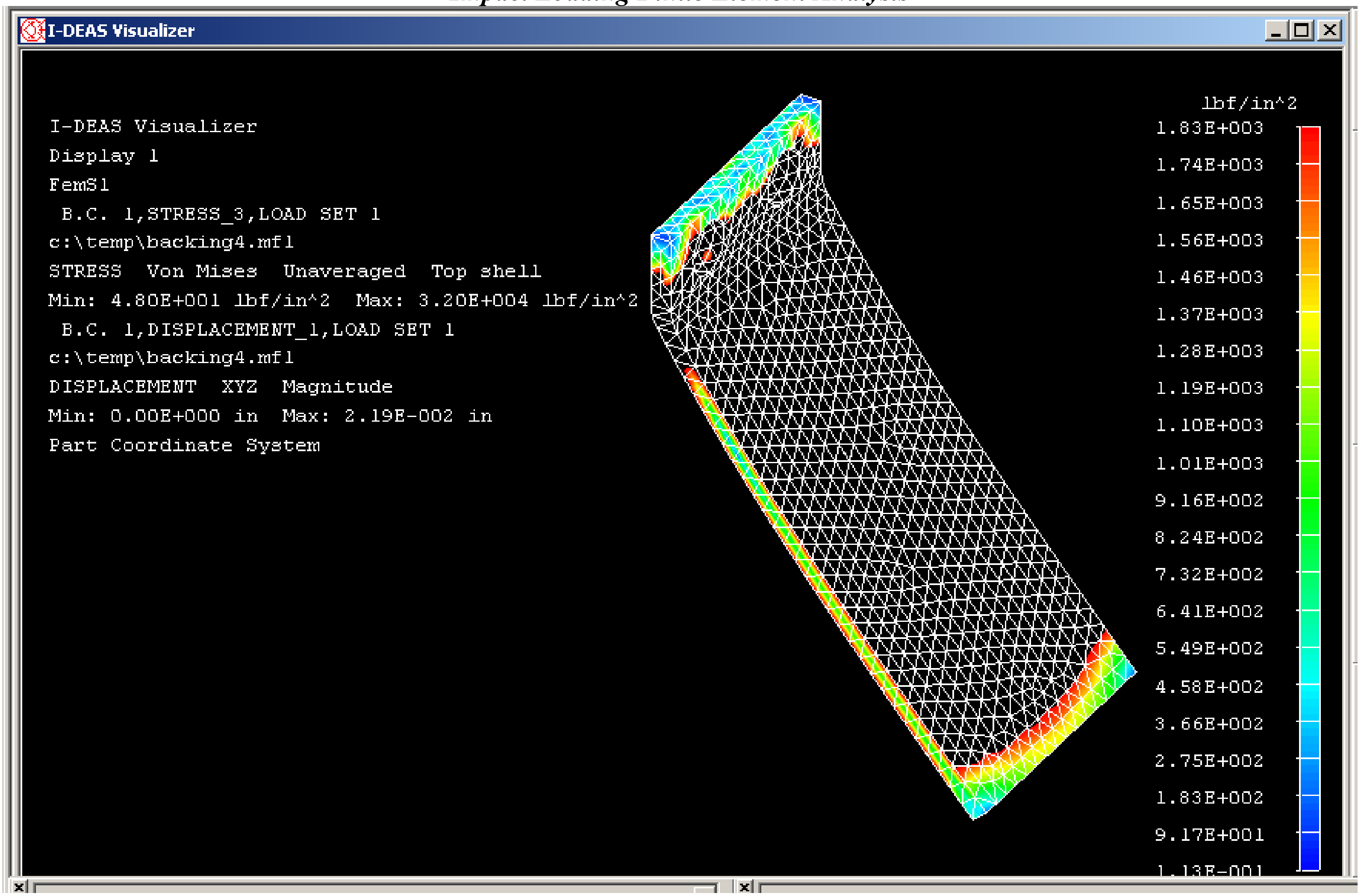
Impact Loading Finite Element Analysis



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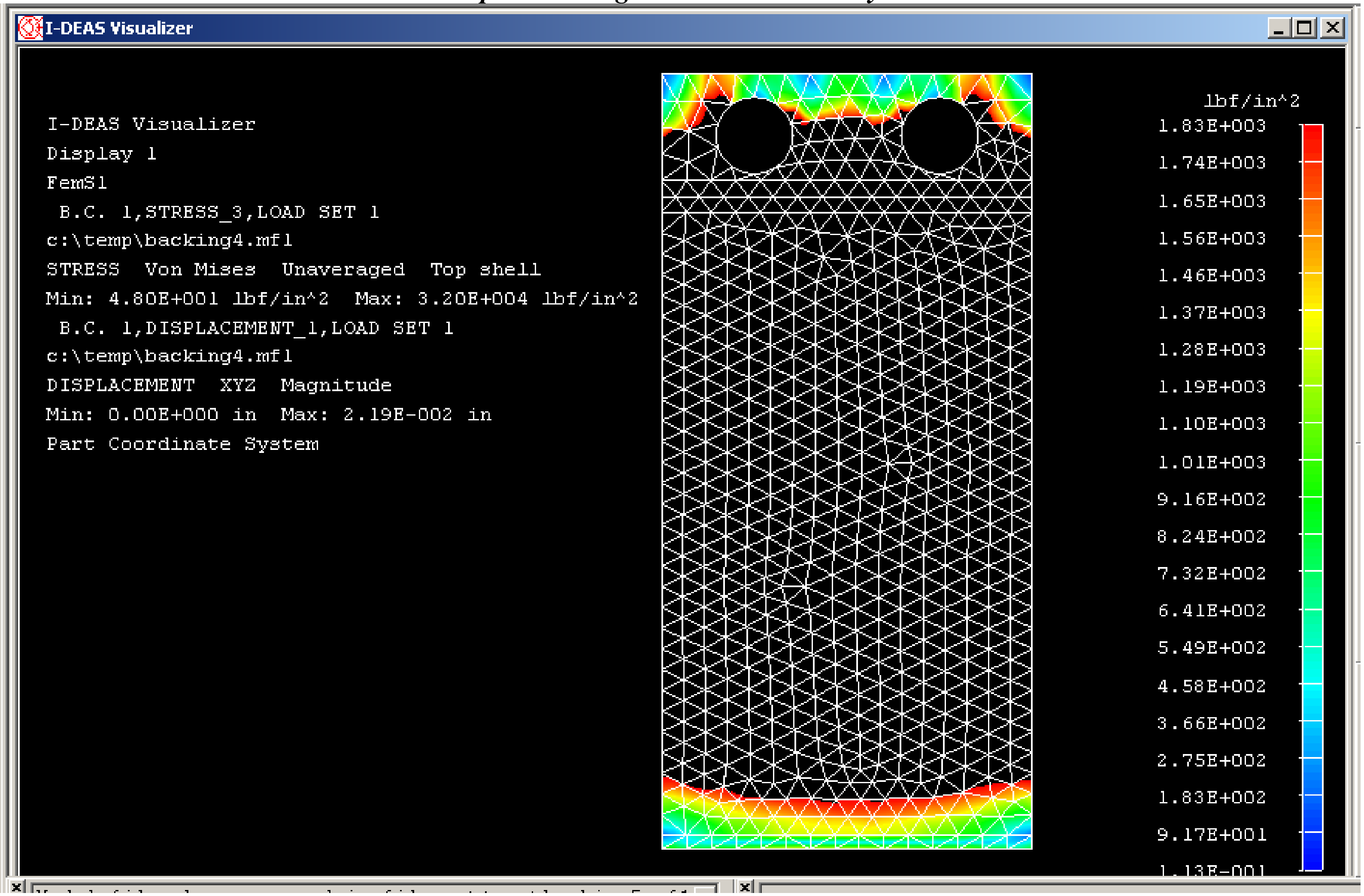


Appendix H

Bill of Materials and Costing

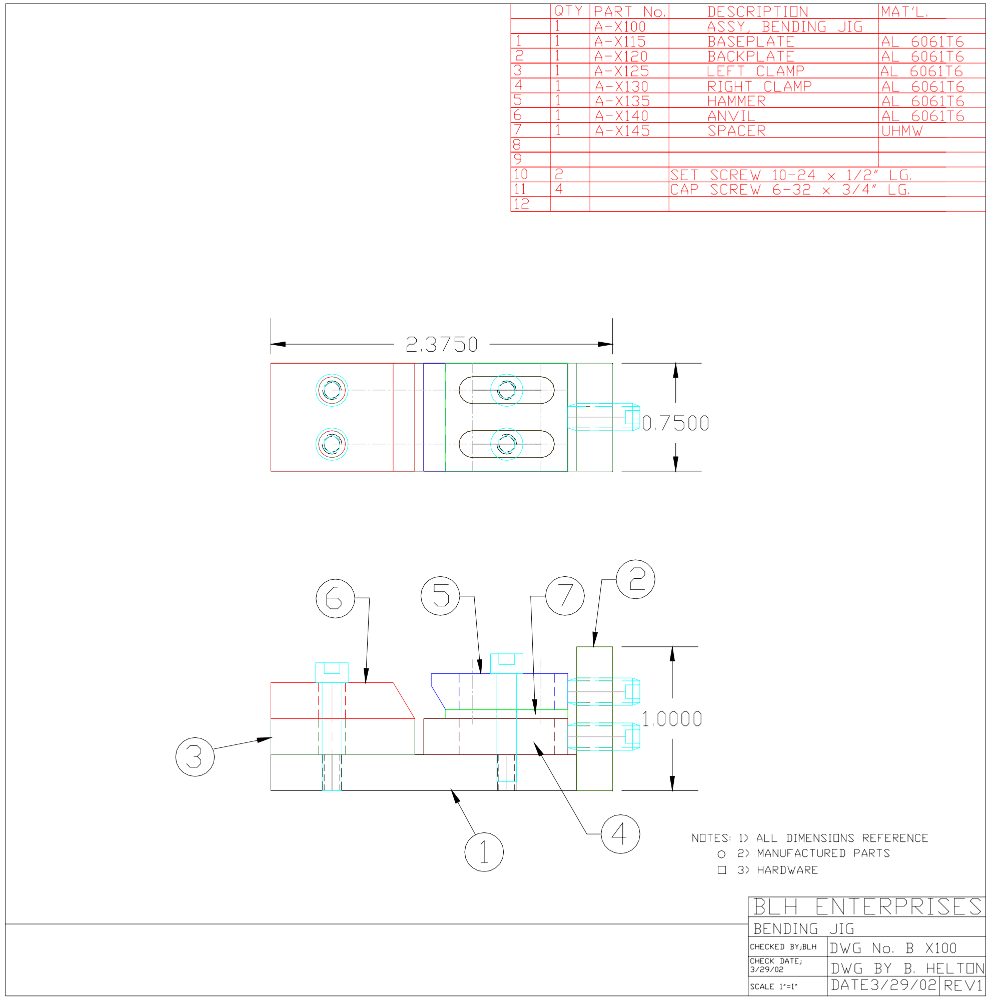
Prototype Parts List and Prices

Part	Material	# Req'd	Size	Supplier	Unit Price	Prototype Price
Handle	Aluminum	1	.75" Dia, 5" long	R&B Tool	$3.25	$3.25
Joint	Aluminum	1	.75"sq. 1.5 long	R&B Tool	$3.25	$3.25
Body	Aluminum	1	1.75"L, .75"W, .25"H	R&B Tool	$3.25	$3.25
Pad Backing	Aluminum	2	1.55"L, .75"W, .063"H	Home	$0.43	$0.86
Grip Pads	Polyurethane	2	1.55"L, .75"W, .375"H	McMaster-Carr	$0.43	$0.86
Screws	Steel	6	4-40 1/4 long	McMaster-Carr	$0.06	$0.36
Spring Pins	Steel	1	.25" Dia, .75"long	McMaster-Carr	$0.04	$0.04
					Total Price	$11.87

Production Parts List and Prices

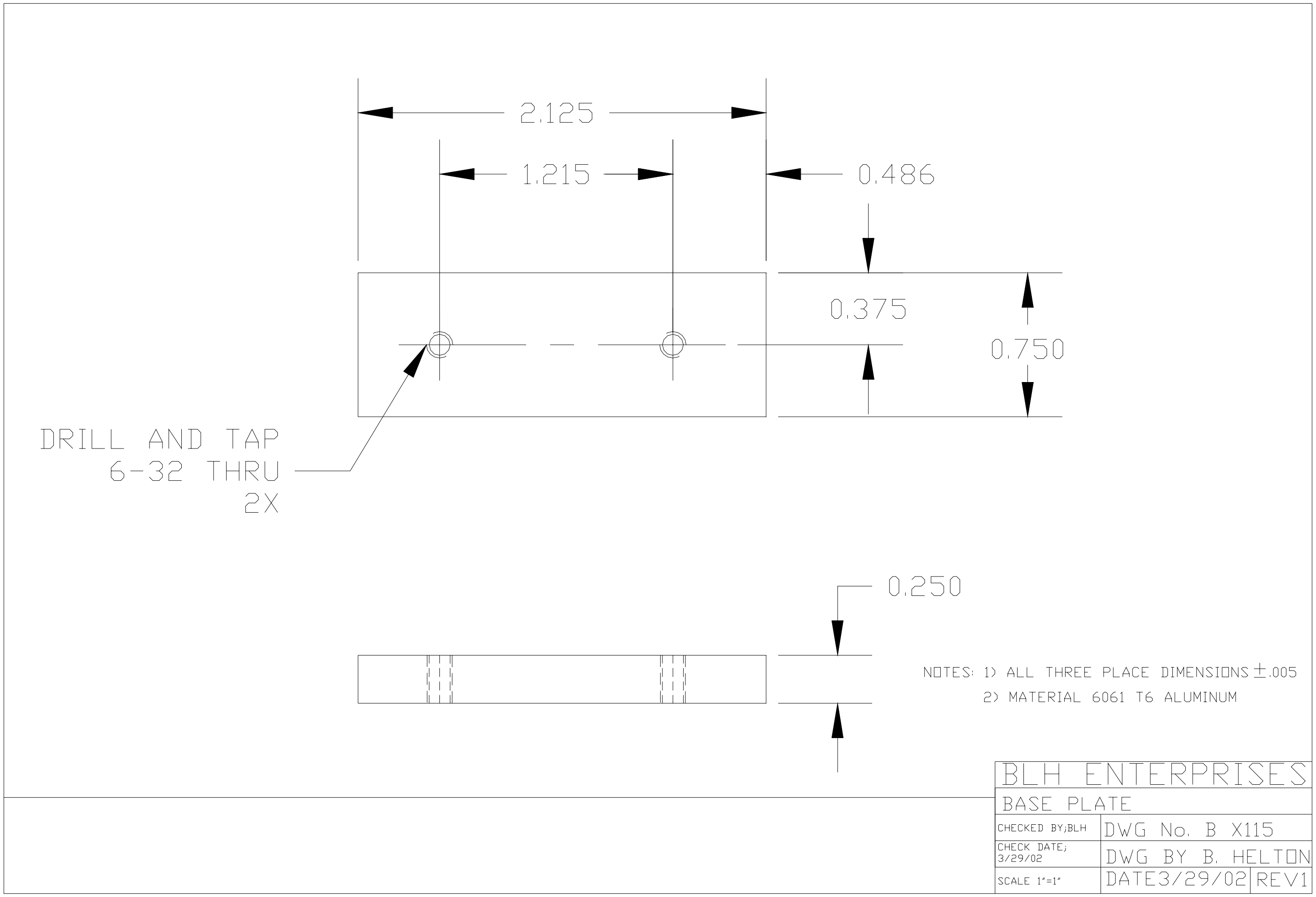
Part	Material	# Req'd	Size	Supplier	Unit Price	Production Price
Handle	Polycarbonate	1	.75" Dia, 5" long	JelliHo Plastics	$0.50	$0.50
Joint	Polycarbonate	1	.75"sq. 1.5 long	JelliHo Plastics	$0.50	$0.50
Body	Polycarbonate	1	1.75"L, .75"W, .25"H	JelliHo Plastics	$0.50	$0.50
Pad Backing	Polycarbonate	2	1.55"L, .75"W, .063"H	JelliHo Plastics	$0.50	$1.00
Grip Pads	Polyurethane	2	1.55"L, .75"W, .375"H	McMaster-Carr	$0.43	$0.86
Screws	Steel	6	4-40 1/4 long	McMaster-Carr	$0.06	$0.36
Spring Pins	Steel	1	.25" Dia, .75"long	McMaster-Carr	$0.04	$0.04
					Total Price	$3.76

Appendix I
Bending Jig Drawings



Appendix I (cont'd)

Bending Jig Drawings



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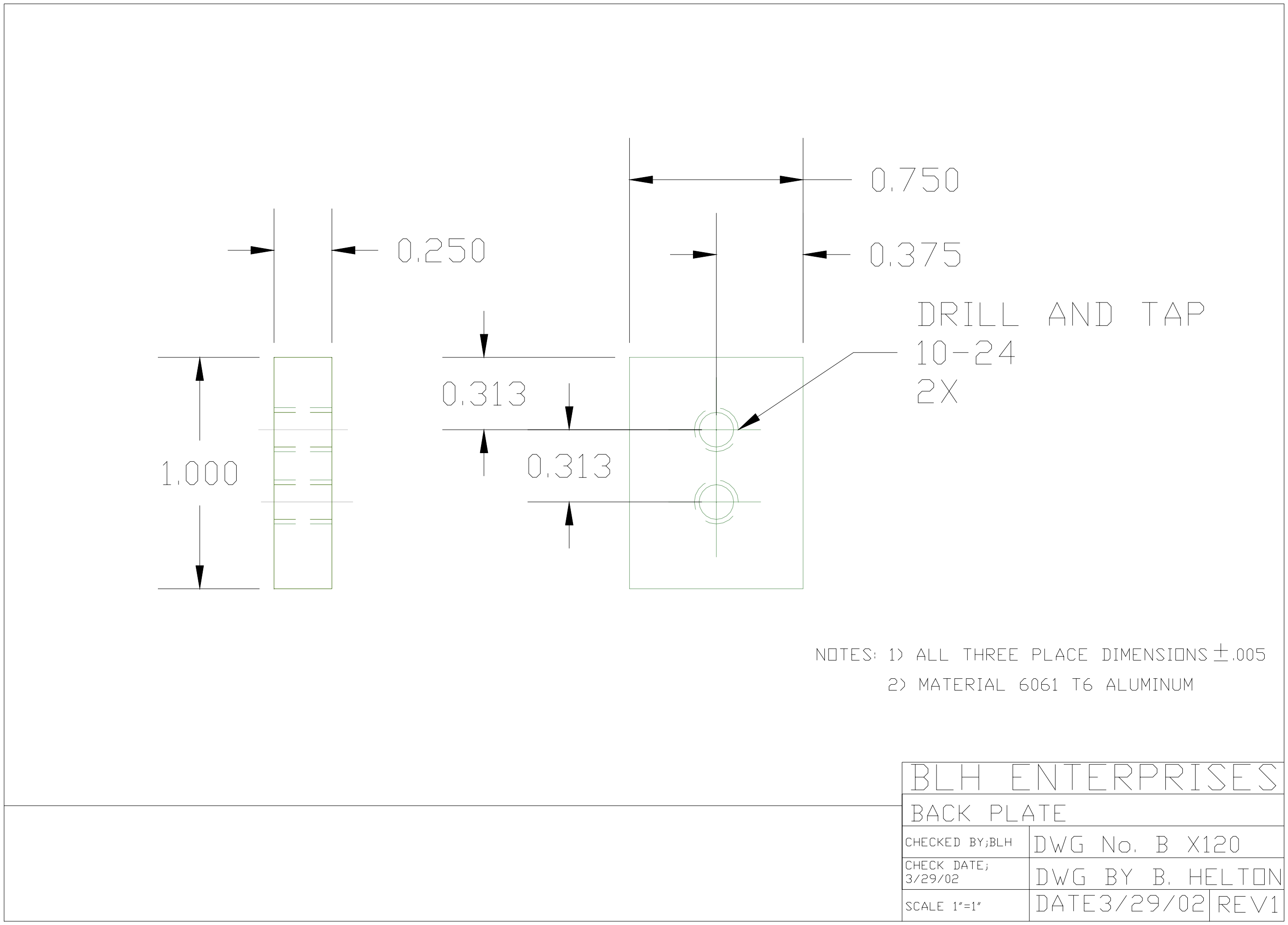
Bending Jig Drawings



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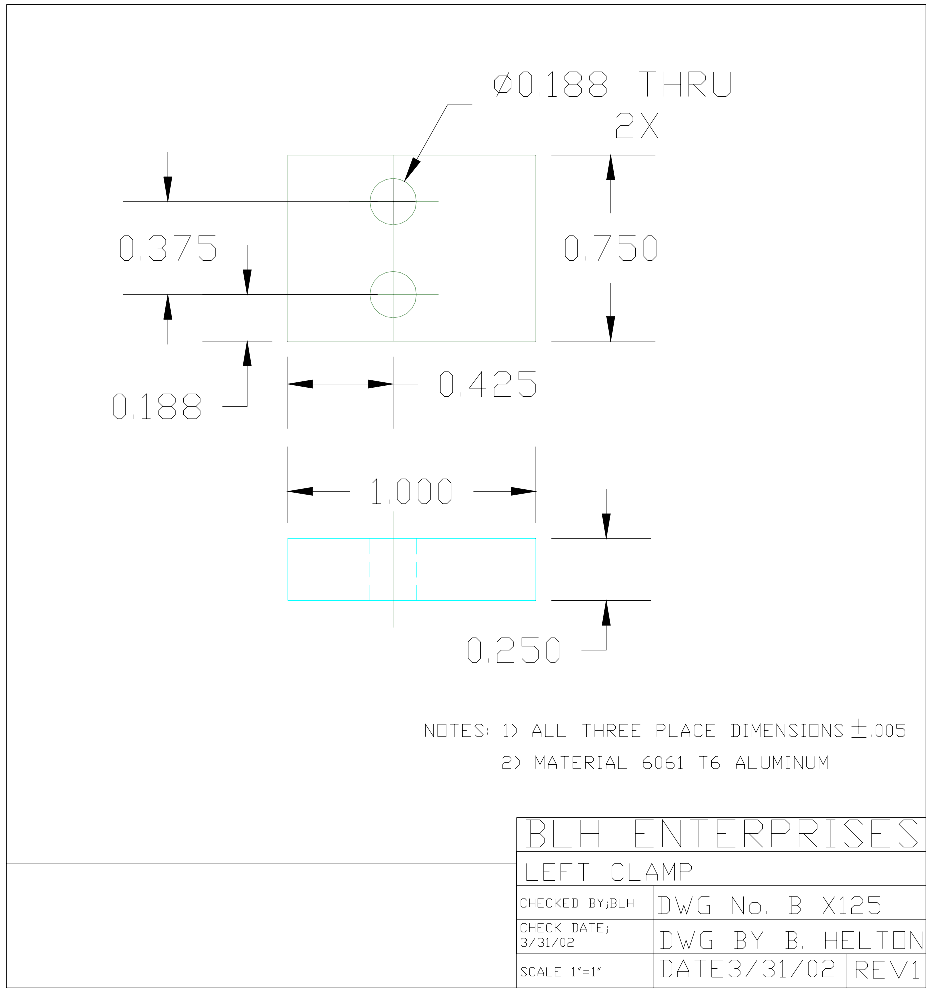
Bending Jig Drawings



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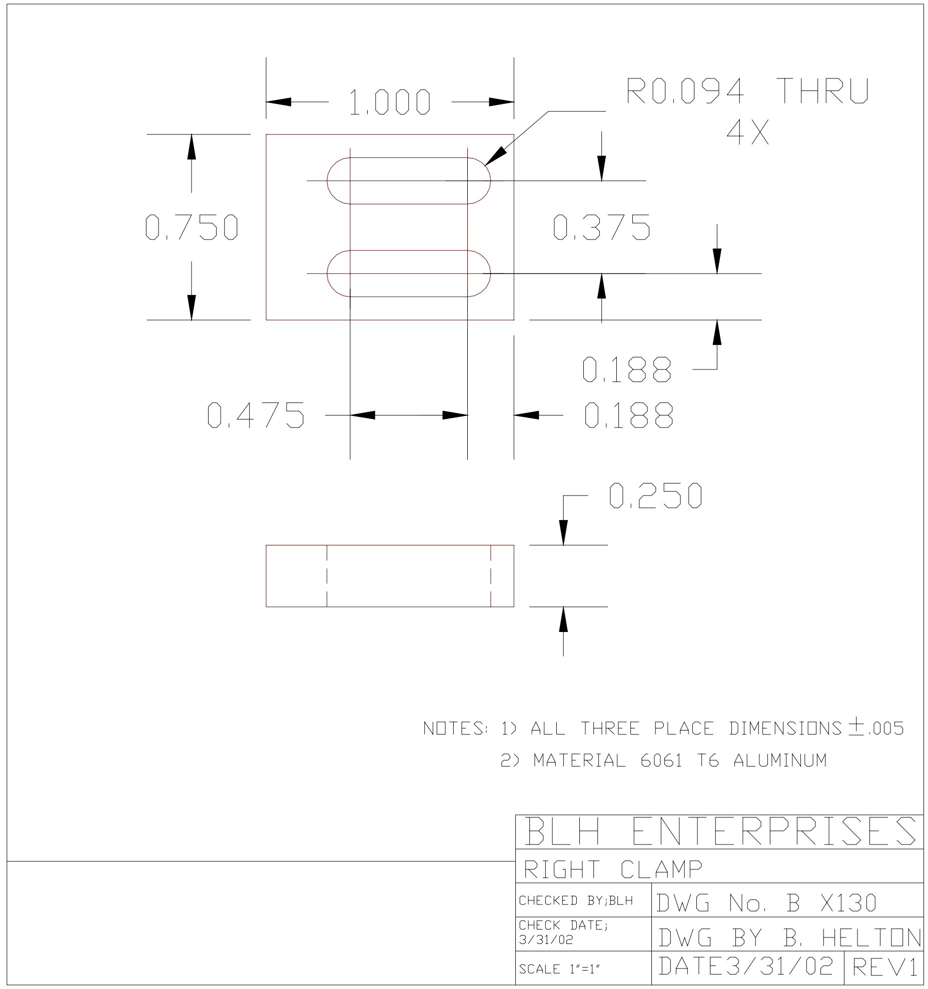
Bending Jig Drawings



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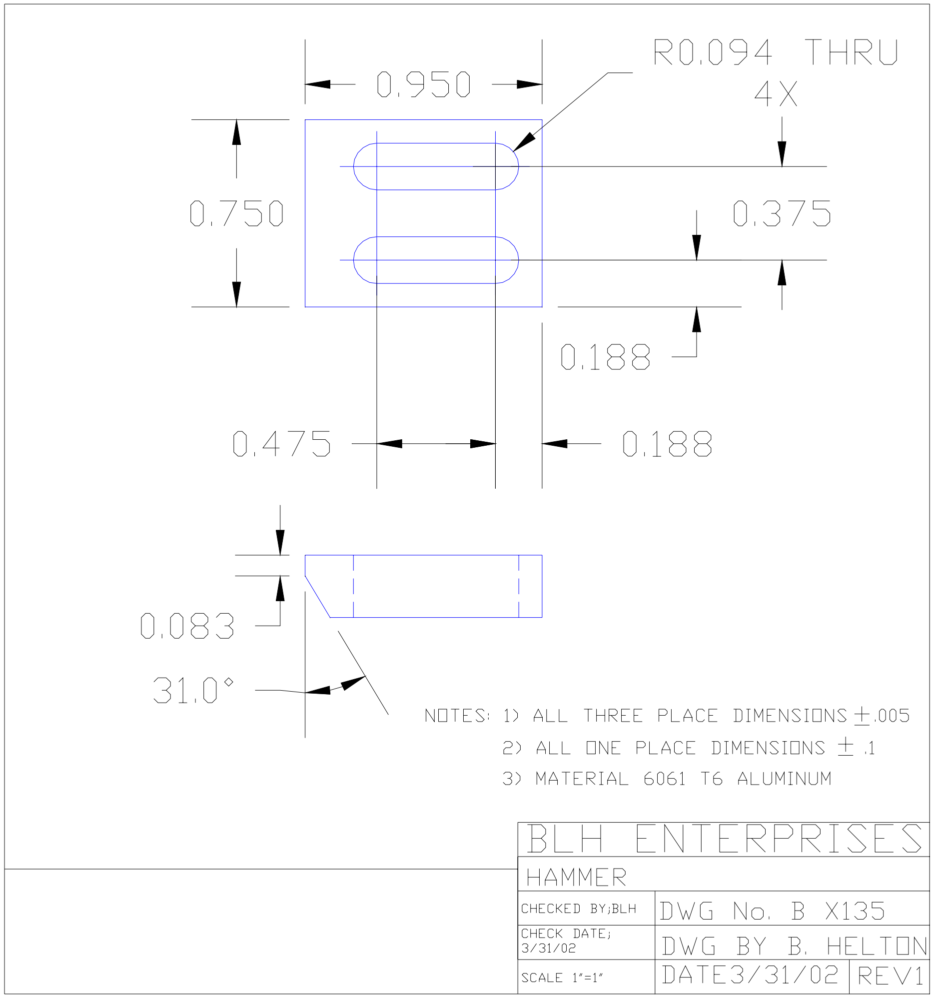
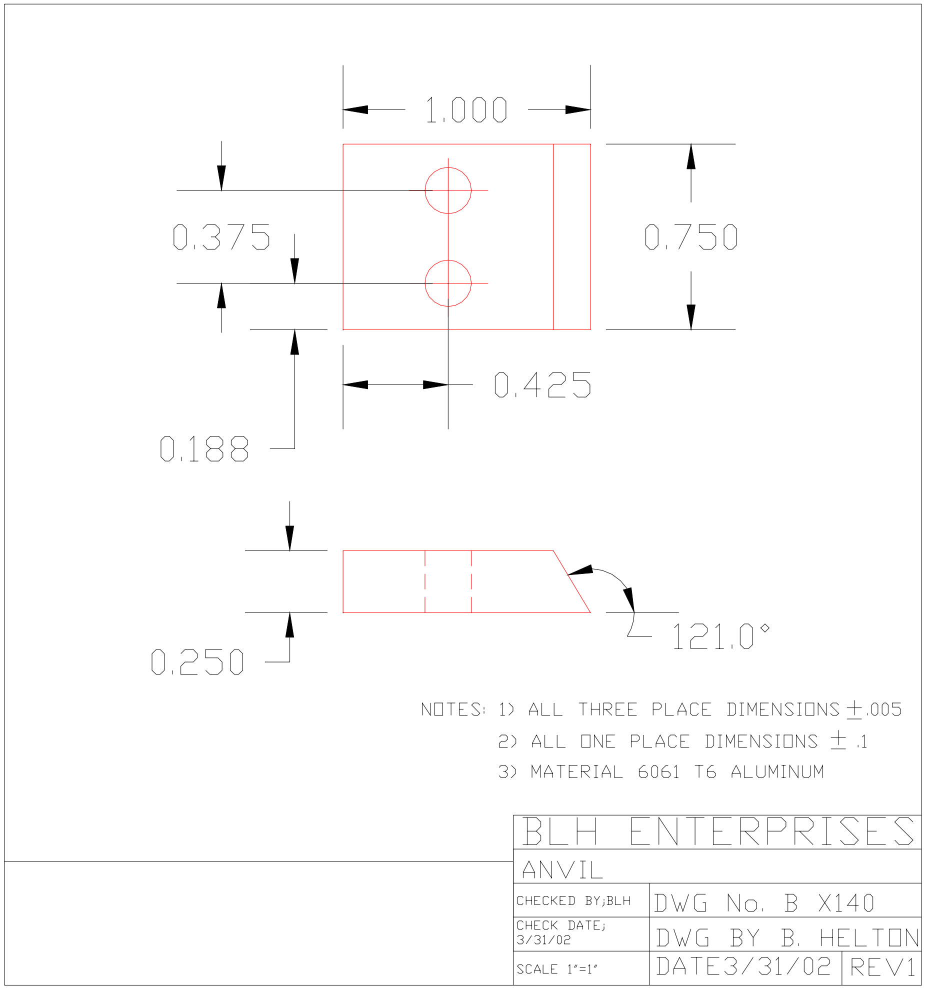
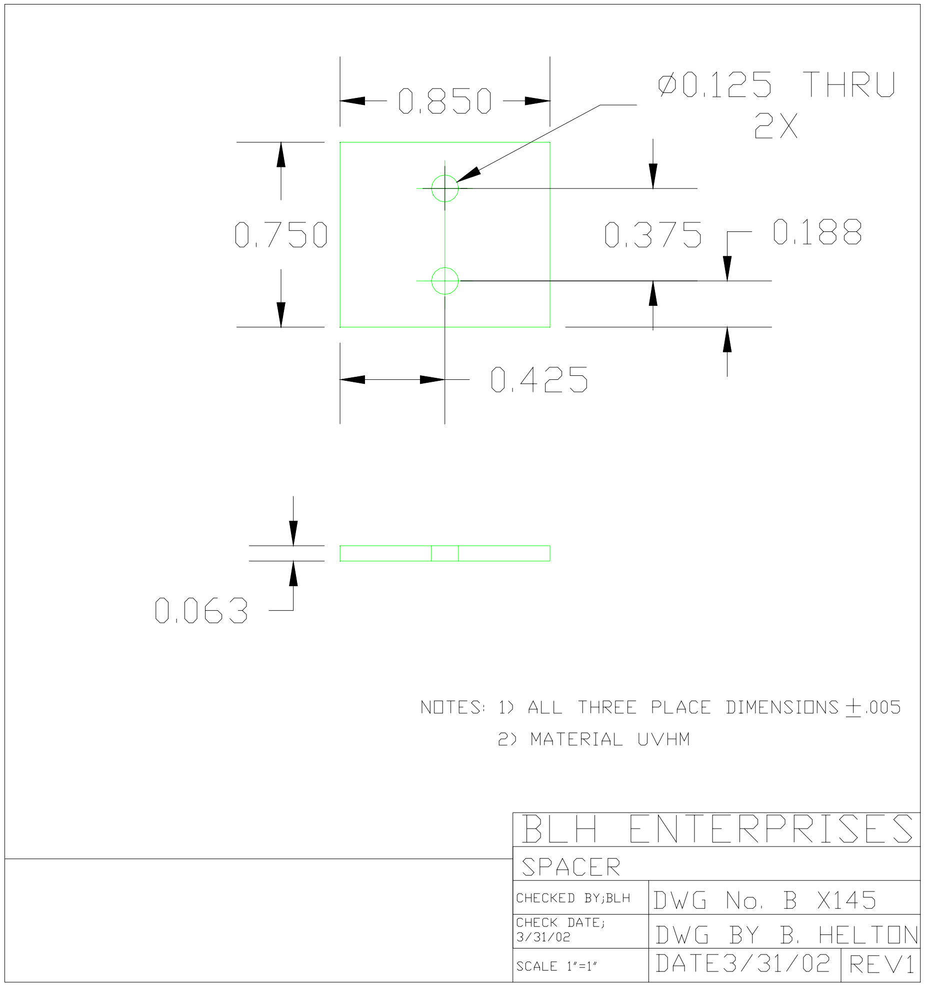
Bending Jig Drawings



Appendix I (cont'd)
Bending Jig Drawings



Appendix I (cont'd)
Bending Jig Drawings



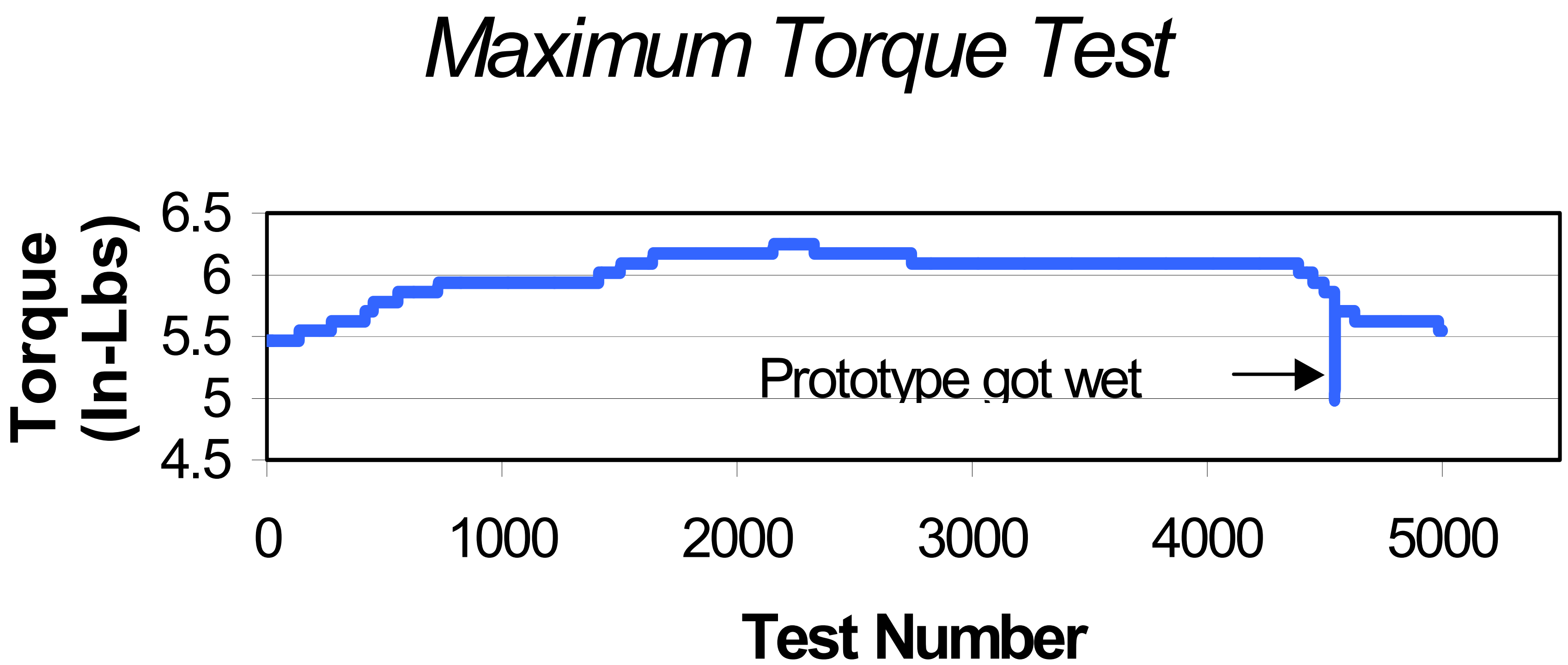
Appendix J
Test Procedure

1. Clamp the test faucet in a vise to eliminate rotation.
2. Determine the total amount of cycles for the test as well as the number of cycles between measurements.
3. Apply the prototype to the knob
4. Turn the knob.
5. Turn the knob to the original position.

If a measurement is desired proceed to step 7, if not skip to step 10.

6. Apply the spring scale to a position 2.5 inches from the center of the spring pin.
7. Place 2 pounds of weight on the top of the prototype, centered above the spring pin.
8. Apply force to the spring pin until the prototype begins to slip.
9. Record the maximum amount of force that can be applied before slippage occurs.
10. Remove the prototype.

Appendix K
Test Results Curve



Appendix L
Proof of Design Solution

In accordance with the Proof of Design Agreement the prototype has the following characteristics:

1. The weight of the complete prototype is .34 pounds.

2. The overall dimensions of the prototype are: 6.25” L by 3.0” H by 75” W.

3. The prototype requires 1.25 pounds of force to turn the water and .875 pounds of force to turn off the water.

4. The cost of bulk manufacture in its current state, including machining, totaled $11.92. For a complete price breakdown see Appendix A.

5. The gap between the polyurethane pads measures 1” at the top and 2.5” at the bottom. This gap corresponds to the amount of flat distance across the top of round knobs measuring from 2” to 3.5 inches in diameter.

6. The prototype is constructed of 6061-T6 aluminum, 50 Durometer (Shore Oo) polyurethane (called Sorbothane), and zinc-plated steel connectors.

7. The handle is constructed of .75” diameter aluminum. This is coated with a rubberizing compound that adds approximately 1/8th of an inch to the diameter of the handle yielding a handle diameter of .875”.

8. Pinch points were eliminated by the rounding of the joint and the handle as well as the utilization of a stop to ensure that the handle does not contact the body of the prototype.

9. The maintenance of the prototype can be accomplished using only two tools, a hammer and a screwdriver. If the spring pin is difficult to remove a small punch may also be necessary. The general maintenance consists of checking the grip pads and replacing them as necessary. This can be performed in approximately 2 minutes as attested to by Liz Gerke. The assembly consists of 5 parts as the grip pads and their backing are one piece. The instructions for the assembly and maintenance of the prototype are shown in Appendix B.

10. Through testing the prototype was shown to be functional over 5000 uses with a gain in gripping force of 1.4% over the duration of the testing. The testing began with a torque of 5.46875 in-lbs and ended with a torque of

Appendix L (cont'd)

Proof Of Design Solution

5.546875 in-lbs with a maximum of 6.25 in-lbs of torque. For a graphical representation of the test data see the graphical representation of the test results in Appendix K.

Assembly Instructions

1. Place the handle and the joint together and line up the holes. Gently tap the spring pin into place using a hammer, making sure that the holes stay aligned.

2. Line up the holes of the joint and the body and attach them using the small screws provided.

3. Attach both of the grip pads to the holes on either side of the body. The pads should angle out and form a shape like this when complete / \ .

Maintenance Instructions

1. The first step in the maintenance process is to examine the grip pads to determine if excessive wear is present. Excessive wear is defined by a deformation of the pad or a rough texture of the pad.

2. If the pads are worn replace the pads by removing the screws and placing another set of pads in the same manner.

3. Check the screws that connect all of the parts to determine if they are in need of tightening or replacement.

4. Check the connection of the handle to the joint. If this is loose replace them both. This should be done per the assembly instructions.