Design Review #5

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Engineering Project Proposal

Geriatric Assistive Device to help into/out of Bath

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ABSTRACT

With the ‘Baby Boomer’ generation growing older and medicine advancing, the population of geriatric patients is rapidly rising. Getting into and out of the bath is a particularly difficult task. Working with Naomi Gilbert at the University Med Rehab and Susan Murphy an assistant professor for physical medicine and rehabilitation at the University of Michigan, our team will improve current assistive bath transfers on the market. Our team will design an assistive device that allows a geriatric patient independence while safely helping them get into and out of the bath.

Team 18: (from left to right) Kate Bateman, Marc Culkin, Steven Ladd, and Nick Hovious.

EXECUTIVE SUMMARY

Background

With the 'Baby Boomer' generation growing older and medicine advancing, the population of geriatric patients is rapidly rising. Getting into and out of the bath is a particularly difficult task. Designing a better assistive transfer device for the bath will help geriatric patients safely bathe while maintaining privacy, allowing them to live a more independent life. Working with Naomi Gilbert at the University Med Rehab and Susan Murphy an assistant professor for physical medicine and rehabilitation at the University of Michigan, our team will improve current assistive bath transfers on the market. Our team will design an assistive device that allows a geriatric patient independence while safely helping them get into and out of the bath.

Customer Requirements

Our sponsor has expressed to our group the need to have an improved assistive device that aids geriatric patients in entering and exiting the bathtub. This device must be dependable and safe, and provide the ability to close the curtain during showering. Currently, there are no affordable assistive devices on the market that meet these criteria.

Concept Generation and Selection

Several different methods to assist geriatric patients into the bathtub were generated through various brainstorming sessions held by our team, also known as the 'Deep Dive'. We worked independently and then together to ensure we had several diverse solutions. After rough drawings of several concepts were generated, we noted the advantages and disadvantages of the various designs. We then reviewed of all of the concepts and voted to determine the most feasible and innovative designs, we were left with five designs. The five finalized designs were then evaluated with respect to our defined functional groups. We then compiled a table demonstrating the advantages and disadvantages of each design. The rough drawings of the five finalized designs were improved upon to explain how each mechanism functioned. Lastly we constructed a selection matrix, using the advantages and disadvantages table, to determine to alpha design to proceed with.

Final Design

From the Concept selection an alpha model was created, this design performed best in our selection matrix. The alpha design was refined into the final design after discussion following DR2. Our final design incorporated a swivel seat which slide along channels using heavy weight rails. Two aluminum extendable legs were used for support. The seat and sliding mechanism was attached to the wall using a steel rod and wall bracket. The sliding mechanism hinged about the rod allowing the seat, sliding mechanism and legs to fold up against the wall. When in the stowed position, a simple gate latch is used to lock the seat to the wall.

Prototype

There are 6 engineering design notifications to demonstrate the changes that were made between our final design and the actual prototype. These changes were made due to availability of product, strength of material, and to add additional support to the prototype.

Testing

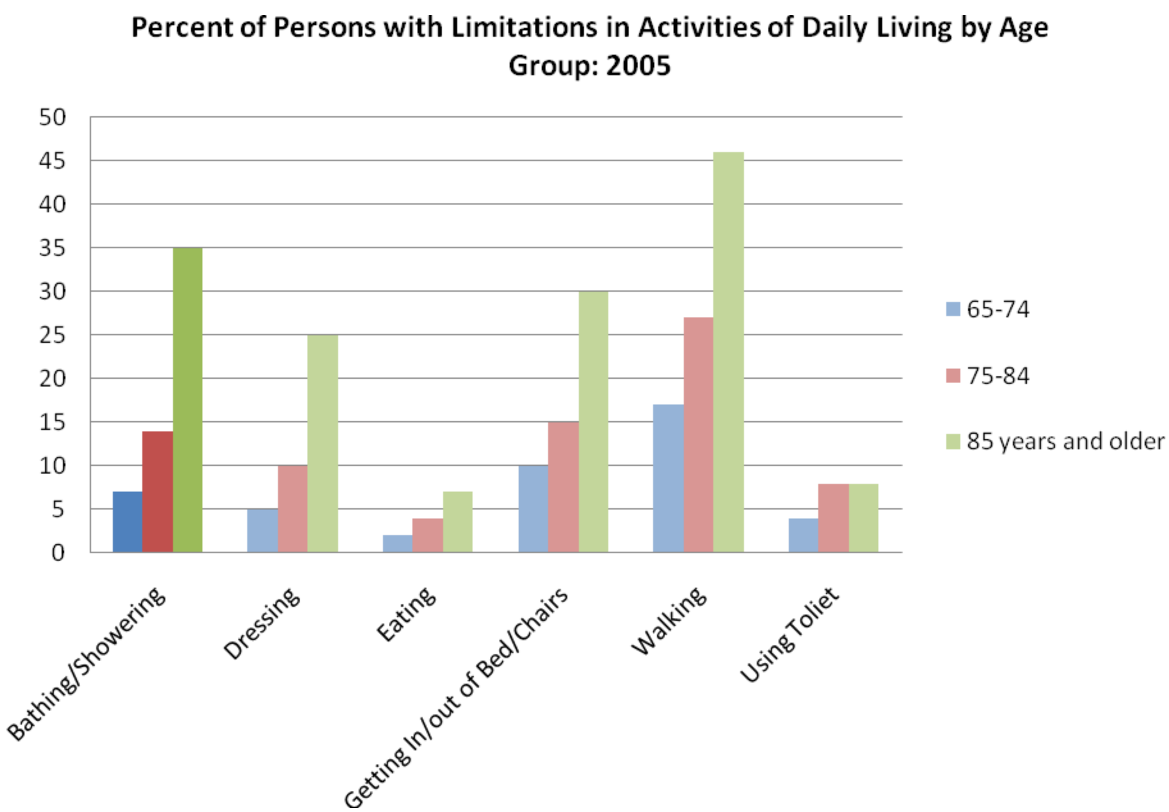
To test the structural stability of our prototype five different tests were performed. The loading weight test, the in use weight test, rocking test, and pull test all passed on the initial try. When the kick test was initially performed, the test failed. To pass the test two changes were made. First the aluminum hinges were replaced with steel hinges. Secondly, a pin was added to lock the legs while the chair is in use.

INTRODUCTION

Background Information and Problem Description

Today the elderly society is growing at a quick pace. "The population age 65 and over will increase from 35 million in 2000 to 40 million in 2010 (a 15% increase) and then to 55 million in 2020 (a 36% increase for that decade). By 2030, there will be about 71.5 million older persons, almost twice their number in 2005. People 65+ represented 12.4% of the population in the year 2005 but are expected to grow to be 20% of the population by 2030. The 85+ population is projected to increase from 4.2 million in 2000 to 6.1 million in 2010 (40%) and then to 7.3 million in 2020 (44% for that decade)."[1] In addition to the increasing number of elderly people, these elderly people have certain needs and limitations. Many of these people have issues with showering/bathing. Fig. 1 below shows that 7% of people age 65-74, 14% of people age 75-84 and 35% of people age 85+ reported showering/bathing limitations in a 2005 study. [2]

Fig. 1: Typical Limitations of Elderly



A major issue is that a large portion of these people live at home by themselves. "About 30.3% (10.7 million) of all non-institutionalized older persons in 2006 lived alone (7.8 million women, 2.9 million men). They represented 38.4 of older women and 19.4% of older men. The proportion living alone increases with advanced age. Among women aged 75 and over, for example, half (48%) lived alone." [1] Also, many of these elderly people live on limited incomes. Statistics show that elderly people who live alone are more likely to have a limited income than an elderly person who lives with a spouse. In consideration of all of the facts provided above we feel that there is a great need for an assistive showering/bathing device that offers many of the features of current expensive assistive devices, but is more affordable while adding some new innovative features.

INFORMATION SOURCES

Research on Geriatric Population

"Older American: Key Indicators of Well-Being" [2]
Findings: This article gave us many important facts about the elderly population including: size, age, physical limitations, living situations and poverty level.

"Common Geriatric Conditions Overlooked" [3]
Findings: This article gave us information about how prevalent certain geriatric conditions are and how often they are overlooked. The article gave the impression that there is not much of an effort to assist the elderly with these conditions.

Research on Existing Patents and Their Descriptions

Several patents are listed below with representative quotes from their abstracts or descriptions.
US Patent **#1805297**
A swivel chair that is very inexpensive to manufacture which mounts over the side of the tub. This patent allows for universal use with different types of tubs.

US Patent **#2142434**
This is another swivel chair with an improved type of hangar bracket over previous patents.

US Patent **#3528112**
A combined bathtub seat and spray head assembly which provides spraying to various portions of the anatomy.

US Patent **#3624666**
A device for assisting handicapped people into and out of the bathtub. This particular design operates on a rack and pinion setup.

US Patent **#4150445**
This is a bath chair that allows for rotational movement and linear movement along the tub which can be used with existing bathing facilities. This design also sprays water in the chair to help clean the areas of the body covered by the seat.

US Patent **#4472844**
This stationary seat attaches to the side of the tub and allows a channel on the side for the shower curtain to fit through.

US Patent **#5010606**
This is a circular bath seat that is secured to the bottom of the tub by suction cups and allows for rotational movement.

US Patent **#5097542**
This seat allows for both sliding and rotating movement and uses suction cups for stability.

US Patent **#5740563**
This seat mounts to a track that is set across the top of the tub. This seat slides along the track and may swivel as well.

Benchmarked Designs

Adjustable Transfer Bench (Fig. 2)
This is a completely removable transfer bench with no moving parts. The design is built out of plastic. This design incorporates suction cup feet and removable back and handle. This design can be used in either left or right hand tubs.

Heavy Duty Sliding Transfer Bench (Fig. 3)
This transfer bench incorporates a sliding motion along two rails. The base is built out of aluminum that uses suction cup feet. The seat is a contoured shape with a non-skid finish. The sliding motion may be restricted to ½" increments by the use of a locking mechanism.

Wall Mounted Shower Seat (Fig. 4)
This wall mounted design incorporates a seat that folds from the vertical to horizontal position for use. This motion causes the support legs to fall automatically to the floor. The leg length is completely adjustable by positioning screws. When the seat is down it has a height of 20". This design can accommodate weights up to 285 lbs.

Fig. 2:
Transfer Bench [4]

Fig. 3:
Sliding Bench [5]

Fig. 4:
Wall Mounted Shower Seat [6]

Lacking Information
What weight must our design me able to hold safely?
What are the dimensions (width, length and depth) of a typical bathtub?

What are the capabilities of the average elderly person (including grip strength and particularly difficult movements)?

Where Will We Find the Lacking Information?

Over the next week or two we will be able to find this lacking information through our main sponsor Naomi Gilbert, our other contact Susan Murphy and through research. We plan on arranging at least one more meeting with Naomi or Susan in the near future. They will be able to give us the information about elderly people based on their extensive work in their respective fields. The dimensions of the typical tub can be found by some online research.

SPECIFICATIONS

Customer Requirements

We developed 10 customer requirements based on our meeting with Naomi Gilbert, Susan Murphy and our trips to local medical supply stores. The customer requirements are listed in Table 1 below. The top four customer requirements are rated 10 because they address the top priorities as laid out by our sponsors and as we found through our research; safety and the ability to have a transfer bench that extends to the edge of the bathtub, to aid in entering the bathtub, while also having the ability to retract so that the shower curtain can close, and finally the ability to retract out of the way of other shower users. These top four customer requirements represent much of the novelty of our design and therefore if they were not met then our design would lose its marketability. The remaining customer requirements address the issues of cost, ease of use, and the flexibility of our design.

Table 1: Customer Requirements

Customer Requirements	Importance Rating (1-10)
Robust / Dependable / Safe	10
Allows shower curtain to close	10
Extend to outer edge of bathtub	10
Non-invasive for other shower users	10
Low cost	9
Adjustable for different bathtubs	9
Simple / Easy to use	8
Set-up conducive for caregiver	7
Space for showerhead attachments / bathtub accessories / hand rails	7
Removable / Easy to install	7

Engineering Specifications

The customer requirements were translated into engineering specifications and target values in Table 2. These engineering specifications are based on our discussions with our sponsors, the specifications of our benchmark designs, measurements of actual shower set-ups, and established general engineering practices. For example, the engineering specifications for the cost, the range of adjustment, the weight that our design must withstand, and the height of the collapsed mechanism are all specified based upon values quoted in the benchmark designs. [3] [4] [5] While the dimension from the inside edge of the bathtub is based on a measurement of the width of an actual shower curtain. Some of the other engineering specifications, such as "No. of attachment locations", come from our sponsor.

The relationships between the customer requirements and the engineering specifications can be found in the quality function deployment (QFD) in Appendix A. These relationships, along with the importance ratings of the customer requirements were used to establish the rankings of the engineering specifications shown in Table 2.

Table 2: Engineering Specifications and Target Values

Engineering Specification	Rank	Target
Dimension from inside edge of bathtub (in)	1	6
Factor of Safety (#)	2	1.5
Cost ($)	3	<150
Range of adjustment (in increments)	4	1/2
Weight of geriatric patient (lbs)	5	285
Dimension from outside edge of bathtub (in)	6	0+
No. of attachment locations (#)	7	4
Weight of mechanism (lbs)	8	<25
Height of collapsed mechanism (in)	9	3.5
No. of steps to get in and out of bathtub (#)	10	4
Maximum deflection (in)	11	<1
Surface roughness of seat (Ra)	12	No skid
No. of moving parts (#)	13	2

CONCEPT GENERATION

Several different methods to assist geriatric patients into the bathtub were generated through various brainstorming sessions held by our team, also known as the 'Deep Dive'. We worked independently and then together to ensure we had several diverse solutions. After rough drawings of 20 concepts were generated, we noted the advantages and disadvantages of the various designs. After a review of all of the concepts was completed we voted to determine the most feasible and innovative designs, we were left with five designs.

Once the five designs were determined we further analyzed them to determine the most create and feasible designs. We developed four main functional groups in which to consider our project: method of attachment, collapsibility, extending mechanism, accessory attachments. The five finalized designs were then evaluated with respect to these four functional groups. We then compiled a table demonstrating the advantages and disadvantages of each design. The rough drawings of the five finalized designs were improved upon to explain how each mechanism functioned. Lastly we constructed a selection matrix, using the advantages and disadvantages table, to determine to alpha design to proceed with.

"The Deep Dive"

The first step when creating a new design is brainstorming. Our team used a method similar to the IDEO method of brainstorming. We began by discussing the product requirements and customer needs. We then worked individually for a short amount of time to create several diverse ideas, both practical and not. Next we gathered all of the concepts we had generated and discussed the different virtues of each.

This method enabled us to consider a wider range of ideas and we came up with ideas ranging from a folding chair design to a swing and to a magnetically operated chair. Appendix B shows the various rough concepts we created.

CONCEPT SELECTION

The Five Final Solutions

After the Deep Dive our team evaluated each design based on its feasibility, and innovation to current products on the market. We then each voted to determine which concepts were best. After the voting process we were left with 5 final designs: the "Sliding Bench", the "Swing", the "Folding Chair", "Rail in the Tub" and the "Cedar Point Ride". Further Illustrations of these concepts can be seen in Appendix B.

Four Functional Groups

Each of the five proposed designs had four main functional groups we considered:

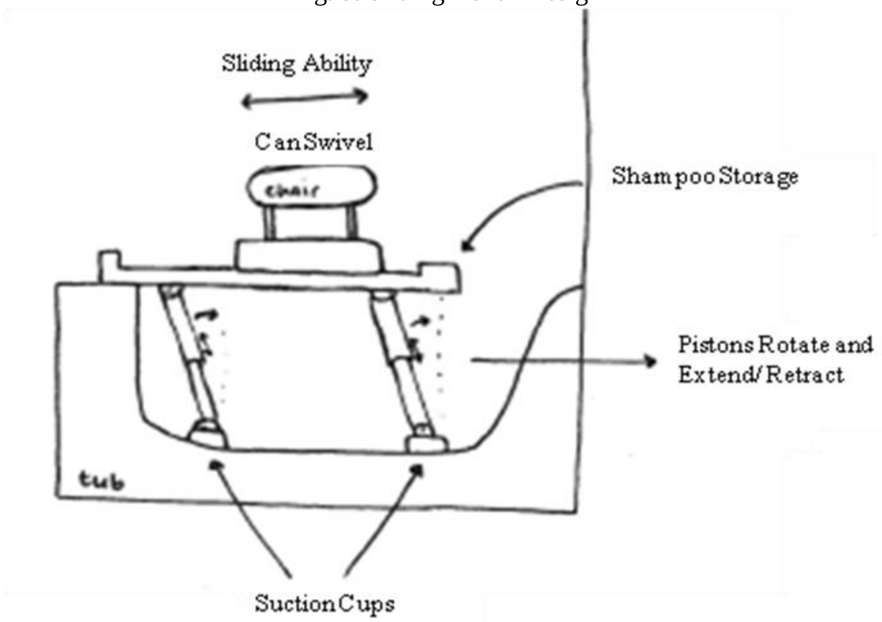
-Method of Attachment
-Collapsibility
-Extending Mechanism
-Accessory Attachments

Below, we describe how each of the proposed designs works with regard to the four functional groups:

Sliding Bench Design: The Sliding Bench design allows geriatric patients to slide into the bath on a swiveling chair, and then lower slightly into the tub. This can be seen in Figure 5 on page #. The advantage of this design is its simplicity, it would be both easy to use and easy to manufacture. The primary disadvantage of this design is its size. While it can be removed from the tub, it is still very bulky and takes a lot of room.

The Sliding Bench design attaches to the bottom of the tub with two suction cups. The whole device can be removed from the tub by releasing the suction cups; however the device does not collapse beyond that. Two pistons allow for the bench to rotate up and over the lip of the bath to assist the person in (see Appendix B). Additionally, the seat both slides and swivels to get the chair as close to the edge of the tub. The design also includes a space for easy access to shampoo and soap on the wall side of the device.

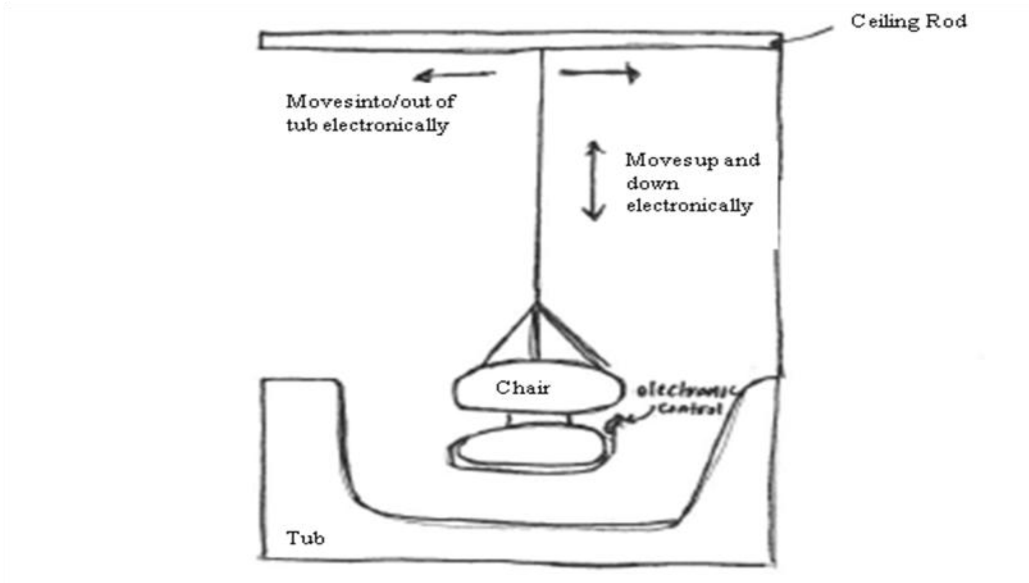
Fig. 5: Sliding Bench Design



Swing Design: The Swing Chair design allows geriatric patients to be easily moved into bathtub by utilizing a ceiling rail, as seen in figure 6. This idea was inspired by products used to aid with pediatric disabilities. This design would also enable the geriatric patient to sit in the tub fully submerged for a bath. Additionally, the swing could be easy detached allowing others to take showers unobstructed. There are 2 primary disadvantages of this design: First, the device would be a permanent fixture in the bathroom. Secondly, there is very limited space for accessories.

To attach the swing, a rail would be mounted to the ceiling. The swing would hang from a cable which moves along the ceiling rail. The cable and swing are detachable resulting in a design that can easily be removed for other people. The cable would electronically extend and retract, and can be controlled using a remote on the chair.

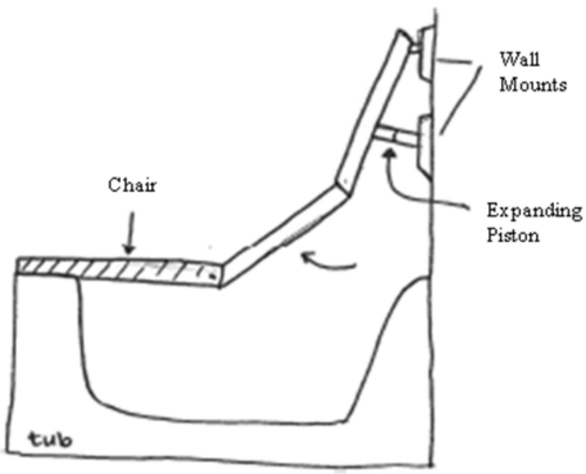
Fig. 6: Swing Design

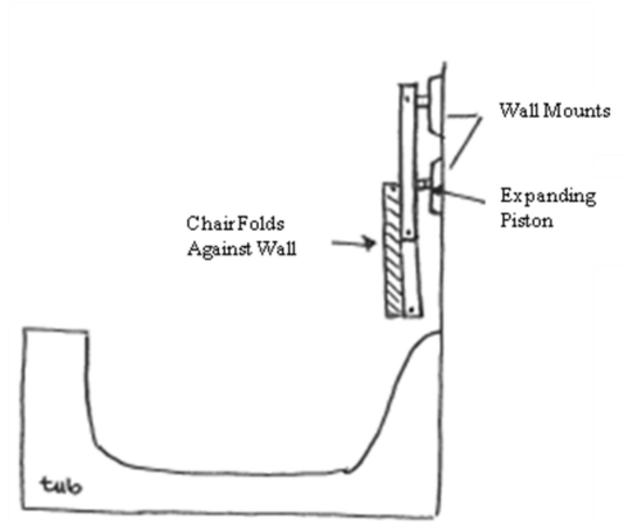


Folding Chair Design: The Folding Chair design works similar to fold away ironing boards. When fully out stretched it would assist geriatric patients into and out of the bath tub, see figure 7. However when not in use the chair folds neatly against the wall. To extend the assistive device a caregiver would manually unfold the bench. The primary disadvantage of this design is that when it is outstretched there is no natural place for the person to sit. Additionally, this design does not allow for the shower curtain to close.

The folding chair method attaches to the wall using high strength suction cups. The design allows for the bench to be folded against the wall, quickly collapsing out of the way for other people taking showers. Additionally, the suction cups could be removed to completely take the device out of the bath. The device would extend using mechanisms similar to those used for fold away ironing boards. The bench would extend using 3 circular pins and as well as a piston. When this design was developed no accessories were accounted for, however this would be a simple addition.

Fig. 7: Folding Chair Design

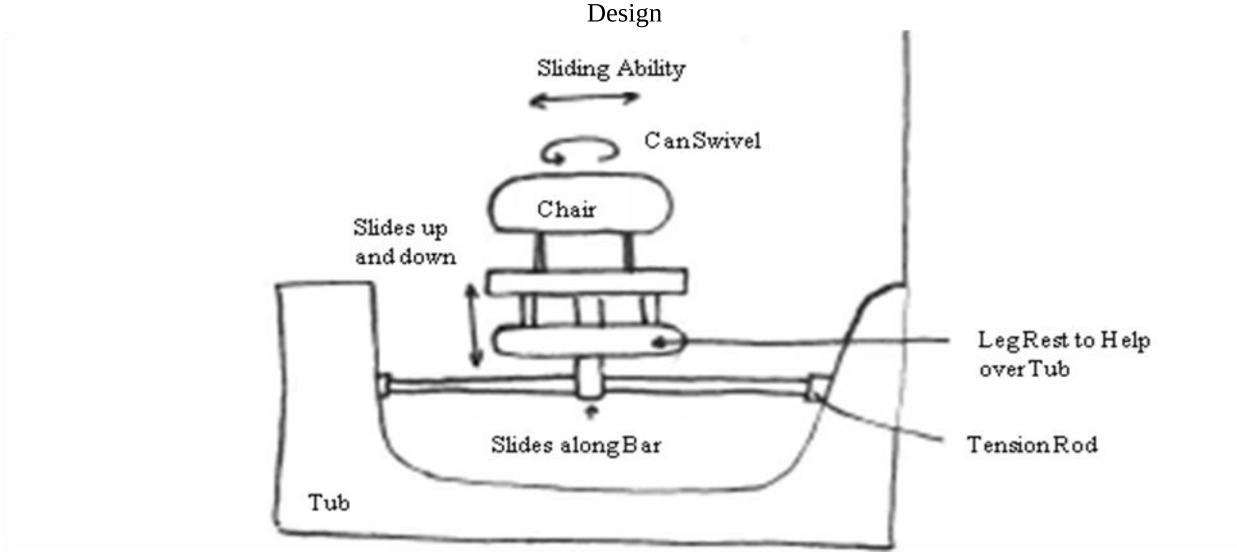




Rail in the Tub Design: For this design a tension rod is secured in the bath tub using suction cups. The swivel chair slides along the rod. The chair can also be raised and lowered using a piston. Space for accessories is available on the wall side of the chair. This design has a few key disadvantages. First, the chair does not fully extend over the lip of the bath tub. Secondly, the inner shower curtain will not be able to fully close.

The Rail in the Tub design is attached using a tension rod. The tension rod spans the middle of the narrow width of the tub, as seen in figure 8. This design can be completely removed from the bath tub by removing the tension rod, however it does not collapse. This device involves no extension device, the chair slides along the tension rod to assist the geriatric patient. Space for accessories is included on the wall side of the device.

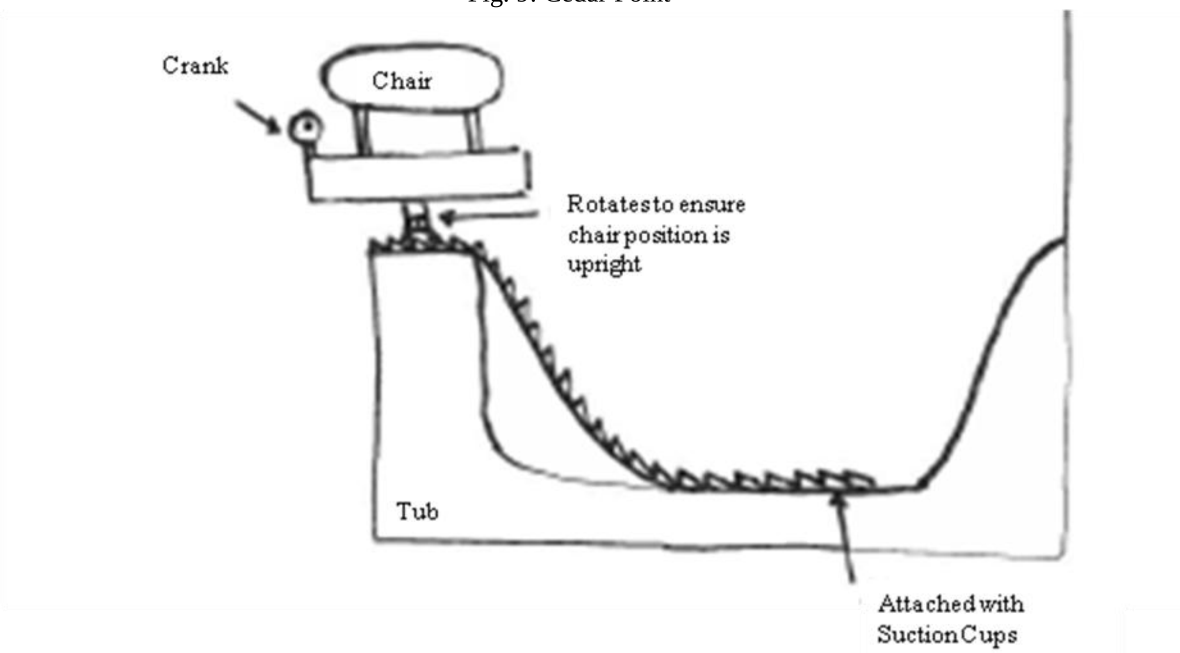
Fig. 8: Rail in the Tub Design



Cedar Point Ride: This idea was inspired by the mechanisms that take roller coasters up to the top. This design uses a ratcheting device to move into and out of the tub, see figure 9. The bottom of the chair would connect to a railing that has ratchets. The chair itself swivels, aiding geriatric patients over the edge of the tub. The geriatric patient or caregiver would mechanically crank the device up and down. There are several disadvantages of this device. First and foremost, the geriatric patient would have to provide the power to get them into the bath. Additionally, the inner shower curtain will not fully close.

The railing along which the chair moves is fixed to the base of the tub using suction cups. The chair is attached to the rail with a ratcheting device. While this can be removed from the tub, it would not be advisable as it would take some time to set back up. It is not collapsible. This device does not make use of an extending mechanism, nor was accessory space accommodated for.

Fig. 9: Cedar Point



Ride

Determining the Final Alpha Design

After determining the final five concepts, we further studied and refined each of them. Each design was analyzed with respect to the customer requirements and the four functional groups defined. Additionally we added a category of “manufacturability”, while this isn’t a customer need; it does affect the feasibility and cost of the product. To help determine the best Alpha Design a table with the advantages and disadvantages was constructed, this is seen in Table 3 on page 13. Then our team used a selection matrix to determine the designs that best met our customer requirements. Using the selection matrix seen in table 4 on page 14, we determined that there were two designs that scored the highest with respect to all of our customer requirements. Therefore we decided the best design would actually be a combination of these two concepts. We combined the “Sliding Bench” and the “Folding Chair” designs to create the “Sliding Folding Chair”, a sliding/ swivel chair that could fold up against the wall. We chose the best qualities from each of the two designs by focusing on which aspects of the two designs best address the four main functional groups mentioned on page 11. Then to verify that our alpha design was actually an improvement on our initial design concepts we used the selection matrix analysis again. Through this analysis, see Appendix C, we determined that our new design concept did meet the customer requirements more effectively.

Table 3: A Summary of Main Design Advantages and Disadvantages

Design	Advantages	Disadvantages
Sliding Bench	-Not a Permanent Fixture -Includes space for Accessories -Easy to operate	-Several Mechanisms -Does not Collapse -Limited Distance into Water
Swing	-Very Simple Mechanisms -Easily Detaches -Submerges into Water	-Permanent Fixture -Limited Space for Accessories
Folding Chair	-Not a Permanent Fixture -Collapses against Wall -Simple Design	-Awkward Seating Area -No Space for Accessories -Does not go into Water -Shower Curtain cannot close
Rail in the Tub	-Very Simple Mechanisms -Easily Removed -Includes space for Accessories	-Does Not Aid in Getting Over Lip -Shower Curtain cannot close -Does not Close
Cedar Point Ride	-Submerges into Water	-Manual Power -Shower Curtain cannot close - Does not Collapse

The Final Alpha Design Concept: The Sliding Folding Chair

We determined the best solution would be to combine the advantages of two different designs, this can be seen from our selection matrix. From discussions with sponsors, and the selection matrix we determined the "Sliding Folding Chair" to be the recommended alpha design. See Table 4 for the detailed selection process.

Table 4: Selection Matrix

Customer Requirements	Importance Rating (1-10)	Average Rating					
		Sliding Bench	Swing	Folding Chair	Rail in Tub	Cedar Point Ride	Alpha
Robust / Dependable / Safe	10	35	37.5	32.5	30	20	45
Allows shower curtain to close	10	50	47.5	30	20	12.5	50
Extend to outer edge of bathtub	10	50	47.5	50	22.5	47.5	50
Non-invasive for other shower users	10	25	40	37.5	25	15	40
Low cost	9	27	24.75	29.25	29.25	15.75	29.25
Adjustable for different bathtubs	9	33.75	31.5	36	33.75	24.75	36
Simple / Easy to use	8	28	28	26	24	18	32
Set-up conducive for caregiver	7	26.25	17.5	17.5	22.75	17.5	29.75
Space for showerhead attachments / bathtub accessories / hand rails	7	28	7	14	15.75	12.25	31.5
Removable / Easy to install	7	19.25	10.5	24.5	22.75	10.5	24.5
Manufacturability	9	24.75	22.5	27	24.75	13.5	33.75
	Total Score:	347	314.25	324.25	270.5	207.25	401.75
	Normalized Score out of 10:	7.23	6.55	6.76	5.64	4.32	8.37

THE ALPHA DESIGN

Alpha Model

As mentioned above our group moved forward designing our alpha model incorporating the best of our preliminary concept sketches. Our goal was to create a shower assisting device that is functional without permanently attaching to the shower or obstructing other shower users. Below are descriptions of preliminary alpha design characteristics by functional group.

Overview of Alpha Design

Combining the four main functional groups as well as some comfort amenities such as a swivel chair, our team was able to create the basic shape of our design. A model of the alpha design while in the extended position used for loading and unloading can be seen in Figure 10. A CAD model rendering of the alpha prototype while in use can be seen in figure 11 a and b. A model of the alpha design while being stored away can be seen in Figure 12 a and b.

Fig. 10: The alpha design in the extended position used for loading and unloading

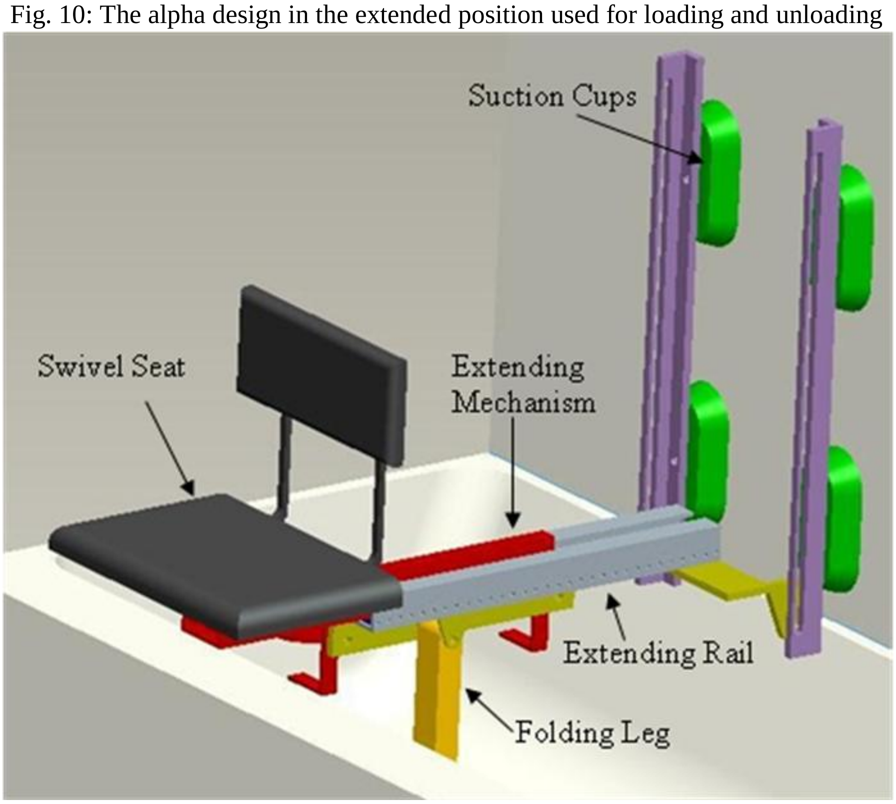


Fig. 11 a and b: Are front and rear views of the alpha design when in use.

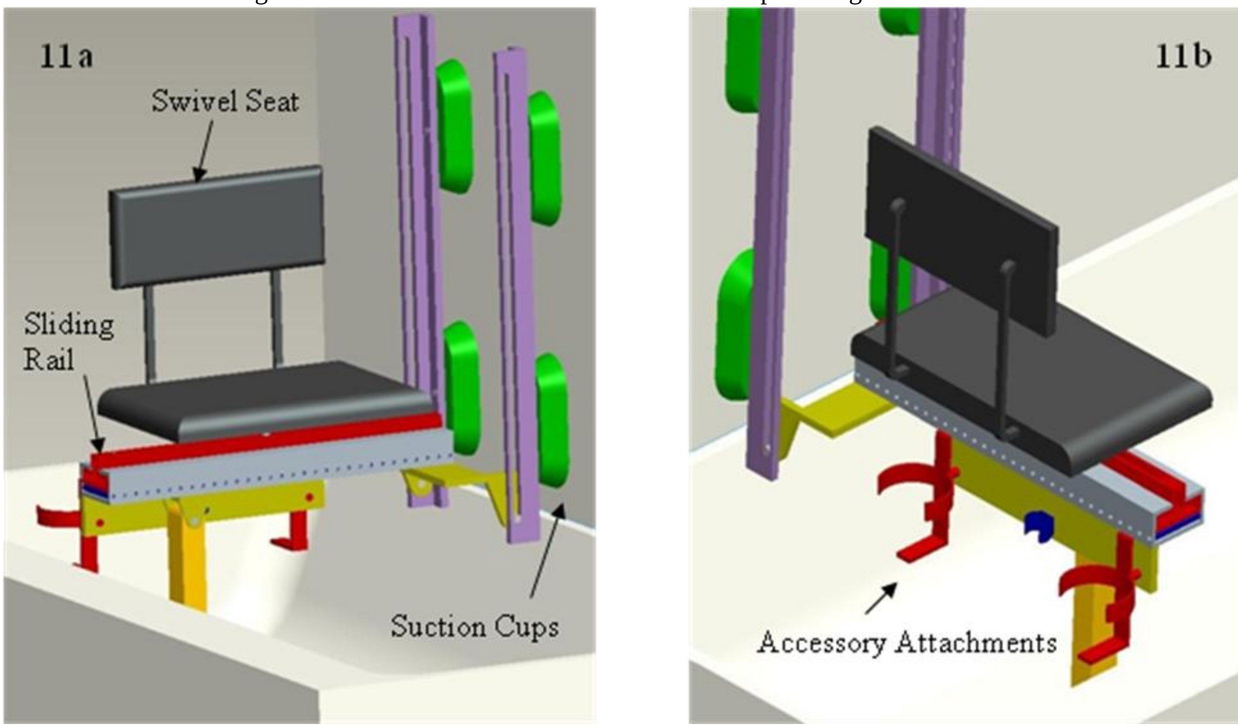
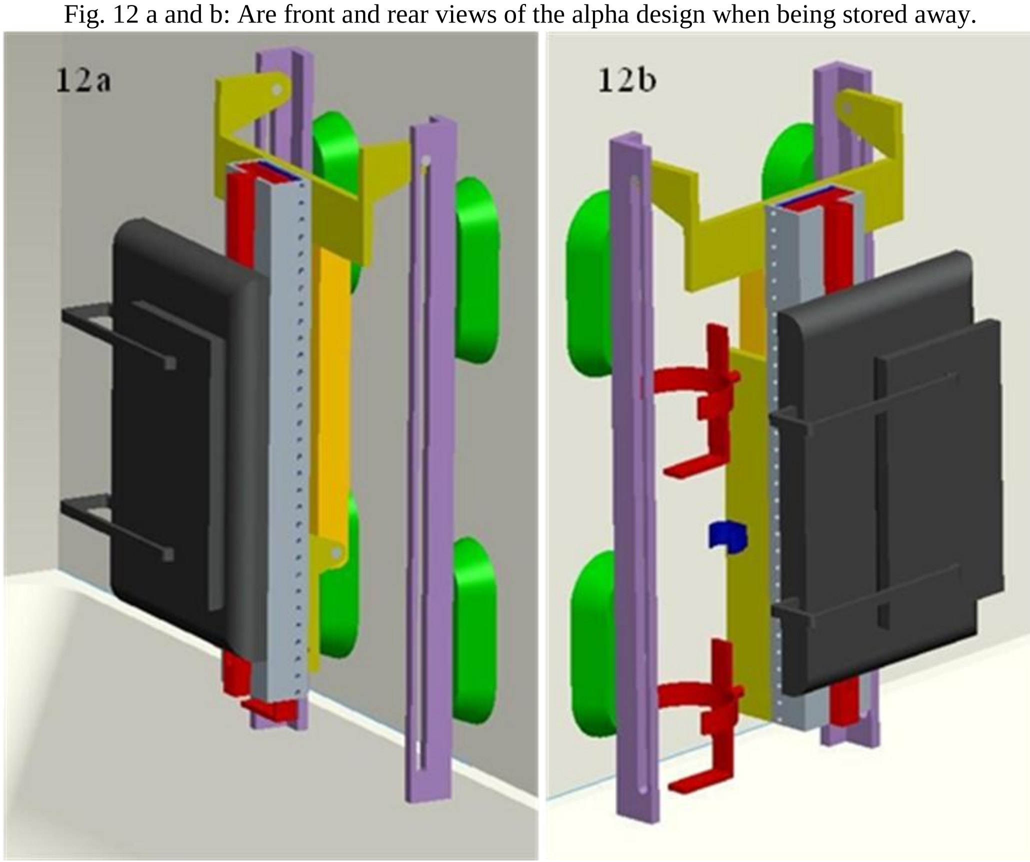


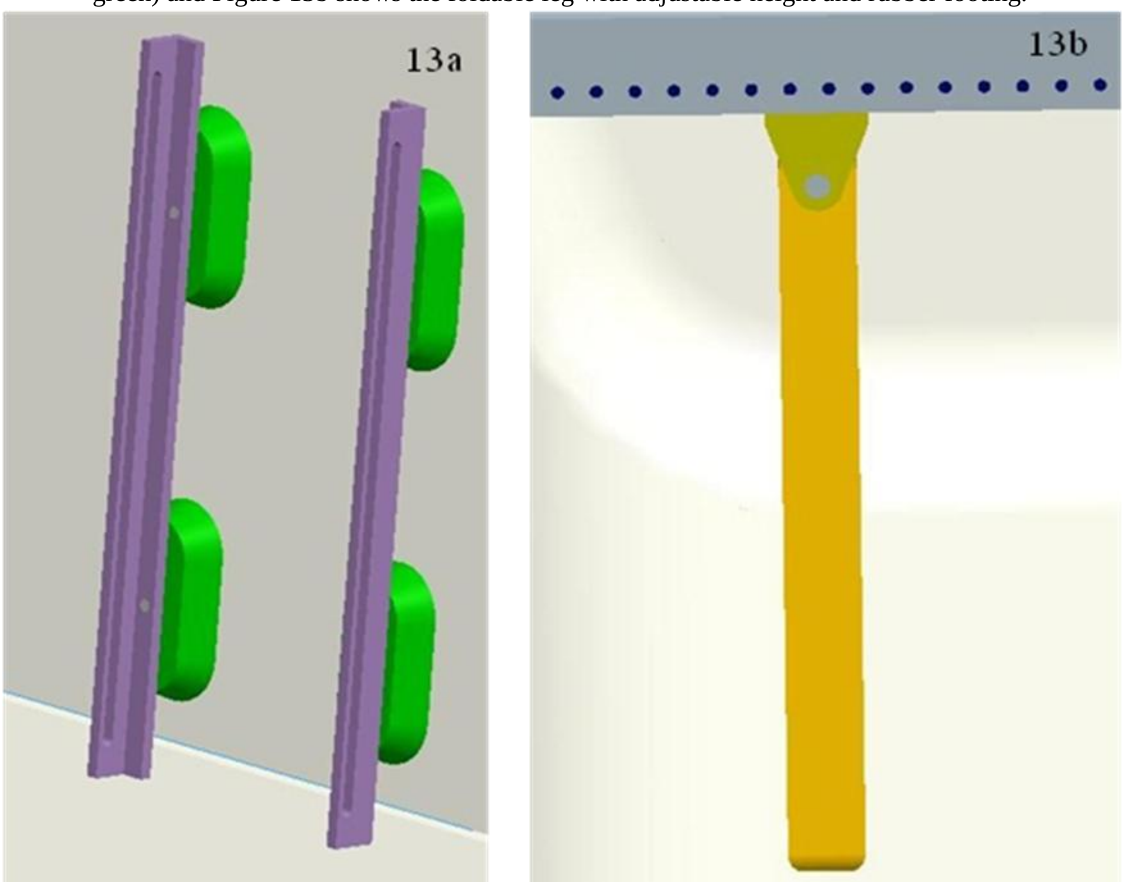
Fig. 12 a and b: Are front and rear views of the alpha design when being stored away.



Non-permanent Attachment

The figure below outlines the basic attachments for our alpha design. Our main attachment support will come from high strength suction cups mounted on the inside shower wall. High strength suction cups are currently on the market used for picking up large glass sheets. For added support a center foldable support will be a mounted under the extension device and rests on the bottom of the bathtub. The center support will mimic that of the bottom half of a crutch, with adjustable height and a rubber foot that protect against bathtub scratches and damage.

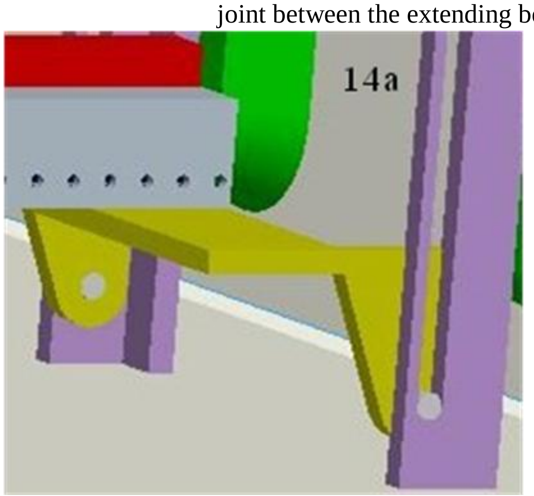
Fig. 13 a and b: The non-permanent methods of attachments. Figure 13a shows high strength suction cups (seen in green) and Figure 13b shows the foldable leg with adjustable height and rubber footing.

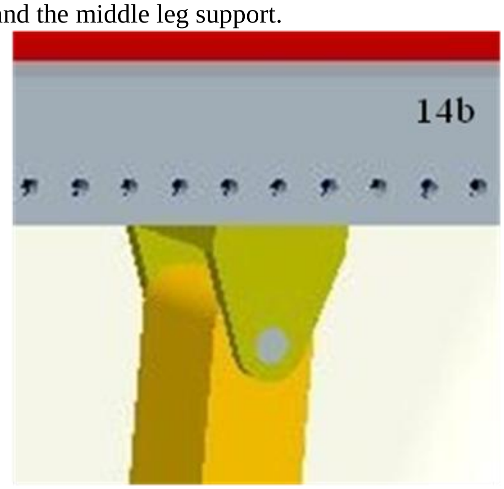


Collapsibility

By having our alpha model collapsible the assisting device can be stored away and be less intrusive to other shower users. To have the bench be functional while in use and out of the way when being stored our group has designed our alpha model to attach to vertical rails located on the inside wall above the bathtub. The bench (with extending mechanism and chair attached) will be mounted to the rails with pins allowed to slide vertically in the rails as seen in figure 12. When in use the bench will be horizontal attached to the bottom of the vertical rails. Before use a foldable leg, under the extension rail, will fold down and add structural support. After use the leg will fold in again and allow the bench to slide up the wall again. Also to reduce the space when in the storage position the chair back will fold onto the seat top. Currently the bench assembly will be put into the using position and storage position by hand, but our team is looking into a pulley mechanism for assistance.   A rough connection setup is shown below.

Fig. 14 a and b: Show how the attachment points that allows our design to collapse. Figure 14a is a close up of the pin attachments between the vertical rails and the horizontal support. Figure 14b is a close up image of the foldable joint between the extending bench and the middle leg support.

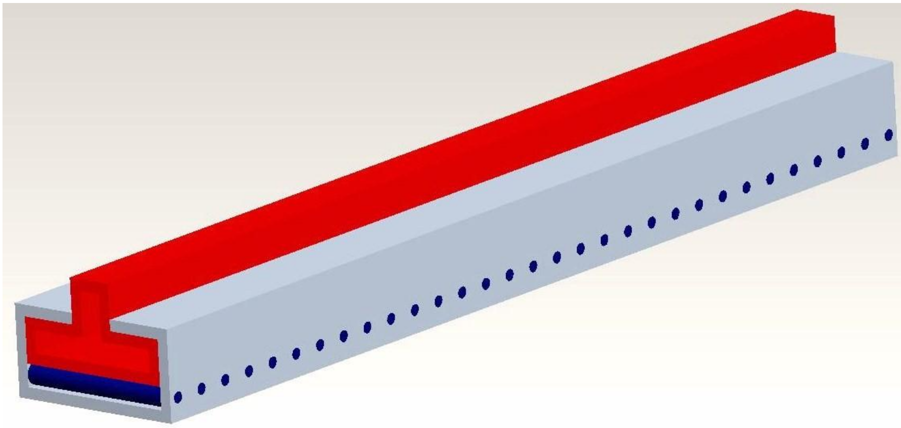




Extending Mechanism

An extending mechanism is critical in our design, because it allows the assisting device to be used properly while allowing the shower curtain to pass freely by. When a person would like to use the bench they (or an assistant) will extend the bench out to the edge of the tub where they can easily sit down on it. After they move their legs to the inside of the tub the extending mechanism can retract so that the bench is located in the middle of the tub. This allows clearance between the bathtub sill and the edge of the bench for the curtain to move past. There will be locking stops at the extended point and fully retracted location. Attached to the sliding rail will be a seat that swivels ninety degrees and locks. Our design for the sliding mechanism is more specifically a track in rail type mechanism. The rail on the inside of the track is supported by bolts surrounded by a low friction sleeves that can free spin around the bolt. Below are preliminary design sketches of the extending mechanism.

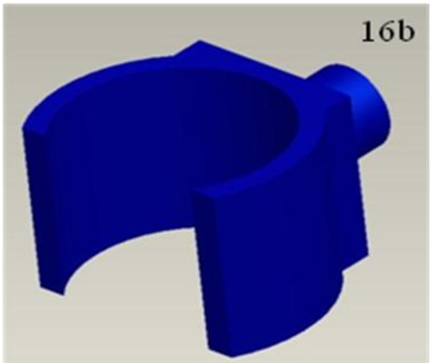
Fig. 15: A close up image of our extending mechanism. The rail (seen in red) will extend out and back on bolts covered with a low friction sheath (seen in blue). The rail will lock to the track (seen in gray) at the most extended and fully retracted locations.



Accessory Attachments

When in use many geriatric bench users clean themselves or have someone assist them without leaving the bench, therefore, we plan on using accessory attachments. The attachments will be able to hold shampoo, conditioner, liquid body soap, and a removable showerhead attachment. For the soaps and conditioner we plan on using a water bottle holder type design for a bike. By using this type of holder many different size bottles can be held, as well as it limits the collection of water with respect to cup holder style holders. The shower head attachment will be a "c hook" type design where the hose can pass through, but the removable head handle is two large and catches. Both attachments will be located at the back of the bench out of the way but still reachable and convenient. Design drawings for both the soap and shower head attachments can be seen below.

Fig. 16 a and b: Shower attachments for shampoo, soaps, and removable shower head. Figure 16a shows the shampoo and soap container holder modeled after a water bottle holder for a bike. Figure 16b shows the "c hook" type shower head holder.



PROBLEM ANALYSIS

Our list of customer requirements came from our sponsor's input during our meeting as well as our own engineering judgment based on our research and personal experiences. In order of importance our requirements are as follows: robust/dependable/safe, allows shower curtain to close, seat extends beyond side of tub, simple/easy to use, low cost, adjustable for different bathtubs, work in glass door shower, non-invasive for other shower users, space for showerhead attachments and bathtub accessories and easy to install.

- The robustness/safety of our assistive device is clearly the top priority. The device needs to safely handle the weight of the user and work dependably so that a user wouldn't possibly become trapped.
- The ability for the shower curtain to close when our device is in the tub is very important. This eliminates the possibility of a slip hazard after the shower/bath and differentiates our device from other products on the market.
- The ability for the device to extend beyond the side of the tub allows the user to get in and out of the tub easily.
- The device must be simple and easy to use so that it improves the user's experience so they are willing to use the device.
- The device must be low cost so that people will be able to afford it and will to purchase it.
- Our device must be adjustable enough to account for dimensional variations in different bathtubs.
- The ability of our device to work in a tub with sliding glass doors would make it completely unique as there is no current solution.
- Our device must be non-invasive for other shower users so that other people may use the bathtub.
- The ability for our device to hold a showerhead attachment and bathtub accessories would eliminate the need for the user to have to reach all over the tub making bathing easier.
- Our device must be easy to install so that an average person could read and understand the instructions so that they could install it by themselves.
-

One of the largest difficulties of our design will be allowing the shower curtain to close and trying to make our device compatible with sliding glass doors. Currently there are not any good products on the market that have these qualities. With the current products users have to cut the shower curtain or remove the glass doors and put up a shower curtain.

THE FINAL DESIGN

After feedback from Design Review 2, our Alpha design underwent significant modifications taking into consideration suggestions from faculty, our sponsor as well as feasibility of manufacturing. There are three main major changes that will be discussed, these include: (1) permanently fixing the design to the wall, (2) Rail extension design, and (3) upward folding design. In the 'Specific Problem Areas' section we discuss why these changes were made, and a detailed description of the new parts can be found in the 'Materials and Parts List' section. The Modified views of the CAD model can be seen in Figures 17 and 18 below and 19 on page 25. For a labeled figure refer to Figure 20 on page 26, this can also be found in Appendix D. Detailed engineering drawings of all parts can be found in Appendix E.

Fig 17: Finalized CAD design in use

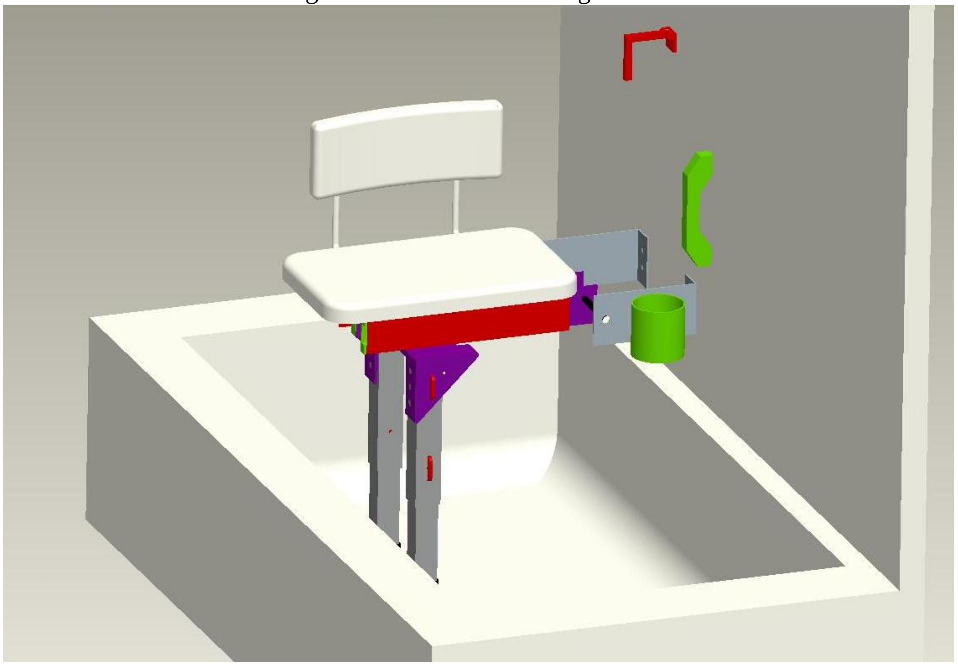


Fig18: Extended Design

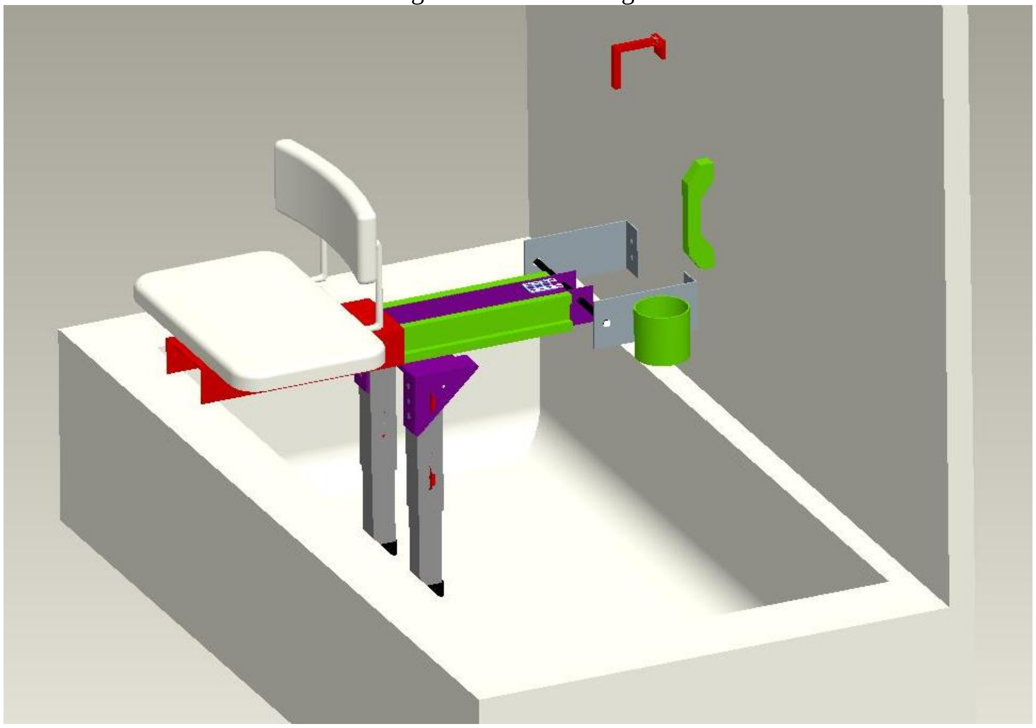


Fig 19: Collapsed Design

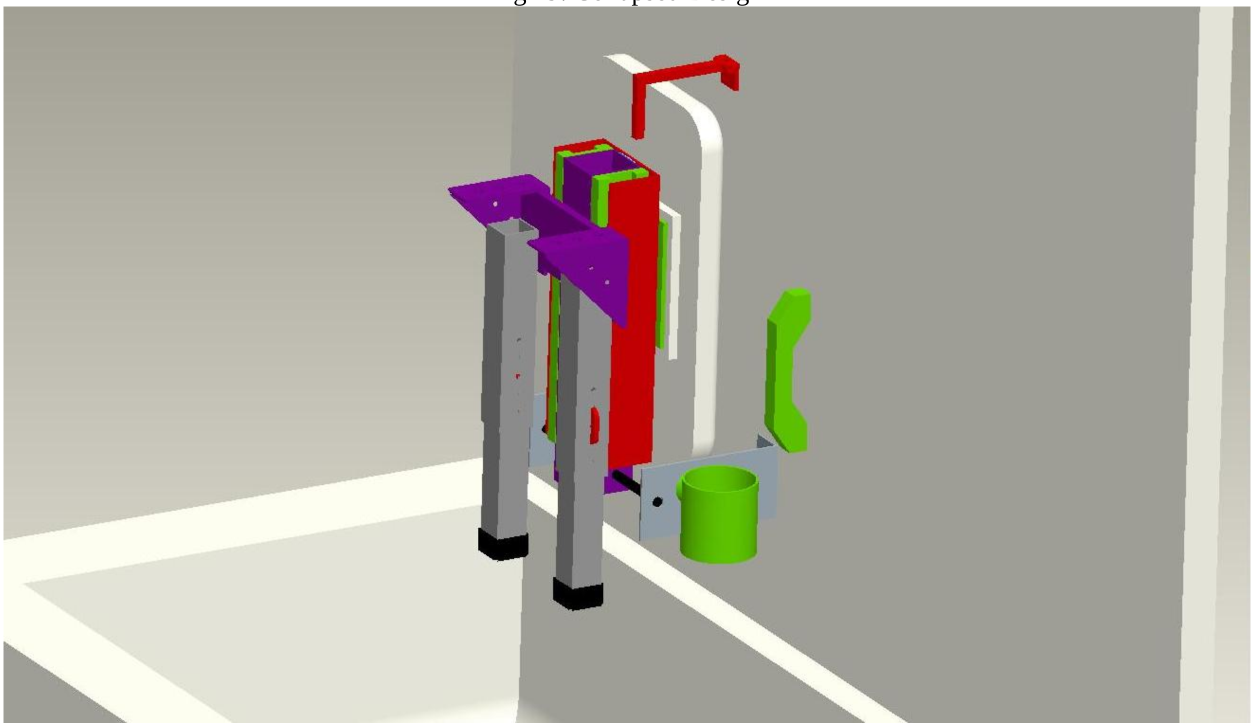
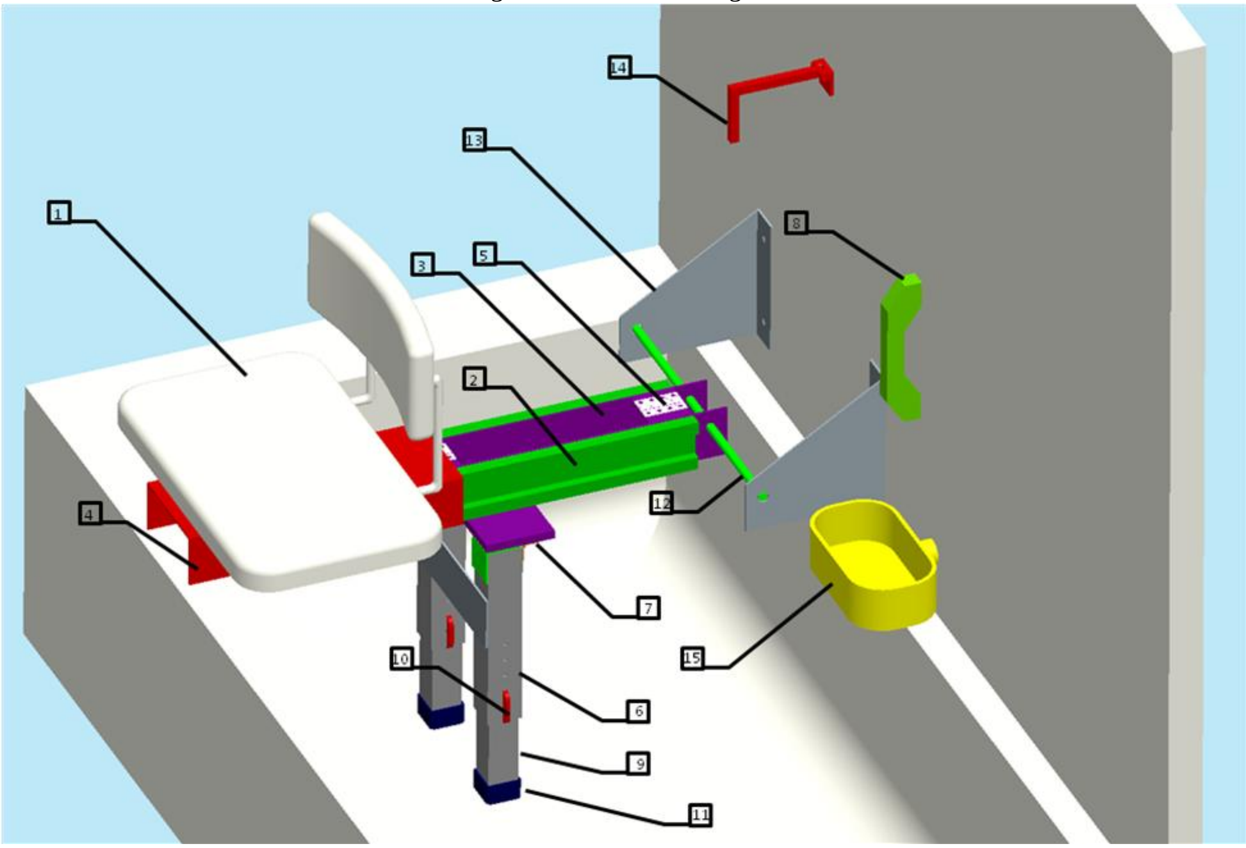


Fig 20: Labeled CAD Figure



In the figure above the numbers refer the following parts:

1. Seat
2. Sliding Rails
3. Inner Channel
4. Outer Channel
5. Magnetic Catches
6. Outer Leg
7. Leg Hinge
8. Wall Handle
9. Inner Leg
10. Leg Locking Pins
11. Plastic Feet Covers
12. Steel Rod
13. Wall Brackets
14. Wall Locking Device
15. Shampoo Holder

SPECIFIC PROBLEM AREAS

The potential areas for trouble in our project can be divided into four main categories: the attachment to the wall, the main structure, swivel seat, and the legs. These areas will be discussed specifically in the following section. Additionally, environmental elements of the bath tub have to be considered for the design. Specifically water and soap scum can lead to rusting and corrosion.

Wall Attachment

Suction Cups: Initially we considered using suction cups to attach the transfer bench to the wall; however we determined the shear stress and tension placed on the suction cups along with the wall surface would make suction cups unfeasible. Additionally in the geriatric market stability is very important. The stability of the structure out weighted the importance of being fully removable. This decision was discussed with both our sponsors and professors; the design still incorporates several new innovative features without being easily removable.

Pulley Design: After discussing with Dan Johnson we determined the pulley mechanism would be unnecessarily complicated, thus we revised the design so the structure folds up and is latched at the top.

Bolts: The bench will be attached to the wall using bolts. The bolts will experience shear stress.

"L" Brackets: The "L" bracket s will experience localized stress where each bolt attaches to the wall, as well as where the pin attaches to the bench.

Rod: The rod holding the bench to the "L" bracket will experience shear stress and tear out.

Main Structure

Bending: There is significant bending moment when the bench is fully extended and the person is getting into or out of the bath tub. This has caused several problems in our design, because it creates very large forces of the design. After much research we discovered a heavy duty sliding rail rated for 400lbs in the fully extended position, which is mentioned below.

Pin Attachments: There will be localized stress where the pin attaches the main structure to the "L" bracket on the wall. Additionally there will be shear stresses in the pin, as mentioned above in the 'Wall Attachment' section.

Corrosion on the Rails: Careful consideration should be taken regarding how to mount the rails to ensure they are not over exposed to water

Swivel Seat

Attachment to Main Structure: The seat will be attached to the main structure using bolts. These bolts will be in tension and have shear stress on them.

Locking Mechanism: Careful attention must be paid to the materials used for the locking mechanism to ensure it does not corrode.

Leg

Folding Joint: A hinge will be used that allows the leg to rotate 90 degrees. There will be localized stress where the legs is attached to the hinge, as well as where the hinge is attached to the main structure. The both attached to the main structure will be in compression as well as have shear stress. The bolt attached to the leg will have shear stress on it.

Bottom of Tub: The foot at the base of the leg will need to have a large enough area to distribute the load, to prevent the base of the tub failing. Additionally, the foot must be designed with a material that will withstand the water in the tub and not slip.

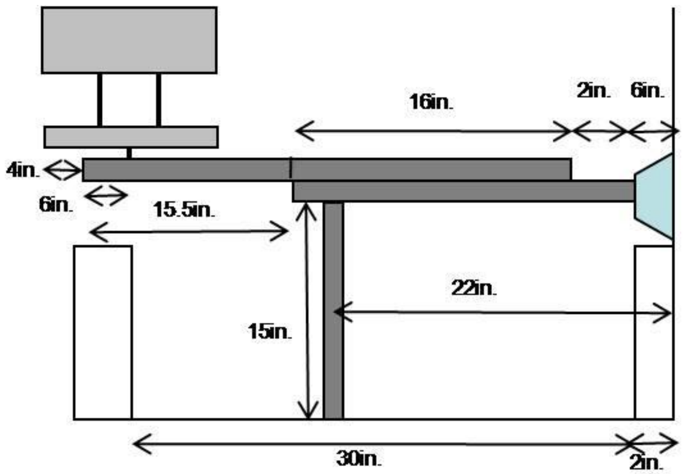
Locking Mechanism: A locking mechanism will be used to ensure the leg is held either in the collapsed position or the fully extended position. The locking mechanism will have shear stress.

TECHNICAL ANALYSIS

The following calculations were performed to determine what type of material properties are needed for the various parts of our design. These values will later be used to select the materials needed in order to ensure a safe design. All of the equations not cited otherwise can be found in the *Statics and Mechanics of Materials* [7] reference book cited in the bibliography.

To perform a technical analysis of the potential failure areas for our design we first had to discover all of the major forces acting on our mechanism. In order to do this we first had to establish the necessary dimensions of our mechanism based on the standard dimensions of a bathtub, as shown in Fig. 21 on page 29.

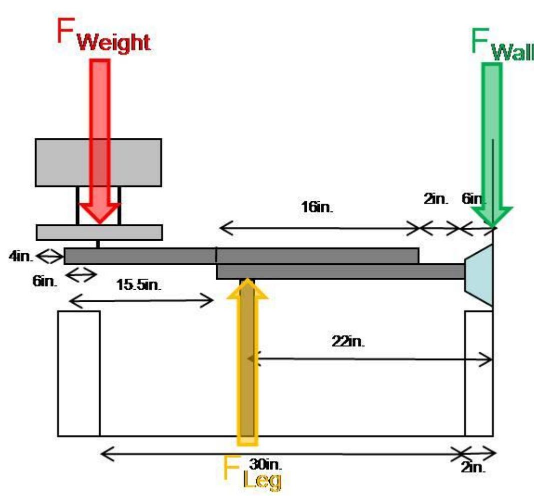
Fig 21: Bathtub Dimensions



The dimensions that could not be chosen were the dimensions of the bathtub and the dimension of the sliding mechanism. The dimensions of the sliding mechanism are that it is 16 inches in length and it can extend an additional 16 inches. We chose to give six inches of room from the wall to the pivot pin to allow area for the mechanism to collapse against the wall, and we chose to place the leg as far from the wall as possible because this is the best location for the leg to combat the force of the 300lb load.

Once these dimensions were established we began our analysis of the major forces acting on our mechanism. Throughout our analysis, our major assumptions were that the weight ratings given by the manufacturers are correct, and that the components that we purchase will perform to specification. One component that required these assumptions was our sliding mechanism. Our sliding mechanism is rated to support up to 400lbs in the fully extended position. Therefore we assumed that our sliding mechanism would act as a rigid member, and we did not perform any calculations regarding the survival of the extension mechanism itself. Using this assumption we found the major forces acting on our mechanism by doing the force and moment balances illustrated in Figure 22 below.

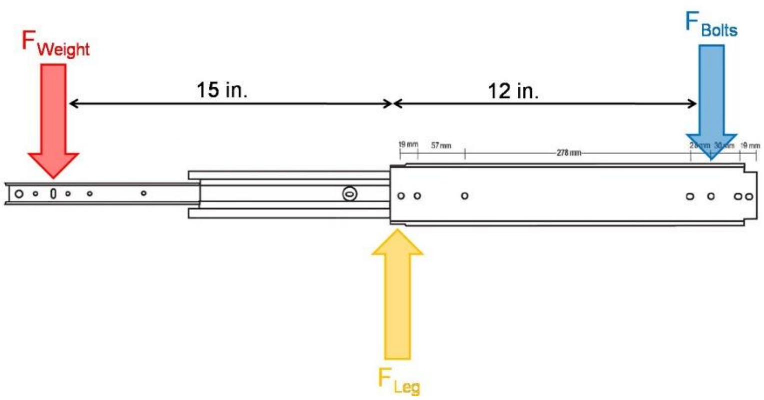
Fig. 22: Overall Moment and Force Balances Free Body Diagram



$$F_{Weight} = 300lbs$$
$$\sum M_{Leg} = (12in.)(300lbs) - (14in)(F_{Pivot}) = 0$$
$$F_{Pivot} = 257lbs$$
$$\sum F_y = F_{Leg} - 300lbs - 257lbs = 0$$
$$F_{Leg} = 557lbs$$

Although we did not need to perform calculations regarding the survival of the sliding mechanism itself, we did however need to perform survival calculations on all the connections of the extending mechanism to the other components of our design. Since we assumed that the extension mechanism is a rigid member our calculations of the survival of the attachments consisted mostly of analysis of shearing of bolts and tear out of bolts through the attached material. First, for the analysis of the shearing of the bolts we analyzed the forces acting on the rigid extension mechanism. These forces will have to be barred by the bolts and are shown in Fig. 23 below.

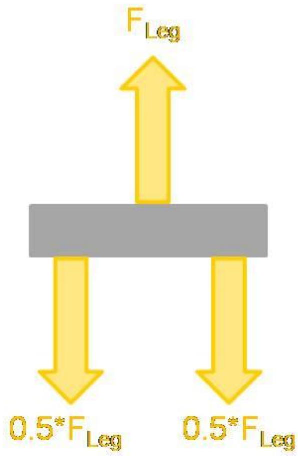
Fig. 23: Moment and Force Balances of Extension Mechanism



$$F_{Weight} = 300lbs$$
$$\sum M_{Leg} = (15in.)(300lbs) - (12in)(F_{Pivot}) = 0$$
$$F_{Bolts} = 375lbs$$

The largest of these forces is the force exerted by the leg when the sliding mechanism is in the extended position, so our approach was to check if the bolts at this point can withstand this force without shearing. If they can, then the bolts at the other locations should be able to withstand the lesser forces, since the same bolts are used at the various locations. For simplicity of this calculation we assumed that the cluster of bolts, that will be attached to the two U-Channels and sliding mechanism, can be grouped together as one bolt. The forces on the bolts are displayed in Figure 24 below. Using this assumption, a safety factor of two, and by choosing to analyze the smallest possible bolt (3/16in.) we solved for the required material yield strength for this application. The following calculations were performed:

Fig 24: Free Body Diagram of Bolts in Extension Mechanism



$F_{Leg} = 557lbs$
$A_c = cross\ sectional\ area\ of\ bolt = 0.03in^2$
$Conversion\ Factor\ from\ Stress\ to\ Shear = 0.55$

$$\sigma_{y,design} = \frac{2}{0.55} \times \frac{F_{Leg}/_2}{A_c} = 36{,}678psi$$

Since the bolts will fail in shear the yield strength had to be converted to a shear yield strength by using the relationship $\tau_y = 0.58*\sigma_y$ [8]. We used the yield strength that we found to determine what material our bolts should be made of.

Next, we performed an analysis of the potential for tear out of the bolts through the U-Channels. The strategy here was very much the same as was used to address the issue of potential shearing of the bolts. We again looked at the area that experiences the largest force and analyzed whether this area can survive. If this area can survive then we assume the other areas with lesser forces acting on them can survive. This area again is the area where the force from the leg acts. The material thickness we chose for the U-Channels was 1/8in. because this is the thinnest material we felt comfortable with. So we chose this thickness in an attempt to save weight and material costs. The following calculations were performed using a safety factor of two and the conversion factor from stress to shear equal to 0.55:

$F_{Leg} = 557lbs$
$d = distance\ of\ bolt\ to\ edge\ of\ U-Channel = 1.25in.$
$t = material\ thickness\ of\ bracket = \frac{1}{8}in.$

$$\sigma_{y,design} = \frac{2}{0.55} \times \frac{F_{Leg}/_2}{2 \times d \times t} = 3{,}241psi$$

For a visualization of the method used to approach this problem, refer to Fig. 27 on p. 35, which visually demonstrates a similar analysis being done to a different part of the mechanism. We used the yield strength that we found to determine what material our U-Channels should be made of.

The next components of our mechanism that we analyzed were the legs see Fig. 23 below. For this analysis we looked at the potential of the legs failing due to tear out of the leg pins through the leg material, failure of the legs due to buckling under compression loading, and failure due to the leg pins being sheared off. For the first calculation we performed similar analysis as before. For the second calculation we assumed the legs to be hollow rectangular extrusions, and solved for the minimum outer width of the legs based on the material yield strength that was found to be needed in the first calculation. Then we checked to ensure that the leg pins would be able to survive the loading. Again here we assumed a material thickness of an 1/8in. in order to save weight and lower cost. The following calculations were performed to analyze this situation:

Tear out of the Bolt through the Legs

$F_{Leg} = 557lbs$

$d = distance\ from\ hole\ to\ hole\ in\ the\ legs = 1.25in.$

$t = material\ thickness\ of\ legs = \frac{1}{8}in.$

$$\sigma_{y,design} = \frac{2}{0.55} \times \frac{F_{Leg}/_4}{2 \times d \times t} = 2{,}025psi$$

For a visualization of the method used to approach this problem, refer to Fig. 27 on p. 35, which visually demonstrates a similar analysis being done to a different part of the mechanism. We used the yield strength that we found and a material software program to determine that the legs should be made of aluminum, see CES Material Selection section. Next, we performed the calculations to determine the minimum width of the legs.

Compression Loading on Legs Calculations

$F_{Leg} = 557lbs$

$\sigma_{y,Al} = 35{,}000psi$

$$w_{min,outer} = outer\ width\ of\ legs = 2 \times \left[\frac{2 \times \left(F_{Leg}/_2 \right)}{\sigma_{y,Al}} + 1/16 \right] = 0.16in$$

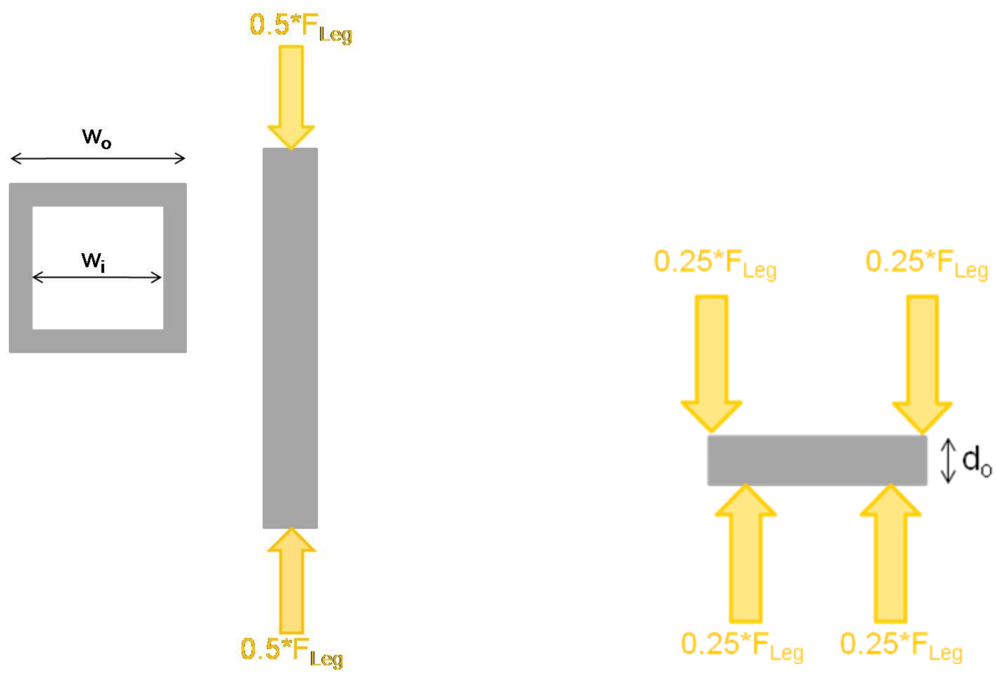
This calculation shows that a very small width of the legs will be sufficient to support the weight. However, we chose legs with a one inch outer width to allow for use of an adjustment pin, and to give more stability to the base of the leg structure. Also this dimension for the legs was very easy to find.

Shear Loading on Leg Pins Calculations

Next, we analyzed whether the leg pin would be sheared off due to the load, see Fig. 23 below. This analysis was made easier by the fact that we found a set of T-Handle Pins that were rated to a double shear strength of 9,200lbs[9]. This is far greater than the force experienced by the pin.

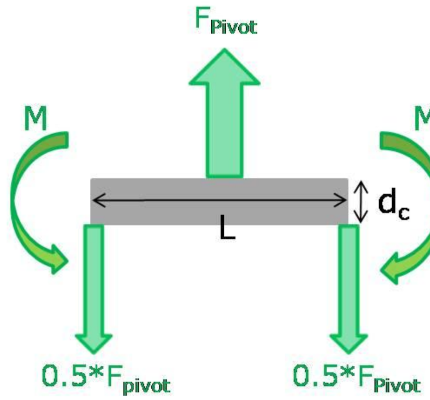
F_{Leg} = 457lbs
Part #: 90293A114
d_o = 0.25in.
Double Shear Strength = 9,200lbs [8]

Fig. 25: Compression Loading on Legs and Shear Loading on Leg Pins



The last part of our mechanism that we analyzed was the attachment of the mechanism to the wall bracket. This analysis consisted of looking at the failure of the rod that the mechanism would rotate about due to bending, potential of shear of the rod, and also an analysis of the potential of tear out of the rod from the bracket to which it attaches. First, we performed bending stress calculations on the rod see Fig. 26 below. In these calculations we modeled the pivot rod as a cylindrical beam simply supported at its end points with a point load at its midpoint. With this assumption the maximum deflection occurs at the mid-point of the rod. We decided that we did not want this deflection to be greater than 0.1in. because we felt that if it was greater than this it may give the user a false sense of instability of the mechanism. Further we analyzed the stress that the pivot rod would experience due to the bending. The maximum bending stress also occurs at the mid-point of the rod. We decided to use a 0.5in. rod diameter because a 0.25in. diameter could not satisfy the load carrying requirements and it would be very easy to find an off the shelf 0.5in diameter rod.

Fig. 26: Free Body Diagram of Rotating Pin



Bending of Mechanism Rotation Pin Calculations [10]

$F_{Pivot} = 257lbs$
$L = length\ of\ rod\ between\ brackets = 14in.$
$d_c = diameter\ of\ rod = 0.5in.$
$I_o = moment\ of\ inertia\ for\ cylinder = 0.003068in^4$
$y_{max} = 0.1in.$
$E_{design} = \frac{F_{Pivot} \times L^3}{I_o \times y_{max}} = 24{,}000{,}000psi$

From these calculations we were able to determine the minimum value for the modulus of elasticity of the rotating pin. We used this information to determine the material the pivot rod should be made of.

Then we analyzed the stress induced on the pivot rod because of bending. The following calculations were performed with a safety factor of 1.5:

$F_{Pivot} = 257lbs$
$V = force\ in\ rod = 0.5 \times F_{Pivot}$
$M_{max} = (7in.) \times (F_{Pivot}) - V \times (7in.)$

$\sigma_{y,bending} = \frac{M_{max} \times y}{I_o} = 110{,}000psi$

We used this necessary yield strength to decide which material the pivot rod should be made of.

Shear Loading of Mechanism Rotation Pin Calculations

Next we analyzed the shear loading in the rotation pin.

$F_{Pivot} = 257lbs$
$A_c = cross\ sectional\ area\ of\ pivot\ rod = 0.2in^2$
$Conversion\ Factor\ from\ Stress\ to\ Shear = 0.55$

$$\sigma_{y,design} = \frac{2}{0.55} \times \frac{F_{Pivot}/_2}{A_c} = 2{,}380psi$$

From this calculation we determined that shear of the pivot rod is not a huge concern.

Potential Tear out of Bracket Calculations

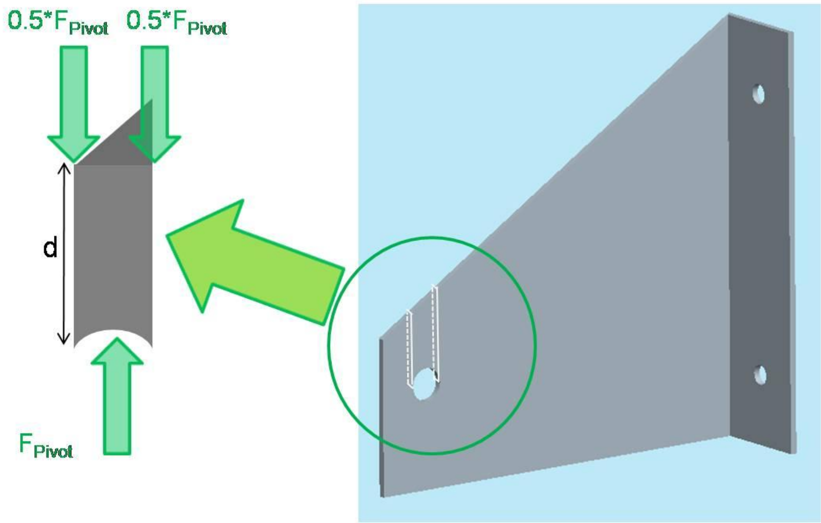
$F_{Pivot} = 257lbs$

$d = distance\ from\ edge\ of\ bracket = 2.5in.$

$t = material\ thickness\ of\ legs = \frac{1}{8}in.$

$$\sigma_{y,design} = \frac{2}{0.55} \times \frac{F_{Pivot}/_2}{2 \times d \times t} = 748psi$$

Fig. 27: Potential Tear Out of Pivot Rod From Bracket



We used the calculated yield strength to determine the appropriate material for our wall brackets. Further, since we decided to permanently mount the mechanism into wall studs we did not feel failure analysis was necessary at that point because we feel that this area is not a failure area of our design. Further, from doing these calculations we feel confident that our design will survive the loads that it will be subjected to during its use, assuming the appropriate materials are selected.

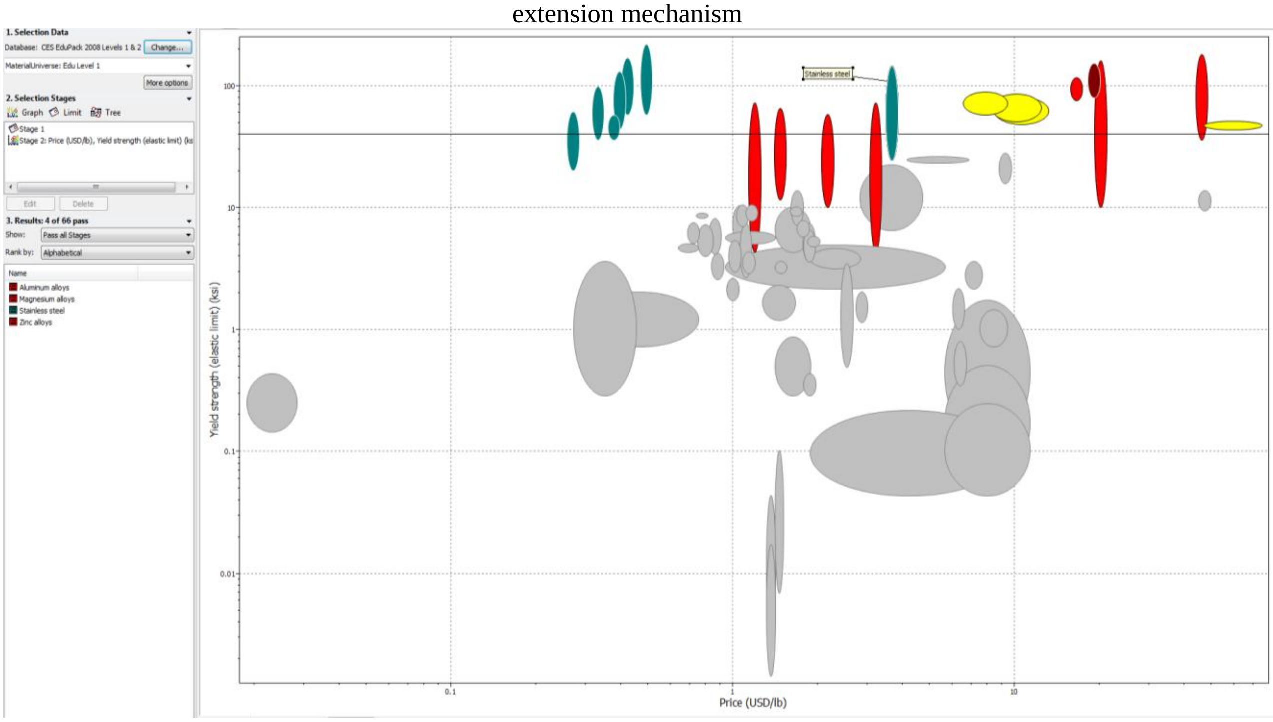
CES MATERIAL SELECTION

We selected the material to be used for each part of our mechanism by using the CES software. The four categories that we looked at to determine the appropriate material selection were resistance to fresh water, strength, weight, and cost. The CES software allows the user to set-up a number of stages that the materials must pass in order to be selected. For all of our material selections, Stage 1 of our selection process included the discrete attribute that the material's relationship with fresh water be very good, and the range attribute that the price must be below 5USD/lb. These two criteria were set to ensure that the materials selected could handle the shower environment and to eliminate any really exotic materials. This price limit was derived from the decision of our group to not purchase any materials more expensive than stainless steel. The CES material selection for the bolts in the extension mechanism, the U-channels and legs, the pivot rod, and the wall bracket are described below.

Material Selection of the Bolts in the Extension Mechanism

For the selection of the material of the bolts in the extension mechanism there were no additions to Stage 1, described above, of the selection process. Stage 2 of the selection process consisted of a graph of yield strength vs. price, see Figure 28 below. The yield strength used to set the cut-off for appropriate materials is necessary yield strength that was found during the technical analysis of the bolts in the extension mechanism, see Technical Analysis section of the report. This necessary yield strength was found to be 36,678psi.

Fig. 28: Stainless steel is found to be the most appropriate material selection for the bolts to be used in securing the extension mechanism

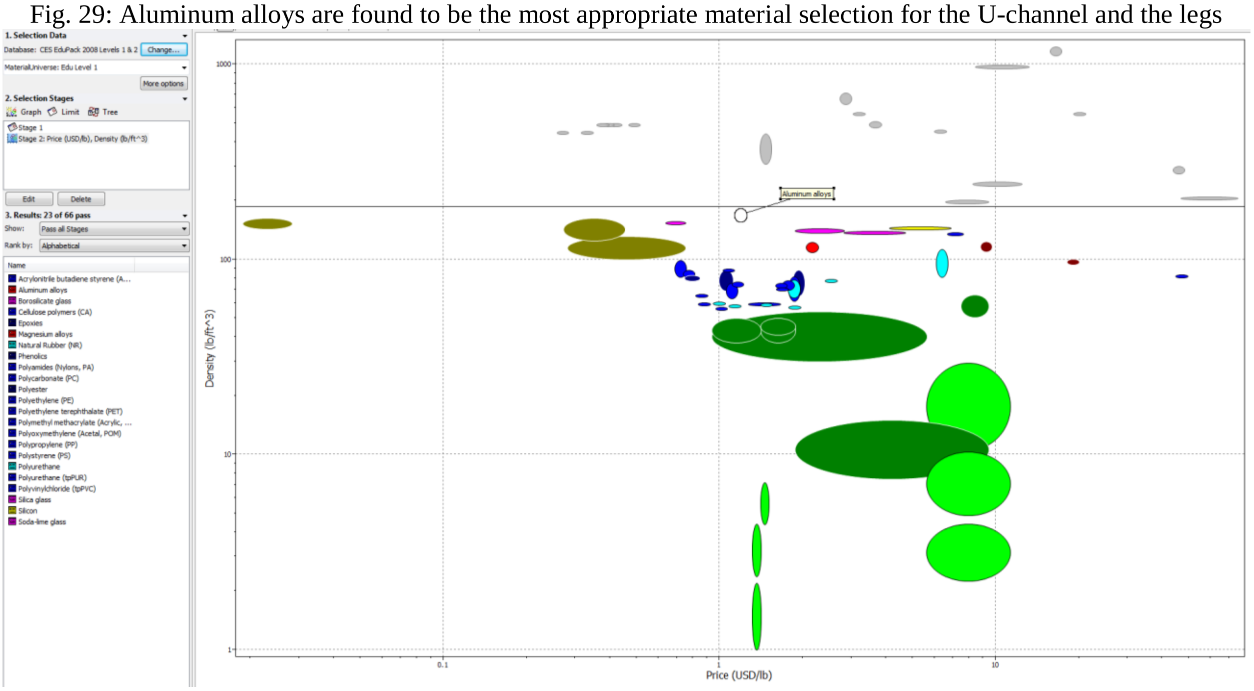


We chose stainless steel because the strength of the bolts is very important to our design, and stainless steel was the only material still listed that was almost entirely above the necessary yield strength. We did not look density for the bolt material because we did not believe that bolts would affect our overall weight by a significant amount.

Material Selection of the U-Channel and the Legs

For the selection of the material of the U-channel and the legs we included a yield strength of 4ksi into Stage 1of the selection process, since the required yield strengths found in the technical analysis for the U-channel and the legs were found to be 3,241psi and 2,025psi respectively. Stage 2 of this selection process then consisted of a graph of Density vs. price, see Figure 29 below. This graph was then analyzed to determine which of the remaining materials from Stage 1 had the best density to price ratio.

Fig. 29: Aluminum alloys are found to be the most appropriate material selection for the U-channel and the legs



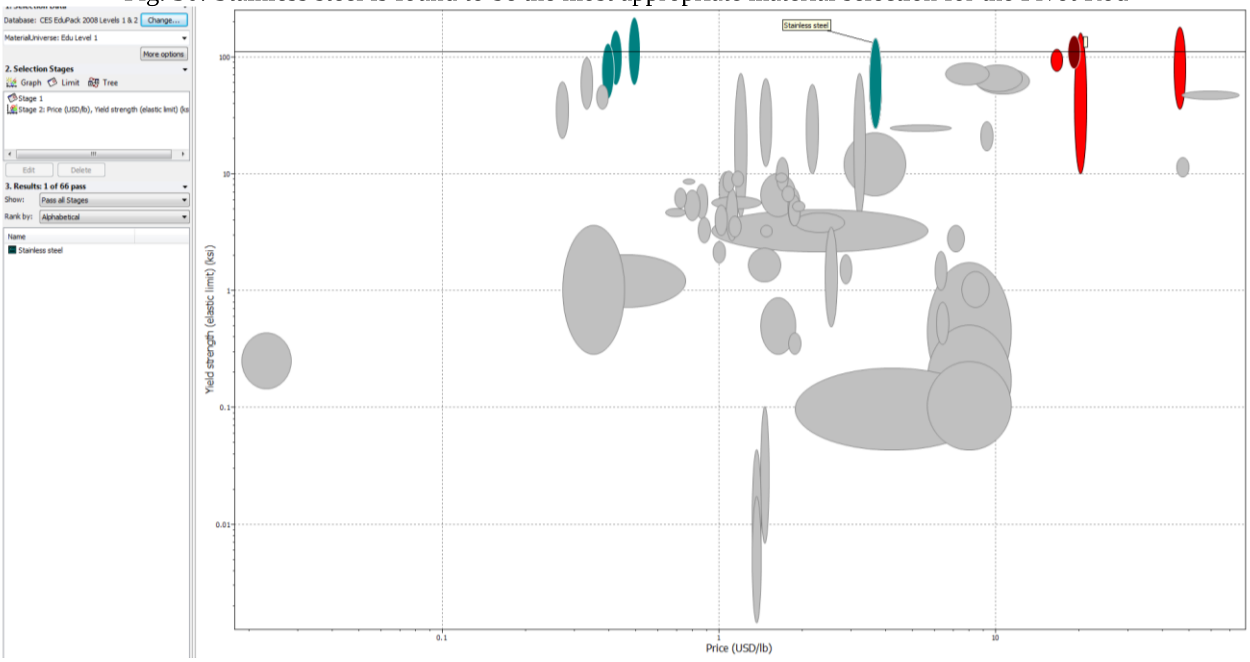
Of the materials that met the specified criteria (those listed on the left of Figure 29), aluminum alloys had one of the lowest density and price. Aluminum alloys are also readily available. Therefore aluminum alloys are the appropriate chose for the material of the U-channels and the legs.

Material Selection of the Pivot Rod

For the selection of the material of the Pivot Rod we included a Young's modulus equal to 24,000,000psi into Stage 1of the selection process. This was included because from the technical analysis we determined that if we wanted a low maximum deflection in the rod we needed a high Young's modulus. Stage 2 of this selection process then consisted of a graph of yield strength vs.

price, see Figure 30 below. The required yield strength for the pivot rod based on the technical analysis is 110,000psi.

Fig. 30: Stainless steel is found to be the most appropriate material selection for the Pivot Rod

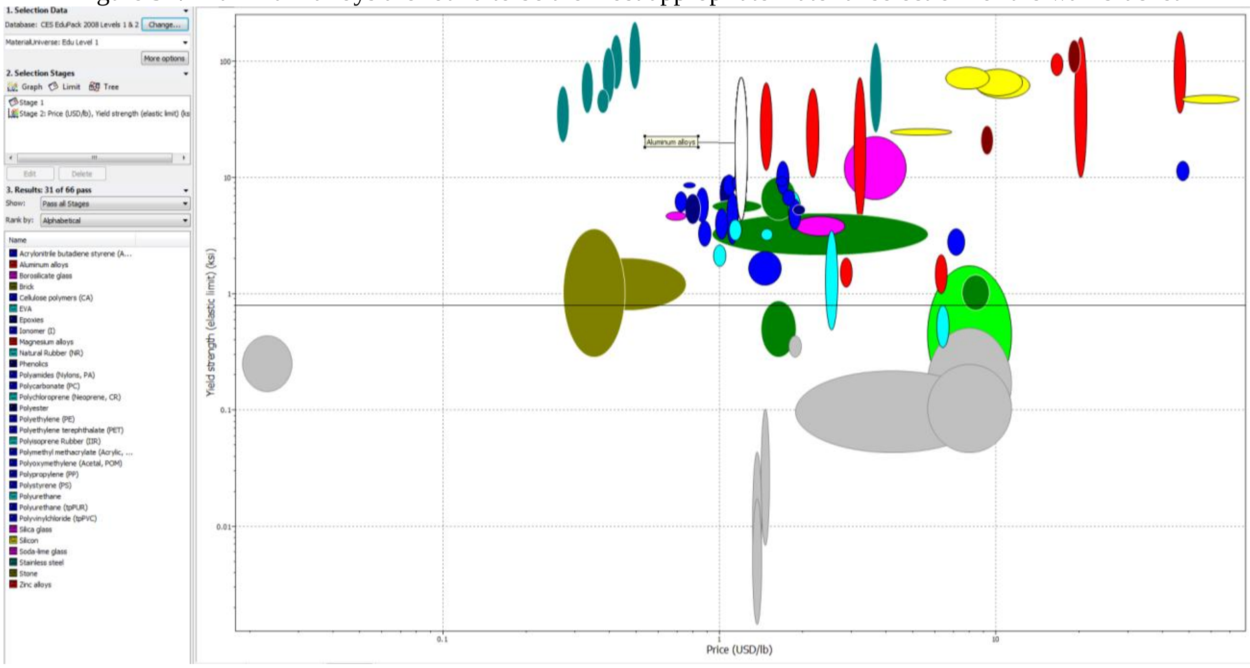


Stainless steel is actually the only material that passed both Stage 1 and Stage 2 of our material selection process, see list on the left of Figure 30 above.

Material Selection of the Wall Bracket

For the selection of the material of the wall bracket there were no additions to Stage 1 of the selection process. Stage 2 of the selection process consisted of a graph of yield strength vs. price, see Figure 31 below. The yield strength used to set the cut-off for appropriate materials is necessary yield strength that was found during the technical analysis of the wall bracket. This necessary yield strength was found to be only 748psi.

Figure 31: Aluminum alloys are found to be the most appropriate material selection for the wall bracket

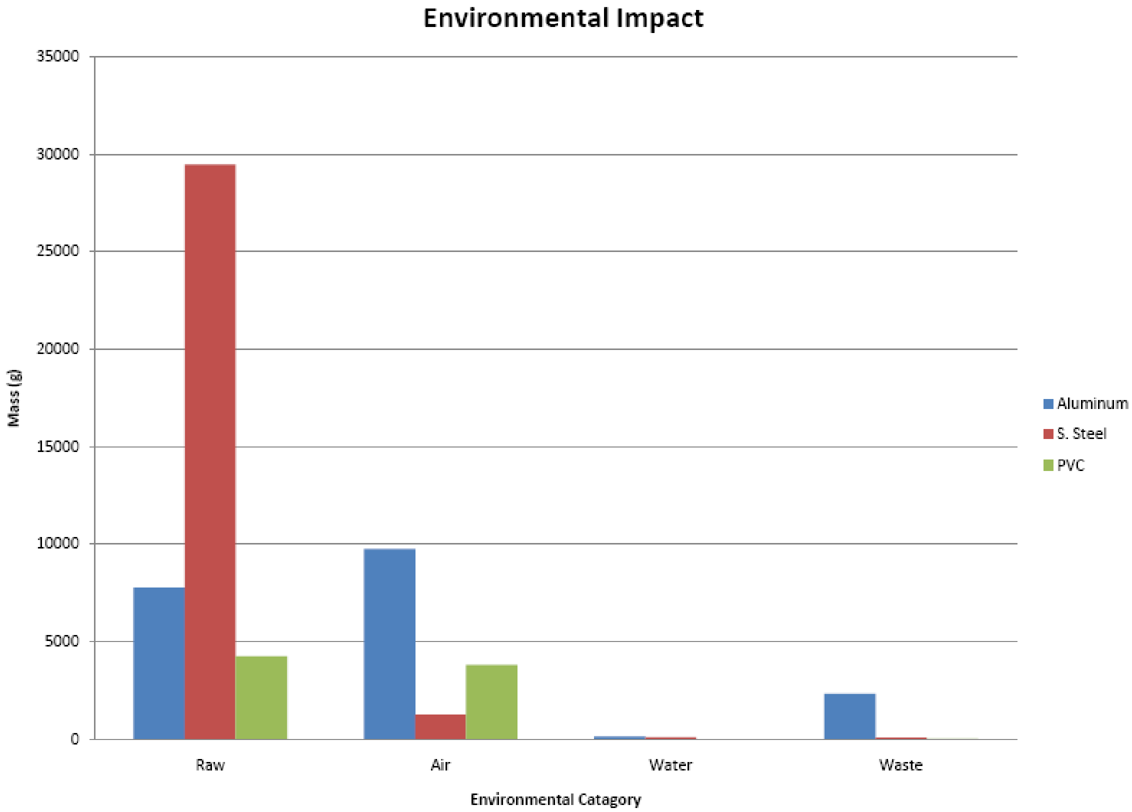


We chose aluminum alloys from those listed on the left of Figure 31 above because aluminum is relatively cheap and readily available. We did not look at density of the wall bracket because the wall bracket is does not add to the overall weight of our mechanism when it is in use.

ENVIROMENTAL IMPACT

Using the SimaPro software our group was able to determine the environmental impact of our material selection. Our design comprised of about 15 lbs of aluminum, 12 lbs of stainless steel, and 5 lbs of PVC plastic. Inputting these materials and quantities, as well as the EcoIndicator 99 method we were able to calculate the environmental impact. According to the software, our material selection has the greatest environmental impact on raw materials totaling nearly 42 kg of raw material. The second largest environmental impact was to the air, releasing 1.4 kg of material during manufacturing. While designing our prototype, we did not take into consideration any environmental impact. Our group figured that our design weighed no more than 30 pounds and the impact would not be that large. According to the software, this was a very wrong assumption, and in the future, we will add more emphasis. Our group also was not left with many options for our material selection. Our PVC plastic seat was pre made by an outside manufacturer. The stainless steel sliders were the only material, within our price range, that the sliders came in. The plot shown below demonstrates the effect the various materials we used will have on different areas of the environment. The environmental impact graphs, including the characterization, normalization, and single core SimaPro plots are found in Appendix F.

Figure 32: SimaPro Results demonstrating Environmental Impact



FAILURE ANALYSIS

Our group preformed FMEA calculations using DesignSafe software. Breaking the full assembly into three main areas that are most at risk for failing we analyzed the safety. Our fist area that we looked at was our sliders and main support assembly. The highest risk associated with the sliders and support was fatigue from use. Extending and retracting the sliders results in cyclic loading on the bolts attaching the channels to the sliders, failure of the sliders or rail will be catastrophic. To reduce the impact, our group advised for uses to check monthly the condition of hardware. The second section of assembly that we looked at was the leg assembly. The highest risk of failure came from crushing when the seat was overloaded. If the legs were crushed the whole apparatus would fail catastrophically. To reduce the risk of the leg assembly crushing we designed the legs to hold 300 pounds, and warning signs should be placed so users acknowledge the weight limit. The third section of the assembly included the wall brackets and steel rod connecting the wall brackets to the main support. According to the parameters set and DesignSafe software, the most causable failure would be fatigue. Cyclic loading occurs when the shower seat is loaded and unloaded, which causes fatigue on the brackets, connecting rod, and screws holding the brackets to the wall. To reduce the risk of failure our team suggests monthly inspections for fatigue cracking around the drill holes and where the rod connects on the bracket. Also signage stating a 300 pound max weight will reduce the effects of cyclic loading. Detailed DesignSafe FMEA reports can be found in Appendix G.

ENGINEERING CHANGE NOTICE

Detailed pictures for all of the Engineering Change Notices can be seen in Appendix H

ECN #1: Pivot Rod

On our pivot rod we changed the material from 6061 aluminum to zinc plated mild steel. We made this change because when we inspected the aluminum rod we found that it was quite easy to bend. We then noticed that we had only analyzed the pivot rod to fail in shear and not in bending when developing our alpha design. After adding this analysis we found that the aluminum would fail in bending and we needed to upgrade the material. We conducted the same analysis on zinc plated mild steel and found it would pass the test so we decided to change to this material since it is also unaffected by water.

ECN #2: Wall Bracket

On our wall bracket we changed the height of the bracket and we also changed the shape. We changed the height of the bracket because we were afraid that the bracket may have torn out of our faux wall. By increasing the height of the bracket we were able to decrease the forces that would be trying to pull the screws out of the wall. We did not to any calculations to verify that this change was necessary, however we felt it was necessary to over engineer this part since we wouldn't be able to test it until the very end and if it failed our device would fail. We also changed the shape of the bracket at the request of our sponsor to make it less invasive and more aesthetically pleasing.

ECN #3: Leg Support Bracket

After assembling our legs we found that they were not very stable because of the tolerances of the hinges. So to solidify the legs we decided to weld a 3" tall cross bracket to connect the legs together. This bracket made the legs one piece so they would not be able to move relative to each other. This also was recommended by our sponsor to give an appearance that the legs were stronger.

ECN #4: Inner Channel

On our inner channel we decided to weld the bottom plate and the leg lock brackets instead of bolting them to make the manufacturing of the mechanism easier. Also, this allowed us to eliminate some unnecessary parts. Also, when we ordered the 10" bottom plate we received a 7" plate instead. Due to our time constraints we decided to proceed with the 7" plate since it did not drastically alter our design.

ECN #5: Lower Leg

On our lower leg sections we changed the height from 12” to 7” because we found that the additional length was unnecessary and was actually too tall for a typical bath tub. This change allowed us to package our design within the tub better.

ECN #6: Leg Hinge

On our leg hinges we changed the material from aluminum to zinc plated mild steel. When we did our “kick test” during our validation testing we bent the aluminum hinges. From this test we found that the aluminum hinges were not strong enough for our application. Therefore, we decided to upgrade to zinc plated mild steel hinges that would also be water resistant.

All of the above ECN’s can be seen in Appendix H

MATERIALS AND PARTS LIST

Below is a list of the all the materials and parts needed for the design. The bill of materials can be viewed below or in Appendix I, and detailed engineering drawings can be seen in Appendix E. Each number next to the component refers to the labeled CAD drawing as seen in Fig 20 on page 26.

Table 5: Bill of Material

Quantity	Part Description	Purchased From	Part Number	Price (each)
1	Seat Assembly	Eagle Health Care	37662	$162.00
1	Aluminum Seat Attachment Plate	Discount Steel		$14.98
1	Set of Drawer Slides	Bold Hardware	16" 7500 Series	$60.00
8	Sliding Lock Mechanism	McMaster-Carr	1745a15	$5.33
1	Aluminum Sliding Channel - outer	Discount Steel		$22.34
1	Aluminum Sliding Channel- inner	Discount Steel		$15.66
1	Steel Rod	Ace Hardware		$6.00
4	PTFE Plastic Bushings	McMaster-Carr	2706T24	$3.93
1	Aluminum Bottom Plate	Discount Steel		$23.13
2	Steel Leg Hinges	Home Depot		$8.00
2	Legs - Outer	Discount Steel		$7.21
2	Legs - Outer	Discount Steel		$6.58
2	Leg Adjustment Locking Pin	McMaster-Carr	90293A114	$17.99
2	Leg Locking Pin	McMaster-Carr	93750A320	$22.98
2	Leg Rubber Ends	Ace Hardware		$3.50
1	Grab Bar	Wright & Filippis		$15.00
1	Shampoo Attachment	Ace Hardware		$10.00
1	Bracket to Lock to Wall	Home Depot		$8.59
1	Mock Tub	Home Depot		$80.00

Seat

[1] Swivel Chair: The swivel seat of the Snap-N-Save Sliding Transfer Bench (Model # 37662) produced by Eagle Health will be used for the chair (see Figure 33). The chair is made of plastic and is contoured for comfort; it also includes a handle on either side, as well as a place to store the shower head. Additionally the chair is equipped with a swivel device that locks every 90 degrees. The back of the chair is contoured as well, and is adjustable to varying depths. The chair back is also removable, when collapsing our design the back of the chair will be removed to collapse it into its most compact position. The Snap-N-Save Sliding Transfer Bench with Swivel Seat is rated to 400lbs according to Eagle Health Supplies. With shipping the chair costs approximately $152.

Fig. 33: Snap-N-Save Sliding Transfer Bench [10]

Seat Attachment Plate: The seat will be attached using a 6061 Aluminum plate measuring 7” x 7” x ¼”. This plate will be ordered from Discount Steel [11] at a cost of $14.98.

Sliding Device

[2] Rails: For the sliding mechanism the “16" 7500 Series 400LB Super Duty Slide” will be used (See Figure 34). This device is produced by Bold Hardware Co and is rated to 400lbs in the fully extended position. The slider extends from 16” to approximately 31.5” fully extended. The sliding device costs $60. A more detailed specification sheet can be found in Appendix J.

Fig. 34: Super Duty Slide [12]

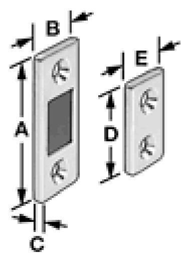
[3] and [4] U Channels: The U Channels will be constructed from aluminum rectangular tube provided by Discount Steel [11]. The outer U-Channel (4) will be 6” x 4” x 1/8” and a length of

16" ($22.34). The inner U-Channel (3) will be 3" x 3" X 1/8" and have a length of 18" ($15.66).

Bolts to Attach the Sliders to the U Channel: The slider has both 3/16" and 3/8" holes. The sliders will be attached using ½" long 3/16" Stainless Steel pan head bolts as well as ½" long 3/8" Stainless Steel pan head with locking washers. All of the bolts and washers were purchased at Ace Hardware.

[5] Locking Mechanism: Our design will lock using Ultra Thin Magnetic Catches produced by McMaster Model #1745A15 [8]. Each catch will provide 8lbs of pull power, and we will be purchasing 8, they each cost $5.33, see Figure 35.

Fig. 35: Ultra Thin Magnetic Catches [8]



[3] Bottom Plate: The bottom plate is welded to the inner channel and measures 6" x 4" x 0.5" 6061 aluminum plate ordered from Discount Steel [11]. Then two L- brackets will be welded to the plate.

[8] Grab Handle: A grab handle will give geriatrics a place to grab for stability and also aid in pulling themselves in. The grab bar was purchased at Wright & Filippis in Ann Arbor.

[15] Shampoo holder: A suction cup affixed shampoo holder was purchased from Wright and Filippis in Ann Arbor for $10.

Wall Attachment

[12] Rod: The design will pivot about a ½" Threaded Steel Rod. The steel rod was purchased at Ace Hardware.

Bushings: 4 Bushings will be used to support the rod and allow for rotation around the wall mount and main structure. We will use flanged sleeve bearings (Model # 2706T24) on McMaster Carr [8] for $3.94 each, see Figure 36.

Fig. 36: Flanged Sleeve Bearings [8]

[13]and [16] Wall Attachment Bracket: Purchasing an aluminum box channel section 8” long we will create three L-brackets which will be used for wall mounting. The brackets will have a 2” base against the wall, extend out 8”, and be 4” high, this is found at Discount Steel [11]. The box channel will cost $28.72. It is further discussed how this piece is made in the ‘Manufacturing’ section.

[14] Locking Mechanism: A locking mechanism used for gates was purchased from Home Depot to lock the device against the wall.

Legs

[6] and [9] Legs: The legs will be constructed using an inner and outer tube to allow the leg to extend. The outer leg (6) will be 2” x 2” x 1/8”, and the inner leg (9) will be 1.75” x 1.75” x 1/8”. The total length of the leg will be 15”. Both will be constructed of Aluminum 6063 square tube and will be purchased from Discount Steel [11].

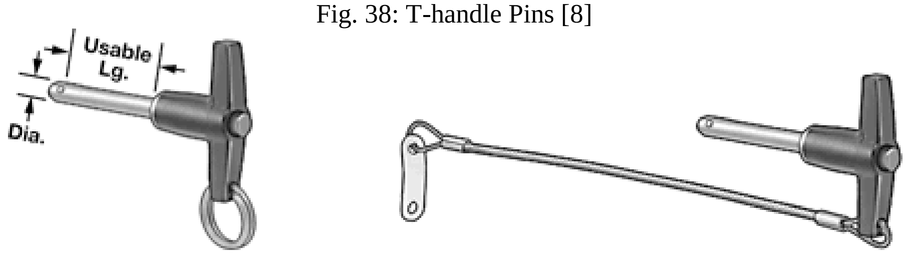
[7] Leg Hinges: The legs will hinge on two 2” by 2”steel hinges purchased at Home Depot. For a picture see Figure 37.

Fig. 37: Hinge

[11]Leg Rubber Ends: To protect the bottom of the tub our team decided to purchase rubber leg ends from Ace Hardware.

Leg Locking Pin and Leg Adjustment Pin: The same pins will be used to lock the leg in place and adjust the length of the leg. The pin used will be an aluminum T-handle Quick Release Pin sold by McMaster Carr Model # 90293A114 [8]. The ¼” Pin is rated for 9200 lbs as listed by McMaster Carr. We will purchase 2 2” pins and 2 2.5” pins with lanyards, these can both be seen in figure 38.

Fig. 38: T-handle Pins [8]



MANUFACTURING PLAN

The following section will break down the manufacturing processes by functional group. Our final prototype design has four main functional groups; the seat and swivel, main support and extending mechanism, wall mount attachments, and leg and folding mechanism. For most of our manufacturing our group will utilize the ME450 lab and the welding equipment of one of our group members.

Seat and Swivel

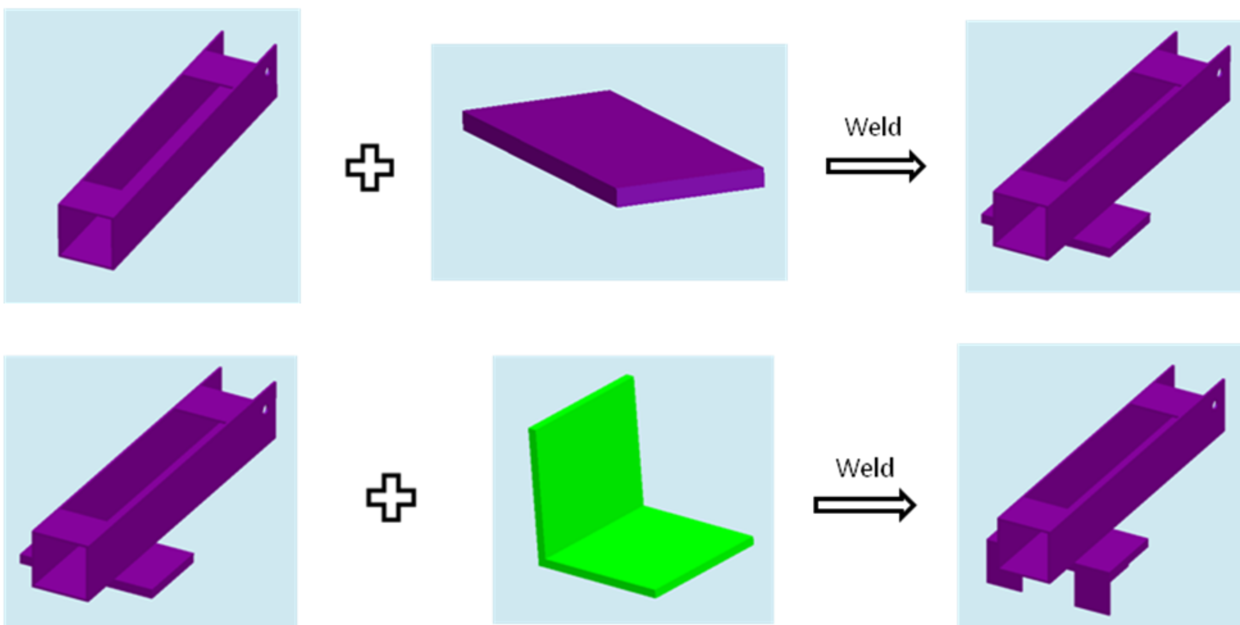
Our group will be purchasing a fully manufactured seat and swivel mechanism from eagle health care. The fully assembled package includes: A blow molded plastic seat and seat back, hard plastic base, swivel and locking mechanism, and all hardware needed for operation. Eagle uses the seat and swivel assembly on many of their applications and have bolt holes already in the plastic base. Our group is planning on using these holes to match up with holes on our attachment bracket, located on the main support, and secure with bolts. The attachment bracket will be created from a plate of aluminum. The current seat assembly comes with a pre-fabricated plastic bracket, which we will be using as a template for our aluminum one. We will machine using the mill the stock aluminum piece to match the existing one, refer to design drawings for dimensions.

Fig. 39: Preassembled Swivel Seat

Main Support and Extending Mechanism

The main support and extending mechanism will compose of four main components; the aluminum top U-channel, the aluminum box channel, the bottom plate, the two leg lock brackets and two heavy duty sliding mechanisms. The two sliding mechanisms will be ordered pre fabricated. Built into the sliders are holes for bolts to be mounted through to both the outer U channel and inner box channel, per our design. The U and box channel will be ordered as stock aluminum piece and cut to length using the band saw in the ME 450 shop. Our design calls for a section of the box rail to have the top cut out, which will also be done using the band saw. Holes for mounting the track will be drilled using the drill press. Holes will be large enough for a tight tolerance with selected bolts. The main support and extending mechanism will have all three of the other main functional groups attaching to it. The seat and swivel mechanism will be attached through the aluminum bracket described above by welding the aluminum bracket to the aluminum U-channel. The wall attachments described below will be attached to the main support with an aluminum rod. The rod will sit on four bushings so no manufacturing is necessary, only assembly. The main support will also be attached to the leg support and folding mechanism described below. These attachment points will be welded to make one piece. Refer to design drawings for specific manufacturing dimensions.

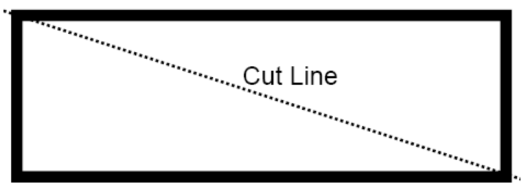
Fig. 40: Manufacturing of Main Support and Extending Mechanism



Wall Mounting Attachments

The wall mounting attachment brackets will be created from 4” segment of 8” by 2” square aluminum channel, with a wall thickness of ¼”. By cutting the square channel at opposite corners our team will produce two L-brackets, this cut can easily be done using the band saw in the ME 450 machine shop. Our design calls for mounting the brackets to the wall with two bolts. On the 4” by 2” side two holes will be drilled for wall anchor bolts to be inserted. The main support and extension mechanism will be attached to the brackets with a pin as described above. The pin will need to slide through a hole drilled through the bracket. A basic sketch of this manufacturing can be seen below. Refer to design drawings for specific manufacturing dimensions.

Fig 41 a and b: Wall Mounting Attachment Bracket Assembly. 17a shows stock purchased from Discount Steel and 17b demonstrates how the wall mounts will be cut and drilled



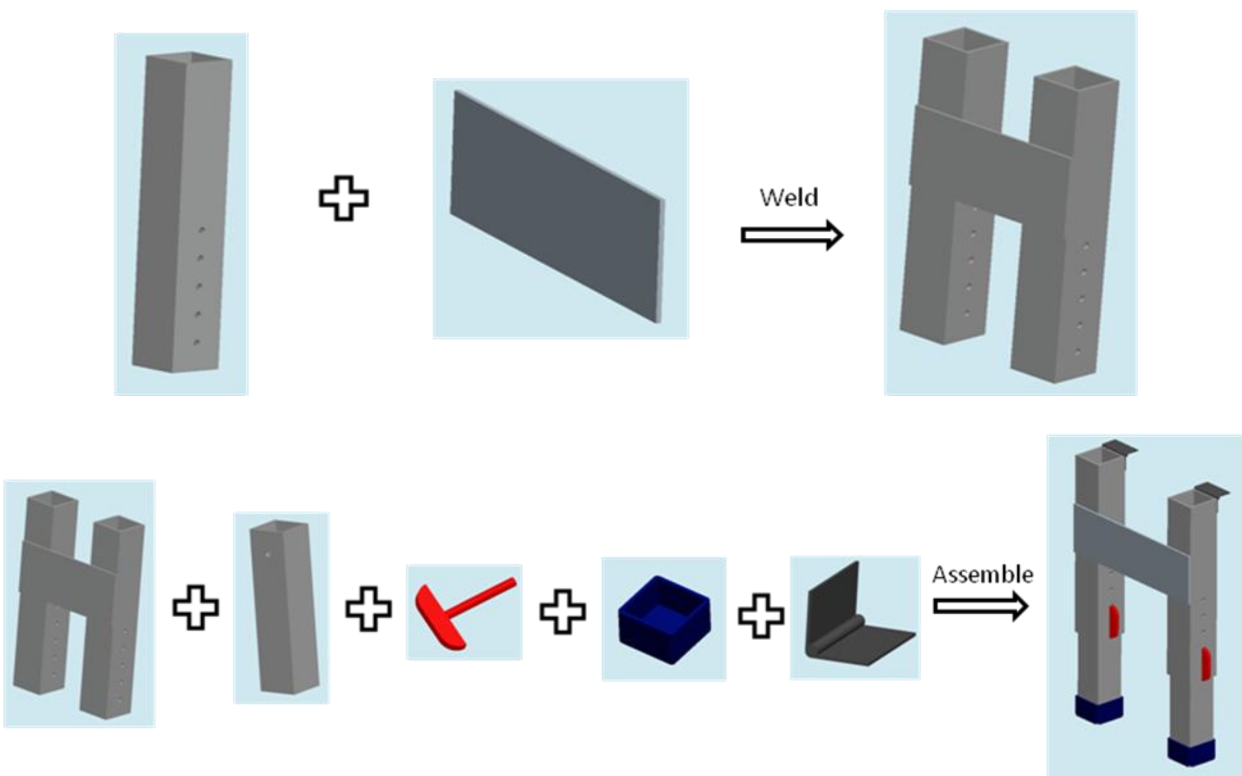
A

B

Leg and Folding Mechanism

The leg folding mechanism will be mostly comprised of pre fabricated parts. The Leg and locking assembly per our engineering specifications will be comprise of: a leg cross bracket, two larger square aluminum tube, two smaller square aluminum tube, two rubber feet, and four T-handled pins. We will need to drill pin holes in the square aluminum tubes for the pins to be pushed through. Also, we will need to weld the cross bracket to attach the legs together. Also, we need to epoxy the rubber feet to the lower leg sections. Refer to design drawings for specific manufacturing dimensions.

Fig. 42 Manufacturing of Leg and Folding Mechanism



VALIDATION TEST RESULTS

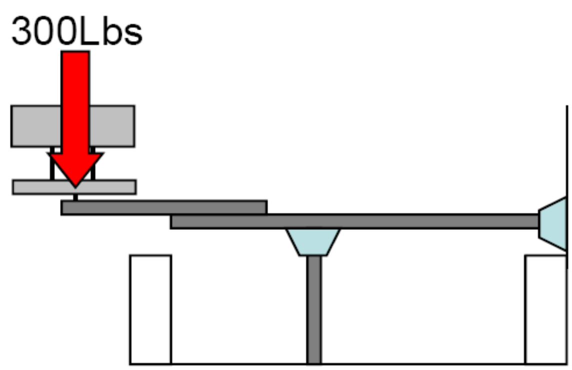
Having a stable design is a very important requirement in our design because users will be geriatrics who could be severely injured by a fall. To test our seat structure we performed a number of tests ensure safety. When the seat is in the "in use" position we performed four tests on the chair. When the seat is in the "stored" position we performed one test. Each test is listed below:

Loading Weight Test

When the seat is down and extend in the loading position 360lbs will be loaded onto the seat. 360lbs is determined from our design weight plus a 20% safety factor. When loaded note any fractures, permanent bending, or catastrophic failure. If the seat remains stable with the weight added and no permanent damage occurs the seat passes the loading weight test. A sketch of the test can be seen below.

When tested the seat was stable and showed no deflection. Additionally, at the Design expo the seat was tested numerous times with many different people. After all of the tests the seat remained stable and did not show any signs of fatigue.

Fig 43: Demonstration of weight test at fully extended position

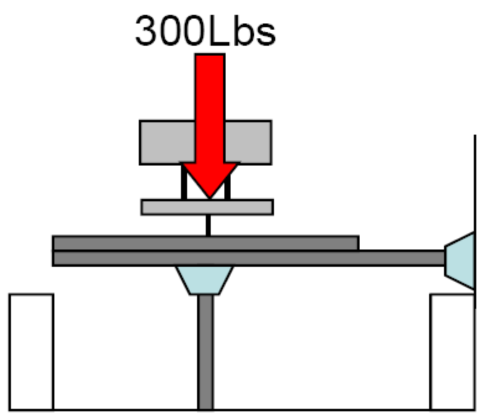


In Use Weight Test

When the seat is down in the normal use position 360lbs will be loaded onto the seat. 360lbs is determined from our design weight plus a 20% safety factor. When loaded note any fractures, permanent bending, or catastrophic failure. If the seat remains stable with the weight added and no permanent damage occurs the seat passes the loading weight test. A sketch of the test can be seen below.

When tested the seat was stable. Additionally, at the Design expo the seat was tested numerous times with many different people. After all of the tests the seat remained stable and did not show any signs of fatigue.

Fig 44: Demonstration of weight test while bench is in use

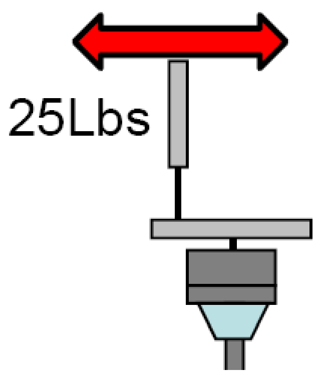


Rocking Test

This test will be preformed twice, once in the loading position and once in the in use position. Using hand strength, a tester will grab the top of the seat and push and pull with reasonable force, roughly 25 lbs, simulating a user leaning back and rocking forward in the seat. 25lbs is estimated by the pushing strength of a geriatric doing a back extension. Repeat 3 sets of 10 cycles of pushes and pulls; note any fractures, permanent bending, or catastrophic failure. If the seat remains stable with the weight added and no permanent damage occurs the seat passes the loading weight test. A sketch of the test can be seen below.

When testing the rocking test the chair remained stable and showed no signs of bending.

Fig 45: The Rocking Test

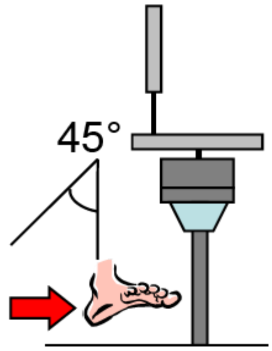


Kick Test

The kick test will test the structural stability of the leg located in the bottom of the bath tub. It will simulate the worst case scenario of a user accidently kicking the leg. The kick will be standardized by bending your leg roughly 45 degrees and releasing it. After one kick on each side of the leg note any fractures, permanent bending, or catastrophic failure. If the seat remains stable with the weight added and no permanent damage occurs the seat passes the loading weight test. A sketch of the test can be seen below.

When the kick test was initially performed we experienced a few failures. First the prototype failed this test because the leg popped out from the supportive position. Second we noticed the hinges used to attach the legs deformed. To strengthen the legs for the kick test, the Aluminum hinges were replaced with steel hinges. Additionally an Aluminum T-handle quick release pin was added to lock the legs in the 90 degree position while the seat was being used.

Figure 46: The Kick Test

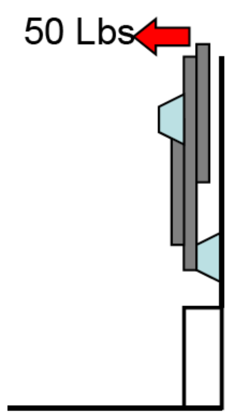


Pull Test

When the bench is in the stored position using hand strength grab the top of the seat and pull the bench down using reasonable strength, about 50lbs. This simulates a child pulling on the seat. To pass the test the chair should not be able to be pulled down. A sketch of this test can be seen below.

This test was performed lightly due to the construction of the mock tub we used. However, the seat did withstand a sizeable force. The seat did not show any signs of fatigue or signs that it may become detached.

Figure 47: The Pull Test



DISCUSSION

While our prototype performed beyond our expectations there is always room for improvement. After each design review our design became further refined and much stronger. However, the swivel sliding transfer bench can certainly be improved upon. The following section highlights the strengths and weakness of the current prototype, and recommendations for further work.

Strengths

Sliding Mechanism: While heavy, the sliding mechanism purchased from Bold Hardware was extremely robust and smooth. The rails which were rated to 400lbs [12] accommodated for our weight limit of 300 lbs, while still including a safety factor.

Stability: The overall structure of the prototype was very robust and felt very stable, a very important customer requirement. The inner and outer channels helped distribute the weight of the person over the rails. Additionally the two legs stabilized the chair while in use.

Seat: The seat was purchased from Eagle Health Care; while expensive the seat was very well designed including handles for the patient and a holder for the shower head. Additionally, the seat swiveled and locked at ever 90 degrees.

Leg Locking Pins: The leg locking pins were a late addition to our design, and provided the extra stability need in the in use position. The T-handle quick release pins with a lanyard were purchased from McMaster Carr. The lanyard was fixed to the lower plate and the pin easily slides through the top of the legs an allowing quick and easy transformation from the stored position to the stable in use position.

Weaknesses

Magnetic Catches: The two sets of magnetic catches where used to help the chair stay in the loading or in use position. The magnetic catches positioned for the in use position worked well, however the set used for the loading position did not provide enough force to keep the chair stable while loading. Occasionally when people were sitting into the chair the seat would slide back, rather than staying fixed until they were fully loaded. This can be fixed a variety of ways. First either more magnets or stronger magnets could be used additionally the machining of the location that they are placed could be done more accurately. Alternatively, the magnetic catches could be replaced with locking pins similar to those used on our swivel seat which are spring loaded pins used in crutches.

Weight: The target weight for our design was 25 lbs, our prototype weighed in at 32 lbs. However much of this weight could be cut by optimizing the design, and ordering more specialized tube sizes rather than using stock material. Additionally 9 lbs of this weight was the rails, further research could be done to find rails supporting 360 lbs that were lighter.

Bulkiness: In the stowed position the chair stuck out from the wall 11", some of this width could be eliminated by using more specialized tube sizing.

Leg Height: After fully assembled we realized our legs were designed too tall. This can be simply fixed by shortening the height of the outer leg by 3 to 4 inches.

CONCLUSIONS AND RECOMMENTDATIONS

Our goal was to design an assistive device that helps geriatric patients safely get into and out of the bath. While there are products on the market, they are sometimes hard to operate, bulky, and don't allow the shower curtain or glass door to close. To design the most effective device for geriatric patients we focused on making the product safe, intuitive and simple to use, as well as compact.

Background

With the 'Baby Boomer' generation growing older and medicine advancing, the population of geriatric patients is rapidly rising. Getting into and out of the bath is a particularly difficult task. Designing a better assistive transfer device for the bath will help geriatric patients safely bathe while maintaining privacy, allowing them to live a more independent life. Working with Naomi Gilbert at the University Med Rehab and Susan Murphy an assistant professor for physical medicine and rehabilitation at the University of Michigan, our team will improve current assistive bath transfers on the market. Our team will design an assistive device that allows a geriatric patient independence while safely helping them get into and out of the bath.

Customer Requirements

Our sponsor has expressed to our group the need to have an improved assistive device that aids geriatric patients in entering and exiting the bathtub. This device must be dependable and safe, and provide the ability to close the curtain during showering. Currently, there are no affordable assistive devices on the market that meet these criteria.

Concept Generation and Selection

Several different methods to assist geriatric patients into the bathtub were generated through various brainstorming sessions held by our team, also known as the 'Deep Dive'. We worked independently and then together to ensure we had several diverse solutions. After rough drawings of several concepts were generated, we noted the advantages and disadvantages of the various designs. We then reviewed of all of the concepts and voted to determine the most feasible and innovative designs, we were left with five designs. The five finalized designs were then evaluated with respect to our defined functional groups. We then compiled a table demonstrating the advantages and disadvantages of each design. The rough drawings of the five finalized designs were improved upon to explain how each mechanism functioned. Lastly we constructed a selection matrix, using the advantages and disadvantages table, to determine to alpha design to proceed with.

Final Design
From the Concept selection an alpha model was created, this design performed best in our selection matrix. The alpha design was refined into the final design after discussion following DR2. Our final design incorporated a swivel seat which slide along channels using heavy weight rails. Two aluminum extendable legs were used for support. The seat and sliding mechanism was attached to the wall using a steel rod and wall bracket. The sliding mechanism hinged about the rod allowing the seat, sliding mechanism and legs to fold up against the wall. When in the stowed position, a simple gate latch is used to lock the seat to the wall.

Prototype
There are 6 engineering design notifications to demonstrate the changes that were made between our final design and the actual prototype. These changes were made due to availability of product, strength of material, and to add additional support to the prototype.

Testing
To test the structural stability of our prototype five different tests were performed. The loading weight test, the in use weight test, rocking test, and pull test all passed on the initial try. When the kick test was initially performed, the test failed. To pass the test two changes were made. First the aluminum hinges were replaced with steel hinges. Secondly, a pin was added to lock the legs while the chair is in use.

Recommendations
The next step of the project would be to develop a more refined prototype. Design changes should be made to the legs to allow them to be shorter, as well as have more adjustability. Additionally the magnetic catches need to be more accurately designed. One solution would be to use additional magnets or stronger magnets when the seat is in the fully outstretched position. Alternatively, the magnets could be replaced with a locking mechanism similar to the spring pins used in crutches.

For the project to be commercialized the design should be optimized to eliminate unnecessary weight. Additionally the design could be made more ascetically pleasing by adding plastic covers to hide the channels for instance.

ACKNOWLEDGMENTS

Prof. Albert Shih

We would like to thank Professor Shih for his all of his help throughout the project. Professor Shih had valuable input into many of our design improvements. Additionally Professor Shih inspired us to pursue the geriatric section, and ultimately helped narrow the focus of our project to the bath tub.

Dan Johnson

We would like to thank Dan Johnson for all of his time and effort into our project. Dan was a wonderful source of support throughout the project, responding to questions at all times of the day. Additionally, he frequently met with us and shared his inputs which improved our design and helped to further our analytical analysis and manufacturing methods.

Naomi Gilbert and Susan Murphy

We would like to thank our sponsors Naomi Gilbert and Susan Murphy for their continued insight and support throughout our project. They each provided a very unique insight into the special needs of geriatric patients. Additionally, they followed our progress through of the semester and made valuable suggestions for design improvement. We were very grateful that both of our sponsors were able to come support us at the Design Expo.

Bob Coury and Marv Cressey

We would like to thank both Bob and Marv for all there help while we were machining the prototype in the ME 450 machine shop. Bob Coury did an excellent job with all of the welding for our project. Marv was very helpful when we were using the mills, he used to years of expertise to teach us when to run at various speeds. Both Bob and Marv were very accessible and helpful when we were looking for advice to manufacturing components.

John Ladd

We would like to thank John Ladd for devoting his time to help construct our Bath mock-up.

Mark Hovious

We would like to thank Mark for supplying and his help in polishing our prototype parts.

BIOGRAPHIES

Kate Bateman is a senior in Mechanical Engineering; she is from Lake Forest, IL. After graduating she will be working for Shell Oil as a drilling engineer in Denver, CO. Kate was a member of the 2005 Solar Car Race Crew and took one semester off to participate in the World Solar Challenge in Australia. She took another semester to study abroad in Rome, focusing her studies on Roman History, Art History and Architecture of the Roman World. She enjoys traveling and traveled Australia and New Zealand after the race, as well as Europe during her studies abroad. Kate has spent the last two summers with Shell and is very excited about starting a career in the energy industry.

Nick Hovious is a senior in mechanical engineering and will be graduating this coming May with a bachelors degree. Nick is a lifelong resident of Michigan growing up in the Kalamazoo area. Over the past two summers, Nick has worked as a co-op at Dana Corporation at their Heavy Vehicle Technology Center. Nick enjoys traveling around the country and watching/playing sports. Recently Nick has been busy with the time consuming process of lining up a job for after graduation.

Marc Culkin is from Denver, CO and is a senior in Mechanical Engineering. He will be graduating this December, at which time he plans to travel to Europe before starting a full-time working position. Over his college career he has gained experience in the general fields of engineering and project management. He has held several jobs in the energy industry; first with Xcel Energy in Denver, CO and then with BP in Houston, TX. Also, for a semester his junior year he worked for BASF in Wyandotte, MI.

Steven Ladd will be graduating this coming May with a bachelors of science in mechanical engineering. Over the past four years he has held Co-op and internship positions at Toyota Motor Corporation and Abbott Laboratories, totaling over a year of on the job experience. While holding these positions he learned valuable leadership and teamwork skills. He brings a great attitude to the team, and will fit very well with the team's dynamics.

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12. http://www.discountsteel.com/
13. http://www.boldhardware.com/product_info.php?cPath=79&products_id=425

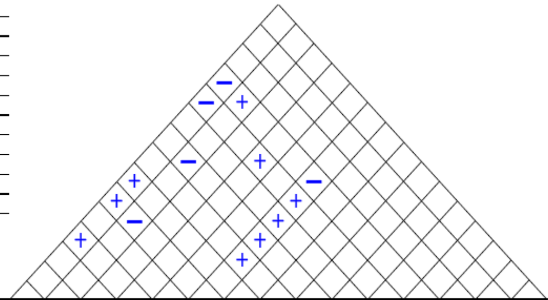
APPENDIX A - QFD

Title: QFD DR2

Author: Team 18

Date: 10/16/2008

Notes: * Yield strenght was removed from the engineering specs because it is addressed by the factor of safety spec.
* Height from edge of bathtub was also removed because upon further discussion with our sponsor it was decided that the ability to function in a glass sliding door is not a priority.
*Weigt of geriatric patient and surface roughness of seat were added.

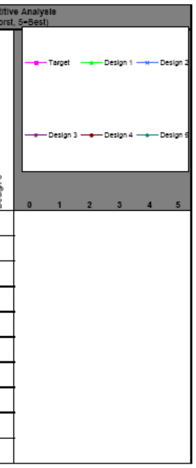


Legend		
Θ	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	
−	Negative Correlation	
▼	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
X	Objective Is To Hit Target	

Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	Factor of Safety (#)	Height of collapsed mechanism (in)	Dimension from inside edge of bathtub (in)	Dimension from outside edge of bathtub (in)	Number of steps to get in and out of bathtub (#)	Cost ($)	Weight of geriatric patient (lbs)	Range of adjustment (1 in increments)	Number of attachment/etc locations (#)	Number of moving parts (#)	Maximum deflection (in)	Weight of Mechanism (lbs)	Surface roughness of seat		
				Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	X	▼	X	X	▼	▼	X	▲	X	▼	▼	▼	X		
1	9	11.5	10.0	Robust / Dependable / Safe	Θ		Θ	▲	O	O	Θ	▲		O	Θ	O	Θ		
2	9	11.5	10.0	Allows shower curtain to close			Θ	▲	▲	▲		O		▲					
3	9	11.5	10.0	Extend to outer edge of bathtub	Θ			Θ	▲	O	Θ	O		▲	O	▲			
4	9	9.2	8.0	Simple / Easy to use			O		Θ			▲	O	O		O	▲		
5	9	10.3	9.0	Low cost	O	O		▲		Θ	▲	O	O	▲	O	O	▲		
6	9	8.0	7.0	Set-up conducive for caregiver			Θ	Θ	▲	▲	▲	O	Θ	▲			O		
7	9	11.5	10.0	Non-invasive for other shower users		Θ			▲	O		▲	▲	▲		O			
8	9	10.3	9.0	Adjustable for different bathtubs	O		▲	▲	▲	O	▲	Θ		▲					
9	9	8.0	7.0	Space for showerhead attachments / bathtub accessories / hand rails		O				O			Θ						
10	9	8.0	7.0	Removable (Not a permanent Fixture) / Easy to install	O	O		▲		▲	▲	O	▲	▲		Θ			
				Target or Limit Value	1.5	3.5	6	0+	4	<150	285	0.5	4	2	<1	<25	no skid		
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	8	9	6	8	7	9	6	8	5	8	9	7	6		
				Max Relationship Value in Column	9	9	9	9	9	9	9	9	9	3	9	9	9		
				Weight / Importance	293.1	182.8	317.2	227.6	170.1	279.3	243.7	273.6	223.0	133.3	169.0	211.5	147.1		

Competitive Analysis (0=Worst, 5=Best)

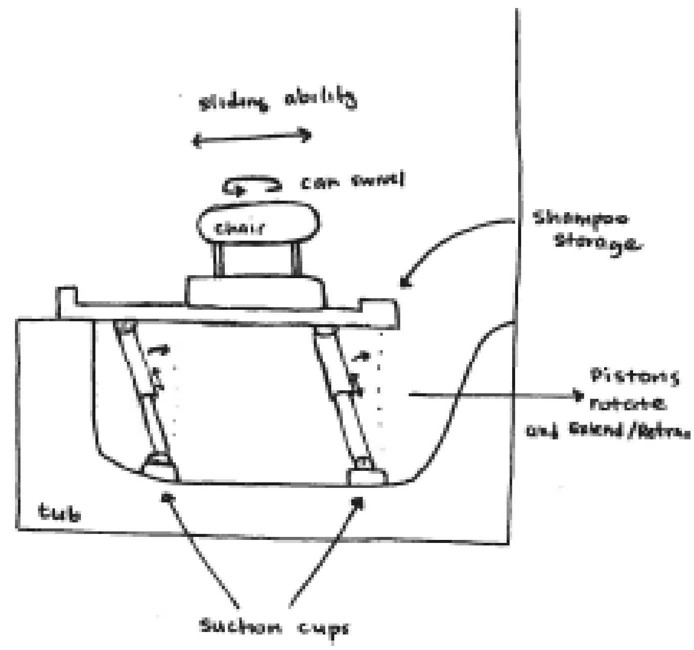
Row #	Target	Design 1	Design 2	Design 3	Design 4	Design 5
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						



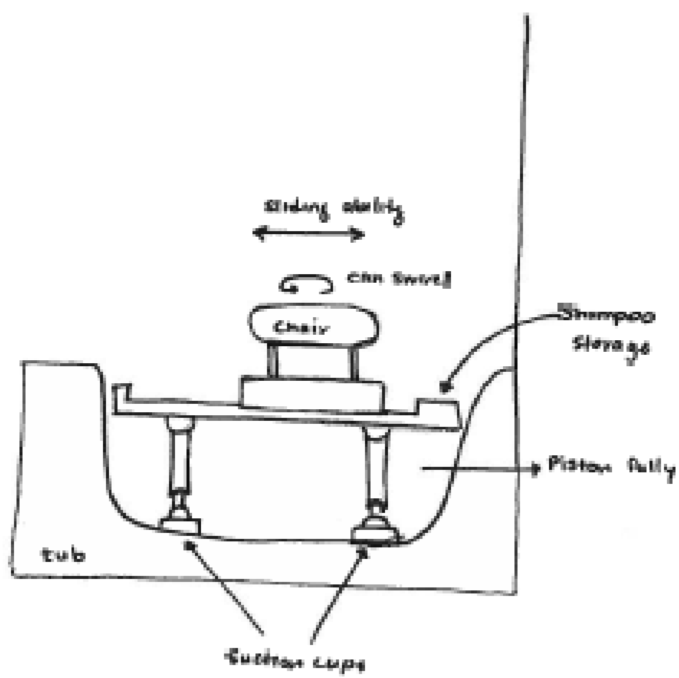
APPENDIX B – CONCEPT DRAWINGS

① Sliding Bench.

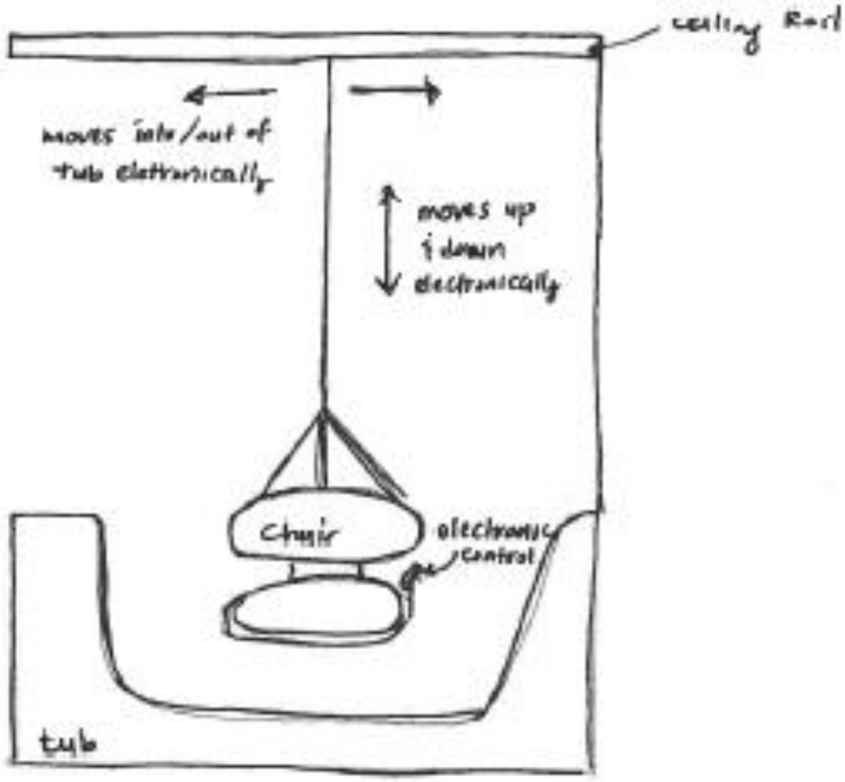
Extended.



Showering Position

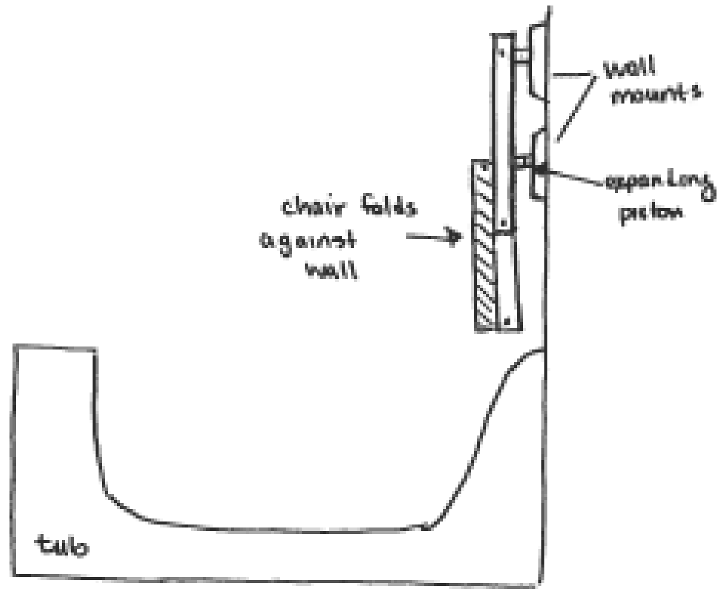


② Swing Design.

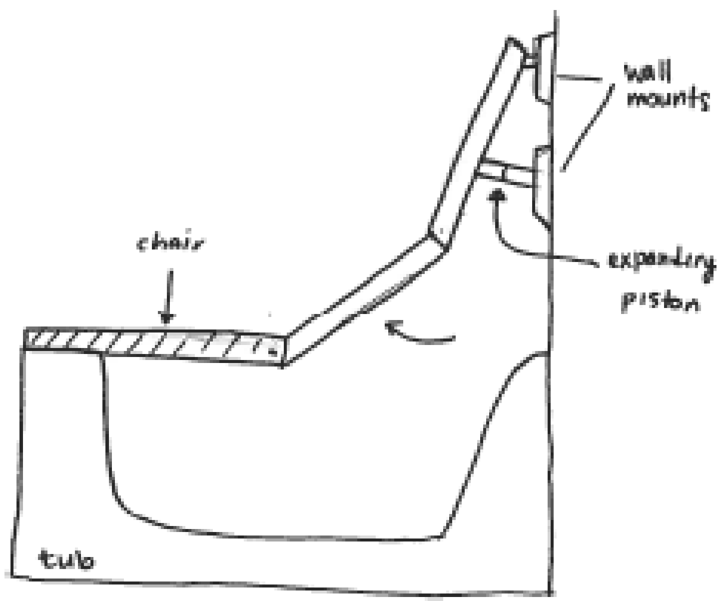


③ Folding Chair Design.

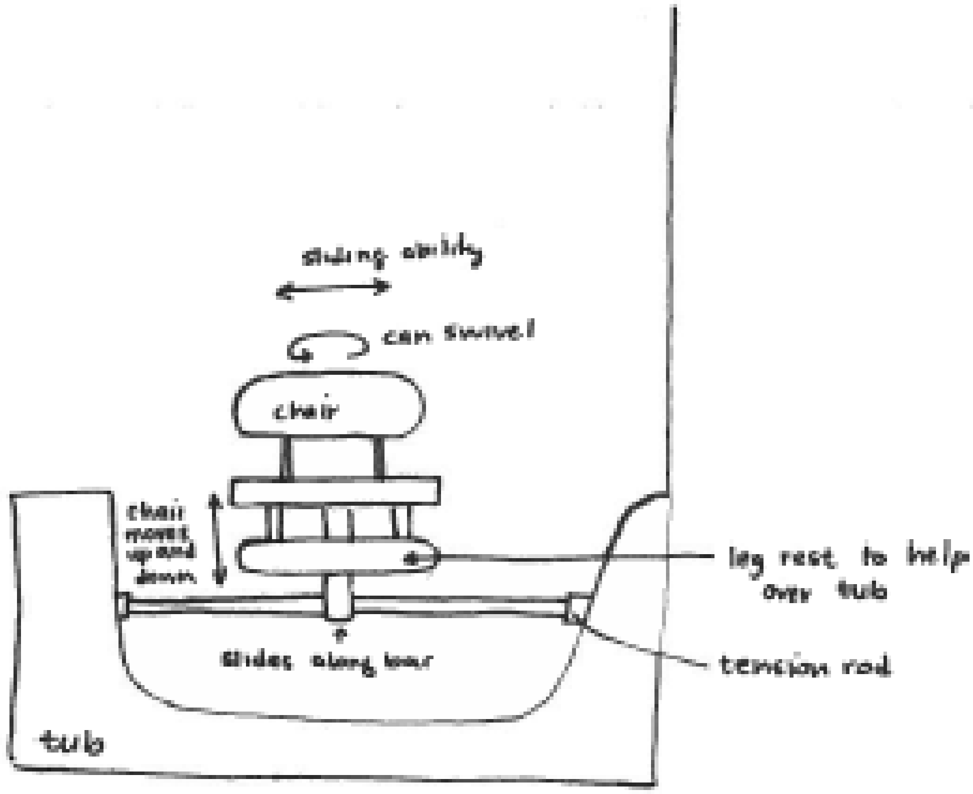
Retracted:



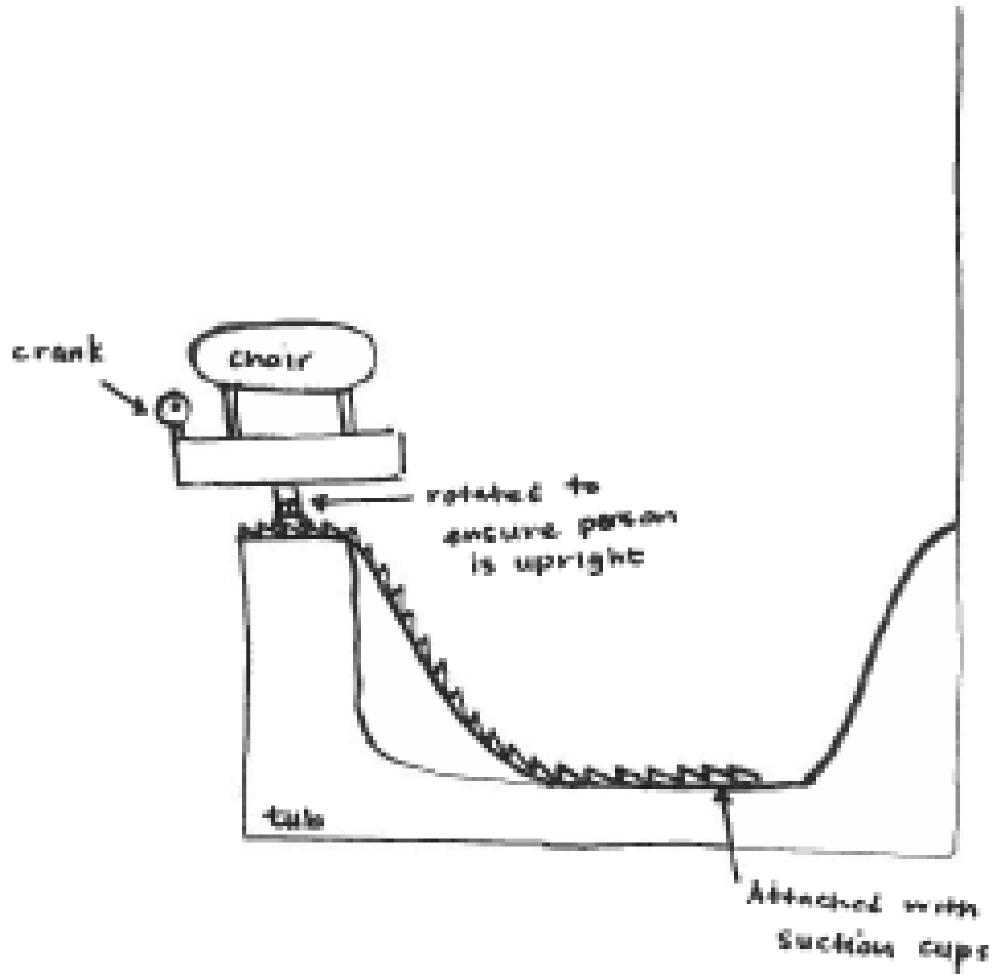
Extended:



④ Rail in the Tub



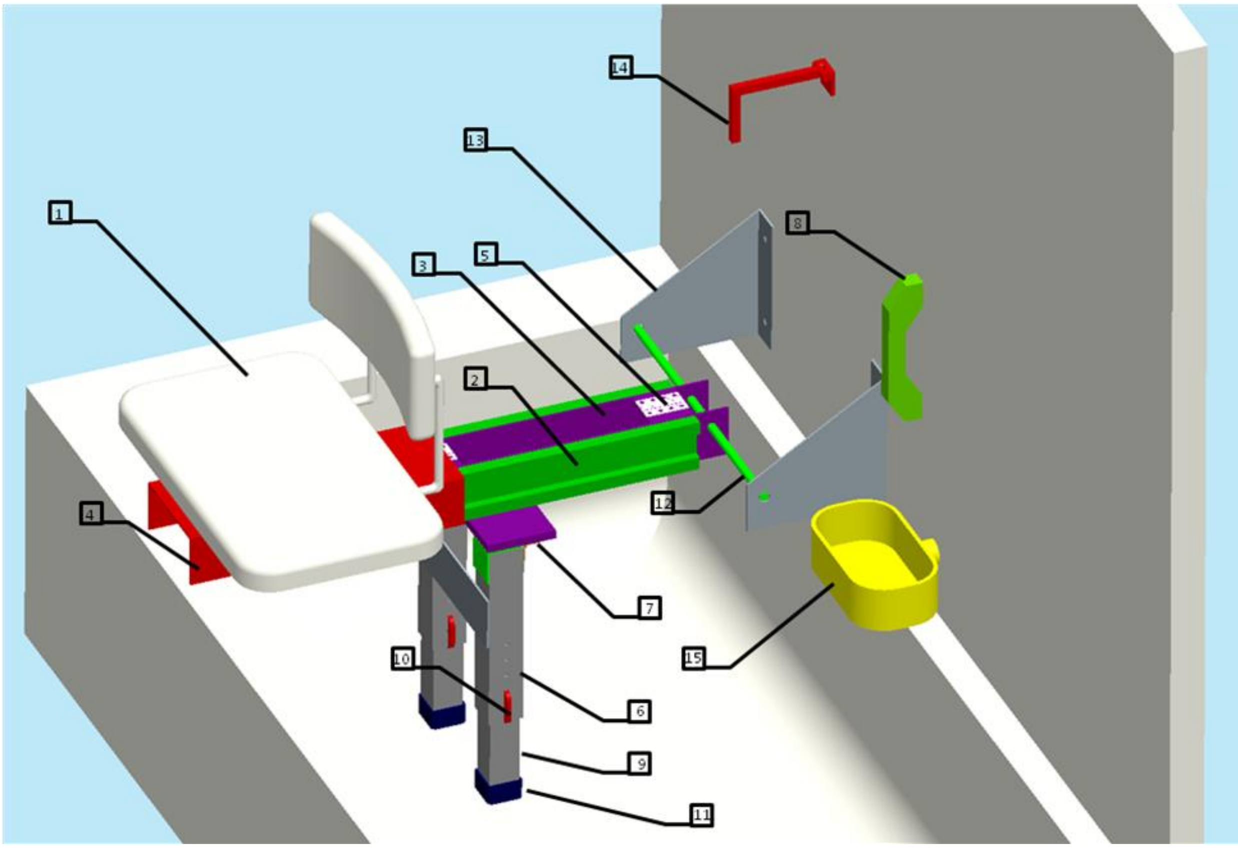
⑤ Cedar Point Ride



APPENDIX C – SELECTION MATRICIES

Customer Requirements	Importance Rating (1-10)	Average Rating					
		Design 1	Design 2	Design 3	Design 4	Design 5	alpha
Robust / Dependable / Safe	10	35	37.5	32.5	30	20	45
Allows shower curtain to close	10	50	47.5	30	20	12.5	50
Extend to outer edge of bathtub	10	50	47.5	50	22.5	47.5	50
Non-invasive for other shower users	10	25	40	37.5	25	15	40
Low cost	9	27	24.75	29.25	29.25	15.75	29.25
Adjustable for different bathtubs	9	33.75	31.5	36	33.75	24.75	36
Simple / Easy to use	8	28	28	26	24	18	32
Set-up conducive for caregiver	7	26.25	17.5	17.5	22.75	17.5	29.75
Space for showerhead attachments / bathtub accessories / hand rails	7	28	7	14	15.75	12.25	31.5
Removable / Easy to install	7	19.25	10.5	24.5	22.75	10.5	24.5
Manufacturability	9	24.75	22.5	27	24.75	13.5	33.75
	Total Score:	347	314.25	324.25	270.5	207.25	401.75
	Normalized Score out of 10:	7.23	6.55	6.76	5.64	4.32	8.37

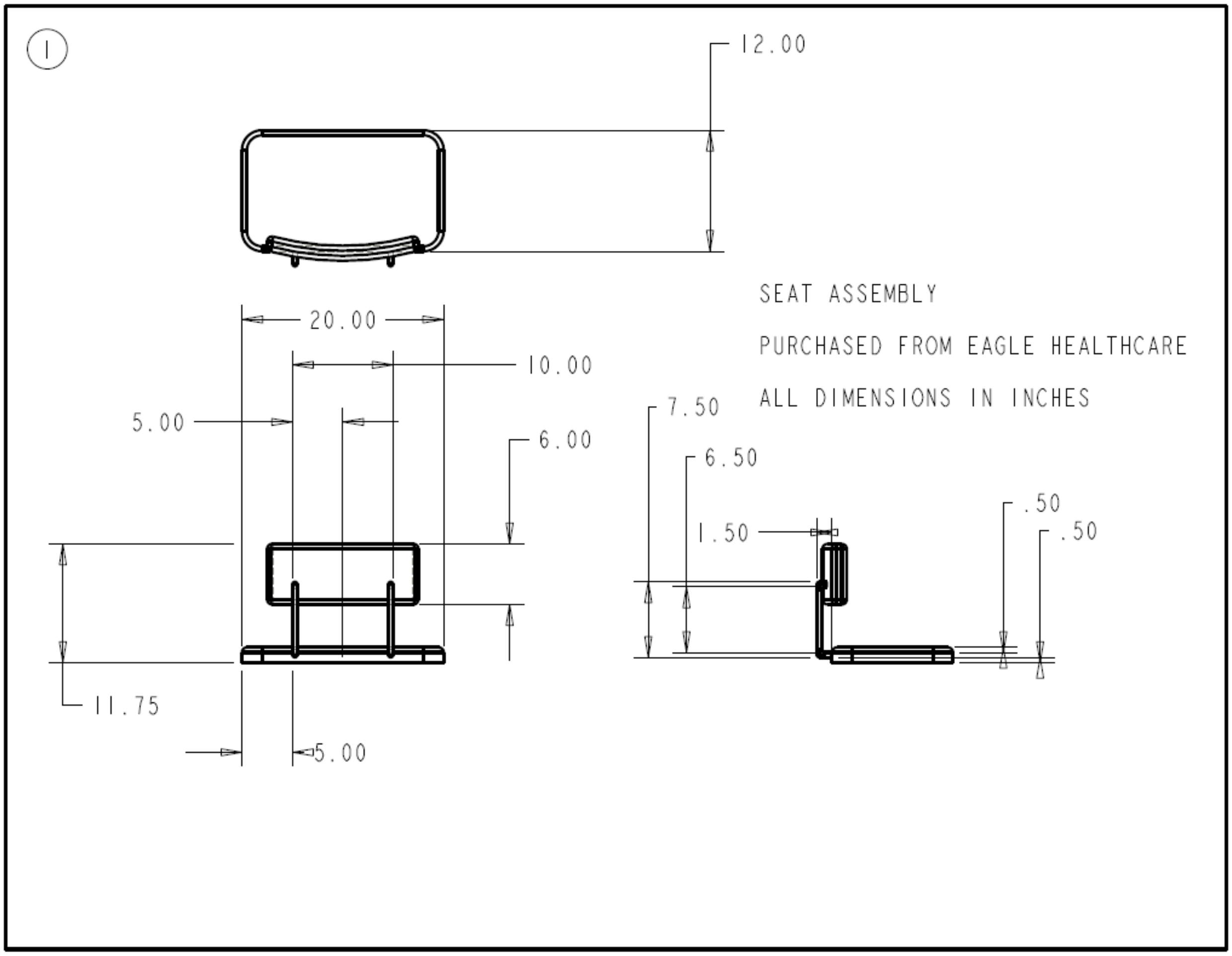
APPENDIX D – LABELED CAD DRAWING

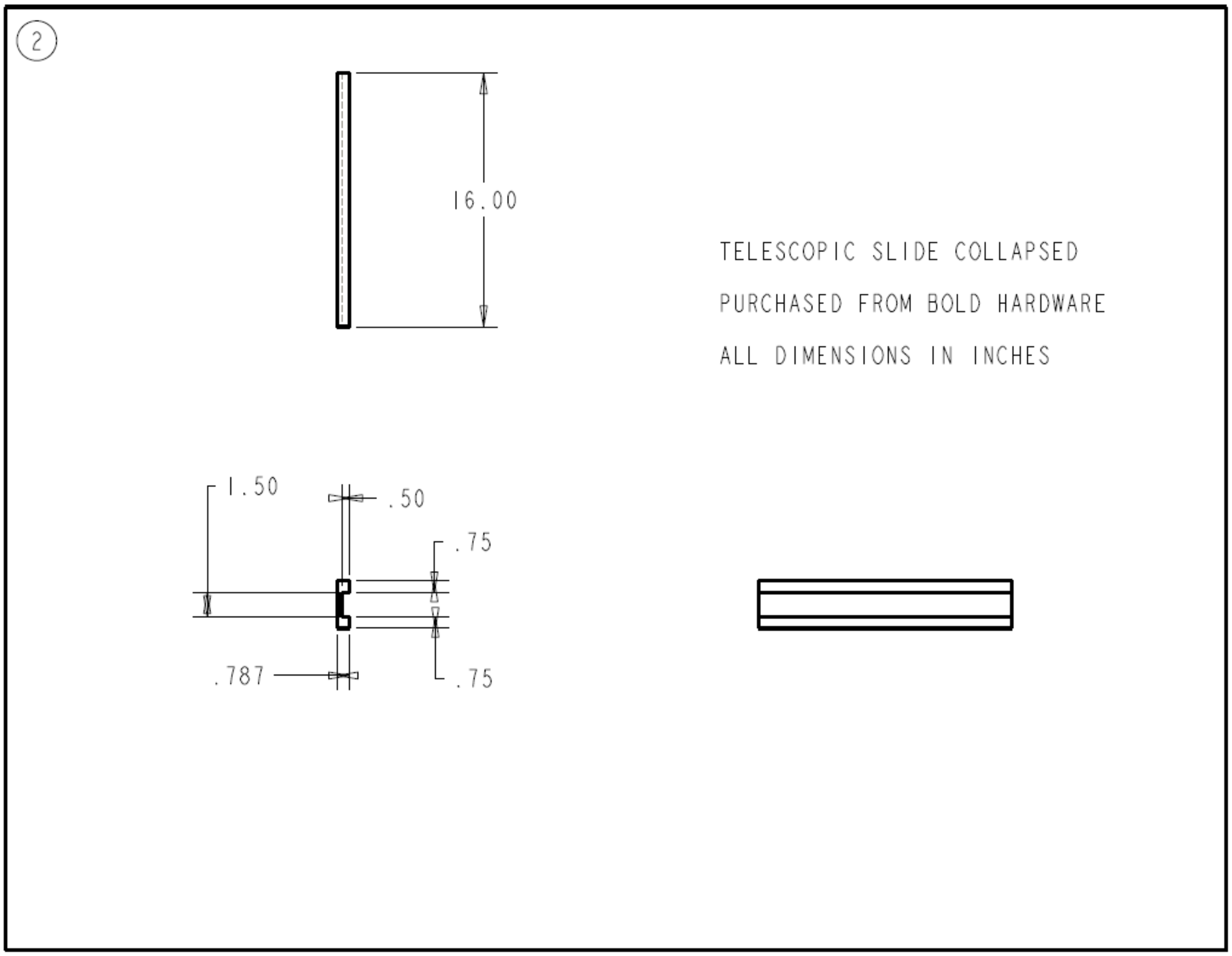


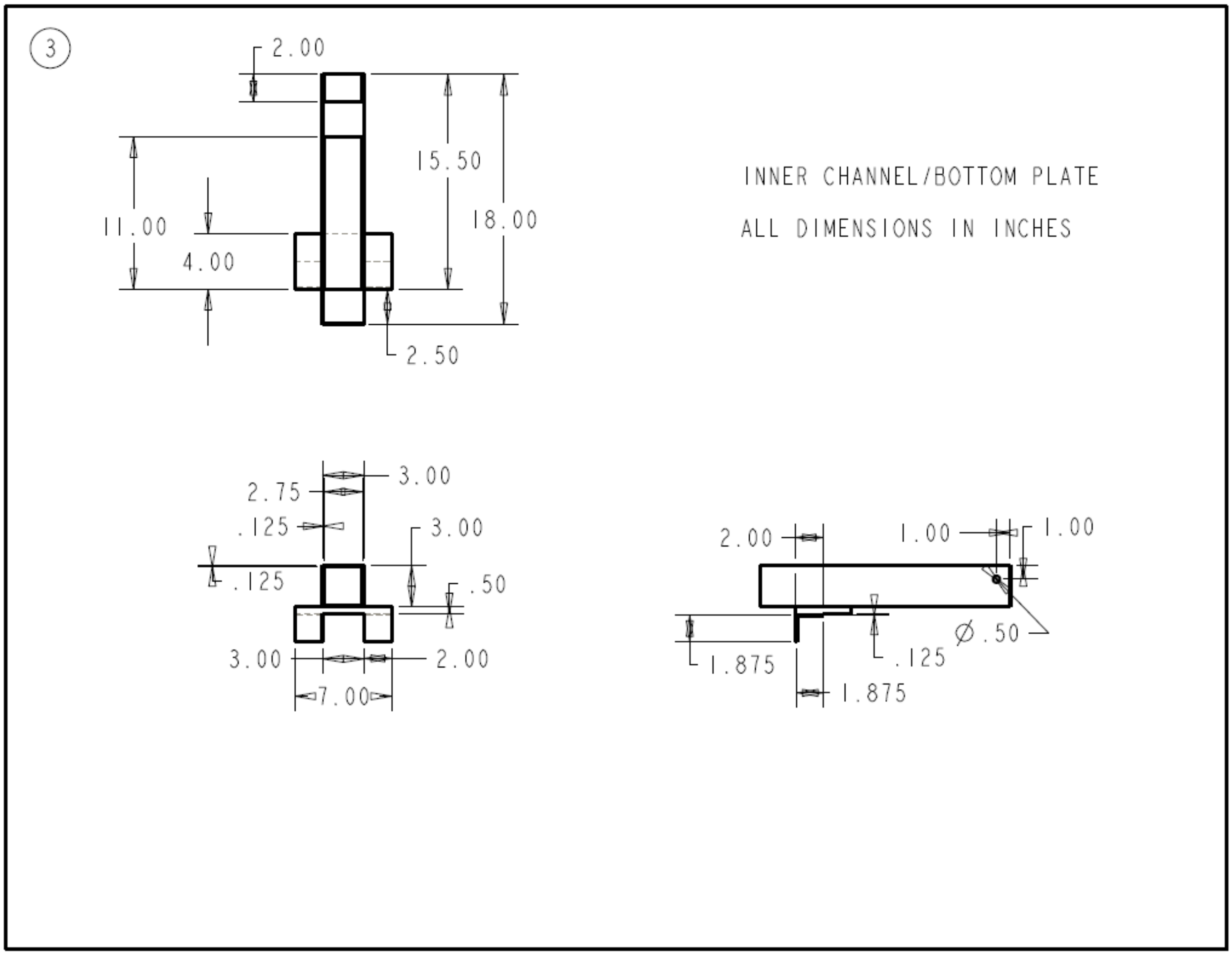
In the figure above the numbers refer the following parts:

1. Seat
2. Sliding Rails
3. Inner Channel
4. Outer Channel
5. Magnetic Catches
6. Outer Leg
7. Leg Hinge
8. Wall Handle
9. Inner Leg
10. Leg Locking Pins
11. Plastic Feet Covers
12. Steel Rod
13. Wall Brackets
14. Wall Locking Device
15. Shampoo Holder

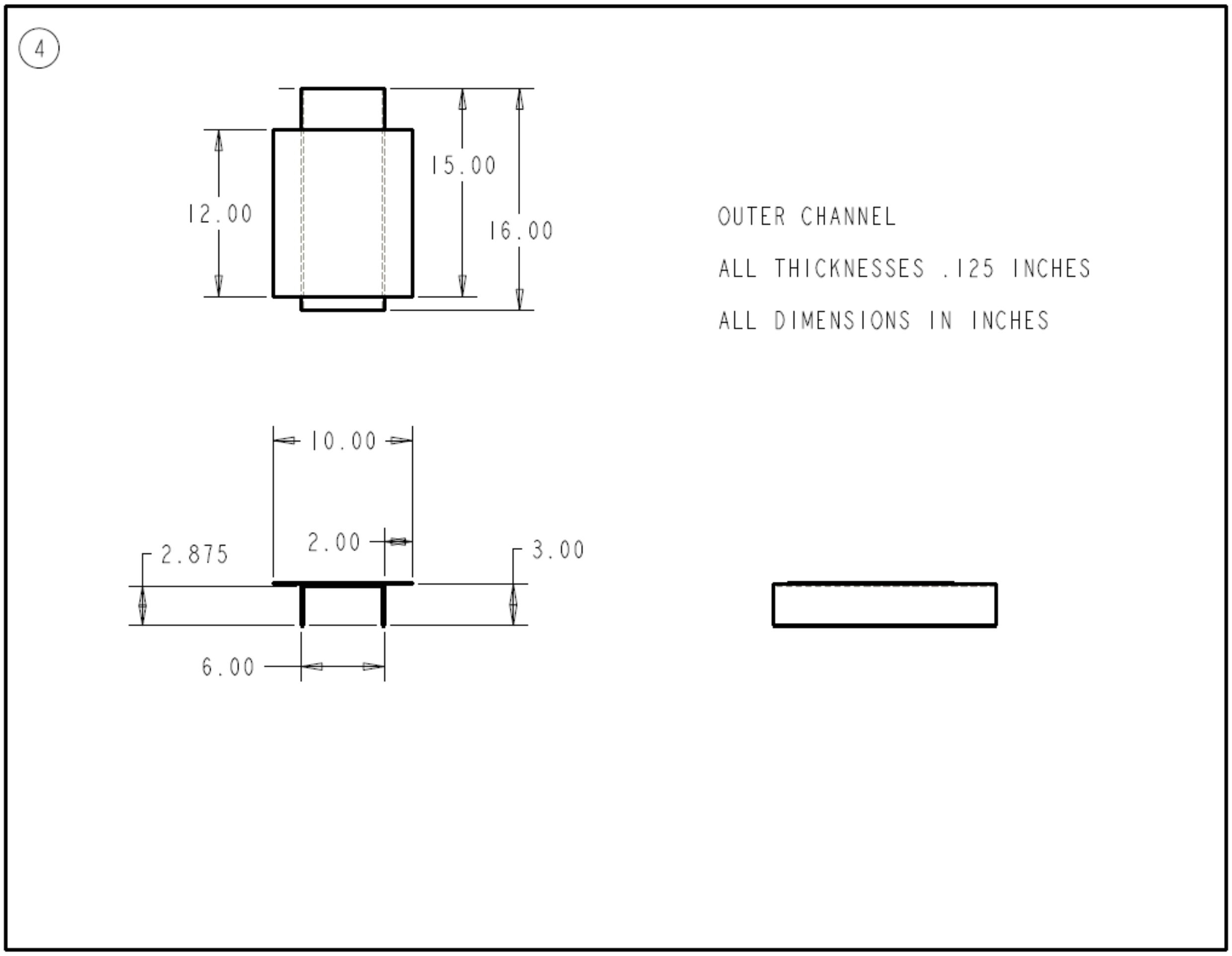
APPENDIX E- ENGINEERING DRAWINGS

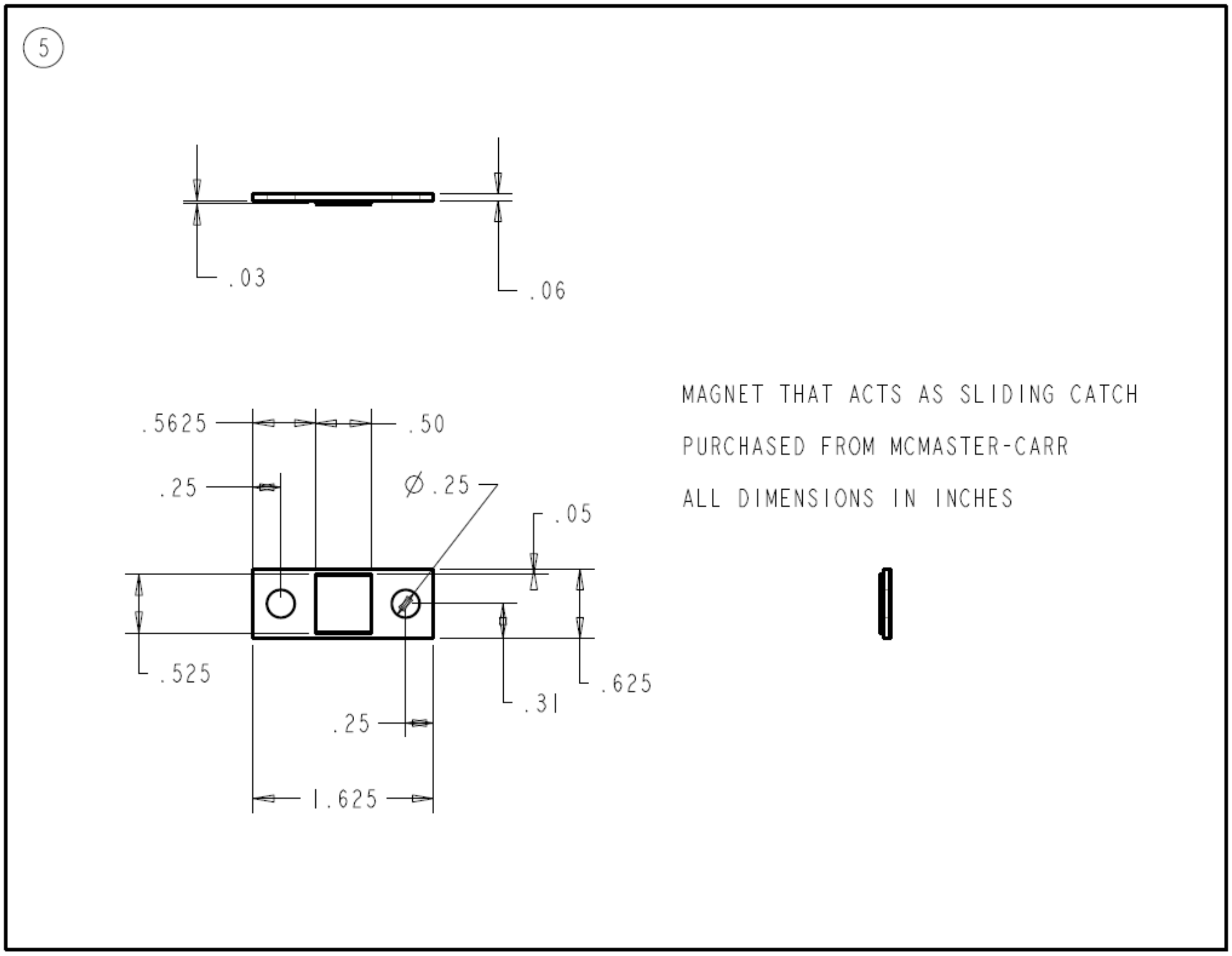


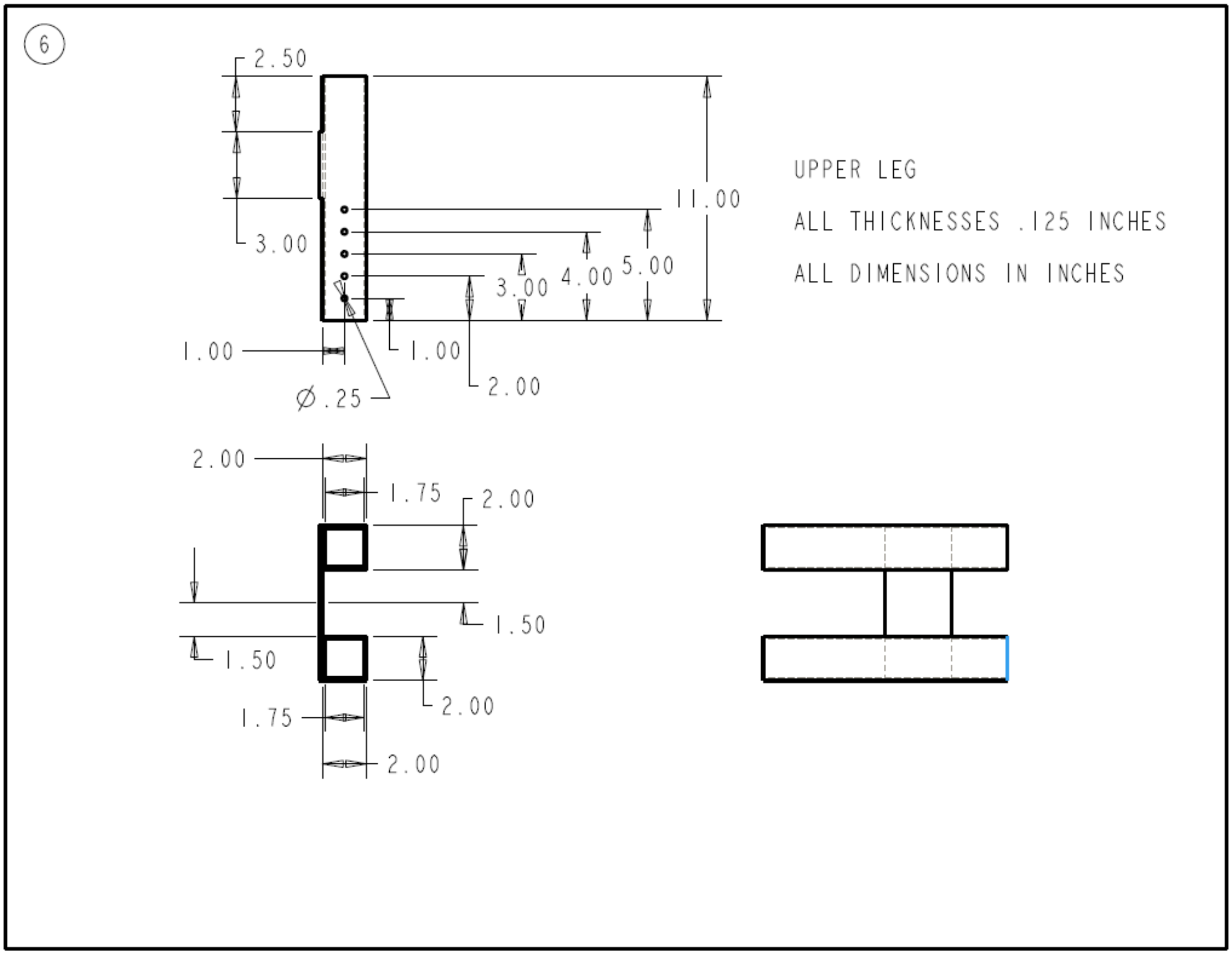

2
16.00
TELESCOPIC SLIDE COLLAPSED
PURCHASED FROM BOLD HARDWARE
ALL DIMENSIONS IN INCHES
1.50
.50
.75
.787
.75

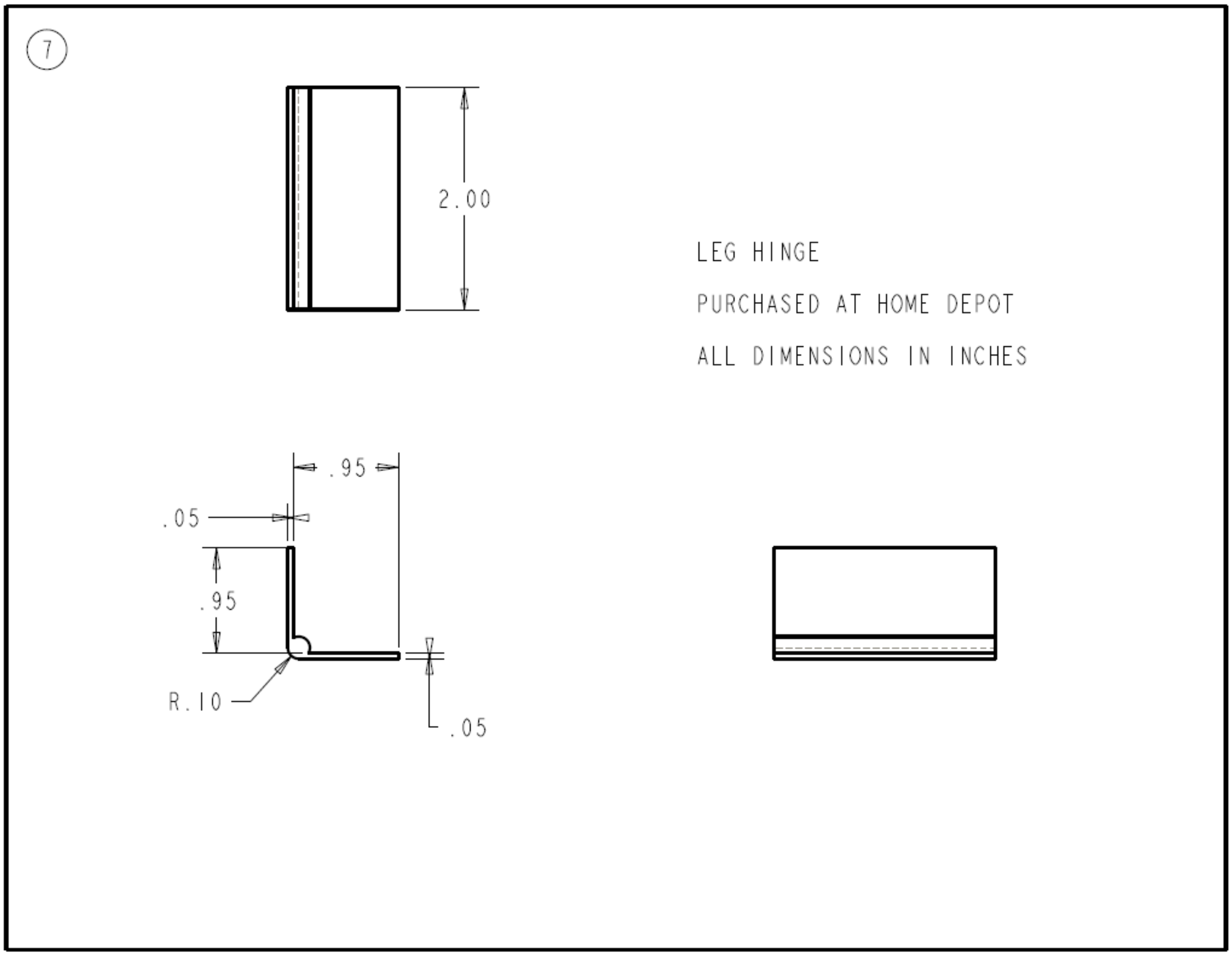


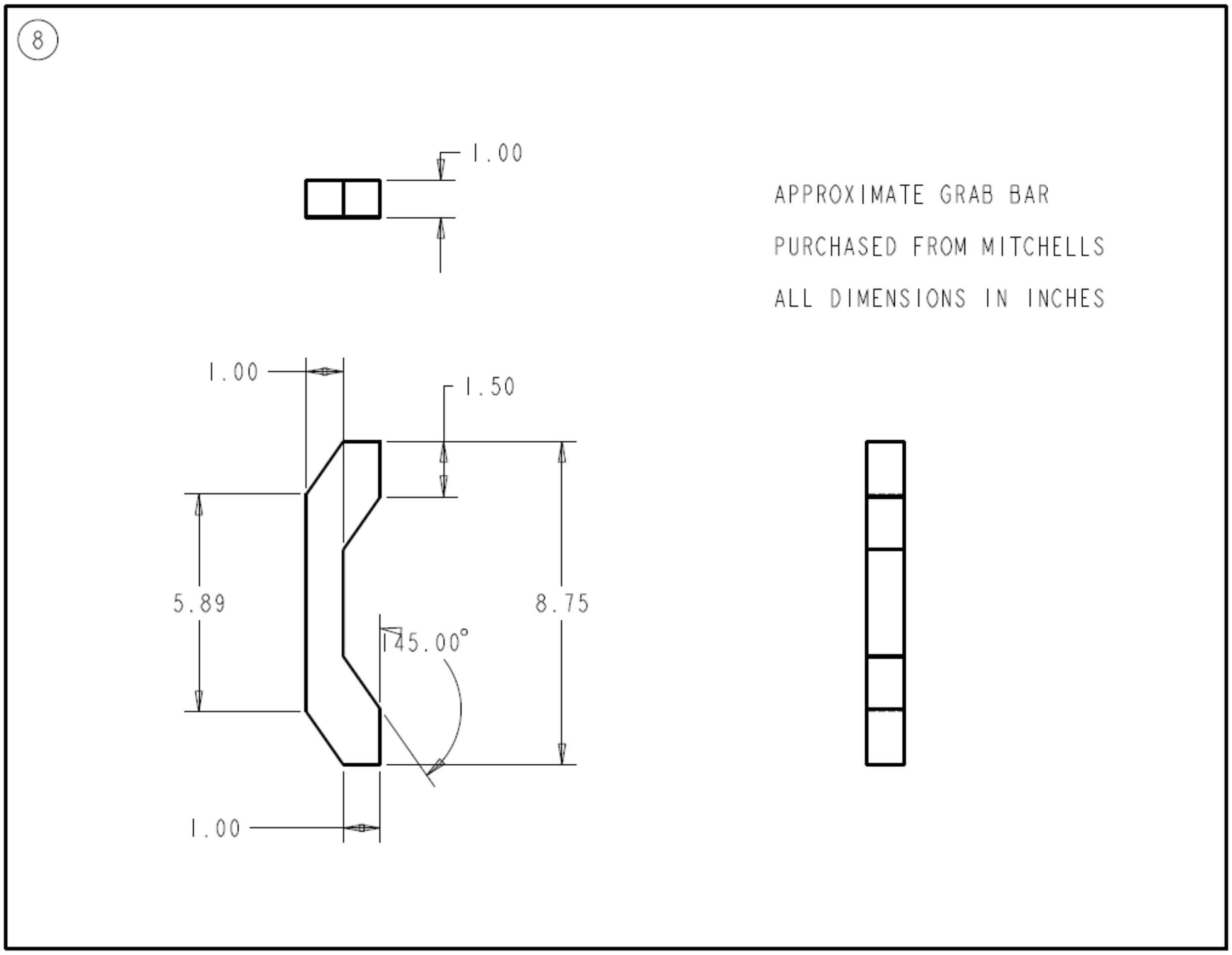
3
2.00
15.50
18.00
11.00
4.00
2.50
INNER CHANNEL/BOTTOM PLATE
ALL DIMENSIONS IN INCHES
3.00
2.75
.125
3.00
.125
.50
3.00
2.00
7.00
2.00
1.00
1.00
Ø.50
1.875
.125
1.875


4
12.00
15.00
16.00
OUTER CHANNEL
ALL THICKNESSES .125 INCHES
ALL DIMENSIONS IN INCHES
10.00
2.875
2.00
3.00
6.00

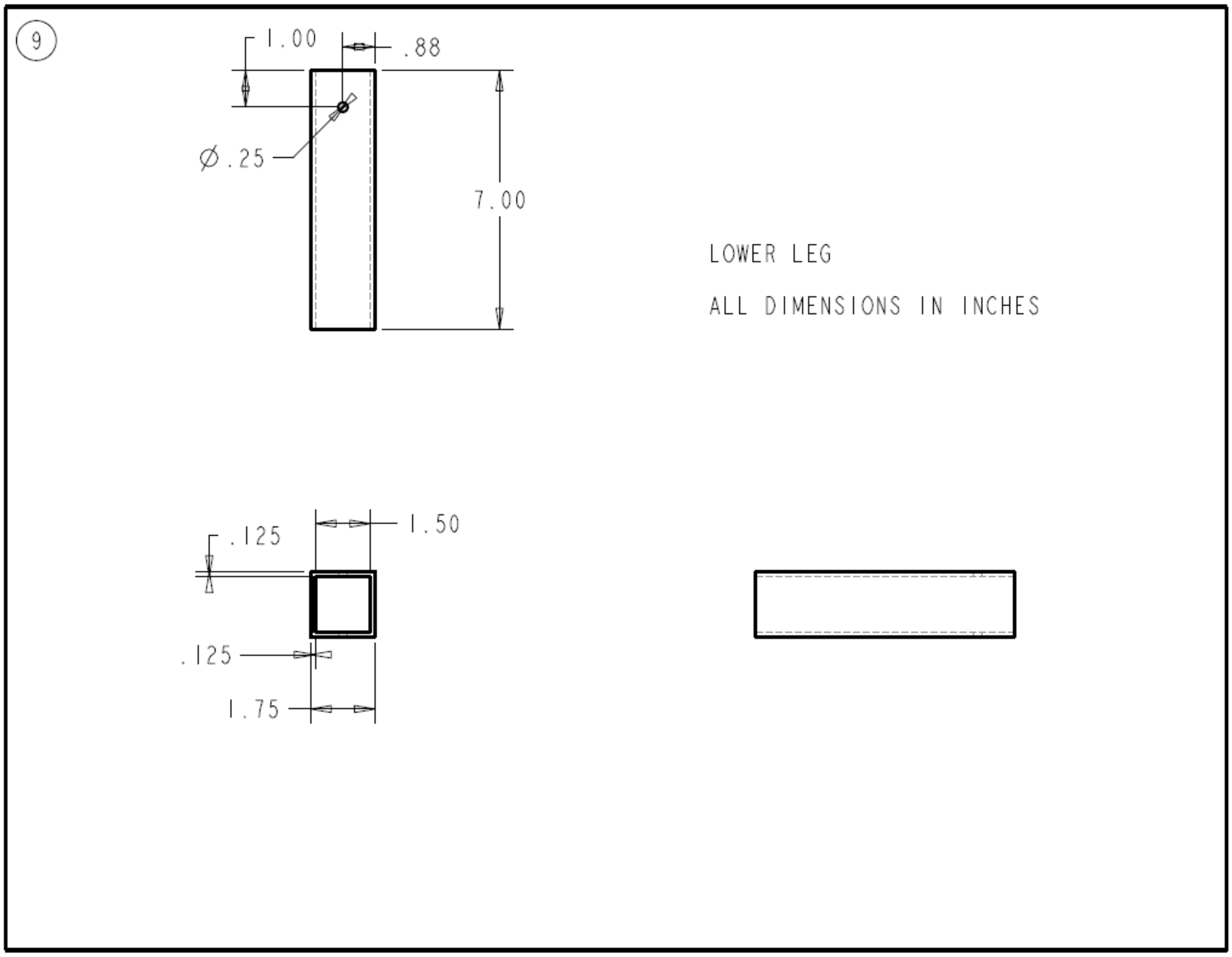

5
.03
.06
.5625
.50
.25
∅.25
.05
.525
.31
.625
.25
1.625
MAGNET THAT ACTS AS SLIDING CATCH
PURCHASED FROM MCMASTER-CARR
ALL DIMENSIONS IN INCHES

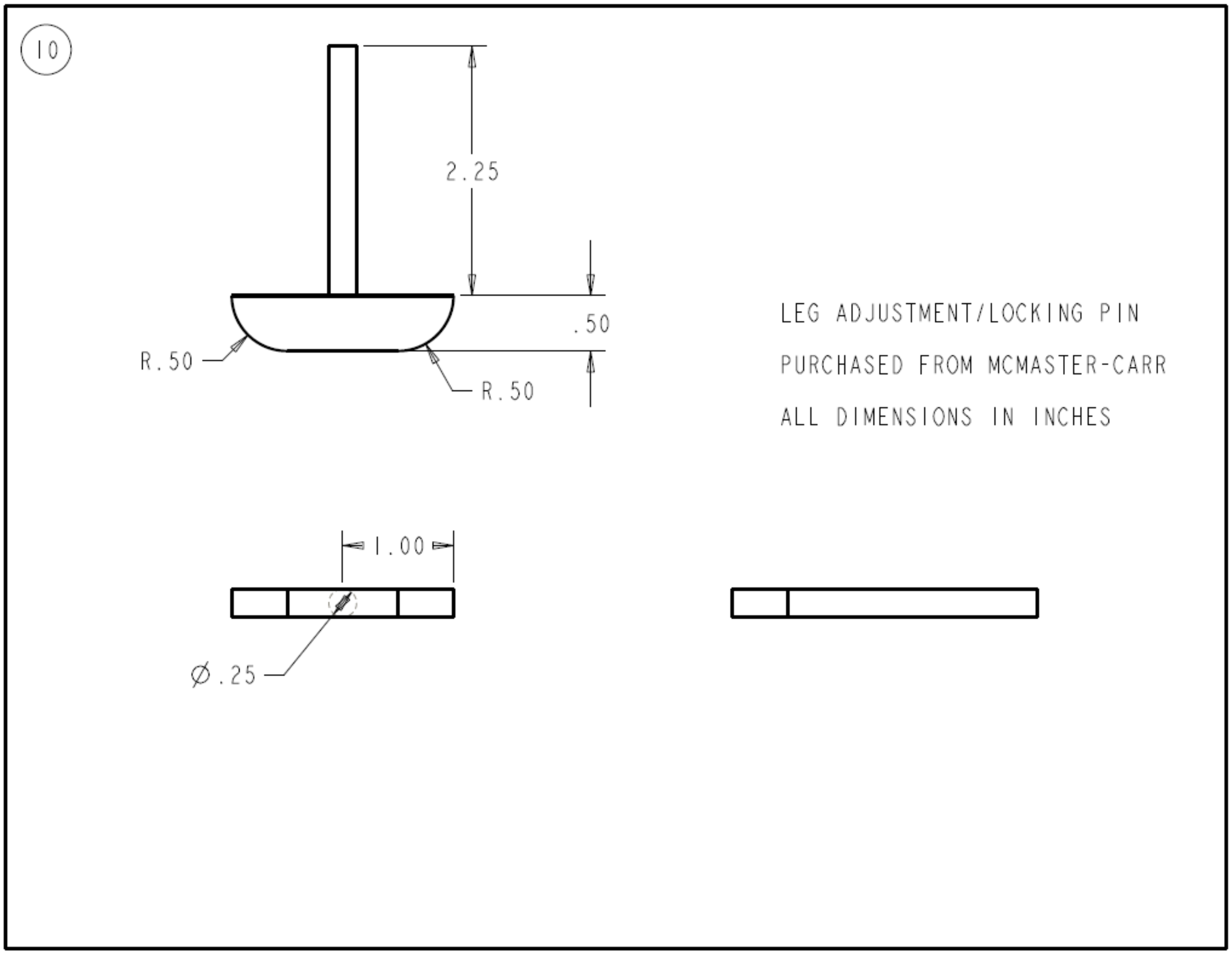

6
2.50
3.00
11.00
5.00
4.00
3.00
1.00
1.00
2.00
Ø.25
UPPER LEG
ALL THICKNESSES .125 INCHES
ALL DIMENSIONS IN INCHES
2.00
1.75
2.00
1.50
1.50
2.00
1.75
2.00

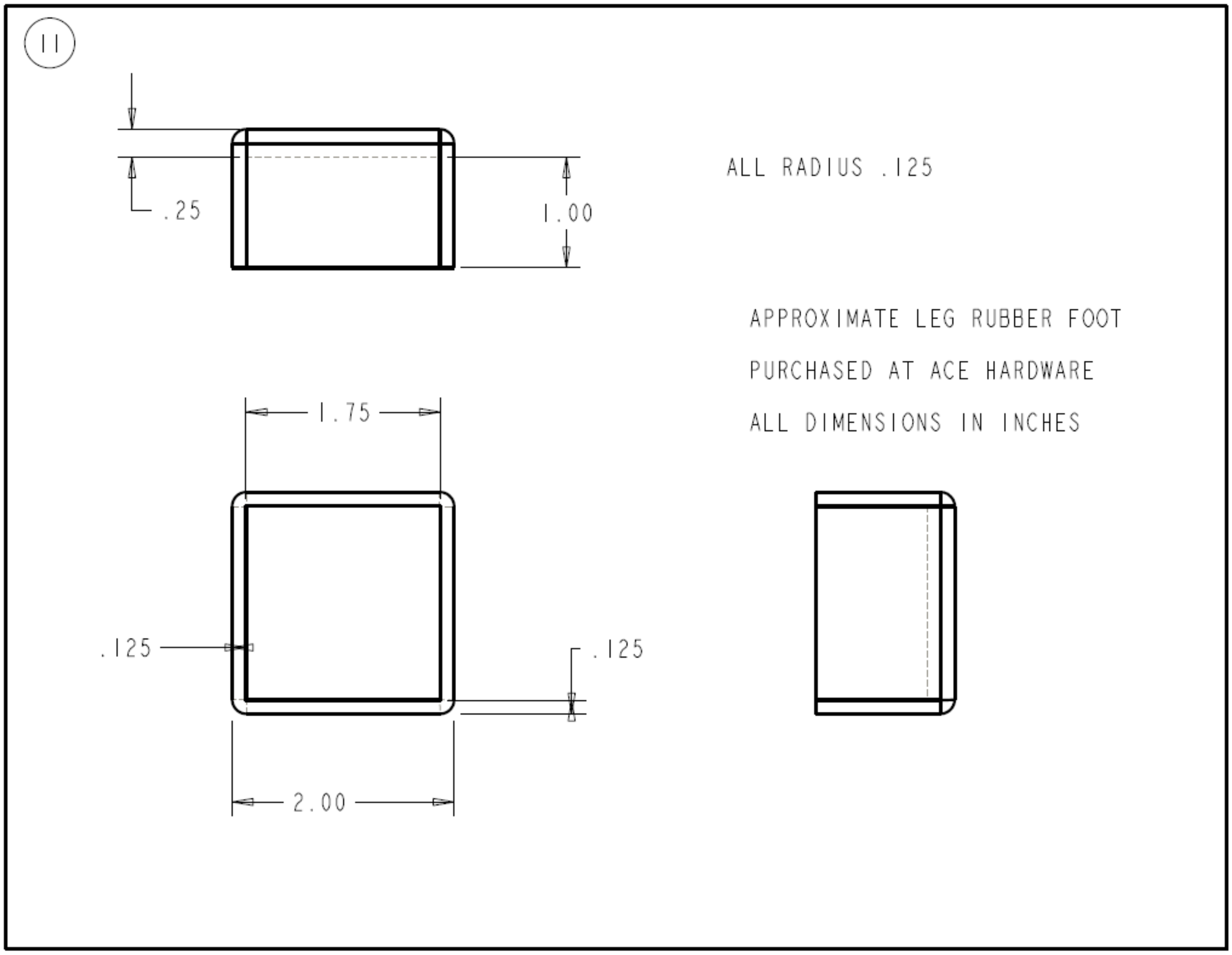

7
2.00
LEG HINGE
PURCHASED AT HOME DEPOT
ALL DIMENSIONS IN INCHES
.95
.05
.95
R.10
.05

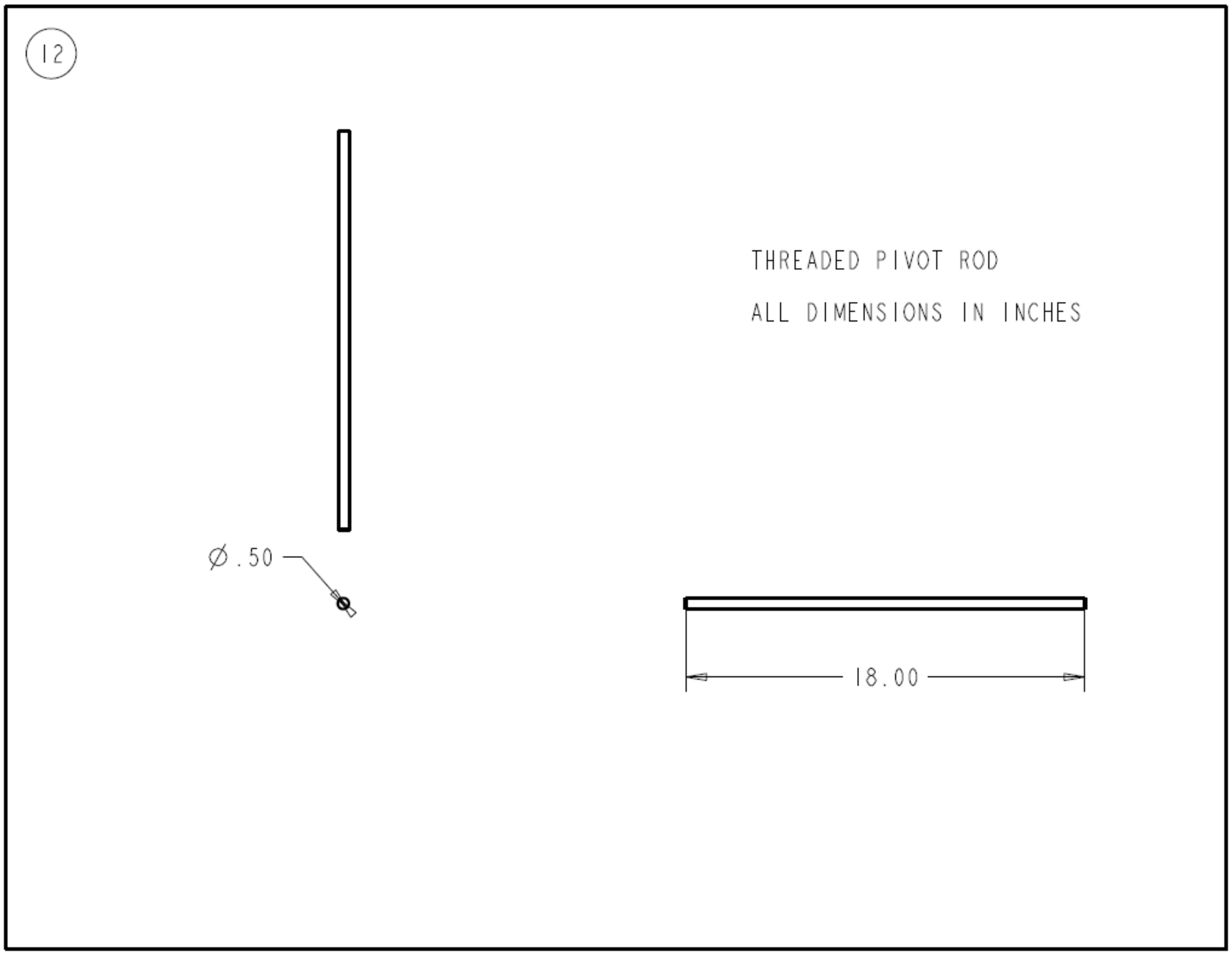


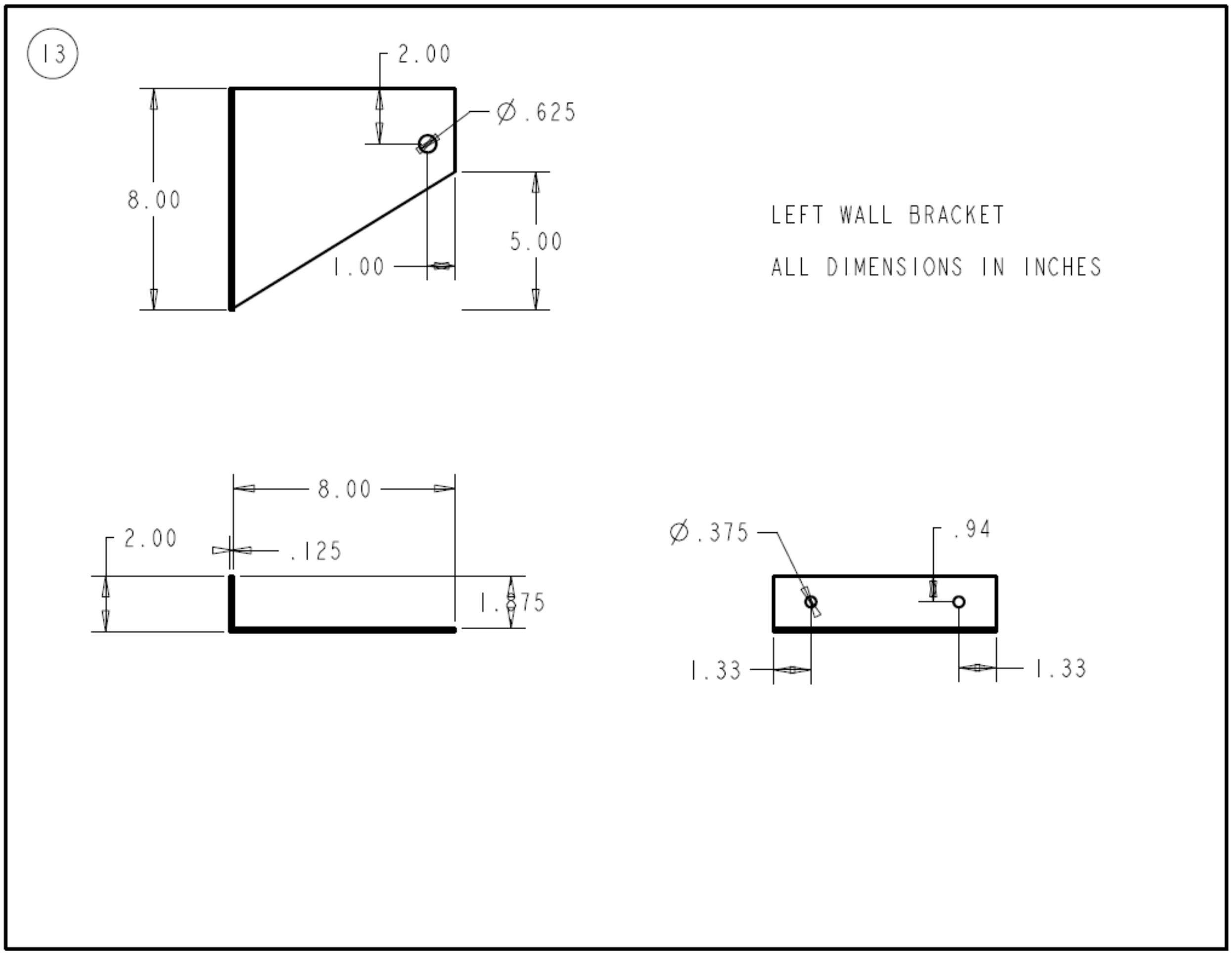
8
1.00
APPROXIMATE GRAB BAR
PURCHASED FROM MITCHELLS
ALL DIMENSIONS IN INCHES
1.00
1.50
5.89
8.75
145.00°
1.00

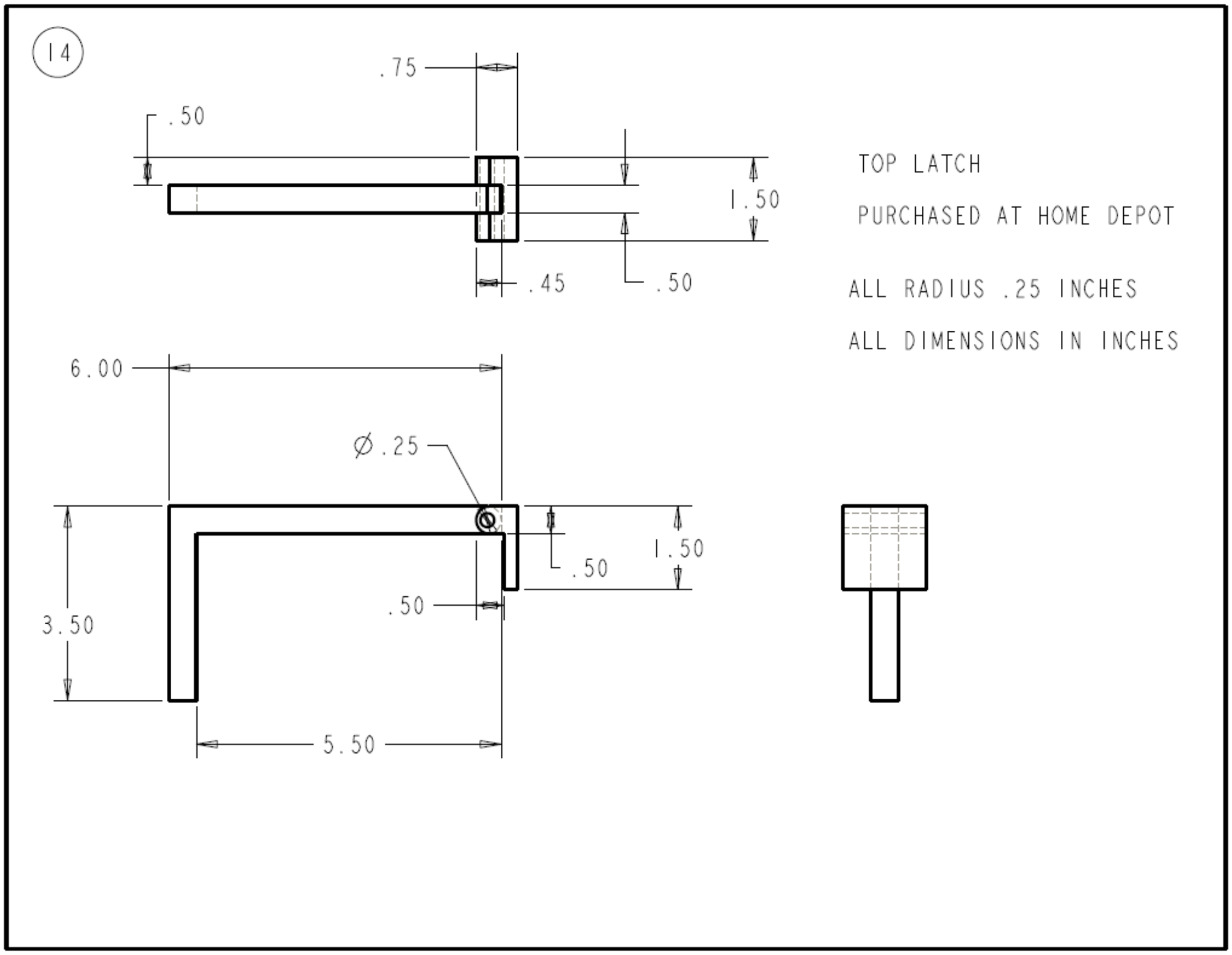

9
1.00
.88
Ø.25
7.00
LOWER LEG
ALL DIMENSIONS IN INCHES
.125
1.50
.125
1.75

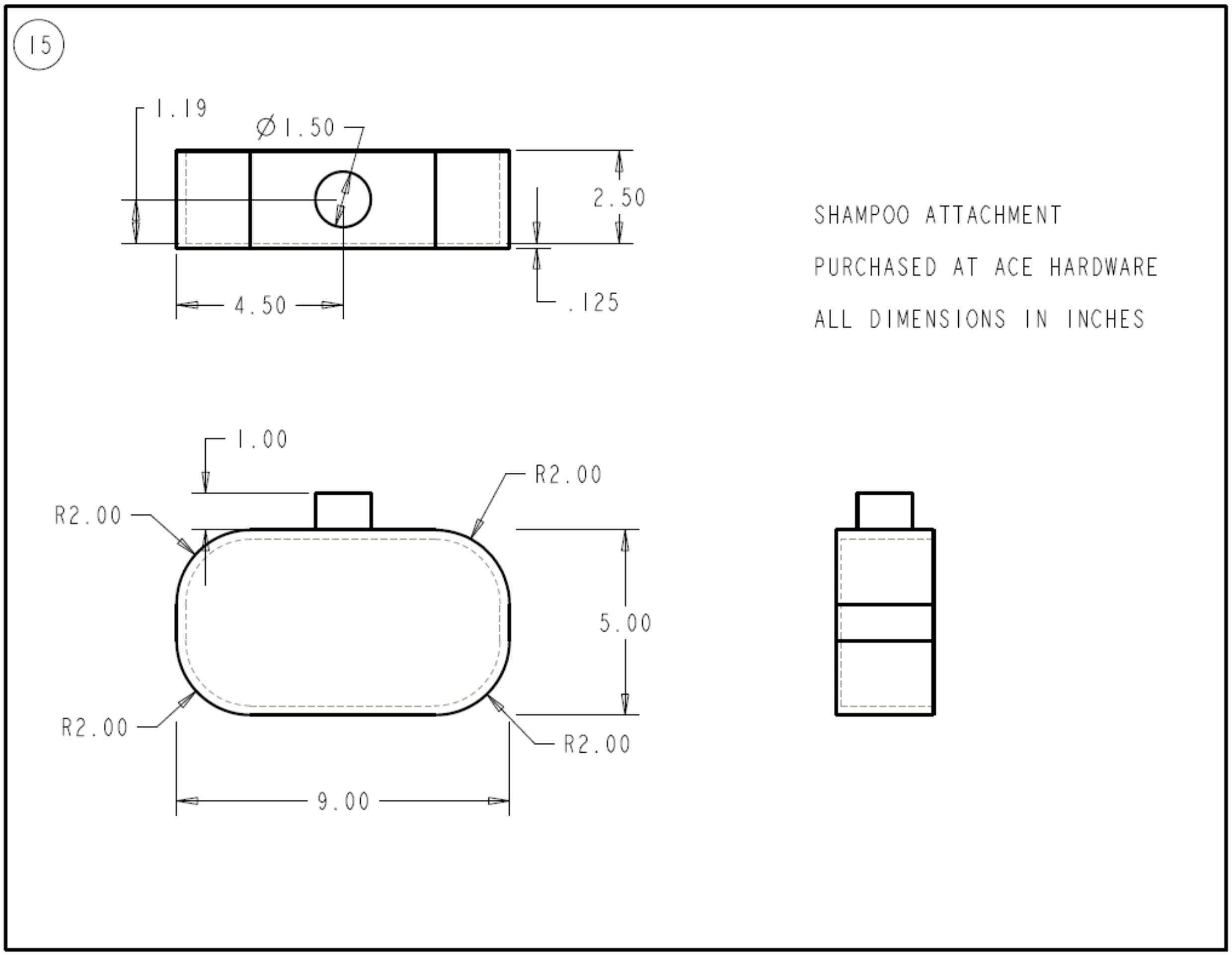

10
2.25
.50
R.50
R.50
LEG ADJUSTMENT/LOCKING PIN
PURCHASED FROM MCMASTER-CARR
ALL DIMENSIONS IN INCHES
1.00
Ø.25

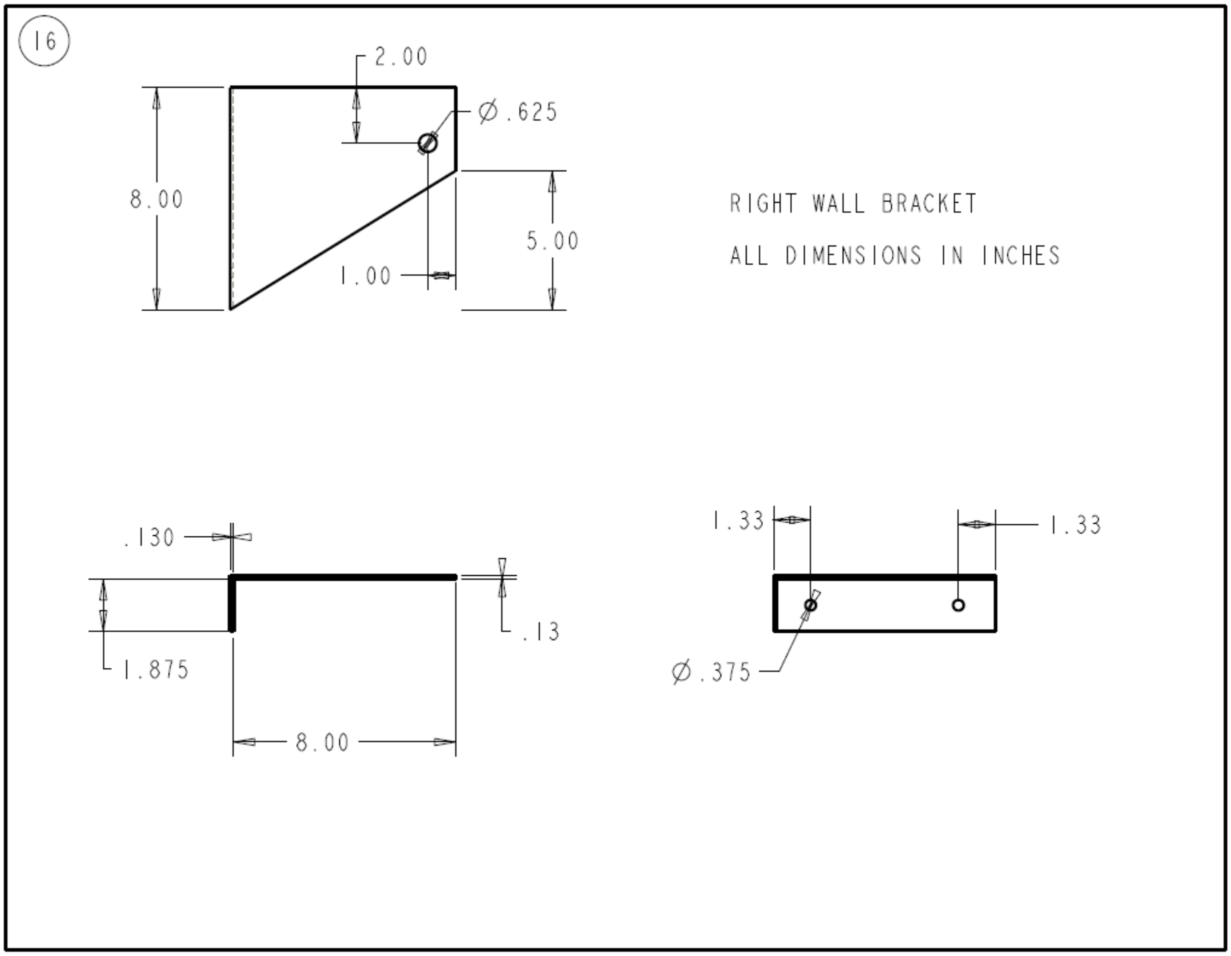

11
.25
1.00
ALL RADIUS .125
APPROXIMATE LEG RUBBER FOOT
PURCHASED AT ACE HARDWARE
ALL DIMENSIONS IN INCHES
1.75
.125
.125
2.00


12
THREADED PIVOT ROD
ALL DIMENSIONS IN INCHES
∅.50
18.00


13
2.00
Ø.625
8.00
5.00
1.00
LEFT WALL BRACKET
ALL DIMENSIONS IN INCHES
8.00
2.00
.125
1.875
Ø.375
.94
1.33
1.33

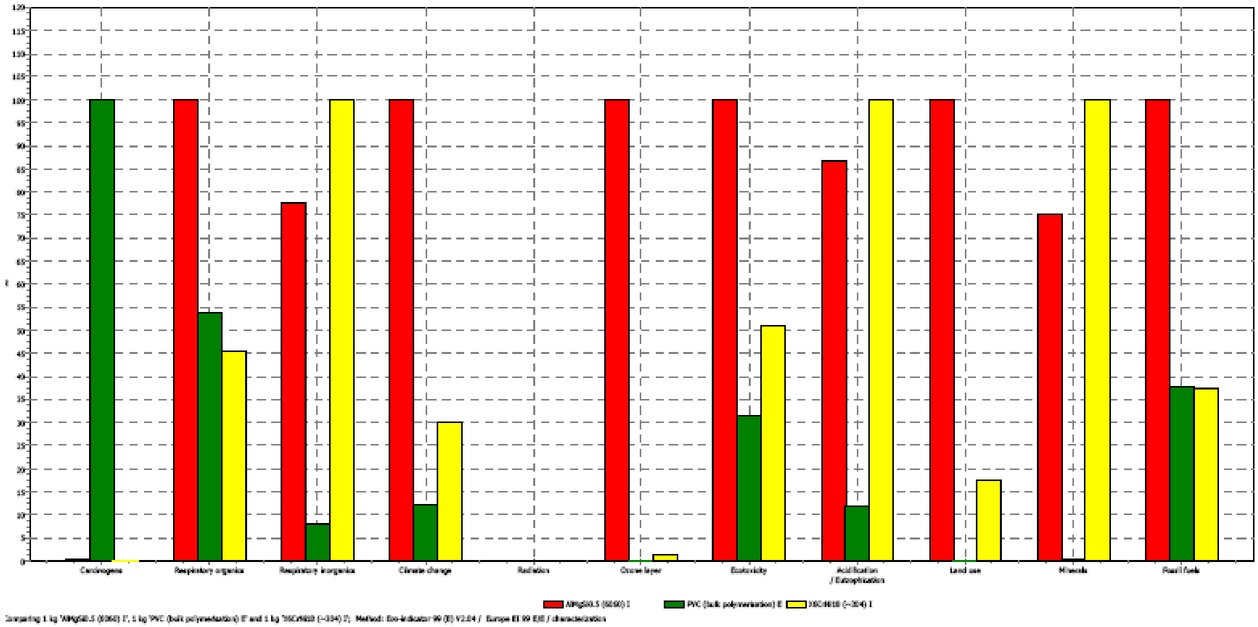

14
.75
.50
1.50
.45
.50
TOP LATCH
PURCHASED AT HOME DEPOT
ALL RADIUS .25 INCHES
ALL DIMENSIONS IN INCHES
6.00
Ø.25
3.50
.50
1.50
.50
5.50


15
1.19
Ø1.50
2.50
4.50
.125
SHAMPOO ATTACHMENT
PURCHASED AT ACE HARDWARE
ALL DIMENSIONS IN INCHES
1.00
R2.00
R2.00
5.00
R2.00
R2.00
9.00

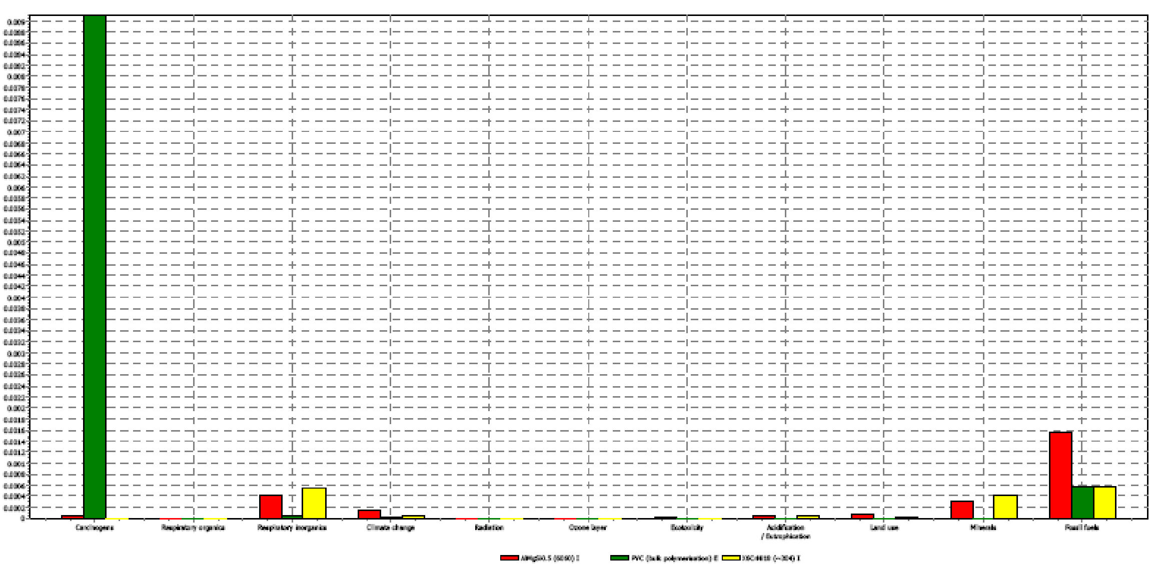

16
2.00
∅.625
8.00
5.00
1.00
RIGHT WALL BRACKET
ALL DIMENSIONS IN INCHES
.130
.13
1.875
8.00
1.33
1.33
∅.375

APPENDIX F – SIMAPRO PLOTS

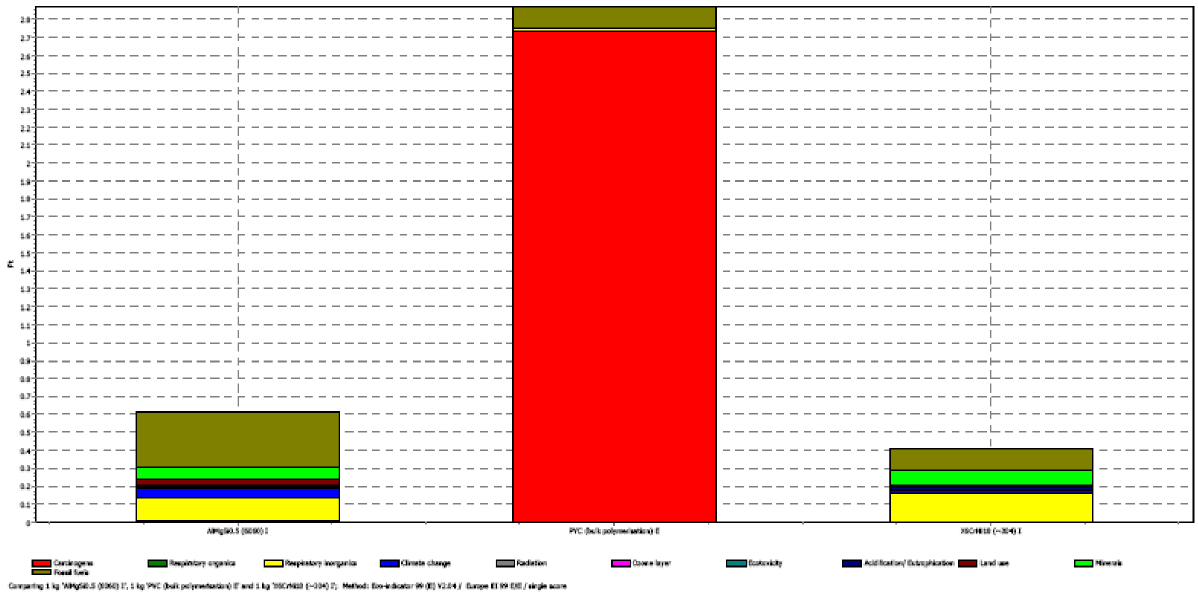
Characterization SimaPro Plot



Normalization SimaPro Plot



Single Core SimaPro Plot



APPENDIX G – FMEA

designsafe Report

Application: Team 19 Legs

Description:

Product Identifier:

Assessment Type: Detailed

Limits:

Sources:

Analyst Name(s):

Company:

Facility Location:

Guide sentence: When doing [task], the [user] could be injured by the [hazard] due to the [failure mode].

User / Task	Hazard / Failure Mode	Initial Assessment Severity Exposure Probability	Risk Level	Risk Reduction Methods /Comments	Final Assessment Severity Exposure Probability	Risk Level	Status / Responsible /Reference
All Users All Tasks	mechanical : crushing Overloading legs could cause crushing of material and leg support pins	Catastrophic Occasional Unlikely	High	warning label(s) 300 Lbs	Catastrophic None Negligible	Low	In-process Team 18
All Users All Tasks	mechanical : cutting / severing If legs are overloaded pins could cut throuh leg material	Serious Occasional Unlikely	Moderate	Engineering falure calculations, monthly inspections for cracks	Serious Remote Negligible	Low	In-process Team 18
All Users All Tasks	mechanical : pinch point Upper and lower leg connect with very low clearance. Pinch could deform material, locking legs.	Slight Remote Unlikely	Low	None	Slight Remote Unlikely	Low	In-process Team 18
All Users All Tasks	mechanical : fatigue loading and unloading legs causes cyclic fatigue	Serious Frequent Possible	High	Engineering falure testing, monthly inspections for cracks	Serious Occasional Unlikely	Moderate	In-process Team 18
All Users All Tasks	mechanical : break up during operation Pins fail, two leg pieces could break apart	Serious Occasional Unlikely	Moderate	Bi-yearly replacement of pins	Serious Occasional Negligible	Moderate	In-process Team 18
All Users All Tasks	mechanical : impact Moving assembly from storage position to in-use position. User may drop causing impact loading	Serious Occasional Unlikely	Moderate	warning label(s)	Serious Remote Negligible	Low	In-process Team 18
All Users All Tasks	material handling : movement to / from storage When moving assembly to storage position, operator must take out pins.	Slight Remote Negligible	Low	warning label(s)	Serious Remote Negligible	Low	In-process Team 18

designsafe Report

Application:	Group 18	Analyst Name(s):	Steven Ladd
Description:	Sliders and main support	Company:	University of Michigan
Product Identifier:		Facility Location:	
Assessment Type:	Detailed		
Limits:			
Sources:			

Guide sentence: When doing [task], the [user] could be injured by the [hazard] due to the [failure mode].

User / Task	Hazard / Failure Mode	Initial Assessment Severity Exposure Probability	Risk Level	Risk Reduction Methods /Comments	Final Assessment Severity Exposure Probability	Risk Level	Status / Responsible /Reference
All Users All Tasks	mechanical : crushing Slider coush crush material pieces together	Serious Remote Unlikely	Moderate	Monthly maintenance to inspect hardware	Serious Remote Negligible	Low	In-process Team 18
All Users All Tasks	mechanical : cutting / severing Too large of force could sever bolts	Catastrophic Remote Unlikely	Moderate	Monthly maintenance to inspect hardware	Serious Remote Negligible	Low	In-process Team 18
All Users All Tasks	mechanical : pinch point Main support and sliding metal could create pinch point	Serious Remote Possible	Moderate	Monthly maintenance to inspect hardware, warning label(s)	Slight Frequent Negligible	Low	In-process Team 18
All Users All Tasks	mechanical : fatigue Coninual use will fatigue material and hardware	Serious Frequent Possible	High	Monthly maintenance to inspect hardware	Slight Frequent Negligible	Low	In-process Team 18
All Users All Tasks	mechanical : break up during operation If harware fails, assembly could fall apart	Catastrophic Remote Unlikely	Moderate	Monthly maintenance to inspect hardware	Catastrophic Frequent Negligible	Moderate	In-process Team 18
All Users All Tasks	mechanical : magnetic attraction / movement Magnets for loading and in-use potion could attract and move	Slight Frequent Possible	High	Monthly maintenance to inspect hardware, use stronger magnet(s)	Slight Frequent Unlikely	Moderate	In-process Team 18
All Users All Tasks	mechanical : impact Telescoping pieces impact one another in extending and retracting of sliders	Serious Frequent Possible	High	Monthly maintenance to inspect hardware	Slight Frequent Negligible	Low	In-process Team 18

designsafe Report

Application:	Team 18 wall brackets	Analyst Name(s):	Steven Ladd
Description:		Company:	University of Michigan
Product Identifier:		Facility Location:	
Assessment Type:	Detailed		
Limits:			
Sources:			

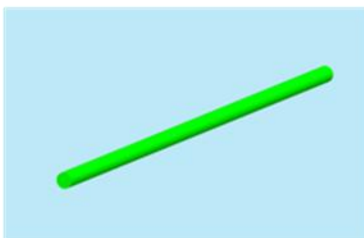
Guide sentence: When doing [task], the [user] could be injured by the [hazard] due to the [failure mode].

User / Task	Hazard / Failure Mode	Initial Assessment Severity Exposure Probability	Risk Level	Risk Reduction Methods /Comments	Final Assessment Severity Exposure Probability	Risk Level	Status / Responsible /Reference
All Users All Tasks	mechanical : cutting / severing Rod can cut through bracket if excess weight is loaded on device	Catastrophic Frequent Possible	High	warning label(s) 300 LBs Max	Catastrophic Remote Negligible	Moderate	In-process Team 18
All Users All Tasks	mechanical : pinch point Pinch point between rod and brackets. Pinching will cause assembly not to fold easily	Slight Occasional Unlikely	Moderate	tighten nuts on rod to ensure that rod rotates correctly	Slight Remote Negligible	Low	In-process Team 18
All Users All Tasks	mechanical : fatigue cyclic loading of brackets and support rod	Catastrophic Frequent Possible	High	Monthly inspections for cracking on metal brackets and rods	Catastrophic Occasional Negligible	Moderate	In-process Team 18
All Users All Tasks	mechanical : break up during operation Screws pull out from wall causing whole assembly to fall	Catastrophic Remote Unlikely	Moderate	monthly inspection for hardware problems	Catastrophic Remote Negligible	Moderate	In-process Team 18
All Users All Tasks	slips / trips / falls : trip Wall brackets extend out from wall 8"	Serious Occasional Unlikely	Moderate	warning label(s), clearly market tripping hazard	Serious Remote Negligible	Low	In-process Team 18

APPENDIX H- ENGINEERING CHANGE NOTICES

ECN: 1

OLD



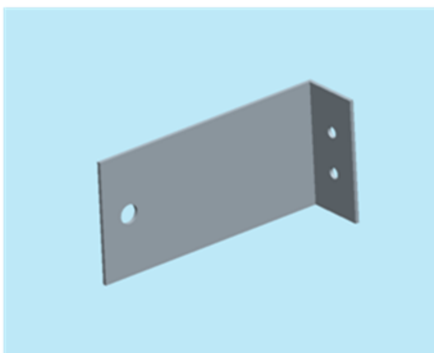
NEW

Note: Changed the material of the pivot rod from aluminum to zinc plated steel to avoid bending.

Team 18	
Project: Showering Assistive Device	
Part Involved	Pivot Rod
Engineer	Nick Hovious
Approved By	Dan Johnson
Date of Change	12/02/08

ECN: 2

OLD



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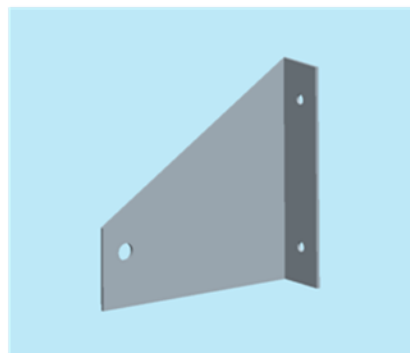
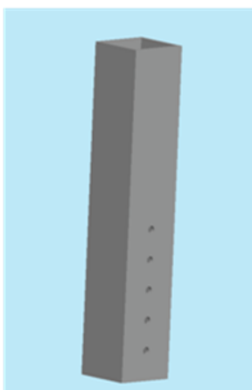


Note: Changed the height of the wall bracket from 4” to 8” to give make sure they wouldn’t tear out of the wall. Also, changed the shape at the request of our sponsor.

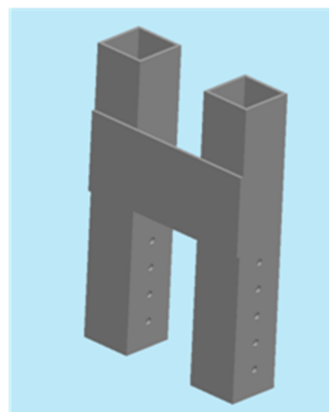
Team 18	
Project: Showering Assistive Device	
Part Involved	Wall Bracket
Engineer	Steve Ladd
Approved By	Naomi Gilbert
Date of Change	11/25/08

ECN: 3

OLD



NEW

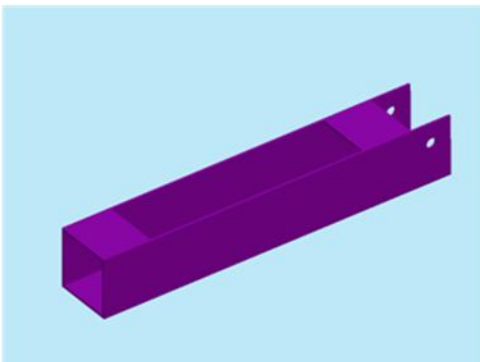


Note: We added a 3" tall bracket to the legs to increase the stability of the legs. this bracket was welded to the legs and helped account for the tolerances of the hinges.

Team 18	
Project: Showering Assistive Device	
Part Involved	Leg Support
Engineer	Kate Bateman
Approved By	Naomi Gilbert
Date of Change	11/26/08

ECN: 4

OLD



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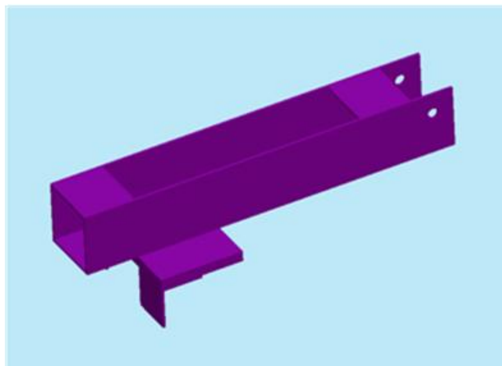
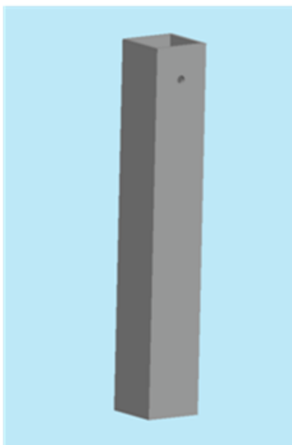


Note: We welded the bottom plate and the leg lock brackets to the channel instead of bolting them to improve manufacturability. Also, the width of the bottom plate changed from 10" to 7" because we were sent the wrong piece, but it still passed failure analysis.

Team 18	
Project: Showering Assistive Device	
Part Involved	Inner Channel
Engineer	Marc Culkin
Approved By	Dan Johnson
Date of Change	11/24/08

ECN: 5

OLD



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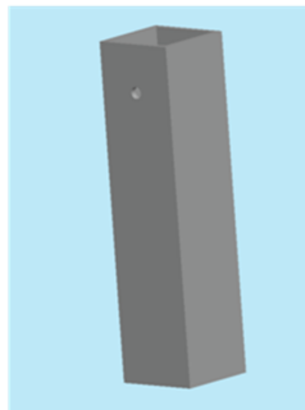
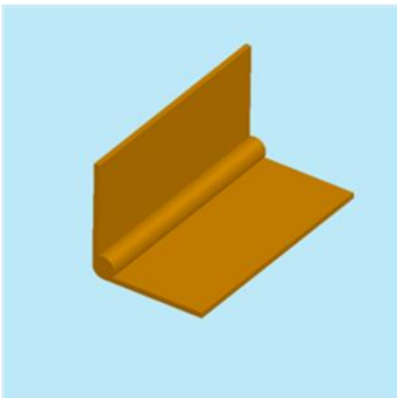


Note: We changed the height of the lower leg from 12" to 7" to better fit the height of the side of the tub.

Team 18	
Project: Showering Assistive Device	
Part Involved	Lower Leg
Engineer	Nick Hovious
Approved By	Dan Johnson
Date of Change	12/01/08

ECN: 6

OLD



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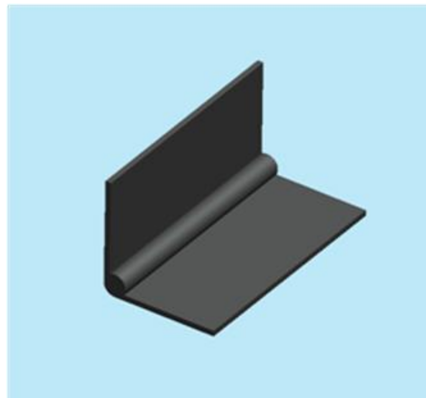


Note: We changed the hinge material from aluminum to zinc plated steel because the aluminum hinges bent when we conducted our validation testing.

Team 18	
Project: Showering Assistive Device	
Part Involved	Leg Hinge
Engineer	Steve Ladd
Approved By	Dan Johnson
Date of Change	11/30/08

APPENDIX I – BILL OF MATERIALS

Quantity	Part Description	Purchased From	Part Number	Price (each)
1	Seat Assembly	Eagle Health Care	37662	$162.00
1	Aluminum Seat Attachment Plate	Discount Steel		$14.98
1	Set of Drawer Slides	Bold Hardware	16" 7500 Series	$60.00
8	Sliding Lock Mechanism	McMaster-Carr	1745a15	$5.33
1	Aluminum Sliding Channel - outer	Discount Steel		$22.34
1	Aluminum Sliding Channel- inner	Discount Steel		$15.66
1	Steel Rod	Ace Hardware		$6.00
4	PTFE Plastic Bushings	McMaster-Carr	2706T24	$3.93
1	Aluminum Bottom Plate	Discount Steel		$23.13
2	Steel Leg Hinges	Home Depot		$8.00
2	Legs - Outer	Discount Steel		$7.21
2	Legs - Outer	Discount Steel		$6.58
2	Leg Adjustment Locking Pin	McMaster-Carr	90293A114	$17.99
2	Leg Locking Pin	McMaster-Carr	93750A320	$22.98
2	Leg Rubber Ends	Ace Hardware		$3.50
1	Grab Bar	Wright & Filippis		$15.00
1	Shampoo Attachment	Ace Hardware		$10.00
1	Bracket to Lock to Wall	Home Depot		$8.59
1	Mock Tub	Home Depot		$80.00
			Total =	$608.57

APPENDIX J –SLIDINGRAILS

FINESLIDE©
7500 SERIES DRAWER SLIDE
SPECIFICATION SHEET

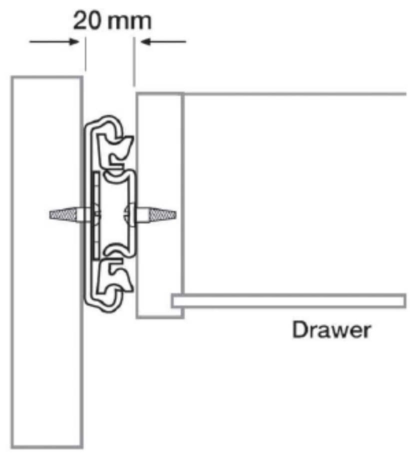
SPECIFICATIONS

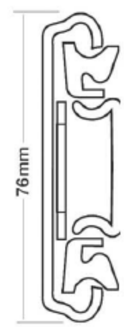
Model: 7500
Sizes: 16”-28”(400mm-700mm)
Load Capacity: 400 lbs(181kg)/pair
Packaging: 2 pair/box

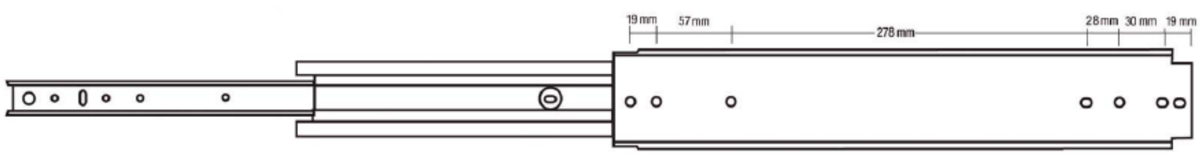
Material: Work hardened cold rolled steel/stainless steel
Finish: Zinc

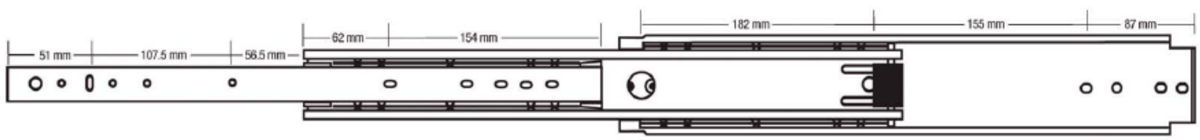
FEATURES

* Super duty construction for truck body, tool chests and metal fabricator applications
* Side mounted
* Chassis allows for welded installations
* High performance precision chassis design
* Non releasable slide members
* No detent or locking mechanism
* Non handed design
* Limited lifetime warranty









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