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ME 450 Design and Manufacturing III

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Shower Curtain for Transfer Benches Final Report

Team 14

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EXECUTIVE SUMMARY

Design Problem

There are many good transfer bench designs on the market. However, none allow the shower curtain to close. Either a new transfer bench that allows the shower curtain to close, or a new shower curtain that closes around existing transfer benches is needed. After much research and conceptual drawings, it was determined that the most feasible option, for both the consumer and manufacturer, was to design a new shower curtain that will keep water from spilling outside the tub.

Customer requirements

There is a need for an affordable, easy to use curtain that allows the user to seal off the transfer bench without assistance from a caregiver. This curtain must effectively contain water within the tub, while having minimal installation steps and easy to use.

Engineering Specifications

The curtain design is based off geometry; therefore most of the engineering specifications are dimensions. Length and height of the overall curtain are both important, but it was the dimensions of where to place slits, flaps or any other device used to seal the curtain around the bench that were the most important specifications. Market research was conducted on both transfer benches and shower tubs to determine the necessary dimensions needed. In addition, sponsor input was considered when dimensioning the final design.

Concepts Considered

The design problem was functionally decomposed to identify what design aspects must be considered. Through brainstorming, sketching, and mind mapping, nine concepts were drawn up for the shower curtain for the various sub-functions of the functional decomposition.

Concept Selection Methodology

There were many aspects to concept selection. We received input from the sponsors on which designs they thought were good, and which aspects they thought would cause difficulties for the user. We then had group discussions on each design, including specific features of each design, and narrowed our selection down to five concepts. We then created a selection matrix based on design criteria and ranked the top five chosen designs to see which scored the highest.

Engineering Challenges

Due to the simplicity of a shower curtain, generating a simple and easy to use, yet effective design, while avoiding patent infringement on the only active patent, has been a unique challenge. Also, designing a device for the geriatric population has been difficult because each user may have unique disabilities that must be accounted for.

Final Design and Prototype

The prototype was modeled directly after the final design selected. We were able to build a working prototype of the final design with no limitations. This design proved effective through the validation process.

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1.0 ABSTRACT

Showering independently and safely is a major concern to our growing elderly population. Currently, there are transfer benches that assist the user into and out of the shower, but do not allow the shower curtain to close. A shower curtain design that prevents water from leaking around these chairs is the most feasible solution to this problem. Therefore, the goal of this project, which is sponsored by Susan Murphy, Naomi Gilbert, and Albert Shih, is to design a shower curtain that will prevent water from leaking out around the transfer benches that are on the market.

2.0 PROBLEM DESCRIPTION

The need for a shower curtain that is specially designed to accompany a geriatric transfer bench is evident. This is proven by examining two factors: the number of these specialty shower curtains that are already on the market and the reduction in the amount of bathroom injuries that could occur if the curtain were used.

Currently, after conducting market research with local medical shops and the internet medical device websites, it was determined that there were not any showers curtains on the market that were designed in conjunction with geriatric transfer benches.

The addition of this new shower curtain has the potential to reduce the number of injuries in the bathroom. This can be done by eliminating issues such as water reaching the ground that could cause the user to slip and fall along with eliminating the need for the user to manipulate the curtain so that it conforms to the geometry of the geriatric transfer bench. According to the research company Aurora, there are nearly 200,000 people that accidently injure themselves in the bathroom every year. Thus, in order to reduce the amount of injuries due to a shower curtain that is not designed for use with a geriatric shower chairs, our design team will engineer a shower curtain exclusively for these special chairs. This report will explain our project.

3.0 INFORMATION SOURCES

To design a shower curtain that can be used with transfer benches, our team researched the need for a shower curtain for transfer benches, the problems faced by current transfer bench users, the existing products and patents of shower curtains for transfer benches, and types of major transfer benches in use. Our information comes from the following sources:

- Sponsor feedback
- Literature review
- Transfer benches' online customer reviews
- Patent search for shower curtain for transfer bench
- Benchmarked designs for shower curtains and transfer benches
- Clinician survey

Our findings showed that current transfer bench users have problems closing regular shower curtains when they shower, leading to a wet floor that poses safety risks. Therefore, the need for a shower curtain which closes when used with a transfer bench is essential.

3.1 Sponsor feedbacks

According to our sponsors, transfer bench users often have issues closing regular shower curtains when transfer benches are in use. The users have to tuck the shower curtains underneath themselves while showering and very often water still spills out from the tub, leading to a wet floor which poses dangers to the users. Our sponsors also added that the transfer benches are usually located far from the shower head to allow for sufficient space for the users to move their legs out of the tub.

3.2 Literature Review

Our team reviewed several articles. The following article best explains the problems faced by transfer bench users and the need for a shower curtain designed for transfer benches.

Activities of Daily Living: Practical Pointers for Parkinson Disease [1]

This booklet by the National Parkinson Foundation explains about aids that will make Parkinson Disease patients' daily life easier and special tips for the Parkinson Disease patients' caregivers. In the booklet, the need for a shower curtain that can close when a transfer bench is used is suggested through the process of cutting slots in a standard shower curtain in an effort to keep the floor dry to prevent slipping. The following excerpts from the booklet explain this.

"The symptoms of PD—tremor, stiffness, slow movement and balance problems—worsen over time, and can make it more difficult to do things like get in and out of a bathtub, stand up from a chair, or walk"

"If you must use a bathtub, a tub transfer bench can help you get in and out of the tub more easily"

"For bathing safety: Cut slots on inside curtain to accommodate the tub transfer bench. This helps to prevent slipping by keeping your floor dryer"

3.3 Transfer Bench Online Customer Reviews

Our team researched the weaknesses of the transfer benches that exist in the market through online product reviews by customers. From the reviews on the transfer bench seller websites, we found that efforts were made to include cuts in the transfer benches' seats to allow the shower curtains to close. However, despite the efforts, the shower curtains were difficult to adjust and could not close fully; water still flowed out of the tub. Below shows some of the transfer benches we reviewed and their respective customer reviews regarding their use with the shower curtain.

Drive Medical Plastic Transfer Bench [2]

- "… water sometimes flows out of tub because the curtain cannot fully close"
- "… difficult to keep the water in the tub… water goes onto the bathroom floor"

Duro-Med Heavy-Duty Sliding Transfer Bench with Cut-Out Seat [3]

- "Shower curtain was difficult to adjust"

Medline Bariatric Plastic Transfer Bench [4]

- "the slot for the shower curtain is not very effective… still get some water in the floor"

Invacare Bathtub Transfer Bench / Bath Chair [5]

- "The awkward part is dealing with the shower curtain situation…bought an extra shower curtain … use it to cover around the shower seat area to prevent leaks"

Moen DN7065 Home Care Tub Transfer Bench White [6]

- "… there is no way to work the shower curtain around it effectively enough to protect the rest of the room from getting soaking wet… frustrating … constantly watching the shower curtain and floor to try and prevent a mess… hard to get anything else done"

3.4 Patent Research for Shower Curtains

Patent research was conducted for shower curtains designed to fit transfer benches. This shower curtain design that we found is unique because it is the only patented design that we found that is designed to function with a flat transfer bench. Figure 1 below illustrates this design. It is important to note that this transfer bench features a slight gap between the main seat and the small platform that is used to allow the user to initially sit down and physically slide over into the tub. This gap allows the shower curtain to drape down around the legs in a bunch. Slots were introduced into the shower curtain material to allow the curtain to drape naturally around the rails. The flap that remains in between the slots prevents splashing water from reaching the outside area of the tub. The slots are reinforced with additional material. Although this may work for benches that have a slit in them, this design does not allow for it to seal well around solid piece transfer benches. Therefore its effectiveness is limited.

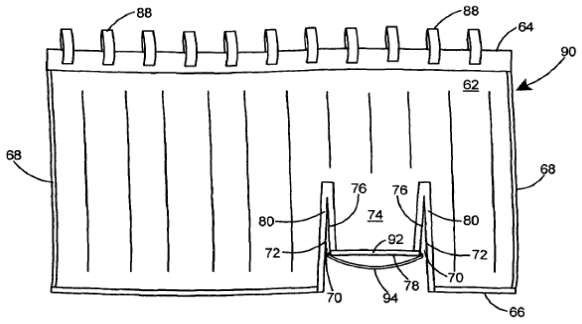


Figure 1: Shower curtain with flap for transfer bench (Patent 7761935) [7]

Patent research was performed for shower chairs prior to the project change and is located in Appendix D.

3.5 Benchmarked Designs

To design a shower curtain for transfer benches, our team benchmarked the only shower curtain that is designed for transfer bench and four major transfer benches which are available in the market.

3.5a Transfer Bench Shower Curtain. Our team performed online searches and benchmarked a shower curtain for a transfer bench. This shower curtain by the Medical Club is the only shower curtain for the use with a transfer bench that we found. It is similar to the one and only one patented design which we found via Google Patent search engine (figure 1). From the benchmarking process, our team is positive that a shower curtain that can accommodate standard transfer benches is necessary, as the current only product is too simple, more innovations can be done, and the market for the shower curtain exists.

This curtain, named the "Transfer Bench Shower Curtain" by the Medical Club, is said to work with all standard tub transfer benches and it comes with a reinforced, weighted flap that slides through the opening in the transfer bench. The curtain can be seen in figure 2 on page 8.

According to its developer, an Occupational Therapist, many of her clients were "reluctant to use a tub transfer bench because water spilled out onto the floor when the bench was used with a standard shower curtain; standard shower curtains are not designed to accommodate a tub transfer bench".

However, we are not able to determine its sale price and its detailed specifications because these were not available on their website. We contacted the company but were not able to get a reply.

3.5b Transfer Benches. Our team benchmarked some existing transfer benches in the market which we would like to design our shower curtain for. Table 1 on page 8 summarizes these benchmarked transfer benches. Specifications for other models of transfer benches can be found at Appendix E.

Figure 2: The Medical Club's Transfer Bench Shower Curtain [7]

Product name	Snap-N-Save Sliding Transfer Bench (with clamp) [8]	Snap-N-Save Sliding Transfer Bench (with extended aluminum frame) [9]	Bariatric Transfer Bench With Back [10]	I-Class Transfer Bench [11]
Company	Eagle Health	Eagle Health	Drive	Invacare
Model no.	37762	37662	12025KD-1	9670
Weight capacity (lbs)	350	400	500	400
Seat dimensions	20.5" x 13.5"	20.5" x 13.5"	26.5" x 16.5"	33.25" x 12"
Seat height	18" – 22.5"	19" – 23.25"	18.25" – 23.25"	18" – 22.5"
Special features	strong suction tipped legs to prevent movement on wet surfaces	strong suction tipped legs to prevent movement on wet surfaces	Suction cup foot pieces secure the bench to the tub	Textured, non-slip seat with drain holes
	the seat and back platform swivels 360˚ and able to slide along 2 rails	the seat swivels 360˚ and slides smoothly over the high strength aluminum frame	Height adjustable	Adjustable legs
		easy to install and no tool is required		back snaps in and out without tools
MSRP ($)	400.40	343.17	194.44	117.64
Product image				

Table 1: Specifications of competitive transfer benches

3.6 Survey Of Residents At Country Living Assisted Living Home

In order to obtain market research data for the shower curtain designed for transfer benches, we visited Country Living assisted home in Hillsdale, MI and interviewed fifteen residents with a survey form we created. The survey can be found in Appendix D. Important information regarding the shower chair was used from the survey. It was found, on average, residents would be willing to spend up to $35.00 on such a curtain. Also, the set up time should not exceed 9.5 seconds. Participants were also asked if they would consider purchasing this product for themselves or a loved one, and 73% said they would purchase a shower curtain designed for a transfer bench.

4.0 PROJECT REQUIREMENTS

4.1 Sponsor Requirements

Our team was originally requested to design a geriatric transfer bench on September 9, 2010. However, as the project progressed, our team determined that designing a new shower curtain which can be used with a transfer bench would be a better solution to address the given problem. In our interview with Professor Susan Murphy on October 8 and with Naomi Gilbert on October 11, we presented our ideas on the shower curtain and the change was approved from designing a new transfer bench to designing a new shower curtain. The sponsor requirements were determined to be the following:

-Prevent water from splashing out of the bathtub from around the transfer bench
-Designed based on geometry
-Require minimum steps to operate
-Can be used without a caregiver
-Can be used with various type of transfer benches other than the Eagle Health's Snap-N-Save sliding transfer bench that satisfied the requirements for transfer benches

From the survey of residents at Country Living assisted living home in Hillsdale, MI. A list of customer requirements were determined for the shower curtain.

-set up time should not exceed 9 seconds
-cost should not exceed $35.00

This shower curtain project is part of the solutions to address the problem given to us at the early stage of the project – designing a transfer bench that will allow the shower curtain to close to avoid the bathroom's floor from gathering water and posing further threats for slipping. Previously, we were given the requirements for the transfer bench. The requirements for our transfer bench, as compared to the requirements given to the previous two teams are as shown in Appendix F. Designing a new shower curtain, along with use of transfer benches like Eagle Health's sliding transfer bench will meet all of these requirements. The sponsor requirements will be prioritized and integrated into the engineering specifications for our designs.

4.2 Engineering Specifications

From the research and market studies for both the regular bathtubs and the transfer benches and the sponsors' requirements and input, we determined a list of seven engineering specifications for the shower curtain for the major models of transfer benches in the market. The specifications were based on the dimensions of bathtubs and transfer benches determined from market research, the dimensions of a regular shower curtain, and the price of a regular shower curtain. Our team aimed to make a shower curtain that will fit regular bathtubs to minimize water splashes. Also, the shower curtain will fit most major models of transfer benches. The engineering specifications and the respective target values for the shower curtain for shower benches are given in Table 2 on page 10.

Engineering Specifications	Target Value
Length of shower curtain (inch)	≥ 75
Height of shower curtain (inch)	72
Location height of slots/holes/flaps to accommodate transfer bench (inch)	25
Width of slots/holes/flaps to accommodate transfer bench (inch)	≥ 24
Width of additional flaps to prevent splashes from end-sides of tub (inch)	> 3
Cost	< \$35
Weight of curtain (lbs)	≤ 3

Table 2: The engineering specifications and target values of the shower curtain

The length and height of a regular shower curtain is approximately 72" x 72". The lengths of regular bathtubs are 60". Therefore, in order to make the shower curtain to better prevent water from splashing out from the side of the tub, we determined that it should have a length of about 75" or more since the normal length might not be sufficient, especially when the transfer bench users might not be able to align the shower curtain as proper as a normal person can do. The height of our shower curtain design follows the height of a regular shower curtain.

We estimated that any slots/holes/flaps to accommodate the transfer benches in our shower curtain should be located about 25" above the bottom of the bathtub. This estimation was based on the maximum height of the Eagle Health's Snap-N-Save Sliding Transfer Bench and other major transfer bench models. The width of the slots/holes/flaps was estimated to be greater than or equals to 24"; this figure is based on the maximum depth of the transfer benches that we studied.

At both sides of the shower curtain, we estimated the width of additional flaps which we plan to add to the shower curtain to be greater than 3". These additional flaps will serve to reduce water splashing out from the end sides of the bathtub.

We estimated that the cost for the final product to be less than twenty five dollars, an affordable and decent price for a shower curtain. Also, the weight of the curtain is targeted to be less than three pounds for easy shipping and handling.

5.0 CONCEPT GENERATION

When we set out to initially generate concepts for the shower chair project, we sketched nine designs. These sketches can be found in Appendix G. To develop the designs for the shower curtain, using the customer requirements, we first developed a functional decomposition diagram that illustrates the overall function of the shower curtain that we envisioned and their corresponding sub-functions. The functional decomposition diagram can be seen on figure 3 (pg. 11).

The overall design needs to be a shower curtain that can fit most transfer benches on the market. To accomplish this, we defined three sub-functions. The sub-functions were horizontal adjustability, vertical adjustability, and sealing around the transfer bench.

Designs were generated to provide horizontal adjustability. Wide bristle areas would allow the bench to move horizontally, while the bristles will seal around the bench. Periodic magnetic strips that would connect a lower and upper half of the curtain could allow the user to place the bench wherever they wanted and then connect the magnets on either side of the bench. Finally, adding extra length to both sides of the shower curtain would allow the user to adjust the location of the bench over a fixed range.

Vertical adjustability was taken into consideration also. One idea was to have two separate pieces, both with Velcro strips, attach at the desired height. One Velcro strip would be six inches wide, giving a range

of adjustability of six inches. An intricate zipper system could also allow the curtain vertical adjustability. Also, a design with a hole large enough for the most transfer benches to fit through could be made.

The design must seal around the transfer bench, keeping the water out. Designs were generated using magnets, bristles and other materials. However, the simplest, yet most effective design was determined to be a "tent" structure with weighted ends.

By combining the best solutions from each sub-function, we came up with a functionally decomposed design. This design incorporated the extra length on both ends of the shower curtain, and had a large hole for the transfer benches to fit through that was covered with a tent-like structure. The tent has weighted ends and a weighted strip to pull the tent down and around the transfer bench. This design is universal; it will fit most transfer benches on the market. Figure 4 (pg. 12) shows the basic 'Tent' design.

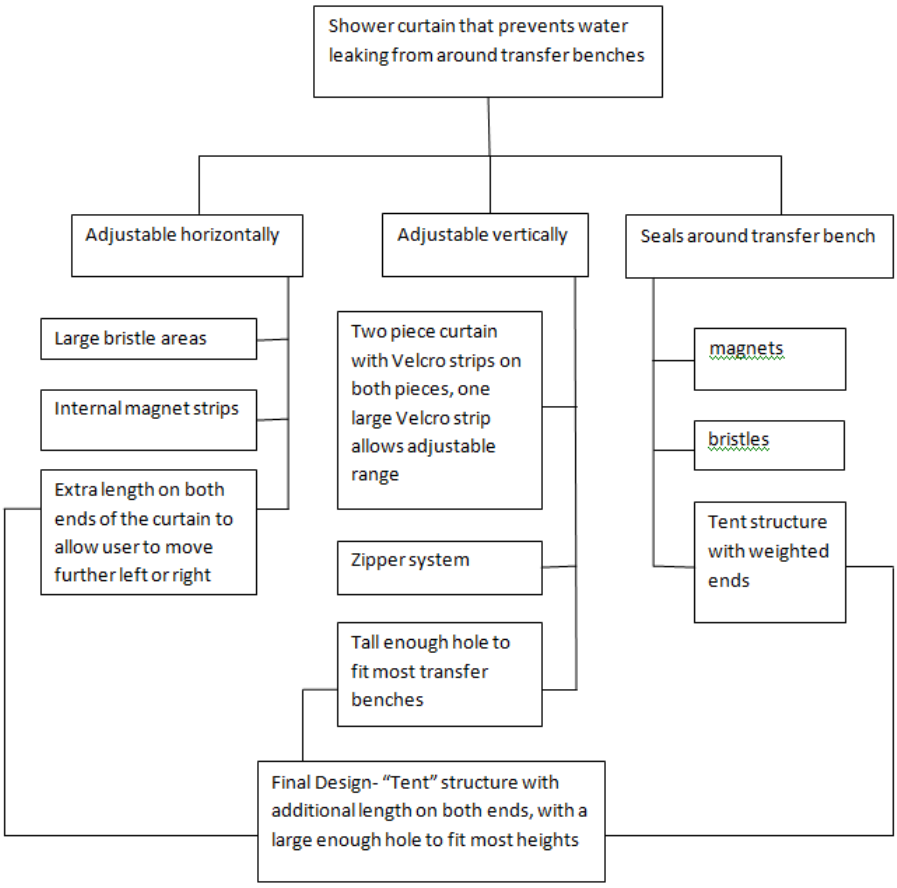


Figure 3: Functional Decomposition for a Shower Curtain

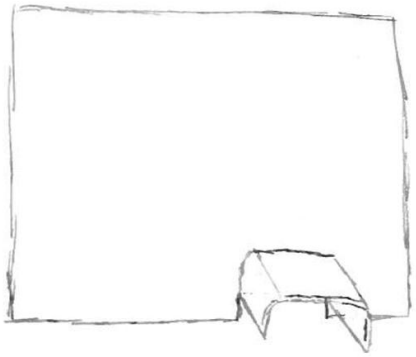


Figure 4: The 'Tent' Concept

6.0 DESIGN SELECTION PROCESS

After concept generation, we needed a strategic method for selecting a design. There were many steps that went in to selecting an "alpha" design. At the start, there were nine unique designs to choose from. In order to narrow our options and give a more in depth look to the more promising designs, we ruled out four of the designs that we determined were not feasible or would not work well. The remaining five went through a rigid selection process to determine which design we would proceed with. All concepts, including the transfer bench concepts, can be seen in Appendix G. From the selection process, the "Tent" design with the highest score was chosen as the selected concept.

To begin, we went to our sponsors for input. We presented them with sketches and received feedback on our concepts. This part of the selection process was particularly helpful for determining the ease of use of the concept. These clinicians have experience working around geriatric patients that we lack. That knowledge helped us determine which designs could be used without a caregiver, and which features may be too difficult for an elderly person to accomplish on their own.

Next we had group discussions. These discussions allowed us to identify areas of strength and potential weaknesses in each design as a whole, as well as individual aspects that could be assimilated into the alpha design. General findings from the sponsor meetings and group discussions are shown in table 3 below.

	"Barn Door"	"Versatile Zip Lock"	"The Jaw"	"Bristle Blockade"	"The Tent"
Disadvantages					
Potential poor seal	X	X	X		
Hard to use	X	X		X	
Difficult to manufacture		X			
Advantages					
Easy to use			X		X
Good seal				X	X
Easy to manufacture	X		X	X	X
Universal design			X		X

Table 3: General Findings from Sponsor and Group Discussions

‘The Barn Door’ (figure L-1, Appendix L) offered a unique way to wrap around the bench. However, closing in from both sides requires the user to reach forward and backward when both entering and exiting the shower. The magnets would assist in closing the curtain by itself when the two sheets were close to each other. The slits in the curtain that let the transfer bench through the curtain do not have a good way to seal, especially where the two sheets come together. Finally, this design is not adjustable to different heights of transfer benches, and only fits the Eagle Health style transfer benches.

The ‘Versatile Zipper Lock’ (figure L-2, Appendix L) offered the greatest adjustability of any of our designs. However, in order to achieve this flexibility, there would be folds of curtain that would be necessary to cover a wide range of widths. The excess curtain would probably let water through as it wouldn’t be sealed to the rest of the curtain. Also, there are too many steps involved. The user would have to zip up to eight of these zippers in order to fully seal off the transfer bench. The zippers were designed with semispherical magnets that, when the two zippers meet, form a protective seal around the aluminum shafts that run through the curtain. This idea of sealing off the shafts could still be incorporated if it is determined necessary. Finally, this concept only fits the Eagle Health style transfer benches and would prove difficult to manufacture in comparison with the other designs.

The appeal of ‘The Jaw’ (figure L-3, Appendix L) was its simplicity and versatility. This design required a minimal amount of steps to set up, one zipper and the curtain is sealed. It also would fit most transfer benches on the market. The drawbacks are obvious, the zipper would not perfectly seal off any transfer bench, and therefore this design would likely be ineffective compared to our other designs. Also, the geriatric user would have to reach behind one’s self, lift the bottom curtain in place and zip it shut. If the user needs a transfer bench, it is unlikely they will have this much mobility and a caregiver would be required.

The ‘Bristle Blockade’ (figure L-4, Appendix L) did provide a range of adjustability, as the aluminum shafts could fit anywhere inside the bristle area. The magnetic flaps on the bottom raised concern over whether a user would be able to close the door independently, and this style once again only fits the Eagle Health style chair. Finally, we were reluctant to choose this design because it was difficult to predict how well this bristle system would work without actual testing.

‘The Tent’ (figure L-5, Appendix L) had many advantages. First, it was a universal design, which was lacking from many of our concepts. Also, its simple design falls into place as the curtain is pulled over the chair. It falls out of the way when a transfer bench is not in use to allow other users full mobility inside the tub. This design would offer only a small amount of adjustability for the placement of the chair, although it will accommodate most sizes of chairs. Finally, by using only geometry, not intricate designs to block the water, it would be easier to manufacture than most of the concepts.

Finally, we used a selection matrix to quantitatively measure the designs against each other. The selection matrix graded each curtain on five categories that were based on design criteria. The first category was ease of use; how easily a geriatric patient can use this, with minimal or no effort from a caregiver. The second category was durability. We ranked each design based on how well we thought it would hold up over time. Designs with intricate parts, of multiple moving pieces are more likely to break down than simpler designs. The third category was assembly and disassembly. The fewer steps during set up and take down the better a score it would have received. The fourth step was manufacturability. We considered how easy or cost efficient it would be to manufacture each design. And finally, we looked at the environmental impact of producing each product. Each category was ranked 1-5 with one being poor and 5 being the best. A perfect score would be 25. The score sheet for the ‘tent’ is seen in figure 5 (pg. 14); it scored a 21/25 which was the highest score of any of the concept. The selection matrix for “The Tent” is shown in figure 6 below, the selection matrixes for the other four designs can be found in Appendix I. After going through the rigorous selection process, all indications suggested we should

proceed with 'the tent' as our alpha design. We also incorporated extendable flaps on each end of the shower curtain in order to retain water missed at the edges by a normal shower curtain.

Selection Matrix	1	2	3	4	5
Ease of use				X	
Durability				x	
Assembly/disassembly					x
Manufacturability				x	
Environmental impact				x	

Figure 5: Selection Matrix for the 'Tent' Concept Design

7.0 SELECTED CONCEPT – THE ALPHA DESIGN

From the selection process, it was determined to move forward with "The Tent" design. This design conforms to the transfer bench using geometry. A rectangular opening is cut at the bottom of the shower curtain to allow the transfer bench through to the outside of the tub. Then around this opening, a flap (the "tent") is attached to the shower curtain. At the outermost end of the flap, a continuous and flexible weight is inserted. This weight forces the tent to fall down around the transfer bench, effectively sealing it off. Setting up consists of pulling the shower curtain over the bench until the bench meets the hole cut in the curtain. At that point, the extendable flap should fall into place, requiring no caregiver. This design follows our functional decomposition model as it only requires pulling the curtain over the bench to seal it. Figure 6 below illustrates our concept and its CAD drawing.

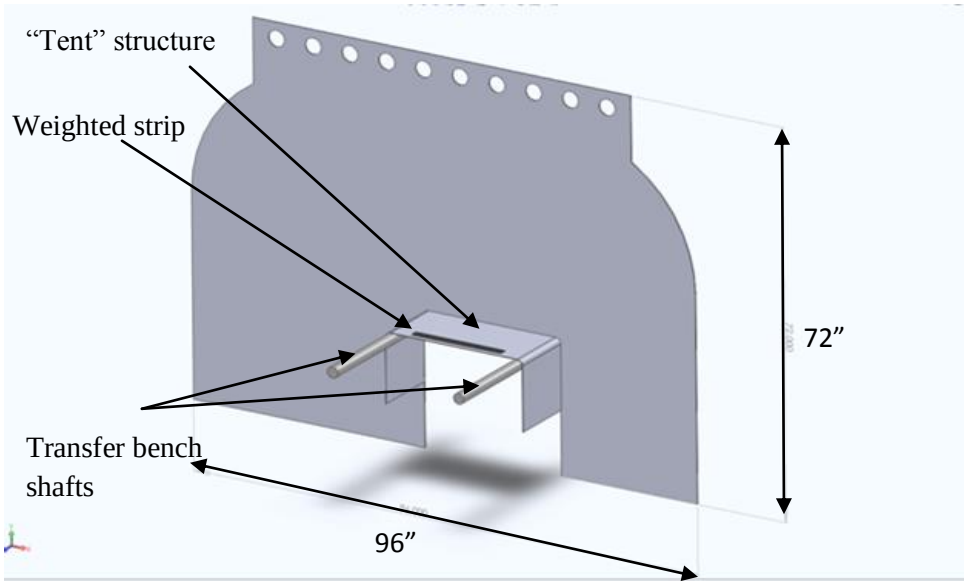


Figure 6: CAD drawing for the Alpha Design 'The Tent'

Dimensions of the "tent" are crucial to the effectiveness of the design. The best possible dimensions for the flap would minimize the length it extends into the tub, but still cover the inside of the tub wall when it is not being used with the transfer bench. It was important to minimize the length it extends into the tub to avoid contact with the user as much as possible. It must still cover the edge of the tub wall or water can spill out. To determine the best possible dimensions we conducted market research on 12 current transfer

benches and six shower tubs. The dimensions that were important were the maximum height and width found for the transfer bench, and the shortest outside tub wall height for the tub. The largest height and depth found for the transfer benches were 23.25" and 22" respectively. The smallest height for the tub wall was found to be 12.625" tall. From this we determined the size of the rectangle cut out of shower curtain should be 25" tall and 26" wide. The flap would then be attached across the top of the cut out and extend down the sides 12".

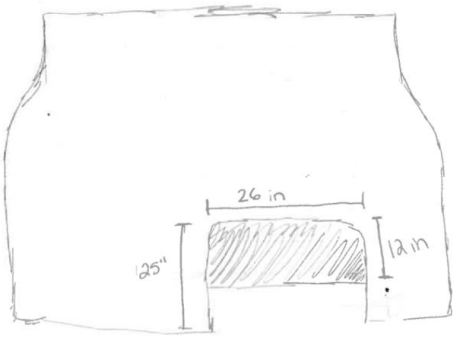


Figure 7: Dimensions of the Tent

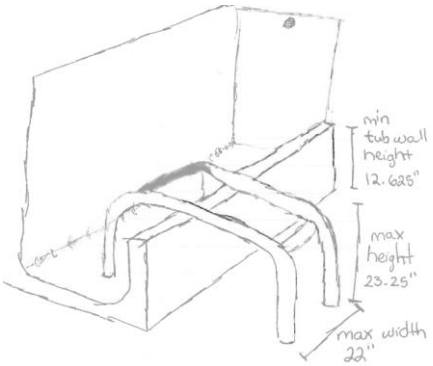


Figure 8:Dimensions of Transfer Benches and Tub Used

8.0 PARAMETER ANALYSIS

Our shower curtain design is based on dimensions and geometries. In our shower curtain design, the specific parameters include:

- the dimensions and geometries of the shower curtain: base curtain, tent structure, and flap
- the type of material of the shower curtain and weighted strips
- the weights of the shower curtain and the weighted strips

For the shower curtain design, our team determined the dimensions and geometries of the shower curtain based on the dimensions of the transfer benches and the tubs. The base curtain has a dimension of 107" W x 72" H. The tent structure has a height of 12", width of 23" and length of 5"; it is located horizontally 50% of the base curtain's width, and attached vertically at 20" above the bottom of shower curtain. The flap is attached 6" above the tent structure. An overview of these structures can be seen in figures11 and 12 on pages 20 and 21.We determined ethylene vinyl acetate (EVA) will be used as the material for the shower curtain while a mixture of copper and plastic BB pellets will be used as materials for the weighted pouches.. A series of failure analysis were conducted with several assumptions made. The expected total weight of the shower curtain was 2.7 pounds. Our team used a safety factor of 3 for the failure analysis calculations. With the safety factor of 3 (Appendix P), the allowed tensile force that a user can apply to the shower curtain was estimated to be 2.7 lbs/in. Table 4 on page 16 summarized the dimensions, structure locations, and weights of the shower curtain before and after the analysis processes and the final prototype. The engineering logics of the steps we used to arrive to the parameters were discussed.

8.1 Dimensions and Geometries

Our team used the dimensions of a regular shower curtain (72" x 72") for reference in designing our shower curtain for a transfer bench. Then, improvements and innovations were made to account for the needs of transfer benches users. The changes made were explained as follows.

	Engineering Specifications	Before analysis	After analysis	Final prototype
Dimensions (in)	Base curtain width	≥ 75	96	107
	Base curtain height	72	72	72
	Tent structure width	≥ 24	26	23
	Tent structure length	12	5	5.75
	Tent structure height	12	12	12
	Flap width	32	32	30
	Flap height	29	29	26
Structures locations	Tent structure horizontal location (% of width of base curtain away from shower head)	50	50	50
	Tent structure vertical location from bottom of base curtain (in)	25	25	20
	Flap horizontal location (% of width of base curtain away from shower head)	50	50	50
	Flap vertical location from bottom of base curtain (in)	29	29	26
Weights (lb)	Base curtain	-	1.32	-
	Tent structure	-	1.30	-
	Flap	-	0.14	-
	Entire shower curtain	≤ 3	2.76	2.95

Table 4: Changes of specific parameters of the shower curtain for transfer benches

8.1a Base Curtain. We estimated the horizontal location where a transfer bench is used in the tub through our sponsors' feedbacks and decided that the tent structure should be located back about 60% of the shower curtain's width, away from the shower head. To allow for horizontal adjustability of the tent structure, account for the uncertainties in the horizontal location of the transfer benches, and to account for the various entry location into the bathtub (right and left sides), our team decided to use a longer shower curtain and fix the tent and flaps at 50% of the shower curtain's width for adjustability. In addition, the extra materials will also decrease the possibility of the water spilling out through the slits between the wall and the base curtain. The height of base curtain is fixed at 72", which is the standard height of shower curtains. Our initial plan was to add 12" of extra materials at each side of the base curtain's width so that the toal width will be 96"; however, the extra wide shower curtain we managed to get in the market is 107" wide. Therefore, our shower curtain will have the dimensions of 107" x 72".

8.1b Tent Structure. The tent structure was designed to fit most of the major transfer benches. Most of the major transfer benches have adjustable legs, thus the height of the tent can be fixed. We determined the optimum height for the tent structure to be 25", which is almost 2" taller than the maximum height of the transfer benches' seats we researched. We determined the tent structure should have a width of 26". The reason for this is that maximum depth of transfer benches we researched was 22"; the additional 2" of materials on each side was to allow extra room for adjustability. We also determined that the tent should have a width of 5", which is approximately the available space between the transfer bench users and the shower curtain. However, experiments in the shower suggested a better dimension for the shower curtain's tent structure is 23" wide, 12" tall, and 5.75" long.

There are three weighted pouches with different lengths at the end of the tent – 1 x 33", and 2 x 5" (shown in figure 12 on page 21). The weighted pouches are thin PEVA pouches filled with plastic and copper pellets and will be sealed in the shower curtain. We estimated the 33" pouch to have above 1 lb of weight, an adequate weight so that the end of the tent can conform to the shape of the transfer bench's seat to prevent water spills. In an event the transfer bench with less depth or more depth, the tent can be squeezed or expanded using the 33" weighted strip. Meanwhile, the additional 2" weighted strips are used to pull the tent down around the transfer bench.

8.1c Cover Flap. The flap served to cover the tent structure to prevent water spill while transfer bench is not in use. The tent will have a length of 30" and a height of 26" and will be attached 6" above the tent structure.

8.2 Material Selection

Our team used a combination of two approaches to determine the material for the shower curtain – CES EduPack Version 6.2.0 and market studies. From the analyses, our team determined that ethylene vinyl acetate (EVA) will be the material used to produce the shower curtain, while copper pellets will be used as the main component of the weighted pouches.

From the market studies, our team determined several possible materials which can be used to make shower curtains. A figure of yield strength (ksi) versus density was made and several engineering limitations were set to narrow down the materials in CES. Table 5 below shows the engineering limitation values we used, while Figure 9 shows a snapshot of the plot and the materials that satisfied the engineering limitations.

Material properties	Values / Comments
Minimum service temperature	120 ℉
Electrical conductor	Poor
Insulator	Good
Transparency	Translucent / Transparent
Price	≤ 1 USD/lb

Table 5: The Engineering Limitations Used To Narrow Down the Materials for Shower Curtain

According to figure9 below, the possible materials include ethylene vinyl acetate (EVA), natural rubber (NR), polyethylene (PE), polypropylene (PP), and polyvinylchloride (PVC).

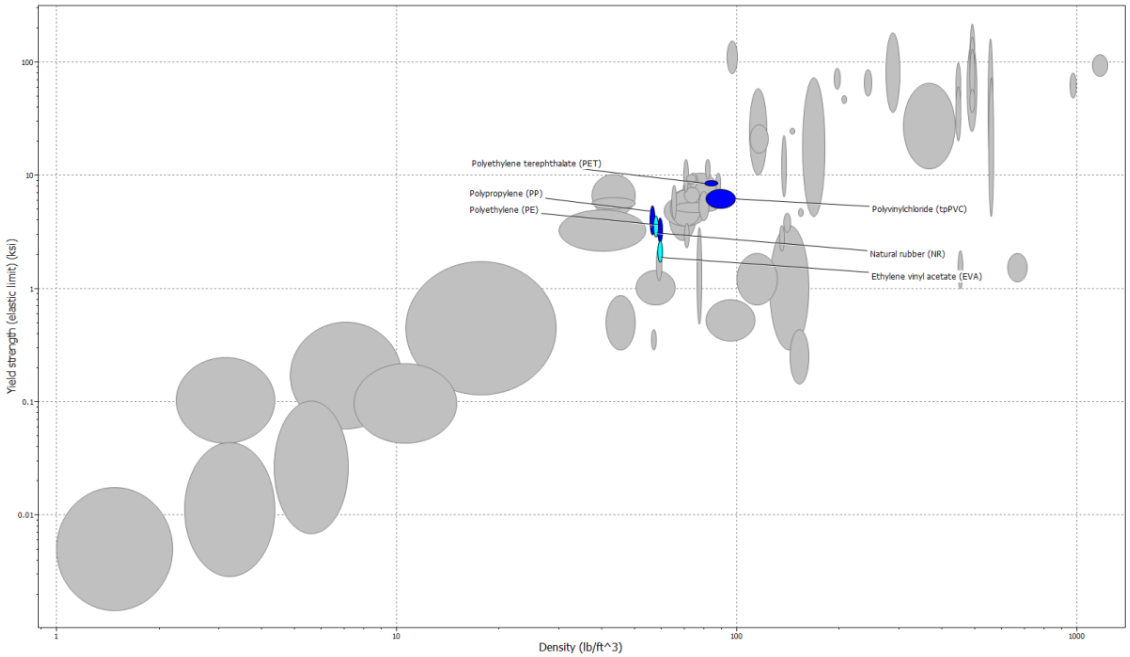


Figure 9: Ethylene vinyl acetate (EVA) has low density according CES

From market studies, our team determined the materials of existing shower curtains include vinyl, ethylene vinyl acetate (EVA), nylon, polyester, cotton, and silk. So the only materials to match both the CES and market research were EVA and vinyl.

We compared the results and determined EVA to be used due to the following reasons:

- commonly used material for shower curtain
- greener than PVC, a type of vinyl
- has low percentage of water absorption
- sufficient yield strength
- low density, light
- cheap and affordable
- translucent

Our team also performed analysis on the materials used for the weighted pouch using CES. Using the limits (minimum density 440 lbs/ft^3, maximum price 2.5USD/lb), our team determined that lead alloys and copper alloys are some possible materials used to for the weighted pouch. A graph of density versus price for the CES is as shown in figure 10.

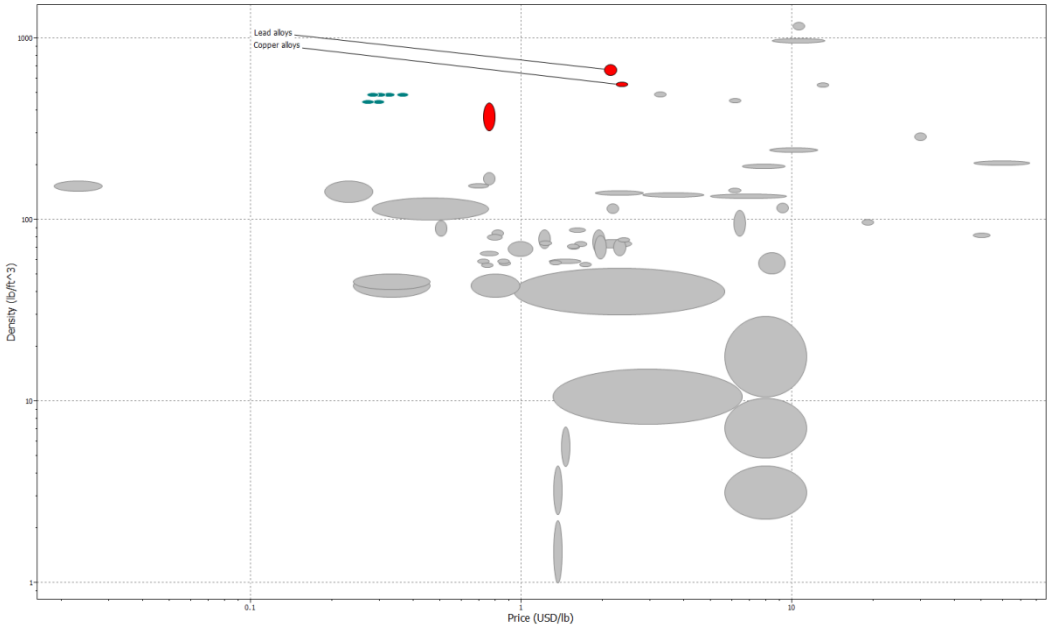


Figure 10: Density versus price for weighted pouch materials using CES with limits of minimum density 440 lbs/ft^3 and maximum price of 2.5USD/lb

Our team chose copper as the weighted pouch material due to its availability in the market and being safer compared to lead alloy, as lead can cause lead-poisoning and anemia.

8.3 Failure Analysis

Failure analyses were performed for the shower curtain, using ethylene vinyl acetate (EVA) as the material for shower curtain, the plastic and copper pellets as the material for the weighted pouches. The safety factor our team used for failure analysis is fixed at 3. The values used for the failure analysis came from experimental data. Our team determined the failure force for EVA and PEVA by using 1.5" wide of strips of the materials with heat seals on them and stretch them with fish scale until failure. We also weighted the plastic and copper pellets using a digital weight scale. The failure analyses were performed

on these locations – the attachment location between tent structure and base curtain, the attachment location between the flap and the base curtain, and at the ring holes on the shower curtain. Our analyses show that the shower curtain can support per unit width of external forces of up to 2.7 lbs/in at our fixed safety factor of 3. Details of dimensions, material properties, and calculations for the failure analysis are included in Appendix K.

To perform the analyses, our team made the following assumptions based on experiments:

- the heat seals are considered as ideal as the deformation for the EVA and PEVA strips occurred far from the seals
- water absorption is minimal for the shower curtain material and is negligible; water from shower head (external force) will have more impact on the shower curtain
- external forces include the inertia from water flow and pulling force from the user

The forces which were analyzed on the structures are explained as followed.

- Tent structure : Weight of EVA sheet, weighted pouches (rubber and copper pellets)
- Cover Flap : Weight of EVA sheet
- Base curtain : Weight of EVA sheet, tent structure, and flap

8.4 Design For Environmental Sustainability

Our team performed analysis for environmental sustainability using SimaPro Version 7.2.4 on the major materials used in our design. The materials analyzed were 1.5 lbs of EVA and 1.02 lbs of copper. Tthe analysis was performed using EI 99 point values.

Copper was found to be the larger source of environmentally hazardous emissions in comparison toEVA. However, neither contributed greatly when the findings were normalized against emissions from an average person per year. The findings on environmentally sustainability can be found in Appendix C.

8.5 Design for Safety

The actions taken during the course of this project were fairly simple and safe for the most part. However, we were able to identify certain risks. First, the heat roller used did not have shield over the roller. This meant that there was a heightened risk of burning ourselves while using the heat roller. To offset this danger, we wore heat resistant gloves while handling the heat roller. Also, we made use of razors and scissors to make some of our cuts. When handling these sharp objects, we made sure that we were on a good cutting surface with no one else within arm's length. Finally, during the yield stress testing, it was possible for flying objects to be launched when the plastic strips failed. To remain safe while performing these experiments, safety glasses were worn at all times.

9.0 FINAL DESIGN DESCRIPTION

The functionality of our final design can be divided into three main categories: the "tent" structure, flap, and extended width of the base shower curtain. Each feature is specifically designed to meet our sponsor and customer requirements while providing a safe showering environment for potential users in their own private bathrooms or showering areas inside of a health care facility. A C.A.D. depiction of the final design of the Shower Curtain for Transfer Bench can be seen in Figure 11 (pg. 20).

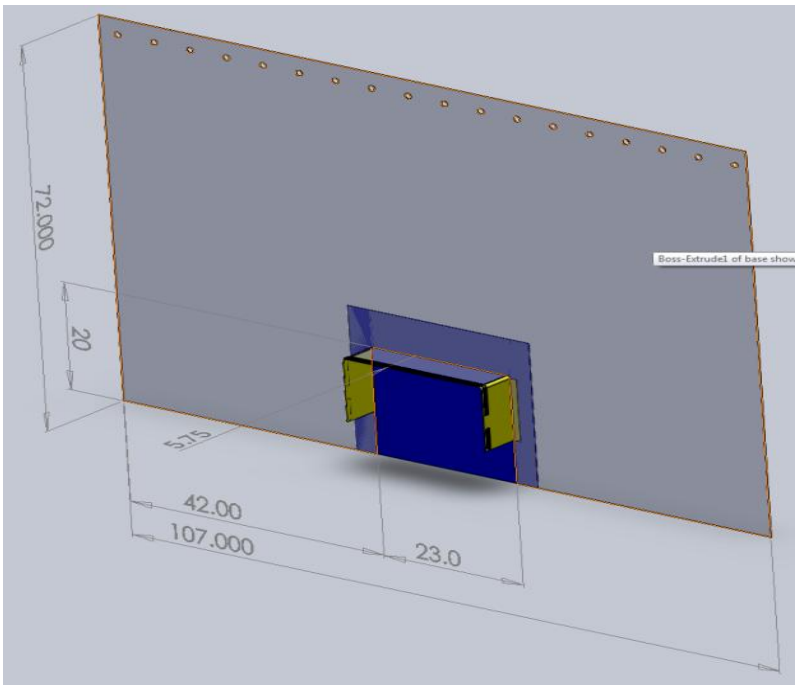


Figure 11: A final depiction of the Shower Curtain for Transfer Bench is depicted in the above figure

Due to the basic design and manufacturing of our design, we were able to produce a prototype very similar to our final design.The following explains our final design (and prototype) in details.

9.1 Extra Wide Base Shower Curtain

The Shower Curtain for Transfer Bench was designed to be wider than traditional shower curtains. Normally, shower curtains are available in dimensions that are approximately 72"W by 72"H. The shower curtain we designed is much wider, with an overall width of 107". This extra length allows the user to alter their showering position in the bath tub either closer or away from the shower head and allows it to be used in bathtubs with left and/or right side entry while keeping the water from the shower from spilling out.

9.2 "The Tent"

The tent structure of the shower curtain, seen in Figure 12 on page 21, is the central component of the shower curtain for transfer bench. It prohibits water from flowing onto the outside of the tub. Before this device was manufactured, users routinely sat on their shower curtains while they showered. This is a dangerous maneuver because water spills onto the floor subsequently creating a slip-and-fall hazard. Additionally, a user could accidentally force the shower rod to fall down onto themselves. Our "tent" design on the shower curtain will solve these problems. The tent structure features three weighted pouches. The, 33" long pouch (pouch A), is designed to block water from leaking from the seating surface by conforming to the geometry of the transfer bench. The two other weighted pouches (pouches B and C) weigh down the tent on both ends to help pouch A provide a better seal. To properly use the tent structure that extends 5.75" past the plane of the shower curtain, the user has to pull the curtain into its closed position while at the same time lifting and positioning the tent structure over the transfer bench so that pouch A lays parallel and flat on top of the transfer benches seating surface.

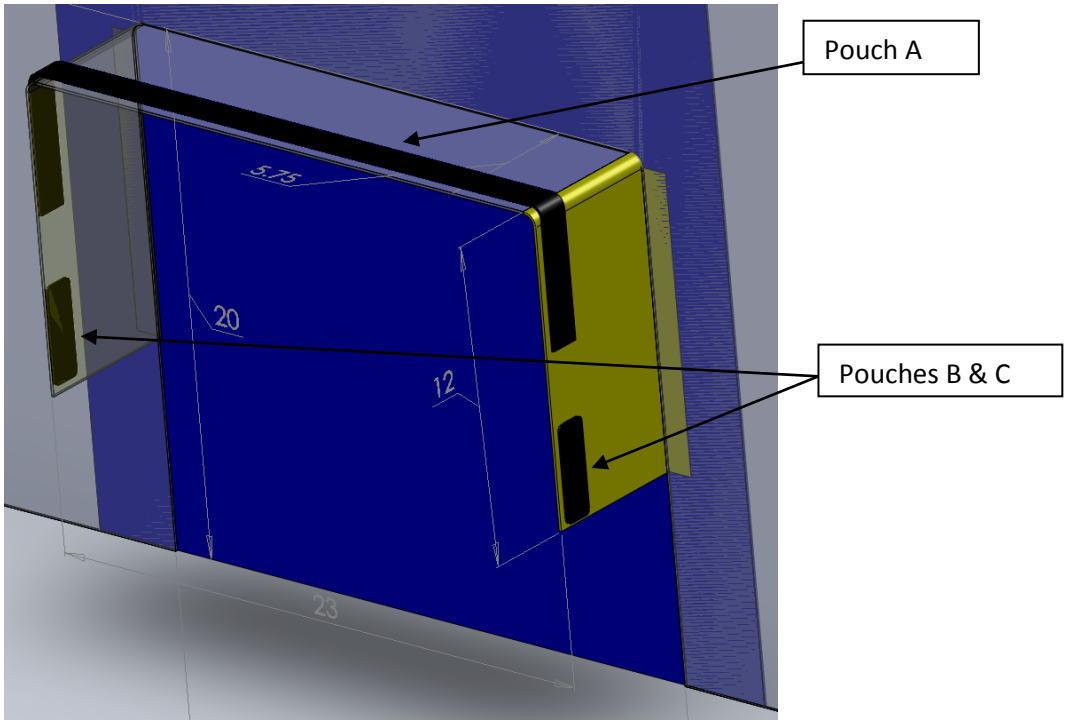


Figure 12: The Tent structure along with the three weighted strips are shown in their assembled positions.

9.3 Flap

The flap, which is located on the back of the shower curtain, gives the shower curtain versatility. It is shown below in figure 13. If a transfer bench is not needed for shower, the flap prevents water from exiting the tub area because it blocks the hole that allows the transfer bench to slide through. This is a great feature because it ensures that the shower curtain will not have to be changed so that able bodied adults or children can use the curtain in the bathing area. This alleviates the issue of worrying about the elderly routinely installing and un-installing their shower curtain that is designed for a transfer bench.

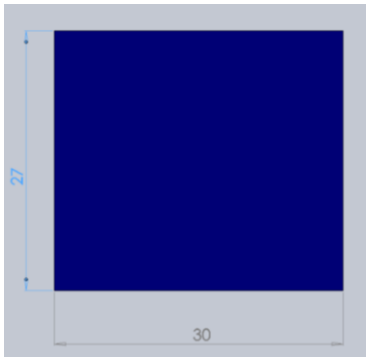


Figure 13: The flap which blocks the opening for the transfer bench to slide through is shown above. It is sealed to the base shower curtain six inches above the top of the tent.

After manufacturing the final design with 100% EVA, we expected that the final design would perform well. This was confirmed after we preformed a simulated shower test in a real bath tub. We pointed the shower head onto the tent structure which is where we felt any leakage would arise from. After running

the shower for 15 minutes straight, there was no leakage found on the outer edge of the tub or the bathroom floor.

9.4 Parts List for Fabrication

Table 6 below lists the components that were for necessary for successful completion of the shower curtain for transfer bench. A discussion of these components can be found in Appendix A on page 34.

Item	Quantity	Source	Catalog Number	Unit Cost	Contact	Notes
Impulse Heat Sealer	1	Ebay	120647941785	$51.98	Ebay.com	-
EVA Shower Curtain	2	Amazon.com	15362	$15.43	Amazon.com	108”x72”
Shower Curtain (PEVA)	1	Target	064080693	$5.99	Target	72”x72”
BB Pellets	1	Meijer	70882024078	$11.99	Meijer	Plastic
BB Pellets	1	Meijer	2847812445	$7.89	Meijer	Copper
Fish Scale	1	Dunham’s Sports	008266553	$14.99	Dunham’s Sports	50lb Limit
9 Volt Battery	1	North Campus Bookstore	03980001361	$7.40	North Campus Bookstore	1 Battery

Table 6: The materials used to fabricate the final design of shower curtain for transfer bench

10.0 FABRICATION PLAN

In order to fabricate a shower curtain liner, well devised plans of action as well as purchased parts are necessary. The detailed steps for the fabrication plan are explained below. This fabrication plan will be utilized by our design team to produce a full-size working prototype. We will submit a safety report to our Professors and Graduate Student Instructors for their review.

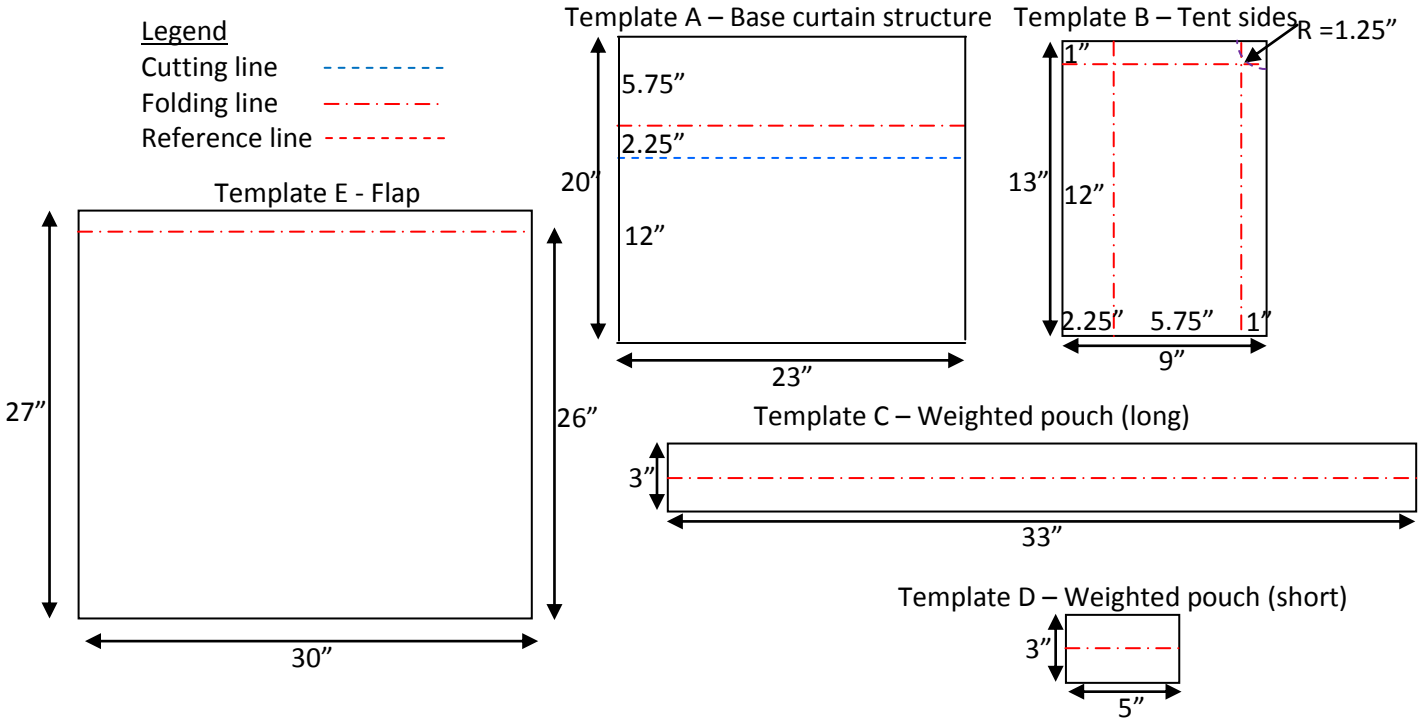
To fabricate the shower curtain for transfer bench, the tools and materials below are used.

Tools : Jores TechnologiesLinear heat sealer (Model MMS-400, 16” seal length, 0.12” seal width)
Thin rubber mat
Razor
Ruler (1m)
Ink pens (blue and red; which ink can be removed from the curtain material easily)
50lb/25kg Rapala Digital Scale and plastic cup

Materials : 1 extra-wide EVA shower curtain of 0.005” thickness (107” W x 72” H)
1 EVA sheet of 0.005” thickness (72” x 72”)
1 PEVA sheet of 0.008” thickness (6” x 33”)
2 cardboards (30” x 35”)
A bottle of 6500 plastic BB pellets (D= .236”)
A bottle of 6000 copper BB pellets (D= .177”)

Step 1. Preparing the templates (Template A – Base curtain; Template B to E –additional parts)

To fabricate the shower curtain, lines were drawn on the EVA shower curtains as guides for attachment, folding and cutting. To accelerate the drawing process, templates A through D are drawn on the first piece of cardboard with the following dimensions and lines (reference, cut, and fold). Then the process is repeated for template E using the second piece of cardboard. After all the lines are drawn, cut the templates out of the cardboard as shown below.



Step 2. Cutting parts from templates

Template A is used on the shower curtain while templates B and E are used on the EVA sheet. Templates B and E are used on the PEVA sheet. Prior to drawing lines on the EVA and PEVA sheets, make sure the templates are arranged such that two part B’s, two part C’s, one part D, and one part E can be made from the materials.

Template A

Locate template A below the shower curtain (107” W x 72” H) and transfer the lines onto the transparent curtain as shown below. Cut the hole (12” x 23”) out of the base curtain and make the remaining cuts along the cuttingg lines (blue stripes) using a razor. The base curtain is now ready.

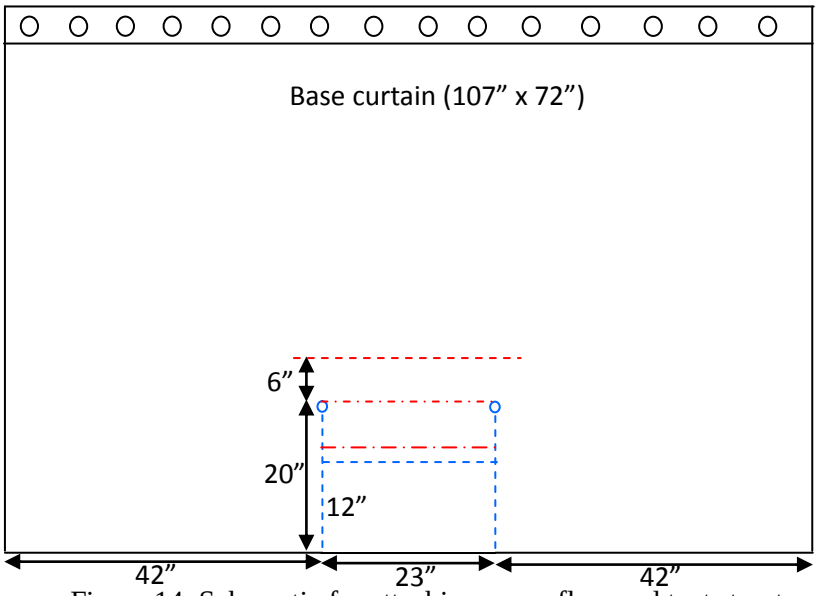


Figure 14: Schematic for attaching cover flap, and tent structure

Template B for two tent sides

Cut 2 pieces of part B (from the 72” x 72” EVA sheet) using a razor to build the sides of the tent structure

Template C for long weighted strip

Cut part C (from the 6” x 33” PEVA sheet) using a razor that makes the long weighted strip pouch on the top of the tent structure

Template D for two short weighted strips

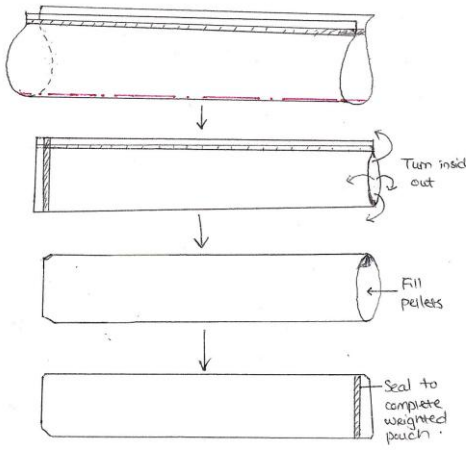
Cut 2 pieces of part D (from the 6” x 33” PEVA sheet) using a razor for the small weighted strip pouches on the lower corners of the tent structure

Template E for flap

Cut part E (from the 72” x 72” EVA sheet) using a razor that will be used as a cover flap when the transfer bench is not being used

Step 3. Making the weighted pouches

The linear heat sealer is used to seal the PEVA sheets for part B and part C together. The heat sealer’s knob is set to “4”, with an approximate temperature of 170 F to perform the sealing operation. Important operational heat temperatures for the impulse sealer can be found in figure 17 on page 26



(i) Fold parts C and D (2 pieces) along the folding lines and seal along 2 of the 3 edges to form pouches
(ii) Turn the inside of part C and the two part D's outside so that the outside of the pouches are now inside
(iii) Using the plastic cup and fish scale, weigh the BB pellets needed to fill the weighted pouches as below.
(iv) Fill the D pouches with copper pellets to a weight of 0.1 lbs and seal the pouches
(v) Fill pouch C with a 50/50 (by volume) mixture of plastic and copper pellets and seal the pouch

Step 4. Assembling the parts

The linear heat sealer is used to seal the parts together. For parts longer than 16", a rubber strip (approximately 1" x 3") cut from the rubber mat has to be used to cover the heating part of the heat sealer so that the extra material on the shower curtain can be rolled together (as less as possible) to allow heat seals to be formed on the intended location. The rubber strip can be adjusted when making the seals as long as the minimum non-sealing length of approximately 1.5" is taken into account when sealing. Figure 15 below explains how this is performed using the heat sealer.

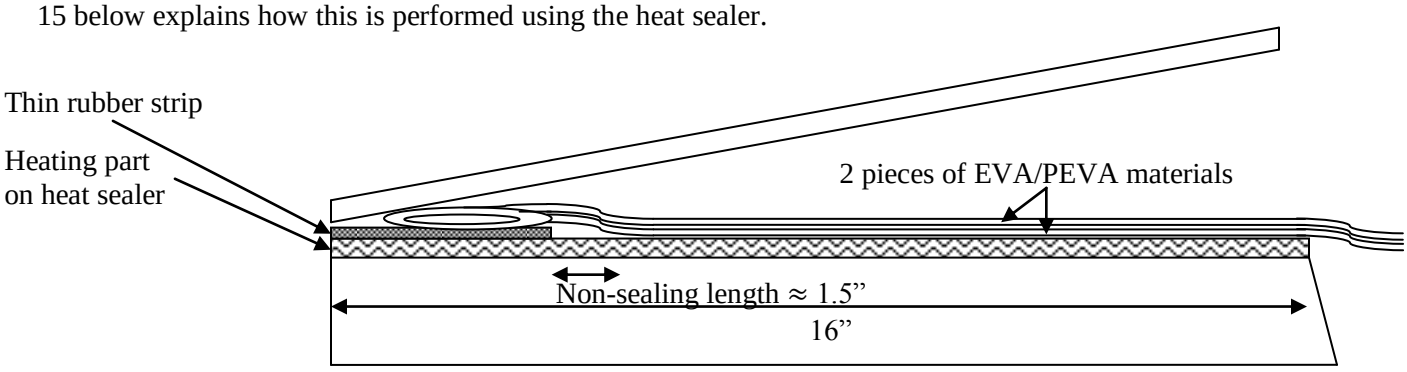


Figure 15: Using the heat sealer to seal 2 pieces of EVA or PEVA sheets with lengths of greater than 16"

An exploded view of the parts for the shower curtain in C.A.D are shown on figure 16 on page 26 below. Figure 19 (Pg. 23) shows the locations where the seals (shaded area) are performed. The following explains the sealing process.

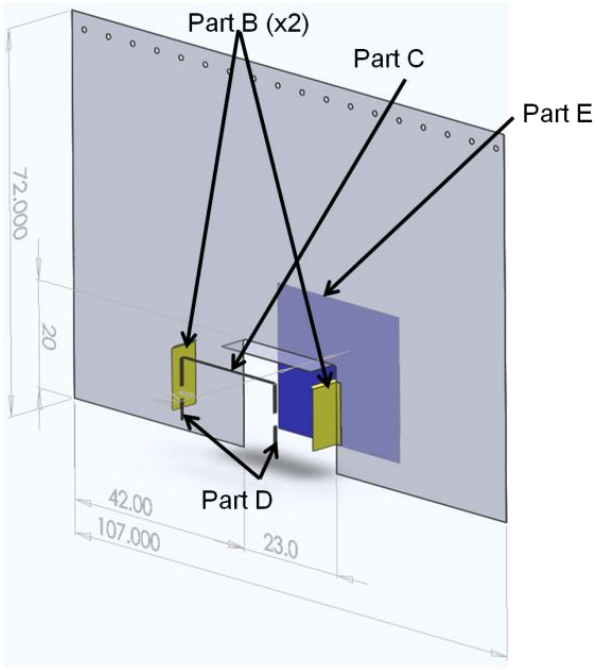


Figure 16: Exploded view of the shower curtain for transfer bench

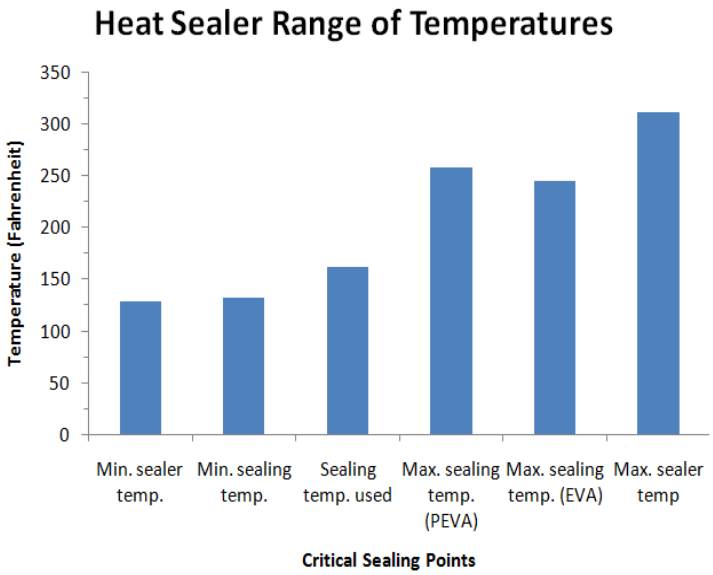


Figure 17:Important heat sealer temperatures

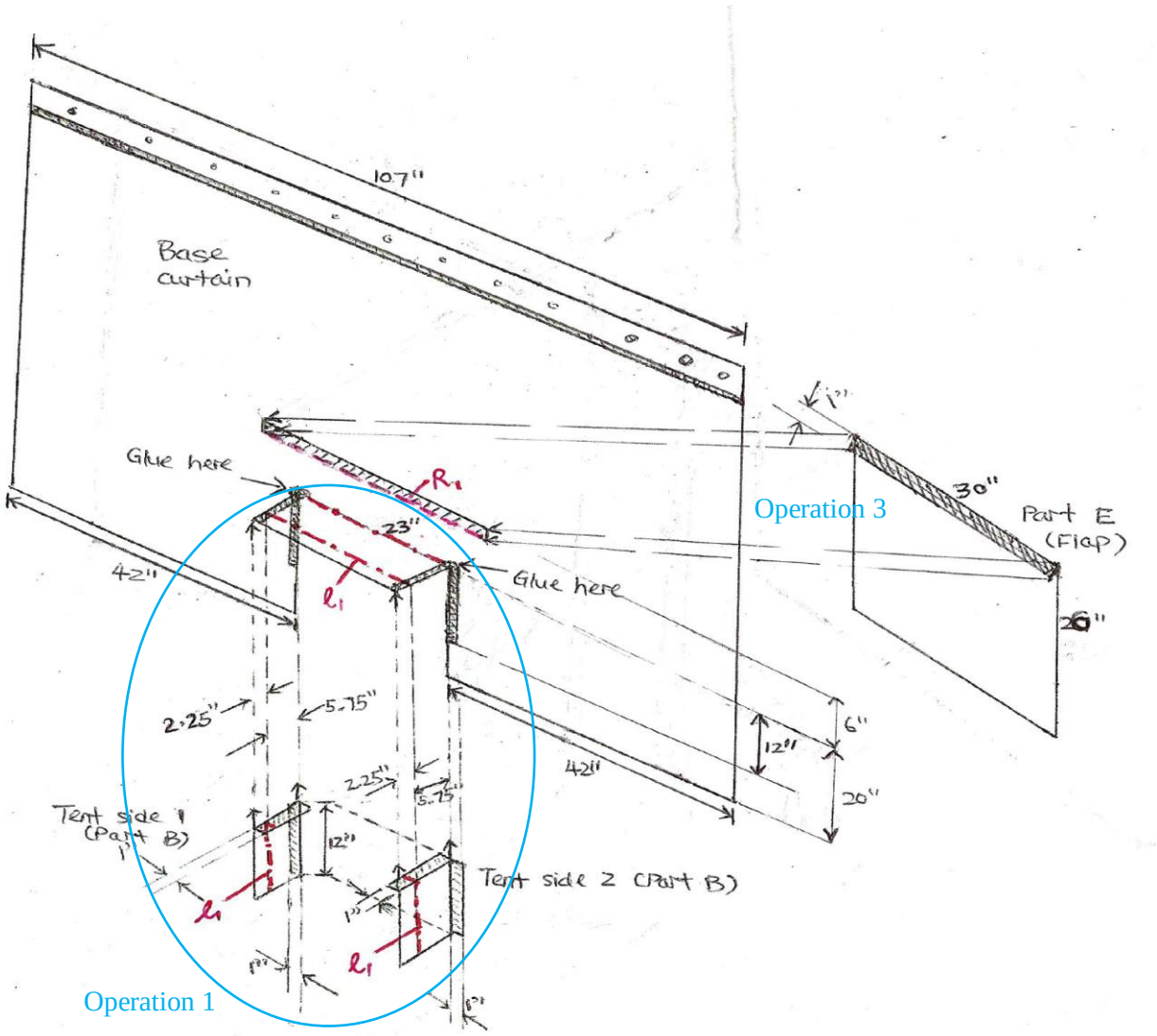


Figure 18: Assembly of parts for shower curtain; shaded areas show the seal locations

(i) Seal parts B onto the base curtain with a linear heat sealer as shown in Operation 1, Figure 18 above.

(ii) Fold part B and the top of the tent structure along the folding lines (l_1) and seal along the edges; this creates sleeve for the weighted pouchesn as indicated by operation 2 (Figure 19) on page 28.

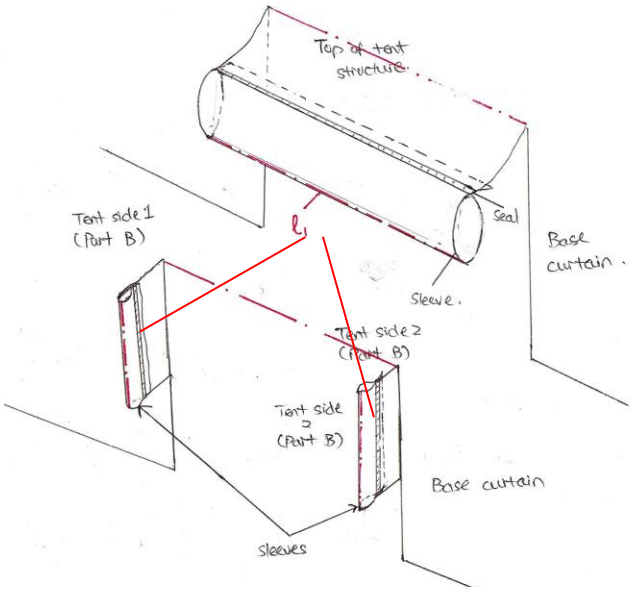


Figure 19: Operation 2 – Sealing the end of the tent structure to make sleeves for the weighted pouches

(iii) Place the weighted pouches into the sleeves and seal the edges of sleeves to fix the pouches in place (figure 19 above)

(iv) Seal part E to the back of base curtain along the reference line as indicated by operation 3 (Figure 18, Pg. 27)

(v) Glue the top corners (Figure 18, , Pg. 27) to complete the seal and let it dry for 20 minutes

The shower curtain for transfer bench is ready to be used. A C.A.D drawing for the completed shower curtain is shown in Figure 20 below.

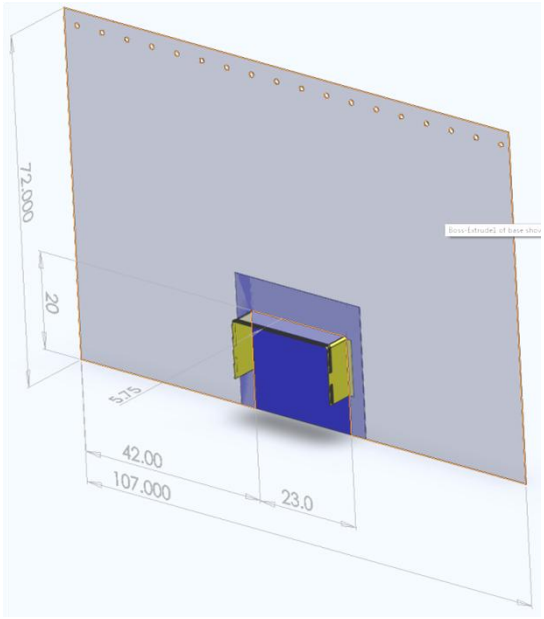


Figure 20: The completed shower curtain for transfer bench

Our team considered that the fabrication plan, if the shower curtain for transfer bench is being mass-produced and a new heat sealer is being used, the manufacturing time and process will be much easier. The heat sealer will feature a similar design to the linear heat sealer, except the hinge will be located at a different location to allow for more space for extra shower curtain materials so that the materials will not be sealed accidentally. A concept design for the heat sealer is shown in figure 21 below. When mass produced, the EVA curtain would be produced using compression molding. The metal and plastic pellets would be manufactured using die pressing and sintering.

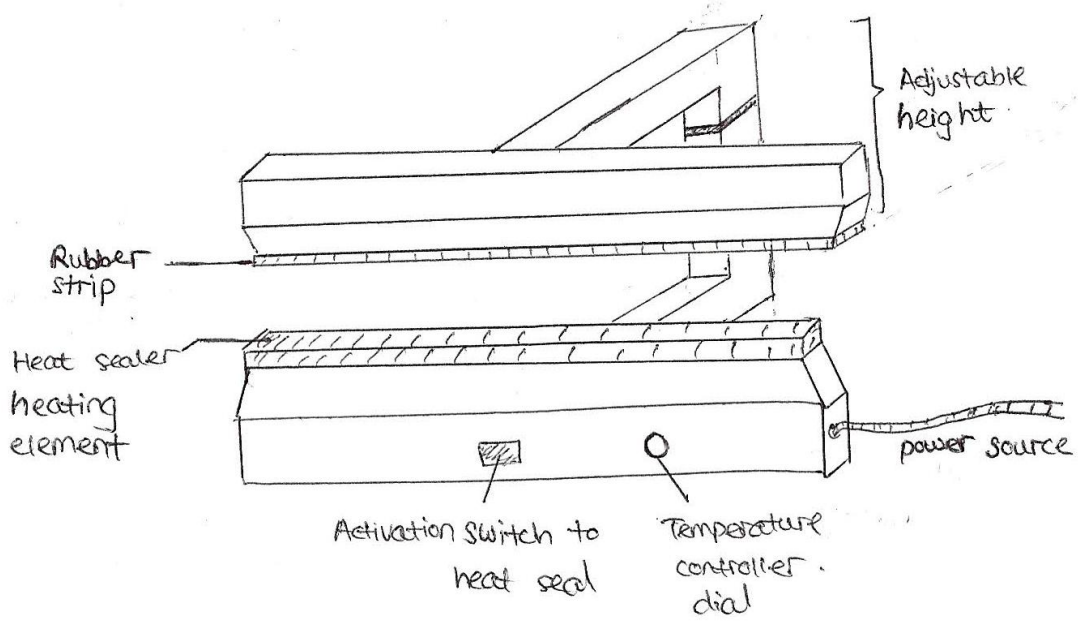


Figure 21: Conceptual design of heat sealer for mass-production of shower curtain for transfer bench

11.0 VALIDATION RESULTS

The most important part of the validation plan was to test that the shower curtain did indeed contain the water from escaping outside the shower tub. To test this, a transfer bench was obtained from our sponsor Naomi Gilbert and placed in a working shower. The prototype was hung from the shower rod and then placed over the transfer bench. To create a "worst case scenario", the shower head was pointed directly at the tent structure where it would be most likely to leak. Also, the legs were adjusted so that the bench sat on angle (making the water run towards the tent structure). The water was allowed to run for 15 minutes and then we checked for any leaks. There were no leaks whatsoever, the bench was completely dry on the outside of the weighted strip, and the floor was completely dry.

Other customer requirements were validated also. The curtain size of the hole will fit most transfer benches on the market. From market research, all transfer benches found will fit the hole size of the prototype. Also, the setup time needed to be less than 9 seconds. This figure was found from a survey conducted of residents at Country Living assisted living home in Hillsdale, MI. By having unaffiliated people sit on the transfer bench and time how long it took them to set up the curtain. From testing, it was found that the average set up time was around 8 seconds. And finally from the same survey it was determined that the price needed to be under $35.00. The prototype can be built for $26.63, the breakdown of this cost can be found in appendix A.

The material selected was also validated to ensure it had the material properties we had chosen. To do this, uniform pieces of EVA were cut and sealed together. Then one end was placed in a vice, the other end was clamped between two pieces of wood with a "C" clamp. A digital fish scale was hooked to the "C" clamp. Then the sheets of EVA were put in tension until failure, and the force (in lbs) was recorded to calculate the yield strength of the materials. It is important to note that the weight of the wood and "C" clamp were obtained and taken out of the recorded weight. The calculated yield strength was 1760 psi, the reference value that was given in CES was 1740 psi, so the material that we have is indeed what we wanted. In addition, the density was calculated by weighing a section of the curtain and calculating its volume.

12.0 DISCUSSION

Overall, we feel that the final design that we constructed is a great depiction of what our sponsors envisioned. During our manufacturing and designing of our first prototype, we used a device called a heat roller. This device allowed us to make seals that were respectable but not up to par with our high standards. We used this heat sealer for a span of three weeks to experiment with different materials and sealing techniques. To our dismay, we could not obtain a consistent seal, so we looked for another heat sealer. This is when we located the impulse heat sealer which makes professional looking seals. Since we did not purchase the impulse heat sealer at the beginning of the manufacturing process, we lost valuable time. This time could have translated to a final design that featured a more elegant looking shower curtain. A final design of this nature would feature designs and patterns that would aesthetically appeal to the end user. Additionally, the impulse heat sealer that we purchased was 16"long. There are currently impulse heat sealers on the market that are as long as 24". This extra sealing surface would aggressively diminish the time that it would take to produce one finished product which could have given us additional time that could be allocated to other tasks.

The final design of the shower curtain for transfer bench is designed to fit common transfer bench designs on the market. This specific transfer bench is essentially a large seating surface that the user can sit down on from the outside of the tub, swing their legs into the tub, and physically slide over into their showering position. Other designs allow the user to slide on rails into their final resting position from the outside of the tub. We believe that testing should be done on these styles that are seen in the two figures on page 8 before we can recommend this shower curtain for those benches. This is because the water could slide down the railings onto the floor outside of the tub. Another aspect of our design that can be improved upon is the material that was used to fill the pouches. Initially, we used sand to fill the pouches. But after further consultation from our sponsors and section instructor, it was determined that sand was not a suitable material. Soon after, we decided that copper and plastic ball bearing ammunition pellets were the elements of choice. We selected this combination of the pellets because of their lightweight and the flexibility that it offered so that the pouch can easily conform to the geometry of the transfer bench. These pellets worked well, but we feel that another, more cost effective solution could be found.

13.0 RECOMMENDATIONS

Upon completion of this project, we feel the further areas could be improved upon. The design manufacturing plan could be more time efficient. As it is, using a 16" linear heat impulse sealer, much time is required to make the seals that are longer than 16". This is because it is very difficult to line up the curtain so that the new sealed part will be in a straight line with the previously sealed part. If the heat sealer were 36" long, then no seal would require multiple seal attempts to complete. This would reduce the effort and time required to construct the design, consequently reducing labor costs and increasing profits. In addition, for mass-production of the shower curtain, our team would suggest a re-design of the heat sealer to allow more space for the shower curtain's extra material so that itwon't be sealed accidentally. The design should also feature adjustable height so that the rubber strip can lay flat on the

heating element of the heat sealer to produce consistent heat seals. The conceptual design can be seen on figure 21on page 29.

In addition, the long weighted strip could be made thinner. If additional tests were run to see how thin the strip could be made and still be effective, the number of pellets used could be reduced. This could also help reduce the overall production costs. Cheaper materials that are just as effective can probably be found to fill the weighted strips.

Finally, the curtain could be made with a design or colors in order to make it more aesthetically appealing.

14.0 SUMMARY AND CONCLUSIONS

After conducting market research on transfer benches and shower tubs, we determined the necessary dimensions needed for the shower curtain. Using a functional decomposition model, we generated designs based on the specific needs of the product. An alpha design was selected after receiving input from the sponsors as well as creating a selection matrix. The final design consists of a "tent" structure with a weighted end attached to an oversized base curtain (107" wide by 72" tall) to provide horizontal adjustability.

Once a final design was selected, more market research was conducted to determine the most commonly used shower curtain materials. CES was then used to determine which common shower curtain material would be used based on highest yield strength and lowest density. EVA was selected as the main material for the shower curtain. However, after testing, PEVA was found to be a more suitable material for the weighted strips. Failure analysis was also performed to see how strong of a pulling force the curtain could withstand, and how durable the tent structure would be when in use. From these tests, we were able to check the reference values for yield strength found in CES to make sure we had the material we had chosen, and found they agreed.

The prototype developed matched the final design. It was run through a series of validation tests, including set up time, cost and most importantly effectiveness. The curtain will can be built for $26.63 and can be set up in less than 8 seconds, both meeting specific customer requirements. The shower curtain was tested in a shower tub under a "worst case scenario" and successfully kept the water from leaking out onto the floor. The curtain passed all parts of the validation process.

After a long process, a solution for transfer benches not allowing shower curtains to close has been found. Designing a new shower curtain was chosen over designing a new transfer bench because it was the more cost effective solution and also has a larger market potential. This new shower curtain will make bathing easier, safer and increase privacy for the elderly and handicapped.

15.0 ACKNOWLEDGEMENTS

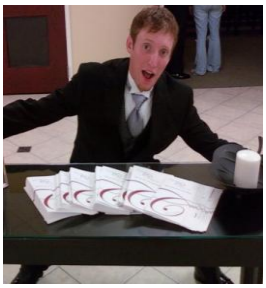
This design would never been successful without the help of several key people. First, Professor Shih's manufacturing knowledge was crucial to the direction of the project. His honest assessment of the cost of our transfer bench designs redirected the course of this project and led us to design a shower curtain instead. His engineering expertise was drawn upon on a consistent basis throughout the project and the critiques created a final design more polished and easier to use than would have otherwise been created.

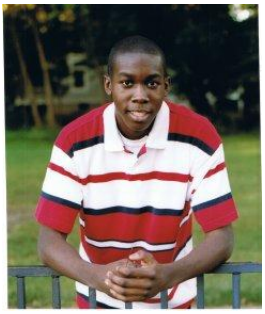
Our sponsors, Susan Murphy and Naomi Gilbert, also made invaluable contributions to this project. First, their open minds allowed us to solve the problem in a completely different way than we set out to. Their knowledge of the problems that would face this curtain and experience provided much needed guidance for the project. Without their help we would not have ended up with a product as practical for use as this.

BIOS

Yung Leong Lee is currently a senior in Mechanical Engineering at the University of Michigan and will be graduating with a B.S.E in April 2011 with an Energy Concentration. Yung Leong is a transfer student from Malaysia. He participated in the Summer Undergraduate Research program organized by the University of Michigan from May to August 2010 and was working on a project on fuel decomposition to improve fuel efficiency. He is currently the webmaster of the Pi Tau Sigma, a mechanical engineering honor society. He enjoys traveling and exploring different cultures around the world.

Brandon Nichols is a senior in Mechanical Engineering at the University of Michigan and will be graduating in April 2011 with a bachelor's degree. Brandon was born and raised in Hillsdale, Michigan. He enjoys playing a variety of intramural sports, and is also the student manager of the Blue Apple. He is also a member of the National Society for Leadership and Success and the Delta Chi fraternity.





Adam Singletery is a senior in Mechanical Engineering and will be graduating in December 2010 with a bachelor's degree. He resides in Pittsfield Township Michigan. Adam is a transfer student from Washtenaw Community College where he earned an Associate's degree in Math and Science in 2007. Adam has worked as a Quality Intern at TG Fluid Systems during the summer of 2010. After graduation, he desires to work and as an Automotive Powertrain engineer where developing new automotive systems for vehicles is essential. He enjoys listening to music and playing basketball as well as football. Adam is a member of the National Society of Black Engineers.

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APPENDIX

APPENDIX A: Bill of Materials

Item	Quantity	Source	Catalog Number	Unit Cost	Contact	Notes
Impulse Heat Sealer	1	Ebay	120647941785	$51.98	Ebay.com	-
EVA Shower Curtain	2	Amazon.com	15362	$15.43	Amazon.com	108”x72”
Shower Curtain (PEVA)	1	Target	064080693	$5.99	Target	72”x72”
BB Pellets	1	Meijer	70882024078	$11.99	Meijer	Plastic
BB Pellets	1	Meijer	2847812445	$7.89	Meijer	Copper
Fish Scale	1	Dunham’s Sports	008266553	$14.99	Dunham’s Sports	50lb Limit
9 Volt Battery	1	North Campus Bookstore	03980001361	$7.40	North Campus Bookstore	1 Battery

Table A-1: Bill of Materials

Impulse Heat Sealer

The linear impulse heat sealer is a very important tool in our manufacturing process because it is the device that uses heat to mend two materials together. The heat sealer works by sending short instances of electricity through metal wire that is hidden by the Teflon sheet. Next, the newly converted electricity energy changes to heat energy which alters the materials in question. In our case, the materials are thin (.005”) pieces of Ethylene vinyl acetate (EVA) and polyethylene vinyl acetate (PEVA). The easy to use heat sealer (Model MMS-400) features a sealing length of 16”, a 3mm sealing width, no warm-up time, adjustment knob to control the sealing time, and a spare parts kit. The impulse heat sealer created professional quality seals without showing signs of diminishing quality throughout our manufacturing process.

EVA Shower Curtain

The base shower curtain of our final design was built with this material: 100% EVA. The length of the shower curtain is especially important because it much longer than a traditional shower curtain which is 72”. This shower curtain is 108” wide and a conventional 72” tall.

PEVA Shower Curtain

This material was used to construct the weighted pouches that contained BB pellets. The use of this material instead of 100% EVA is a better solution so that the pellets will not be as visible to the human eye in comparison to the 100% EVA. After we conducted the failure analysis on the weighted pouches that were comprised of both materials, we found that the PEVA performed much better.

BB (Ball Bearing) Pellets

Initially, our design team chose to use sand to fill the pouches but after further review and consultation, we decided to change the filler material to BB pellets: a mixture of copper and plastic pellets was used. The diameters of the copper and plastic are .177" and .236" respectively.

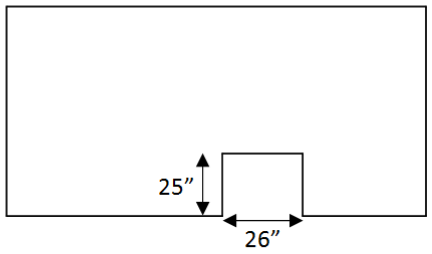
Fish Scale & 9 Volt

We purchased a fish scale to perform our failure analysis. The scale was used to obtain the failure force that was required to break the seal from the two materials EVA and PEVA. The fish scale has the ability to measuring a maximum load of 50 pounds. We were well under this load because our force values were less than 10 pounds. The fish scale required a 9V battery for operation.

APPENDIX B: Description of Engineering Changes

Engineering Change Notice

WAS:



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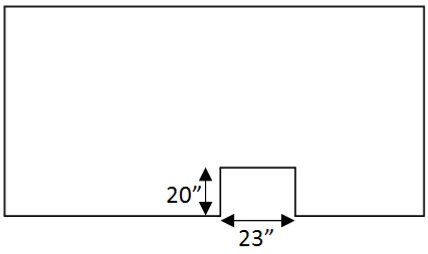

Notes:
Dimensions for the hole cut out of the base curtain Changed from 25” tall by 26” wide to 20” tall by 23” wide.

ME 450 Team 14	
Shower Curtain for Transfer Bench	
Ref. Drawing: Hole in base curtain	
Engineer: Team 14	11/28
Proj. Manager: A. Shih	11/30
Mgmt./Sponsor: S. Murphy	11/30

Engineering Change Notice

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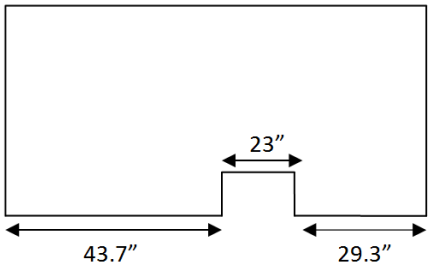

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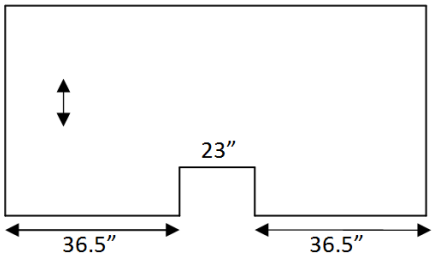

Notes:
Placement of the hole on the base shower curtain is changed from 60% to the from the left (or right depending on location of shower head) to the center.

ME 450 Team 14	
Shower Curtain for Transfer Bench	
Ref. Drawing: Placement of hole in base curtain	
Engineer: Team 14	11/28
Proj. Manager: A. Shih	11/30
Mgmt./Sponsor: S. Murphy	11/30

Engineering Change Notice

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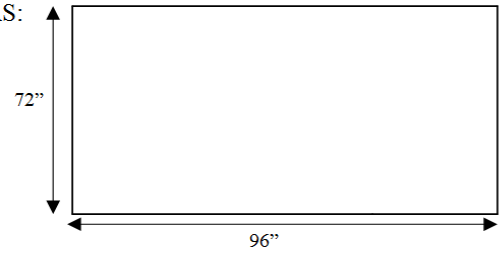

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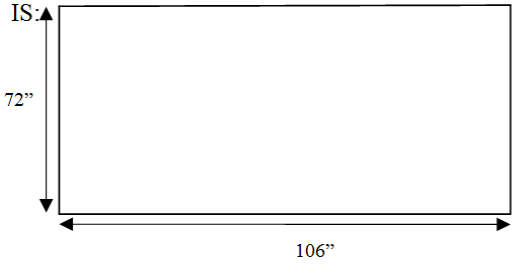

Notes:
Dimensions for the hole cut out of the base curtain Changed from 25” tall by 26” wide to 20” tall by 23” wide.

ME 450 Team 14	
Shower Curtain for Transfer Bench	
Ref. Drawing: Base curtain	
Engineer: Team 14	11/28
Proj. Manager: A. Shih	11/30
Mgmt./Sponsor: S. Murphy	11/30

Engineering Change Notice

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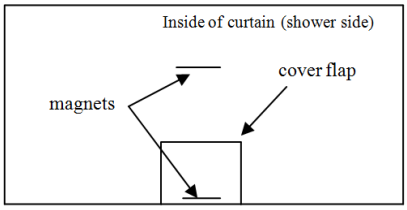

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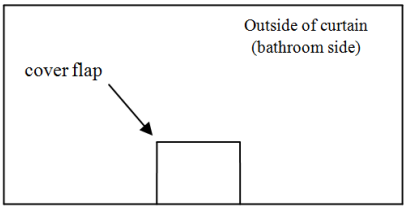

Notes:
The cover flap is moved from the inside of the curtain to the outside of the curtain. This move eliminates the need for the magnets so they are no longer used.

ME 450 Team 14	
Shower Curtain for Transfer Bench	
Ref. Drawing: Placement of cover flap	
Engineer: Team 14	11/28
Proj. Manager: A. Shih	11/30
Mgmt./Sponsor: S. Murphy	11/30

Engineering Change Notice

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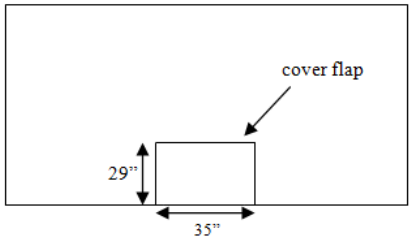

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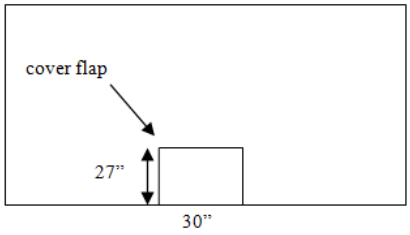

Notes:
The cover flap dimensions are changed from 35” wide by 29” tall to 30” wide by 27” tall.

ME 450 Team 14	
Shower Curtain for Transfer Bench	
Ref. Drawing: Cover flap dimension	
Engineer: Team 14	11/28
Proj. Manager: A. Shih	11/30
Mgmt./Sponsor: S. Murphy	11/30

Engineering Change Notice

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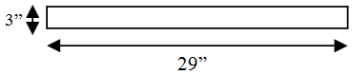

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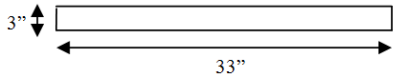


Notes:
The length of the long weighted strip was changed from 29” to 33” to allow for more flexibility when wrapping around the corners of the transfer bench.

ME 450 Team 14	
Shower Curtain for Transfer Bench	
Ref. Drawing: Long weighted strip	
Engineer: Team 14	11/28
Proj. Manager: A. Shih	11/30
Mgmt./Sponsor: S. Murphy	11/30

APPENDIX C: Design Analysis
FUNCTIONAL PERFORMANCE

The shower curtain
The shower curtain material must have the following:
-Function: block water, lightweight but durable
-Objective: low weight
-Constraints: water resistant material, flexible

These lead to a material index of:
$M=\frac{yield\ strength}{density}$

Using CES EduPack Version 6.2.0, the top 5 materials that matched this were ethylene vinyl acetate (EVA), polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET) and polyvinyl chloride (tp PVC). From these, EVA and PVC were the best options, but EVA was selected over PVC because it was more environmentally friendly. Also, we know that EVA is a common material used for shower curtains from our market research and suited perfectly for our intentions. A graph of yield strength vs density can be seen below in figure C-1.

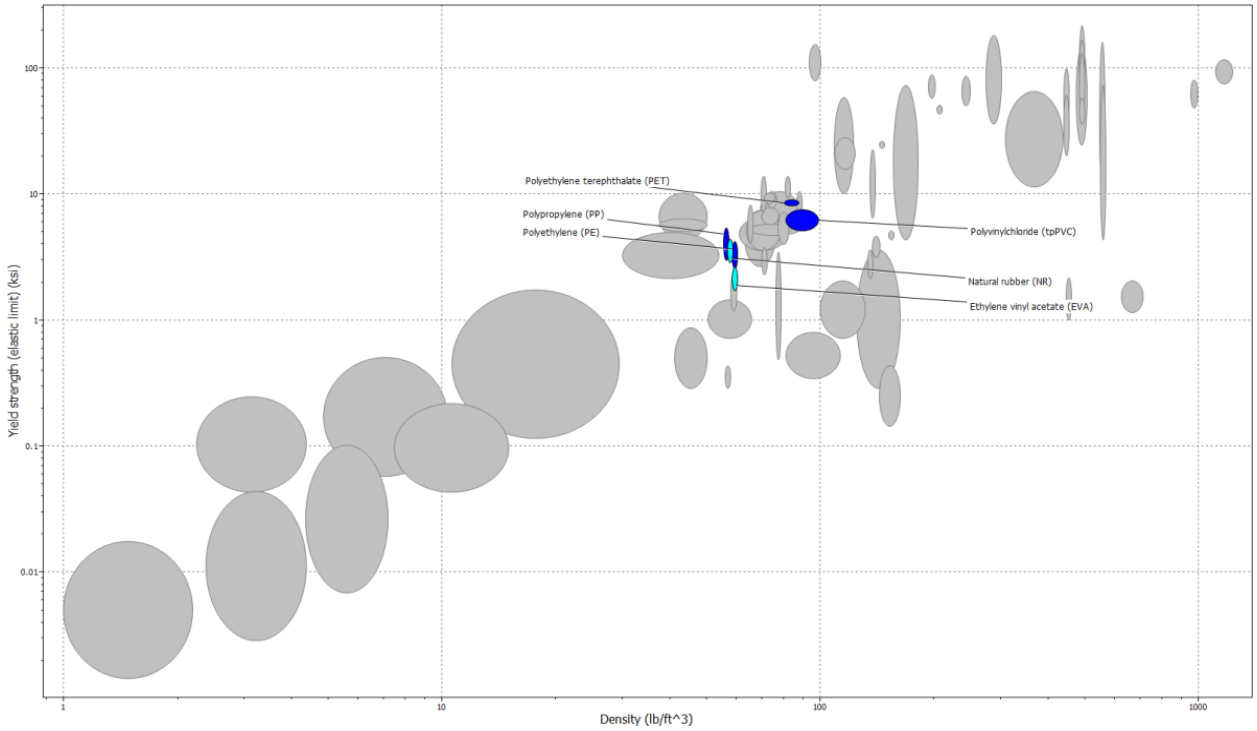


Figure C-1: EVA was selected as the best choice using CES

Material for weighted pouches
The material used for the weighted strips must have the following:
-function: create a seal to block water
-objective: high density
-constraints: must have flexibility, or be made small enough to create many particles that would provide flexibility

These lead to a material index of:

$$M=\frac{density}{cost\ per\ lb}$$

Our team performed analysis on the materials used for the weighted pouch using CES EduPack Version 6.2.0. Using the limits (minimum density 440 lbs/ft^3, maximum price 2.5USD/lb), our team determined that commercially pure lead, brass, lead alloys, copper and copper bronze are some possible materials used for the weighted pouch. Our team chose copper as the weighted pouch material due to its availability on the market and being safer compared to lead alloys. Lead can cause lead-poisoning and anemia. A graph of density versus price for the CES is as shown in figure C-2 below.

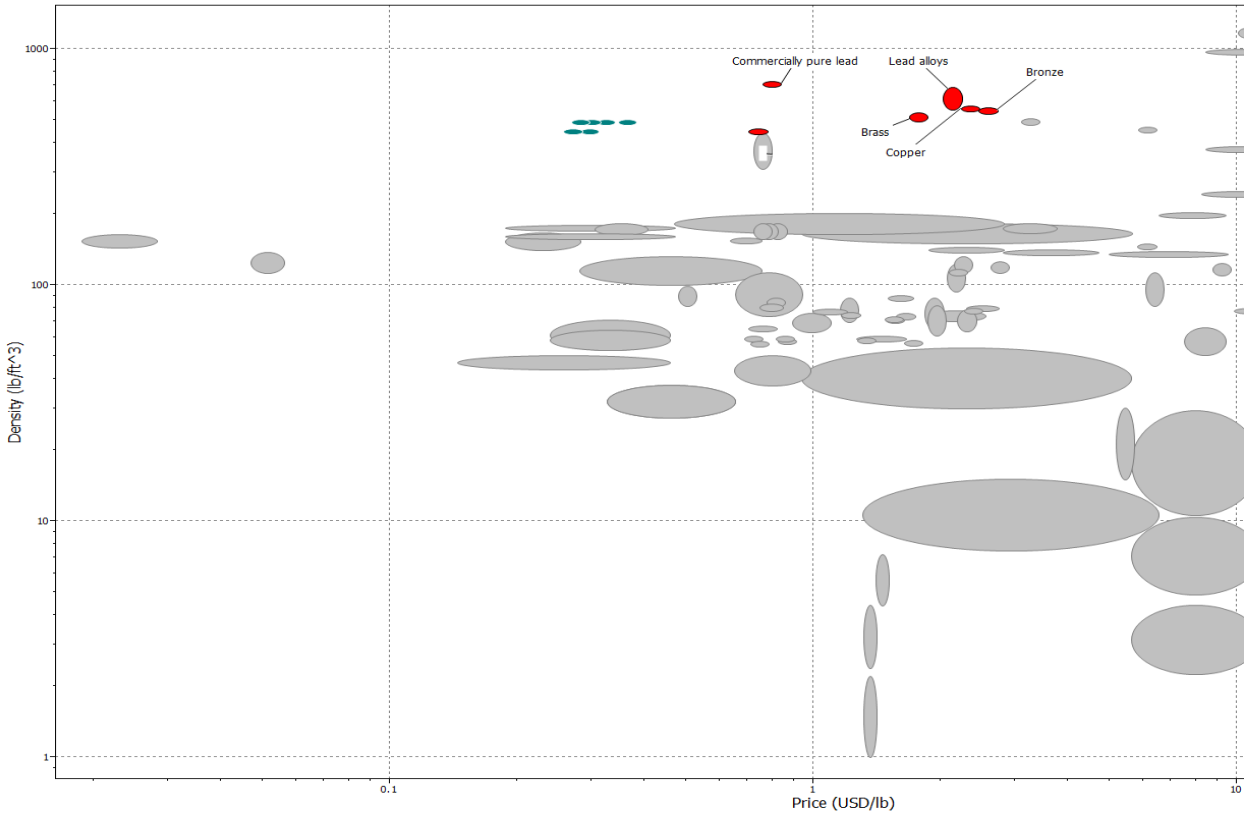


Figure C-2: Copper was chosen as the material for the weighted strips

ENVIRONMENTAL PERFORMANCE

Copper and EVA will be used for the environmental assessment of this product as these are the two materials that are used most in the shower curtain. There are 1.5 lbs of EVA and 1.02 lbs of copper used in this design. SimaPro version 7.2.4 was used for the assessments.

Using the data from SimaPro, and an Excel spreadsheet, the total mass for air emissions, water emissions, use of raw materials and solid waste were calculated. It is clear that copper gives off more total emissions in overall and in each category. The findings are presented in figure C-3 below on page 40.

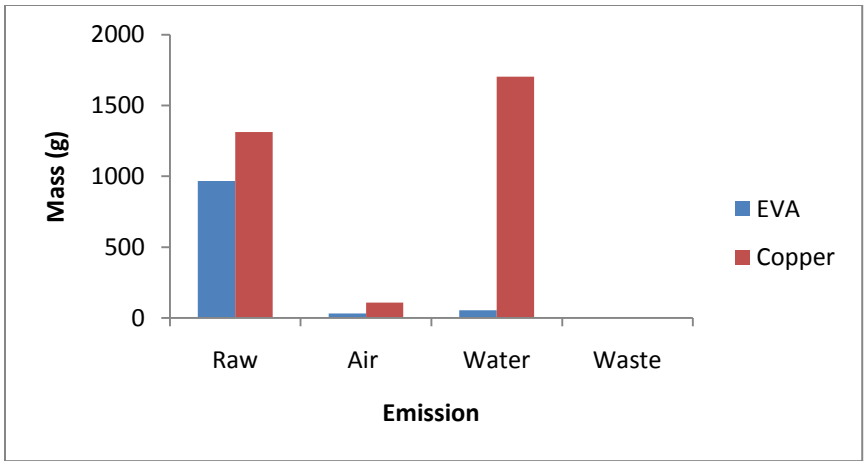


Figure C-3: Copper emits more emissions in each category and overall

Next, we compared the emissions using the EI99 Impact Categories in SimaPro. The 9 different categories can be grouped into sets of human health, eco-toxicity and resources. Whichever material gives off the most emissions in each category is set to 100%. The other material's emissions are given as a percent of the larger number. Copper is the major contributor to all categories in resources. In human health, copper again proved to be more dangerous than EVA overall. The majority of the designs eco-toxicity wastes also came from copper the findings are shown below in figure C-5..

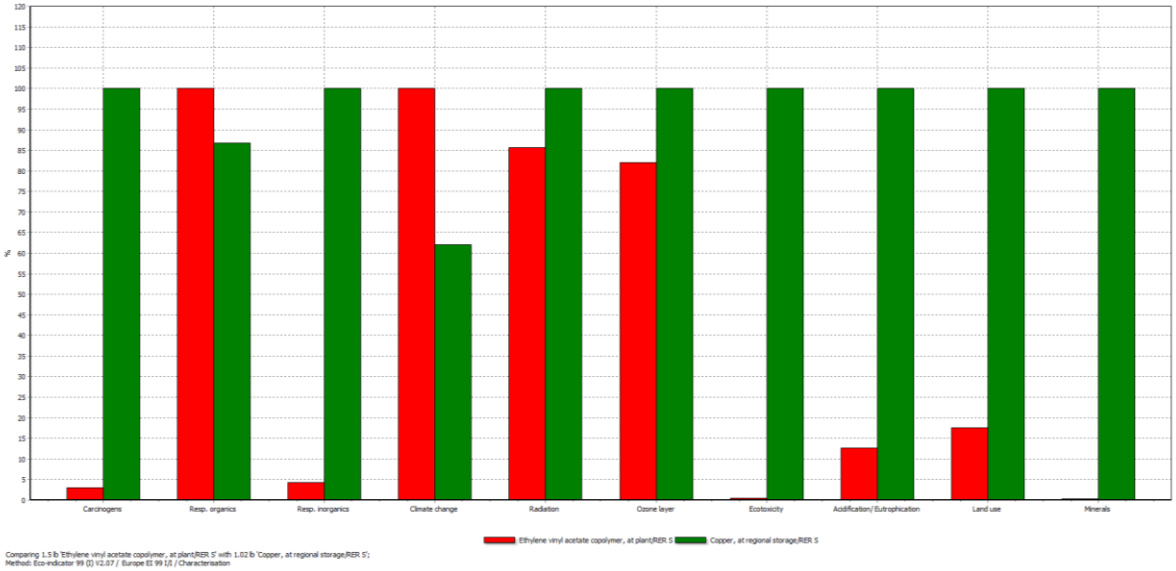


Figure C-4: SimaPro emission findings

Next, this data was combined into the three larger categories of human health, eco-toxicity and resources and normalized against an average European person's yearly emissions in these categories. EVA is very low against human emissions in all categories. Copper is higher than EVA in each category. In resources though, copper rates significantly high against average human yearly emissions. The results of the normalization are shown below in figure C-5 on page 40.

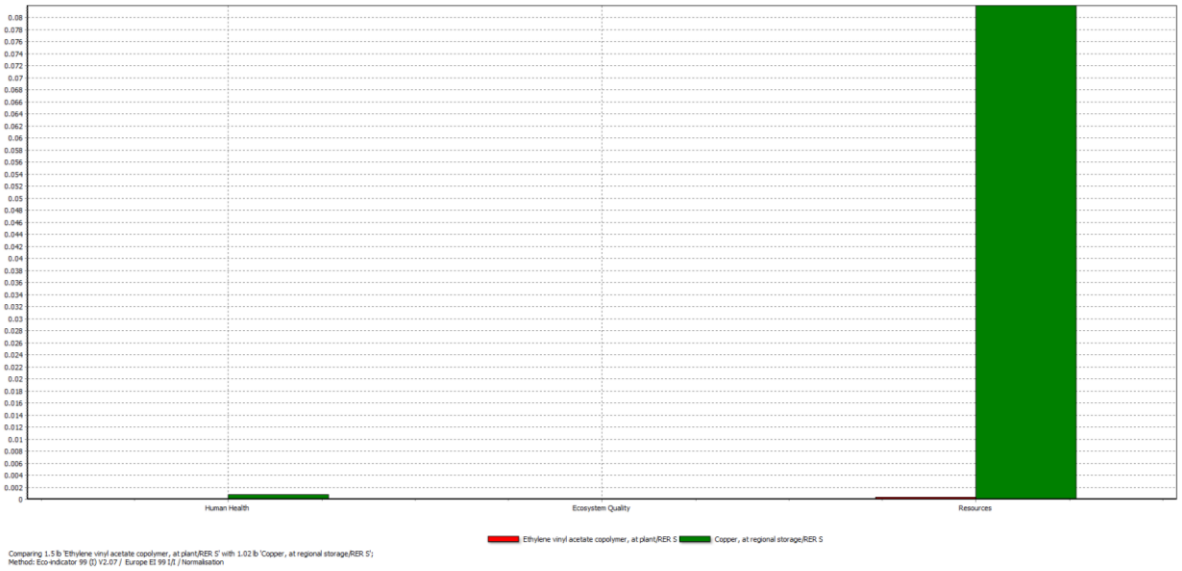


Figure C-5: Copper's resource emissions is significantly higher than any other category against the normalized human emissions

Finally, the total EI99 points are tallied in SimaPro. This is done by weighting the various categories and emissions in each and normalizing the scores. The total EVA emissions are extremely low compared to the environmental impact of copper. However, the main contributor to copper's emissions is the resource emissions. The normalized results are shown below in figure C-6.

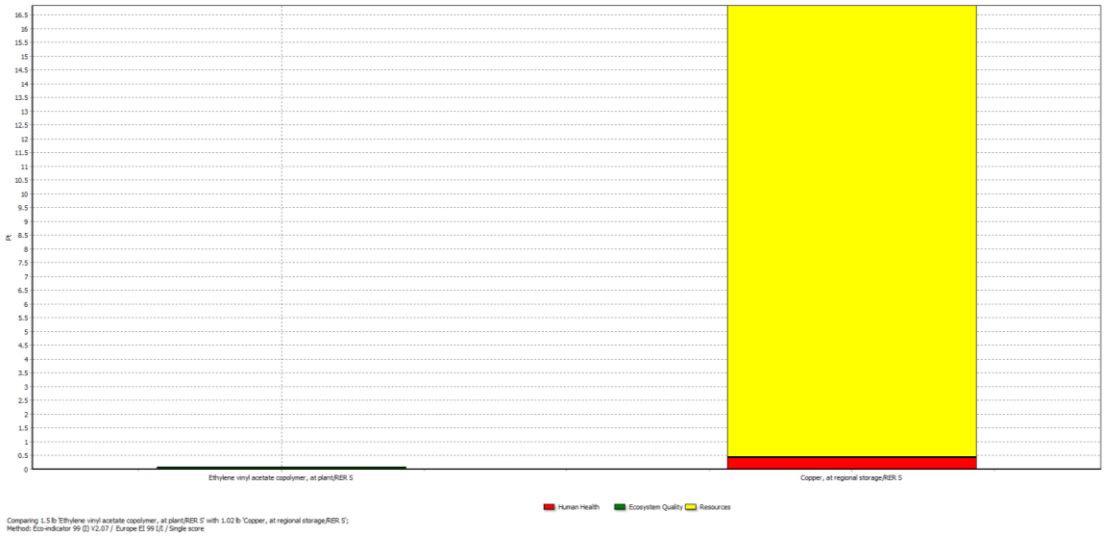


Figure C-6: Copper's resource emissions has the largest environmental impact of any factor

MANUFACTURING PROCESS SELECTION

Determining a real world production value was difficult as there is not much information on how many transfer benches are actually sold. However, from research, it is known that there are currently around 40 million people in the U.S. who are above the age of 65. Of those elderly, 12% are either in assisted living, or have 3 or more limitations in daily activities (such as eating, dressing or walking). This is the target group for transfer bench users and is around 5 million people [12]. Assuming 1% of those transfer bench users actually buy this shower curtain, a production level of 50,000 curtains is necessary.

CES Manufacturing Process Selector was used to determine the best process to manufacture the copper BB's and EVA sheets. For the copper BB's, the manufacturing process had to be able to produce a metal spherical shape with a small diameter (around .08 inches) at a high production rate per hour and an extremely high batch size. If there are 50,000 curtains to be made, hundreds of BB's will be needed per curtain. Shell casting, compression molding, and die pressing and sintering were the top three choices. Die pressing and sintering was chosen because its production rate per hour was the highest, with a maximum of 12,000 pieces manufactured per hour. Also, it was the most cost effective process of the three. Below, figure C-7, is the CES selection graph plotted as relative cost index vs. batch size.

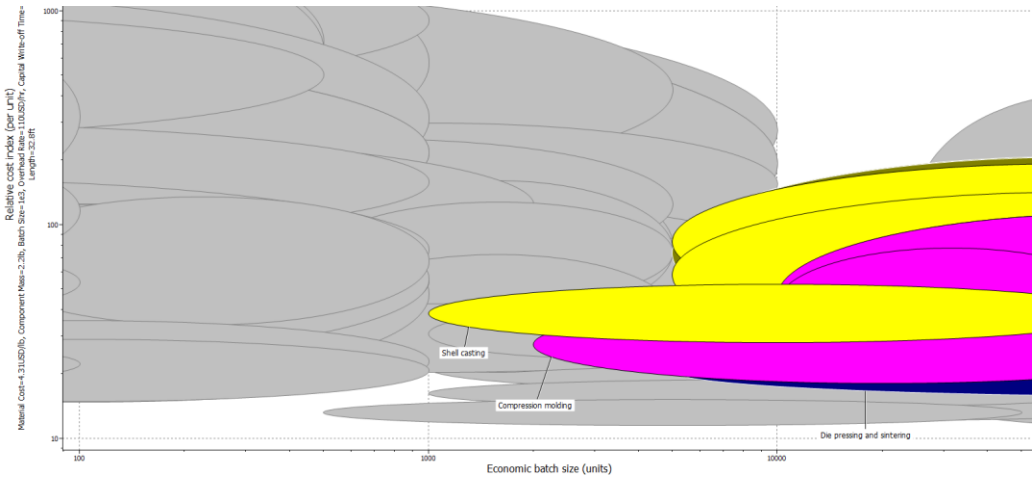


Figure C-7: Die pressing and sintering is the best manufacturing process for the copper BB's

The EVA manufacturing process was centered on creating a very thin flat surface. CES narrowed the selection down to four processes that were rated by relative cost index vs batch size: micro blanking, stamping, compression molding and BMC molding. Micro blanking and stamping were thrown out as they did not fit for this application. Compression molding is the more cost effective solution over BMC molding, so compression molding was selected as the manufacturing process for the EVA shower curtains. Figure C-8 shows the CES selection process below.

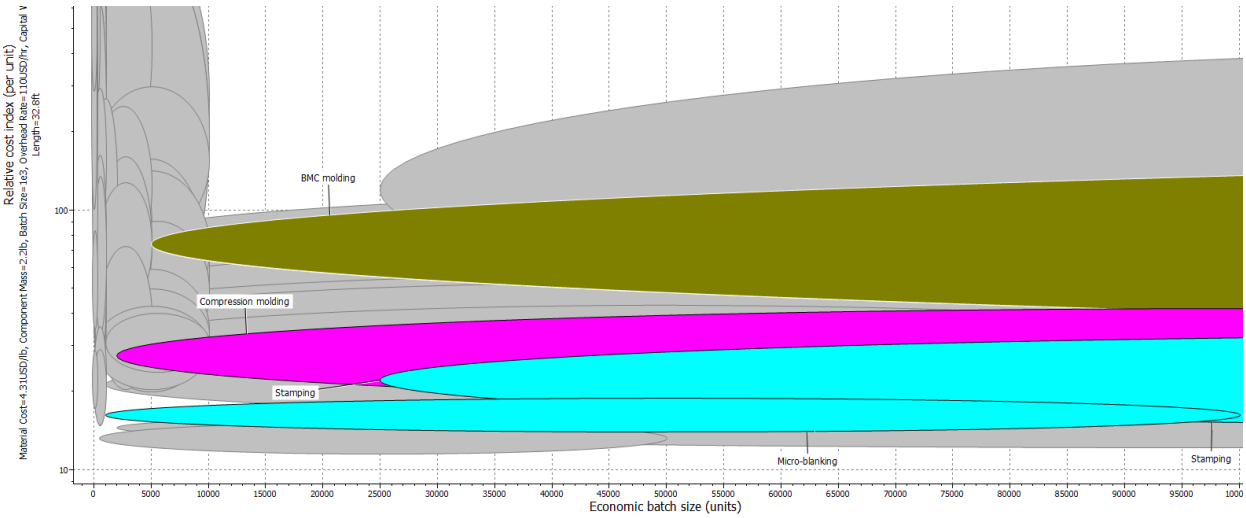


Figure C-8: Compression molding should be used for production of the EVA shower curtain

APPENDIX D: Shower Curtain Survey of Country Living Residents

A survey was conducted of residents at Country Living assisted living home in Hillsdale, MI. The purpose of the survey was to gather information about the desire for a new shower curtain, set up time projections and cost projections. Fifteen residents were interviewed. Below in table D-1 are the results from the survey and figure D-1 on page 44 is a copy of the survey used.

Question Surveyed	Average value
Price willing to spend on normal shower curtain	$16.33
Average set up time of normal shower curtain with use of transfer bench	15 seconds
Price willing to spend on shower curtain for transfer bench	$35.00
Expected set up time of shower curtain for transfer bench	9.46 seconds
Willing to purchase for self or loved one	73%

University of Michigan
ME450 Design And Manufacturing Project
Team 14
Contact person: Brandon (Phone: 517-610-3707 Email: bwnic@umich.edu)

Our team is designing a shower curtain for transfer bench users to prevent water spills in shower. Water spills often occur due to normal shower curtains which do not close properly when a transfer bench is in use and the wet floor poses great danger. Our team would like to understand how important is the need for a shower curtain which closes properly when transfer benches are used. Therefore, we cordially invite you to fill out this survey. Your feedback is highly appreciated and we thank you for your time and patience. We sincerely apologize should any questions be intrusive and/or offensive.

Please answer the questions below by choosing the most appropriate answer.

1. Are you a transfer bench user?
   Yes / No (If YES, please proceed to Q2. If NO, please proceed to Q5)

2. Does an assistant/caregiver assist you when you are taking shower?
   Yes / No

3. Is water spill a problem when you are taking a shower?
   Yes / No

4. What is the type of shower curtain you are currently using and how long it takes for you to close your current shower curtain? (Please choose ONE and specify the approximated needed time)
   - ☐ Normal shower curtain: _____ seconds/ minutes
   - ☐ Modified shower curtain/Shower curtain for transfer bench: _____ seconds/ minutes
   - ☐ Other (Please specify): _____

5. If there is a shower curtain for transfer bench in the market, are you interested in purchasing one for yourself / your loved ones/your client who need(s) one?
   Yes / No

6. What is the maximum price you or your client is willing to spend on a normal shower curtain?
   - ☐ <$10.00
   - ☐ $10.00 – $14.99
   - ☐ $15.00 – $19.99
   - ☐ $20.00 – $24.99
   - ☐ $25.00-$29.99
   - ☐ Other: $_____

7. What is the maximum price you or your client is willing to spend on a shower curtain designed for transfer bench users?
   - ☐ <$10.00
   - ☐ $10.00 – $19.99
   - ☐ $20.00 – $29.99
   - ☐ $30.00 – $39.99
   - ☐ $40.00-$49.99
   - ☐ Other: $_____

8. What is the maximum time you are willing to spend to close the shower curtain just before you begin to shower in the bath tub? Please specify below?
   A. Normal shower curtain: _____ seconds/ minutes
   B. Shower curtain for transfer bench: _____ seconds/ minutes

9. Would you rather buy a new transfer bench that allows the shower curtain to close or a new shower curtain designed for transfer bench to prevent water spill?

Thank you for helping us to complete this survey!!

Figure D-1: Survey form for the shower curtain

APPENDIX E: Online Survey Form

A list of ten questions were answered by 47 University of Michigan Clinicians. The ten questions are listed below, along with a sample question shown in figure E-1.

1. Importance of low cost
2. Stability/safety of the shower chair
3. Ability for chair to extend to the edge of the bathtub for ease of accessibility
4. If the chair extends to the edge of the tub, should the chair itself be able to swivel toward the user for easier access?
5. Comfort and aesthetic appeal for the shower chair
6. Easy to use and maintain
7. Easy to install
8. Allows shower curtain to close
9. How important is it that the design be a non-permanent, detachable device?
10. From your experience, who of the following groups would be best suited for a target of likely users?
    a. Persons suffering from normal ageing issues
    b. Persons suffering from strokes, spinal injury or paralysis
    c. Persons suffering from obesity that affects mobility

The results of the survey are below in table E-1.

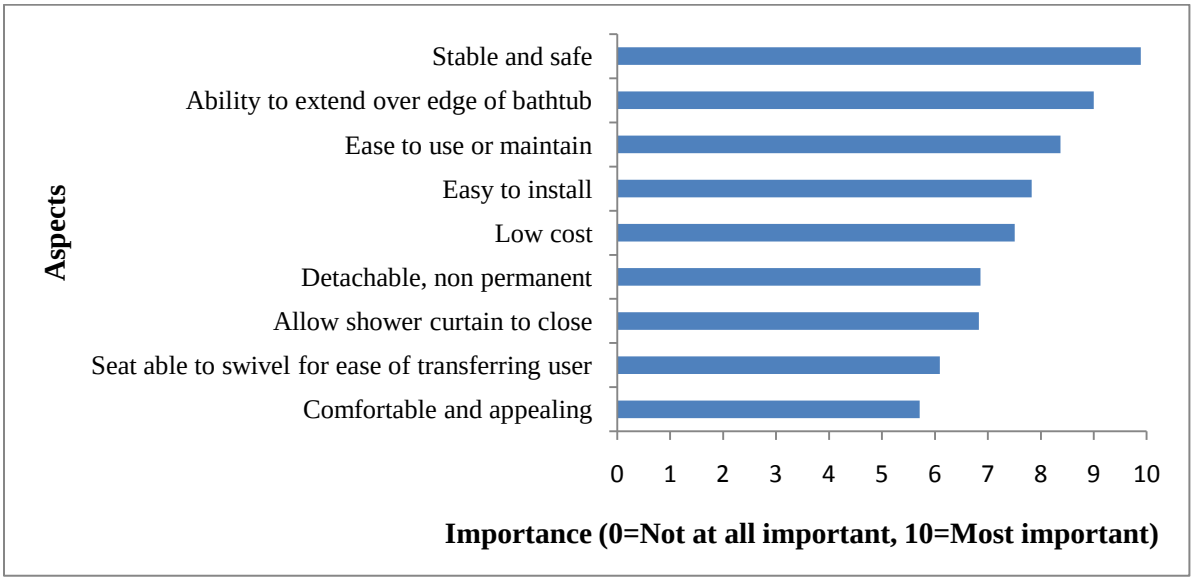


Table E-1: Results of online survey sent to University of Michigan Clinicians

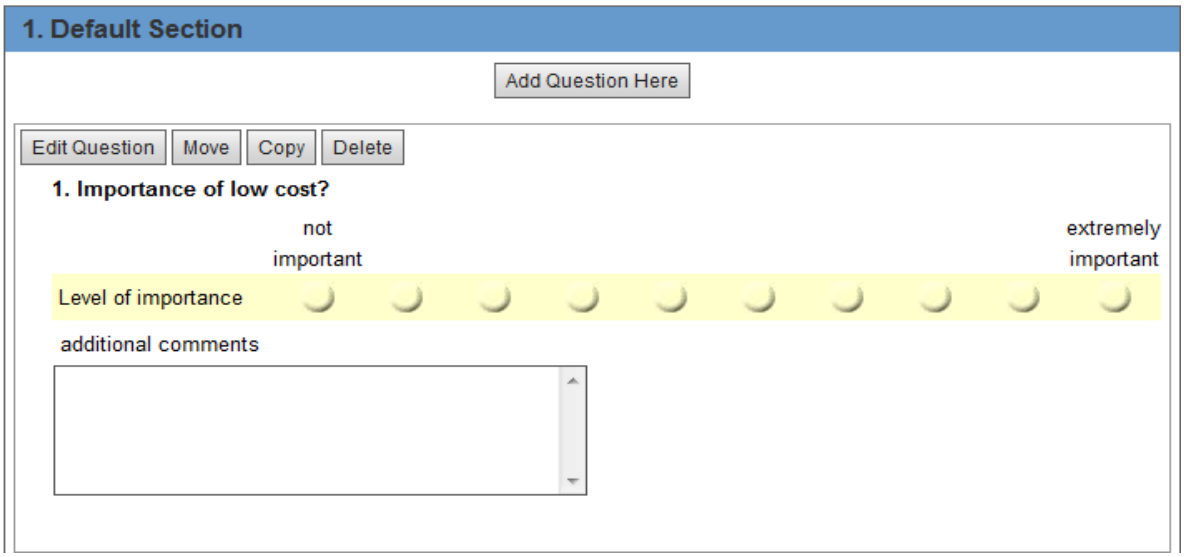


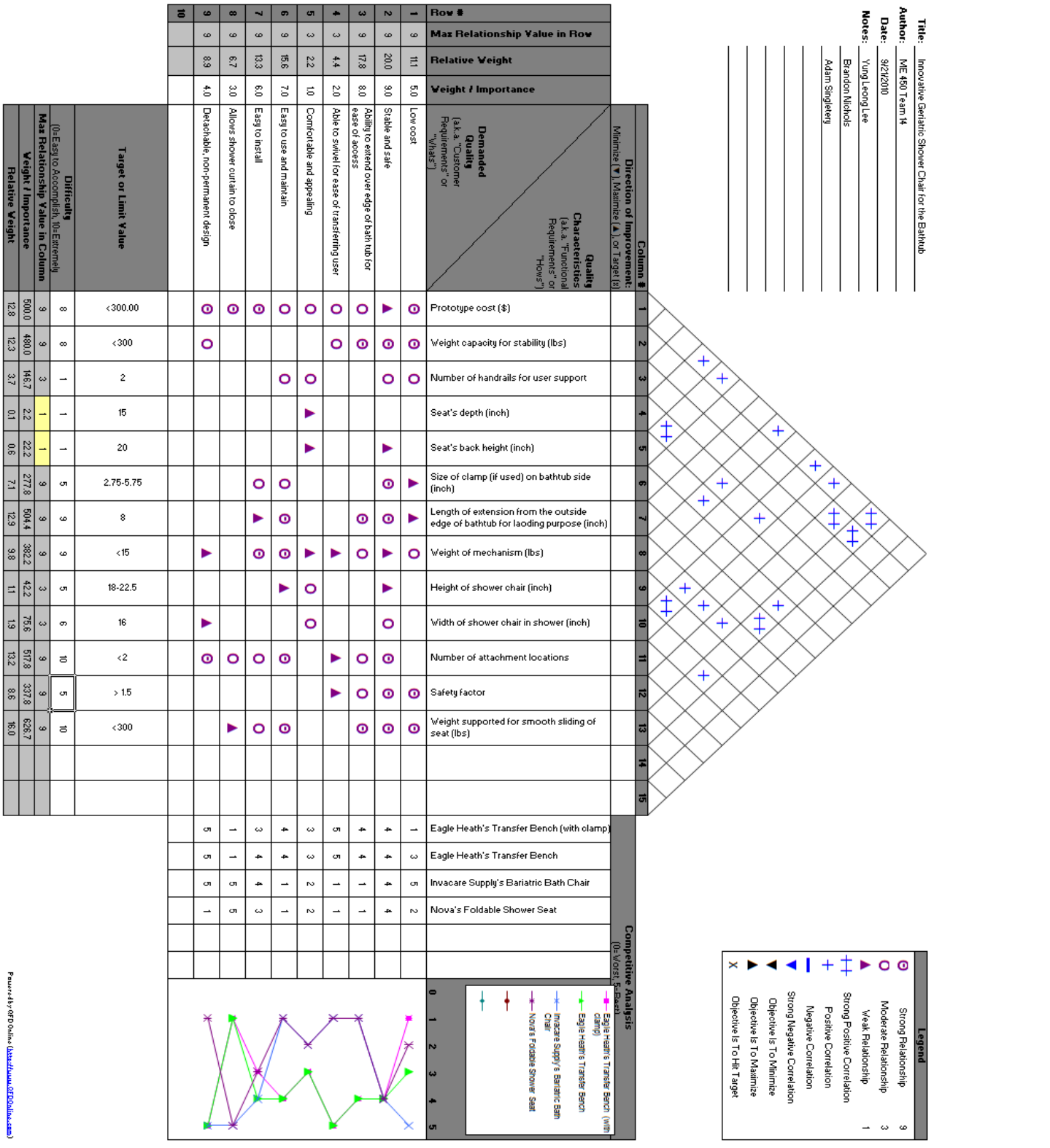
Figure E-1: Sample Question From Online Survey

The survey was assisted by our sponsor, Professor Susan Murphy; 47 responses were received. The survey consisted of 10 questions. A sample of the survey can be found in Appendix A. Figure 3 below summarizes the importance of the nine aspects we covered in our survey and their respective averaged rankings. The ranking system was such that 0 was not at all important and 10 was extremely important.

According to the results in figure 3 above, the main concern for transfer bench users is about stability and safety of the benches. Our team researched the specifications and dimensions of 12 models of transfer benches (Appendix E) and tested some of these benches at two local stores – Mitchell Home Medical and Wright & Phillip. The tested benches were Eagle Health's transfer bench, Eagle Health's Transfer Bench with clamp, Drive's transfer bench and Pinnakel's bariatric transfer bench (Appendix D). All the tested benches were stable when applied with a weight of 230 pounds. It is also determined that all except one of the aspects needed by the transfer bench users can be easily satisfied by the Eagle Health Snap-N-Save transfer bench (Table 1, pg. 7); the only problem remained is that the regular shower curtains cannot close properly with all the current transfer bench designs.

In our opinion, allowing the shower curtain to close is related to safety as explained in the previous sections, making it one of the top concerns. Therefore, it is crucial that we design a shower curtain that will close when used together with the transfer bench.

APPENDIX F: Quality Function Deployment (QFD) Diagram for Transfer Bench



APPENDIX G: Project Gantt Chart

ID	Task Name
1	**Project selection**
2	Meet sponsor for sponsor requirements
3	Survey about costomer requirements
4	Determine specific challenges
5	Information sources
6	US patent search for existing products
7	Determine engineering specifications
8	Project plan
9	Abstract, executive summary, and bios
10	**DR1 presentation**
11	**DR1 report due**
12	Concept generation for transfer bench
13	Concept selection
14	Alpha design of transfer bench
15	CAD drawing for transfer bench alpha design
16	Meeting with sponsor; change of project
17	Concept generation (shower curtain for transfer bench)
18	Concept selection
19	Alpha design of shower curtain
20	CAD drawing for shower curtain alpha design
21	Model of shower curtain
22	**DR2 - Alpha design presentation**
23	**DR2 report due**
24	Finalizing dimensions and geometries for parts of shower curtain
25	Material selection using CES and market studies
26	Force calculation and failure analysis
27	Cost analysis; bill of materials
28	Final parts selection for final design
29	Fabrication plan for prototype
30	**DR3 - Final design presentation**
31	Approval from sponsor for final design
32	Safety report
33	Purchase of materials and tools needed
34	**DR3 report due**
35	Fabrication of prototype
36	Permission to borrow transfer benches through sponsor
37	Prototype testings (water spill and failure tests)
38	Material testing (EVA sheet)
39	Prototype enhancement
40	Preparation for report in event of changes in design
41	Presentation and report preparation
42	**DR4 - Alpha prototype presentation**
43	Final validation testes and prototype enhancements
44	Purchase of materials and assessories for design expo
45	Preparation of presentation slides, fabrication of supporting structuresfor shower curtain, and product video/animation for design expo
46	Finalizing design expo materials
47	**Design Expo / Presentation**
48	Prepare for final report
49	**Final report due**

APPENDIX H: Transfer Benches Patent Search
Ergonomic Transfer bench (Patent Number: 10393547; Figure 16)

The ergonomic transfer bench is a very basic style transfer bench. It is the cheapest style transfer bench on the market. This specific chair does have some interesting features. It has a bidet on the front that allows one to put a hand-held showerhead in it and it forces water up through the seat to clean the underside of the user. However, the chair offers no help getting in and out of the shower. It could only be useful for someone who can climb into the shower on their own. If a caregiver were to have to help the user into the shower, this chair would be of no help.

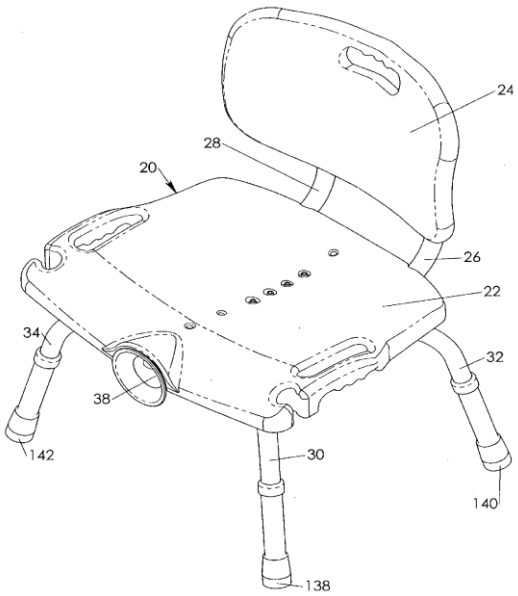
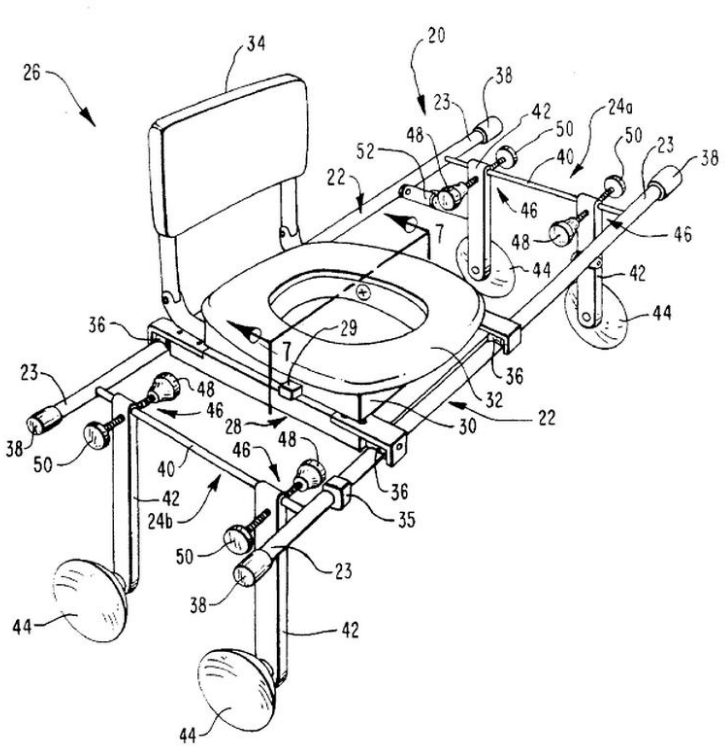


Figure H-1: The Ergonomic Transfer bench

Transfer bench and Bathroom Assembly (Patent Number: 5606751; Figure 17 on pg. 34)

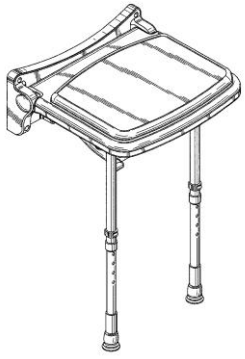
This transfer bench can only move between the inside walls of the tub. Because of this, it requires greater effort to get into the shower than if it extended out past the edge of the tub. This design does have a seat that swivels 360 degrees. This allows the user to turn the seat towards them when loading unto the chair, if it did not have this feature loading would be extremely awkward since the chair will not extend past the edge of the tub. This design rests on top of the edges of the tub and is secured with screw clamps and suction cups on both of the sides. We don't believe that this is the most secure way to clamp down the structure. Finally, and perhaps the largest drawback, the shower curtain cannot close with this design.



H-2: Transfer bench and Bathroom Assembly

Foldable Shower Seat (Patent Number: D536889; Figure 18)

The strength of this design is in its ability to fold up and out of the way for other people who might use the shower. While this chair would allow the shower curtain to close, it is once again does not assist the user with getting into the tub. Also, this is a permanent structure, which not only adds to installation costs, but means that it can not be removed.

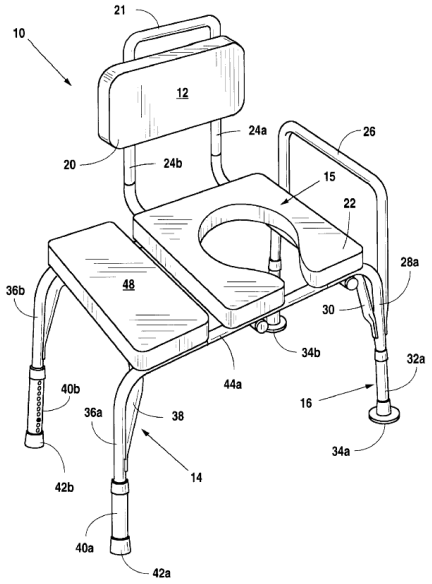


H-3: Foldable Shower Seat

Shower/Tub Transfer Chair (Patent number: 6039403; Figure 19)

This design extends past the edge of the tub, for easier and safer access. There is also a hand rail to aid the user as they get in and out of the tub. The chair for this design is fixed. The transfer bench is stationary

and the user must slide across it. Both of these areas could be improved for a more user friendly design. The bench should slide out, rather than the user slide across the bench. Most importantly, the shower curtain cannot close.



H-4: Shower/Tub Transfer Chair

APPENDIX I (1): Market Research- Transfer Bench Specifications

Table 7: Transfer Bench Dimensions

Transfer Bench Models and Specifications

No.	Company	Model no. / ID	Product name	Seat height (in) Min.	Seat height (in) Max.	Width (in) Min.	Width (in) Max.	Width (in) Seat	Depth (in) Min.	Depth (in) Max.	Depth (in) Seat	Product weight (lbs)	Weight capacity (lbs)	MSRP ($)	Market price ($)
1	Eagle Health	37762	Snap-N-Save Sliding Transfer Bench (with clamp)	18	22.5	39.5	39.5	20.5	18.5	18.5	13.5		350	400.4	272.11
2	Eagle Health	37662	Snap-N-Save Sliding Transfer Bench (with extended aluminum frame)	19	23.25	39.5	40.5	20.5	18.5	20.5	13.5		400	343.17	232.1
3	Drive	12025KD-1	Bariatric Transfer Bench With Back	18.25	23.25	33		26.5	25		16.5	12	500	194.44	131.35
4	Moen	DN7065	Tool Free Adjustable Transfer Bench	17	21								300	139.17	94.83
5	Guardian	SM98013A	Guardian Padded Transfer Bench with Commode Opening	17	22			22			17	16	300	406.84	269.43
6	Invacare	9670	I-Class Transfer Bench	18	22.5	30.5	31	33.25	16.5	17	18	12	400	117.64	88.59
7	Ableware	192776	Bath + Safe Adjustable Transfer Bench	16	21		30						350	140	56
8	Invacare	96752	Bariatric Transfer Bench	16.25	18.63	21	23	27	18.25	18.63	16		700	187.44	142.35
9	Carex	B154	Bathtub Transfer Bench	18	22		29.34			22		11		171.68	121.79
10	ConvaQuip	1730-XFL	Bariatric Tub Transfer Bench		18.5	18.5	20.5	20		22	20		850	573.3	359.86
11	Nova	9080	Padded Transfer Bench with Back	18.5	22.5									207.39	148.97
12	ConvaQuip	1731	Bariatric Transfer Bench					26.5			16		500	223.3	172.79
	Values ("min"=minimum of minimum; "max"=maximum of maximum; "avg"=average)			16 (min)	23.25 (max)	18.5 (min)	40.5 (max)	24.25	16.5 (min)	22 (max)	20 (max)	12.75	465 (avg)	258.73 (avg)	174.18 (avg)

No.	Websites
1	http://www.eaglehealth.com/index.php/snap-n-save-sliding-tub-mount-transfer-bench-with-swivel-seat-and-back.html
2	http://www.eaglehealth.com/index.php/snap-n-save-sliding-transfer-bench-with-swivel-seat-and-back.html
3	http://www.allegromedical.com/bariatric-c6776/bariatric-transfer-bench-with-back-p562343.html
4	http://www.allegromedical.com/bathroom-assists-c517/tool-free-adjustable-transfer-bench-p558767.html
5	http://www.allegromedical.com/bathroom-assists-c517/guardian-padded-transfer-bench-with-commode-opening-p191957.html
6	http://www.allegromedical.com/bathroom-assists-c517/i-class-blow-molded-transfer-bench-p174503.html
7	http://www.allegromedical.com/bathroom-assists-c517/bath-safe-adjustable-transfer-bench-adapts-easily-for-left-or-right-hand-showers-p192776.html
8	http://www.allegromedical.com/bathroom-assists-c517/bariatric-transfer-bench-p550390.html
9	http://www.allegromedical.com/bathroom-assists-c517/carex-bathtub-transfer-bench-p558282.html
10	http://www.allegromedical.com/bariatric-c6776/bariatric-tub-transfer-bench-model-1730-xfl-p554921.html
11	http://www.allegromedical.com/bathroom-assists-c517/padded-transfer-bench-with-back-p191971.html
12	http://www.allegromedical.com/bariatric-c6776/bariatric-transfer-bench-model-1731-p554895.html

APPENDIX I (2): Market Research- Bathtubs Specifications

We conducted research on twelve transfer benches currently on the market and gathered all pertinent information regarding dimensions, weight and specifications that were available. We also conducted research on four shower tubs currently on the market for important dimensions needed.

Bathtub make and model	Tub length (in)	Tub bottom width (in)	Tub top width (in)	Tub side width(in)	Tub internal height (in)	Tub external height (in)
Lasco Bathware 2603-30	60	13.625	22.25	3.5	12.625	15.125
Lasco Bathware 2603-N2P	60	16	21.25	4.5	12.625	15
ASB Deep-soak Bathtub	60	14	23.75	4.5	15.5	18
Sterling Caulkless Accord Bath Shower	60	18.75	22.625	4.5	13.125	15
Average value	60	15.59375	22.46875	4.25	13.46875	15.78125
Min value	60	13.625	21.25	3.5	12.625	15
Max value	60	18.75	23.75	4.5	15.5	18

Table E-1: Bathtub Dimensions

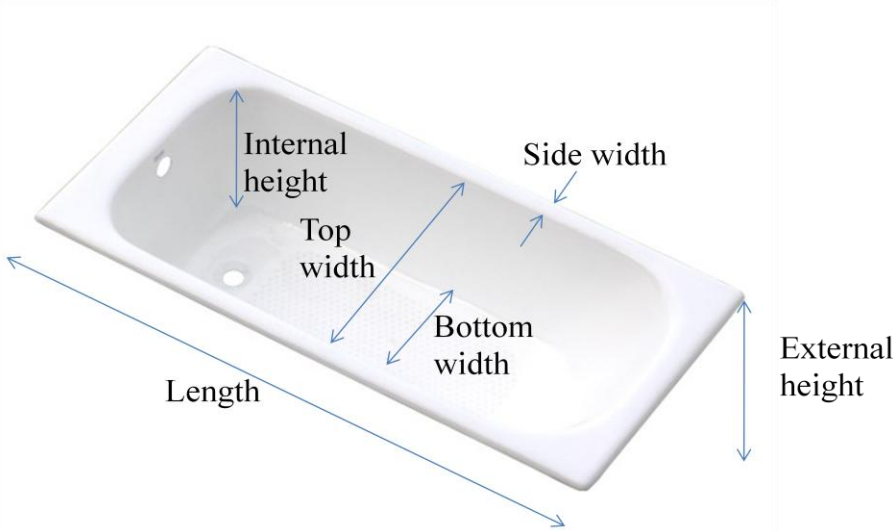


Figure I.1: Dimensions of a regular household bathtub in the US

APPENDIX J: Sponsor Requirements Compared to Previous Groups

Table J-1: Sponsor requirements for the geriatric transfer bench

Current design	1st generation	2nd generation
Solid, safe, and stable	Robust / Dependable / Safe	Maintaining stability when in use / Safe
Easy to use	Simple / Easy to use /Set-up conducive for caregiver	Easy to use / install
Allow shower curtain to close	Allows shower curtain to close	Allows shower curtain to close
Detachable and non-permanent structure	Non-invasive for other shower users/ Removable / Easy to install	Non-invasive for other shower users
Transfer bench design to allow for easy access into and out from the tub	Extend to outer edge of bathtub	Extend to outer edge of bathtub
Affordable	Low cost	Low cost
-	Adjustable for different bathtubs	The comfort of the seat
-	Space for showerhead attachments / bathtub accessories / hand rails	Handrails
-	-	No sharp edges

APPENDIX K: Engineering Specifications of the Transfer Bench

From the information sources and the sponsor requirements, a list of thirteen engineering specifications was developed to satisfy the requirements by the sponsors and attend to the needs of the users, care givers, and manufacturer. The importance of each engineering specification was ranked (Table K-1, pg. 57) via a quality function deployment (QFD) diagram (Appendix F) using information obtained from the information sources. Our design will be based on a regular bathtub used in a US household (refer to Appendix I).

In our design, stability will be an overlying concern. According to the National Center for Health statistics, the average weight of a male adult is 189.8 lbs and 162.9 lbs for a female adult in the US. We aim to design a transfer bench that can support a weight of up to 300 lbs for a safe, stable structure and to account for the obese community. We also aim to achieve a design that allows the sliding seat to glide smoothly at the weight capacity of 300 lbs. The number of attachment locations should be two or less to allow for ease of installation and removal, to allow the shower curtain to close, and to allow for a design which is detachable.

Another deciding factor, from both the consumer and supplier, is cost. Since a transfer bench falls outside the realm of what most insurance policies will cover, the user will directly incur the cost of the device. Because of this, the target audience will be looking for a product that not only meets their needs, but is priced competitively. In addition, the manufacturer needs a design that is low cost and easy to manufacture in order for the transfer bench to be economically viable to produce. Therefore, we aimed to produce the prototype with a target prototype cost of less than $300 so that the final retail price would be affordable.

The targeted weight for the chair should be less than 15 lbs. The entire transfer bench should be built with a safety factor of greater than 1.5. The clamp for the edge of the tub, if used in our design, will have an adjustable range between 2.75” to 5.75”.

The number of handrails will be increased to two compared to the previous design. One of the handrails will be on a swivel to allow for easy access and extra room if needed, while another will be fixed. The seat will have a depth of 15”, width of 16” and the seat’s back will have a height of 20”. The chair will have an adjustable height from the tub floor of between 18” to 22.5”.

The transfer bench will also feature a sliding seat that can slide up to 5 to 8 inches past the outside edge of the bathtub when loading. This will allow an easier transfer of its user into and out from the bathtub.

Table K-2 (pg. 57) shows the importance of the engineering specifications for our project, 1 being the most important specification, and 13 being the least important specification. These values were compared against previous teams’ values (1st generation and 2nd generation) for comparison.

Table K-1: The ranked engineering specifications for the geriatric transfer bench and the targeted values

Rank			Engineering Specifications	Target values		
Current	1st gen.	2nd gen.		Current	1st gen.	2nd gen.
1	-	-	Weight supported for smooth sliding of seat (lbs)	300	-	-
2	7	14	Number of attachment locations	≤ 2	4	< 4
3	6	8	Length of extension from the outside edge of tub when loading (inch)	5 - 8	0+	1
4	3	1	Prototype cost	< $300.00	< $150	< $250
5	5	3	Weight capacity for stability (lbs)	300	285	300
6	8	12	Weight of mechanism (lbs)	< 15	< 25	< 20
7	2	15	Safety factor	> 1.5	1.5	2
8	-	-	Size of clamp (if used) on bathtub side (inch)	2.75-5.75	-	-
9	-	3	Number of handrails	2	-	1
10	-	10	Width of chair in shower (inch)	16	-	20
11	-	9	Height of transfer bench (inch)	18 - 22.5	-	19 - 23
12	-	11	Seat's back height (inch)	20	-	13
13	-	7	Seat's depth (inch)	15	-	15

Table K-2: Engineering specifications and target values for our transfer bench as compared to the Eagle Health's Snap-N-Save Sliding Transfer Bench

Rank	Engineering Specifications	Target values	Snap-N-Save Sliding Transfer Bench specifications
1	Weight supported for smooth sliding of seat (lbs)	300	400
2	Number of attachment locations	≤ 2	0
3	Length of extension from the outside edge of tub when loading (inch)	5 - 8	~ 14
4	Prototype cost	< $300.00	$232.10 (Market price)
5	Weight capacity for stability (lbs)	300	400
6	Weight of mechanism (lbs)	< 15	< 15
7	Safety factor – 200 lbs reference	> 1.5	2
8	Size of clamp (if used) on bathtub side (inch)	2.75-5.75	-
9	Number of handrails	2	0
10	Width of chair in shower (inch)	16	NA
11	Height of transfer bench (inch)	18 - 22.5	19 – 23.25
12	Seat's back height (inch)	20	13.25
13	Seat's depth (inch)	13	13.5

APPENDIX L: Concept Generation: Shower Curtains

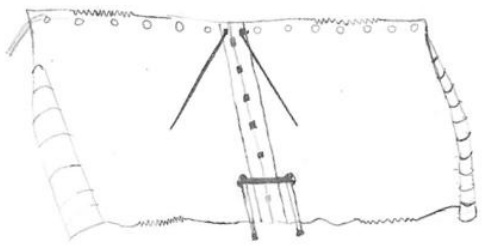


Figure L-1: The ‘Barn Door’

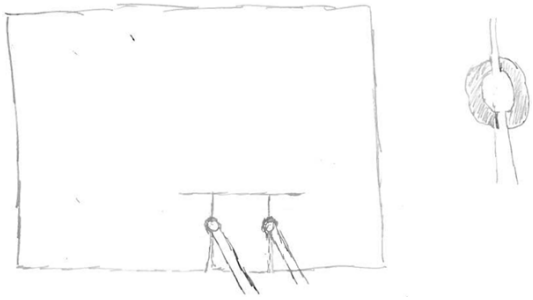


Figure L-2: The ‘Versatile Zip Lock’

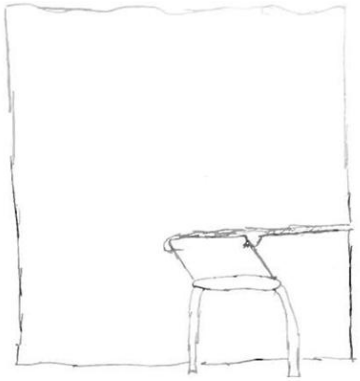


Figure L-3:‘The Jaw’

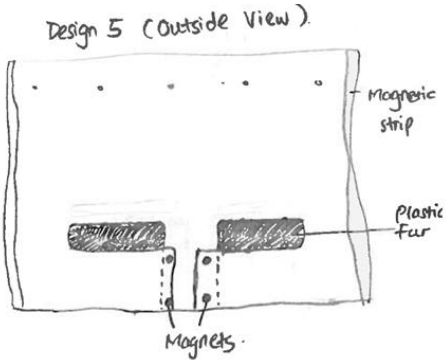


Figure L-4: The ‘Bristle Blockade’

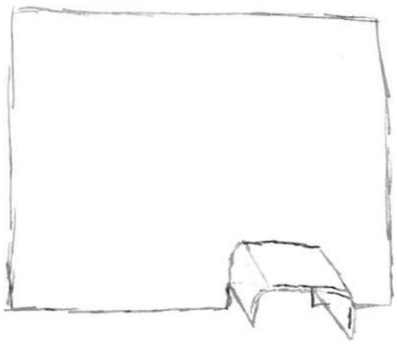


Figure L-5: ‘The Tent’

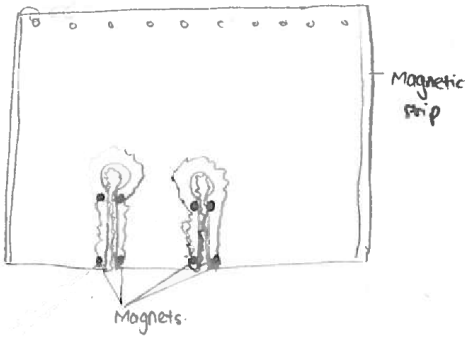


Figure L-6: Design 6

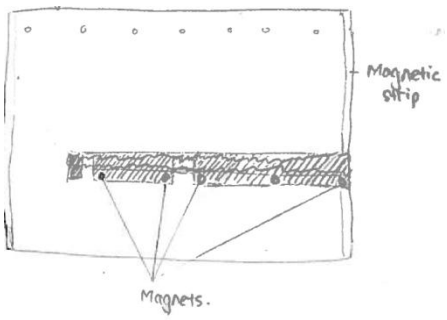


Figure L-7: Design 7

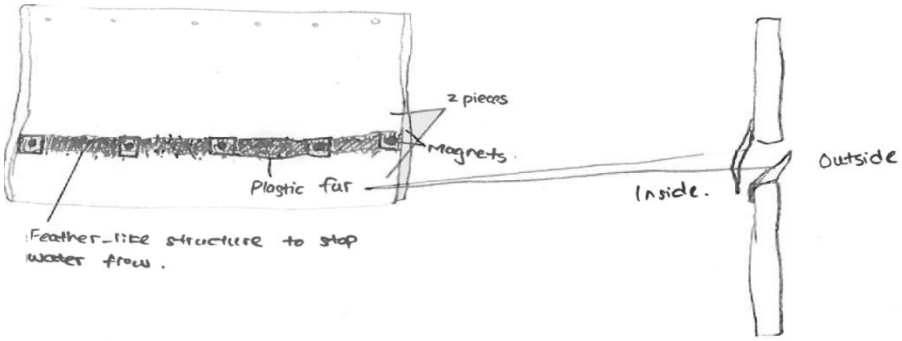


Figure L-8: Design 8

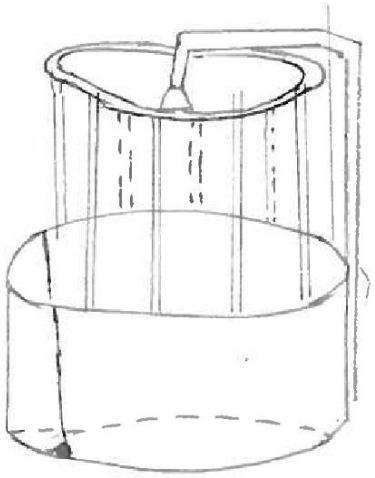


Figure L-9: Design 9

Brief explanation of designs 1-4

Concept Design #1 The “Barn Door”

This design is named the barn door due to the main feature of a barn door; the two doors slide away from each other. This is exactly how the two main pieces of the shower curtain slide open and shut. In the closed position, the two curtains are held together by magnets. These magnets would need to be selected so that the force needed to pull them apart would not be excessively large. If it were too high, this could cause the user to injure them self. To assist with the opening and closing of the shower curtain, this design incorporates a plastic rod that is placed at top of each of each half of the curtain and towards the middle. This allows the end user to grab onto the rod with one hand to pull the curtain along the rod more efficiently than grabbing the curtain with their hands. Lastly, both ends of the curtain are curved to provide better protection to the outside floor from splashing water. This sketch is designed exclusively for designs that include two rails that protrude on the bathroom floor. Figure 7 below illustrates this design. To protect the bathroom floor from water that might creep down from the rails, a zippered slot is included so that the curtain can slide into the final resting hole for each rail rest at. The hole incorporates flaps that touch rail around the entire perimeter to prevent water from flowing down and onto the floor. To compensate for additional shower chair locations that are located closer and farther to the shower head, there is extra material that allows for altered position placement.

Concept Design #2: ‘Versatile Zip Lock’

This design incorporates a zipper system that operates like zip lock bag. The zippers allow the user to customize the design based on the height and width of the shower chair. Also, to prevent water from flowing onto the bathroom floor, a circular magnetic ring is attached to the zipper. Once showering is complete, the user has to unzip the curtain from around the geometry of the shower chair. Figure 8 below illustrates this design.

Concept #3 ‘The Jaw’

This design has a zipper system that allows the lower portion of the shower curtain to slide underneath the bench. After the curtain is fully closed, the zipper can then be closed to prevent water from seeping onto the floor from the slot opening. Figure 9 below illustrates this design.

Concept #4 ‘Bristle Blockade’

This design uses two flaps that allow the shower chair to slide through the opening in the shower curtain. Then, the flaps connect to a centerpiece that falls between the spaces in the transfer bench like that of the Eagle Health’s models. The openings are protected by bristles to prevent water from seeping through onto the floor. Each end of the shower curtain is laced with a magnetic strip that prevents any splashing water from reaching the outside of the tub. An opposite polarized magnetic strip must be placed on each edge of the outside wall. Figure 10 below illustrates this design.

APPENDIX M: Concept Generation: Transfer Benches

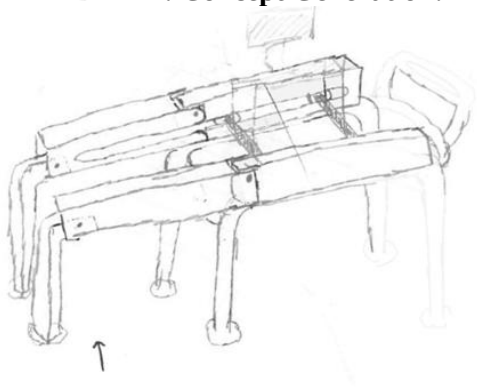


Figure M-1: Design 1

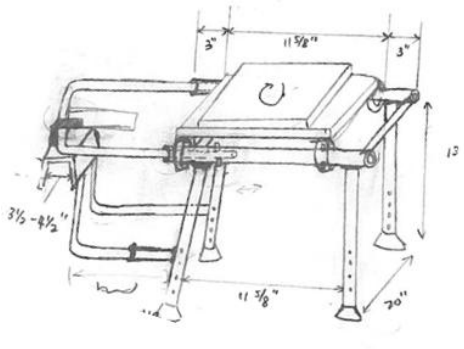


Figure M-2: Design 2

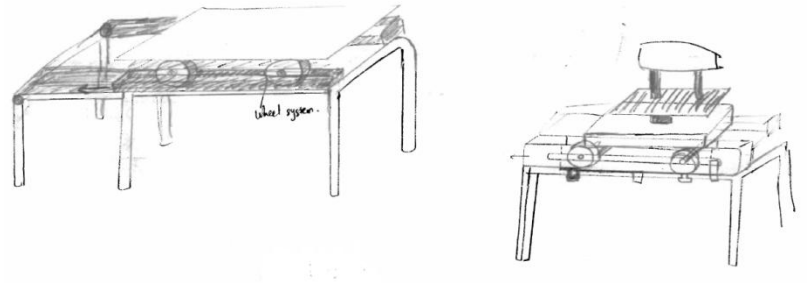


Figure M-3: Design 3 (extended and folded in)

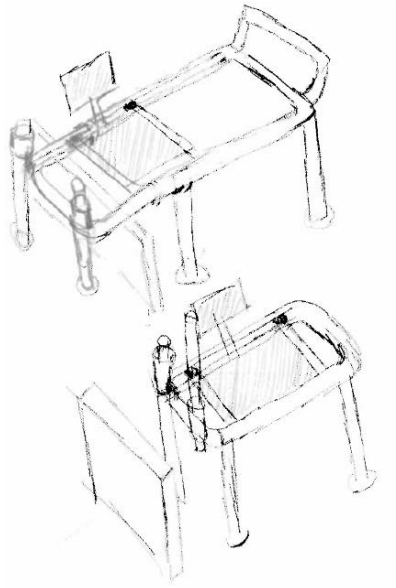


Figure M-4: Design 4 (extended and folded in)

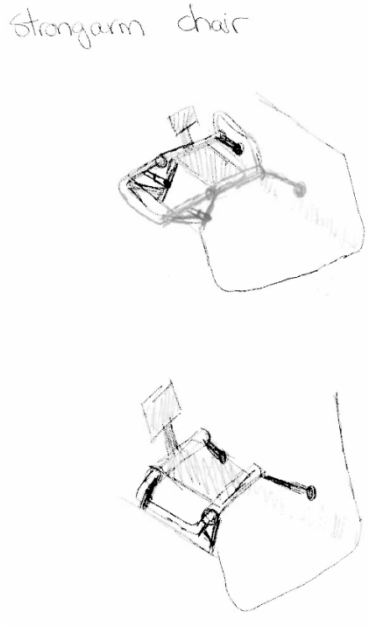


Figure M-5: Design 5 Strong arm Chair

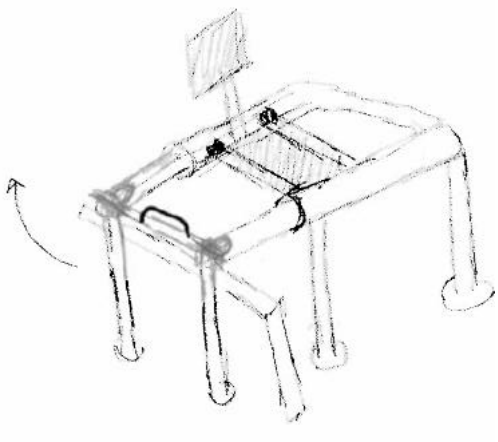


Figure M-6: Design 6

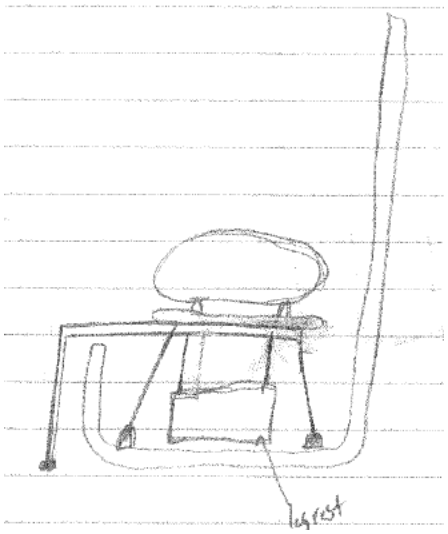


Figure M-7: Design 7

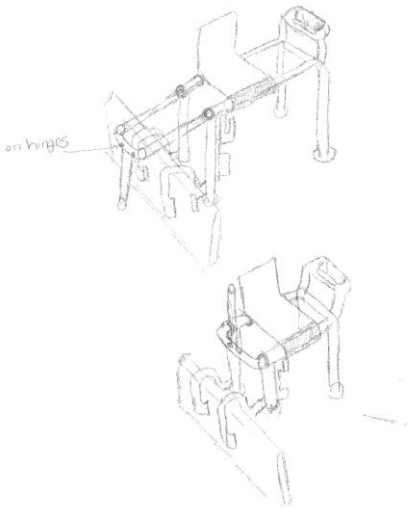


Figure M-8: Design 8 Hydraulic Clamping Chair (extended and folded in)

APPENDIX N: Selection Matrixes for Shower Curtains

The design matrix was created using input received from both Naomi Gilbert and Professor Murphy, as well as information gathered from our group discussions.

Selection Matrix	1	2	3	4	5
Ease of use				X	
Durability				X	
Assembly/disassembly					X
Manufacturability				X	
Environmental impact				X	

Table N-1: **“**The Tent”

Selection Matrix	1	2	3	4	5
Ease of use			X		
Durability			X		
Assembly/disassembly			X		
Manufacturability		X			
Environmental impact				X	

Table N-2: “Bristle Blockade”

Selection Matrix	1	2	3	4	5
Ease of use		X			
Durability		X			
Assembly/disassembly			X		
Manufacturability		X			
Environmental impact				X	

Table N-3: **“**Barn Door”

Selection Matrix	1	2	3	4	5
Ease of use		X			
Durability		X			
Assembly/disassembly		X			
Manufacturability		X			
Environmental impact				X	

Table N-4: “Versatile Zip Lock”

Selection Matrix	1	2	3	4	5
Ease of use		X			
Durability				X	
Assembly/disassembly				X	
Manufacturability				X	
Environmental impact				X	

Table N-5: “The Jaw”

APPENDIX O: Previous Design

We analyzed the design from the previous ME 450 team (2nd generation shower chair) in our attempts to design a new transfer bench. The design is wall mounted and is able to slide to the edge of the bathtub for ease of transferring the users. One of our team members assessed the shower chair design by sitting on it. Our team member is a male adult weighing 150 lbs.

We determined that stability and safety issues are the main problems in their design. The mechanism is quite heavy. It was barely stable, as the four legs struggled to match up with the floor. As it extended out past the bathtub, deflection occurred in the design due to insufficient supports and incapability of the legs to overcome the load. The shower chair bent with an angle about 5 degrees from the horizon. Also, the mechanism came with a torsion spring; our team decided that it was still quite heavy for its users to lift it up.

Therefore, our team decided that a new transfer bench must address these stability and safety issues. The figure below illustrates the previous team's design.

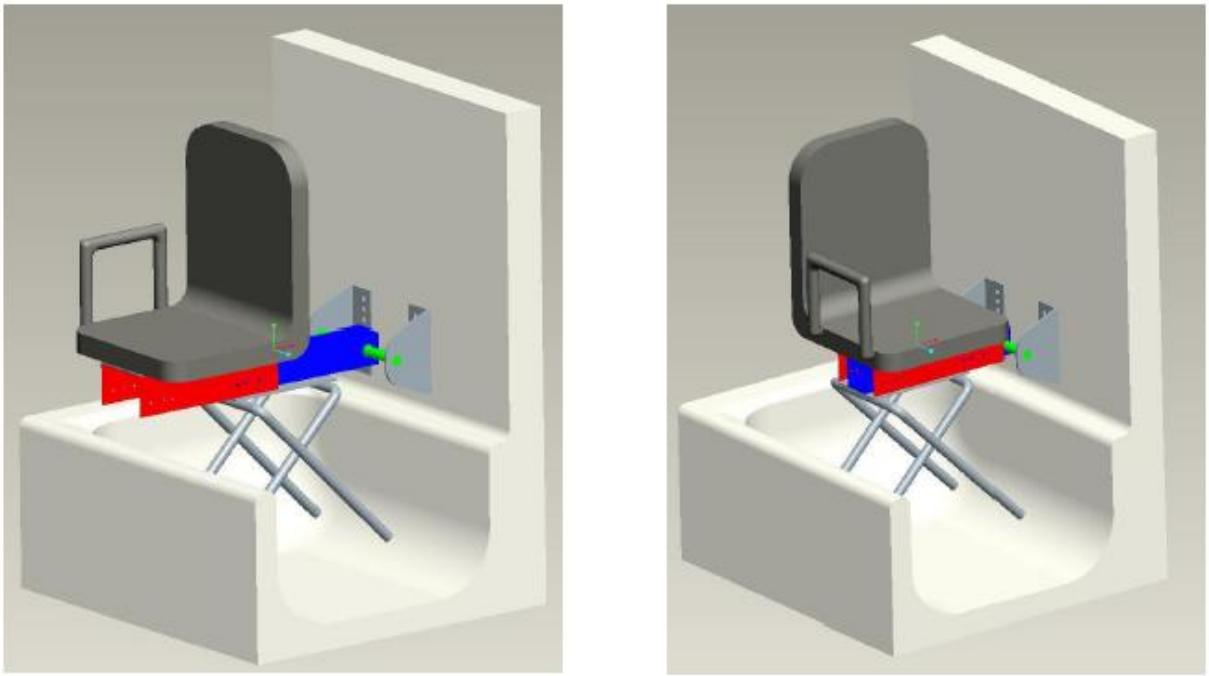


Figure O-1: Previous Team's Shower chair (extended and in use positions)

APPENDIX P: Failure Analysis Calculations

Table P-1: Material properties for ethylene vinyl acetate (EVA) from CES

Material property	Value
Density (lb/in^3)	0.036
Young's Modulus, E (psi)	3625
Price (USD/lb)	0.86
Shear Modulus, G (psi)	1305
Poisson's ratio	0.48
Yield Strength (psi)	1740
Elongation (% Strain)	0.455
Fracture toughness (ksi·in$^{1/2}$)	0.455
Maximum service temperature (F)	116
Transparency	Translucent
Water Absorption (Max % @ 24 hrs)	0.5
Durability (weak alkali/acid)	Excellent

Material Properties

The material properties used for the failure analysis that followed are determined from experiments. The results are compared to the values obtained from CES. All the seals on EVA and PEVA are sufficiently strong such that deformations occur far from the seal; therefore, the seal locations can be assumed to be ideal for analyses.

Table P-2: Dimensions and properties of materials determined from experiments

Dimensions / Properties	(Actual)	(CES Reference)
EVA thickness, t_{EVA} (in)	$5 \cdot 10^{-3}$	-
PEVA thickness, t_{PEVA} (in)	$8 \cdot 10^{-3}$	-
EVA density (lbs/in^3)	0.036	0.034
PEVA density (lbs/in^3)	0.019	-
Yield force per unit length of EVA, $P_{Y,\,EVA}$ (lbs/in)	8.8	-
Yield force per unit length of PEVA, $P_{Y,\,PEVA}$ (lb/in)	9.5	-
Yield strength of EVA, $\sigma_{Y,\,EVA}$ (psi)	1760	1740
Yield strength of PEVA, $\sigma_{Y,\,PEVA}$ (psi)	1890	-
Copper pellet density (lbs/in^3)	0.28	0.32
Plastic pellet density (lbs/in^3)	0.04	-
Weight of final shower curtain (lbs)	2.95	-

Dimensions

Dimension of Base Curtain (B) (Plain EVA sheet)

Overall width, W_B = 107 in
Overall height, H_B = 72 in
Original base curtain area, $A_{B,O}$ = $W_B \bullet H_B$
= 7704 in^2
Tent's hole area, $A_{B,T}$ = 276 in^2
Number of ring holes, N_R = 18
Diameter of ring holes, D_R = 0.4 in
Area of ring holes, $A_{B,R}$ = $N_R \bullet \pi \bullet (D_R/2)^2$
= 2.26 in^2
Net frontal area of base curtain, A_B = $A_{B,O} - A_{B,T} - A_{B,R}$
= 7425 in^2
Volume of base curtain EVA, $V_{B,EVA}$ = $t_{EVA} \bullet A_B$
= 37.13 in^3
Tent on base curtain width, $W_{T,B}$ = 23 in
Tent on base curtain length, $L_{T,B}$ = 8 in

Dimension of sides of tent structure (T) (per side)

Height, H_T = 13 in
Width, W_T = 9 in
Corner cut radius = 1.25 in
Total area, A_T = 114.5 in^2
Volume of EVA, $V_{T,EVA}$ = $A_T \bullet t_{EVA}$ = 0.57 in^3

Dimension of flap structure (F) (Plain EVA sheet)

Width, W_F = 30 in
Height, H_F = 27 in
Total area, A_F = 810 in^2
Volume of EVA, $V_{F,EVA}$ = $A_F \bullet t_{EVA}$
= 4.05 in^3

Failure Analysis

For the following calculations, our team will fix the safety factor to 3 for failure analyses purposes.

Tent Structure (T) – 2 tent sides (12" x 8") and 1 tent top on base curtain (23"x8")

Weight of copper BB per short weighted pouch, $P_{Copper,S}$ = 0.1 lbs
Weight of copper BB per long weighted pouch, $P_{Copper,L}$ = 0.8 lbs
Weight of plastic BB per long weighted pouch, $P_{Plastic,L}$ = 0.2 lbs
Weight of EVA sheet, $P_{T,EVA}$ = $\rho_{EVA} \bullet (V_{T,EVA} + W_{T,B} \bullet L_{T,B} \bullet t_{EVA})$
= 0.07 lbs
Total estimated weight of tent, P_T = $P_{T,EVA} + P_{Copper,S} + P_{Copper,L} + P_{Plastic,L}$
= 1.3 lbs
Given safety factor at attachment location, SF_T = 3
Supported per width tensile force at tent attachment location, $P_{T,S}$ = $P_{Y,EVA} / SF_T$
= 2.9 lbs/in
Allowed per width external tensile force on tent, $P_{T,ALLOWED}$ = $P_{T,S} - (P_T / W_{T,B})$
= 2.87 lb/in

Flap (F)

Weight of flap, P_F = $\rho_{EVA} \bullet V_{F,EVA}$
= 0.14 lbs
Given safety factor at attachment location, SF_F = 3
Supported tensile stress at flap attachment location, $P_{F,S}$ = $P_{Y,EVA} / SF_F$
= 2.9 lbs/in
Allowed external tensile force on flap, $P_{F,ALLOWED}$ = $P_{F,S} - (P_F / W_{F,B})$
= 2.9 lbs/in

Base Curtain (B)

Assumption: ½ of the bottom base curtain (final dimension of 96" x 72") is wet:

Weight of dry base curtain, P_B	$= \rho_{EVA} \bullet V_{B,\,EVA}$
	$= 1.32$ lbs
Total weight of the shower curtain, P_{TOT}	$= P_B + P_F + P_T$
	$= 2.76$ lbs
Given safety factor of base shower curtain, SF_B	$= 3$
Supported per unit width tensile force at base shower curtain, $P_{B,\,S}$	$= P_Y / SF_B$
	$= 2.9$ lbs/in
Length of EVA sheet less ring holes' diameter, L_R	$= L_B - N_R \bullet D_R$
	$= 99.8$ in
Cross sectional area at ring holes center, A_C	$= L_R \bullet t_{EVA}$
	$= 0.52$ in^2
Supported tensile force at ring holes, $P_{B@ring}$	$= P_{B,\,S} \bullet A_C$
	$= 293$ lbs
Allowed external tensile force on base curtain, $P_{B,\,ALLOWED}$	$= P_{B@ring} - P_{TOT}$
	$= 290$ lbs
Allowed per unit width tensile force on base curtain	$= 290$ lbs / 107 in
	$= 2.7$ lbs/ in

Conclusion:

The allowed external force to be applied on the shower curtain is 2.7 lbs/in at our fixed safety factor of 3.