Bulkhead St. Xavier High School

A Baccalaureate thesis submitted to the
Department of Mechanical and Materials Engineering
College of Engineering and Applied Science
University of Cincinnati

in partial fulfillment of the
requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology

by

Ryan Fischer, Gretchen Kellerstrass, Nicholas Greiwe

April 2018

Thesis Advisor:

Professor Ahmed Elgafy, Ph.D.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

St Xavier is an all-boys high school that is well known for setting many swimming records. The pool that they use in the Keating Natatorium is used for both long course, 50 meters, and short course, 25 meters. The bulkhead is used to divide the pool so that each of these lengths of courses can be possible. The bulkhead not only acts as a wall but also acts as a bridge. With a bulkhead acting as bridge it gives coaches and racing officials the ability to walk across the middle of the pool without having to be on the side. With our new design we still have to follow rules set by USA Swimming regulations during events.

Installing a bulkhead can become very hard and tedious with all the heavy parts that are used. Installation can take a lot of time to complete. Decreasing the weight of parts and improving the process is the central idea to making this application easier to use.

The new design is focused on using more individual pieces as well as using a more lightweight steel to make the installation process easier on the volunteers. The project was split up into three parts, the walls that make up the frame, the decking that sits on top of the frame and the cart system, which makes it easier to install the bulkhead by assembling it out of the water and moving it to the center of the deck. The frame will be made of smaller, lighter individual pieces that will be bolted together along the way. The frame will then be lifted using the cart system to be moved to the middle of the pool. After that the decking will be able to slide across the frame with the assistance of ball bearings that are attached to the top of the frame. The decking is made of stainless steel and plastic tiles. The tiles are strong, resistant to water and allow water to pass through them.

Overall, this design is more modern than the previous and allows the volunteers to more easily install the bulkhead.

PROBLEM DEFINITION AND RESEARCH

PROBLEM STATEMENT

The Keating Natatorium was built and hosted its first swimmers in 1969. It is a 50-meter pool on the campus of St Xavier High School. The current bulkhead that separates the pool into two is in disrepair and causing many problems. The pieces are old and very heavy and it takes an army of people a long time to install the bulkhead.

(Figure 1: St. Xavier High School Current Bulkhead)

BACKGROUND –

The Keating Natatorium was built almost 50 years ago. It is a 50-meter pool that can be divided into two sections. Swim seasons consist of short and long course format. The long course runs from April to August. The pool length at this point is the full 50 meters. The short course runs from September until March. The pool length in short course is 25 yards.

When the bulkhead is installed it splits the pool into 2 sections each 25-yards. The bulkhead currently in use was built at the same time as the pool. The current bulkhead consists of galvanized steel with fiberglass inserts. The bulkhead is almost 50 years old and the current one present's difficulties when being installed.

The bulkhead consists of 21 pieces. Some pieces can weigh up to 800 pounds. It takes 14-16 men and women, 2 hours to remove/install the structure. With pieces like these weighing so much, it's a very time consuming and strenuous task to undertake. In the past several years no one has been hurt.

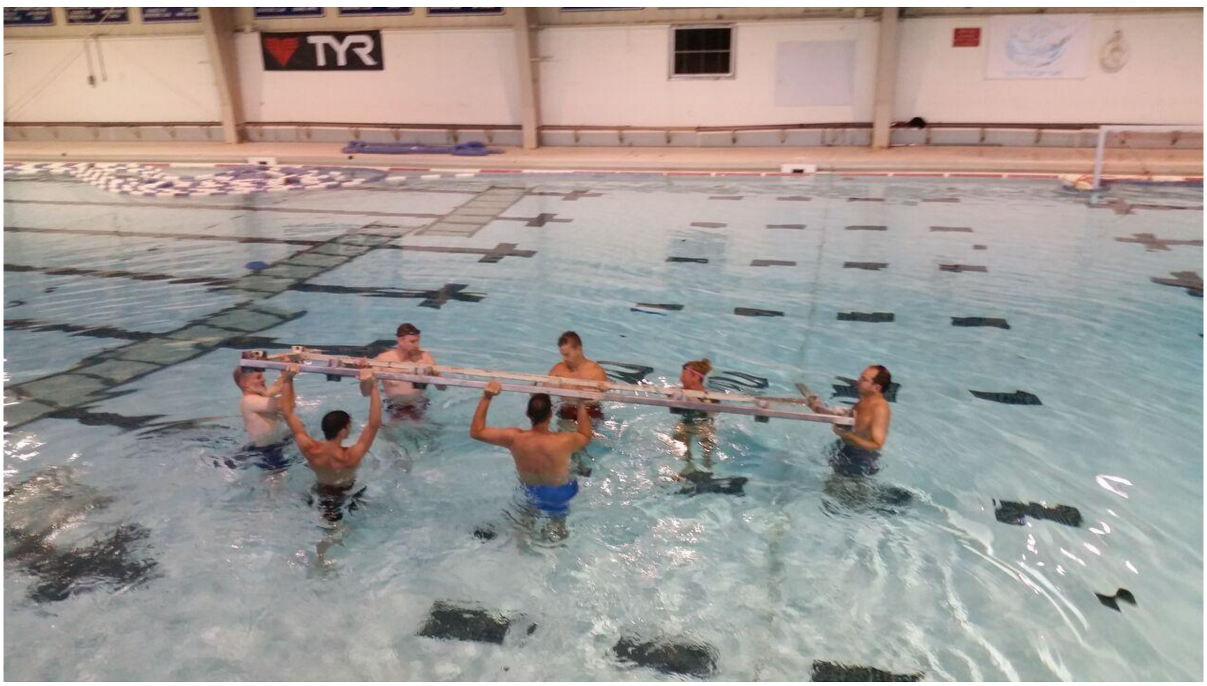
Our main goal is to produce a bulkhead that is more user friendly, easy to move, lighter weight and doesn't require a long amount of time to install. By reducing the amount people needed and less time to install, all the time that was needed in the past to install this, can now be used on something else. By not coming up with a new solution, people will have to take time out of there day and lift very heavy objects twice a year to install this bulkhead.

RESEARCH

SCOPE OF THE PROBLEM

There is no standard procedure for installing the bulkhead. With the current state of the bulkhead pieces at St. Xavier being so heavy, this takes a lot of manpower and time to complete. Bulkhead technology has come so far in the world that now they are easy to move and store and can be easily moved by one or two people but with our current situation we can't make any alterations in/out of the pool. Since we can't make any alterations in/out of the pool we will most likely have to use the current design and modify it to fit any alterations we make.

If you think about each of these pieces being installed some of which weigh 800 lbs, you can tell that this activity is strenuous. As shown in the picture below, you can see how many people it takes in the pool just to move one of the many pieces into place.



(Figure 2: Heavy piece of frame being lifted)

The current bulkhead consists of two bridges which are separated by 5.5 feet of space. One of our tasks is to take this wasted space and make the bulkhead one bridge.

With a lighter and automated bulkhead, we can reduce the amount of people that needed to be on site during installation and reduce the amount of time needed to install. People should not have to suffer just to install this structure.

CURRENT STATE OF THE ART

As the industry stands right now there are currently 3 standard types of bulkheads available for swimming pools. The 3 standard types of bulkheads are movable bulkheads, stationary bulkheads, and vertical bulkheads. Movable bulkheads (1), the most common, can move on a track or on wheels while in the pool. A stationary bulkhead is set in place once in the pool and can't move. Finally, a vertical bulkhead is permanently in place in the pool but can be lowered into a storage space underneath the pool when not in use. Among these groups there are different types of structures that each can be built out of, single piece construction and piece by piece construction. (2)

Currently at St. Xavier High School is a stationary bulkhead that is piece by piece construction. This means that once the bulkhead is in the water, it can't move and is assembled piece by piece every time it is put in and taken out of the water. The other type of structure, the more popular design, is single piece construction. A single piece bulkhead is, as it sounds, made to be installed as a single piece and requires the assistance of either cranes or forklifts. This design is not applicable at St. Xavier because of space limitations.

There are many commonalities between all of the current bulkheads available in the market. In general the structure of the bulkhead is made of stainless steel and the deck and walls is made of PVC plastic. These materials are chosen because of their durability, resistance to pool water and also their relatively light weight. Some other similarities include a "flow through" design that also dampens waves and creates a quiet water surface on opposing sides. Also, many can be removed and reinstalled at any point.

There are many points that the current market fails to address with current bulkheads. We hope to design a bulkhead that address these points and fix some others. The biggest point we want to address is the difficulty of installation of piece by piece construction bulkheads. We hope to create lighter pieces that are easier to install by fewer people. Another point that is missed is bulkheads with extra wide decks. Most current bulkheads are at most 8 feet wide. St. Xavier and many other applications desire a wider deck, in our case 13.5 feet. Finally, we also see a lack of adaptability in current designs, older pools are not exactly standard sizes and premade bulkheads can't be installed into them.

END USER

The end user for this project is St. Xavier High School located in Cincinnati, Ohio. The Natatorium holds several events for the school such as water polo, and swimming events. The parents volunteer to construct and deconstruct the bulkhead at the two different types of seasons. As mentioned earlier, the bulkhead gets assembled and inserted into the pool in August to prepare for the split pool (25 meters for each section) and removed in March for the full-length pool (50 meters).

Due to the large design and heavy parts, the main request was to make each sub-assembly part light weight and easier to handle. The faculty has asked to have approximately 3-4 people handling each of the sub-assembly parts. The current bulkhead has lasted about 50 years, having durability in the new bulkhead is another request. They would like the next bulkhead to last just as long or longer if possible. Both of these concerns will be addressed by using the correct material that will not deteriorate in the chlorinated pool water.

Since the previous bulkhead was custom made to the pool at the time of installation, a requirement is to not make any alterations to the pool in or out of the water. This will limit the design to become custom fit to the pool, and capable of using the already existing storage area that is outside the Natatorium. Another request is to have each of the parts of the bridge be 13.5 feet continuously rather than two 5.5 feet bridges separated with a gap in the middle. This will be a challenge to create parts easy to maneuver through the doors. The parts are left out in an open area outside (exposed to all of the elements) through double doors. Each part was moved inside during the installation using two large dollies, using 4-6 people to maneuver the parts to the middle of the pool.

Finally, the last request was to have the design meet and be able to maintain all of the USA Swimming specification for length (3). Each lane in the pool has a length specification of within an 1/8 of an inch. That way St. Xavier High School can compete or hold events that are capable of setting team, national, or world records because the lane will measure to code. The end goal will be to make each part easy to move, having a lightweight material that is durable through all weather conditions, but also safe to install to continue the no incidents streak. While adapting to a new design, the pool cannot have any alterations to it and each part should be able to be handled by 3-4 people. The final design should be within the USA Swimming specifications to keep the ability to hold official events & records.

CONCLUSIONS AND SUMMARY OF RESEARCH

When it comes to designing our bulkhead specifically to our customer there are many trends and themes that we are trying to follow. There are many problems with the current bulkhead at St. Xavier that we want to address and fix in our new design, the main problem being the difficulty of installation. We also want to address the width of the deck and the adaptability to the old pool. With the combination of our own ideas and other trends in the industry, our new bulkhead design should be the most practical for our customers at St. Xavier High School.

CUSTOMER FEATURES

Although no formal surveys have been taken, when observing the installation process of the current bulkhead we asked the schools staff and parent volunteers what they wanted most out of a new bulkhead. For this, the overwhelming response was that they wanted it to be lighter, less pieces and overall easier to install. Some other features that were requested were to have a full deck across the width (13.5') and for it to last for at least as long as the current bulkhead (50 years).

We interviewed Arthur Allen, the person who proposed the project, over email to get more specifics about the pool and what is needed. From this interview we learned what is expected of us at the end such as a prototype, detailed designs for a manufacturing company and instructions for installation. Some details about the chemicals put in the pool and pool specifications were also brought to our attention.

PRODUCT OBJECTIVES

We have taken into account from the wish list of what the customer would like to incorporate into the new product and have weighed out the importance of each of the features. With the primary objective of the product being lighter weight, material is the ultimate hurdle in this course of action. We aim to find a lighter weight material that is strong, resilient to corrosion, light weight and cost effective. Ultimately finding this certain material will then guide us to our next two core objective. One of which is having a long life span of this product. The other core objective is having smaller parts which will play a key factor into the material of choosing.

These top three objectives are illustrated in the QFD below. We not only take into account what the customer really wants but we also want to understand on a deeper level the mindset of the customer. If we get into the mindset of the customer, we can understand what they truly want if we were in their shoes. Engineers should understand that when developing a product, they need to understand the end user and who will ultimately benefit from this. In our case we won't be the ones using this product but the people at St. Xavier will be. For the time that we spent watching them put the product together, we witnessed the struggles that they encountered. Watching the volunteers put it together and taking a lot of pictures, helped us to make an informed decision on how to best approach this problem.

QUALITY FUNCTION DEPLOYMENT

			Engineering Characteristics (units)																
		Importance wt.	Life Span (years)	Corrosion Factor (in)	Weight of parts (lbs)	Size of parts (ft)	Force (lbf)	Flexibility - movement in Δx (in)									Customer Satisfaction Rating (0.00 - 1.00)		
	Customer Requirements		1	2	3	4	5	6	7	8	9	10	11	12	13	14	CP	A	B
1	Robustness	0.30	9	3															
2	Walk ways Continuous	0.15				9													
3	Light Weight Parts	0.30			9	3													
4	Smaller Parts	0.10			1	9													
5	Stability	0.15		1			9	3											
6																			
7																			
8																			
9																			
10																			
	Total Importance	1.00																	
	Engineering requirement importance		2.70	1.05	2.8	3.15	1.35	0.45											
Performance	current product(CP)		50	XX	up to 800	Varies	XX	+1/8											
	competitor A:																		
	competitor B																		
	New Product Targets		50	XX	<800	Vary	XX												

(Figure 3: QFD)

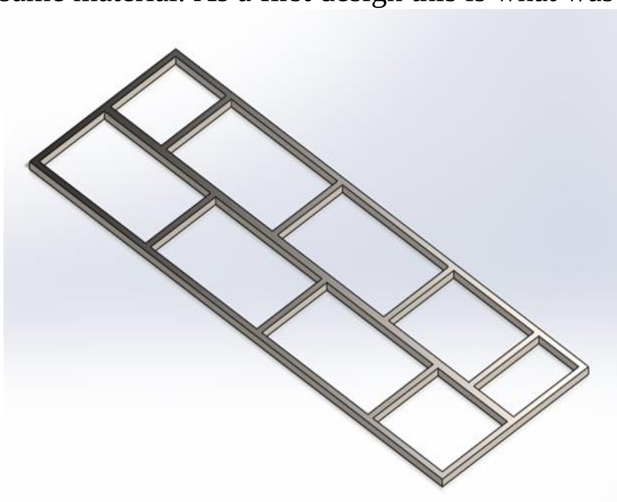
Above is the QFD for this project. But to talk about the QFD, let's start with the company requirements. We came up with 5 requirements that seem to fit the customer's needs and wish list. After filling out the QFD our final list of key design features are stated below in order of importance:

1. Size of parts
2. Lightweight parts
3. Long life span

Showing that the size of the parts will be the most crucial and is on par with what we were listening to and observed during the installation during this fall term. We will aim to create a better performing bulkhead than the current design and hope to achieve a lost cost solution.

Design Alternatives and Selection - Decking

When first starting the project selecting the right material was a big factor when taking into account the design for the decking. The initial design of the decking was going to be made of 304 Stainless steel solid bar. The decking support material that would hold the decking itself would be made of the same material. As a first design this is what was made.

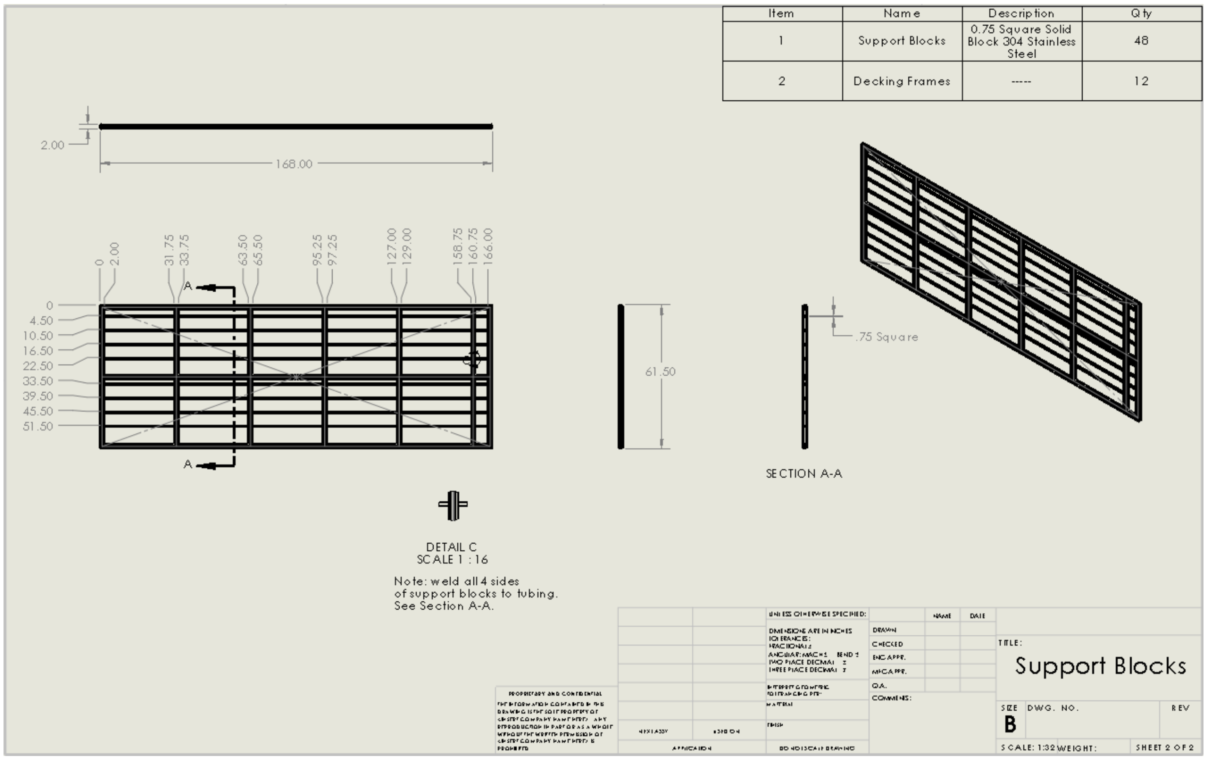


(Figure 4: Alternative 3D Model of Decking)

This design was accurately made from what is currently in use. You can see that all the sections in the frame are all different sizes. Upon getting quotes for this the price was astronomical. The quotes that were received from three different distributors average to around $45,000. After doing some research it was found that solid steel is very heavy so lifting this frame would be a lot heavier than the current application itself.

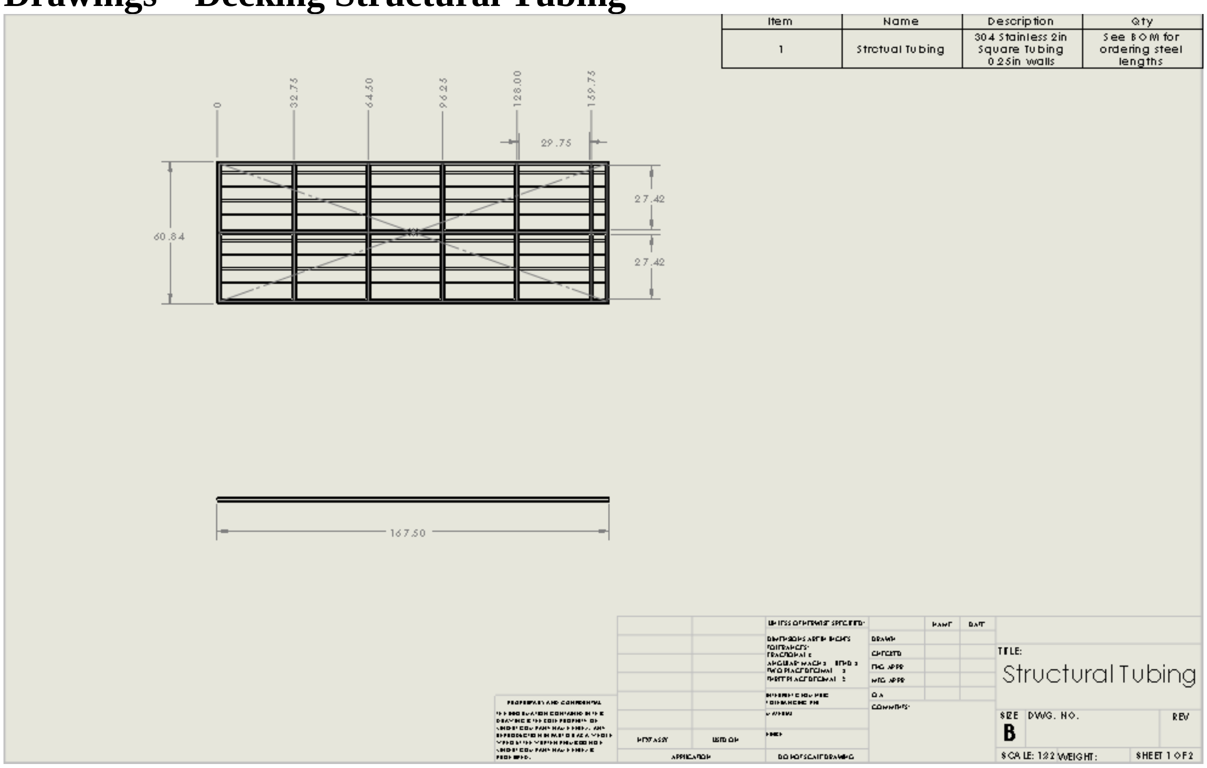
For the decking that was going to be walked on it was first thought that using fiberglass would be the ideal solution. The plan was to have a solid piece of fiberglass which would lie on top of the supports. Unable to find manufacturers that could do this, a manufacturer was found that supplied plastic decking that met the criteria needed. Taking into account the sizes of the sections as seen in (Alternative 3D Model of Decking), the price came in at $4,658.

Drawings - Decking Support Blocks



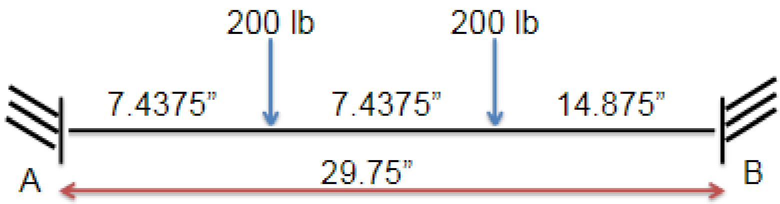
(Figure 5: Drawing of Support Blocks)

Drawings – Decking Structural Tubing



(Figure 6: Drawing for Structural Tubing)

Loading Conditions



200 (7.4375) + 200 (14.875) -Rb(200)=0

4462.5 lb-in = 29.75 in

Rb=150 psi

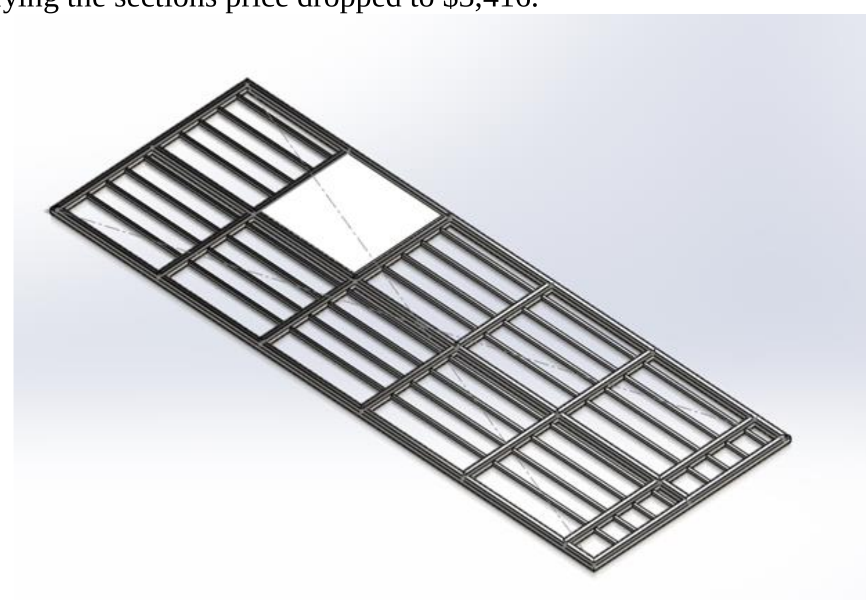
Ra+150 = 400

Ra = 250 psi

(Figure 7: Free body Reaction Diagram)

Design Analysis

Since our constraints defined what we could do, we had to improvise and come up with a solution. Although we could have just taken the original design and modernized it a bit more, we wanted to make our design unique. As you can see on page 10 for figure 2, the original idea was to take the exact design and modify it accordingly. Since that didn't work the decking was simplified. Looking below in Figure 3, the decking was simplified to have all uniform sized sections. It simplified the area for the amount of decking needed to be put down and made the design more unique. When getting quotes between the original design and the one seen below, there was a small price reduction. The original quote was $4,658 and after simplifying the sections price dropped to $3,416.



(Figure 8: Actual 3D Model of Decking)

In the way of steel cost it was originally thought to have the whole frame made of solid bar stainless steel. This would have made the frame very heavy to lift not to mention very expensive. We then changed the steel to square tubing. It still provided the support needed but it would make the frame lighter and the cost for the steel would be cheaper. We still kept the structural supports that held the decking solid steel bars. Comparing the original to the one now the original price was averaged around $45,000. The newer design came out to around $25,000.

In terms of calculations which you can see a load applied to one section of the frame in Loading Conditions, the structure would have no problem holding up the weight that is applied to it.

Factors of Safety of Concern (if near design factor)- Decking

With 304 Stainless having a yield strength of 31,200 psi according to MATWEB an online database for material property data, this yield strength is still high enough to support any load that is placed on it. For one section of decking we can compute the safety factor as followed:

29.75” x 27.42” = 815.74 in^2

Assume 3 people 200 lb/each

Stress=600lb/815.74in^2 =0.735 psi

S.F.=31,200psi/0.735psi=42,418

Now this was only computed for 3 people on one section of frame. We need to compute for multiple spread out across one decking frame because that is the more realistic option. For a factor of safety, if you were to apply that a load across the entire 14 foot span of frame but with 10 people you would have 1 ton of weight applied to the frame or 2000lb. When we compute for this we get the following:

163.5” x 56.84” = 9293.34 in^2
These dimensions are the inner area
Assume 10 people 200 lb/each

Stress=2000lb/9293.34in^2 =0.215 psi

S.F.=31,200psi/0.215psi=144,976

To note these values are just for the strength of the steel. The decking that they will be walking on hasn’t been taken into account yet. According to the manufacture of the plastic decking, the rated load is 5120 psi. I assume at best that per section of decking there will be about 5 people. When recalculating to compute the safety factor for the decking we get the following:

29.75” x 27.42” = 815.74 in^2

Assume 5 people 200 lb/each

Stress=1000lb/815.74in^2 =1.22 psi

S.F.=5,120psi/1.22psi=4,197

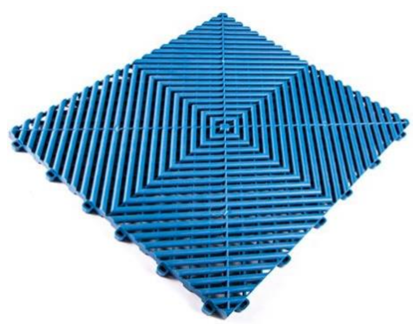
We don’t need to compute for the span over the entire decking because each section of the decking is sectioned off as seen in on the previous page.

The safety factor was increased due to the chlorinated environment which over time will deteriorate the structure due to corrosion. It was said to us by Mark Dulle who runs the business operations of St Xavier swimming; he said that on average he estimates that across the entire span of the whole pool there could be about 50 people. With the 12 pieces that will be installed that's about 4 people per decking frame. Looking back at the 10 people we assumed that would be spread out across one frame piece as a safety, it doesn't even come close to the average 4 people. In terms of safety for the decking these pieces should have no problem. If we wanted to get a safety factor lower hypothetically to the common safety of 2, the highest load on the decking we could apply safely would be close to 5000lb. Even when applying that load to one section that would be about the equivalent of 25 people per section. In reality each section of frame won't even come close to seeing that amount of people. It's also due to the fact that the area of one section can't contain that many people. The load on the frame is spread out and is not centralized. So while one frame may experience 5000 lb spread out, another could experience a little more or less.

Component Selection - Decking

After going back to the drawing board, a final design was created. To reduce the weight of the frame, the steel was changed from solid steel to 304 Stainless square 2in tubing for the frame and solid steel for the supports. This certain type of steel provides many unique attributes. It provides enough strength to support the load that is placed on it; its chemical attributes give it good corrosion resistance for the chlorine environment and the price and weight of tubing steel is lighter and cheaper than solid. Although solid is still used for the cross supports to hold the decking, those pieces are smaller in size and won't be as heavy.

For the decking itself instead of doing a solid piece of fiberglass, plastic decking from a certain manufacturer was found to be more suitable. The decking will be made of high impact polypropylene which is a durable hard thermoplastic as seen below.



(Figure 9: Plastic Decking)

These plastic decking pieces are extremely light weight and are easy to install and take apart. These pieces also have a load rating by manufacturer of 5120 psi.

Bill of Material -Decking

Item #	Product Name	Qty	Price	Distributor	Additional Info
1	Garage Floor Ribtrax Tiles	528	$3,416	Rubber Flooring Inc.	Search for Ribtrax Tiles on distributor website
2	304 Stainless Steel 2in tubing 0.25in walls	36	$15,091	Steel can be ordered from any supplier. *Note Ryerson and Riverfront Steel are 2 local steel distributors.	14.5ft of steel is needed in this quantity
3		84			5ft of steel is needed in this quantity
4	304 Stainless Steel Bar 0.75in square	480	$7,118		2.5ft of steel is needed in this quantity
5		96	$357		5in of steel is needed in this quantity
Total			$25,982. *Note the price of steel changes so besides the decking; the steel cost reflected above is not current upon reading this.		

PROJECT MANAGEMENT

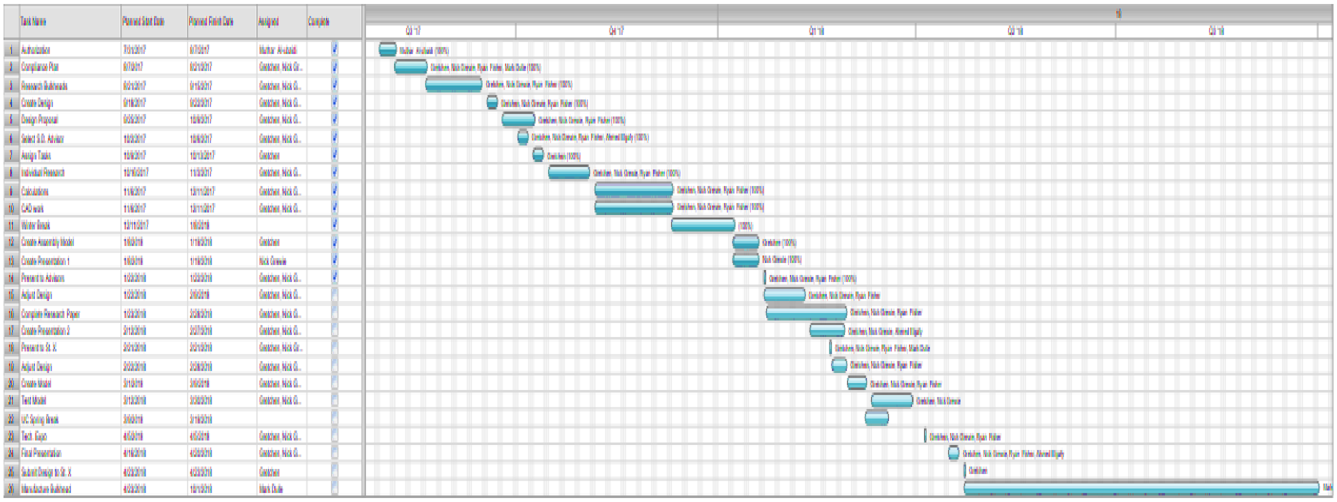
BUDGET, PROPOSED/ACTUAL

As it was said to us by Mark Dulle before starting the project and doing research, they expected the system to cost around $100k minimum which is labor and material. In material alone we priced it around $67,401. When we presented to St Xavier and showed them material cost, they said that it was on par with what they predicted. They received a quote from a manufacture which includes labor and material and the quote they received was about $107,000. If we were to predict how much it would cost for labor I believe that we would be on par for what they quoted.

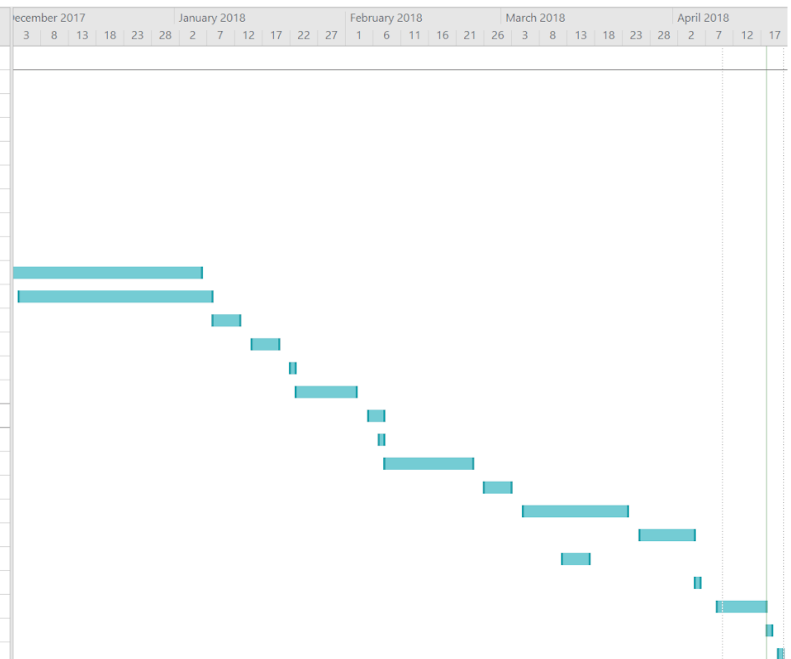
SCHEDULE, PROPOSED /ACTUAL

(Proposed Schedule)

Bulkhead - Project Management - 18 Feb 2018



Task Name	Duration	Start	Finish	Predecessors
Authorization	5 days	Mon 7/31/17	Fri 8/4/17	
Compliance Plan	5 days	Mon 8/7/17	Fri 8/11/17	1
Research	14 days	Mon 8/14/17	Thu 8/31/17	
Concept Design	11 days	Fri 9/1/17	Fri 9/15/17	
Assign Design Roles	1 day	Mon 9/18/17	Mon 9/18/17	
Design Proposal	4 days	Tue 9/19/17	Fri 9/22/17	
Select S.D. Advisor	1 day	Tue 9/19/17	Tue 9/19/17	
Individual Research	15 days	Mon 9/25/17	Fri 10/13/17	
Individual Calculations	25 days	Mon 10/16/17	Fri 11/17/17	
CAD Design	35 days	Mon 11/20/17	Fri 1/5/18	
UC Winter Break	26 days	Mon 12/4/17	Sun 1/7/18	
Create assembly model	5 days	Mon 1/8/18	Fri 1/12/18	
Create Presentation 1	5 days	Mon 1/15/18	Fri 1/19/18	
Midterm Presentation	1 day	Mon 1/22/18	Mon 1/22/18	
Adjust Design	9 days	Tue 1/23/18	Fri 2/2/18	
Create Presentation 2	3 days	Mon 2/5/18	Wed 2/7/18	
Present to St. X	1 day	Wed 2/7/18	Wed 2/7/18	
Adjust Design	12 days	Thu 2/8/18	Fri 2/23/18	
Order Material	5 days	Mon 2/26/18	Fri 3/2/18	
Create model	15 days	Mon 3/5/18	Fri 3/23/18	
Test Model	8 days	Mon 3/26/18	Wed 4/4/18	
UC Spring Break	5 days	Mon 3/12/18	Fri 3/16/18	
Technical Expo	1 day	Thu 4/5/18	Thu 4/5/18	
Write Research Paper	7 days	Mon 4/9/18	Tue 4/17/18	
Presentation 3	1 day	Wed 4/18/18	Wed 4/18/18	
Submit Design	1 day	Fri 4/20/18	Fri 4/20/18	



(Actual Schedule)

Between the proposed schedule and the actual schedule, the actual was a lot more pushed for time. As we had to do testing as part of the requirements for senior design, getting the right amount of material without breaking the bank was a problem. It wasn't until after spring break that I finally was able to get a handle on what I wanted my design to look like and still be able to prove that the concept worked.

PLAN TO FINISH

The primary goal of this project was to come up with a new concept and be able to hand it over to the people of St. Xavier. The cost to build this entire contraption would cost a little over $100,000.

For finishing the project, finalization of all drawings and bill of materials will be put together and handed to St. Xavier. At that point it's up to them whether or not they would like to have this plan built or to just take ideas from our concept and go with another builder.

Works Cited

1. Bulkheads. *Paddock Industries.* [Online] May 1, 2017. [Cited: September 15, 2017.] http://www.paddockindustries.com/wp-content/uploads/2017/05/Movable-Bulkhead-Cut-Sheets-fb-5-1-17.pdf.

2. Moving Bulkheads Start to Finish. *Natare.* [Online] [Cited: August 25, 2017.] https://www.natare.com/equipment-systems/bulkheads/.

3. Certifying Pools. *Pacific Swimming.* [Online] 2010. [Cited: September 6, 2017.] http://www.pacswim.org/certifyingpools.pdf.

APPENDIX A - TESTING

Testing Model Build - Decking

For testing the model, ½ scale model of one section was built. This used the same grade of steel that would be used in the actual. As seen below in Figure 5, only half of one section was built. The 4 going across are the support blocks that the decking will be resting on. The supports are welded to the two tubing's on the side. In the full scale model there would be tubing going across the top and bottom of the section. To save money for testing the top and bottom pieces were not needed because the forces being applied are not being applied to those parts but only the support blocks.

Testing Method & Results

Once this ½ scale as seen below was built, the plastic decking as seen on page 37, was placed on top of the supports. The structure was elevated to simulate the decking over water. A human was placed on top and was able to stomp and jump on it. The structure was able to hold up to the movements that were placed on it without any problems.

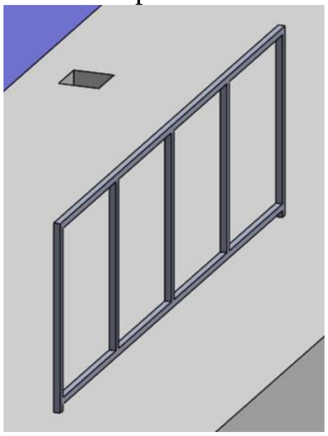
(Figure 10: Half Size Test Model)

Appendix B - Installation Instructions

The following instructions are what would be provided to the St. Xavier staff to assist with the installation of the new bulkhead design. The illustrations are a simplified version of what the actual bulkhead looks like but it is made simply to make it easier for volunteers to follow. With the first installation, it would be recommended that we were there to assist with the installation so that everything is assembled correctly.

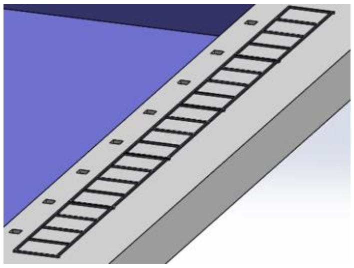
Step 1:

- Assemble each section of the vertical walls
  - Place and secure all bolts for vertical supports and horizontal cross beams
- Repeat for each section



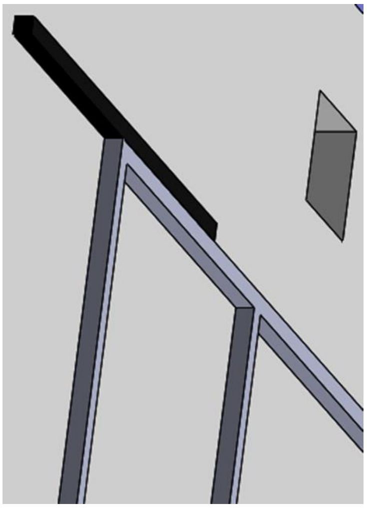
Step 2:

- Lay completed selections flat on pool decking
- Connect vertical sections for full width of the pool
  - Drop in bolts and tightly secure in place



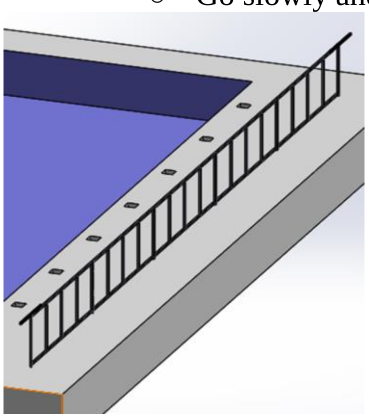
Step 3:

- Connect Connector piece to horizontal supports on each end
    - Place and secure all bolts



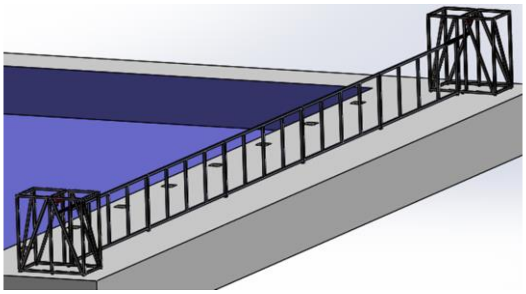
Step 4:

- Lift total length of vertical wall vertical
    - Go slowly and hold in place



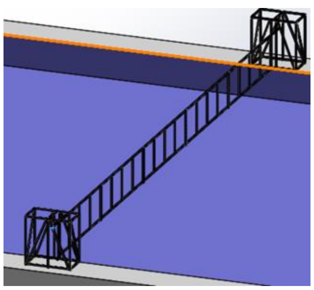
Step 5:

- Connect vertical wall to cart
  - Connector piece will connect to chain hoist system



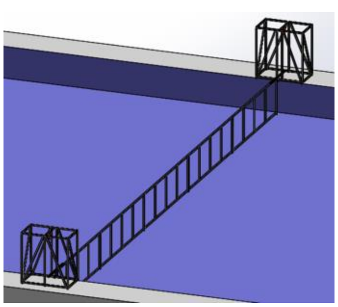
Step 6:

- Lift vertical wall up slightly off the ground
  - Use the chain hoist
- Move vertical wall to center of the pool over the shoes in the bottom of the pool
  - Push carts slowly and evenly



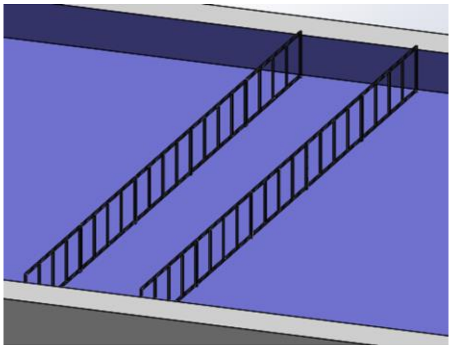
Step 7:

- Lower vertical wall into the shoes in the bottom of the pool
- Bolt the vertical supports into the shoes
  - Make sure bolts are tightly secure
- Release vertical from chain hoist and cart system
- Remove connector pieces from each end
- Bring carts and connector pieces to the edge of the pool for next wall



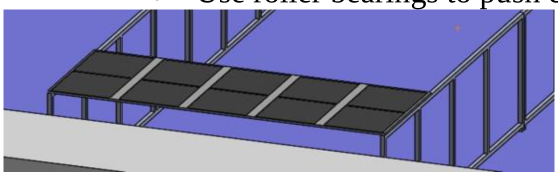
Step 8:

- Repeat steps 1 through 8 for other vertical wall



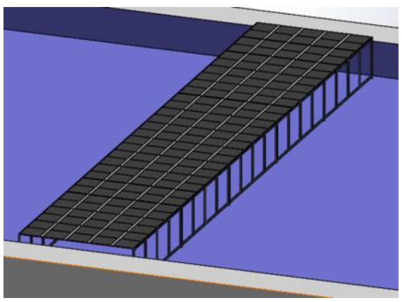
Step 9:

- Slide decking pieces onto vertical walls
    - Decking will fit into vertical walls into L slot
    - Slide on piece by piece
    - Use roller bearings to push each piece to the center



Step 10:

- Repeat decking installation procedure for entire width of pool
    - Push each piece to the center of the pool



Disassembly:

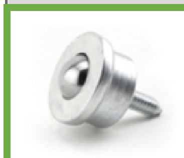
To disassemble the bulkhead and move it out of the pool and back into storage, these steps will be followed in reverse order. In the storage area, the parts should be stored in a method that makes it most convenient to remove for the installation process.

Appendix C – Frame Design

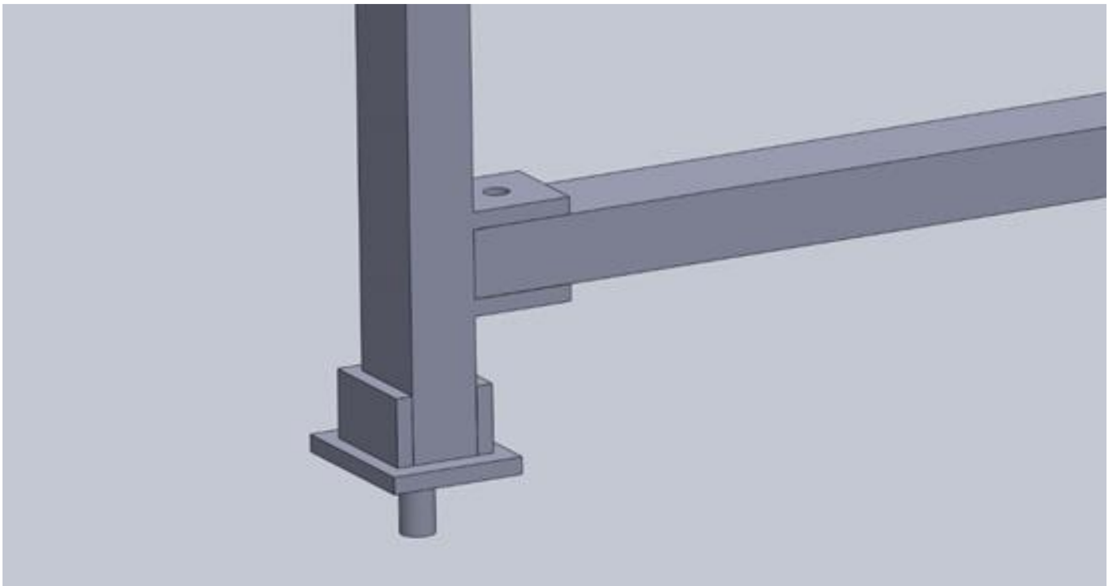
The individual parts of the design were going to reflect a similar design to the current bulkhead, due to the constraints of not being able to change the pool. The design of the feet (that anchor the frame to the pool floor) had to be the same for the design. All other parts of the frame was made of lighter weight but yet still strong material. The next decision that I had to make was between 2”x2”, 3”x2”, or 3”x3” tubing. The tubing selection depends on which part of the frame. After completing my calculations and making assumptions the frame is made up of the following:

Part Name	Total Qty	Size
Column - end	4	3"x3"x1/4"
Column - middle	6	3"x3"x1/4"
Wall Upper Beam	8	2"x2"x1/4"
Wall Lower Beam	8	2"x2"x1/4"

To reduce the amount of work and lifting that will be done to slide the decking one. These stainless steel ball bearings were used. They will help the volunteers to slide the decking on with ease.

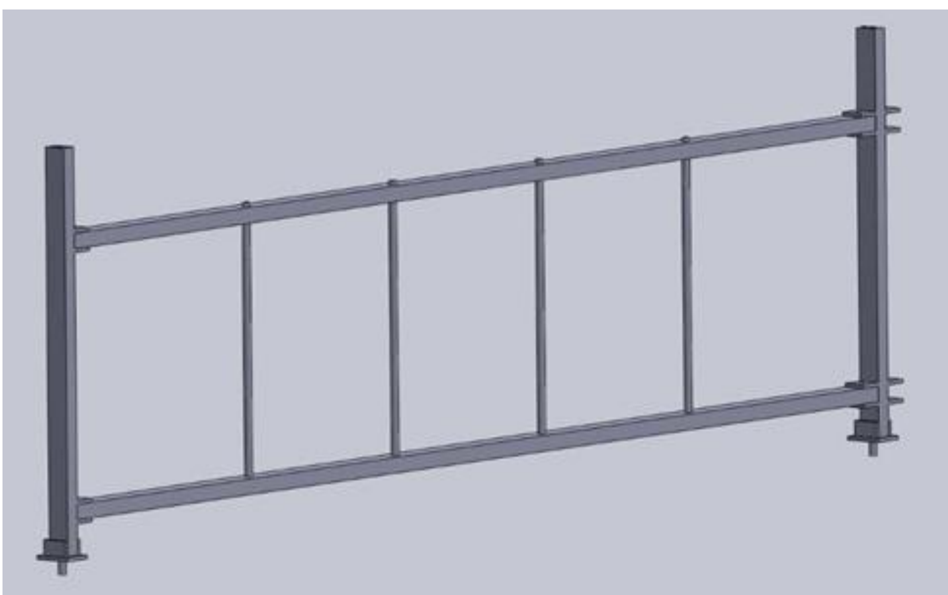
Item	Price	Capacity (lb.)	Mounting Bolt (in.)	Weight (lb.)	Width (in)	Height (in)	Ball Diameter (in)
 Hudson Bearings 5/8" Stainless Steel Main Item #: T9FB536724	$ 19.50	125	1/2 x 1/4-20	0.14	1-3/16	13/16	5/8
 Hudson Bearings 1" Stainless Steel Main Item #: T9FB536728	$ 31.95	200	3/4 x 5/16-18	0.45	1-43/64	1-1/4	1

(Figure 11: Ball Bearings Selected)



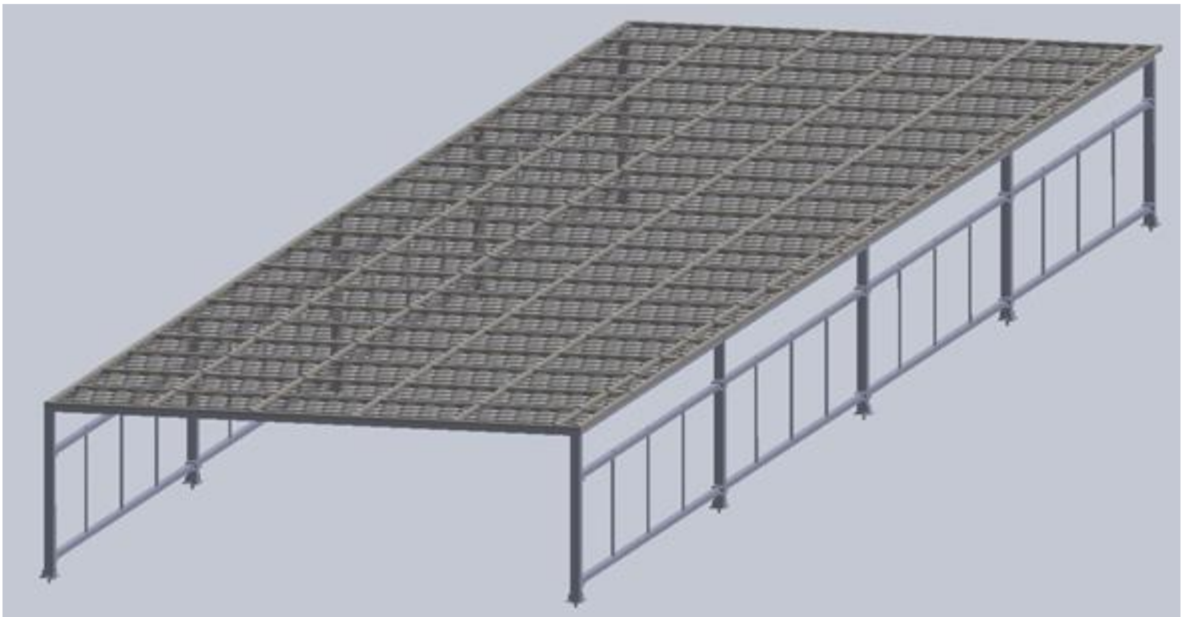
(Figure 12: Foot Design)

These are the designs for the foot. They are directly similar to the ones that are used in the pool. The supports will slide into these shoes which will slide into holes at the bottom of the pool.



(Figure 13: End Sections of Frame)

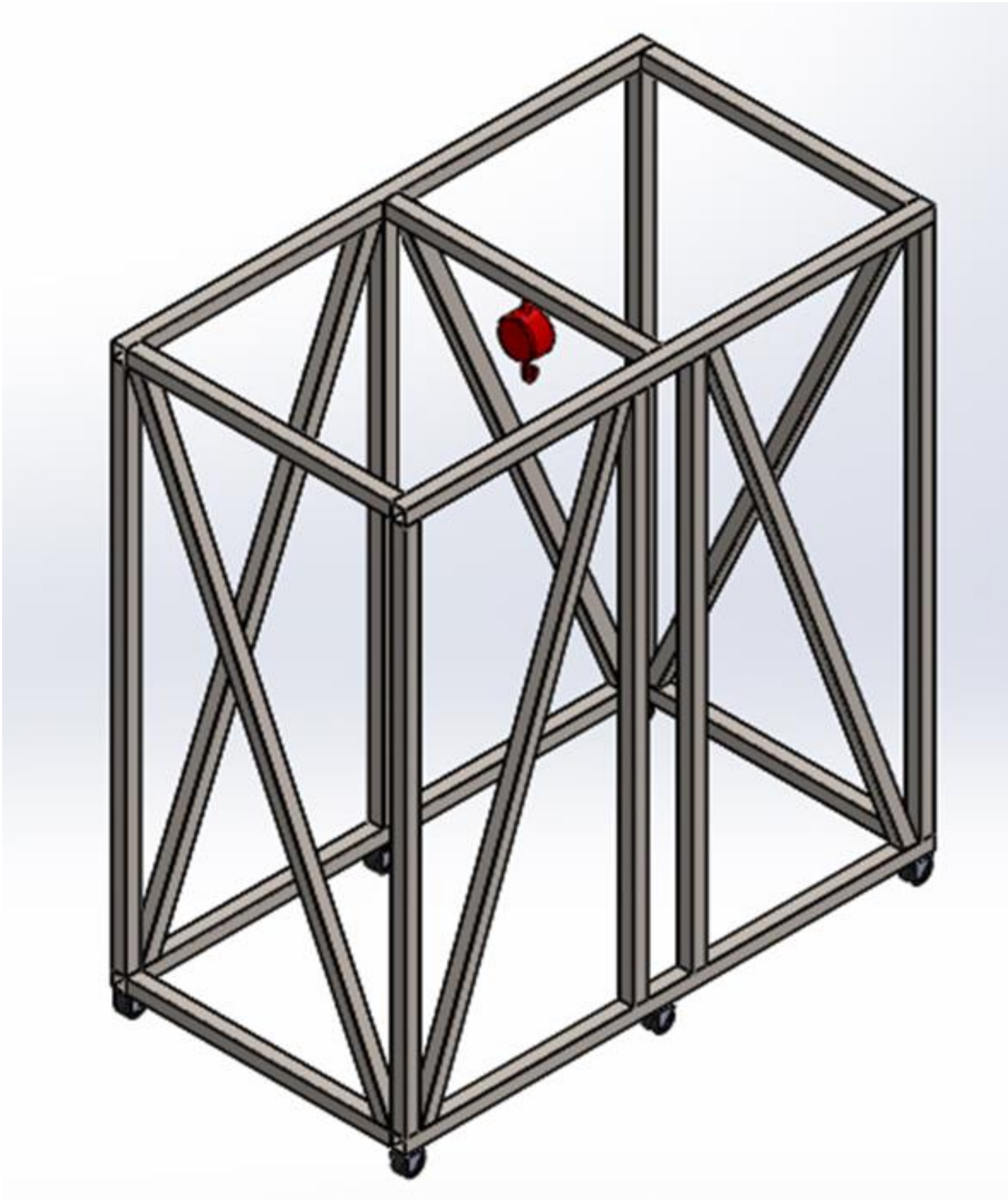
You can see above what a piece of the frame on how this works.


(Figure 14: 3D Overall Design with Frame and Decking)
Here is the overall design of the system

Appendix D – Cart System

As the current system for assembling the bulkhead is putting the pieces into the pool, we wanted to create a way for the structure to be assembled out of the pool then lifted and sent down into the pool. This would help reduce the amount of people needed to lift.

The pieces would be assembled out of the pool then lifted and sent down. See Appendix B for a more detailed representation of how the frame would be installed into the pool. On the next page you can see an overall design of the cart system.



(Figure 15: Overall Design of Cart System)