The redesign of the WaterWave

A bachelors final assignment

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UNIVERSITY OF TWENTE.

ProSun®

Bachelors assignment
The redesign of the ProSun WaterWave

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This report is written for the bachelors final assignment for the bachelor study Industrial design.

Preface

This bachelors final assignment has been done for the University of Twente, study industrial design. For a few months I was fortunate to learn more about the company ProSun in Florida. I learned their ways, their products and the people in the company. The goal was to redesign the WaterWave to be more cost efficient. A description of the redesign as well as the final design are described in this report.

I would like to thank everyone at ProSun for their support during my stay. I especially want to thank Tom and Katrina Henkemans for enabling me to stay at their home and intern at their company. Also I would like to thank my office roommate Arjan Domisse for his extensive support and help during the project.

From the university i would like to thank Wessel Wits for his support and guidance which aided me in bringing the assignment to good end.

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1. Introduction

This report describes the redesign of the ProSun WaterWave. A massage bed which uses hydro massage.

In the first chapter a short description of the assignment will be discussed. This description includes the initial goals and requirements set for the redesign.

The second chapter describes all the analyses which were done to setup the final requirements for the redesign. The first analysis is an analysis of how the product works, the second analysis is the cost and component analysis, the third is the bottleneck analysis and last is the noise analysis.

Chapter three discusses the redesign of the several main components and subassemblies of the product. First for every subassembly a set of requirements is made based on the analyses, second a redesign of that product is done, third a cost estimation of the component is done and last the component is checked to the requirements.

Chapter four describes the final redesign and the integration of all the components. First an overview is given on how all components are placed, second a few potential problems when assembling is given and the solution for these problems is discussed.

The last chapter, chapter five, gives the conclusion, evaluation and recommendations concerning the redesign and process.

2. Assignment description and goals

For this bachelors final assignment a redesign is done for ProSun international located in St. Petersburg Florida. ProSun produces wellness equipment for the professional and private market. In this chapter the assignment description and the goals for the redesign will be discussed.

First the assignment description will be discussed, second the goals of the assignment, third the initial company requirements are discussed and last a glossary is given.

2.1 Assignment description

ProSun has developed a massage bed called the WaterWave. This product is currently produced inefficiently and still has a lot of room for improvement. The assignment is to redesign the ProSun WaterWave to reduce production costs while keeping the same quality of massage. The current massaging technique, massaging with water jets, has to stay the same.

2.2 Goal for the assignment

The goal for the bachelors final assignment is to redesign the WaterWave so it can be produced more efficiently and more cost effective. While redesigning the product the usability and serviceability has be kept in mind.

First a product analysis is done to explore how the current parts work. Second an analysis is done to explore which parts are currently in the product and how much they cost. Fourth a bottleneck analyses is done to explore any problems within the product. Fifth the components are redesigned to reduce production cost or remove occurring problems. Last all components are combined and integrated.

The end result is a concrete proposition for the redesign of the WaterWave in the form of a 3-D model. Also an estimation is done of the expected cost reduction of the redesign. The proposition can be developed by ProSun to a new version of the WaterWave.

2.3 Initial company requirements

At the start of the project ProSun had some initial requirements. The main requirement is the cost price requirement but there were also some others.

- The total cost price of the total product must be reduced to $2500 or less
- The massage technique of the product must stay the same
- The quality of the massage must improve by improving the nozzles
- The outside dimensions of the product must stay the same.
- ProSun does not wish to acquire new machines
- ProSun does not want to replace existing molds.
- ProSun wants to use as much standard parts as possible, preferably from one supplier per part category

2.4 Glossary

Some terms will play an important role in the report and might get confused with something else. These will be explained here.

The product

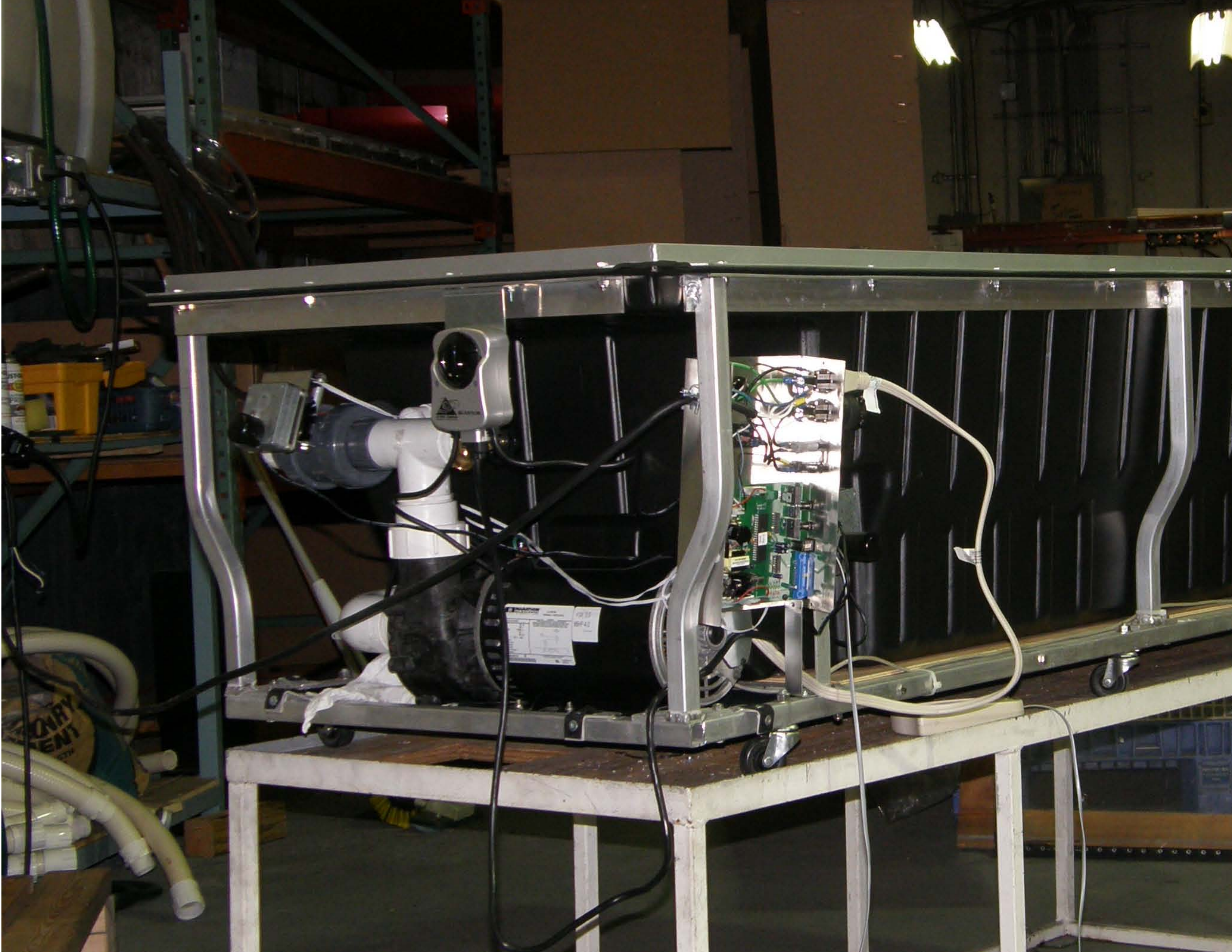
The ProSun WaterWave

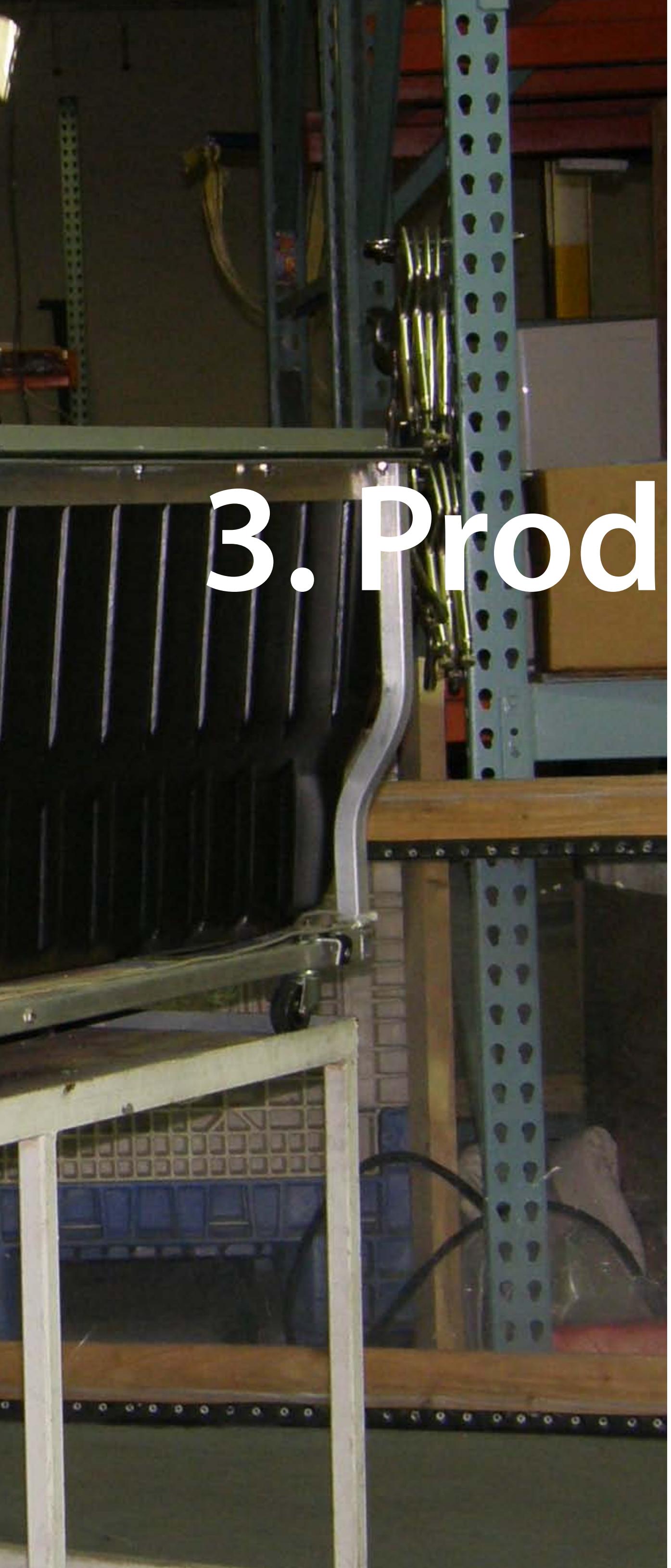
Product Tree

A specification of the product assemblies and components, structured in a tree diagram. Going in more detail as levels decent.

Cost efficient

Cost being as low as possible yet maintaining the required quality.





3. Product analyses

This chapter describes the product analyses which are done to get a comprehensive idea of the product and opportunities for improvement. At the end of this paragraph the product can be divided in a selection of subassemblies which are redesigned. The chapter consists of an analysis of how the product works, the parts, the cost, the bottlenecks and the unwanted noise the product produces when running. These analyses and the companies initial requirements are used to determine the resulting requirements for the redesign of the WaterWave.

3.1 How the product works

The WaterWave is a complex product, but the massaging technique itself is actually a very simple but clever concept. In this paragraph an explanation will be given on how the WaterWave works.

First the massage method will be discussed, and second the technical working of the product

3.1.1 Massage method

The Pro Sun WaterWave uses a technique called hydrotherapy massage. This means that the WaterWave uses high powered water jets to massage the muscle tissue on the human body. By propelling pressurized water onto the muscle tissue it improves the blood circulation. This relieves stress in the muscles. The water inside the WaterWave is heated as well helping with pain relief.

3.1.2 Technical working of the product

The WaterWave can massage from head to toe depending on the length and size of the person that's laying on it. The user has control of the area, duration and pressure of the massage using a remote control. The user lies on a thin net with a thin layer of cloth over it above the water nozzles. This means the user will not get wet during the massage. Figure 3.1.1 shows a picture of the outside of the WaterWave before redesign.

Figure 3.1.1

Figure 3.1.2 shows an overview of the inside of the WaterWave. In this paragraph the main parts of the WaterWave and how they work will be discussed.

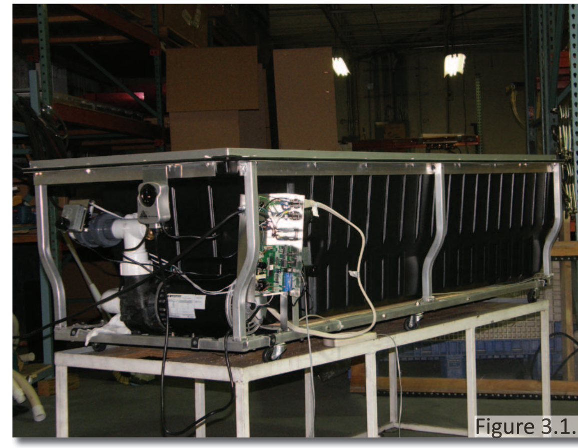


Figure 3.1.2

A 1,5 horsepower electric motor is used to pump 70 gallons of water through a network of pipes through a hose to the nozzles.

Temperature is regulated using a thermal pad heater and a digital thermostat. The thermostat is shown in Figure 3.1.3. The water is heated continuously so the WaterWave is ready to use instantly. Besides the heating mat the water is also heated by the pump once it starts pumping.

Figure 3.1.3

The mechanism to move the nozzles up and down in the tub is located partially in and partially outside the tub. The drive motor is located outside of the tub, to prevent short circuits that could happen if it would be in contact with water. Figure 3.1.4 shows the drive motor. The rest of the mechanism is located in the tub.

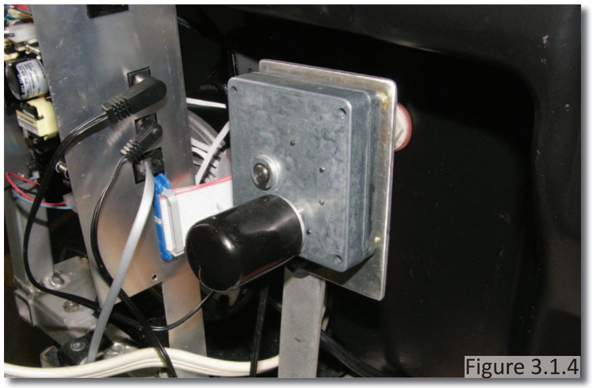


Figure 3.1.4

On the right, in Figure 3.1.5, an overview of the inside of the tub is shown, the inside of the tub contains the rest of the driving mechanism for the nozzle carriage. The hose in the tub provides the flexibility to move the carriage up and down and provides enough water for the desired massage intensity.

The carriage moves by being towed up and down a track which is mounted at the inside of the tub. The guidance is done by wheels on the nozzle carriage. The towing is done by a thin cable which is fixed on one side on the carriage and rotates on a pulley on both ends of the tub. One of these pulleys is driven by the drive motor.

The nozzles are holes drilled in a straight line in a piece of normal pvc pipe. The holes are aimed upwards. By putting enough water pressure on this pipe the water jets upwards in a continuous stream.

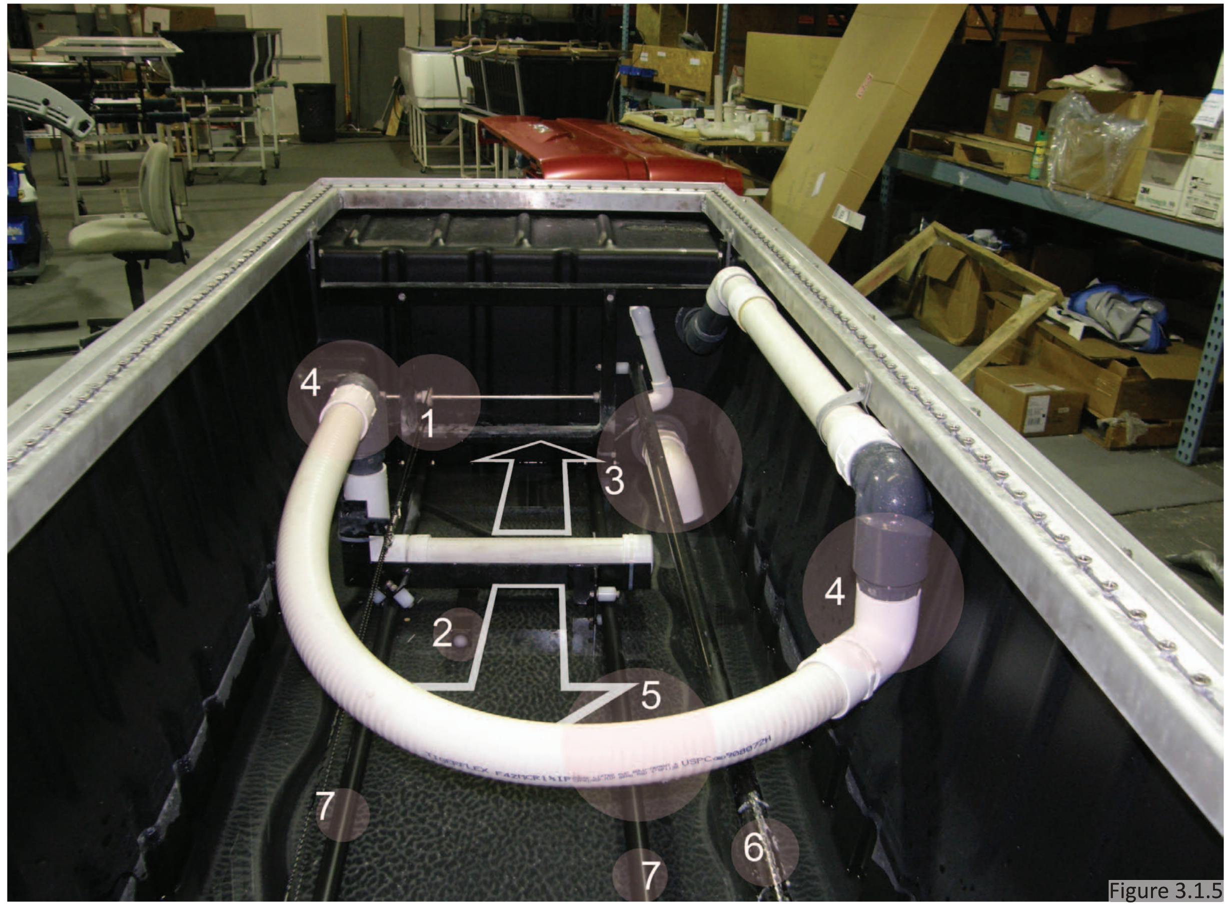


Figure 3.1.5

Legend

1. *Drive pulley with synchromesh cable, this cable is attached to the cradle.*
2. *Magnet. By detecting if the magnet is close by, the distance between the cart and obstacles is measured*
3. *Water intake*
4. *Swivel connections. By being able to rotate at these connections the water hose will not get stuck or hold back the cradle.*
5. *Water hose*
6. *Hose guidance. This rail makes sure the hose does not fall down causing the hose to get stuck*
7. *Cradle guidance rails. These rails guide the cradle up and down the tub, making sure it stays straight and does not get stuck.*

3.2 Component and cost analysis

To find out which parts and assemblies could lead to cost reduction and which components are suitable for redesign a component and cost analysis is made. The analysis gives an overview of the components and their cost. The analysis is done by taking the product apart and analyzing the bill of material. During this process every part is checked for cost and redundancy. From this analysis several tree diagrams are made. By studying these diagrams a conclusion is made on which components to possibly focus on during the redesign of the product.

First the main components in the first level are discussed. Second the main components in the second level of the product are discussed. Third the high and low quantity parts are discussed, fourth the expensive components are elaborated. Fifth the components which can removed without problems are discussed and last a conclusion is made on which parts should be redesigned based on the cost perspective.

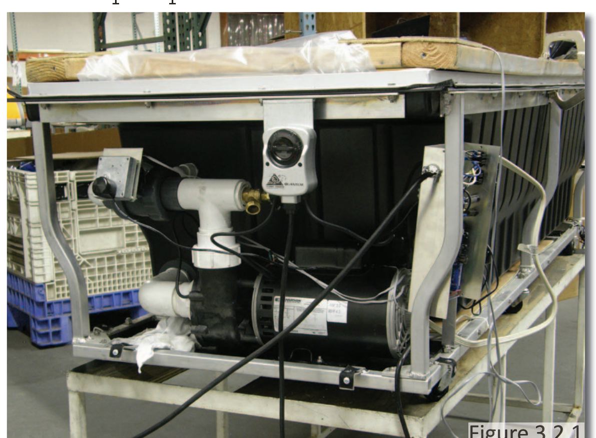


Figure 3.2.1

3.2.1 Main components first level

Figure 3.2.3 shows a tree diagram, this diagram is extracted from the tree diagrams in appendix A, which are in turn extracted from the bill of material for the WaterWave supplied by the company. The tree diagram shows the main first level subassemblies and components. In the box below the component or subassembly the total cost and quantity is shown. The total cost of the residential 110v WaterWave is about $ 2700.

In the diagram it is shown that the "subassembly unit WaterWave 110v" takes up a big part of the total production cost. The reason for the large cost is that this subassembly houses all the technical equipment of the product.

In the diagram it is also shown that the top of the product is quite costly. The top consists of the bladder, a net with reinforcements, bacteria resistant sheet and the front, back and side rails. Adding up to a total of around $ 270. A picture of the top of the WaterWave is shown in figure 3.2.2.

Figure 3.2.2

The four cover plates of the product are used to cover up any electronics, the internal framework and tub. These have to be of good quality and good looking materials because they are the face of the product. They add up to $ 250 and are also a quite big chunk of the total production costs. In figure 3.2.4 two mounted cover plates are shown.

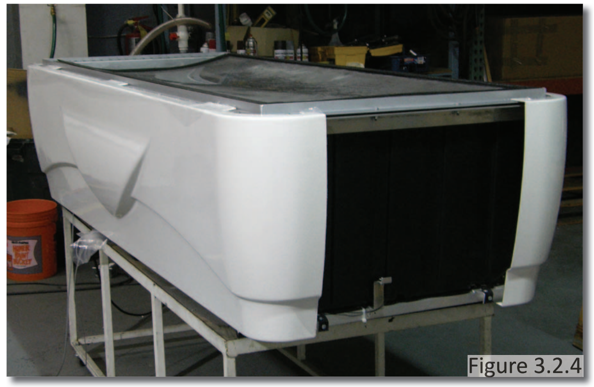


Figure 3.2.4

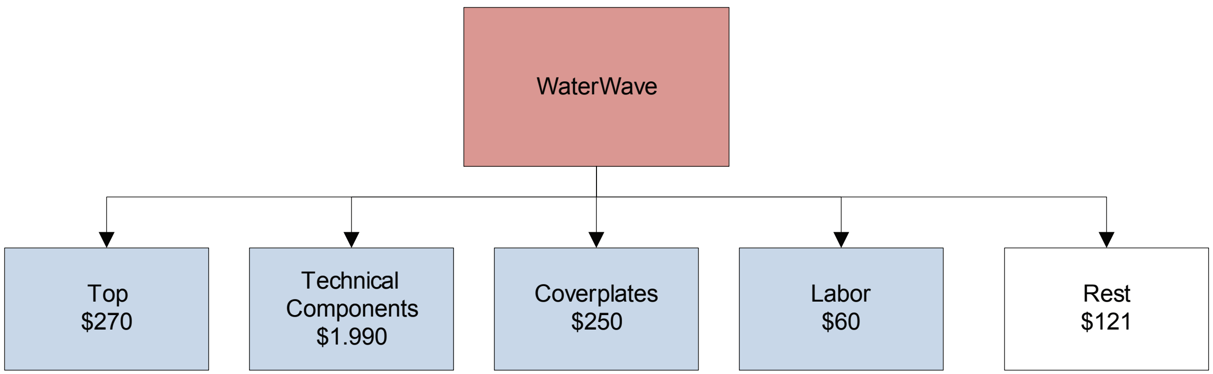


Figure 3.2.3

3.2.2 Main components second level

On the right page in Figure (..) a tree diagram for the "Subassembly Unit WaterWave 110v" is shown. This was done because this subassembly is the main technical assembly and it is therefore an important part of the product.

In the tree diagram again an overview of subassemblies and components is given. The box below every subassembly or component shows the total price of it and the quantity used. Apart from labor, which is $ 144. There are several main subassemblies for this assembly which have high production cost, these subassemblies are listed below.

The "Subassembly Pump WaterWave" is the pump which pumps the water through the plumbing system in the WaterWave. This is a pump also used in spa's to power the water jets.

The "Subassembly PCBA Hand control" is the hand control used to operate the product. The hand control is attached to the control box by a wire.

The "Subassembly Drive Motor" (Figure 3.2.5) which drives the carriage system inside the tub. This is a motor which drives the axle for the carriage system. The axle is going through the tub with a watertight seal.

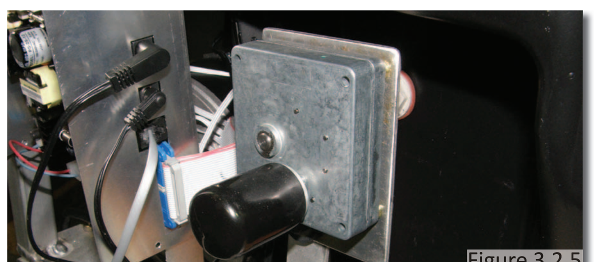


Figure 3.2.5

The "Subassembly Rev 2 Valve Motor" is the part which controls the amount of water flowing through the system, and with that the strength of the water jets. This is not regulated by varying the motor power but by the amount of water that is let through. This is done because a variable motor is costs more than adding an extra component like this valve and valve motor.

The "Subassembly Rev 2 Control Box" (Figure 3.2.6) is the control box with all the electronics, circuit boards and connectors. This subassembly controls the working of every part in the product.

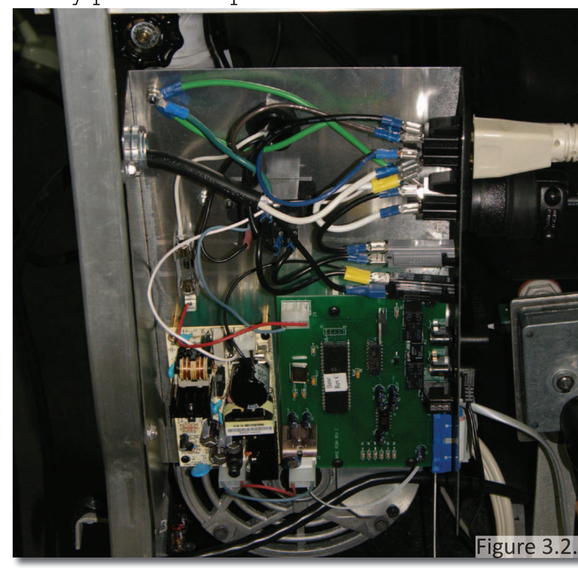


Figure 3.2.6

The "Subassembly Frame Prep" is the frame which is the backbone of the product and determines all of it's strength. It is made out of aluminium and consists of two main parts. The main frame and the top frame. The tub is mounted in between these frames. The main frame, shown in Figure 3.2.7, is the basis for all components to be mounted on.

Figure 3.2.7

The frame has some unnecessary bends in the posts. It also has some bolts which could easily be replaced by a weld, making the frame stronger and less complicated.
The second part of the frame is the top frame, shown in Figure 3.2.8. The top frame is the basis on which the top of the product is mounted.

Figure 3.2.8

The "Subassembly Tub Prep with heater 110v" is the tub with a heating pad, shown in Figure 3.2.9. The tub is made out of polyethylene, a good chemical resistant material. The tub is made by thermoforming and is not made in house. The tub has ribs formed into the design to ensure strength and rigidness. The heating pad is taped on to the bottom of the tub and heats the water from below. The heater is connected to the control box with a thermostat. This to make sure the water always has the right massaging temperature.

Figure 3.2.9

The "Subassembly Tub Frame" is the frame on which the nozzle cradle is moving up and down and the cradle itself. This subassembly is continued to be called the carriage system. The carriage system is shown in Figure 3.2.10.

The last subassembly is the plumbing in the tub, shown in Figure 3.2.11. This is a piece of spa hose and 2 swivel adapters to make sure the nozzles can move freely up and down the carriage system. The nozzle is a piece of pipe with holes drilled into it.

Figure 3.2.10

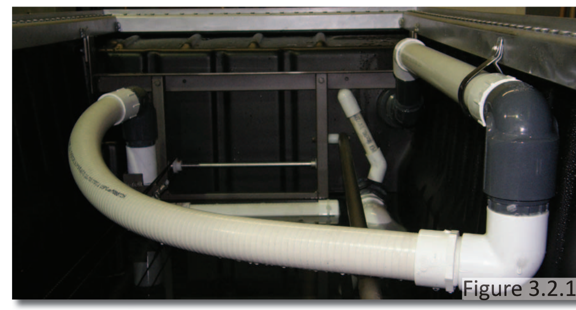


Figure 3.2.11

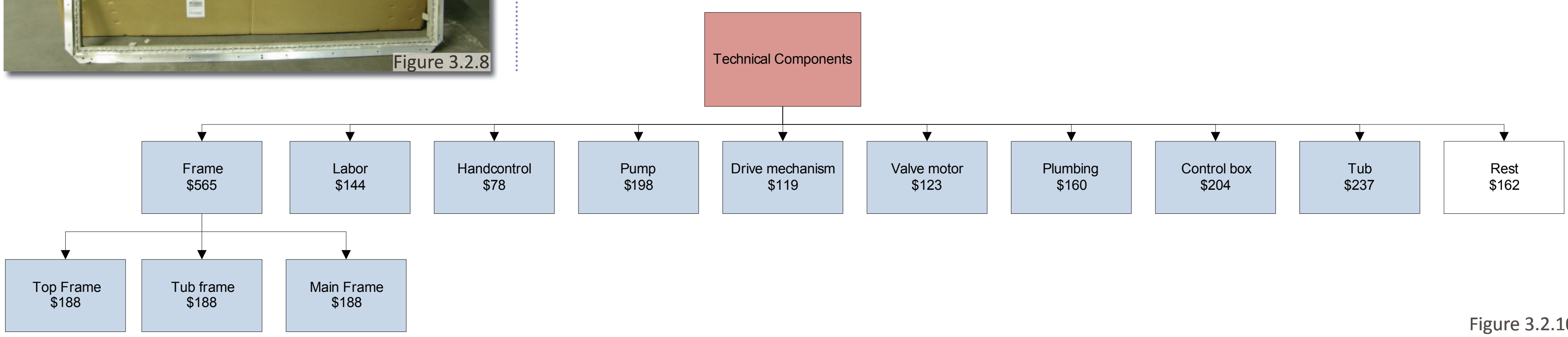


Figure 3.2.10

3.2.3 High and Low quantity components

From the analyses made there is no indication of parts being used in high quantity in the product besides nuts and bolts. On the other hand there is a great deal of components which are used only once in the product, but when analyzing these parts further they are all standard parts bought at other companies or big parts which should only be used once. It seems impossible to use similar parts more than once in the product, with the exception of nuts and bolts and other fasteners.

3.2.4 Expensive components

There are a few expensive components within the product. Components are of high cost are the frame, the skirts, all the motors, the hand control, the tub and the control box. Most of these parts are part of a costly subassembly called subassembly Unit WaterWave. These expensive components are all on the list to be redesigned to make them less costly. It is important to keep looking for more cost effective alternatives for these components.

3.2.5 Components to be left out

The product does not have any components which are not used in any way. Every component contributes directly or indirectly to the working or exterior looks of the product. This means no parts can be eliminated without first redesigning the product. Possibly the redesign will make some parts needless.

3.2.6 Redesign based on cost

To find out which parts and assemblies could lead to cost reduction by redesigning, a selection of them is made based on cost. This selection is analyzed to greater detail to see which parts qualify for redesign based on cost. Table 3.2.1 shows a list of the cost based selection, their price and if they are recommended for redesign. A product tree of the, for redesign recommended, subassemblies can be found in appendix A. The main areas for redesign based on cost are the top, the plumbing, the tub, the tub frame, the frame and the hand control. During the redesign process the assembly time, which is also a big cost factor, should be taken into account as well. The assembly time for the final assembly of the product is 1hr 40mn. The time used to assemble the final technical subassembly is 4 hours.

The product trees of some assemblies which are not redesigned are also shown in appendix A. These assemblies consist of one major costly component and the cost of the rest of the subassembly is negligible. Also a choice is made not to get into the electronics of the product as this lies not within the area of expertise.

Item	Item Description	Quantity	Price	Total price	Redesign	Part of
LABOR	5 Minute Unit of Labor Assembly	20	$3.00	$60.00		
ACCE6610225	6 Mil Urethane Top Barrier With Welded Blatter	1	$90.19	$90.19	Yes	Top
ACCE6610140	Commercial Net With Reinforcement	1	$45.10	$45.10	Yes	Top
CVPL6601055	Head Plate Plastic Prosun Red	1	$32.02	$32.02	No	
CVPL6601056	Foot Plate Plastic Prosun Red	1	$32.02	$32.02	No	
CVPL6601050	Front/Back Plate Plastic Prosun Red	2	$95.42	$190.85	No	
SUBC6610120	Side Rails (Front/Back) Complete Asembled	2	$29.14	$58.27	Yes	Top
SUBC6610125	End Rails (Head/Foot) Complete Asembled	2	$26.90	$53.80	Yes	Top
ACCE6610128	Bacteria Resistant Sheet Black With Out Logo	1	$26.46	$26.46	Yes	Top
SUBU66501010	Subassembly Unit Waterwave 110v	1	$1,987.31	$1,987.31	Yes	
LABOR	5 Minute Unit of Labor Assembly	48	$3.00	$144.00		
SUBM6610105	Subassembly Pump Waterwave 120V	1	$198.55	$198.55	No	
SUBM6610110	Subassembly PCBA Handcontrol	1	$78.40	$78.40	Yes	Handcontrol
SUBM6610115	Subassembly Magnetic Switch	1	$16.50	$16.50	No	
SUBM6610120	Subassembly Drive Motor	1	$86.41	$86.41	Yes	Tub Frame
SUBM6610100	Syncromesh Cable Complete	1	$33.00	$33.00	No	
SUBM6610125	Subassembly Rev 2 Valve Motor	1	$122.68	$122.68	No	
SUBM6610130	Subassembly Jet Motor/Hose Assembly	1	$53.02	$53.02	Yes	Plumbing
SUBM6610140	Subassembly Bulkhead Hose	1	$43.44	$43.44	Yes	Plumbing
SUBM6610170	Subassembly Pump Bulkhead Intake	1	$24.51	$24.51	Yes	Plumbing
SUBM6610180	Subassembly Pump Valve	1	$21.31	$21.31	Yes	Plumbing
SUBM6610200	Subassembly Rev 2 Control Box 120V	1	$181.02	$181.02	No	
SUBM6610210	Subassembly Airvent	1	$4.67	$4.67	No	
SUBM6610220	Subassembly Main Wireharness	1	$22.92	$22.92	No	
SUBM6610230	Subassembly Frame Prep	1	$565.08	$565.08	Yes	Frame
SUBM6610240	Subassembly Tub Prep With Heater 110V	1	$236.95	$236.95	Yes	Tub
SUBM6610250	Subassembly Tub Frame	1	$39.02	$39.02	Yes	Tub Frame
SUBM6610260	Subassembly Plumbing Tub	1	$18.37	$18.37	Yes	Plumbing
SUBM6610270	Subassembly Electrical Tub	1	$9.95	$9.95	Yes	Tub
SUBM6610280	Subassembly Final Assembly	1	$15.31	$15.31	Yes	

Table 3.2.1

3.3 Bottleneck analysis

A bottleneck analysis is done to uncover any problems occurring in the product. This bottleneck analysis consists of interviewing key stakeholders to identify any problems in the product. Based on interviewing the assembly employee and the sponsor, a list of bottlenecks of the product is made. The list contains bottlenecks to do with assembly time, production time, experience with occurring problems and difficulties while making or assembling parts and experience with occurring problems in the product.

First the assembly employee interview is discussed and last the sponsor interview is discussed.

3.3.1 Assembly employee interview

The assembly employee is interviewed to identify any occurring problems during the assembly of the product. For this interview a questionnaire is made, shown in Appendix B.

The interviewed assembly employee stated that just a few simple parts, like brackets, are made in house. This is why no interview is done with a production employee.

Hard or time consuming to assemble

- Lining up the plumbing in the tub and making sure its not too tight or too loose is hard and time consuming.
- Mounting and lining up the skirts is hard.
- Mounting the bladder and polyurethane sheet, without having pre drilled holes is hard and is time consuming.
- Drilling holes and lining up everything that is not pre drilled is time consuming and presents a challenge.

Problems

- The steel framing electrolyzing when in contact with water can make components fail.
- Once the water hose inside the tub gets heated up, it tends to sag and hit the drive wire.
- While servicing a WaterWave it is annoying that it is not able to drain completely.

3.3.2 Sponsor interview

The sponsor interview is done to identify more problems and bottlenecks which are occurring in the product while and after assembly. This includes customer complaints. The results of this interview are shown in Appendix C.

Cost

- The frame is expensive. The extrusion profile with screws to hold the net is hard to make and inefficient. Some parts of the frame are bend where its not needed. The material is a cost factor as well.
- The tub is too high, it needs too much material to form.
- The top takes too long to assemble because its not a subassembly which can just be screwed on.

Problems

- The tub frame is e-coated but makes electrolysis with water making white flakes which causes the product to malfunction.
- Tub is too high which causes problems when forming. The problems occur in the corners where the tub is too thin.
- The net stretches over time making tune-ups necessary to keep the right height
- The anti bacteria sheet doesn't look right, it's loose and does not look tidy.
- The bladder sometimes leaks.

3.4 Noise analyses

This paragraph will explain how and where the product produces noise. This is done to be able to recommend areas of improvement based on noise reduction.

First specific parts or by functions of the product producing noise will be discussed, second the methods for noise reduction which are used in the pre redesigned product will be discussed.

3.4.1 Parts which produce noise

There are several parts which produce noise, one more than the other. The main noise producing part in the product is the motor in the pump which pumps the water through the nozzles. This is quite a heavy motor, often used in pools and spas. The reason for this part to produce noise is that the rubbers isolating the motor from the frame are not damping the vibrations of the motor sufficiently. Besides this, the motor itself is also very noisy.

Another component that produces a little noise when the product is in operation is the driving motor. The drive motor is mounted on a very thin bracket which makes it easy to vibrate. Even while it is damped out by a rubber connector. Between the motor and the bracket.

Last component which produces a little noise is the cooling fan mounted inside of the product. Though this noise is negligible when comparing it to the pump motor when in operation. The fan is a low noise good quality fan.

3.4.2 Functions which produce noise

The water spraying function is the only function to produce a lot of noise when the product is running. Analysis shows that there are certain regions where the noise is louder than in other regions. This has a lot to do with where the person is laying down and the shape of the human body. Most noise occurs in regions where it is not in contact with the surface of the bladder. The cause of the increase in noise is the water hitting a thin surface with nothing behind to damp the vibrations. If there would be a human body

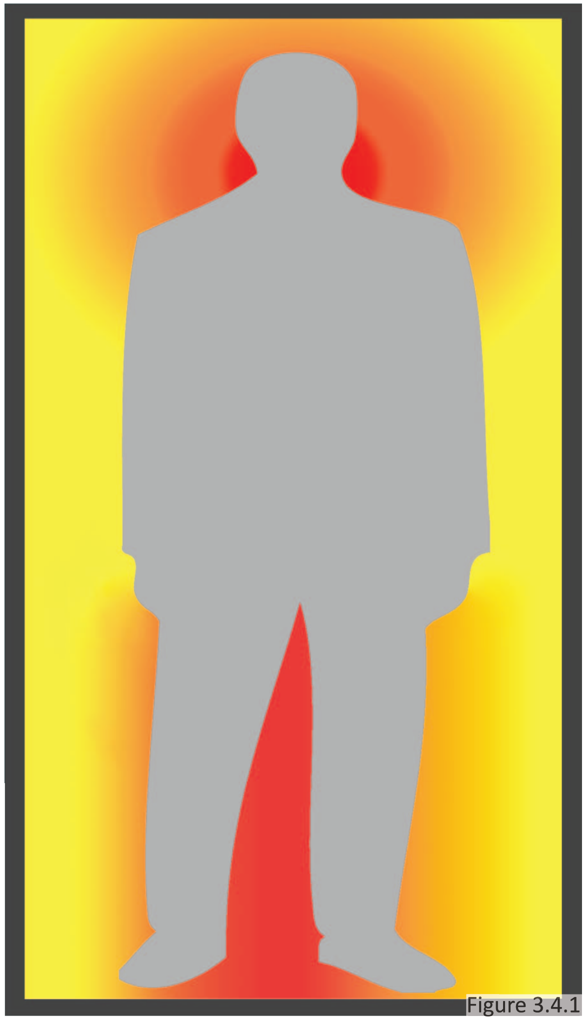


Figure 3.4.1

laying there it would hit a solid, damping body. Figure 3.4.1 gives an overview of the regions and intensity of noise, red being the most noise, and yellow the least. The figure is made by measuring the sound with a decibel meter.

3.4.3 Noise reduction techniques used

The noise reduction techniques used are very limited at the moment. There is no insulation on the inside of the skirts or bottom of the product. The only insulation used is the bladder filled with water. The water in the bladder works for noise reduction of the water hitting the massaging surface but does not work for insulating the noise made by the motors. A problem with the bladder is that the water does not cover all areas where the body is not touching, like the neck area and between and under the legs.

The pump motor is insulated by rubber fittings on each end of the mounting bracket. To isolate vibrations to the motor itself and not transfer these vibrations through the rest of the product.

3.4.4 Possible noise reduction

The analysis of which components and functions produced noise showed some ways of improving the noise reduction.

- Improve the rubber fittings on the mounting brackets
- Use specialized rubber fittings or a mounting plate to mount the motors
- Find a better way to insulate the surface hit by the water.
- Put more insulation around the motor areas.

3.5 Analysis Conclusion

It is clear the product needs improvement on some aspects, not only based on lowering the production costs but also in respect to problems occurring in the product and specific company wishes for areas of improvement.

The cost analysis shows that the main parts & subassemblies to tackle are the tub, the frame, the top and the carriage system used to move the nozzles. These parts have either unnecessary production techniques or large amounts of material and all take up a good chunk of the total production cost. Besides the redesign of these parts Pro Sun would do good to find more cost effective variants of parts to cut more cost.

The product analysis showed some occurring problems in the product. One being the electrolysis of the metals which are in or around water, causing the product to malfunction. Another problem is the net which supports the weight of the person when laying on the product stretching over time.

The interview with the sponsor revealed more problems and wishes. The company wants better massaging water nozzles and it wants to replace the anti bacteria sheet for something which is nicely stretched on top of the product to make it better looking. Other problems are the tub which sometimes has defects when forming and the bladder which sometimes tends to leak, making the user wet.

The interview with the assembly employee revealed the need for a subassembly for the top. To be able to assemble faster and easier. It also revealed some other minor problems.

The results of the analyses are used to aid into making the requirements and to structure the rest of the design process. The subassemblies of the product which are to be redesigned are the water nozzles, the tub & carriage system, the top and the frame. The parts have to be redesigned in this order due to dependability on each other. For the redesign, the main goal is to reduce the cost of the product and solve most problems the product has.

4. Resulting requirements

This chapter describes the main resulting requirements and wishes of the product.

4.1 Resulting requirements

This paragraph shows the main resulting requirements. These requirements are extracted from the analyses phase and the initial requirements of the company. These requirements are the requirements for the total product. Table 4.1.1 shows the requirements, they are divided into 4 categories: general, maintenance, production and purchasing & storage.

All the requirements in the maintenance category have to do with the accessibility and maintenance friendliness of the product. The product must be able to get a normal service treatment in one and a half hour.

The requirements in the production part all have to do with how the product is produced and the ease of production. For example pre drilled holes are needed for a more easy assembly.

Purchasing and storage are also cost factors in the product. By being able to order large quantities of parts or parts from the same suppliers the price can be reduced.

The requirements for the individual subassemblies are stated in the paragraph in which their redesign is explained. The subassembly requirements are based on the resulting requirements in this chapter as well as on the initial requirements and the analyses chapter.

Category	***Requirement***	***Extra info***
General	The production cost must be reduced	To $2500
	The quality of the massage the product gives must improve by improving the nozzles	-
	The usability of the product must stay the same	-
	The outside dimensions of the product must stay the same	Appendix. D
	The noise the product makes must be the same	Old: 80 dB
	The massage technique of the product must stay the same	
Maintenance	The product must function with half yearly maintenance	-
	The product must allow for easy maintenance	90 Minutes
	Parts must be easy accessible	-
Production	One person should be able to assemble the product in one day	8 hours
	The product must be assembled on a production line	Pre-made sub-Assemblies
	The product must have the same fasteners everywhere	As is possible
	The product must have as much pre drilled holes as possible	-
	The redesigned parts must not require additional machines for ProSun	
	The redesigned parts may not require a change in the existing molds ProSun has.	
Purchasing & Storage	The product must have a high number of identical parts	-
	Ordering materials in large quantities must be possible	-
	The material cost must be as low as possible	-
	The product must have as many standard parts as possible	-

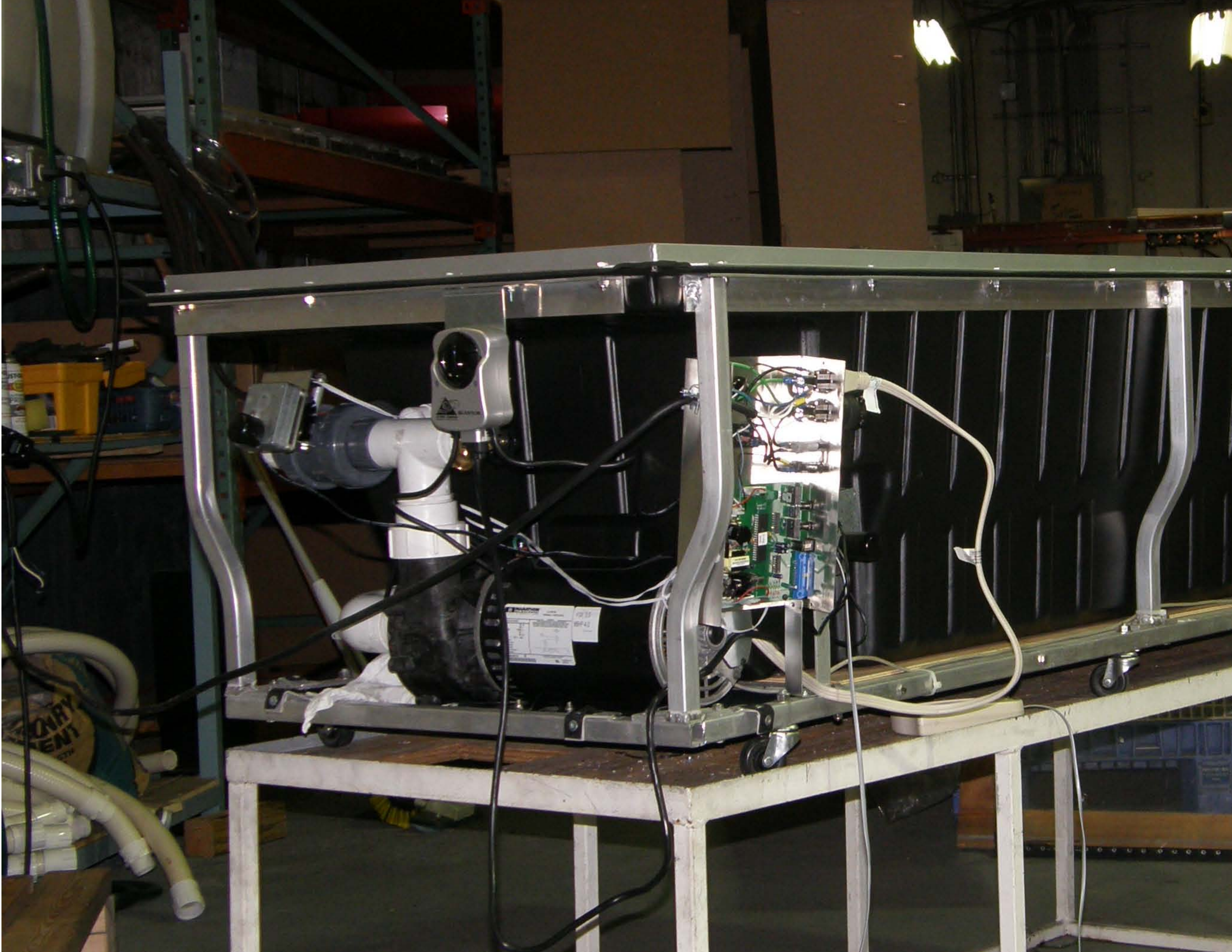
Table 4.1.1

4.2 Resulting wishes

The wishes are also extracted from the initial requirements and analyses. The wishes are listed in table 4.2.1. The company of course prefers that the cost is reduced below the target of $2.500. Other wishes are the improvement of the usability of the product, adding new techniques such as headphones or and mp3 player. The company wants to integrate more techniques and gadgets into the product to make the product more attractive to their customers. The company also wishes the noise is reduced but as this is not a main goal in the redesign this is a wish.

Category	***Wish***	***Extra info***
General	It is preferred to reduce the production cost to below $ 2500	< $2500
	It is preferred that the usability of the product improves	-
	It is preferred to add new techniques to the product to make it more interesting	Headphones/ mp3
	It is preferred that the noise the product produces is reduced	Old: 80 dB
	It is preferred to find a different solution for the bladder	-
	It is preferred to find a different solution for the loose anti bacteria sheet	-

Table 4.2.1



5. Component redesign

In this chapter the several different redesigned components will be discussed. The main redesigned parts of the product are the nozzles, the tub & carriage system, the top and the frame.

5.1 Nozzle assembly

The nozzle assembly is the assembly that consists of all the parts directly involved in spraying the water. The nozzles are the most essential part of the product as they, for the most part, produce the massaging experience of the product. The focus on redesigning the nozzles is not on cost reduction but on comfort. The company has the requirement to redesign the nozzles so they massage better.

First requirements for the nozzle assembly are extracted from the analyses. Second different ways of spraying water are explored and third different set-ups for nozzles are modelled. Fourth the prototypes of a selection of these models and the user test are discussed. Fifth a nozzle setup is chosen and last an estimation of cost of the redesign is made.

5.1.1 Requirements

The requirements (Table 5.1.1) for the nozzle assembly are extracted from the analysis phase and the requirements of the company. The two most important requirements for the nozzle assembly are the quality of the massage and the pressure improvement as these make or break the product. If there are no water jets, there is no massage.

5.1.2 Ideas

In order to explore the different ways and techniques to spray water, a brainstorm session and internet research is done. Figure 5.1.1, enlarged in Appendix E, shows the results of the brainstorm session with the best options circled afterwards. These options are explored further and a choice is made to go with spa parts. This because spa parts are professional looking and standard parts, designed to spray water or air.

After the choice was made for the pool and spa equipment a *WaterWay* pool and spa representative was invited to come and show different parts they could offer for the nozzle assembly.

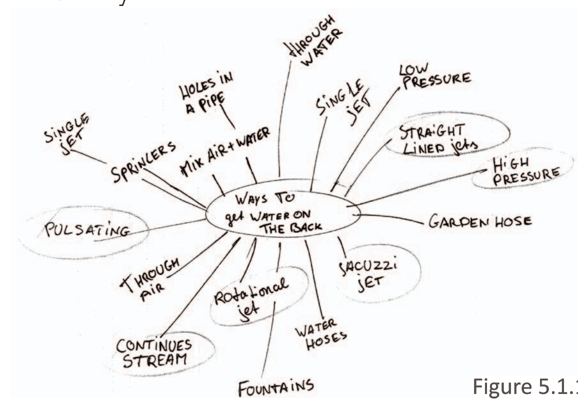


Figure 5.1.1

Table 5.1.1

Requirement	***Extra info***
The intensity of the massage must improve	
The quality of the massage must improve	
The pressure of the water on the back must improve	
The nozzles must give a better resemblance with a hand massage	
The nozzles must cover the whole back body surface	At least 80%
The nozzles must consist of standard parts	
The nozzles must fit the old and the new product with little modifications	
The nozzles must make the same or less noise	Old: 80 dB

5.1.3 Concepts

In order to explore the possibilities with the pool and spa products of WaterWay they are modelled and made into different concept assemblies. These assemblies are reviewed based on expected feeling, cost, feasibility and expected water flow.

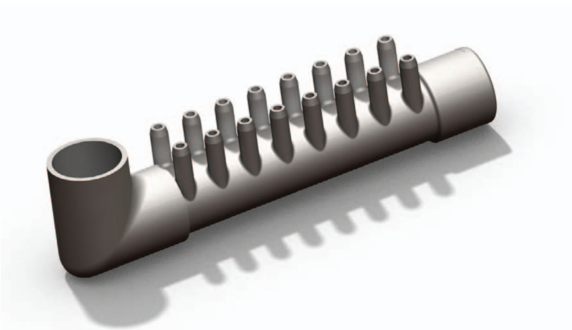


Figure 5.1.2

This nozzle (Figure 5.1.2) resembles the old nozzle the most. The part is used as an air dispenser in the pool and spa industry but can also function as a water jet. By closing off some of the holes a higher water flow can be reached.

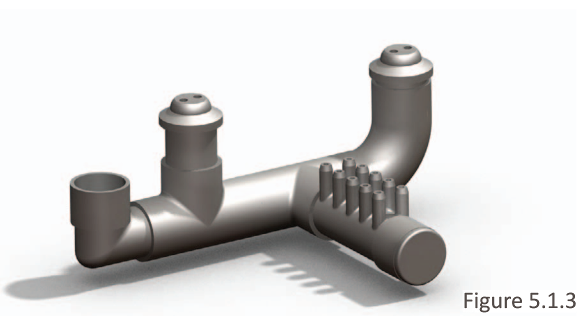


Figure 5.1.3

A combination of rotational jets and a smaller air dispenser (Figure 5.1.3) to get a spinal massage and a side massage. Again a set of holes can be closed off to increase water flow.

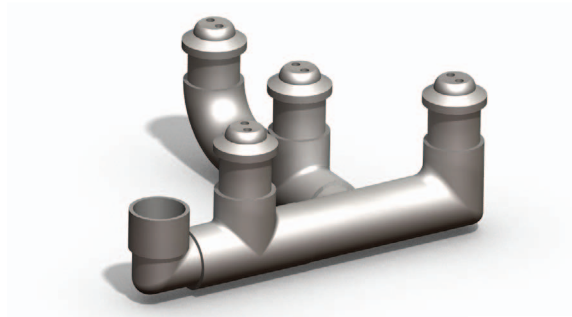


Figure 5.1.4

This nozzle (Figure 5.1.4) focusses on the spinal area as well but is supposed to have a bigger coverage of that area.

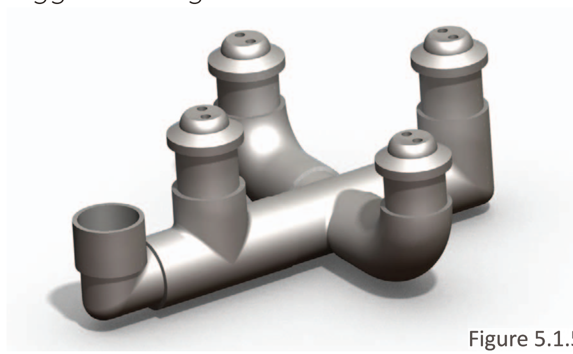


Figure 5.1.5

Four rotational nozzles (Figure 5.1.5) to get a big coverage area and is expected to have an overall good massaging effect because of the rotating nozzles.

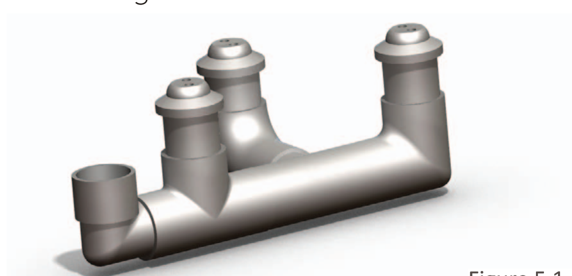


Figure 5.1.6

This nozzle assembly (Figure 5.1.6) is a variation on the previous one. But with using three nozzles the water flow will be higher.

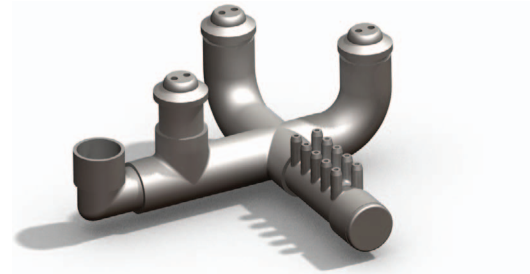


Figure 5.1.7

Combining 3 rotational nozzles and one small air dispenser (Figure 5.1.7). The great amount of holes is expected to give a relatively low water flow.

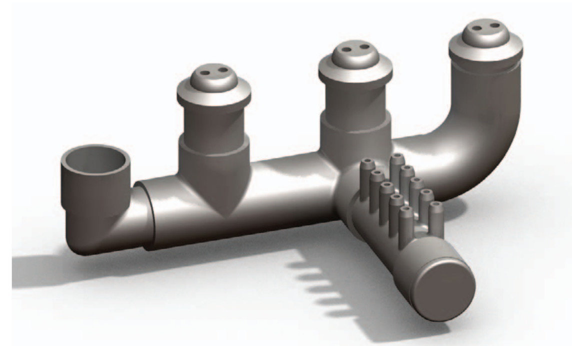


Figure 5.1.8

In variation of the previous set-up this nozzle assembly (Figure 5.1.8) is made to be more compact. Unfortunately a part from this setup is not available on sale.

Figure 5.1.9

This nozzle set-up (Figure 5.1.9) is the most basic and is expected to give the most water flow. This nozzle does not provide spinal coverage.

After reviewing the concepts a choice is made to exclude two concepts from prototyping. The first is the concept in Figure (..), as this concept has a big resemblance with the concept in figure (..). Because the carriage is going up and down the body no great advantage of this option is expected. Second concept which is not tested is the concept in figure (..). This concept contains a part which is not for sale, so there is no use to prototype this concept.

5.1.4 Prototypes

The selection made after reviewing the concepts is made into made into prototypes. These prototypes are used in a user test to determine which concept is the best choice.

Table 5.1.2 gives an overview of which prototypes are made. All these prototypes are made so they fit in the aluminium carriage used in the WaterWave, making it possible to test them.

To get a coverage width of 1ft in every set-up, the height of the nozzles had to be determined. The height was calculated by the angle between the two water streams of the jets and the necessary width per nozzle (Figure 5.1.10). The distance between the nozzle and the back has to be 7.5in to ensure 1ft width by two nozzles.

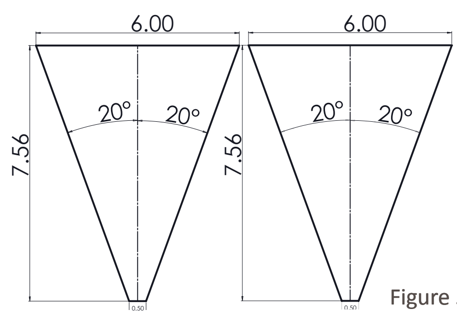


Figure 5.1.10

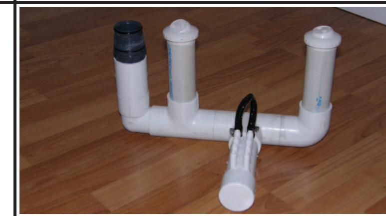
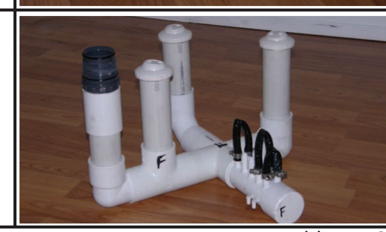
Option	Photo
Option A	
Option B	
Option C	
Option D	
Option E	
Option F	

Table 5.1.2

5.1.5 User test

It is hard to make the right choice just by looking at the different prototypes and seeing them in action spraying on an acrylic plate. This is why a user test is done to determine which nozzle set-up is the best choice.

The user test is done using two identical WaterWave units with small modifications to be able to mount every prototype in them. The units were set up in the showroom of Pro Sun. The prototype nozzle set-ups were exchanged every day making the duration of the user test three days to get all set-ups done. The different options are prototype options A through F and Option G, being the old nozzle.

The company personnel was asked to do a massage session on each prototype not knowing which nozzle set-up was in the bed. After each session they were asked to fill in a form to rate the massage experience.

The results of the forms can be found in Appendix F. These results are combined in a spreadsheet to get an overview of ratings with respect to one another. The results of this analyses is shown in Figures 5.1.11 and 5.1.12. A weighting factor is used for the different criteria, table 5.1.3 shows these weighting factors The factors are chosen based on the importance of the criteria. The quality of the massage is the most important and has weighting factor 5, because the amount of body surface hit is hard to describe and is hard to simulate with the tested prototypes this has a low weighting factor.

Conclusion of these results is that option D scores the best out of all the options on almost every subject and overall as well. This means that it is the best nozzle set-up tested. Based on the results the choice is made to use option D in the redesign of the product. Scores on the subject ''resemblance with a hand massage'' revealed that none of the nozzles resembled a hand massage. Conclusion of this is that the WaterWave with its current massage technique will not likely ever resemble a hand massage.

Intensity	4
Comfort	3
Amount of body surface hit	2
Feeling afterwards	4
Hand massage	1
Quality of massage	5

Table 5.1.3

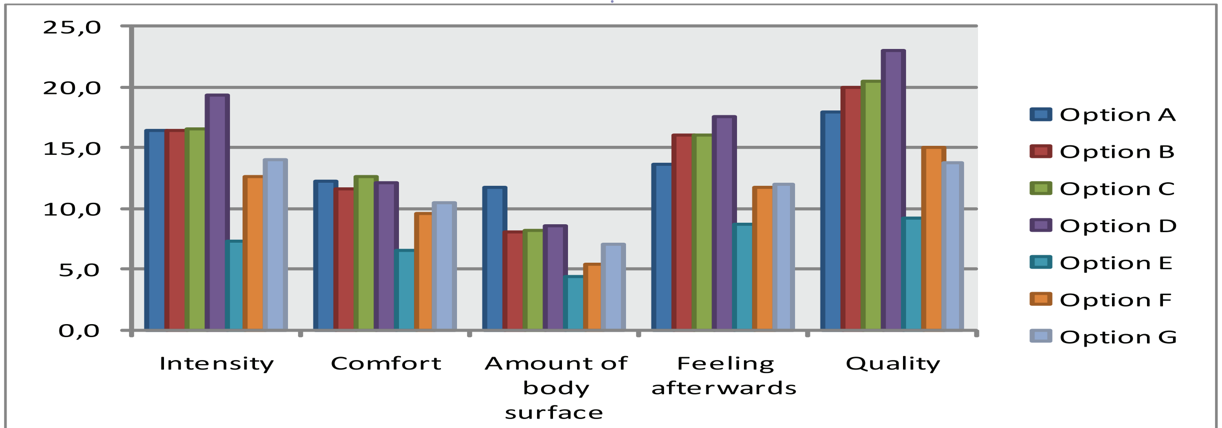


Figure 5.1.11

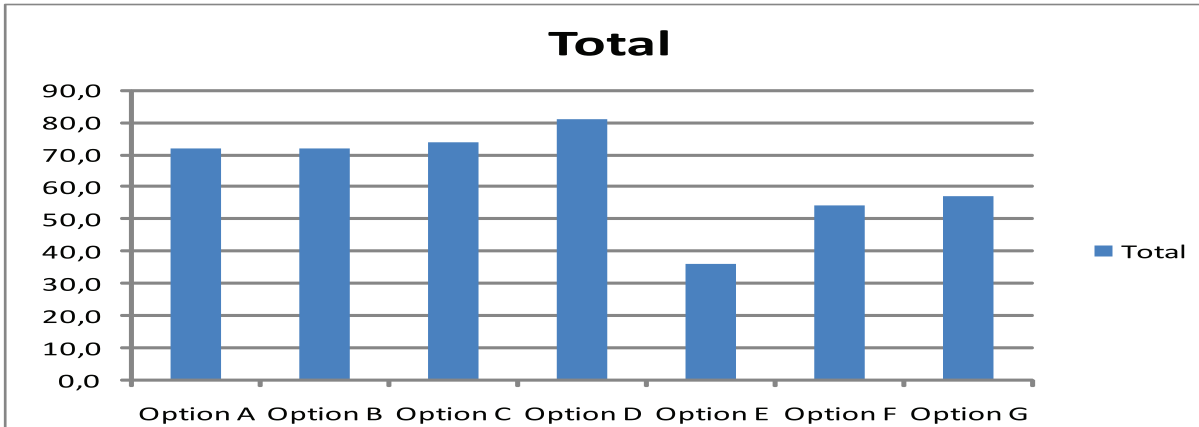


Figure 5.1.12

5.1.6 Selected concept

Based on the user experience a selection from the concepts is made. The option selected to be used in the redesign is option D, shown in Figure 5.1.13. The selected concept is also directly implemented in the old WaterWave.

The selected concept meets most of the requirements. Table 5.1.5 shows the requirements and if they are met. The noise came down to a reduction of 10 dB to a sound level of 70dB. The amount of body surface hit is about 80%. The only body surface the water does not hit are the feet, which contain no big muscles, and the neck.

The user test showed that none of the made prototypes or the old nozzle resembled a hand massage. Which is the only requirement that is not met.

5.1.7 Estimated cost

Though cost reduction is not the main goal this is taken into account during redesign. Comfort plays a bigger role which means the cost has gone up slightly. The pool and spa products are more expensive than just a pipe with holes in it. The cost of this assembly has gone up from $29 to $49. Though the improvement of the massage is well worth the increase of cost. Table 5.1.4 shows an overview of the parts and the total cost:

Part	***Quantity***	***Total price***
1-1/2" Swivel Fitting A	1	$12.57
Rotating nozzles	3	$23.88
Ell 1 1/2in SxS 90	3	$1.50
Tee 1 1/2in SxSxS	2	$1.62
Pipe 1 1/2in L: 2 1/4in	4	$0.38
Pipe 1 1/2in L: 1 1/4in	3	$0.10
Labor 5 min	3	$9.00
Total		**49.05**

Table 5.1.4

Requirement	***Met?***
The nozzles must look more professional	Yes
The quality of the massage must be the same or improve	Yes
The pressure of the water on the back must improve	Yes
The nozzles must give a better resemblance with a hand massage	No
The nozzles must cover the whole back body surface	Yes
The nozzles must consist of standard parts	Yes
The nozzles must fit the old and the new product with little modifications	Yes
The nozzles must make the same or less noise	Yes

Table 5.1.5

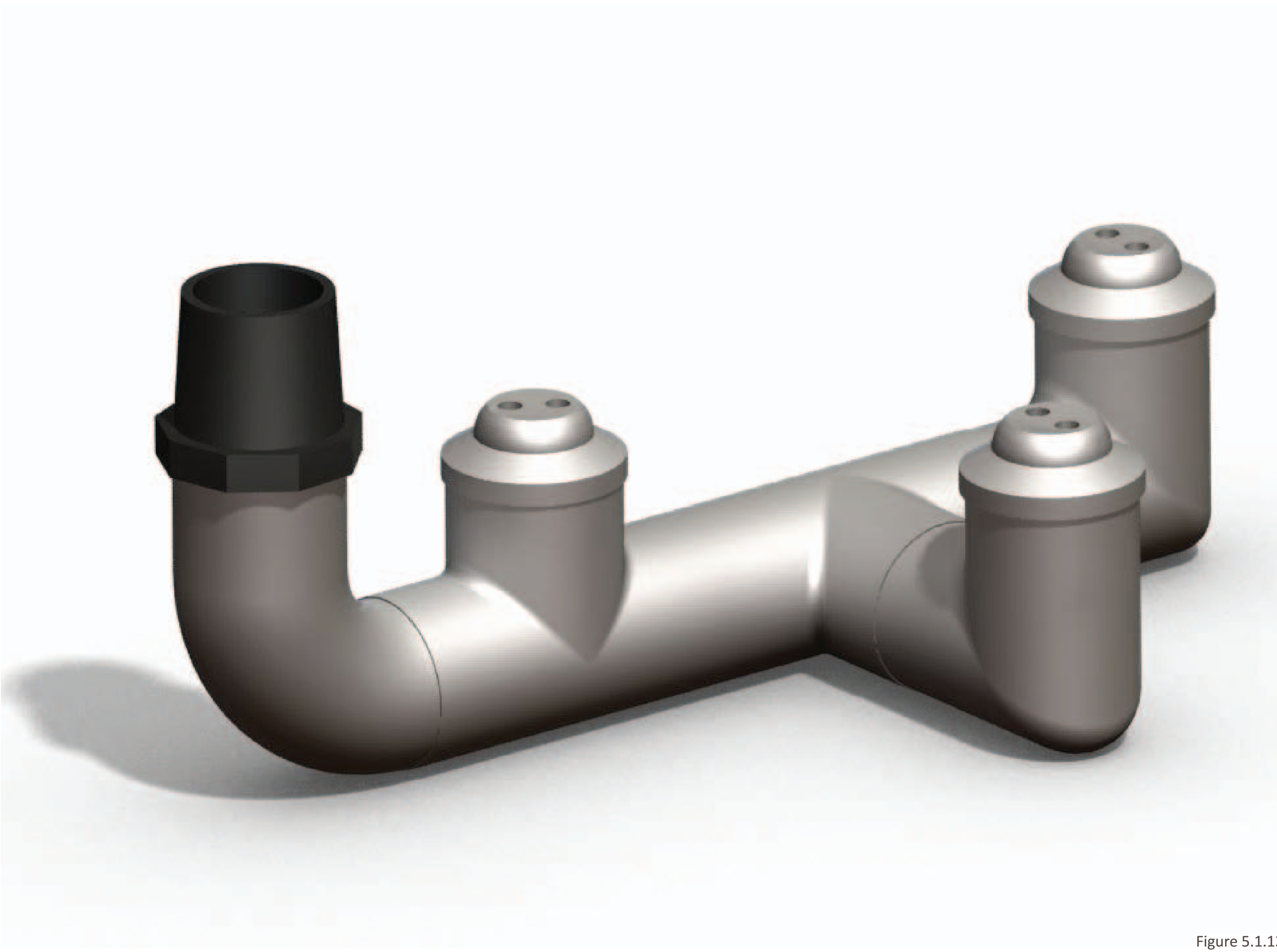


Figure 5.1.13

5.2 Tub & carriage system

The cost analysis shows that the tub and the carriage system are a great factor in the cost of the total product. The tub, Figure 5.2.1, holds the water and is thermoformed. The carriage system is a frame of aluminium with a carriage on it. The carriage, Figure 5.2.2, is driven by a drive motor driving a synchromesh cable attached to the carriage. The carriage holds the nozzle assembly. While redesigning the tub, the plumbing inside the tub was also redesigned to fit the redesigned tub.

First the requirements are discussed, second ideas for the carriage system are shown, third the chosen concept for the carriage system shown which is detailed further. Fourth, concepts are discussed for the tub to match the carriage system concept. Fifth the detailed tub is shown. Sixth, the redesigned plumbing is discussed and last an estimation is done on how much cost reduction the redesign realizes.

5.2.1 Requirements

The requirements are divided into three segments, the tub itself, the carriage system and the plumbing which goes into the tub. Table 5.2.1 gives an overview of the requirements.

Apart from the cost perspective, there are a lot of bottlenecks which have to do with the tub and the carriage system. These bottlenecks are part of the requirements. The different metals inside the tub make electrolysis when they come in contact with water, which causes the product to malfunction, this is why only one kind of metal or no metals at all can be used inside the tub.

Currently the tub is too high which causes problems while forming with corners being to stretched out. These corners sometimes leak. This is why the tub must be less deep than it is now.

The bottleneck analysis shows that it is annoying that the tub can not be drained

Figure 5.2.1

Figure 5.2.2

completely. This is something that the redesign will have to solve.

The tub and the carriage system are very much related to each other. Since the goal is to not have a metal frame inside of the tub, the tub will be the support for the carriage system.

The tub can only have a small deformation when there is water in it. The reason it may only deform 0.25in or less is that if it deforms more than that, the carriage is expected to get stuck.

To have as low maintenance as possible the abrasion of the sliding mechanism of the carriage system must be as low as possible. The friction must be low as well. If this friction is too high the synchromesh cable will slip on its pulley and break causing the product to malfunction.

The plumbing itself also takes up quiet a big part of the production cost, this is something that could easily be reduced by searching alternative components and redesigning the plumbing so that it fits the redesign of the tub.

Tub requirements	***Extra info***
The tub must be able to be drain completely	
The tub must support the carriage system	
The tub must house the driving mechanism for the carriage system	
The amount of material used in the tub must be reduced	
The material of the tub must be low cost	
The tub must be strong enough to hold the water	
The tub must be able to hold enough water to run the machine	30 gallons
The top dimensions of the tub must match the current product dimensions	Appendix D
The tub must be less deep to make forming easier	
The tub must leave room for the mechanical and electrical components	On outside
The tub may have a maximum deformation of 0.25in.	

Carriage system requirements	***Extra info***
There may not be any metals inside the tub	
The sliding mechanism for the carriage must have low friction	
The sliding mechanism must be strong enough to all force	Water+pressure
The sliding mechanism must have as low abrasion as possible	
The carriage system must become cheaper	Old: $145.00
The sliding mechanism must have low maintenance	Once a year

Plumbing requirements	***Extra info***
The plumbing must be cheaper	Old: $166.99
The suction in the tub may not suck up air.	May not vortex
The plumbing in the tub must able to fit on the plumbing on the outside	
The plumbing must consist of standard parts	

Table 5.2.1

5.2.2 Ideas carriage system

During the idea generation focus lays on eliminating metals inside the tub and to use standard parts where possible. Figures 5.2.3 and 5.2.4 show an overview of the ideas made for the carriage system. Options for forming a guide rail into the tub are considered as well as an external rail mounted inside the tub. Also it was tried to eliminate the carriage itself and let the nozzle assembly to be self supporting.

The second idea in figure 5.2.3 was chosen to continue with and detail further. This idea is chosen because it is expected to be the most feasible idea. It is the most feasible because this idea does not require complex forming, and blocks the two degrees of freedom. Also the carriage slides in a rail and not on the tub itself which means the tub itself does not wear. It is an external rail mounted inside of the tub. The nozzles are mounted on two sliding blocks with a bracket. This idea is using the strength of the nozzle assembly to be stay leveled and not fall out of the rails.

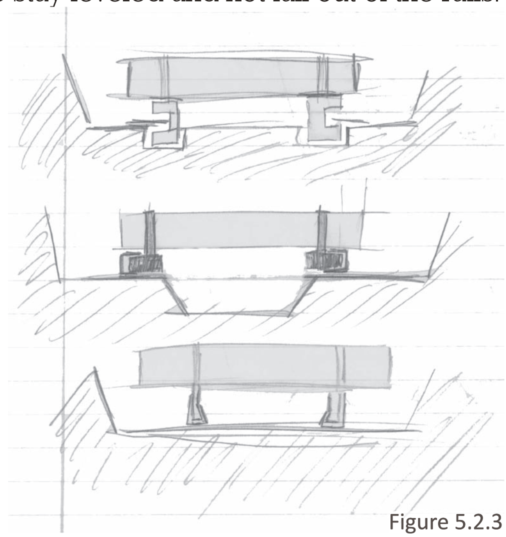


Figure 5.2.3

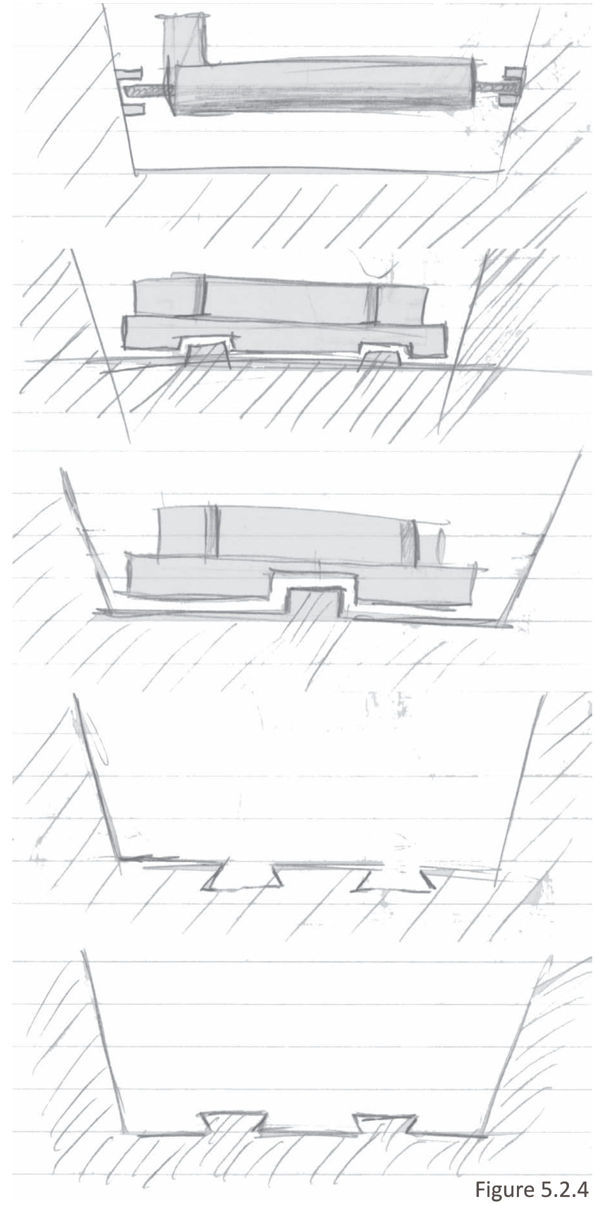


Figure 5.2.4

5.2.3 Detailing carriage system

To develop the carriage system further, different solutions for the guide rail and guide block are explored, shown in Figure 5.2.6. By taking into account assembly, maintenance and cost it is decided to go with the most simple option which also means the most simple assembly. This design consists of a U-shaped guide rail and an L shaped sliding block sliding into the guide rail as can be seen in Figure 5.2.5. The L shape is chosen to make sure the nozzle assembly is lifted up high enough to clear the guide rail and other parts that might stick out above the guide rail.

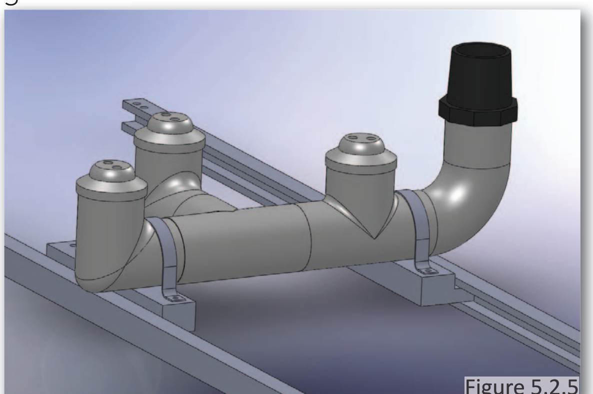


Figure 5.2.5

The nozzle assembly is mounted on the guide blocks with standard PVC pipe clamps. Figure 5.2.7 shows the used PVC clamp. These clamps are normally used for mounting PVC pipes on the wall. This bracket will be clamped as tight as possible on the nozzle assembly with rubber in between. The clamps will be fastened with stainless steel bolts and nuts. This is making sure the guide blocks cannot move and that the nozzle assembly cannot rotate either.

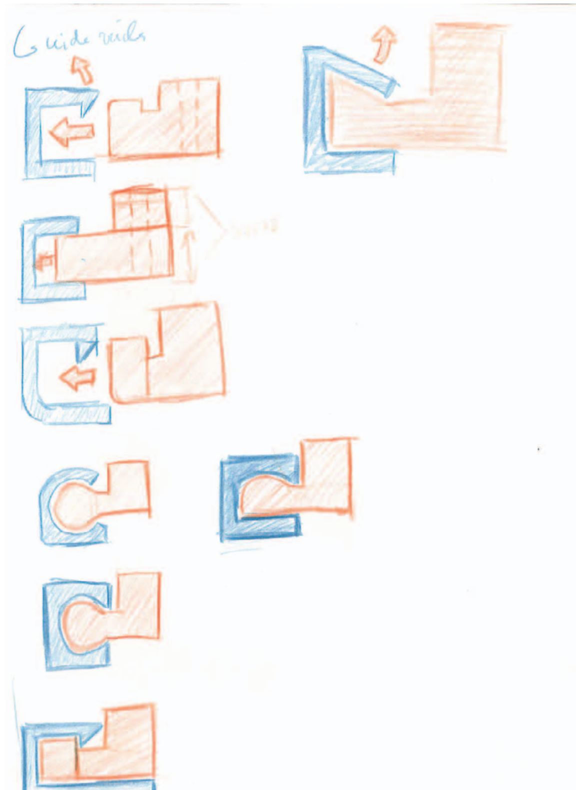


Figure 5.2.6


Figure 5.2.7

The thickness of the sliding block and the guide rail are determined while keeping in mind the abrasion that might occur when sliding the block up and down the track. Figure 5.2.8 gives an overview of the dimensions.

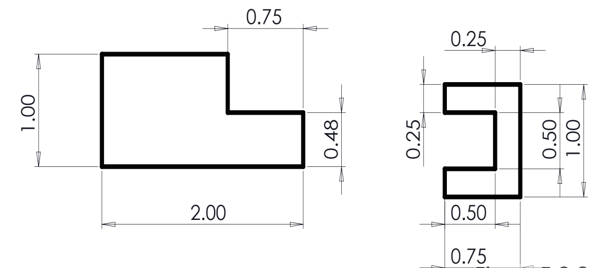


Figure 5.2.8

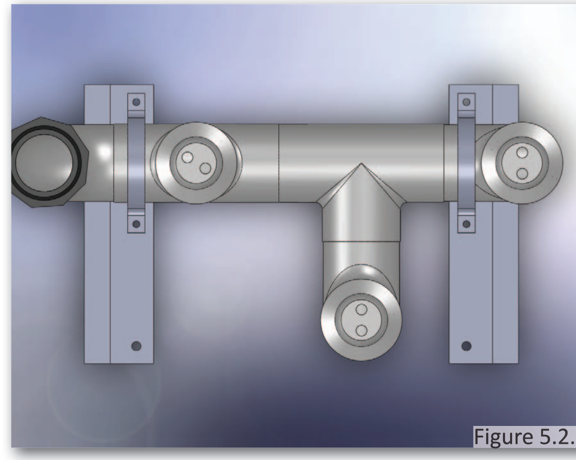


Figure 5.2.9

The length of the sliding block is determined by two criteria. First is that the block has to be long enough to make sure the carriage will not tilt if it is pulled on one side. The cart may not tilt as this means it will get stuck in the rail. Also corners are filleted to decrease the chance of getting stuck. Second the length is determined by the dimensions of the nozzle assembly, making sure the block sticks out on both ends so the magnet can be mounted on each end and is detected before the nozzles the walls of the tub. This length comes down to 8 inches.

5.2.4 Carriage system material

After doing internet research and consulting several experts at plastic companies, revealed two materials which were a good choice for the application. These materials are Teflon and ultra high molecular weight polyethylene (UHMW-PE). Both of these materials have about the same properties, with Teflon being slightly better. Both materials have a low abrasion factor, low friction coefficient and good heat and water resistance. The drawback of the materials are that they are both very hard to bond to same or other materials. As UHMW-PE has a lower abrasion factor[1] and is about 1/3rd the price[1] of Teflon the choice is made for UHMW-PE.

5.2.5 Ideas tub

Besides the cost perspective, a goal for the redesign is decreasing the stretch on the material when thermoforming. The tub needs to become less deep to make it easier to form without defects. Other solutions for this problem could be changing the vacuum process or material. Changing the process would require a different machine for forming which is not an option for the company. Choosing a different material for forming will be discussed. It must also support the carriage system. Figure 5.2.10 shows some shapes which are explored during the idea phase for the tub. Considering mold making, support for the guide rail and ease of assembly a choice is made for number four. The choice has to niches for the guide rails to sit in, this makes placing them easier and already stops two degrees of freedom. The design also has angled walls to ensure the mold will loosen from the tub after forming.

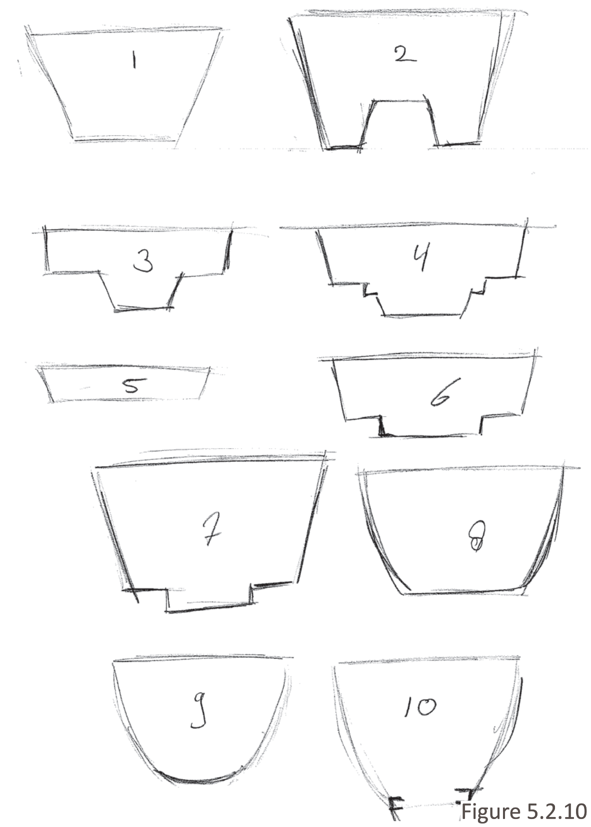


Figure 5.2.10

1) Crown Plastics, *Teflon vs UHMW,* http://www.crownplastics.com/Teflon-UHMW.htm

5.2.6 Suction

Some of the dimensions of the tub are determined by the size of the suction device. This is why a suction is chosen before detailing the tub. The main requirement for this suction is that it is not allowed to vortex when emptying the tub. Tests show that just a hole in the bottom does not work well. This does not work well because it allows debris being sucked into the motor and that the suction force of the pump creates a vortex very easily. If the pump creates a vortex, air is sucked into the motor, causing it to malfunction.

In order to try to eliminate the vortex a choice is made to use pool and spa suctions specially designed for anti vortexing. To determine which suction would be the best for this application some tests are done with the different suctions, shown in Figures 5.2.11, 5.2.12 and 5.2.13. The suctions are mounted in the old tub. By measuring at which water level a vortex is pulled by each suction and cost it is determined which suction to go with in the design.

Table 5.2.2 shows the results of the test. The test revealed that all suctions need at least one inch of water to not create a vortex. By taking into account cost the choice is made to go with one small suction. This suction filters all big debris, costs the least.

Measured with the old tub, new nozzles and the 220v 50hz pump at maximum pressure for highest suction rate			
Suction	***Vortex (in)***	***Cost***	***Debris***
Old	1	$ 25.16	Yes
1 Small	1	$ 8.00	No
2 Small	1	$ 18.00	No
1 Big	1	$ 15.00	Only small

Table 5.2.2

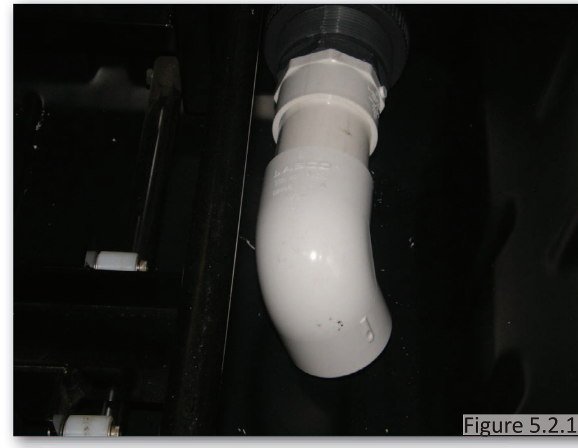


Figure 5.2.11

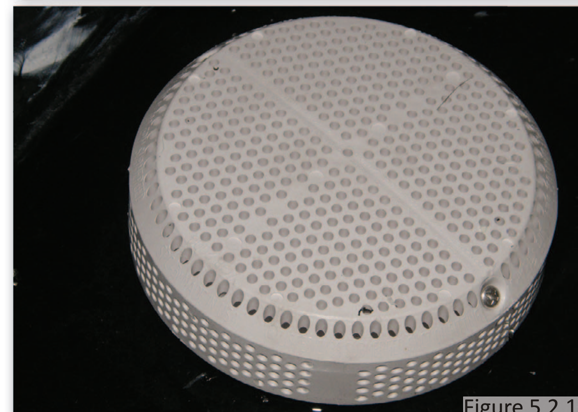


Figure 5.2.12

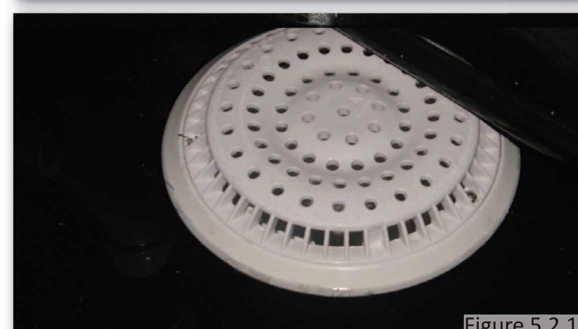


Figure 5.2.13

5.2.7 Drive mechanism

As one of the requirements for the tub is that it must house the drive mechanism for the carriage system this is designed before detailing the tub.

The drive mechanism is designed to be as cost efficient as possible. Besides the cost efficiency it must also be strong enough and durable enough to not break or deform under the force of the moving hose and carriage system or the tension of the synchromesh cable. First several ways of mounting the drives haft are explored, second a choice is made and modelled.

First different brackets to be mounted on the guide rail are explored (Figure 5.2.14). The the material for the rail does not allow to be bonded or glued and bolts are not preferred. Because the tub is ABS the brackets which is bondable, a choice is made to mount the brackets on to the tub using bonding or gluing.

The design of the brackets is made with production techniques of the company in mind. ProSun does not have the technology to mill their own brackets, however they do have the technology to form plastic brackets using vacuum forming or bend metal brackets using a bending machine. By discarding the metal brackets as the goal is to eliminate metals contact with water, a choice is made for a plastic bracket which can be formed using vacuum or press forming.

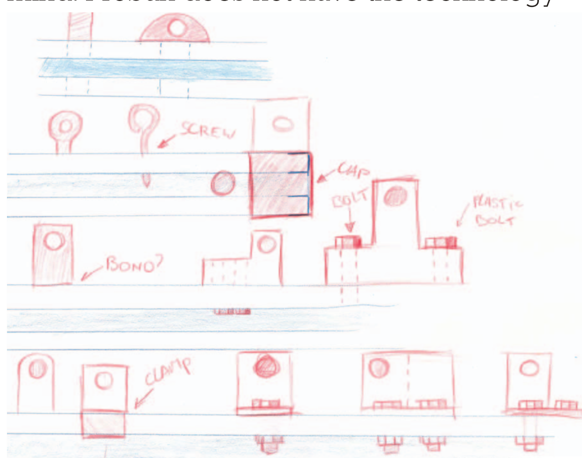


Figure 5.2.14

The bracket is designed to be as simple as possible (Figure 5.2.15) yet being strong enough to endure the pulling load.

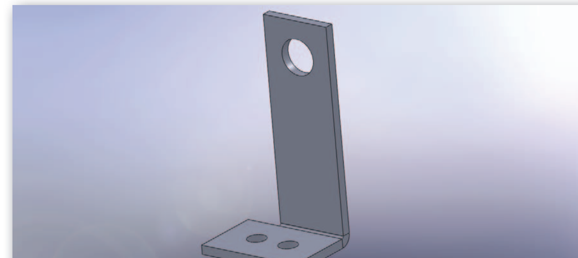


Figure 5.2.15

A prototype of ABS of this design is tested in a strength test and failed (Appendix G). The prototype deformed under the tension of the synchromesh cable. Therefore a modification on the design is made (figure 5.2.16).


Figure 5.2.16

The modification is also prototyped and tested (Appendix G). The modification performed good under the tension of the synchromesh and the force of pulling on it.

The material chosen for the bracket is ABS. There is an abundance of still usable scrap ABS within the company. ABS proved to be strong enough in the prototype and is also easy to form.

5.2.8 Detailing tub

The tub has to be designed in more detail to fit the carriage system and fulfill the requirements. An important requirement is that the tub must match the dimensions of the pre-redesigned frame. These dimensions can be found in Appendix D.

After considering several possibilities (appendix H) for the design of the tub the design in figure 5.2.17 is chosen. The sloping tub and a suction on the bottom to make sure the tub can be emptied completely.

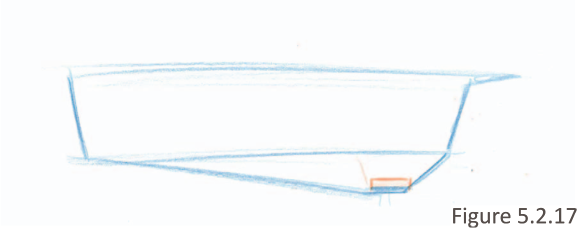


Figure 5.2.17

Next the design is modelled into a live sized mock up frame making sure all dimensions are right. Figure 5.2.18 shows a picture of this model.

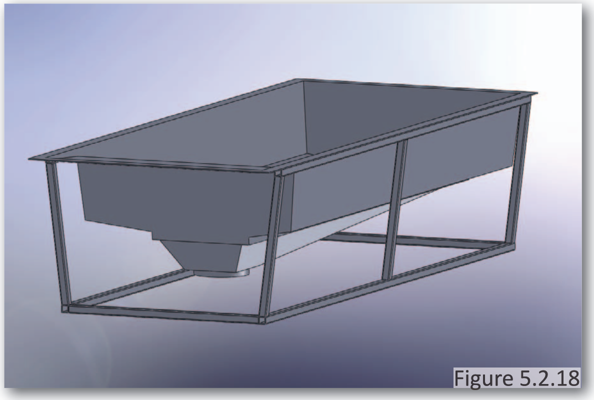


Figure 5.2.18

The tub is then detailed further to be able to accommodate the drive mechanism, the carriage system and the suction.

The company has requested a back up plan if one suction would unexpectedly produce a vortex. This is why in the design room is left for the placement of an extra small suction on the suction mounting area. The area where the suction will be mounted is also sunk a little bit more to ensure that the tub empties as much as possible. The design of the tub is shown in figure 5.2.19.

Because the nozzles are slightly off centered the tub is not symmetrical. The location of the corners in which the guide rails are mounted are determined so that the nozzles are exactly centered. The depth of the tub is determined by height of the nozzles and the distance the nozzles have to be from the back of the person to have the required surface area. The total depth of the tub is 13 inch, the depth up to the guide rails is 10 inch.

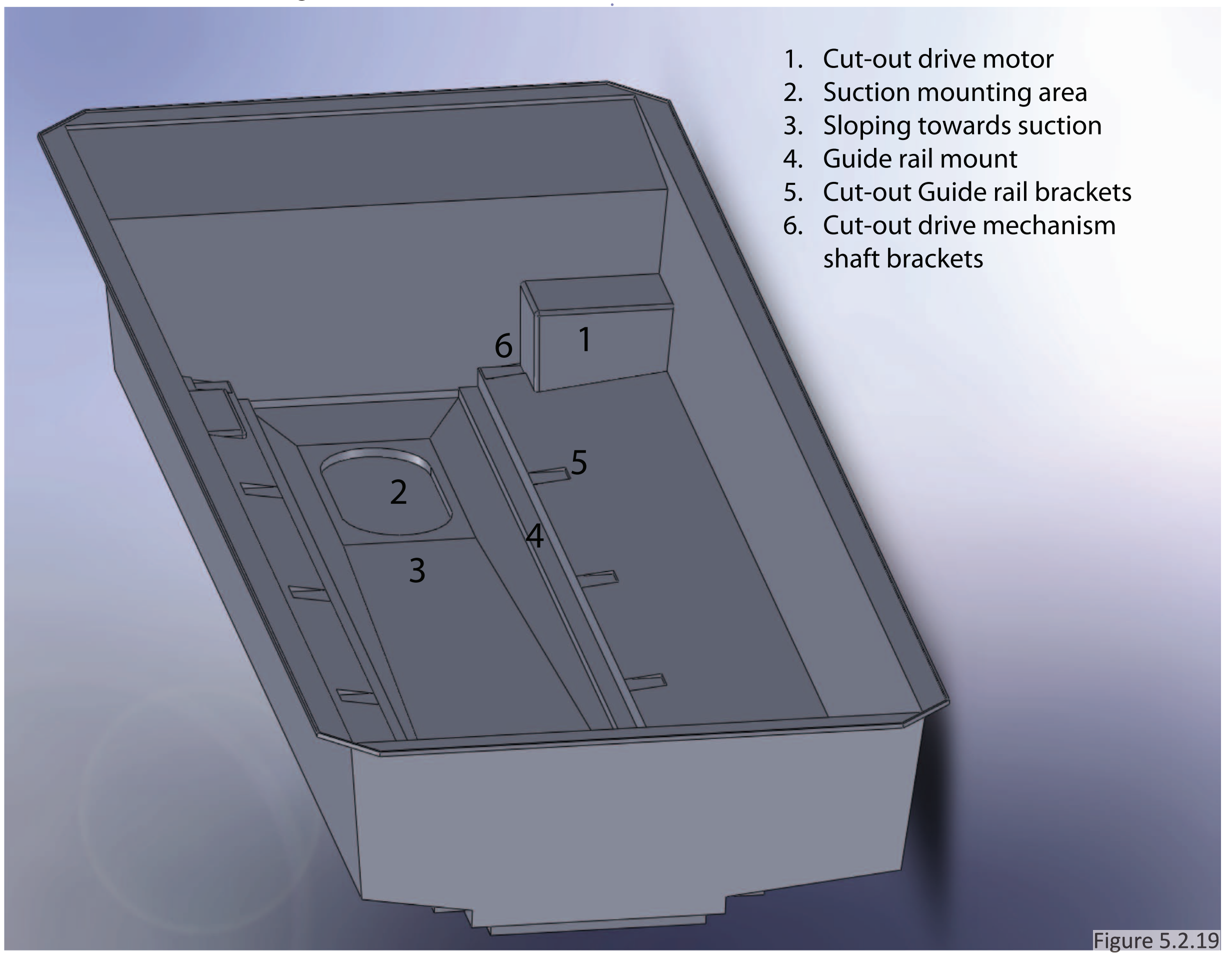


Figure 5.2.19

The tub must accommodate the carriage system and the guide rail. The material of the guide rail is not bondable so cut-outs are made on places where brackets go to hold down the guide rail, these notches are slightly angled (1 degree) to make sure there is always a little pressure on the guide rails so these are not able to move. Notches are also made on both ends of the tub to accommodate the brackets of the drive mechanism. The brackets to hold down the guide rails and the brackets for the drive mechanism are glued in place in these notches. The drive motor is mounted on the outside of the tub. To minimize the length of the drive shaft a cut-out is made to be able to mount the drive motor as close as possible to the drive mechanism.

Figure 5.2.20 and 5.2.21 show two cross-sections of the tub assembly. The first cross-section shows the mounting of the brackets which hold the guide rail in place. The brackets (blue) are placed over the guide rails and have a lip on the end securing the guide rail in the corner of the tub. The second cross-section shows the mounted drive mechanism. The shaft brackets (red) are mounted on either end of the tub. The drive motor is mounted in the cut-out, in this picture shown on the left. The axle is fed through the tub by a water tight connection, already used in the old product. The bearing of the axle in the brackets will be done by a slide bearing placed in the holes of the brackets.

Figure 5.2.20

5.2.9 Material tub

The current material of the tub is polyethylene (PE) which is a material with good properties concerning chemical resistance. The drawback of this material is that it is relatively expensive and it does not bond to itself or other materials. After a consult with the plastics expert within Pro Sun a decision is made to change the material to consider ABS as a material. ABS is about 1/3rd the price of PE.

One of the big pluses of ABS, apart from the cost, is that it is bondable. This means glue or other bonding techniques can be used to bond parts in place. No bolt or screw holes have to be made in the bottom of tub to keep the drive mechanism brackets and the guide rail brackets in place. This eliminates potential leaks in these places.

ABS also forms well by vacuum forming or pressure forming, keeping its shape well when cooling down. This makes it possible to form with small tolerances and tight corners. Also Pro Sun is able to form ABS in house which gives a production advantage.

ABS is strong enough to hold the weight of the water and is not affected by water. This shows in applications in which ABS is used as a standard material. Some of these applications are: jacuzzi's, water tanks and bathtubs.

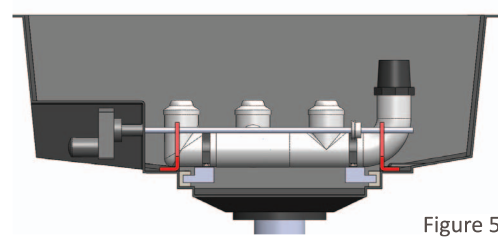


Figure 5.2.21

5.2.10 Strength analysis tub

To determine the strength of the tub a strength analysis is done using cosmos. The maximum deformation allowed is 0.25in. The load on the tub was similar to the weight of 40 gallons of water. Material used for the strength analyses is ABS. Figure 5.2.22 shows the deformation for the tub design. Appendix I shows enlargements of the deformation picture.

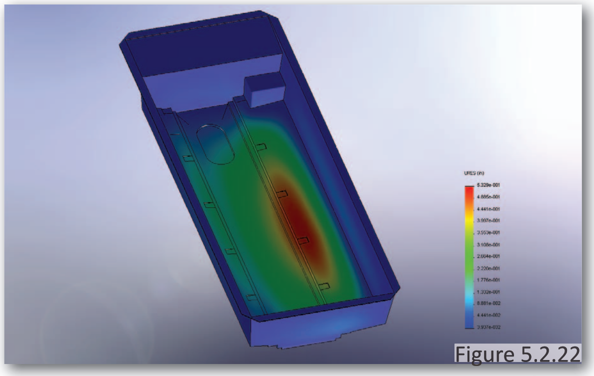


Figure 5.2.22

The red zones in this figure indicate the maximum deformation which in this case is 0.53 inch. This deformation is unacceptable.

To strengthen the tub and minimize the deformation under the 40 gallon load ribs are added. The designs with ribs are also subjected to the same strength test. Figure 5.2.23 shows the deformation with just side ribs.

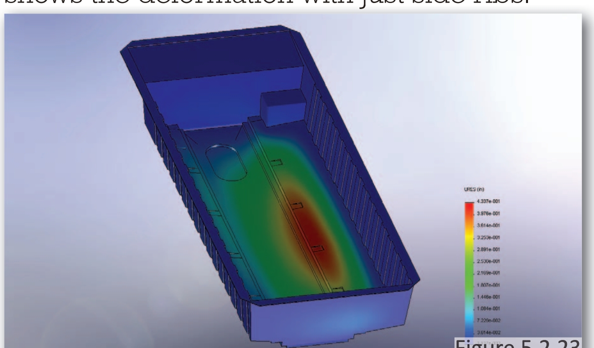


Figure 5.2.23

With adding the side ribs the maximum deformation is reduced to 0.43inch. This deformation is also unacceptable.

Figure 5.2.24 shows the deformation after adding ribs in the bottom of the tub.

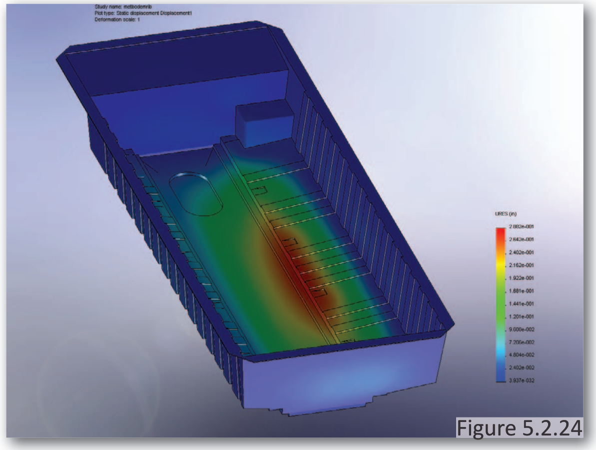


Figure 5.2.24

Adding ribs to the bottom of the tub reduces the maximum deformation to 0.29 inch. This comes closer to the 0.25in allowed but is still to much.

To minimize deformation even further it is decided to place a tube in the frame to support the tub under the red area. Figure 5.2.25 shows the deformation when this support is in place. The maximum deformation for this design is 0.11inch, which is acceptable.

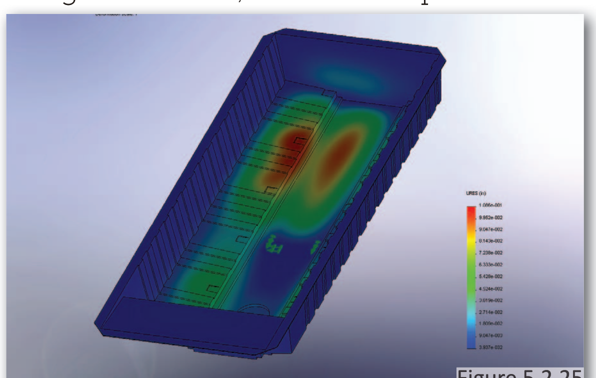


Figure 5.2.25

5.2.11 Plumbing

A costly factor within the tub is the plumbing. This is why the plumbing is redesigned to contain less parts and be less expensive. The plumbing of the tub consists of the suction, which is already selected, the hose in the jet/motor/hose assembly and the bulkhead hose assembly, which is the plumbing that transports the water to the nozzle assembly. The old jet/motor/hose assembly is shown in figure 5.2.26.

Figure 5.2.26

The main goal while redesigning the plumbing is to eliminate unnecessary or expensive parts. The most expensive parts within the plumbing are the swivel adapters, $ 25 each, and the tank adapters, $14 each.

By eliminating the whole bulkhead hose assembly and hose ($ 48.49) and replacing this with a long hose and one swivel adapter on the end of the hose (figure 5.2.27) cost is reduced to $28.29. Calculation of the cost can be seen in table 5.2.3.

The cost reduction of the whole plumbing including The bulkhead-hose assembly, the suction, tank adapter, plumbing tub and motor plumbing is calculated in table 5.2.4.

In this table the cost for the plumbing tub is removed as this has been taken up by the bulkhead hose assembly. The total cost reduction for the plumbing is $166.99-$91.81=$75.18.

Figure 5.2.27

Part	***Quantity***	***Total price***
1/2in spa hose tigerflex	6.75	$10.94
1-1/2'' Swivel Fitting A	1	$13.39
1-1/2'' PVC N40 Coupler FemaleTreadxSleeve	1	$0.50
1-1/2'' PVC N40 Male Adapter MTxS	1	$0.47
Labor 5 min	1	$3.00
Total		**28.29**

Table 5.2.3

Part	***Old price***	***New price***
Bulkhead & hose	$48,49	$28.29
Suction	$25,16	$8.00
Tank adapter	$22.16	$2.50
Plumbing tub	$18.16	-
Plumbing motor	$53.02	$53.02
Total	**$166.99**	**91.81**

Table 5.2.4

5.2.12 Estimated cost reduction

The cost reduction for the tub, the carriage system and the plumbing is estimated based on material cost, labor, pre-redesign cost.

The carriage system is part of the tub frame which is bought by Pro Sun as a whole. It is estimated that the frame inside of the tub is about 1/3rd of the price of the total frame. This is about $145. This frame is now replaced by the redesigned carriage system. Estimated cost for the carriage system are calculated in Table 5.2.5. The estimated cost of the guide rail and sliding block are based on quotes from plastic manufacturing companies (Appendix J). Other costs are based on labor and material cost estimates and current prices of components.

Table 5.2.5

Part	***Quantity***	***Total price***
Guide rail	2	$34.00
Sliding block	2	$16.00
Guide rail brackets	8	$4.00
Nozzle brackets	4	$4.00
Special ABS glue	0.1	$3.00
Labor 5 min	4	$12.00
Total		**$73.00**

The cost of the drive mechanism has gone up slightly due to the extra shaft needed and the brackets that hold the shaft inside of the tub. The cost of the drive mechanism is estimated to increase by $10.00.

To determine the difference in cost of the tub itself the material cost for the new tub is estimated. The mold is estimated to be $1600 to make. The company expects to discard a wooden mold after 500 pieces. If 500 tubs can be formed from this mold the cost of the mold per tub is $3.20. To be on the safe side a cost of $ 5.00 per tub for the mold is calculated. Vacuum forming labor is more expensive than normal assembly labor and is $5 per 5 minutes. The material cost for the polyethylene is estimated to be $70. Table 5.2.6 gives an overview of the calculation.

Part	***Quantity***	***Total price***
Sheet ABS 48x96x0.25	1	$97.00
Mold	.005	$5.00
Labor 5 min	2	$10.00
Total		**112.00**

Table 5.2.6

The estimated cost reduction for the tub and carriage system is estimated to be about $127,00, as is shown in Table 5.2.7. Although the tub is $10,00 more expensive than the old solution it has the advantage of being able to be produced inhouse. Which saves storage costs and means that the tub does not have to be produced or bought in high quantities. The drive mechanism is expected to cost $10.00 more than the old system as in the redesign two axles are needed as well as 2 slide bearings on each side.

Assembly	***Old price***	***Cost reduction***
Carriage system	$145	$72.00
Plumbing	$166.99	$75.18
Tub	$102.00	-$10.00
Drive mechanism	--	-$10.00
Total		**$127.18**

Table 5.2.7

5.2.13 Selected concept

The selected concepts for the tub and carriage system are designed as shown in figure 5.2.28 and figure 5.2.29. The tub is designed to hold a low friction carriage system and a water suction. Also there is room for the drive mechanism driving the carriage.

The tub has ribs and a support from the frame to ensure it remains in the same shape under the water load and the pressure of the water jets. It also keeps its shape when the temperature exceeds the normal operating temperature

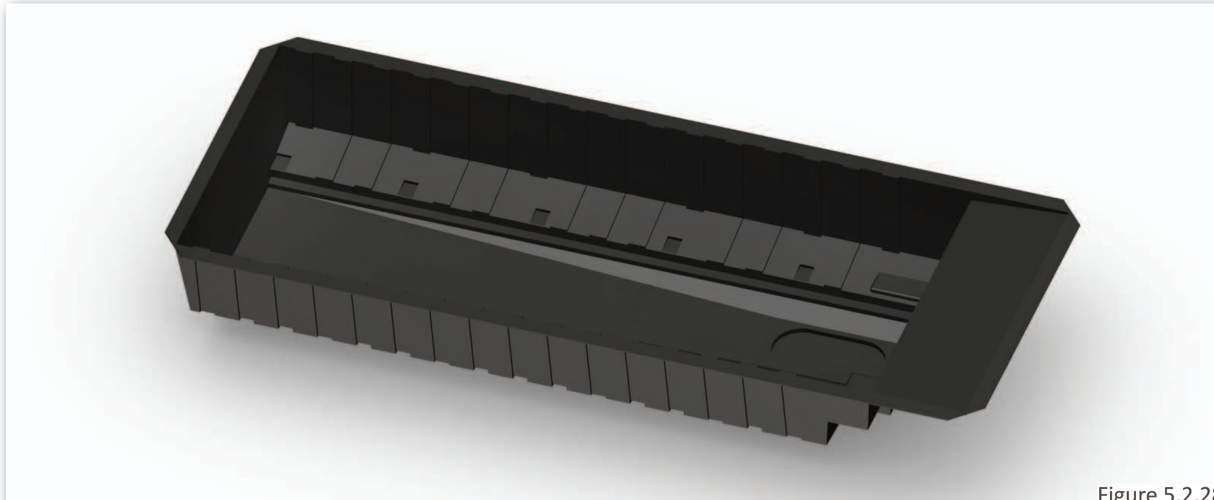


Figure 5.2.28

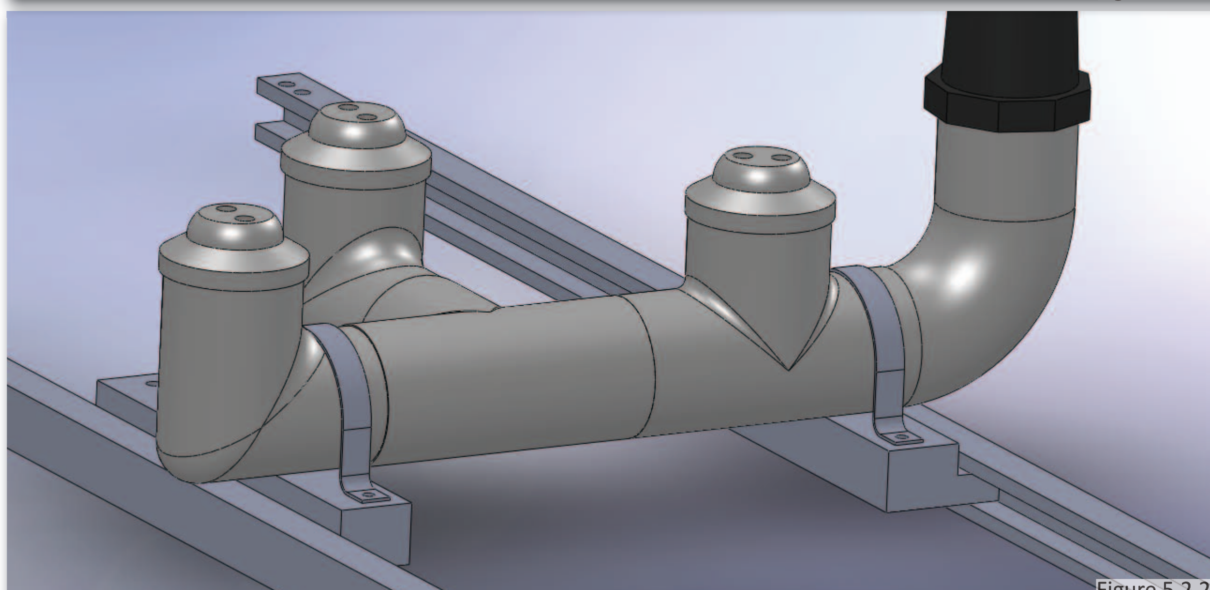


Figure 5.2.29

Table 5.2.8 shows the requirements and if they are met. The selected concept for the tub and carriage system meet almost all initial requirements. There is a total of three requirements which are not met.

The tub has two requirements which are not met or not completely met. The first of these requirements is to be able to empty the tub completely. During the design process this proved to be a difficulty. The tub can not be emptied completely because the pump does not work if air is sucked into the pump. As soon as the water reaches 1 inch in height, every suction makes a vortex and thus will suck air into the pump. The sloping of the tub makes sure the tub can be emptied to about half a gallon which can then be left in or be dried out. The other requirement for the tub which is not met is the reducing of the material. As the molds come in standard sizes for the forming machines of Pro Sun, the amount of material could not be reduced. A different material is chosen instead which comes at a lower price.

The carriage system failed one requirement. The reason for this requirement was initially because of the electrolysis of the metals in the tub. Because plastic bolts are not strong enough to mount the nozzle assembly on the guide block a choice is made to use Stainless steel bolts, but as long as only one type of noncorrosive metal is used this is no problem as electrolysis appears only with two different metals.

Every other requirement is met, and the production cost is reduced with $127.

Tub requirements	***Met?***
The tub must be able to empty completely	No
The tub must hold rails for a carriage to let the nozzles travel up and down the bed.	Yes
The tub must house the driving mechanism for the carriage system	Yes
The amount of material used in the tub must be reduced	No
The material of the tub must be low cost	Yes
The tub must be strong enough to hold the water	Yes
The tub must be able to hold enough water to run the machine	Yes
The top dimensions of the tub must match the current product dimensions	Yes
The tub must be less deep to make forming easier	Yes
The tub must leave room for the mechanical and electrical components	Yes
Carriage system requirements	***Extra info***
There may not be any metals inside the tub	No
The sliding mechanism for the carriage must have as low friction as possible	Yes
The sliding mechanism must be strong enough to all force	Yes
The sliding mechanism must have as low abrasion as possible	Yes
The carriage system must become cheaper	Yes
The sliding mechanism must have low maintenance	Yes
Plumbing requirements	***Extra info***
The plumbing in the tub must be cheaper	Yes
The suction in the tub may not suck up air.	Yes
The plumbing in the tub must able to fit on the plumbing on the outside	Yes
The plumbing must consist of standard parts	Yes

Table 5.2.8

5.3 Top

The product analyses showed that the top is one of the most labor intensive and also costly parts of the product. The top consists of the upper frame, the net mounted on the upper frame, the bladder, the anti-bacteria sheet and the side cushions. The main goal for redesigning this part is to make it possible to be one big subassembly. This subassembly can be mounted in one piece, while making sure different components can still be replaced if they are broken or if they need to be washed. The total production cost of the top now is $454,00.

First the requirements will be discussed, then the ideas for the frame are shown, next the detailed design for the frame is discussed and last the requirements are checked with the design to determine if every requirement is met.

5.3.1 Requirements

The requirements (Table 5.3.1) are set up based on the analyses made in the analyses chapter. The main requirement for the top besides the cost effectiveness is that every part has to be easily replaceable for servicing or replacement. Other requirements which are important are the replacing of the net with something which does not stretch and feels better when laying on it. Also the top being easily removable for maintenance and filling the tub with water.

5.3.2 Ideas

For the top several ideas are explored. First different solutions for the mounting of the net are explored to replace the screws the net is mounted on in the old product. Only one of these solutions is promising enough to detail further. This solution is a rectangular frame on which the net is mounted and can be laid in the product directly without the need of screws in the top frame.

Table 5.3.1

Requirement	***Extra info***
The top must be easy removable for maintenance and adding water	
The top must fit correctly and neat	
The top must have a watertight seal	
The anti-bacteria sheet must be nice and tight looking	
The net must be replaced with something which has minimal stretching over time	
The individual parts must be able to be replaced easily	
The top frame must match the dimensions of the tub.	
The top frame must be more cost effective	Old: $145.00
The top must be easy to assemble	
Wish	***Extra info***
It is preferred the anti-bacteria sheet is nice and tight looking	
It is preferred that the top is one subassembly	

Next different solutions to replace the net are explored. Figure 5.3.1 shows a brainstorm which is made to find a different solution for the net which still allows enough water to go through to ensure the massage quality does not decrease. Figure 5.3.2 shows a collage of different net types, which is enlarged in Appendix K.

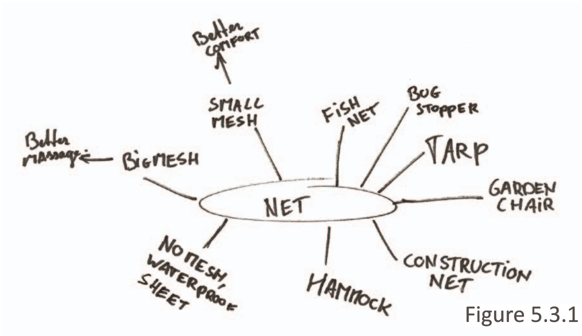


Figure 5.3.1

Figure 5.3.2

To eliminate the necessity of using the bladder a solution is explored to replace the net with waterproof fabric. This was discarded as making the corners waterproof seems impossible. A choice is made for a small mesh netting usually used in garden chairs. The net will have sowed sleeves in which tubes are inserted.

5.3.3 Detailing

Designing the top in more detail consists of detailing the frame on which the net is mounted, detailing the top frame and then integrating these designs with the soft rails, bladder and antibacterial sheet.

The net frame is first designed as a rectangular frame of PVC tubes connected in the corners by corner pieces. From this design a prototype is made to see whether this is easy to assemble, strong enough and see how many mounting points are needed. Figure 5.3.3 shows a picture of this prototype.

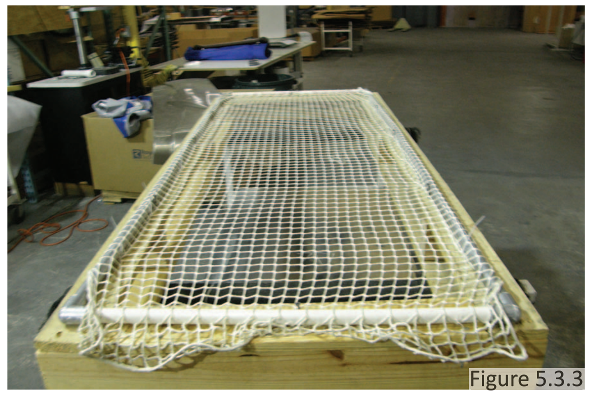


Figure 5.3.3

The prototype showed that there needs to be a mounting point every foot. Next another test is done without the corner pieces. This test showed that it made no difference if the corner pieces are left out as long as the tube was supported at each end. The design without corner pieces has the preference because it is easier to transport and has less parts. The frame consists of standard tubes. The material for the tubes is standard high pressure PVC tubing.

Next the top frame is designed. Figure 5.3.4 shows several ideas which are explored. The main objective for the redesign of the top frame, apart from making it cheaper, is to make sure it completely seals all round so no water can leak out of the tub.

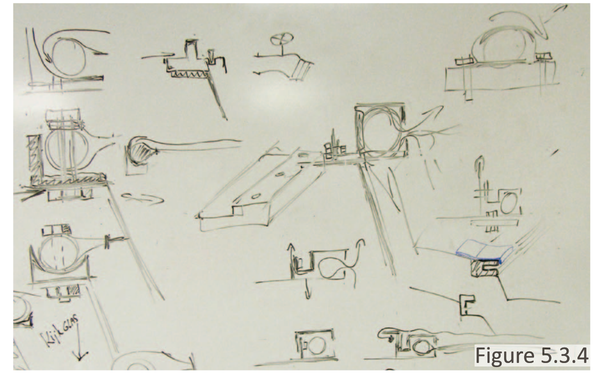


Figure 5.3.4

The chosen design is a combination of two extruded shapes which enclose the tube frame. The design of this top frame is shown in figure 5.3.5.

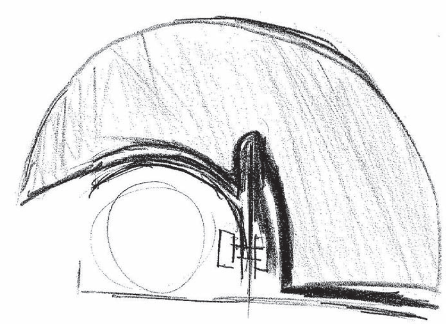


Figure 5.3.5

The top frame is detailed further into a 3-D model of which a 2-D view is shown in Figure 5.3.6. The bend at 1 is made so the net is not stretched over a sharp corner potentially causing tears. The maximum diameter tube that fits in the design 0.5 inch. The ridge at 2 is made to clamp on the bladder and anti bacterial sheet with trim. The lip at 3 is made so the top frame can be easily positioned on top of the tub.

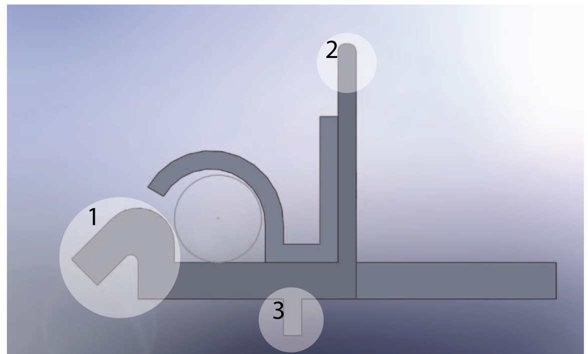


Figure 5.3.6

This frame is then mounted on the main-frame by bolts with the tub in between. To ensure no water can go through the connection between the tub and the top frame a rubber seal is used. The seal is placed in between the tub and the top frame. The 3-D model of the mounting of the top frame is shown in figure 5.3.7.

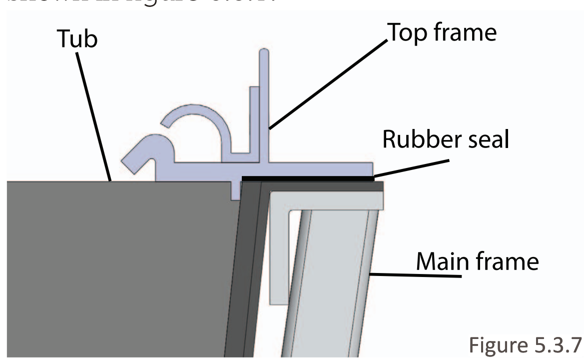


Figure 5.3.7

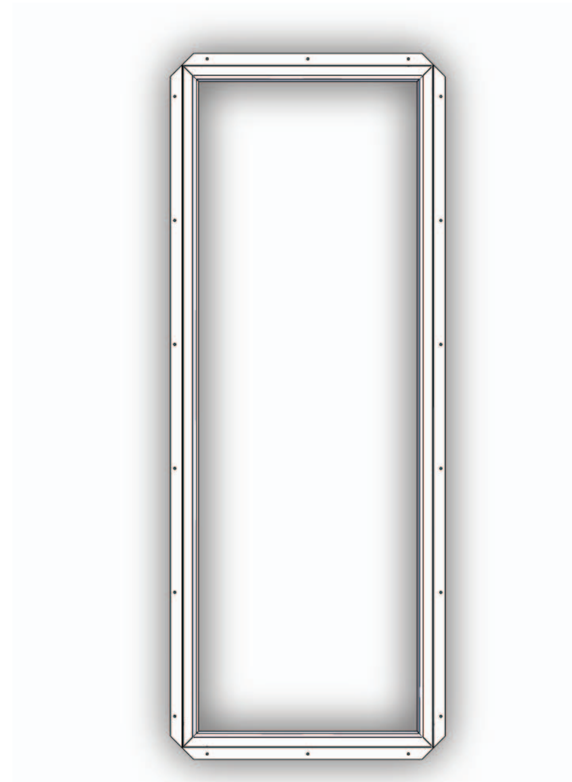


Figure 5.3.8

The bottom pieces of the top frame are first cut to size and then welded together to form a rectangle which matches the dimensions of the tub (Figure 5.3.8). The upper pieces of the top frame are cut to size and bolted onto the bottom piece with the net frame in between.

The leather rails are mounted on a one piece vacuum formed support rail as shown in Figure 5.3.9. The support rail matches the dimensions of the top frame and fits over it to cover up all the aluminum parts.

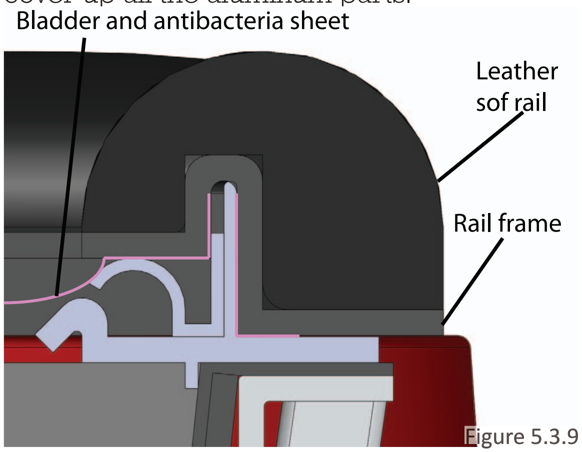


Figure 5.3.9

The bladder and anti-bacterial sheet are mounted in between the support rail and the top frame.

The rectangular support rail Figure 5.3.10 can be formed out of one sheet. The middle section which is not used for the frame support, can be utilized to form brackets for inside the tub, a drip tray and anything else that might be needed.

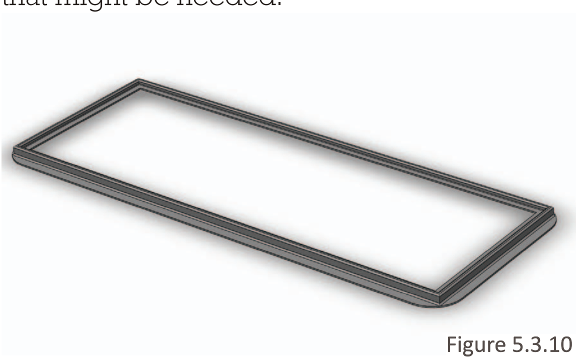


Figure 5.3.10

5.3.4 Estimated cost reduction

The top has three main subassemblies which are all calculated apart from each other. The calculations of the net is shown in Table 5.3.2, the calculation for the top frame is shown in Table 5.3.3 and the calculation for the soft rails is shown in Table 5.3.4 The costs are estimated based on material cost, current cost from the bill of material and labor cost.

After all individual subassemblies are calculated the total cost reduction for the tub is estimated by adding up all components. This calculation is shown in Table 5.3.5. The estimated cost reduction for the total top is $33.00.

Part	***Quantity***	***Total price***
Mesh fabric outdoor chair per sq ft	20	$20.00
Labor sewing mesh fabric	4	$12.00
Plastic tube per ft	18	$ 10.00
Total		**$42.00**

Table 5.3.2

Part	***Quantity***	***Total price***
Extruded aluminium top piece per ft	20	$80.00
Extruded aluminium bottom piece per ft	18	$40.00
Stainless steel bolts & nuts	18	$5.00
Labor 5 min (cutter & drill)	4	$12.00
Labor 5 min (welder)	1	$3.00
Total		**$140.00**

Table 5.3.3

Part	***Quantity***	***Total price***
ABS sheet 0.25in	.5	$47.00
Foam pieces	4	$9.46
Staples	300	$2.85
Vinyl for rail	1	$20.00
Labor 5 min (assembly)	4	$12.00
Labor 5 min (forming)	2	$10.00
Total		**$101.31**

Table 5.3.4

Assembly/part	***Old price***	***Cost reduction***
Top frame	$145	$5.00
Net	$45.00	$3.00
Soft rails	$112.00	$9.00
Anti bacterial sheet	$26.46	$0.00
Bladder	$90.19	$0.00
Labor assembly	$36	$18.00
Total		**$33.00**

Table 5.3.5

5.3.5 Selected concept

The selected concept and detailed concept is shown in Figure 5.3.11. The design is not one subassembly due to every part having to be easy replaceable. Though it is not one assembly the easy of assembling as improved dramatically. The net is easier to assemble as just 4 tubes have to be inserted in sowed sleeves, the rails do not need 4 parts anymore, and the net is fastened in place easily as well.

The design meets all requirements, and unfortunately none of the wishes (Table 5.3.6). Both wishes proved to be impossible to realize. The wishes not met are, the top must be one subassembly and the anti-bacteria sheet must be neat and tight looking. The first of these, as explained earlier, is a wish which was not possible due to the requirement of parts having to be replaceable. The second requirement means changing the anti bacteria sheet for something that is stretch and still anti bacteria. This material

Figure 5.3.11

Requirement	***Met?***
The top must be easy removable for maintenance and adding water	Yes
The top must fit correctly and neat	Yes
The top must have a watertight seal	Yes
The net must be replaced with something which has minimal stretching over time	Yes
The individual parts must be able to be replaced easily	Yes
The top frame must match the dimensions of the tub.	Yes
The top frame must be more cost effective	Yes
The top must be easy to assemble	Yes
Wish	***Met?***
It is preferred the anti-bacteria sheet is nice and tight looking	No
It is preferred that the top is one subassembly	No

Table 5.3.6

5.4 Main frame

The frame is the main support and the mounting place for all components and parts of the product. All electrical, mechanical and plumbing components which are not mounted in the tub, are mounted on the frame. The frame also supports the tub. The goal for redesigning the frame is to make it cost effective while still maintaining its strength.

First the requirements will be discussed, then the ideas for the frame are shown, next the detailed design for the frame is discussed and last the requirements are checked with the design to determine if every requirement is met.

5.4.1 Requirements

The requirements for the main frame are listed in Table 5.4.1. One of the key requirements for the frame is the strength. The frame must be able to support the weight of the water, the tub, the motor and a person without breaking. The frame failing would have devastating consequences for the whole product. Another key requirement is that the frame must match the outside dimensions of the old frame. The reason for this requirement is that the cosmetic cover plates are mounted on the frame. The company already has a mold for these cover plates and does not wish to change these.

Requirement	***Extra info***
All the unnecessary bends must be removed from the frame	
The frame must hold and support the redesigned tub	
The frame must fit the new top	
The frame must be strong enough to hold all the weight	At least: water+ user+ tub=600 pounds
The frame must be able to have 6 wheels	
The frame must match the outside dimensions of the current frame	
The frame must be able to hold the electrical and mechanical components of the product	
Both motor footprints must be mountable on the frame	220v 50hz & 110v/220v 60z
The frame must cost less than the old frame	Old: $145.00
The top frame must be mounted on the bottom frame with the tub in between	

Table 5.4.1

5.4.2 Ideas

In order to explore different shapes which can be used for the frame some sketches are made. These are shown in figure 5.4.1. Ideas ranged from a frame based on a hanging bridge to a construction crane. Because there is a requirement to minimize the amount of unnecessary bends a choice is made to keep the frame as simple as possible. Also thinking about the least difficult cuts. This means the straight frame on the top left of figure 5.4.1.

5.4.3 Material

Before detailing the frame a choice is made on which material is going to be used. For the frame material there are several options. These options are all metals because a plastic with the strength of a metal is not possible due to its cost. With plastic eliminated three options are left, steel, stainless steel and aluminum. Each material has its advantages and disadvantages. The comparison is made assuming the structural design is the same for all materials.

Steel is cheap and easy to weld. The drawback of steel is that it has the property of being highly corrosive, which means it would need to be painted or galvanized. Another drawback to steel is its density, a steel frame would weigh way more than the current frame which means shipping costs will increase. The e-modulus of steel is 200.

The main advantage of stainless steel is that it does not corrode. It also is easy to weld meaning it induces less labor cost. Stainless steel however is relatively expensive at about four times the price of normal steel. Another disadvantage is that it, like normal steel, has a high density. The e-modulus of stainless steel is 195.

The third option aluminum is the material currently used in the frame. The advantages of aluminium are its low corrosive properties, the density and the cost. The cost is about one and a half times the cost of steel. One of the disadvantages is the strength of aluminium, which is a lot less than steel with an e-modulus of 69. Another disadvantage is the discomfort of welding aluminum.

Aluminium is the material of choice because it is strong enough for the application in the frame and does not need any treatment. It also is the cheapest option for a low corrosive material.

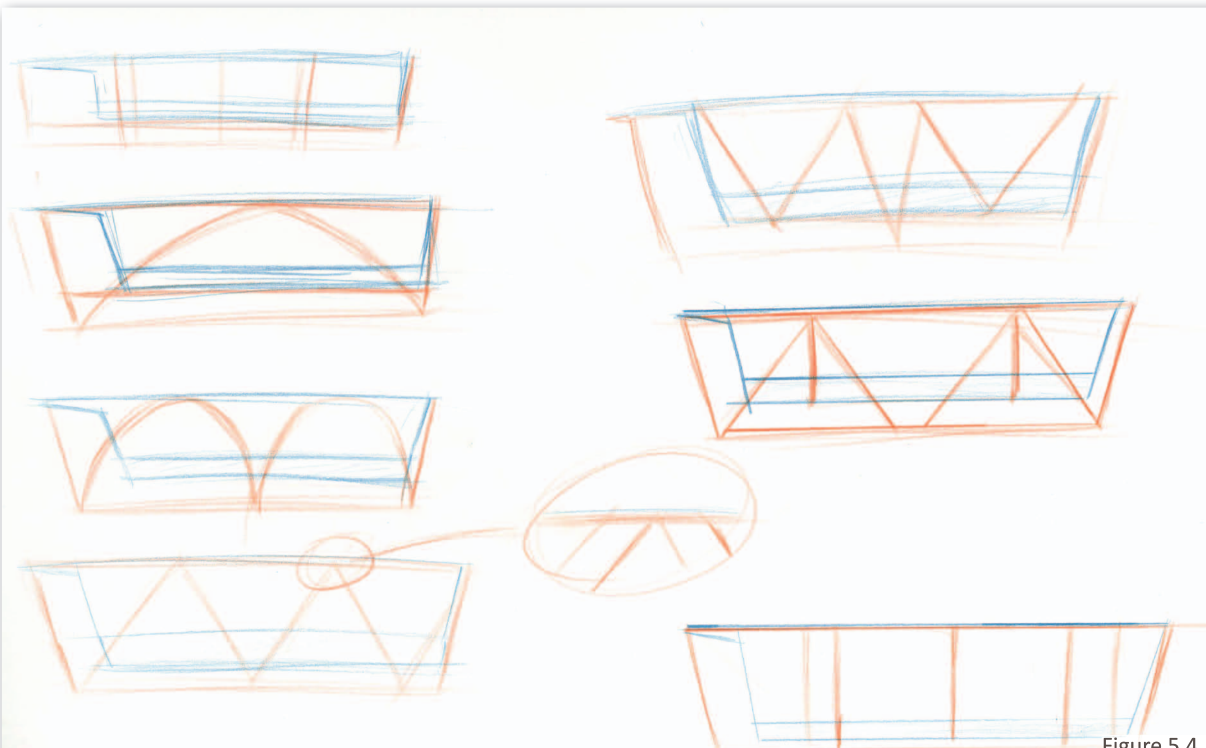


Figure 5.4.1

5.4.4 Detailing

The frame is detailed based on the requirements and the already redesigned parts of the product. The idea of the straight legged frame is first modelled in solid works just to accommodate the tub, as shown in Figure 5.4.2.

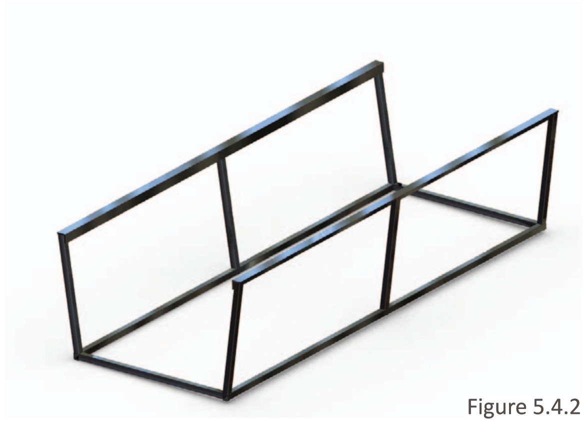


Figure 5.4.2

After this the frame is designed to accommodate the motor mounting plate as well. Making sure there is enough room between the motor and the tub so that they do not hit each other. This could cause overheating and unwanted noises and vibrations. Figure 5.4.3 shows the model of the frame as it is first designed.

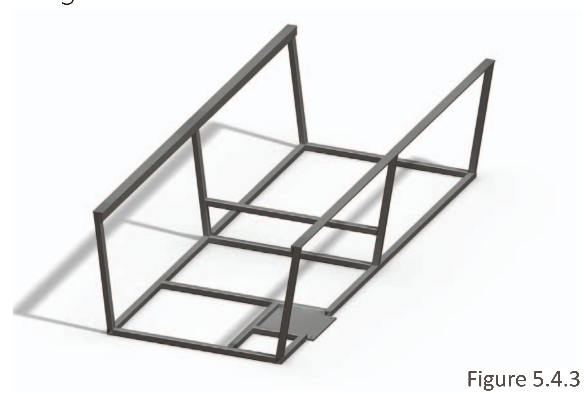


Figure 5.4.3

To determine if three posts on each side suffice a strength analyses is done in cosmos works (appendix L). The load for this test is set at 600 pounds. The load is equal to a 400 pound person and 30 gallons of water pressing down together on the frame. It is assumed that the sideways load of the water is negligible compared to the load downwards.

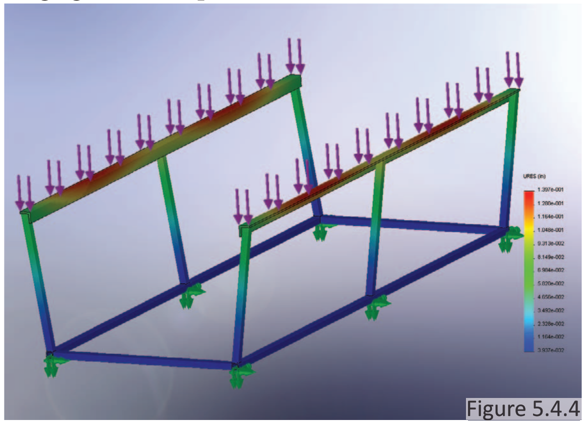


Figure 5.4.4

The maximum displacement for the three post design with three wheels on each side is 0.13in (Figure 5.4.4), which is an acceptable displacement. A strength analysis was also done with four posts and three wheels. This gave a bigger displacement of 0,17in. If four wheels are put on each side this displacement is less.

To keep cost and parts to a minimum a choice is made to go with the three post frame. This requires one less post and one less wheel on each side, saving production and part costs.

5.4.5 Selected concept

The selected concept for the main frame is shown in figure 5.4.5. The frame is made out of aluminium. For the structural base of the frame 1 inch square tubing is used. The top of the frame are standard extruded L-shapes, the reason no tubing is used here is because if tubing is tightened too much with a bolt it can deform. An insert could be a solution to use square tubing here as well, but this will only add more work and material. The top of the main frame is where the tub is mounted in between the top frame and the main frame, to ensure no leakage here, a rubber strip is mounted in between the two frames.

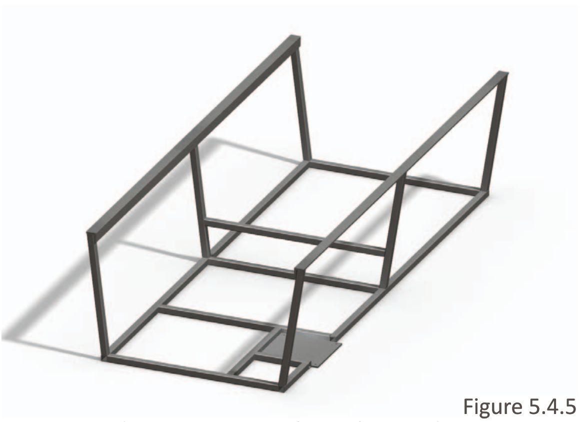


Figure 5.4.5

The estimated cost of the frame is calculated in Table 5.4.2 and is $93.00 This is less than the previous frame, which is estimated at $145.00, because it is a lot easier to make due to the bends not in the frame. Also it being produced in house helps with the costs as the profit margin of the old producer is eliminated and labor cost are about the same.

All of the requirements set for the frame are met. The frame fits both motors because a motor base plate can be mounted on the frame. The numeric stress test shows it is strong enough to hold all the weight.

With the frame being more cost effective an amount of $52 dollar is saved from the production cost.

Part	***Quantity***	***Total price***
1in Rectangular tube alu per ft	45	$40.00
0.25 in plate alu per sq ft	1	$10.00
L-shape 1.5x1.5x0.25in per ft	13	$15.00
Labor 5 min (cutter)	4	$10.00
Labor 5 min (welder)	6	$18.00
Total		**$93.00**

Table 5.4.2

Requirement	***Met?***
All the unnecessary bends must be removed from the frame	Yes
The frame must hold and support the redesigned tub	Yes
The frame must fit the new top	Yes
The frame must be strong enough to hold all the weight	Yes
The frame must be able to have 6 wheels	Yes
The frame must match the outside dimensions of the current frame	Yes
The frame must be able to hold the electrical and mechanical components of the product	Yes
Both motor footprints must be mountable on the frame	Yes
The frame must be cheaper	Yes
The top frame must be able to mount on the bottom frame with the tub in between	Yes

Table 5.4.3

6. Final Product

In this chapter the final product will be discussed. The final product consists of all redesigned and non-redesigned parts together and integrated. Topics are the arrangement and integration of parts and assemblies, a total overview of the final product and the total cost reduction of the redesign,

6.1 Component arrangement & integration

In this paragraph the arrangement of the several parts as well as how they work together and are integrated is explained.

First the arrangement of the parts will be discussed, second the integration of the parts will be discussed.

6.1.1 Part arrangement

The parts are arranged to be as economical and accessible as possible. Every component is accessible from the back end of the WaterWave. This is to make sure the product is easily serviceable by just taking off one cover plate.

Figures 6.1.1, 6.1.2 and 6.1.3 give different overviews of the product and how the components are arranged in the final design. The components are listed below with their numbering.

1. The main frame
2. The cooling fan, to make sure the water does not over-heat
3. Valve and valve motor
4. Control box, which operates the bed and has the remote control attached to it.
5. The motor base plate which fits both the 50hz and 60hz motors
6. A model of the biggest pump motor used, if this one fits, all of them will fit.
7. The tank adapter, which is a leak less connection through the tub.

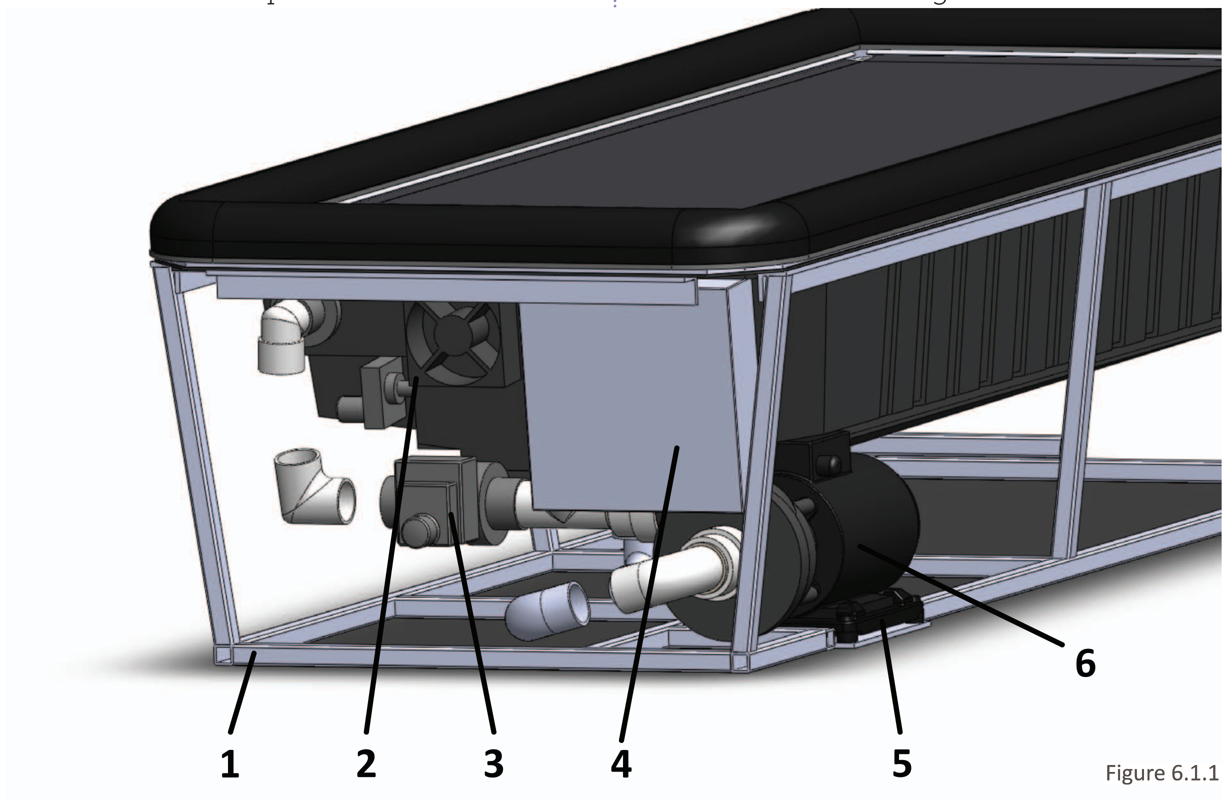


Figure 6.1.1

8. The drive motor, used to drive the carriage system.
9. A faucet to drain the water out of the tub when servicing is needed.
10. The soft rail with its support
11. The top frame
12. The ABS tub
13. The carriage and nozzles
14. The suction
15. The guide rail which guides the carriage.

The suction is connected to the motor by a 2 inch PVC pipe, a flexible hose and two 2 inch L bends. The valve motor is connected to the tank adapter by a 90 degree bend, a piece of PVC pipe and a piece of PVC hose. The PVC pipe is mounted in between the valve motor and the bend, the PVC flexible hose is mounted between the L bend and the tank adapter because this angle can not be made by a straight piece of non flexible PVC pipe.

The inside plumbing is not modelled into the 3-D model. The plumbing inside the tub consists of a piece of spa hose connected to the tank adapter which is then connected to a swivel adapter. This swivel adapter is mounted to the nozzles making the nozzles able to move up and down the tub without getting entangled into the hose.

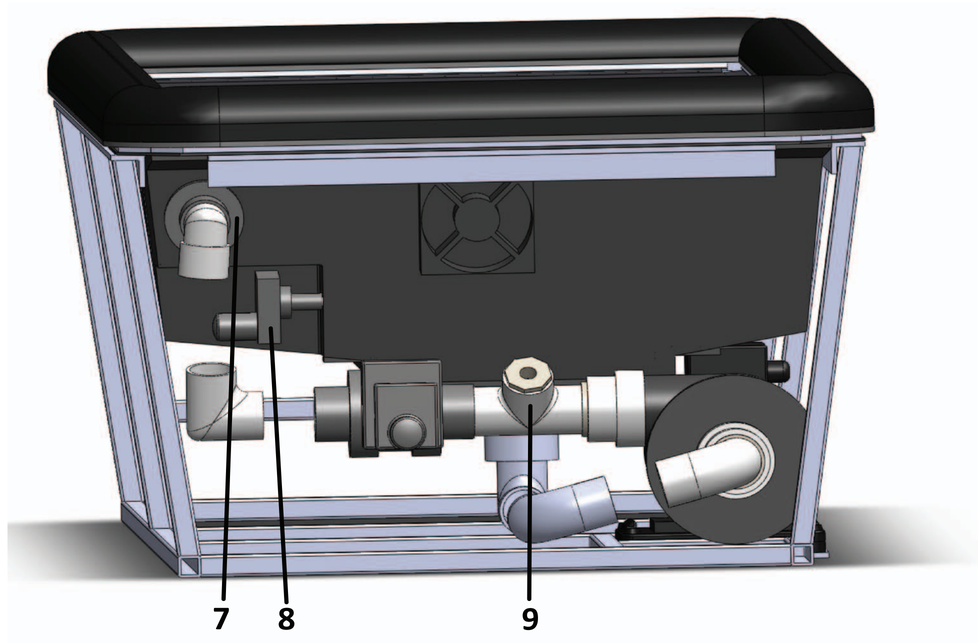


Figure 6.1.2

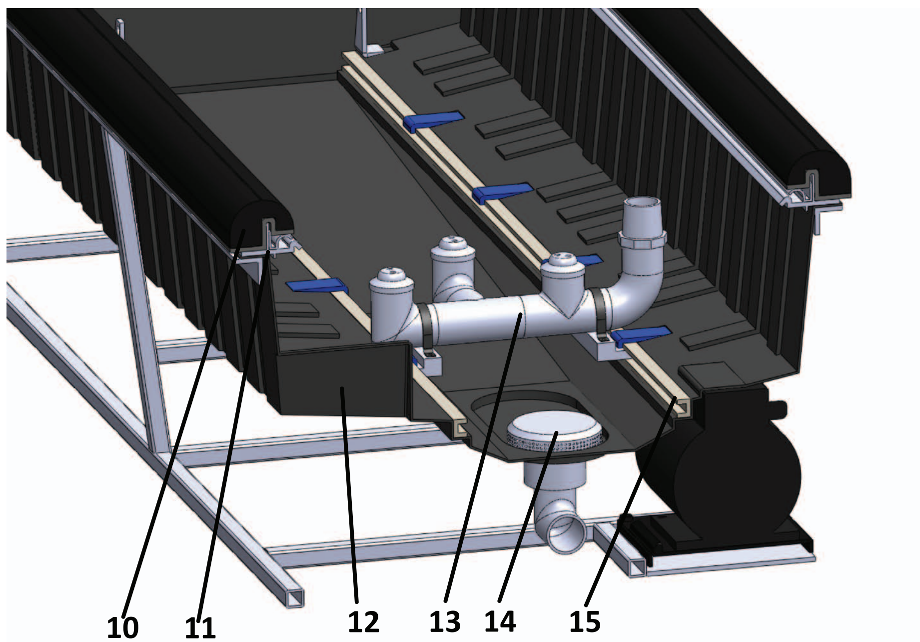


Figure 6.1.3

6.1.2 Part integration

When assembling all parts there are several things that can go wrong. Unwanted noise or vibrations can occur, parts can get stuck or parts do not fit or leaks that might occur.

To ensure no leaks occur it is important that every hole through which water can go through is sealed off by a gasket or an O-ring. The tank adapter and the suction both have these.

To seal the top (figure 6.1.4) from water penetrating through, a rubber seal is placed in between the top frame and main frame. To make sure no water comes through in between the bladder and the top frame the bladder is clamped on by the trim, which is in turn clamped down by the rail support.

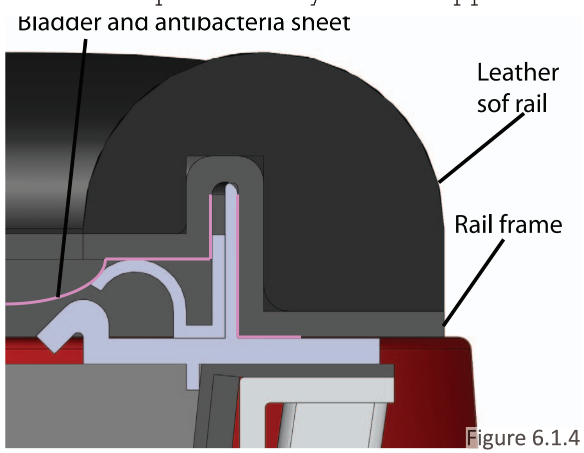


Figure 6.1.4

To make sure the tub fits into the main frame it is important that the forming is exact and the angles on which the frame is are correct. If these angles are too small the tub will not fit, if the angles are too big the tub will not be supported well enough to hold the weight of the water.

If the crossbar between the middle posts of the main frame is aligned with the indent in the tub, the tub is centered within the frame making sure there is room for all components.

The top frame has lips to center it on top of the tub. The top frame can then be bolted on the main frame with the tub in between. The side skirts are bolted on the top frame. The the soft rails are placed over the top frame hiding all the screws and bolts, making the appearance neat and clean.

To prevent unwanted vibrations the motor is mounted on a base plate which is mounted on the frame with rubbers. These rubbers dampen the motors vibrations. To prevent the tub from vibrating through the plumbing mounted to the motor, the pieces connecting the tub to the plumbing system are flexible PVC hose which functions as a damper.

6.2 Cost reduction

In this paragraph the total estimated cost reduction of the product is discussed. The cost reduction is calculated by the cost estimations on the redesigned subassemblies, the assembly time and replaced parts. The cost estimation is shown in Table 6.2.1.

The assembly time for the final product is the same as the old product. The reason for assembly time staying the same is that the amount of components has stayed almost the same in compared to the pre redesigned WaterWave. All components are essential to its working. There are some changes made to the set up of the plumbing but it is estimated to be the same assembly time.

While redesigning the product several components have been replaced with cheaper ones. One of these components is the motor which is now $50 cheaper than the old motor.

Assembly/part	***Old price***	***New Price***	***Cost reduction***
Nozzles	$29.00	$49.00	-$30.00
Tub & carriage	$342.00	$215.00	$127.00
Top	$418.65	385.65	$33.00
Frame	$145.00	$93.00	$52.00
Motor	$187.00	$120.00	$67.00
Labor assembly	$144.00	$144.00	$0.00
Total	**$2688.00**	**$2461.00**	**$227.00**

Table 6.2.1

6.3 Requirements & wishes

This paragraph will give a conclusion on the final design and if it has met all the resulting requirements, discussed in the chapter *Resulting requirements*.

The initial goal of this redesign was to make a concept for the improvement of the WaterWave in order to make it more cost effective and better massaging. The final product has succeeded in achieving this goal. The quality of the massage has gone up, while the cost of the product has gone down.

First the requirements will be discussed, second the wishes will be discussed.

6.3.1 Requirements

Almost all of the requirements resulting from the analysis are met (table 6.3.2). For two of these requirements the outcome is still unknown. The product is not fabricated yet in the way it is redesigned nor has it had a half year test. This means the half year maintenance requirement and the assembly requirement have not been determined yet. However it is expected that these requirements are met as well. Unfortunately one requirement is not met. The use of identical parts, apart from fasteners, proofed to be an impossible task as every subassembly has a different function and different requirements. Ordering materials in large quantities, making the price cheaper is partly possible.

6.3.2 wishes

The wishes with their result are shown in Table 6.3.1. From these wishes only 2 wishes are met, the other 4 are not. The reason for not meeting these wishes are mainly lack of time during the design process. Finding a different solution for the bladder and anti bacteria sheet proved to be more time consuming than expected and hence are discarded. The implementation of new techniques into the product is certainly something that has to be explored further to make the product more interesting.

Category	***Wish***	***Met?***
General	It is preferred to reduce the production cost to below $ 2500	Yes, $2.461
	It is preferred that the usability of the product improves	No
	It is preferred to add new techniques to the product to make it more interesting	No
	It is preferred that the noise the product produces is reduced.	Yes, 75dB
	It is preferred to find a different solution for the bladder	No
	It is preferred to find a different solution for the loose anti bacteria sheet	No

Table 6.3.1

Category	Requirement	Met?
General	The production cost must be reduced	Yes
	The quality of the massage the product gives must improve by improving the nozzles	Yes
	The usability of the product must stay the same	Yes
	The outside dimensions of the product must stay the same	Yes
	The noise the product makes must be the same	Yes
	The massage technique of the product must stay the same	Yes
Maintenance	The product must function with half yearly maintenance	Unknown
	The product must allow for easy maintenance	Unknown
	Parts must be easy accessible	Yes
Production	One person should be able to assemble the product in one day	Yes
	The product must be assembled on a production line	Yes
	The product must have the same fasteners everywhere	Yes
	The product must have as much pre drilled holes as possible	Yes
	The redesigned parts must not require additional machines for ProSun	Yes
	The redesigned parts may not require a change in the existing molds ProSun has.	Yes
Purchasing & Storage	The product must have a high number of identical parts	No
	Ordering materials in large quantities must be possible	Partly
	The material cost must be as low as possible	Yes
	The product must have as many standard parts as possible	Yes

Table 6.3.2

7. Conclusion

To conclude the report a conclusion is made and design recommendations are made per redesigned component.

7.1 Conclusion

The assignment beforehand was to "re-design the ProSun WaterWave so it can be produced more efficiently and more cost effective while still remaining the same massage technique and improving the quality of the massage.

Because there was no time to produce a full scale prototype of the concept there is no proof that it is indeed more cost effective and can be produced more efficiently. The cost-estimation however showed that with the redesign the production cost of the WaterWave is estimated to be reduced with over 225 dollars.

The massage quality improvement has been proved. In the user test the new nozzles showed a considerable advantage over the old nozzles. The improvements have been directly implemented by the company in their old product and customers confirm the improvement.

The dividing of the product into several main subassemblies, redesigning these and then integrating them is key to the success of the redesign. The integration played a big role during the design of the main subassemblies and iterations were constantly done to make sure all components fit together properly.

Overall the redesign is considered a success due to the cost reduction, the great amount of met requirements and the improvement of the massage.

7.2 Recommendation

7.3 Recommendations

In this paragraph recommendations for further development are discussed per redesigned component and in general.

General

- Look at alternative production methods to reduce cost.
- Look for alternative materials to reduce cost.
- Find cheaper alternatives for components to reduce cost.
- Redesign electrical components to reduce cost.
- Test the product for a long period of time to explore any defects that might occur. This to reduce recalls and maintenance calls.
- There are a few wishes which could not be integrated in the product due to lack of time, these could be good features to add to make the product more interesting.
- On the part of noise reduction there is a lot to gain. In the paragraph *noise analysis* a few suggestions are done on what to tackle for noise reduction

Nozzles

- Design a tool so that the nozzles can be easily assembled, saving more production time and cost

Tub & Carriage system

- Explore other solutions for mounting the rails inside the tub
- The brackets which hold the nozzles onto the sliding blocks could be replaced by brackets which are more durable and stronger

Top

- Explore solutions for an anti bacteria sheet integrated with the bladder.
- Find a way to make the production of the leather soft rails easier.

Main Frame

- When a new tub is produced, prototype the main frame to test its strength
- Try the frame with two wheels on each side instead of 3 to see if this is still strong enough.

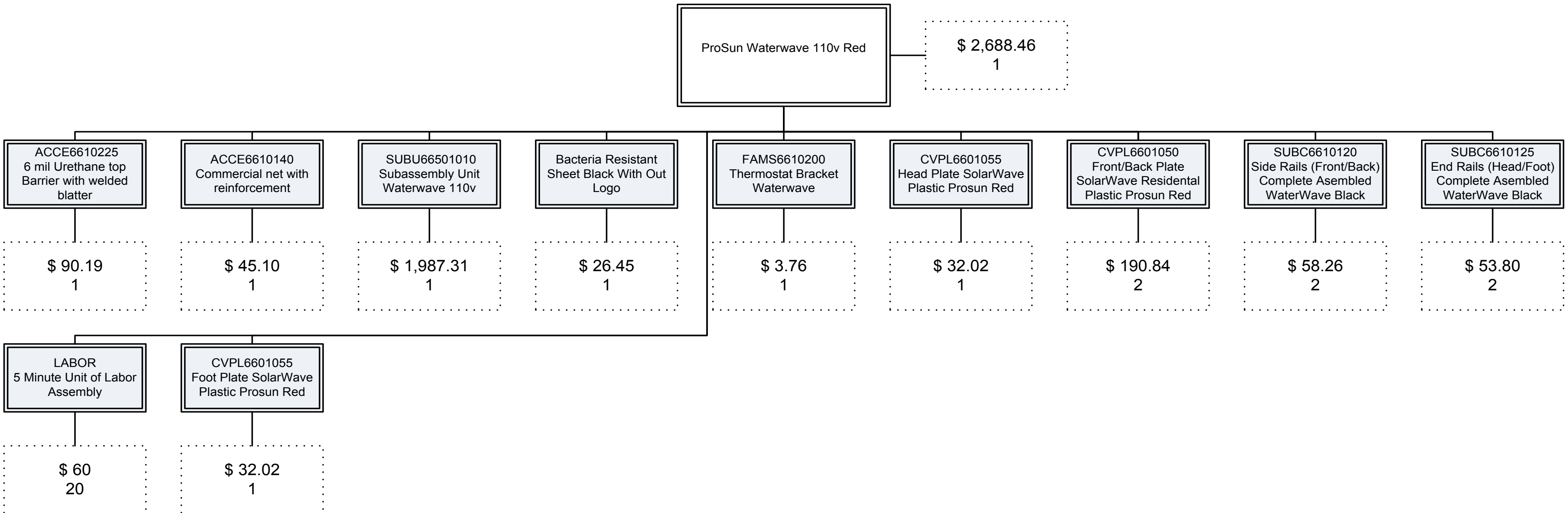
Appendices

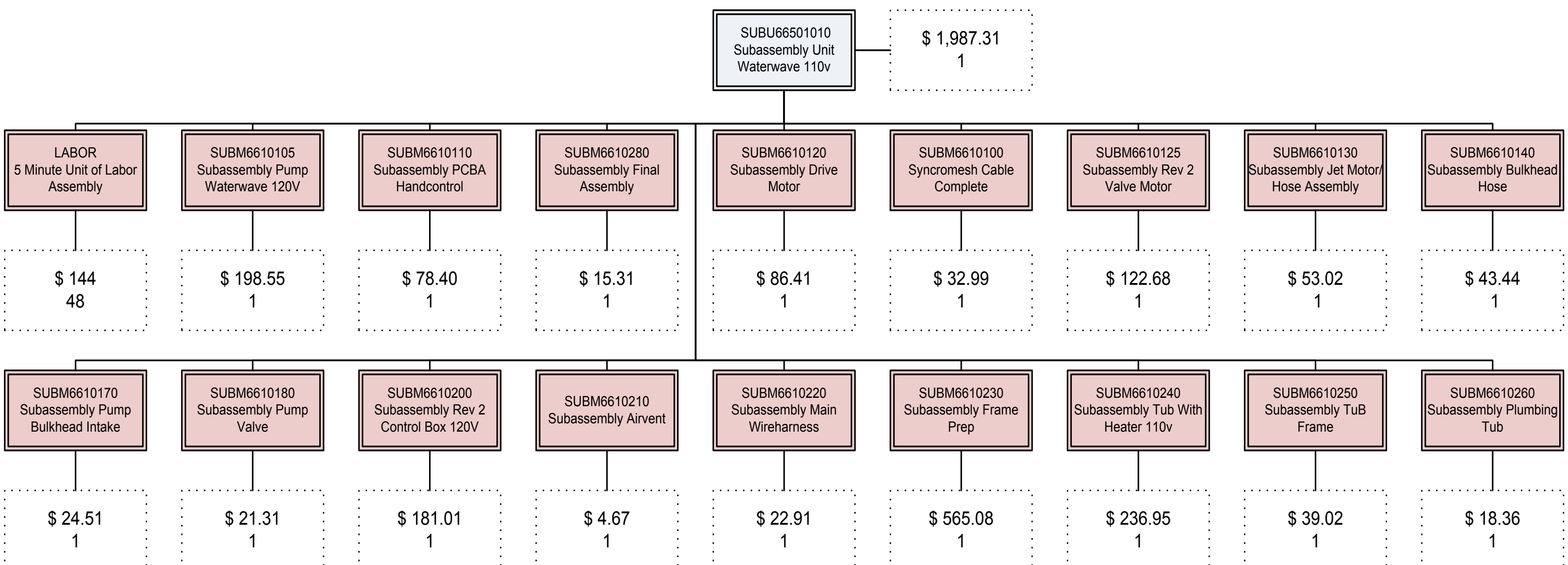
This chapter contains the appendices for the report they are ordered as follows:

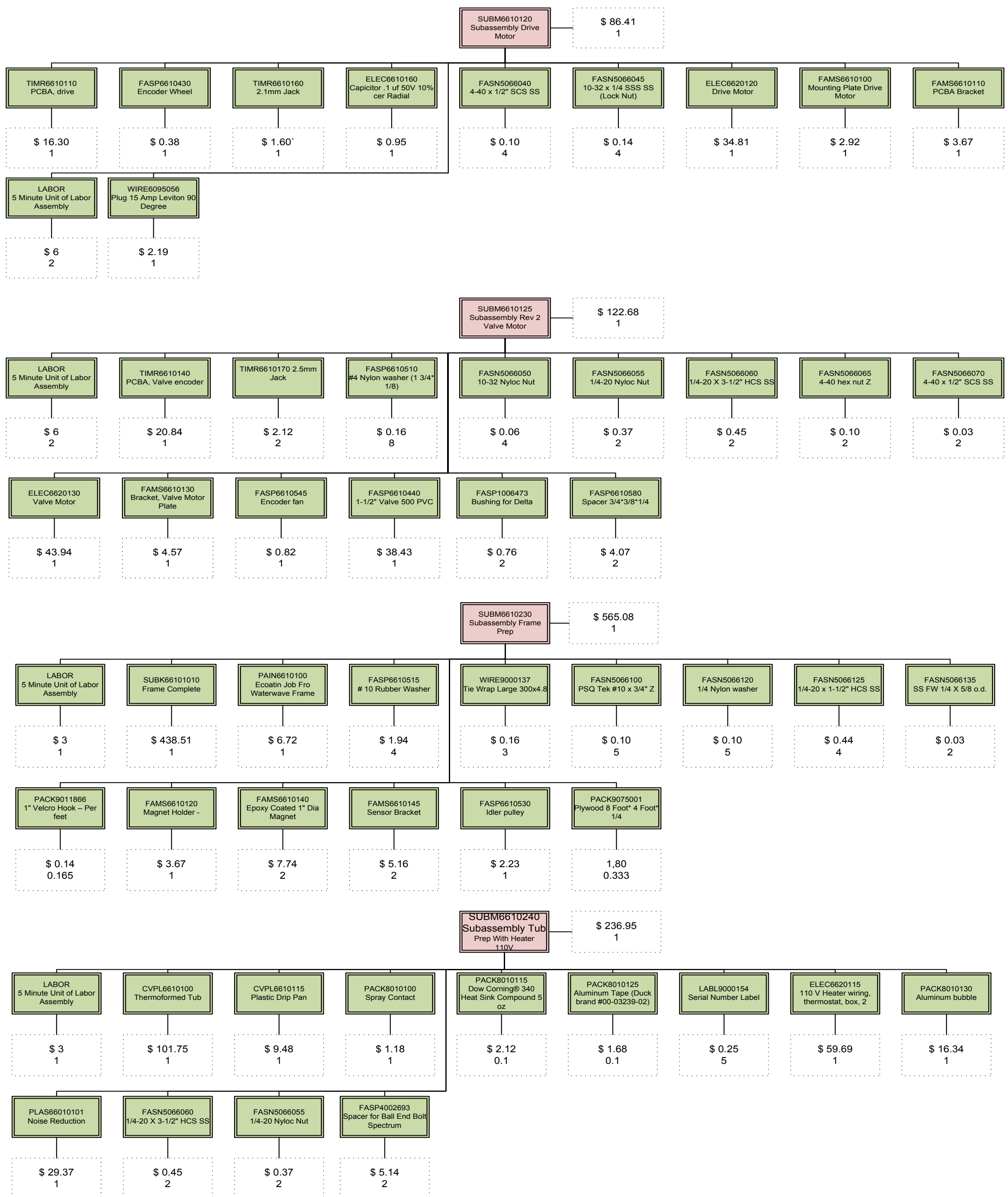
A Tree diagrams of the product
B Assembly employee interview
C Sponsor interview notes
D Dimensions of the product
E Brainstorm nozzles
F Results user test nozzles
G Test prototype bracket
H Tub designs
I Strength analysis tub
J Quote guide rails and slide blocks
K Collage nets
L Strength test main frame

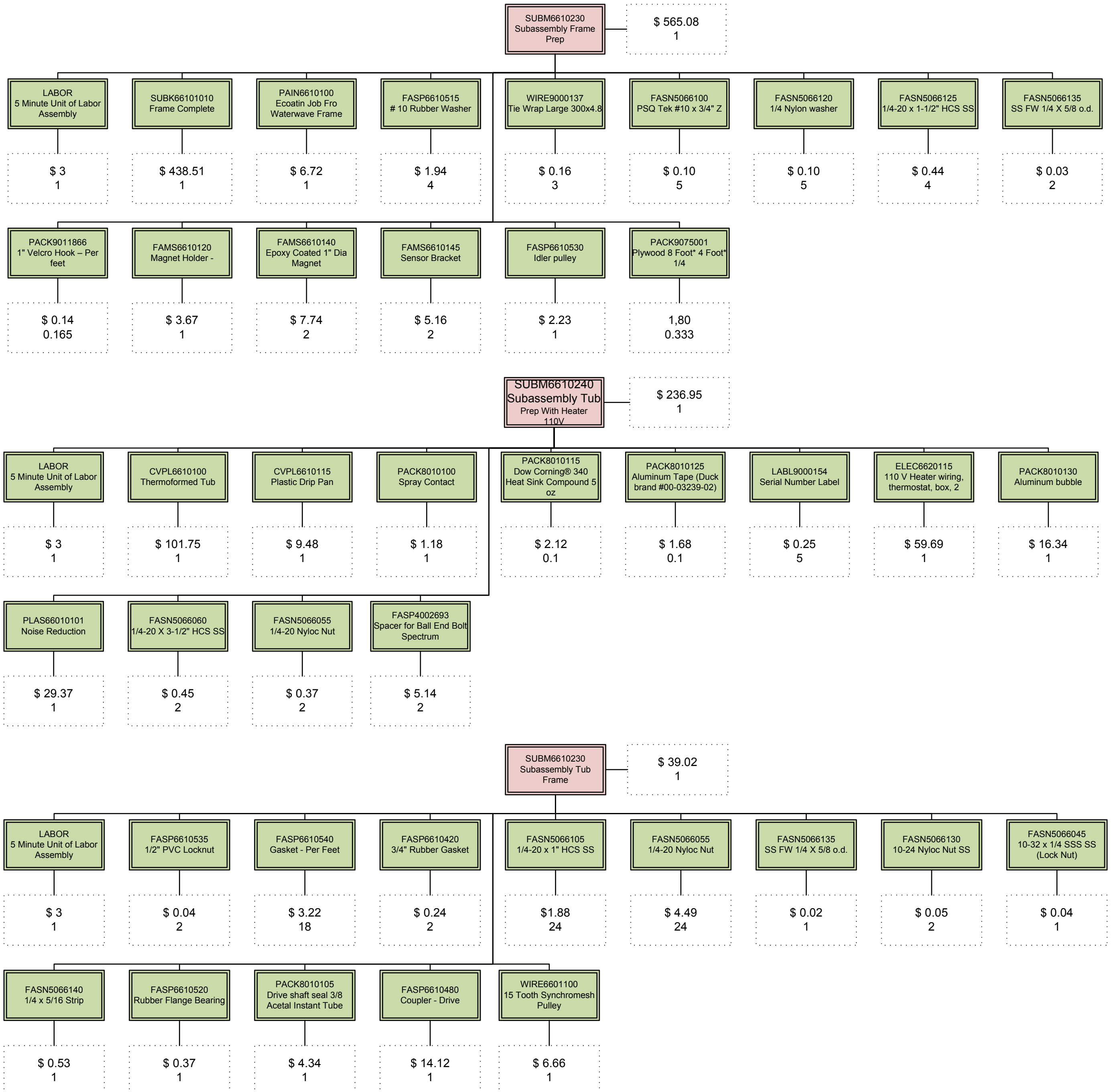
Appendix A

The product tree diagrams for the different subassemblies.






SUBM6610120 Subassembly Drive Motor
$ 86.41
1
TIMR6610110 PCBA, drive
$ 16.30
1
FASP6610430 Encoder Wheel
$ 0.38
1
TIMR6610160 2.1mm Jack
$ 1.60`
1
ELEC6610160 Capicitor .1 uf 50V 10% cer Radial
$ 0.95
1
FASN5066040 4-40 x 1/2" SCS SS
$ 0.10
4
FASN5066045 10-32 x 1/4 SSS SS (Lock Nut)
$ 0.14
4
ELEC6620120 Drive Motor
$ 34.81
1
FAMS6610100 Mounting Plate Drive Motor
$ 2.92
1
FAMS6610110 PCBA Bracket
$ 3.67
1
LABOR 5 Minute Unit of Labor Assembly
$ 6
2
WIRE6095056 Plug 15 Amp Leviton 90 Degree
$ 2.19
1
SUBM6610125 Subassembly Rev 2 Valve Motor
$ 122.68
1
LABOR 5 Minute Unit of Labor Assembly
$ 6
2
TIMR6610140 PCBA, Valve encoder
$ 20.84
1
TIMR6610170 2.5mm Jack
$ 2.12
2
FASP6610510 #4 Nylon washer (1 3/4" 1/8)
$ 0.16
8
FASN5066050 10-32 Nyloc Nut
$ 0.06
4
FASN5066055 1/4-20 Nyloc Nut
$ 0.37
2
FASN5066060 1/4-20 X 3-1/2" HCS SS
$ 0.45
2
FASN5066065 4-40 hex nut Z
$ 0.10
2
FASN5066070 4-40 x 1/2" SCS SS
$ 0.03
2
ELEC6620130 Valve Motor
$ 43.94
1
FAMS6610130 Bracket, Valve Motor Plate
$ 4.57
1
FASP6610545 Encoder fan
$ 0.82
1
FASP6610440 1-1/2" Valve 500 PVC
$ 38.43
1
FASP1006473 Bushing for Delta
$ 0.76
2
FASP6610580 Spacer 3/4*3/8*1/4
$ 4.07
2
SUBM6610230 Subassembly Frame Prep
$ 565.08
1
LABOR 5 Minute Unit of Labor Assembly
$ 3
1
SUBK66101010 Frame Complete
$ 438.51
1
PAIN6610100 Ecoatin Job Fro Waterwave Frame
$ 6.72
1
FASP6610515 # 10 Rubber Washer
$ 1.94
4
WIRE9000137 Tie Wrap Large 300x4.8
$ 0.16
3
FASN5066100 PSQ Tek #10 x 3/4" Z
$ 0.10
5
FASN5066120 1/4 Nylon washer
$ 0.10
5
FASN5066125 1/4-20 x 1-1/2" HCS SS
$ 0.44
4
FASN5066135 SS FW 1/4 X 5/8 o.d.
$ 0.03
2
PACK9011866 1" Velcro Hook – Per feet
$ 0.14
0.165
FAMS6610120 Magnet Holder -
$ 3.67
1
FAMS6610140 Epoxy Coated 1" Dia Magnet
$ 7.74
2
FAMS6610145 Sensor Bracket
$ 5.16
2
FASP6610530 Idler pulley
$ 2.23
1
PACK9075001 Plywood 8 Foot* 4 Foot* 1/4
1,80
0.333
SUBM6610240 Subassembly Tub Prep With Heater 110V
$ 236.95
1
LABOR 5 Minute Unit of Labor Assembly
$ 3
1
CVPL6610100 Thermoformed Tub
$ 101.75
1
CVPL6610115 Plastic Drip Pan
$ 9.48
1
PACK8010100 Spray Contact
$ 1.18
1
PACK8010115 Dow Corning® 340 Heat Sink Compound 5 oz
$ 2.12
0.1
PACK8010125 Aluminum Tape (Duck brand #00-03239-02)
$ 1.68
0.1
LABL9000154 Serial Number Label
$ 0.25
5
ELEC6620115 110 V Heater wiring, thermostat, box, 2
$ 59.69
1
PACK8010130 Aluminum bubble
$ 16.34
1
PLAS66010101 Noise Reduction
$ 29.37
1
FASN5066060 1/4-20 X 3-1/2" HCS SS
$ 0.45
2
FASN5066055 1/4-20 Nyloc Nut
$ 0.37
2
FASP4002693 Spacer for Ball End Bolt Spectrum
$ 5.14
2



Redesign of the Pro Sun WaterWave

Appendix B

Interview production and assembly employee

1. Are there parts which you find hard to make, if so, which?

I don't make parts myself. Every part is pretty much a standard part. And there are 2 parts made in the machine shop and the skirts are made in the plastic department.

2. Which parts take up a lot of your time when fabricating?

N/A

3. Are there subassemblies which you find hard to assemble, if so, which?

The hardest subassembly to do is definitely the plumbing inside the tub. There are a lot of things to glue and fit and everything has to line up just right. Also getting the balance between too tight, and not being able to move, and too loose, meaning leaking, is hard to get right.

Skirts are also hard to assemble. They have be precisely lined up because it's the outside. The holes are not pre drilled so it makes it harder to fit.

Assembling the pump valve used to be a hard job, because holes were too small, this has been fixed now, making it a lot easier to assemble.

4. Which subassemblies take up a lot of time to assemble?

The subassemblies I named at the previous question also take up a lot of time.

Mounting the bladder on the product as well as securing it is also hard to do. Again no pre drilled holes, meaning it has to be measured and placed just right while assembling, taking up a lot of time. Putting on the polyurethane sheet to be just tight enough is also a pain.

In general drilling holes and lining up parts and subassemblies which do not have pre drilled holes take up the most time during assembling. It takes me about 1 day (8 hrs) to make a WaterWave when all subassemblies are pre assembled.

5. How hard is it to put on the net, I heard it was quiet a hassle?

Putting on the net is easy we now have a special tool used to mount the net on the screws on the frame. Takes me about 5 minutes.

6. Are there any parts in the product of which you think that they are not needed or should be done a different way?

The metal should go out, its oxidizing and it messes up the water and movement of the parts inside.

Assembling is simple, no hard parts, but its very important to make sure it doesn't in any spot, taking up time.

One problem is, once the hose heats it tends to sag hitting the drive wire.

7. Which parts or subassemblies do you find make a lot of noise?

The pump motor definitely makes the most noise of all components. You can hear the drive motor as well but it is nothing compared to the pump motor.

The water hitting the bladder is the thing making the most noise of all. The water is resonating the bladder.

Appendix C

This appendix are the notes of the sponsor interview, unfortunately these are in dutch.

De WaterWave is ontstaan uit eigen ontwikkeling en conceptuering, begonnen +/- 1 jan 2009
Bestaande buitenmaten moeten worden gehandhaafd in verband met de skirts die hetzelfde moeten blijven, deze zijn net herontworpen.

Grote knelpunten:

Frame

- o Aluminium extrusie profiel met schroeven is omslachtig
- o Frame raar gebogen
- o Aluminium?
- • Tub Frame
- o E-coat, werkt het?
- o Oxideren met water door verschillende metalen
- o Karretje rijdt nu over metalen rails, kijken of dit allemaal van kunststof kan.

Tub

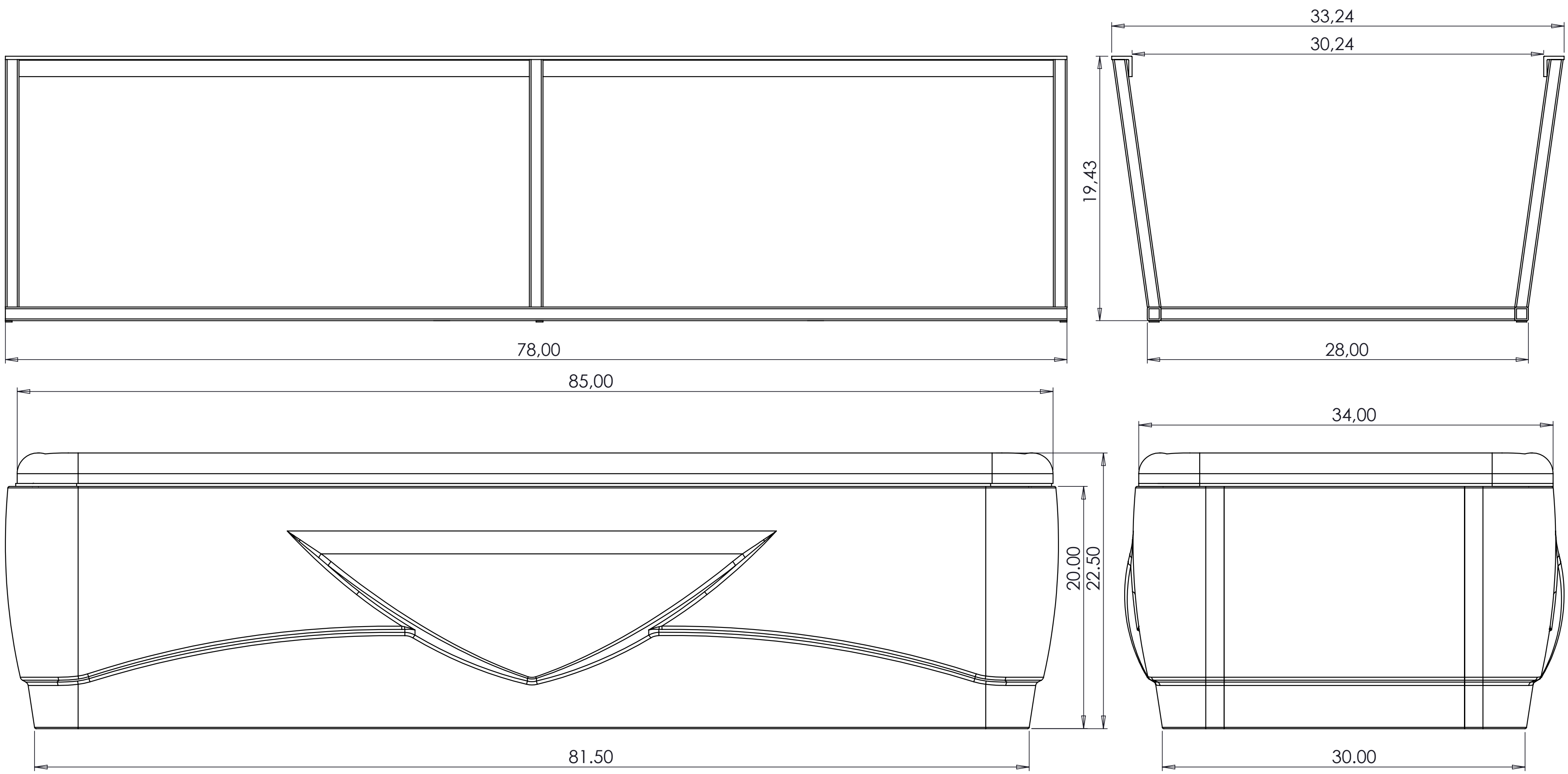
- o Niet meer zo groot/hoog
- o Makkelijker te vormen
- o Kijken naar rek in de hoeken
- o Drainage aansluiting (voor tuinslang?)

Top

- o Kan misschien een subassembly zijn die er ineens opgezet wordt
- o Net erop krijgen veel werk
- o Nu niet gemakkelijk te onderhouden
- o Net dat rekt uit naar verloop van tijd
- o Parachutedoek ziet er niet netjes uit
- o Hoeveelheid water toevoegen in de bladder.
- o Bladder gaat soms lek

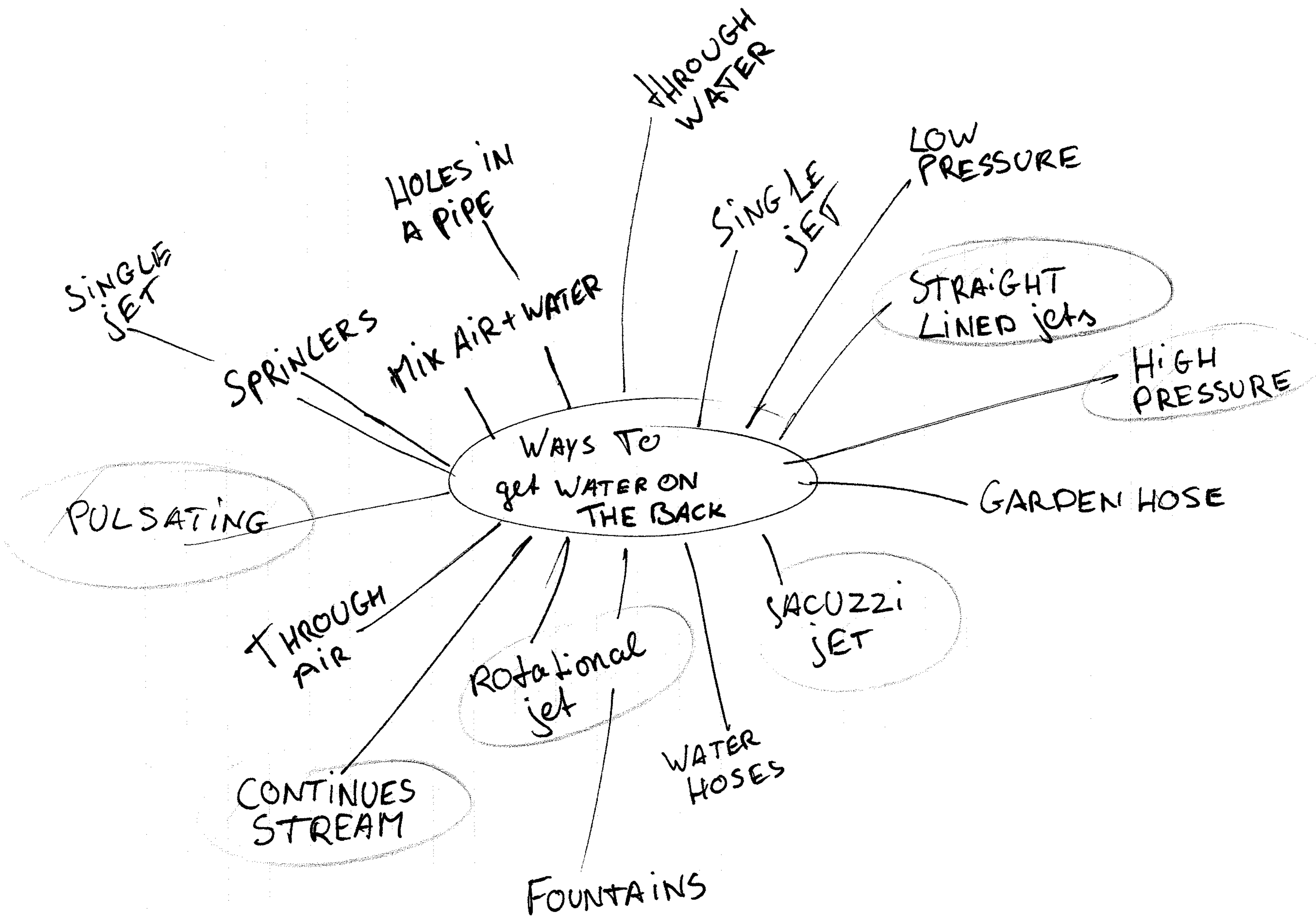
Appendix D

This appendix contains the dimensions of the product.



Appendix E

This appendix consists of the brainstorm for the redesign of the nozzles.



Appendix F

This appendix contains the results of the questionnaire that was used during the user test for the nozzles.

	1	2	3	4	5	6	7	8	9	10
Option A										
Intensity	5	4	5	5	5	2	3	4	4	4
Comfort	4	4	5	4	5	2	4	4	4	5
Amount of body surface	4	4	5	5	4	2	4	5	3	3
Feeling afterwards	4	4	3	4	4	2	2	4	3	4
hand massage resemblance	3	3	2	2	3	2	2	3	1	1
quality of the massage	4	4	5	3	4	2	2	5	3	4
Option B										
Intensity	5	4	5	4	3	5	4	4	3	
Comfort	4	3	4	3	5	5	3	4	4	
Amount of body surface	4	3	4	4	4	5	4	5	3	
Feeling afterwards	4	3	5	5	4	5	3	4	3	
hand massage resemblance	3	4	2	4	2	2	3	3	1	
quality of the massage	4	3	4	5	3	5	4	4	4	
Option C										
Intensity	5	4	4	4	5	5	4	1	4,5	5
Comfort	4	4	4	4	5	5	5	2	4	5
Amount of body surface	4	4	4	4	4	4	5	3	4	5
Feeling afterwards	4	4	3	4	5	5	5	1	4	5
hand massage resemblance	4	2	2	3	3	1	3	1	1	1
quality of the massage	4	4	4	4	5	5	5	1	4	5
Option D										
Intensity	4	5	5	5	4	5	5	4,5	5	6
Comfort	3	4	3	5	4	5	3	4,5	3	6
Amount of body surface	4	4	3	5	4	5	4	4	4	6
Feeling afterwards	3	5	4	5	4	5	4	4	4	6
hand massage resemblance	2	3	3	4	1	2	3	1	1	2
quality of the massage	4	4	5	5	4	5	4	4	5	6

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Intensity	2	2	2	1	2	2			
Comfort	3	3	2	1	2	2			
Amount of body surface	3	3	2	1	2	2			
Feeling afterwards	2	4	2	1	2	2			
hand massage resemblance	2	2	1	1	1	2			
quality of the massage	1	3	2	1	2	2			

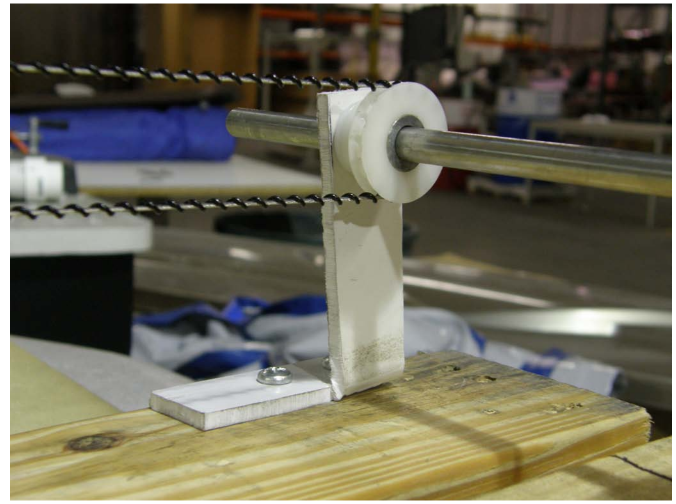
Option F							
Intensity	2	4	3	1	3	5	4
Comfort	3	4	3	1	3,5	4	4
Amount of body surface	1	4	3	1	2	4	4
Feeling afterwards	1	5	3	1	3,5	4	3
hand massage resemblance	1	3	1	1	1	3	3
quality of the massage	2	4	3	1	4	4	3

	Intensity	Comfort	Amount of	Feeling aft	Quality	Total	
Option A	16,4	12,3	11,7	13,6	18,0	72,0	Intensity
Option B	16,4	11,7	8,0	16,0	20,0	72,1	Comfort
Option C	16,6	12,6	8,2	16,0	20,5	73,9	Amount
Option D	19,4	12,2	8,6	17,6	23,0	80,8	Feeling
Option E	7,3	6,5	4,3	8,7	9,2	36,0	hand
Option F	12,6	9,6	5,4	11,7	15,0	54,4	quality
Option G	14,0	10,5	7,0	12,0	13,8	57,3	

Appendix G

This appendix shows the prototype test for the brackets for the drive mechanism in photographs.

The test setup



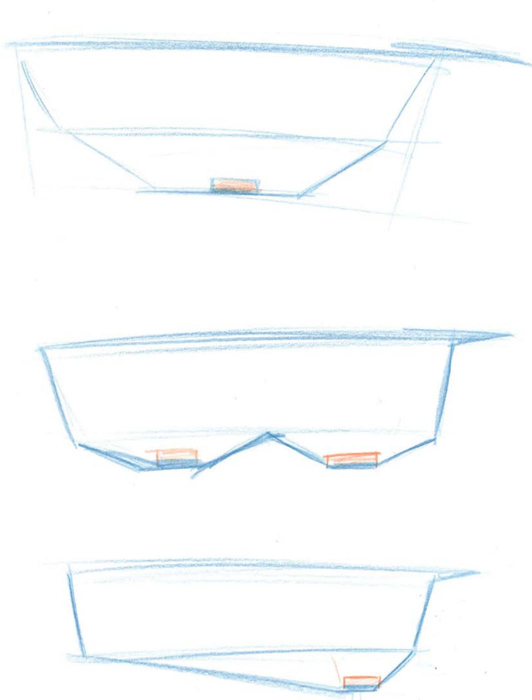
Before the test (on both sides)

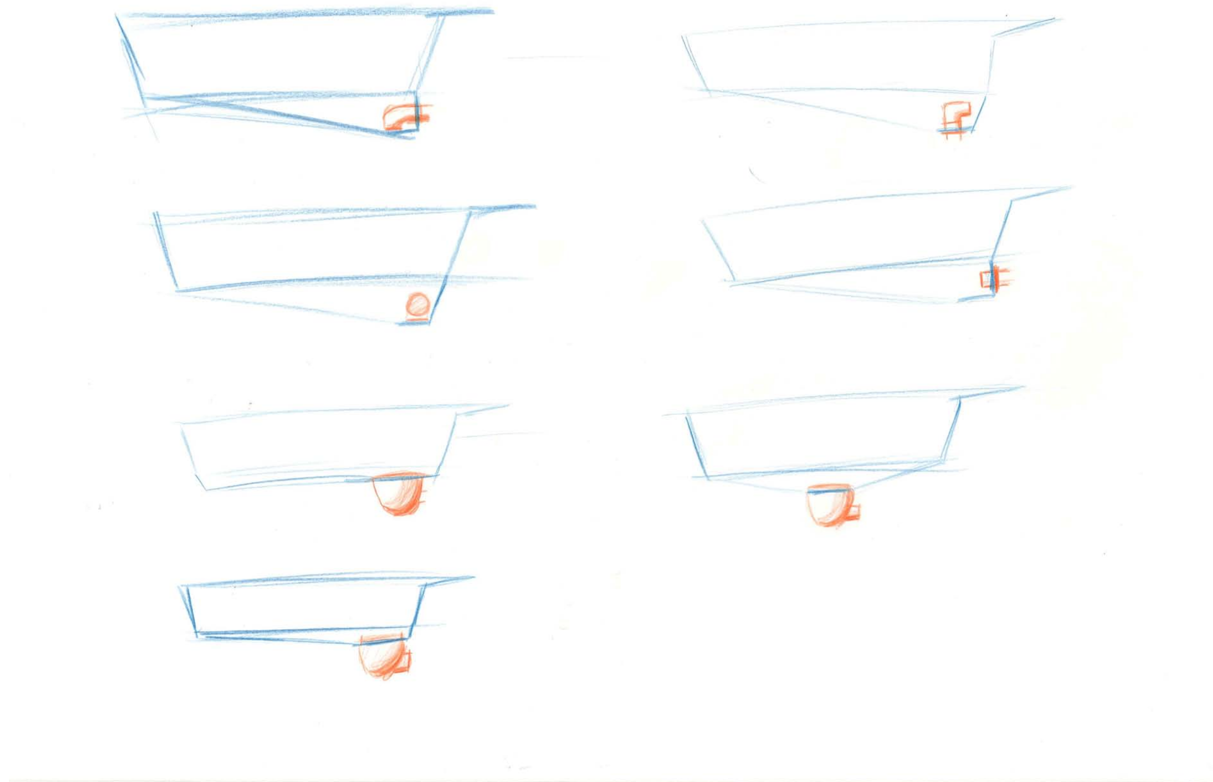
After the test (on both sides)

The redesigned brackets did work and kept their shape

Appendix H

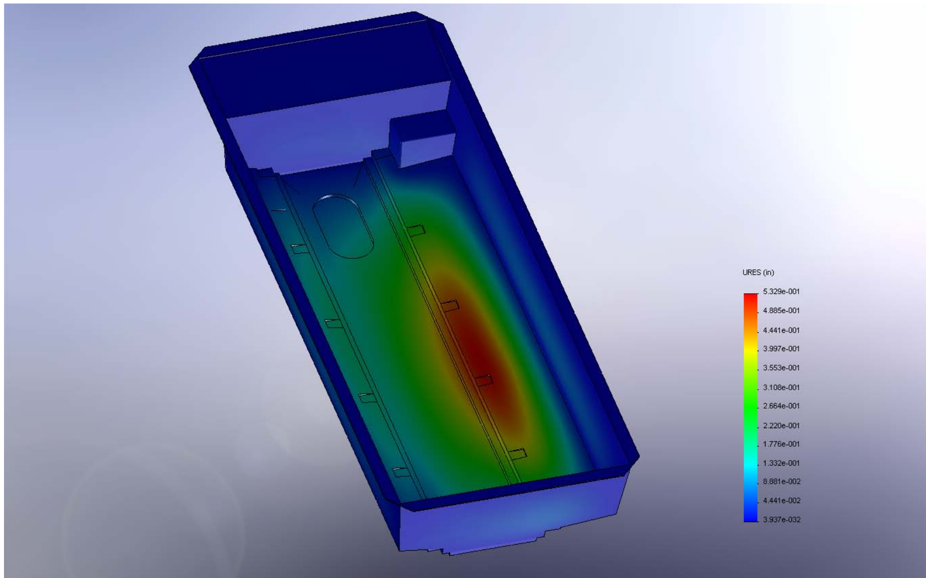
This appendix contains the sketches for different tub designs.



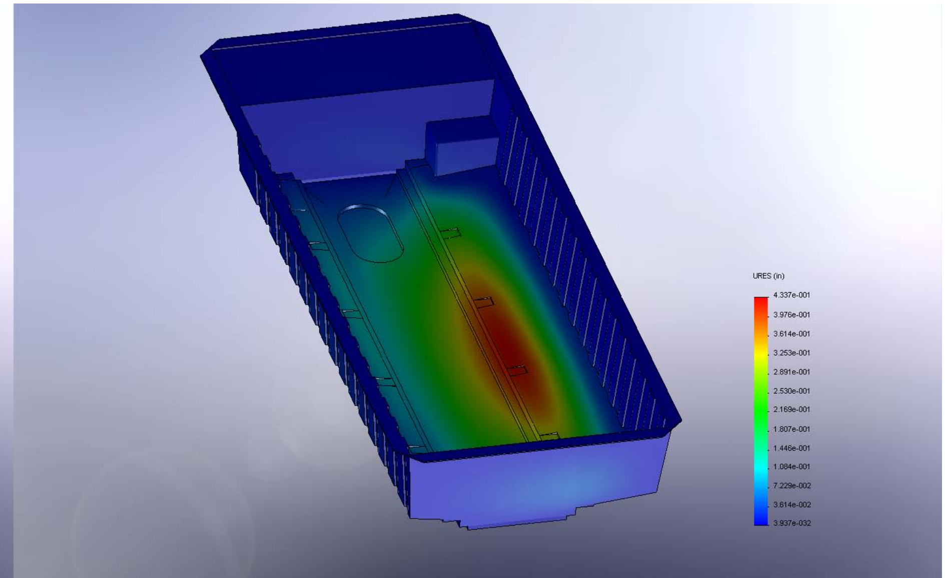


Appendix I

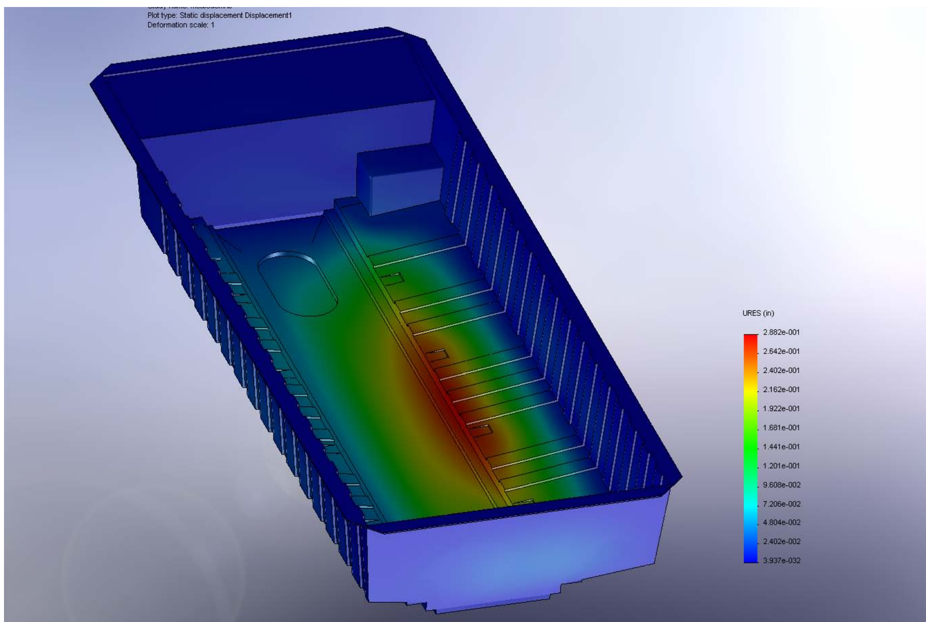
This appendix contains the pictures of the strength test of the tub



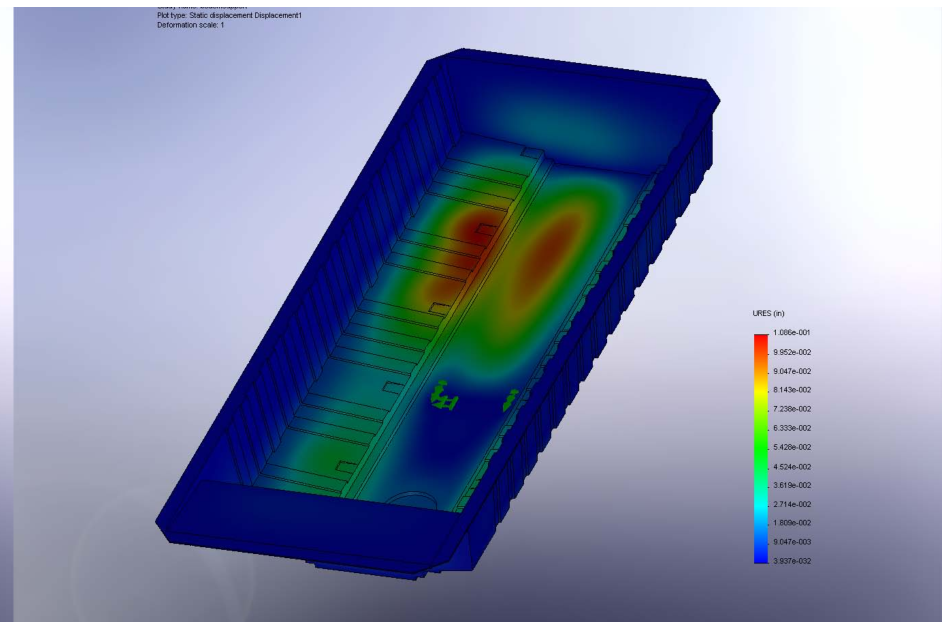
No ribs



Side ribs



Bottom ribs and side ribs



Bottom & side ribs with frame support

Appendix J

This appendix shows the quotation for the UHMW-PE parts of the slide mechanism from the company slide ways. This is how the cost for these parts is estimated.

Slideways, Inc.
705 Plantation St.
Worcester, MA 01605 USA

Phone: 508-854-0799
Fax: 508-854-0711
Fed ID: 04-3243492

Quote No: 22755
Wednesday, June 16, 2010
Page: 1

Attention: **DONALD MERKS**

PROSUN INTERNATIONAL, LLC
2442 23RD STREET NORTH
ST. PETERSBURG, FL 33713
Phone: 423-465-1812

Dear DONALD

Slideways is pleased to present this quotation for your consideration.

Line: ***1*** *Part ID:* ***MTO FABRICATION - PROFILE*** *Rev:* ***00***

UHMW CHANNEL - MACHINED
3/4" X 1" X 68.50" LENGTH
1/2" X 1/2" CHANNEL (NO HOLES)
Material: UHMW NATURAL WHITE

Quantity	U/M	Unit Price	Addl Charge	Lead Time	Total Price
250.00	EA	$17.90		3 WEEKS	$4,475.00
500.00	EA	$16.49		3 WEEKS	$8,245.00

Line: ***2*** *Part ID:* ***MTO FABRICATION - PROFILE*** *Rev:* ***00***

UHMW CHANNEL - MACHINED
3/4" X 1" X 68.50" LENGTH
1/2" X 1/2" CHANNEL (WITH 4 HOLES)
Material: UHMW NATURAL WHITE

Quantity	U/M	Unit Price	Addl Charge	Lead Time	Total Price
250.00	EA	$22.80		3 WEEKS	$5,700.00
500.00	EA	$21.39		3 WEEKS	$10,695.00

Salesperson: RCB INTERNATIONAL
Prices are Valid Until Friday, July 16, 2010

We look forward to meeting your plastic machine component needs.

Thank you for your inquiry!

Paul LaMalva
plamalva@slideways.com

Appendix K

This appendix is the collage of nets made for the redesign of the top.

Appendix L

This appendix shows the stress test done with cosmos works on the main frame. The first picture shows the displacement with 3 posts and 3 wheels on each side. The second picture shows the displacement with 4 posts and 3 wheels on each side.