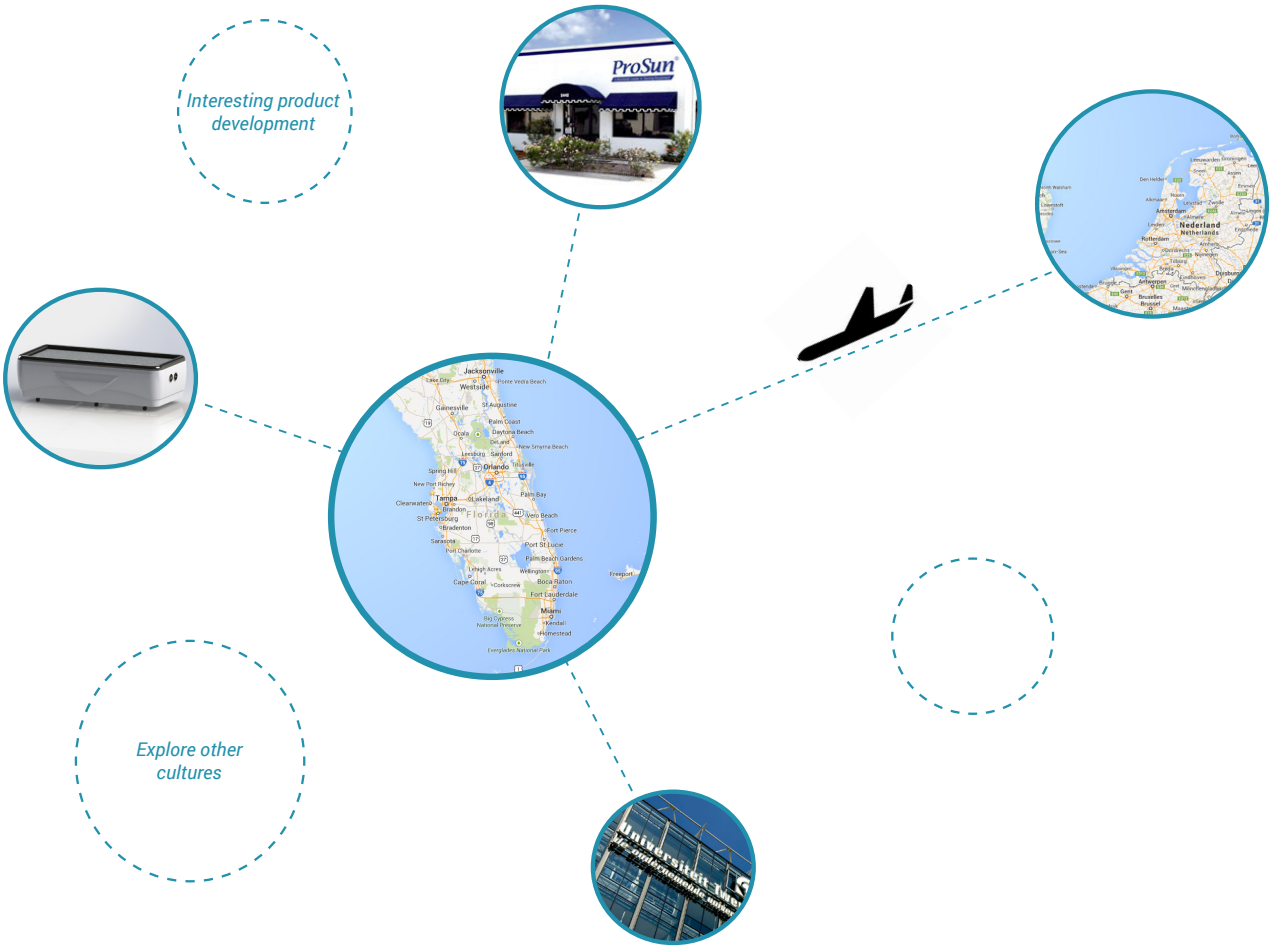
HYDRO MASSAGE BED "AQUAFRIXIO"

The development of a manufacturable new massage concept for the Hydro Massage Bed "AquaFrixio".



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Bachelor Thesis Industrial Design Engineering
University of Twente
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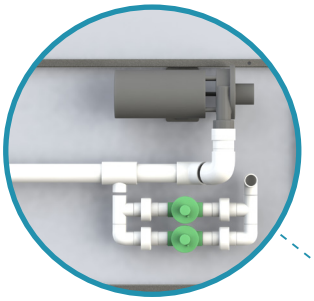

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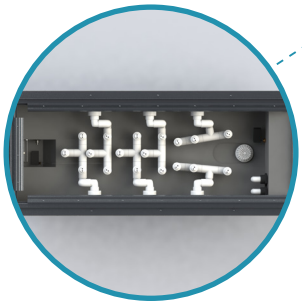

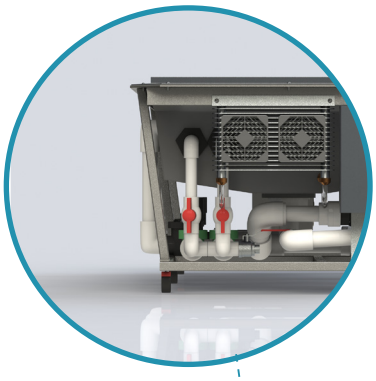

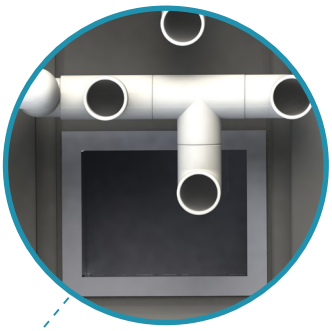

18 Appendix

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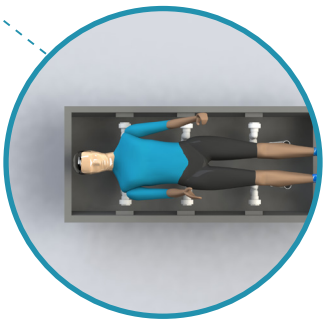

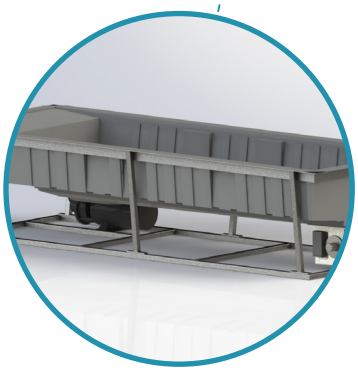

Preface

This research and design project is completed as a graduation requirement for my Bachelor's degree in Industrial Design Engineering at the University of Twente. This project was conducted at ProSun International LCC in Florida, in the south eastern of the United States of America, within a period of three months.

The motive for the assignment for ProSun was to improve and redesign their existing Massage Bed. The University of Twente is eager to work with companies such as ProSun, to create the opportunity for students to broaden their experience. For me, Daniël Janson, this was an interesting opportunity to combine my interests in the world with gaining experience in design.

I want to thank everyone that contributed to making this project a success: First, I would like to thank Juan Jauregui Becker for the guidance and critical feedback. The input of Tom Henkemans, CEO of ProSun, was very helpful during this project. At last, the helping hand of Arjan Dommisse, Product Manager of ProSun, was very appreciated.

Now, 5 months after the start of this project, I hope and expect that its results will contribute to the further development and successful launch of the AquaFrixio.


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Summary

The objective of ProSun is to develop a manufacturable new massage concept for their massage bed, the AquaFrixio. Their former massage bed, the WaterWave, was removed from the market, as the product experienced problems on several levels. In the past few years, multiple designers tried to solve these problems with small adjustments to the mechanical system and other components. Unfortunately, these adjustments never delivered the performance that were required. Therefore, ProSun decided to take other directions to solve these problems. This project aims at designing a new concept for the massage mechanism that will be used for the AquaFrixio.

To be able to do this, an extended product analysis is done, to identify the problems which were encountered with the WaterWave. This product analysis consisted of the disassembly of the WaterWave, several interviews, competitors analysis, a Quality of Function Deployment and a Failure Mode and Effects Analyses. Based on the analyses that are done, the following list of components needs to be redesigned is composed:

- *The massage mechanism*
- *The pressure controller*
- *The chiller*
- *The framework*
- *The tub*
- *The top frame*

The massage mechanism is the key functioning device of the massage bed, being the main component which is redesigned. The redesign of the massage mechanism had influence in the design of the other components as well. The requirements that were focussed on during the redesign of these components, were the use of basic parts, the relocation of the production to their own facility and the focus for delivering a prototype.

Within a short amount of time, each of these six components were redesigned for the AquaFrixio. Due to the limited time and the size of the assignment, it was not possible to elaborate deeply about every component or go deep into the technique which will be used. Instead, the focus was set on developing a new potential massage mechanism.

In the end, a working prototype of the AquaFrixio is delivered. The main goal was to see if the redesigned massage mechanism was a good potential concept which is designed for the AquaFrixio. Based on the prototype, it can be said that it is feasible that the AquaFrixio can meet the requirements.

The two main recommendations are focussing on the technical development of the massage mechanism and manufacture a prototype that contains the components which will be used in the real AquaFrixio.

Samenvatting

Het doel van ProSun is het herontwerpen van hun massagebed de WaterWave. De WaterWave moest van de markt gehaald worden, aangezien het product op verschillende gebieden problemen ondervond. In de afgelopen jaren hebben verschillende ontwerpers geprobeerd de problemen op te lossen, dit middels aanpassingen aan het mechanische systeem en veranderingen aan andere onderdelen. De aanpassingen leverden niet het gewenste resultaat, wat er voor heeft gezorgd dat ProSun opzoek ging naar een heel nieuw massage mechanisme dat wel aan deze voorwaarden voldoet.

Om dit mogelijk te maken moest een uitgebreide product analyse gedaan worden. Deze product analyse bestond uit meerdere interviews, een kosten analyse, een concurrentie analyse, een Quality of Funtion Deployment, een Failure Mode and Effect Analyses en het demoteren van de WaterWave zelf. Dit creëerde een gefundeerde basis aan informatie, dat gebruikt kon worden voor het opstellen van de volgende lijst met onderdelen die herontworpen moesten worden:

- *The massage mechanism*
- *The pressure controller*
- *The chiller*
- *The framework*
- *The tub*
- *The top frame*

Het massage mechanisme is het meest belangrijke onderdeel in het massage bed, de focus werd hier dan ook op gelegd tijdens de ontwikkeling van het massage bed. Het herontwerpen van het massage mechanisme heeft ook invloed gehad op het herontwerpen van de andere onderdelen. De eisen waren voornamelijk gericht op het gebruik van standaard onderdelen, de verplaatsing van de productie van de onderdelen naar hun eigen werkplaats en het afleveren van een werkend prototype.

In een vrij korte periode zijn de zes onderdelen herontworpen. Het was echter niet mogelijk om diep in te gaan op de technische aspecten van elk onderdeel of het uitdiepen van de techniek die gebruikt werd. Dit kwam voornamelijk door de breedte van de opdracht in combinatie met de geringe tijd die stond voor de uitvoering.

Het is uiteindelijk gelukt een werkend prototype af te leveren. De hoofddoel was het ontwikkelen en ontwerpen van een maakbaar concept voor de AquaFrixio. Gebaseerd op de prototype kan gezegd worden dat de AquaFrixio aan deze eisen heeft voldaan.

Er zijn twee aanbevelingen voor de verdere ontwikkeling van de AqiaFrixio. Alseerste, de verdere ontwikkeling van het technische aspect van het massage mechanisme en daarnaast een prototype maken waarbij gebruik gemaakt wordt van onderdelen die ook daadwerkelijk in de AquaFrixio gebruikt zullen worden.

1. Introduction

Think of that moment when you are relaxing in a hot tub with warm water jets against your back. Imagine that moment while you are staying dry, that is what a HydroMassage bed is able to do for you. ProSun is one of the leading companies in this branch with their own Hydro Massage bed namely, the WaterWave. They produced hundreds of those beds and sold them all over North- and South-America. Recently, they experienced several problems regarding their Massage Bed, which desperately has to be solved. The development of a working concept for their massage bed is the key topic in this bachelor thesis (Watermassagebed, 2011).

This chapter provides background information about ProSun and elaborates on the assignment of this project. First, the background information is discussed which is about their massage bed, their business model and the stakeholders. Second, more information regarding the assignment is presented which is about the goal of the project and the method used.

1.1. ProSun International LLC

This report is the result of a bachelor thesis that was realized by a collaboration of the University of Twente with the company ProSun International LLC.

ProSun is an indoor tanning bed manufacturer, established in 1994. The roots of the company go back to 1979 when Tom Henkemans founded the company HAPRO in the Netherlands. ProSun has been manufacturing quality, high-end and affordable tanning beds for over 25 years now. Fulfilling their customers wishes and continuing their quality and service is their principle goal. Besides producing indoor tanning beds, the company also provides equipment, realizes the installation and gives in-salon training about the use of their products. They support clients starting a new salon and walk them through the whole process (ProSun, 2013).

1.1.1. The WaterWave

About ten years ago, ProSun launched the Hydro Massage Bed “WaterWave” on the market. The product was brought from an other company with the required techniques to be able to produce and manufacture this product. The WaterWave is a complex product, but the massaging technique itself is actually a very simple but clever technique. The WaterWave uses a technique called hydrotherapy massage. Here high powered water jets massage the muscle tissue on the human body. This increases the blood circulation which relieves stress in the muscles.

After a while, the massage bed experienced several problems that finally resulted in the removal of the massage bed from the market. In fact, the moving parts within the product broke down because of the frequent use of the product. Unfortunately, these parts could not easily be repaired or replaced. Another problem is that the water reached an uncomfortable high temperature after some period in time.

Figure 1.1.1. ProSun's business accommodation


Figure 1.1.2. My accommodation in Florida for those three months

The company decided to start developing an improved version of the massage bed named the Hydro Massage Bed "AquaFrixio". For the development of the AquaFrixio, they would like to use the framework of the WaterWave, as a base for the development of the new massage bed. ProSun tried to improve the current massage mechanism by making small changes to the concept. Unfortunately, they were not able to solve the problems encountered with the massage bed. Therefore, a new massage concept needs to be developed. Further deepening about the these problems will be discussed in the next few chapters.

1.1.2. The division of labor

ProSun is divided into multiple departments. This tells shortly about the responsibilities of each department.

The management team consist of five Dutch people that flew over in the past twenty years, with Tom as CEO. Three of the managers are head of their own department. One is the head of the sales, another for the financial department and the last for the purchasing department. And the last manager is responsible for two departments, the service and manufacturing department. The sales, service and financial departments all consist of two other employees. The purchasing department has no employees. The manufacturing department consist of eleven employees.

The sales department is the division which is responsible for selling the tanning beds, the massage bed and other accessories. The financial department is responsible for the financial structure of the company. The service department handle all service calls and solves problems encountered with their products. The manufacturing department is responsible for the assembly of their product. The employees working at the assembly line are able to assemble multiple product.

The main research and design department is located in the Netherlands, at their affiliated company Hapro. Small changes to their products are done at the production facility of ProSun, which are done by the manager responsible for the manufacturing department. The major product developments are done at Hapro International.

1.1.3. The business model

ProSun uses a business model that is divided into two parts: business to business (B2B) and business to consumer (B2C).

The sales department focusses on selling their product to consumers (B2C). The products sold by these employees have a standard price that goes to the company, the amount that comes on top of this price is for the sales employee. A huge discount for the customer will influence the hight of their income. The consumers are the residential users and salon owners, which are spread over North- and Central-America.

On the other hand ProSun works with several intermediairs that stand between the customer and ProSun, which are also spread over North- and Central-America. They sell the product locally and earn a little amount of every product they sell. These people do not work directly for ProSun.

1.1.2. The Stakeholders

For the development of a new massage concept for the Aquafrixio it is important to identify ProSun's stakeholders and their perspectives and interests. To clearly understand the relationship between all the stakeholders an overview is made, which is shown in figure 1.1.3. The size of the circle identifies the importance of the stakeholder.

The stakeholders influence the redesign of the product, as some of them featured ProSun with some essential feedback. The maintenance and service department are two important stakeholders during the concept development as they will be responsible for the manufacturing and maintenance of the product. The salon owner is slightly more important then the residential user because they often have more products and use the product more frequently. Hapro is a small stakeholder because the close collaboration and the opportunity to involve the Dutch market. The delivered work and experience comes together in this final report which means that the University is a small stakeholder for this project.

1.2. Bachelor assignment

This assignment has as goal to develop a new concept for the massage mechanism which can be used for the AquaFrixio. During this assignment the focus is on the manufacturability of the new designed massage concept.

1.2.2. The goal

ProSun needs to structure the problems they encountered with the WaterWave and to find a sustainable solution for these problems. In the past few years, ProSun tried to solve several problems with small modifications to the WaterWave. The small modifications were not enough to solve the overall problems encountered with the WaterWave.

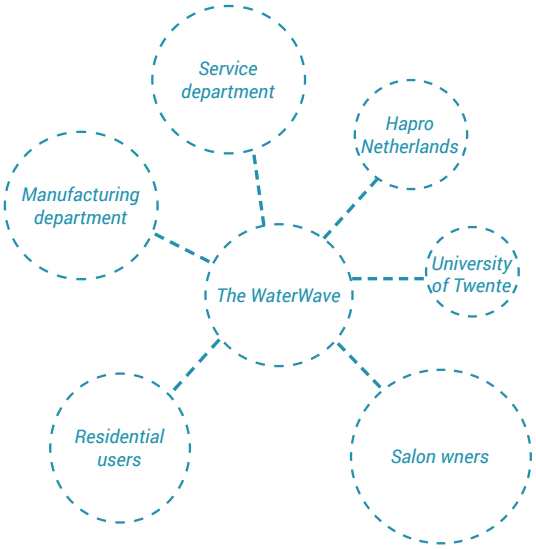

Figure 1.1.3. Stakeholders visualisation

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Liters	to	Gallon
0,264	x3.785411784	1,00
Kg	to	Pound
0,454	/0,45359237	1,00
°C	to	°F
0°	/9x5+32	32°

Figure 1.2.1. The conversion form American standards to European standards.

At this point, they want to revise the massage bed and come up with a whole new massage concept which will solve these problems. **The main goal of this bachelor assignment is to develop a manufacturable new massage concept for the AquaFrixio.**

To establish this goal, it is not possible to elaborate deeply about every component that is redesigned or go deep into the technique will be used for the AquaFrixio. The first reason for this is the time which is available in combination with the size of the assignment. The second reason is that the company pushes for a working prototype which means that the focus lays more on the manufacturability of the mechanism. The third reason is the missing knowledge about this technical subject at ProSun. The final reason is the available personal and material at the workshop which means that ideas easily can be translated into prototyping.

The next step after this bachelor assignment will be about finalizing the product and deepen the technology used inside the product. This cannot be done within three months but is an essential step to succeed this product.

1.2.4. Methods

A combination of multiple methods is used to accomplish this determined goal. Using a variation of methods is a good way to verify the results and by comparing the information of the different methods, it is more likely to catch biases or false information. The use of multiple methods structures and quantifies all the information.

The first method used is a product analysis which gives insight in the current product. The second method is expert interviews, which gives insight in the experience and problems with the product. The third method is a market research that helps during the idea generation. The fourth method is a cost analysis which gives insight in the current costs for the WaterWave. The fifth method is a Quality of Function deployment which can improve the experience of the user. The final method is the Failure Mode and Effect Analysis which elaborates on the failure of the product.

This method form is a logic sequence because it goes slowly deeper into the matter. The first few methods give a broad base of information which can be used for the more specific research methods.

1.2.5. Structure report

This has the following structure.

Chapter 2 is about analysing the product determining the problems regarding the WaterWave. This is done by doing the methods explained in the previous paragraph. This will result in the requirements for developing a manufacturable new concept for the AquaFrixio.

Chapter 3 includes designing a manufacturable new concept which focus on the essential problems that were encountered. The redesigned components needs to meet the conformed requirements.

Chapter 4 is about manufacturing a prototype of the concept that is designed during chapter 3. It includes the prototype testing that should be done.

Chapter 5 elaborates on the feasibility of the new designed concept for the AquaFrixio. The end result is a 3D model of the AquaFrixio, that can be used for the further development of the product.

Note: This project uses English standard units that are shown in figure 1.2.1 and will be used in this report.

Figure 1.2.2. View at the environment of Florida

2.Product and manufacturing analysis

This chapter describes several analyses used to quantify the problems, define the requirements and understand the product and its working mechanism. To realise this, three expert interviews, manufacturing analysis, failure modes and effects analysis and a cost analysis are done. Besides this, the product is also disassembled and a house of quality is made. A synthesis of the results of these analysis is used to define the specification of the requirements.

2.1. The WaterWave

This paragraph explains the technique used for the massage bed and provides information regarding the components that are used to create the massage effect.

2.1.1. The massage mechanism

The Waterwave provides a hydro massage therapy through a traveling water jet, that delivers a powerful stream of warm water along your entire body. The WaterWave keeps you dry using a thin flexible bladder. The bed massages the muscle tissue to increase the blood flow and release the stress. Figure 2.1.1 shows a figure of The WaterWave. (PolarSpas, 2010)

A schematic visualisation of the Massage Bed, shown in figure 2.1.2, gives more insight in the functioning of the WaterWave. The Massage Bed is powered by a 1½ HP pump, that stows the water though 2" PVC connected to the jet located inside the tub. The jet is mounted on a rail system that is able to position the jet at the location the user prefers. The next paragraphs will give more clarification about the components used insight the product, this will be done by showing images of those components.

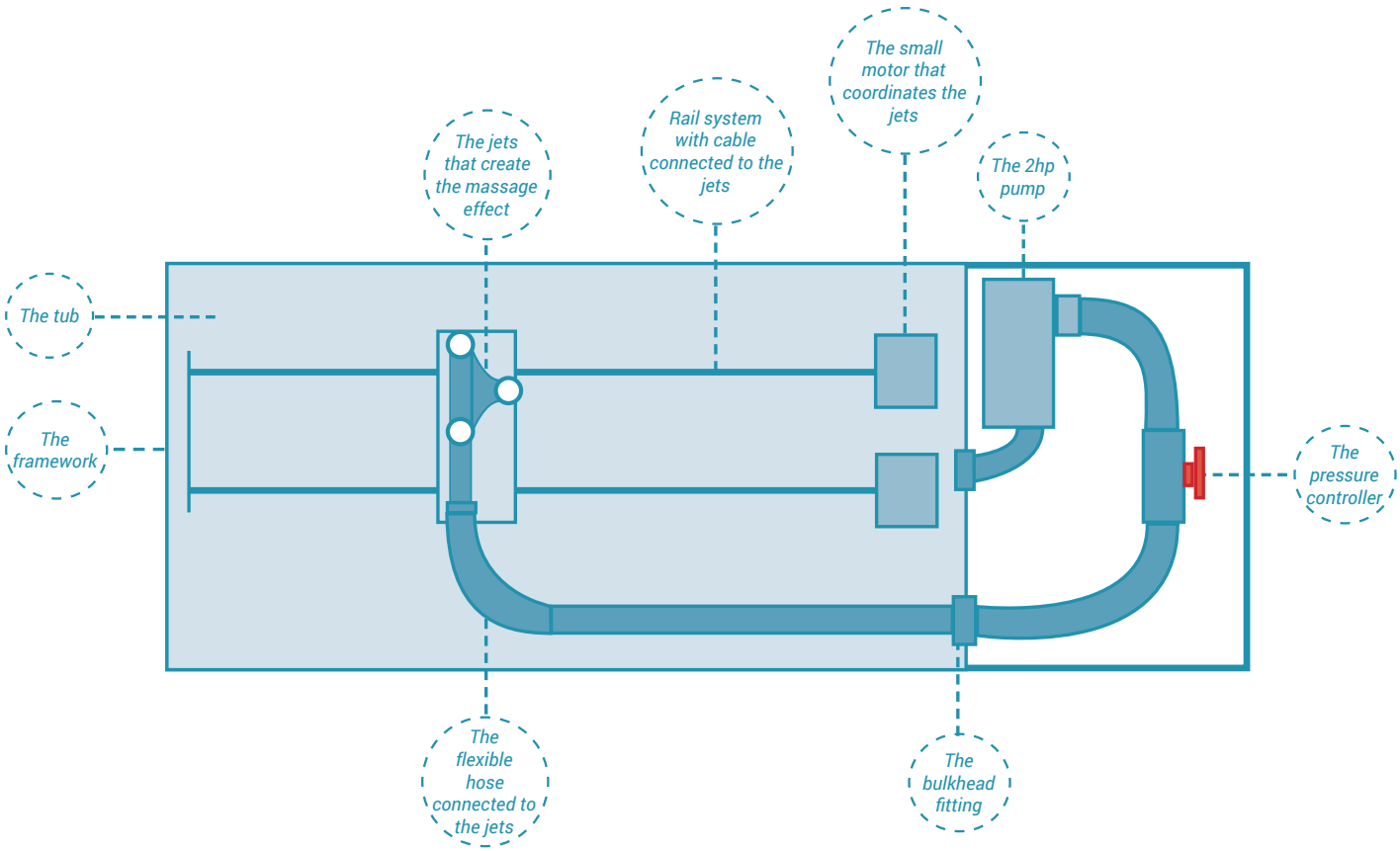


Figure 2.1.2. The schematic top view of the WaterWave

Figure 2.1.1. The WaterWave

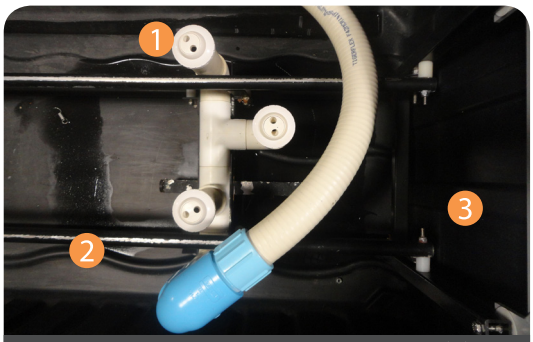


Figure 2.1.3. This shows the jet (1) connected tot the rail system (2) inside the tub (3).

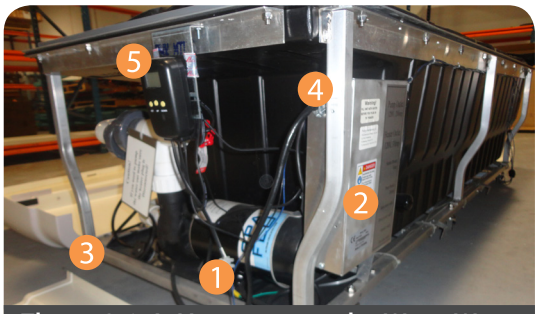


Figure 2.1.4. Here you see the WaterWave without the skirting.It shows the pump (1), the electric box (2), the frame (3), the tub (4) and the remote controller (5)

2.1.2. Components to provide the massage effect

The WaterWave consist of a aluminium framework, that serves as base for the whole product. The framework gives a solid base for the placement of the tub, the massage equipment with related components and the heating system.

The tub is filled with 70 gallons of water that stand directly in contact with the jet that provide the actual massage. The jet is placed on a rail system, that is attached to the aluminium frame. Two little and synchronised motors drive the jet. An electronic system is responsible for the positioning of the jet and a 2 HP pump is circulating the water through the jet, so it gives a desired massage effect. Figure 2.1.2 shows the tub with the rail system and jet inside.

A stainless steal thermostat heats the water and controls the temperature within the system. The heating element takes around 4¼ hours to get the 70 gallons of water at the desired temperature. The heating element is positioned at the side of the tub, close to the pump and the other electronics.

The tub is sealed watertight by using a top frame with three layers of different fabric placed on the edge. The first fabric is a rope net that supports the weight of the user, the second is a latex cover that seals the tub watertight and the last fabric is a nylon anti bacterial sheet that covers the top of the bed. Figure 2.1.3 shows the WaterWave without the skirting with the basic parts mounted on the frame. (SolaJet, 2007)

2.2. Expert interviews

After getting the first information about the functioning of the WaterWave, some more information regarding the problems that were encountered is preferred. To acquire this information, three interviews with different people within the company are done. A more extensive version of the interviews can be found in appendix A.

The first interview is with Tom Henkemans, the CEO of ProSun. He will elaborate on the fact that he removed the WaterWave from the market. The second interview is with an assembly mechanic, who will speak about his experience during the manufacturing of the WaterWave. The last interview is with a maintenance mechanic, who tells about his experience with the maintenance of the WaterWave.

2.2.1. The CEO

In brief, Tom stated that there were several problems responsible for removing the WaterWave from the market:

- The water rose above usable temperature.
- The mechanical system within the WaterWave broke down and could not be easily repaired or replaced.
- The tensioned net broke to easily.

Tom continued with a number of initial requirements that will be important during the development of a new massage concept for the AquaFrixio. These requirements will influence the process and give boundaries to the freedom during the design phase (Henkemans, 2014).

The initial requirements are:

- The outside dimensions of the product must stay the same, because the existing skirt is still intact and complies with the requirements.
- ProSun prefers to use as much standard part as possible, to prevent additional mold costs.
- ProSun does not wish to purchase new machines for other production techniques, what costs to much money.
- ProSun prefers to produce most of the components at their own facility, to stay independent and keep the stock low.

2.2.2. Assembly mechanic

The assembly employee described the WaterWave as a “product with many problems”, as it was difficult and took to long to assemble. It would take two people 8 till 10 hours to assemble the WaterWave. A small displacement could cause major problems within the product and everything needed a double check to get it waterproof (John, 2014).

2.2.3. Maintenance mechanic

At the maintenance they experience two mayor problems. The first one, was regarding the heating system. Customers were experiencing a high temperature and were not able to turn it down. The second problem had to do with the mechanical system inside the WaterWave. The tracking system coordinating the nozzles broke down to easily and could not be replaced that easily. Most of the time, the whole mechanical system had to be recalibrated (Eddy, 2014).

The problems mentioned by Tom and the maintenance mechanic correspond with each other. These problems are derived from long term use. The problems mentioned by the assembly mechanic are more focussed on logistic level.

2.3. Disassembly of the product

By disassembling the WaterWave it is possible to complete the overview of the product. This is useful during the redesign of the components that experience the fatal problems. The disassembly of the WaterWave will be divided into multiple categories to provide a clear view of the components used. These components will be discussed step by step, starting with the body, then the top and finally the mechanical system.

2.3.1. The body

The body consist of the skirt, the tub, four leather pads and the framework, as shown in figure 2.3.1. The skirting creates the appearance of the product. The skirting is made out of two different panels, a side-panel and an end-panel. Both panels are vacuum formed in the manufacturing facility of ProSun and made out of polyester.

The tub is made out from polyethylene, formed using thermoforming and manufactured by an external company. The tub has several ribs and a wall thickens of ¼" which creates the desired strength and stiffness. Since several components are placed underneath the tub, which means that the head-end has not the same depth as the rest of the tub which ensure that components like the motor and valve are place underneath the tub.

The framework is made out of several aluminum parts, which are welded together and severs as a skeleton for the WaterWave. This framework is produced by an external company.

The four leather pads are used to cover the mounting locations of the panels and protect the user. Two side-pads secure the long side of the bed and two end-pads secure the shorter side of the bed. The end-pads come with a rounding at the end of the pads. The pads are show in figure 2.3.1. The parts for the pads are brought externally and assembled at the workshop.

2.3.2. The top frame

The top frame consist of an aluminum frame and three layers of different fabric. The three layers are shown in figure 2.3.2. The frame is made out of an aluminum extrusion which is welded together. The frame is modified to the three layers that are placed on the frame. The frame is made by an external company.

The first layer is a black net which is stained between the frame and supports the weight of the user. The net has a thickness of 1/8" and a mesh size of 1" by 1". The net is fastened to the framework using screws for every mesh (around 64 screws). There are several thick threads in the midsection of the net as reinforcement.

The second layer is a polyurethane bladder that provides a watertight sealing to the bed. It is made out of two layers of polyurethane and the sides contain a strip of polyvinyl chloride (PVC) and thermoplastic polyurethane (TPU).

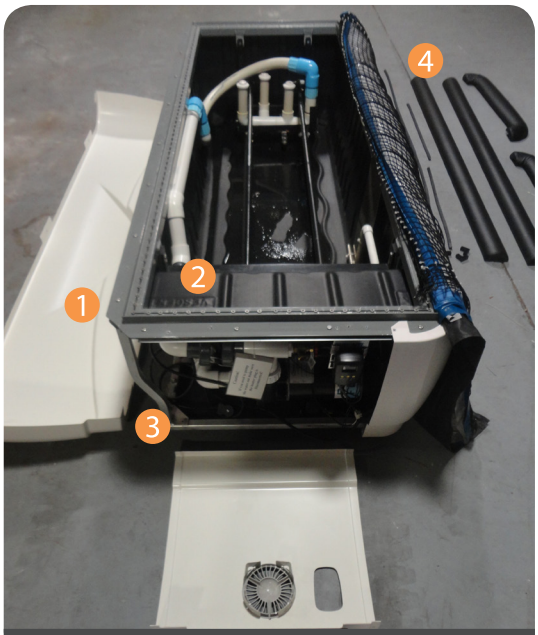


Figure 2.3.1. Shows the WaterWave with the skirting loose next to the bed. The skirt (1), the tub (2), the framework (3) and the leather pads (4).

Thermoplastic polyurethane is used to stick the polyvinyl to the bladder, because the polyvinyl is not able to stick on its own. The polyvinyl is a reinforcement to fasten the bladder to the WaterWave.

The third layer is a nylon anti-bacterial sheet that protects the polyurethane bladder and makes it comfortable for the user.

2.3.3. The mechanical system

The mechanical system consist of three nozzles that are combined to one jet that is mounted on a carriage system. The jet is driven by two swivel adapters that make sure that the jet can freely move up and down the rail. The two swivel adapters are connected with a control box which makes it able to control the positioning of the jet. The two swivel adapters are connected to two cables that move synchronized. (ProSun WaterWave 230, 2010)

Figure 2.3.2. The net (1), the Polyurethane bladder (2) and the Nylon anti-bacterial sheet (3)

A 500 watt heating element, placed at the head end of the tub, ensures that the water is at the desired temperature. The heating element is shown in figure 2.3.3. To keep the water a the right temperature, the heating element is connected to a control box with a thermostat, which switches the heating element off when the desired temperature is reached.

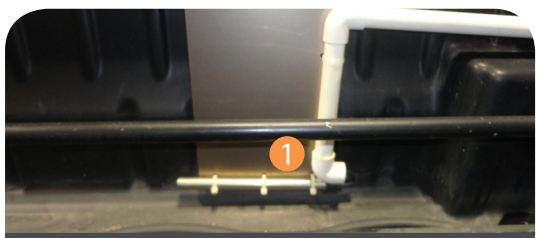


Figure 2.3.3. Heating element (1)

A 1½ HP electric pump produces water pressure that stows the water out of the jet and creates the massage effect. Before the water reaches the jet, is goes through a whole plumbing system. The plumbing system consist of a valve and several pipeline parts. A small electronic motor, on top of the valve, makes it able to vary the water pressure that creates a different massage effect. All the electronics come together in the electronic box at the foot-end of the bed. A wired remote control is connected to the box to operate the bed.

Hardware with preprogrammed software is placed to be able to use various massage programs. It regulates the water pressure, positions the jet and controls the water temperature. Figure 2.3.4 gives an overview of the parts used for the WaterWave which is shown on the next page.

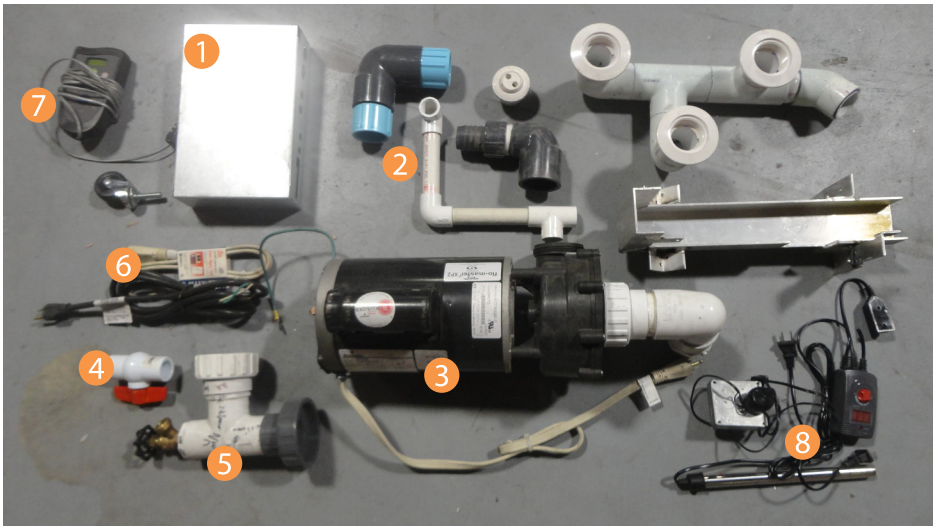


Figure 2.3.4. An overview of the parts used inside the WaterWave:

1. The electronic box
2. The plumbing
3. The pump
4. The valve
5. The drain
6. The wiring
7. The remote control
8. The thermostat

2.4. Cost analysis

Analysing and structuring the costs for the components used inside the WaterWave provides information about the cost division. This way it is possible to estimate the influence of the redesigned components that shall be used for the AquaFrixio. The costs will also influence the design decisions.

The data shown in this paragraph is delivered by ProSun and originates from the parts list used during the production of the product. The parts list consist of more then 300 parts which are categorised in sub-components. The costs shown in this paragraph are structured and categorised in the same categories used in chapter 2.3.

Figure 2.4.1 shows the overall cost for the production of the WaterWave. The total costs of $2709,09 are divided into the following four categories:

1. The body
2. The top frame
3. The mechanical system
4. Others

These categories are divided into several components, as shown in figure 2.4.1. Each component is the combination of several individual parts. Not only the material costs but also the labor costs to assembly the component are covered by these costs. The labor costs to assemble the whole WaterWave is assigned to the category others.

The mechanical system is the most expensive section of the bed. This category consist of many different parts, which is the reason why it is divided into several sub-components. This is also the reason that it needs a bit more attention.

The list below gives some clarification regarding the most important parts which are connected to the sub-components:

1. Drive mechanism: rail system, 2 cables and two little motors
2. Heating element: the heating element and thermostat
3. Electronics: wiring, hand-controller, electronic box and the fan
4. Jet mechanism: all the plumbing, jets, drain and the hose
5. Electronic valve: the manual valve and the motor
6. Labor: the labor for the assembly of the mechanical system
7. Extra: part that cannot be categorised

Other is the category that does not directly refer to parts used for the WaterWave. This category consists of the proceedings for shipment, the labor costs for the final assembly and the amortisation costs which are the cost for designing the WaterWave.

Finally, this information will be used when there is more clarity about the components that need to be redesigned. The focus is about design for performance which means that the costs are less relevant during the development of the potential concept. This information is an addition to the product analysis.

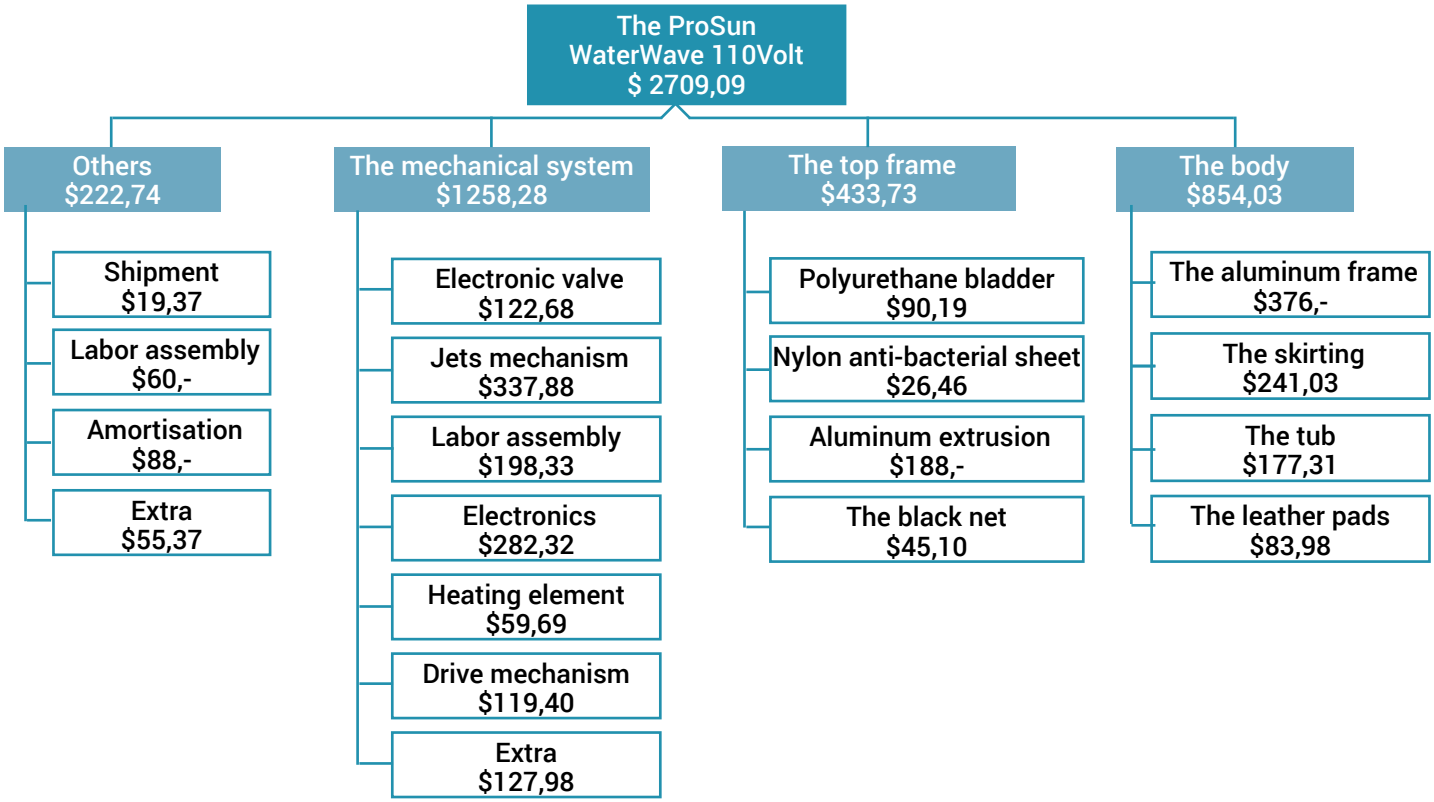


Figure 2.4.1. The cost for the materials and labor the produce the WaterWave.


PEGA-345
NCT
MADA
HAPRO
HAPRO

2.5 Manufacturing analysis

ProSun has brought several machines to support multiple manufacturing processes. Beside the basic manufacturing process, they are also able to use more advanced manufacturing processes.

Over the past few years, they brought several machines so they are able to produce components for their tanning beds, what made them more independent and more self-sufficient. The following three machines increased their independence:

1. The punch press they use to make aluminum and steel plate material parts which are used inside their tanning beds. This machine is shown in figure 2.5.1.
2. The hydraulic press is able to bend the plate material with maximum force off 350 ton. This machine is used to make parts similar to the electronic box which is used inside the WaterWave.
3. The vacuumformer is used to fabricate the skirt for several tanning beds as well as the WaterWave.

As mentioned earlier in the interview with Tom, ProSun prefers to produce parts at their own facility, to reduce the costs and create more independent construction.

The goal is to make use of these manufacturing processes during the development of the new massage concept used of the AquaFrixio.

Figure 2.5.1 The punch press

2.6. Competitor analysis

Before starting with the redesign of the WaterWave, it is important to explore the market and compare the current competitors. They might use different techniques that could provide a solution for the problems encountered. It also gives an idea of the level of performance that needs to be acquired and what market group the AquaFrixio is focussing on.

Currently there are three real competitors in North-America. Two of the three competitors have a product that is in the exact same segment as the WaterWave. The third competitor has two products on the market that use a slightly different technique.

Hydro Massage

The first competitor is Hydro Massage which uses the same technique used for the WaterWave. A rail system guides a jet which is electronically controlled with a interactive touch screen. The user can select different programs which massage from your feet up to your head. Besides selecting different programs, the user is also able to set the time and the temperature of the bed. The starters price for this bed lays around the $18000.- and increases for the more extended versions (HydroMassage, 2009). The Hydro Massage is shown in figure 2.6.1.

H2OMassage

The second competitor is H2O Massage which has also a product that uses the same technique as the WaterWave. They mounted four jets on a carriage system which are controlled by a touch screen, were the user is able to select different types programs. The bed is available in several versions that extends the amount of options on the product. This product is slightly lower of quality then the one from Hydro Massage and the price starts from $12000,-. The H2O Massage is shown in figure 2.6.2. (H2OMassge Systems, 2012)

Hydrojet Massage

The third competitor is Hydrojet Massage which has two massage bed that are located in a slightly different segment. The top of the Spa Jet completely closes with the user inside. Water sprinkles out of different jets located around your body, what means that the person has to were a bathing suit.

The Medi Jet is a more similar product and keeps the user dry while using the product. However, the Medi Jet does not use the water through air principle but the water though water principle. This means that the bed is completely filled with water. Multiple pumps produce enough pressure to force water through two jets. These jets create a massage effect similar to a hot tub. The jets are controlled by a mechanical system that uses a carriage system inside the product. Through a touch screen it is possible to run different programs that create a variety of options for the sure (Hydrojet, 2014). The Hydrojet products are shown in figure 2.6.3.

This information is used during the redesign of the massage mechanism inside the AquaFrixio. Their techniques will be examined and used during the idea generation.

2.7. Other improvements made by ProSun

In the past few years several other designers improved various components of the bed. These improvements should have fixed the problems with the WaterWave, but never delivered the required performance. Some enhancements did improve some components of the massage bed, so those improvements were not entirely a waste.

Figure 2.6.1. The Hydro Massage

The enhancements they designed are reviewed, to see if some of these can be useful for the AquaFrixio. The enhancements which can be useful for the AquaFrixio, are shown in the table below (Merks, 2010) (Motie, 2011).

Figure 2.6.2. The H2O Massage system

What part	Improvement
The massage mechanism	A jet with three nozzles. The nozzles are able to circulate the water what covers a larger area.
The framework	A framework already designed for production facility of ProSun. These steps are useful for the redesign of the framework.
The anti-bacteria sheet	A human pattern in the anti-bacteria sheet guides the user to the desired position, to ensure the positioning of the jet is correct and reduces the amount of noise created.
The net	An increase of the mesh size of the net to 1,5" x 1,5" with a thickness off 0,25"
The tub	The tub size is decreased to 30 gallons of water. Less material is used for the tub, they can produce it at their own workshop and more space is left inside the massage bed.
	A special drain is installed that prevents a vortex

Figure 2.6.3. The Spa Jet (1) and the Medi Jet (2)

More elaboration about these improvements can be found in appendix B.

2.8. Quality of function deployment

Quality Function Deployment is used to design on the customers demands and how these demands can be reached. The QFD is used to transform qualitative user demands into quantitative parameters. The House of Quality consists of translating customer desires into design characteristics (Institute, 1999). The house of Quality can be found in Appendix C.

The information that is used for the QFD is gathered from the interviews that were done and the product analysis that is done. The QFD is made in cooperation with ProSun, unfortunately do they not have any experts on this field that was familiar with a QFD.

The following results came forward out of the QFD:

	Importance
Software	566,7
Size of the nozzles	183,3
Amount of nozzles	138,9
Length rail system	341,7
Mesh size of the net	38,9
Tension of the net	222,2
Heating element	194,4
Positions of the jets	150,3
Electronics	463,9
Watertight sealing	163,9
HP of the pump	244,4
Size of the plumbing (1", 1,5", 2")	63,9
Length of the plumbing	47,2
Ventilation	127,2

The two most important characteristics fall outside the boundary of this bachelor assignment. The electronics and software have an important part in the performance of the massage bed but the focus of this assignment is more on developing a new massage concept. The implementation and customization of the electronics and software are of importance during the finalization of the AquaFrixio, what is way ahead of this assignment.

The three design characteristics which are important during the development of a manufacturable concept are: length rail system, HP of the pump and tensions of the net. Two of these characteristics are components of the massage mechanism, which are the key functioning device of the massage bed. The other characteristics play a less important role in formulating and defining the requirements for the redesign of the AquaFrixio.

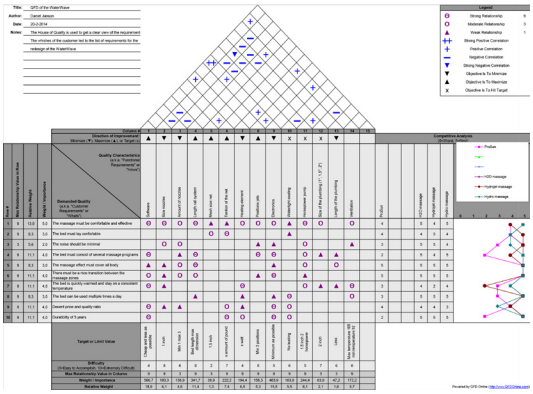


Figure 2.8. The House of Quality.

Number	Place, part or process	Failure mode	Failure effect	Severity (1,4,6,16,25)	Cause	Occurrence (1,3,5,7,9)	Detectability	Detection (1,3,5,7,9)	RPN	Action (Yes/No)
1	Rail system	Cable snaps	Massage effect on one uncontrolled position	25	The nozzles mix one of the two magnets through water level fluctuation, what only ensures that one motor stops	9	Bed not working properly	9	2025	Yes
2				25	No cleaning inside the tub	7	Bed not working properly	9	1575	Yes
3		Motor breaks down	Massage effect on one uncontrolled position	25	Failure of the electronics	1	Bed not working properly	9	225	Yes
4		Motor doesnot work properly	The bed is not controlled properly	25	Failure of the electronics	1	Testing of the bed	3	225	Yes
5	Waterflow	Pump breaks down	Massage bed is not working anu more	25	Failure of the electronics	1	Bed not working properly	9	225	No
6		Valve breaks down	No pressure regulation possible but water can get through	16	To much torque produced by the motor that controls the valve	1	Bed not working properly	9	144	Yes
7			Waterflow shut down	25	To much torque produced by the motor that controls the valve	5	Bed not working properly	9	1125	Yes
8	Temperature regulation	Fan breaks down	Water reaches uncomfortable temperature	1	Failure of the electronics	1	Using the bed	5	5	No
9		Fan not strong enough	Water reaches uncomfortable temperature	16	To much heat produced by pomp and friction of the water in the plumbing	5	Using the bed	5	720	Yes
10		Thermostat breaks	Water stays at room temperature	16	Failure of the electronics	5	Using the bed	5	225	Yes
11		Thermostat will not turn off	Water gets to warm	4	Failure of the electronics	1	Testing of the bed	3	12	Yes
12	Comfort	The net snaps	Sinks slowly in the tub	9	The screws cut the the thread	1	Using the bed	3	27	Yes
13		The net looses the tention	Sinks slowly in the tub	9	Frequent use of the bed with a lot of weight	3	Using the bed	3	81	Yes
14		Securing the bladder to make it watertight	Tub is not covered properly	1	Cutting equipment	1	After detecting water leaking	5	5	No
15				4	Frequent removing of the bladder	1	Placing the bladder after removal	1	4	No
16	Plumbing	The plumbing doesnot fit	A lot of men hours adapating the bed	9	Division cutting the plumbing	3	Assembly of the product	1	27	Yes
17				9	Mixing up the parts	1	After assembly of the product	3	27	Yes

Figure 2.9. The Failure Modes and Effect Analysis.

2.9. Failure modes and effects analysis

The Failure Modes and Effect Analysis (FMEA) is used to get a clear view into the problems regarding the WaterWave. The product quality regarding the potential failure, of all important components, is quantified during the FMEA. The FMEA is established with the same information gathered for the QFD (PQRI, 2008). The full version of the FMEA can be found on Appendix D.

Based on the Failure Mode and Effect Analysis, the following conclusion can be made. First, the failure of the cable that snaps during the use of the WaterWave can be caused by two things:

1. The jet misses one of the two magnets through the fluctuation of the water level, which means that only one motor stops and the other one continues. This way the carriage system wants to move sideways and wrecks the cable controlling the movement of the carriage system.
2. Two times a year would be enough to keep the inside of the bed clean. When the user forgets to do so, the carriage system will fail to preform and finally the cable will snap.

Second, the failure of the valve with the small motor mounted on top of the valve that regulates the water pressure. The torque of the motor is extremely high producing the failure of the valve. The failure of the valve can have two consequences: the whole bed wont work or the bed still works but with one pressure level. Third, the increase of water temperature while using the massage bed. The friction of the water circulation through the plumbing system, heats the water to an uncomfortable level. This effect is definitely occurs when the massage bed us used for multiple times a day in a salon.

Another issue that is noticed during the FMEA, is the importance of the electronics and software. As is explained earlier, this falls outside the boundaries of this assignment but is an important factor that should be acknowledged during the finalization of the AquaFrxio.

2.10. Analysis conclusion

In this chapter the problems encountered with the WaterWave were mapped, the production facility of ProSun was analysed and the elements that were redesigned by previous designers were examined. This summarizes the outcome of this chapter.

2.10.1. Components to redesign

Based on the analyses that are done, the following list of components needs to be redesigned for the new massage concept that will be developed.

- **The massage mechanism**

The massage mechanism is continuously experiencing problems regarding the carriage system used inside the massage bed, which results in extremely high maintenance costs. The previous improvements did not solve the problems and ended up having the same problems all over again. The existing mechanism needs to be replaced with a new mechanism that works properly.

- **The pressure controller**

The valve with a small motor mounted on its top experiences many problems that needs to be replace with an other solution to control the pressure.

- **The chiller**

The fan is not able to keep the water at the desired temperature, therefore it is important to design a chiller that makes sure that the water temperature stays at a comfortable level.

- **The framework**

The manufacturing of the framework needs to be relocated to production facility of ProSun, which means that the frame needs to be redesigned to fit the manufacturings methods used by ProSun.

- **The tub**

The changes to the massage mechanism will affect the form and dimensions of the tub. A tub that fits the dimensions of all redesigned components needs to be developed.

- **The top frame**

Currently the user mounts the net on the top frame, using a not efficient and user-friendly approach. The top frame needs to be redesigned to fit these requirements.

2.10.2. Competitors

There are a few companies that manufacture similar products as the WaterWave. Only two products use a similar technique as the WaterWave and can be of use during the design of the AquaFrixio. Their techniques need to be examined during the development of a new massage mechanism. It can bring new insight into the mechanism and reduce the time to develop a new mechanism. It will not offer any guarantee as it is hard to find detailed information about their mechanism.

2.10.3. Production Methods

In the past few years, ProSun brought several machines do be able to produce and manufacture components they use for their product, at their facility. They want to relocate more of the development of components they use, to their facility. In the end it will reduce the manufacturing costs and make them more independent.

2.10.4. Size of the assignment

The QFD and the FMEA give more clarity about the size of the assignment. The two most important characteristics which were qualified fall outside the scope of this assignment, since the task will be to complex in three months. Therefore, the focus is on developing a manufacturable new massage concept for the AquaFrixio. The specific technical details will be left out the assignment.

2.10.5. Course of action

It is decided to start redesigning the massage mechanism. This components creates the massage effect and is the most essential component inside the WaterWave. The other components are redesigned, based on the changes made to the massage mechanism.

2.11. Requirements specifications

The following list of requirements which can be seen in figure 2.11.1, is compiled out of the information that is gathered during the analysis phase. To illustrate why some requirements were set, an elaboration on the requirements is added below.

The overall requirements are divided into functional, maintenance and production requirements. This subdivision is made because of the relation between the problems that were encountered and the section were the problems were encountered.

Besides the overall requirements, the components that need to be redesigned got more specific requirements. These requirements are discussed before redesigning the components because these requirements can change during the redesign of other components.

During the cost analysis it became clear that there is no overall target for the costs of the AquaFrixio. It is more important to develop the manufacturable massage concept, then reducing the costs. That is why there is no overall cost requirement. Figure 2.11.2 shows the current costs for every component that will be redesigned, what is analysed during the costs analysis.

Components	Costs	Total
Massage mechanism		$783,59
Jets mechanism	$337,88	
Drive mechanism	$119,40	
Extra	$127,98	
Labor assembly	$198,33	
Pressure control		$122,68
Chiller		-
The framework		$376,-
The tub with heat element		$237,-
Tub	$177,31	
Heating element	$59,69	
The top frame		$188,-
Total costs old		$1707,27

Figure 2.11.2. The cost for every component that will be redesigned for the AquaFrixio

Purpose

The purpose is to develop and design a manufacturable new massage concept used inside the AquaFrixio. Therefore the six main components in the massage bed need to be redesigned.

Functional
The usability of the product must stay the same.
The outside dimensions of the product must stay the same.
The noise must be reduced to a comfortable level.
WISH: The massage effect is preferred to be in improved.
WISH: The usability is desired to improve.
Maintenance
The product must function with half yearly maintenance.
The product components must be accessible.
The product must have an easy maintenance.
The product must include of consistent components.
Production
The product must be able to be assembled in one day by two person(s).
The product must be produced at the production line in the workshop.
The product must have identical part as much as possible.
The product must be as symmetric as possible.
The product must consist of pre-drilled holes as much as possible.
The material cost must be as low as possible.
The materials must be able to be ordered in bulk numbers.
WISH: The production cost are desired to be lower then 2909,09.

Figure 2.11.1. The overall requirements for the redesign of the WaterWave.

3. Component redesign

The problems were quantified, the requirements were established and the goal was formulated. This chapter is about changing ideas into concepts.

Every component that is selected in the previous chapter, will be redesigned in this chapter. Multiple ideas will be generated and these will be translated into a concept. For every component, several concepts are generated, what ends with making a decision for one of the concepts.

In order to explore different solutions and generate ideas, a brainstorm session is done. The brainstorm session is done based on the information gathered during the analyses phase, what focussed on every component which needs to be redesigned. Figure 3.0 shows the results of the brainstorm session.

As the time is progressing rapidly and due the size of the assignment, not every component can be widely discussed. The focus lays on developing a prototype for the new designed massage concept for the AquaFrixio.

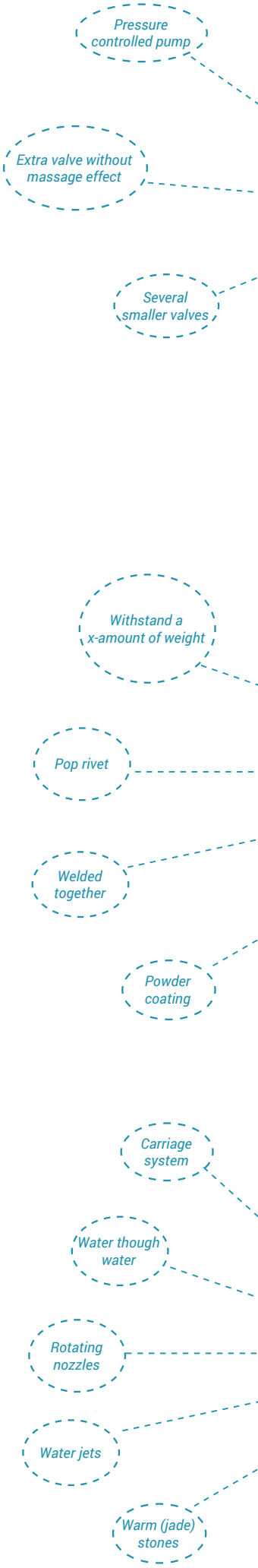
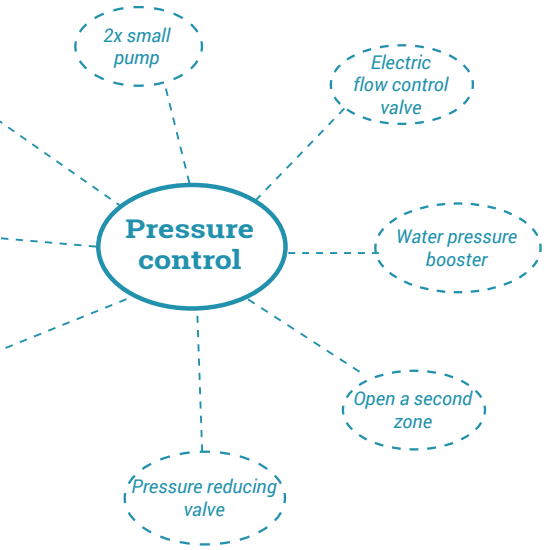
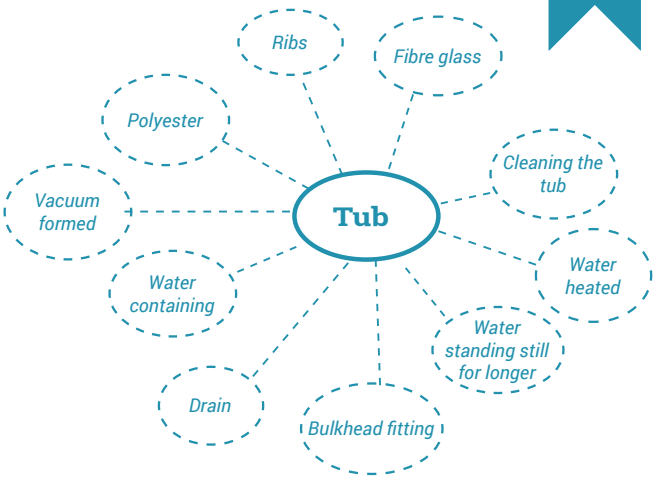
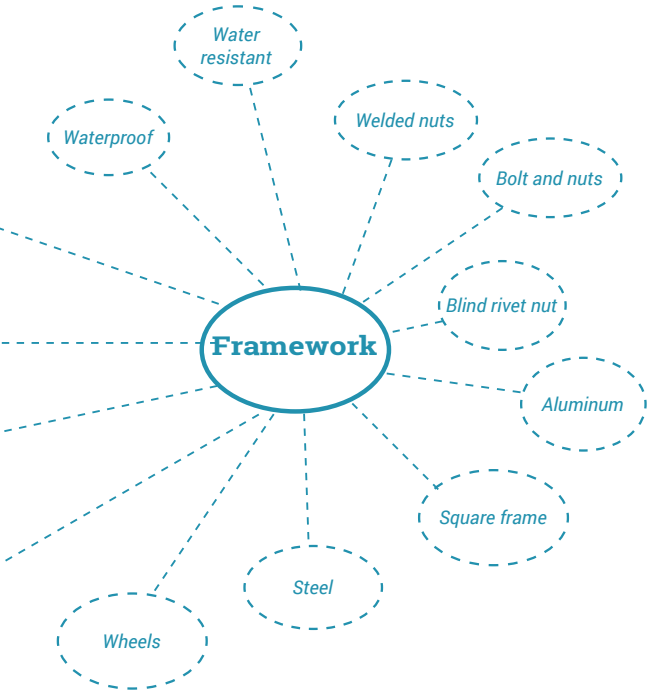
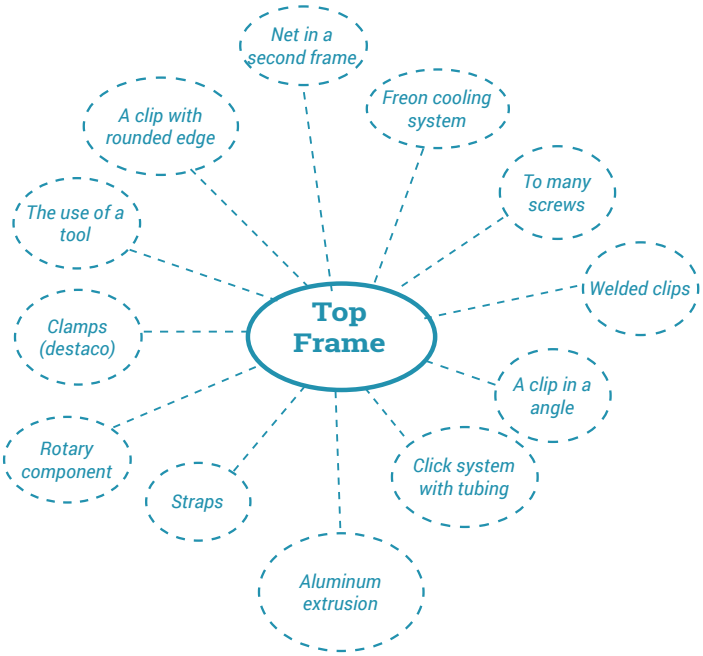


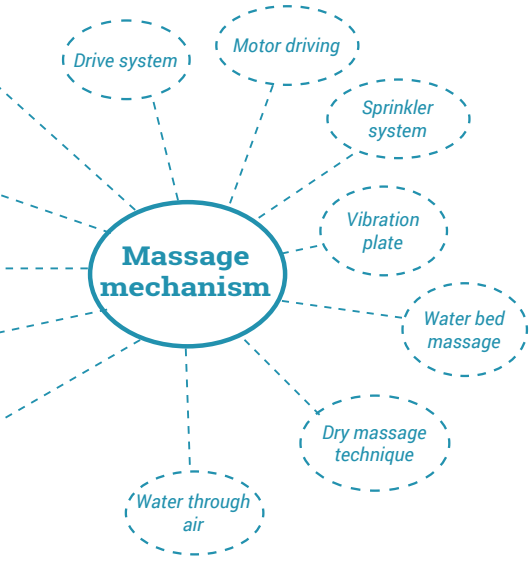
Figure 3.0. The results of the brainstorm session

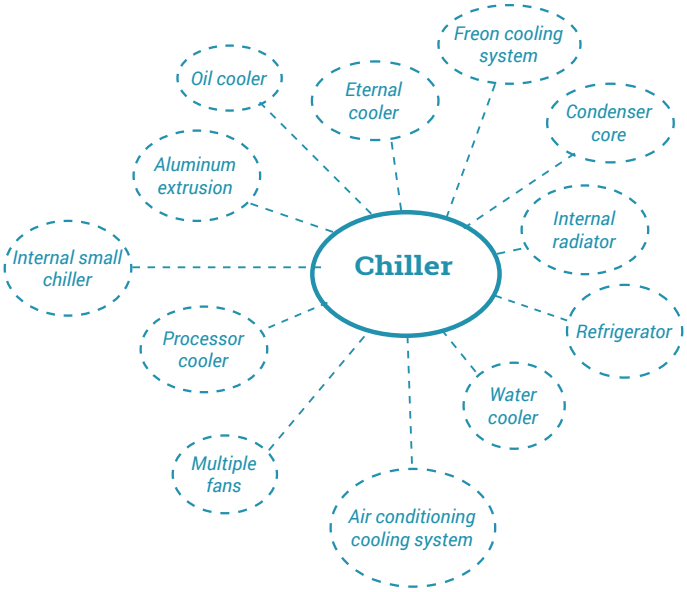

Pressure control
2x small pump
Electric flow control valve
Water pressure booster
Open a second zone
Pressure reducing valve


Tub
Ribs
Fibre glass
Polyester
Cleaning the tub
Vacuum formed
Water heated
Water containing
Water standing still for longer
Drain
Bulkhead fitting


Framework
Water resistant
Waterproof
Welded nuts
Bolt and nuts
Blind rivet nut
Aluminum
Square frame
Steel
Wheels


Top Frame
Net in a second frame
A clip with rounded edge
Freon cooling system
To many screws
The use of a tool
Welded clips
Clamps (destaco)
A clip in a angle
Rotary component
Straps
Click system with tubing
Aluminum extrusion


Massage mechanism
Drive system
Motor driving
Sprinkler system
Vibration plate
Water bed massage
Dry massage technique
Water through air


Chiller
Freon cooling system
Oil cooler
Eternal cooler
Condenser core
Aluminum extrusion
Internal radiator
Internal small chiller
Refrigerator
Processor cooler
Water cooler
Multiple fans
Air conditioning cooling system

3.1. The massage mechanism

The massage mechanism is the most important component of the AquaFrixio, as it delivers the key function of the product. Because of that, this component will be the first one that will be redesigned. The product analysis determined the current solution is not delivering the required performances, which means that there will be looked for a whole new mechanism.

3.1.1. Requirements

The requirements specific for the massage mechanism are shown in figure 3.1.1. The most important requirement for the massage mechanism is the quality of the massage effect. The other requirements are formed based on the current mechanical system, the objective that is in mind and on basis of the problems that currently exists. These requirements will be the guideline during the redesign of the massage mechanism

The cost of this component is less important than the quality of the mechanism, which is the reason that the costs are a wish and not a requirement. Out of the cost analysis became clear that the current massage mechanism has a total cost off $937.93 what includes the following sub-components: the jets mechanism ($337,88), the electronics ($282.32), the drive system ($119,40) and the assembly labor ($198,33).

Component 1: The massage mechanism
Quality of the massage effect must stay the same or be improved
Pressure of the massage effect must be improved
The massage technique must fit the 1-Speed Spa Flo 48-Frame Pump
The massage technique must fit in the new tub
The massage technique must cover the whole body
WISH: The massage mechanism is desired to cost less then $937.93
The massage technique must consist of 4 zones minimum

Figure 3.1.1. The requirements for the massage mechanism

3.1.2. Idea generation

After the brainstorm is decided to go through with the water though air technique, which means that the water leaving the jet travels through air before reaching your back. This effect can be created using a tub that is not completely filled with water.

This technique is used because the company has many experience on this field that can be handy during the design of the AquaFrixio and the other techniques are mostly based on mechanical techniques that do not deliver the required massage effect.

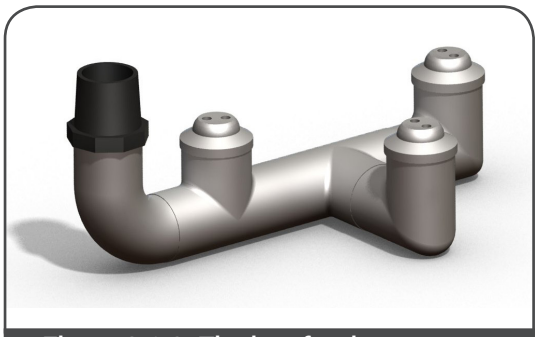


Figure 3.1.2. The jets for the massage technique

Figure 3.1.3. Basic frame with tub used during the concept detailing

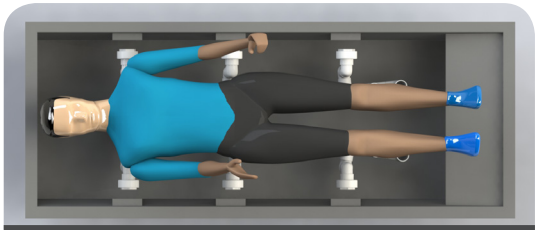


Figure 3.1.4. An example of a human body laying on top of the AquaFrixio

Another decision that is made effects the size of the tub. The current tub cover almost all the dimensions of the bed, which leaves less space for the mechanical components and creates weak points as that tub is to deep to be vacuum formed. That is why the tub must be less deep so there is enough space left for components underneath the tub and the weak spots within the tub are solved.

The QFD showed the importance of the water pump. The pump used is a 1½ HP pump, but is also available in a 2 HP version. To increase the water pressure, the 2 HP version will be used for the massage mechanism. This is advised by an expert of Waterway, who are specialised in pools and spas (Waterway, 2011).

An other important restriction is the inside dimensions of the skirt. Appendix E shows those dimensions that need to be kept in mind during the design of the mechanical components. This influences the overall dimensions of the massage mechanism.

There is also more clarity on the jets that will be used for the AquaFrixio. A previous designer already did some research to the jets that will deliver the desired performances. These jets will be used based on his findings. Figure 3.1.2 shows a image of those jets. Sketches of ideas that are made in during the idea generation can be found in Appendix F. (Merks, 2010)

3.1.2. Concept design

There are a few restrictions during the redesign of the massage mechanism, since it is the most essential component for the redesigned AquaFrixio.

The frame with tub shown in figure 3.1.3 are based on the decisions made during the idea generation and the outside dimensions of the skirt. The frame and tub will be modified and fit the massage mechanism later on during the design process, but this will be used as a guideline during the design of the massage mechanism.

The positioning of the jets is important to create the required quality of massage. Therefore the average body height of North-Americans will be used to estimate the positioning of the jets. The average body size of the North-Americans is taken as guideline because that is the target group for the AquaFrixio. Figure 3.1.5 shows an example of a human body laying on top of the AquaFrixio. (Disabled World, 2008) (DINED, 2014)

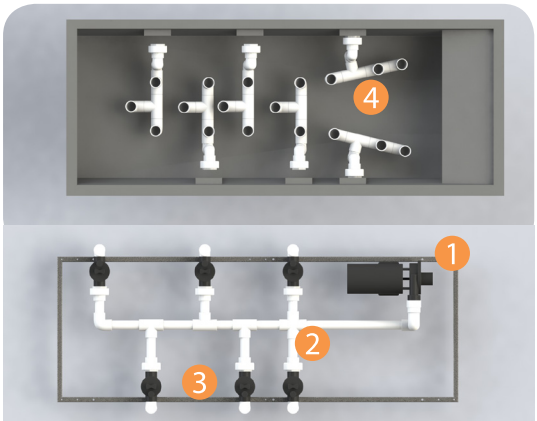


Figure 3.1.5 Concept 1 with the pump (1), plumbing (2), valves (3) and jets (4).

Based on the sketches shown in Appendix F and the gathered information during the analyse phase, three concepts are created.

Concept 1.

The first concept focusses on using as few components as possible. A 2" mainline plumbing guides water through six different zones. The main line is like a spine as it is exactly in the middle of the bed. Every zone is provided with a electric valve that controls the passage of the water. The water goes through the wall of the tub and divides into three jets. The nozzles on top of the jets great the massage effect against the body. Figure 3.1.5 shows a model of concept 1.

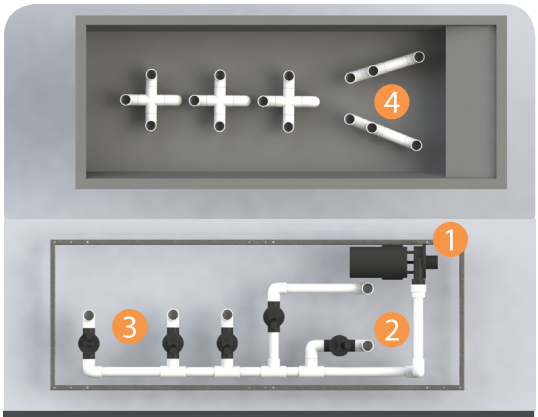


Figure 3.1.6 Concept 2 with the pump (1), plumbing (2), valves (3) and jets (4).

Concept 2.

The second concept uses a mainline that lays at the side of the bed. The 2" mainline splits into five zones that are also provided with electric valves to control the passages of the water. The water goes through the bottom wall of tub and ends up in the middle of the tub. The water splits into three different jets and sprays the person through the nozzles on the jets. A model of concept 2 is shown in figure 3.1.6.

Concept 3.

A 2" mainline is connect with six valves which are connected to different zones and can be controlled by the hand-controller as the valves are connected to the electric circuit. The ramifications in the main line are symmetric, what ensures that the gaps in the tub are at the opposite of each other. This all is shown of figure 3.1.7. that creates a overview of concept 3. (Waterway, 2011)

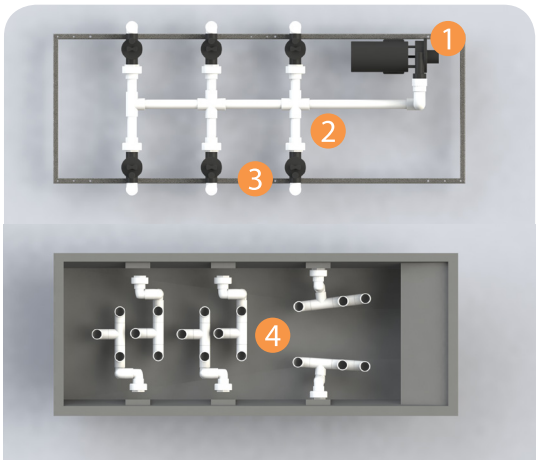


Figure 3.1.7. Concept 3 with the pump (1), plumbing (2), valves (3) and jets (4).

3.1.3. Concept choice

Figure 3.1.8 shows the outcome of the concepts that were criticized using the specific requirements.

To be able to make this decision, an employee of Waterway was able to come over and give some useful information about spa and pool components. With his help and the use off the internet, it is also possible to further develop a new concept which creates a similar massage effect and is easier for maintenance and production.

Component 1: The massage mechanism	Concept 1	Concept 2	Concept 1
Quality of the massage effect must stay the same or be improved	/	/	/
Pressure of the massage effect must be improved	/	/	/
The massage technique must fit the 1-Speed Spa Flo 48-Frame Pump	+	+	+
The massage technique must fit in the new tub	+	+	+
The massage technique must cover the whole body	++	+	++
WISH: The massage mechanism is desired to cost less then $937.93	-	-	-
The massage technique must consist of 4 zones minimum	++	++	++

Figure 3.1.8. The requirements for the massage mechanism

The first two requirements are difficult to asses, as the quality of the massage affect needs to be tested during the development of a prototype and all three concept use the same 2HP pump and 2" plumbing. Without examining the concepts deeply it is hard to decide which concept preforms better.

Concept three is more symmetric, uses less parts and covers more area of the body which is the reason to choose concept three over the other two concepts. Less parts and the symmetry makes it easier for assembly and maintenance. The six zones cover more are than five zones.

The cost estimation of the three concepts are close together. Unfortunately, it does cost around the $1300,-. The functioning of the massage bed is of that importance that the costs are accepted.

This results in the final selection of concept three, that is based on all the arguments described above.

3.1.4. Concept description

The massage mechanism is mostly build out of basic plumbing parts that can supplied by all plumbing suppliers. As it is importance that the defected components can be replaced easily, the mechanism is made out of many consisted components and the maintenance can be done easily, which is necessary to use some specialised parts.

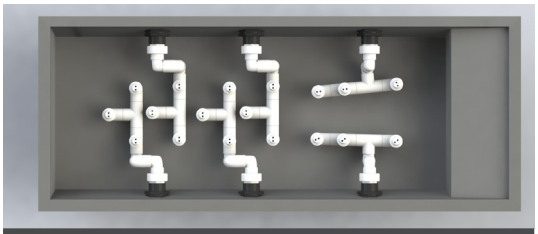


Figure 3.1.9. Top view of the mechanism.

Figure 3.1.9 and 3.1.10 show the working of the massage mechanism. The 2HP pump is connected to the 2" mainline positioned in the middle of the bed. Three ramifications divide the mainline into the six zones. Every ramification is connected to a valve with a union which makes it able to replace the valve when it is broken without replacing any other valve. The plumbing enters the tub using a bulkhead tank fitting which seals the tub watertight. Between the jets and the bulkhead tank fitting is another union, that makes it possible to replace the valve and simplifies the assembly of the AquaFrixio.

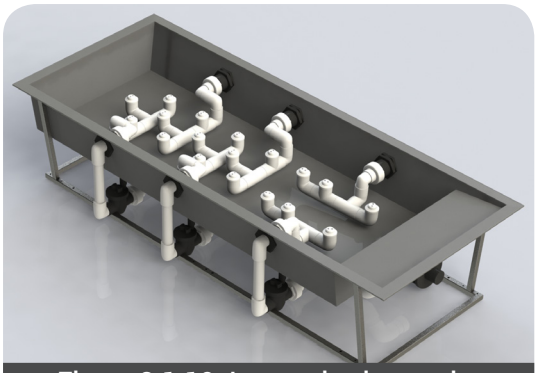


Figure 3.1.10. Isometric view to the massage mechanism

The average body height is used to determine the positioning of the jets. More detailed drawings are shown on Appendix H. As explained earlier, the previous designed jets are used for the upper for jets inside the mechanism. For the legs is a different type of jet designed, that is shown in figure 3.1.11. The jets used for the legs is also build out of three nozzles that are positioned in one line. The two upper nozzles create the massage effect in the thigh and the lower nozzle creates the massage effect in the lower leg (DINED, 2014).

Figure 3.1.11. The jet used for the legs

3.1.5. Estimated costs

The exact cost estimation can be found on Appendix G. The estimated cost for the massage mechanism is $1.025,92. This includes the pump, all the plumbing and the labor to assemble the mechanism.

3.2. Water pressure regulator

Every user prefers a different pressure for the massage technique. Currently there is a manual valve mounted with a small motor on top of the valve to control the water pressure. The motor has too much torque that demolishes the valve and makes the bed unusable. The current valve needs to be replaced with a component that is able to regulate the water pressure properly.

3.2.1. Requirements

There are two things that are most important for the water pressure regulator. First, the water pressure regulator needs to be compatible with the new massage mechanism. Second, the water pressure needs to be regulate on three different levels, as it is preferred to be able to put the pressure harder and lower. The pressure regulator is of that importance that a good placement is more in need then the cost reduction. The requirements are shown in figure 3.2.1.

Component 3: The water pressure regulator
The water pressure regulator must be compatible with the redesigned massage mechanism
The water pressure regulator must regulate the water pressure on three different levels minimum
The water pressure regulator must be replaced easily
The cost of the water pressure regulator must be as low as possible
WISH: The cost of the water pressure regulator is desired to be lower then $122,68

Figure 3.2.1. The requirements for the water pressure regulator.

These requirements will be used to search for an alternative that replaces the current valve and makes it possible to regulate the pressure used for the massage technique.

3.2.1. Idea generation

Several ideas are generated which differ from a pressure controlled pump to a water pressure booster. Appendix F shows several drawings of ideas that came forward out of the brainstorm session.

3.2.2. Concept design

Based on the sketches made in the idea generation phase, the information gathered during the analyse phase and the formulated requirements, three concepts are made.

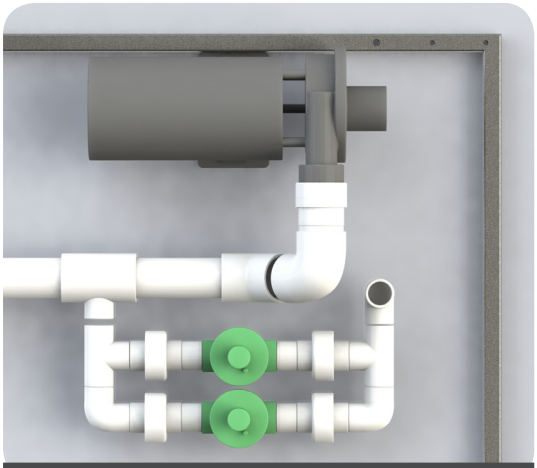


Figure 3.2.2. The 2 times 1" valves

Concept 1.

The first concept is replacing the current water pump with a variable speed water pump. The variable speed pumps available variate from 2 till 4 different speeds. The size and the price of the pumps increase tremendously. The pump can be connected tot the electronic circuit of the AquaFrixio which it possible to adapt the speed of the pump with the hand-controller (TomTom2, 2011).

Concept 2.

The second concept is about a valve that is able to electronically controls the amount of water that goes through the valve. The water pressure is at maximum when the valve is completely open. To lower the water pressure, the valve will narrow the gap so that less water goes through the main line. This way the pressure of the AquaFrixio can be controlled using the hand-controller. The valve is located at the mainline.

Concept 3.

The third concept is about two smaller valves that are connected to the main line. The two valves can be switched on and off separately. When the two valves are closed, the water pressure is at maximum. If one valve is open, the water pressure will drop down. The minimum water pressure is acquired when both valves are open. These valves are connected to the electric circuit and can be controlled with the hand-controller (see figure 3.2.2.).

3.2.3. Concept choice

To be able to make a funded decision, some internet research is done and an expert is consulted. The expert was able to provide more information about the different types of valves that are on the market. Figure 3.2.3 shows the outcome of the requirements compared to the three concepts.

Component 3: The water pressure regulator	Concept 1	Concept 2	Concept 3
The water pressure regulator must be compatible with the redesigned massage mechanism	++	+/-	++
The water pressure regulator must regulate the water pressure on three different levels minimum	++	++	+
The water pressure regulator must be replaced easily	-	+	++
The cost of the water pressure regulator must be as low as possible	-	+/-	+
WISH: The cost of the water pressure regulator is desired to be lower then $122,68	--	-	+

Figure 3.2.3. The outcome of the requirements for the water pressure regulator.

Currently there is no standard electronic valve on the market that is compatible with the new designed massage mechanism. The other two concepts are compatible with the new mechanism, which is an advantage for concept one and three.

Concept one and two have far more options than the required pressure levels. Concept three is only able to use three different levels of water pressure, as more levels will need to much space inside the AquaFrixio.

The advantage of concept three is its easy to replace the two valves. The variable speed pump is mounted on the framework which is difficult to replace and the electronically controlled valve is connected to the mainline, which needs a lot of effort to replace this component.

The variable water pump cost around $1200,-, the variable valve costs around the $300,- and two smaller valves cost about $12,- each. In the end is concept three way cheaper then the other two, what is a huge advantage for this concept. (Pentair, 2014)

Based on these arguments and the requirements for the water pressure regulator, concept 3 is chosen to use for the AquaFrixio.

3.2.4. Concept description

To control the pressure of the massage mechanism, two smaller electric valves are connected to the 2″ mainline. The two valves go separately up through a bulkhead tank fitting into the tub. The bulkhead tank fitting is placed above the water level to reduce the amount of potential leaks.

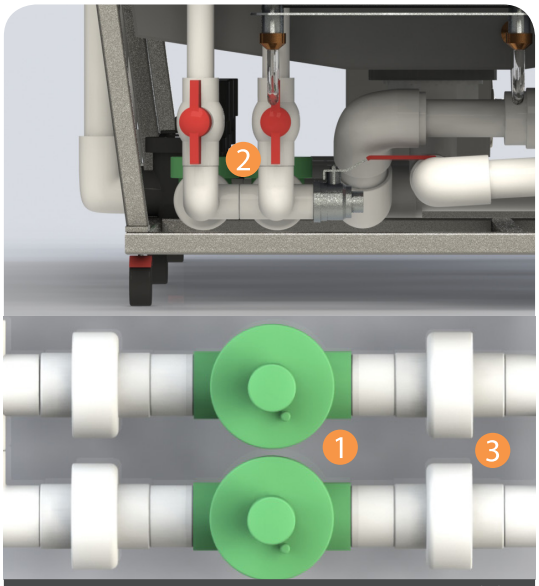


Figure 3.2.5. The 1″ electronic valves (1), the 1″ manual valves (2) and the unions (3)

The two manual valves in line with the two electronic valve are able to reduce the passage of the water. This way the user can variate the three different levels of water pressure. A narrower passage reduces the pressure difference between the three levels. The manual valve will be set to a standard position and the user has to remove the skirt to change the position.

At both sides of the valve is a union located that makes it possible to replace one valve when it is damaged. This to keep the maintenance user-friendly.

3.2.5. Estimated costs

The pressure control is build out of basic parts that are available at most of the plumbing suppliers. The cost of the pressure controller is estimated at $83.74, which is shown on Appendix G. The estimated costs for this component are less expensive compared to the current component.

3.3 The chiller

Currently there is one fan that moves air out of bed through a opening in the skirting. This is not enough to keep the water at comfortable level when the bed is used for multiple times a day. Unfortunately, there is no working WaterWave left to measure the temperature, which means that the current problems is based on customer experience and cannot be verified.

The use of the massage bed differs from ones a day to several times a day, which affects the temperature of the water. Frequent use means a huge increase in water temperature, as the movement of the water creates heat due to the friction between the water and the plumbing (Gramoll, 2008). The aim is to sell the AquaFrixio to salon owners that use the bed multiple times a day, which means that there can be assumed that the temperature needs to be chilled a lot.

3.3.1. Requirements

Figure 3.3.1. shows the requirements specific for the chiller. Because the missing experience, some more experimentation has to be done afterwards. This assignment focusses on a workable solution but the deepening into the exact working of the chiller is not possible within the timeframe of this assignment.

Component 2: The chiller
The chiller must keep the water at 95 degree while using the AquaFrixio
The chiller must be placed within the AquaFrixio
The chiller must be made out of standard parts
The chiller must be as cheap as possible

Figure 3.3.1. The requirements specific for the chiller

An important requirements of the chiller is keeping the water at 95 degrees. This is the average temperature that is used for the AquaFrixio (ProSun WaterWave 230, 2010). Another requirement is that the chiller needs to be placed inside the AquaFrixio and not outside the bed, what limits the possible solutions. The final requirement is the use for standard parts, to keep the labor restricted..

3.3.2. Idea generation

The ideas that are generated for the chiller are based on similar products. The Hydro Massage and H2O Massage are reviewed, based on information that could be found on the internet about these products. Appendix F shows several sketches of ideas that could solve the problem encountered.

3.3.3. Concept design

The size of the chiller plays an important role. The amount of space that is left within the AquaFrixio is limited with the new technique that is used. Another element that influences the variety of options is the requirement that the chiller needs to be made from basic parts. Designing an aluminum extrusion with ribs that transfer heat to air, does not directly meet the requirement. In the end, three concept are created.

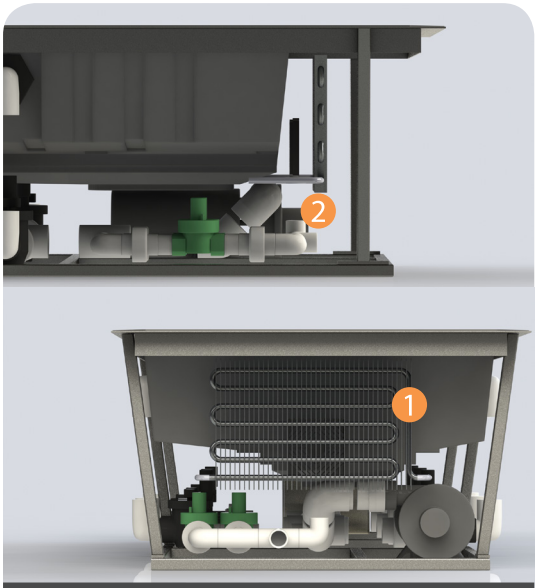


Figure 3.3.2. The Condensor core (1) with a fan behind (2) the core.

Concept 1.

An air conditioning uses a condensor core to cool down water at the back of the conditioning. The water flows to tubing that is inside a framework. A fan blows air through the framework so the heat from the water is transferred to the air as the framework has many contact points with the air. Figure 3.3.2 gives an idea of the size and positioning of the condensor core within the product.

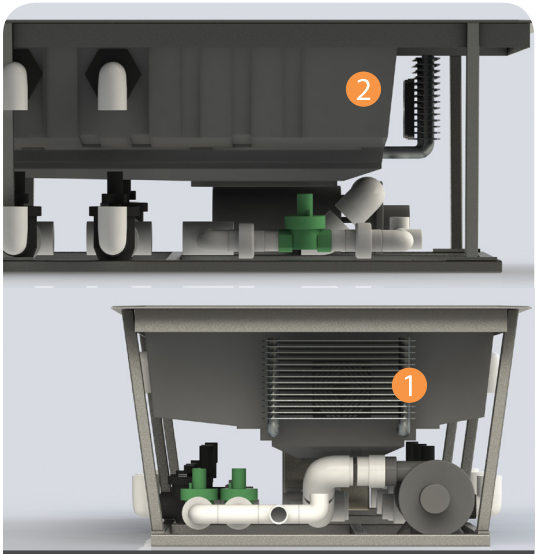


Figure 3.3.3. The Oil cooler (1) with a fan behind the cooler (2)

Concept 2.

An oil cooler is frequently used inside cars and motorcycles. It works the same as the condensor core as the oil goes through the cooler were the heat is transferred to the air. The oil cooler can be brought externally and does not need any modification. Figure 3.3.3 shows a oil cooler of medium size located within the product.

Concept 3.

A new designed aluminum extrusion is filled with water. When the water reaches an certain temperature, the chiller will go on. Two smal pumps go on and push water through the aluminum extrusion. Two fans blow air through the ribs of the extrusion which will transfer the heat from the water to the air. This is shown in figure 3.3.4.

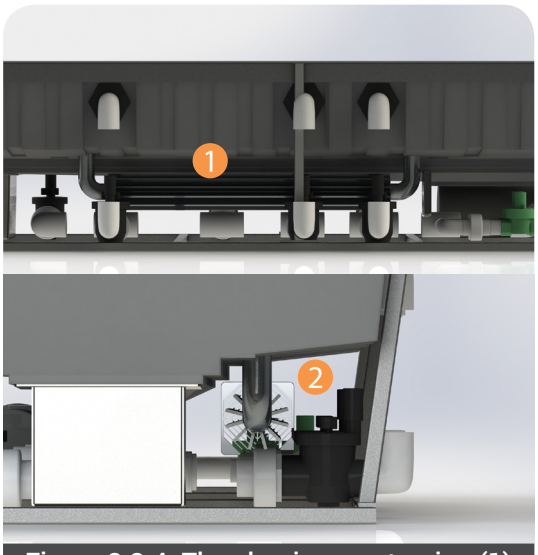


Figure 3.3.4. The aluminum extrusion (1) with the fan (2)

3.3.4. Concept choice

As the knowledge about a chiller is limited, the choice for the best qualified chiller is difficult. Based on the gathered information, a decision is made. Figure 3.3.5. shows the outcome of the requirements regarding the three concepts.

Component 2: The chiller	Concept 1	Concept 2	Concept 3
The chiller must keep the water at 95 degree while using the AquaFrixio	/	/	/
The chiller must be placed within the AquaFrixio	+	+	+
The chiller must be made out of standard parts	+	+	+/-
The chiller must be as cheap as possible	+	+	-

Figure 3.3.5. The outcome of the requirements specific for the chiller

The first requirement is hard to evaluate, as the functioning of the part will be tested with the prototype. Deeper research is required to determine the functioning which is not possible within the time frame of this assignment.

An estimation is done to be able to make a decision. The disadvantage of concept one is the width and height of the core, as the to fans have a limited area they can cover. The second concept has the disadvantage of the low capacity compared to the other concepts, what can minimize the effect of the chiller. The third concept has the disadvantage that the end of the extrusion cannot be place near the skirt to mount the fan, what makes it hard to circulate the air.

A problem encountered with concept one core, is the availability of this component. It is hard to find the part separated, because it is mostly delivered as a component within a product. Concept two is available as a part and can be delivered in all different dimensions. The concept three is not made from basic parts, as a mall for the aluminum extrusions has to be made.

The costs for these components differ tremendous. The price for the aluminum extrusion is not that expensive, the problems is the purchase of the mall. This starts somewhere around the $2.000,-. The condensor core and oil cooler both fit in the same price range, starting form the $40,- till somewhere &120,-.

Based on these arguments, the decisions is made to use the oil cooler for the AquaFrixio.

3.3.5. Concept description

The chiller is shown in figure 3.3.4 and operates on the following approach.

The oil cooler is attached to the framework, hangs in the front of the end-skirt and is connected with the tub by two hoses. A small water pump is located inside the tub that activates when the water reaches a certain temperature and start pumping water through the oil cooler. The two fans both activate when the small water pump starts running.

3.3.5. Estimated costs

The estimated costs for the chiller increase slightly as the focus lays on basic components. The standard Oil cooler has a slight different fitting then normally used as the part is manufactured for the automobile industry. The costs for the chiller are estimated at $112,47, what can be found in Appendix G.

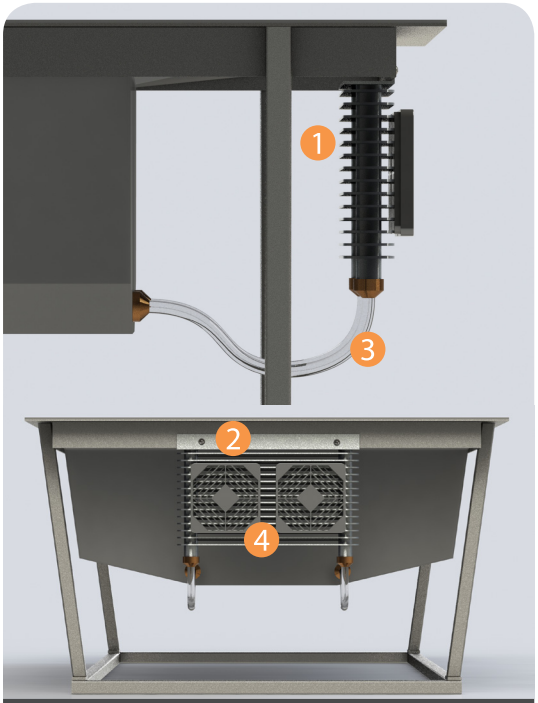


Figure 3.3.6. The Oil cooler (1), the aluminum plate (2), the hose (3) and the two fans (4)

3.4. The framework

The framework is one of the most fundamental parts of the product. The framework keeps all the other components together, as they are all mounted on the frame.

3.4.1. Requirements

The main reason for the redesign of the framework, is because of the changes that are made to the other components.

Making the framework costs efficient while maintaining its strength, reducing the complexity and manufacturing the framework at their facility, are important requirements during the redesign of the framework. The outside dimensions of the framework is an important restriction, as the company has multiple molds for the cover plates of the product.

Component 4: The framework
The frame must be produced at the workshop of ProSun
The frame must fit the current skirt
The frame must fit the new top frame
The frame must hold the new tub
The frame must consist of six wheels
The frame must hold the weight of the user, 30 gallons of water and the other components (600 pounds)
The pump must be mountable on the frame (110v 60hz)
The frame must be able to hold the electronic and mechanical components of the product
The frame must be as cheap as possible (Old $376,-)
The frame must be water resistances

Figure 3.4.1. The requirements for the framework.

3.4.2. Idea generation

Sketches of ideas generated can be reviewed in Appendix F. The ideas variate from simple basic frameworks to a construction crane. To be able to produce the framework and to minimize the amount of unnecessary bends, the decision is made to keep it as simple as possible. Also thinking about the variety of ways to keep the frame together and what way to cut the framework, will have attention during the concept design.

3.4.3. Concept design

Multiple factors influence the design of the framework. The material, cutting method and mounting method play an important role during the concept generation.

Multiple materials can be used. The options are basically all metals, as a plastic with the desired strength is to expensive. The options left are steel, stainless steel and aluminum. Steel is cheaper and easy to weld. The down side is the weight of the material and that it is highly corrosive. Stainless steel does not need a powder coating but is almost four times the price of normal steel. Aluminum has low corrosive properties and is lighter then the other two materials. The disadvantage aluminum is the strength of the material and discomfort of welding.

The assembly of the framework can be done on three different ways or a combination of those. The different mounting methods influence the degrees of freedom, what is an important boundary during the concept development. First, welding the frame together is the easiest option which means that the frame cannot be disassembled. Second, using rivet nuts is a good alternative which simplifies the assembly of the frame but it is an additional part with an additional operation to mount the rivet nuts. Third, using bolts and nuts which is a standard way to fasten the framework but tight spaces can be a problem.

There are two options of cutting the material. First, cutting the material straight is easy and the most standard way of doing. The disadvantage of doing it this way, is the possible water that enters the tubes. Second, cutting the material in 45 ° corner is harder to do. The advantage is that the tubes can be closed so no water can enter.

This all comes together into two final concepts.

Concept 1

The first concept is based on minimizing the material used for the framework. That is the reason for only 2 ribs in the bottom of the framework and 1 rib at every side of the framework, this is shown in figure 3.4.2. The frame is made out of 1/8" thick steel which is cheaper and stronger than aluminum. The framework will need a powder coating as the water affects the steel what will rust eventually. The bottom of the frame is mounted with bolts and nuts, to keep the costs low for shipping the framework to the painter. The other parts are welded together.

Concept 2.

Concept two is made from Aluminum, what is slightly more expensive but has a higher resistance against the water what could mean that it does not need a surface treatment. This will save costs for the production of the framework. The material is slightly weaker which means that an extra rib is added to the framework. The entire frame is welded together, so it cannot be disassembled any more. This will save addition actions during the assembly of the AquaFrixio.

Figure 3.4.2 framework concept 1.

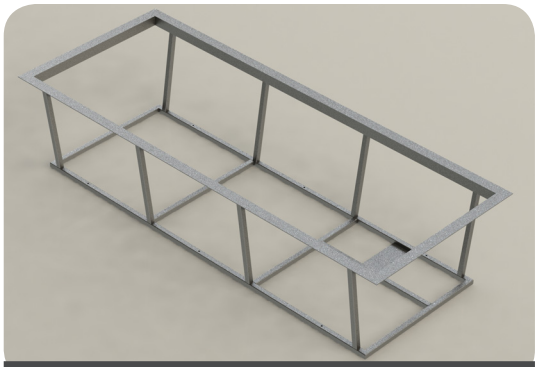


Figure 3.4.3 framework concept 2.

3.4.4. Concept choice

Concept one is selected based on the requirements and the already redesigned components of the product. This paragraph will explain reason why concept one is selected.

The material that will be used for the framework is steel. The material is easy to weld, the costs for the material are low and it is stronger that aluminum. The estimation was made that aluminium would not need a coating. Unfortunately, this estimation was not correct as the painter advice to anodize the aluminum because of the frequent contact with water (Cardinal Aluminum Co., 2005). All summarized made the decision to use steel.

Requirements	Concept 1	Concept 2
The frame must be produced at the workshop of ProSun	+	+
The frame must fit the current skirt	+	+
The frame must fit the new top frame	+	+
The frame must hold the new tub	+	+
The frame must consist of six wheels	+	+
The frame must hold the weight of the user, 30 gallons of water and the other components	+	+
The pump must be mountable on the frame	+	+
The frame must be able to hold the electronic and mechanical components of the product	+	+
The frame must be as cheap as possible	++	+/-
The frame must be water resistances	+	+

Figure 3.4.4. List with requirements and if their are met?

3.4.4. Concept description

The framework is made form 1/8" thick steel. One size steel prevents confusion by the employees while manufacturing the framework.

The framework has three ribs that support the tub and the user, with a required maximum of 600 pounds. The vast majority of the framework will be welded together. The ribs are mounted with bolts to the bottom of the frame, using welded nuts. This ensures that the frame can be stacked when it needs to be shipped for the powder coating. The powder coating protects the steel, when it comes in contact with water.

A little plate, welded on the bottom of the frame, is made to mount the pump on the frame. There are six wheels mounted at the bottom of the framework, which makes it able to relocate the bed easily.

Figure 3.4.1. A render of the framework

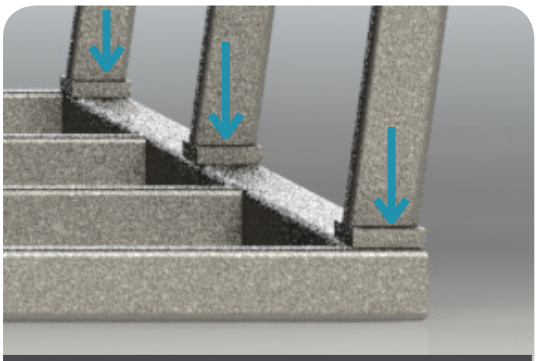


Figure 3.4.2. The part of the frame that will be fastened with bolts and nuts.

3.4.5. Estimated costs

The production of the framework at ProSun's facility does not only have a costs reduction but also an other advantage.

The frame will cost $281,90, what is slightly lower then the current costs. The other advantage is that they are able to produce when needed, what means that less frameworks must be stored. The total costs for the framework can be found on Appendix G.

3.5. The tub

The tub will change as the whole massage mechanism is redesigned. The current tub is an already improved version of the tub that was designed for the WaterWave, nevertheless it is necessary to redesign the tub as it is not compatible with the redesigned massage mechanism.

While designing the tub, the position and design of the thermostat and heater will be included. This is done because most of the components used inside the AquaFrixio will be different than the current design, more electronic components are added to the product and the current heat element is not functioning as required.

3.5.1. Requirements

By getting a clear view of the changes that are made to the other components, is it possible to compose a list of requirements specific for the tub. Requirements specific to the heat element and thermostat are also listed below besides the requirements for the tub.

Component 5: The tub
The tub must be able to empty completely
The tub must hold the box with heat element and thermostat
The tub must be compatible with the massage mechanism (as well inside the tub as outside)
The tub must hold 30 gallons of water and the weight of the massage components (250 pounds)
The tub must fit in the new framework
The depth of the tub must be minimized

Figure 3.5.1. The requirements for the tub

3.5.2. Idea generation

The new massage mechanism involves a huge change to the design of the tub which ensures that there are many limitations during the redesign of the tub. Sketches of the tub with the important elements can be found on Appendix F.

3.5.3. Concept design

The tub is detailed further to accommodate the box with heating element and thermostat, the massage mechanism and the suction.

The suction is analysed by a previous designer that solved the problem of the water forming a vortex. When a vortex occurs, not only water but also air enters the plumbing and wrecks the pump (Merks, 2010).

Based on the amount of space of the massage mechanism, the depth of the tub can be estimated. The size of the plumbing, the valves, the chiller and pressure control are know, which can calculate the amount of space that is needed underneath the tub. Modelling this in SolidWorks gives a good view of the product and estimates the exact size of the tub. This way it is also possible to model the vertical areas for the jets.

The box with heating element and thermostat developed by the designer, is the replacement for the old heat element with thermostat. This box contains the heat element, the thermostat for the heat element, the thermostat for the chiller and a smaller pump to circulate the water.

Figure 3.5.2. The suction that resolves the vortex in the water.

The smaller pump is also able to empty the box when the whole massage bed needs to be drained. The box is made from flat steel with a powder coating what is able to mount every element. Figure 3.5.4 shows the box with the elements mounted on the box. One thermostat will switches off the heat element when the water is at the 95°F temperature (ProSun WaterWave 230, 2010). The second thermostat switches the chiller on when the water reaches 96°F temperature. The heat element is mounted into an adapter that is welded on the side of the box. The box needs to be mounted somewhere in the bottom of the tub, what influence the design of the tub.

Figure 4.5.3. The steel box with thermostat, heat element, etc.

This information is used to create four different concepts that are shown on the next page.

Concept 1

The first concept is about modifying the current mall made for the tub that is designed for the rail system, that is shown in figure 3.5.4. First, the mall needs to be incremented to increase the depth of the tub, to get the nozzles low enough for the massage mechanism. Second, the suction mounting area needs to be moved as it blocks the 2" mainline. Third, the cut-out for the jets in the wall of the tub need to move over to get them symmetric. These three changes should make it possible to use the for the AquaFrixio. The box with the heat element and the two thermostats is mounted at the head-end of the tub. A slight disadvantage is that the wiring has to come form the other end of the bed.

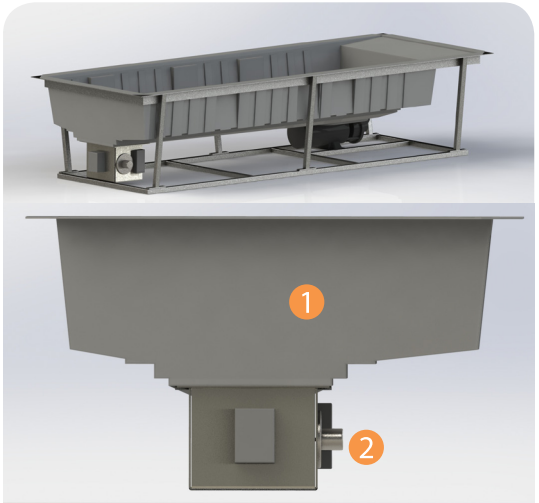


Figure 3.5.4. The tub (1) with a box for the heat element and thermostats (2)

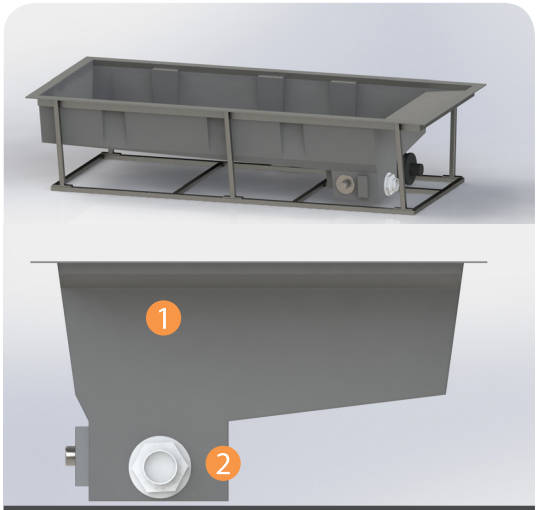


Figure 3.5.5. The tub (1) with a box for the heat element and thermostat (2)

Concept 2

A whole new mall is made based on the changes that are implemented. The mall is made so that the tub can be vacuum formed at the workshop of ProSun, which means that the tub is made out of polyester. The box with the heat element and the thermostat is changed to the side and foot-end of the product, what is shown in figure 3.5.5.

This way it does not block the 2" mainline and can be used for the suction as well. The electronic components are positioned at the same side as the pump and electronic box, so that all the electronic are clear and organized.

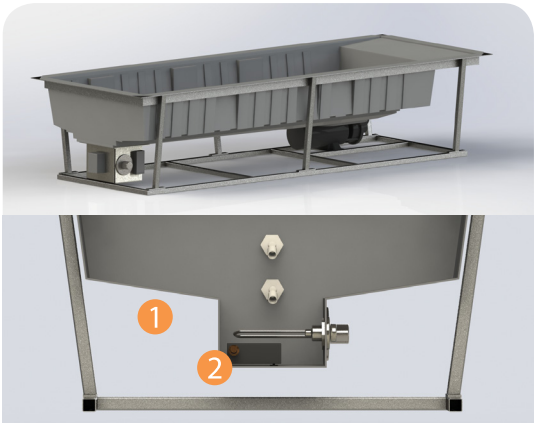


Figure 3.5.6. The tub (1) with a box for the heat element and thermostat (2)

Concept 3

The third concept is similar to concept two, but the positioning of the box with heat element and thermostats will be changed to the head-end of the bed. This because the spacing that is left at the foot-end will make it hard during assembly of bed and maintenance that has to be done. It will have the same disadvantage as concept one, regarding the wiring.

Concept 4

Another solution would be using a tub that is made out of fibreglass. The tub is stronger what means that the heat element and thermostat can be mounted on the fibreglass instead using a metal box, that is shown of figure 3.5.6. The fibreglass tub is around 20 till 40 percent more expensive and needs more labor to get it produced and installed (Productive Plastic, 2008).

3.5.4. Concept choice

The following arguments will explain the choice for concept three. All the requirements are accomplished by every concept, what is shown in figure 3.5.7. This complicates the decision making for the tub.

Every concept is able to empty the tub completely. This because the pump positioned inside the box, will transfer the water out of the box. The slope in the bottom of the tub makes it able to drain the tub completely.

The mall of the old tub needs that many changes, that it is more profitable to make a whole new mall. Too many problems have to be worked around make a workable tub.

Using fibreglass for the tub would be a good choice, because the strength and properties of the material. But currently there is no experience with this type of material, what would be a risk to use fibreglass (BuyPlaneParts, 2014).
Positioning the box with heat element and the thermostats at the foot end, would be a good solution to combine several component of the bed. Unfortunately, there is not enough space to position the box at the foot end. The assembly and maintenance would be complicated and could cause problems.

Component 5: The tub	Concept 1	Concept 2	Concept 3	Concept 4
The tub must be able to empty completely	+	+	+	+
The tub must hold the box with heating element and thermostats	+	+	+	+
The tub must be compatible with the massage mechanism (as well inside the tub as outside)	+	+	+	+
The tub must hold 30 gallons of water and the weight of the massage components	+	+	+	+
The tub must fit in the new framework	+	+	+	+
The depth of the tub must be minimized	+	+	+	+

Figure 3.5.4. The components reviewed based on the requirements.

3.5.5. Concept description

The tub that is selected for the AquaFrixio will be formed with a whole new mall. The mall is such that the tub can be vacuum formed at the workshop of ProSun. The tub will be made from 0,25" thick ABS that has good properties concerning bonding. This means glue or other bonding techniques can be used to bond parts in place.

The box with the heat element and the two thermostats is positioned at the foot-end of the massage bed. The wiring for these elements has to come form the other side of the bed, but it gives enough space to freely mount or replace components.

3.5.6. Estimated costs

All the elements together will have a total cost of $302,30. One third of the costs are from the tub that will formed at ProSun's facility. The other two third of the costs are derived from the heat element, thermostats and water pump.

3.6. The top frame

The top frame is one of the problematic parts of the WaterWave. The net is replaced by several other materials, they tried several enhancements to the frame and many other frames has be thought off but never met the desired requirements.

3.6.1. Requirements

Using the experience of previous designers that tried to solve the problem with the top frame, makes is possible to compose a list of requirements. During the examination of the frame, there can be assumed that the design of the top frame influence the ease of use and performance of the top frame.

Component 6: The top frame
The top must be able to be removed easily for maintenance
The top must fit correctly and perfectly
The top must have a watertight seal
The top must consist of a net that can be replace by the user
The top must consist of a net with enough tension to hold a person of 200 pounds weight
WISH: The net can get in place without using an extra component

Figure 3.6.1. The requirements for the top frame

After a period of use, the net sags what makes the massage bed unusable. Replacing the net will solve this problem, but the complex design makes the replacement complicated. A tool will simplify the replacement of the net but increases the costs and adds an additional component to the product. The aim is to keep the component user-friendly.

3.6.2. Idea generation

Based on previous designers research, several decisions are made. First, the net that is used for the WaterWave will still be used but with double the mesh size then the current net. Second, the wiring of the net is thicker what makes it less likely to be weakened. Third, all possible solutions with the current frame have been examined but did not deliver the required performance, which means the whole frame will be replace with a new framework.

An important decisions is made for the top frame before the concept design starts. Because of the size of the area that the top frame needs to cover, the high risk of getting in contact with the water and the complicated dimensions of the framework, is ensured that aluminum will be used for the top frame. Aluminum is slightly weaker then steal but reacts less to water and less heavy then steel (Aluminiumdesign, 2014).

Based on the information that is gathered, multiple ideas are created and can be found on appendix F.

3.6.3. Concept design

The dimensions for the top frame are know, based on the redesign of the tub and the dimensions of the outside skirting.

As the net is changed to a mesh size bigger and sleeves at the sides of the net, it is possible to use PVC or aluminum tubes to fasten the net. This way it wont be necessary to use 164 screws and can be looked for a kind of click mechanism.

The following four concepts are created.

Concept 1.

This concept is about a frame with several aluminum clips that keeps the aluminum tube through the net on its place. The frame is made out of basic aluminum parts that are welded together and falls on top of the edge of the tub, which ensure that the tub is sealed watertight. The aluminum clip is placed on several point around the basic frame, so that it keeps the aluminum tube on the right place, what creates the desired tension. Small cuts in the sleeve of the net, makes is possible for the clip to secure the tubing. This is shown in figure 3.6.2.

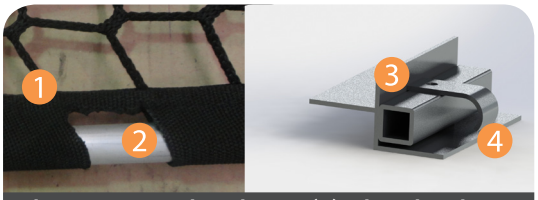


Figure 3.6.2. The sleeve (1), the aluminum tube (2), the frame (3) and clip (4)

A tool will be used to get the aluminum tubes in place as there is to much tension to get them there with bare hands. The tool is made out of a standard tool with a slight modification. The tool will be delivered with the bed, so that the customer is able to replace then by themselves.

Concept 2.

This concept is about a framework made out of basic material. The different forms of material will be welded together and form the frame that is placed on the edge of the tub. Several clips positioned around the frame makes it possible to place tubes, that go through the sleeve of the net, into place. Figure 3.6.3. shows a model of this concept.

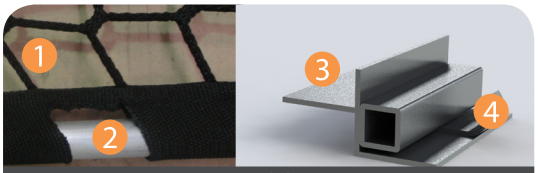


Figure 3.6.3. The net (1) with aluminum tub (2), the frame (3) and the clip (4)

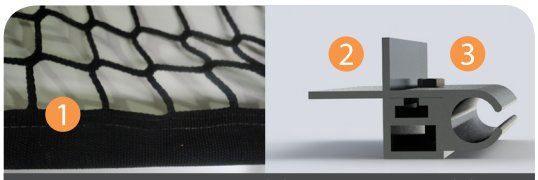


Figure 3.6.4. The net (1), extrusion 1 (2) and extrusion 2 (3)

Concept 3.

The third concept is about two aluminum extrusions. One extrusion will be used as frame that is place at the edge of the tub. The extrusion is cut into two lengths that are welded together to form the square frame. The extrusion has a sleeve for nuts to fasten the second extrusion on the frame. The second extrusion slides over the net with a PVC tube inside, this to keep the net in place.

Concept 4.

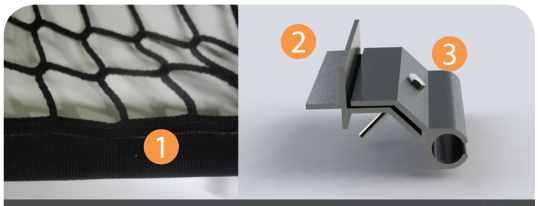


Figure 3.6.7. The net with PVC inside (1), extrusion 1 (2) and extrusion 2 (3)

This concept consist of two aluminum extruded profiles. One profile is used as basic frame, that falls on the edge of the tub. The second profile will fall over the net with a PVC tube inside and will be drawn to the other profile by using a bolt. Figure 3.6.7. gives a representation of the working of this concept.

3.6.4. Concept testing

Because of the continuous problems with the top frame, the many different concepts that were generated and the many factors that are uncertain, there is decided to test the designed concepts before the final concept is chosen and a whole top frame is made for the prototype.

Every concept is tested using available steel parts, even through the final component will be made out of aluminum. Concept testing gives the possibilities to make a informed decision.

Concept 1.

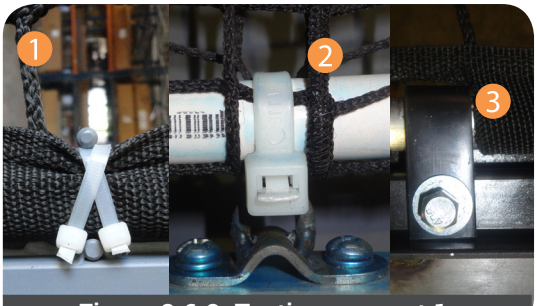


Figure 3.6.8. Testing concept 1.

Figure 3.6.8. shows pictures of concept one, the first one that is tested. The elaboration of this concept can be done in several ways.

Three different versions of the concept are shown in figure 3.6.8 One shows a steel pipe that is bended in half a circle to place the tube that goes through the sleeve of the net. The second shows a standard clip that is mounted on the frame with two bolts and nuts. The cut in the sleeve of the net secures the tubing in place using a zip-tie. The third shows a steel clip mounted on top of the frame and secures the tube through the sleeve of the net.

Figure 3.6.9 shows pictures of several tools that were made or modified to position the net with pipe on the desired position. These tools are made because of the high tension of the net, what makes it impossible for the user to replace the net without a tool. Positioning the net for the top frame is not a issue in the workshop of ProSun, but replacing the net at home makes it way more difficult. A minimum of two tools is needed to get the pipe of the net in place. This creates an extra costs of minimum $25,- up to a $120,-, depended on the tool and the labor.

Figure 3.6.9. Tools to get the net in place.

Concept 2.

Concept two is tested on two different ways, that is shown in figure 3.6.10.

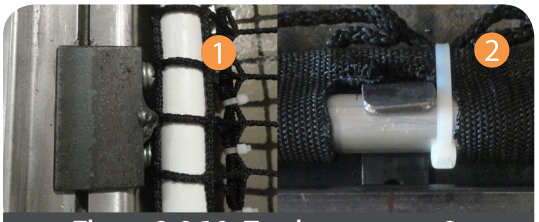


Figure 3.6.10. Testing concept 2.

The first one shows a steel part bended in 90 degrees. On one side is a hook mounted that will secure the pipe through the sleeve of the net. Two bolts with nuts are mounted in the frame to secure the part. Picture two shows an other elaboration of concept four. A small flat piece steel with a bend at the end of the parts is mounted at the bottom of the frame. The tube that goes through the sleeve falls into the bend, which will secure the tube. Multiple parts will be place around the framework to keep the tube through the net in place. This applies to both elaborations of concept two.

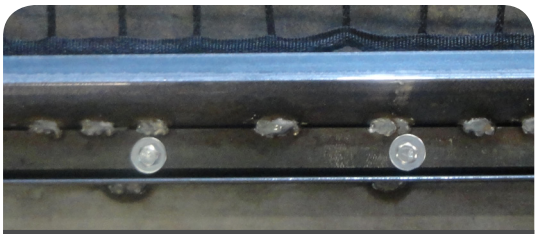


Figure 3.6.11. Testing concept 3.

During the manufacturing of this concept, the same problem as with concept one occurred. The tube through the sleeve is not getting in place without using a tool for the customers at home.

Concept 3.

This concept is elaborated on the following way. Two angled pieces steel are welded together with a small gab on one side. The gab gives room for the tube with net to slide in.

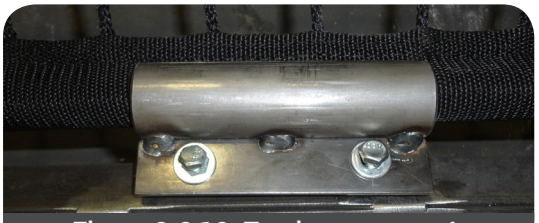


Figure 3.6.12. Testing concept 4.

An other angled piece is welded to the corner of those two pieces to secure the part to the frame. This part has almost the same length as the frame and is secured with a bolt and nut ever few inch.

Concept 4.

A small piece of flat steel is welded to a piece of tubing. A sleeve is cut into the side of the tube to make it able to slide the net with tubing through. The small piece of flat steel is secured to the frame with a bolt and nut. Multiple of those parts will be place around the framework to keep the tube through the net on place.

The frame for this part is slightly different, because the frame is in a 45 degree angle. The bolt used to secure the part to the frame has about 2" thread. This ensures that the tension increases while mounting all the parts on the frame.

3.6.5. Concept choice

Based on the idea generation, concept design and concept testing, the decision is made to use concept four for the AquaFrixio. This can be explained using the following arguments and the requirements that are shown in figure 3.6.14.

Component 6: The top frame	Concept 1	Concept 2	Concept 3	Concept 4
The top must be able to be removed easily for maintenance	-	+/-	+	++
The top must fit correctly and perfectly	+	+	+	+
The top must have a watertight seal	+	+	+	+
The top must consist of a net that can be replace by the user	+	+	+	++
The top must consist of a net with enough tension to hold a person of 200 pound weight	+	+	+	+
WISH: The net can get in place without using an extra component	-	-	-	+

Figure 3.6.1. The requirements for the top frame

Concept one functioned as preferred and can easily be manufactured, but a problem that was encountered with this concept is the use for an extra tool to replace the net. There is to much tension when the new net needs get in place. This means that the user needs a tool that has to be delivered with the net or with the massage bed. One of the requirements is to replace the net easily and that requirement is not achieved when a tool is needed replacing the net. A similar problem is encountered with concept two and three.

Because of the long struggle with this component is decided to put the usability above the costs of the component. The idea of using a 45 degree angled part that tightens the net while mounting the parts, seemed to work perfectly. This increased the usability, user-friendly and efficiency of the top frame. That is why concept four is chosen is final component. Figure 3.6.13 shows a drawing of the final design of the top frame.

3.6.6. Concept description

Figure 3.6.13 shows the final concept for the top frame. The frame is made form two different extrusions. One extrusion will be used to make the basic frame that lays on top of the edge of the tub, the other extrusion is made to fasten the net.

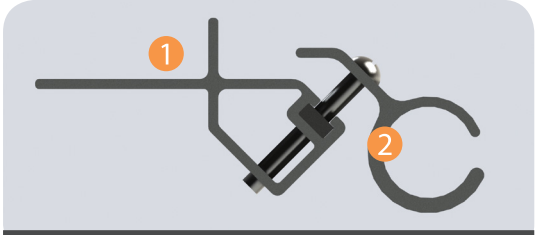


Figure 3.6.13. Chosen concept for the AquaFrixio

An angle of 45 degree will make it able to tighten the net without using an extra tool. Tightening every bolt step by step, will slowly increase the tension on the net.

This way it is possible to leave a small gab between the frame and the second extrusion. After a year, the gap can be closed which will increase the tension of the net. This way the durability of the net will increase.

3.6.7. Estimated costs

The estimated costs for the top frame are $308,72. The costs mostly depends on the costs for the extrusion. The extrusion is made by an external company, who needs to make two custom malls for the framework. After the production of these parts, they will be anodized and shipped to ProSun. The total costs calculation for this part can be found in Appendix G which includes an offer for the aluminum extrusion.

The costs for the mall are not included with the estimated costs for this component, as these costs will be included in the amortisation costs. Unfortunately are these malls really expensive, what costs over the $4000,-.

3.7. Cost calculation

In this paragraph the total estimated costs of the product are discussed. These costs are compared with the current production costs of the WaterWave. The cost is calculated by the costs estimation on the redesigned component, the labor that is required and the parts that are needed. The cost estimation is shown in figure 3.7.1.

Components	Old costs	New costs
The massage mechanism	$783,59	$1.025,92
The water pressure control	$122,68	83,74
The chiller	-	$112,47
The framework	$376	$281,90
The tub with heal element and thermostats	$237,-	$312,30
The top framework	$188,-	&308,72
Total costs old	1707,27	2125,05

Figure 3.7.1. The costs for the redesigned components

This all refers to an product cost increase of $417,78 which is 24,5%. The two main reasons for the cost increase is the redesigned massage mechanism and the extra components which are added to the AquaFrixio. The overall goal of the redesign of the massage mechanism was finding a solution for the continuously occurring problems. What resulted in no particular requirement for the costs of the massage mechanism.

In the end two things can be said about the cost of the AquaFrixio. First, the cost for the AquaFrixio is an estimation, more clarity will come forward during the further development of the product. Second, the cost increase of 25% can be overlooked, as the whole mechanism is redesigned and an extra component is added to the product.

3.8. Overall product

In this paragraph the arrangement of the components and how they work together is explained. This will be done by using two schematic images that represent the functioning of the AquaFrixio. Starting with figure 3.8.1 what represent the bottom of the AquaFrixio and 3.8.2 the inside of the tub.

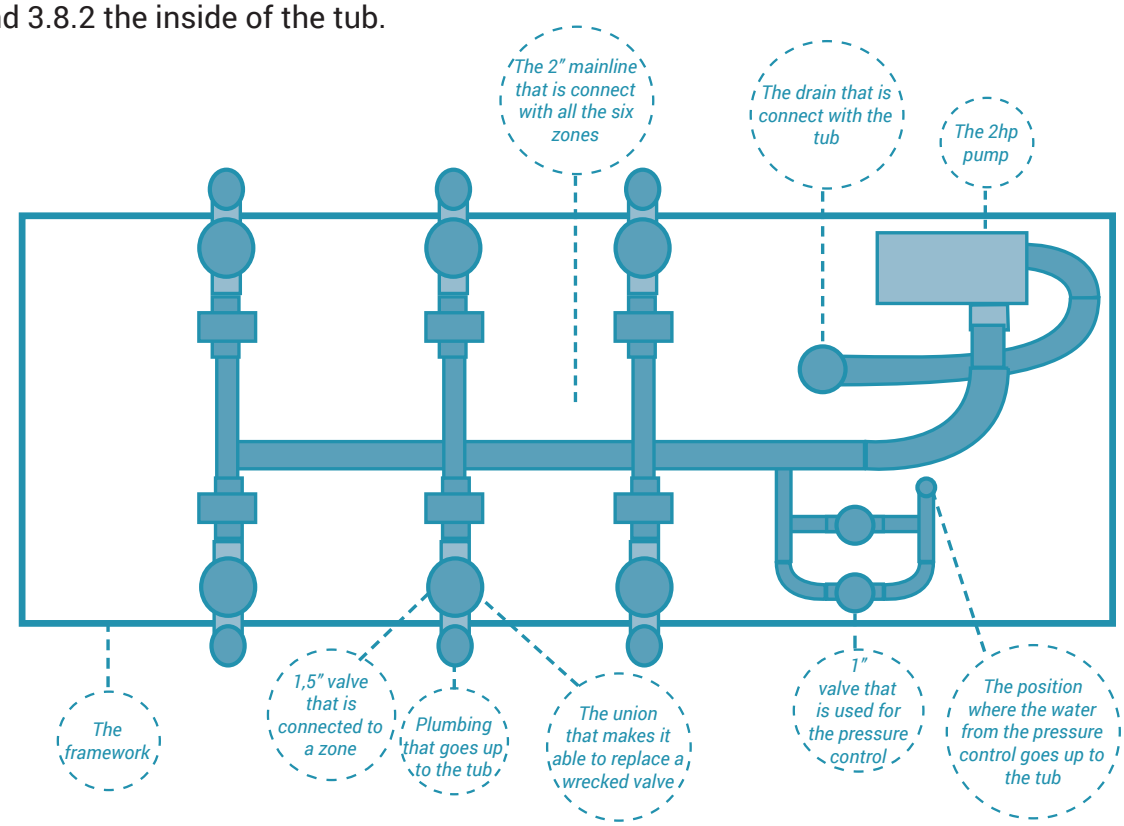


Figure 3.8.1 The schematic of the bottom of the AquaFrixio

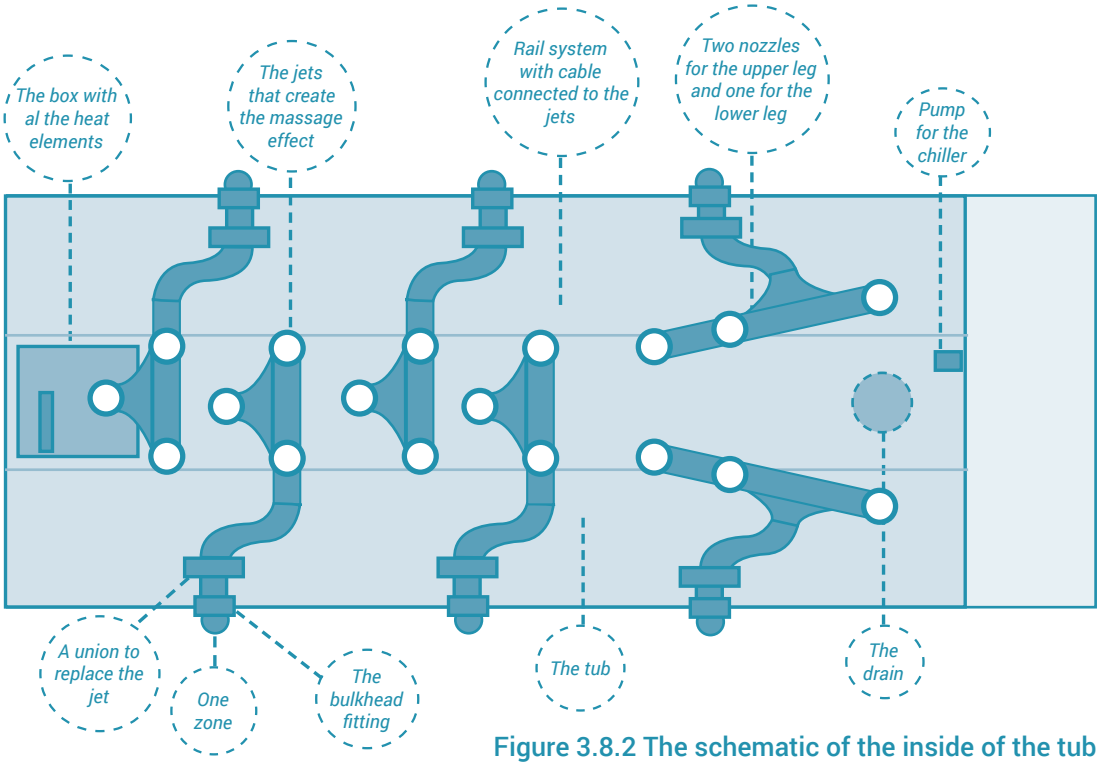


Figure 3.8.2 The schematic of the inside of the tub

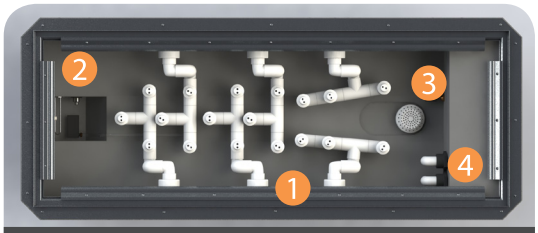


Figure 3.8.3 View at inside the tub

Figure 3.8.3 is a view from above into the tub. The following component are shown inside the tub:

1. *The six zones, made from multiple standard plumbing parts which creates the massage effect.*
2. *The box with all the electric elements used, that arrange the heat and cooling system of the massage bed.*
3. *The drain were the water gets sucked through.*
4. *The spot were the water pressure regulator discharges the water.*

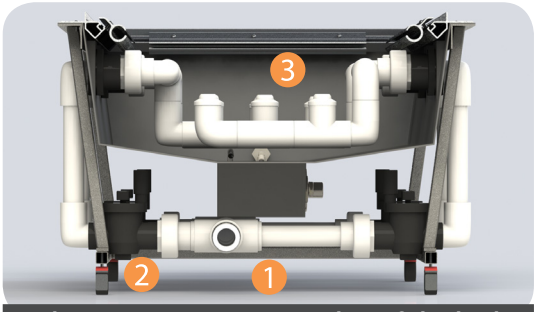


Figure 3.8.4 A cross-section of the bed

The second figure shows a section-view of the product. This gives a good representation of the amount of space left underneath the tub. The following components are shown on the figure:

1. *The 2" mainline that is connected with all six zones.*
2. *The valve that controls the opening and closing of the zone.*
3. *The jets that create the massage effect.*

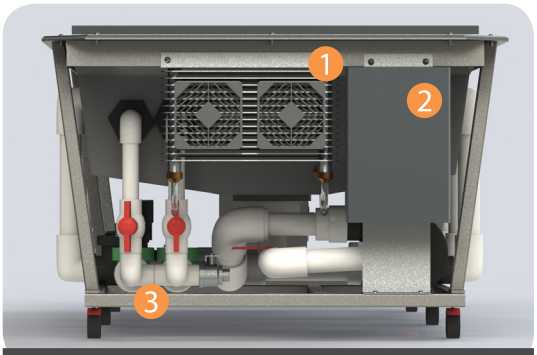


Figure 3.8.4 A view at the foot-end of the bed

The third figure represents a view at the foot-end of the bed. The following components are shown on the figure:

1. *The two fans that blow air from the outside through the chiller and the chiller can be seen behind the two fans.*
2. *The electric box were all the electronics come together which is a part from the former WaterWave.*
3. *The two manual valves that can control the amount of water entering the tub through the water pressure regulator.*

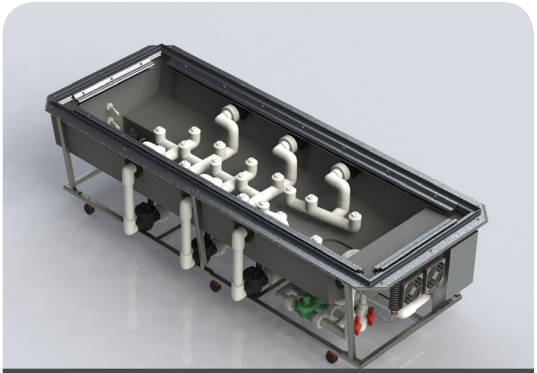


Figure 3.8.6 An overview of the bed without the skirting and top fabric on

The fourth figure shows an overview of the massage bed without the top fabric and skirting on. It gives a good representation of all the components combined into one product.

The last figure shows the end result of the AquaFrixio. The outside is not changed compared to the start of the assignment, but the whole mechanism inside the product has changed.

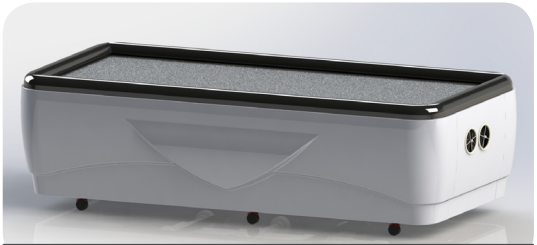


Figure 3.8.7 The end result

4. Prototype

The components that are redesigned and radical changed, will be tested in a full scale prototype. This way it is possible to see if the components work properly and meet the requirements. The focus lays on testing the manufacturability of the prototype and the outcome can be used during the further development of the AquaFrixio.

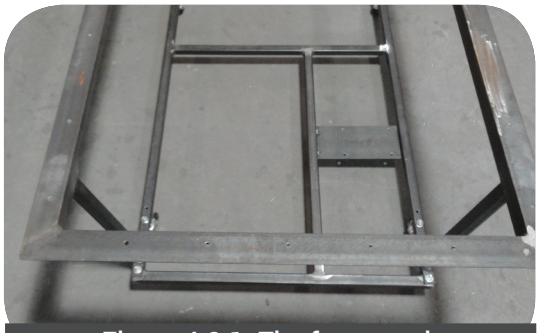


Figure 4.2.1. The framework.

4.1. Boundaries

The project is limited to a tight time schedule which means that there are some restriction with the build of the prototype and finalize the product. Most of the elements within the product are made out of standard parts which means that those are easily to realise for the prototype.

Figure 4.2.2. The box (1) with heat element (2) and the thermostat (3), sealed to the tub (4).

However, the easy realisation does not apply to every component within the product. The realisation of the tub takes several weeks, even up to several months. Due to the fact that the production of a mall takes several weeks which means that it is not possible to use the new tub for prototyping. Therefore, the prototype will use the already improved tub of ProSun which is based on the rail mechanism that is not used any more.

A production time of multiple weeks is also applies to the top frame which is made out of aluminum extrusions. A mall has to be made for the aluminum extrusions what takes several weeks and needs some testing before it can be used for the prototype. A frame made out of standard steel parts will be made for the prototype.

Figure 4.2.3. The tub with jets and filled with water with anti freeze.

A manual hand-controller is installed to control the six zones that create the massage effect and the two smaller valves to reduce the pressure. Every valve can be switched on and off with this controller. Further during the development of the AquaFrixio, a whole new software system has to be made to control the bed. This will take several months to accomplice and needs to be done by an external company.

Figure 4.2.4. The two 1" valves (1) with a 1" union (2) at each side.

4.2. Prototype

This paragraph gives a clear view of the components manufactured for the prototype. The more comprehensive explanation of the prototype can be found in appendix I.

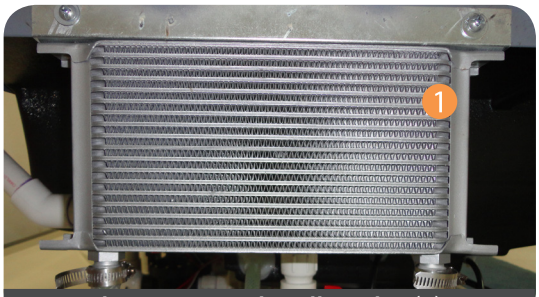


Figure 4.2.5. The oil cooler (1).

The framework

The framework is made according to the components redesign phase. The frame is made from three basic steel parts and is manually sprayed with a coating to protect corrosion. The result is shown on figure 4.2.1.

The tub

The old mall is slightly modified, to be compatible with the new massage mechanism. First, the tub is placed inside the framework. Afterwards, the other components are mounted on the tub. The box with heating element and the thermostats is shown on figure 4.2.2.

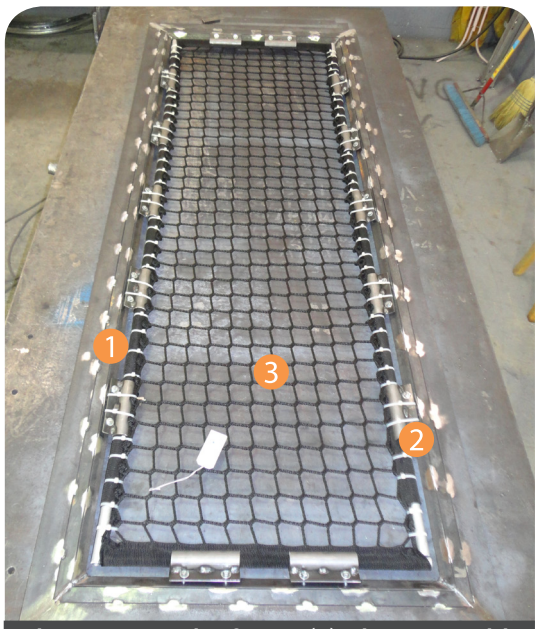


Figure 4.2.6. The frame (1), the parts with the cared slots (2) and the net (3).

The massage mechanism

Figure 4.2.3 shows the jets, which create the massage effect. The massage mechanism is build out of several demountable parts using multiple unions, what makes maintenance more easy. Antifreeze is used to reduce the rust effect of the water. The jets are positioned based on the ratio of an average human body.

The water pressure regulator

Two valves are separately connected to the hand-controller, which makes it able to reduce the pressure while using the bed, Opening one valve will reduce the pressure a bit and opening both valves will reduce the pressure even more. The unions between the valves make maintenance more easy. This is shown in figure 4.2.4.


Figure 4.2.7. The end result with the skirting on.

The chiller

An 19 aluminum oil cooler is connected with 5/8" hoses that enter the tub. A ½" water pump is able to pump 80 gallons of water through the cooler. Figure 4.2.5 shows the used cooler .

The top frame

The top frame is build with leftover steel parts, due to the limitations in the workshop and the costs of the material. The frame consists of two parts, a basic framework and the parts that fasten the net, which are shown in figure 4.2.6.

The final result is shown in figure 4.2.7.

4.3. Prototype testing

It is important to test the prototype on the problematic areas experienced with the WaterWave. Both, the maintenance and assemble personal, experienced many problems during the manufacture of the WaterWave. The following tests were formulated for the prototype.

To be able to quantify the performance of the prototype, extensive testing has to be done. The testing will focus on the performance and the ergonomics of the product. Based on the testing, a fundamental statement can be made regarding the achievement of the requirements (Materials, 2011).

General testing

Starting with several general tests to verify the working of the massage mechanism and the other components that were redesigned which focusses on the global performance of the components. The testing focusses on the functioning of the following components:

- The functioning of the massage mechanism and the six zones.
- The actual three levels of water pressure.
- The performance of the chiller.
- The functionality of the top frame.

Maintenance & assembly tests

The maintenance and assembly of the product were important during the concept development. Scenario based testing will be done to examine the functionality during the maintenance and assembly of the product. The following scenarios need to be tested which is done using the Think Aloud method (Materials, Think Aloud, 2011):

- Replace a multiple parts related to the massage mechanism.
- Replace a the jets and nozzles inside the tub.
- Replace the essential parts for the pressure regulator.
- Replace the net for the top frame without using an extra tool.

Extreme testing

During extreme testing, the durability of the components can be verified. This needs to be done, based on several scenario's. The following scenarios need to be tested:

- Multiple hours non-stop running to test the functioning of the massage mechanism.
- Multiple times a day to test the functioning of the chiller.
- Several days in a row to test the durability of the massage mechanism.

This covers the most important areas of the prototype and can be used to revise the concept that is designed. Unfortunately, it was not possible to perform these tests, because the prototype was finished two days before the end of the assignment.

4.4. General things noticed

During the two days that were left, it was possible to collect some addition information. Multiple things occurred during the manufacturing, assembly and testing of the prototype. This paragraph explains things that were noticed which had impact on the prototype.

Leaks

The bulkhead fittings did not seal the tub perfectly. When the tub got filled with water, several points started to leak. A silicone glue was able to seal the leaks and made the tub watertight. This solved the problem for now, but these problems cannot occur during the mass production of the AquaFrixio. The following things are probably the reason that those problems occurred. The components were used in a previous prototype, the tub does not have the desired dimensions and it was all provisionally applied. Those things together might be the reason that the problem occurred.

The threaded unions and valves were hard to tighten. The two 1" valves leaked water because the thread fitting did not fit perfectly. This problem might easily be solved using slip fittings and not threaded, especially the thread is not needed.

Pressure control

The pressure control between full pressure and one of the 1" valves open is working perfectly. When the user wants to reduce the pressure from one valve open to two valves open, the pressure seems not to lower that much. This influences the water pressure what delivers the low performance between the two 1" valves and needs some further examination.

Using multiple zones at the same time

The zone located at the head-end of the bed is the strongest one, while running two zones at the same time. The other zone does not produce the same amount of pressure as the zone at the head-end which occurs because the water coming out of the pump first passes all the other zones before it reaches the last zone at the head-end of the bed. Water going straight is easier then redirecting from the mainline. This should not be forgot while designing the software for the AquaFrixio.

Positioning zones

During the design phase, the decision is made to position the six zones from the centre to the ends of the bed. This was based on the thinking that the user would position itself starting form the centre of the bed. With the new bladder, the user will start with positioning the head-end first which means that the zones need to be repositioned starting from the head-end.

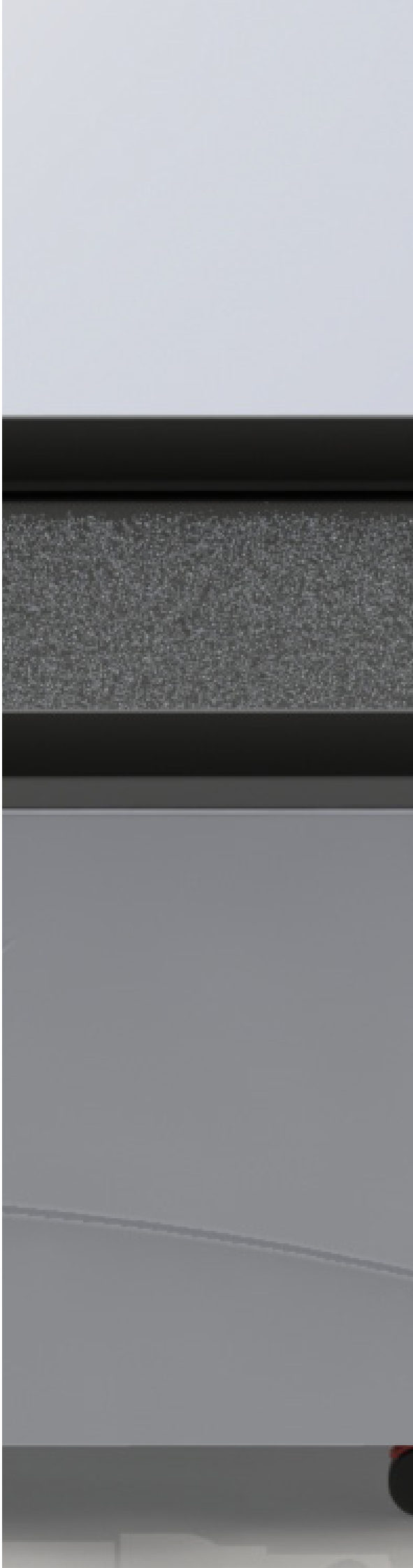
Wave effect

The dynamic effect of the WaterWave is replaced with six fixed zones. The goal is to simulate the wave effect using those six zones. The simulation will be made with a preprogrammed hardware and software installed inside the AquaFrixio, which will control the valves to simulate that wave effect. It seemed possible to simulate the wave effect by manually turning the switches of the valve on and off.

4.5. Conclusion

The conclusion of this assignment is ongoing according to the formulated requirements and the functionality of the prototype. Due to the focus on developing a new massage concept and knowing that further technical development is required, is it not possible to formulated one conclusion.

Normally it would be possible to review the requirements that were formulated, based on the information gathered during the concept design phase and manufacturing the prototype. Unfortunately, it is not possible to evaluate the outcome of the requirements, as the final quality of the product is unknown.



4.6 Design recommendations

In this paragraph recommendations for the further development are discussed per redesigned component. The recommendation in general will be done in the next chapter.

The massage mechanism

- Use unions and valves without threads to reduce the change on leaks.
- Reposition the zones, starting from the head-end and not the middle of the bed.

The water pressure regulator

- Use unions and valve without threads to reduce the change on leaks.

The chiller

- Explore the option for an external chiller, which gives the AquaFrixio more options. The customer can choice his preferred version.

The framework

- *Explore other combinations of mounting methods to reduce the labor costs.*

The tub

- Explore the option for fibreglass to simplify the tub with the box and all the electronics.

The top frame

- Find a way to simplify the manufacturing of the leather bumpers.
- Explore options to combine the bladder and anti-bacterial sheet into one layer.

Features

- To keep up with the market, explore the option for a tablet as hand-controller.
- Overlook the option of tanning compartment, like a simple canopy.

5. Conclusion

While looking back at the progression that is made during the past few months, the following conclusions can be made about the result that is delivered.

5.1. Feasibility

The objective was to develop a manufacturable new concept for the AquaFrixio. The massage mechanism which is the main function device inside the massage bed, had full priority during the redesign of the AquaFrixio. To gather enough information and accomplish the redesign, an extensive analyse phase is completed. Afterwards, the project moved into the design phase while keeping the feasibility in mind.

In the end can be said that the development of a manufacturable new concept for the AquaFrixio is accomplished and with further development of the technical aspect, the AquaFrixio will feasible. The first foundation is laid which can be used for the further development of the AquaFrixio and the next step is focussing on the technical realization of the AquaFrixio.

Figure 5.1 A view at Tampa Bay, one of the largest metropolitan statistical areas in the state.

5.2. Conclusions

The overall conclusion of this project, is that the goal of the assignment is accomplished and a fundamental new massage mechanism is designed.

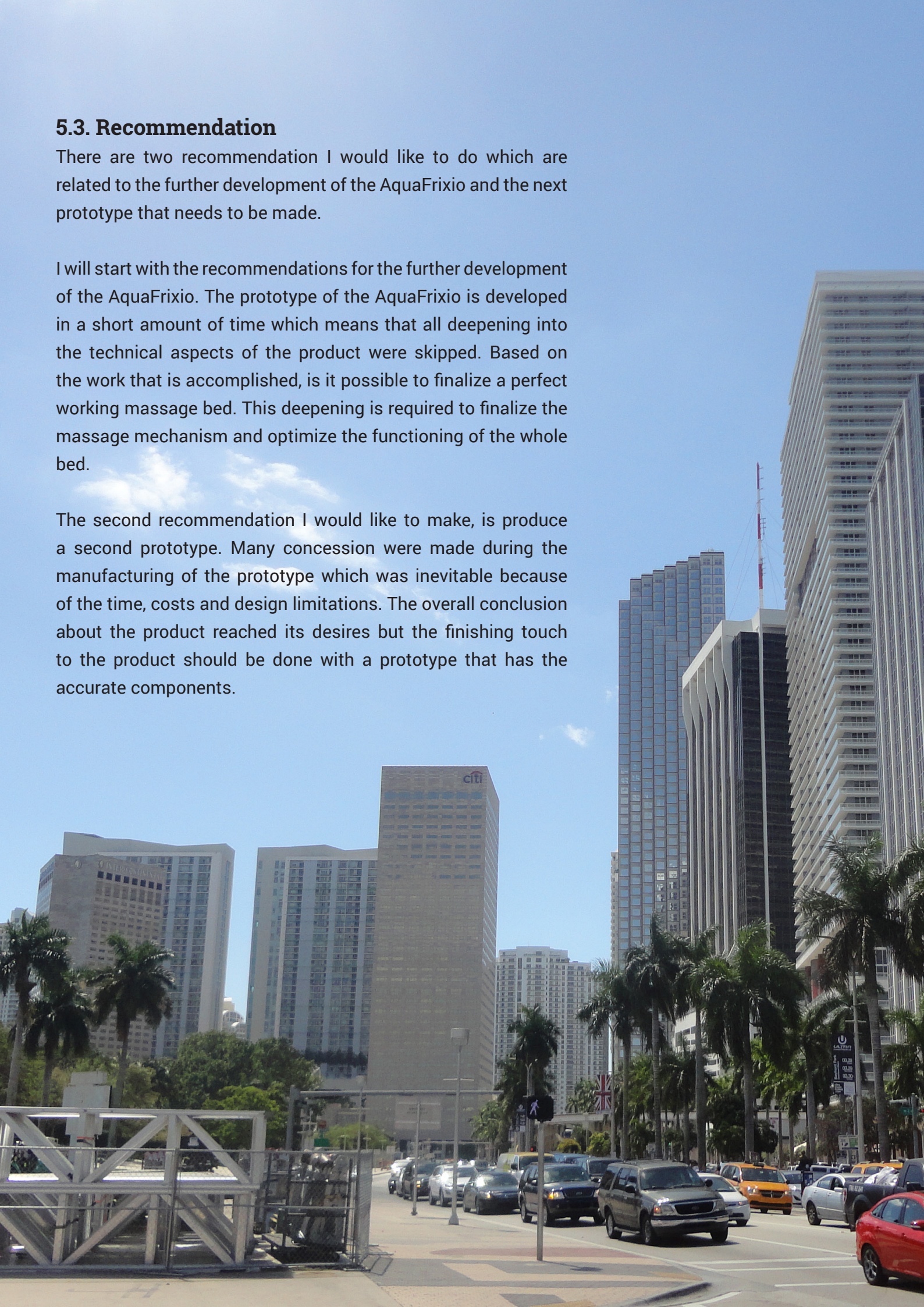
The further development of the technical aspects will be the next step in the optimisation of the AquaFrixio. The work which is delivered functions as a basis for the further development of a working massage principle. This due to the major changes that are made to the mechanical system and the redesign of the other components.

5.3. Recommendation

There are two recommendation I would like to do which are related to the further development of the AquaFrixio and the next prototype that needs to be made.

I will start with the recommendations for the further development of the AquaFrixio. The prototype of the AquaFrixio is developed in a short amount of time which means that all deepening into the technical aspects of the product were skipped. Based on the work that is accomplished, is it possible to finalize a perfect working massage bed. This deepening is required to finalize the massage mechanism and optimize the functioning of the whole bed.

The second recommendation I would like to make, is produce a second prototype. Many concession were made during the manufacturing of the prototype which was inevitable because of the time, costs and design limitations. The overall conclusion about the product reached its desires but the finishing touch to the product should be done with a prototype that has the accurate components.



5.4. Evaluation

Having the opportunity to complete my bachelor assignment in Florida was amazing. Besides learning a lot from my thesis, I learned a lot about adapting alone in a whole new environment. The challenge to go to another country compared to the bachelor assignment, was impressive on its own.

The collaboration with ProSun was pleasant. The communication was smooth due to the fact that most of the management is from the Netherlands. They provide me with enough information and gave me plenty space to give my own touch to the project. Besides my supervisor, there worked enough people which were kind enough to help me out were needed.

Despite the time difference and distance, I think the collaboration with the University of Twente was managed well. The communication with my supervisor Juan Juaregui Becker was planned and structured, using e-mail and Skype frequently.

One point of criticism, is the size of the assignment. Arie-Paul pointed out that I had to make sure that the assignment was broad enough. This in combination with the focus of Prosun to develop a prototype of the product, did I miss a bit of deepening with my assignment. I focussed more on prototyping and design a working concept which ensured that it was not possible to elaborate deeply into the technical aspects of the components.

In the end, it was satisfying that ProSun suggested that I could stay for another three months. Unfortunately I had to decline this offer, due to the fact that my visa ended shortly and I wanted to finish my bachelor thesis.

All in all it was an unforgettable experience which I recommend to every student. If the opportunity is there, I will definitely visit Prosun one day.

Figure 5.2. Another view at Tampa Bay.

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Appendix

Appendix A - Interview

A1. Director

What is the reason for removing the WaterWave from the market?

There were to many problems on different areas which could not be solved easily. We were not able to solve the problems with a number of small fixes which resulted in the removal of the Water from the market.

What were the problems encountered?

- The water temperature was rising above comfortable temperature. This often occurred at salons, as they used the WaterWave multiple times a day.
- The mechanical system inside the WaterWave broke down and could not be replaced easily. This could have multiple reasons. First, the cable snaps while the bed is used. Second, the user forgot to clean the product what wrecks the mechanism. Third, the water pressure regulator brakes down which wrecks the mechanism.
- The net sagged after a long time of use, which made the WaterWave unusable.

How long did it take to make this decision?

After about three years of struggling and a huge cost increase, the project was not realistic any more. On that point the plug was pulled from the project.

What will be important during the development of a manufacturable concept?

- The outside dimensions of the product must stay the same, because the existing skirt of the WaterWave is still intact and usable. This skirt will be used to limited the costs.
- We prefers to use as much standard part as possible, which prevent additional mold costs and keep the stock low. Especially as we purchased more machines in the past few years.
- We prefer to use the production processes we are able to do now. An expansion of production process is to expensive which is not affordable.
- ProSun prefers to produce most of the components at their own facility, to stay independent and keep the stock low.

This needs to be taken into consideration during the development of a new massage concept.

A2. Assembly employee

Did ProSun produce most of the parts by themselves or brought externally?

Majority of the part were fabricated here, like brackets/skins/harness. We buy large batches basic material and produce the parts our selves. The parts that are moulded in different shapes, are brought externally. Besides that, the whole frame is brought externally.

Did you encounter problems during the production of those parts?

If you ask me, the whole bed was a problem. It took two people around 8 till 10 hours to assemble the product. Due to the low production and the high deviation, we decided to keep the stock as low as possible. That is the reason we had to produce most of the parts every time a product was sold.

Appendix A (2) - Interview

As we were forced to produce every part at exact moment we assembled a product and the material PVC changed slightly in dimensions, the assembly was a precise task to do. We also had to make sure the product was waterproof, what took quit long.

Were there many problems with the parts brought externally?
Not in particular, we had to double check the whole product to be sure it was waterproof.

Did you experience many problems during the assembly of the WaterWave?
Assembling the top into the frame took like 1,5 hours and when it deviated for like ½", we were forced to do it all over again.

What part of the assembly did take most of the time?
Besides what i mentioned earlier, assembling the skirt on top of the frame was quit some task. This is because it has three double curved shapes and the dimensions deviated sometimes a bit.

What would you change if possible?
Besides scrapping the whole product, i would remove one of the two motor that drive the tracking system for the nozzles and replacing it with one stronger one. An other thing i would change is placing a safety pin inside the whole system. This way it will not destroy the whole mechanical system but only a little pin to let you know that the cable that drives the gear needs to be replaced.

A3. Maintenance employee

Was ProSun responsible for the maintenance?
ProSun was responsible for the maintenance and would send someone if needed. Basically we first tried to help the customer with the problem by walking through the problem by phone. If that did not work out that well, we sent someone to them. Basically this would take several hours, as most of the products were not sold in the neighbourhood.

What kind of problems did you encounter?
Basically the main two problems, besides the several small ones, was the heating system and the tracking system. The WaterWave got to hot which was unpleasant to use and the mechanical system for the nozzles broke many times, so the system was malfunctioning.

What other problems did you encounter?
The whole bed needs to be cleaned minimum two times a year and the water needs to be refreshed. Customers seemed to be to laze for that, so we have seen many smoggy and dirty beds. Furthermore, people have to use special shampoo for the mechanical parts, what seemed to go wrong many times.

How many hours did the maintenance take?
As I mentioned earlier, most of the massage beds were sold in different states what took around 3 hours to drive. Then it will take around half a hour to get the skirt off and get inside the bed. The total maintenance would probably take around 2,5 hours, without the driving. So you can imagine how expensive it must have been.

Appendix B - Solutions of other designers

This appendix tells a bit more about the improvements made by the other designers, as is explained in paragraph 2.8. They were not able to solve all the detected problems but were able to try other adjustment and eliminated the ones that did not deliver the required performances. The enhancements they designed and implemented are shortly discussed.

The framework

One of the designers made the first steps to relocate the production of the framework to the production facility of ProSun. The frame is never made but provides a good start for designing and prototyping the framework.

The net

In paragraph 2.3 is explained that the net consist of a mesh size 1″ by 1″ and that they need several thicker thread to reinforce the net. In the AquaFrixo will use a net consisting of a mesh size 1½″ by 1½″ and a thickness off ¼″. Various other possibilities are tried but neither of them gave the desired performance.

The tub

ProSun was bound to an external company to fabricate the tub despite of the fact that they are able to vacuum form in their workshop. Another designer developed a tub that can be produced by ProSun. The redesigned tub has a whole different form then the WaterWave tub. The height almost halved which significantly reduced the amount of material used and the bottom of the tub is designed for a rail system what needs to be changed when the massage system changes. With this tub, they also installed a new type of drain that prevents the water from creating a vortex. This way it is possible to reduce the amount of water that is needed but keep the system workable.

The massage mechanism

Paragraph 2.3.6 explains the mechanical system used inside the tub to create the massage effect. During the interviews the problems with the mechanical system was mentioned several times. In the past few months they tried to improve the carriage system by trying other materials and adept the system slightly.

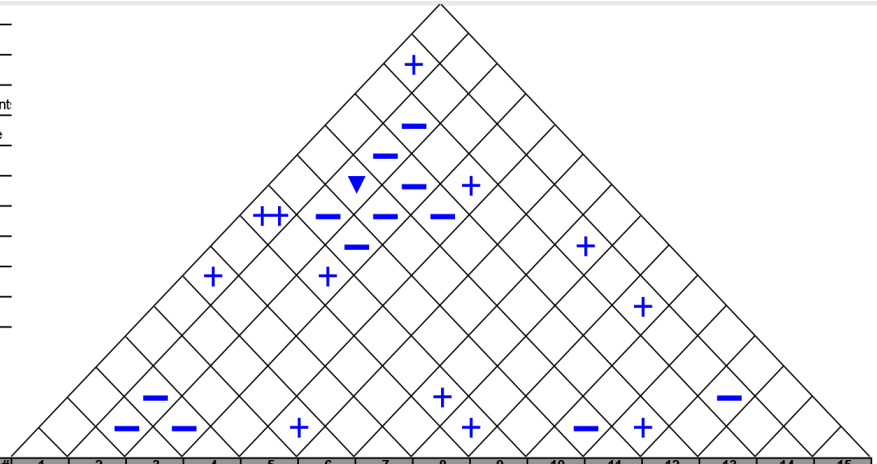
After these changes the problems were not solved completely, that is why they decided to replace the whole system. The problems with the carriage system were still to expensive and not easily repaired or replaced.

Anti-bacteria sheet

A new anti-bacteria sheet was designed with a second layer which is filled with foam that reduces the amount of noise created and positions the user perfectly on top of the jets of the massage bed.

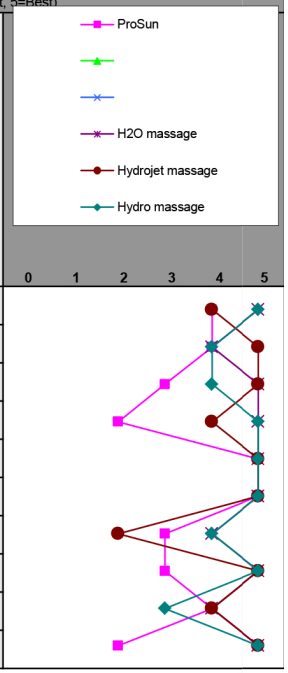
Appendix C - House of Quality

Title: QFD of the WaterWave
Author: Daniel Janson
Date: 20-2-2014
Notes: The House of Quality is used to get a clear view of the requirements
The whishes of the customer led to the list of requirements for the
redesign of the WaterWave



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

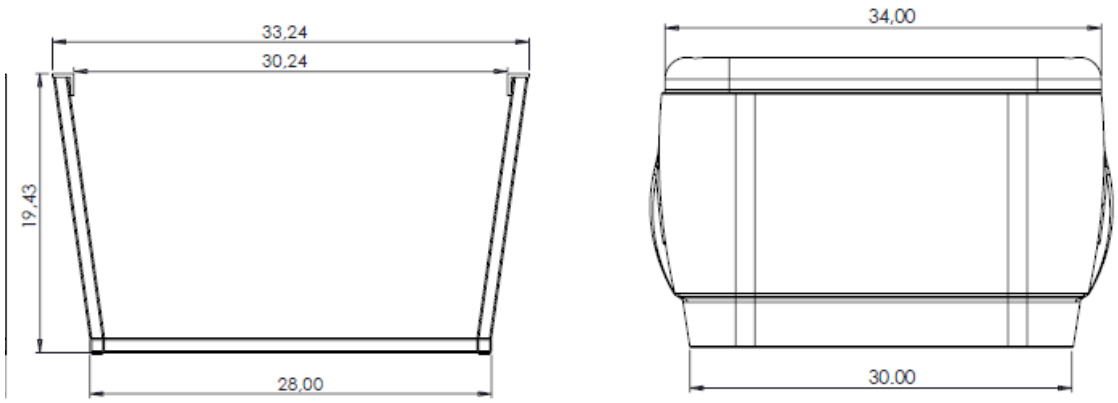
Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	1 Software	2 Size nozzles	3 Amount of nozzles	4 Length rail system	5 Mesh size net	6 Tention of the net	7 Heating element	8 Positions jets	9 Electronics	10 Watertight sealing	11 Horsepower pump	12 Size of the plumbing (1", 1,5", 2")	13 Length of the plumbing	14 Ventilation	15	Competitive Analysis (0=Worst, 5=Best): ProSun			H2O massage	Hydrojet massage	Hydro massage
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	▲	▼	▼	▲	▲	▲	▼	▲	▼	X	X	X	▼									
1	9	13,9	5,0	The massage must be comfortable and effective	Θ	Θ	O	Θ	▲	▲	O	O	O	▲	Θ	O		O		4			5	4	5
2	9	8,3	3,0	The bed must lay confortable					O	Θ				▲						4			4	5	4
3	3	5,6	2,0	The noise should be minimal		O	O					▲	▲		O			▲		3			5	5	4
4	9	11,1	4,0	The bed must consist of several massage programs	Θ		▲	Θ				Θ	Θ		O	▲	▲			2			5	4	5
5	9	8,3	3,0	The massage effect must cover all body	▲	▲	O	Θ					▲		O		O			5			5	5	5
6	9	11,1	4,0	There must be a nice transition between the massage zones	O	▲	O	O				▲	Θ		▲					5			5	5	5
7	9	11,1	4,0	The bed is quickly warmed and stay on a consistent temperature	Θ	▲					Θ				O	▲	▲	Θ		3			4	2	4
8	9	8,3	3,0	The bed can be used multiple times a day				▲			▲		▲	Θ				O		3			5	5	5
9	9	11,1	4,0	Decent price and quality ratio	Θ	▲	▲			O	▲		Θ	O						4			4	4	3
10	9	11,1	4,0	Duratibilty of 5 years	Θ					Θ	O		Θ	O						2			5	5	5
				Target or Limit Value	Cheap and less as possible	1 inch	Min 1 max 3	Bed length max dimension	1.5 inch	x amount of pound	x watt	Min 3 positions	Minimum as possible	No leaking	1.5 inch 2 horsepower	2 inch	Less	Max temperature 105 min temperature 92								
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	4	8	6	8	2	7	4	8	5	6	5	7	6	8								
				Max Relationship Value in Column	9	9	3	9	3	9	9	9	9	9	9	3	3	9								
				Weight / Importance	566,7	183,3	138,9	341,7	38,9	222,2	194,4	158,3	463,9	163,9	244,4	63,9	47,2	172,2								

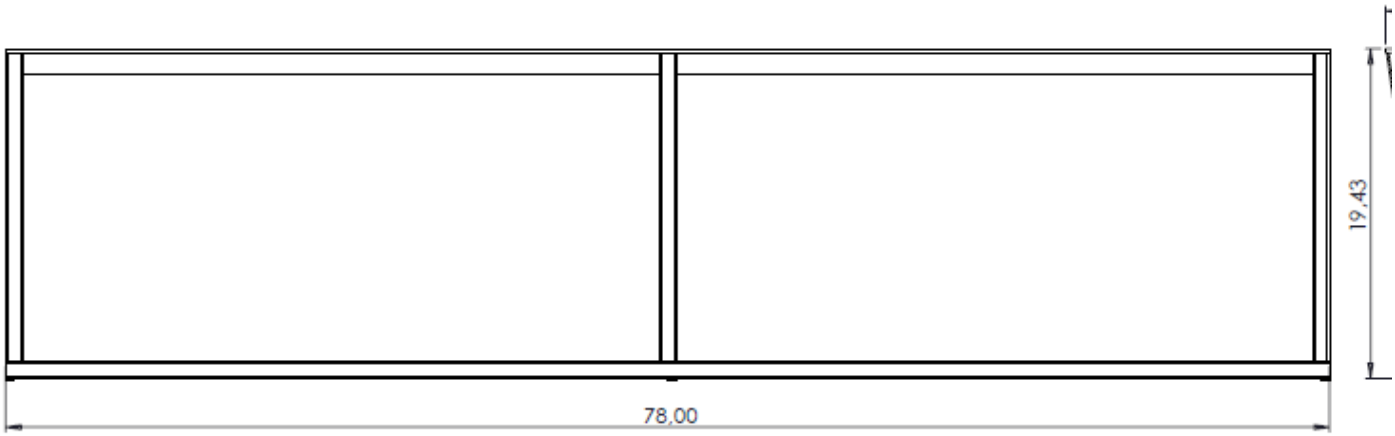


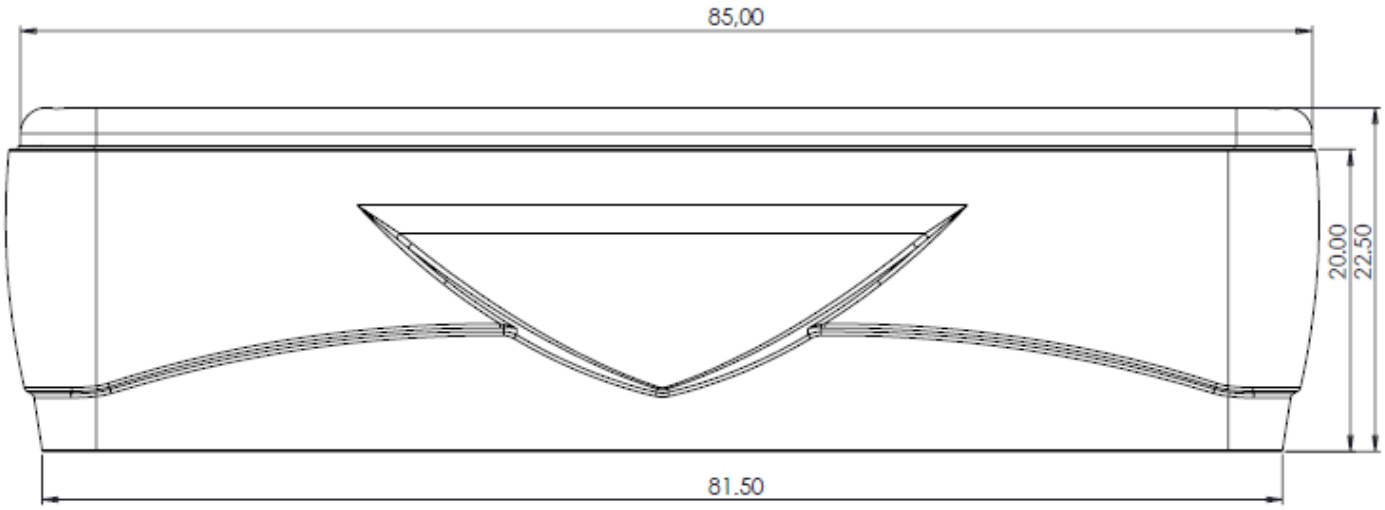
Appendix D - Failure Modes and Effect Analysis

Number	Place, part or process	Failure mode	Failure effect	Severity (1,4,9,16,25)	Cause	Occurrence (1,3,5,7,9)	Detectability	Detection (1,3,5,7,9)	RPN	Action (Yes/No)
1	Rail system	Cable snaps	Massage effect on one uncontrolled position	25	The nozzles mis one of the two magnets through water level fluctuation, what only ensures that one motor stops	9	Bed not working properly	9	2025	Yes
2				25	No cleaning inside the tub	7	Bed not working properly	9	1575	Yes
3		Motor breaks down	Massage effect on one uncontrolled position	25	Failure of the electronics	1	Bed not working properly	9	225	Yes
4		Motor doesnot work properly	The bed is not controlled properly	25	Failure of the electronics	3	Testing of the bed	3	225	Yes
5	Waterflow	Pump breaks down	Massage bed is not working any more	25	Failure of the electronics	1	Bed not working properly	9	225	No
6		Valve breaks down	No pressure regulation possible but water can get through	16	To much torque produced by the motor that controls the valve	1	Bed not working properly	9	144	Yes
7			Waterflow shut down	25	To much torque produced by the motor that controls the valve	5	Bed not working properly	9	1125	Yes
8	Temperature regulation	Fan breaks down	Water reaches uncomfortable temperature	1	Failure of the electronics	1	Using the bed	5	5	No
9		Fan not strong enough	Water reaches uncomfortable temperature	16	To much heat produced by pomp and frixion of the water in the plumbing	9	Using the bed	5	720	Yes
10		Thermostat breaks	Water stays at room temperature	9	Failure of the electronics	5	Using the bed	5	225	Yes
11		Thermostat will not turn off	Water gets to warm	4	Failure of the electronics	1	Testing of the bed	3	12	Yes
12	Comfort	The net snaps	Sinks slowly in the tub	9	The screws cut the thread	1	Using the bed	3	27	Yes
13		The net looses the tention	Sinks slowly in the tub	9	Frequent use of the bed with a lot of weight	3	Using the bed	3	81	Yes
14		Securing the bladder to make it watertight	Tub is not covered properly	1	Cutting equipment	1	After detecting water leaking	5	5	No
15				4	Frequent removing of the bladder	1	Placing the bladder after removal	1	4	No
16	Plumbing	The plumbing doesnot fit	A lot of men hours addapting the bed	9	Diviation cutting the plumbing	3	Assembly of the product	1	27	Yes
17				9	Mixing up the parts	1	After assembly of the product	3	27	Yes

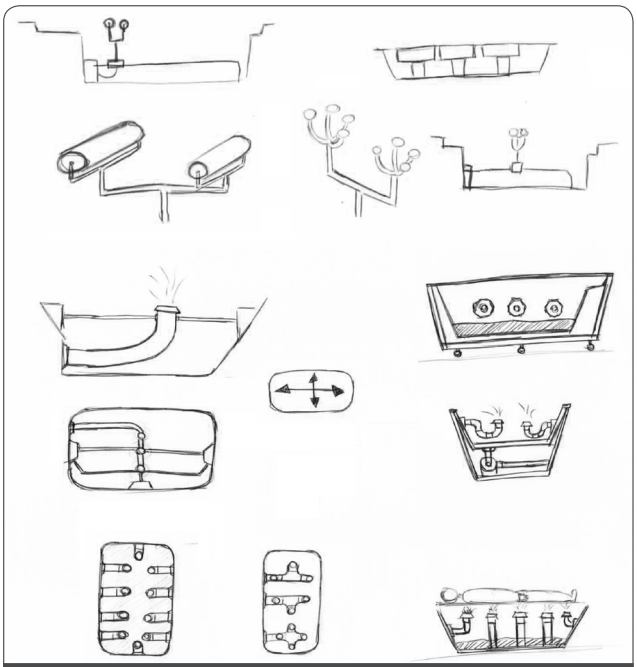
Appendix E - Outside dimensions WaterWave



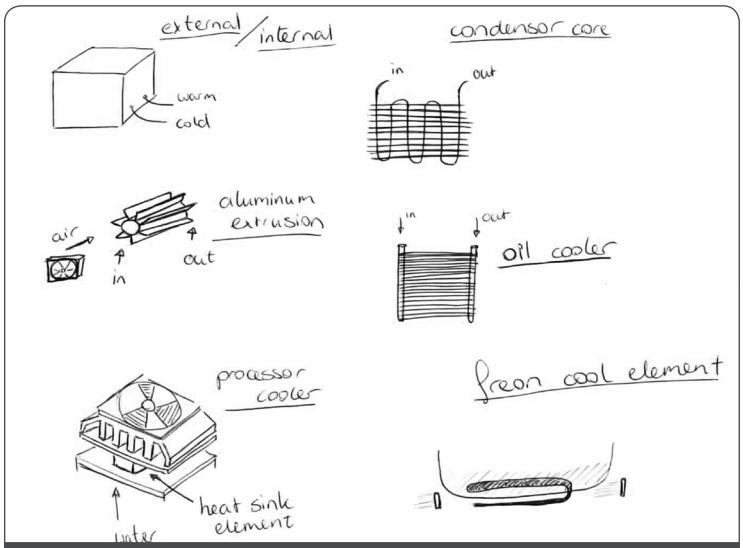




Appendix F - Sketches



Sketches massage mechanism



Sketches chiller

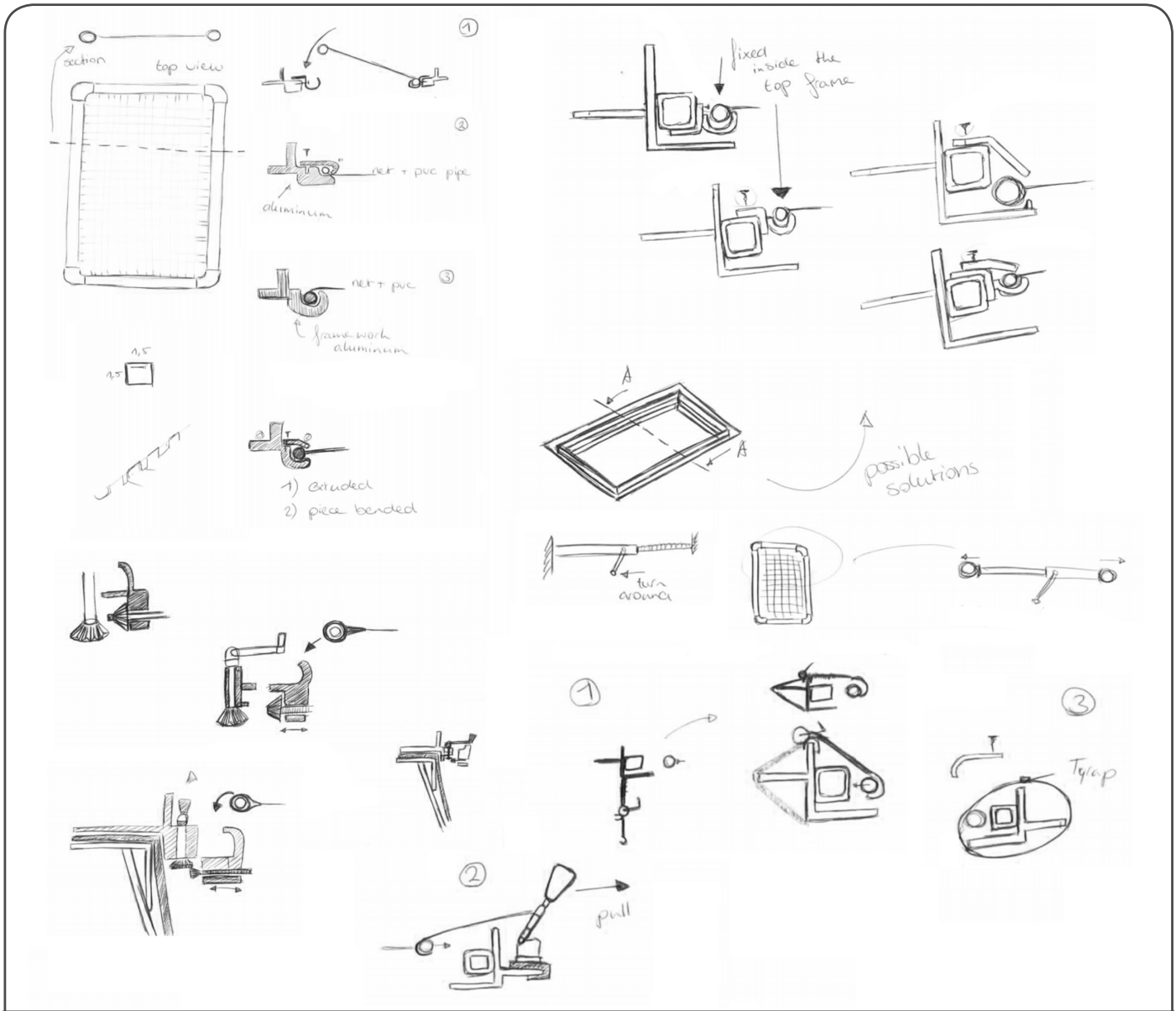
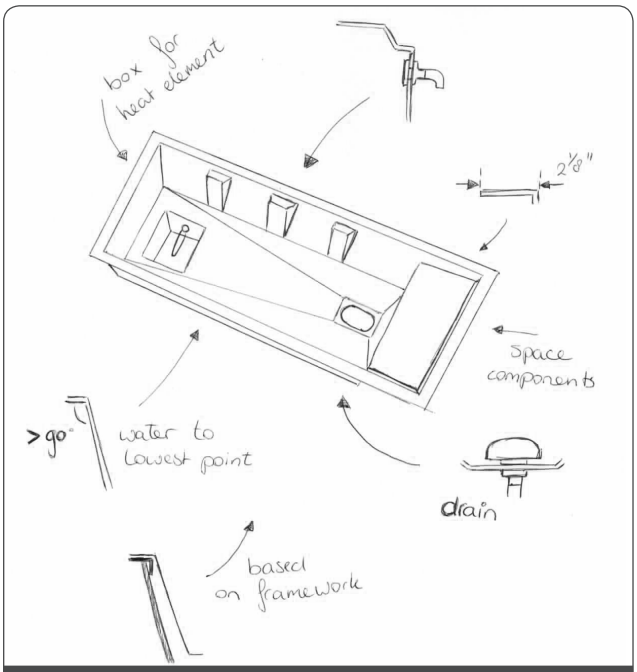
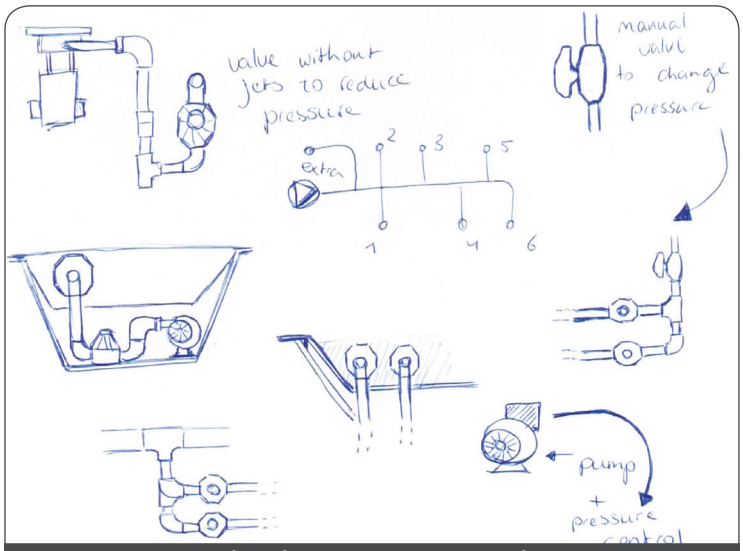


Figure 3.6.2. Ideas regarding the top frame.

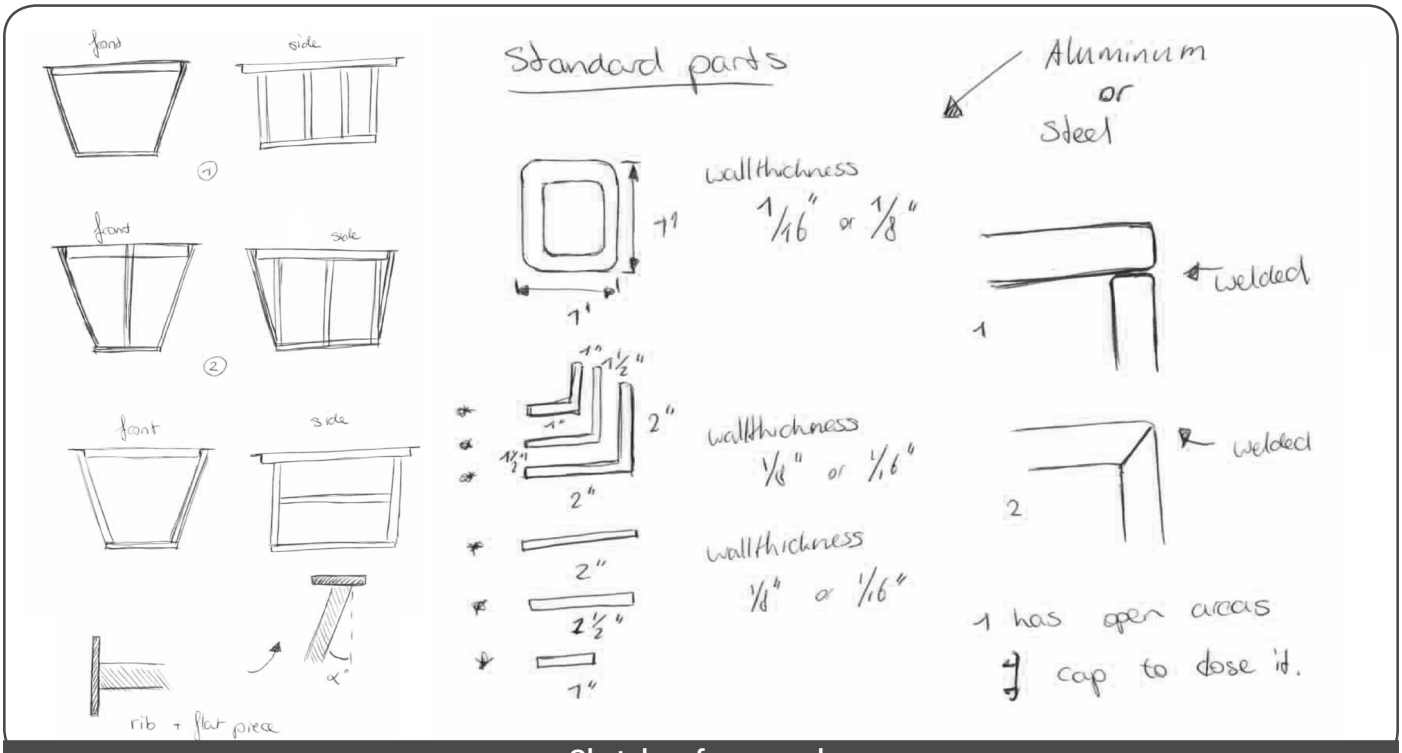
Appendix F (2) - Sketches



Sketches tub



Sketches pressure control



Sketches framework

Appendix G - Costs

Part: The massage mechanism	Qty	Price (p. u.)	Total price
1.5" Union Nut with 1.5" S Tailpiece and O-ring	14	$4,19	$58,66
1.5" Buttress thread x 1.5" MPT Tailpiece (cheaper 1 for 2.09)	12	$2,44	$29,28
90 Ell - 1.5" Spigot x 1.5" Spigot	6	$3,65	$21,90
Super Hi-Flo sunction Assembly - 2" S	1	$22,07	$22,07
1-Speed Spa Flo 48-Frame Pumps	1	$596,64	$169,51
Rotating nozzle	18	$8,80	$158,40
Hunter PGV-151 1.5 in. FPT Valve with Flow Control	6	$43,95	$263,70
1-1/2" Polypropylene Bulkhead with Santoprene Gasket	6	$9,37	$56,22
90 Ell - 2" S x 2" S	4	$1,47	$5,88
45 Ell - 2" S x 2" S	1	$1,69	$1,69
Cross - 2" S	2	$3,94	$7,88
T - 2" x 2" x 1.5" S	1	$1,95	$1,95
Reducer - 2" x 1.5" S	5	$2,03	$10,15
90 Ell - 1.5" S x 1.5" Thread	12	$1,57	$18,84
90 Ell - 1.5" S x 1.5" Spigot	6	$1,99	$11,94
90 Ell - 1.5" S x 1.5" S	18	$0,94	$16,92
T - 1.5" S x 1.5" S	12	$1,23	$14,76
Tubing 1,5" (price per foot)	12	$0,62	$7,45
Tubing 2" (price per foot)	5	$1,56	$7,80
Silicone Caulk	1	$5,64	$5,64
Oatey 32 oz. PVC Cement	1	$14,81	$14,81
32 oz. PVC Purple Primer	1	$12,47	$12,47
Labor (minutes)	90	$1,20	$108,-
Total price			$1.025,92

Part: The water pressure control	Qty	Price (p. u.)	Total price
1" Polypropylene Bulkhead with Santoprene Gasket	2	$5,51	$11,02
T - 2" S x 2" S x 1" S	1	$2,92	$2,92
T - 1" S x 1" S x 1" S	2	$0,65	$1,30
90 Ell - 1" S x 1" S	7	$0,49	$3,43
Cross - 1" S	1	$1,54	$1,54
Union - 1" S x 1" S	4	$2,82	$11,28
Hunter PGV-101JTG-S PGV 1 in. Jar-Top Plastic Flow Control	2	$12,24	$24,48
Tubing 1" (price per foot)	2	$0,41	$0,82
Manual Ball Valve 1" Solvent end	1	$2,95	$2,95
Labor (minutes)	20	$1,20	$24,-
Total price			$83,74

Appendix G (2) - Costs

Part: The chiller	Qty	Price (p. u.)	Total price
Universal 19-row oil cooler	1	$51,95	$51,95
45 female flare	2	$4,80	$9,60
0.5" clear pvc tubing (price per foot)	4	$0,38	$1,52
Beckett 80 GPH Submersible Fountain Pump	1	$18,98	$18,98
Silicone Premium Caulk 9.8 oz	1	$5,64	$5,64
Stainless steel truss heas machine screws 1/4-20 0.5"	2	$0,18	$0,36
Stainless steel square nut 1/4-20	2	$0,13	$0,25
Blind aluminum rivets 0.25"	2	$0,04	$0,07
Aluminum plate 90 degrees bend	1	$0,20	$0,20
Fan Box 110V/60Hz	2	$5,95	$11,90
Labor (minutes)	10	$1,20	$12,-
Total price			$112,47

Part: The frame	Specific information	Qty	Price (p. u.)	Total price
Side bar	1" x 1" x 11GA (1/8 in wallthickness)	2	$28,-	$7,23
Front bar	1" x 1" x 11GA (1/8 in wallthickness)	2	$77,5	$20,02
Support bar	1" x 1" x 11GA (1/8 in wallthickness)	2	$26,-	$6,72
Motor plate bar	1" x 1" x 11GA (1/8 in wallthickness)	1	$24,-	$3,10
Rib	1" x 1" x 11GA (1/8 in wallthickness)	6	$18,375	$14,24
Side bar L form	2" x 2' x 1/8" Angle	2	$34,25	$8,45
Front bar L form	2" x 2' x 1/8" Angle	2	$85,25	$21,03
Motor plate	4" x 1/8" Thickness	1	$9,-	$1,33
Plate rib	2" x 1/8" Thickness	6	$5,-	$2,10
Bolts	Stainless steel truss heas machine screws 1/4-20 2"	28	$0,45	$12,73
Nuts	Round base weld nuts 1/4-20	44	$0,07	$2,95
Powder coat		2	$50,-	$100,-
Transport		1	$10,-	$10,-
Labor		60	$1,20	$72
Total price				$281,90

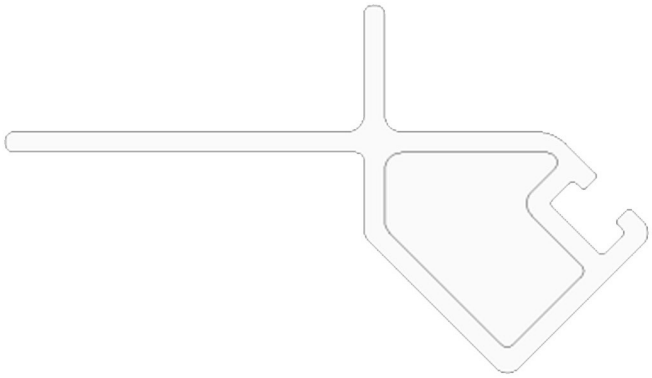
Figure 3.3.5. Estimated costs chiller

Appendix G (3) - Costs

Part: The tub	Qty	Price (p. u.)	Total price
Water heater element Rheem	1	$13,08	$13,08
Flange adapter kit	2	$18,86	$37,72
Single point level switches	2	$35,00	$70,00
Thermo fan switch	1	$25,00	$25,00
0.5" clear pvc tubing (price per foot)	4	$0,38	$1,52
Beckett 80 GPH Submersible Fountain Pump	1	$18,98	$18,98
Tub	1	$112,00	$112,00
Labor	20	$1,20	$24,00
Total price			$312,30

Part: The top frame	Qty	Price (p. u.)	Total price
Extrusion framework long	2	$25,95	$51,91
Extrusion framework short	2	$10,79	$21,58
Extrusion netframe long	2	$19,67	$39,34
Extrusion netframe short	2	$6,82	$13,63
Stainless steel truss heas machine screws 1/4-20 1.5"	18	$0,35	$6,37
Stainless steel square nut 1/4-20	18	$0,13	$2,27
Shipping	1	$31,62	$31,62
Anodization	2	$35,00	$70,00
Labor	60	$1,20	$72,00
Total price			$308,72

Appendix G (4) - Costs



ProSun Tanning Ind., Inc.

Part # : **Top Frame "Part 2"**
Part length 81.660 inches.
Estimate Number 61467

Part # : **Top Frame "Part 1"**
Part length 30.660 inches.
Estimate Number 61467

6063-T5. Satin clear anodized. Cut to length - double 45's on each end. Paper wrapped and packed on skids.

See quote 91518 for tooling costs
Saw cut ends are not anodized.

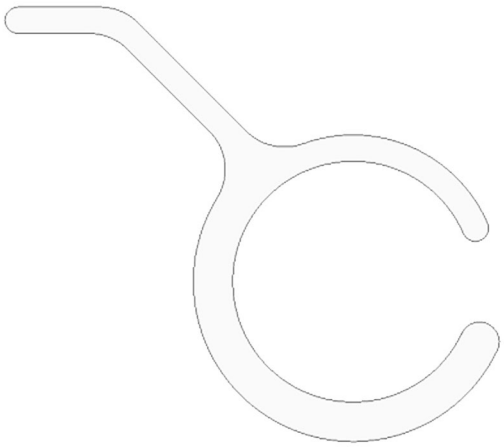
Pieces Qty	$ / Piece
50	25.594
75	22.613
125	20.300
250	19.652
650	19.232
1275	19.040

Pieces Qty	$ / Piece
100	10.792
175	9.669
350	8.799
675	8.555
1700	8.397
3400	8.324

$2,190 Die Service Charge
$1,375 Fab Tooling Charge

Minimum Lead Times
3 weeks for samples
5 weeks for production

Price subject to change.
For exact quantity shipments, add 25% to piece price shipped.



ProSun Tanning Ind., Inc.

Part # : **Net frame "Part 4"**
Part length 72.000 inches.
Estimate Number 61468

Part # : **Net frame "Part 3"**
Part length 20.000 inches.
Estimate Number 61468

6063-T5. Satin clear anodized. Cut to length. CNC machine 6 holes thru 1 surface. Paper wrapped and packed on skids.

Saw cut ends are not anodized.
See quote 91520 for tooling costs

Pieces Qty	$ / Piece
50	19.670
100	17.253
175	15.386
350	14.814
900	14.448
1800	14.289

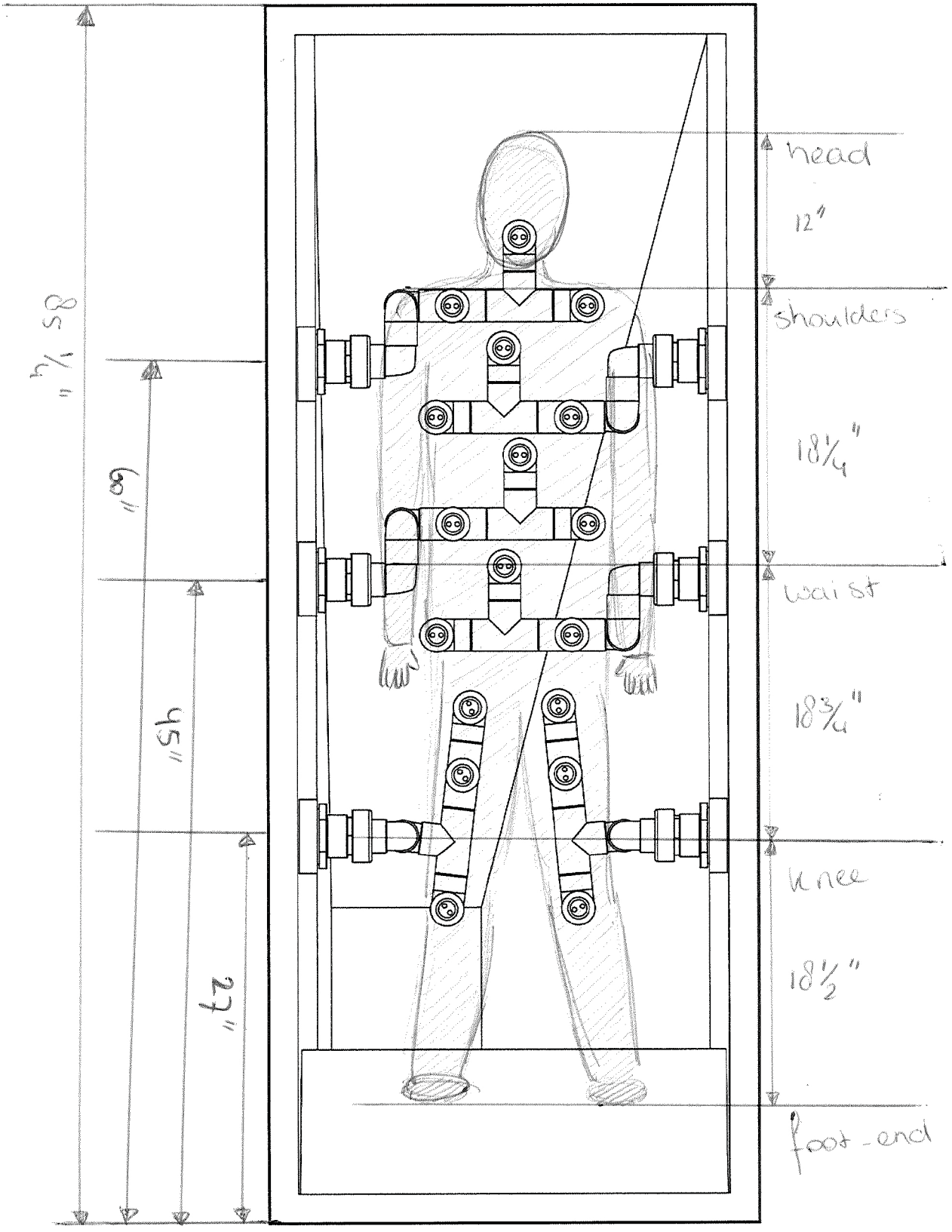
Pieces Qty	$ / Piece
200	6.815
325	6.141
650	5.621
1300	5.461
3225	5.359
6475	5.315

$2,190 Die Service Charge
$1,375 Fab Tooling Charge

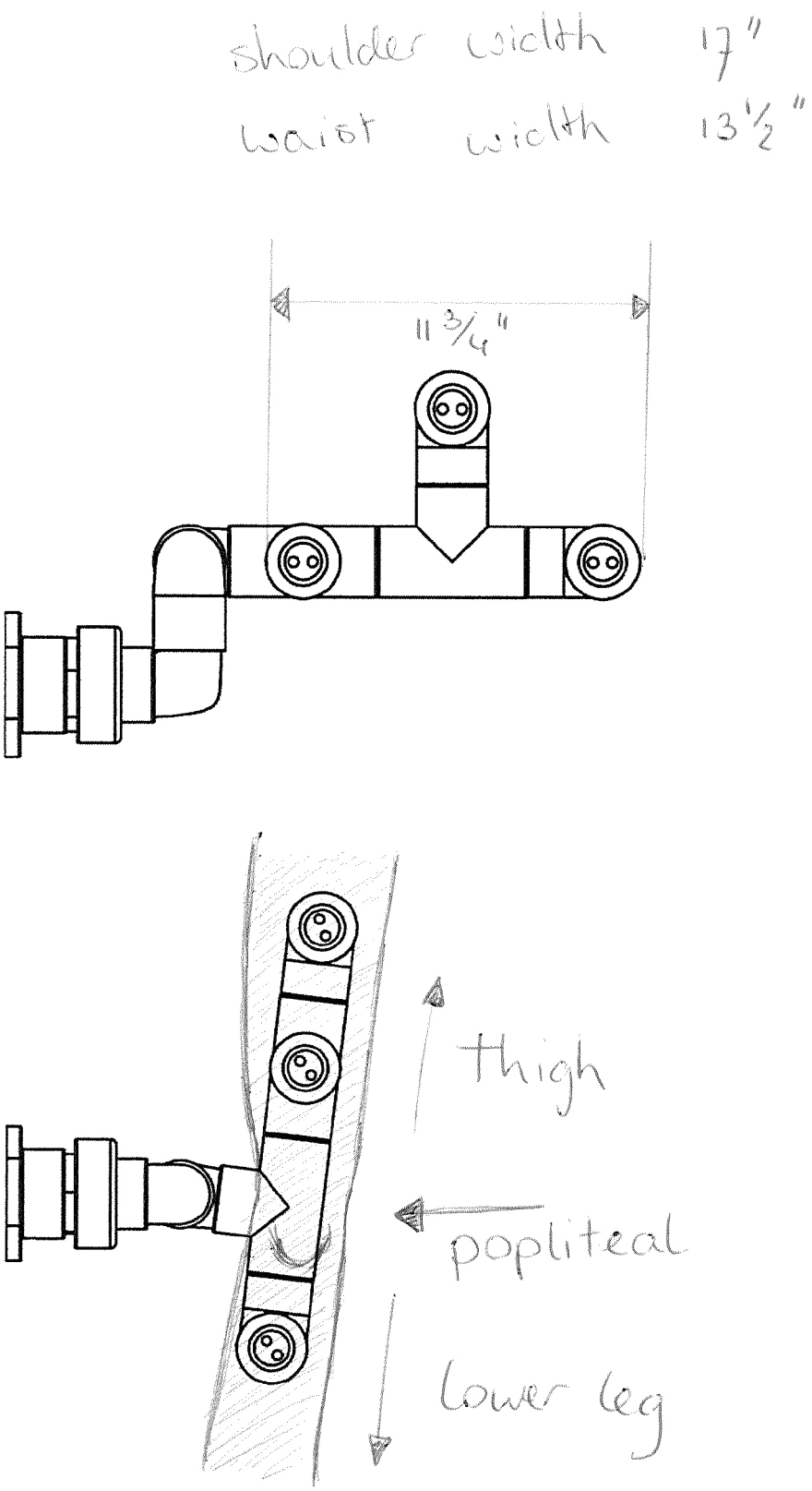
Minimum Lead Times
3 weeks for samples
5 weeks for production

Price subject to change.
For exact quantity shipments, add 25% to piece price shipped.

Appendix H - Positioning of the nozzles



Appendix H (2) - Positioning of the nozzles



Appendix I - Prototype

4.2. Prototype assembly

This shows step by step the content of the prototype. The order of showing the components is changed to give a clear view of the components inside the prototype and which way it is produced/ assembled.

4.2.1. The framework

The framework is made according to the component design phase. Figure I.1 shows a picture of the frame that is made for the prototype. The frame is made out of 3 basic steel parts:

- 1″ x 1″ x 0.125″ steel square tube
- 2″ x 2″ x 0.125″ steel angle
- 2′ x 0.125″ hot rolled flat steel

The frame would be strong enough when some parts are made from thinner steel which would create the risk to mix up the materials and make it more complicated. This way there is only one wall thickness that is used for the frame, which reduces the changes on mistakes made by the employees.

Figure I.1. The framework.

The frame is manually sprayed with a coating to protect it form corrosion. Its is done manually to save time and money during the development of the prototype. The result after the coating is shown in figure I.2.

Figure I.2. Frame with coating, wheel and mounted together.v

4.2.2. The tub

As mentioned earlier, ProSun made a mall for a tub based on the old massage mechanism. Producing a new tub takes too much time to be able to test the massage mechanism so it is decided to modify this current mall. The mall is designed for a rail system which is not used any more. The mall is slightly modified to be able put the tank adapter vertical through the tub which makes sure that there are no angles in the plumbing what could create leaks or other problems.

Figure I.3. The tub with vertical cut-outs (1) for the tank adapter.

Figure I.3 shows an image of the tub before the edges are milled off. The image also shows the vertical cut-outs for the tank adapter. The tub falls into the framework and the other elements are placed afterwards.

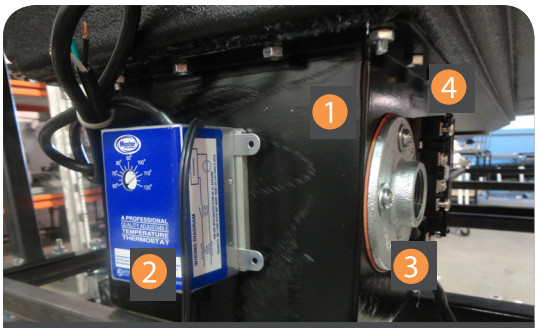


Figure I.4. The box (1) with heat element (2) and the thermostat (3), sealed to the tub (4).

Appendix I (2) - Prototype

Figure I.5. The 2 HP pump.


Figure I.6. The one and a ½" valve.

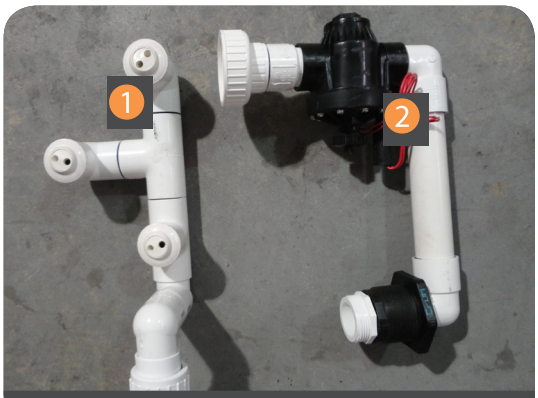


Figure I.7. The demountable parts.

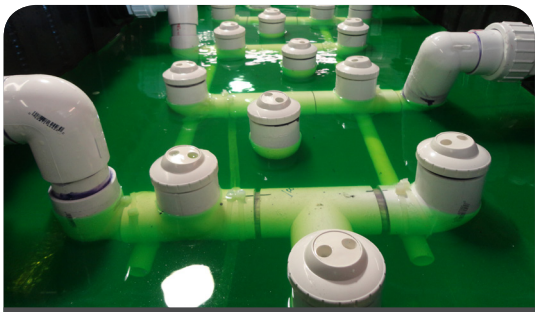


Figure I.8. The tub with jets and filled with water with anti freeze.

As explained earlier, the AquaFrixio will be equipped with two sensors and the thermostat. These element will be concealed within the product. Because of the limited time, it was not possible to finishing the hardware and programming it properly. That is why two standard thermostats and a heat element are used. Figure I.4 shows the steel box with those elements mounted on. The box is welded together, manual sprayed with a powder coat and mounted on the tub using glue and multiple bolts. One thermostat will switches off the heat element when the water is at the desired temperature. The second thermostat switches the chiller on when the water reaches an uncomfortable temperature. A little water pump is mounted inside the box to circulate the heated water inside the tub.

4.2.3. The massage mechanism

To drive the massage mechanism, a 2 HP pump is connected to the 2" mainline. The pump has a output fitting of 1.5" so a reducer adapts the 1.5" plumbing to the 2" plumbing. The pump with the mainline is shown in figure I.5.

Six ramifications in the mainline create the six zones that are used for the massage effect. Figure I.6. shows a ramification connected to a sub-component. This subcomponent is build out of several demountable parts using one union that is at the end of the sub-component and another one after entering the tub through the bulkhead fitting. The union positioned after the bulkhead fitting is composited out of three special ordered parts to save space within the tub.

The two unions together are able make it possible to replace a broken valve or jet, without wrecking the whole massage mechanism. The two demountable parts are shown in figure I.7. The first part is one of the jets that ensures the massage effect. The second part involves the 1,5" valve. When one of the valve is wrecked, only one zone needs to be replaced with a similar part which solves the problem. This saves time for the maintenance mechanic and money for the company.

Appendix I (3) - Prototype

Figure I.8 shows the inside of the tub were the six zones are located. Approximate 60% water and 40% antifreeze is used for the prototype, this to test the effect of antifreeze on the system. A similar fluid as antifreeze is needed to reduce rust effect on the metal parts and make sure that the water left in the product while shipping will not freeze.

Figure I.9. The two 1" valves (1) with a 1" union (2) at each side.

The position of the jets are based on the ratio of an average human body. The nozzles can be adjusted a little to finalize the positioning of the jets. This way the massage effect is as much optimized as possible.

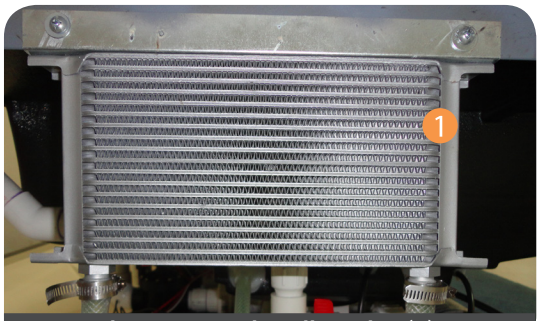


Figure I.10. The oil cooler (1).

4.2.4. The water pressure regulator

Two 1" valves are used to regulate the water pressure and are connected to the 2" mainline plumbing. The two valves are separately connected to the hand-controller, what makes it able to reduce the pressure using the hand-controller. Opening one valve reduces the pressure slightly and opening both valves will reduce the pressure drastically.

The unions between the valves make it able to replace a valve when it is damaged without replacing the whole mechanism. The two 1" valves are shown in figure I.9.

Figure I.11. The two fans (1) that cool the water.

4.2.5. The chiller

To reduce the water temperature a 19 row aluminum oil cooler is used. The measurements of the oil cooler are: 10" x 7" x 2" thick. The oil cooler is shown in figure I.10 and is connect with a 5/8" hose to the tub. Inside the tub a 1/2" water pump is able to pump 80 gallons per hour though the oil cooler.

To test the performance of the chiller, two fans mounted on the skirt and positioned against the chiller will blow are through the oil cooler. The two fans are shown in figure I.11. The chiller will be tested using only one fan and both fans, to see what difference it makes.

Appendix I (4) - Prototype

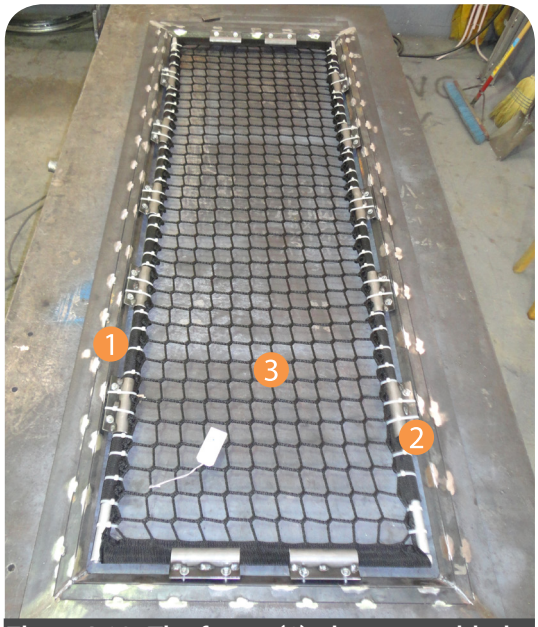


Figure I.12. The frame (1), the parts with the cared slots (2) and the net (3).


Figure I.13. The end result without the skirting on.


Figure I.14. The end result with the skirting on.

4.2.6. The top frame

Figure I.11. shows the top frame that is made for the prototype. The redesigned top frame will finally consist of two aluminum extrusions, as is explained earlier. Due to the limitations in the workshop and the costs of the materials, is there decided to use basic steel parts. The steel is easy to use and gives a good preview of the appearance and use of the top frame.

The prototype consist of two parts. One parts is the square frame that is made form flat rolled steel and angled steel parts that are also used for the framework. The second parts is made out of a tube with a carved slot and flat rolled steel. The goal was to produce this parts over the whole length of the bed, but finally decided to use five pieces with a length of 5”, because of the difficulty of carving the slot.

The frame influences the size of the net which means that zip-tie are used to get the right tension for the prototype. The net will be changed to fit perfectly for the actual product.

The end result

The end result is shown in figure I.12 and I.13. The first figure is without the skirting of the AquaFrixio. This creates an overall view of the prototype. The other figure shows the AquaFrixio with the skirting on and gives a good representation of the appearance of the product.