Design of a filter cloth analyser

Development of a portable filter cloth selection tool for filters used to regenerate the acid used in the pickling process during the production of stainless steel

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Industrial Design Engineering, master's level
2018

Luleå University of Technology
Department of Business Administration, Technology and Social Sciences
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Master of Science Thesis

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ABSTRACT

The stainless steel industry is an industry which manufactures one of the most used materials in the world. Even though the vast size of the industry may not reflect were the steel comes from when buying their IKEA cutlery etc. But in fact this industry is more intricate and complex than one might think. During the manufacturing process, the steel goes through several processes. One of those processes is done by treating the steel with strong acid. This chemical process is called pickling. The pickling process is what creates the characteristic smooth and shiny surface of a product made in stainless steel.

This thesis is about the development of a test unit that is able to effectively test the ASRA (Acid Sludge Removal Apparatus) filter cloths. The ASRA is a filtration system developed by Scanacon in Stockholm that filtrates and purifies acid that is used during the pickling process of a steel manufacture process. Today, it is complicated, time consuming and dangerous to test and evaluate different filter cloths in order to find the cloth that provides the best result, since the tests has to be conducted on the real systems. The aim of this thesis was therefore to solve these problems. Scanacon wanted to find an alternative solution, that would not include interaction with the real filtration system. They also wanted a portable and safe solution.

To solve the problem a iterative design process called RDCD which stands for research, design, create & delivery was developed. The processes was heavily influenced by the CDIO process (Conceive, Design, Implement & Operate). After the research phase was conducted it was decided that a small filter analysis product would be the best way to solve the problem. The product was then developed one component at a time. During the project several prototypes and test was created and conducted in order to validate the design.

The result is a small filtration unit specially designed to simulate the ASRA system. The product is able to rapidly test various filter cloths in an easy way, without putting the user in harm’s way. After the tests has been performed can the user identify which cloth that worked the best. The product is small enough to be possible to be carried in a hard case bag, which in turn affords portability.

Keywords: ASRA, RDCD, test unit, filter cloth, pickling
SAMMANFATTNING


Det här examensrapporten handlar om utvecklandet av en test enhet som effektivt kan testa filter dukarna till ASRA (Acid Sludge Removal Apparatus) systemet. ASRA systemet är ett filtreringssystem utvecklat av Scanacon i Stockholm som filterar och renar syran som används under betningsprocessen vid ståltilverkning. Idag är det komplicerat, tidskrävande och farligt att testa och utvärdera olika filterdukar för att ta reda på vilken duk som ger bäst resultat, eftersom att testerna måste genomföras på de riktiga systemen. Målet för det här examensarbetet var därför att lösa de här problemen. Scanacon ville ha en alternativ lösning som inte kräver interaktion med de riktiga systemen. De ville också ha en portabel och säker lösning.


Nyckelord: ASRA, RDCD, test enhet, filterduk, betning
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During the spring of 2018 we conducted a product development process in a symbiosis together with Scanacon. We were given an opportunity to perform our master thesis in product design and Scanacon were given help to solve a crucial problem with one of their products. This thesis describes the process and result of the project.

Scanacon is a world leading company in the field of acid management for steel industries. Today they create filter and processing solutions for treatment and recirculation of acids. When companies manufacture e.g. stainless steel plates, made from alloys consisting of iron, chrome, and nickel in various concentrations, the plates have to be treated in a pickling bath in order to get rid of different kinds of particles (oxides) which has arisen in the production. After a while the acid bath becomes saturated and the cleansing becomes less effective. Instead of switching out the entire bath of acid, Scanacon have constructed an advanced filter system called ASRA (Automatic Sludge Removal Apparatus) (see Figure 1.1) that cleanses this very acid with the help of a filter medium (in this case, a filter cloth). The acid can then be recirculated back into the pool and by using this system manufacturers can save up to 70% of acid. This is of course a huge benefit for both their customers, who saves money by buying this system, but also for the environment due to the acids toxicity.

Figure 1.1: The ASRA system with all its piping. Picture provided by Scanacon
1.1 BACKGROUND

Even though Scanacon have an effective system today, they are still faced with some challenges as mentioned in the introduction. When Scanacon visits a steel industry somewhere in the world it is not always obvious which type of filter cloth they should implement. Due to the fact that companies use different alloy compounds together with different types of acid the concentration of those particles will vary in size when treated in acid. As a result of the big variation of particle size, Scanacon’s technicians may have to stay on site calibrating their choice of filter cloth for up to 12 weeks, which is inefficient, time consuming and expensive both for Scanacon and the company installing the new system.

To summarise the thesis is conducted in order to investigate the problem connected to the ASRA system and to create a solution.

1.2 STAKEHOLDERS

A solution to the problem would be interesting several different types of stakeholders. According to Friedman & Miles (2006, p.13) is stakeholders “groups of people with a distinguishable relationship with corporations”. They further states that the most common group of stakeholders are: shareholders, customers, suppliers/distributors, employees and local community. Anderson, Briggs & Burton (2001) acknowledges this and continues to describe the stakeholders by dividing them into two categories, external and internal stakeholders. Internal stakeholders could be the management, employees & current businesses and external stakeholders could be local businesses, suppliers/distributors and new potential areas of development. They also describes the importance to find which stakeholders are the most important because as they describe “Not all stakeholders can be at the forefront of consideration all the time”. By interpreting this one could say that the stakeholders can be divided into primary and secondary stakeholders. The primary stakeholders in this project are the internal stakeholders, such as Scanacon’s installations technicians. They are the users that will work and handle the product. Secondary stakeholders (the external) are Scanacon’s customers who will benefit from the faster installation process as well as from the more accurate filter choice which advantages has been described earlier (see 1.1 Background). Should a reliable solution be created, the opportunities are huge and could open up business opportunities for Scanacon in new sectors, such as in the pharmaceutical and food industries. The sales personal at Scanacon can therefore be viewed as an internal secondary stakeholder.

1.3 PROJECT OBJECTIVES AND AIMS

The problems that Scanacon identified regarding current methods for filter selection became the foundation of the objectives and aims of this thesis. The objective are therefore to develop solution that optimizes the filter configuration of the ASRA system by aiding the user in the decision making of the filter selection. The aim is to provide the user with a safe, portable and usability friendly solution. The aim is also to provide Scanacon with 3D models (if relevant) as well as a functioning method or prototype at the end of the project. In this case a functioning prototype refers to a solution that can be used in the thought environment and will deliver relevant data. It may not however be fully automatic and some controls will be steered through manual handling. The design will also be delivered digitally to Scanacon in form of part files from NX. The design will be based on a thorough research phase that aims to further identify and dissect current issues.
Since Scanacon has clients all over the world it’s necessary that a product is portable so that it can easily be carried on and off an airplane, which leads to ergonomic aspect such as weight limits and how to move a heavy object, to minimize the human effort when using the product. Because of the hazardous environment that Scanacons technicians operate in, and the highly corrosive acids they handle, it is important that the design provide a safe way to use the product. The risk of using the product should be minimal, if an accident were to happen the damage should be as small as possible due to thoughtful design. Usability refers to the ease of use of the product. It should provide the user with clear data on which filter that is the best. In order to solve these problems a couple of research questions was formulated:

- How can a solution in a quick and easy manner help a user select the optimal filter for a filtration system?
- How can a solution provide a safe usage?
- How can a solution be portable?

1.4 PROJECT SCOPE

As mentioned in section 1.3 Project objectives and aims the definition of a functional prototype, in our case, means that the solution should be ready for usage in a real environment. The solution does not however need to be fully automatic, since this would require a longer and more expensive development process. Due to the time limit of 20 weeks the primary goal will be to create a solution which operates manually that strives to implement as much automation as possible. During this time a thesis report will be written simultaneously with the development of the functional prototype. It is therefore important to efficiently distribute the time. Scanacon made it clear from the beginning that they were willing to provide the project with funding in order to be able to finish the project and develop a functional prototype. They did not however state exactly how big the budget was but a rough estimate of how much it would cost to develop the prototype landed on approximately 60,000 SEK in total, 20,000 SEK in material cost and 40,000 SEK in work hours (500kr/h times 80 hours). The work hours represents the time of which employees at Scanacon will provide help with e.g. programming, electrical work or building of prototype. The work made by us is not taken into account.

1.5 THESIS OUTLINE

This section describes the layout of the thesis. The first chapter presents a short introduction to the project. Chapter two is about the context of what the project is based on. It includes a current state analysis and a benchmarking formally based from research methods described in chapter four. Chapter three treats the theoretical framework. This chapter involves different theories concerning the project, for example usability, portability and ergonomics. The fourth chapter describes the process in which the project has been conducted, it also include methods that have been used to gain further knowledge and inspiration or used as evaluation tools. The fifth chapter describes the result of the methods and the result of the project. Finally the sixth chapter is a discussion section where the process, methods, result etc, will be discussed and evaluated.
CHAPTER 2

CONTEXT

This chapter is intended to provide the reader with a bit more context and information relevant to the project. Some of the information presented in this chapter were given to us by discussions with our mentor at Scanacon, David Stenman. Other information comes from our research phase were we conducted interviews with employees and observations at some of their customers factories. The chapter describes Scanacons system, some filtration theory, a benchmarking were a test unit was evaluated and a benchmarking of two particle detection methods.

2.1 CURRENT STATE

Scanacon have roughly 40 employees situated in Shanghai, HongKong, Ohio and Stockholm where the headquarter is located. Today the company has over 30 years of experience and have found their niche: to filtrate and treat acid for stainless steel and titanium manufacturers. Because of the hazardous environment and the complicated solutions that follow, Scanacon are today specialist on the area with little competition. Thanks to their specialist knowledge they have stainless steel manufacturers all over the world as customers. (Scanacon, n.d.)

Humans and industries all over the world benefits from filtration. Filtration is defined as “the separation of a fluid-solid mixture involving passage of most of the fluid through a porous barrier which retains most of the solid particles contained in the mixture” (Green & Perry 2008). The filtration process consists of a filter medium that is “the barrier that lets liquid pass while retaining most of the solids: it may be a screen, a cloth, paper or a bed of solids” (Green & Perry 2008). One of the most noticeable benefits of filtration is our drinking water. Without filtration the tap water would be undrinkable, fortunately the waste water treatment plants uses different filtration operations to clean our freshwater which makes the water drinkable. (Stockholm vatten och avfall, 2017).

Each industry has different needs and challenges and as a result there exists a range of solutions consisting of different filtration processes. Filtration challenges could be particle size, flow rate or pressure. According to Green...
& Perry (2008) there is a filtration theory that defines a liquid-solid system, it is however inferior to a small scale filter test, which is both faster and more accurate to determine the filter requirements such as pureness and flow rate. Since there may be fluids of unknown chemical compositions it is important that the small scale filter test provides a safe and easy way of interaction. It should also help the user complete the intended task with minimum interaction errors.

In addition to acid filtration Scanacon delivers complete processing solutions for their customers such as electrowinning and filtration of acid. But as explained in the introduction the aim for this thesis is to develop a solution for filter selection mainly for the ASRA-system. Therefore no further discussion will be held concerning electrowinning. Through interviews and observations an understanding for the problem and current situation was formed and investigated.

As an initialisation to enhance our understanding of what Scanacon does, a presentation was given by Thorsten Schneiker (personal communication, 5 feb 2018), to describe the manufacturing process concerning stainless steel: Stainless steel is an alloy consisting of iron nickel and chrome to give it the characteristic corrosive resistance towards water and air (British stainless steel association, n.d). To manufacture a steel plate the alloy is melted and shaped into 20 tons ingots. These ingots are then hot/cold rolled into a long thin steel plate.

![Stainless steel manufacturing process](image)

Figure 2.1: Stainless steel manufacturing process. Illustration made by Andersson Egerlid & Westin, inspired by Thorsten Schneikers presentation.
During the hot rolling process a thick layer of oxide is formed on the surface of the stainless steel substrate. In order to remove these impurities and give the steel plate its characteristic glanz and smooth surface, it undergoes a pickling process where the stainless steel plate is dipped into strong acid baths. These pickling baths consist of a mixture of hydrofluoric and nitric acid or hydrofluoric and sulphuric acid (Peiyang, S. Haonan, S. Chengjun, L & Maofa, J, 2017). The acids react with the substrate and dissolve the top layer of the plate which helps the oxide impurities to fall off. Scanacon have developed an acid filtration system called the ASRA, which cleanses the acid from the impurities (oxides) with the help of a filter medium (filter cloth) and recirculates it to the acid bath. In this way the acid consumption for a company could be cut by 70% which is beneficial both economically and for the environment due to the acids toxicity. An illustration of the process can be found in the Figure 2.1. The ASRA system is explained in section 2.1.1 ASRA.

Through interviews (see chapter 4. Method and Implementation) we received knowledge about the process Scanacon goes through when making an installation or reconfiguration today. They always work in pairs if something were to happen and they always use the right equipment and clothes that protect them from dangerous acids. Today the filter cloth is chosen through a couple of methods. The choice is made by:

1. Gathering information about the customer: what type of steel are they producing (High level of chrome, nickel etc)? What acid (Sulfuric acid, hydrofluoric acid or mixed acid) do they use?
2. Which filter usually work best for a similar customer?
3. By a sedimentation sample, how much sludge are there?
4. By filtration, how big are the particles in the sludge?

Many industries are unwilling to share any information about their steel recipe and acid baths because it is their only intellectual property. This lack of information makes it hard for Scanacon who then only has previous experience to rely on. Sometimes the decision results in a working system other times it results in a massive workload for Scanacon’s technician who has to reconfigure the system.

### 2.1.1 CHEMICALS

As mentioned in section 2.1 Current state, the acid which is used in the pickling process are hydrofluoric acid, nitric acid and sulphuric acid. During the research phase it was acknowledged that these acids are very dangerous and therefore further research was made.

- **Hydrofluoric acid** - Hydrofluoric acid is the aqueous solution of hydrogen fluoride (HF) (Summers, 2017). Hydrofluoric acid is considered a weak acid but is still very dangerous to humans due to its excessive ability to penetrate tissue, (Centers for Disease Control and Prevention, 2017). According to Torsten Schneiker (personal communication, 4 may, 2018) are the concentration of hydrofluoric acid at most 15% in the mixed acid solution, these concentration are still very dangerous for humans. According to Summers a patient exposed to a solution exceeding 15% will notice signs and symptoms immediately but if the concentration is lower it can take up to 36 hours before the first signs of contamination occurs. Summers continues by saying that it’s the release of hydrogen ions H- that causes the initial damage to the skin. But it is the fluoride ion F- that is the real culprit. It penetrates deeper into the skin and damage the cells which causes liquefaction necrosis of soft tissue. It also reacts heavily with the calcium in our bones, which leads to decalcification and corrosion of...
the bones. This can lead to hypercalcemia if untreated which is lethal. A exposure of a solution containing a concentration above 50% on an area of 1% of the body area is enough for a fatal outcome (Summers, 2017). Depending on if the exposure is by skin contact, ingestion, eye contact, and inhalation the outcome is severe. If inhaled pulmonary edema could be a fatal result (Centers for Disease Control and Prevention, 2017). The article mentions systemic toxicity which by analyzing Summer's article means that the hydrofluoric acid does not stop to react as long as there are fluoride ions left. This can take up to 36 hours depending on the size and concentration of the exposure.

- Nitric acid - Nitric acid is a highly corrosive and oxidizing acid. It produces toxic, nitrous fumes that are very dangerous to inhale, when heated or introduced to metals or organic material. Reaction with iron produces nitric oxide, which is especially corrosive to the mucous membrane, and in higher concentrations also corrosive to the respiratory. Since it’s highly corrosive it is very dangerous for humans (Hydrosafe AB, 2008). It reacts directly even in small concentrations due to its corrosive properties in comparison with the hydrofluoric acid mentioned earlier which will lead to ulcerations. Inhalation of the toxic fumes can also be fatal since it can cause pulmonary edema if not treated (Hydrosafe AB, 2008).

- Sulphuric acid - Sulphuric acid is a highly corrosive acid (Hydrosafe AB, 2008). According to CNN (2017) when sulphuric acid make contact with our skin, it will cause “coagulation necrosis, an accidental cell death that leads to tissue ulceration”. The damaging effect has a direct correlation with the ulcerations. Which often results in extensive irreparable damage. The acid will continue to burn until all the acid has reacted or is removed, CNN (2017).

The after effect of a sulphuric acid burn can be chronic pain since the acid has damaged the nerves. It can also be a contributor to cancer (Hydrosafe AB, 2008).

In addition to all the dangers mentioned above it’s crucial to mention the acid’s temperature. Depending on concentration and mixture the temperature will range from about 60-90 degrees celsius which can cause burn damage (Personal communication with Thorsten Schneiker March 1 2018). This further contributes to the harmful effects of the acids.

2.1.2 ASRA

The Automatic Sludge Removal Apparatus (ASRA) is an automatic acid filtration system designed by Scanacon. It is “designed to facilitate the removal of suspended solids where the concentration is high to very high in mixed acid and single acid processes (mostly sulphuric, hydrofluoric and nitric acid). Applications include hot rolled and annealed stainless and titanium flat products pickling and de-glassing & pickling for stainless extruded products”. (Scanacon, 2018)

The system is designed to remove a large quantity of suspended solids from acid, with a dead end filtration technique. “During dead-end filtration the solution to be filtered passes the membrane (filter medium) surface orthogonally” (Microdyn Nadir, n.d). Since it’s a one way path its impossible for the solution to go the opposite direction hence its name.

The acid is pressed through a filter candle (figure 2.2 shows the scale of the candle) wrapped in a filter cloth with a varying mesh (ranging from a few micrometers to almost millimeters) with a pressure of 2.5-3 bar. As the acid is getting filtered the bigger particles will start to accumulate on the filter surface while the liquid continue through. (Green & Perry 2008)
Figure 2.2: Filter Candle for the ASRA system to the left compared to the Fundabac filter candle to the right (introduced in section 2.2.1). Photographed by Andersson Egerlid & Westin.
Since the particles accumulate on the cloth surface it becomes harder for the liquid to find its way through. Smaller and smaller particles will be rejected by the filter cloth, and the filtration becomes more effective over time. This process is called cake building and helps to filter the acid even more (see figure 2.3, 2.4 & 2.5). As the cake gets thicker the pressure will increase accordingly and eventually nothing will pass through. If the pressure exceeds 3 bars, the force applied to the filter cloth may rip a hole in it. To prevent that from happening, the system automatically detects the increase of pressure and when the pressure approaches 3 bar the system stops to clean itself with air and dispose the cake through a valve at the bottom of the container. The automation minimizes human interaction with the highly corrosive and dangerous acids. ASRA is a modular based system which means it can be incorporated in bigger systems by linking it to other Scanacon products to further extend the filtration process.

Figure 2.3: Simplified illustration of the ASRA system. Illustrated by Andersson Egerlid & Westin.
Figure 2.4: The particles eventually create a cake, which prevents smaller and smaller particles to pass alongside the liquid. Illustrated by Andersson Egerlid & Westin
Figure 2.5: When the cloth is fully clogged the system automatically performs a backwash. Illustrated by Andersson Egerlid & Westin
The performance or efficiency of a given filter medium (filter cloth) is determined by the flow, is called flux. Flux is defined as “the volume flowing through a membrane per area unit and time” (Mulder, 1997). This has direct connection to the correlation between the pressure inside the filter chamber and the pureness of the acid. The pressure increases due to the cakebuilding from the build up of particles on the filter cloth surface. This decreases the amount of acid passing through which in turn will decrease the flux of the acid. For instance if the mesh on the cloth is so big that no particles manage to stuck on the cloth, the dirty fluid will flow straight through. Which result in a filtration process with a low pressure, highflow and dirty solution. If the particles manage to stuck you will gradually get a higher pressure with a higher pureness and a reduced flow, all thanks to the cakebuilding process mentio-

ned earlier. It’s essential to find the sweet spot (cut off point) and try to stay there as long as possible. Where the systems still has a good flowthrough and high pureness without the pressure breaking the roof. Because if the pressure gets to high (3 bar) it might rip the cloth or the flow will be so low it will be cost ineffective (See figure 2.6 for a better understanding).

According to Thorsten Schneiker (personal communication, 15 march 2018) is the flow rate for the ASRA system initially 1500L/h and the filter cloth area 0.325m² Which means that the flux is 1500/0.325 = 4615L/m²h. The average flow rate for the system is 500L/h which gives a flux value of 1538L/m²h, and a minimum value for the system of 300L/h gives a flux value of 923L/m²h. If the flux value decline further the efficiency will be to low, and the backwash function will be initialized.

Figure 2.6: The correlation of pressure, flow and pureness of the acid. Illustrated by Andersson Egerlid & Westin

TOTAL FILTERFLOW CHART

PRESSURE (P: Bar)

CLEAN FILTERFLOW (Optimal)

FLOW RATE (pureness of acid)

Time and Pureness
2.1.3 DETECTION OF PARTICLES

Scanacon has a range of both filter cloths and filtration methods and are often faced with a difficult decision on how to choose the right cloth when installing a new system. Today the company do not have an easy or reliable way of making that decision. Instead their workers has to stay at the installation site for weeks trying to calibrate and determine which filter is best suited. Much of the decision making are just guesses and estimates based on previous knowledge. They do however use two tools:

- **Funnel** : A funnel is filled with the “purified” acid and left for 24 hours. After the acid has rested any particles left in the purified acid will have sunk to the bottom and can be measured (see figure 2.7). This process is called sedimentation.

- **“Bills box”** : A single or several fine circular filter cloths with varying degree of mesh size (finer than the actual filters on the ASRA) is put in a two piece container. In the top part of the container filtrated acid from the real system is put and the bottom part is put into a vacuum. The acid is thus forced through the filter and down into to bottom part of the container. After the test in acid every circular filter cloth is observed and it is possible to determine the size of the particles depending on which filter that caught most debris (see figure 2.8).

Figure 2.7 & 2.8. Funnel with sedimented iron powder in water to mimic the acid solution (left). “Bills box” (right). Photographed by Andersson Egerlid & Westin
The use of a funnel is a method that is simple and that gives the user a clear answer, but it can take up towards 24 hours to receive a result from a single sample. Testing of several filter cloths demands that a new filter cloth is installed in the ASRA. Then the system has to run for a while in order to create a new sample. After that the new sample can be tested. If the sample still doesn’t give a result the cycle has to be repeated again, and again, and again until a good enough filter cloth has been found. While this method gives a reliable answer it does not give it fast, it takes 24 hours for just one test result. Considering that the production line also is closed during the testing it is easy to see why this method quickly becomes very expensive.

Scanacon has around 20 different filter cloths and to test all of them for each new industry is today almost impossible or at the very least impractical. Every replacement of filter cloth takes several hours and is risky momentum. “Bills box” is also a fairly simple tool to get a hint of how clean the acid has become after the filtration. This method does however not test the real filter cloths and is therefore not especially useful for making an informed filter decision. These evaluation tools are fairly small and therefore portable. This is something that the new small scale test unit also should strive to achieve.

2.2 BENCHMARKING

In order to further identify problems and establish an understanding for relevant or similar solutions to the project a benchmarking was performed. To understand the ASRA-system better and to get inspiration for solution to our problem a Fundabac unit was investigated. We also investigated two different methods to detect and measure particles submerged in liquids.

2.2.1 FUNDABAC

Fundabac (see figure 2.9) is a small pilot test rig manufactured by DrM, a company that develops technical solutions for acid filtration. The purpose of the rig is to simulate a dry cake discharge and a slurry discharge. The Fundabac works similar to the ASRA system but on a smaller scale and everything is handled manually. The equipment consists of a chamber that contains a small filter staff similar to the one used in the ASRA system (see figure 2.2). A pump transfer liquid through the filter membrane that is placed on top of the filterstaff, which catches particles in the liquid passing by (Dead end filtration). A cake will start to take shape when particles are starting to add up. As mentioned before in chapter 2.1.1 ASRA, the cake building process is a crucial step in the filtration process as the cake itself will start to function as a filter which filtrate the acid even more. The big difference compared to the ASRA system is that the Fundabac has air inlets connected to the chamber at the top to be able to dry the cake whereas in the ASRA the cake is wet. What happens is that air is forced the same way as the slurry which is through the filter cloth and out into the clean acid tank. This dries the cake at the filter membrane.

The system also has air inlets inside the filter candle to disperse air from the inside after the cake has dried to break the cake outwards into the filter chamber. A drainage valve in the bottom of the chamber is used to discharge the acid slurry that remains.

For a better understanding of the parts see figure 2.9.
Figure 2.9. Fundabac. Photographed by Andersson Egerlid & Westin

**FUNDABAC**
A: INLET  
B: DISPOSAL VALVE  
C: DRAINAGE VALVE  
D: PRESSURE GAUGE  
E: OUTLET  
F: AIR RELEASE  
G: AIR FOR DRYING CAKE  
H: FILTER CHAMBER
2.2.2 TURBIDITY METER

A method to measure the rate of particles in liquids that Scanacon does not use today is to use a Turbidity Meter. Turbidity is the term for the optical phenomenon that occurs when light passes through a liquid with particles in it. When the light hits the particles it scatters and can be measured. In other words turbidity is the opposite of clarity. (Sadar 1998). The most usual way of measuring turbidity is done via a nephelometer, a detector that detects scattered light 90 degrees from the original path and compare it with the amount of light that manage to travel straight through the fluid. See figure below. The result is presented in the unit NTU which stands for Nephelometric Turbidity Units. This method can detect concentrations up to 6000mg/L (Huang et al., 2013).

![Illustration of the function of a turbidimeter. Illustrated by Andersson Egerlid & Westin](image)

2.2.3 ULTRASONIC FLOW METER

Ultrasonic flow meter is a device which measures the amount of particles in a fluid with ultrasound. It functions in a similar way as the turbidity meter. But instead of light, sound is used to create sound waves from two probes facing each other. The sound waves change direction when they hits a particle. The waves are then picked up by two sensors (inside of the two probes), and depending on how scattered the interpreted signal is, the amount of particles in the fluid can be decided. The method can be used to detect particles with a concentration of 1000mg/L - 300000 mg/L (Huang et al., 2013).
CHAPTER 3
THEORETICAL FRAMEWORK

This chapter contains theory that was valuable during the development of the functional product. Its purpose is to act as a guideline in order to avoid wrong usage of the product as well as how to prevent injuries by investigating areas such as Usability, Ergonomics and Mechanical Components.

3.1 INDUSTRIAL DESIGN ENGINEERING

One might think that Industrial design only focuses on the appearances and esthetics of a product. While the appearance definitely is a relevant part of industrial design it is far from the whole picture. Industrial design is just as much about function but most importantly it is about delivering a value and an experience for users. (Industrial Designers Society of America, 2018)

An important attribute for a designer to be able to deliver more than just esthetics is empathy. An empathic designer will have an easier time identifying problems since the designer will understand people and their problems during research, interviews and observations and when a designer have a good understanding for a problem they can avoid bad solutions. (Industrial Designers Society of America, 2018)

Designers play an important role in the making of new innovations. Design is the tool that drives things to evolve and change. (Nielsen 2013)

3.2 DESIGNING FOR SAFETY

Safety is of utmost importance in this project, since the acid used in the filtration process could be lethal. Therefore a design which provides the user with a safe and easy interaction is indeed necessary. In order to achieve this several areas concerning safety related usage have been investigated to aid in the design and creation stage.

3.2.1 USABILITY

The product should afford good usability to maximize the output and prevent accidents/injuries. According to Jordan (2000) usability means in short “how easy a product or system
is to use”. A product or system designed with good usability has taken the intended users requirements, physical and psychological limitations under consideration (Jordan 2000). In this case that would be the hazardous environment and liquids that plays a central role in the design.

Usability consists of 3 segments: effectiveness, efficiency and satisfaction. Effectiveness refers to “the extent to which a goal, or task, is achieved” (Jordan 2000). Efficiency refers to the amount of time and effort invested to achieve the intended result. It is therefore possible to have different efficiency but the same effectiveness. The third and last thing is satisfaction. Which is a subjective aspect of how the user experience (level of comfort) and feels during an interaction with a system or product to fulfill the intended task or goal. A well designed system or product often comes with a higher satisfactional level for the user, which in turn can overthrow the effectiveness and efficiency by its subjective impact. As mentioned in the beginning it’s necessary to take the users limitation into consideration because age, gender, cultural beliefs, experience and domain knowledge will have different impacts which can change the overall effectiveness and efficiency. Our design will mainly be designed for Scanacons employees which will be given instructions of how to use the product and different users will therefore not vary much.

Norman (2013) Talks about the necessity to “design for errors”, he implies that a design where the usability is good, everything works well, and people use the device as intended, is relatively easy. The hard part is to design for when unforeseen things happen which causes errors. Norman (2013) has formulated some ideas to think about when designing:

- Understand the cause of error and design to minimize those causes.
- Do sensibility checks. Does the action pass the “common sense” test?
- Make it possible to reverse actions: 
  - to undo them
  - or make it harder to do what cannot be reversed.
- Make it easier for people to discover the errors that do occur, and make them easier to correct.

The sentence, “What if?” should be implied in all design (Norman, 2013). This forces the designer to think of the eventualities that may occur, and what potential damage those eventualities would cause. Since safety is of importance to our design it can be very useful to make use of the sentence. For this project the design for error is very crucial since an error could be lethal and the design should prevent injury if a error were to occur.

### 3.2.2 AFFORDANCE

Affordance is a common term used by designers, which was invented by James. J. Gibson (1986). It’s a noun that connects the universal environment to all the living organisms. Gibson is suggesting that the environment has a certain affordance. It “affords, provides or furnishes” for us humans. He continues this suggestion by dividing affordance into a psychological and physical segment. Gibson means that depending on if the ground is flat, full of rocks, trees or water our perception of that specific area of environment changes and the affordance change with it. A flat solid surface affords walking whereas a lake afford swimming. This is connected to the physical affordance. For a tiny insect, the water would still afford walking and not swimming. This means that the environmental affordance and the observational affordance are individual. It’s denoted on the visual perception of the observer. Affordance is what the object or environment tells us through visual communication. By interpreting Gibson (1896) it is crucial to say that the psychological affordance changes
Affordance could be direct linked to Normans (2013) bad design theory, which relies on the fact that 75-90% of all errors in the industry is connected to human errors. He implies that it is not due to incompetent people, it is caused by bad design. By interpreting Norman (2013) one could say that: If a design provides good affordance the interaction with that object or product would be smooth and easy. But if the design affords mixed perception input, the output could differ enormously, and an incorrect action may be the result. An object or product with good usability does also provide good affordance as it’s this that determine how easy a object or product is to use and interact with.

For this project affordance is crucial. Since the goal is to develop a functional design that is going to withhold pressurized acid, error is not an option. Through a proper design with good affordance, mistakes or missguided use of the device should be out of question. Affordance will also be a valuable tool when designing for errors.

3.2.3 PORTABLE ERGONOMICS

Heavy physical work generally raises the risk of injury in the musculoskeletal system. Heavy lifts are especially risky and if the lifts are done so that the body has to be twisted or bent forward the risk for injury becomes even greater. It can often be hard to design fully ergonomic solutions but heavy lifts in awkward positions should be avoided as far as possible. (Hägg, Ericson & Odenrick, 2010) Arbetsmiljöverket agrees with this and further states that manual lifts weighing more than 25 kg should be avoided but may occasionally be accepted provided that a safe lifting position can be acquired (Arbetsmiljöverket, 2018). To avoid heavy lifting they suggest the usage of rolling devices to ease the handling as well as other technical lifting aids.

The hand is a highly complex and flexible body part that allows humans to perform complex tasks. The hand can both be used for precision-and for power demanding tasks. Depending on the grip, humans can move heavy objects or with high precision perform elegant movements. The amount of force that the hand can handle reduces linearly with how fine the precision needs to be. Higher force - lower precision and vice versa. (Hägg, Ericson & Odenrick, 2010)

3.3 MECHANICAL COMPONENTS FOR SAFETY

Mechanical components such as O-rings and threads have a huge impact on safety due to the pressure and temperature inside the filtration chamber which needs to be sealed off. Therefore theory regarding this matter has been put forth in order to aid in the fortbring of a secure and safe design.

3.3.1 O-RINGS

One way of sealing containers is to use O-rings. O-rings are used to seal compartments from leaking air or fluids. A metric ISO Standard (ISO 3601/1) describes how to use the O-rings in order to maximize its durability and function. The Standard includes specifications on how to apply a specific O-ring with a certain dimension in a product. It include radius diameters and depth of the track which the oring will be placed in and it includes values of surface tolerances. The ISO standards comes with a table that describes which O-ring should be used for a certain diameter (Teknikprodukter n.d). According to Ola Rising (personal communication, april 3 2018) should mechanical solutions consisting of a male and female
part, that aims to seal a medium from leaking, contain a groove on the male part where an o-ring can be inserted (see figure 3.1).

3.3.2 THREADS

Threads is the technical term for the shape that helps a nut and a bolt fit together. There are metric standards for how the fittings should be between the two. Sandvik has a good reference list to check for ISO standards concerning the fit. (Sandvik Coromant n.d). It consists of dimensions for the bolts inner and outer diameter, as well as pitch and angle of the thread. And the same for the nut with slight changes to withhold a tolerance space (see figure 3.2 & 3.3). These dimensions must be followed in order to get a safe fit. There are numerous websites where the ISO standards for each dimension can be read.

3.4 DESIGNING FOR FUNCTIONALITY

Since the whole project aims to deliver a fully functional prototype valuable information has been extracted in order to aid in the designing and decision making.

3.4.1 PROTOTYPING IN GENERAL

The definition of a prototype is according to Oxford dictionary “A first or preliminary version of a device or vehicle from which other
forms are developed”. Prototyping and manufacturing are similar but different activities. An assembly line demands special tooling and extensive preparation. Prototypes that usually are created in a much fewer number can make use of different production methods. Prototyping is about testing a design and be allowed to rework it where it is needed. (Hallgrímsson 2012)

They are tools in the creation, development and design process, which have traditionally been shaped in different ways depending on the field. (Gengnagel, Nagy & Stark, 2016)

Ideas and approaches for practical solutions become manifest in prototypes. They enable us to consider and test them as well as to communicate about them. Prototypes inspire new ideas, demonstrate problems and let us test solutions.

3.4.2 CAD

CAD stands for Computer Aided Design and is a notion for software tools used to visualize and create 3D models via a computer. CAD allows designers to quickly create designs that are ready to be manufactured or for prototype testing. By using CAD the designer are given more options than by just using pen and paper. CAD softwares also usually allows the user to assemble several parts into a bigger model. (Bryden, 2014). it is a software tool often used by designers to make drawings for prototypes etc.

3.4.3 RAPID PROTOTYPING

Rapid Prototyping is a term that cover several processes used to create physical models with the help from CAD substrates. By using CAD data a physical 3D model can be created by 3D printing. The word “rapid” is used because this process is much quicker than more traditio-
CHAPTER 4

METHODS & IMPLEMENTATION

This chapter describes the different methods used in the project. It starts with a description of the design process. Continued by the project planning with regards to time management, budget and other resources. Finally every major step of the process is explained in a chronological order as well as the methods that were used during the project. As previously explained the aim of the project was to find a solution of how to in an easy, safe and reliable way choose the right filter cloth for Scanacons ASRA system. During examination of the ASRA system, through interviews with employees and discussions with engineers responsible for the system we found out that it is extremely hard to simply calculate which filter cloths that should be used since so many different variables affect the result. The solution therefore had to be some kind of test that acknowledge all these variables. When the process of designing the solution started it was not clear how the test would look like, if the test would be performed through a machine and in that case which components the machine needed. In order to ease the understanding of the design process some of the result is presented in this chapter since some of the methods used depended on the result of other methods.

4.1 DESIGN PROCESS

The design process for this project is based of the CDIO process. CDIO is short for conceive, design, implement and operate. Conceive refers to the identification of the problem and is the phase were needs and problems are identified as well as where the strategy to solve the problems is formed. Design is the phase where drawings and solutions are created. Implement serves as the transformation phase were ideas and drawings are created and tested. Finally the Operate stage is the phase where a product is delivered and put into use. Depending on the type of product this phase includes things such as customer support, distribution, upgrades, maintenance and retirement. (Crawley, 2014)

CDIO is a design process which works in a divergent/convergent way that first widen the perspective and then narrows it down to a few ideas or solutions. This method does also consist of some iterative possibilities to enable rethinking/redesign (see figure 4.1). Iterative defines as repetition of a operation or procedure (merriam-webster, 2018).

Since the projects goal was to develop a fully functional product, a lot of testing was needed
throughout the whole process in order to ensure the functionality. The process chosen for this purpose was therefore a modified CDIO process which enables a much wider iterative process to make space for research, design and creating in several stages. The name of our modified design process is called RDCD which stands for Research, Design, Create and Delivery. The definition of the four phases is the following:

- Research - Information gathering.
- Design - Ideation and Evaluation.
- Create - Prototyping and Evaluation.
- Delivery - Final preparations on product.

This process can be divided into two paths: one main path that looks like the process in the CDIO illustration (see figure 4.2). The second path shows the iterative process which enables early design and creating of prototypes etc to evaluate different ideas (see figure 4.3), this iterative part can be implemented already in the research phase to for example establish a better understanding of how things work, in order to secure a good foundation.

The first picture shows the main path and that it is divergent/convergent based and that the direction is pointing from start to finish. The second picture illustrated is the iterative path that shows that research, design and create are working much closer and enables designs to be reworked.
4.2 PROJECT PLANNING

A project plan was formed during the first week of the project. The project plan was made to get a hold of the magnitude of the project in order to distribute labor and time appropriately. The plan was made in accordance with Kerzner’s (2009) three aspects of why project planning is good:

- To improve efficiency of the operation
- To obtain a better understanding of the objectives
- To provide a basis for monitoring and controlling work

The project plan is based on Kerzner (2009) who is stating that a project plan should include a program, time and budget. In this project the program consists of different methods to conduct research, design and creation, in accordance with the design process. A Gantt chart was used to distribute the time, since it is a simple and effective way to keep track of time in each stage in the process (Baxter 1996). In the gantt chart the time was distributed between the different phases (RDCD) and assignments to provide monitoring and get a enhanced view of the objectives, as suggested by Kerzner. Alongside the design process and problem solving this thesis was written. Time for the thesis this was also implemented in the Gantt chart (see figure 4.4).

During this project it was decided to not predetermine every methods instead relevant methods were researched when it was required. To cope with the iterative process a more open approach was implemented where the time
was not labeled with specific titles in the Gantt chart. Instead the time were distributed in the more general labels, research, design, create and delivery. Which gave space for a freer design process were time was not wasted on unnecessary methods.

Scanacon did not present any specific budget for the project, instead we were told that “if you need something we will provide it”. But nevertheless a rough estimate on what the material cost for the prototype would be are regarded important (Kerzner 2009). With little prior knowledge of the industry and their prices the material cost of the product were estimated to 20 000 SEK for material. In addition to this a calculation of the man hours that was estimated needed from Scanacon employees was performed. They were estimated to 80 hours at a price of 500 SEK/h = 40 000 SEK. The total amount would therefore be material cost + man hours which equals 60 000 SEK.
4.3 RESEARCH

The first phase (except the planning stage) of the project was the research phase. This phase aimed to provide us with information of the current state, help us understand the problem better and serve as a foundation for the following stages of the project. The methods used to gather information were interviews, observations, literature review, benchmarking and laboration.

4.3.1 LITERATURE REVIEW

This method was used to find relevant information concerning different areas in order to accomplish the intended task which is a fully functional prototype. The literature review was conducted in accordance to Milton & Rodgers (2013). First of information to answer the research questions was sought after. Since the whole project was an iterative process a lot of additional informations has been added throughout the project. To aid in the answering of the questions the main areas investigated was: usability & affordance for safety, portable ergonomics, dangers of acids and filtration.

Luleå University of Technology’s internet library have played a vital part in the retrieving of information where the authenticity easily could be validated through peer reviewed searches. This was complemented with other sources of information such as books and documents provided by Scanacon. Keywords used was: Pickling acid, Affordance, Usability, Design of experiment, Gibson affordance, Turbidity definition, Portable Ergonomics, Donald Norman and Design for safety. The results varied greatly in relevance. By using secondary keywords such as Pickling hydrofluoric acid the amount of hits could be narrowed down and be more precise to the subject of interest.
4.3.2 INTERVIEWS

Interviewing is a good tool to utilize at the beginning of a research phase to gather data. Because you get knowledge from experts in the specific field. Depending on how the method is implemented the outcome will either be quantitative data or qualitative data. Quantitative data comes mainly for simpler surveys which is good if you want to reach out to as many people as possible. Qualitative data comes from deeper interviews with a single person at a time. (and is appropriate if you want to conduct an interview that is built on that very person’s qualifications, knowledge and experience, which was important in our study. The respondents had the practical knowledge we were unable to get from other sources. (Osvalder, Rose & Karlsson, 2010)

Depending on how the questionsheet is formed different levels of information is inherited. An interview can mainly be conducted in three different ways: unstructured, semi structured and structured. An unstructured interview is carried out by an interviewer who asks open ended questions to the person being interviewed. The interviewer should try to keep the discussion on the topic. An advantage with this method is that the person being interviewed can talk very freely about the topic and may speak of things that otherwise wouldn’t have been discussed. A structured interview is the opposite, here the person being interviewed is only allowed to answer predefined questions by the interviewer. A semi structured interview is a mixture of both where the interviewer have prepared a couple of questions but let’s the interview be open and the person being interviewed talk about other things that seems relevant to the topic. (Osvalder, Rose & Karlsson, 2010)

In order to secure a well founded base for the project, five interviews were conducted with Scanacon employees with different occupations within the company (see figure 4.5). We chose the unstructured approach because this enabled the participants to speak more freely and create a more continuous flow in the questions and answers that followed. Based on the research a few questions was prepared regarding the present situation at the company, the field and were the dangers comes into play. The question were very basic in order to open up the flow and get them to narrate. The initial questionsheet can be found in the APPENDIX B.

All interviews were held in a conference room and was recorded with sound in order to enable a more thoroughly analysis afterwards, by doing this the conversations became unified without any interruptions from writing. Due to the unstructured method the interviews varied in time because of the very different narratives from the respondents. since some questions afforded to leave the conference room to be visually presented in the establishment.
4.3.3 TEST OF FILTRATION

In order to understand the ASRA systems filtration process and the theory behind dead end filtration, a filtration test was performed with the Fundabac system which largely reassembled Scanacons ASRA mentioned in the benchmarking chapter 2.2. It was therefore an ideal tool to be investigated for a couple of reasons. One reason was to investigate the chemical process called cakebuilding (Green, W. D., & Perry, H. R., 2008) that occurs on the outside of the filter candle. Another reason was to provide us with inspiration for a future solution. The test was conducted with water saturated with grounded coffee to act as a supplement to the dirty acid to prevent any injuries (see figure 4.6). A manual constructed for the Fundabac was followed during the whole experiment. The manual used can be found in APPENDIX C.

4.3.4 OBSERVATION

Observation is a method used to gather information of how humans behave and interact in different situations. According to (Osvalder, Rose & Karlsson, 2010) this method is often used in the beginning of a project since it is a
good way of getting information on how things currently are done and the method gives an understanding for a user situation without disrupting the ongoing process. An observation can be divided into two different types of observations, systematic and unsystematic. Systematic observations means that the observer may have a specific research question that need to be investigated, it can be a specific problem or an occasion etc. An unsystematic observations is conducted when you don't have any initial research question/questions. Observations can either be noted on paper or recorded on film to enhance the understanding by watching them afterwards under more controlled environments. (Osvalder, Rose & Karlsson, 2010).

During this project two observations was made, one at the stainless steel factory Outokumpu in Avesta and one at Fagersta Stainless in Fagersta (see figure 4.7). They were mainly conducted during the research phase to get an understanding for how the environment, where the future product was going to operate in, looked like. But also to investigate if there was any differences concerning the acid system between the two. The observation was made with an unsystematic approach since we lacked previous knowledge of how things were done in the factories. This approach was also thought to effectively broaden our understanding of how the environment looked like. Even though the observations was conducted through an overall unsystematic approach, two questions was constructed to keep in mind during the observations:

- Where can acid be gathered?
- What are the constraints while analyzing acid in field today?

A mobile camera was used to record the findings, and provided material for further discussion in the future.

Observation 1: Outokumpu
The first observation was conducted at Outokumpu in Avesta, a major stainless steel company. The observation started with a tour across the factory lead by employees from both Outokumpu and Scanacon. Due to the dangers of the chemicals used in the manufacturing process, helmets provided with safety visor was used as well as shoes with steelcap. First of the stainless steel manufacturing process was observed, where big slabs of iron is rolled into thin plates. The tour continued to the area where the concentrated acids is unloaded and distributed into the filtration system. Further into the tour the filtration hall was presented, where Scanacons filtration system was implemented. The tour ended in a laboratory room where the acid is regularly analyzed several times a day. During the tour several opportunities were given to ask questions in an unstructured manner.

Observation 2: Fagersta stainless
The second observation was conducted 10 miles from avesta at Fagersta Stainless in Fagersta. This tour started with equipping safety equipment (same as the previous observation), Then an half hour long meeting where safety was properly discussed. Especially the hazardous chemicals that are used when producing stainless steel was discussed. See chapter 3.7 Chemicals to read more about the dangers that the acids possesses. Then the observation continued as a tour through the factory in a similar fashion as the previous observation. Fagersta Stainless manufactures steel wires in different sizes. First of the manufacturing of stainless steel wires was briefly observed, then we were lead to Scanacons filter system, were photos where taken, and finally to the laboratory room where the acid is analyzed.
Figure 4.7. Pictures from the Observations at Outokompu Avesta and Fagersta Stainless. Photographed by Andersson Egerlid & Westin
4.3.5 BENCHMARKING - PUMPS

Based on the results from the interviews, pumps are the core of the filtration system and is the powerhouse that drives the entire system. Some demands appeared: the pump has to be able to handle corrosion and acids. The pump also has to be able to deliver a pressure of at least 3 bar and has to deliver a certain amount of l/m² h (Flux) to match the real conditions. A benchmarking concerning chemical resistant pump was conducted in order to see what is available on the market. During the first week at Scanacon it was evident that there was several types of pumps for disposal. Since the goal was to develop a functional prototype this had to be investigated. Size, weight and flow capacity for each type was inserted in a table to ease the comparison (see APPENDIX D). The benchmarking was conducted through research on the internet.

Figure 4.8. Pictures of different pumps. Seen from the left; Peristaltic pump, Centrifugal pump and Diaphragm pump. Photographed by Andersson Egerlid & Westin.

4.3.6 TECHNICAL REQUIREMENT SPECIFICATION

In order to compile all the information found during the research phase in a comprehensive way a technical requirement specification was formed.

A requirement specification states what a product or system should do and which requirements it should meet. The specification can for example include ergonomic, economic, physical, functional and quality requirements. When writing a requirement specification it is important to not present solutions on problems but instead objectively present desires and requirements that has appeared during the research phase. The specification is a document that is encouraged to be altered and updated as the project advances and new information shows up. (Karlsson, Osvalder, Rose, Eklund & Odenrick 2010)

Since this project aimed to solve a fairly complicated problem in an hazardous environment it was important to identify requirements. Both technical requirements, such as that the product should function with acid, but also human desires, such as that the product should be easy to use. This has also a direct correlation to the research questions formed in Chapter 4.1 design process. The results was listed in a table with two columns, one for requirements and one for desire. The TRS can be found in APPENDIX E.
4.4 DESIGN

The research phase served as an foundation for the second phase of the project; The Design phase. During this phase a layout for the system was created, several components were designed and a P&ID (flow chart) was created. As explained in the beginning of this chapter, the entire project was conducted through an iterative approach, many methods were therefore used several times at different times. Some methods did however particularly belong to the design phase, these methods were: Brainstorming, Visual communication and P&ID in order to create ideas. Other methods that were used during this phase were CAD, Rapid Prototyping and Interviews to evaluate the ideas, to ensure the functionality.

4.4.1 SYSTEM LAYOUT

The requirement specification together with other information gathered in the research phase led to the decision of creating a product, that could solve the problem of selecting filter cloth for the ASRA system. The decision to make a product that could solve these problem, rather than a calculation or theoretical solution, was made by two reasons: 1 - It became clear that the decision making depended on several different variables, a strictly theoretical solution would risk missing many variables and might give an unreliable result. 2. We who were given the task to solve the problem are trained specifically in product development and therefore felt more confident in solving the problem that way. A product can also consider all the different variables that affect the ASRA better than a theoretical method would.
The components that we thought were needed to reliably deliver a recommendation for a filter cloth were:

- A small Pump.
- A sealed cylindrical chamber in which a filter candle wrapped in a filter cloth can be placed for testing. (inlets and outlets for acid, water and air. The chamber should also be able to be opened for cleaning and changing of filter cloth.)
- A filter candle.
- A method for detecting particles.
- A pressure gauge.
- A control system.
- Electrical power to the system.
- Hoses in acid resistant material.
- A container in which the acid that will be analyzed can be placed.
- A flow meter.

The first step in the Design phase was therefore to develop system layout designs based of the newly presented components. The purpose of the layouts was to get an initial overview of what components are needed and how they should be arranged in order to fulfill the demands identified in the technical requirement specification conducted in the research phase. The layouts were produced by implementing the ideation method brainstorming. The philosophy of this design was to rapidly test several filter cloths and simply see which one that worked best without having to interact and interrupt the real ASRA system.

Brainstorming is an idea generation method created and coined by Alex F Osborn 1939. Osborn describes the method as a "creative collaboration by groups" (Osborn, 2013). The purpose of the method is to ease the creation of ideas and is useful when solving problems in a short period of time. (Osborn has very critical rule : during a brainstorming session critic is not allowed, all ideas are equally good, this is to prevent the stimuli for the creativity to go down. Osborn (2013) also mention the importance to find a suitable number of participants, to many attendants may result in a situation were dominant persons take over and limit other participants ideas. Persons that have a negatively attitude towards the problem should be avoided as they may damage the creativity of the group. A brainstorming session can either be performed in written texts and words or in pictures/sketches. (Karlsson, Osvalder & Rose, 2010).

The brainstorming session was performed by Fredrik and Axel solely, in accordance with Osborn (2013). In order to enhance the understanding of the layouts and create discussions to advance forward. Visual communication was implemented as an ideation method to visualize the layout sketches during the brainstorming.

The simplified version of visual communication defines as "a set of visual resources to communicate a set of ideas, attitudes and values to other" (Machin, 2014). Through simple and rough sketches it's easy to make yourself understood since a picture has a higher informational value than words. Visual communication does also cross language barriers since they have “brought with them meanings of global references” (Machin, 2014). The sketches was created in powerpoint in order to quickly create simple and repeatable figures and layouts to give more space for the brainstorming. Five layouts were created: (see figure 4.9-4.13)
Figure 4.9. Layout 1. This system can test four different filter cloths at a time by using four filter chambers, four analysing containers and four pumps driven by pressurized air. Illustrated by Andersson Egerlid & Westin.
Figure 4.10. Layout 2. Like the previous system this one is able to test several different filter cloths at a time by using several filter chambers and several analysing containers. This system uses peristaltic pumps instead of pressurized air. Illustrated by Andersson Egerlid & Westin.
Figure 4.11. Layout 3. In this system only one analysing container is used. The idea is that whilst one cloth is analysed other test can be prepared which saves time. Illustrated by Andersson Egerlid & Westin.
Figure 4.12. Layout 4. This system doesn’t use any pumps. Instead pressurized air is introduced into the initial container which forces the liquid to travel through the hoses into the filter chambers. The liquid cannot go back to the starting chamber and the system therefore demands a second chamber where recycled acid can be dumped. Illustrated by Andersson Egerlid & Westin.
Figure 4.13. Layout 5. A stripped down system where only one filter cloth at a time is tested. This system is the smallest and also the most transportable system. Illustrated by Andersson Egerlid & Westin.
4.4.2 PERISTALTIC PUMP EVALUATION

The benchmarking of pumps in correlation with the system layouts led the project into further investigation of the peristaltic type, as this pump seemed to be the most suitable for its purpose. It is small and powerful and the only thing needed to be chemical resistant is the hose which contains the acid. The pump transfer liquid by rotating a wheelhouse that trapps and propels it in the direction of the rotation (see figure 4.14). The wheel can rotate in both directions. Therefore a small peristaltic pump was purchased and a first product evaluation was performed with the help of design of experiments (DOE). The DOE was conducted to validify the functionality of that pump, as well as further enhance the knowledge about dead end filtration.

Design of experiments (DOE) is a method that describes a way to create experiments to evaluate ideas. This method is typically used by engineers to increase the understanding and knowledge by exploring, estimating or confirming products/processes (Antony, J. 2003). The method is divided into four phases:

- Planning: The planning stage aims to problem recognition and formulation: What needs to be investigated? How is this going to be tested? Where and by whom is this test going to be performed?
- Designing: The designing stage aims to solve the design of the experiment in order to test the previous stated questions.
- Conducting: The conducting stage aims to perform the experiment at the designated area which was decided in the planning stage. Thus prior executing the experiment: availability of material, parts, operators, machines etc needed for the experiment needs to be investigated.
- Analysing: The analysing stage is the last one, its during this stage the results are analysed and interpreted in order to present valid conclusions.

In accordance with (Antony, J. 2003) DOE, our design of experiment was divided into the four phases.

Planning:
The main objective concerning the functionality was to investigate the maximum pressure the pump could produce and also enhance the understanding of dead end filtration. It was decided that the pump should be tested through a dead end filtration test conducted by Axel and Fredrik in Scanacons workshop.

Design:
In order to establish a design that could test the pump a brainstorming session were held. In accordance to (Osborn, 2013). During the brainstorming session there were three attendants, Fredrik, Axel & Karl Sjöblom whom is a pro-

Figure 4.14. Illustration of how a peristaltic pump functions. Illustrated by Andersson Egerlid & Westin.
cess engineer at Scanacon. He was invited since he sits on a vast amount of knowledge when it comes to manufacturing products. The goal of the brainstorming was to develop a functional solution in order to validate the pumps functionality. Based on (Karlsson, Osvalder & Rose, 2010) a whiteboard was used in order to visualize the ideas, to enhance the power and the ability to form a discussion and improve each others ideas. The design was based upon a pool filter which served as a container since building a container from scratch was deemed very costly and time consuming (see figure 4.15). A analog pressure gauge was implemented in the design in order to give direct visual feedback of the pressure the pump delivered. When the design was finished Karl created the prototype at Scanacons workshop in Spånga.

Conducting:
Before the experiment could be conducted, the pump had to be modified in order to connect it to a voltage converter which enabled speed control. To simulate acid filled with metal particles, solutions of water and coarse ground black pepper, iron oxide and paprika powder was blended. A few trays and buckets had to be bought to prevent spillage. The experiment was then conducted by Axel and Fredrik (see figure 4.16).

Analysing:
The analysation of the result were directly visualised and noted thanks to the analog pressure gauge. The pump could transfer 30 liters of liquid per hour at maximum speed.
4.4.3 PROTOTYPING FILTRATION CHAMBER

Based of the system layouts it was time to investigate the individual components of the system. The first component investigated was the chamber were the filtration process takes place. In order to not miss out of any crucial functions the design of the chamber was thoroughly thought through and a brainstorming session with one of Scanancons experienced service technicians, Karl Sjöblom, was conducted. The brainstorming was conducted in order to find a way for the acid to enter the container, but also maintain an easy and safe access to the filter staff without disconnection hoses etc. The chamber should also simulate the ASRA chamber and afford a safe usage since the chamber is going to be pressurized. Thirdly a configuration of inlets/outlets connected to measurement systems as for example a pressure gauge had to be figured out.

During the session, the whiteboard was used yet again as it proved to be a good way of visualising ideas through sketches and formed discussions around the matter. A few sketches was refined after the brainstorming to enhance the visual communication. It was decided that the filter candle with appurtenant filter cloths from the Fundabac system should be implemented in the design (see figure 4.17). As it was a small scale replica of the filter candles used in the ASRA system. The design of the container became very complicated to visualise by hand, the brainstorming were continued with Fredrik and Axel solely with the usage of Computer Aided Design (CAD), (see theory chapter 3.5.2 CAD for more information). The CAD tool used was Siemens NX 12 and was very efficient when investigating the configuration of the container as the tool enabled several features to quickly see how parts intersected etc which otherwise would have been nearly impossible and very time consuming to do with pen and paper. Through the usage of...
CAD the iterative design process became very clear as this method provided several stages of redesign and evaluation in fast order to achieve a final design. The final design consisted of two parts: a chamber and a lid.

Since the functionality for this project was of essence the design had to be tested practically. In order to perform a design of experiments in the future, the design had to be physically created. As the design was very intricate, it was decided to use a method called Rapid Prototyping in order to speed up the manufacturing process (see theory chapter 3.5.3 Rapid Prototyping).

As the design already existed as a CAD substrate the only problem left was to find a 3D printer. KTH’s prototype center was contacted where access was given to a 3D printer of type Ultimaker 3, the only printer that can print using a material (in this case Polypropylene) that fulfills the demands of safety as it’s a plastic often used by Scanacon. Two models were created with different parameters to refine the structure (see figure 4.18).

### 4.4.4 REDESIGN OF FILTRATION CHAMBER

At KTH’s prototype center it was discovered that the chamber part was too big to 3D-print in the Ultimaker 3, hence another solution had to be found. In order to manufacture the chamber a different method had to be implemented to produce it. A company called Åbax mekaniska verkstad (mechanical workshop) was contacted, which is one of the head suppliers of CNC milled components to Scanacon. For them to be able to manufacture the chamber through CNC milling the part had to be redesigned yet again due to the tool’s limit. CNC milling stands for computer numerical controlled (CNC) machining and milling is a cutting process similar to drilling (thomasnet, 2018). Through a quick brainstorming session the part was divided into 3 smaller parts which would afford to be welded together later on. 2D-CAD blueprints were sent to the workshop as a foundation to produce the prototype (see figure 4.19).
Figure 4.19. Extracts from the drawings which was sent to Åbax. Created by Andersson Egerlid & Westin.
4.4.5 P&ID - SYSTEM LAYOUT

In order to finalize the hose/valve configuration in order to determine a final theoretical system design. A method called P & ID was used. It stands for piping & instrumentation diagram and is a standard industry method used to, in detail, visualize physical process flows in the industry (Lucidchart, 2018). P&ID is basically a 2D blueprint which shows the piping, vessels, instrumentation and control devices in the shape of lines and symbols in accordance with the International Organization for Standardization (ISO, 2015). According to (Lucidchart, 2018) P&ID is preferably implemented as a way to improve maintenance, modification and design as it gives the user a good overview in comparison with the physical process which can be hard to visualize.

The method was used in combination with a brainstorming session together with Scanacons R&D manager, David Stenman. The goal was to find a reliable solution, that would function as a blueprint for what components are needed, and furthermore, what components exist in stock(such as valves, hoses and clamps) and what needs to be ordered. As mentioned before the P&ID method gives a good and fast overview instead of trying to design the whole system 3-dimensional. A whiteboard was used as a medium for visual communication to form discussions around different solution to how everything should be interconnected.

The P&ID (see figure 4.20) was conducted in accordance with Autodesk’s (2018) vision of a P&ID, which should include (if there are any):

- Equipment (such as pumps, tanks, and vessels)
- Nozzles (such as flanged or flow)
- Instruments (such as control valves, flow meters, and instrument bubbles)
- Inline components (such as valves and reducers)
- Non-engineering items (such as connectors, flow arrows, and other items that are placed on a drawing but do not contain any reportable data)
- Pipe lines (such as primary line segments, secondary line segments, and jacketed pipe segments)
- Signal lines (such as electrical, hydraulic, and pneumatic)

Figure 4.20. Photograph of P&ID with all the components, electrical wiring and hoses. Photographed by Andersson Egerlid & Westin.
4.4.6 TURBIDITY SENSOR

One of the biggest issues based on the interviews was to measure the amount of particles left in a filtered acid sample. Based on the benchmarking conducted in the context phase (chapter 2.2.2 Benchmarking) we decided to use turbidity as a mean to detect particles.

In order to investigate if a turbidity meter would suit our design, a couple of small turbidity sensors was bought for 10 $ /piece (see figure 4.20). The sensors delivered a voltage between 0-5V that changes depending on how clean the tested medium is (dfrobot, 2017). According to dfrobots description of the turbidity sensor, a higher voltage value equal lower turbidity, which in turn means fewer particles.

To test these a DOE was formed in accordance with the definition given by Anthony (2003). As mentioned earlier the DOE method was divided into 4 phases (Planning, Design, Conducting and Analysing).

Planning:
The goal was to establish an understanding for the connection between voltage, turbidity and g/L (grams of particle/L liquid). In addition to this investigate how the sensors functioned in daylight as they are intended to be mounted inside a dishwasher to control the dish waters purity were its pitch black. The test was decided to be conducted by Axel and Fredrik at Scanacons laboratory were different help instruments was situated, such as: measurement vials, beakers and weighing instruments.

Design:
In addition to this a small test rig had to be designed and created to equally test the sensors. Two vials were created one opaque and one transparent that enabled the sensor to be inserted at the top to function as a lid (see figure 4.22). The two vials was created to investigate if surrounding light affected the sensors.
Conducting:
To conduct the experiment a mixture containing water and aluminium oxide was prepared with an initial concentration of 2 g/l. In addition to this a PLC program had to be coded in order to receive and interpret the output signals from the sensor. PLC stands for Programmable Logic Controller and is according to Unitronics (n.d) a “ruggedized computer used for industrial automation”. A PLC system can be used for automation of specific processes, machine function or whole production lines in the industry. Siemens PLC was chosen because it is the system that Scanacon uses for their other products and applications.

The PLC functions with an I/O (input/output) model. It receives input from input devices or sensors, which is processed by the PLC’s CPU which in turn triggers outputs based on programmed parameters. Unitronics continues to say that “I/O can be either analog or digital; input devices might include sensors, switches, and meters, while outputs might include relays, lights, valves, and drives”. This means that the user can change the PLC’s I/O to get the right configuration. The PLC system is programmed by a separate computer and then transferred and downloaded into the PLC. Scanacon codes in Step7 which is linked to the Siemens PLC system.

Two different turbidity sensors were then tested to examine the voltage output, these numbers were directly inserted in an excel document, to enable further analysis later. In order to test the sensors’ accuracy a high end turbidity sensor was bought which delivers a direct NTU (see picture 4.23 & 4.24). The high end sensor was used to find the conjunction between the NTU value and voltage for the same mixture. Each sensor was tested in the mixture three times each to gain more trustworthy results. The mixture was then diluted to a new concentration of 1.75 g/l and the previous procedure was performed again. The test continued in the same order from 2.0 g/l to 0 g/l with 0.25 steps.

Analysing:
With help of Excel graphs were plotted to investigate if there were any anomalies between the results. (see figure 4.25)
Figure 4.25. Diagrams from the testing of the conjunction between Voltage and NTU. The top diagram shows that the connection between Voltage and NTU is nearly linearly. The bottom diagram shows the same linearity but this time between Voltage and g/L particles submerged in a liquid. Together these diagrams confirms that the small turbidity meter gives reliable readings which can be translated both into NTU and g/L. Plotted by Andersson Egerlid & Westin.
4.4.7 REDESIGN OF CHAMBER LID

As previously mentioned the project was conducted through an iterative design process were redesign not only was allowed but also encouraged in order to effectively find functional solutions. The first design of the lid proved itself to contain a couple of flaws mostly thanks to the chosen production method but also due to some design flaws. Rapid prototyping as a production method proved to be the wrong direction to go as it failed to deliver a desirable result. The structure was fragile and would not support the pressure applied during a filtration (see figure 4.26).

It was therefore determined that an another kind of method should be used for the manufacturing of the lid. This time it was chosen that the lid should be manufactured in a traditional way with a CNC (computer numerical control) mill. The change of manufacturing method did however demand an updated CAD model since some shapes that was possible to create by 3D printing was impossible to create by CNC milling. Siemens NX was used in correlation with a brainstorming performed by Axel and Fredrik in order to solve the problem. Whilst the redesign of the lid with regards to manufacturing was a float, one major problem surfaced: how should O-rings be implemented in order to provide a safe usage, since the system is going to be pressurized with highly corrosive acids.

An interview was conducted in order to seek guidance in the matter. The interviewed was Ola Rising an expert of mechanical fittings. He provided us with valuable input and folders filled with information. Where different configurations of the O-ring was discussed with regards to Pros and Cons. Two different solutions was created, with aid from Ola and the theory regarding O-rings and threads described in section 3.4.2 THREADS, in Siemens NX (see figure 4.27 & 4.28). In the first design the O-ring was squeezed between the male and female part. In the second design the O-ring simply seals the container by being applied on the male part and by friction alone seal it with the female part. Through a discussion with Rising it was concluded that the second design was best since it afforded an easier and foremost, safer usage.

Åbax mekaniska verkstad was yet again contacted to manufacture the lid. Due to the manufacturing method of CNC milling, very low tolerances was given which is perfect when installing O-rings to ensure that they work as intended.
Figure 4.27 & 4.28. 2 Different O-rings design. The picture at the top shows a design were the O-ring is pressed between two surfaces. The picture at the bottom presents a design where the O-ring instead slides between the lid and chamber. Created by Andersson Egerlid & Westin with advises from Ola Rising.
4.5 CREATE

The Create phase was the third phase of the design process and was all about manufacturing and building. Due to the nature of the iterative design process create have already played a vital role in the design phase with the usage of creating methods such as CAD, rapid prototyping and prototyping. In this phase the main focus is to take all the information from the previous phases and compile it into a product. This phase also took advantage of methods used before such as brainstorming and benchmarking to finalize the design.

4.5.1 WALL ASSEMBLY

Based of the P&ID brainstorming session conducted with Scanacons R&D manager, David Stenman (see 4.4.4 P&ID - SYSTEM LAYOUT) the P&ID blueprint was translated into the physical world. This was made it possible to visualize the system configuration in reality and to clarify the space every component needs. The translation were made by mounting every component described in the blueprint onto a carpented OSB wall (see figure 4.29). This was also the first attempted to create a prototype fully equipped with all components. First the pump was installed by Angelo Anguilli, a project engineer at Scanacon, who also built a control panel that allowed steering of the pump. For this assembly we could reuse the control system that were created during the peristaltic pump evaluation. However the control system needed to be somewhat modified with an On/Off button (see figure 4.29). Since different electrical components used different voltages Angelo installed some voltage converters and a coded a program for the PLC system.
Figure 4.29. Pictures of the 2D assembly of the system onto a OSB wall. The top picture shows the chamber, pressure gauge, pump and control system. The picture in the bottom left corner shows the control system and the bottom picture to the right shows the PLC. Photographed by Andersson Egerlid & Westin.
The lid and chamber was placed in the middle of the board and the peristaltic pump was connected to it via hoses. We installed a pressure gauge that allowed us to observe the pressure. The pump was connected to a plc system which provided it with electrical power and the plc system was connected to a laptop that enabled programming in order to maneuver the pump via simple buttons.

4.5.2 SYSTEM EVALUATION

Product testing is an integrated part of product development according to White (1946). In order to test and evaluate the newly built system, a method was created by us that enable the testing of all the components to investigate how they functioned in practice rather than in theory. Any flaws should be noted and photographed to enable the iterative process to take place yet again with rethinking and redesign if needed. When the wall assembly prototype was completed the system was tested several times with various solutions in order to see if there were any flaws with the newly installed components. The components that were tested were the lid and chamber, the pump and a pressure gauge as well as the electrical control system. By filling the chamber with help from the pump and sealing the chamber it was possible to observe whether the pressure went up, if the lid and chamber was completely sealed and how much pressure the pump could create in practice. All couplings and valves was inspected.

To fulfill one of the goals that emerged from the technical requirement specification, the desire to create a digital/automatic system, the regular pressure gauge was switched into a digital one. In order to evaluate the new pressure gauge new code had to be added to the PLC system.

During the initial test it was proven that the original peristaltic pump was a bit to weak and not reliable under longer system runs. Therefore Gregor Stalinski was contacted, since he was an expert of peristaltic pumps who works at Watson Marlow (a pump manufacturer). By explaining our system and requirements that the pump has to fulfill, Gregor was able to recommend us a pump that would solve all our problems (see figure 4.30). The new peristaltic pump was therefore purchased and installed. It was able to build up a pressure of up to 4.5 bar compared to 3 bar and transfer 78L/h compared to 30L/h. When these numbers are combined with the surface area of the filter candle (0,01035 m2 ) the new pump give a maximum flux (as described in the context, flux is the value of L/h multiplied with area surface) value of up to 7325L/m2h which is almost twice the flux for the ASRA system. Which means that the new pump is more than qualified.

Figure 4.30. Picture of the new pump with the previous pump as scale. Photographed by Andersson Egerlid & Westin.
4.5.3 FLOW THROUGH METER

As everything started to take shape on the OSB wall one final problem had to be solved in order to have a complete filtration system. It was to implement the turbidity sensor. The best method for this problem was to use the DOE according to Anthony (2003) because the turbidity sensor had to be investigate so see if it could be mounted directly on the system to send live feedback to the user instead of having to take manual samples every now and then. This would not just be time saving it would also be much safer as this enable less interaction with the system. A brainstorming was conducted with Karl Sjöblom the same process engineer as in the very first session, together with Axel and Fredrik to find a solution to mount the turbidity like a flowthrough meter.

The design involved a modified T-coupling that enabled the sensor to be fasten and connected to the outlet of the chamber. To prevent air pockets inside the coupling it was designed to stay vertical to remove all the air inside (see figure 4.31).

The design was then tested to see if it actually worked. To conduct the experiment a heavily saturated mixture off coffee and water was made. The T-coupling did function and was then installed on the OSB wall. Due to the electrical output the sensor gave, the readings became very easy to notice. The result from the first experiment initiated a second experiment. Were the goal was to investigate if the flow through meter was affected by color. Three bottles with food coloring was prepared and runned through the system. (see figure 4.32)

Figure 4.31. Picture of the flow through meter. Photographed by Andersson Egerlid & Westin.

Figure 4.32. Picture of the bottles for the color test. Photographed by Andersson Egerlid & Westin.

4.5.4 REDESIGN FLOW THROUGH METER

As the first flowthrough meter functioned very well, it was time to overlook the safety of the component, due to the T-coupling the design did not afford any mounting, it was simply pressed inside. This had to be changed without altering the functionality. A quick brainstorming session was conducted with Fredrik, Axel and Karl Sjöblom (process engineer) to solve the problem. The idea was to utilize the mount that came along the original sensor. The new flowthrough meter originated from a square plastic block of PP(Polypropylene) where a O-ring was used to seal the compartment where the readings took place with the mount that followed (see figure 4.33).
To evaluate the re-designed flow through meter, a test was conducted. This time it was water saturated with dirt and aluminium oxide to get particles in different sizes and weight in order to investigate a solution that has a higher similarity to the acids.

4.5.5 MODELING OF COMPONENTS

During the project several components have been designed and evaluated in order so secure a safe design and also validate the functionality. The last part of the project was to configure all these components into a single functional product. In order to do so, CAD was going to be utilised to conduct the configuration virtually to test different solution. But before this could be set in motion, the components had to be constructed in CAD. The components was constructed virtually in Siemens NX by Fredrik and Axel with the usage of a ruler and a caliper. Some of the components could be directly imported from the suppliers website.

4.5.6 CASING

As the components started to take shape in the CAD program, next task was to create a casing for all the components and find a suitable configuration. A brainstorming session was held to determine what the casing should fulfill. The brainstorming was conducted with a process engineer from Scanacon that travels the world a lot. By performing the session with him the aim was to get an insight on problems that can occur when traveling with dangerous goods. Also what he prefered as the most suitable solution. A whiteboard was used to write down keywords in a mind map like structure where CASING was placed in the middle using a mindmap it was easy to categorize the ideas (see figure 4.34).

Figure 4.33. Picture of the updated flow through meter. Photographed by Andersson Egerlid & Westin.
4.5.7 PELICAN HARD CASE

Based from the mindmap conducted in the previous brainstorming session, it was decided that the configuration of components should fit in a hard case bag with wheels. The bag was chosen with regards to portable ergonomics explained in section 3.3.3 PORTABLE ERGONOMICS. Apparently Scanacon uses hard case bags from Pelican when they travel since they are durable and suits their harsh work environment (see figure 4.35). As of this a benchmarking was initiated to investigate what types of hard case bags Pelican deliver, since they are already a supplier to the company. The benchmarking was conducted on the base of weight and size since all the components are to be fitted inside, it can not be too heavy when empty. It was an internet based benchmarking and the result was inserted in a Excel sheet for easier comparison (see APPENDIX F).
4.5.8 CASING DESIGN

In order to finalize the product a casing had to be made. By using the mind map from the previous brainstorming and the result from the benchmarking and technical requirement specification made in the research phase, CAD was used to discuss ideas as this made it easier to see directly how all the components would fit. An hollow box was created in CAD to act as a replacement for the hard case bag. This enabled the configuration of the components much easier. Drawings was then made out of the CAD file, in order for Scanacon employees to aid in the prototyping which was done manually. The casing was mostly made out of Polypropylene (PP) as this material is often used by Scanacon when manufacturing their own products. All the PP sheets was welded together to create a sealed and solid casing. The product were then assembled with the help of Angelo Anguillo, Roger Fröderberg, Jimmy Andersson, Karl Sjöblom and Karl Brodie (see figure 4.36).

In order to design for safety, Normans (2013) designing for error was be applied. If a coupling filled with hot acid suddenly bursts, how will the user avoid being injured?. To prevent this from happening a transparent safety lid was created to prevent any splash and minimize the area affected. A clear safety lid was constructed in clear polyvinyl chloride (PVC). Due to the transparency the user still have the opportunity to observe what is happening. A valve was added in the corner to enable easier emptying of the trough if a leakage were to happen. The design also separated the electricity from the rest of the product to prevent any liquids to from reacting with the electronics which would result in a malfunction of the product.

4.5.9 ACID TEST

The goal for the thesis project was to deliver a fully functional prototype, in order to achieve this the product had to be tested with real acid at a stainless steel company. But to be able to visit a factory a initial acid test had to be performed to determine any eventual flaws. Again a DOE was constructed according to Anthony (2003). By following Anthony’s (2003) way: the planning stage - consisted of investigating if all the couplings functions properly and if the sensors transmits to the PLC system and how a filter cloths functions. The experiment was decided to be conducted by Fredrik, Axel and Thorsten (vice president at the R&D department) in Scanacons laboratory where safety precautions had to be made. After the planning stage it is time for the design stage: however this time no improvements was made on the product design. As of this the Conducting stage could begin right away. Contaminated acid had to be initially heated to the right temperature to simulate the real environment. When it was ready the experiment was performed. Acid was pumped into the chamber and through the flow through meter and back into the acid tank (see figure 4.37). Everything that happened was documented through pictures and was verbally discussed. As of this the Analyzing stage became very clear it was noted on a paper what actions had to be made in order to fix the flaws discovered in order to enable a visitation at a stainless steel factory.
Figure 4.36. Assembly of product. Photographed by Andersson Egerlid & Westin.
Figure 4.37. Pictures from the first Acid test. Photographed by Andersson Egerlid & Westin.
4.6 DELIVERY

The final phase of the project was the Delivery stage where the product was completed. No new methods were used but specific to this stage were that a Risk analysis were performed as well as a field test of the product at a steel manufacturer.

4.6.1 RISK ANALYSIS

The first thing that was done during this phase were that a risk analysis were created. Even though the product were designed in order to be safe it is always important to carefully evaluate a product and identify potential risks. The filter analyser will be used exclusively with acid which made the risk analysis ever more important. Since Scanacon long have worked with products in a hazardous environment they already had a template for risk analysis that we used (see Appendix G). Along with the risk analysis template, a procedure template for our system was created that describes how to operate the product in a step by step manner.

4.6.2 FINAL DESIGN

During the final stage we also created some final renderings of the product that allows for easier explanation and visualisation of the product. The pictures were created in Siemens NX.
4.6.3 SHARP TEST AT OUTOKUMPU

The final thing that was done with the product before handing it over to Scanacon was to put it in the newly acquired hardcase bag and drive it to Outokumpu in Avesta where a final product evaluation was made. But before this could be done we had to visit the Company on a safety demonstration and to investigate the environment to locate water, electricity and compressed air outlets. The test started with a sample test were a bucket was filled with acid from Outukumpus acid tank. This was deemed insufficient as the amount of particles is limited and decreases over the filtration time. A new test was therefore performed where acid was directly pumped from the Outokumpu acid system into the product and out in their spillage tank, this way a homogeneous acid circulation was created with the same amount of particles at the whole filtration process (see figure 4.38).

Figure 4.37. Pictures from the Acid test at Outokumpu. Photographed by Andersson Egerlid & Westin.
4.7 METHOD DISCUSSION

When we dove into the project we had little previous knowledge of acid recycling but thanks to some early, deep unstructured interviews with cunning personal we quickly gained insight into the problems as well as an understanding for the connection between Scanacon and the stainless steel factories. This was then enhanced during our two observations at the stainless steel factories in Outokumpu and Fagersta Stainless. The unstructured interviews started with a few pre determined question that made the initial minutes of the interview semi structured just to get things rolling. By using the unstructured method we felt that a deeper connection could be made with the participant since the interview became more like a conversation. The RDCD design process which we developed specific for this project gave us the ability to whenever needed dive into research, design, and creation to widen our base of understanding without feeling that we jumped ahead in the process. Which can be compared to other processes which often are strictly divided into sections such as research, ideation, and creation stages. This gave us an upper hand to gather information and build a strong foundation to work from. By using the iterative RDCD design process, it was easy to test functionality in order to evaluate different components to attain a desired and suitable solution. The iterative workflow was however very hard to plan beforehand. We constructed a Gantt chart (the one visualised in chapter 4.2 planning) to use as an initial guideline, what we did not know at the time was how inter braided the stages would become. In reality the schedule came to look like the chart in figure 4.38, where the research, design and creation stages worked much closer than anticipated.

Scanacon Stockholm is very male dominated. All technicians and engineers are males which resulted in interviews exclusively conducted with male participants. In addition to the interviews, dialogues have been conducted with all the employees which has been just as valuable for us to gather quick data. But the dialogues shouldn’t be viewed as a sole method as it has a very spontaneous character, a question is asked during a conversation that creates a dialogue. It could at most be viewed as small interviews where one or two specific questions have been asked, without any recording or pre notice.

Figure 4.38. Illustration of how the process actually looked like. Photographed by Andersson Egerlid & Westin.
Brainstorming was a very useful method throughout the whole design process, as it is a process that quickly generates ideas. All our brainstorming sessions were conducted alone or at most with one additional employee from Scanacon. This could be viewed both as good and bad if interpreting (Osborn, 2013). He implies on the importance to find a suitable number of participants. The reason for only being three attendants often depended on the fact that it was hard to find time for several employees to attend at the same time. Based on the employees knowledge and our own it may would have been better if at least one more employee would have attended to enhance the creativity and discussion even more. These are of course just our own speculations and will probably never can be answered. However the usage of only three participants in total did make way for fast dialogues and a quick forth-bring of functional solutions. Illustrating was a very important tool when communicating ideas, during the brainstorming sessions as this made it easier to understand each other’s ideas.

Throughout the whole design process, validating the functionality of a component or system have been top priority, the usage of Design of Experiments method was perfect for this. The method enabled us to use our iterative design process model to its full potential by implementing research, design and creation all in one to find or test a solution. This was also the most challenging aspect of the project, there were no previous components or product to build from, neither any competitors that could be used for a benchmarking. To design a new product that function with the dangerous and corrosive acids demanded a close cooperation with Scanacon. Due to the DOE method and the close cooperation with Scanacon, the different components that are incorporated in the final product could be constructed during the development rather than manufacturing everything in the end. This made it easy to hold the timeframe and get the product finalized on time.

During the design process we created several prototypes and performed lots of tests in order to ensure that the product was safe to use even though it contained dangerous acid. At the time of the process it seemed appropriate to build these prototypes and conduct these tests but while reflecting back we realized that this approach was crucial for the success of the project.
CHAPTER 5

RESULT

This chapter presents the result that were achieved during the project. The method chapter focused on how the development process were performed. It also gave an explanation of why and when things were done. The result chapter on the other hand aims to present the actual result of the project. Since the process already have been explained, the result will be presented not by the different development phases but by the different components that together constitutes the final product. The main part of the final product is the filtration chamber, the flow through meter, the pump and the control system.

5.1 FILTRATION CHAMBER

The heart of the developed product is the filtration chamber in which a filter candle wrapped with a filter cloth is placed. The chamber went through several design stages and were perfected until it fulfilled enough requirements to be able to function as a pilot solution in a sharp situation.

5.1.1 THE POOL FILTER

The evolution of the chamber started with a pool filter which served as a foundation for what the filtration chamber later became. The pool filter chamber consisted of a chamber body, a filter candle and a lid (see figure 5.1). The lid could be opened in order to access the filter candle. In the lid there were also an inlet and outlet connection in which liquid was supposed to enter and exit the system. Into the inlet and outlet there were also hoses connected and the whole chamber were placed on a stand since the chamber could not stand on its own (see figure 5.1).

The pool filter was of course designed to filtrate water for a pool and not serve as a component for some peculiar filter cloth analysisation machine. It was therefore not especially strange that the design didn't fit right away. The lid was for example not ultimate for our product. The hoses that were connected to the lid made it complicating to remove the lid in order to replace the filter candle, something that were of major concern to us. The chamber were also a bit clumsy, again something that would not work for us. A third problem was that the chamber was made in materials that couldn't handle warm acid particularly good.
Figure 5.1. Picture collage of the Poolfilter. In the top right corner the pool filter can be seen hanging from the support structure. The bottom picture shows the entire system configuration with the power source, controls, pump, "acid tank", filter chamber and pressure gauge. Photographed by Andersson Egerlid & Westin.
5.1.2 CAD & 3D PRINTING

The next evolution step of the filter chamber mostly took place in NX with help from what we had learned from the interviews, prototypes and the Fundabac test. The first CAD drawings can be seen in figure 5.2 (to the right). As the pictures in figure 5.2 shows the chamber is equipped with four different holes (apart from the big hole where the lid will be installed) from which liquids and air are supposed to move through. In the bottom of the container two holes can be found, one hole that serves both as the inlet of acid and, after the test has been completed, the outlet that empties the chamber. The other hole located in the bottom serves as a hole from which pressurized air can be let in into the chamber in order to dry out and clean the chamber after a test has been performed. On the upper part of the chamber two holes that faces each other can be found. The holes are supposed to allow the liquid to either go through an recirculation hose to the initial container from which the acid is gathered or through another hose leading to a container in which the cleaned acid can be further analyzed (see figure 5.3). As the design evolved it was later found that the hole for recirculation was superfluous thanks to the flowthrough meter which continuously analyses the liquid (see section 5.2 FLOW THROUGH METER and figure 5.4). The inner diameter of the chamber was decided by combining the diameter of the small filter candle, two centimeters for the cakebuilding and finally an extra centimeter that allows for easier removal of the cake without damaging it.

In order for the design to work and at the same time completely seal the system from leaking, even under pressure of up to 3 bar, the design of the lid was crucial. Furthermore the liquid also has to go through the filter candle before being let out through one of the two holes in the upper part of the chamber. With help from Ola Rising (see section 4.4.6 REDESIGN OF CHAMBER LID) two appropriate grooves were implemented in the design, one below the holes and one above. The lid was also equipped with a t-shaped cavity which creates a path from the candle and lines up with the holes. To avoid a mismatching of the holes in the lid and chamber in case of the lid being twisted to hard, both sides were equipped with a small cavity that allows a bit more leeway.

Figure 5.2 CAD images of the filter chamber and lid. Created by Andersson Egerlid & Westin
Figure 5.3 Illustration of how our chamber works. Created by Andersson Egerlid & Westin

Due to the 4 O-rings, the acid only have two options to go, either Re-circ if the outlet is closed to build a cake, or forward if the Re-circ is closed to analyze the acid.

Recirculation for cake building

Outlet

Acid will be pushed through the filtercloth on the filter staff

Inlet for acid or water for cleaning

Inlet air to dry the chamber after usage
Figure 5.4 Illustration of the filtration chamber after the recirculation channel became obsolete. Created by Andersson Egerlid & Westin.
The lid was then 3D printed in PP(polypropylene). The 3D print did however not turn out as good as we had hoped for. The overall shape looked as it should and the threads worked perfectly but the composition of the material was very poor. The lid could not contain liquids without leaking and it could absolutely not contain liquids under pressure. The second print was in a bit better condition but still had the same problems (see figure 5.5).

Figure 5.5 Pictures of the 2 versions of the 3D printed lid. The first one was a little bit rougher than the second one. Figure 5.5 also shows how the 3D print was arranged first in the software and later in the 3D printer. Photographed by Andersson Egerlid & Westin
5.1.3 CNC MILLING

The chamber was too big to be 3D printed and was therefore created by CNC milling three PVC (polyvinyl chloride) parts and then welding them together (see figure 5.6). CNC milling generally gives higher tolerances than 3D printing, which also was the case this time.
5.1.4 ASSEMBLY & TESTING

When the body of the chamber and lid was constructed, we installed the pre-ordered o-rings and applied an appropriate lubricant that made it easier to insert the lid in the chamber. A couple of minor adjustments were also performed such as filling and removal of the end bit of the beginning and end of the thread in order to prevent self-locking since the plastic is a fairly soft material. The chamber was put to a range of tests during our project, it was exposed to high pressures, high temperatures, and corrosive acids. The chamber could handle them all (see figure 5.8).

After witnessing the great result of the chamber body, it was decided that the lid also should be manufactured by CNC milling. The CAD file of the lid was reworked and then sent for production. The lid was now also made in PVC (polyvinyl chloride) instead of PP (polypropylene) (see figure 5.7).

Figure 5.7 Picture of the CNC milled lid. Photographed by Andersson Egerlid & Westin

Figure 5.8 Picture of the chamber under some early tests. Photographed by Andersson Egerlid & Westin
5.2 FLOW THROUGH METER

As explained in the method chapter we decided to use a turbidity meter to solve the particle detection problem. The thought was (simply put) that by measuring the amount of particles left in acid after the filtration it would be possible to determine which cloth had worked best. In order to get a more accurate answer, the amount of particles left after a filtration of course needs to be combined with how long it takes to filtrate, how much pressure that builds up, how long it takes to build a cake and how long it is possible to be in the sweet spot before the filter cloth fully clogs.

5.2.1 TURBIDITY METER

The first evolution step of the flow through meter began with dfrobots turbidity sensors. In order to prevent that disturbing light from the surroundings interfere with the signal from the sensor, a small casing was built that ensures that no light can interfere with the turbidity sensor (see figure 5.9).

The first design is used by carefully filling the pipe(casing) with liquid, the turbidity sensor is then pushed against the top end of the pipe in order to seal it. The turbidity sensor connected to a plc system will then read a signal which is presented on a computer screen.

5.2.2 FLOW THROUGH METER 1

We quickly realized that it would be far more convenient for a user of the product if the sensor could continuously read the purity of the liquid passing through the filter. This would make sampling redundant and removing a work step were the user has to interact with acid. We therefore created a flow through meter (see figure 5.10).

The design works in a very similar way as the first design but this time the process is automatic. By connecting the flow though meter to the outgoing pipe from the chamber the meter is automatically and continuously filled with new liquid. It is however important that the new casing for the turbidity meter is filled from the bottom and up in order to minimize bubbles and making sure that the entire cavity is filled with liquid. If the forks of the turbidity meter is not completely submerged in the liquid the reading will not be accurate since the readings will vary between measuring liquid and air.
5.2.3 FLOW THROUGH METER 2

The first flow through meter didn't allow for a proper mounting of the turbidity sensor. The design was therefore improved so that the sensor could be fastened with screws (see figure 5.11). The function still was exactly the same.

5.3 PUMP

Another key component of the system is the pump. It is what gives life to the system. After a long search for a suitable pump it was decided that a peristaltic pump would be the best choice thanks to its lightweight and compactness (for more information of the pump choice see section 4.3.5 BENCHMARKING - PUMPS).

5.3.1 PUMP 1

Even though the type of pump had been chosen the exact model remained had not. After some further research a decision was made. The pump was as small as it possibly could be and still fulfill the requirement to handle over 3 bar. The pump looked as following (see figure 5.12).

5.3.2 PUMP 2

Even though pump 1 seemed be a perfect match for our system it was just a little bit too weak and had to work at maximum speed all the time to handle the requirements. This was not a reliable long term solution which led to the decision to upgrade the pump. The upgrade came with the prize that the pump now had to be significantly larger than before (see figure 5.13).
5.4 CONTROL SYSTEM

The product contains several parts and a couple of components that either output signals, requires power or require steering. It was therefore crucial that some kind of control system was developed along with the product.

5.4.1 MANUAL STEERING

The controls for the system also went through an evolution. The first controls were made for the testing of the pool filter. The controls consisted of a power supply unit (the black box) and a custom made relay along (see figure 5.14 & 5.15). With this controller it was possible to turn on and off the pump and adjust the speed of it. To be able to detect the pressure an analog pressure meter was used (see figure 5.16).

Figure 5.14 Picture of power supply unit. Photographed by Andersson Egerlid & Westin

Figure 5.15 Picture of the relay which controls the speed of the pump. Photographed by Andersson Egerlid & Westin

Figure 5.16 Picture of the analog pressure meter. Photographed by Andersson Egerlid & Westin
5.4.2 PLC

As the product grew and more components were implemented the controls was updated. The turbidity meter demand power supply. As explained in the context chapter the turbidity unit outputs a small current which has to be presented in some way. These problems were solved by installing a PLC system (see figure 5.17) connected to a laptop on which the turbidity was presented. The pressure meter was also updated into a digital one which also presented the values on the laptop screen (see figure 5.18 & 5.19). Further more the on and off button were transferred from the power supply unit into an extra consol which also has the ability to change the direction of the pump (see figure 5.20).

Figure 5.17 Picture of PLC system. The old power supply unit can be seen to the right. Photographed by Andersson Egerlid & Westin

Figure 5.18 Picture of the updated digital pressure gauge. Photographed by Andersson Egerlid & Westin

Figure 5.19 Picture of how numbers are presented on the laptop. The number to the right of the text saying "OUT" shows the current pressure in the chamber. Photographed by Andersson Egerlid & Westin
5.4.3 SEMI AUTOMATIC CONTROLS

The hoses in which the liquid flow through are controlled by a couple of relays that allows a user to perform intended tasks (see figure 5.21).

5.4.4 TOUCH SCREEN

In the final step for the evolution of the controls, the laptoped were replaced with a touch screen from which the speed of the pump can be adjusted and pressure and turbidity readings are presented (see figure 5.22). This eliminated the need for the laptop and the first relay.

5.5 ASSEMBLY

The product is made by combining several components into a system. The keyparts are the filter chamber, the turbidity unit, the pressure meter, the power supply and all the hoses.

5.5.1 WALL ASSEMBLY

The first version of the product was made by creating a two dimensional version that were assembled on a wall (see figure 5.23).
Figure 5.23. Pictures of the 2D assembly of the system onto a OSB wall. The top picture shows the chamber, pressure gauge, pump and control system. The picture in the bottom left corner shows the control system and the bottom picture to the right shows the PLC. Photographed by Andersson Egerlid & Westin.
5.5.2 CAD

Between the final prototype and the wall assembly, the system was created in NX. In NX the components were arranged until a suitable arrangement was found. The key components will first be presented one by one and then in the chosen arrangement (see figure 5.24, 5.25, 5.26, 5.27, 5.28, 5.29, 5.30 & 5.31).

Figure 5.24. The Pump. Created by Andersson Egerlid & Westin.

Figure 5.25. The pressure gauge. Created by Andersson Egerlid & Westin.

Figure 5.26. Exploded view of the Flow through meter. Created by Andersson Egerlid & Westin.

Figure 5.26. The Flow through meter. Created by Andersson Egerlid & Westin.
Figure 5.27. Exploded view of the filter chamber. Created by Andersson Egerlid & Westin.
Figure 5.28. The filter chamber. Created by Andersson Egerlid & Westin.

Figure 5.29. The touch screen. Created by Andersson Egerlid & Westin.
Figure 5.30. Arrangement of components with connecting hoses. Created by Andersson Egerlid & Westin.

Figure 5.31. Arrangement of components and the safety lid. Created by Andersson Egerlid & Westin.
5.5.3 FINAL PROTOTYPE

By following the design created in NX the final prototype was made (see figure 5.32). The components were already completed, all that remained was to create the casing for the product and the safety lid. The casing was made by welding several PP sheets together and the safety lid was made by welding PVC sheets together. Then the components were mounted onto the casing. We also named the product FA100.

Figure 5.32. Picture of the completed product, named FA-100. Photographed by Andersson Egerlid & Westin.
5.6 FIELD TEST

Before wrapping up the project, the product was evaluated and tested in order to see if it actually could solve the problems that it was made to handle. The goal was to take the product to a steel manufacturer and do a real test but before we could do that some requirements had to be fulfilled.

5.6.1 ACID TEST

After the prototype was completed we performed a test with acid to ensure that the product could handle it and to see that there were no production flaws. After the test were competed it was decided that some guide flanges should be added (see figure 5.33).

5.6.2 RISK ANALYSIS

Before putting the product through the final test, a risk analysis were created that aimed to identify any risk that might occur during a test run. The analysis also contains a step by step guide of how to perform test. The risk analysis can be found in the appendix.

5.6.3 OUTOKUMPU

After the acid test checked out and the risk analysis were made we were allowed to take the product for a test run at Outokumpu (see figure 5.34). During these test it was concluded that the FA100 effectively could analys the acid in a significantly faster time than what was previously possible. Thorsten Schneiker from Scanacon who joined us on our trip to Outokumpu in Avesta were very pleased with the result.

Figure 5.33. Picture of the product with the added guide flanges. Photographed by Andersson Egerlid & Westin.

Figure 5.34. Picture of acid before and after it went through the FA-100. Photographed by Andersson Egerlid & Westin.
6. DISCUSSION

This chapter discusses the outcome of the entire project. First the result is evaluated and discussed followed by a section that handles future work of the product.

6.1 RESULT

As always when a product is to be developed it is important to figure out exactly what is asked for. By working close to Scanacon and always listening to the problems that they were experiencing we were able to create a product that is able to solve their problem of selecting an appropriate filter cloth. Scanacon is a company that has deep knowledge in their field of work. By combining their knowledge of their branch with our industrial design background it was possible to go from a problem statement to a product in just a couple of months.

However some obstacles had to be conquered along the way, the biggest of them was lead times. Gross & McInnis (2003) is describing lead time as two separate lead times, the first is the internal lead time, and the second is supplier lead time. Supplier lead times are the times needed for a supplier to produce and deliver an order and an e.g. of internal lead times could be employees not being able to help all the time due to their own time frames.

During this project both lead times have been encountered, were the lead time from suppliers have had the biggest impact on the time frame. As the product demanded parts from different suppliers in order to be functional, such as valves and hoses that needed to be corrosive resistant to the acid. Sometimes the options for ordering or manufacturing have been limited which has resulted in long lead times. At few occasions the design was even updated during the waiting time, e.g. O-rings which results in outdated parts and a waste of the budget. This problem was directly connected to the testing and experimenting of certain solutions which could not be performed before the parts were available at our disposal. Unfortunately there was not much that could be done to avoid the waiting. If parts
and components had been ordered in advance to save time, we could not have been sure that the right parts was ordered since the design was incomplete. As Scancon’s own employees had their own tasks some internal lead times occurred, with people being abroad on service errands. This demanded a constant dialog with the employees in order to plan in advance and give the employees a heads up for coming help in order for them to plan their own time. By doing this the product was done on time.

The product which we named FA-100 is able to within a day test several filter clothes and at the same time present the user with values which can be used to compare the different cloths. Even though it still takes some time to complete the tests, the upgrade makes the task several magnitudes easier and quicker. Before the product it was not even possible to compare, let us say, 10 filter cloths for a single application since it would have taken far to long.

### 6.2 CONTRIBUTION

Our design aids Scancon in their field work, by cutting time and effort to find the most suitable filter in a controlled and safe environment. The product design is focus on usability and affordance to ease the workflow and the risk of injury. FA-100 will support Scancon’s technicians worldwide due to its portability, and cut the down time of the stainless steel industry when service/maintenance is needed. The sole fact that the product is 100 % functional and tested in a real acid usage environment with good results proves the effectiveness.

As discussed in the introduction, new potential stakeholders for this product could be every company that uses filtration in their line of work. Due to the materials used in the product it is extremely versatile and can handle any situation since it is already designed to withstand the most harsh work environment one could find. By this Scancon has the ability to broaden their spectra and start viewing towards other industries in order to spread the company name by selling the FA-100 filtration analyzer or use it and offer services.

The usage of different methods of prototyping showed the employees at Scancon the effect of evaluating and testing ideas practically in order to evaluate the theoretical ideas. Rapid prototyping had a positive effect on the company and everyone seemed eager to learn more about 3D-printing to implement it as a method of development for future projects.

### 6.3 RECOMMENDATIONS AND FUTURE WORK

Based of the technical requirement specification conducted during the research phase, one development would be to digitize everything. At the moment speed regulation of the pump is manual and have to be adjusted by viewing the monitor displaying the pressure inside the chamber. This is a little tricky as the peristaltic pump has a inhomogeneous flow at low rpm, which makes the pressure to jump up and down a little. Digitalizing the pump speed would imply a safer usage due to the fine tuning adjustments a sensor could do. To avoid a homogeneous flow at low rpm a peristaltic pump with a greater number of rollers would be ideal as this will cut the portions of acid with each turn and the portions will be closer in time.

The product should also be fitted in a bigger hard case with more support foam to handle transports better, to protect the technology inside. This will also provide room to bring service tools and spare parts for the product that is necessary.
6.3 CONCLUSION OF RESEARCH QUESTIONS

This section wraps up the thesis by reconnecting with our initial research questions.

6.3.1 How can a solution in a quick and easy manner help a user select the optimal filter for a filtration system?

To get a complete answer to this question one should read the entire thesis. In short, our answer to this question was to create a product that analyzes different filter clothes and lets a user compare them with each other by simulating the filtration process of the ASRA system.

6.3.2 HOW CAN A SOLUTION PROVIDE A SAFE USAGE?

By diving deep into the theories concerning usability and affordance, the design took shape to cover all possibilities of errors that could occur based on the (Norman, 2013) designing for error principle. And at the same time, provide an easy usage that made the task of finding the right filter cloth, time-saving, and cut the amount of labor work in a dangerous work environment.

6.3.3 HOW CAN A SOLUTION BE PORTABLE?

By a thorough research phase and a close dialog with the employees of scanacon, the best solution was to create a small product that could fit in a suitcase to bring on an airplane. This had to be done with weight restrictions towards the airlines flight rules. In addition to this, the weight restrictions from Arbetsmiljöverket for heavy lifts (Arbetsmiljöverket, 2018) had to be included. The product itself had a handle incorporated in the middle of the design to ease the movement from the case to the table or counter.
REFERENCES


GANTT CHART USED FOR THE PLANNING OF THE PROJECT
Semi structured interview
(Translated from swedish)

Name:__________________ Interviewer:____________________Date:__________________

1. What is your official title and what do you do for the company?
(Vad är din titel och vad har du för arbetsuppgifter?)
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
__________________________________________________

2. How would you determine which filter that should be installed?
(Hur skulle du avgöra vilket filter som borde installeras?)
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
__________________________________________________

3. What are the pros and cons with this way?
(Vad är för- och nackdelarna med det här sättet?)
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
__________________________________________________

4. How does this affect the situation for the client and you (in terms of time and money)?
(Hur påverkar det arbetssituationen hos kunderna och för dig?)
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
__________________________________________________
5. What are the problems according to you?
   (Vilka problem upplever du?)
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________

6. What are the problems for the customer?
   (Vilka problem upplever kunden?)
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________

7. What would an ultimate screening tool look like according to you(desire/needs)?
   (Hur skulle ett ultimat screening verktyg se ut enligt dig(önskmål/krav)?)
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________

8. Does the customers have own screening systems?
   (Har kunderna egna testsystem?)
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
The steps were:

1. Fill the filter chamber by pumping liquid from the feed tank.
2. Pre filtrate by open and closing the valves so that the liquid is forced through the filter candle.
3. Clean the cloth by stopping the pump and letting air run through the filter cloth.
4. Refill the chamber by restarting the pump again.
5. Pre filtrate and start the filtration by opening and closing the valves so that the liquid is forced through the filter candle again.
6. Drain the filter chamber and candle when the filtration is finished by turning off the pump, opening the bottom valve and letting air at a pressure of 1-2 bar blowing out any remaining liquid.
7. Dry the cake on the filter candle by letting in air for 3-5 minutes.
8. Ventilate the filter chamber and slowly let the pressure sink in order to avoid that the cake gets blown away.
9. Remove the bottom of the filter chamber carefully. Raise the air pressure from 0 to 2 bar. Blow away the cake down to a container. Inspect the cake.
10. Reassemble the filter. Run the system with water before performing a new test in order to ensure that there are no leaks.
# BENCHMARKING - PUMPS

Table 1. Evaluation of advantages and disadvantages for different pumps. Concluded from the benchmarking.

<table>
<thead>
<tr>
<th>Pressure system</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peristaltic pump</td>
<td>Small and light pump that push liquid through a hose. The pump never gets in contact with the liquid and only the hose has to be chemical resistant.</td>
<td>It is uncertain if this pump can build up the needed pressure.</td>
</tr>
<tr>
<td>Compressed air into a sealed tank</td>
<td>No need for a expensive chemical resistant pump. Several hoses can be linked to the same tank.</td>
<td>Uses a sealed tank to build up pressure. Makes it hard to reintroduce liquids to the starting tank after the system is running.</td>
</tr>
<tr>
<td>Membrane pump</td>
<td>They can be very compact and they rely on external pressure hoses instead of a motor. This makes it easy to control the pressure of the input.</td>
<td>Because of the membrane the pumping process becomes pulsating, which gives a irregular pressure for the output. One pump can only pressure one hose at a time. Very heavy pump.</td>
</tr>
<tr>
<td>Magnetic drive pump</td>
<td>Strong pump that can build up the pressure needed.</td>
<td>Takes up a big volume and can only pressure one hose at a time.</td>
</tr>
</tbody>
</table>
## TECHNICAL REQUIREMENT SPECIFICATION OF THE SYSTEM

Table 2. User and technical requirements.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Requirement</th>
<th>Desire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>Able to bring on a flight</td>
<td>Fit in a suitcase</td>
</tr>
<tr>
<td>Weight</td>
<td>Max 25-30 kg</td>
<td></td>
</tr>
<tr>
<td>Safety</td>
<td>safe to use</td>
<td></td>
</tr>
<tr>
<td>Pump</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating Pressure</td>
<td>At least 3 bar.</td>
<td>2.5-3 bar.</td>
</tr>
<tr>
<td>Material of pump</td>
<td>Chemical and thermal resistant for strong acids</td>
<td>Up to 60 degrees celsius</td>
</tr>
<tr>
<td>Weight</td>
<td>Max 10kg in total</td>
<td>As small as possible</td>
</tr>
<tr>
<td>Filtration</td>
<td>Test at least 1 filter cloth</td>
<td>3-4 at a time</td>
</tr>
<tr>
<td>Filter chamber</td>
<td>Chemical resistant &amp; thermal resistant</td>
<td>Clear material</td>
</tr>
<tr>
<td>Filter candle</td>
<td>Easy to change.</td>
<td>Up to 4 candles, each require a separate filter chamber.</td>
</tr>
<tr>
<td>Filter cloth</td>
<td></td>
<td>Easy to change</td>
</tr>
<tr>
<td>Filter cake</td>
<td>Up to 2 cm thickness of particle cake</td>
<td></td>
</tr>
<tr>
<td>Backwash</td>
<td></td>
<td>Be able to simulate backwash.</td>
</tr>
<tr>
<td>Measurement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purity of fluid</td>
<td>Able to detect particles.</td>
<td>Digital/automatic</td>
</tr>
<tr>
<td>Flow Rate</td>
<td>Measure of flow rate.</td>
<td>Digital/automatic</td>
</tr>
<tr>
<td>Pressure</td>
<td>Pressure gauge.</td>
<td>Digital/automatic</td>
</tr>
<tr>
<td>Safety</td>
<td>Easy to use &amp; maintain.</td>
<td></td>
</tr>
<tr>
<td>Presentation of Result</td>
<td>Flow rate, pressure, cake building &amp; purity must be presented.</td>
<td>All information should preferably be presented on a single screen.</td>
</tr>
</tbody>
</table>
## BENCHMARKING - HARD CASE BAGS

<table>
<thead>
<tr>
<th>Typ</th>
<th>Vikt med skum</th>
<th>Dimensioener</th>
<th>Pris</th>
<th>Länk</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEU Storm 2790</td>
<td>8 kg</td>
<td>559 x 482 x 333 mm</td>
<td>2930, 40 SEK</td>
<td><a href="http://www.example.com">Länk</a></td>
</tr>
<tr>
<td>FEU Air 1557</td>
<td>3.7 kg</td>
<td>414 x 33 x 24.8 cm</td>
<td>2464 SEK</td>
<td></td>
</tr>
<tr>
<td>FEU Air 1607Y</td>
<td>7.3 kg</td>
<td>535 x 402 x 295 cm</td>
<td>2959, 40 SEK</td>
<td></td>
</tr>
<tr>
<td>FEU Air 1557</td>
<td>8.8 kg</td>
<td>559 x 446 x 331 cm</td>
<td>3593, 60 SEK</td>
<td></td>
</tr>
</tbody>
</table>
1. Prepare the system for test - Press the STOP button and turn the control to LEFT. Close the bottom valve, open the upper valve.

2. Start the test - Press the start button. Carefully adjust the speed (start slow and increase until max speed is reached). Observe the pressure value along with the turbidity value. Once the test, the pressure is around 2.5 bar.

3. Finish the test - Press the stop button, turn the control to the LEFT, close the upper valve, flip the switch to reverse direction of the pump. Press the start button and empty the chamber, let in air through the bottom valve, remove the lid and filter staff.

The FA 100 will be tested with acid.

First test with Acid in FA 100
system of any remaining liquid.

with air dispersed through the bottom valve. In order to stir up eventual sedimented particles, let in pressurized air to dry the

4. Clean the system - Reapply the lid (without filter stack) and pump in water and recirculate for a while, empty the chamber of water

lab title

2018-05-14

Frederik B. Axel

Method description and risk assessment

sc anos
Table 2: Identification of components that may pose a risk of accidents and/or ill health

| Component Around Plant | Criteria | RISK Assessment | CAS-IR | Solution
|------------------------|----------|----------------|-------|----------
| Hygiene Hazard         |          | 4.5                   |       |          
|                        |          | H2O2, water           |       |          

Note: The above table is an example of how to identify and assess the risks associated with chemicals used in the plant environment. The table includes criteria such as hygiene, RISK assessment, CAS-IR, and solution. The table is designed to help identify and assess the risks associated with chemicals used in the plant environment.

Table 1: Work Time Including Chemicals, Mixtures and Solutions

<table>
<thead>
<tr>
<th>Production Department:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other:</td>
</tr>
<tr>
<td>Project Department:</td>
</tr>
<tr>
<td>Red Department:</td>
</tr>
</tbody>
</table>

Risk assessment in Laboratory work with chemicals (AFS 2014:43)

2018-05-14

Hand B and J
<table>
<thead>
<tr>
<th>Component/Activity</th>
<th>Risk Mitigation Step</th>
<th>Likelihood</th>
<th>Consequence</th>
<th>Initial Action(s)</th>
<th>Predicted Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Filter chamber</td>
<td>Low</td>
<td>Minor</td>
<td>Not sold property</td>
<td>Liquid sight out</td>
</tr>
<tr>
<td>2</td>
<td>Couplings with the product</td>
<td>Moderate Risk</td>
<td>Unlikely</td>
<td>Liquid sight out</td>
<td>Liquid sight out</td>
</tr>
<tr>
<td>3</td>
<td>The pump is covered with a filter</td>
<td>Low</td>
<td>Likely</td>
<td>Not sold property</td>
<td>Liquid sight out</td>
</tr>
</tbody>
</table>

The pump has been covered. The pump is able to remain physically. There is a minor risk if the pump is not able to remain physically. The pump leaks. The pump leaks.
Execution: Press the stop button and the system is safe to leave until one can return.

Water outages: The system is safe to leave until the water returns. After the water returns the system can be cleaned.

Pressure in the chamber will automatically equalize to the outside pressure and no risk of burst can therefore occur.

Power outages: The product is completely sealed and in the event of a power outage the system can be left to wait for the power to return. The product will not be damaged.

If there are, describe risks and routines for power outages, water outages and evacuation.

☐ No ☐ Yes

Power Break, Water Cancellation and Definition

If yes above, which moments cannot be done alone?

☐ No ☐ Yes

Are there work moments, where work alone is not allowed?

☐ No ☐ Yes

Are rules for working alone taken into account?

☐ No ☐ Yes

Working Alone

Are there possible references and/or attachments?

☐ No ☐ Yes

References / Appendices

Method description and risk assessment

2018.05.14

Lab title: [Redacted]

Scancon
Equipment Inspection

Comment on Personal Protective Equipment:

Instructions: This includes both the need for self-checking and the need for external control as well as the time interval for control.

Equipment Inspection

Comment on Emergency Equipment:

Needs of emergency equipment such as alarms, etc.

Yes/No

Place to enter any other kind of info

Yes/No

Personal, including cleaning staff

Yes/No

Special instructions for other

Yes/No

Signs of safety

Yes/No

Such as gas bottles

Yes/No

Person in charge:

Yes/No

Name and telephone number of the


Required Type of Information / Type of Sign

Information on Sign / Type of Sign

2018-05-14

Feedback:

Lab Title:

Method description and risk assessment

SCANCON
Instructions: Below are the names of persons who are allowed to perform the work and/or a description of who is responsible for the performance undertaken.

Description of work moment may be performed by a person other than the one who made the risk assessment.

Preparation for accidents and waste

<table>
<thead>
<tr>
<th>Type of expected waste</th>
<th>Waste and waste management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planned waste management</td>
<td></td>
</tr>
</tbody>
</table>

Lab title: Felix B. Axel

Method description and risk assessment

SCANCONF

2018-05-14