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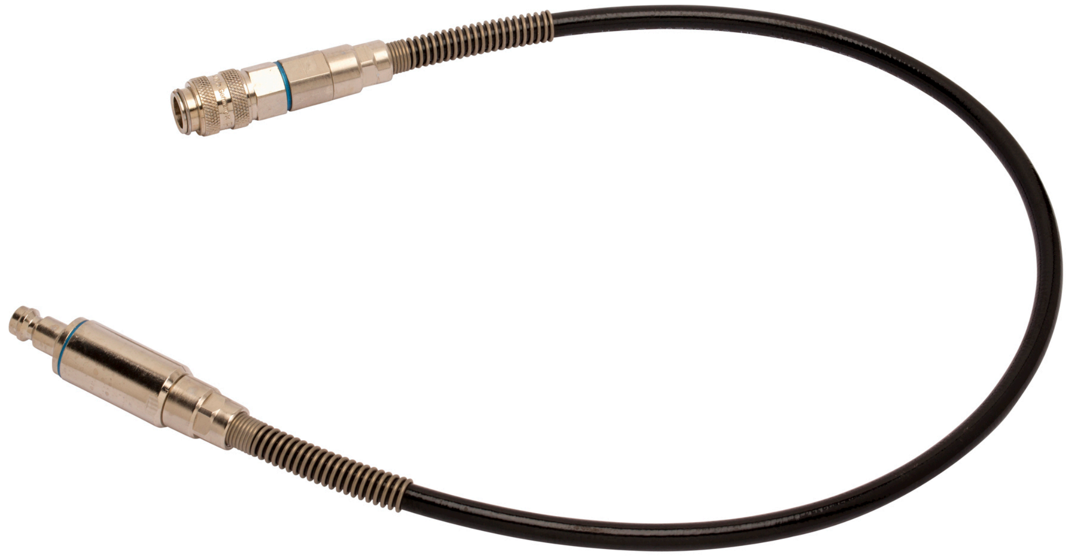

Kostnadsreducering av trycksslangar med bibehållen kvalitet

Cost reduction of pressure hoses while maintaining quality

Examensarbete för högskoleingenjörsexamen inom Maskiningenjörsprogrammet

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Cover:
Current TA-Scope hose.
Description found on page 9 under the chapter 4.1.1 Existing product.

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Preface

This thesis is made by Markus Nilsson and Simon Aspegren. The work was made during the spring of 2016 by order from IMI Hydronic Engineering located in Ljung, Sweden. IMI Hydronic Engineering is one of three divisions in the IMI plc concern. Beyond Hydronic Engineering there is Critical Engineering and Precision Engineering. IMI plc is notated on the London-stock FTSE 100 list. The work comprises 15hp and is the ending part of our Mechanical Engineering education at Chalmers University of technology.

We want to thank all employees at IMI Hydronic in Ljung for being helpful and encouraging during our time at the company. A special thanks to Daniel Jilderos and Christofer Sundqvist who has been our supervisors during the project. Your engagement and experience has been very much appreciated. We also want to thank Peter Hammersberg, our supervisor representing Chalmers. Always able to help us making progress and open new ways to think.

Simon Aspegren
Markus Nilsson

Sammanfattning

Syftet med detta arbete är att utveckla en högtrycksslang med avseendet att minska dess kostnad utan att påverka användarvänligheten och kvaliteten. Slangen används till att sammankoppla ett värme- eller kylsystem till ett mätinstrument som genererar värden. Dessa värden kan i sin tur användas vid injustering av systemet så det verkar på ett så effektivt sätt som möjligt. Problemet i dagens läge är att slangen är för dyr för att vara en konkurrenskraftig produkt på marknaden. Projektet utförs på uppdrag av IMI Hydronic i Ljung. Det är till deras mätinstrument TA-Scope som slangarna används till. Frågeställningarna under projektet har bland annat varit, var ligger kostnaderna i produkten och vad kan vi göra för att på ett så effektivt sätt som möjligt minimera dessa utan att påverka kvaliteten på produkten?

Ovanstående frågeställning ledde till att en omkonstruktion blev aktuell. Denna omkonstruktion ledde i sin tur till tre stycken huvudkoncept som med tiden utvecklades med hjälp av tester och analyser av koncepten. Koncepten bestod av tre olika lösningar på kopplingen mellan slang och snabbkoppling. De resterande delarna valdes sedan för att passa in med det valda konceptet. I slutändan valdes genom en urvalsmatris ett koncept som inte kunnat testas fullt ut på grund av att ett specialverktyg till stångbearbetningen krävdes för att kunna ta fram prototypen. Dock har tester på ett liknande koncept utförts med goda resultat vilket tyder på goda möjligheter hos det vinnande konceptet. Utifrån de kostnadsanalyser som gjorts kan man konstatera att priset på den nykonstruerade slangen får ett pris som är ca 46 % lägre. Denna kostnadseffektivisering fås genom att minimera antalet delar till slangen och att införa monteringen till IMI's egna produktion.

De enda avgränsningarna som applicerats i projektet är de kopplingar som används till den äldre versionen av slangen. Dessa kopplingar var tvungna att användas även i den nya omkonstruerade slangen. Även tilläggskostnader vid försäljning blev en avgränsning då arbetet utförs på IMI's R&D (Research & Development) som inte kontrollerar försäljningskostnader. Eftersom ett sätt att undvika försäljningskostnaderna mellan det företaget som i dagsläget monterar slangen är att sköta monteringen själv, vilket blev ett av målen som sattes under projektets gång.

Nyckelord: Kostnadsreducering, Produktutveckling, Kvalitet

Summary

The purpose with this work is to develop a high pressure hose with respect to minimise its cost without affect the user-friendliness and its quality. The hose is used to connect a heat- or cooling system to a measuring instrument which generates values that can be used when balancing the system in a way it can work in the most efficient way possible. The problem nowadays is that the hose is too expensive for being a competitive product on the market. The project on order of IMI Hydronic located in Ljung. It's to their measuring instrument TA-Scope that the hoses is used. The question formulation during the project has included, where is the cost in the product and what can be done to in the most efficient way minimise these without affect the quality.

The abovementioned question formulation led to a reconstruction of the hose became relevant. The reconstruction process led to three different head concepts which by the time where developed after tests and analyses of the concepts. The concepts consist of three different solutions to the connection between the hose and the quick connection. The remaining parts were then selected to fit with the selected concept. In the end one concept was selected by a selection matrix. The selected concept has not been able to be tested due to a custom made tool that was needed to produce the prototype. However, a similar concept has been tested with good test results and indicates good potential in the winning concept. By the cost analysis made, the total price of the new constructed hose had a price which is about 46% cheaper. This percentage is reached by minimising the parts of the hose and bring the assembly back to IMI's production.

The only limitations set before the start of the project was the connections which also is used to the already existing hose. These connections had to be used in the new version of the hose also. Additional costs from sales became a limitation because the work is executed on IMI's R&D (Research & Development) who doesn't control selling costs. Since a way to avoid the additional costs between the company which currently assemble the hose is to do the assembly yourself which became one of the goals during the project.

Keywords: Cost reduction, Product Development, Quality

Table of content

1. Introduction

In this initial chapter, the background to the project and the reason the task occurred will be explained. Also the purpose and goals with the task together with the limitations are presented to get a good understanding about from what point the project started.

1.1 Background

IMI Hydronic Engineering is a leading company in the energy-efficiency business in both heating and cooling systems, delivering unique solutions to their customers. In order to optimise the systems performance, they are using a measurement instrument called TA-Scope. The TA-Scope is used for measuring the differential pressure, flow, temperature and power over a valve in liquid borne heating or cooling system. The TA-Scope is connected to the system with two pressure hoses which also is connected to a sensor unit that wirelessly transmits information to the TA-Scope handheld unit. From the results, the system can be adjusted to minimise the energy consumption. The hoses used today was developed at the same time as the TA-scope project took place. At the time, the focus on price was not prioritised due to the tight time frame. The result of that, the hoses doesn’t fulfil the demands on the added value for the customer related to the price. Since the project was complete no further work has been made to minimising the price until this project started.

Picture 1- The current product in use.

1.2 Purpose and objectives

The two hoses connecting the sensor unit to the valve aren’t cost-efficient enough, which are leading to reduced sales. The mission in this work is to minimise the cost of the existing hoses without impairing the user-friendliness and the quality of the product by redesign it in a profitable way. To enable that, information about what parts that fulfil the customers’ expectations and demands is needed. Information that is limited today.

1.3 Limitations

A limitation in this project is the couplings between the system that is being tested and the hoses. The same type of coupling is also being used between the sensor unit and the hoses. These couplings are a standard in the business and can therefore be used on all of IMI's systems. The same type of couplings will be used in the reconstructed version of the hoses.

All changes to the product must be done without affecting its performance and quality. The hose must achieve the same strength with respect of pressure and temperature. A filter must be placed into the coupling to avoid out wash to flow through the hose and in to the sensor unit, just as in the original version of the hose. Hence that the project is done at the section R&D (Research and Development) no weight will be put on selling cost or other additional administration costs.

1.4 Project questions

The questions that this thesis is to answer are the following:
Questions to ask in the beginning of the project:

- Which part of the product will be optimised to minimise the cost?
- What is the best way to produce and assemble the product?
- Is it more cost-efficient to buy in finished parts?

Questions to ask in the end of the project:

- Did the product maintain its functionality and quality?
- Did the hoses get cheaper?
- Is the product attractive to the market?

1.5 Outline

This thesis is divided into three major parts starting after the theories on the next page. The three main chapter is Method, Result and Analysis. In the Method chapter the methods used to accomplish the final result is presented. The next one is Result and as the headline says all the results from the methods used is presented. The last part is the analysis, this chapter includes discussions and analysis of all the results.

2. Theories

In this chapter different theories are explained in order to understand the background to particular decisions that were taken during the project.

2.1 Quality feel

Quality feel is an abstract feeling giving the customer a better experience of the product. The word “quality” is referred in (Lai, Chang, Chang, 2005) as the ability to satisfy a customer. How to measure quality feel in a concrete way is very hard given that the feeling varies from different persons. The only way to control if the right amount of quality is reached is to ask the concerned parties and let them use the product.
“A feeling is an uncontrolled product feature” written in (Lai, Chang, Chang, 2005).

2.2 Kansei Engineering

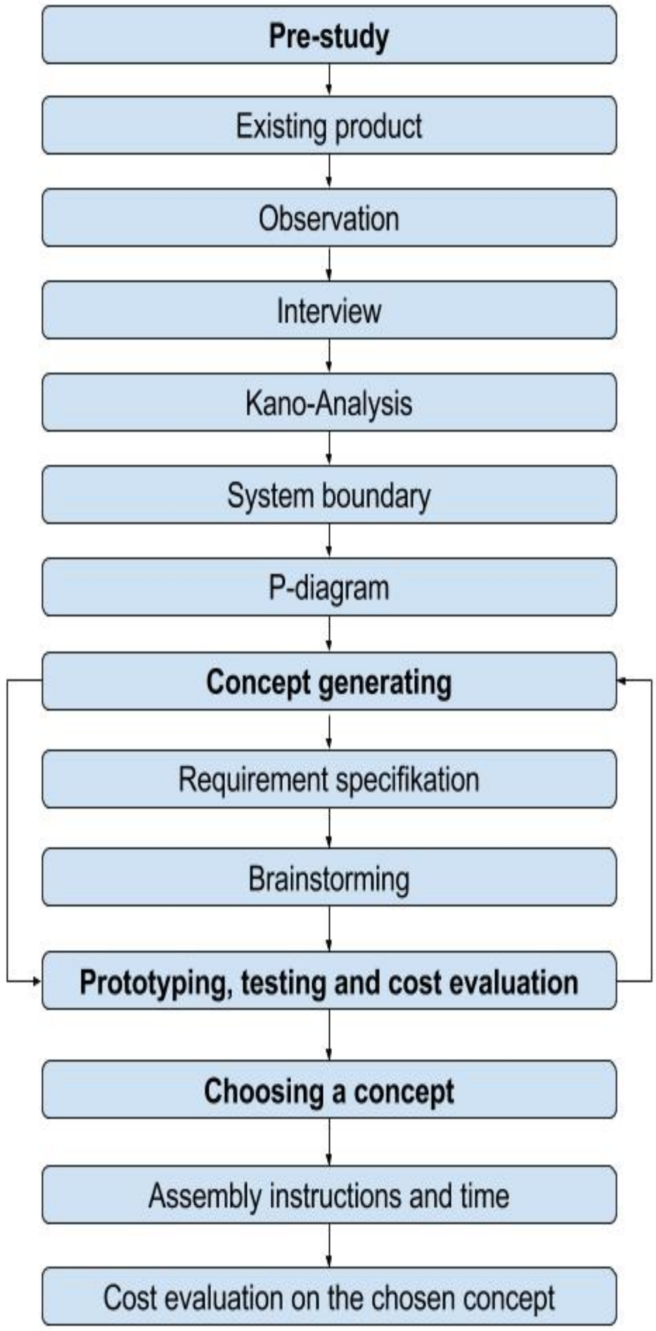
Kansei Engineering is a 30-year-old method, implementing customers demand and feelings into product function and design. Described in (Nagamachi 2002) product engineering is being more and more oriented on customer feel and demand, seen as invaluable for any product. Collecting data and opinions from the chosen segment, implementing this on your product to get customer satisfaction. An important step in Kansei Engineering is carefully choosing your segment asking the questions, given that opinions and demand vary a lot from different segments. Different persons from different segments want different things from a product.

2.3 Lean Six Sigma

(George, Rowlands, Price, Maxey, 2005) Lean Six sigma is a methodology using various methods improving management strategies and manufacturing processes. The Lean Six Sigma is based on using **DMAIC,** an acronym for the five different phases: **Define, Measure, Analyse, Improve and Control**. Within every phase there are different tools helping the project evaluating, improving and help to think creative. The methodology is based on completing the phases step by step with the tools described, at the end evaluating the results gathered, zooming out and think about it in a bigger perspective.

3. Method

In this following chapter all the methods used to accomplish what later is explained in the result chapter is presented. The chapter is divided into four parts, "Pre-study", "Concept generating", "Prototyping, Testing & cost evaluation" and "Choosing a concept". Under every main heading all the used methods will be theoretical explained under their own subheading.



Picture 2- How the Method chapter is built.

3.1 Pre-study

This pre-studies purpose is to find the most valuable part of the project concerning the price. More easily expressed, what make the already existing product cost so much and what can be done to minimise it. This step is very important to avoid unnecessary work that in the end shows up to be not that effective on the price reduction as expected. The pre-study will make sure the problem is 100 % understood and find parameters that effects the outcome of the new product during the manufactory or production etc. The pre-study also enables thoughts and opinions of the existing product to be gathered from both customers and people manufacturing the product. This is helpful when considering preserving the benefits of the product and minimise the changes of things that are appreciated about the product.

3.1.1 Existing product

An important step before starting the project is to evaluate the existing product. Taking it apart and finding what the different parts contribute to the different functions. Going through all the different parts and investigate how they interact with eachother.

3.1.2 Observation

A big part of the pre-study is observing the processes and the usage of the product. Giving a deeper understanding of reality, the limitations of a specific machine and understand what operations cost money. Observing the process and the process-time gives an understanding of how the cost can be reduced. Another important part of the observation is conversation with an operator working with the product, this gives another point of view of potential problems. Observe the product in use gives a view of how the overall impression of the product is. (George, Rowlands, Price, Maxey,2005)

3.1.3 Interview

In order to get a different angle on the problem and to learn what is important to the customer, a semi-constructed telephone-interview was made. Semi-constructed interviewing is an interview where both direct- and indirect questions will be answered (Paine, 2015). Choosing a telephone-interview was simple because of the customer's geographical location. Just one interview was made because of the information gathered and the value of the answers. The person chosen for the interview was a person who regularly is using the product, adjusting systems to their correct settings. Before having the interview, a few questions was put together. The questions helped getting a new perspective on how the product is perceived from the adjuster's point of view. The questions in the interview were semi-structured to make the person interviewed describe his feelings concerning the problem more detailed.

3.1.4 Kano-Analysis

A Kano-analysis is used in the project to get a better understanding of what is expected of the product concerning VOC (voice of customer). When using a Kano-analysis there are three different levels: Satisfiers, Dissatisfiers and Delighters.
Satisfiers are also called performance requirements for example price, "ease to use" or "simplified features". Dissatisfiers are also called basic requirements, what is expected of the product and dissatisfy the customer if not fulfilled. Delighters are things that will make the customer impressed by the product, that little extra that isn't expected when buying the product. (George, Rowlands, Price, Maxey,2005)

3.1.5 System Boundary

The reason the method "system boundary" was used was to limit the project and specify what part and sub-system that is relevant for the project. The system boundary method doesn't only describe which parts is relevant, it also describes the interaction between the parts and sub-systems.

The system boundary is made by identifying all the parts and present them in a block. Then draw and classify the existing interfaces between the parts. The next step is to determine where to put the system boundary. With other words determine what parts will be focused on henceforth.

3.1.6 P-diagram

P-diagram or Parameter diagram which is the methods full name is a method used to clearly describe what parameters that effects the outcome of the system under investigation. The main reason the p-diagram was made was to get a better understanding of how the products noise signals like tolerances effect the performance and quality of the finished product. By doing a detailed p-diagram a better understanding of what changes can be made and how the changes effect the outcome. When making a p-diagram you proceed from the finished system boundary and use the defined system in the p-diagram. The first step is to specify the intended and unintended output signals. The intended signals are the functions of the product while the unintended output is the errors with the product. Step three is to describe the input signals. The input signals are what the product need to provide the intended system outputs. Both the input and the output should be presented in measurable parameters. Next step is that the control parameters should be specified. The control parameters are parameters that effects the output and can be adjusted by the designers to achieve the desired output. The last step is the noise parameters; these are often divided into five categories. Piece-to-piece variation, degradation over time, customer usage, environment, and system interaction. All the noise parameters are unavoidable and effect the output negatively. They can in some cases be controlled even though it's not easy and often expensive. (George, Rowlands, Price, Maxey,2005)

3.2 Concept generating

When the evaluation step is finished it's time to generate concepts. The method used to produce ideas was brainstorming. Working in loops meaning that the concepts developed from the brainstorming is made into a prototype, then the prototype is being tested. The test results and analyses is the basis to new and even more developed prototypes. The concepts are developed to the point where it's considered a worthy opponent and is later on put into the evaluation matrix.

3.2.1 Requirement specifikation

A requirement specification was made, listing what is expected of the product in form of demands and what wishes are put on it. It's also a good way to start when getting ground for the testing later on in the project. The requirements listed must be tested to make sure the product fulfil the needs. Together with the Kano-model, requirement specification is great to collect and rate the different aspects needed to keep in mind when brainstorming. Making it easier to visualise and realise what is needed to be focused on.

3.2.2 Brainstorming

Brainstorming makes it possible to gather as many ideas as possible in a short amount of time (George, Rowlands, Price, Maxey, 2005). Brainstorming stimulates the creative thinking so it's important not to get yourself limited. It also makes sure that every group members opinion is considered. Every idea is important, providing new ways to think. It's more important to have a lot of ideas rather than a few good ones. Making it possible for other group members to build on another idea. You aren't allowed to criticise ideas and it's important not to allow one person to dominate the session. First after the brainstorming session you are free to organise, categorise and evaluate the different ideas. Preferably modelling the different concepts in a CAD program.

3.3 Prototyping, testing and cost evaluation

When the concepts are ready to be evaluated, prototyping is a method to get an impression of how good the concept would work in reality. The first prototypes made came from a 3D-printer just to get a good feeling about the size of the detail. Later on, steel details were made. On these prototypes, it was possible to perform tests. Every prototype was assembled with a hose to ensure the assembling was possible. Looking at the interaction between the parts and how it was perceived. Tests controlling leaks in air and water, both under room temperature and in a climatic chamber to simulate a hot medium. Also the possibility to assemble a bend protection to the hose was evaluated for the different concepts. After testing the product, the results were evaluated and different adjustments were made to the concepts to optimise it until it was good enough.

After making it through the testing all the different concepts were going to be cost evaluated. All the different parts was given an estimated processing time in the preferable machine. Dimensions, weight of the components and the selected material, together with the batch size gives the total manufacturing costs.

3.4 Choosing a concept

After testing and making all the cost evaluations it was time to choose the right concept for further development. As tool for selecting the concept most worthy and with the most potential a custom made evaluation matrix was used. The evaluation matrix consisted of eight different criteria which concern the value of the concepts. These criteria are rated from 1-5 due to the customer value but also the importance of the criteria for the project overall.

The three concepts evaluated in the matrix got a grade from 1-5 depending on how good the concept fulfil the criteria. Also an uncertainty level, low, medium or high which is a value on how uncertain the given value is. With all the values inserted into the matrix, a total score determines the winning concept.

3.4.1 Assembly instructions and time

The chosen concept will be given an assembly instruction and a specific assembly time to calculate the total assembly costs that can be included in the final price. Information about what operation, how long it takes and if assistance of a machine will be needed are presented. Helping to understand the different steps and evaluating the time to cut down on the cost.

3.4.2 Cost evaluation on the chosen concept

Finally, a complete cost evaluation will be made, comparing the price ot the new product with the current product. All the different parts are given a price and are compared to the corresponding parts solving corresponding function. The batch size is included in the operating and setup cost calculations.

4. Results

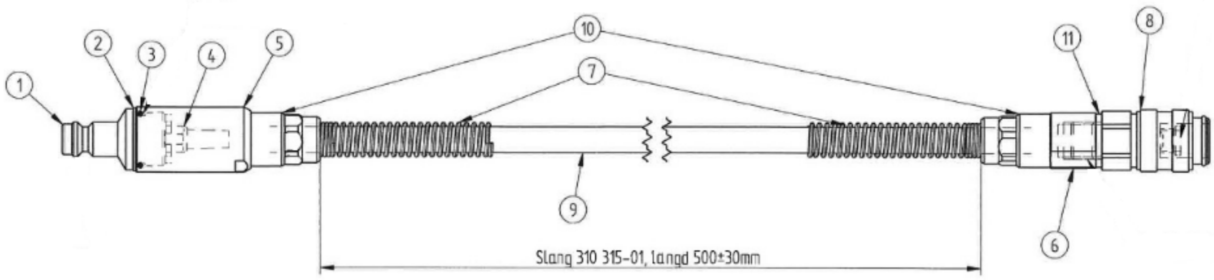
In this chapter all results from the already mentioned methods will be presented.

4.1 Pre-study

In the initial part of the pre-study information about the existing product were gathered. Information about all the different parts, the manufacturing method of them, total price of every product and the additional costs when selling the product. The hose was disassembled to enable every part to be thoroughly investigated. The product consisted of eleven different parts where IMI hydronic manufactures four of them by themselves (filter holder, union nut, filter house and hose nipple). The four parts are later sold to a sub-contractor that buy in the rest of the parts and assemble the hose and sell it back to IMI. That means there is three additional costs added during the whole manufacturing process after IMI have sold the hose to their customers. Cost calculations on every part and additional costs were given as a reference. A more detailed description of the hose follows below.

4.1.1 Existing product

The existing product consists as mentioned of eleven different parts. According to the picture (3), Part 1, is a male quick connection. The part is also used as a filter holder as picture (4 and 5) shows. The filter (part 4) is a brass feet silencer and is connected with a M5 thread on the backside of the quick connection. The filter is put into the hoses to prevent deposit from the measured system to flow through the hoses and into the sensor unit. This could potentially effect the values calculated. Part 2 and 11 in the picture below is a hose marking ring. It comes in two different colours, red and blue, and in two different dimensions. The purpose of the markings is to separate what hose is connected to the high pressure side and the low pressure one. The quick connection with the filter attached on the back side is connected with a M14 thread to the filter house (part 5). In between those an O-ring (part 3) is used to seal the connection properly without any leakage. The filter house is hollow enough to allow the fluid to spread out around the filter and minimise the risk of the filter getting clogged. On the side of the filter house where the hose is connected there is a pin with a hose barb that is pressed into the hose and then a union nut (part 10) that is connected on the outside to prevent the hose to expand when the hose is set under pressure and heat. The union nut is constructed to enable a bend protection (part 7) to be assembled under the nut and over the hose. The bend protection is left threaded because otherwise it gets wound up when assembling the union nut to the hose barb details. The hose (part 9) is a high pressure hose with a 1/8" dimension, enable to make a pressure up to 21MPa. In the other end of the hose another hose barb is connected into the hose but this time stuck on a hose nipple (part 6). The union nut and bend protection is assembled the same way as on the other side. The hose nipple got a female G1/8 thread where the female quick connection (part 8) part of the type RECTUS type 21 is connected. It's from this side the water flows when connected to a valve.



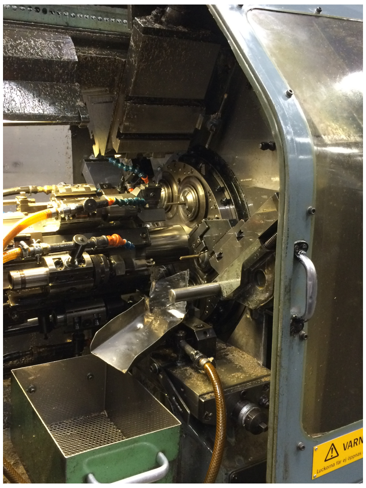
Picture 3- Existing product with numbered parts.

Picture 4- Male quick connection.

Picture 5- Male quick connection with filter unattached.

4.1.2 Observation

IMI Hydronic in Ljung has their own rod processing hall where four of the parts are manufactured as mentioned. In the processing hall there is some different machines. They have single spindle and multi spindle rod processing machines. The benefits of the multi-spindle machine is that it makes the parts in one sixth of the time compared to the single spindle one since it has six working arms (picture 6). The single spindle can only process one detail at the time but can on the other hand make more advanced details (picture 7). For example, the filter holder is made in the single spindle machine, the reason it's not made in the multi spindle is that the detail has to be turned around and processed from the backside to make the threads to the filter. This isn't possible in the multi spindle machine. The conclusion from the information given, the information gathered from the processing hall and the employees working there is that a construction able to make in a multi spindle machine is beneficial. A visit was made during the manufacturing of the filter holder. When consulting about the processing of the part, the difficulties about the product was mentioned and that the estimated time for manufacturing all parts was meagre calculated and always took longer time than expected.



Picture 6- Multi-spindle lathe.

Picture 7- Single-spindle lathe.

4.1.3 Interview

The purpose of the interview which was held in the early stage of the project to get a good understanding of what the customer appreciates about the hose and maybe find something that can be changed without influence the impression of the hose negatively. It also prevents changing something the customer highly like about the hose. The person interviewed, Peter Birgersson, is an experienced installer and continuous user of the hose. In other words the perfect person to ask this kind of questions.
When constructing the questions for the interview, questions about already known problems like the filter and general questions about the performance and quality of the hose were put together. Below there is a list of all question asked (Birgersson, 2016).

Questions for the interview:

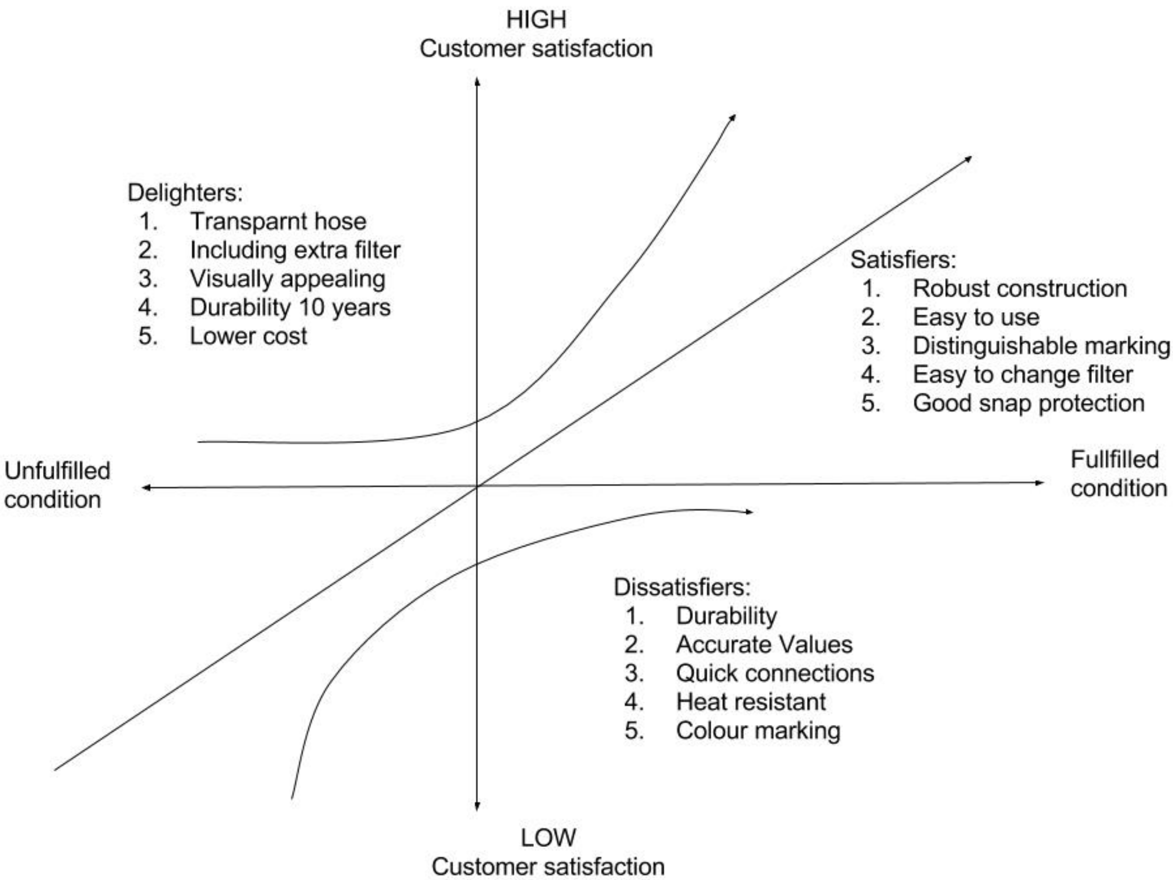
1. *What is your general impression of the product today? (With consideration of user-friendliness and durability)*
2. *Is there any problem with the hose today in your point of view?*
3. *The hose today is relatively stiff. What is your impression of that?*
4. *Does the outwash from the system measured often affect the results negatively?*
5. *How often is the filter changed and are you doing it by yourself?*
6. *The markings, are they clear enough?*
7. *The bend protection, do the hose often bend that much so the protection is needed?*
8. *What is your impression of the hose visually?*

Answers:

1. *The general quality is good, way better than the older version which could malfunction time to time.*
2. *The connections may in time get stiff and won't work properly.*
3. *Appreciate the stiffness.*
4. *It could but the hose is flushed and the filter is changed regularly.*
5. *The filter is changed 3 to 4 times per year at a service centre. Should change it by himself if it was easier.*
6. *Yes, the marking is clear enough.*
7. *Yes, the bend protection is important. Often the hose is used in narrow spaces.*
8. *The shiny hose (The hose used today) looks better and have meant fewer problems.*

4.1.4 Kano-Analysis

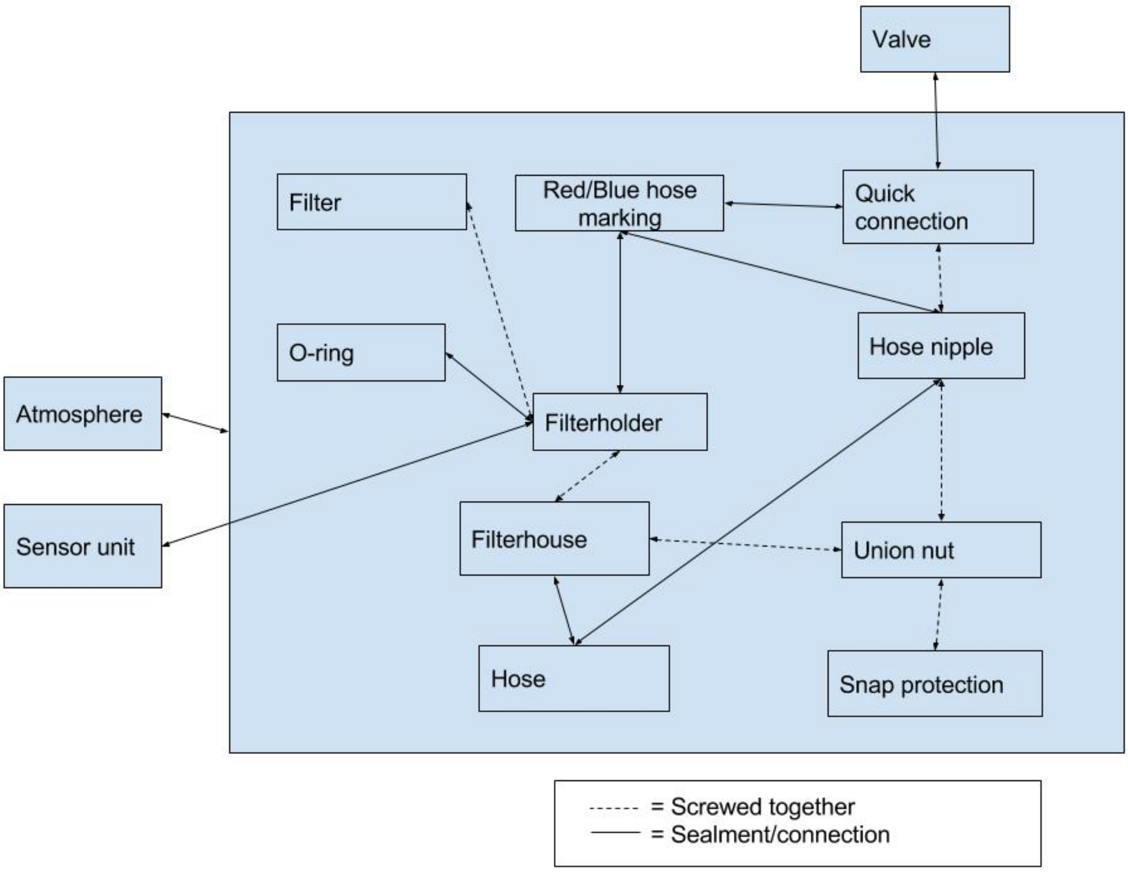
With the information taken from the observation, interview and the evaluation of the existing product, could things that was expected of the product called “Dissatisfiers” be listed. These were mostly the same as in the existing product. Things that were expected of the current product was: Durability, accurate values, quick connections, heat resistant and colour marking. Hence the current product had some things that satisfied the customer: Robust construction and snap protection was added to the “Satisfiers”. Adding on things the pre-study showed were making the customer satisfied: Easy to use, easy to change filter and distinguishable marking. The things that wasn’t expected on the product are called “Delighters” giving the customer an even better experience. The “Delighters” were: Transparent Hose, including extra filter, visually appealing, durability ten years and a lower cost.



Picture 8- Kano-analysis showing the “Delighters”, “Satisfiers” and “Dissatisfiers”.

4.1.5 System Boundaries

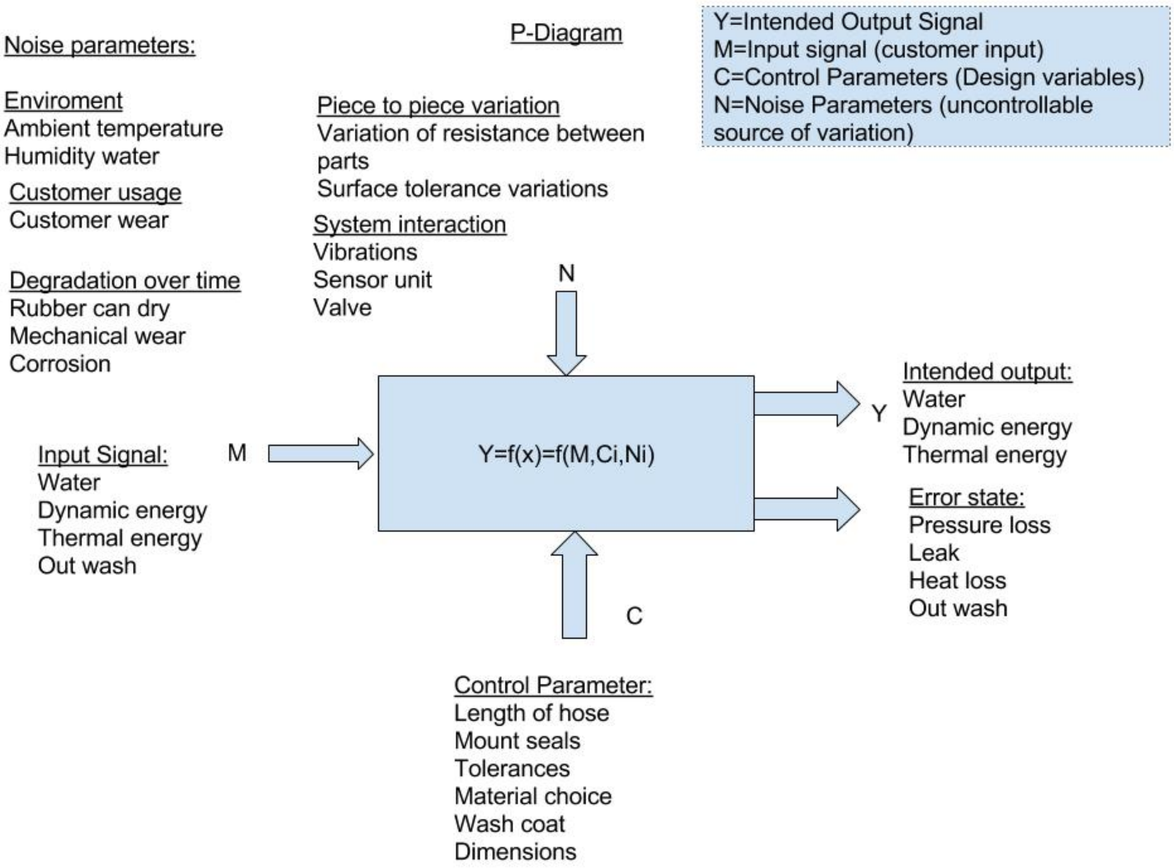
All the different parts and subsystems are shown in the picture below (picture 9), the parts are either screwed together or connected with some sort of sealment or otherwise affecting each other. The system boundary was put together like the picture below. Hence that the sensor unit and the valve were things that the company wanted to keep. Because of that reason, these parts were put outside the system boundaries. The atmosphere isn't a part controllable but still something to keep in mind.



Picture 9- System boundaries.

4.1.6 P-diagram

Based on the system boundaries a P-diagram was made overlooking the systems different parameters. The input signal (M) in our system are water, dynamic energy, thermal energy and outwash. Parameters controlling the systems output are our control parameters (C) also called design parameters: Length of hose, mount seals, tolerances, wash coat and Dimensions. Built on information from the pre-study different noise parameters (N) were found in different areas. Environmental effect such as temperature and humidity of water were one of areas viewed. Another is customer usage and degradation over time, making sure that the product maintains quality over time. Parameters like piece to piece variation and system interaction were also taken into consideration. More detailed information is shown in the picture below (picture 10).



Picture 10- P-Diagram used in the project.

4.2 Concept generating

In the first part of this chapter, the requirement specification is shown and explained. Later on the different concepts generated are presented. Every concept is a solution of the connection between the hose and the quick connections. To every concept there are different solutions on the remaining parts of the whole product. These are presented in the sub heading after all the concepts.

4.2.1 Requirement specification

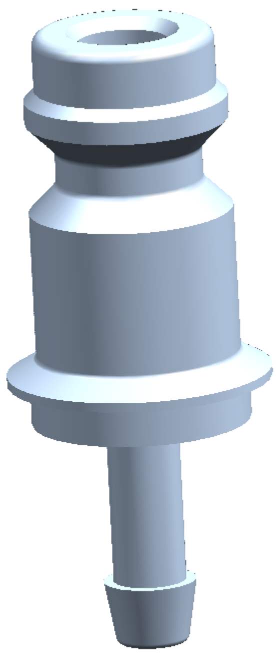
With information from the Kano-modell the requirement specification was put together, listing demands on what the product must achieve. For this product the demands were: No leakage, durability, quick connection, manage the pressures range, temperature range both inside and outside the tube, trust test, colour marking and that the product achieves accurate values. This were all demands put on the current product making sure that the new product will be just as reliable. From the interview, observation and pre-study some wishes were found giving the product an extra level. All the demands and wishes are listed in the table (1) below with a given reference value.

Description	Demand/Wish
No leakage at 40bar and 120degrees Celsius	D
10 year durability (2 year warranty)	D
Quick connector type 21	D
Max 500 kPa differential pressure	D
Max 2500 kPa pressure overload	D
-20-+120 temperature range (℃)	D
0-+70 operating temperature (℃)	D
Manage 1 meter drop on concrete floor.	D
Robust feel	W5
Colour marking	D
Lower cost	W5
Bend protection	W5
Easy to change filter	W4
Accurate values	D
Easy to use	W4
Transparent hose	W1

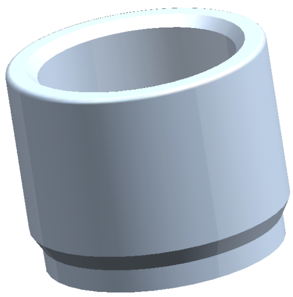
Table 1- The chosen Requirement specification.

4.2.2 Concept 1

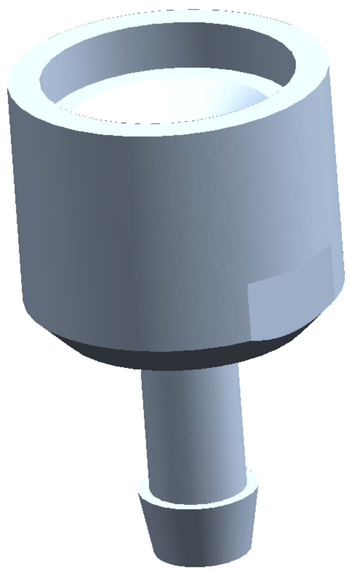
The concept is made of two different parts that together makes a coupling around the hose when pressed by a custom made pressing machine. The first part is a male quick connection with a hose barb (picture 11). The second part is a simple socket (picture 12). When assembling, the hose is pushed over the hose barb and then the socket is pressed with a custom made pressing tool. When the socket is pressed over the hose barb it enables the hose to expand when pressure and heat is put on the hose. The female side of the quick connection is connected with threads to the hose barb detail in picture (13). The picture also shows the space in which the filter will be placed.



Picture 11- Concept 1 male quick connection.



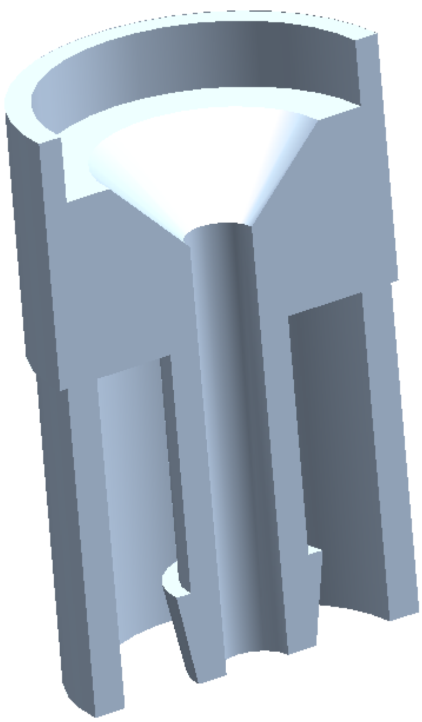
Picture 12- The socket.



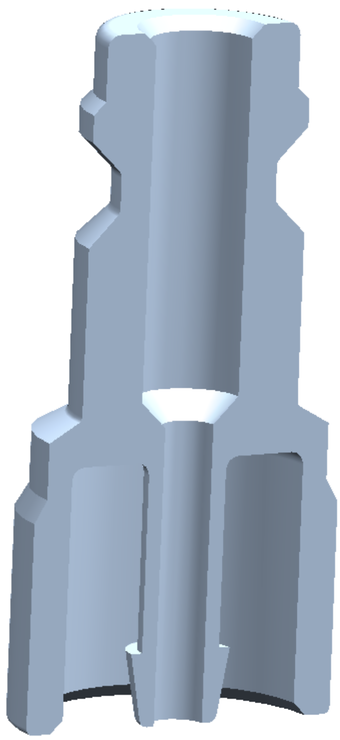
Picture 13- Threaded filter holder.

4.2.3 Concept 2

This concept involves only one part with different properties. On one side there is the usual quick connection and in the other end there is a hose barb with an integrated socket instead of a loose socket like concept 1. This works just like concept 1, where the socket locks the hose to the hose barb component. The perk of using an integrated socket is that less material goes to waste when manufacturing the component and the gap between the quick connection and the socket is eliminated and may result in a better looking component. Since the hose barb is hidden under the integrated socket, there might be some problem due to the limited space for the cutting tool. The cost of the detail might be a bit higher due to the manufacturing time, but then again, it’s just one part instead of two. The assembly works just like the previous concept. The hose is pushed over the hose barb and then the socket is pressed with a custom made pressing tool. The filter is placed in the space at the top of picture (14).



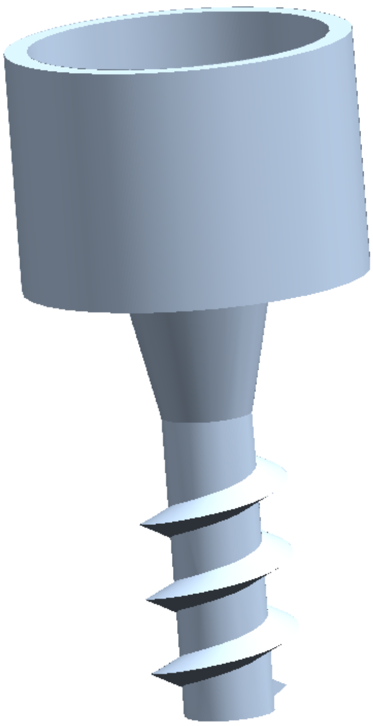
Picture 14- Threaded filter holder with integrated socket.



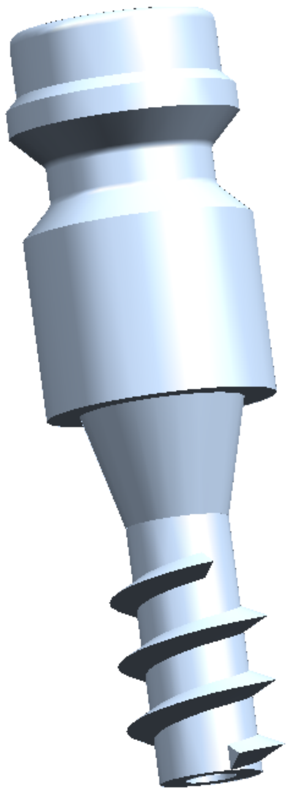
Picture 15- Concept 2 male quick connection.

4.2.4 Concept 3

The concept is a quick connection in one end and in the other a screw is placed to connect the coupling to the hose. If necessary, there will also be placed a socket making sure that the coupling doesn't leak. The concept is based on that the hose has a plastic inner centre, otherwise the tread will not stick to the hose. At the end of the screwing the tube is broader making sure that the hose is sealed. The concept is equipped with a space to place the filter in, shown in picture (16).



Picture 16- Concept 3 filter holder.



Picture 17- Concept 3 male quick connection.

4.2.5 Remaining parts
In the descriptions of all the concepts, only the couplings have been mentioned. To all the concepts there is a need of a hose, bend protection, some kind of colour marking, a filter and the REKTUS type 21. A short description of the different alternatives follows below.

Hose: The alternatives are endless. A lot of hoses fulfil the requirements but some properties are extra beneficial. As mentioned in the interview, a stiff hose contributes with a quality feel. Like the hose on the existing product the hose is both stiff and shiny. Concept 3 got a bit more demands on the hose. It needs a wider dimension and a good material on the hose core since it has to be screwed into the hose.

Bend protection: There are some alternatives also on the bend protection. To get a high quality and maintain the quality feel the existing bend protection is an alternative. As mentioned in the description of the existing hose the bend protection is left threaded and tightly wound in one end. This is not necessary in the new concepts and will result in a cheaper bend protection. Other possibly solutions could be some kind of shrink tube.

Colour marking: The colour marking can be put on almost all the components. The hose can be ordered in colour for 15 % higher price. The bend protection can be chromed into a colour and the shrink tube also exists in different colours.

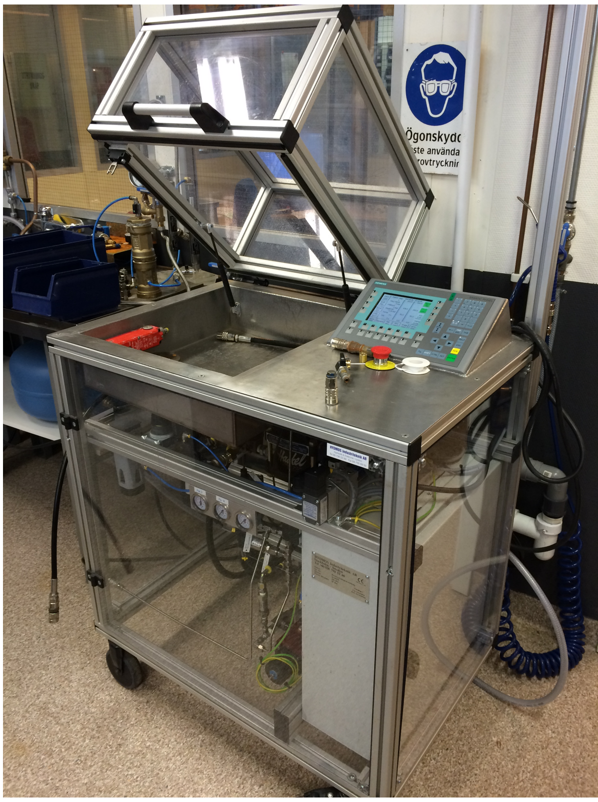
Filter: A flat filter is chosen to fit in the concepts made (picture 18). The filter is a simpler model than the current one making it a bit cheaper. Still in the same material.

Picture 18- Flat brass filter.

Female quick connection: The RECTUS type 21 is the version that should be used due to the project limitations set in the beginning. The concepts are designed to enable a RECTUS type 21 with a female thread to be connected to the side where the filter is placed.

4.3 Prototyping, testing and cost evaluation

All the concepts showed in the concept generating were first 3D-printed, to get a feel on how the product will be perceived. The three concept was taken to the next step and with a few changes the prototypes were made in to drawings and then sent to the specific workshop for manufacturing of the prototypes. Three tests were made on the prototypes, one in air, one in water and finally one made in a climatic chamber. The air-test was made first getting a quick indication on how the concepts performed. Later on the prototypes were tested in water with the pressure raising from 10 to 40 bars in 5 different steps. The specific machine is shown in picture (19). The last test made was in the climatic chamber shown in picture (20). Performing a test with 40 bars of pressure and 120 degrees Celsius under a few hours to determine if the hose is sensitive against heat. How the different concepts performed in the metal prototyping, testing and cost evaluation will be showed in the sub-headings on the next page.



Picture 19- Water pressure test rig.

Picture 20- Climatic chamber.

4.3.1 Concept 1

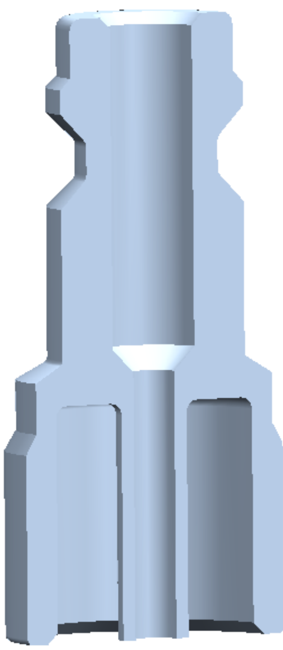
This concept had no problem being prototyped in the workshop with the dimensions to fit the current hose. Tests with the current hose and bend protections was made. A small gap was detected between the two parts, giving it an unwanted look. Testing was made on the assembled product and it came through with no leakage in all three tests. To make sure this wasn't a one-time thing another assembly and test was made. This was successful qualifying it to continue to the cost evaluation. The cost evaluation showed that the concept could be produced in the multi-spindle lathe giving it a significantly lower price than the current solution. The test was made with a bend protection placed under the socket like the picture below (picture 21). The picture also shows the gap between the socket and quick connection.

Picture 21- Showing the gap between socket and quick connection.

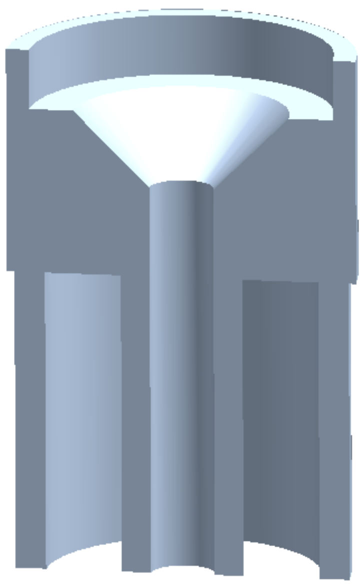
4.3.2 Concept 2

Concept 2 was taken to prototyping, unfortunately this wasn't possible in this project because of the need of a special tool. This was too time inefficient and too expensive, however it's possible later on, if the concept still is under consideration. So no test was made on the specific concept but since concept 1 is similar to this concept the conclusion that also similar results will come out in the end was made. Advancing to cost evaluation, because of the geometry the concept had to be made in the single-spindle lathe giving it a higher price than wanted. It was redesigned taking away the hose barb. By doing that, the special made tool was no longer needed and the concept could be made in the multi spindle machine. To assure that the new concept without hose barb will make through the testing, the hose barb on concept 1 was removed, assembling this version and the tests were made again. The climate chamber test caused the quick connection to slide out a bit of the hose due to the pressure and heat shown in picture (22). Not yet eliminated another cost evaluation was made giving the new version the lower and updated price. The redesign of concept 2 can be viewed in the pictures (23&24) below.
It's also possible to add a snap protection under the socket before pressing. This is a cheaper alternative than the existing alternative where the protection is connected with threads.

Picture 22- Showing the gap after the climatic chamber test.



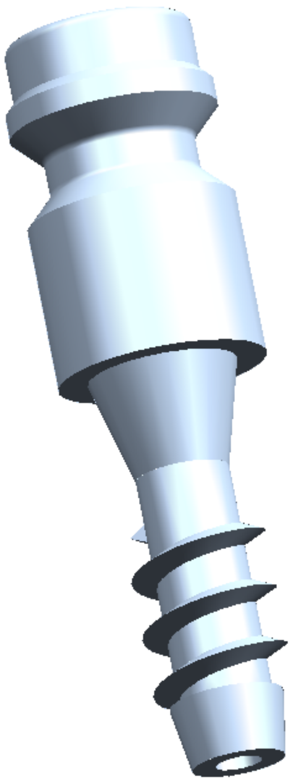
Picture 23- Concept 2 male side redesign.



Picture 24- Concept 2 female side redesign.

4.3.3 Concept 3

When producing concept 3 the dimensions had to be changed because of the force the operation made on the concept. The dimension was changed to enable it for testing, making it only possible to test with another hose in an other dimension. Concept 3 was assembled experiencing some difficulty staying straight making it hard to assemble. Finally, the concept was mounted and test was made. The tests showed severe leakage in all the tests, a redesign was needed to stop the air and water to get inside the threads causing it to leak. A hose barb was placed at the end of the concept stopping the water from getting back up the tube, showed in the picture below. This concept has not yet a solution on the bend protection. Tests were conducted on the redesign which made it qualify for cost evaluation. The redesign of the concept had no problem being produced in the multi-spindle lathe giving it the beneficial price.



Picture 25- Concept 3 redesigned with hose barb.

4.4 Chosen concept

With all the results from the functional tests and the cost analysis for all the concepts, it was time to pick a concept for further development. All the values entered to the evaluation matrix (Appendix (2)) is based on all the test results and analysis but also general assessments have been made to evaluate for instance the uncertainty level of the result set.
The winning concept from the matrix became concept 2. The main reasons this concept ended up winning is the low cost and the assembly friendliness.

4.4.1 Assembly instructions and time

A rough estimation was made approximating the time to assemble the product. Performing all the steps needed and calculating time. The estimation of the time gave a price around 45 % cheaper than the assembly costs at the sub-contractor. For more assembly instructions, table (2) is showed below. The estimated time is calculated for one hose to be assembled.

Instructions	**Time in seconds**
Grab a hose, making notice of the colour.	2
Mount on the two bend protections.	5
Place in the tool and press the ends into the hose.	15
Place the bend protection in the right place under the socket.	5
Hold the bend protection and use the pressing machine.	5
Rotate and do the same thing on the other side.	10
Take an O-ring and a filter, place it in the filterholder.	13
Screw on the quick connection with a given force.	10
Put the assembled hose in the correct bin.	1
Total estimated time in seconds:	66

Table 2- Estimated assembly time for the chosen concept.

4.4.2 Cost evaluation on the chosen concept

A result was reached giving the new product a 46 % price reduction compared to the current product. Big impacts were made on the parts manufactured at IMI taking away two or three parts combining them in to one. The filter house and the union nut is now replaced with the male quick connection. The hose nipple and the second union nut is now replaced with the filter holder. Even more savings were made taking away the colour marking and instead making the hose in the wanted colour. Finally taking away “the middle man” excluding the additional selling costs making further reductions on the total price. For more detailed information, see the Appendix (1).

Picture 26- CAD-Picture of the chosen concept.

5. Analysis

In this chapter an analysis of the work will be made, analysing decisions taken in the project and discussing what could have been made different.

5.1 Pre-study

The pre-study is the biggest and most important part of the project therefore a big focus was put on getting this right. All the information mentioned in the result is a detailed information on how the different parts are bought or produced. Focusing on cutting out the “middle man” to cut down the cost of the product even more. However, making a different focus such as focusing on the cost of the hose or different material in the both the couplings and the hose could also have effected the price. This is a problem that would be suitable for another thesis making the product even cheaper, but because of the time restriction the focus was put on the redesign were the pre-study showed the biggest impact could be made. Another goal was set on minimising the number of parts and closing out the “middle man” which limited the other assembly possibilities. The decision made this an “In-house project” taking the assembly to IMI’s own production.

5.1.1 Existing product

Evaluating the current product, taking it apart and looking at all the different parts one by one. A first view of the product got us to question the placing of the filter. A decision was made to change the side of the filter because it doesn’t make the concept harder to make and it prevents the outwash to enter the hose at all, unlike the current version. Looking at the products all eleven parts made us think about how big of an impact this has on the final product. Maybe a product with fewer parts would be something cutting down the cost?

5.1.2 Observation

One of the most crucial observations was made when visiting the production to pay attention to one of the parts being made. The machine used was a one-spindle lathe. Our question to the operator working the machine was simple. Why is the product being produced in the one-spindle lathe instead of the multi-spindle giving it a faster manufacturing time which cuts down the costs? Because of the geometry of the product, it has to be operated from both sides instead of doing it in one operation which means that it’s necessary to turn the part around inside the machine. An operation not possible inside the multi-spindle lathe. Maybe a construction possible to make in the multi-spindle lathes would lower the cost? At least giving it a faster operating time. Another interesting observation made in the production was the IMI’s well working department for assembling other products. Why aren’t the TA-Scope also assembled here?

5.1.3 Interview

The interview gave important and relevant information that guided the continued work. Information about the general impression of the hose was good. It was mentioned that the current hose worked a lot better than the older version which could malfunction time to time but also the new one could get a bit stiff and not work properly after long time of usage. Rewarding criticism were given to the hose. The fact that it’s stiff is better than the old and sloppy hose according to Peter.

As earlier noticed the filter is placed in the end of the hose according to the water flow. This is the reason Peter has to turn in his hoses at a service centre for filter change and a flush. If it was easier to change the filter and the filter stopped the outwash from the inflow side the flush

would not be needed and a lot of money could be saved in service fees. Peter turned his hoses into service 3 to 4 times per year.
In the interview the bend protection is described as a necessary part and cannot be taken away since the hose often is used in narrow spaces which can bend the hose and potentially damage the hose.
The main conclusions made from the interview is that the bend protection and the hose are two details that contribute with quality in both visual and sustainability aspects. In fact, the only negative thing about the product is that it's too expensive. Since the project also includes to preserve the quality of the product these two components could be two good alternatives to keep in the new product or change it to other components with similar properties.

5.1.4 Kano-Analysis

Adding all the different things heard about the product and collecting them together in a Kano-Analysis helped us understand what the customer really demanded of the product and what makes them satisfied. Simply explained, all the things that the current product is doing has to be achieved by the new product, adding on things like more noticeable marking which we think the current product is lacking.

5.1.5 System boundary

Analysing the system boundary, you find that the parts inside the box are parts focused on in the project. Making all the factors/parts outside the box limitations, however it's important to think about the outside factors and how they interact with the system. Inside the box you see all the different parts included in the project but also how they interact with each other. Is it really necessary for the parts to be screwed together? How does this affect the impression of the hose?

5.1.6 P-diagram

In the making of the P-diagram the six sigma tool book was used to make sure that we got all of the different parameters right, not forgetting anything. This was a good eye-opener understanding all the different things controlling the output. This together with the pre-study gave us all the information we needed. It's still important to look over and check all the noise parameters before taking it to production. Is the intended output reached, and are there any errors in the system?

5.2 Concept generating

A concept generation made by only two people enables the risk that many possible ideas are left out. A way to cover the risk that good ideas goes to waste is to invite other people and discuss different ideas to get new inspiration. However, a lot of discussions were made in the project with Daniel Jilderos trying to think about new concept not yet thought about. Brainstorming all sort of different ideas. The concept generation was focused on the connection between the hose and the quick connection detail. The generating was successful and three concepts were taken to further development. Of course there is concepts not yet discovered but that's always the case.

5.2.1 Requirement specification

The demands listed in the requirement specification were taken from the old specification since the new product should manage the same strains and functionality. The wishes is a mix of information from the interview and other collected data also presented in the Kano-model. The wishes are weighted from 1-5. Lower cost, robust feel and bend protection got the grade

5 since these are the most important things among the wishes. Also the “easy to use” and “easy to change filter” aspects got quite high grade. The reason of that is that if the filter is easy to change the customer can change it by themselves which saves them even more money. The last wish in the list is transparent hose. It only got a low grade since it actually doesn’t contribute with much more than a good look.

5.3 Prototype, testing and cost evaluation

Making 3D-printed concepts helped us feel the quality holding the product testing the interaction between all the different parts and evaluating if the quality feel was still there. From our opinion the wanted feeling was still there taking the concepts to the next step. Simple drawings were set up delimitating our self from controlling tolerances, something delegated to the operator controlling the machine. This because of the limited time on the machine and making the tolerances so tight was unnecessary. Doing three test on the prototype was pretty obvious since this is the biggest stress put on the product. Of course more test could have been made but was considered unnecessary.

5.3.1 Concept 1

The first concept is a concept inspired a lot from older versions of the hose that got discovered under the observation phase. The simplicity of the concept is what makes it interesting when considering the cost but also the possibility of applying the assembly in IMI’s production. Other things that speaks for the concept is the opportunity to assemble the bend protection under the socket before pressing the detail. On the other side, what talks against the concept is that when pressing, the socket slightly slips down and makes a gap that can be experienced as lack of quality even though the functionality is not effected. The problem could probably be minimised by a more developed construction and is therefore not excluded.

5.3.2 Concept 2

Concept 2 is like already known like concept 1 with the only difference that the socket is integrated on the quick connection. Also the hose barb had to be removed since the lathe tool was not able to make the barb due to the narrow space under the socket. The problem that can appear is that the quick connection is pressed out of the hose when it’s set under pressure due to the absence of a hose barb as discovered in the earlier tests made in the climate chamber. The reason this still is a viable concept is the fact that the friction between the inside of the socket, the bend protection and the hose is added to the total resistance to pull out the detail which should be more than enough.

Compared to concept 1 this concept has the favour of being in just one part. Even though the part takes a bit longer to produce there is just one setup time. There is also a lot less material that goes to waste when manufacturing the part compared with the loose socket which make the part more profitable. Also the problem that a gap appeared is solved if this concept is used and that might lead to a better looking solution.

5.3.3 Concept 3

When prototyping the concept, a thicker dimension was needed which led to that another hose was needed. Beyond the changed dimension other demands of the hose like the material on the inside of the hose was needed. Since the bend protection was a wanted part on the product concept 3 was tried with an overlap. This could however not be performed in the machine because of the advanced operation needed to produce the screw function. An idea of putting a shrink hose there instead emerged.

Things that spoke for the concept was the cheap price just being in one part and that with the hose barb at the end it would be possible to assembly. However, not having a bend protection but instead giving it a shrink hose did not give the desired feel of quality, lowering the rating.

5.4 Chosen concept

As expected, judged from the cost analyses and the perks of concept 2, it was precisely concept 2 that ended up victorious from the elimination matrix. The concept is the one with the most potential to accomplish a high quality product to the lowest cost possible among the concept produced.
Considering the elimination matrix all the values entered was like previously mentioned an estimated value. Since it can be hard to judge if all the concepts evaluated are good or bad at something compared to a possible concept that never came up in the concept generation phase, all the values is mostly weighted against each other.
Concept 2 got highest value on the cost criteria since it's the cheapest concept generated. Both Concept 1 and 3 got the second highest value. The two concepts are similar in price and a lot lower than the existing one but never the less not as cheap as concept 2.

5.4.1 Assembly instructions and time

The estimated time on the assembly instruction were made by ourselves and is something that has a lot of possibility cutting down time on. An organised and fully working station will most certainly make reductions on the calculated time. The pressing machine used in the assembly was not optimised for the diameter used causing it to take more time than needed. Possibly a pressing tool is needed to get the hose on the quick connection and might affect the assembly time slightly.

5.4.2 Cost evaluation on the chosen concept

A 46 % reduction on the new model is a good result, however some uncertainties are still there. The new product is an untested concept, of course some similarities with concept 1 can give you a guideline on how it will perform in the testing. Nevertheless, the chosen concept will still have to be tested, something we couldn't do, because of the special tool and the time restrictions.

6. Conclusion

In this last chapter, there is an evaluation of the results from the project. The purpose and project questions are verified and answered. A summary of the reached results and a recommendation for the future and remaining part of the project.

6.1 Evaluation of the result

The purpose with this exam thesis was to minimise the cost of a hose used to IMI Hydronic TA-scope, without affecting its quality and the performance. With no more information than that a formulation of questions were put together. The questions aimed for the early stage of the project was which part of the project will be optimised to minimise the price. Basically meaning if a reconstruction of the product is the most beneficial way to minimise the price or if there is other possible and even better way to do so. Other questions relevant during the project was what is the best way to produce and assemble the product and is it more cost-efficient to buy in the finished parts?

The first part of the project consisted of a pre-study with the purpose to evaluate how the continues work should be performed. This step took a lot longer time than expected and led to more limited time to develop a new concept. However, the time spent on the pre-study was not wasted time. The pre-study could also have shown that other strategies than reconstruction to minimise the price could have been better.

The main strategy to minimising the price is to lower the amount of parts of the hose and move the assembling process to IMI's factory. By doing that all the additional selling prices are eliminated. The winning concept is a mix of the old hose and new constructed couplings between the hose and the quick connection. The problem with the project was not to minimising the price but at the same time preserve the quality feel.

The concept with the integrated socket was the concept chosen for having the most potential to be a good product on the market. The concept have a lot of perks and has a very appealing price tag. Along with the concept the already existing hose and bend protection is used but since the hose is ordered in another colour it replace both the hose and the marking ring and the price is therefore reduced. The bend protection as before was left threaded was changed to a right threaded which is the standard and that makes it cheaper. Also the tightly wounded part is removed. Regarding the filter, the model used and the model all the concepts are designed for was found under the observation. It was the most simple and affordable version but it was assumed to do the job just as good as the older version. There are also some aspects worth noticing about the changes that can affect the quality feel of the hose. Since there is a lot less steel material in the end of the hoses, it might feel less attractive in terms of quality feel.

6.2 Recommendation for the future

The concept is as mentioned significant much cheaper but, it's still just a concept and there are a lot of things that needs to be evaluated. To start with, there are some adjustments needed to get the perfect product. In the connection where the filter is, a redesign for an O-ring is needed to seal the connection with the RECTUS type 21 properly. The integrated socket is just prototyped in one dimension. Tests with different dimensions is needed to accomplish the best possible pressing result. Except the redesigns to accomplish the most perfect results possible for the concept the VOC (Voice of Customer) has to be tested to assure the product is viable on the market.

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7.1 Vocal reference

Birgersson, Peter interviewed by the authors 2 mars 2016.

8. Appendix

Appendix 1

Kalkylsammanställning

Uppdragsgivare:

Vgr: 504 CBX

Sortimentsgr: TA-Scope

Figur nr	RM	KD	DA	DK	MO	RTO	FTO	FABO	SPO	AO		FC (Sum Factory cost)	FP	TB	TG	Anmärkning Årsantal ca:	Partistorlek
Div slanglösningar																	
TA-Scope																	
Quick connection male	x	x	x	x				x	x	x	x	-86,95%				3 000	1 000
Quick connection female	x	x	x	x				x	x	x	x	-76,65%				3 000	1 000
Hose	x	x	x	x				x	x	x	x	-22,86%					1 000
Rectus inköp	x	x	x	x				x	x	x	x	-29,56%					1 000
2 Bend protection	x	x	x	x				x	x	x	x	-71,43%					2 000
Filter	x	x	x	x				x	x	x	x	-9,09%					1 000
O-ring	x	x	x	x				x	x	x	x	-9,41%					1 000
Assemble 66 sek	x	x	x	x				x	x	x	x	-45,45%				3 000	250
Total kostnad												100,00%				3 000	
Procent cheaper												46,10%					

Appendix 2

Evaluation matrix	Cost (How cost effective is the design, no parts/complexity/size etc)			Manufacturability/Component complexity (Can the parts easely be produced and assembled in standard and machines)			Assamble friendly			Tolerance sensivity (How sensitive will the design be to manufacturing tolerances)			Dirt/air sensivity (Will the design allow the water to contain dirt/air without major functionallity loss)			Sealing complexity (Do the design require comlex and/or special sealings or can standard sealing be used)			Design flexibility (Can the pars in the design easily be changed to create variants for testing)			Physical size (Do the design keep the overall size down, P-part and body)			Total sum
Customer value (5 Critical to customer, 3 important for customer, 1 not important)	5			5			4			1			1			4			2			1			
Project risk (5-show stopper, 3 big impact on timing/function, 1 not important	5			5			4			1			1			3			2			1			
Grade:1-5 1=Bad 5=Good Uncertainty level: 0,5 - high Uncertainty 1 -medium Uncertainty 1,5 - Low Uncertainty	Grade	Uncertainty	Sum	Grade	Uncertainty	Sum	Grade	Uncertainty	Sum	Grade	Uncertainty	Sum	Grade	Uncertainty	Sum	Grade	Uncertainty	Sum	Grade	Uncertainty	Sum	Grade	Uncertainty	Sum	
Original hosebarb	4	L	6	5	L	7,5	3	L	3,6	3	L	0,9	5	L	1,5	4	M	2,8	5	L	3	5	L	1,5	26,8
Integrated hosebarb	5	L	7,5	4	L	6	5	L	6	3	L	0,9	5	L	1,5	4	M	2,8	5	L	3	5	L	1,5	29,2
Screw	4	L	6	3	M	3	3	L	3,6	3	M	0,6	5	L	1,5	2	H	0,7	5	M	2	5	L	1,5	18,9