Master Thesis

Refrigerated Display Unit

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Faculty of Engineering LTH • Lund University • 2016

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Smurfit Kappa

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Preface

I have a number of people to thank for providing valuable information and expertise throughout my master thesis. Smurfit Kappa Sweden where I especially would like to thank my supervisors, Ingvar Persson and Lube Belokozovski for always finding the time to discuss the project and contributing with valuable input. Thanks to the thermal engineering specialist at EG Electronics for providing valuable information of Peltier elements, crucial for the fulfillment of the function of the prototype. I would also like to thank Optocomp AB and Lilja Group AB for providing material and expertise in the process of prototyping. A special thanks to Johnny Eliasson at Optocomp AB for taking the time to provide guidance during manufacturing, despite a busy schedule. And Michal Wieloch during tests at ICA Supermarket Fäladen, for providing the display area and comments of great importance for the evaluation of the product.

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Abstract

In today's competitive food marketing, new innovative ways of standing out in a crowd grows more important by every day. Smurfit Kappa Sweden AB, a leading manufacturer of cardboard, paper and packaging products desired to meet customer demands, displaying refrigerated products in the same manner as non-refrigerated products. The objective of the thesis work was to examine and develop a new kind of technology that combined compressor refrigeration and cardboard displays.

The initial phase presented existing products of the concept and the focus was changed to finding solutions optimizing the power consumption. During the investigation of suitable compressor refrigerators, the technology of Peltier elements was found. The technology was investigated and found suitable for the project due to its outstanding qualities in low maintenance and long life expectancy. Due to a power consuming technology, the integration of the Peltier elements was to be made by developing a refrigerated module to be integrated in a cardboard display.

The selection of technology was based on the results of the investigation and the concept generation conducted for both technologies. The concept chosen was an insulated Peltier refrigerated module with an acrylic glass lid.

Further development of the concept was conducted and the main focus was to reduce power consumption and fulfill customer requirements. The final concept was prototyped and tested where results of the tests provided information that the display functioned as desired and fulfilled most of the measurable specifications, though requiring minor changes in design. The amount of energy required was found to be 0.31 kWh/day, about 9% of the target value, and production cost of the display of 1,084.3 SEK which is lower than the target value of 1,871 SEK.

Keywords: *Refrigerated display*, *Cardboard display*, *Peltier elements*, *Power consumption*, *Exposure*

Sammanfattning

I och med en ökad konkurrens på marknaden blir det viktigare för var dag att hitta nya och innovativa sätt att urskilja sig på. Smurfit Kappa Sweden AB, en ledande tillverkare av produkter av wellpapp, papper och förpackningar letar alltid efter nya sätt att tillfredsställa nya kundbehov, ett av dem var att presentera kylvaror på liknande sätt som icke kylda varor. Syftet med examensarbetet var därför att undersöka och ta fram en ny typ av teknik som möjliggör en kombination av kompressorkyla och displayer av wellpapp.

Den initierande fasen presenterade resultat att existerande produkter av konceptet redan var tillgängliga och fokus ändrades därför till att hitta lösningar för att optimera energiförbrukningen. Vid undersökningen av passande kompressorkylar, upptäcktes tekniken Peltier element. Tekniken undersöktes och ansågs passande för projektet på grund av framstående kvaliteter som lång livslängd och utan krav på underhåll. Då tekniken är energikrävande, var Peltier elementen tänkta att kyla moduler som integreras i en wellpapp display.

Valet av teknik baserades på resultatet från undersökningen och konceptgenereringen som utfördes gentemot bägge tekniker. Valt koncept var en isolerad Peltier-kyld modul med ett akrylglas lock.

Fortsatt utveckling av konceptet utfördes med fokus att reducera energiförbrukningen och samtidigt uppfylla kundbehov. En prototyp tillverkades av valt koncept och testades där resultaten visade att önskad funktion var uppnådd och de flesta mätbara målvärden uppfyllts, dock krävdes mindre ändringar i designen för att helt uppnå önskat resultat. Energiförbrukningen för en dag var 0.31 kWh/dag, ungefär 9% av målvärdet, och en produktionskostnad av 1,084.3 SEK vilket är lägre än uppsatt målvärde av 1,871 SEK.

Keywords: *Kyld display*, *Wellpapp display*, *Peltier element*, *Energiförbrukning*, *Exponering*

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1 Introduction

The first chapter is an introduction describing the underlying conditions and problem definition of the thesis work, purpose, aims and delimitations

1.1 Background

In today's competitive food marketing, new innovative ways of standing out in a crowd grows more important by every day. As the new innovative ways to display non-refrigerated products are becoming more advanced, the cooled products are still often being marketed in permanent refrigerators, right next to other brands and offers. The main difference of the marketing of a non-refrigerated product and a refrigerated product is the cost of energy needed to cool the product but also the casing. Smurfit Kappa Sweden AB today has no product in their portfolio to display cooled products and the desire to meet customer needs was the introduction to this master thesis.

1.2 Company presentation

Smurfit Kappa Sverige AB, referred to in the text as Smurfit Kappa, is a leading manufacturer of cardboard, paper packaging and products. The company was formed in 2005 after a merge of the companies Jefferson Smurfit and Kappa Packaging. The merge opened up for a company with a large variety of products to offer customers. One of Smurfit Kappa´s strengths is that they are a part of the entire life cycle of the products, creating a larger understanding of the process. Among other products, the company offers paper manufacturing, unique and innovative packaging and products of solid board- and corrugated cardboard solutions. Smurfit Kappa Sweden has 1400 employees distributed over 14 production units and two sale offices in Sweden. Smurfit Kappa Sweden is a part of the global Smurfit Kappa Group with 43 000 employees all over the world [1].

Through a great interest in innovative solutions, Smurfit Kappa is at the cutting edge of packaging technology. One of their latest inventions is the ”*Experience Centre*”, where a 3D view is used to evaluate customer experiences of a product when used in its natural environment [2].

The master thesis was performed at Smurfit Kappa Sweden headquarter in Eslöv.

1.3 Aims

The aim of this master thesis is to provide brand owners of refrigerated products the possibility to market their products in a new manner. The objective of the thesis work was from the beginning to examine and develop a new kind of technology that combined compressor refrigeration and cardboard displays. After findings during the project, the objective was altered to find a solution with improved features compared to competing products.

1.4 Delimitations

The product is to be used within an ICA store and therefore the surrounding conditions are set accordingly. The reason that ICA was chosen as the customers of this product was due to the fact that ICA stores were perceived as more concerned with interiors and the marketing of quality.

At first the product to be displayed was set to ICA branded products. Due to a change in cooling technology, the product was changed to 33 cl cans due to their standardized surface. This cooling technology also required a developed power supply and temperature controller, which is not included in the master thesis.

1.5 Method

The method followed during the master thesis is a product development method by Karl T. Ulrich and Steven D. Eppinger [3]. Knowledge of the method is already obtained and should therefore not cause obstacles in the development process. The method has been modified to better suit the project and Smurfit Kappa`s development strategy.

The structure of the report is the same as for the following steps of the development strategy

Ch.1 Introduction
- Background of the project, aims, problem definitions and delimitations

Ch.2 Feasibility study
- Review of the technology of compressor refrigeration
- Patent search - to research the legal rights of the project
- Benchmark – research the market due to findings of the patent search

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- Selection of refrigeration system based on the results in chapter 5 *Investigation of Peltier elements -Thermo Electric Coolers (TEC)* and chapter 7 *Concept generation*

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- Analysis of the customer interaction and fulfillment of subjective specifications

Ch. 13 Conclusion and discussion
- The fulfillment of the aims and measurable specifications
- Future work

2 Feasibility study

The second chapter describes the feasibility study for the thesis work, performed in order to create an understanding of the project and the market. The feasibility study includes a review of the theory of the compressor refrigeration process, a patent search and benchmark

2.1 Review of the theory of the compressor refrigeration process

In order to secure the function of the project and gain knowledge regarding the compressor refrigeration process, a minor review of the theory was performed. The result from the review can be found in Appendix A, describing the dynamics of the refrigeration process and thermodynamic laws supporting it.

2.2 Patent search

A patent search can both be used as an insurance that the product to be produced, does not interfere with a patent, but also for generating ideas. The primary use of this patent search was to gather information regarding patents already existing to assure the legal rights to develop the product. It was though possible for the information gathered to be used at a later stage in the master thesis. The patent database Espacenet, used for the patent search is a free database that can be used by the public [4]. In addition to this search a google search was also performed. It should be noted that there are data bases not open for the public containing more information. In the process of launching the product, a more extensive patent search should be performed to secure that no interference with an existing patent is being made.

2.2.1 Search process

Within the database smart search was used. The results were reviewed and patents similar to the product idea was further examined. Information that could be of interest for the project was documented. If the patent was similar to the product idea, the status and application date of the patent was examined. The same procedure was made for the google search.

2.2.2 Result of the patent search

The results of the patent search revealed that patents of similar applications were no longer active and did not cause a threat for the legal rights of the product development. Descriptions of the patents found similar to the product to be developed can be found in Appendix B.

2.2.3 Conclusion of the patent search

The patent search revealed a number of patents similar to the product meant to be developed during the master thesis. All of the patents found were no longer active, except for the *Cooler merchandiser with customizable graphics* [B8]. One main difference from this product was that the cooler was not made out of cardboard but instead only covered with cardboard on the outer sides. If a patent application was t be of interest in the future, the product will have to be substantially different from the products found in this patent search. If there is no interest to apply for a patent, this patent search provides information that the product of this project will not interfere with any existing patents. From the patent search some interesting facts were found. The air curtain, used in order to retain the cool air. The improved usage of energy by reusing the cooled air by redistributing it back to the cooling unit. The method of blowing the air laterally instead of from the back in order to gain a cooler environment. Some different methods of reducing the impact of moisture. But also the different ideas of how the shelves could be designed, nets, rigid or extra support from other materials.

2.3 Benchmark

As the patent search revealed a number of patents similar to the product to be developed, an existing market was a possibility. A benchmark was therefore conducted with the purpose of gathering information of competing manufacturers and products.

2.3.1 Process

The benchmark was performed in two steps. The first step was to do an internet search, followed by a research at grocery stores in Lund, Sweden. The aim of the internet search was to research if there were any existing refrigerated cardboard displays produced today. As the aim of the grocery store search was to investigate if there were any existing cardboard refrigerators in use, but also to get an understanding of what other type of refrigerators that were in use today.

2.3.2 Results of the internet search

2.3.2.1 Coolio

Coolio is a company founded in 2009, specializing in refrigerated cardboard displays. Their idea is to create a cooling solution that gives brands a possibility to “stand out from the crowd”. There are two parts of the Coolio products. One part is the permanent compressor cooling unit, and the other is a temporary part made out of cardboard or acrylic glass [5].

From the search it was found that Coolio produces two different compressor refrigerators used for cooling cardboard displays. Aside from the newly developed e-Coolio R290, presented in figure 2.1 below [6], the older version of the compressor refrigerator Coolio R290 [7] is also a part of Coolios collection.

Figure 2.1 Newly developed compressor refrigerator e-coolio R290 [5]

The parameters found during benchmark provided information that the refrigerant of the compressor refrigeration is the climate friendly R290 and that the energy consumption of the compressor refrigerators is 6 kWh/day measured under an ISO 23953 standard, 22˚C and 60% humidity. The development of the older version is visible when investigating the temperature span that the compressor refrigerator presents. The older version provided a span of +3-+7 ˚C while the newer version ranges from 1-6 ˚C with a double fan. The life expectancy of the compressor refrigerators was found to be three to five years. More information of parameters can be found in Appendix C.

Coolio also produces cardboard displays to be used in combination with the compressor refrigerators. One of the cardboard displays, Freshboard traditional 3.0 is one of the larger displays that is commonly used for product introduction, secondary placement and promotions [8]. The Freshboard traditional can be seen in combination with the e-coolio R290 in figure 2.2 below. Parameters of interest to get and understanding of advantages and disadvantages are found to be that the material is 100 % recyclable and that the installation only requires 5-10 minutes. Each shelf within the 160 liters display can handle a load of 25 kg which is a large amount for a cardboard display. The reason that the shelves can handle this much weight is due to the fact that the shelves are combined with additional supports made out of wood. The Freshboard traditional 3.0 is not entirely made of cardboard and manufactured in different parts.

Parts of the Freshboard traditional 3.0

- 1 freshboard sleeve
- 3 trays
- 3 tray inlays
- 1 headcard
- 1 air-circulation top
- 6 wooden tray supports
- 2 extra clips

Figure 2.2 Freshboard traditional 3.0 in combination with e-coolio R290[5]

More information of the parameters of the Freshboard traditional 3.0 can be found in Appendix C.

Coolio also have a smaller cardboard display, Freshboard check-out 3.0 that is used to promote products in check-out areas, isles with height restrictions and smaller stores [9]. Within their collection there is also the X-Fresh that is made of recycled fibers [10]. This cardboard display is about the same size as the Freshboard traditional 3.0 but differs in material. This display is of interest while some consumers are interested in promoting eco-friendly products requesting an eco-friendly display alternative. Additional information of parameters can be found in Appendix C.

Usage constrains of the Coolio concept [11]

- The display should be placed 20 cm from surrounding walls
- The filling of the Freshboard has to make sure that the air inlet and outlets are not blocked

- The compressor refrigerator have to be put out of order 4 hours every month to clean air circulation
- Environmental conditions max 22 ˚C, 60% HR, 0,2 m/s
- The quality of the Freshboard is only guaranteed by single use and during a maximum period of 12 months

The permanent compressor cooling units e-coolio R290 and Coolio R290 are used by other display manufacturers found during the search. One of the Swedish supplier of Coolio products is Nordic solutions AB [12] that have Coolio products in their collection of refrigerators. Other interesting display manufacturers were Print point displays [13] a company located in the Netherlands, with the main focus on display and packaging manufacturing and ECO Display (Economic and Convenient Oriented Display) [14], a company located in Shenzhen China, producing cardboard displays. But also Promocarton [15], a company located in Prague that have a production of both paper and plastic displays. All of the companies mentioned are all using the Coolio compressor refrigerators in combination with their own cardboard displays. The reason that these companies were regarded as the most interesting was because they were the most common result during the internet search.

2.3.3 Conclusions of the internet search

The internet search of the benchmark revealed that there were existing products with the concept of the project. As there were existing products, the focus was to develop a solution that provided improved features of existing products. The cardboard display was to be more consumer oriented and offer solutions that created the best possible usage of the compressor refrigerator. The efficiency was to be optimized and a solution to reduce the consumption of energy in an open refrigerated display was to be found.

The findings of the internet search also provided information that there was a market for the product. Smurfit Kappa, as one of the larger producers of cardboard solutions, should be able to offer this product to customers with the need of refrigerated displays. Some companies found during the internet search offered this solution, but with the refrigerator unit Coolio produces. The main competitors on the market for this product was therefore found to be Coolio.

On Coolio's homepage [5] a patent was referred to. This patent was not found and the nature of this patent was therefore not possible to declare. From the patent search performed earlier in the thesis there were expired patents found similar to the concept, which prevents the patent Coolio is referring to, to be a patent of the entire concept. Instead the patent is believed to be a patent of the Freshboard or the Coolio refrigerator as a single unit.

2.3.4 Results of the research at grocery stores in Lund

The combination of grocery stores and their sizes were chosen in order to get a greater understanding of a larger part of the market. As some pictures were taken, the stores did not want to be specified with more information than the type of store.

- ICA Nära
- Coop Nära
- Willys
- Lidl
- ICA Kvantum x 2
- City Gross

From the research made it was found that most grocery stores used the same type of refrigerated displays. Most of the refrigerated displays for drinks were of the type "Glass door merchandiser", the other most common ones were "Bins" and the third, "Open air merchandisers". None of the refrigerated displays found were made out of cardboard. Not many of the displays were used for the purpose of a campaign, nor for only one brand. The displays that were used for only one brand were all the size of a quarter pallet. All of the refrigerated displays were equipped with wheels. The displays were not tall and the advantages of the high sealing of the stores was not used. The displays used for only one brand or campaign, were equipped with a refrigeration unit at the bottom and a display case on top often made out of acrylic glass, in combination with a cardboard display, see figure 2.3 below.

Figure 2.3 Refrigerated displays used for only one brand

Most of the displays were placed on the edges of other refrigerators or close to similar products. From one of the stores it was found that some stock for refill was placed on top of the displays. Some of the refrigerated displays were also covered with glass doors in order to reduce the use of energy.

According to one of the grocery store owners, it was believed that the usage of display refrigerators would create a feeling of disorder and make it harder for the customers to

find what they are looking for. From a smaller discussion with two of the larger grocery store owners it was also found that the profit of a campaign display was often not large enough to be of interest. Instead larger permanent refrigerated displays or refrigerators were used in combination with signs marketing the offer.

From a smaller discussion with one of the smaller grocery store owners it was found that the main problem with refrigerated displays for campaigns was that they are space consuming.

2.3.4.1 Attractive characteristics

During the research at grocery stores some characteristics were found to be more attractive and managed to stand out from the crowd. One of these displays can be seen in figure 2.4 below.

Figure 2.4 Display with attractive attributes

Compared to figure 2.5, where the products were presented in the same refrigerator as other products, the products in the display in figure 2.4 were presented in a new and innovative way within the display. The display was also placed at a position where the connection to surrounding products was clear. The placement of the product within the display made it clear to consumers what the product was and the product packaging was selling itself without any extravagant advertisement required of the display. The display was simple but at the same time provided the support needed for the product.

Figure 2.5 Permanent display

2.3.5 Conclusion of the research at grocery stores

Refrigerated products are not displayed in the same way as other products while a refrigerated display is more expensive than a regular display. Most of the refrigerated displays used today are not used only for one brand and the refrigerators that have been used for a specific brand are later used for other products. A refrigerated cardboard display could be a solution while it is cheaper and easier to replace for different brands. One possibility could be that the refrigerated displays could display different brands in different sections. The products displayed should always be presented in the best possible way as well as always give the impression that the display is full. It should be easy to refill the display, especially if the display is small. One possibility could be to have storage close by. In order to optimize the space consumption of the display, one possibility is to maximize the usage of the height.

2.4 Conclusions of the feasibility study and change of direction of the master thesis

The findings of the feasibility study provided information that there were existing products of the concept to be developed within the master thesis. Due to this information the focus of the project was altered to develop an improved version of the product, focusing on an improved energy consumption without compromising the marketing effect and the flexibility of cardboard. From the benchmark it was also found that the energy consumption of an open air refrigerated display was the main problem. The reason for using open front merchandisers was to create easy access to products.

3 Identification of customer needs

Chapter 3 presents the process and results of the identification of customer needs

3.1 Process

In order to develop a product that meets the requirements of customers, the research and identification of these requirements is of great importance. The requirements found during the identification of customer needs are later used in the process of concept generation and throughout the entire project.

The different steps for identifying the customer needs follows the product development process used during the master thesis. [3,pp.116-136]

Step 1 Gather raw data from the customers

Step 2 Interpret the raw data

Step 3 Organize the needs hierarchically

Step 4 Determine the relative importance of the needs

Step 5 Reflect over the results and the process

3.2 Gathering of raw data from customers

3.2.1 Customers

The primary customers of this project were staff members of ICA stores with knowledge of the refrigerators used today. At the beginning of the project the primary customer was the head office at ICA Sweden AB but after a discussion with Sandra Haglind [16] and Annica Sager [17] at ICA Sweden AB it was found that the best customer needs would be found by interviewing employees of ICA stores in combination with some foundational facts acquired from the head office.

3.2.2 Process

In order to obtain information from customers, interviews at five different ICA stores were performed. The advantages of interviews as opposed to questionnaires is the possibility to gain more information and ask follow up questions when needed. The question-guide used during the interviews Appendix D was produced in collaboration with Smurfit Kappa. The guide focuses on finding customer needs regarding the appearance and function of the display. The guide and answers are documented in Swedish and the interviews were performed in Swedish.

The documentation of the interaction with the customers was made by continuous documentation during the interviews. In the literature [3, p. 124] it is advised that one person focuses on interviewing and the other on the documentation. As the interview was performed by one person, this was not an option.

3.2.3 Stores used for gathering of information

- ICA Nära Söderlivs, Stora Södergatan 57 Lund, Östergren, Andreas
- ICA Nära Satelliten, Råbyvägen 15 Lund, Jarl, Jörgen
- ICA Nära Tornet, Uardavägen 131 Lund, Fors, Jörgen
- ICA Kvantum Malmborgs, Clemenstorget 5 Lund, Magnusson, Erik
- ICA Supermarket, Fäladstorget 14 Lund, Wieloch, Michal

The number of interviews should, according to figure 5.4 in the literature contribute to about 78% of customer needs [3, p. 120].

In addition to the interviews of employees at ICA stores, a gathering of information of limitations regarding the refrigeration unit was made. A minor questionnaire was developed and sent to the project-coordinator of ICA Sweden AB [17]. The purpose of this questionnaire was to get an understanding of the limitations and requirements of the refrigeration unit. The following questions were to be answered:

- What environmental requirements are there regarding refrigeration systems?
- What safety requirements are there regarding refrigeration systems?
- Is ICA the owner of all refrigeration systems and what are the requirements for ICA stores to handle the cost?
- Is it common that the owner of a brand provide the refrigeration system?

3.2.4 Results

From the interviews of employees at ICA stores, many customer needs were found. One interesting fact was that no one had heard of refrigerated cardboard displays before but there was an interest in the product. All of the questions produced for the interviews were answered. If the reader is interested in the full answers during the interviews, these can be found in Appendix E.

From the questionnaire sent to the project-coordinator of ICA Sweden AB [17], the following answers were obtained.

What environmental requirements are there regarding the refrigeration system?

- The refrigerant is required to be natural, i.e R744, R290 and R600.

Is ICA the owner of all refrigeration system and what are the requirements for ICA to handle the cost?

- The ICA store owner always own the refrigeration systems.

Is it common that the owner of a brand provides the refrigeration system?

- All refrigeration systems are permanent. The refrigerators are used for ICA´s brand and it is up to the store if they want to use them to display other brands.

Who is the retailer of refrigeration systems today?

- Ajo Kylindustri AB, who also offer a compressor refrigerator for products similar to the concept, the EzyCooler 450 [18].

3.3 Interpretation of customer needs

Using guidelines from the product development method [3, p. 126], the answers from the interviews were interpreted into customer needs. The interpretations can be found in Appendix E. Some of the interpreted needs were describing the same need and therefore merged, the number of needs with the same interpretation is of importance in step 4 when the relative importance is determined.

3.4 Hierarchical organization of customer needs

During this step the interpreted needs are to be hierarchically organized in order to get a better overview of the customer needs. The needs are usually categorized as primary and secondary but for this project the needs are categorized in sections to create an understanding of what the different needs are affecting. A classification of primary and secondary needs is not made while the needs found are of a large variety. It is also believed that the hierarchical organization will be a part of the next step, where the relative importance is determined.

Safety – needs that effect the safety of perishable goods but also the safety of the surrounding

Effects of life of display – needs that effect the life expectancy of the cardboard display

Shelves – needs effecting the design of the shelves displaying the products

Flexibility- needs effecting the requirements of flexibility

Efficiency – needs effecting how efficient the cooling is

Features display – needs describing features improving the displays marketing effect

Print –needs describing desired marketing using prints

Mobility – needs describing the desire of a mobile solution

Usability – needs describing how to make the handling of the product easier

Positioning – needs describing where the product is to be placed

*Si*ze – needs affecting the size of the product

3.5 Determining the relative importance of needs

Determining the relative importance of the needs is made in order to allocate resources and determine the needs that are to be in focus. According to the development method in Ulrich and Eppinger [3, p. 131] there are two ways of deciding the factor of significance and relative importance, either by the development team or customer surveys. During the interviews, a good understanding of the customers was able to be formed. It is also believed that Smurfit Kappa has a good understanding of the customers and therefore the determination of relative importance was made through a combination of the knowledge of Smurfit Kappa and the number of times the need had been expressed. The scale of importance is presented below.

5 - The attribute is a requirement, the product would not be considered without it

4 - The attribute is most desirable, but the product would be considered without it

3 - The attribute could be of interest, but it is not necessary

2 - It does not matter if the attribute is a part of the product or not

1 - The attribute is unwanted, the product would not be considered with it

The result is presented in Appendix F. Most needs were assigned within the range of five to three. The reason of this may be that the questions used during the interviews were too precise and made the customer focus on the question rather than express themselves freely. The reason that none of the needs were assigned with the lowest importance factor one, is probably due to the fact that the lowest importance factor should only be assigned a need when it describes a feature not desired by the customer.

3.6 Reflection over the results and process

The most interesting findings during the identification of the customer needs were the following.

There is an interest in the product. The most important aspect of the product is to decrease the consumption of energy while the largest concern of the customers was the effect of moisture on cardboard. The most attractive part of the concept was the fact that cardboard is easier to customize.

In order to gather complementary information, interviews of consumers of ICA stores should be made in order to find information regarding their needs of the display. This aspect will be evaluated during prototype testing while it is believed that the best way to gather information from a customer is to see the customer interact with the product. For further information regarding customer needs, it was believed that the most suited customers that were interviewed were the following

ICA Kvantum Malmborgs, Clemenstorget 5 Lund, Magnusson, Erik

ICA Supermarket, Fäladstorget 14 Lund, Wieloch, Michal

If the identification of customer needs would have been performed again the main difference would have been to create less specific questions. Also a better description of the concept would have been created in order for the customer to better understand the concept.

4 Concept generation and selection of the refrigeration system

Chapter 4 presents the generation and selection of the refrigerating part of the product

4.1 The process

The selection of cooling device was crucial to fulfill the function of the refrigerated display. In order to generate concepts and perform analyses of the cardboard display, knowledge of parameters of a specific cooling device had to be set.

From an internet search and a discussion with Professor Olaf Diegel [19] at LTH it was found that there were not many different types of cooling devices, except for the compressor refrigerator, suitable for the project. As the development of the compressor refrigerator was not included within this project, the identified costumer needs regarding the refrigerator part was merely described and possible features discussed. An existing compressor refrigerator was chosen in order to be used during analyzes and prototype testing. In future work, development of the refrigerator part is of interest in order to further increase efficiency and customer satisfaction.

4.2 Concept generation of the cooling device

The compressor refrigerators that were of interest were the e-coolio R290 [6], the latest compressor refrigerator from Coolio found during benchmark and the EzyCooler 450 [18], the compressor refrigerator of the distributor of ICAs refrigerators, found during the identification of customer needs.

Other cooling devices found with a different technology that was of interest to the project was Peltier elements. This device and its features were discussed with Professor Olaf Diegel [19] at LTH.

4.3 Concept e-coolio R290

During the feasibility study a cooling device from Coolio was found, the e-coolio R290. As mentioned earlier, Coolio is a company that is a big part of the market of this type of compressor refrigeration. They are also interested in the development to increase efficiency and customer satisfaction. The cooling device, e-coolio R290 is an improved version of the former Coolio R290. According to the company webpage [20], improvements have been made regarding the material of the casing; LED connections, simplified water drain and maintenance. E-coolio R290 could be of interest while the company is a large distributor of cooling solutions of this type and are most likely to have good knowledge of the market.

4.4 Concept EzyCooler 450

The EzyCooler 450 was found from the questionnaire sent to the project-coordinator of ICA Sweden AB [17] during the identification of customer needs. From this questionnaire it was found that the EzyCooler 450 from Ajo Kylindustri AB was the cooling device used today for products of the ICA brand. The advantages of the EzyCooler 450 was that the stores were familiar with the product and that they have been used at different ICA stores, securing the main function of cooling. During the interviews of ICA store owners it was found that some changes of the existing cooling device was of interest.

The cord - the cord is hard to handle and too long in order to create an attractive appearance when connected to the roof.

Not user friendly - it is believed to be hard to understand and set to desired settings.

Space consuming – it is too large compared to the amount of products that can fit.

High cost maintenance – it is very expensive to repair.

Not energy efficient – it is too expensive to use, the use of energy is not efficient.

4.5 Peltier elements

The technology of Peltier elements was not the same as for the other two cooling devices and would require a different design. Peltier elements could be used for cooling a surface or a closed area. Peltier elements are thermoelectric coolers and function according to the Peltier effect that says that if two conductors of different materials are passed with an electric current, heating or cooling will occur [21].

The idea of what this concept could have been used for was to cool the shelves. The technology could also be used in another type of refrigerated display, where the cooling is performed locally and not an entirely cooled display. In order for this to work the elements must be connected to heatsinks in combination with fans that remove the heat from the hot side, and possibly a fan to distribute the cold from the cold side.

4.6 Selection of concept

A comparison of some features of the e-coolio R260 and EzyCooler 450 was made. The result can be found in table 4.1. As can be seen, the compressor refrigerators had similar parameters and the decision was therefore to be made to best suit the situation of Smurfit Kappa.

Table 4.1 Comparison of the two compressor refrigerators

	e-coolio R260	**EzyCooler 450**
Price	598 €	
Size	520x450x440	440x440x520
Weight	25 kg	32 kg

Elecrical data	2,3 A 230V 50Hz, 529W, 6kWh/day	370 W
Refrigerant	R290	R290
Temperature range	1/6 °C with double fan	2/10 °C
Wheels	4 (2 with brake)	4
LED connections	Yes	Yes
Ambient conditions	22°C /60%Hum	-
Temp control	Yes	Yes
Material	Metal, Expanded polypropylene	-

The reason that table 4.1 is not complete is because more information of the EzyCooler 450 was not possible to obtain without purchasing one example.

During a meeting at Smurfit Kappa with Lube Belokozovski [22] the selection of the cooling device was made. The selection of the concept was based on what Smurfit Kappa believed to best suit their situation. As they are a manufacturer of cardboard displays and not cooling devices, the selection of concept was founded on criterions that put their product at the best-selling point. The fact that most ICA stores already own an EzyCooler 450, and that ICA has a contract with the manufacturer, makes it easier for Smurfit Kappa to promote their solution while there is no extra cost for the stores.

The customer needs regarding the cooling device was not possible for Smurfit Kappa to implement but the knowledge of them could help improve the overall satisfaction of the product. The e-coolio R290 was probably a better candidate as a cooling device regarding energy efficiency, but for this project the EzyCooler 450 was the best choice to the display to be developed. The idea of Peltier elements as a complement to the cooling device was seen as expensive and hard to implement while more electrical inputs were needed. It was also believed that the fans used for removing heat from the heatsinks would interrupt the air current created to cool the products and instead push the cooled air out of the cooled area.

Even though the idea of using Peltier elements as a complement to the compressor refrigerated display was rejected, the idea of developing a different type of refrigerated display using only Peltier elements as the cooling device was discussed during the meeting at Smurfit Kappa [22]. Smurfit Kappa found the technology interesting and an investigation, of the possibility to use Peltier elements was initiated. The concept generation was therefore to be performed both regarding concepts of a refrigerated display using the EzyCooler 450, but also concepts using Peltier elements. From information gathered during the investigation and the concepts generated, a decision was to be made regarding cooling technology to be used during

further development and prototyping. The investigation of Peltier elements was initiated and can be found in the following chapter.

5 Peltier elements -Thermo Electric Coolers (TEC)

Chapter 5 presents the process and results of the investigation of Peltier elements

In order to get a better understanding of Peltier elements an investigation was conducted. The purpose of this investigation was to get an understanding of the possibility to use this technology for the product and how it could be implemented. It was also made in order to get an understanding of opportunities and obstacles related to the technology.

5.1 Function

Peltier elements are thermo electric elements that provide one cool end while the other is heated. Two ceramic plates are put on each side of an array of semiconductor elements, often of the material Bismuth Telluride Bi_2Te_3. The elements are of two different types P,N, figure 5.1 where the P type semiconductor is doped with atoms with a higher number of electrons, and the N-type conductor is doped with atoms with a lower number of electrons, creating "holes". The temperature difference will occur when a current is passed through the elements from one type of conductor to the other. When the current is applied, the electrons transport heat that is absorbed, creating a cold side where electrons require energy to go from e lower energy state, and released creating a hot side when electrons goes from a higher to a lower energy state [21],[23].

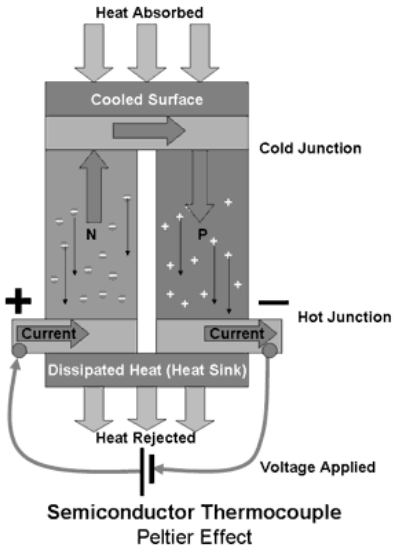

Figure 5.1 Overview of the function of a Peltier element [23]

5.1.1 Areas where Peltier elements are used today

Peltier elements, also known as thermoelectric elements, are not only used for converting electricity to heat and cool. They are also used the other way around, generating electricity by absorbing heat, a phenomena known as the Seebeck effect. The Seebeck effect says that a difference in voltage is obtained when semiconductors of different types are exposed to a temperature difference.

A lot of research has been made within this area where all processes generating heat are of interest. From a research made by IDTechEx [24] a growing interest of the thermoelectric energy harvesting is shown and provides information that the overall market will reach $ 750 million by 2022. One example is researches in the possibility to use thermo electric elements in the car industry, converting waste heat of engines to electricity. Another application is consumer applications, both monitoring of vitals, power sources for mobile phones etc. but also within the military and aerospace where the availability and not cost is of main importance [24]. An overview of the forecast for growth in the thermoelectric generators market to 2014 can be found in figure 5.2.

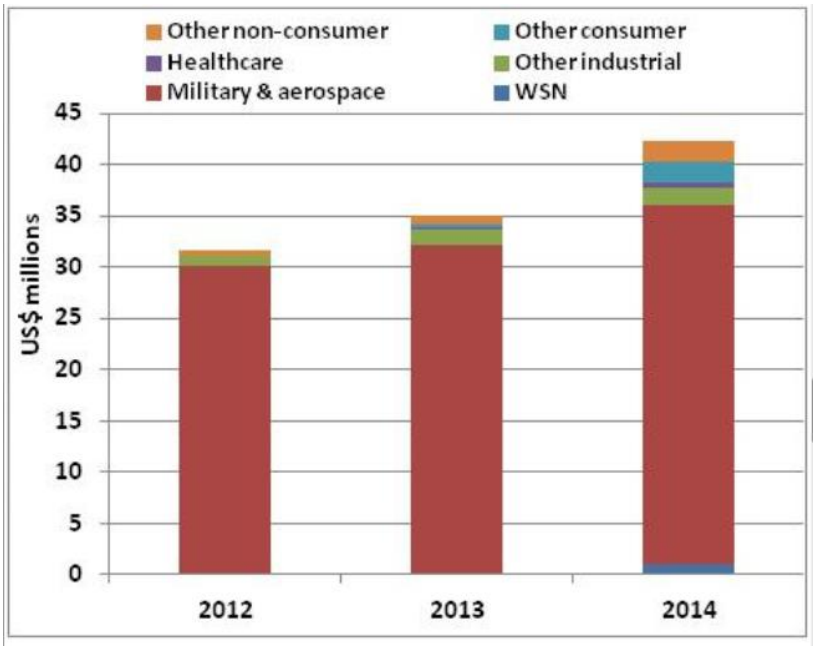

Figure 5.2 Forecast for growth in the thermoelectric generators market to 2014 [24]

5.1.2 Advantages and disadvantages

Advantages

- Cheap
- Small
- No maintenance needed if fans are not used
- Not effected by vibrations from the surrounding while there are no moving parts
- Long life expectancy
- Possible to use as modules where local cooling is made instead of an entire display
- Interesting technology that is progressing. Progress has been made within the research regarding the energy efficiency of Peltier elements creating a bright future for the usage of this as a cooling device
- Quiet
  [25]

Disadvantages

- Not energy efficient, Peltier elements require six times the amount of energy needed for refrigeration through the conventional compression cycle
- The hot side require an efficient cooling, normally by heatsinks in combination with fans
- The hot and the cold side have to be insulated from each other in order to not reach an equilibrium where cooling stops
- Other materials than cardboard of the shelves is required to insulate and distribute the cooling
- If the cooling fan breaks down, the Peltier element could overheat
  [25]

5.2 Improvements in energy efficiency

5.2.1 Research

As the largest problem of the otherwise cheap Peltier elements is the large energy consumption, a lot of research has been made where the object has been to find ways to reduce the energy input needed.

One research that was found, presented results creating an increase in efficiency by 10 to 15 times [26].

This finding was made by a PhD student during his research at the department of Theoretical Physics at Lund University. In order to get a better understanding of the research and also the future of Peltier elements, an interview with the PhD student, Magnus Hivert was set up.

From the meeting it was found that the reason that Peltier elements have a large consumption of energy was due to the large amount of heat being transferred back to the cold side of the Peltier element.

This transfer is made by vibrations in the atoms, also known as phonons, moving in the opposite direction to the electrons within the bismuth antimony telluride. Thermal energy is stored in phonons and contribute to material properties, such as thermal conductivity.

Magnus found a way to stop the phonons by creating a vacuum where phonons were prevented from moving any further, without interfering with the passing of electrons.

The project is no longer active due to problems with material requirements and trouble with funding. Even though the project has ended, Magnus Hivert is positive about the possibilities with future development of improving the energy efficiency of Peltier elements. He believes that the development is progressing and that when the efficiency is increased, the advantages of Peltier elements will make it a desired technology on the market [27].

Other researchers have also made attempts in increasing the energy efficiency by preventing the movement of phonons. Students at Boston College and MIT found a way to increase the relative performance of bismuth antimony telluride by 40 percent.

The increase of the relative performance was made by crushing bismuth antimony telluride to nanoscopic dust and rebuild it. As the reconstruction created irregular placing of the grains of the material, phonons were slowed down and therefore the heat flow was reduced without compromising the movement of electrons [28].

5.2.2 Conclusion

The findings provided information that there was a possibility to make the Peltier elements as energy efficient as compressor refrigeration. The advantages would create a competitive product and be of great interest to the market. The possibility to improve the energy efficiency had already been found but due to the complexity of technique used to create the improvements, the elements were expensive. Because of the widely spread interest in the product, the research to make it commercially available has every opportunity to be fast in order to meet the demand on the market.

5.2.3 Methods to improve energy efficiency of existing Peltier elements

Even though research is moving forward in improving the energy efficiency of Peltier elements, the ones used on the market today require other methods.

In order to improve the energy efficiency of common Peltier elements a number of approaches can be made. To start, the number of Peltier elements is of interest. Instead of using one efficient Peltier element, a number of less efficient Peltier elements can be used. From this approach, less energy will be needed per element and therefore less heat would have to be discharged. In order to keep the temperature difference of the hot and cold side, the heatsinks should have as high transport capability as possible, and if fans were used to remove heat from the heatsinks, they should be as efficient as possible. Another given factor of improving the energy efficiency is the insulation, the better the insulation of the area being cooled, less energy will be required to maintain desired temperature [29].

5.3 Conclusion of investigation

During the investigation it was found that Peltier elements were not nearly as efficient as common compressor refrigeration. It was though believed to be a technology that was improving and where researchers were finding ways to improve the energy efficiency, the obstacle was to make it commercially available.

When commercially available, the technology is believed to become widely used. At the time the technology is of interest for a smaller application where the energy efficiency is made as great as possible using available Peltier elements.

Smurfit Kappa would not only be the first on the market with the product but also at a head start when the improvement in energy efficiency is commercially available, and the interest on the market increased.

As the technology is rather new to the market, cooling of a product that would not degrade if not cooled is of interest. The product chosen is 33 centiliter cans of soda. The reason why this product is chosen is due to the fact that a new technology could be hard to market for perishable goods while the requirements are very strict for products of that sort. It also provides security for prototype testing, if the prototype was to malfunction, the product would not degrade.

Main advantages of using Peltier elements in a refrigerated display compared to compressor refrigeration is that they do not require maintenance, have a long life expectancy and are cheaper to repair. During the investigation of customer needs it was found that the cost of repairing the compressor refrigerators was an issue. These advantages could create a possibility for the customers to overlook the main disadvantage of the energy consumption. The technology is believed to be suitable for the application and of interest to the project.

6 Product specifications

In this chapter the process of defining the product specification and the final product specifications are presented

6.1 Process

As the cooling technology is different for the two concepts, different product specifications were produced for the compressor and the Peltier refrigerated display.

The product specification is a description where customer needs are connected to specifications that can be measured. The product specification is later used when evaluating product concepts. According to the product development method [3, p. 141] the process of creating a product specification is made in four steps. During these steps, the target values are identified. At first these steps were used to generate the product specification of the compressor refrigerated display followed by the generation of the product specification of the Peltier refrigerated display and last the cardboard display. Due to difference in technology, some needs were added and used for the product specifications of the Peltier refrigerated display and the cardboard display.

Step 1 Prepare a list of the specifications

Step 2 Benchmarking – gather information of competitors

Step 3 Establish ideal and marginally acceptable target values

Step 4 Reflect over the result and the process

No distinction was made between ideal and marginally acceptable target values (step 3) in this work.

According to the development method these four steps are followed by five steps [3, p. 153] where the target values are further examined and ideal values set. These steps, if used, are not used until after the primary prototyping. The reason for this is because the ideal values are hard to interpret before concepts are generated and tested.

6.2 Compressor refrigeration

6.2.1 List of specifications

The specifications were produced to suit the customer needs. Many of the specifications were hard to provide a metric value for and were instead given a subjective metric. The evaluation of these specifications was made by the development team in combination with tests of the prototype later in the project.

Need number 3, *The refrigerator is easy to set to desired settings,* was not a need that was affected by the display part and was therefore left out of the table of specifications. Also need number 43 regarding a mobile solution was no longer of interest while this would require a development of the power source.
The importance was set by the combination of the needs relative importance and how the need was connected to the specifications. For instance specifications 7, *The coating can handle the amount of moisture built during the desired use without being unattractive,* connected to need 8 and 12, where need 8 has a relative importance of 5 and need 12 of 3. The reason that specifications 8 still was given an importance of 5 was due to the fact that need 12 was connected to the overall specifications 8 but not the specific part of the need that caused the low classification of the relative importance. The list of specifications can be found in Appendix G.1 where information presented in steps later in the project also is presented.

6.2.2 Benchmarking

The primary benchmark made during the feasibility study was performed in order to get an understanding of an unknown market. In this chapter the benchmark was performed in order to find information about competing manufacturer's products. The competing manufacturers products researched were the companies found during the benchmark of the feasibility study. The reason to gather this information was in order to get an understanding of what specifications the product to be developed had to exceed in order to gain success on the market. Most of the values for the specifications of the product specification were subjective and not possible to find values for. Since Smurfit Kappa had the knowledge of most of the specifications that were subjective, only some of the specifications were researched through benchmarking. Values of some of the specifications were found during the interviews for customer needs, these were implemented in the benchmarking table while the selection of values also was effected by values the customers expressed as their expectations of the product. The result of the benchmarking can be found in table 6.1.

Table 6.1 Result of benchmark of the compressor refrigerated display

Nr	Measurable specifications	Customer needs	Freshboard traditional 3.0	ECO Display	Promocart on Chillair
3.	The maximum weight each shelf can handle	12 kg	25 kg		20 kg
19.	The maximum amount of energy consumption of one day		6kWh/day		
26.	Minimum amount of time the display can be used	2 weeks to 6 months	12 months		
28.	Maximum cost		401-500 units: 68 Euro		
29.	Maximum time for assembly	5 min	5 - 10 min	5 min	

The table is not complete while the manufacturers of the refrigerated cardboard displays only provided full information to companies that were interested in purchasing a number of displays, providing information of the company.

6.2.3 Target values

The specifications that were subjective were evaluated by prototype testing. The specifications that could be evaluated by a metric value were presented with the target value and a description of the approach to decide the target value can be found in table 6.2.

Table 6.2 Measurable specifications and the approach of defining the target value.

Nr	Measurable specifications	Unit	Target value	Approach for defining the target value
1.	Temperature range to maintain	˚C	4-12	Mean value of the expressed target values
2.	Ambient temperature	˚C	19-20	Mean value of the expressed target values
3.	The maximum weight each shelf can handle	kg	15	A decision in order to keep the cost down by only using cardboard as opposed to Coolio, but still exceed the expressed customer needs
4.	The product will not turn over when hit by a shopping cart or pushed	Subj.	Yes	Test by crashing with a shopping cart
5.	The sensitivity of an indicator if temperature is lower than desired settings, the amount of time the temperature is not optimal	sec	60	An approximation of acceptable time
9.	The display will not be damaged when hit from any angle by a shopping cart	Subj.	Yes	Test by crashing a shopping cart
10.	The edges of the display will not be noticeably destroyed when hit by a shopping cart	Subj.	Yes	Test by crashing a shopping cart
16.	The maximum amount of shelves that can be used within the same display without compromising the function	Pieces	4	Maximum number of shelves expressed during the search of customer needs
19.	The maximum amount of energy consumption of one day	kWh/day	6	Value found by benchmarking
20.	Maximum time to cool the product	s	60	Value decided by Smurfit Kappa

26.	Minimum amount of time the display can be used	Months	4	Value decided by Smurfit Kappa
28.	Maximum cost at 401-500 units	SEK	638	The price of Coolio Freshboard 3.0
29.	Maximum time for assembly	Min	5	The time is decided by comparing the customer needs and the values of existing products

6.3 Peltier refrigerated display

6.3.1 Additional technology specific needs for the Peltier refrigerated display and cardboard display

As the technology of Peltier elements is different from compressor refrigeration, the customer needs that were found were more oriented towards the development of a cardboard display. From the customer needs it was found that there was an interest in the opportunity to present a number of products within a display and also a desire for each store to design displays suited for that particular store. In order to meet these requirements the Peltier refrigerated display was to be used as a module within a cardboard display where non refrigerated products could be presented at shelves not occupied by the refrigerated display. In order to secure the function of the technology of Peltier elements, some needs were added. According to the development method used for the master thesis [3], all customer needs are to be found and processed during an earlier stage. All steps for processing customer needs were also made for the needs connected to the technology. The customer needs that were added were given a need number starting with a P for Peltier, i.e P1. The technology specific needs are presented in table 6.3.

Table 6.3 Technology specific needs of the Peltier refrigerated display

Nr	Need	Importance
P1	The product is suitable for 33 cl cans	5
P2	The surfaces transferring heat or cooling provides the best possible transfer	5
P3	There is room for heatsinks and possibly fans	5
P4	A number of less efficient Peltier elements are used	4
P5	The heat is easily discharged from the hot side	5
P6	The display is insulated	5
P7	The advantages of the technology is easy to understand	4

6.3.2 List of specifications

The list of characteristics was created by combining the technology to best suit the customer needs but also with the desire to make the cooling as efficient as possible, using the information gained during the investigation of Peltier elements.

The first ten of the measurable specifications were the same as for the compressor refrigerated display. These specifications were of importance for the Peltier refrigerated display while they were not affected by the technology. The measurable specifications of the Peltier refrigerated display can be found in Appendix G.2.

6.3.3 Benchmarking

Measurable specifications that were of interest for benchmark were

5. Maximum amount of energy consumption of one day [kWh/day]
9. Minimum amount of time the display can be used [Months]
10. Maximum cost [SEK]
11. Amount of cans that can be fitted in the display [Units]

As the Peltier refrigerated display was new to the market and the main competition was compressor refrigerated displays, the benchmarking was conducted researching compressor refrigerated products and apply it to Peltier refrigeration.

The maximum amount of energy consumption of one day for the Coolio, presented earlier in table 6.1 of the benchmark of the compressor refrigerator**,** was 6 kWh/day. During the investigation of Peltier elements it was found that they were about six times less energy efficient than compressor refrigeration [25]. The energy required for the Peltier refrigerated display should therefore be multiplied by six in comparison. As the Peltier refrigerated display is closed, the amount of energy required would be less than compared to an open air merchandiser. From an investigation [30], the amount of energy needed for a closed door merchandiser was only 28% of the energy required for an open air merchandiser. As the size of the Peltier refrigerated display compared to Coolio Freshboard 3.0 was about one third, the maximum amount of energy required for the Peltier refrigerated display should be the following.

$$6kWh/day * \frac{6 * 0.28}{3} = 3.36kWh/day$$

The minimum amount of time the display can be used was set to add up to the lifetime of a compressor refrigerator. From the investigation of Peltier elements it was found that Peltier elements did not have any moving parts, contributing to a longer life time expectancy. According to the specification of the e-coolio R290, presented in Appendix C of the primary benchmark, the life expectancy of this compressor refrigerator was a minimum of three to five years. From this the minimum amount of time the Peltier refrigerated display can be used was set to five years.

The maximum cost of the Peltier refrigerated display was decided by comparing it to the e-coolio R290 with a cost of 597 Euro, information gained from contact by email with sales at Nordic Cooling Solutions, distributor of Coolio products [31]. As the compressor refrigerator was used to cool an area of about three times the size of the

Peltier cooled display an approximation of a price of one third of the e-coolio R290 was made. The cost of the Peltier display was therefore set to 199 Euro, approximately 1,871 SEK [32].

The number of cans that can be fitted in the display was decided both by the measurements and the weight of the can. The measurements and weight was found by measuring a 33 centiliter Loka can with calipers and weighing it using a scale in one of the laboratories at LTH, The engineering faculty of The University of Lund. The following dimensions were found.

Height = 115 mm

Diameter = 65 mm

Weight =350 grams

There was a tradeoff in deciding the number of cans to be displayed. The number of cans would increase the weight that the shelves of the cardboard display must handle, but at the same time there was a desire to display a larger amount of products. From Coolios Freshboard Traditional 3.0 it was found that 24 cans were possible to present at each shelf, information gained from a PDF retrieved from sales at Nordic Cooling Solutions [31]. From the weight of one can it was found that 24 cans weigh 8400 grams. The Freshboard Traditional 3.0 is manufactured to suit the compressor refrigerator and therefore has more requirements in rigidity and resistance to moisture. These requirements were not set as high for the cardboard display of the Peltier refrigerated display. From this information a decision was made to display 18 cans in total, still a larger amount but with a decrease of 2100 grams.

The total weight of 18 cans was 6300 grams.

6.3.4 Target values

The measurable specifications presented in Appendix G.2 are combined with target values. The approaches for defining the target values are presented in table 6.4 below.

Table 6.4 Measurable specifications and approach for defining the target value for the Peltier refrigerated display

nr	Measurable specification	Unit	Target value	Approach for defining the target value
1.	Temperature range to maintain	˚C	4-12˚C	Mean value of the expressed target values
2.	Ambient temperature	˚C	19-20 ˚C	Mean value of the expressed target values
3.	Attractive and presents the products in the best possible way	Subj.	Yes	
4.	The products are easy to access	Subj.	Yes	
5.	The maximum amount of energy consumption of one day	kWh/day	3.36	Decided in comparison to the amount of energy used for a compressor refrigerator

6.	Maximum time to cool the product	Min	30	The amount of time the customers are believed to be willing to wait
7.	Source of light	Subj.	Yes	
8.	The cord is handled in an attractive and efficient way	Subj.	Yes	
9.	Minimum amount of time the display can be used	Years	5	The maximum for the e-coolio R290
10.	Maximum cost	SEK	1,871	one third of the e-coolio R290
11.	Number of cans that can be fitted in the display	pieces	18	A compromise of weight and the desire to display a larger number of products
12.	The minimum transfer of thermal energy of the desired cooled surfaces	W/mK	205	The thermal conductivity of aluminum [33]
13.	The heat is discharged in a way that allows the Peltier elements to be as efficient as possible	Subj.	Yes	
14.	Number of Peltier elements	pieces	3	Evenly distributed over the surface
15.	The maximum transfer of thermal energy from the display to the surrounding	W/mK	0.03	As little transfer as possible from the cooled surface, but at the same time using a common material
16.	The technology is easily recognized	subj.	Yes	

6.4 Cardboard display

6.4.1 List of specifications

As the needs found at an earlier stage concerned the cardboard display, the same measurable specifications were used, excluding the ones affected by the compressor refrigeration. Specifications 19-22 were also added concerning the adjustment needed to suit the Peltier refrigerated display. The measurable specifications of the cardboard display can be found in Appendix G.3.

6.4.2 Benchmarking

As Smurfit Kappa is a company specialized in packaging, the target values for the cardboard display were decided using their expertise. Therefore a benchmark was not performed regarding the cardboard display.

6.4.3 Target values

The measurable specifications presented in Appendix G.3 were combined with target values. The approach for defining the target values are presented in table 6.5 below.

Table 6.5 Measurable specifications and the approach for defining target values for the cardboard display

Nr	Measurable specification	Unit	Target value	Approach for defining the target value
1.	The minimum weight each shelf can handle	kg	15	The weight of 18 cans of soda plus an approximation of the weight of the Peltier refrigerated display
2.	The product will not turn over when hit by a shopping cart or pushed	Subj.	Yes	Test by crashing a shopping cart
3.	The display will not be damaged when hit from any angle by a shopping cart	Subj.	Yes	Test by crashing a shopping cart
4.	The edges of the display will not be noticeably destroyed when hit by a shopping cart	Subj.	Yes	Test by crashing a shopping cart
5.	Attractive and presents the non cooled products in the best possible way	Subj.	Yes	
6.	The products are easy to access	Subj.	Yes	
7.	Different products are possible to display	Subj.	Yes	
8.	A larger amount of products can be presented	Subj.	Yes	
9.	The product is designed with the possibility to customize both display and shelves	Subj.	Yes	
10.	The maximum amount of shelves that can be used within the same display without compromising the function	Pieces	3	Decided by customer needs and symmetry where 2 shelves are used for non-refrigerated products
11.	The product is easy to move around	Subj.	Yes	
12.	The cord is handled in an attractive and efficient way	Subj.	Yes	
13.	Extra information can be added	Subj.	Yes	
14.	The print does not interfere with the products packaging, it is simple and informative	Subj.	Yes	
15.	Minimum amount of time the display can be used	Month	6	Decided by customer needs and the knowledge of Smurfit Kappa where a comparison to a non-cooled display is made
16.	The product is possible to fold to a flat sheet	Subj.	Yes	

17.	Maximum cost	SEK	200	Decided by the knowledge of Smurfit Kappa, where a comparison to a non-cooled display is made
18.	Maximum time for assembly	Min	20	Decided by customer needs and the knowledge of Smurfit Kappa
19.	The display is adjusted to suit the need for heat to be discharged from the hot side of the refrigerated display	Subj.	Yes	
20.	The display presents the technology of the refrigerated display	Subj.	Yes	
21.	The display is manufactured to suit the size and appearance of the refrigerated display	Subj.	Yes	

6.5 Reflection of the result and process

The product specifications that were set are believed to fulfill the customer needs and be of help to secure commercial success. Many of the measurable specifications were subjective. Subjective target values are harder to evaluate but can still be used as guidance during the following chapters, concept generation and selection. As the product specifications and the evaluation of them was set by one person, the subjective specifications are believed to be evaluated as intended.

7 Concept generation

Chapter 7 presents the process and results of the concept generation of ideas that are developed in order to fulfill product specifications

7.1 Process

According to the development method used for the master thesis, the generation of concepts is performed in five steps [3, pp. 168-192].

Step 1 Specify the problem

Step 2 External search

Step 3 Internal search

Step 4 Search systematically

Step 5 Reflect over the solutions and the process

These steps were first followed to generate concepts of the compressor refrigerated display, followed by repeating the process for the generation of concepts of the Peltier refrigerated display.

7.2 Compressor refrigerated display

In order to understand the difficulties of the design of the product and make sure that a solution to all problems are implemented in the product, it can be of interest to divide the problem into sub-problems. In order to get a better view, the sub-problems are presented as questions.

7.2.1 Specify the problem

Sub problems to be solved and implemented in the product:

Energy efficiency – How is the air to be:

- Distributed?
- Retained?

Shelves – How can the shelves be designed to:

- Withstand the weight of the products?
- Make it easier for customers to access the products?
- Present products in an attractive way?

- Create a possibility to customize the number of shelves to be used?
- Make it easy to assemble?

Display – How can the display be designed to:

- Withstand forces?
- Easily transported?
- Cheaper to manufacture?

Material – What kind of material have to be used in order to:

- Withstand moisture?
- Cheaper to manufacture?

Add-ons - How is the product to be designed in order to make it possible to attach:

- Positioning of cord?
- Night curtain?
- Led lights?

7.2.2 External search

An external search of solutions for the sub-problems is an effective way to find existing solutions that can be of help. Some findings of the patent search during the feasibility study at the beginning of the master thesis, Appendix B, were used. The findings used and examined contained information about energy efficiency by optimizing the air flow. From the patent search the following was found.

Airflow from diffuser holes at the back panel, pressed down by using a vertical flap at the top [B4].

Decrease the impact of cooling when stacking a larger amount of products by using shelves made out of ribs [B10].

Lateral airflow where the outlet is positioned at one of the lateral walls and the inlet at the other which guides the cooled air back to the cooling device. The openings are in the shape of elongated slots, the inlets are larger than the outlets [B11].

Creating an air curtain by using an outlet adjacent to the open front, an air outlet at the bottom part of the open front and an inlet at the top part of the open front producing a column of air [B12].

Turbulence area to force the air to be in contact with the product to be cooled. Turbulence generating elements positioned at the bottom part of each shelf and the top wall. The turbulence elements are made out of the covering cardboard of the shelves by creating a fold where the turbulence is to take place [B12].

7.2.3 Internal search

Using information gained during the external search, concepts were generated by the method of brainstorming. The reason that brainstorming was found to be the best concept generation method was because Smurfit Kappa has a lot of knowledge within

the area of cardboard display design and manufacturing. The brainstorming was performed in the presence of packaging designer, Ingvar Persson and design and innovation manager, Lube Belokozovski [34].

7.2.4 Search systematically

This step of the product development method used during the master thesis [3] is not followed while the number of concepts is manageable without classification as the concepts already were divided into groups before the generation of concepts.

7.2.5 Concepts

From the internal and external search of solutions to the sub problems, concepts were generated. The concept generation and selection was modified to suit the development method Smurfit Kappa uses today, a "trial and error" method where a number of prototypes are built and tested. During the prototype manufacturing, adjustments are made regarding the design both manufacturing and the aesthetic. The reason that this method is used is because the prototypes are cheap to manufacture and makes it easier to understand and evaluate the design. The concepts are used as guiding means and may be altered during the prototype manufacturing.

The add-ons are to be applied at a later stage where prototypes have been manufactured and a better understanding of the final concepts is gained.

7.2.5.1 Energy efficiency

Different solutions using the information gained from the patent search was used. The following air distribution ideas were found:

Concept 1.1

Air distributed through hollow shelves and the top part, creating an air flow from the top over the products. In figure 7.1 the concept is presented without shelves in order to better illustrate the flow of air.

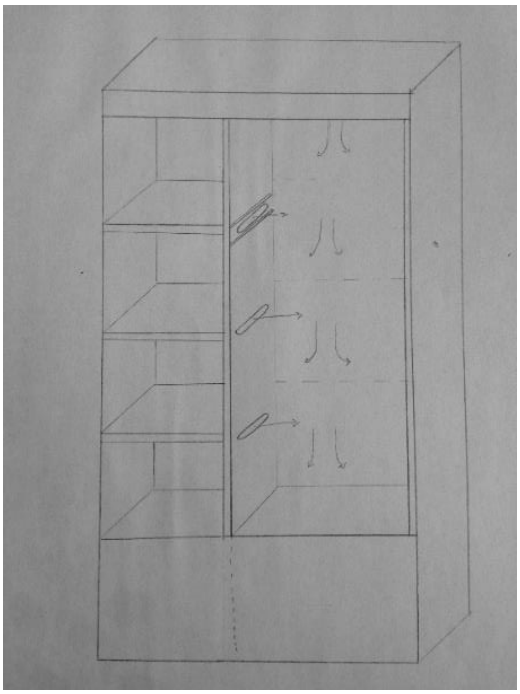

Figure 7.1 Concept 1.1 Air distributed through the shelves and pressed down towards the products

Concept 1.2

Air distributed through elongated inlets on one of the lateral walls and distributed back to the cooling part through elongated outlets at the opposite wall. The air is blown towards shelves that are equipped with a turbulence area, forcing the air down over the products. There is also an air curtain created at the front. This air curtain is created by a smaller opening at the front of one of the lateral walls to an outlet on the opposite wall. The walls are insulated with channels for the air distribution. The concept can be found in figure 7.2. The picture on the top left is an overview of the channels for air distribution.

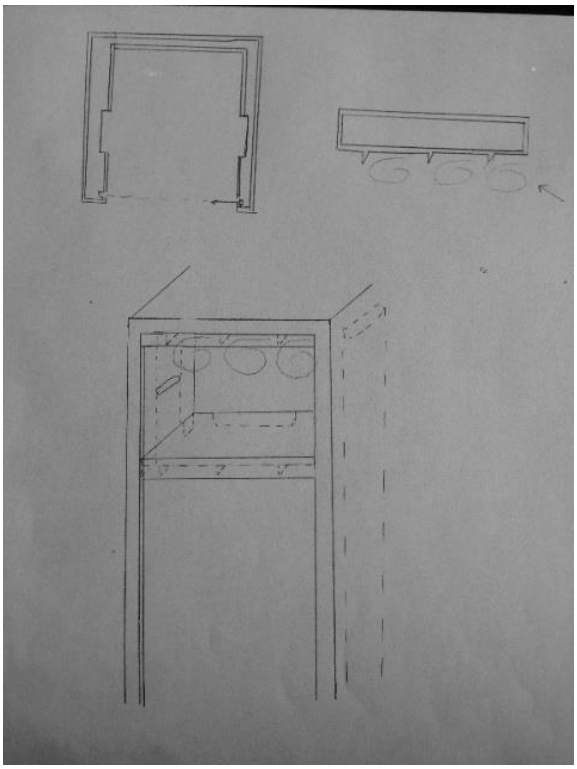

Figure 7.2 Concept 1.2 Air distributed through channels in the lateral walls in combination with an air curtain. A turbulence area is created at the bottom of the shelves, seen in the top right of the sketch. On the top to the left of the sketch an overview of the air distribution channels are presented

Concept 1.3

Air distributed in the same way as concept 1.2 but without the channel for the air curtain.

Concept 1.4

Air distributed through the back wall close to the bottom of each shelf. The air is pressed down towards the products by elements attached to the shelves.

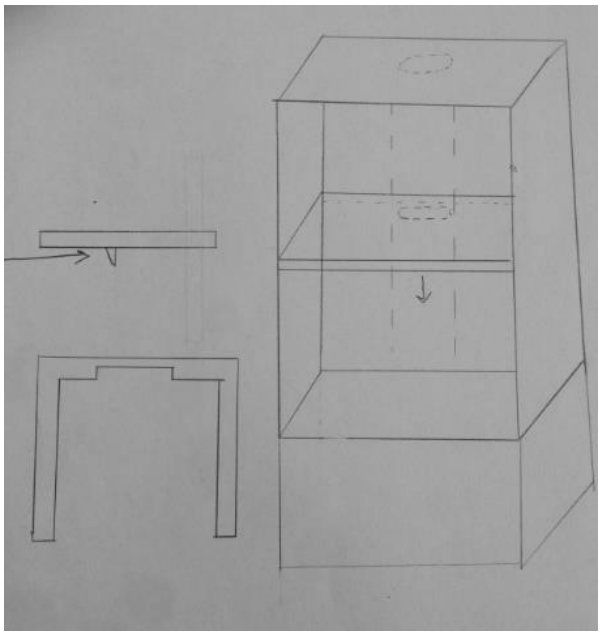

Figure 7.3 Concept 1.4 air distributed through the back wall that is pressed down towards the products using the turbulence elements presented at the top left in the figure

Solutions to the other sub problems can be found in Appendix H where solutions suitable for each of the concepts of the energy efficiency are presented.

7.3 Peltier refrigerated display

7.3.1 Specify the problem

Energy efficiency – How is the product to be designed in order to:

- Remove the hot air from the hot side?
- Isolate hot and cold sides from each other?
- Distribute the cooling?

Technique specific – how is the product to be designed to:

- Express the new technology
- Raise interest and questions

7.3.2 External search

In order to generate concepts of the cooling, the understanding of existing solutions was of interest. Peltier elements are used in a variety of applications and not all of them were suited for the function of the project. During an external search, the following applications were found to be of interest, air coolers for refrigerated cabinets and cold plate coolers.

7.3.2.1 *Air coolers*

Peltier air coolers are used for cooling products that cannot be cooled by direct contact to a cool surface. The air coolers are not as efficient as the cold plate coolers but are useful for products within the food industry while the cooling is distributed throughout the entire cabinet. The use of air coolers are similar to the traditional compressor refrigeration systems. The difference is that they are cheaper and smaller which provide the possibility to use them for a smaller area. The air coolers are built by connecting each side of the Peltier to a heatsink and a fan. On the hot side of the heatsink a fan is used to remove the heat to the surroundings while on the cold side, the air is distributed to the insulated area to be cooled. Between the hot side of the element and the heatsink a distance can be used to create a gap to fit the insulation [35]. An example of a system of this type can be found in figure 7.15 below.

Figure 7.4 Air cooler system [36]

7.3.2.2 Cold plate coolers

Cold plate coolers are used to cool a surface in direct contact to the Peltier element. The hot side of the Peltier element is designed in the same way as the air coolers. The cold side of the Peltier element is instead connected to a plate, with low thermal resistance, where the cooling is distributed, cooling products in contact with the cold plate. The cold plate cooler is more efficient than the air cooler while there is a direct contact between the Peltier element and the surface to be cooled. This creates requirements of the surfaces in contact while the better the contact, the better the cooling. Some of the cold plate coolers require a distance between the hot side of the Peltier element and the heatsink in order to fit insulation. In figure 7.16 one example of this type of system is presented. For this system, the plate is small while it is used for cooling small laser diodes and laboratory instruments [37].

Figure 7.5 Cold plate cooling system [38]

7.3.2.3 Consulting an expert

Within the external search, it could be of interest to consult an expert within the area. For this project it was believed that a better use of an expert was made when concepts were generated beforehand and further development discussed. This step was therefore to take place during the selection of concept.

7.3.3 Internal search

Concepts were generated using the information gained from the investigation of Peltier elements and the external search. The concepts generated were to be discussed and further developed through discussions with an expert. The method used for generating concepts was brainstorming.

7.3.4 Search systematically

This step of the product development method used during the master thesis [3] was not followed while only three concepts were generated. The reason that only three concepts were generated was because they were concepts of the overall function. The concepts were to be discussed and further developed.

The reason for generating concepts of the overall function and not the entire display was because it was believed that the communication with an expert over the different concepts of the overall function would save time and a direct input on ideas could be found.

7.3.5 Concepts

Concept 1

An insulated box with a transparent acrylic glass front in order for customers to easily get a view the content of the box. The insulation is a common material, usually polystyrene extruded. The cooling combines 2 fans, 2 heatsinks, 1 Peltier element and

one distance in order to fit the insulation between the hot and cold side of the element. A combination of more than one of the cooling installation is possible in order to create a better air flow. In figure 7.17 below, the concept is presented.

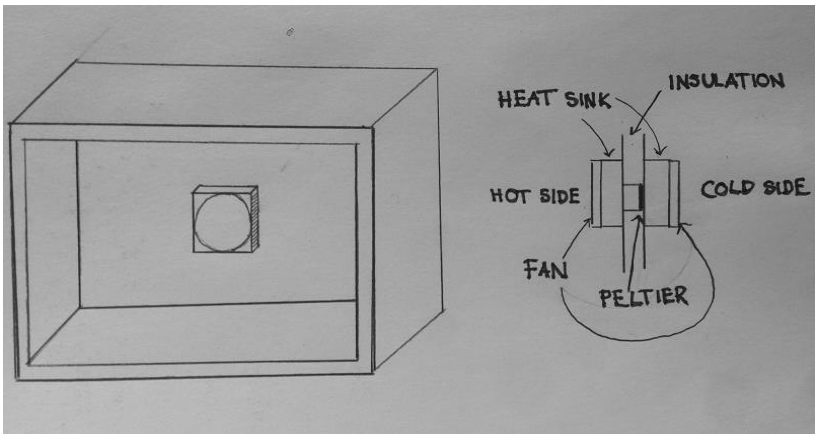

Figure 7.6 Concept 1, an insulated box with an acrylic front cooled by an air cooler system

Concept 2

This concept is a cooled shelf where the cooling is made by connecting one Peltier element to an aluminum plate that distributes the cooling over the surface. A heatsink is connected to the hot side of the Peltier through a distance in order to fit insulation between the hot and cold side of the Peltier. The heatsink is connected to a fan that removes the heat. The bottom part of the aluminum plate is insulated from the area where the hot air is distributed. The bottom part of the shelf is insulated with a plate that tilts in order to create an air flow out through the back where the shelf is open. More than one Peltier cooling device can be used distributed over the surface. The shelf is not capsuled and is therefore used where the surrounding air is ambient temperature. An overview of the concept can be found in figure 7.18 below where the figure at the top presents the function of the shelf while the figure at the bottom presents the casing of the shelf.

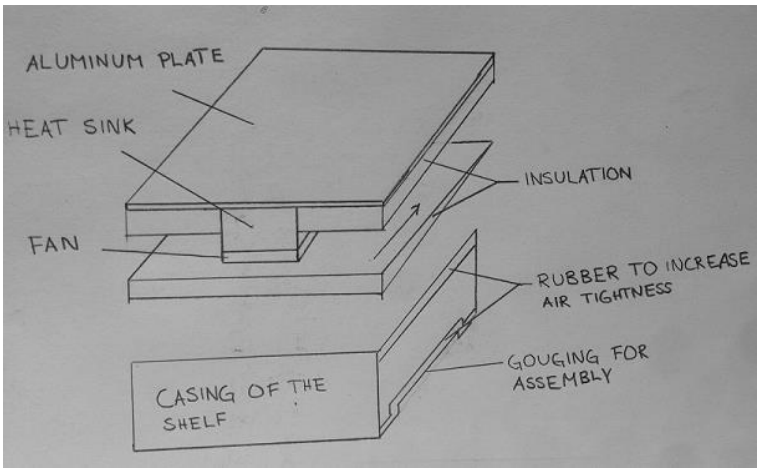

Figure 7.7 Concept 2 with a plate cooler system, cooling the top of the shelf made out of aluminum

Concept 3

This concept is a cold plate cooler that is capsuled in an insulated area. The cold plate is like in concept 2, connected to a Peltier element that is connected to a distance where insulation is fitted. The distance is connected to a heatsink that is cooled by a fan distributing the hot air to the outside of the insulated area. The insulated area is similar to concept 1 where the front side is a see through double wall acrylic glass with a gap of air in between, creating improved insulating properties. The cold plate, and the number of Peltier elements can be adjusted to suit the cooling needed. In figure 7.19 below the concept is presented. As can be seen at the top of the figure, the back of the insulated area is tilted in order to easily distribute the heat to the surrounding. The figure at to the right presents the cold plate to be inserted in the insulated area.

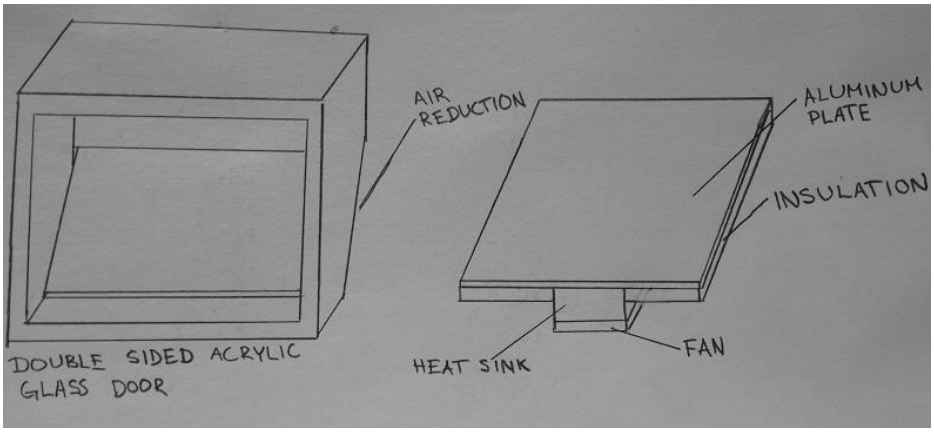

Figure 7.8 Concept 3, a cold plate cooler kept in an insulated area

7.4 Cardboard d*isplay*

As stated earlier, the compressor refrigeration was oriented towards the cardboard display. The sub-problems of the cardboard display for the Peltier refrigerated display are the same as for the compressor refrigeration apart from the energy efficiency.

As the development of the Peltier refrigerated display was time consuming, the cardboard display was decided to mainly be manufactured by Smurfit Kappa. The idea was for Smurfit Kappa to develop the concept to meet customer needs and later make adjustments to meet the requirements of the Peltier refrigerated display. These adjustments were made in collaboration when the selection of concept of the refrigerated display was made and prototyping initiated.

8 Final selection of the refrigeration system

Chapter 8 presents the final selection of refrigeration system that is to be further developed and prototyped.

In chapter 4 it was determined that the final selection of technology would be based on the investigation of Peltier elements in combination with the concepts generated during the generation of concepts. The two technologies that were to be compared were compressor refrigeration and Peltier elements.

8.1 Comparison of compressor refrigeration and Peltier elements

Compressor refrigeration is the common refrigeration system in use today. There is an advantage where it is well known and has been developed for a long period of time. Peltier elements have been known for a long period of time but the interest for using the technology has started to grow during the last few years where cooling of smaller applications is becoming more and more interesting. Due to the newly found interest in the technology, the development of the power consumption is of great interest and as mentioned earlier breakthroughs have been met.

Compressor refrigeration is less power consuming than Peltier elements. Looking at the problem through an environmental and economical perspective, the Peltier element is more expensive to run and requires more electricity. At the same time, the life expectancy is much longer than for compressor refrigeration and the system does not require any maintenance due to its non-moving parts. The energy required to manufacture a new compressor refrigerator may be as power consuming as the power consumption of the Peltier system in use. As the Peltier system for the Peltier refrigerated display is not developed, the system can be built using modules. The advantage of building the system using modules is that the Peltier element could be replaced when a developed Peltier element with a lower use of energy is commercially available. This would mean that the casing of the display would not have to be changed until the grocery store owner demanded a newer model.

Due to the technology of Peltier elements the display would be developed as a smaller refrigerated module to be combined with the presentation of non-refrigerated products. The new way of presenting the products could be of interest to the market while it would not be as space consuming as the compressor refrigerators and therefore not cost as much to display, an issue mentioned during the first part of the benchmark. The fact that the display would be used as a module within the cardboard display creates the possibility for different designs of the cardboard display as long as the shelf used for the refrigerated display is adjusted to suit the requirements of the refrigerated display.

The possibility for customers to choose a design suitable for their store and campaign is made possible.

The possibilities with Peltier element refrigeration is to provide a new technology that provides new opportunities in the way products are presented. For Smurfit Kappa, the technology would create an opportunity to stand out on the market while offering a new kind of technology for the presentation of refrigerated products. During the primary investigation of products similar to the compressor refrigeration it was found that there are existing manufacturers of refrigerated cardboard displays. By using the technology of Peltier elements, Smurfit Kappa would be able to introduce their own product on this market.

8.2 Selection of technology for further development

From the comparison of compressor- and Peltier element refrigeration, it was found that the most suitable for Smurfit Kappa would be to develop their own product using technology not before used for the application. The product would stand out on the market and suit the innovative nature of the company. It was a choice between the *Red Ocean Strategy*, and the *Blue Ocean Strategy*. The Blue Ocean Strategy is to take a new approach and stand out and at the same time place yourself at a market without competition. The risk of doing so is to not be accepted on the market while The Read Ocean strategy is the direct opposite where you compete in an existing market where the product is known to be desired. The advantages of the Blue Ocean Strategy is that if the product is successful, the growth of the market of the product is fast [39].

9 Selection of concept

Chapter 9 presents the selection of concept and further development of the Peltier element concepts that were determined to be the technology to be used for the refrigerated display

The selection of concept and further development was made in collaboration with a thermal engineering specialist with great knowledge within the area of Peltier cooling technology, employed at Eg electronics [40].

9.1 Choice of concept

The selection of concept of the function was concept 3. The selection was based on the fact that the cold plate was more efficient than air cooling. The cold plate cooling also presented the opportunity to create an optimal contact between the standardized cans and the cooling surface.

In concept 3 the cold plate was also placed within an insulated area. The insulation created a more efficient cooling than if the cold plate was to be placed in the ambient temperature as in concept 2. During the investigation of customer needs it was found that there was a desire to display products in an open air display. As the main problem with Peltier elements was their consumption of energy it was believed that all improvements of energy consumption was positive for marketing.

9.2 Further development

When the concept of the function of the system had been determined, concepts of the details of the display were generated. The development was made by finding a solution and from that solution make improvements to the final solution, optimal for the product. The main purpose of the improvements was to minimize the consumption of energy without compromising customer needs. As the product was to be prototyped, the possible manufacturing processes were examined.

The main improvement to be made was to minimize the amount of air within the display and a good insulation. With less air, less energy is needed for cooling.

9.2.1 Cold plate

The cold plate where the cans were to be placed, was to be optimized to best suit the connection to the cans and at the same time the Peltier elements. The cold plate was to be made of aluminum due to its properties in thermal conductivity. From the product specification, found in Appendix G.2, 18 cans in total were to be displayed. The most

attractive display was believed to be three cans high with six bars beside each other, providing the following information.

Parameters of a 33 cl soda can presented earlier.

Height = 115 mm

Diameter = 65 mm

Minimum internal height

$$115 * 3 = 345\ mm$$

Minimum internal width

$$65 * 6 = 390\ mm$$

A gap between the cans was set to three millimeters in height and six millimeters in width in order to keep the amount of air within the display to a minimum but at the same time make it easy to remove the cans from the display.

Internal height

$$345\ +\ (3 * 4)\ =\ 357\ mm$$

Internal width

$$390\ +\ (6 * 5)\ =\ 420\ mm$$

Concept 1.1

A tray where 180˚ of the cans are surrounded by material. One possible manufacturing method was milling a block of aluminum to the desired shape. From calculations made in Creo Parametric, the weight was found to be approximately seven kilograms. The manufacturing method was found to be too expensive, and the amount of material too large, both concerning the weight but also the cooling capacity.

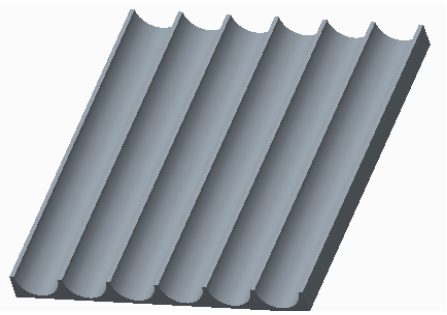

Figure 9.1 Concept 1.1, tray of aluminum surrounding 180 ˚ of the cans with a weight of 7 kg

Concept 1.2

By reducing the amount of material leaving a flat surface at the back to attach the Peltier elements, the weight was lowered to approximately 4.7 kilograms. The weight was calculated in the same manner as in concept 1.1, using Creo Parametric. The tray was still heavy and required milling a block of aluminum as manufacturing method for a prototype. The profiles could also be manufactured by extrusion, a manufacturing method suitable for the production of multiple products where the cost of the tool is distributed over the amount of products, not one prototype.

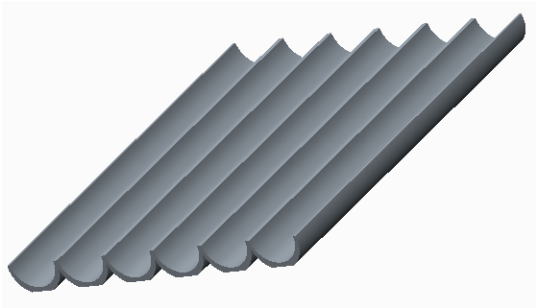

Figure 9.2 Concept 1.2, a tray of aluminum with reduced amount of material

Concept 1.3

By changing the manufacturing method, another concept was found. The concept was a sheet of aluminum that was to be pressed to the desired shape. The weight was calculated to approximately 1.72 kilograms, which was an improvement. As the weight was much lower, the concept was of interest but the manufacturing method was still found to be expensive. For the manufacturing a die had to be manufactured, a large sheet of aluminum purchased and a suiting press had to be used. Also due to the fact that the back of the tray was round, extra material was needed to attach the Peltier elements to the tray.

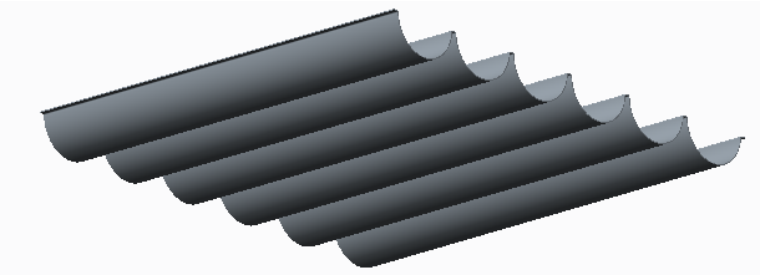

Figure 9.3 Concept 1.3, a pressed aluminum sheet

Concept 1.4

In order to reduce the weight as much as possible and also create a possibility to use a cheaper manufacturing method, another concept for the cold plate was designed. Bars covering 90˚ of the cans were connected in pairs to the Peltier element as in figure 9.4.

The weight of three sets of the cooling assembly was 1.13 kilograms using a material thickness of 3 mm. The manufacturing method could either be cutting an aluminum tube in to fitting parts or a sheet of aluminum being pressed to desired shape. The cans were no longer in contact with the cooling surface by 180 ˚ but it was believed that 1/4th of the can being in contact would be enough for the desired cooling due to the insulating properties of the surrounding air.

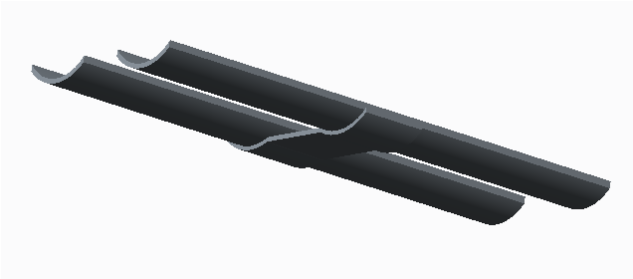

Figure 9.4 Concept 1.4, two bars of aluminum connected in pairs

9.2.2 Distance

Concept 2.1

The heat generated by the Peltier elements have to be removed from the enclosed area. This was made by attaching a block of aluminum to the hot side of the Peltier that transports the heat. The hole in the middle was made in order to attach the end located on the outside of the display to a heatsink. Only one concept of the distance was made while they were to be adjusted to suit the Peltier elements.

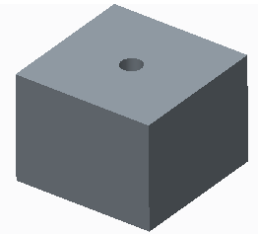

Figure 9.5 Concept 2.1, aluminum block used as a distance through insulation

9.2.3 Attachments

In order to attach the bars to the connector, the Peltier to the connector, and the Peltier to the distance, a thermal adhesive was to be used. For the connection between the distance and the heatsink, a screw was used. In between the distance and the heatsink a silicon paste was used to increase the connection between the surfaces.

9.2.4 Insulation

The chosen concept had a larger volume than necessary for cooling the cans. An optimization of the insulated area was therefore of interest.

Concept 3.1

In order to further reduce the amount of air within the capsuled area, the bottom part was designed to fit the cans and the cooling assembly. The insulating material provided the cans with 180 ° of coverage. In order to keep the costs down, rigid extruded polystyrene foam, was to be used. The insulating properties of the material 0.03W/mK, was not the best available on the market, but it had advantages concerning cost and availability [41].

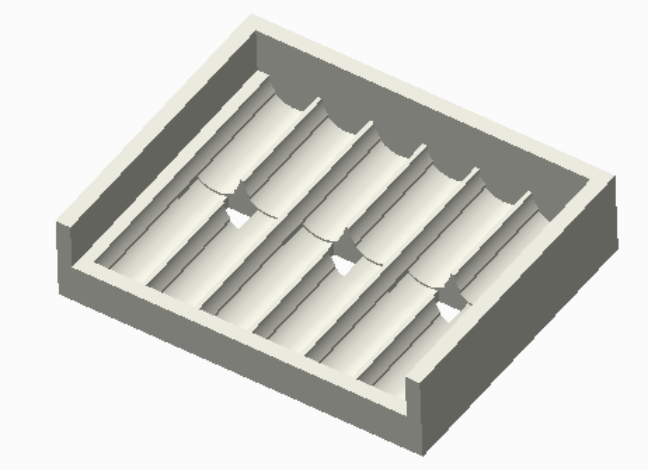

Figure 9.6 Concept 3.1 insulation with a design fitted to the cans

Concept 3.2

The design for concept 3.1 required expensive and advanced manufacturing, not suitable for prototyping. In order to make the design more suitable for prototyping, concept 3.2 was redesigned without the fitting of the cans and the cooling assembly. The redesigned concept can be found in figure 9.7 below.

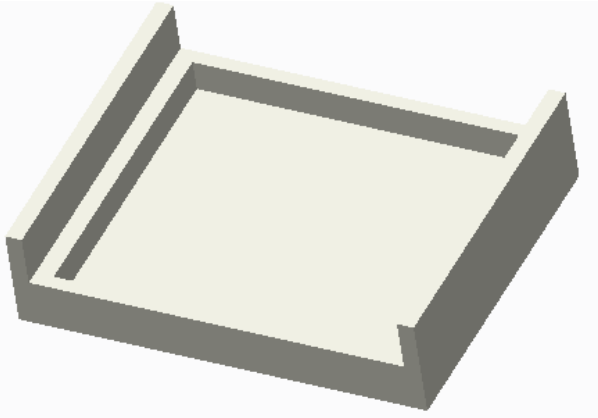

Figure 9.7 Concept 3.2, simplified design of the insulation

9.2.5 Aluminum casing

Concept 4.1

In order to fulfil the rigidity that was needed and create a point for attaching the lid, an aluminum casing was designed to fit the insulation within. The cutouts were made in order to create a possibility to fit the distances, transferring heat from the hot side of the Peltier through the insulation. The reason that the edges on the sides were designed to be higher is because it was easier to create an air tight solution if the lid was internal. The lower edges created a possibility to attach the lid with hinges and at the same time make it easier to open. Other materials could have been researched but the advantages of the simple manufacturing method and the outstanding rigidity was decided to be reasons for choosing the concept.

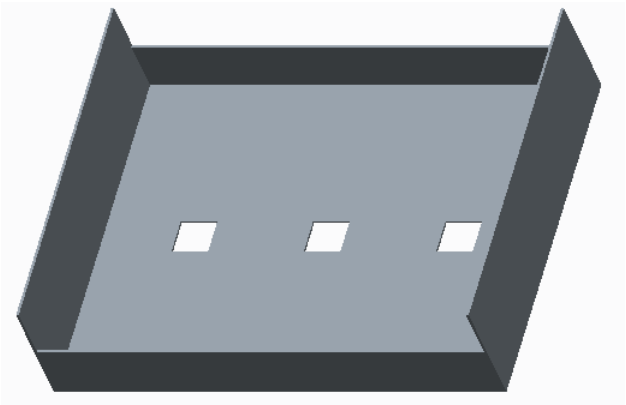

Figure 9.8 Concept 4.1 aluminum casing

9.2.6 Acrylic glass lid

Concept 5.1

The lid is made of acrylic glass for customers to easily get a view of the content of the display. As acrylic glass does not have very good insulating properties, 0.19 W/mK, compared to the polystyrene extruded 0.03W/mK [41] the lid was designed with a ten millimeter gap with capsuled air between the surfaces, creating an improved insulation. Possible manufacturing methods was to bend the top and bottom part and glue them together, creating the air gap using edge pieces.

In order to further reduce the amount of air, the part of the cover closest to the cans was made to fit the outline of the cans, leaving a ten millimeter air gap between the cans and the lid. The reason for leaving an air gap between the cans and the lid was because the direct contact between the cans and the lid would affect the cooling capacity. While the manufacturing method for the design was too expensive, a redesign was made were the design was made simpler and therefore less expensive. It should be mentioned that this type of design could be of interest for future production.

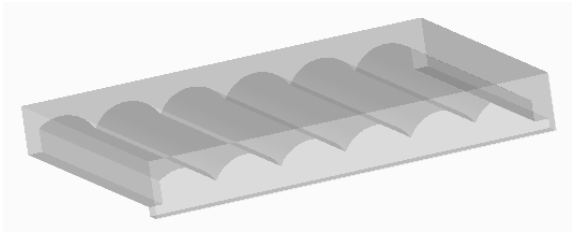

Figure 9.9 Concept 5.1, acrylic glass lid with an adjustment to fit the outline of the cans

Concept 5.2

Concept 5.2 was designed with a simpler design and therefore the manufacturing was made simpler.

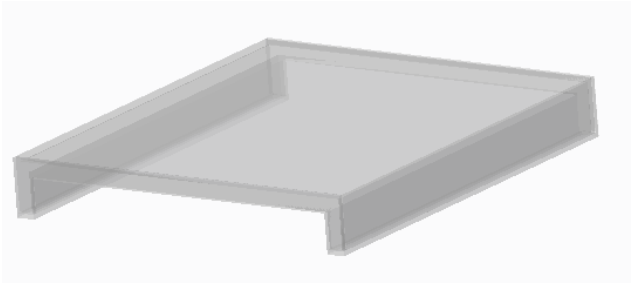

Figure 9.10 Concept 5.2, acrylic glass lid with a ten millimeter air gap

9.2.7 Support

In order to create an attractive angle of the display and fit the heatsinks, supports at the back of the display were of interest. The main focus when generating concepts was to find a simple solution that was cheap and easy to assemble.

Concept 6.1

A simple support of aluminum. The manufacturing method was rather simple, cutting desired strips and bend them to desired shapes. Possible improvements of the support regarded the manufacturing as well as the assembly. Required improvements of the manufacturing was to avoid the tight angles while this could lead to a more expensive manufacturing. Regarding the assembly the main improvements that were of interest was to avoid the interference with surrounding material. This support could possibly need a special tool for attachment.

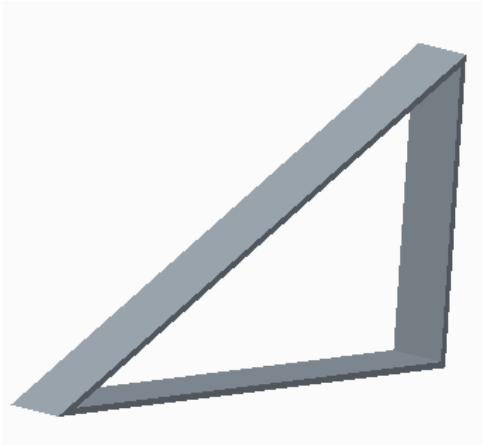

Figure 9.9 Concept 6.1, a simple support in aluminum

Concept 6.2

In order to create a simpler way to attach the supports to the back of the aluminum casing and avoid the small angles, the support was designed to be connected to the casing at the ends. The attachment was simplified and the small angles are avoided.

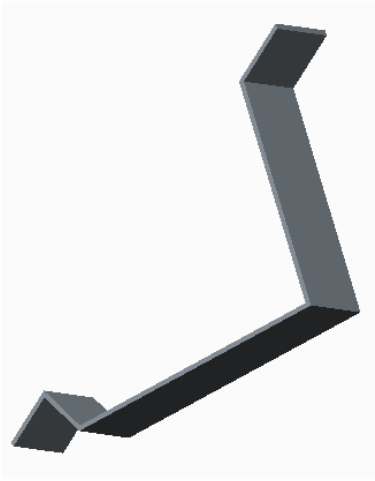

Figure 9.10 Concept 6.2 a simplified support creating an easier way to attach the support to the casing and avoid small angles

9.3 Final selection of detailed concepts

According to the development method used as a guide during the master thesis, the selection of concept can be made in a number of ways [3, p. 199]. One major factor affecting the selection of concepts was the possibility to manufacture a prototype in order to test the function and the overall appearance of the display. The concepts were chosen by consulting the expert [40] regarding the compatibility with the technology

in combination with the possible manufacturing method of each concept. The concepts chosen were the following.

Concept 1.4, the cold plate cooler made out of bars connected in pairs.

Concept 2.1, the distance transferring heat from the hot side of the Peltier to the heatsink.

Concept 3.2, the insulation without the design fitted to the cans.

Concept 4.1, the aluminum casing chosen for its rigidity and simplicity.

Concept 5.2, the acrylic glass lid without the fitted surface for cheaper manufacturing.

Concept 6.2, the support with the simplified attachment and larger angles creating an easier manufacturing and assembly.

Attachments

- Thermal glue between all surfaces except between the distance and the heatsink where the heatsink is screwed on to the distance with a silicon paste in between.
- Two hinges connecting the lid to the aluminum casing.

9.3.1 Reflection over the results and the process

The selection of concept was not performed as for the development method used during the master thesis [3, pp. 197-221]. The purpose of selecting the concept of the overall function created a possibility to have a meaningful collaboration with the thermal engineering expert. When the concept of function was chosen, the detailed concepts were evaluated by the fulfillment of the measurable specifications as well as the manufacturing possibilities. Many of the measurable specifications, found in Appendix G.2 were subjective which required some sort of evaluation of the result. According to the literature [3, p. 214], subjective criterions are hard to interpret requiring an evaluation of the concept where the fulfillment of the subjective criterions are possible to determine.

The process created the opportunity to from a manufacturing perspective evaluate and improve concepts during the generation of concepts. By doing so, the manufacturing costs and methods were already evaluated, reducing the probability of unforeseen consequences. The concepts chosen are believed to contribute to a product suitable for the market and fulfill consumer requirements.

10 Detailed design

Chapter 10 presents the drawings and the model of the selected concept

10.1 Model

The model was created in Creo Parametric where each of the parts were created according to the concepts chosen, and later assembled. Some parts were to be added during prototyping such as hinges that attach the lid to the aluminum casing and a handle used to open the product. The reason that some parts were to be added later was because the placement and size of them was easier to evaluate when parts of the product already were manufactured.

10.2 Drawings

Drawings of the chosen concepts can be found in Appendix I

Requirements on the display from the 33 cl cans, presented earlier in the report

Internal height

$$345 + (3 * 4) = 357\,mm$$

Internal width

$$390 + (6 * 5) = 420\,mm$$

10.2.1 Bars

The measurements of the bars were decided by the desired internal height and the 90 ˚ coverage of the cans.

10.2.2 Peltier connector

The measurements of the Peltier connectors were decided by the desired distance between the cans of 6 mm and the internal width. They were also designed to suit the outline of the bars in order to create as good contact as possible between the surfaces. The Peltier connector also had to be large enough to fit a Peltier element.

10.2.3 Distance

The distances were designed in order to reach from the hot side of the Peltier, through the insulation and out through the back of the aluminum casing. The surface connected to the Peltier had to be large enough to fit a Peltier element.

10.2.4 Insulation

The measurements of the insulation were based on the requirements of the internal width and height. A thickness of 20 mm was believe to be enough to create the desired insulating properties.

10.2.5 Acrylic glass lid

The measurements of the acrylic glass lid were based on the requirements of the internal width and height. The lid was also designed to leave a ten millimeter air gap between the cans and the lid.

10.2.6 Aluminum casing

The aluminum casing was designed to fit the insulation and the lid.

10.2.7 Support

The supports were designed in order to create an attractive angle of the products and leave room at the back for heatsinks. The exact positioning of the supports was to be decided during prototyping in order to secure the stability and the attractiveness of the display.

10.3 Selection of Peltier elements and heatsink

The selection of Peltier elements and heatsinks was possible to make when the knowledge of design parameters were set. In order to choose a suitable Peltier element, a design guide at Meerstetter Engineering was followed [42]. The process of finding a suitable Peltier element can be found in Appendix J

10.3.1 Selection of Peltier

From the process found in Appendix J a suitable Peltier element was possible to find. In order to secure the function of the display it was advised by the thermal engineering specialist that a Peltier with maximum cooling capacity Q_{max} a bit larger than the optimum of $14.76\,W$ $(J.7.1)$, should be chosen for the prototype. While doing so, the prototype would be able to maintain required cooling if any leakage of air in to the display would take place when tested. Choosing a Peltier with a larger capacity leads to a greater need of cooling of the hot side of the element.

The chosen Peltier element specifications can be found in table 10.1 combined with figure 10.1 on the next page.

Table 10.1 Specification of chosen Peltier [43]

Specification table	
Distributor	Farnell
Manuacturer	European Thermodynamics
Item nr	APH-127-10-25-S
Imax [A]	1.9
Qmax [W]	17
Vmax[Vdc]	15.4
DeltaTmax [˚C]	68
A [mm]	30
A1 [mm]	30
B [mm]	30
H [mm]	4.5
L [mm]	100
Wire [AWG]	n/a
Price [SEK]	199.41

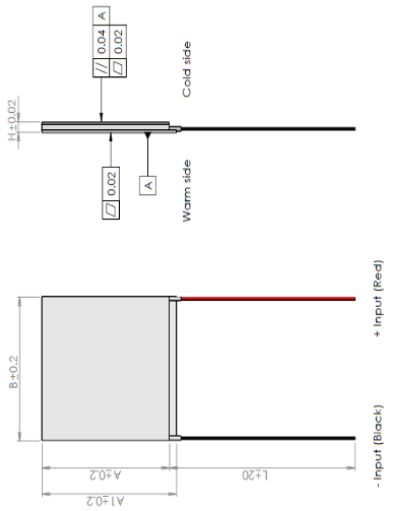

Figure 10.1 Specification of chosen Peltier element

10.3.2 TEC Controller and object temperature sensor

At this stage a suitable TEC controller and object temperature sensor should have been selected. As the prototype was only to be used for testing the function, these parts were not researched. The Peltier elements were instead to be controlled by adjustable power sources. At a later stage when the function is confirmed and improvements of the

prototype is made, a TEC controller and temperature sensor should be researched in order to not require manual control.

10.3.3 Selection of heatsink

In order to transport the heat from the hot side of the Peltier to the surrounding a heatsink was required. The thermal resistance of the heatsink was the parameter to be researched.

$$RthSink = \frac{\Delta T}{P} \quad (10.1)$$

RthSink = Thermal resistance of the heatsink [K/W]
ΔT = Temperature difference between the heatsink and the ambient air temperature [K], not the same as the temperature difference calculated earlier
P = Heat load to be absorbed [W], the amount of heat to be emoved from the enclosed area in order to reach desired temperature

The heat load P was assumed as heat load of the object (10.1) Qc= 3.36 W plus heat load of the Peltier element due to losses. As found during the investigation of Peltier elements, the better the heatsink, the better performance of the system. Due to this information and consulting the specialist, the heat load to be absorbed was doubled.

The heat load was therefore assumed to be

$$P = 6.72\ [W] \quad (10.2)$$

The temperature difference ΔT between the heatsink 40°C and the ambient temperature 20 °C should not be higher than 20 K. So

$$\Delta T = 20\ [K] \quad (10.3)$$

Using (10.2) and (10.3) in equation (10.1) the thermal resistance was possible to calculate

$$RthSink = \frac{\Delta T}{P} = \frac{20\ K}{6.72\ W} = 3K/W$$

The smaller the thermal resistance, RthSink, the larger the heatsink. So a heatsink with RthSink smaller than 3 K/W was chosen. The selected heatsink can be found in table 10.2.

Table 10.2 Specification of chosen heatsink [44]

Specification of	chosen heatsink
Model	KS105-100E
Width [mm]	105
Length [mm]	100
Height [mm]	19
Thermal resistance [K/W]	1.3
Price [SEK]	89

I_{max}The current for the Peltier element should be between 0.3 and 0.7 times I_{max}

10.4 Comments on the detailed design

The reason that the cooling of the display was dimensioned to be greater than necessary was because of the probability that some changes was to be made during prototyping. Due to economic reasons, the available manufacturing methods was also a possible contributor to a lower performance of the system. In order to create an ideal system, the surfaces that was to be in contact required tight tolerances. With tighter tolerances, the production cost of the prototype rises.

11 Prototyping

In this chapter the process of the manufacturing of the prototype is described.

11.1 Process

From the product development method used during the master thesis [3] there are four steps to be followed when manufacturing a prototype.

Step 1 Define the purpose of the prototype

Step 2 Determine the level of approximation of the prototype

Step 3 Determine a plan of experiments, how is the prototype used to be tested?

Step 4 Determine a plan for gathering supplies, building and testing

11.1.1 Purpose of prototype

Four main purposes of prototypes were described in the literature [3, pp. 378-381]. These purposes are learning, communication integration and milestones. The prototype was to be used for learning, where the refrigeration was to be tested in order to determine if the refrigeration works in reality. Within the purpose of learning, the prototype was also to be used in order to get an understanding of the customer satisfaction of the concept. It was believed that a physical prototype was easier for customers to understand and provided information of greater importance while reducing the probability of customers misunderstanding the concept. The Peltier refrigerated display prototype was first created virtually as an analytical CAD model in Creo parametric. This model was later used for manufacturing a physical prototype where the model was adjusted for manufacturing where necessary.

11.1.2 Level of approximation

The prototype of the Peltier refrigerated display was to be manufactured where the manufacturing methods used were cheap and created a possibility to estimate the cooling capacity of the product but also to communicate the product to consumers. The level of approximation of the prototype was therefore not a completely accurate model, but the overall function of the product had to be fulfilled. In order to communicate the product to consumers and create a possibility to evaluate subjective specifications, the prototype had to provide an appearance similar to the product. As the manufacturing costs were to be kept as low as possible, the prototype was not possible to make as accurate as producing a series. Important factors that were to be made as accurate as possible regarding the cooling capacity were; the degree of insulation and air tightness but also the surfaces in contact where cooling and heating was to be transferred. The

cooling capacity is dependent on the transfer of heat and cool. Also for the surfaces in contact, the manufacturing methods available were important factors of the level of approximation.

11.1.3 Plan of experiments

The refrigeration and the appearance of the prototype was to be tested. The first part of the experiments was to evaluate if the design satisfied the cooling capacity needed and finding suitable settings for usage in a store. The second part of the experiments was to evaluate the prototype through customer input and if the subjective metric values determined at an earlier stage, were fulfilled. During the second part of the experiment, the refrigerated display was placed as a module within the cardboard display manufactured by Smurfit Kappa. The prototypes were evaluated as one part while they were to be marketed in combination with each other.

11.1.4 Planning of prototype

A template of the plan of the prototype is presented in table 11.1. The purpose of the template was to get an overview that could be used to secure that all parts were fulfilled of the prototype.

Table 11.1 Template for prototype

Prototype	**Refrigerated display**
Purpose	Evaluate the function Find appropriate settings Evaluate customer satisfaction
Level of approximation	The appearance is similar to the overall appearance of the product The function is made as similar to the product as possible
Plan of experiments	• Build Peltier refrigerated display • Laboratory test of function and settings • Build cardboard display and adjust printing to suit products to be displayed • Testing in grocery store to evaluate customer satisfaction and subjective specifications
Time plan	19th of October- Manufacturing of refrigerated display **9th of Nov**- Bucket of parts, all parts of the prototype is finished 13th of Nov - Refrigerated display finished **17th of Nov** - Laboratory test and adjustments 25th of Nov – Laboratory test ended 26th of Nov- Manufacturing of cardboard display 10th of Dec - Selection of product and printing 16th of Dec - Test in grocery store 18th of Dec- End of experiments **22nd of Dec** - Analyses of test results finished

11.2 Manufacturing of Peltier refrigerated display

The virtual prototype created in Creo parametric was produced with the desired shapes. During the primary prototyping, the function of the product was to be tested, "proof of concept". The manufacturing methods used were not as advanced as required for some of the parts and some desired shapes that were hard to manufacture were altered but the overall concept stayed the same.

11.2.1 Parts for refrigeration

All parts of aluminum was manufactured at facilities of Optocomp AB in Gislaved. All material and guidance throughout manufacturing was donated by the company.

11.2.1.1 Bars

The desired shape of the bars was manufactured by pressing a 3 mm sheet of aluminum between a simpler tool that was welded together to create edges, and a solid pipe made of steel with the outer diameter of 60 mm, figure 11.1.

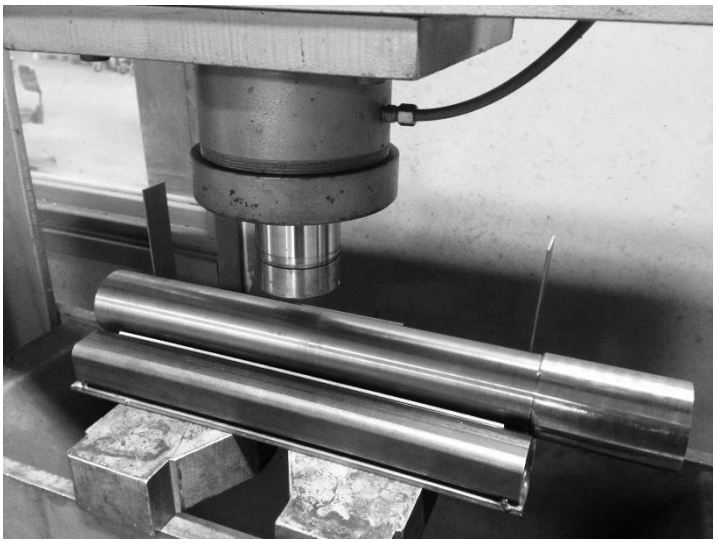

Figure 11.1 Manufacturing of the bars

The reason that the diameter was made smaller than the outer diameter of the cans to be refrigerated, was due to the spring back of the material. The sheet of aluminum was made larger in order to force the sheet to be in contact with the tool at all times. The edges were later cut to the desired length using a regular band saw and the sharp edges were grinded. In order to obtain a smoother surface, the inner sides of the bars were sand blasted with grains of the size 30µm, see figure 11.2.

Figure 11.2 Sand blasting of bars

In total six bars were manufactured.

Figure 11.3 All six bars after sand blasting

11.2.1.2 Peltier connectors

The desired shape of the Peltier connectors was manufactured in the same manner as the bars. The tool used was made by attaching two parts of a solid pipe made of steel with a diameter of 66 mm, also for these parts, the diameter was made smaller due to the spring back of the material. The tool was pressed against a part with a flat surface with an edge length of 40 mm, with a sheet of aluminum in between, see figure 11.4.

Figure 11.4 Manufacturing of Peltier connectors

When pressed against the flat surface, the edges of the material was manually pressed against the surface of the two rolls to create a greater coverage of the surface. In total three Peltier connectors were manufactured.

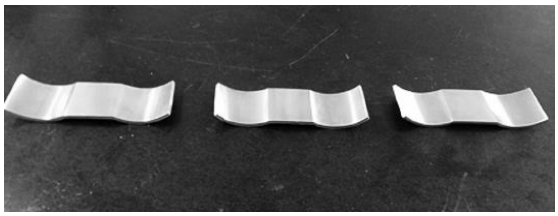

Figure 11.5 All three of the Peltier connectors

11.2.1.3 Fixating bars

It was at an early stage found that it would be too expensive to manufacture the shape of the extruded polystyrene bottom part for only one prototype. As the rigidity of the bars was lost with the redesign of the bottom part, two aluminum bars were manufactured to be used to fixate the bars when placed within the display, see figure 11.6. The fixating bars are of the size 410x30x3 mm.

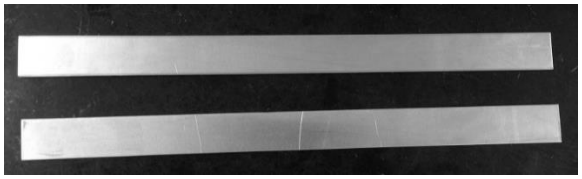

Figure 11.6 Fixating bars

11.2.1.4 Distances

The distances that are used to transport heat from the hot side of the Peltier elements through the insulation to the heatsinks were manufactured by milling a larger piece of aluminum to desired size 35x35x30 mm. In the center of the distance a hole was drilled and threaded in order to create the best possible connection to the heatsinks. The size of the hole was made suitable for a M6 screw.

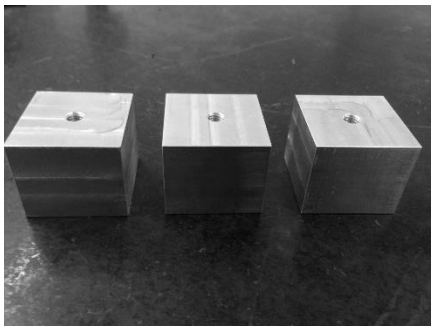

Figure 11.7 Distances

11.2.1.5 Assembly of the cooling parts

In order to create the best possible attachment between the bars and the Peltier connectors a thermal adhesive was used. The thermal adhesive used was Arctic Silver Thermal Adhesive from Coolerkit.se [45]. According to the company homepage the thermal conductivity of the adhesive containing 62-65% silver is greater than 7.5 W/mK. The fixating bars were only used for fixating and were therefore assembled with regular Superpoxy.

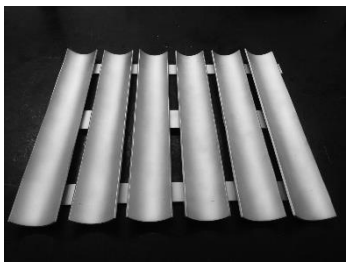

Figure 11.8 Assembly of cooling parts

11.2.2 Aluminum casing

The aluminum casing was made in three parts. The largest part made up the bottom, the front and back of the casing while two smaller parts were made for the sides, figure 11.9. The front and the back was made by bending the edges of the bottom part. The parts were later assembled by manufacturing and attaching eight bent corner-pieces that were drilled and attached by pop rivets, figure 11.10.

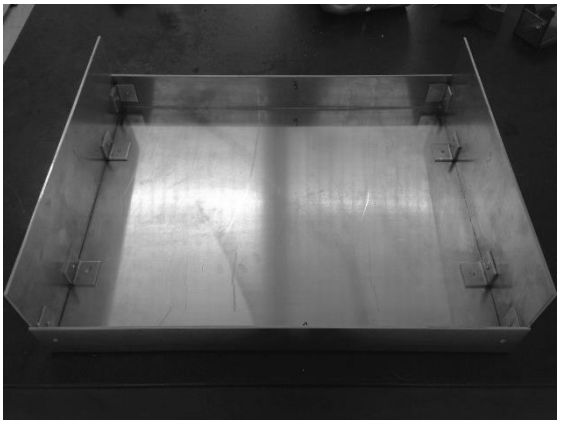

Figure 11.9 Aluminum casing

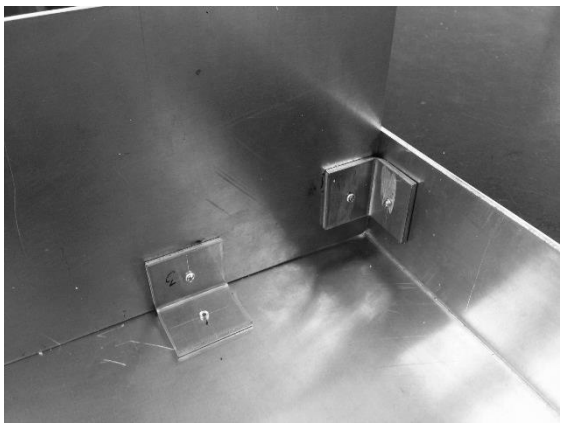

Figure 11.10 Corner pieces attached by pop rivets used for assembly

11.2.3 Support

In order to create an angle of the display, two supports were manufactured. The design of the supports created an easy attachment to the aluminum casing. By simplifying the assembly, a reduction of manufacturing cost can be met. The attachment was made by drilling and threading holes suitable for M6 screws. The manufacturing method used was pressing. The positioning of the supports was made by testing different placements. One placement where the supports created stability and at the same time an illusion of floating was chosen. Selecting a placement where the display was lifted from the ground also created a greater air supply to the back of the display and protection from damage.

Figure 11.11 Manufacturing of supports

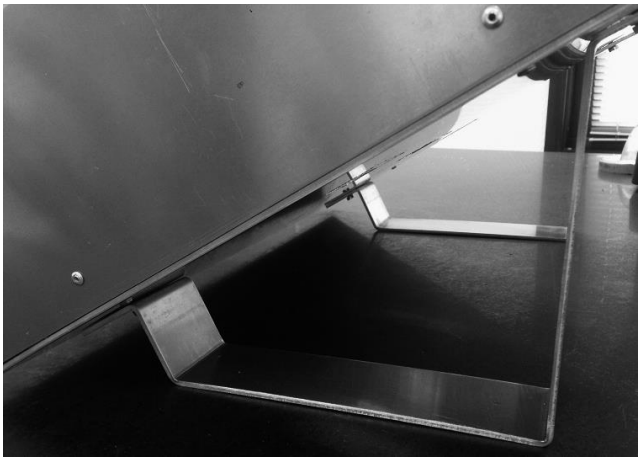

Figure 11.12 Supports attached to the aluminum casing

11.2.4 Extruded polystyrene insulation

In order to get the desired shape of the insulation, a number of parts had to be cut and glued together. In total the insulation was built using seven parts, figure 11.13. The extruded polystyrene was cut to desired sizes using a band saw. The manufacturing and assembly to get the desired shape was time consuming and not a method to be used for production.

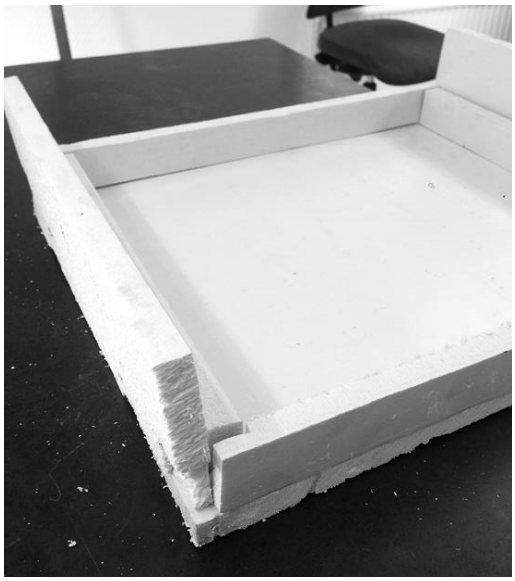

Figure 11.13 Parts of the insulation

Due to the advantages in availability and cost, extruded polystyrene was selected as the insulating material.

In order to assemble the parts of the extruded polystyrene an assembly adhesive of the type Illbruck PL600 was used. The adhesive and the extruded polystyrene was donated by Woody Bygghandel Anderstorp.

The space to fit the distances was made by drilling four holes and the remaining material removed using a jigsaw. The manufacturing method was not very precise and additional insulation may be required where material has been removed.

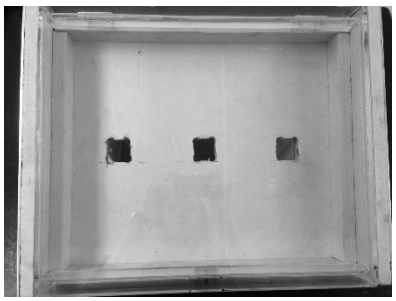

Figure 11.14 Holes created to fit the distances

The desired manufacturing method of the extruded polystyrene insulation was to create the desired shape using a mold and die. Using this manufacturing method would create the possibility to use the fitted design where the insulation is fitted to the cans. This manufacturing method was not an option during prototyping due to economic reasons.

11.2.5 Lid

The acrylic glass lid was manufactured by Lilja Group AB in Gislaved. The lid was manufactured by pressing the top and bottom part with 90 degree edges and glue the parts together with distance parts, vertical and horizontal side, fitted to create the 10 mm air gap in between the inner and outer surface. If the design where the bottom part of the acrylic glass was designed to fit the cans would have been used, it would have required vacuum forming where the tool alone would cost about 5-15 000 SEK. Information acquired during a meeting at Lilja Group AB [46]. This could be a possibility for manufacturing a series of the product but not for a prototype.

The lid was attached to the aluminum casing by hinges. The hinges were attached to the lid and the aluminum casing by drilled and threaded holes. The hinges were purchased at Jem &Fix in Gislaved.

Figure 11.15 Hinges used for attaching the lid to the aluminum casing

11.2.6 Attachment of Peltier element

The Peltier elements were delayed in transport and were attached to the display part at a later stage. After a conversation with Gunnar Lindstedt at LTH [47] it was advised that the Peltier elements were not mounted to the distance and the Peltier connector using an adhesive as planned. The reason for this was to create the possibility for maintenance if needed. Instead some sort of attachment had to be manufactured. Six attachments were manufactured by 3D printing, figure 11.16 and attached to the distance by drilling and threading holes where the attachments were placed and clipped to the top part of the Peltier connector. The reason that the attachments were created by 3D printing was due to the simplicity in manufacturing and the poor thermal conductivity of plastic. Between the connecting surfaces, a silicon paste from Electro Kit of the model 41000867 was used to increase the contact.

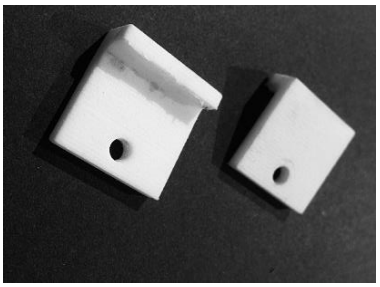

Figure 11.16 3D printed attachments creating the connection between Peltier element – Peltier connector and Peltier element – distance

11.2.7 Additional details

11.2.7.1 Handle

As stated earlier, the handle used to open the refrigerated display was not added in the model while the placing would be evaluated during prototyping. The handle was decided to be placed on the front of the display in order to not interfere with the cardboard display when opened. While the handle chosen had two attachment points, the handle should have been attached before the lid was assembled. In order to attach the handle with the only possibility to attach it from the outside, two holes were drilled and threaded where two screws were attached. The attachment points of the handle were placed on the screws and attached by two additional screws inserted through the handle to the screws connected to the lid, figure 11.17. The handle was chosen to make it as easy as possible to open and at the same time create an attractive appearance. The handle was purchased at Jem & Fix in Gislaved.

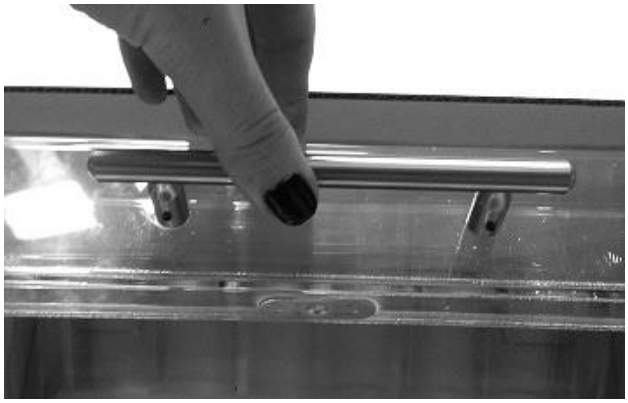

Figure 11.17 Handle with customized attachment

11.2.7.2 Magnet

In order to create a greater sealing of the display some extra details were added. A magnet was attached to the front of the display. One end was attached to the edge of the aluminum casing and the other to the lid. The magnet forced the lid to be in contact

with the bottom part and created a reassurance that the lid was closed at all times. The magnet was purchased at Jem & Fix in Gislaved.

11.2.7.3 Insulating rims

The contact between the lid and the insulation did not provide an air tight enclosure. Due to this, insulating rims were attached to the insulation. The insulating rims were purchased at Biltema in Lund.

11.2.7.4 Lights

According to the product specification of the Peltier refrigerated display, lighting was of importance. In order to avoid any heating within the display, LED lights were used. The LED lights were purchased at IKEA in Malmö and were of the model L1324 Dioder. The selection of source of light was made based on availability, functionality and price. The lighting could be improved but this was not seen as necessary for the purpose of the prototype.

11.2.7.5 Appearance

As the display was to be tested within a store the internal part of the insulation was decided to be covered in order to make it more attractive. The cover chosen was a silver contact plastic from Panduro Hobby model number 101465. The plastic was cut to desired size and attached to the insulation.

11.3 Comments on the manufacturing of Peltier refrigerated display

The prototyping of the Peltier refrigerated display was time consuming and required a lot of knowledge about manufacturing processes. Main parts that would have been made differently were to attach the handle to the lid before assembling the parts and also to make the Peltier connectors and the distances wider. If these parts would have been designed wider, the attachment of the Peltier would have been possible using plastic screws in combination with a spring, creating a possibility to adjust the pressure between the Peltier elements and connecting surfaces. In total the manufacturing process was educational and the result is believed to be similar to the CAD model that was used. The total cost of the manufacturing of the Peltier refrigerated display prototype was 2,316.39 SEK, an overview of the cost can be found in Appendix K. The prototype was more expensive than the price desired in the product specification, including donated material. As prototypes commonly are more expensive than the product, the desired price is believed to be possible to reach using standard dimensions and optimized manufacturing processes. Many of the details are believed to be less expensive when purchasing a larger amount and the possibility to buy them from the manufacturer instead of retail.

Figure 11.18 Full prototype of the Peltier refrigerated display

11.4 Manufacturing of cardboard display

As stated earlier, the cardboard display was designed by Smurfit Kappa and adjustments made in collaboration. The product specification was followed throughout the prototyping in order to meet customer needs that are to be evaluated during tests in a grocery store.

Prototype 11.1

The first prototype was designed to suit the refrigerated display and to get an understanding of the possibilities of the size of the display. The prototype was manufactured in four parts and assembled. The possibility to easily access the product within the refrigerated display was made by designing the opening where the refrigerated display was to be placed. During the first prototype it was found that in order to get rigidity from the cardboard display, the module was best placed at the bottom shelf. The size of the display was set by the size of the shelves while they are a part of the front of the display. In order to make the cardboard display easy to move around, a tray of four double well sheets with four wheels was manufactured, figure 11.19. The prototype was also made with a large hatch on the bottom part to place the power supplies, and a large opening at the back of the shelf where the refrigerated display was to be placed in order to easily remove the hot air from the hot side of the Peltier. See figure 11.20 for these features.

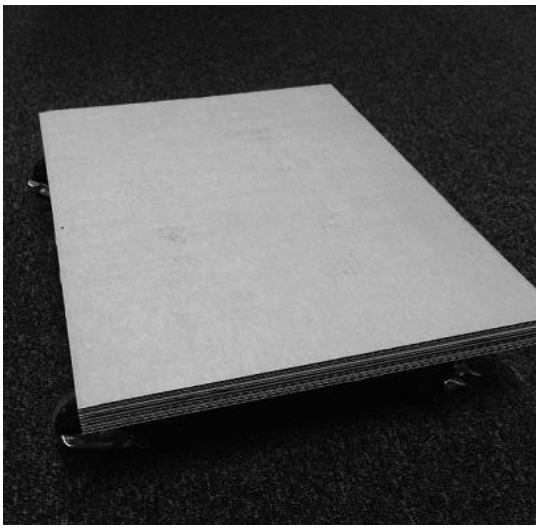

Figure 11.19 Tray with wheels for easy transport

Figure 11.20 Cutout for easily removal of hot air and hatch for power supplies

The prototype was tested by placing the power supplies inside the hatch and the refrigerated display on the bottom shelf. From this test it was found that the cutout for the removal of hot air was larger than necessary in combination with affecting the rigidity of the cardboard display. It was also found that the hatch for the power supplies was larger than necessary and that the lid to close the area of the power supplies was not suitable while the power supplies generated more heat than expected. The bottom shelf was also not strong enough to hold the weight of the refrigerated display and required improvements.

Prototype 11.2

The second prototype was changed by making the cut out for the removal of hot air and the power supplies smaller. The hatch was also removed in order to create a better circulation of air for the power supplies, figure 11.21. This was not believed to be a problem at a later stage when the power supply is more compact and does not generate as much heat. For the test in a grocery store, the display will not be possible to display from the back.

Figure 11.21 Prototype 11.2 with a reduced size of cut outs

In order to easily attach the power cords from the Peltier elements and fans to the power supplies, cutouts were made at the bottom shelf, figure 11.22. There was also a smaller cutout made at the back of the display where the power cord to the wall is to be guided.

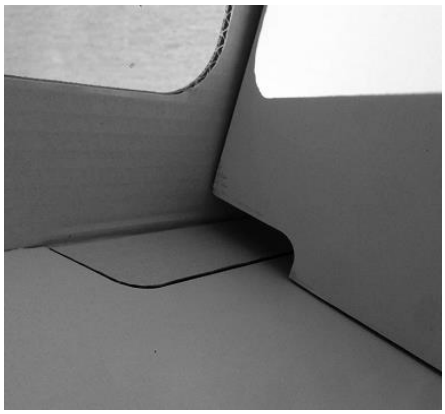

Figure 11.22 Cutouts at the bottom shelf to neatly store cables

In order to increase the strength of the bottom shelf to handle the weight of the display, a tray of four double fluted well sheets was placed at the bottom.

Prototype 11.3

The design of prototype 11.3 is the same as for 11.2 but with a customized print to suit the products to be displayed. The products to be displayed were 175g Sourcream & Onion chips and 33 cl Coca cola cans, decided by Michal Wieloch at ICA Supermarket Fäladen. Figure 11.23 presents the display when printed and as can be seen, the bottom part of the print represented ice. The reason for this was for the consumers to get an understanding that the Peltier refrigerated display contained cold beverages.

Figure 11.23 The final cardboard display with prints

12 Analysis of prototype

The analysis of the prototype was performed in two steps, one where the Peltier refrigerated displays function was tested and one where customer interaction was tested

12.1 Process

There were two parts of the analysis of the prototype. One part where the Peltier refrigerated display was tested in a laboratory environment where the function and appropriate settings were evaluated, and one where the refrigerated display was placed as a module within the cardboard display as meant. During the second test at the grocery store, the prototypes were evaluated as one product.

12.1.1 Laboratory test of Peltier refrigerated display prototype

The laboratory tests were performed in order to evaluate the function and find appropriate settings of the adjustable power supplies.

12.1.1.1 Instruments used

- Three adjustable power sources to the Peltier elements of the type 0-30 V and 0-2A
- One adjustable power source for two fans run at 24 VDC, 0.27A
- Two fans of the type 24VDC, 0.135A
- Six electrical cords
- Six connectors
- One temperature diod - type Digitron Instrumentation Ltd Model 2754-PT100

The reason for using three power supplies for the Peltier elements was in order to be able to control the input to each of the elements.

12.1.2 Test 1

The aim of the first tests was to research if the function was fulfilled, if the desired temperature was possible to reach.

Question: *Are temperature requirements met?*

- Desired temperature: 4-12˚C
- Time of test: 90 minutes
- Time lapse for measuring: 5 minutes, in total 18 measurements
- Units measured: Temperature, current and voltage for each power supply

12.1.2.1 Result of test 1

The result of test 1 proved that the temperature span was not met. Details of the measurements can be found in Appendix L1.1

12.1.2.2 Conclusion of test 1

The results from test 1 provided information that the prototype was not functioning correctly. The fact that the insulation of the prototype was not possible to manufacture to exactly fit the outline of the cooling assembly made the heat generated from the hot side to leak in to the cold insulated area, reducing the performance of the display.

Additional insulation was added in order to research if this was the primary cause of the low performance.

12.1.3 Test 2

The aim of test two was to research if the additional insulation was enough improvement of the display in order to reach the desired temperature.

Question: *Are temperature requirements met?*

- Desired temperature: 4-12˚C
- Time of test: 90 minutes
- Time lapse for measuring: 5 minutes, in total 18 measurements/test
- Units measured: Temperature, current and voltage for each power supply

12.1.3.1 Result of test 2

The desired temperature span was met. Details of the measurements can be found in Appendix L1.2

12.1.3.2 Conclusion of test 2

The desired temperature span was met. After 65 minutes, the current and the voltage was increased compared to test 1. The reason for this was because the result was providing information that the insulation had improved the cooling effects. It was therefore of interest to research what temperature could be reached within the time span with increased voltage and current. From information gained earlier in the report, the maximum current the Peltier elements should be powered by is 0.7*Imax = 1.33A.

12.1.4 Test 3

From test 2 it was found that the temperature span was met. From discussions with Smurfit Kappa the temperature to keep was set to 8 ˚C. Test three was set up in order to evaluate how long time it would take at a minimum to cool the display at maximum power input, I=1.33A.

Question: *What is the minimum amount of time to reach a temperature of 8 ˚C?*

- Desired temperature: 8˚C
- Time lapse for measuring: 5 minutes

- Constant setting of current = 1.33 A
- Units measured: Temperature, current and voltage for each power supply

When the temperature was close to 8˚C the measuring was constant in order to get the exact time of reaching the desired temperature. The current was held constant while the voltage was adjusted to suit the desired current.

12.1.4.1 Result of test 3

The minimum amount of time to reach a temperature of 8 ˚C was 34 minutes and 56 seconds. Details of the measurements can be found in Appendix L1.3

12.1.4.2 Conclusion of test 3

The time required to reach desired temperature was rather long but it was believed that the time was acceptable. By consulting Gunnar Lindstedt, associate professor in industrial electrical engineering [47], it was found that thermoelectric elements are slow in generating cooling and that the time found during test three was acceptable.

12.1.5 Test 4

In order to run the display without supervision, the power input that keeps the display continuously at 8 ˚C had to be found. The display was powered at maximum power input, I=1.3A and when desired temperature was reached, the power input was varied until a setting where a stable temperature was found.

Question: *What settings of the power supply creates a constant temperature of 8 ˚C?*

- Desired temperature: 8˚C
- Time lapse for measuring: 5 minutes
- Amount of time at a constant power supply without change in temperature that is acceptable: 60 minutes
- Units measured: Temperature, current, voltage for each power supply

12.1.5.1 Result of test 4

Settings of the power supply that generates a temperature of 8˚C is I=0.65A and U=5.7V. Details of the measurements can be found in Appendix L1.4

12.1.5.2 Conclusion of test 4

The settings of the power supply was not enough to control the Peltier refrigerated display. In order for the display to function at the desired temperature at all times would require the use of the temperature control not selected during the master thesis. The control would have to regulate the power supply at all times, for example increase the power supply when the lid is opened and surrounding air enters. The selection of this control was not a part of the master thesis and the power input was therefore manually adjusted. For the prototype, the tests provided information that the desired temperature of 8˚C was relatively constant for 90 minutes at the settings, I=0.65A and U=5.7V.

12.1.6 Test 5

The display was powered at maximum power input until 8 ˚C was reached, and held constant at settings found in test 4. The lid was opened and a can removed. The temperature rise was noted and the time for the display to reach the desired temperature again was evaluated. The test was made ten times and an average time was calculated.

Question: *How is the display effected by opening the lid while removing a can of soda?*

Desired temperature: 8˚C

Constant setting of current: 0.65A

Constant setting of voltage: 5.7V

Units measured: Temperature, time

12.1.6.1 Result of test 5

An average of the time for the display to return to initial temperature was 9 minutes and 54 seconds. Details of the measurements can be found in Appendix L1.5

12.1.6.2 Conclusion of test 5

The reason that the time for the air within the display to return to its initial temperature differs was believed to be caused by the difference in time between each opening and the amount of time the display was open. The reason that the test was set with these variables set to random was because that is believed to best describe the usage in stores. It takes a long time for the display to return to its initial temperature when the lid has been opened. The reason for this was believed to be the low power supply and as stated earlier, that thermoelectric coolers generate cooling at a slower rate. The increase in temperature was only 0.2 ˚C which was believed to have no influence on the perception of the temperature of the soda to the customer.

12.2 Test of the combined prototype in grocery store

The second part of the experiments was to evaluate the prototype through customer input and if the target values determined at an earlier stage, were fulfilled. Another dimension of the test was to get an understanding of how the product would function in its natural environment. The test was performed at ICA Supermarket Fäladen in Lund during 16/12-2015-18/12-2015.

12.2.1 Test setup

- Surrounding of test: ICA Supermarket Fäladen, Lund
- Placement within the store: At the end of a gable by the candy section
- Products: Coca cola 33 cl cans, 175 g Sourcream & Onion chips
- Campaign: 20 SEK for one Coca Cola and one bag of Sourcream & Onion
- Time for test: 08.00-22.00 three days 16/12-2015-18/12-2015

Information gained through interviews and analyzing customers interact with the prototype

Figure 12.1 Test within ICA Supermarket Fäladen in Lund

12.2.2 Interviews

In total seven interviews were performed. In order to get a broader understanding of the different type of customers, the interviewees were of different ages and genders.

12.2.2.1 Result

The questions asked and the answers can be found in Appendix L2. From the first question, if the products were found to be presented in an attractive way, the general opinion was found to be positive. The second question, if the products were easy to access, the general opinion was that they were but that the refrigerated display should have been placed on the second shelf in order to make it easier to handle. It was also found that there were some trouble with the weight of the lid and that it required both hands for removing a can from the refrigerated display. One customer also mentioned that the space between the cans should be made larger in order to make it easier to remove a can from within the display but that it also could contribute to making the display less attractive. Some of the customers had trouble with understanding if the coca cola cans were refrigerated and desired some sort of information that made it clear that the cans were chilled.

The most appreciated aspects of the prototype was the possibility of combining products which made the campaign more attractive and fun. It was also found that the display stood out from the crowd and was easy to spot without the print interfering with the products.

The main improvements found were that the refrigerated display should be placed on the second shelf of the cardboard display in order to make it easier to open. The

placement of the display within the store was also discussed where it was found that a more suiting placement would have been at the entrance or at the check-out counters. One of the customers also found the display a bit small for the size of the store, and mentioned that some sort of additional placement of the cans could be of interest.

From a discussion with Michal Wieloch [48], the owner of ICA Supermarket Fäladen, it was found that the general opinion of the staff was that the display stood out from the crowd. The possibility to display both refrigerated and non-refrigerated products was found to be new and fun. Michal really liked the rigidity of the cardboard display and believed that it could last for a long time and be reused. He also liked that the print did not interfere with the products packaging but instead made the products more visible. He believed that the presentation of the products was attractive but that there should be some extra space for the cans in order to not have to refill the display all the time. Overall the impression of the display was found to be positive and the technology interesting. On the question if he would be interested in a product like the one tested, he was positive and saw many opportunities of different kind of uses. He was also interested in combining other kinds of refrigerated products which would require another design of the cooling assembly. The fact that the refrigerated display is a module to the cardboard display was found to be interesting while it opened up for the possibility to design your own layout.

12.2.2.2 Comments

The information generated by the interviews provided information that was of great importance to the evaluation of the prototype. The overall impression of the prototype was found to be positive and the improvements mentioned were minor changes in the design. The concept of having chilled products displayed in combination with non-refrigerated products was found to be the most appreciated aspect. The amount of interviews was rather few due to the low amount of customers purchasing the campaign. According to the owner of the store Michal Wieloch [48], campaigns usually take some time for customers to find, and that the type of campaign was more suitable for weekends. He also mentioned that the amount of products within the store was much larger before Christmas while people tend to do more shopping at that time of year. The more products within the store, the harder it is for a product to stand out.

12.2.3 Prototype – customer interaction

The evaluation of the customer interaction revealed that attention was drawn to the product. Most customers within the area of where the display was placed noticed the display and stopped in front of it to get a closer look. A number of customers discussed the display with each other but did not purchase the products within. The discussions were mostly positive. The customers who purchased the products within the display seemed to struggle a bit with the opening of the lid of the refrigerated display. The main trouble seemed to be the low placement, the same reason found during the interviews. Most of the customers were also carrying a shopping basket which restricted them from using both hands.

13 Conclusion and discussion

Chapter 13 presents concluding comments of the fulfillment of measurable specifications and the aim of the master thesis

13.1 Fulfillment of measurable specifications

The analysis of the prototypes provided information that the refrigerated display functioned as intended, both during laboratory tests and the test within the grocery store. The subjective target values are believed to have been evaluated as intended and the results of the tests indicates that the general opinion is that they are fulfilled with some design changes.

13.1.1 Peltier refrigerated display

As one of the main disadvantages of Peltier elements was that they require more power than a compressor refrigerator, one of the more interesting aspects of the products commercial success is the power consumption.

From the product specification of the Peltier refrigerated display the target value of the maximum amount of energy of one day, measurable specification number 5, is 3.36 kWh/day. In order to get an approximation of the amount of energy required for one day, the results regarding the power consumption of the Peltier refrigerated display was used.

How large is the power consumption of one day?

- Target value: 3.36 kWh/day
- Opening hours ICA Supermarket Fäladen: 08.00-22.00, 14 hours
- Additional time for cooling: 34 minutes and 56 seconds, about 0.58 hours, found in test 3
- Time of one day equals 14.58 hours

$$P = U * I \quad (13.1)$$

Input for Peltier elements: 0.65A, 5.7V each, found during test 4, used for equation (13.1)

$$(5.7 * 0.65) * 3 = 11.12\ W \quad (13.2)$$

Input for fan: 0.135A, 24V each, used for equation 13.1

$$(24 * 0.135) * 2 = 6.48W \quad (13.3)$$

Input for LED lights: 3.4 W

The total amount of energy required, calculated in (13.2), (13.3) and the input of the LED lights

$$11.12 + 6.48 + 3.4 = 21\,W \quad (13.4)$$

As one day equals 14.58 hours, the total amount of energy (13.4) is multiplied by the amount of hours of one day of usage.

$$21 * 14.58 = 306.18Wh/day \approx 0.31kWh/day$$

The amount of energy required is found to be 0.31 kWh/day, about 9% of the target value, *maximum value of the power consumption*. The result indicates that the power consumption would not cause any trouble while promoting the product. Possible aspects causing the low usage of energy is that the amount of air within the display is much smaller than the amount of air within a compressor refrigerated display. The comparison of the amount of energy required for an open air merchandiser and a closed merchandiser 28%, was also made for refrigerators of commercial applications. The doors of the closed merchandiser are not well insulated and often made out of glass. The amount of energy required for a closed merchandiser is larger than for a domestic refrigerator that is well insulated. A domestic refrigerator of the size, height: 1854mm, width: 595 mm, depth: 668 mm has an energy use of 117kWh/year [49], about the same energy consumption as for the much smaller Peltier refrigerated display. The result of the amount of energy required for the Peltier refrigerated display is believed to suit the information gathered during the project.

The manufacturing cost of the Peltier refrigerated display is also of great importance for commercial success. The *maximum cost*, measurable specification 10, is set to 1,871 SEK. In order to evaluate the production cost, information was gathered for the cost of producing 500 units. Enquiries were sent to the manufacturers of parts of the prototype in order to present a better approximation. The assembly of all parts was to be made at Optocomp AB. The production cost of the refrigerated display is approximated to 1,084.3 SEK per unit, excluding the cost of the tools. The overview of the allocated cost can be found in table 13.1.

The reason that the cost of the tools is excluded from the approximated manufacturing cost is due to the potential market of the display that has not been evaluated. The possible market includes all sorts of grocery stores but also smaller convenience stores such as Pressbyrån etc. The cost of the tools should be divided over the amount of units for the entire life span of the tool. Adding the cost of the tool contributes to a manufacturing cost of 1,453.02 SEK per unit, an increase of 368,72 SEK.

Table 13.1 Overview of the allocated production cost

Part	Amount	Manufacturer	Cost/unit [SEK]	Cost of tool [SEK]	Total cost [SEK]
Peltier element	1500	European Thermodynamics limited	99.34	-	149 010
Heat sink	1500	Austerlitz Electronic	20	-	10 000
Extruded polystyrene insulation	500	Havd Group AB	35	50 000	67 500
Acrylic glass lid	500	Lilja Group AB	290	-	145 000
Assembly & aluminum parts	500	Optocomp AB	640	35 000	355 000
Total cost	500	**-**	**1,084.30**	**85 000**	**726 510**

For the Peltier refrigerated display measurable specification number 4, the products are easy to access, the tests of the prototype revealed that some changes in the design was of interest in order to meet customer needs. The changes required are not believed to cause any larger changes in cost nor power consumption. Another measurable specification not fulfilled is number 16 where the technology is requested to be easily recognized. During the prototyping and the test it was found that the technology is not something of interest to the consumer but instead the advantages and technology should be marketed and promoted towards customers of the refrigerated display. As the type of technology creates the possibility for refrigeration in a new way, the technology is also believed to present itself.

13.1.2 Cardboard display

For the cardboard display most of the target values of the measurable specifications are fulfilled. One of the measurable specifications not found to be fulfilled is number nine, which is a subjective specification regarding the possibility to customize both display and shelves. The design does not create this possibility while the rigidity was found to be at risk if the amount of shelves were possible to change. It is though believed that the design of the cardboard display is suitable for most stores while it is of a simple shape and not very restricted by the surrounding.

Another measurable specification that was not found to be fulfilled was number 13 regarding the possibility to add extra information. The possibility to add extra information was found best solved using an add-on. The stores often prints extra information, such as a campaign or offer within the store on an A4 paper and attaches it to the display. While the amount of time was limited, the development of an add-on suitable for this extra information was not performed.

13.2 Fulfillment of aims

From the prototyping and the tests the product is believed to fulfill the aims of the master thesis. The product creates the possibility for Smurfit Kappa to provide their customers with a solution that presents cooled products in an attractive and new way. From the tests the product stands out from the crowd while presenting the products in a new way, made possible using Peltier elements. The aim of creating a product with a favorable price was a challenge while the main disadvantage of Peltier elements was the large power consumption. From the tests is was found that the power consumption of the refrigerated display is advantageous compared to other commercial refrigerators. The aim of creating a product with a favorable price is also met concerning the production cost.

13.3 Further work

From the tests and the evaluation of the prototype, the product is functioning and of interest to the market.

In order for the product to be commercially applicable, the power supply and temperature controller have to be chosen. As mentioned these decisions were excluded from the development project while the main purpose of the prototype was to evaluate the function and the appearance of the product. The product is not finished and require some changes in the design in order to meet customer requirements. When these features are changed and evaluated, the selection of power supply and temperature controller should be made in collaboration with and expert within the area.

The changes in design both concern the cardboard display and the refrigerated display. Changes of the cardboard display have to be made in order to create the possibility to place the refrigerated display at a higher position. This require the cardboard display to be adjusted to suit the requirements of the refrigerated display. The height required should be evaluated by consumer tests. By placing the display at a higher position the stability of the display may be affected. Due to this the stability should be evaluated and if needed, supports of some sort should be added.

The changes of the design of the refrigerated display required to meet customer demands are to create a larger distance between the cans in order to make it easier to remove a can from the bars. The distance chosen should be made without compromising the appearance of the display. Also the larger the distance between the cans, the larger amount of air to be cooled, contributing to a larger power input needed. With this change of the design the laboratory tests should be performed again in order to secure the function and provide information that is to be used for the selection of power supply and temperature controller. The weight of the lid was also found to be an issue for consumers. A development of the ease of opening the lid and provide the possibility to open the lid and remove a can using only one hand is of interest. During prototyping, the possibility to use a gas spring was discussed. This possibility was examined but no suitable gas springs were possible to find. Possible solutions that provides this function should be evaluated and integrated in the product without any substantial increase in cost.

For further development it would be of interest to redesign the display in order to create the possibility to display other types of refrigerated products. It would be of interest to test the possibility of displaying perishable goods. There are two different ways of doing so. Either the cooled bars could be changed for a flat aluminum plate where products were placed on top of the cooled plate. The problem with this design is that the cooling would not be evenly distributed and cool the product at the position closest to the plate. In order to distribute the cooled air evenly, an air cooler should be used. As the tests provided information that the plate cooler did not require a substantial amount of energy compared to other commercial refrigerators, the air coolers that are less efficient and therefore dismissed at an earlier stage could be of interest. This application would require a different kind of design but the concept of a cooled module would remain the same.

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Appendix A: The dynamics of compressor refrigeration

The purpose of this literature study is to create an understanding of the basic dynamics of compressor refrigeration. The information gained from this literature study is later used throughout the master thesis in order to secure the function of the final product.

Required parts

- Thermal expansion valve
- Compressor
- Evaporator
- Condenser
- Refrigerant
- Evaporator fan
- Condenser fan

Process

The vapor compression cycle

A thermal expansion valve is used to reduce the pressure of a refrigerant when it is inserted in the system as a high pressurized liquid. This valve causes a pressure drop in the refrigerant, also creating a temperature drop. Due to the drop in pressure the boiling point of the refrigerant is lowered. The cold liquid refrigerant, with some vapor due to the lowered boiling point, is then passed through the evaporator where it absorbs heat from the surrounding area. See the second law of thermodynamics, equation (A.1) below. Due to the heat absorption process the refrigerant evaporates to a pure vapor. If the refrigerant is not pure vapor when exiting the evaporator, superheat occurs in order to protect the compressor used in the following step.

In order to change the state of the refrigerant from low pressure vapor to its original state as high pressure liquid, it firstly has to pass through a compressor. This process is also the part that pumps the refrigerant through the system. The compressor creating the original high pressure, also raises the boiling point. The high pressurized vapor is passed through a condenser where heat, both latent and sensible, is exchanged to the surrounding air. Also at this process, the second law of thermodynamics, equation (A.1) below, explains the process. The temperature will reach a normal level and the refrigerant will reach its original state as high pressure liquid. After this step the liquid reaches the expansion valve and the process is restarted [A1]. The vapor compression cycle is illustrated in figure A.1 below.

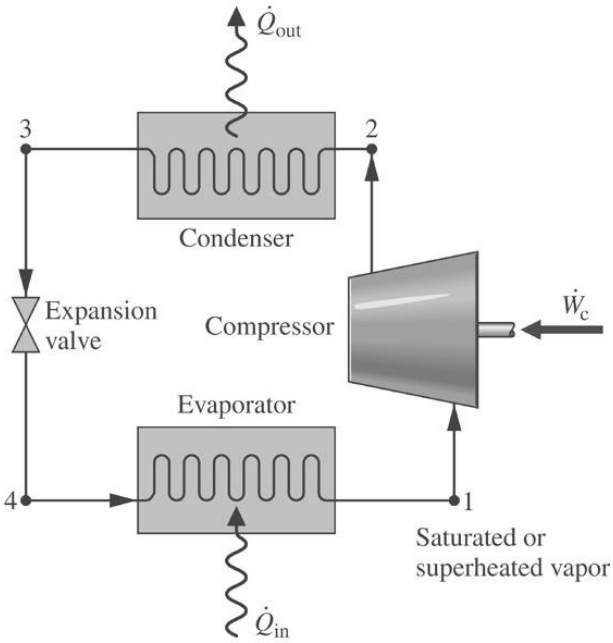

Figure A.1 Overview of the vapor compression cycle [A2]

In order to produce an even distribution of the cold air, a fan can be used. As hot air has a larger kinetic energy, and therefore a larger distance between its´ molecules, the weight of hot air is lower than for cold air. If a fan is not used, the cold air will therefore sink to the bottom of the refrigerator at the same time that the hot air rises to the top, creating an uneven cooling of products within the refrigerator. If a fan is to be used it is therefore to be placed at the bottom part, forcing the cold air upwards.

Humidity

When the door of a refrigerator is opened, moist air enter. On a fridge the moist air condenses on the back panel, and is later drained through a hole on the bottom of the back panel. The condensed water ends up in an evaporation tray on the compressor, the evaporation tray is hot and the condensed water evaporates to the surrounding.

Thermodynamic laws of the vapor compression cycle

The refrigerant of the system is the part that causes the cooling effects. In Figure A.2 below the PH chart of the refrigerant of the compressor refrigeration cycle can be found,

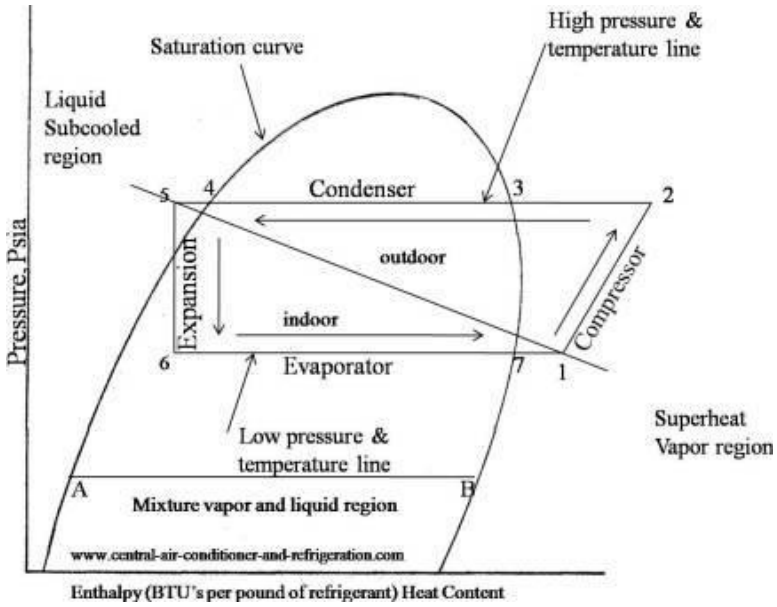

Figure A.2 The PH chart of the refrigerants different stages of the vapor compression cycle [A3]

The first law of thermodynamics

Energy cannot be created nor destroyed, it can only transform [A4].

The second law of thermodynamics

Heat will naturally flow from a hotter area to a cooler area [A4]

$$dS = \delta Q/T \quad (A.1)$$

dS change in entropy of a system

δQ the amount of heat that has entered a closed system

T the temperature when the heat transfer took place

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Appendix B: Result of patent search

B.1 Result of keyword: Refrigerated cardboard

B.1.1 Packaging case

This patent is not a refrigerated cardboard display but still of interest to the project while it describes a way to avoid moisture in cardboard packaging. The patent is of the combination of a cardboard inner surface that is connected to a paper outer surface with a polyethylene film. The polyethylene film prevents the moisture from the internal products to affect the outer surface [B1].

Filing date: 25.11.2004

Legal status: the patent is no longer active

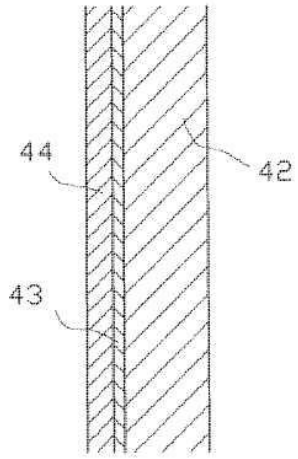

Figure B.1 Patent where the paper 44, and the inner surface of the cardboard 42 is bonded by a polyethylene film 43. The outer surface is to be the paper surface 44 [B1]

B.1.2 Packaging and cabinet for displaying perishable goods

The patent is similar to the product to be developed while a refrigerated cabinet used also for point-of-sale display is described. The cabinet may be made of cardboard or paper and an air in- and outlet linked to an air ventilation is described [B2].

Filing date: 18.02.1997

Status: The application is deemed to be withdrawn

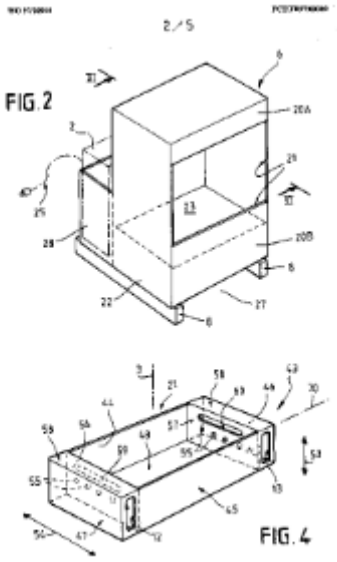

Figure B.2 Drawing of the patent packaging and cabinet for displaying perishable goods [B2.A]

B.1.3 Collapsible refrigerated cabinet

The patent describes a refrigerated cabinet made of a cardboard material. The removable cabinet is connected to a base where fresh air is being circulated. The patent describes the possibility to integrate transparent cutouts where light and more visibility for the customers can be provided. The base pallet is produced in order to ease the handling and transport of the display cooling unit [B3].

Filing date: 11.02.1994

Status: No opposition filed within the time limit

The filing date is more than 20 years ago and according to regulations the patent is no longer active.

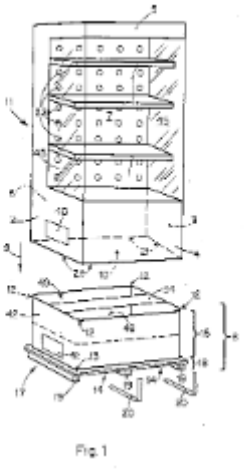

Figure B.3 Drawing of the patent Collapsible refrigerated cabinet [B3.A]

From the findings, the inventor Andre Renard was found patenting similar objects why the following keywords were used:

B.2 Result of keyword: Renard Andre cardboard

B.2.1 Disposable refrigerated display

The description of the patent is similar to the function of the product within this project. The patent describes a refrigerated display made out of cardboard that is mounted on a pallet. The cardboard display is refrigerated by a chilled air flow that enters the display through diffuser holes at the back panel. The shelves are described as either nets or rigid. The cold air will be lead up by the back panel and distributed by diffuser holes and the top part has a flap that forces the air down. Some of the cold air will be recycled in order to be more efficient and create a wall from the surrounding room temperature. The display is folded by the dotted lines and is self-explanatory. In order to avoid the engine of the cooling device to be too hot, an opening in the back-panel can be made where cool air is blown over the engine [B4].

Filing date: 13.07.1998

Status: The application is deemed to be withdrawn

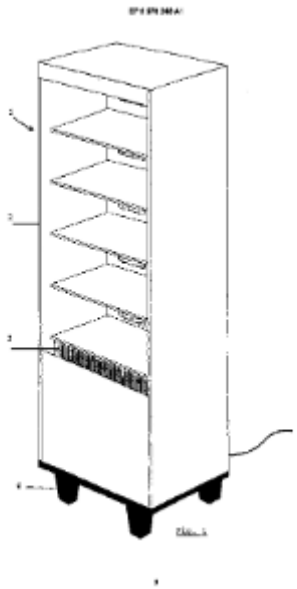

Figure B.4 Drawing of patent Disposable refrigerated display [B4.A]

B.2.2 Apparatus and system for displaying products

The patent is similar to the product in this project while a refrigerated product display cabinet is being described. The display unit is mounted on the cooling unit by a structure, creating the possibility to change the positions along an axis. Some sort of transport and distribution of the chilled air is made through a transport line [B5].

Filing date: 03.11.2010

Status: The application is deemed to be withdrawn

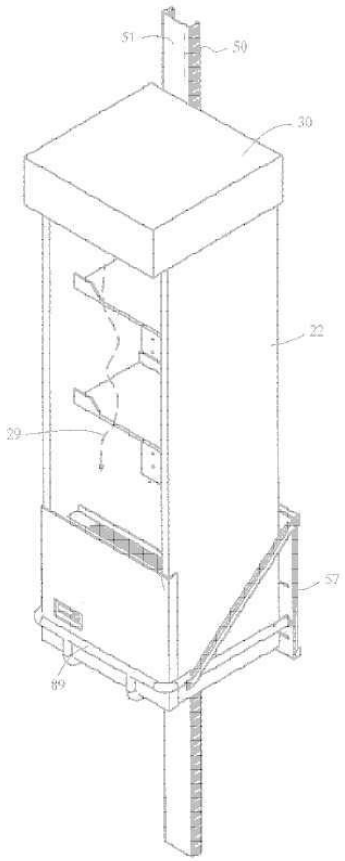

Figure B.5 Drawing of patent Apparatus and system for displaying products [B5]

B.2.3 Refrigerated cabinet for displaying food or the like

The patent describes a refrigerated cabinet that is similar to the product within this project. The display with air flow means, is a module that is easily removed and mounted on an air cooler. The bottom part is described as a pallet with air guide means. The patent describes possible ways to handle larger loads from 50-300 kilograms. The display is mounted on a pallet that is possible to transport with a forklift [B6].

Filing date: -

Status: Expired due to failure to pay maintenance fee

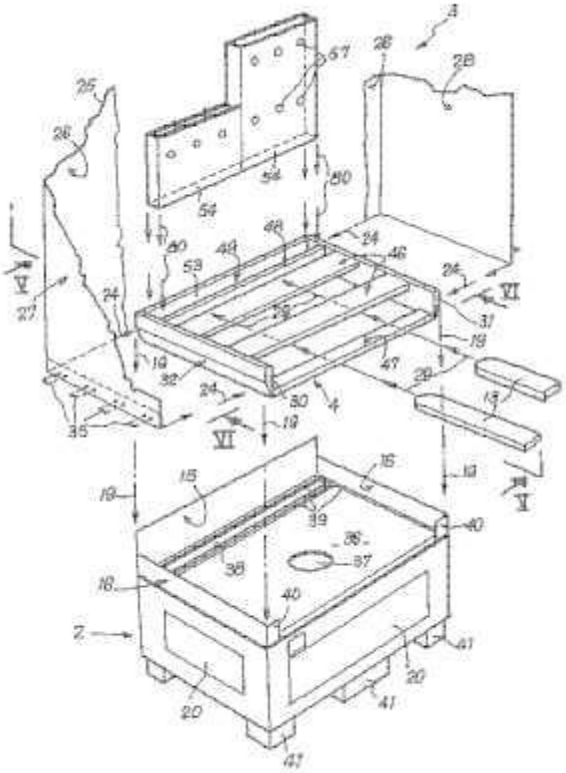

Figure B.6 Drawing of patent Refrigerated cabinet for displaying food or the like [B6]

B.2.4 Removable cover for refrigerator cooler unit is made from paper, cardboard or plastic with hinged section for access

The patent is similar to the product of this project while it is a refrigerated cardboard container for perishable products. The difference between this patent and the ones found prior to this patent is that the product is described as a container and not a display. Another difference is that one of the walls have a hinged section, not described in the other patents found [B7].

Filing date: 05.12.1999

Status in France: **Dossier déchu définitivement. –The file is no longer active**

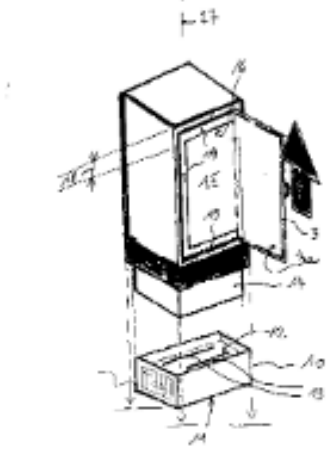

Figure B.7 Drawing of patent Removable cover for refrigerator cooler unit is made from paper, cardboard or plastic with hinged section [B7.A]

B.3 Result of keyword: Drink cooler cardboard

No similar product found

B.4 Result of keyword: Display Cardboard Cooler

B.4.1 Cooler merchandiser with customizable graphics

This patent is not made out of cardboard but is similar to the product idea while the product is used for marketing refrigerated products. Instead this patent is described as using a rigid styrene material. The sides of the cooler can be covered by an inserted cardboard sheet. The product is described as divided where one part is a cooling portion and one part is a display portion. The patent leaves the possibility to attach a frame and an opening to the housing [B8].

The reason that this patent is presented in the report is while it is a common refrigerated display, used at many grocery stores. The applicants are Pepsico Inc, the owners of many known brands, such as Pepsi, Lipton tea etc. [B9].

Date of filing: 09.07.2009

Status: -

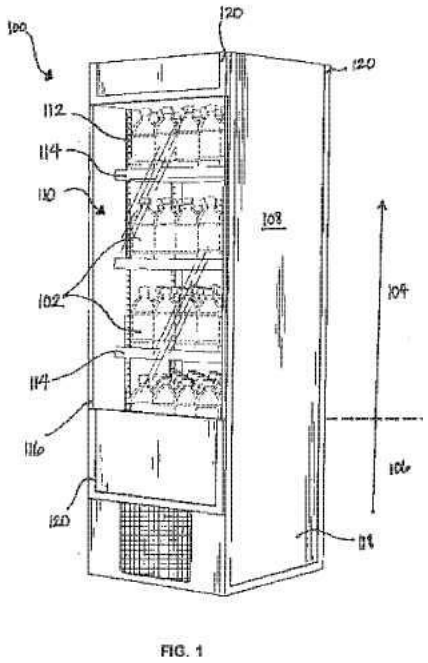

Figure B.8 Drawing of patent Cooler merchandiser with customizable graphics [B8.A]

B.5 Result of keyword: Disposable refrigerated display

B.5.1 In-store refrigerated display system

The patent is of interest while it is a refrigerated cardboard display. In order to remove the problem with tightly stacked products, the shelves are made out of ribs. The ribs have to be tight enough to not let any of the products to fall through the holes. Due to the ribs the air will flow through each section [B10].

Filing date: 12.04.1989

Status: Expired due to failure to pay maintenance fee

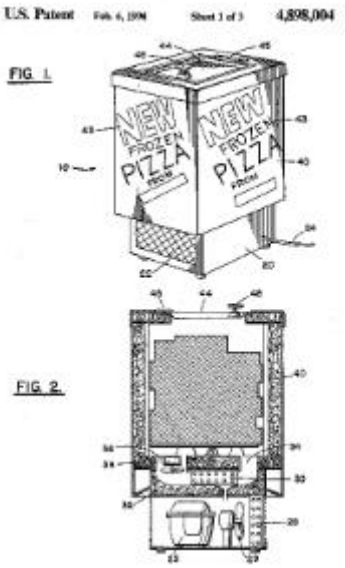

Figure B.9 Drawing of patent In-store refrigerated display system [B10]

B.6 Result of google search

B.6.1 Refrigerated display cabinet

The patent is of interest while it is a refrigerated cardboard display. Some interesting findings of the airflow was found. Instead of the regular airflow from back to the front, the air flows laterally. The outlet is positioned on one of the lateral walls and the inlet, which guides the cold air back to the cooling device, is positioned on the other. Due to this the patented solution allows a cooler temperature. The openings are in the shape of elongated slots, where the outlets are larger than the inlets, in order to spread the cooled air uniformly and use the cold air for a longer time.

The patent also describes an air curtain in order to prevent the cooled air from escaping the refrigerated area. This curtain is created by an air outlet guide in the back wall and top and along the open front. A deflector positioned along the open front, between the lateral walls, is used in order to orient the air to the cooling unit [B11].

Filing date: 06.07.1999

Status: The application is deemed to be withdrawn

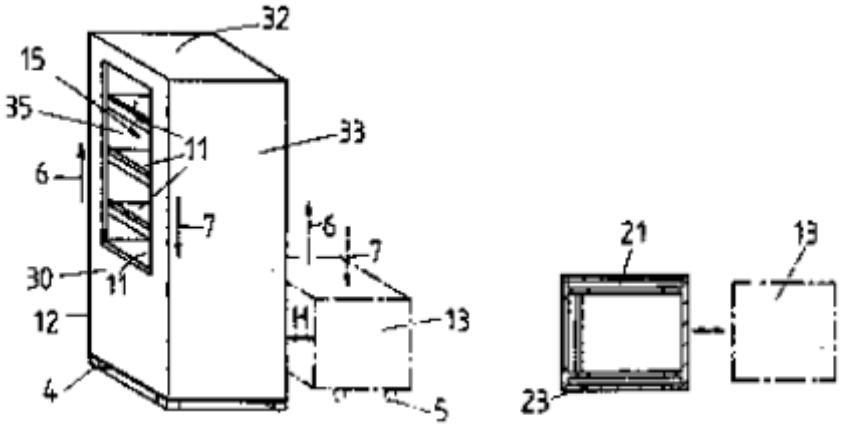

Figure B.10 Drawing of patent Refrigerated display cabinet, (12) – frame, (15) refrigerated area, (33) - lateral wall, (32) - top wall, (30) – open front, (13) – cooling unit, (21) – outlet guide located on the first lateral wall, (23) – air inlet guide located in the second lateral wall (6),(7) – direction of air, (11) –shelves [B.11.A]

B.6.2 Refrigerated merchandising apparatus

This patent is of interest to the project while it is a disposable refrigerated merchandiser. From this patent it was found information that the common permanent refrigerators produces an air curtain by using an outlet adjacent to the open front. The air curtain is described as an air outlet from the upper part of the refrigerator and an inlet at the bottom, producing a column of air. It is also commented that the common use of material is a wax coated corrugated cardboard. The patent is made for increased strength and air flow.

The refrigerated air passes a turbulence area in order to force the air to be in contact with the product to be cooled. The turbulence generating elements are positioned at the bottom of each shelf and the top wall. All of the turbulence generating elements are vertically positioned. The cardboard parts are covered with wax, plastic or any other suitable element to resist moisture.

In order to create strong shelves, foam elements with c-channel elements placed on the ends. These core parts are covered with corrugated cardboard, where the ends facing the walls are uncovered. The turbulence generating elements are made out of the covering cardboard by creating a fold where the turbulence is to take place [B12].

Filing date: 15.01.2004

Status: Expired due to failure to pay maintenance fee

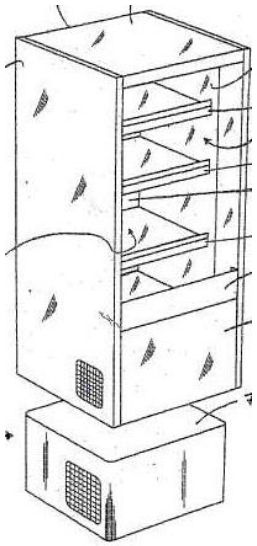

Figure B.11 Drawing of patent Refrigerated merchandising apparatus [B12.A]

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Appendix C: Parameters of Coolio products

C.1 E-coolio R290

Table C.1 Parameters of the permanent compressor cooling unit e-coolio R290 [C1]

e-coolio R290
Height: 520 mm
Width: 450 mm
Depth: 440 mm
Weight: 25 Kg
Electrical data: 2,3 A • 230 V • 50 Hz.
Refrigerant: Climate-friendly R290
Temp.: +1°C / +6°C
Wheels: 4 (2 with brake)
Ambient conditions: 22°C / 60% Hum.
Digital electronic temp. control
Automatic water evaporation
Plug-and-play cooler
Integrated transformer and LED light connections
Life expectancy of a minimum 3 to 5 years
Lightweight of energy absorbing, high thermal insulated EPP (Expanded polypropylene) combined with metal
Easy maintenance and service via quick access (closing grid with magnets)
Simplified water drain via removable plug
Cooling capacity: 1-6 ˚C with double fan

C.2 Coolio R290

Table C.2 Parameters of the permanent compressor cooling unit Coolio R290 [C2]

Coolio R290
Height: 538 mm
Width: 460 mm
Depth: 460 mm
Weight: 25 kg
Technical Data: 2,3 A • 230 V • 50Hz
Energy Consumption: 6 kWh/day (measured under ISO 23953 "refrigerated display cabinets" standard (22°C/60%H)

Refrigerant: R290
Temp.: +3° C / +7° C
Wheels: 4 (2 with brake)
Polyethylene Casing
Noise level: 55 dB
Ambient conditions: 22°C / 60% Hum.
Digital electronic temp. control
Automatic water evaporation
Plug-and-play cooler
No defrost time
Option: 115 V

C.3 Freshboard Traditional 3.0

Table C.3 Parameters of the Freshboard traditional 3.0 [C3]

Freshboard traditional 3.0
Humidity protection through a UV-layer
Standard product tray fit
LED wiring special cable ducts are integrated in the Freshboard front and side panel
Carry on handle on the transportation box
100% recyclable material
5-10 minutes installation
Standard loading for transportation and logistics 100*120 cm
Height: 2035 mm
Width: 445 mm
Depth: 440 mm
Shelves: 3 cardboard trays (410 x 280 x 35 mm) + 1 bottom tray
Max. load per shelf: 25 kg
Weight : 7,5 kg (approx.)
Content: 160 L (approx.)
Material : Cardboard / Wood
Options: LED Light, Night Curtain, Scanrails (data strips), Sound device, Shelve dividers

C.4 Freshboard Checkout 3.0

Table C.4 Parameters of Freshboard Checkout 3.0 [C4]

Freshboard checkout 3.0
Humidity protection through a UV-layer
Recyclable material
2 adjustable shelves + bottom tray that can hold each 30 kg
Optional Night Curtain, Scan-rails (data-strips)
Installation time 5-10 min
100%recyclable materials
Height: 1575 mm
Width: 445 mm
Depth: 440 mm
Weight : 7 kg
Content: 123 L
Material : Cardboard / Wood
Shelves: 2 + bottom 410 x 280 x 35 mm

C.5 X-fresh

Table C.5 Parameters of the X-fresh [C5]

X-fresh
Made from recycled fibers
Height: 2070 mm
Width: 457 mm
Depth: 442 mm
Shelves: 3 trays (410 x 280 x 40 mm) + bottom
Content: 160 L (approx.)
Weight: 5,7 kg
Material: X-board Lite (FSC certified)

Appendix D: Question Guide used during interviews

Question-guide
1. Används kyldisplayer i wellpapp i butiken idag?
2. Hur undviks fukt i kyldisplayerna?
3. Vad är de största problemen med de displayer som finns idag?
4. Är de svåra att hantera?
5. Vad brukar vara största orsaken till att de skadas/ går sönder? Om ej wellpapp kyldisplayer används berör frågan wellpapp displayer för icke kylda varor
6. Vilka attribut hos displayen verkar ge mest positiv feedback?
7. Är nattgardiner använda? Är de svåra att använda? Vilka problem finns med dom?
8. Brukar ni plocka ut varorna eller placera en displaykartong i displayerna? Varför/varför inte?
9. Energikonsumtion kWh/dag, vad är en acceptabel minskning för att byta produkt?
10. Vilka temperaturområden ska hållas?
11. Är det önskvärt med en mobil lösning?
12. Hur lång tid får den ta att montera?
13. Under hur lång tid ska den användas?
14. Hur mycket last ska den klara?
15. Är belysning någonting som är av intresse trots ökat pris?
16. Vilken storlek för displayen är mest anpassad för butikerna?
17. Vart ska den helst placeras?
18. Hur stort är området som den kan placeras i?
19. Vilka begränsningar kommer av omgivningen?
20. Icke sladdlösa lösningar, hur hanteras sladdar?
21. Vilken temperatur i genomsnitt har en ICA butik?
22. Vilken produkt skulle kunna vara av intresse att använda produkten till?
23. Föredras färdigmonterad eller omonterad?
24. Är öppna eller slutna hyllplan att föredra? Varför?
25. Vilken volym är optimal för placeringen?
26. Hur många hyllplan är att föredra och varför?
27. Övriga kommentarer?

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Appendix E: Expressed an interpreted customer needs

E.1 Interview at ICA Kvantum Malmborgs

Customer: ICA Kvantum Malmborgs, Erik Magnusson	**Date: 9 September 2015**	
Fråga	Svar	Interpretation of customer needs
1. Används kyldisplayer i wellpapp i butiken idag?	Nej	No
2. Hur undviks fukt i displayerna?	Kondens kommer oftast när det är varmt i butiken, höst och vinter är det inte problem. Torkar av för hand. Håller kylarna stängda så mycket det går, säkert att det ska vara stängda hela tiden	The product can handle temperature differences in the surrounding air. The product is always closed when products are not removed
3. Vad är de största problemen med de displayer som finns idag? Om ej wellpapp kyldisplayer berör frågan displayer för icke kylda varor	Dålig hållbarhet, kan inte hantera så tunga produkter skaderisk, fukt vid golvtvätt. Använder ofta pall under så att den kommer upp lite	The product is of a strong material. The bottom part is protected from moisture
4. Är de svåra att hantera?	Nej, smidiga, lätt konstruktion även med info om hur man gör	The product is easy to assemble and understand
5. Vad brukar vara största orsaken till att de skadas/ går sönder? Om ej wellpapp kyldisplayer används berör frågan displayer för icke kylda varor	Kunder kör emot, stor flöde av kunder ger mycket slitage	The product is protected from impact
6. Vilka attribut hos displayen verkar ge mest positiv feedback?	Mer utstickande färger och mönster	The product stands out in the store
7. Är nattgardiner använda? Är de svåra att använda? Vilka problem finns med dom?	Ja, håller översikt när de går ner. Smidigt med automatisk funktion i de stora	Night curtains, if used are automatic
8. Brukar ni plocka ut varorna eller placera en displaykartong i displayerna? Varför/varför inte?	Plocka ur, det är snyggare och passar in i butiken	The product fulfills its purpose without trays. The product makes it easy to stack products without trays

9. Energikonsumtion kWh/dag, vad är en acceptabel minskning för att byta produkt?	Intresse av att se hur mycket ström som används - ger ekonomiska fördelar - alla säljare vill få in en kyl, byter saker i displayerna hela tiden	The product is equipped with a display of energy consumption
10. Vilka temperaturområden ska hållas?	Vara och förpackning 4-8 grader mejeri, egenkontroll nästan dagligen för att undvika spill extrakoll för att hålla temperaturen. Alla fasta kylar har larm - jour dygnet runt som styr kylan och hanterar den, finns inte i plug-in dock finns en temperaturmätare	The product is efficient enough to handle the required temperature. The product is equipped with indicators providing information if the temperature is lower than the setting
11. Är det önskvärt med en mobil lösning?	Nej mer energibesparande lösningar, solcell eller liknande	The product is energy efficient
12. Hur lång tid får den ta att montera?	Max några minuter	The product is easy to assemble and understand
13. Under hur lång tid ska den användas?	Hålla samma kvalitet som innan, så länge som möjligt	The product is easy to maintain and usable during a longer period of time
14. Hur mycket last ska den klara?	Ca 5 kg per hylla max 10	The product can handle the weight of common products
15. Är belysning någonting som är av intresse trots ökat pris?	Ja LED	The product is equipped with a source of light
16. Vilken storlek för displayen är mest anpassad för butikerna?	Butiksanpassning, rita sin egen kyl, och bestämma volym, inte bara göra standard. Placeras ofta i hörnen och kanter så att den passar så bra som möjligt	The product may be varied depending on the size of the store. The consumer can customize their individual solution
17. Vart ska den helst placeras?	Hörnor och gömda utrymmet skaffa en merförsäljning, vid kassa, mycket kundflöde	The product is possible to display where a lot of customers pass. The product is represented in an attractive way from all angles
18. Hur stort är området som den kan placeras i?	1-2 kvadratmeter	The product is suitable for smaller areas
19. Vilka begränsningar kommer av omgivningen?	Sladdar, och att folk inte ska gå in i dem, mycket kundflöde, snäva svängar, små smällar, stötskydd	The product is designed to handle the cord in an attractive way. The product is protected from impacts
20. Icke sladdlösa lösningar, hur hanteras sladdar?	Helst enkel inte för mycket plotter	The product is designed to handle the cord in an attractive way
21. Vilken temperatur i genomsnitt har en ICA butik?	Varierar mycket med årstid, ca 20 grader	The product temperature is set to handle the surrounding temperature, also with a varied temperature range

22. Vilken produkt skulle kunna vara av intresse att använda displayen till?	Alla to go-saker, snabb omsättning, lätta att flytta, bra omlopp, inte stående produkter, mestadels tillfälliga kampanjer	The product shelves are made in order for the customer to easily grab the products within
23. Föredrar färdigmonterad eller omonterad?	Omonterade	The product is sent to the retailer non-mounted. The product is easy to assemble and understand
24. Är öppna eller slutna hyllplan att föredra? Varför?	Öppna, ska gå snabbt	The product shelves are made in order for the customer to easily grab the products within
25. Vilken volym är optimal för placeringen?	Kundanpassade produkter, cyklister, kundkorgar. Beror på exakt vart man vill ha kylen, anses allra bäst att bygga sin egna	The consumer can customize their individual solution
26. Hur många hyllplan är att föredra och varför?	Beroende på 4-5	The number of shelves and the distance between them can be varied at the desire of the store
27. Övriga kommentarer?	Ultimat att få bygga sin egen. Ekonomiskt att få ner driftskostnaden. Efter tidigare erfarenhet av en wellpapp-kyl (ett företag med ost) så ansågs kundtrycket vara så stort att modellen inte höll. Det fanns även en osäkerhet i att kylan var konstant och inte skulle förstöra maten	The consumer can customize their individual solution. The product is energy efficient. The product is equipped with indicators providing information if the temperature is lower than the setting

E.2 Interview at ICA Nära Satelliten

Customer: ICA Nära Satelliten Jörgen Jarl	**Date: 9 September 2015**	
Fråga	Svar	Interpretation of customer needs
1. Används kyldisplayer i wellpapp i butiken idag?	Nej	No
2. Hur undviks fukt i displayerna?	Inga problem sätter ej in med kartong, kan bli kondens om det är för varmt i butik	The product can handle temperature differences in the surrounding air
3. Vad är de största problemen med de displayer som finns idag? Om ej wellpapp kyldisplayer berör frågan displayer för icke kylda varor	Går sönder, wellpappen måste vara inplastad	The product is of a strong material
4. Är de svåra att hantera?	Första gången svåra att hantera	The product is easy to assemble and understand
5. Vad brukar vara största orsaken till att de skadas/ går sönder? Om ej wellpapp kyldisplayer används berör frågan wellpapp displayer för icke kylda varor	Kör på dem och de viker sig. Hanteringsfel vid montering med dålig info, beskrivningar dåliga eller ej befintliga	The product is easy to assemble and understand. The product is always completed with a description
6. Vilka attribut hos displayen verkar ge mest positiv feedback?	Inget som lagts märke till, produkten som avgör	The product makes it easy for the customers to see the content
7. Är nattgardiner använda? Är de svåra att använda? Vilka problem finns med dom?	Ja. Nej, går upp samtidigt som nödutgångar	Night curtains, if used are automatic
8. Brukar ni plocka ut varorna eller placera en displaykartong i displayerna? Varför/varför inte?	Undviker kartonger i kylar, på grund av fukt, blir kondens vid avfrostning	The product fulfills its purpose without trays
9. Energikonsumtion kWh/dag, vad är en acceptabel minskning för att byta produkt?	Vet ej	-
10. Vilka temperaturområden ska hållas?	4˚C	The product is efficient enough to handle the required temperature
11. Är det önskvärt med en mobil lösning?	Ja men merjobb att ladda den, kanske som kombination. Bra för demovaror,	The product is mobile if not too expensive and charges automatically
12. Hur lång tid får den ta att montera?	Max 10 minuter, liknande i utförande, ibland sätter ihop stället och sätter kartongen på	The product is easy to assemble and understand
13. Under hur lång tid ska den användas?	Icke kyld - 2 veckor för kampanjer, man kör efter kampanjerna, veckovis	The product is usable during the time of a campaign
14. Hur mycket last ska den klara?	50 kg - totalt	The product can handle the weight of common products

15. Är belysning någonting som är av intresse trots ökat pris?	Ja	The product is equipped with a source of light
16. Vilken storlek för displayen är mest anpassad för butikerna?	60x60, höjd 150-160	The product is square shaped and tall
17. Vart ska den helst placeras?	nära ingången, eller vid kassorna	The product is possible to display where a lot of customers pass. The product is represented in an attractive way from all angles
18. Hur stort är området som den kan placeras i?	Relativt ensam så att den syns	The product is represented in an attractive way from all angles.
19. Vilka begränsningar kommer av omgivningen?	Intill en vägg, om man har ett torg kan man dra sladdarna upp i taket	The product is easy to connect to a power source far away
20. Icke sladdlösa lösningar, hur hanteras sladdar?	Både vägg och tak	The product cord is flexible and suits a connection to the roof. The product is easy to connect to a power source far away
21. Vilken temperatur i genomsnitt har en ICA butik?	20-21 ˚C	The product temperature is set to handle the surrounding temperature, also with a varied temperature range
22. Vilken produkt skulle kunna vara av intresse att använda produkten till?	Framförallt dricka, mozzarella om man kan hälla i dem, Toppmatad	The product is used for displaying a large number of items. The product displays products in an attractive way where the products are required to be stacked in a certain way (brand facing forward)
23. Föredrar färdigmonterad eller omonterad?	Icke monterade så man kan hantera dom om man inte använder dom direkt	The product is sent to the retailer non-mounted. The product is sent to the retailer in an easily stored size
24. Är öppna eller slutna hyllplan att föredra? Varför?	Skjutdörrar hade varit att föredra	The product is easily sealed with a closure that does not affect the customers availability to the product
25. Vilken volym är optimal för placeringen?	60x60x150-160 beror på storlek av butik	The product may be varied depending on the size of the store
26. Hur många hyllplan är att föredra och varför?	4-5 anpassad för produkten, känsliga produkter behöver mer hyllplan och kan inte staplas på varann, kanske kan variera antalet	The number of shelves and the distance between them can be varied at the desire of the store
27. Övriga kommentarer?	Passar butiken, flexibel, energieffektiv, enkel att ställa undan	The product is easy to store when not used. The product is energy efficient. The consumer can customize their individual solution

E.3 Interview at ICA Nära Tornet

Customer: ICA Nära Tornet, Jörgen Fors	**Date: 8 September 2015**	
Fråga	Svar	Interpretation of customer needs
1. Används kyldisplayer i wellpapp i butiken idag?	Nej	No
2. Hur undviks fukt i displayerna?	Endast vid avfrostning försvinner med kyla	The product is quick to cool a new display part
3. Vad är de största problemen med de displayer som finns idag? Om ej wellpapp kyldisplayer berör frågan displayer för icke kylda varor	Kylan åker rakt ut, öppna kylar, ej energieffektiva	The product is possible to easily close if wanted
4. Är de svåra att hantera?	Nej, måste dammsugas vid framsidan vid flänsarna, tappas temperatur om de inte är rengjorda	The part that covers the inlet of air to the compressor is easy to clean
5. Vad brukar vara största orsaken till att de skadas/ går sönder? Om ej wellpapp kyldisplayer används berör frågan wellpapp displayer för icke kylda varor	Om de står för länge, fukt av städning, säljs ofta slut snabbt, grillställ som står 3 månader fukten nertill som viker, liten yta att placera produkter på, snabb avverkning	The bottom part of the display is protected from moisture. The product is protected from impact. The consumer can customize their individual solution
6. Vilka attribut hos displayen verkar ge mest positiv feedback?	Inget som lagts märke till	
7. Är nattgardiner använda? Är de svåra att använda? Vilka problem finns med dom?	Ja, automatisk stängning i större, mindre stängning på rutin, känsliga att ställa in, får ej röras då trasslar den, skevar sig jätteenkelt	Night curtains, if used, are easy to handle and are not affected by a smaller impact
8. Brukar ni plocka ut varorna eller placera en displaykartong i displayerna? Varför/varför inte?	Ta ur dem, vill ej ha kartonger i hyllorna, har ej plats	The product fulfills its purpose without trays. The product is designed with the possibility to easily fill and display many products.
9. Energikonsumtion kWh/dag, vad är en acceptabel minskning för att byta produkt?	Vet ej	The product is equipped with a display of energy consumption
10. Vilka temperaturområden ska hållas?	4-8 ˚C	The product maintains a desired temperature, also during stacking of products.
11. Är det önskvärt med en mobil lösning?	Nej, jobbigt att glömma ladda, leder till mer problem	The product is mobile if not too expensive and charges automatically
12. Hur lång tid får den ta att montera?	Max 2 minuter, ska vara enkelt, leverantören får annars ställa upp den	The product is easy to assemble and understand

13. Under hur lång tid ska den användas?	Vet ej	
14. Hur mycket last ska den klara?	5 kg minst per hylla	The product can handle the weight of common products
15. Är belysning någonting som är av intresse trots ökat pris?	Ja	The product is equipped with a source of light
16. Vilken storlek för displayen är mest anpassad för butikerna?	För liten butik passar denna storlek väldigt bra, går åt snabbt i stora butiker	The product may be varied depending on the size of the store
17. Vart ska den helst placeras?	Impulsköp, kundstråket	The product is possible to display where a lot of customers pass
18. Hur stort är området som den kan placeras i?	Hörna eller gavel där kunder går förbi	The product is possible to display where a lot of customers pass
19. Vilka begränsningar kommer av omgivningen?	Sladd ska kunna dras, redan kontrollerat vart man vill ha kylen	The product is designed to handle the cord in an attractive way
20. Icke sladdlösa lösningar, hur hanteras sladdar?	Drar bakom, kan vissa i tak	The product cord is flexible and suits the connection to the roof
21. Vilken temperatur i genomsnitt har en ICA butik?	16-17 ˚C	The product temperature is set to handle the surrounding temperature, also with a varied temperature range
22. Vilken produkt skulle kunna vara av intresse att använda produkten till?	Alla olika produkter används i kylen ska vara flexibla	The product easily displays different brands
23. Föredrar färdigmonterad eller omonterad?	Icke monterad, inte för mycket mek	The product is sent to the retailer non-mounted. The product is easy to assemble and understand
24. Är öppna eller slutna hyllplan att föredra? Varför?	Öppna då det är impuls kylar	The product shelves are made in order for the customer to easily grab the products within
25. Vilken volym är optimal för placeringen?	För liten butik är mindre bättre, kopplat till storlek på butik	The product may be varied depending on the size of the store
26. Hur många hyllplan är att föredra och varför?	3 hyllor	The product is designed with shelves
27. Övriga kommentarer?	Billigare att reparera, kompressorn går sönder, kyltekniken, inbyggd felsökning, dammsuga flänsarna kontinuerligt för att inte gå sönder	The product is easy to repair and indicates when the cooling capacity is lowered

E.4 Interview at ICA Nära Söderlivs

Customer: ICA Nära Söderlivs Andreas Östergren	**Date: 7 September 2015**	
Fråga	Svar	Interpretation of customer needs
1. Används kyldisplayer i wellpapp i butiken idag?	Nej	No
2. Hur undviks fukt i displayerna?	Torkar av den, kondens på insidan, sker endast efter avfrostning och går på igen	The product has surfaces that are easy to clean and can handle moisture
3. Vad är de största problemen med de displayer som finns idag? Om ej wellpapp kyldisplayer berör frågan displayer för icke kylda varor	Hålla kylan, drar på några extra grader istället, inställning svåra att hantera	The refrigerator is easy to set to desirable settings. The product maintains a steady temperature
4. Är de svåra att hantera?	Enkla att förflytta, anslutning till uttag	The product is easy to move around in the store.
5. Vad brukar vara största orsaken till att de skadas/ går sönder? Om ej wellpapp kyldisplayer används berör frågan wellpapp displayer för icke kylda varor	Felhantering vid utkörning från lager	The product is protected from impacts.
6. Vilka attribut hos displayen verkar ge mest positiv feedback?	Gavel nära till andra liknande varor, man går till dit man vet att varan ligger	The product provides enough information to the customer about the content.
7. Är nattgardiner använda? Är de svåra att använda? Vilka problem finns med dom?	Nej, gärna fastmonterade i kylarna så att de är enkla att använda	The product is possible to easily close if wanted
8. Brukar ni plocka ut varorna eller placera en displaykartong i displayerna? Varför/varför inte?	Plocka ur varorna, kan placeras snyggt eller inte bestäms av produkten. Billig vara – störtexponeras för att det ser billigare ut. Varierar likt en modegrej	The product fulfills its purpose without trays. The product is designed with the possibility to easily fill and display many products.
9. Energikonsumtion kWh/dag, vad är en acceptabel minskning för att byta produkt?	Vet ej hur mycket som dras /dag	The product is equipped with a display of energy consumption
10. Vilka temperaturområden ska hållas?	Precis under 8 mejeriprodukter, en under 4 ˚C pålägg kött etc. Omständigt att ställa om	The product maintains a constant temperature, also during stacking of products. The refrigerator is easy to set to desired settings.
11. Är det önskvärt med en mobil lösning?	Fullständigt lysande, längre hållbarhet minst hålla en dag i batteritid, kan förstöra produkter och ge mer svinn	The product is mobile of not too expensive and has a battery time of at least one day
12. Hur lång tid får den ta att montera?	Inte mer än en halv dag, 5-10 minuter, instruktioner ska vara lätta att förstå!	The product is easy to assemble and understand

13. Under hur lång tid ska den användas?	Beror på om leverantören eller butiken tar kostnaden, längre hållbarhet om man köper in. Varor som säljer bra minst 6 månader för vinning, butiken använder kakdisplay i flera år om den säljer bra	The product is easy to maintain and usable during a longer period of time
14. Hur mycket last ska den klara?	10-15 kg minst 500 gram ost	The product can handle the weight of common products
15. Är belysning någonting som är av intresse trots ökat pris?	Ökar försäljning - ja - finns i alla kyldiskar	The product is equipped with a source of light
16. Vilken storlek för displayen är mest anpassad för butikerna?	Hellre bredare än hög, halv halvpall	The product is broad but not deep nor tall
17. Vart ska den helst placeras?	I anslutning till andra varor på en gavel. Bygga in i en befintlig display exempelvis vid frukt fast utan sladd!	The product is possible to display with other products within the same category. The product is easy to install at places not common to refrigerated displays.
18. Hur stort är området som den kan placeras i?	Vid gavlar ungefär en halvpall i bredd	The product is suited for a positioning at gables in an ICA store
19. Vilka begränsningar kommer av omgivningen?	Kör in med kundvagnar, sladdar går alltid dra	The product is protected from impacts
20. Icke sladdlösa lösningar, hur hanteras sladdar?	I närheten av ett uttag, hänger från tak	The product cord is flexible and suits the connection to the roof
21. Vilken temperatur i genomsnitt har en ICA butik?	mellan 24-26 grader	The product temperature is set to handle the surrounding temperature, also with a varied temperature range
22. Vilken produkt skulle kunna vara av intresse att använda produkten till?	ICA Basic mozzarella fetaost	The product is used for displaying a large number of items
23. Föredrar färdigmonterad eller omonterad?	Kostnadsfråga	The product is cheaper to assemble in store than transported assembled
24. Är öppna eller slutna hyllplan att föredra? Varför?	Stängning med en plastbit, behåller kylan bättre	The product makes it easy for the customer to see the products within. The product is energy efficient
25. Vilken volym är optimal för placeringen?	Halvpall 15- 20 lådor mozzarella som de som används idag,	The product can display an average order of a smaller product (15-20 boxes of mozzarella)
26. Hur många hyllplan är att föredra och varför?	2-3, fler blir för hög- rasrisk	The product is designed with shelves. The product does not overturn
27. Övriga kommentarer?		

E.5 Interview at ICA Supermarket Fäladstorget

Customer: ICA Supermarket Fäladstorget Michal Wieloch	**Date: 4 September 2015**	
Fråga	Svar	Interpretation of customer needs
1. Används kyldisplayer i wellpapp i butiken idag?	Nej, förstärkt wellpapp för icke kylda, icke kampanjvaror 3 månader, minst 1 månad	No
2. Hur undviks fukt i displayerna?	Papp behandlad med yta som kan torkas av, kontinuerligt underhåll, reservdelar	The product makes it easy to remove moisture from the surface and a possibility to change some parts that are easier to damage
3. Vad är de största problemen med de displayer som finns idag? Om ej wellpapp kyldisplayer berör frågan displayer för icke kylda varor	Varan ska synas så att den säljer sig själv, effektiv och lite budskap på underdelen, för mycket möbel, för lite vara, för små göra kylardelen liten	The product presents the product in a manner where the product is highly visible. The display allows a lot of room for products
4. Är de svåra att hantera?	Tar för mycket plats för hållande till försäljning	The product is not space consuming
5. Vad brukar vara största orsaken till att de skadas/ går sönder? Om ej wellpapp kyldisplayer används berör frågan wellpapp displayer för icke kylda varor	För klena, svåra att hantera sätta upp, ej intuitiva. Behandlad längst ner och har förstärkta hörn.	The display assembly is easy to understand. The display is created to withstand forces on edges
6. Vilka attribut hos displayen verkar ge mest positiv feedback?	Hur displayen är gjord, för lite verklighetstänk, slänger displayerna ej anpassade för butiken utan efter vad marknadsavdelningen tror. Att folk dras till produkten. Information utan kampanjdelar och extrapriser och grejer. Tänker inte på att anpassa mått kvartspall eller halvpall. Kan bli att man ser produkten från fler vinklar än man tänker sig, vill inte ha massa utstickande delar. Praktiska lösningar, då används displayen	The display is attractive from all angles. The product is possible to place at all positions within an ICA store and not bound to a specific position. The display does not remove focus from the product.
7. Är nattgardiner använda? Är de svåra att använda? Vilka problem finns med dom?	På allt nytt används någon typ av stängning, sparar energi, stora automatisk, små dra ner själv - rutin	The product is possible to close if wanted.
8. Brukar ni plocka ut varorna eller placera en displaykartong i displayerna? Varför/varför inte?	Beror på varan och hur den ska exponeras, brukar inte stoppa in hela lådan - blir rörigt i displayen. Hur hanteras stök? Kontinuerligt arbete - rutiner anses naturligt	The product fulfills its purpose without trays

9. Energikonsumtion kWh/dag, vad är en acceptabel minskning för att byta produkt?	EzyCooler 450 drar mycket, plugin drar för mycket ström, leder istället ner en kylning från en extern del. MÅSTE bli billigare drift för att de ska användas!	The product is energy efficient and affordable during use
10. Vilka temperaturområden ska hållas?	Mellan 4-8 chark ca 4 grader. Svårt att ställa in kylan borde finnas enkelt sätt exempelvis 4-8-12. Svårt att hålla temperaturen, ska testas med varor i! Undersöka att en egenkontroll fungerar, uppfyller temperaturer som angivits	The product maintains a required temperature also during stacking of products. The Refrigerator is easy to set to desired settings. During prototyping, tests similar to usage conditions are performed
11. Är det önskvärt med en mobil lösning?	Batteridrivet 50% dyrare - får plats med mer, helt ny design- mer flexibilitet	The product is mobile if not too expensive
12. Hur lång tid får den ta att montera?	Max 5 minuter sedan blir det aggressioner - för att få in varorna så snabbt som möjligt	The product is easy to assemble and understand
13. Under hur lång tid ska den användas?	Minst 1 månad, helst 3 månader - finnas möjlighet att sedan enkelt kunna beställa nya, lätta att torka av, finns behandlat hos ICA	The product is easy to maintain, order and usable during a longer period of time
14. Hur mycket last ska den klara?	Oftare små produkter från 100-400 grams produkter, mindre produkter	The product can handle the weight of common products
15. Är belysning någonting som är av intresse trots ökat pris?	LED belysning tar inte plats, önskvärt att alla hyllor belyses	The product is equipped with a source of light
16. Vilken storlek för displayen är mest anpassad för butikerna?	Inte stor, ska enkelt kunna flyttas runt, halv halvpall delad halvpall på mitten	The product is easy to transport within the store, request half of a half pallet
17. Vart ska den helst placeras?	Ska kunna placeras vart som helst, där kunden minst anar att den ska finnas, kanske redan vid entrén, flexibilitet	The product is designed to fit at every location within the store
18. Hur stort är området som den kan placeras i?	Överallt, beror på varan, ska kunna placeras överallt	The product is designed to fit at every location within the store
19. Vilka begränsningar kommer av omgivningen?	Vägguttag, bättre att ha sladden kort på själva kylaren och lägga till förlängningssladd	The product is designed to handle the cord in an attractive way
20. Icke sladdlösa lösningar, hur hanteras sladdar?	Förlängningssladd i taket - det som är det fula	The product cord is flexible and suits the connection to the roof
21. Vilken temperatur i genomsnitt har en ICA butik?	Kring 18-20 ˚C, beror på butik	The product temperature is set to handle the surrounding temperature, also with a varied temperature range

22. Vilken produkt skulle kunna vara av intresse att använda produkten till?	Grana padana, produkterna man kan skriva mer om, ICA selection eller produkter i tiden ekologiska, mozzarella. Pris och produktbeskrivning	The product is used for more expensive products. Information regarding the product is available and easy to see
23. Föredrar färdigmonterad eller omonterad?	Ej möjligt med färdigmonterad, tar mkt plats	The product is sent to the retailer non-mounted
24. Är öppna eller slutna hyllplan att föredra? Varför?	Öppna	The product shelves are made in order for the customer to easily grab the products within
25. Vilken volym är optimal för placeringen?	Halv halvpall	The product is of standard measures and easy to use within the store
26. Hur många hyllplan är att föredra och varför?	3 plan 175-180 cm, skyltfönster	The product is designed with shelves
27. Övriga kommentarer?	Kunden är i fokus, tänk utifrån hur butiken ser ut, hur kunden ska vilja hantera varan, enkel information att hantera, fickor för A-4 reklam som skrivs ut av butiken, liten del som är en typ låda och sedan täcker väggen med varor. Mycket varor ska få plats för at det ska vara värt.	The product is adjusted to suit any placement within the store. The marketing is simple and informative. The product is equipped with possibilities to add information. The product gives the possibility to both display products in a quantitative way in a combination with a commercial way. The product is of a volume that makes it possible to store many products if wanted.

Appendix F: Category and relative importance of needs

Nr	Need	Importance
	Safety	
1.	The product maintains a temperature that suits the products, also with a varied temperature range	5
2.	The product can handle the weight of common products	5
3.	The Refrigerator is easy to set to desired settings	3
4.	The product does not overturn	5
5.	The product is easy to repair and indicates when the cooling capacity is lowered	3
6.	The product is equipped with indicators providing information if the temperature is lower than the setting	4
7.	The refrigerant is natural	5
	Effects of life of display	
8.	The product makes it easy to remove moisture from the surface	5
9.	Some parts that are easier to damage are replaceable	3
10.	The display is created to withstand forces on edges	4
11.	The product is protected from impacts	4
12.	The bottom part of the display is protected from moisture	3
	Shelves	
13.	The product presents the products in a manner where they are highly visible	4
14.	The display is attractive from all angles	3
15.	The product fulfills its purpose without trays	5
16.	The product makes it easy to stack products without trays	5
17.	The product shelves are made in order for the customer to easily grab the products within	5
18.	The product is designed with shelves	3
19.	The product easily displays different brands	4
20.	The product is designed with the possibility to easily fill and display many products	5

	Flexibility	
21.	The customer can customize their individual solution	4
22.	The number of shelves and the distance between them can be varied at the desire of the store	3
23.	The product is easy to transport within the store	5
24.	The product is designed to fit at every location within the store	3
25.	The product may be varied depending on the size of the store	4
26.	The product is used for more expensive products	3
	Efficiency	
27.	The product is possible to close if wanted	3
28.	The product is energy efficient and affordable during use	5
29.	The product is quick to cool a new display part	3
30.	The part that covers the inlet of air to the compressor is easy to clean	4
31.	Night curtains, if used, are easy to handle and are not affected by a smaller impact	2
32.	The product is always closed when products are not removed	3
	Features display	
32.	The product is equipped with a source of light	5
34.	The product cord is flexible and suits the connection to the roof	4
35.	The product is designed to handle the cord in an attractive way	4
36.	The product is equipped with possibilities to add information	3
37.	The product gives the possibility to both display products in a quantitative way in combination with a commercial way	3
38.	The product is possible to display with other products within the same category	3
	Print	
39.	The marketing is simple and informative	4
40.	The product provides enough information to the customer about the content	4
41.	The product makes it easy for the customer to see the products within	4
42.	The display does not remove focus from the product.	4
	Mobility	
43.	The product is mobile of not too expensive and has a battery time of at least one day	3
	Usability	
44.	The product is easy to maintain and usable during a longer period of time	5

45.	The product is sent to the retailer non-mounted	5
46.	The product is cheaper to assemble in store than transported assembled	5
	Positioning	
47.	The product is possible to install in all positions within an ICA store and not dedicated to a specific position	5
48.	The product is adjusted to suit any placement within the store	3
49.	The product is suited for a positioning at gables in an ICA store	3
50.	The product is easy to install at places not common to refrigerated displays	2
51.	The product is possible to display where a lot of customers pass	5
52.	The product is suitable for smaller areas	4
	Size	
53.	The product is not space consuming	3
54.	The product allows a lot of room for products	4
55.	The product is of standard measures and easy to use within the store	4
56.	The product is broad but not deep nor tall	2

Appendix G: List of specifications

G.1 Compressor refrigerated display

Measurable specification nr	Need nr	Measurable specification	Importance	Unit	Value
1.	1	Temperature range to maintain	5	˚C	4-12˚C
2.	1	Ambient temperature	5	˚C	19-20 ˚C
3.	2	The maximum weight each shelf can handle	5	kg	15
4.	4,51	The product will not turn over when hit by a shopping cart or pushed	5	Subj.	No
5.	5,6	The sensitivity of an indicator if temperature is lower than desired settings, the amount of time the temperature is not optimal	4	sec	60
6.	7	The refrigerant is natural	5	According to norms	
7.	8	The coating can handle the amount of moisture built during the desired use without being unattractive	5	Subj.	Yes
8.	8,12	The coating can handle the amount of moisture built during the desired use without compromising the function	5	Subj.	Yes
9.	9,10,11,51	The display will not be noticeably damaged when hit from any angle by a shopping cart	4	Subj.	Yes
10.	10	The edges of the display will not be noticeably destroyed when hit by a shopping cart	4	Subj.	Yes
11.	13,14,15,16,18,37	Attractive and presents the products in the best possible way	4	Subj.	Yes
12.	13,15,16,17	The products are easy to access	5	Subj.	Yes
13.	19,26,38	Different products are possible to display	4	Subj.	Yes
14.	20,54	A larger amount of products can be presented	5	Subj.	Yes

15.	21,22,24,25,37,48,49,50,52,55,56	The product is designed with the possibility to customize both display and shelves	4	Subj.	Yes
16.	22	The maximum amount of shelves that can be used within the same display without compromising the function	4	pieces	4
17.	23,43	The product is easy to move around	5	Subj.	Yes
18.	27,31,32	The product can be closed when wanted	4	Subj.	Yes
19.	28	The maximum amount of energy consumption of one day	5	kWh/day	6
20.	29	Maximum time to cool the product	3	s	60
21.	30	Easy access to the inlet of air to the compressor	5	Subj.	Yes
22.	33	Source of light	5	Subj.	Yes
23.	34,35	The cord is handled in an attractive and efficient way	4	Subj.	Yes
24.	36	Extra information can be added	3	Subj.	Yes
25.	39,40,41,42	The print does not interfere with the products packaging, it is simple and informative	4	Subj.	Yes
26.	44	Minimum amount of time the display can be used	5	Months	4
27.	45,46	The product is possible to fold to a flat sheet	5	Subj.	Yes
28.		Maximum cost at 401-500 pieces	5	SEK	638
29.	45,46	Maximum time for assembly	5	Min	5

G.2 Peltier refrigerated display

Nr	Need nr	Measurable specification	Importance	Unit
1.	1	Temperature range to maintain	5	˚C
2.	1	Ambient temperature	5	˚C
3.	13,14,15,16,18,37	Attractive and presents the products in the best possible way	4	Subj.
4.	13,15,16,17	The products are easy to access	5	Subj.
5.	28	The maximum amount of energy consumption of one day	5	kWh/day
6.	29	Maximum time to cool the product	3	Min
7.	33	Source of light	5	Subj.
8.	34,35	The cord is handled in an attractive and efficient way	4	Subj.
9.	46	Minimum amount of time the display can be used	5	Years
10.		Maximum cost	5	SEK
11.	P1	Amount of cans that can be fitted in the display	5	pieces
12.	P2	The minimum transfer of thermal energy of the desired cooled surfaces	5	W/mK
13.	P3, P5	The heat is discharged in a way that allows the Peltier elements to be as efficient as possible	5	Subj.
14.	P4	Number of Peltier elements	3	pieces
15.	P2,P6	The maximum transfer of thermal energy from the display to the surrounding	5	W/mK
16.	P7	The technology is displayed	4	subj.

G.3 Cardboard display

Nr	Need nr	Measurable specification	Importance	Unit
1.	2	The maximum weight each shelf can handle	5	Kg
2.	4,53	The product will not turn over when hit by a shopping cart or pushed	5	Subj.
3.	9,10,11,53	The display will not be damaged when hit from any angle by a shopping cart	4	Subj.
4.	10	The edges of the display will not be noticeably destroyed when hit by a shopping cart	4	Subj.
5.	13,14,15,16,18,37	Attractive and presents the non-cooled products in the best possible way	4	Subj.
6.	13,15,16,17	The products are easy to access	5	Subj.
7.	19,26,38	Different products are possible to display	4	Subj.
8.	20,56	A larger amount of products can be presented	5	Subj.
9.	21,22,24,25,37, 48,49,50,52,55,56	The product is designed with the possibility to customize both display and shelves	4	Subj.
10.	22	The maximum amount of shelves that can be used within the same display without compromising the function	4	Pieces
11.	23,43	The product is easy to move around	5	Subj.
12.	34,35	The cord is handled in an attractive and efficient way	4	Subj.
13.	36	Extra information can be added	3	Subj.
14.	39,40,41,42	The print does not interfere with the products packaging, it is simple and informative	4	Subj.
15.	44	Minimum amount of time the display can be used	5	Weeks
16.	45,46	The product is possible to fold to a flat sheet	5	Subj.
17.		Maximum cost	5	SEK
18.	45,46	Maximum time for assembly	5	Min
19.	P3,P5	The display is adjusted to suit the need for heat to be discharged from the hot side of the refrigerated display	5	Subj.
20.	P7	The display presents the technology of the refrigerated display	4	Subj.
21.		The display is manufactured to suit the size and appearance of the refrigerated display	5	Subj.

Appendix H: Complementing concepts of the compressor refrigerated display

H.1 Shelves

The main focus during the concept generation concerning the shelves, was the sub-problems to withstand the weight of products and create a possibility to customize the number of shelves. The sub-problems to present the product in an attractive way and make them easy to access, were problems that could be modified after the first prototypes. The sub-problem to make it easy to assemble was a manufacturing problem that had to be modified when the prototypes were manufactured. The concept generation of the shelves was focused on the adjustment to suit the air distribution and at the same time withstand the weight of products and customizability.

For concept 1.1 the shelves required some sort of air distribution within the shelves, the following concepts were generated to suit this type of air distribution.

H.1.1 Concept 2.1

A center of honeycomb with a channel distributing the air, surrounded by coated standard material. The concept is presented in figure H.1 below.

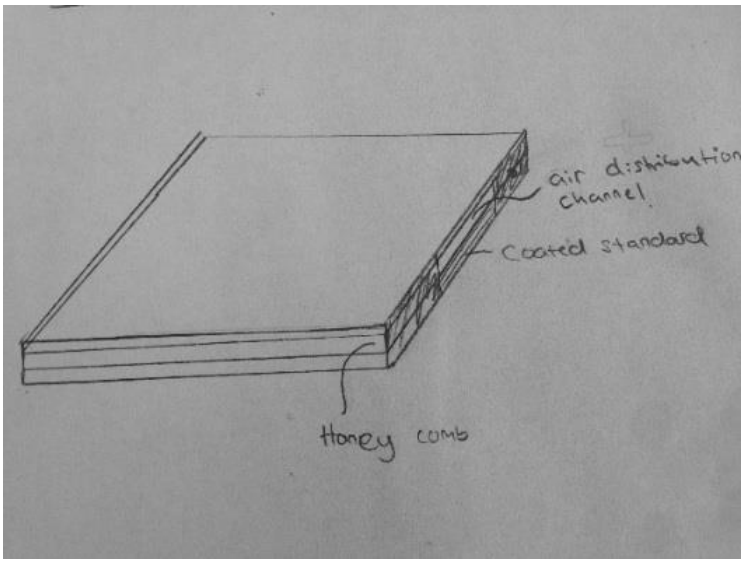


Figure H.1 Concept 2.1 A shelf that is suitable for the air distribution of concept 1.1

In order to attach the shelf to the display, a list of possible concepts was produced, presented in figure H.2 below. The air distribution channels had to be placed at the correct position and at the same time not causing a loss in air flow.

From the top left, two rims of plastic are attached to the walls and provide the possibility to slide the shelf to the correct position. The one to the top right, two sticks of plastic or wood attached through holes not interfering with the air distribution channel at the center of the walls. The concept on the bottom left presents a net that is attached through holes not interfering with the air distribution channel. And the last concept at the bottom right presents pockets at the display which require edges on the shelves. When the edges on the shelves are inserted into the pockets of the display, the shelves are locked into place.

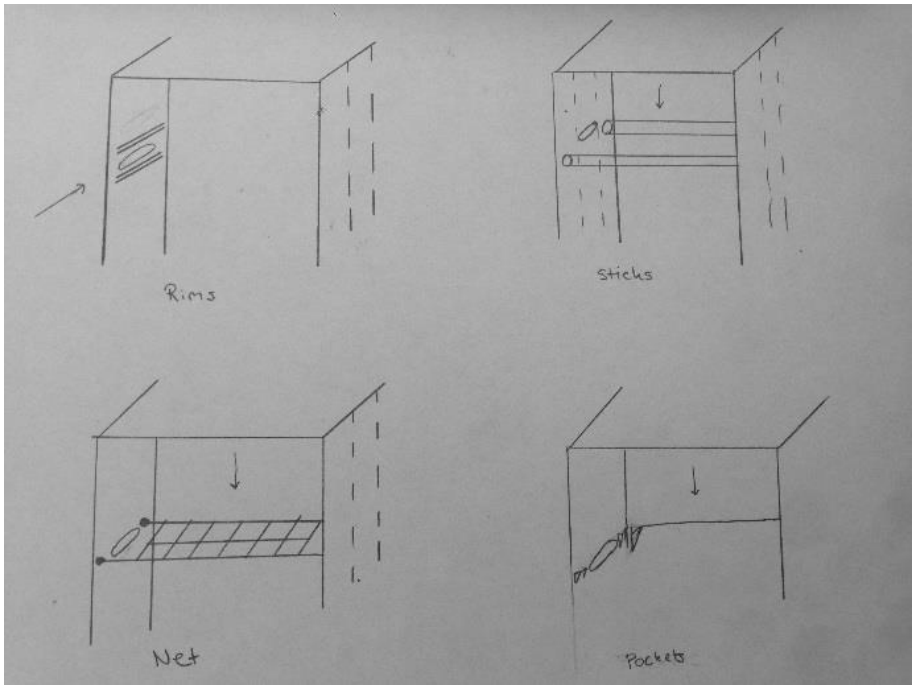


Figure H.2 Possible attachments for concept 2.1. From the top left, plastic rims, top right sticks, bottom left net, bottom right pockets

H.1.2 Concept 2.2

Corrugated cardboard with a gap where air is distributed. The reason that the entire shelf is open to the air flow and not through a channel is in order to create a cooling of the shelf in combination with cooling of the products below.

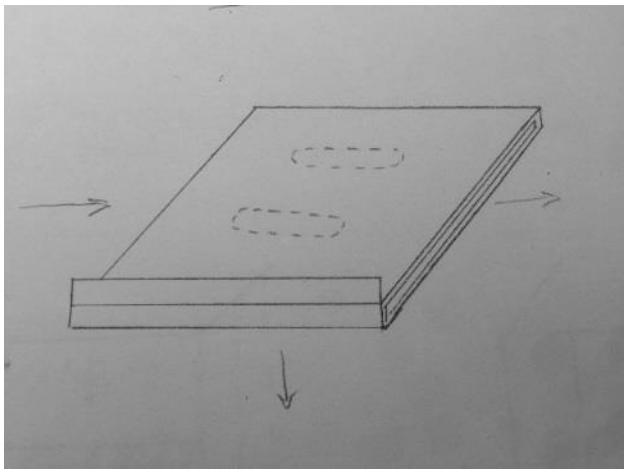


Figure H.3 Concept 2.2 shelf with air distributing hole on the bottom part of the shelf

In order to create the stability that is needed and support the weight, internal supports could be used. A list of possible supports are listed in figure H.4 below. At the top left three sticks are placed in the holes of the air distribution to the shelf. At the top right the attachment concept presented is a plastic rim with an air distribution hole in the middle. The hole is surrounded by an edge that is in made in order to fit the air distribution hole in the display, the plastic rim is to be attached to the side of the shelf and inserted to the air distribution hole. The concept at the bottom left presents a paper or plastic shelf with edges that are inserted in the air distribution hole. The shelf is to be placed on top of the attachment. Also for the concept at the bottom right, the shelf is to be placed on top of the attachment, the attachment for this concept is in the shape of a net.

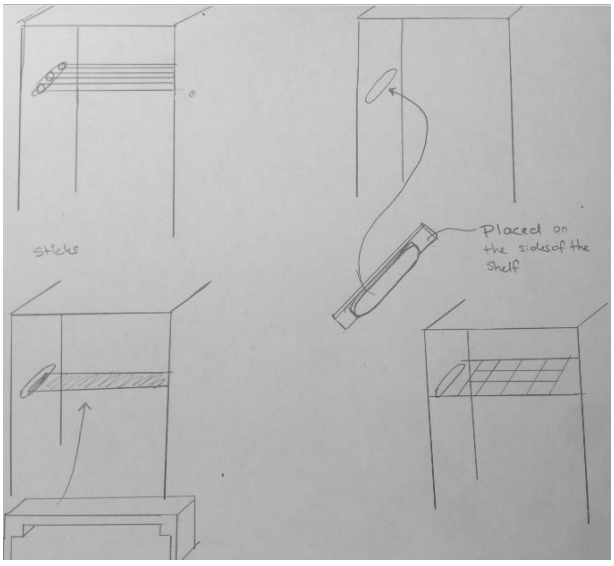


Figure H.4 Possible attachments suitable for concept 2.2

For concept 1.2 and 1.3 the shelves had to be designed in order to suit the distribution of air. The following concepts were generated to suit this type of air distribution. All the shelves are made out of a full honeycomb sheet wrapped with a coated cardboard.

H.1.3 Concept 2.3

The shelves are attached to the walls by cutouts. As there is no air flow through the back wall, the cutout can reach through the entire wall side. On the sides connected to the walls where air flow is distributed, the cutout have to be adjusted to not interfere with the air flow.

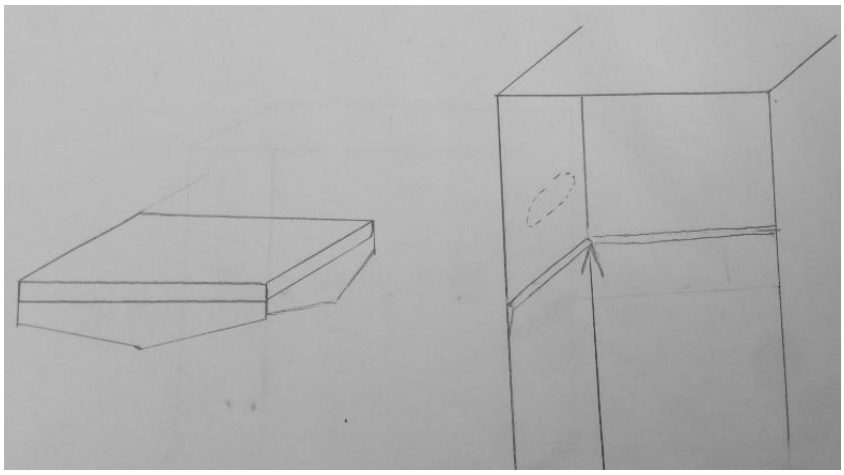


Figure H.5 Concept 2.3 shelf and attachment for concept 1.2 and 1.3

H.1.4 Concept 2.4

For this concept, the shelf is attached to the diffuser holes of the shelf above. In figure H.6 below, the concept is presented. The core is made of honeycomb while the edges are made of a double layer of coated well.

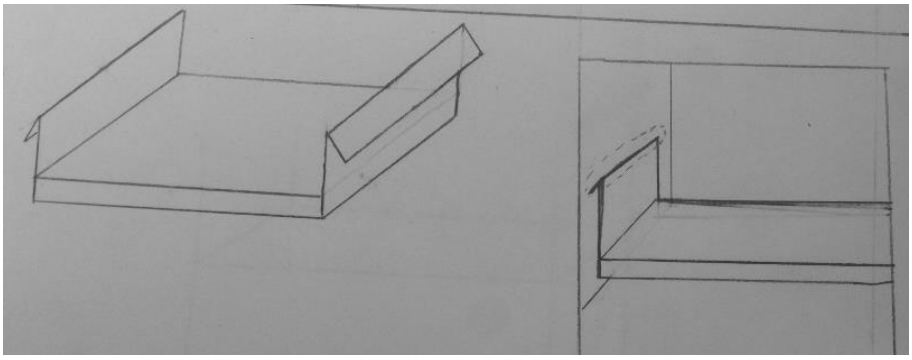
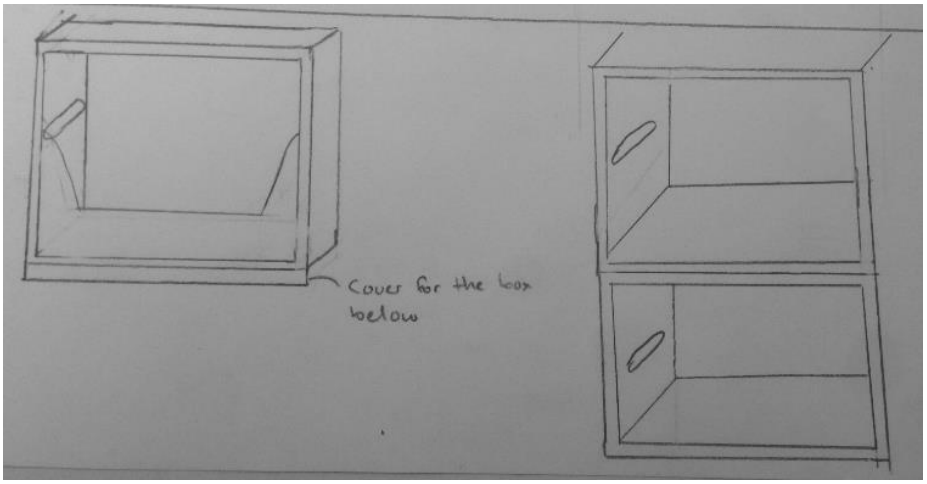


Figure H.6 Concept 2.4 shelf and attachment for concept 1.2 and 1.3

H.1.5 Concept 2.5

The internal space is made of insulated boxes that can be stacked on top of each other, creating shelves. On the bottom part of the shelf there is extra material that covers the edge to the box below. The concept is presented in figure H.7 below.



Fi**gure H.7** Concept 2.5 insulated stackable boxes

H.1.6 Concept 2.6

The shelf is attached to the back by cutouts. As can be seen in figure H.8 below, the shelf is later stabilized with rims attached to the walls of the display.

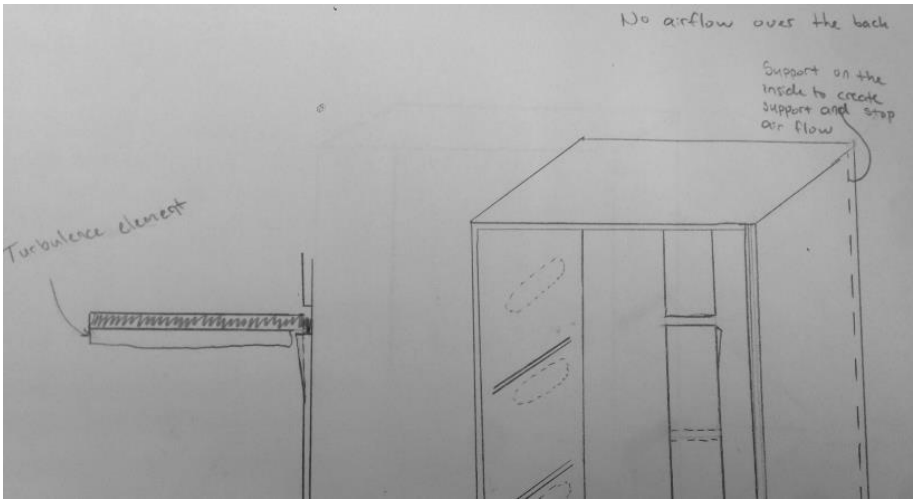


Figure H.8 Concept 2.6 shelf attached at the back panel and rims

H.2 Display

The sub-problems to easily transport the display was a problem to be addressed during manufacturing of the prototypes where Smurfit Kappa has the knowledge to make it easy to assemble and manufacture. In order to withstand the forces applied to the display, extra material can be added. The most important aspect of this was to not destroy the overall impact of the display.

The fact that the display will be designed with some sort of insulation creates an improved strength. There will also be an improved strength by the display being connected to the cooling device, preventing it from overturning.

H.3 Attractiveness

In order to make the product attractive to consumers and at the same time create an opportunity for stores to display a larger amount of products, the following concepts were generated.

H.3.1 Concept 4.1

The left part of the display is a non-refrigerated area where non-refrigerated products can be displayed. The point of this is to create the possibility to display matching products rather than just one product. For example the refrigerated area can display minced meat while the non-refrigerated area displays taco chips and spices.

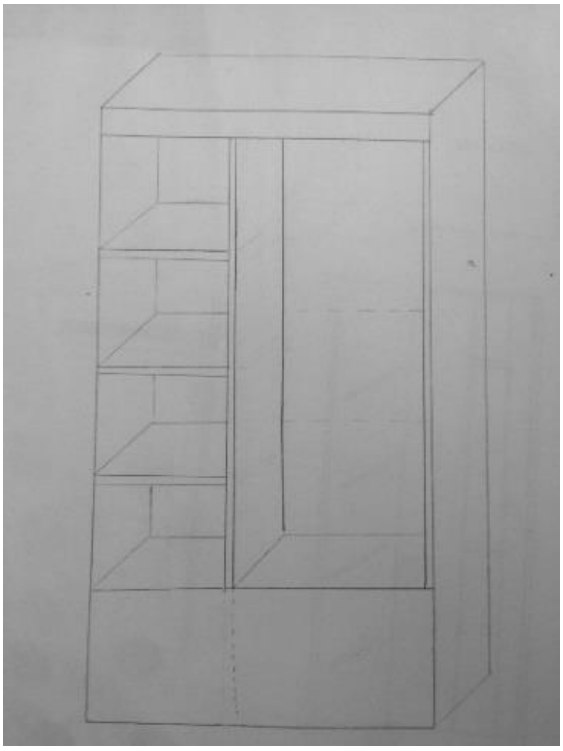


Figure H.9 Concept 4.1 display for both refrigerated and non-refrigerated products

H.3.2 Concept 4.2

In order to reduce the energy consumption, acrylic-glass doors could be produced and the display adjusted to allow the use of these if wanted. The acrylic glass door could be manufactured to be adjusted to cover only one of the refrigerated areas, as shown in figure H.10, or more if desired.

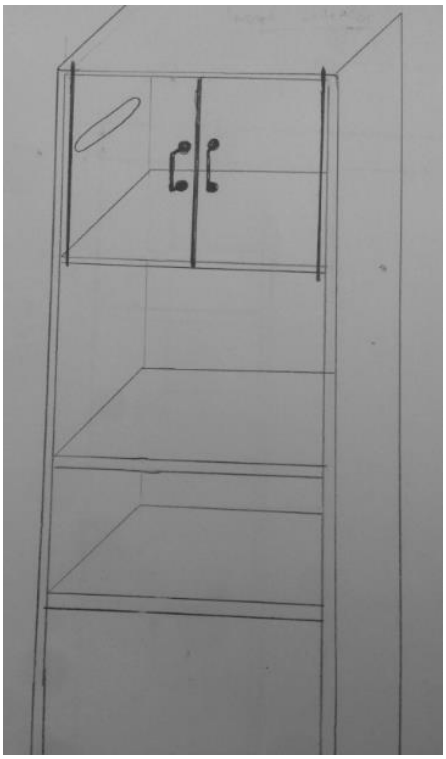


Figure H.10 Concept 4.2 display with acrylic glass doors to retain cold air

H.3.3 Concept 4.3

The display has a normal sized shelf at the top in combination with a smaller shelf that allows customers to easily grab products from the bottom open top display made out of acrylic glass. The reason that the design is made with a smaller shelf is because it can be used to display products and at the same time decrease the opening of the open top. The open top container creates the possibility to display bulk products. The concept is presented in figure H.11 below.

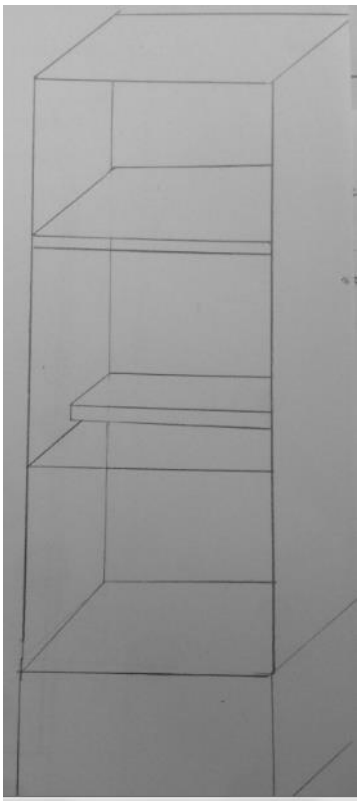


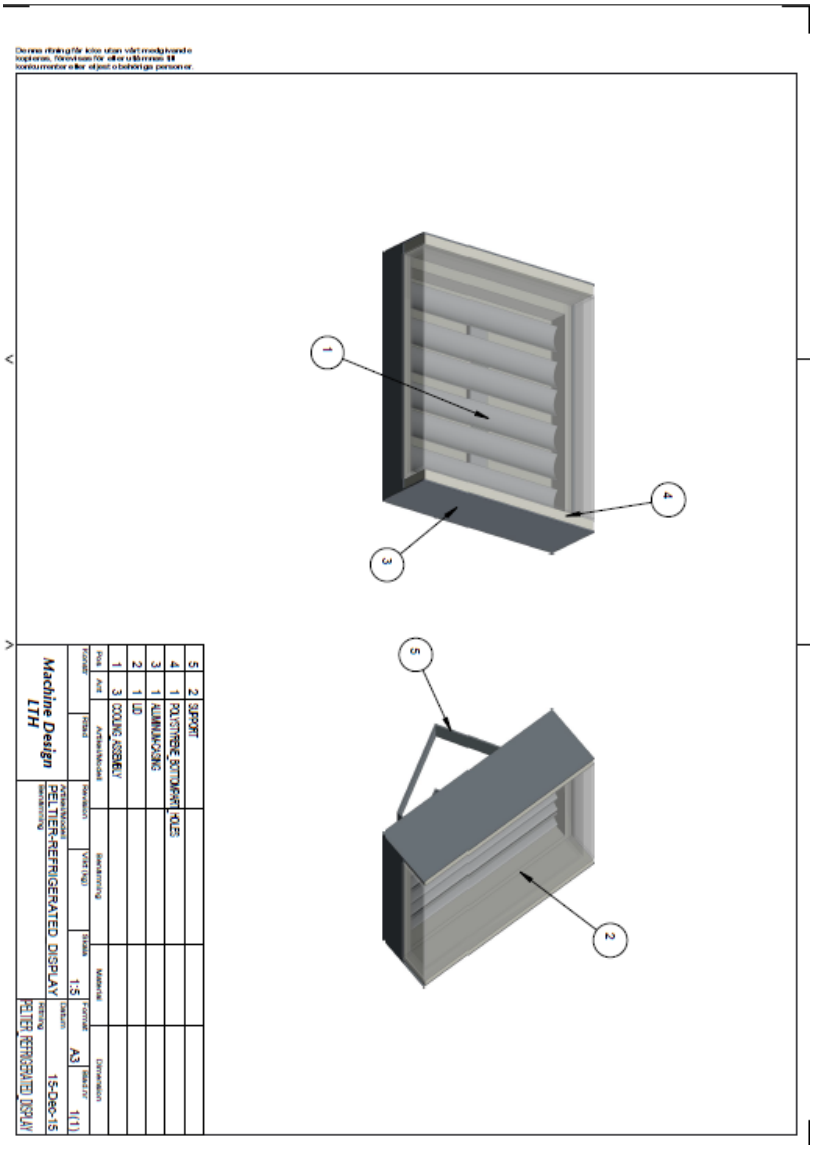
Figure H.11 Concept 4.3 combination of open top and shelves

H.4 Material

The selection of material will be made by Smurfit Kappa in order to make the product cheaper but at the same time withstand moisture and impacts. The materials that are of interest are a combination of double well that is a standard material keeping the costs down and a newly developed material of honeycomb structure to increase the strength. If the standard material is not enough to withstand the moisture, a coating of wax could be of interest.

Appendix I: Drawings of the chosen concept

I.1 Assembly of full model



Pos	Ant	Benämning	Material
5	2	SUPPORT	
4	1	POLYSTYRENE_BOTTOMPART_HOLES	
3	1	ALUMINUMSKIN	
2	1	LID	
1	3	COOLING_ASSEMBLY	

Machine Design LTH

PELTIER-REFRIGERATED DISPLAY

PELTIER_REFRIGERATED_DISPLAY

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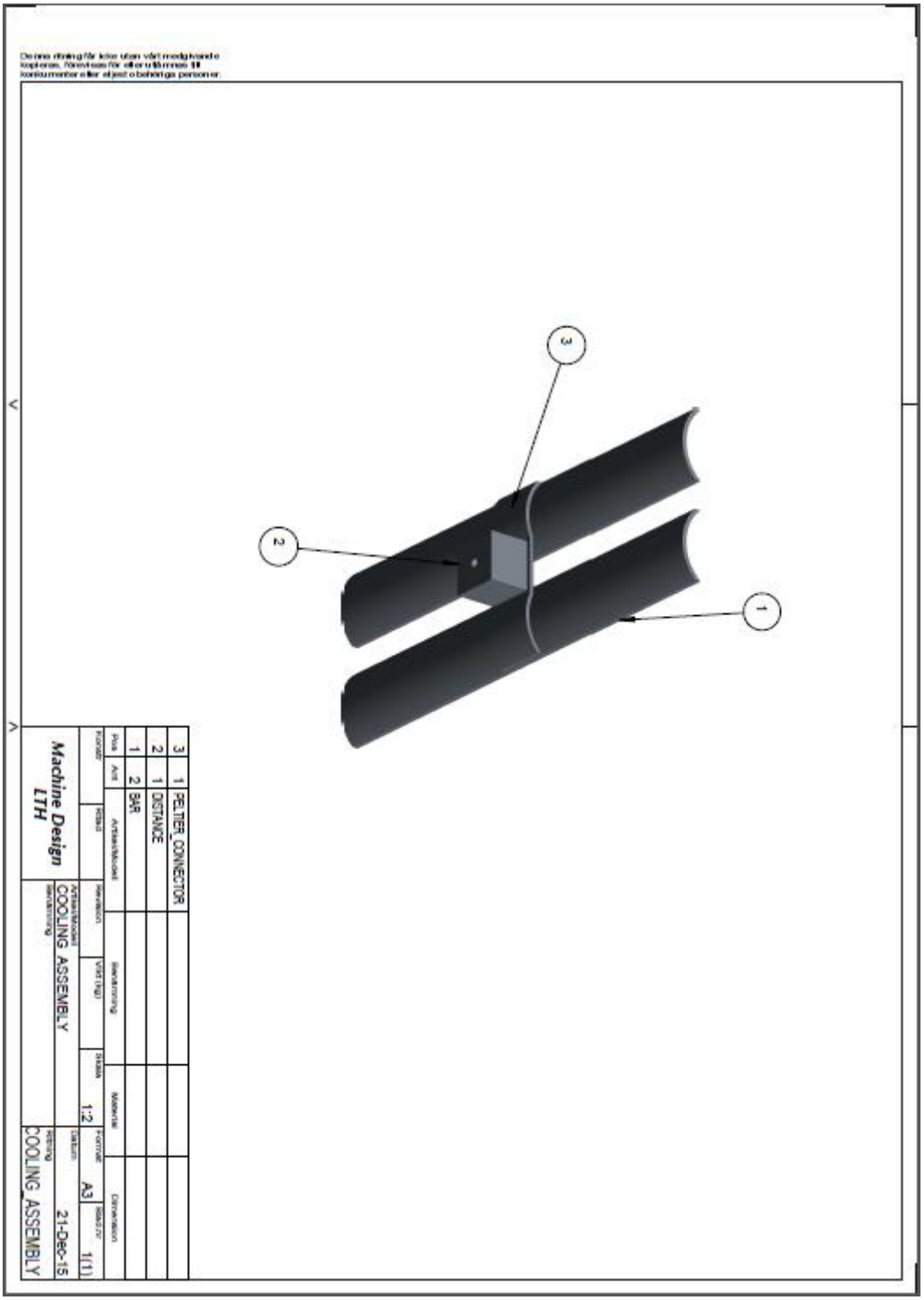
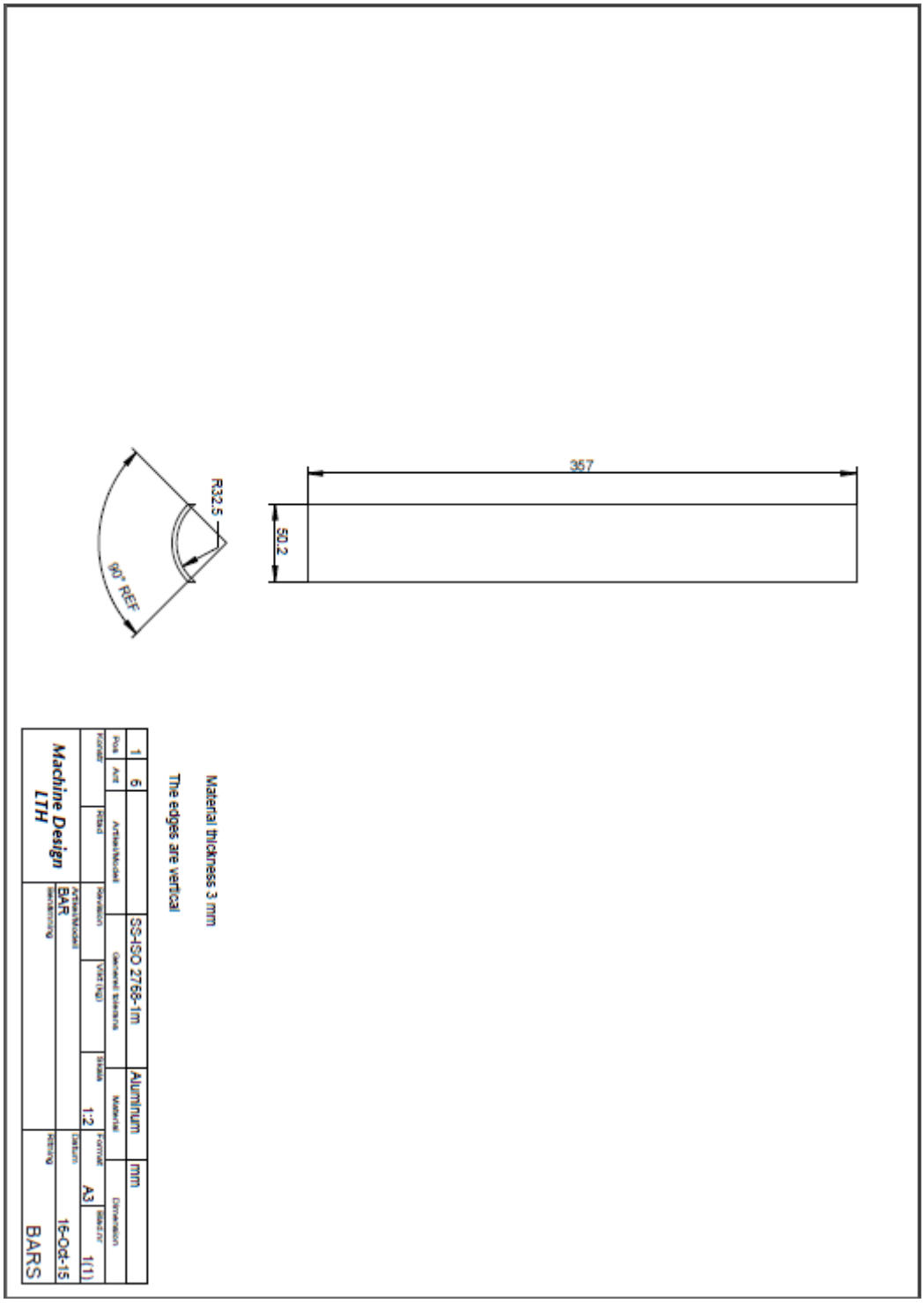
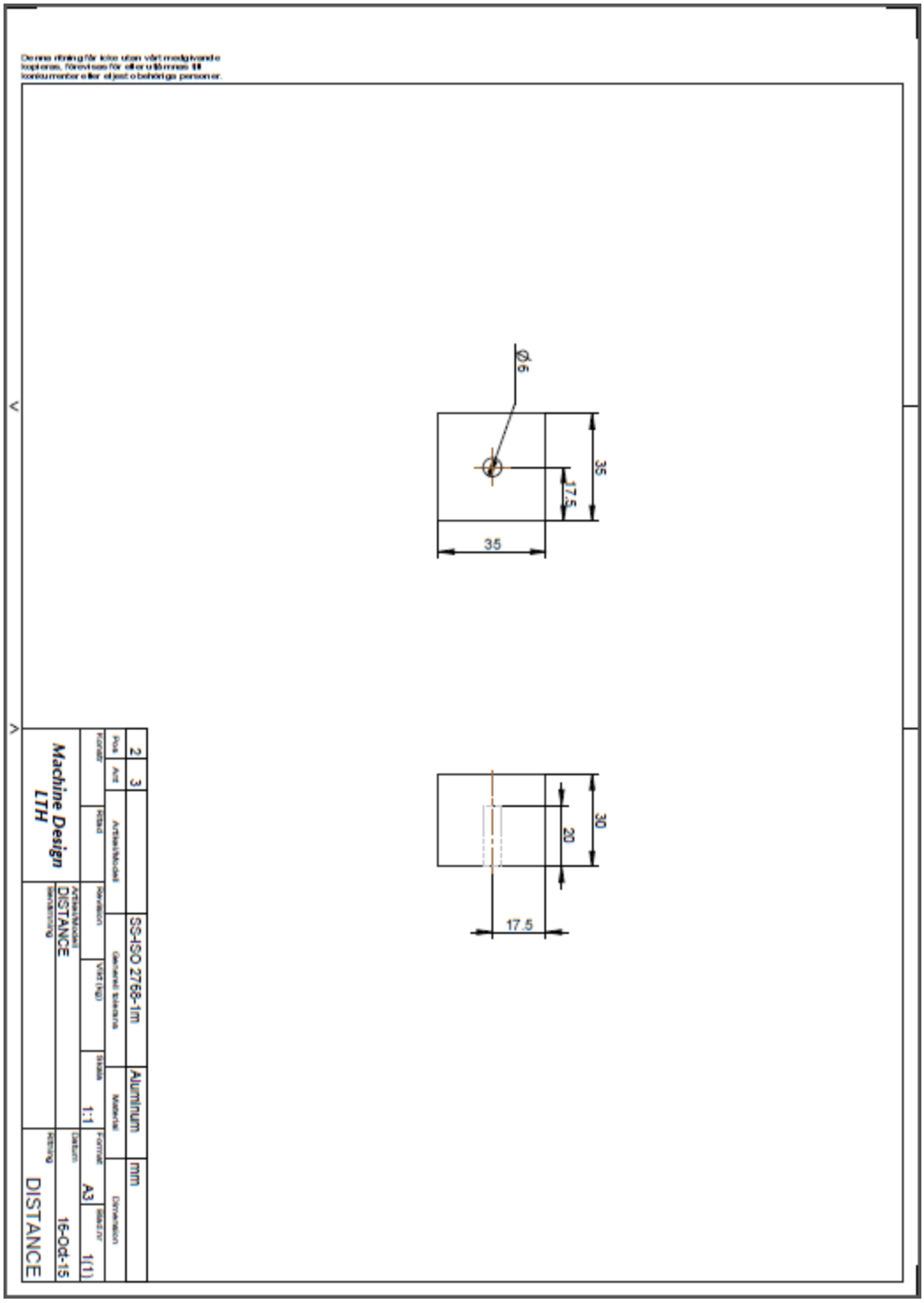
I.1.1 Cooling assembly



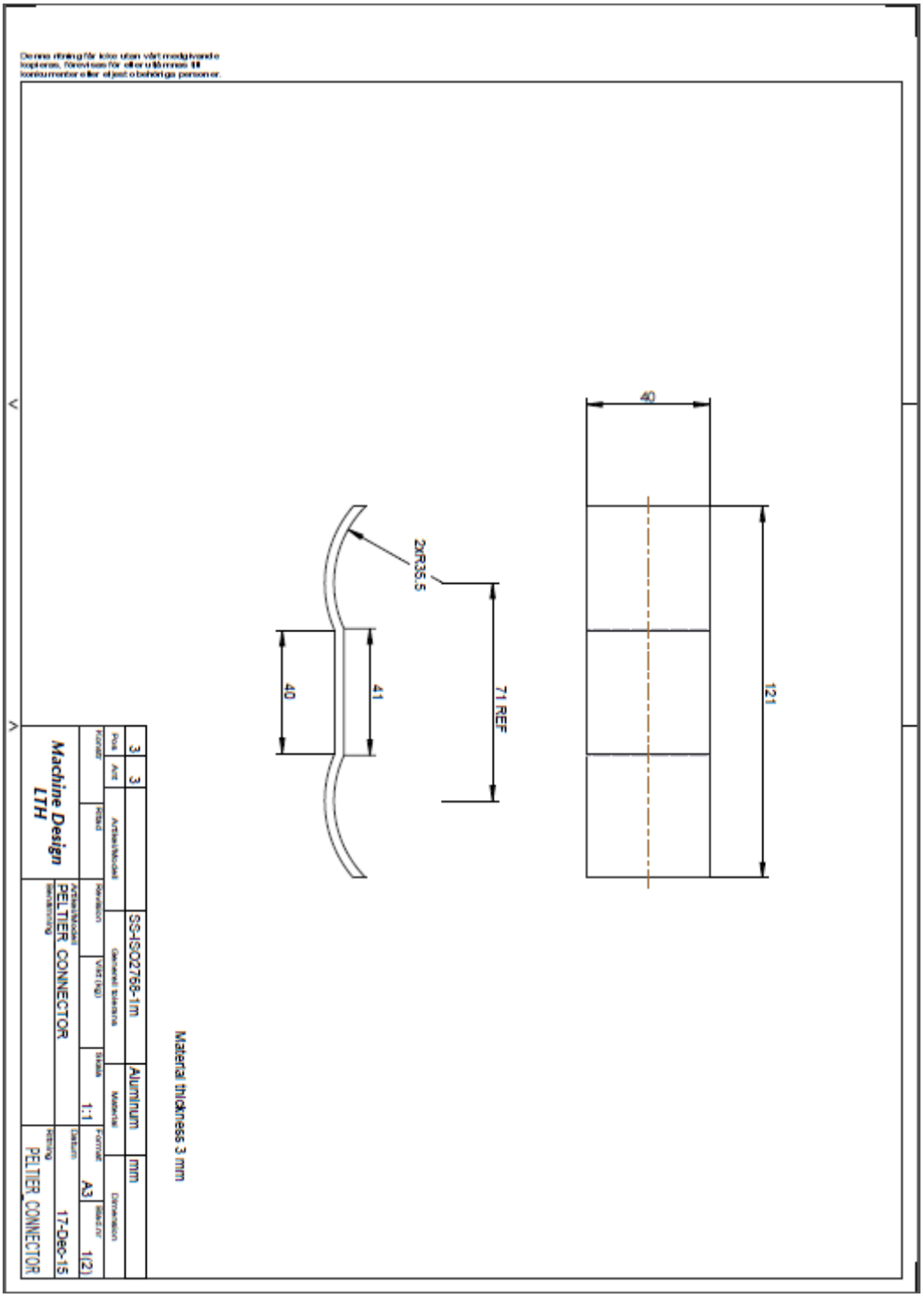
I.1.1.1 Bar


357
50.2
R32.5
90° REF
Material thickness 3 mm
The edges are vertical
1
6
SS-ISO 2768-1m
Aluminum
mm
1:2
A3
1(1)
16-Oct-15
BARS
Machine Design
LTH
BAR

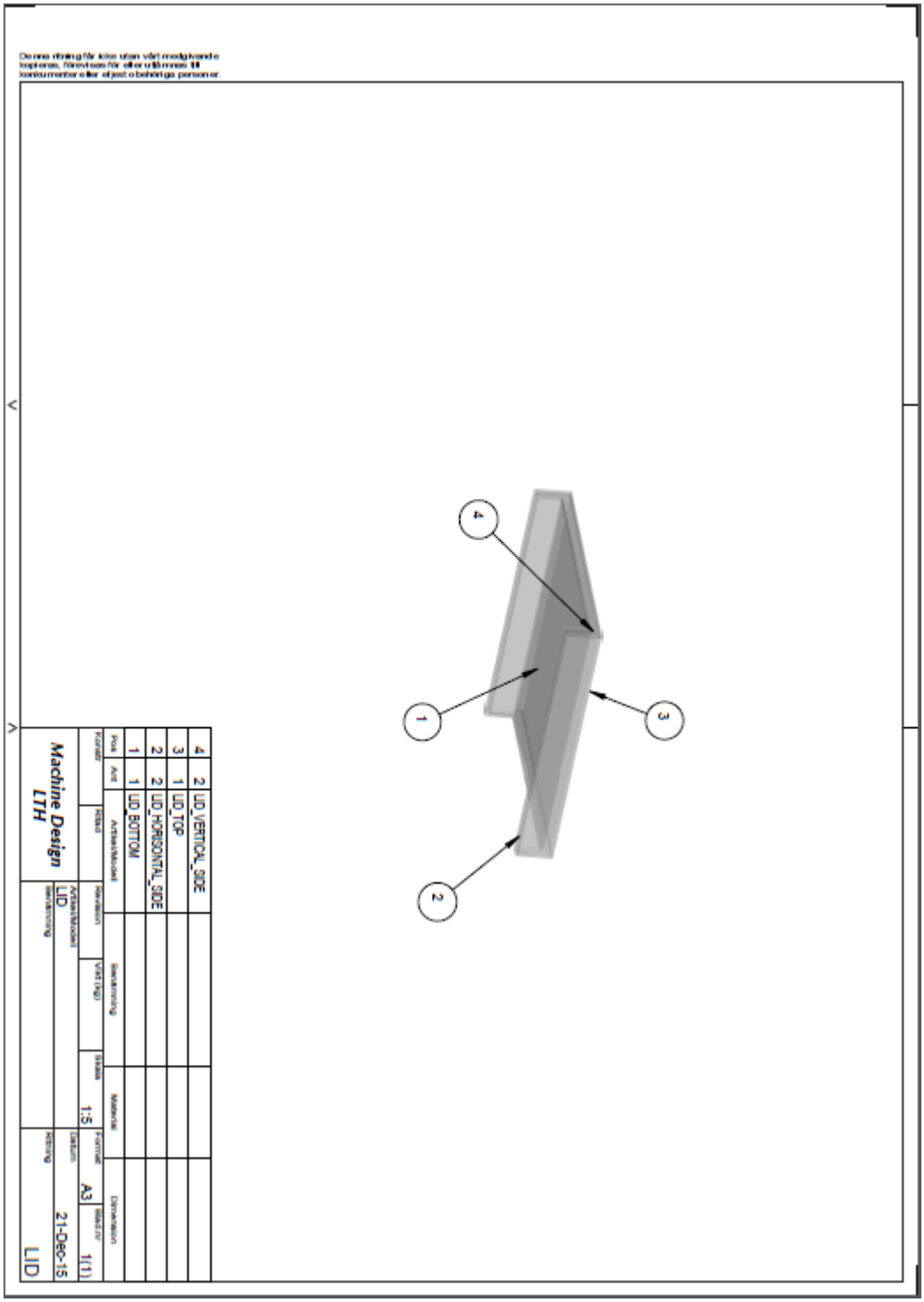
I.1.1.2 Distance



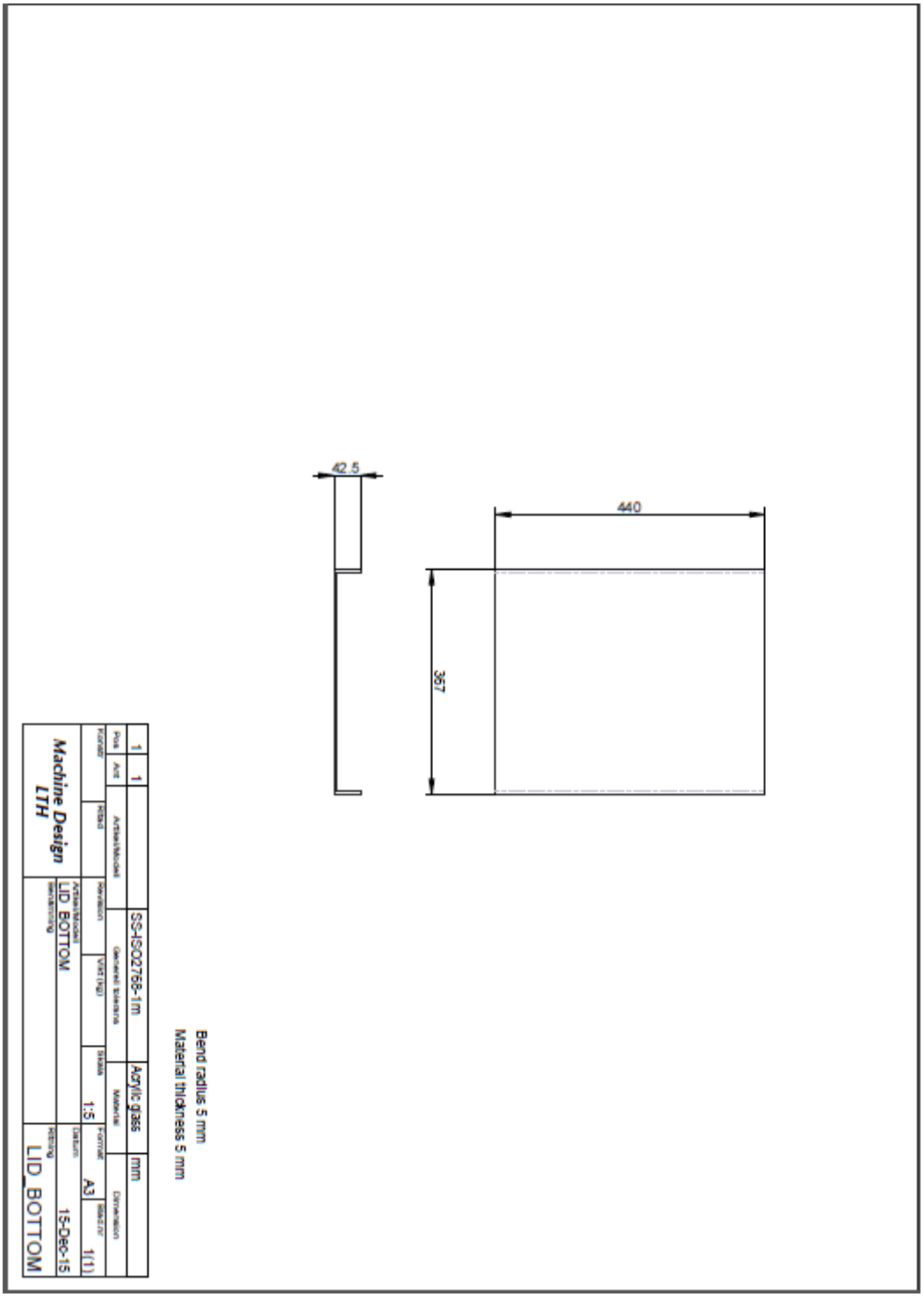
I.1.1.3 Peltier connector



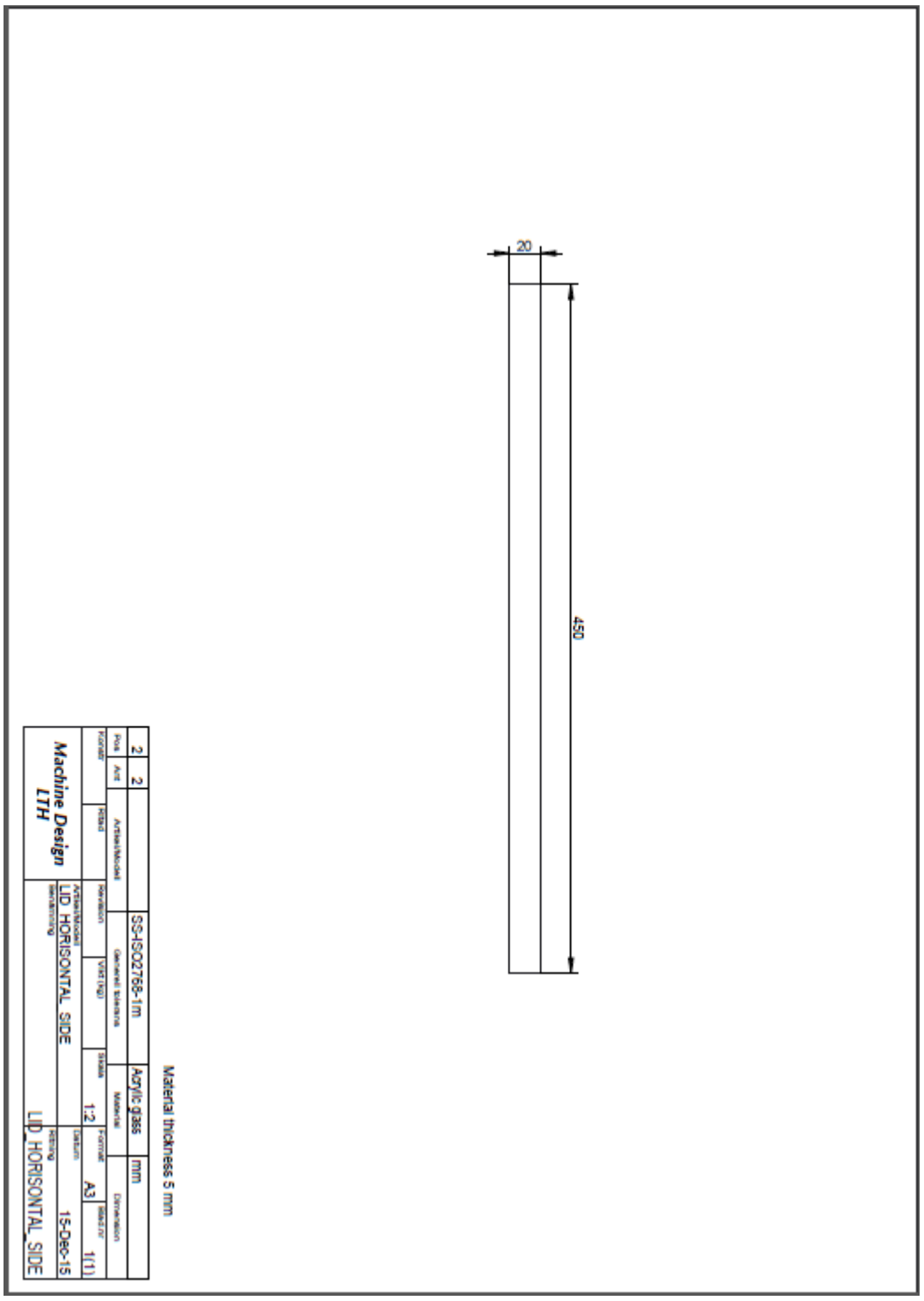
I.1.2 Lid


Machine Design
LTH
LID
21-Dec-15
1(1)
A3
1:5
4 2 LID_VERTICAL_SIDE
3 1 LID_TOP
2 2 LID_HORISONTAL_SIDE
1 1 LID_BOTTOM
1
2
3
4

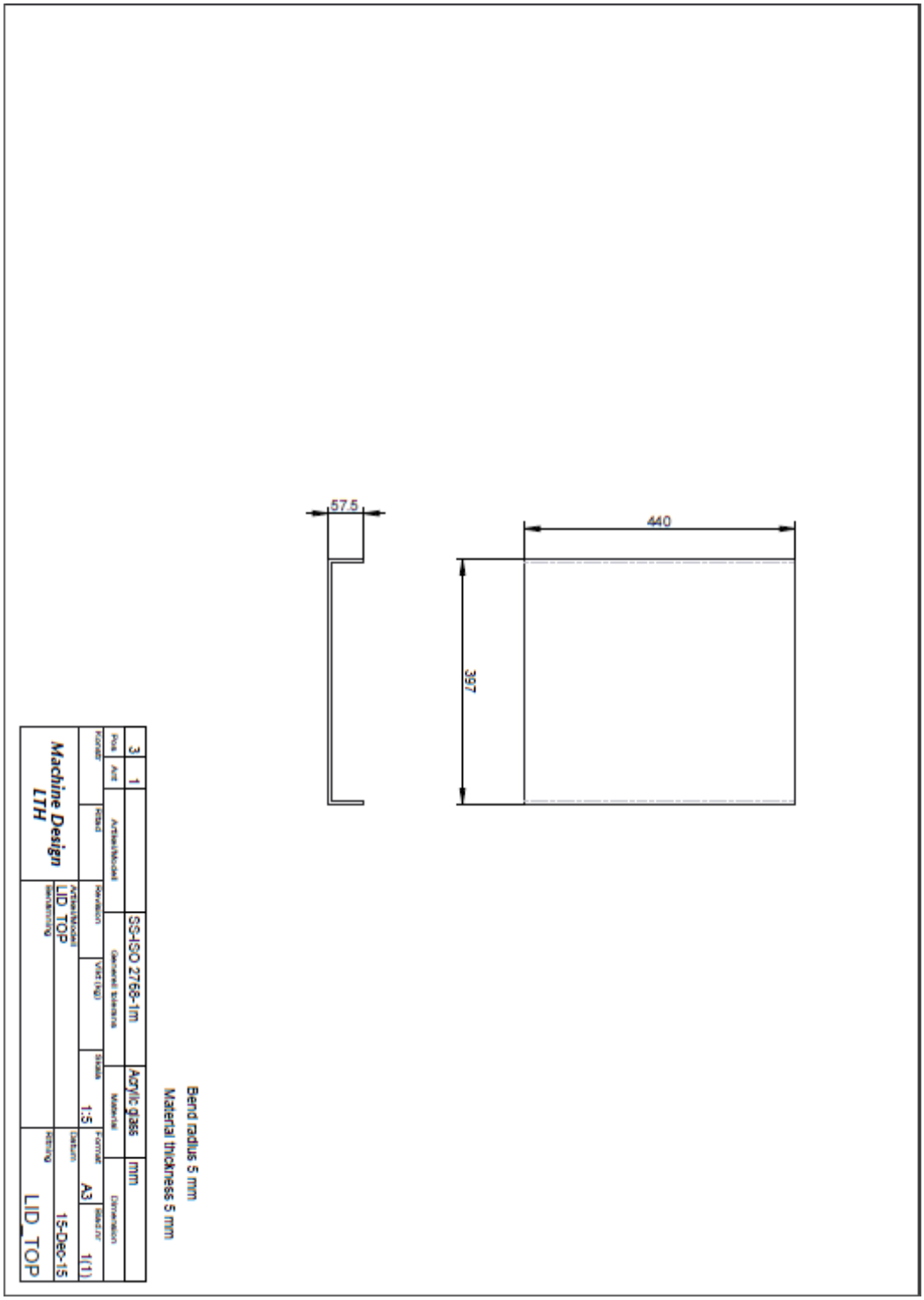
I.1.2.1 Lid bottom



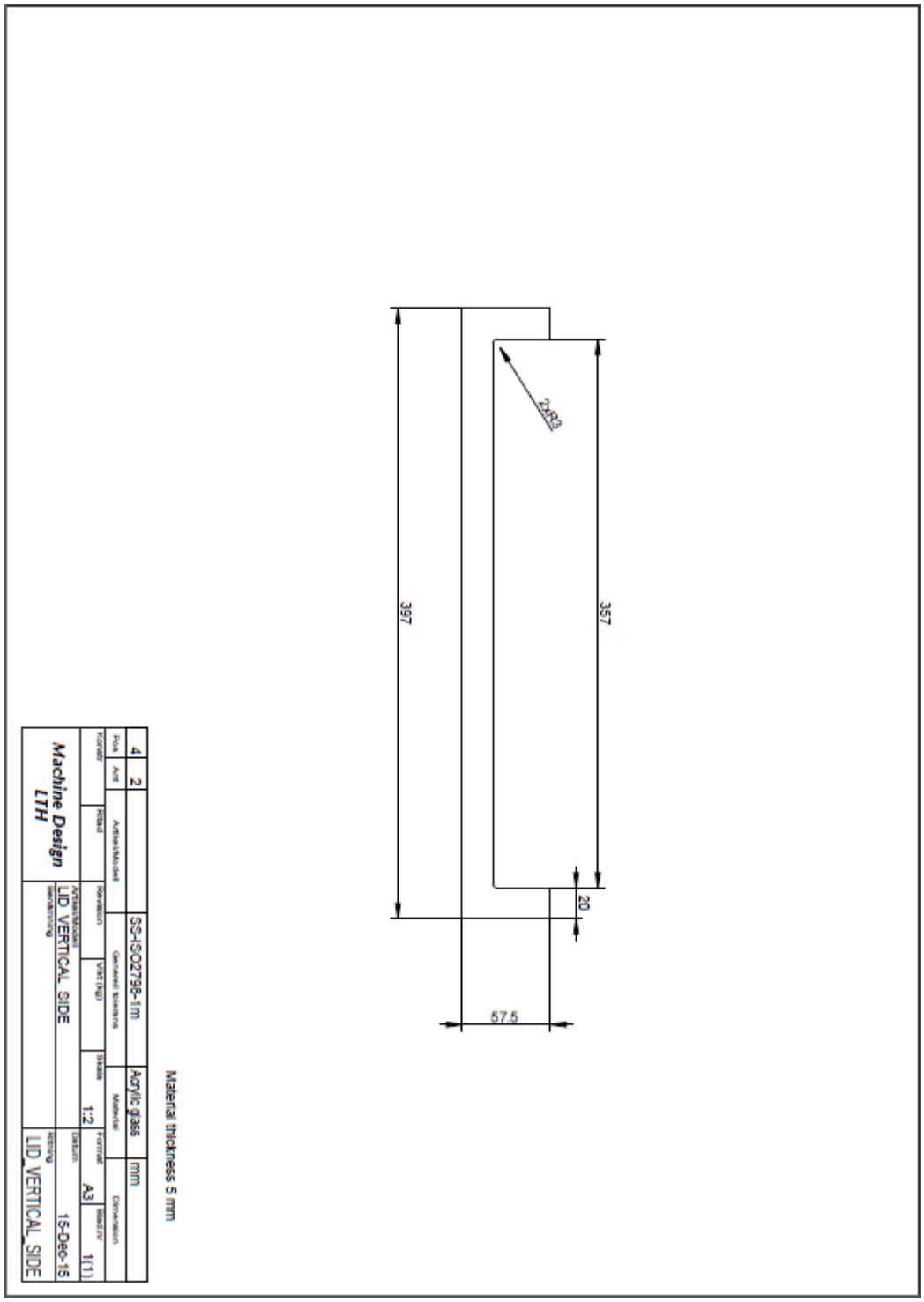
I.1.2.2 Lid horizontal side



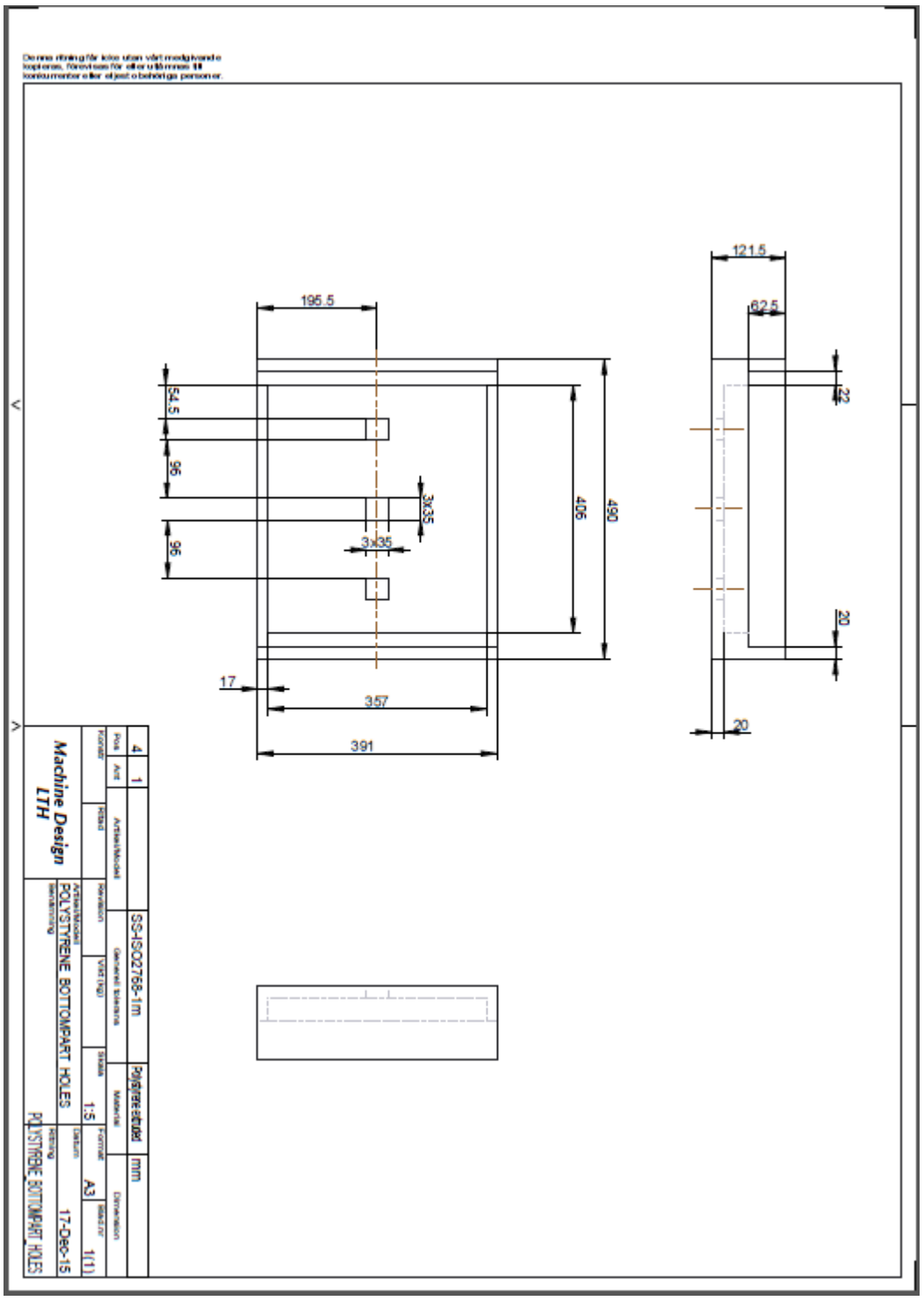
I.1.2.3 Lid top


57.5
440
397
Bend radius 5 mm
Material thickness 5 mm
3
1
SS-ISO 2768-1m
Acrylic glass
mm
A3
1:5
15-Dec-15
1(1)
LID_TOP
Machine Design
LTH

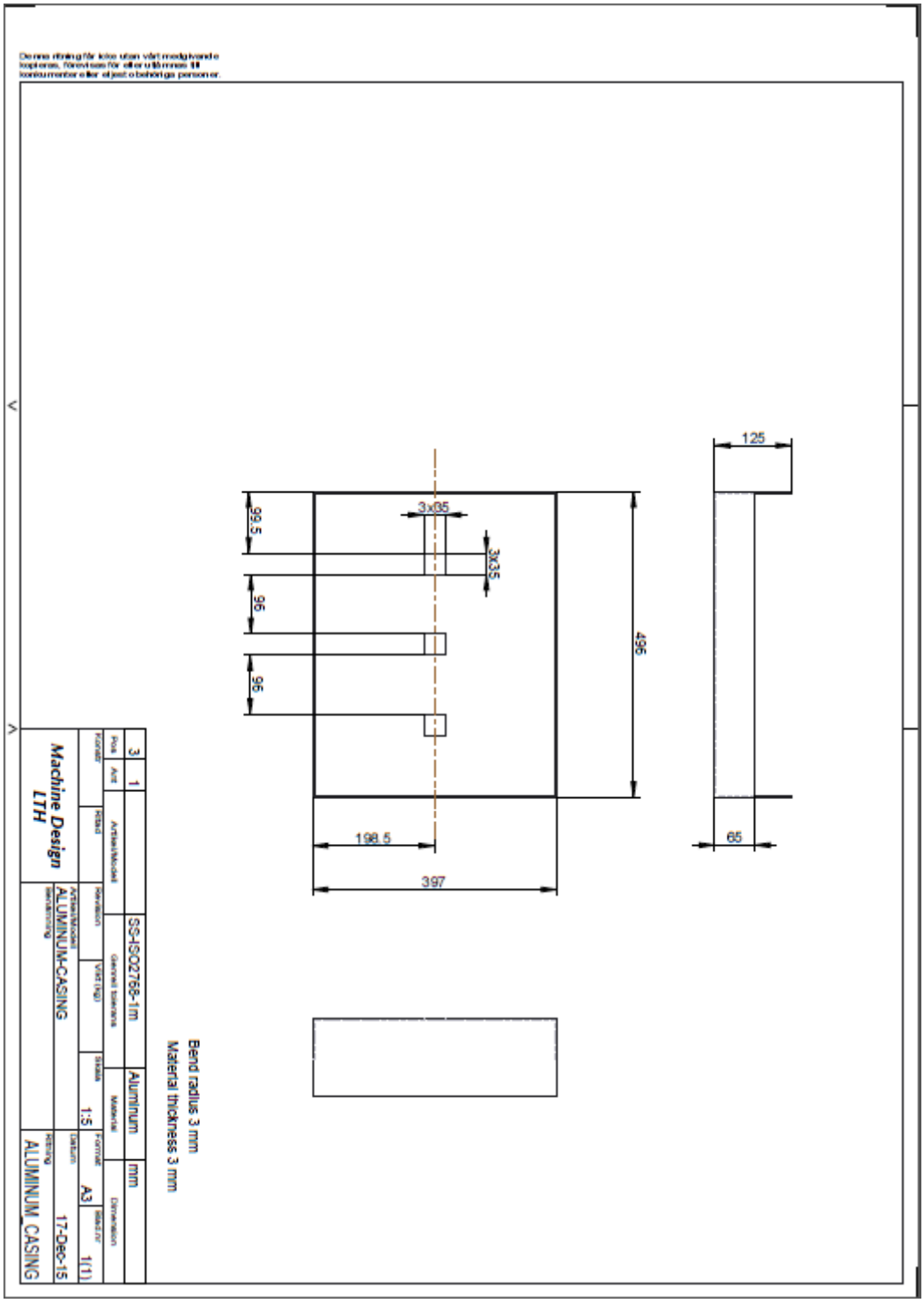
I.1.2.4 Lid vertical side



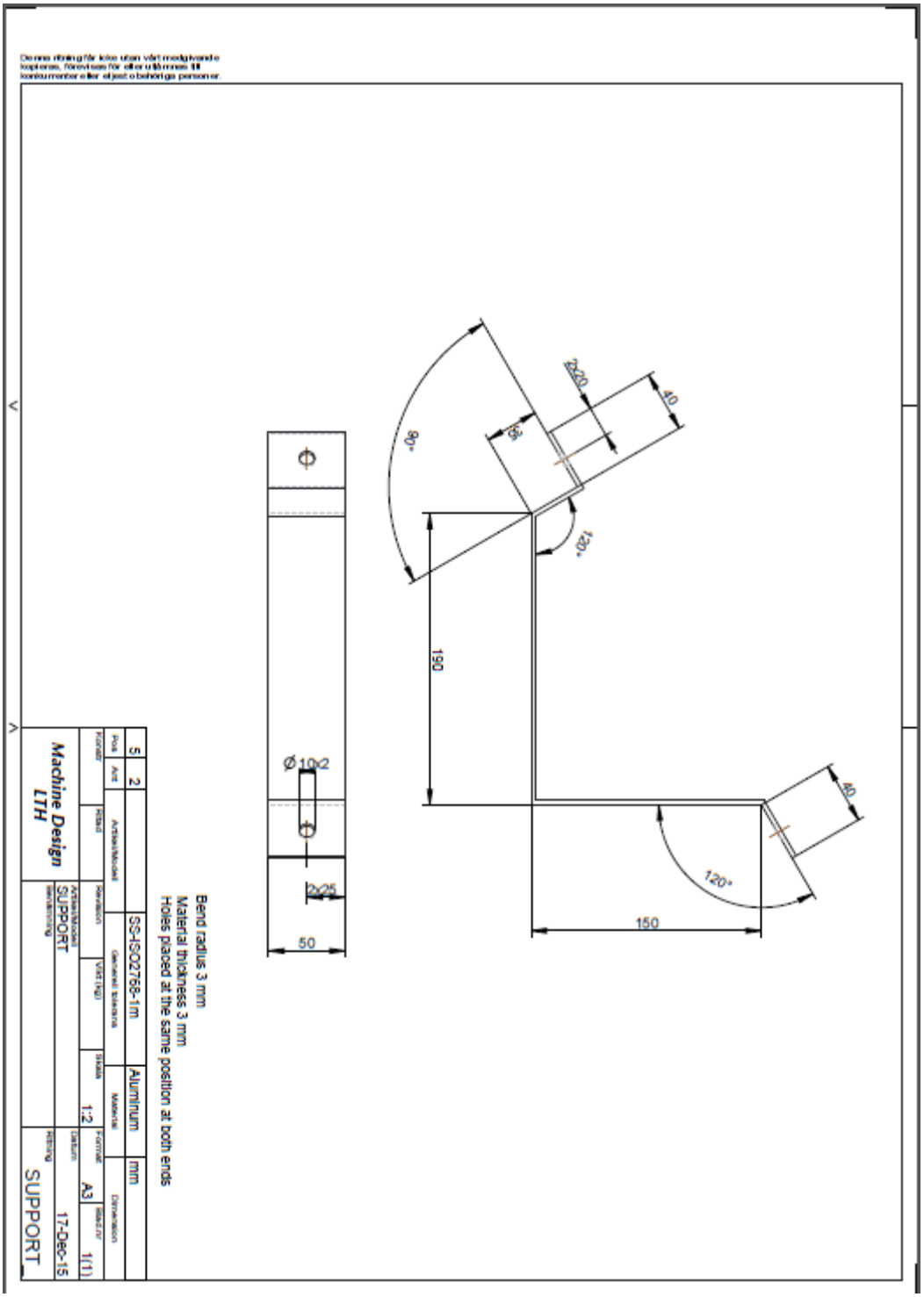
I.1.3 Extruded polystyrene insulation



I.1.4 Aluminum casing



I.1.5 Support


Bend radius 3 mm
Material thickness 3 mm
Holes placed at the same position at both ends
Machine Design
LTH
SUPPORT
SS-ISO2768-1m
Aluminum
mm
A3
1:2
17-Dec-15
1(1)
SUPPORT
50
25
10
190
150
40
120°
90°
20

Appendix J: Process of selecting a suitable Peltier element

J.1 Selection of Peltier element

At first an estimation of the heat load of the object to be cooled have to be made. The heat load is the amount of heat that is to be removed from an enclosure in order to reach desired temperature

J.1.1 Heat load

In order to estimate the heat load, a calculator based on a model on the homepage of TE Technology was used [J1]. Information regarding the model used for the calculations can also be found on TE Technology homepage [J2]. The power supply was positioned on the outside of the enclosure and was therefore not included in the calculations. The following information was used as input for the calculations.

- System Type: Cold plate solid
- Warmest External Temperature: 20˚C
- Highest External Humidity: 60 %
- Lowest Desired Temperature: 4 ˚C
- Internal Width: 357 mm
- Internal Height: 75 mm
- Internal Depth: 460 mm
- Insulation Thickness: 20 mm
- Insulation type: Polystyrene Foam [0.03W/m/K]
- Heat generated inside the enclosure: 0

J.1.1.1 Result

- Total Heat Load. 11.08 W
- Exterior wall temperature: 18.16 ˚C
- Interior wall temperature: 4.00 ˚C
- Dew point Temperature: 12.01 ˚C

J.1.1.2 Comments

From the product specification Appendix G.2, the amount of Peltier elements to be used was three. The heat load would therefore be equally distributed over the Peltier elements and was divided by the amount of elements used.

$$Q_c = \frac{11.08}{3} = 3.69\ W\ (J.1)$$

J.1.2 Define temperature working range

$$T_O Object\ temperature\ range\ (cold\ side\ temperature) = 4℃\ (J.2)$$

$$T_S Sink\ temperature\ range\ (hot\ side\ temperature) = 40℃\ (J.3)$$

$$\Delta T = 36\ K\ (J.4)$$

The sink temperature range was an estimation made by the thermal engineering specialist [J3] decided by experience with similar systems.

A single stage Peltier can handle a ΔT_{max} of 72K, if a greater difference is needed, stacked modules have to be used. As can be seen in (J.4) above, there is no need to use stacked modules. While a single stage Peltier is enough to cool to desired temperature, ΔT_{max} was chosen to be the largest amount possible. By doing so, the Peltier element would not be destroyed if larger temperature differences occurred during use.

$$\Delta T_{max} = 72K\ (J.5)$$

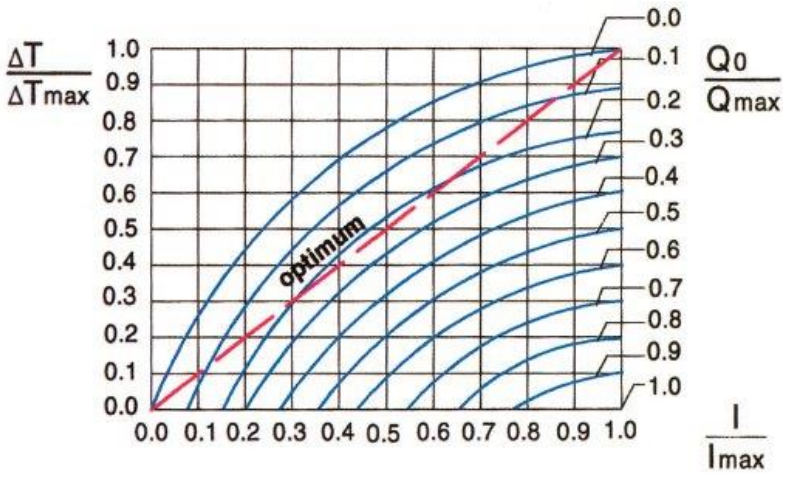
ΔT_{max} is the maximum difference in temperature for the Peltier element when the heat load is zero and the direct current producing the maximum difference in temperature is inserted in the Peltier element.

J.1.3 Selection of a Peltier element that satisfies the requirements

In order to choose a suitable Peltier element, the maximum cooling capacity Q_{max} and the temperature difference ΔT have to be determined. These parameters are determined using a normalized performance graph for Peltier elements, table J.1. From the graph an interval of the maximum and the optimum of Q_{max} can be determined. The closer Q_{max} is to optimum, the better efficiency but with increased cost. COP- Coefficient of Performance is the ratio of work required for the cooling or heating acquired. This is an important criterion while the better the COP, the more efficient system. If the COP equals 1 it means that there is no loss of energy within

the system and that all work that is put in to the system is transformed to heating or cooling. It is though not always possible to select a system with the greatest COP while it is expensive.

Table J.1 Normalized performance graph for Peltier elements with optimum line (straight line) in relation to COP – Coefficient of Performance, $Q_0 = Q_c$ [J4].



Using the information of calculations (J.4) and (J.5), the starting point in table J.1 could be found, see calculation (J.6).

$$\frac{\Delta T}{\Delta T_{max}} = \frac{36}{72} = 0.5 \; (J.6)$$

The optimum value of $\frac{Q_c}{Q_{max}}$ was found by following the intersection of the horizontal line where $\frac{\Delta T}{\Delta T_{max}} = 0.5$ and the straight optimum line, and from this point follow the blue lines.

$$Optimum \; \frac{Q_c}{Q_{max}} = 0.25 \; (J.7)$$

While $Q_c$was known from calculation (J.1) and $Optimum \; \frac{Q_c}{Q_{max}}$ (J.7) was known from table J.1, the optimum of Q_{max} could be calculated.

$$Optimum \; Q_{max} = \frac{3.69}{0.25} = 14.76 \; W \; (J.7.1)$$

The maximum value of $\frac{Q_c}{Q_{max}}$ could also be found using the graph. By using the same starting point as before at $\frac{\Delta T}{\Delta T_{max}} = 0.5\ (J.6)$ and following the horizontal line to the opposite side of the diagram, following information could be found

$$Maximum\ \frac{Q_c}{Q_{max}} = 0.5\ (J.8)$$

While Q_c was known from calculation (J.1), and maximum $\frac{Q_c}{Q_{max}}$ (J.8) was known from the table, the maximum of Q_{max} could be calculated.

$$Maximum\ Q_{max} = \frac{3.69}{0.5} = 7.38\ W\ (J.8.1)$$

From calculations (J.7.1) the optimum value of Q_{max}, and (J.8.1) the maximum value of Q_{max}, the following interval was found.

$$7.38\ W < Q_{max} < 14.76\ W$$

As stated earlier the Peltier element should be chosen within this interval and the closer Q_{max} is to optimum, the better efficiency but with increased cost.

References

[J1] [TE Technology Homepage, Heat load calculator] (n.d) Retrieved October 29, 2015

http://tetech.com/cooling-assembly-and-heat-load-calculator/

[J2] [TE Technology Homepage, Information on the model of the Heat load calculator] (n.d) Retrieved October 29, 2015
https://tetech.com/cooling-assembly-and-heat-load-calculator/Instructions-and-Information-on-Model/

[J3] Thermal Engineering Specialist, Engineered Solutions Business Professional, Discussion over the phone October 07, 2015

[J4] [Meerstetter Engineering Homepage, TEC / Peltier Element Design Guide] (n.d) Retrieved October 07, 2015
http://www.meerstetter.ch/compendium/tec-Peltier-element-design-guide

Appendix K: Overview of the manufacturing cost of the Peltier refrigerated display prototype

Prototype	Price/item	Number of items	Shipping+ VAT [SEK]	Total cost [SEK]
Bars	Donated by Optocomp AB	6	0	0
Peltier connector	Donated by Optocomp AB	3	0	0
Fixating bars	Donated by Optocomp AB	2	0	0
Distances	Donated by Optocomp AB	3	0	0
Thermal adhesive	148	1	29	177
Superpoxy	Donated by Optocomp AB	3	0	0
Aluminum casing	Donated by Optocomp AB	1	0	0
Support	Donated by Optocomp AB	2	0	0
Extruded polystyrene insulation	Donated by Woodys bygghandel Anderstorp	1	0	0
Assembly adhesive	Donated by Woodys bygghandel Anderstorp	1	0	0
Acrylic glass lid	520	1	110	630
Peltier elements	199.41	3	149.56	747.79
3D printed attachments	Donated by LTH	8	0	0
Handle	24.90	1	0	24.90
Magnet	24.90	2	0	24.90
Insulating rims	34.90	2	0	69.80
LED lights	199	1	0	199
Contact plastic	69	1	0	69
Silicon paste (2 x 10g)	31.20	2	0	62.40
Heatsink	71.20	3	23.20+74.80	311.6
Total cost of prototype [SEK]				2316.39

Appendix L: Prototype analysis results

L.1 Results of laboratory tests

L.1.1 Test 1

Time [min]	Temp [C]	Current [A]	Voltage [V]
0	20.8	0.5	3.8
5	19.2	0.5	3.8
10	17.8	0.5	3.8
15	17.2	0.5	3.8
20	16.7	0.5	3.8
25	16.3	0.5	3.8
30	16.1	0.5	3.8
35	15.6	0.8	6.2
40	15.1	0.8	6.2
45	14.7	0.8	6.2
50	13.9	0.8	6.2
55	13.6	0.8	6.2
60	13.4	0.8	6.2
65	13.2	0.85	6.7
70	13.1	0.85	6.7
75	13.0	0.85	6.7
80	12.9	0.85	6.7
85	12.9	0.85	6.7
90	12.9	0.85	6.7

L.1.2 Test 2

Time [min]	Temp [C]	Current [A]	Voltage [V]
0	19.2	0.5	3.8
5	17.9	0.5	3.8
10	16.5	0.5	3.8
15	15.6	0.5	3.8
20	14.9	0.5	3.8
25	14.3	0.5	3.8
30	13.8	0.5	3.8
35	13.0	0.8	6.2
40	12	0.8	6.2
45	11.3	0.8	6.2
50	10.5	0.8	6.2
55	10.2	0.8	6.2
60	9.8	0.8	6.2
65	9.3	1	8.5
70	8.8	1	8.5
75	8.5	1	8.5
80	8.1	1.33	11.1
85	7.6	1.33	11.5
90	7.4	1.33	11.5

L.1.3 Test 3

Time [min,s]	Temp [C]	Current [A]	Voltage [V]
0	19.2	1.33	10.3
5	16.3	1.33	10.3
10	13.7	1.33	11.4
15	11.8	1.33	11.6
20	10.4	1.33	11.9
25	9.4	1.33	12
30	8.6	1.33	12.1
34.56	8.0	1.33	12.1

L.1.4 Test 4

Time [min]	Temp [C]	Current [A]	Voltage [V]
0	8	1.33	12.1
5	7.8	1	9.3
10	7.8	0.8	7.5
15	7.8	0.8	7.3
20	7.8	0.8	7.1
25	7.7	0.7	6.3
30	7.8	0.7	6.2
35	7.8	0.7	6.2
40	7.8	0.7	6.1
45	7.7	0.7	6.1
50	7.7	0.7	6.0
55	7.7	0.7	6.0
60	7.7	0.7	6.0
65	7.7	0.65	5.7
70	7.8	0.65	5.7
75	7.8	0.65	5.7
80	7.9	0.65	5.7
85	7.9	0.65	5.7
90	7.9	0.65	5.7
95-125	7.9-8	0.65	5.7

L.1.5 Test 5

Test nr	Temperature before opening of lid	Temperature after opening of lid	Time for returning to initial temperature [min,s]
1	8	8.2	5.13
2	8	8.2	7.43
3	8	8.2	12.9
4	8	8.2	8.10
5	8	8.2	8.48
6	8	8.2	6.28
7	8	8.2	9.22
8	8	8.3	12.42
9	8	8.2	10.9
10	8	8.3	14.49

L.2 Questions and answers from test of the combined prototype in grocery store

Question	Tycker du att produkterna, både kylda och icke kylda, presenteras på ett bra sätt?	Är det lätt att komma åt produkterna?	Förstår man att displayen är kyld	Vad tycker du mest om?	Vad skulle kunna förbättras?
Answer Woman 20-30 years of age	Ja	Ja men tajt mellan cola burkarna och att den bör vara i facket över	Ja de kalla färgerna hjälpte till men även ljuset skulle kunna vara kallare	Snygg kombination, är anpassad för sitt syfte, sakerna är lättillgängliga, lättplacerad i butik för att den ändå står ut från omgivningen, säljer sig själv, trycket tog inte över	Placera kyldisplayen ett fack upp, större mellanrum mellan burkarna, säljbudskap på kartong displayen, kallare ljus i kyldisplayen
Answer Man 20-30 years of age	Ja	Ja men kyldelen är lite lågt placerad, kunde varit bra med något som hjälpte till att öppna locket	Ja	Produkterna presenteras snyggt och man går inte förbi utan att titta till	Placeringen av displayen i butiken, hade varit bättre vid kassan. Att placera den kylda delen ett steg upp
Answer Man 40-50 Years of age	Ja, men jag har ett mål när jag handlar och vet redan vad jag ska ha	Nej, det är jobbigt att behöva använda båda händerna	Ja	Att produkterna säljs i samma ställ	Placera den kylda delen högre upp
Answer Man 20-30 Years of age	Ja, produkterna är lättillgängliga och det ser snyggt ut	Locket är kanske lite tungt för äldre men det är enkelt att plocka ur läsken	Nej	Det är en bra kampanj	Det hade varit bra att placera den närmre kassan eller vid entrén. Det kan också vara bra med någon text att läsken är kall

Answer Woman30-40 Years of age	Ja, de presenteras tydligt och bra	Ja men den borde kanske vara placerad högre upp då det blir svårt när man har en korg	Ja, det är tydligt då den har ett lock	Belysningen gör att den syns mer	Den kylda delen borde placeras högre upp
Answer Boy 10-15 Years of age	Ja, den är cool	Ja men läsken ligger så fixat att man nästan inte vågar ta en	Ja, lätt	Att produkterna ställs fram på ett kul sätt, jag har inte sett något som denna innan	Sätt coca colan högre upp
Answer Man 50-60 Years of age	Ja, displayer brukar vara intetsägande och ha en kort livslängd, denna är stabil och riktigt snygg	Ja, jag gillar verkligen plexiglaslocket	Ja det tycker jag men det kan vara bra att vara övertydlig, exempelvis lägga till en text eller liknande	Att olika kombinationer kan göras som annars inte varit möjliga	Den display som är gjord nu hade kanske bättre passat en mindre butik men med kombination av exempelvis en störtdisplay av colan undertill hade varit bra

Appendix M: Accepted and actual schedule

Table M.1 Accepted schedule

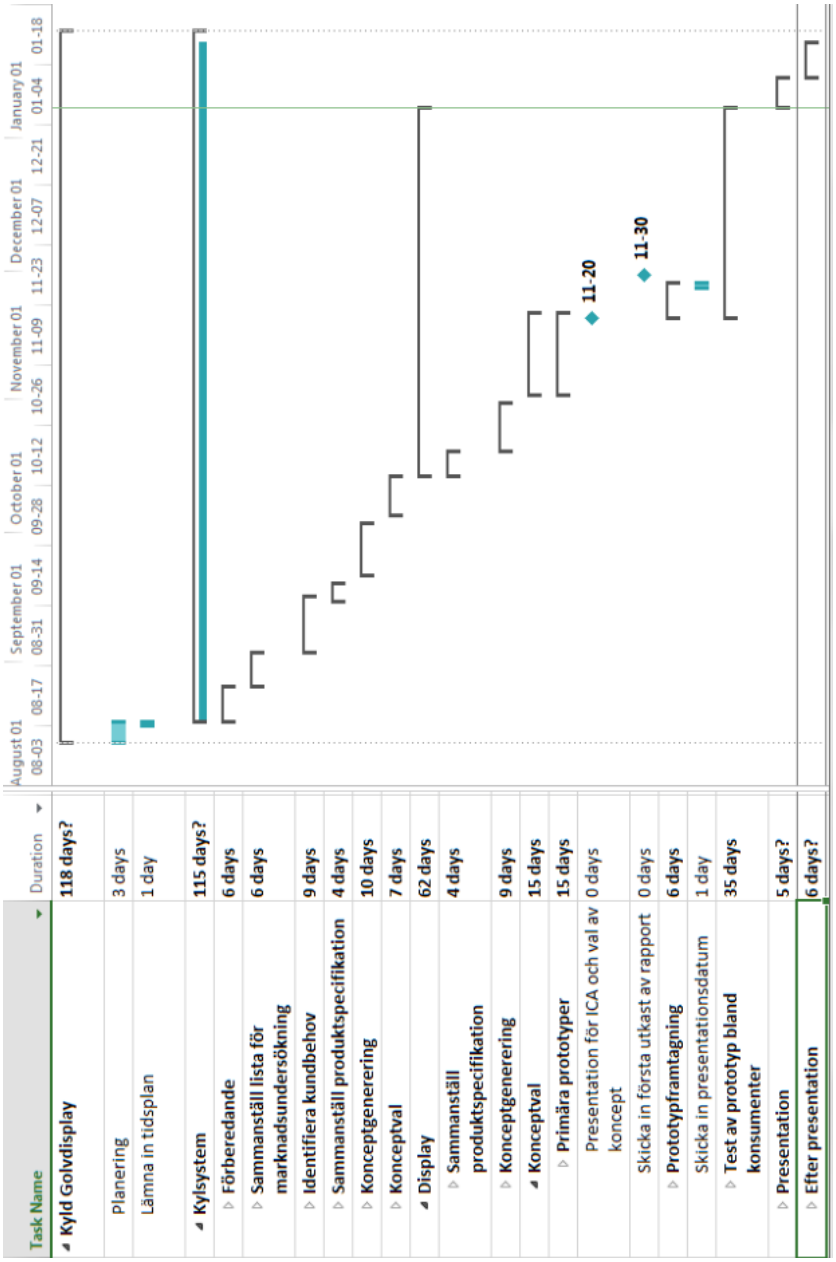


Table M.2 Actual schedule

GANTT CHART

	Task Name	Duration	Start	Finish
1	**Kyld Golvdisplay**	**123 days?**	**Wed 15-08-12**	**Fri 16-01-29**
2	Planering	3 days	Wed 15-08-12	Fri 15-08-14
3	Lämna in tidsplan	1 day	Mon 15-08-17	Mon 15-08-17
4	**Kylsystem**	**119 days?**	**Tue 15-08-18**	**Fri 16-01-29**
5	**Förberedande**	**11 days**	**Tue 15-08-18**	**Tue 15-09-01**
11	**Sammanställ lista för marknadsundersökning**	**8 days**	**Fri 15-08-21**	**Tue 15-09-01**
19	**Identifiera kundbehov**	**11 days**	**Wed 15-09-02**	**Wed 15-09-16**
24	Litteraturstudie Peltier element	3 days	Fri 15-09-18	Tue 15-09-22
25	**Sammanställ produktspecifikation**	**2 days**	**Tue 15-09-22**	**Wed 15-09-23**
30	**Konceptgenerering**	**6 days**	**Thu 15-09-24**	**Thu 15-10-01**
35	**Konceptval**	**1 day**	**Thu 15-10-01**	**Thu 15-10-01**
42	**Vidareutveckling av projektet**	**62 days**	**Thu 15-10-01**	**Fri 15-12-25**
43	**Extra information kring peltier undersöks och koncept vidareutvecklas**	**5 days**	**Thu 15-10-01**	**Wed 15-10-07**
48	**Modellering och ritningsunderlag för prototyp**	**7 days**	**Thu 15-10-08**	**Fri 15-10-16**
56	Prototypframtagning	20 days	Mon 15-10-19	Fri 15-11-13
57	**Test av funktion**	**8 days**	**Mon 15-11-16**	**Wed 15-11-25**
62	**Förberedande inför test bland konsumenter**	**11 days**	**Thu 15-11-26**	**Thu 15-12-10**
72	Prototypbygande av wellpapp display	14 days	Thu 15-11-26	Tue 15-12-15
73	Test av fullständig prototyp bland konsumenter	3 days	Wed 15-12-16	Fri 15-12-18
74	**Presentation**	**6 days**	**Fri 16-01-15**	**Fri 16-01-22**
82	**Efter presentation**	**6 days?**	**Fri 16-01-22**	**Fri 16-01-29**

M.1 Differences between accepted and actual schedule

The differences between the accepted schedule and the actual schedule was mainly due to the changes of focus during the project. The accepted schedule was very specific and difficult to change during the project which lead to large differences. The primary phase was more time consuming than expected while it at this time was found similar concepts requiring a patent search and benchmark for evaluation of the market. The part where a list was to be gathered for market research was combined with concept generation of the refrigeration system, contributing to this phase being more time consuming than expected. The identification of customer needs was performed at an

earlier stage than planned, though this part took longer time than expected due to the process of waiting for answers from customers to be interviewed.

A literature study of Peltier elements was also added to the actual schedule in order to gather knowledge of the technology before the selection of refrigeration technology was to be made. Also the phase of concept generation was moved while concepts where further developed after the selection of refrigeration technology was made. The selection of concept was made in one day while the decision could be made without interaction with the head office of ICA as planned for the accepted schedule. Primary prototypes including virtual prototypes that were to be tested using thermal analyses was not made due to the selection of refrigeration technology.

As can be seen, the manufacturing of the Peltier refrigerated prototype was time consuming. The reason for this was due to the required input from different sections and different manufacturers. It is though believed that this process normally is time consuming. For the accepted schedule, all parts was to be available at the start of the prototyping. The preparations for the tests of consumer experiences was time consuming due to problems contacting the owner of the store where the prototype was to be tested. During this time the prototyping of the cardboard display was also initiated. Overall the accepted schedule has not been fulfilled due to unexpected changes of direction within the project. Though the desired result is believed to have been achieved within the planned time of the project.

Appendix N: Self - evaluation

Overall I am satisfied with the result of the master thesis. The product developed fulfills the requirements and presents a new and interesting product to the market suitable for Smurfit Kappa. The product is not completed and require some extra time for development but the concept and function is evaluated where the result provide information of a product with the desired function and an interest from the market.

The project has been a great challenge where all knowledge obtained during my education has been put to test. The main part that I have learnt is the importance of connections and how to gather information necessary for a project. During the master thesis I have been in contact with people from a number of different manufacturers and experts of different areas. It was hard and at times frustrating trying to find the right people to get in contact with, but I believe that this has made me better equipped for future projects.

During the master thesis I have also learnt a lot about, and had the opportunity to try, different manufacturing methods. I have also learnt a lot about the technology of Peltier elements which was a completely new technology for me. The fact that I managed to use and build a system using a technology that was new to me, has made me more confident in my product development skills.

The changes of direction of the master thesis was time consuming and required me to rethink and start over multiple times without losing any information gathered to the point of the change. Due to this, the report contains some information not necessary for the result of the project but still of great importance for the process of getting there.

Using compressor refrigeration, the project could have been delimited to create and analyze a virtual model while all parameters would have been known after the selection of type of compressor refrigerator. While using the technology of Peltier elements, these parameters were not known and the function required testing. The product is to be transported and delivered mounted to the grocery stores in order to remain rigidity and avoid breaking the cardboard display when mounted, a problem found during customer needs investigation.

Due to the requirement of building and testing the refrigerated display, it was not possible for me to be as involved in the development of the cardboard display as I would have liked.

For future projects I will take with me that research that is dependent on the contact with other people is time consuming and meetings and interviews should therefore be planned and booked at an early stage of the project. I will also make my planning

considering possible delays in manufacturing and the possibility of redesign during testing. I will also try to find more confidence in taking faster decisions.