Improving Product Level Sensing in Filling Tubes

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MASTER THESIS

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Abstract

This thesis examines the possibility to improve the product level sensing in one of Tetra Pak's filling machines, because the current solution does not detect this with the desirable precision, as well as measuring range. Today, a magnetic float is used together with 16 separate capacitive sensors. The issue with this is that packages get rejected due to a faulty amount of product. This occurs because of two factors, one being that the precision is too low, due to an insufficient amount of sensors, and because a device floating on the liquid's surface is used to measure the product level, and its position does not always correspond to the actual level.

The methods include researching currently used measuring techniques, determining which of them that are adaptable in the context, ascertaining the needs and requirements of a well-suitable solution in a hygienic food industry environment, and testing the suggested new measuring technique.

The results showed that using a magnetic position sensor with a float was a suitable solution, if it is combined with a cover, as the sensor needs to be protected from the strong detergents used to clean the filling machines. Though, adaptations of the sensor calibration and cable are needed to fulfil the requirements.

The advantages of the new solution are that it gives a very high resolution and that the whole range of the filling tube can be measured. The major disadvantage is that there is still a need for a float, which requires frequent cleaning to obtain a high hygiene standard and can give incorrect signals due to oscillation.

Keywords: level sensing, hygienic design, manufacturing, product development

Sammanfattning

Detta examensarbete undersöker möjligheten att förbättra produktnivåmätningen i en av Tetra Paks fyllnadsmaskiner, eftersom den nuvarande lösningen inte detekterar den med den önskvärda precisionen, samt mätområde. Idag används en magnetisk flottör tillsammans med 16 separata kapacitiva sensorer. Problemet med detta är att förpackningar blir avvisade på grund av en felaktig mängd produkt. Detta sker på grund av två faktorer, den ena är att precisionen är för låg, på grund av en otillräcklig mängd sensorer, och eftersom en anordning flytandes på vätskans yta används för att mäta produktnivån, och dess position motsvarar inte alltid den faktiska nivån. Till metoderna hör att undersöka nuvarande använda nivåmätningstekniker, avgöra vilka av dem som är anpassningsbara i kontexten, säkerhetsställa uppfyllnad av behoven och kraven i en lösning väl anpassad till en hygienisk livsmedelsindustrimiljö, och testning av den nya föreslagna mättekniken.

Resultaten visade att avvändandet av en magnetisk positioneringssensor med en flottör vad en passande lösning, om den är kombinerad med ett skydd, eftersom sensorn behöver vara skyddad från de starka medlen som används för att rengöra fyllnadsmaskinerna. Dock behövs anpassningar av sensorns kalibrering och kabeln göras för att uppnå kraven.

Fördelarna med den nya lösningen är att den ger en väldigt hög upplösning och att hela räckvidden på fyllnadsröret kan mätas. De främsta nackdelarna är att det fortfarande finns ett behov av en flottör, vilket kräver frekvent rengöring för att uppnå en hög hygienstandard, och kan även ge inkorrekta signaler på grund av oscillation.

Nyckelord: nivåmätning, hygienisk design, tillverkning, produktutveckling

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Lund, May 2023

Hannah Schrewelius

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1 Introduction

The section includes introductive information about the company's background, the problem and what the goals of the project are.

1.1 Background

Tetra Pak is one of the world's leading food processing- and packaging solution companies. With more than 25 000 employees working in over 160 countries, the company sold products for 12,495 billion euros, and 193 billion packages in 2021. [1]

The agriculture, forestry, and land use sector stand for approximately 20% of the global greenhouse gas emissions. This makes the food industry one of the largest contributors to global warming and is one of the main focuses when working against climate change. [2]

One way of tackling this problem is reducing food waste, as it would lead to that less food would need to be produced, and therefore would the environmental impact from the food industry be decreased. Today, one-third of produced food is lost or wasted globally. Not only is the waste unnecessary damage to the environment, but the food is also worth around ten trillion SEK, meaning that people and companies pay an unnecessary amount for the wasted food. [3]

The company currently offers a great variety of filling machines, which both fill and form their own set of products.

Tetra Pak’s A1 filling machines currently come in four different versions, which each produce one type of packaging. To limit the range of the project, the focus has been set on the TCA (Tetra Pak A1 for Tetra Classic Aseptic) machine, and TFA (Tetra Pak A1 for Tetra Fino Aseptic) machine, which each produce different types of packaging. [4]

Figure 1 The two types of packaging produced by each filling machine. TCA is shown on the left side [5] , TFA on the right side. [6]

1.2 Current solution

The method currently used to measure the product level is by using a float. In the float, there are magnets communicating with a capacitive measuring system. The system consists of 16 sensors evenly distributed over a length of 180 mm detecting whether the float is present or not. Depending on which sensor that detects the float, the position of the float can be determined. The measuring system communicates with the regulator controlling the inflow rate into the tube. [7]

The float is surrounding the filling tube and is floating in the product, which is represented by the yellow colour. In this project, "product" refers to the liquid/food in the packaging, as the word is used in that manner at Tetra Pak. The lines surrounding the float and filling tube are the packaging material, which is moving downwards and then sealed into a product-filled packaging at the bottom of Figure 2 . The figure is simplified, meaning that for example the filled packaging looks completely filled, but this is incorrect. [7]

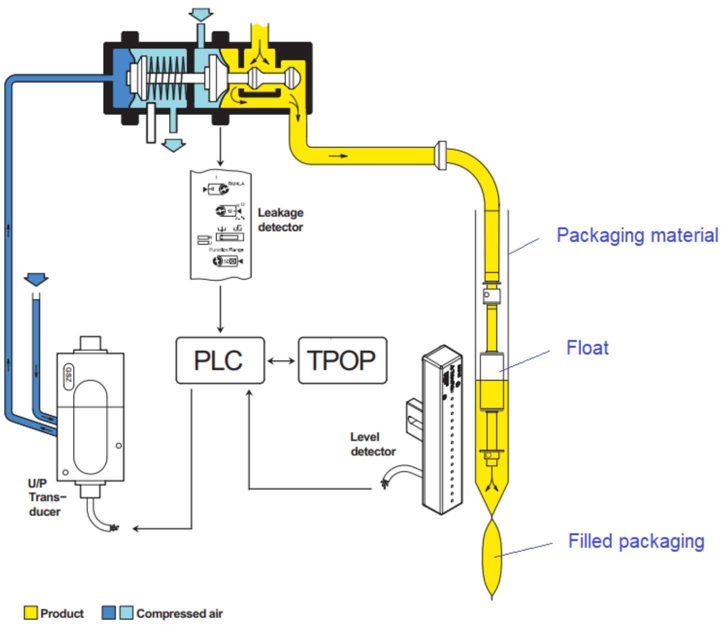

Figure 2 Overview of the filling system of the A1 machine. Yellow colour represents the product, and blue colour represents compressed air. The blue lines and text have been added to the original figure gathered from source [7]

1.3 Problem description

The current measuring system in the filling tube has a measurement precision of ± 5mm. With the influx from the pipe, the float occasionally oscillates under the liquid surface and sends incorrect signals to the sensors measuring the position of the float. The sensors have an 11 mm distance between each other, which is also a contributor to inaccuracy during the measurement. The other problem with the technique is that the measuring range is shorter than what is preferred.

The imprecision leads to packages being discarded, due to a faulty volume of liquid in the product. The volume should correspond to what their customers wish for, within a specified margin. This leads to losses both environmentally, and economically. Attempts on finding a better measuring system have been made, but the solutions have not been implemented due to that they have not been effective or cheap enough.

The task is to find a solution that is more precise and that has a wider measuring range than the present measuring system. It is desirable that the solution can measure the whole filling tube, is easy to implement, and preferably works on more machines than the A1 model.

1.4 Project goals

The main goal of the project is to find a solution with higher precision when measuring the product level in a filling tube. The solution should include a measuring technique that works in theory, preferably practically as well. There should also be a plan how to implement the technique, such as designing a way to insert the solution in the machine. The current precision is ± 5mm, and the desired is ± 1mm. The width that the system currently can measure is 180 mm, and it is desired that the new system could do measurements on a wider range, preferably the whole tube, which is 800 mm long. The design should also be hygienic, to minimalize the risk of contaminating the liquids.

2 Methodology

This part describes the processes of generating the solution, which mainly consists of an adapted version of Ulrich and Eppinger's methodology. Descriptions of the different steps and the time plan are included.

2.1 Time plan

At the start of the project, a Gantt chart was made to get a plan with the main activities of the project. It was based on previous product development projects, and the deadlines of the report and presentations were used to decide when the project should end. The actual outcome of the stages of the project was added to a separate chart, to allow comparison between the assumption and outcome in a simple way. The Gantt chart can be found in Appendix A.

2.2 Approach and Design Process

The foundation of the methodology was based on the book "Product Design and Development" by Karl T. Ulrich and Steven D. Eppinger. [8]

Below is an overview of the process of product development. For this master's thesis, changes have been made because the project differs slightly from a regular product design development. For example, did the team technically only consist of one person, and tests were needed to be made meanwhile doing the design process.

A schematic overview of the design process is shown below in Figure 3.

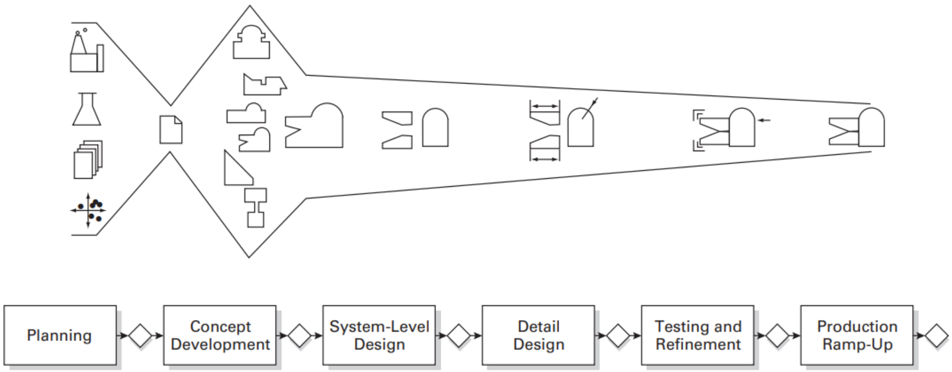

Figure 3 Schematic overview of the steps in a product development process. [8]

2.2.1 Planning

In this phase, companies prepare projects and evaluate which to develop further, depending on several factors. The market, manufacturing, and economic restraints are examined, as well as creating a time plan over when segments should be completed. The segment is an iterative process, where decisions can change over time due to for example delays and market changes. [8]

Different technologies are assessed, so that the development team knows what is available on the market and what product ideas are realistic to produce. It can also give ideas on new innovative concepts. [8]

2.2.2 Concept Development

In this phase, needs of the customers are identified. This can be done by for example interviewing and observing how similar products are used. The needs are ranked and grouped based on importance. The goal of the process is to ensure that the resulting product is focused on what the customer needs, the product specification choices are based on facts, latent and hidden needs are found, and to expand the development team's understanding of the needs. [8]

Several concepts are both generated and assessed through for example screening. The concept ideas are described and are not completely specified. There are descriptions of the form, functions, and features, and do sometimes include specifications. Benchmarking of similar products can be made to be inspired and to know what specifications are reasonable to aim for. [8]

2.2.3 System-Level Design

Here is the product architecture defined, which means that the product is divided into subsystems and components and a preliminary design of the key components is made. An assembly scheme is described. [8]

2.2.4 Detail Design

Components are completely specified, by stating the design, material choices, and measurements. Drawings of all parts are made, defining the geometry and tolerances. The drawings both be made in 2D or/and 3D. It is decided which parts should be imported from other companies, and which the company should produce themselves. A production plan is made, including needed tools and process plans. [8]

Product specifications are measurable details of what the product must do. When the customer needs are identified, wished specifications from the development group are then set. They are then often changed after the product concept is set, since it is difficult to anticipate what is possible to achieve. The specifications can be set by first preparing a list of metrics, which shows the importance of the specifications, and which need each relates to. Then benchmarking is performed, to see what specifications have been achieved by competitors in the market. This gives a realistic view of what values are reachable. Ideal and marginally acceptable target values are then set. [8]

A product concept is a fundamental description of what form, working principles, and technology the product is finally going to have. It is often described with a drawing and an explanatory text. Several concepts should be produced, to later be evaluated chosen between, to make a final decision. By evaluating several concepts, a superior idea can hopefully be discovered early in the process. [8]

The concept generation process is initiated by studying and understanding the problem. Later, internal and external investigations are made. This is made by for example benchmarking, researching literature and, interviewing. Then a systematic exploration can be made by splitting the parts of the product up, to get a deeper understanding of the different systems involved in the concept. [8]

Concept selection can be executed in several different ways, such as voting, weighing pros and cons, and using decision matrices, which is the method Ulrich and Eppinger highlight. Concept screening is the first step, where rough concepts are compared, and some are eliminated afterwards. The matrix consists of several selection criteria, and one of the concepts is set as a reference. For each concept and criteria, a +, - or, 0 is set depending on if it performs better, worse, or equally than the reference concept. A net score is then calculated for each concept to see which alternatives to continue with. [8]

Next, concept scoring is executed, where more detailed analyses are made. The matrix is similar to the concept screening one, but the selection criteria are weighed this time, in order to increase resolution. Instead of only giving the criteria +, - or, 0 as a score, they are given a rating between 1-10, where 10 is the highest. [8]

2.2.5 Testing and Refinement

Prototypes of the product are made and tested. Prototypes do not need to be produced in the final thought way. The purpose of the prototype is to see if the product satisfies the customer needs and requirements, by performing concept tests. The process is initiated by defining the purpose of the test, where the team defines questions that should be answered after the testing. Afterwards, a survey population should be chosen which represents the target market and has a reasonable size. Then there are several different survey formats to choose between, for example, face-to-face interaction, telephone, and internet, each with their own advantages and disadvantages. The concept should be communicated in a way that represents the product well, either with for example a sketch, storyboard, or physical model. During the survey, the responses should be measured, by for instance grading different statements, or choosing between concepts. The results should then be considered and interpreted when developing the product further. [8]

2.2.6 Production Ramp-Up

The final step before the product is produced as intended.

The product is produced in the intended way, but at a slower scale and pace. The products are then sold to key customers. It is an opportunity for the workforce to be trained before full-scale production is implemented. The production gradually increases its speed during this phase until the production is full-scale. [8]

2.3 Usage of the methodology

The project started with the planning phase, with a significant focus on researching different sensor types and current level detection technologies. This was done through literature studies online, which mainly included studying articles and books regarding this subject.The order of the steps was changed to optimise the process. The foundation of the project was the chosen sensor, which meant that design choices could not be made to a larger extent until the sensor type was chosen. After finding an applicable sensor type, research had to be done to see if it satisfies the needs.

The order of the design process was first to identify needs and requirements. The step was followed by a research phase, where current level detection methods were investigated. Afterwards, concept generation, selection, prototyping, and testing were performed. The results were then collected and presented, and a discussion of them was made.

3 Needs and Requirements

The section contains a composition of the needs and requirements gathered from the problem description, research, and interviews of employees. These have been given grades of priority and have been described further. Requirements and needs have been separated into two lists, as there was no need of prioritizing the requirements.

To set up lists of requirements and needs, the information gathered through the literature study was combined with knowledge presented by employees at the company. The group of employees consisted of people with varying relevant knowledge, such as electrical engineering, construction and machine operation, and were chosen due to their deep knowledge about the relevant areas.

Notes were taken during the sessions, and the result was summarised into one list each. The needs were ranked after what the group found the most important, which was found out through questioning the information gathered.

3.1 Requirements

Table 3.1 List of requirements, sorted according to which category they belong to.

Requirements
Measurements
The precision is better than ± 5 mm. Ideally ± 1 mm.
The measuring range should be wider than today's width of 180 mm. Preferably the range of the whole tube, 800 mm.
No sensor calibration is needed depending on measured product.
Hygiene
Cleaning according to CIP (cleaning in place) is possible.
The materials in contact with the product are complied with regulations regarding food safety and hygiene.
Design
The solution is developed according to the rules of hygienic design.
The solution does not deteriorate in the environment.
The solution is safe for people working around the machine.
It is possible to replace the sensor.

3.1.1 Measurements

Requirements regarding the measuring resolution and range were stated in the problem description. The goal was set to be that the solution should be able to measure the product level with a precision of ± 1 mm, and a length of 800 mm.

The precision was set due to the fact that the influx system does not operate with tolerances high enough to benefit positively from a higher resolution. The difference it would make is negligible.

3.1.2 Hygiene

To keep a machine hygienic, cleaning is crucial. The equipment should therefore be designed in a way which makes cleaning fast and easy.

The company has a rule that all machines should be able to be cleaned according to CIP (Cleaning in Place), which is described further in Hygienic Design. This is because the time used for disassembling leads to high operator costs. [7]

There are laws regarding hygiene in the food industry which must be followed, and the regulations vary in different countries. Tetra Pak has an international market, which means that the solutions must follow the laws of all these regions. The chosen materials in use must therefore be selected according to these.

3.1.3 Design

Hygienic design should be in focus when developing equipment for machines in the food industry, since it eases the cleaning processes, which makes it easier to fulfil the hygiene requirements for the processing.

A part of hygienic design is to choose materials that do not deteriorate, for example rusting, as the particles risk getting into the product, which causes health hazards. In this statement, scratching is also included. Scratches both lead to that bacteria can accumulate in those areas because they can be difficult to reach during cleaning, and that particles from the scratch can end up in the product. Hygienic design also includes choices of shapes and components.

Both the sensor and the bracket should be designed so that it does not risk the health of the people working at the machine. The sensor should therefore not use techniques that can harm the workers by for example radiation, lasers aimed at an angle that could cause damage to their eyes, or sounds that can cause loss of hearing. The bracket should be designed so that it will not cause harm by for instance squeezing or through sharp edges.

All technology breaks occasionally, which means that they should be able to be replaced, and not be locked into a construction, even though it means that the design would be less hygienic.

3.2 Needs

The needs in Table 3.2 were gathered by consulting with the same group of employees as mentioned in the start of this section.

Table 3.2 List of needs, with belonging priority grade. The scale goes from one asterisk to three, where three asterisks represent the highest priority.

Priority	***Needs***
	Measurements
***	Surrounding factors do not affect the result.
**	All products can be measured regardless the viscosity.
	Hygiene
**	The setup is not in contact with the product.
	Design
***	The setup is stable and will not move if a worker accidentally bumps it.
***	Splashing is minimised.
*	The product is aesthetically pleasing.

3.2.1 Measurements

Especially when sensors that detect metallic parts are used, there is a risk that there will occur disturbances due to nearby metals. There is therefore a need that the sensor should be affected as little as possible by the surroundings. The focus is therefore on minimizing the risk to a level where the precision requirement is still met.

There was a wish that the new solution should be able to detect the product level of all products, regardless of the viscosity. Today, it is not possible to measure the level of high-viscosity products, as the float cannot move well in them.

It was stated that there should not be a need of calibrating the sensor depending on the type of product in the tube, as the customers do not want this, since it is costly, both time- and economy-wise.

3.2.2 Hygiene

It would be favourable if the solution had no parts in contact with the product, in contrast with today when the float is constantly in the liquids. This is because it would reduce the time needed for cleaning and a higher hygiene standard would be achieved.

3.2.3 Design

For some measuring techniques, the distance to the product is of great importance, which means that the position of the sensor should not change if someone bumps into it with a reasonable force. It was given a high priority grade because if this happens without noticing, it would lead to that incorrect measurements would be sent to the part controlling the inflow, which would lead to several faulty products being produced.

It occurs some splashing from the machine. The risk of liquid covering the sensor should be considered if the sensor type gets affected by it. It was given a medium priority since all sensors are not affected by this.

The aesthetic design of the solution was given a low priority because the type of customers that buy the machines do not look after those properties, since the machines are only displayed in factories, where aesthetic design does not matter much compared to machines being sold in a traditional store.

4 Research

Descriptions of different level measuring techniques, as well as a compilation about hygienic design. The information was used to do evaluations during the further phases.

The research focused on finding solutions measuring the product level. Finding techniques to for example measuring the product flow, and use those signals instead to control the influx system was considered, but discarded due to the difficulties implementing such system, as it was assumed by the group that it would take more resources than what is profitable.

The research phase was performed through online literature studies. Different types of sensors, hygienic design and currently used level measurement techniques were investigated. Benchmarking was performed through using search engines.

A float has buoyant properties and follows the surface of the liquid. The position of the float is measured by a transducer, and therefore can floats be combined with several different technologies. It is a common technique used for level measurement since it is an inexpensive method and can be applied in many different circumstances and for different products. One of the greater downsides of this technique is that the float is in direct contact with the liquid, leading to higher maintenance needed to keep it clean. [9]

4.1 Inductive proximity sensors

A proximity sensor can detect the position of a magnetic object without being in direct contact with it. The sensor creates an electromagnetic field which can then be opposed by a metallic object, which leads to that eddy currents build up in the object. The eddy currents reduce the sensor's field. The reduction is read and interpreted to a comprehensible output. [10]

This type of sensor is often applied for position detection for moving mechanical parts. [10]

4.2 Capacitive proximity sensors

Capacitive proximity sensors can be used to detect the presence of objects that is either conductive or has a dielectric constant that is different from air. The sensors are used in several different contexts, including fluid level detection. The benefit of using this kind of sensor instead of an inductive one, is that the object observed does not need to be metallic. [10]

To do this, an electrostatic field is produced by the sensor. The field gets disturbed by the present object, which leads to changes in the capacitance. The sensor then sends signals regarding the change in the field. [10]

By changing the position of the two plates, the operating distance is adjusted. Adjustments are needed to adapt the sensors to the dielectric constants of the object. [10]

To do level detection, a capacitive proximity sensor can both be in direct and indirect contact with the product. In indirect contact sensing, the tube and product act as the dielectric medium together, which is the part of the capacitive sensor which is the basis of measurements. [10]

4.3 Ultrasonic position sensors

The sensor type works by sending an ultrasound wave. The wave is reflected on the object in front of it, which then comes back to the sensor. The time taken for the wave to travel back and forth is then used to calculate the distance to the object. The sensors generally have a precision of 1 mm when operating at distances of 100 mm to 6000 mm. [11]

They are useful under circumstances where the air is particle-laden, splashing liquids are present, and when the measured object is not metallic. They are also useful when sensing clear objects. Since the sensor does not require contact with the examined object, they are currently used for fill-level control of the food and beverage industries. [11]

4.4 IR camera

Unlike regular cameras, IR cameras detect infrared light, which is perceived as heat. Several sensors collaborate to build a picture, where a colour code represents the levels of infrared light. The technology can be used to measure product level by comparing the temperature of the product, and the air surrounding it. The level is placed where the two temperature differences meet. [12]

As different material releases thermal energy at different speeds, even two objects with the same temperature can be discovered separately by the camera. This type of camera cannot see through solid objects and can only detect the heat emitted from the body behind it, affecting the solid object. [13]

4.5 Radar level sensor

It is beneficial to use this type of sensor under difficult circumstances, such as closed tanks and steamy environments. It works by sending a microwave signal to the surface of the product measured. Then a receiver reads the phase difference between the sent and received signal. The phase difference is linearly proportional to the product level. The measuring technique is the least affected by fluctuations in temperature, moisture, and density of the product. The advantages are that they are non-contact and do not need to be calibrated depending on product type. The main disadvantage of radar level sensors is that they are expensive. [9]

4.6 Magnetic sensors

There are several different magnetic sensor types available on the market, and they are crucial in several different applications and industries. This is because can be used to detect positions, directions, rotations, angles, and if an electric current is nearby. The main advantages of using magnetic sensors are that they are cheap, robust, have high sensitivity, can work where optical sensors cannot be used, and are less sensitive to disturbances from metallic parts. [14]

4.6.1 Hall effect sensor

The sensor type detects the presence of a magnetic field through the Hall effect. The working principle of the hall effect is that a current is applied to a thin film of semiconducting material, which creates a magnetic field. A difference in potential emerges perpendicular to the direction of the current. The field strength is directly proportional to the detected voltage. [15]

Hall effect sensors can be used for numerous applications, such as precise proximity sensing, positioning and, speed detection, which can all be useful when pursuing level sensing. [15]

4.6.2 MPA magnetic position sensor

This type of sensor is developed and sold by the company Sick. The sensor consists of an array of hall sensors to without contact detecting presence of magnets. The sensor is programmed to interpret the movement of the magnet, between the hall sensors, to give a linear result. The sensor is available in lengths between 107 and 1007 mm, a resolution of 0,5 mm, sampling rate of 1.15 milliseconds and accuracy of 0,03%. [16]

Figure 4 Picture of Sick's MPA sensor [17]

4.7 Hygienic Design

Food safety is described as “Assurance that food will not cause harm to consumers when it is prepared and/or eating according to its intended use”. [18]

If this is not fulfilled, it can lead to health hazards, economic consequences, and impaired reputation. For this reason, it is important to implement hygienic design when processing food. [19]

Hygienic design must be considered for all parts that can encounter food, not only through direct contact, but also through for example splashing or condensing. [19]

CIP, cleaning in place, is currently the method used for cleaning Tetra Pak’s machines. It means that cleaning can be performed without disassembling any of the equipment. [19]

Contamination of products can occur in different forms, both in microbial, chemical, and physical (such as pieces of material) form. Implementing hygienic design involves minimising all these contamination forms. [20]

The crucial criteria to be taken into consideration is to minimise contamination can occurrence and to make cleaning, maintenance, and inspection possible and easy to perform. Areas where contamination can occur should be avoided through good design, both shape- and material-wise. [20]

To avoid these areas, the constructor should take several design choices into account. Firstly, should the surfaces be smooth, and not contain crevices. This leads both leads to easier cleaning and reduces deterioration. Crevices can be prevented by avoiding metal-to-metal contacts (welds are exceptions), as it causes scratches. To hinder this, elastomers that fulfil hygienic standards can be utilized. [20]

Sharp corners should be avoided, by for instance rounding them. Corners would have a radius of 3 mm minimum, but ideally 6 mm or larger. [20]

Screws and similar fasteners should be avoided due to that there will occur areas that cannot be cleaned under and around them. Joints should preferably consist of smooth and continuous welds instead. Optimally should bending pipes be used if possible. [20]

Controls and instruments should be possible to clean and mount in a hygienic way. Product residue can accumulate in worse designed areas, leading to quick accumulation of bacteria. This means that the equipment needs to be cleaned more frequently, and with stronger detergents, leading to higher costs due to faster wear out of materials and higher maintenance. [20]

4.7.1 Hygienic materials

Tetra Pak delivers packaging solutions to an international market, meaning that legislations from all countries' need to be fulfilled. Therefore, when choosing a material, all countries laws were needed to be taken into consideration.

Stainless steel is a common choice of material in hygienic design. Many alloys fulfil all the wanted properties, such as strength, handling of temperature fluctuations, lifetime, non-absorbance, shaping ability, cleanability, non-toxicity, and resistance to cracking, chipping, corrosion, and abrasion. [21]

The most used types of stainless steels in the food industry are SS 2333/EN 1.4301, SS 2320/EN 1.4016 and SS 2343/EN 1.4436 due to their hygienic properties. All three types have similar strengths. SS 2320 has the best anti-corrosive properties and is useful in the most severe environments, followed by type SS 2343 and lastly SS 2333. [21] [22]

The heat during welding can cause intergranular corrosion. To avoid this, steel which lower carbon content should be used, for example, SS 2352 /EN 1.4307 or SS 2348/EN 1.4404. [21] [22]

Aluminium is also commonly used in the food industry, as it has corrosion resistance and is of lower cost, and is more light weight than stainless steel. The disadvantages of using aluminium compared to stainless steel is that it has a low tensile strength and impact tolerance, leading to that breaking occurs more easily. [21]

4.7.1.1 SS 2333-02

The material is an austenitic chromium-nickel steel and is non-magnetic after its heat treatment, which is crucial due to the sensor choice. It is approved in the food industry in all the countries Tetra Pak has customers in, which was also one of the requirements. In the concept selection, it was decided that Tetra Pak's standard rectangular pipe was going to be used for the final concept. This material is the only one the pipe is produced in, meaning that this was the only available material. [23]

The advantages of using this metal are that it is relatively cheap, has good corrosion resistance and, high toughness. Disadvantages include that the corrosion resistance is less good austenitic stainless steels, and that it is not suitable in high-stress constructions. The corrosion resistance is however considered as good enough for this project's purpose, as it still fulfils all of the requirements. [23]

5 Concept generation

This section included selecting which sensor technology to use. It also consisted of designing different options for the setup holding the sensor in place.

5.1 Selection of technology

Through researching which level detection methods that are currently used, a summary of the most relevant properties could be made, which was used to filter out which measuring methods that were not possible to implement in this project.

Table 3 Summarising the different level measurement technologies. Sources are the ones mentioned in the research segment, with a supplementary one. [24]

Technology	***Price***	***Non-contact***	***Continuous***	***Able to measure through packaging material***	***Accuracy***
Float systems	Low	No	Depends	Yes	Medium
Inductive proximity sensors	Medium	No	Yes	No	Depends
Capacitive proximity sensors	-	-	-	-	-
In contact	High	No	Depends	Yes	Medium/High
Non-contact	Medium	Yes	Yes	No	Depends
IR camera	Medium	Yes	Yes	Yes	Medium
Ultrasonic sensors	Medium	Yes	Yes	No	Medium
Magnetic sensors	Medium	No	Yes	Yes	High
Radar level sensor	High	Yes	Yes	Yes	High

The width of the packaging material surrounding the filling tube varies, leading to that it could be difficult to place a sensor to measure the level from above, meaning it would be needed to be done from the side. Another difficulty of placing a sensor measuring from above is that the electronics are at greater risk of being damaged, and it is less hygienic to place them close to the product. Therefore, all sensors that cannot detect through the packaging material needed to be eliminated. This means that inductive proximity sensors, independent capacitive proximity sensors and ultrasonic sensors were rejected from the investigation.

Capacity proximity sensors are required to be in contact with either the fluid or the outside of the tube to work. As mentioned before, a new solution which is not in direct contact with the product is wished for, due to food hygiene criteria. The current solution uses a technique of this kind, but there are already procedures implemented to avoid bacteria build-up. A capacity proximity sensor which does not require direct contact needs to be placed directly on the outside of the liquid filled container. This is not possible in this context, due to that the container is always moving rapidly. Because of these reasons, the technique was discarded.

An IR camera requires a connection to a computer to be used in an optimal way. That would require that the computer needs protection from steam or splashing liquids. The computer would also be hard to keep hygienic enough for that environment. Another great disadvantage of this technology is that if the product is warm, it will fume, leading to that there will be a less distinct border between product and air, leading to less accuracy. For the mentioned reasons, the technology was eliminated.

Radar level sensors can be very precise and hygienic, as they do not need to be in contact with the product, while still measuring with a continuous and precise manner regardless of the fluid viscosity. After consulting with one of Tetra Pak's sensor distributors, it was discovered that implementing the technology would be very time-consuming and would not be possible to perform within a master's thesis. Consequently, the sensor type needed to be discarded.

The only new sensor type that fulfils all requirements is the magnetic sensor type. After researching the market, and Tetra Pak's current sensor distributors[1], it was decided that a magnetic positioning sensor (MPA) was the most suitable choice of sensor, as it is both fast, precise and can be implemented in a relatively simple way into the filling machines.

[1] Delivered by Sick AG

5.2 Updated list of requirements

As the sensor type was chosen, new requirements arose. This is because the sensor is not adapted to the environment in machine halls where frequent cleaning with strong detergents is required, which leads to that it must be put in a protective case. It should also be possible to adjust the distance from the tube, as the sensor requires the magnetic flux from the float to be within its limits of 2-15 mT. After discussions with the distributor, the list of requirements was updated and concluded in Table 4.

Table 4 Updated list of requirements for the concept.

Requirements
Measurements
The precision is better than ± 5 mm. Ideally ± 1 mm.
The measuring range should be wider than today's width of 180 mm. Preferably the range of the whole tube, 800 mm.
Hygiene
Cleaning according to CIP (cleaning in place) is possible.
The materials in contact with the product are complied with regulations regarding food safety and hygiene.
Design
The solution is developed according to the rules of hygienic design.
The solution does not deteriorate in the environment.
The solution is safe for people working around the machine.
Possibility to replace broken sensors.
Cleaning detergent will not be sprayed directly on the sensor.
The case is either completely leak proof or has a drainage.
It is possible to adjust the distance between the sensor and the tube.

5.3 Mechanical design development

The currently used sensing system can easily be removed, as no additional components are attached to its bracket. To ease the fastening of the new sensor and reduce costs, it was decided that the holes the current systems bracket was attached to could be used for the new one. The need to be able to adjust the height depending on which packaging is being filled was also in great focus.

For construction, Tetra Pak has standardized parts to choose between. It was decided that these parts should be used to lower costs, and to make the construction more effective. This meant that design choices should be made considering what is available.

The construction concept generation could be divided into two parts: The sensor case, and the bracket.

5.3.1 Sensor case

The main goals are that the sensor should not move, is protected from the surroundings and that it does not get scratched.

The chosen sensor cannot work in the food industry for several years without a protective cover since the environment wears on it.[2] The chosen material for the cover was stainless steel because of its hygienic properties and that it does not affect the sensor outcomes, as the material is not magnetic.

It was considered important to be able to detach the sensor easily from the case to provide easy cleaning and replacement if it breaks. This meant that fasteners were necessary, even though they are not optimal in a hygienic design. Using fasteners was considered unavoidable, and therefore was there an attempt to use as few fasteners as possible.

The inability to avoid fasteners leads to that the cover could not be 100% leakproof, meaning that fluid could enter the case. This could lead to a build-up of liquid in the cover, leading to damage to the sensor. To avoid this, it is necessary to have some type of opening in the bottom of the cover, so that liquid can leave. It was therefore decided that a completely leak-proof design should not be considered for further development.

[2] Delivered by Sick AG

The current solution does also have a protecting case. It can not be used due to that the measurements are not correct, and that there are pockets to put each respective sensor in. The current design can therefore not be used.

The development process started with a module approach. Different design choice ideas were brainstormed and written down in Table 5, with the purpose of then considering different combinations of the modules, leading to several possible ideas.

The concepts were weighted against each other, and afterwards it was decided whether continuing the development of the design choice should be considered.

With **fastened side**, it is meant what side of the cover should be connected to the bracket.

The **insertion side** is where there should be an opening for the sensor to be inserted in. This choice determines where the removable part should be.

Cover fastening refers to where the fasteners connected to the cover should be placed. The alternatives are between having the fasteners on the inside of the case, or outside.

With **stabilisation**, it is meant how to make the sensor stable in the case. The suggestions are to make use of the tracks in the sensor, and either use screws/bolts to keep it in place or shape the case.

Table 5 Summarising different design alternatives/options. Advantages, disadvantages, and whether the choice should be discarded or not were concluded.

Alternative	*Advantages*	*Disadvantages*	*Continue?*
Fastened side			
1. Wide side	Easier stabilisation	Current bracket needs to be adjusted	Yes
2. Short side	Less changes to the current bracket	Less stable	Yes
Body			
2. Welded plates	Less spacious	Harder manufacturing. Less hygienic edges	Yes
3. Pipes	Easier manufacturing More hygienic edges	More spacious	Yes
Insertion side			
4. Top	Less cracks.	Spacious while inserting. Hard to clean.	No
5. Bottom	Less cracks.	Spacious while inserting. Hard to clean. Harder to insert.	Yes
6. Wide side	Easy to clean.	More cracks.	Yes
7. Short side	Less cracks.	Slightly hard to clean.	Yes
Cover fastening			
8. Inside	Convenient.	Might scratch sensor	No
9. Outside	-	More complicate to implement	Yes
Stabilisation			
10. Screws/Bolts	Can be combined with fastening the cover parts to each other	Might scratch the sensor. Leaking can occur.	Yes
11. Shaping	No external parts required	Difficult to implement	No

5.3.1.1 Concept A

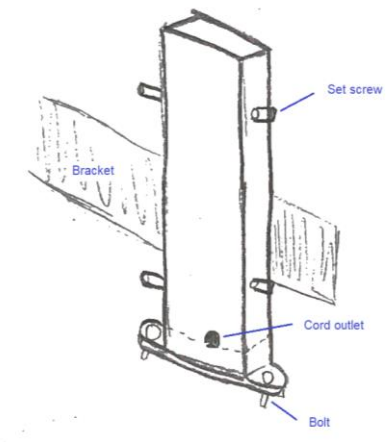

Figure 5 Basic sketch of concept A.

A rectangular pipe is used as the body, where the sensor is inserted from underneath. The advantage of inserting on that side compared to the top of the pipe is that the gaps which occur down there can also act as a drainage. After the insertion, the bottom is sealed with a bottom lid, which is fastened with two bolts. A hole for the cord is placed on the pipe, to enable a smaller hole to be needed. If the hole was placed on the bottom lid, it would require a bigger diameter, so that the whole cord could pass through it. By putting the hole on the pipe, the possibility to make a hole with the diameter of the thinnest parts of the cord is enabled, since the cord can be placed in it while the bottom is open.

The sensor is stabilized with the help of two set screws, which each goes into each track in the sensor.

5.3.1.2 Concept B

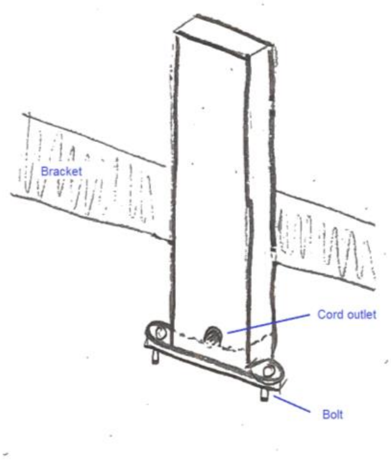

Figure 6 Basic sketch of concept B.

This concept is the same as concept A, with the exception that four plates are welded together to form a pipe, instead of using a standardised pipe. The purpose of this is to make the cover tighter, which leads to that less space is taken up by the construction. The tightness also leads to that no set screws are needed to stabilize the sensor, since the cover could be tight enough to stop movement.

5.3.1.3 Concept C

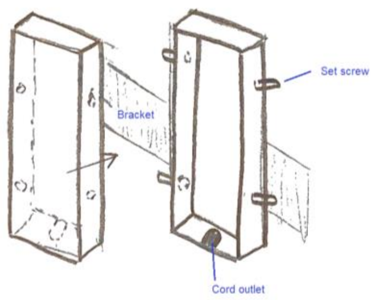

Figure 7 Basic sketch of concept C.

Two ”boxes” made of welded plates are screwed together to form a compact metal box. The wide side of the box is fastened to the bracket with two screws on the inside, which allows a narrower or smaller design of the cover, compared to the two previous concepts. The other wide side is the insertion side. The boxes are fastened together with set screws on the side, which also act as stabilizers of the sensor, in the same way as in concepts A and B. The hole for the cord is placed in the bottom here as well, for drainage purposes. Thanks to a track in both of the box pieces, the hole is not bigger than the thinner part of the cord.

5.3.1.4 Concept D

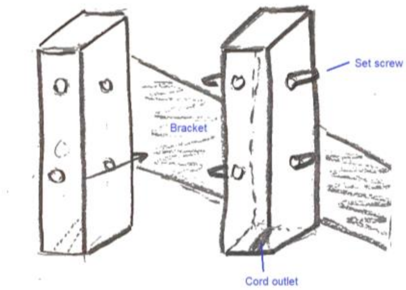

Figure 8 Basic sketch of concept D.

This concept is principally constructed in the same way as concept C, with the choice of fastened side to the bracket as the main difference. The sensor is stabilized by making the cover tight enough to hold the sensor up without any set screws. The sensor is inserted on the narrower side of the box, which does not allow set screws in the convenient tracks on the sides of the sensor. Screws are placed on the wide sides to fasten the boxes together.

5.3.2 Bracket

The aim was to create a design that was both inspired by the current solutions in the machines, and to make a simple but functional one. The dimensioning includes taking the size of the cover into consideration, and ensuring that the sensor can be placed at the right distance from the tube no matter the sizing. The design should therefore include mechanics to allow adjustments of the distance.

The design of the bracket cannot be made until the cover design has been decided, because it is heavily dependent on it. For example, if holes for bolts are needed to fasten the cover, they cannot be placed until the bolt size and placement are made.

It is therefore assumed in this section that it is already known that concept A was selected, to be able to put all concept generating in the same section, for report structure reasons.

As the design of the bracket is heavily dependent on the final layout of the cover, concepts could not be developed until a cover concept had been chosen.

TFA bracket

Concept E

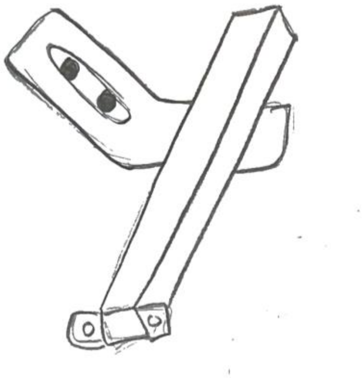

Figure 9 Basic sketch of concept E.

The bracket is welded to the sensor, works with one elongated hole, and is bent. It is connected to the machine by the bolts that are already placed there, through the elongated hole. The advantages are that the welding reduces the need for fasteners, which improves the hygiene, and that bending is a cheap process compared to welding and angle to the plate. The disadvantage is that it is harder to insert and take out the construction, because it is bulky.

Concept F

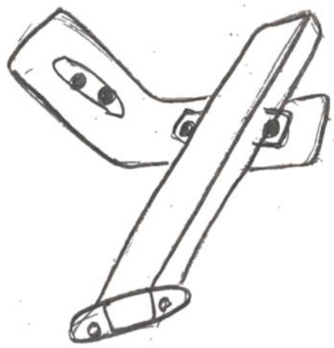

Figure 10 Basic sketch of concept F.

The same concept as concept E, but the cover is bolted on the bracket instead of welded, with the help of ears that are welded to the sides of the cover. The advantage of doing this is that the insertion and removal of the cover are easier because the case is less spacious. The disadvantage is that it is less hygienic to use fasteners, and it could take a longer time to insert it since more screwing has to be performed.

TCA bracket

Concept G

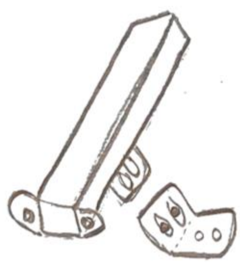

Figure 11 Basic sketch of concept G.

A plate with two elongated holes is welded directly on the cover. It is connected to a bent plate, also with two elongated holes with two bolts. The bent plate is bolted two the machine in a place where the current solution already is bolted.

The advantages are that the construction is stable thanks to the parallel holes, and that the distance between the sensor and the float can be extended more with the same hole size compared to if one elongated hole is used with two bolts. The disadvantage is that it will be bulkier compared to a solution with only one elongated hole, and that more material is required.

Concept H

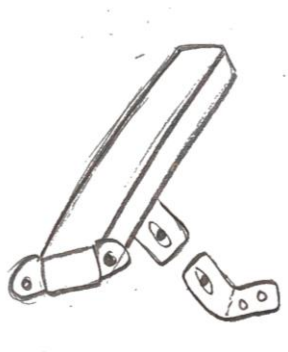

Figure 12 Basic sketch of concept H.

The same as concept H, but there is only one elongated hole on the respective plate. The advantage of this concept is that the construction is neater and requires less material. The disadvantages are that it cannot be as elongated as concept H, and that it will be less stable.

5.3.3 Material choices

As mentioned before, Tetra Pak has a collection of corporate standard components. It was decided that material choices should be made from what is available. It was important to keep weldability in consideration, as only metal parts made of the same material can be welded together.

The materials could not be chosen until the concept was selected. The choice of material is described in the “Concept selection” segment.

6 Concept selection

This section shows the process of selecting the final concept, by using the methods presented by Ulrich and Eppinger.

6.1 Cover

To select one of the four concepts, a concept-scoring matrix was used. There are different approaches when constructing one. Since some attributes are far more important than others, it was decided to use a weighted matrix accordingly to "Pugh concept selection", which Ulrich and Eppinger suggest. The attributes were chosen from the list of needs, to increase the chance of getting a suitable solution. The resulting matrix is shown in Table 6.

In the matrix, the different wanted properties of the product are listed. Each property is given a weight depending on the importance between 1 and 10, where 10 is the highest. The different concepts are lined up, and are given a rating between 1 and 10, just as the weighting. The rating and weight are then multiplied to create a weighted score for each property in each concept. The scores are then added together in every concept. The concept with the highest sum is then selected.

In addition to using the concept-scoring matrix, the different concepts were discussed with employees at the company.

Table 6 Concept scoring matrix. Concepts have been scored depending on how well they fulfill needs, which have been given an importance grade. Each attribute was given a rating between 1 to 10, where 10 is the highest. The weighted score was calculated by multiplying the rating and the weight.

		Concept A		Concept B		Concept C		Concept D	
Selection Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Hygiene	10	8	80	9	90	4	40	4	40
Anti-leakage	8	6	48	8	64	6	48	6	48
Drainage	9	7	63	7	63	7	63	7	63
Manufacturing	8	9	72	5	40	3	24	3	24
Appearance	2	5	10	3	6	3	6	2	4
Stability	7	8	56	8	56	8	56	8	56
Total	-	-	329		319		237		235

Concept A got the highest score, with Concept B close to the same result. Concept C and D were far behind and were therefore rejected. The biggest reason why the concepts got similar points is that they are similar to each other, with only details being different, for example using a pipe compared to forming a fitted pipe. Also because distinct criteria for the design were not stated apart from it being hygienic. It led to difficulties giving weights and grades to the different selection criteria, which may have caused misleading results.

The major advantage concept A has compared to B is that the manufacturing would be less expensive, as less welding is required. The surfaces would also be smoother because of the same reason, which increases hygiene, which is the most important factor. Concept B's major advantage is that no set screws are needed, which decreases the risk of bacteria build up where the screws otherwise would be located, and cleaning detergent in contact with the sensor.

After discussions, the conclusion was that concept A is more suitable, as the cover will not be in direct contact with the food and are the consequences of bacteria build-up and the risk of damaging the sensor not exceptionally severe. After making measurements of both of the machines, it was discovered that the MPA sensor with a detection range of 395 mm should be selected, and the case length should therefore be adapted after it.

6.2 Bracket

6.2.1 TFA machine

Concept F was chosen even though it is less hygienic, because it was considered more important to be able to insert it in the crowded space more easily than with concept E. A picture can be found in the results.

6.2.2 TCA machine

Concept G was chosen, because the sensor needed to be able to move within a bigger range. With the design, it was not possible to move concept H far away and close enough to the tube, because of the placement of the part of the machine the sensor was planned to be connected to. A picture can be found in the results.

6.3 Material

The rectangular tube is only available in one material, which is SS 2333-02. As said in the research segment, this is a hygienic material used in several food industries. All components were needed to be made of this material, since they cannot be welded together otherwise. The parts that are not welded were also chosen to be in this material, to ease logistics and manufacturing, which lowers production costs.

7 Concept prototyping and testing

This section describes the process of testing the sensor and the setup, which were tested with different methods.

7.1 Testing the sensor

7.1.1 Magnetic field test

Firstly, a test of the magnetic field from the float was needed to be tested to know what distance the sensor should have from the tube, and how the MPA sensor should be calibrated. To work precisely, the MPA sensor needs to detect a magnetic field strength between 2 mT and 15 mT. [25]

Because of the positions of the magnets inside the float, the magnetic field needed to be analysed both when the float is rotated so that the distance between a magnet and the sensor is the highest, and lowest.

For the analysis, an MPS-G sensor developed by Sick was used, which gives an output of the magnetic field strength in mT. The sensor was connected through an I/O link to a computer, and the results were read through the program “Sopas”.

The sensor was placed at the height of the magnets in the float using a stand. A checkered paper with square sizes of 2,5 mm was taped on a table, to allow a simple measurement of the float’s placement. The float was first put on a 0 mm distance from the sensor. The magnetic flux density was read and noted, both when the float was rotated in its ideal and unideal position. The float was then moved 2,5 mm away from the sensor, and the process was repeated until no magnetic field was detected.

The test result can be shown in the section “Magnetic field test”, and shows that an appropriate distance between the outer edge of a float and the sensor is between 5 and 12,5 mm if the sensor used is calibrated to its standard.

The longest distance between the float edge and tube is 11,9 mm, and the smallest is 3,8 mm, meaning that calibrations to the sensor are needed to give satisfactory results.

7.1.2 Angle impact test

The float was moved from the left side to the right at every test.

Due to that the filling tube can oscillate during filling, the distance between the sensor and float can vary. It was therefore interesting to see how the measurement was affected when the float was moving with an angle.

The test was executed by fastening an MPA sensor with a length of 467 mm to a wooden plank. The MPA sensor was not the same as that was intended to be used in the final solution. As seen in Figure 13, a float was placed on a rod with an adjustable height on two sides. The MPA sensor was connected to a computer through an I/O link, and the program “Sopas” showed the position of the magnetic float. Different configurations of the height adjustments were made while moving the sensor to see the output of the position through the program connected to the sensor. The float was moved from the left side to the right at every test.

Figure 13 Setup for the angle impact test. The MPA sensor is mounted on the wooden plank, and the grey I/O link is placed in front of the plank.

It was discovered that the detecting distance varied depending on if the float was risen from the sensor, or to the sensor. The range was larger when it was lifted from the sensor, which meant that it was difficult to get clear results of how the pipe could oscillate without losing contact. Once the contact is lost, the results showed that the float was required to get closer to the sensor, compared to the losing point.

Testing the sensor properly would require a more advanced setup, to get more exact measurements of especially the heights, therefore should the results from this test be seen as a pre-study of how the results would be in an actual environment.

Due to the construction, it was not possible to test the whole range of the MPA sensor. Therefore, it has been made from 35 mm to 439 mm.

It was also calculated how the measurements are affected by the angle since it decreases the measuring range, and therefore worsens the resolution. Both the actual worsening of the resolution and the maximum angle allowed to stay within the required resolution were calculated through trigonometry formulas.

7.1.3 Testing in the TFA filling machine

The sensor was mounted in the machine, to see how satisfying the mechanical properties were, and to see how the connection between the float and sensor worked in the real environment. Because Sopas does not provide graphs of the detection, the focus was on seeing if the contact between the two components was lost, and in that case how often.

7.2 Prototyping and testing the setup

The two constructions were modelled in Creo, and with the help of existing models of the TFA and TCA machines, suitable dimensions could be set for them. Most importantly, it was checked how long the sensors could be, and if any components were in the way. The mechanics could also be tested, to see if the calculations of the elongated holes lengths were correct. Final adjustments of the lengths during this part of testing.

After the models were done, technical drawings were made. Because only corporate standard components were used during the design process, the drawings could be sent to one of the company's workshops for production.

Due to that the pipe was not available in the storage, a pipe of the same size was formed by bending stainless steel plates and welding them together.

After forming the pipe, all parts were laser cut. Later, the parts were welded together, and the threaded holes were made. The sensor was inserted, and all screws were fastened. Thanks to that the construction was designed so that current parts in the machine could be benefited, it was possible to set up the result in the machine.

The prototype was used to see if the correct dimensions were implemented, and if any information in the drawings were incorrect or unclear. It was both checked how well the sensor fit, to see how pleasing the stability was, and if the mechanics of the bracket worked properly when inserted in the machine. It was also beneficial to see how the sturdiness felt, and if any parts needed to be thicker.

8 Results

Presentation of the final concept, including drawings and material choices. The test results and manufacturing process are shown as well.

8.1 CAD model

8.1.1 TFA

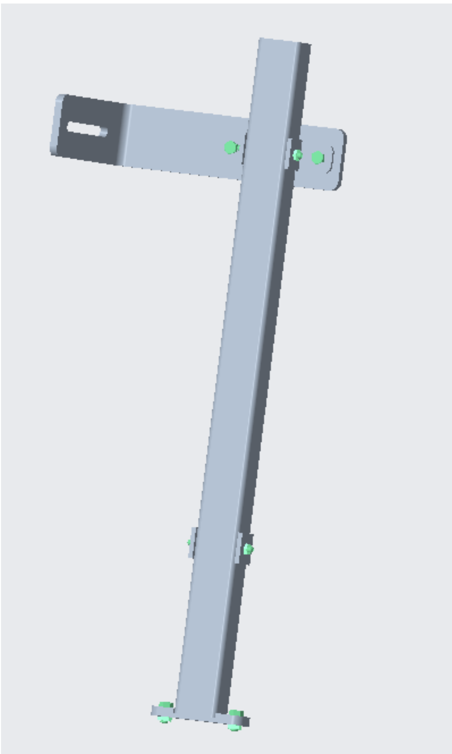

Figure 14 Screenshot of the TFA bracket assembly in Creo.

8.1.2 TCA

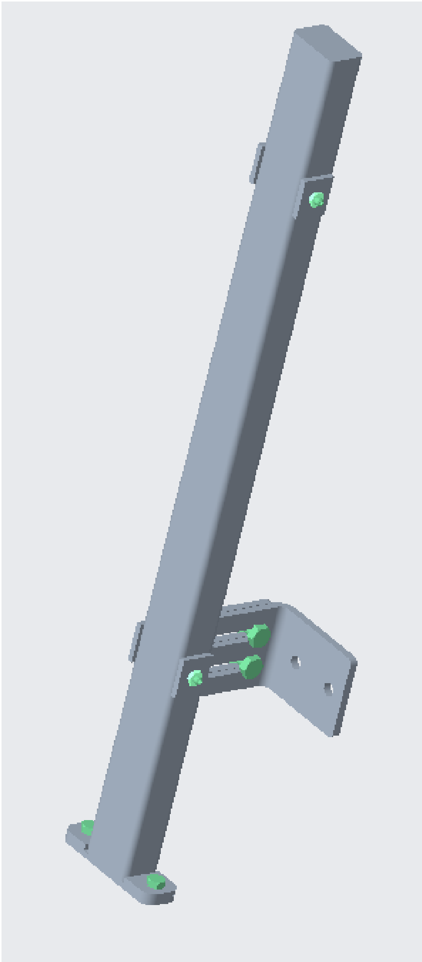

Figure 15 Screenshot of the TCA bracket assembly in Creo.

8.2 Technical drawings

8.2.1 TFA

The technical drawings can be seen in Appendix A. The appendix includes part drawings, weld drawings, and assembly drawings made according to Tetra Pak standards.

8.2.2 TCA

The technical drawings can be seen in Appendix A. The appendix includes part drawings, weld drawings, and assembly drawings made according to Tetra Pak standards. Only drawings that are not common between TFA and TCA are shown.

8.3 TFA Prototype

The prototype has been produced with the method described in 7.2.

Figure 16 The prototype of the setup in the TFA machine.

8.4 Magnetic field test

Table 7 Result from the investigation of the appropriate sensor distance from the float. Distance refers to the distance between the sensor used, and the outer edge of the float. The table also shows whether the flux density was within the range proposed by the sensor's manual.

Distance [mm]	***Magnetic flux density, optimal angle [mT]***	***Magnetic flux density, inferior angle [mT]***	***Within range***
0	20,6	18,0	No
2,5	17,8	12,4	No
5,0	10,6	7,3	Yes
7,5	6,5	4,9	Yes
10,0	4,3	3,7	Yes
12,5	2,7	2,3	Yes
15,0	2,1	1,9	No
17,5	1,4	1,4	No
20,0	1,3	1,3	No
30,0	0,6	0,6	No
40,0	0,4	0,4	No
50,0	0,4	0,4	No

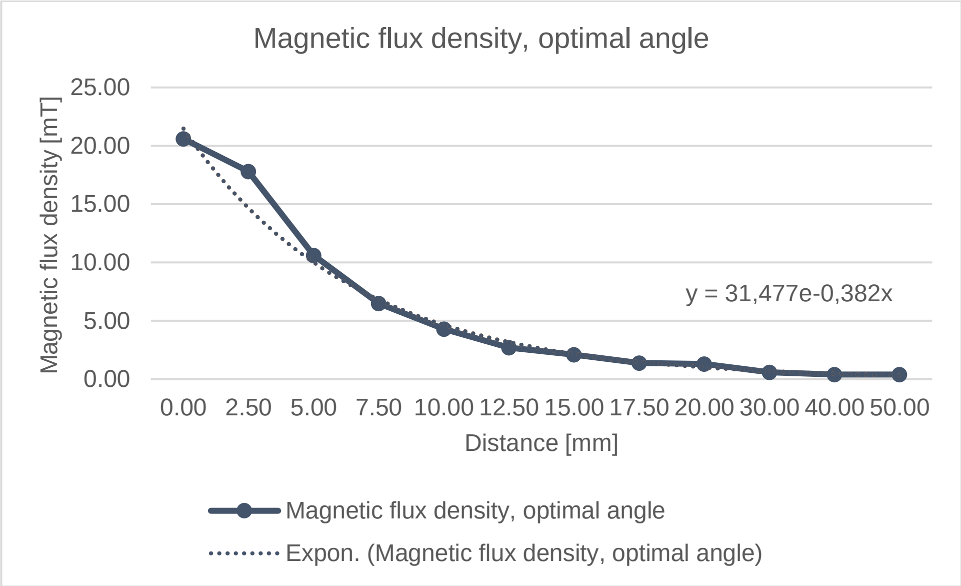

Figure 17 Test result from measuring the magnetic flux density of a sensor from different distances. The measurements have been done when the float is at its optimal angle. The continuous line represents the actual outcome, and the dotted line is the exponential trend line, with a belonging equation.

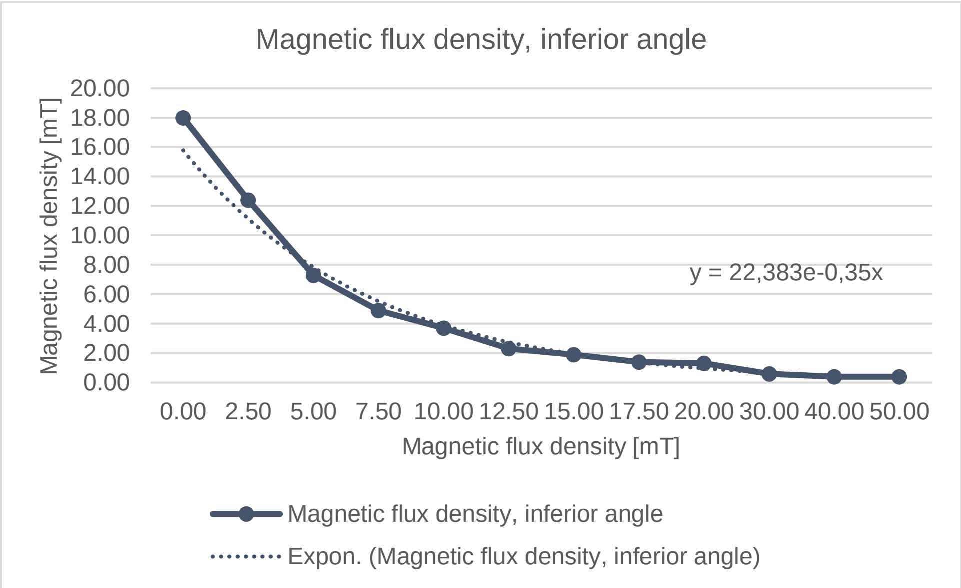

Figure 18 Test result from measuring the magnetic flux density of a sensor from different distances. The measurements have been done when the float is at its inferior angle. The continuous line represents the actual outcome, and the dotted line is the exponential trend line, with a belonging equation.

8.5 Angle impact test

The measurement where the float has been lowered from above has been marked with “*”.

The “Angle” column refers to the angle the bar had compared to the sensor, which visualised the filling pipe at oscillation compared to its normal vertical position. “Height” refers to the height distance between the sensor and the float, which represents the distance between the filling pipe and the sensor.

“Max detection height” is the highest height where the sensor still detects the position of the float, when the float is raised away from the sensor (apart from the value marked with “*”). “Range” shows which measuring range the sensor had at a bar’s specific angle.

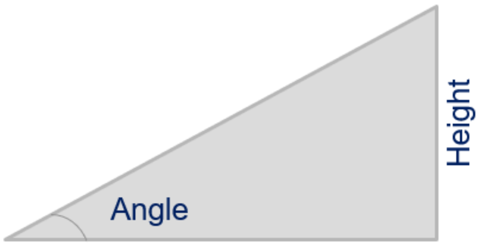

Figure 19 Explanation of the headlines in the angle impact test results.

Table 8.8 Summary of the angle impact test, where finding maximum allowed height and angle was in focus.

Angle [°]	*Height [mm]*	*Max detection height [mm]*	*Range [mm]*
0	0	0	35-439
0*	5*	5*	35-439*
0	16	16	35-439
1,30	10	10	35-439
2,6	20	15,40	35-338
3,26	25	15,83	35-278

8.5.1 Properties at maximum theoretical angle

The measurement resolution requirement is fulfilled when the detected position is at maximum ±1 mm incorrect. The bottom line represents the vertical measuring range along the sensor. The triangle with a bottom length of 395 mm represents the measuring range when the filling pipe and sensor are parallel. The angle is 0 in this case.

The smaller triangle with a bottom length of 394 represents the measurement range when the filling pipe has an angle compared to the sensor, and the measurement range therefore is shortened. The length of 394 has been chosen since only an error of 1 mm is allowed. The height is then 28,09 mm and the angle is 4,078° according to the calculations below.

$$cos(angle) = \frac{394}{395} \Rightarrow angle = 4{,}078° \tag{8.1}$$

$$sin(4{,}0778) = \frac{height}{395} \Rightarrow height = 28{,}09 \tag{8.2}$$

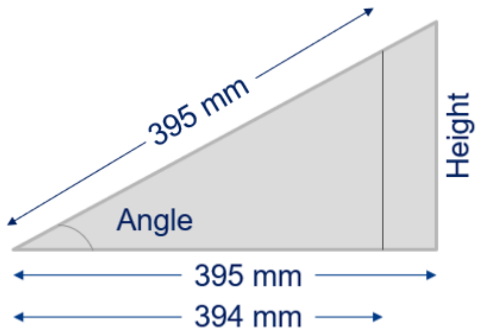

Figure 20 Visualisation of the calculation.

8.5.2 Resolution error at maximum detection angle

The maximum distance the sensor and float could have without losing contact was previously found to be 16 mm. In this test, it was investigated how great the measurement error would be if the angle between the filling pipe and sensor was long enough to cause a 16 mm distance between the end of the sensor, and the pipe. The error would be 0,32 mm.

$$sin(angle) = \frac{16}{395} \Rightarrow angle = 2{,}32° \tag{8.3}$$

$$cos\,2{,}32° = \frac{length}{395} \Rightarrow length = 394{,}68 \tag{8.4}$$

$$395 - 394{,}68 = 0{,}32 \tag{8.5}$$

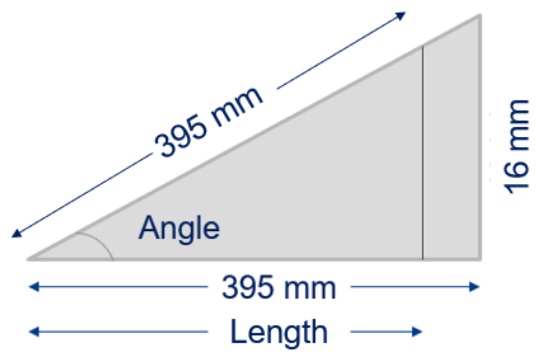

Figure 21 Visualisation of the calculation.

8.6 Testing in the TFA filling machine

The prototype was mounted to the filling machine successfully. The dimensions were correct, it was easy to fasten it, and it was stable. It was also possible to adjust the distance between the sensor and the tube easily.
Contact between the sensor and the float was not lost at any point.

8.7 Manufacturing process

The pipes can be made in different ways. The imported pipes are produced by cold forming and welding metal strips.

The used plates are produced by cold rolling and are treated with grinding afterwards.

The technical drawings can be converted into DXF files, which are then used to laser cut the parts made of plates with high precision. This is executed on all parts except the pipe and the fasteners. The cutting is set so that the edges are blunt. The need for fillets is thereby reduced.

After the cuttings are done, the brackets can be bent by using standard tools.

The welding is performed according to ISO 5817-C and 141- ISO 4063, according to Tetra Pak standards.

After the welding is done, the threads holding the sensor in place are made.

Surface treatment is performed according to YK 01/-- B 2118.32, according to Tetra Pak standards.

After these steps are the parts ready to be assembled. The sensor is first fastened with set screws, then is the bottom lid fastened with bolts and nuts. The construction is then fastened to the machine, also with bolts and nuts. If the bracket has two parallel elongated holes, one bolt is inserted in the respective hole. If it only has one, two bolts are inserted to achieve stability.

9 Discussion and Conclusions

Discussion about how the product could be developed further, advantages and disadvantages.

9.1 Design choices

Mainly, the goal was to achieve a design that fulfils the legal requirements of the food industry. It was also aimed to follow the hygienic design theory described in the research section as far as possible.

All the components are grinded, which makes the wish for smooth surfaces fulfilled. The surface finish will lead to that the cleaning will be easier to perform, and the results are more satisfactory.

A radius of 3 mm minimum, but ideally at least 6 mm was considered during designing, and was implemented where it was considered possible. All the four ears have a radius of 6 mm, and the two bracket holders have edges of the same radius. The pipe has a radius of 3 mm, which also fulfils the demand. There are several sharp corners left on the designs. It was decided that they should remain due to that the mechanics would be less stable. Also, because the components are very thin, there is a risk that the edges become too thin, leading to breakage.

It was decided that fasteners should be used, even though it could lead to “dead areas” that cannot be cleaned. It was considered necessary since there was a need to be able to remove the sensor if needed, which would be hard to do otherwise. The sensor also needed to be stabilised in some way, and using set screws was considered the simplest and cheapest way of doing this. To minimise dead areas, only the holes for the set screws were threaded.

It was determined to use nuts at all holes to both minimise leakage into the bracket, but also to avoid the need to thread them, as the force of them is enough to keep the construction stable.

The components that were not needed to be disassembled were welded together, to allow smooth edges and avoid “dead areas”.

There was an attempt to make a design with as few unique parts as possible. The plates stabilising the ears were also used to thicken the walls where the set screws were placed, to give more stability. It would have been possible to use the same design for both the upper ears and the bottom ears, but it would mean that the bottom ears would be more spacious than necessary. It was therefore considered that it was more meaningful to use different designs to avoid this.

The pipe's dimensions are significantly larger than necessary, although it was the smallest suitable size available in the corporate standard library. Other alternatives could have been to order a pipe with more suitable dimensions from an external company, or to bend and weld plates together. Potentially, if the dimensions were optimised in one of those ways, there would be no need for set screws, and the construction could be designed completely leak-proof. It was still decided to use the standard pipe, thus it would likely be less costly and more profitable.

9.2 Test results

9.2.1 Prototypes

The outcome of the physical prototype corresponded to the expectations, with some minor flaws. Two of the welds at the bottom ears were missing, which indicates that the technical drawings should have been clearer. The parts could be assembled easily, and everything was stable, which means that proper dimensions had been chosen.

9.2.2 Magnetic field test

The test was difficult to perform with high precision, since the tested distances were diminutive, and proper equipment for handling it was not available, therefore should the result only be seen as an indication of the proper distances between the sensor and the float. Regardless, the graphs show that the result follows an exponential line well, which means that the results most likely are reliable.

For the A1 machine, several different floats are used, all with different strengths. This test only shows the proper distances for one of them, and it would be beneficial to test the suitable distances for all of them. Though, as the magnet properties are known, it is possible to calculate the suitable theoretical distances.

9.2.3 Angle impact test

By looking at the results, it is clear that the results are affected more by the distance between the float and the sensor, than the angle. The resolution error calculations show that when the maximum distance is applied, the error is only 0,32 mm. This means that the problem with oscillation is the risk of the sensor losing contact with the float, and not the measuring error itself. This is especially since the oscillation can occur in all directions.

The “properties at maximum theoretical angle” calculations tell us that the filling pipe can have an angle of circa 4°, which is a distance of circa 28 mm at the bottom of the sensor. This is further proof that the inclination will not give an imprecise resolution, as the sensor cannot detect the float from that distance. If the sensor is recalibrated, this test should be executed again.

The test showed that the sensor delivers reliable numbers even when it is closer to the float than it is meant to, which is favourable since there is a risk that the sensor gets placed too close to the float without noticing.

The previous test showed that the distance between the components should be between 5 mm and 12,5 mm, to work optimally. This test showed that the distance should be maximum 5 mm, or 16 mm depending on how the sensing starts. The test results do not match, which indicates that errors have occurred.

9.2.4 Testing in the TFA filling machine

The test showed that the suitable dimensions had been implemented and that it is possible to use the design in further development. It also showed that it was easy to replace the current solution with this new one, thanks to that it has been adapted to the holes that are already in place.

The sensor did not lose contact with the float at any point, which shows that the sensor works well in the environment and is not disturbed by the metal in the case, or any parts in the machine. Correct numbers of the position were given as well, with strengthens this statement. The accuracy was determined through a comparison between the given digital number, and using a ruler on the machine.

9.3 Fulfilment of needs and requirements

In this section, the listed needs and requirements are evaluated one by one, to discuss how well they were fulfilled and why. They are divided into the same categories as in the lists.

9.3.1 Measurements

9.3.1.1 Surrounding factors do not affect the result.

Thanks to the choice of level measurement method, the surrounding environment does not affect the result. The sensor does only detect magnetic objects present within a small distance. It has been placed at a distance from other components, and the setup does not affect the results since non-magnetic materials have been used. During the mounting test, it was shown that the sensor does not detect anything but the float. The need is therefore fulfilled.

9.3.1.2 All products can be measured regardless of the viscosity.

Just like with the current solution, it is not possible to do level measurements on high-viscosity products, as the float cannot work properly in those fluids. To achieve this, the method should not include a float. The new solution still works on the previously measured products, so the need is not fulfilled, but it is not worse than before.

9.3.1.3 No sensor calibration is needed depending on the measured product.

Thanks to the sensor choice, this is not needed. The only calibration needed is to detect the lowest and highest location of the float, to provide outputs interpretable by the influx system. The requirement is fulfilled.

9.3.1.4 The precision is better than ± 5 mm. Ideally ± 1 mm.

The sensor has a resolution of 0,06 mm and a linearity error of 0,6 mm, meaning that it fulfils the requirement. As shown in the angle impact test, the sensor could have an angle of 4,0778° and still have a precision within ± 1 mm mathematically, if the sensor was able to measure from a distance of 28 mm. With the current calibration, the sensor can have an angle of 2,32 without losing contact with the float, and then have a measurement error of 0,3241, which is within the wished resolution. The requirement is fulfilled.

9.3.1.5 The measuring range should be wider than today's width of 180 mm. Preferably the range of the whole tube, 800 mm.

It was decided that the case and sensor should fit in both the TFA and TCA machines, which meant that the sensor was shorter than necessary in the TFA machine. The measuring range has increased to 395 mm, but can be modified easily and be elongated to a maximum length of 1007 mm. The requirement is fulfilled but could be improved.

9.3.2 Hygiene

9.3.2.1 The setup is not in contact with the product.

Developing a method that does not require a float, or any parts in contact with the product was concluded to be unmanageable within this type of project, because of the limited space and due to that the filling pipe is surrounded by moving material. The non-contact sensors found during benchmarking required the surroundings of the product to be static. As a float still is used for this solution, the need is unfulfilled.

9.3.2.1.1 Cleaning according to CIP (cleaning in place) is possible.

The sensor is not needed to be removed to clean the construction according to CIP. The inside is not reachable during cleaning, but it does not need to be cleaned regularly since it is not in direct contact with the product. The requirement is fulfilled but could be improved by making the construction completely tight.

9.3.2.1.2 The materials in contact with the product area complied with regulations regarding food safety and hygiene.

Apart from the sensor itself, only materials approved in the customers' countries have been used. Stainless steel with great food hygiene properties has been used, including the fasteners. The sensor is, as mentioned before, protected, and should not cause harm, although this should be tested properly in the future. The requirement is fulfilled.

9.3.3 Design

9.3.3.1.1 The solution is developed according to the rules of hygienic design.

The rules have been followed to a large extent, for example by adding fillets with desirable measurements, avoiding tracks and cracks, aiming for smooth surfaces, and avoiding sharp edges. There was an attempt to reduce the number of fasteners because they cause “dead areas”, but the use of them were unavoidable in this project. As mentioned before, it would be highly beneficial if the case was completely tight, and it would lead to a higher fulfilment of this need, but the solution is perceived to be acceptable.

9.3.3.1.2 The solution does not deteriorate in the environment.

Only stainless steel with good hygienic properties have been used for the construction. The biggest risk is that the sensor is exposed to too much cleaning detergent. The risk has not been investigated, so this cannot be discussed. Apart from that, the requirement is fulfilled.

9.3.3.2 The setup is stable and will not move if a worker accidentally bumps it.

The bracket is stable and will not move if this occurs. There is a risk that the cover and sensor will move slightly if this happens, as it is only fastened in one spot. Though, it is placed where it is difficult to accidentally reach it with a high force, so the need is considered as fulfilled.

9.3.3.3 The solution is safe for people working around the machine.

The sensing does not include any radiation, laser beams, or high noises, and will therefore not harm the workers. The construction does not have any sharp edges, thanks to the design choices and manufacturing methods, so the risk of harming skin is low. It is placed inside the machine, so the risk of bumping into it is non-existing. The requirement is fulfilled.

9.3.3.4 Splashing is minimised & The cleaning detergent is not sprayed directly on the sensor.

Thanks to the cover, splashing cannot occur directly on the sensor. The sensor type’s results are not affected by non-magnetic substances. The use of a cover also includes the need that the spray should not be sprayed directly on the sensor. The requirements are fulfilled. Splashing was also minimised by deciding to keep the float, as the gadget blocks product from splashing upwards.

9.3.3.5 The product is aesthetically pleasing.

The material, shapes, and component choices correspond to what are currently used in the machines. Therefore, the new components do not stand out, which is aesthetically pleasing enough for its purpose. The need is fulfilled.

9.3.3.6 A sensor case should either be completely leakproof or have drainage.

It was decided that the case would have a drainage, the hole where the cord protrudes also acts as a drainage, which means that the need has been fulfilled. It should be tested whether more drainages are needed or not, to see if this requirement is fulfilled satisfactorily.

9.3.3.7 It is possible to adjust the distance between the sensor and the tube.

The use of elongated holes allows the sensor to be moved with simple mechanics. The sensor can be moved both vertically and horizontally, which allows adjustments both depending on tube size and how high up the level detection should occur. The requirement is fulfilled.

9.4 Advantages and disadvantages of the solution

9.4.1 Advantages

The solution delivers high precision which was the most wanted attribute. The precision leads to that the influx can be smoother and more precise. The smoother influx could lead to less oscillation of the float because lower forces are affecting it, which also improves the accuracy.

By using a magnet to detect the product level, the risk of disturbance from other components is reduced, compared to if a sensor that detects any metal parts would be used. Thanks to this, other components do not need to be modified or moved to achieve a great result. The usage of magnets also leads to that the cover could be made in stainless steel, since it does not affect the result if the steel is non-magnetic. The possibility to use stainless steel leads to that the design being strong, sturdy, and hygienic. If no metal material could be used for the cover, it would be more complicated to find a suitable solution, since it is difficult to find materials that fulfil all requirements.

The design of the cover and bracket is simple, and only consists of standardized parts available at Tetra Pak. This is advantageous because it lowers costs and guarantees that only materials approved in a hygienic environment are used. It lowers costs because less time is spent on assembling the parts together, and the parts do not need to be ordered from an external company, which can be expensive when it is a low-quantity order.

The sensor can be replaced by simply unscrewing the lid, and putting the new one in, as the solution is not electronically advanced for the customer to use. If the solution consisted of several sensors, just like the current one, more time would need to be spent to replace it.

It is relatively easy to adjust the solution to run in other machines. It means that labour costs are reduced, since time on designing and building the construction can be shortened thanks to that there are sketches and routines ready to use.

The case is not designed with the intention to be completely leak-proof. It reduces the risk of build-up of product inside the cover, which lowers the risk that the sensor deteriorates.

The new solution most likely has a similar or lower price than the current one. This is because the current one has a device that converts the signals from every sensor to signals comprehensible to the influx system, while this sensor sends correct signals immediately. It also only consists of one sensor, compared to 16 separate ones, which means that it likely costs more, and requires more service time, because they are harder to replace if they break.

9.4.2 Disadvantages

The solution still requires a float, which is one of the greatest disadvantages. The same floats that already are in use can still be utilized, which means that procedures for keeping the float clean do not need to change, but a removal of the float would lead to higher hygiene standards, since components in direct contact with food risk contaminating it. It would also lead to lower costs, both because the production of the float is not needed anymore, and because time and detergent do not have to be spent on cleaning the float, which leads to lower labour and material costs.

Due to the influx, the float is sometimes placed oscillating underneath the product surface, leading to inaccurate signals to the sensor, which causes a faulty product flow. Since the same floats still are utilized in the new solution, the problem still maintains, but in a lower occurrence than before, which is explained in the advantages section.

As mentioned in the research section, the machines at Tetra Pak are designed so that components do not need to be disassembled to accomplish a thorough cleaning. If the need for a float is eliminated, it leads to that the goal of not needing to disassemble machines is achieved further.

The sensor is originally not adapted to be used in a hygienic environment, which was the reason for the development of the cover. The need for a cover leads to that there are more surfaces where bacteria can grow, and therefore are do more surfaces need to be cleaned, which increases costs. The wire outside of the cover needs to be adapted especially for Tetra Pak for the same reasons, which has higher costs consequently. It would be more optimal if a sensor already adapted for that environment would be used.

Because the cover is not completely tight, there is a risk that both product and strong cleaning detergents get inside the cover. Since the cover will not be disassembled every cleaning, there is a risk that bacteria grow inside the cover, and in the areas that cannot be reached during cleaning, especially where the screws are placed. There is also a risk that the sensor gets damaged over time, which is a health hazard for the previously mentioned reasons. It also leads to higher costs and dissatisfied customers, since it means that the sensor needs to be replaced more frequently than the current solution.

All A1 machines look different, which means that if the whole filling tube range should be measured, adaptations for the setup must be made for every machine. Even the length of the sensor may require adaptations. A unique design for every machine is costly and time-consuming, even though the adaptations are simple thanks to that the sensor has a similar form to the current solution.

Because of the sensor’s length and sensitivity to distance from the float, it can be difficult to adjust the distance from the tube properly, leading to a decreased precision and perhaps even lost contact between the sensor and float. The disconnection could lead to an incorrect inflow of product into the tube, leading to that packages need to be discarded. This has both negative environmental, economic, and customer satisfaction consequences.

9.5 Further development

If the company decides to take this project further, the major next step is to connect the sensor to the influx system and reprogram it. The sensor should also be calibrated so that it works optimally in the machine, and perhaps be able to work from a further distance from the float. As mentioned in the disadvantage section, the wire needs to be redesigned because the material is not suitable in a hygienic environment for a longer period of time.

As mentioned before, the bracket for the cover needs to be adapted for every machine. It could be worth investigating a solution where the positioning of the sensor can be made in a way that works for all machines and is independent of the placement of the current solution. It would most likely decrease costs, because the parts could be mass-produced more effectively, and only one design is needed to be developed.

It could also be researched if there is a better side of the tube to place the sensor on. The sides chosen for this project were decided due to that they were the only ones where components were not blocking the sensor, and a base for the attachment of the sensor was already placed there. It could be investigated whether it is possible to move the other components or not, to give space for the new sensor.

As it could be challenging to place the sensor at the correct distance from the tube with only one bracket, a second bracket could be implemented to stabilize the sensor. The implementation would lead to additional costs, but increase customer satisfaction, which could be profitable.

A relevant investigation would be to study how the sensor is affected by the cleaning detergent during longer periods of time, to see what the risk of leakage could lead to. Potential build-ups in the areas that are more difficult to reach during cleaning should also be a part of a further development process since hygiene is one of the most important factors to take into consideration.

The filling pipe oscillates sideways while running the machine. The movement leads to that the distance from the sensor varies, which could affect the result. It would be relevant to study how great this oscillation is, to calculate the appropriate distance the sensor more accurately should be placed on, and to see if a calibration of the sensor is necessary, to achieve fulfilling results.

The current solution utilizes LED lamps to show the level of the float. It gives customers an easy way of seeing if the level detection lives up to their standard. It is worth investigating if it is worth the extra cost of implementing this, to achieve a higher customer satisfaction, even though it is possible to see the positioning is correct in other ways.

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Project plan and outcome

There arose major changes between the project plan and the actual outcome. Benchmarking became included in “Research”, as it did not become an actual activity. The research activity was prolonged because the problem was more complex than anticipated, and different types of sensing techniques were therefore needed to be further.

Identifying needs was executed during several meetings with different people. It therefore took longer time than anticipated. New needs emerged when the sensor was chosen.

The concept generation activity was delayed due to that the need identification activity was prolonged.

Concept evaluation and selecting were emerged to one activity and was delayed because of other delays.

Defining a product activity was considered unnecessary, and it was therefore not performed.

The testing phase was shorter than expected, and it could be performed earlier than expected since most parts were ready. The mounting test was performed later due to the waiting time at the workshop.

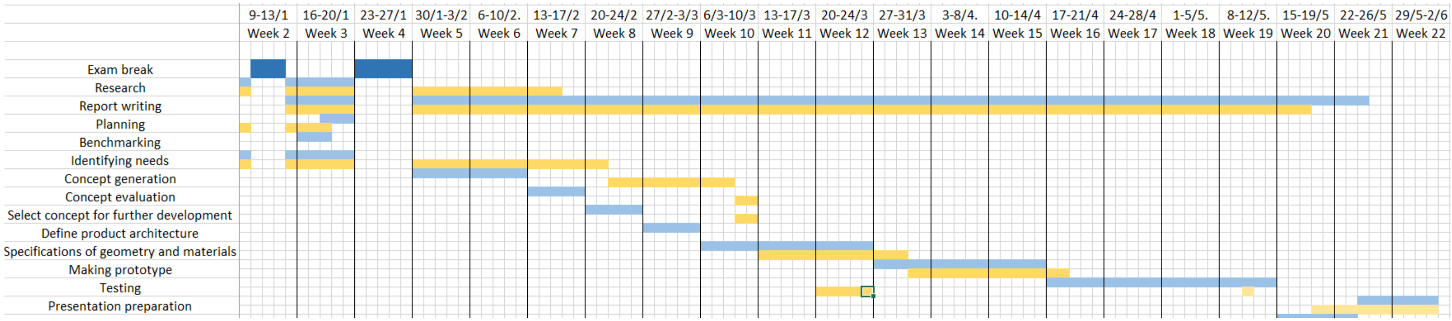

Figure A.4 Planned and performed activities. Planned activities are marked with blue, and the actual outcome with yellow.

Appendix A Technical Drawings

Technical drawings of the brackets for the TFA and TCA machines. The TCA drawings have been limited to the parts that are unique for that machine.

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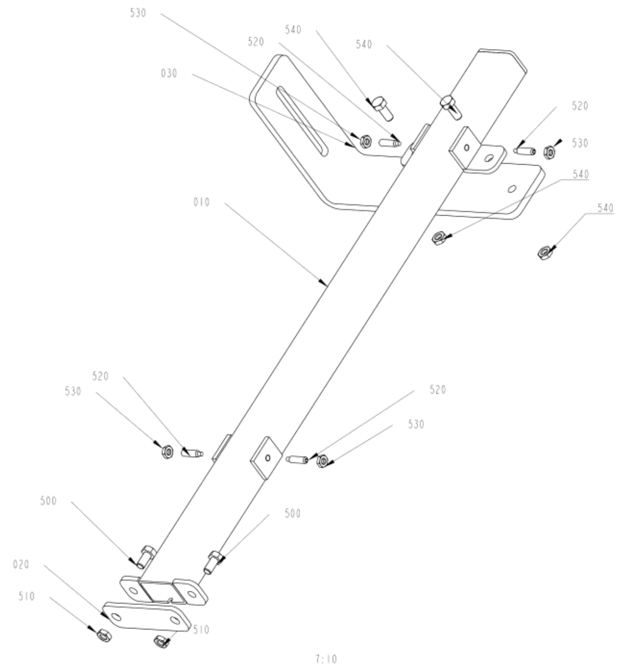
A.1.1 TFA Drawings

Bill of Material for 3774847-0101						
Pos No	Model Name	Identity	Rev	Description	Qty.	Units
010	3772578	3772578	.0+	COVER	1	
020	3772622	3772622	.0+	BOTTOM LID	1	
030	3779073	3779073	.0+	BRACKET	1	
500	312105-0325	312105-0325	4.4	SCREW ISO 4017 M5X10	2	
510	312625-0314	312625-0314	1.16	HEX.NUT ISO 4035 M5	4	
520	344324-0293	344324-0293	1.1	Set screw ISO 4028 M4X16	4	
530	312625-0312	312625-0312	1.16	HEX.NUT ISO 4035 M4	4	
540	312105-0327	312105-0327	4.3	SCREW ISO 4017 M5X12	2	



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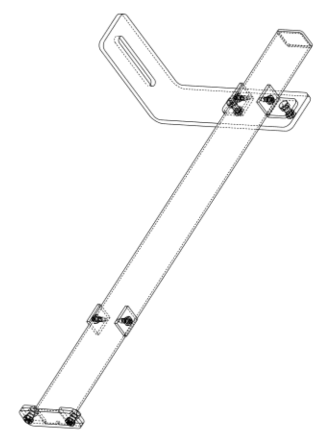
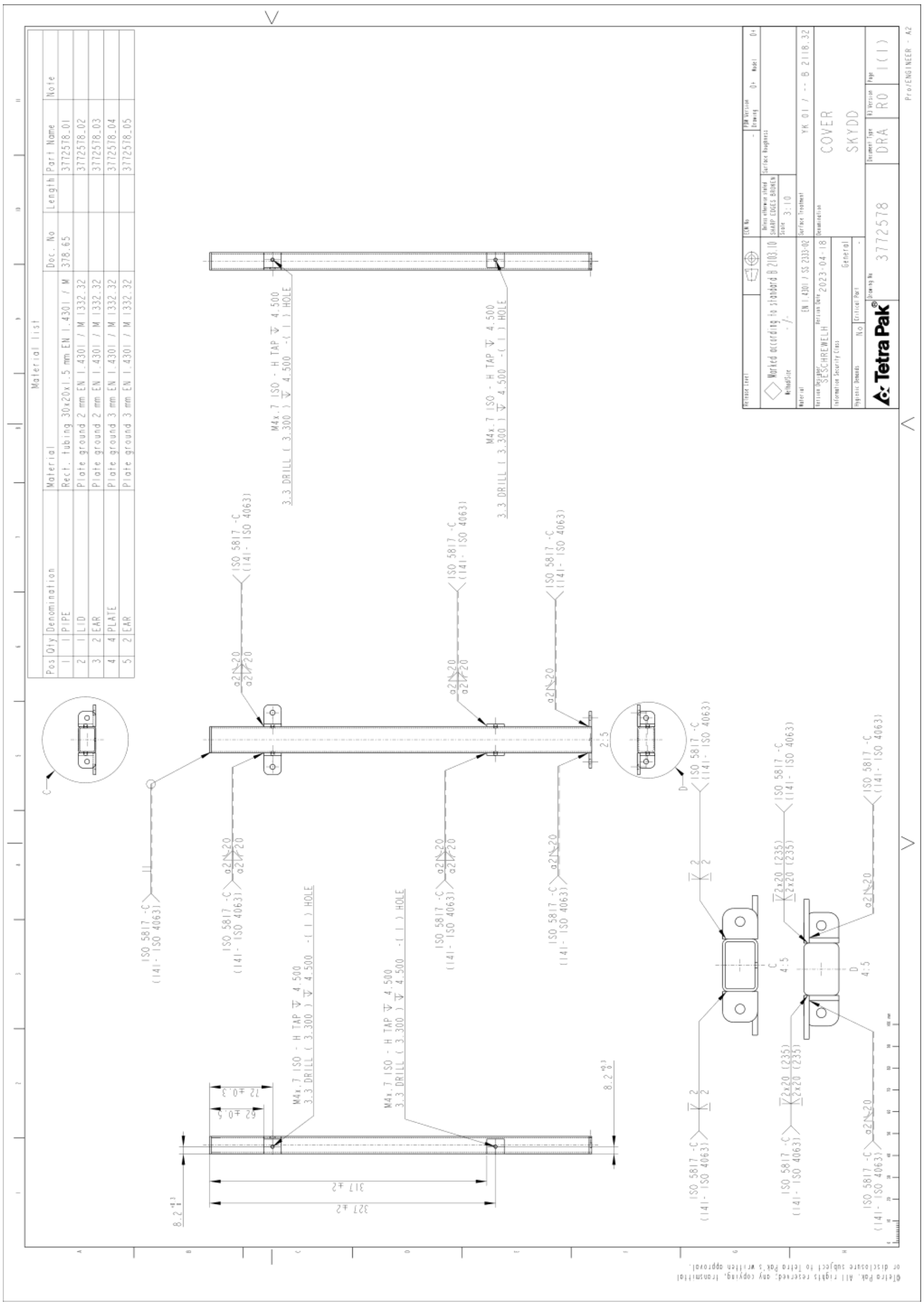


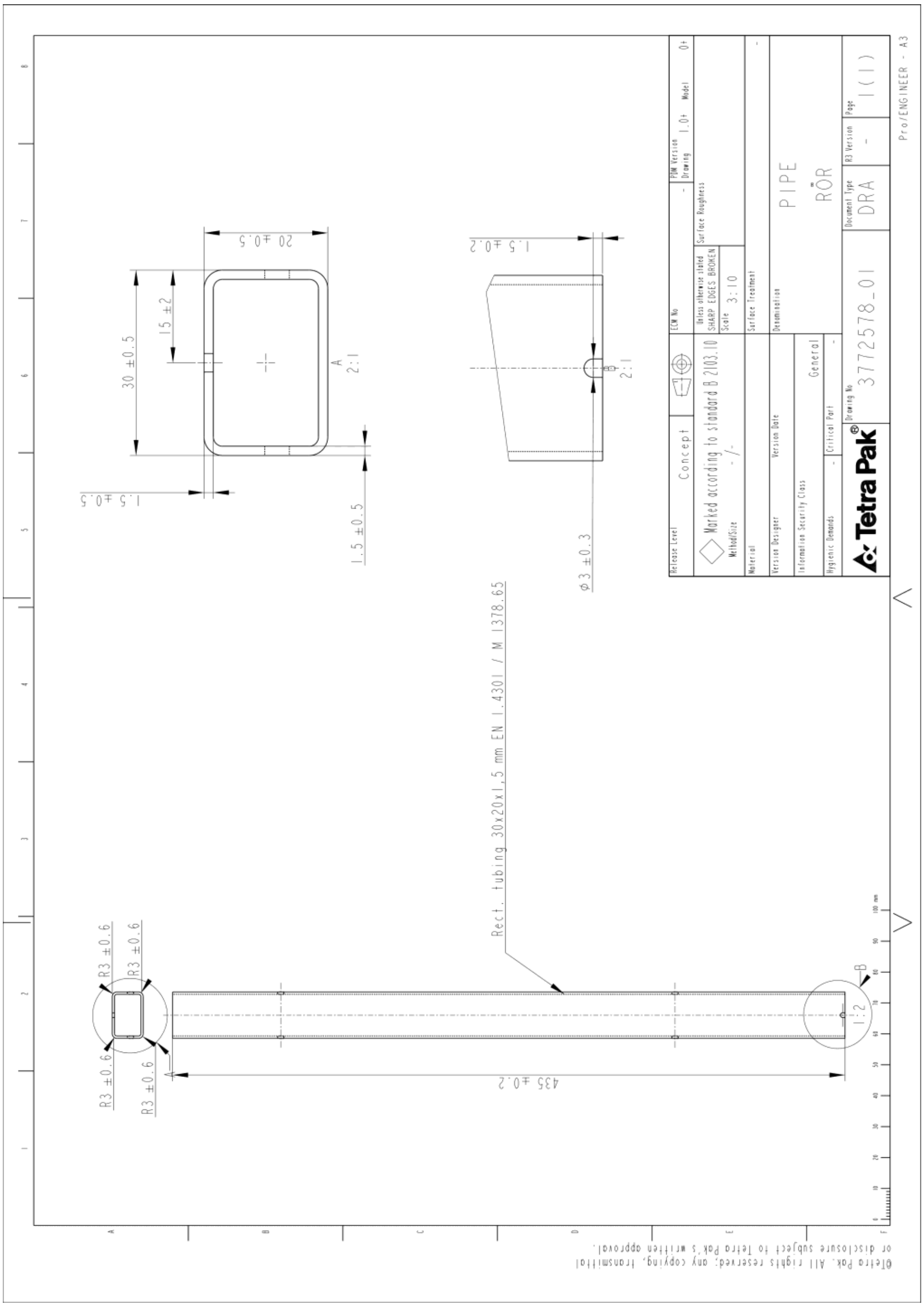
1:2

Release Level: Concept
Version Designer: -
Version Date: -
Information Security Class: -
ECM No: -
PDM Version: Drawing 1.0+ Model 0+
Denomination: - -
Tetra Pak®
Drawing No: 3774847-1
Document Type: ASS
R3 Version: -
Page: 1(1)

Pro/ENGINEER - AA2



Pos	Qty	Denomination	Material	Doc. No	Length	Part Name	Note
1	1	PIPE	Rect. tubing 30x20x1.5 mm EN 1.4301 / M	378.65		3772578_01	
2	1	LID	Plate ground 2 mm EN 1.4301 / M 1332.32			3772578_02	
3	2	EAR	Plate ground 2 mm EN 1.4301 / M 1332.32			3772578_03	
4	4	PLATE	Plate ground 3 mm EN 1.4301 / M 1332.32			3772578_04	
5	2	EAR	Plate ground 3 mm EN 1.4301 / M 1332.32			3772578_05	


Rect. tubing 30x20x1.5 mm EN 1.4301 / M 1378.65
435 ±0.2
R3 ±0.6
30 ±0.5
20 ±0.5
15 ±2
1.5 ±0.5
Ø3 ±0.3
1.5 ±0.2
Concept
Marked according to standard B 2103.10
SHARP EDGES BROKEN
Scale 3:10
PIPE
RÖR
DRA
3772578_01
General
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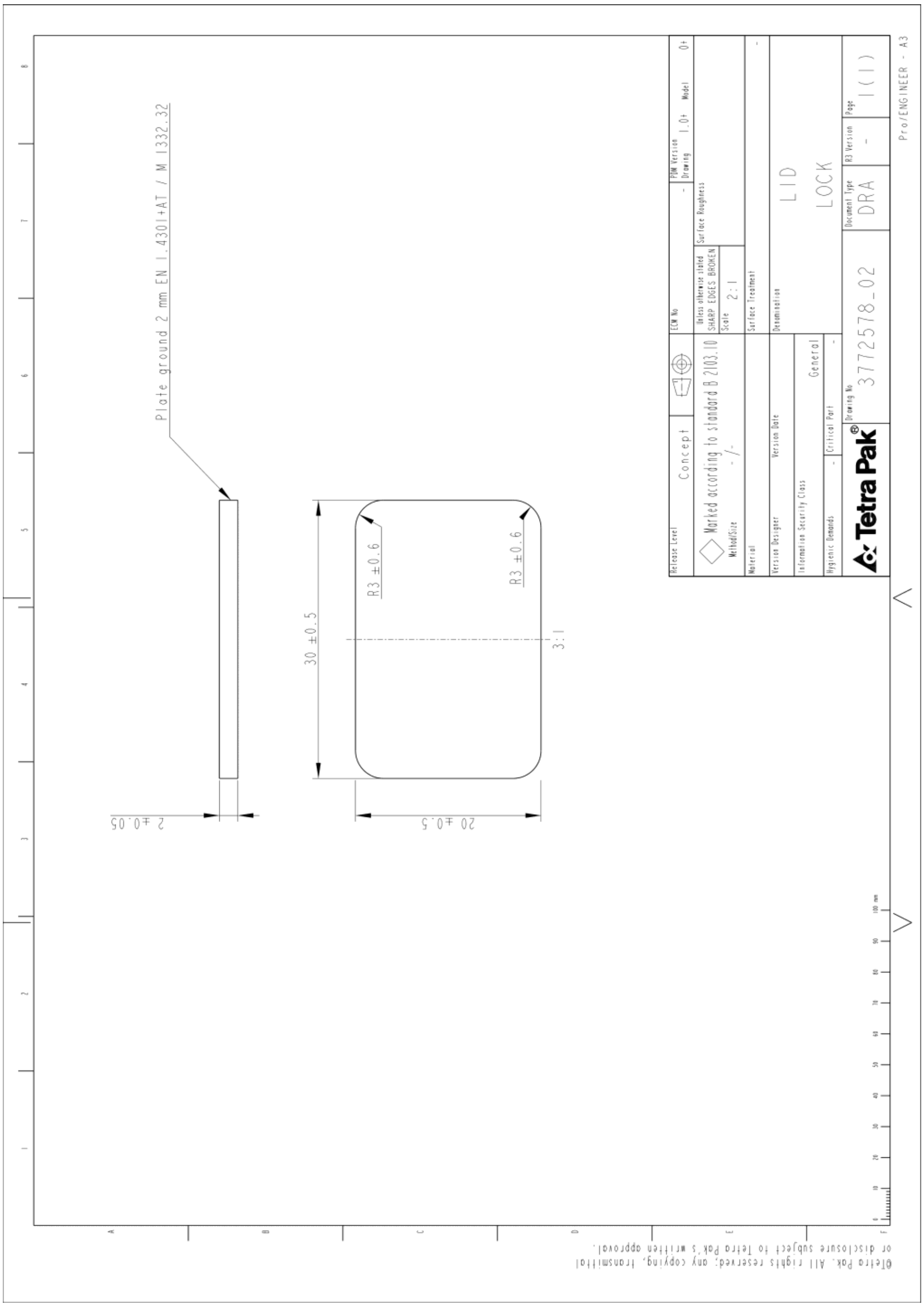
Plate ground 2 mm EN 1.4301+AT / M 1332.32
2 ±0.05
30 ±0.5
20 ±0.5
R3 ±0.6
R3 ±0.6
3:1
Concept
Marked according to standard B 2103.10
Unless otherwise stated SHARP EDGES BROKEN
Scale 2:1
General
LID
LOCK
Tetra Pak
3772578_02
DRA
1(1)
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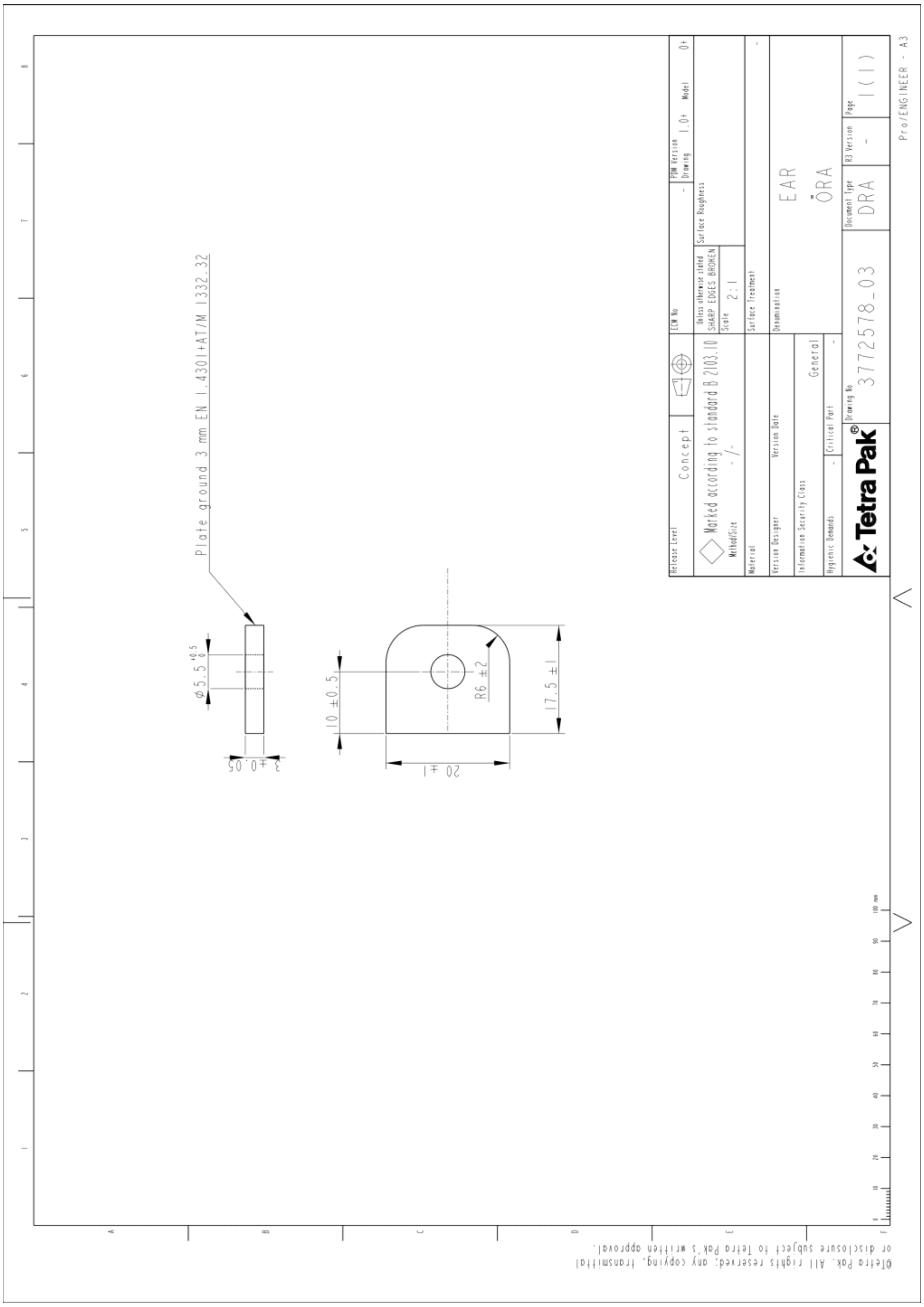
Plate ground 3 mm EN 1.4301+AT/M 1332.32
20 ±1
17.5 ±1
10 ±0.5
R6 ±2
3 +0.05
Concept
Marked according to standard B 2103.10
SHARP EDGES BROKEN
2:1
General
Tetra Pak
3772578_03
EAR
ÖRA
DRA
1(1)
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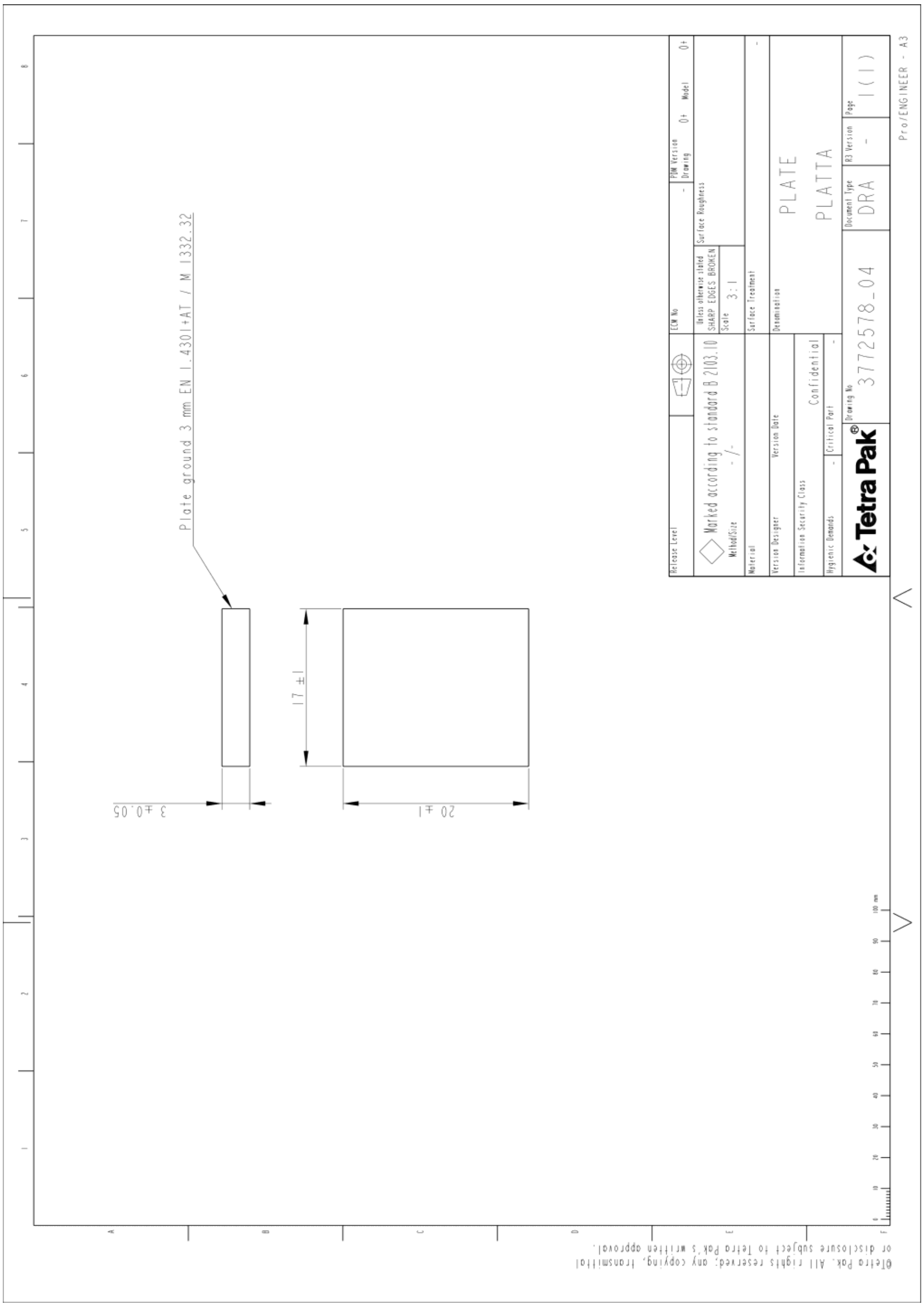
Plate ground 3 mm EN 1.4301+AT / M 1332.32
17 ±1
20 ±1
3 ±0.05
Marked according to standard B 2103.10
SHARP EDGES BROKEN
Scale 3:1
Confidential
PLATE
PLATTA
DRA
3772578_04
1(1)
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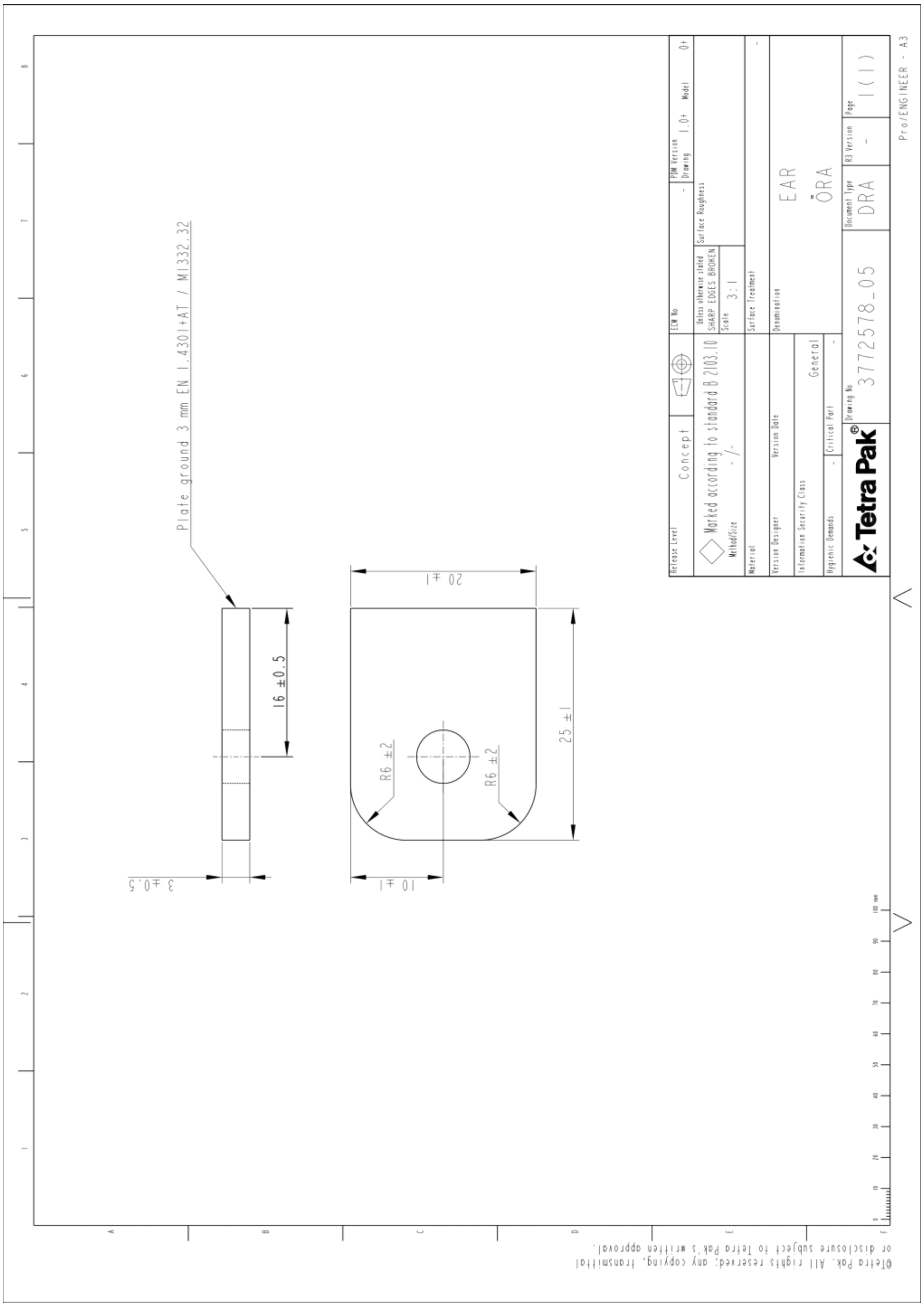
Plate ground 3 mm EN 1.4301+AT / M1332.32
16 ±0.5
20 ±1
25 ±1
R6 ±2
R6 ±2
3 ±0.5
10 ±1
Release Level
Concept
ECM No
PDM Version
Drawing
1.0+
Model
0+
Marked according to standard B 2103.10
Method/Size
Unless otherwise stated
SHARP EDGES BROKEN
Scale
3:1
Surface Roughness
Material
Surface Treatment
Version Designer
Version Date
Denomination
Information Security Class
General
Hygienic Demands
Critical Part
EAR
ÖRA
Drawing No
3772578_05
Document Type
DRA
R3 Version
Page
1(1)
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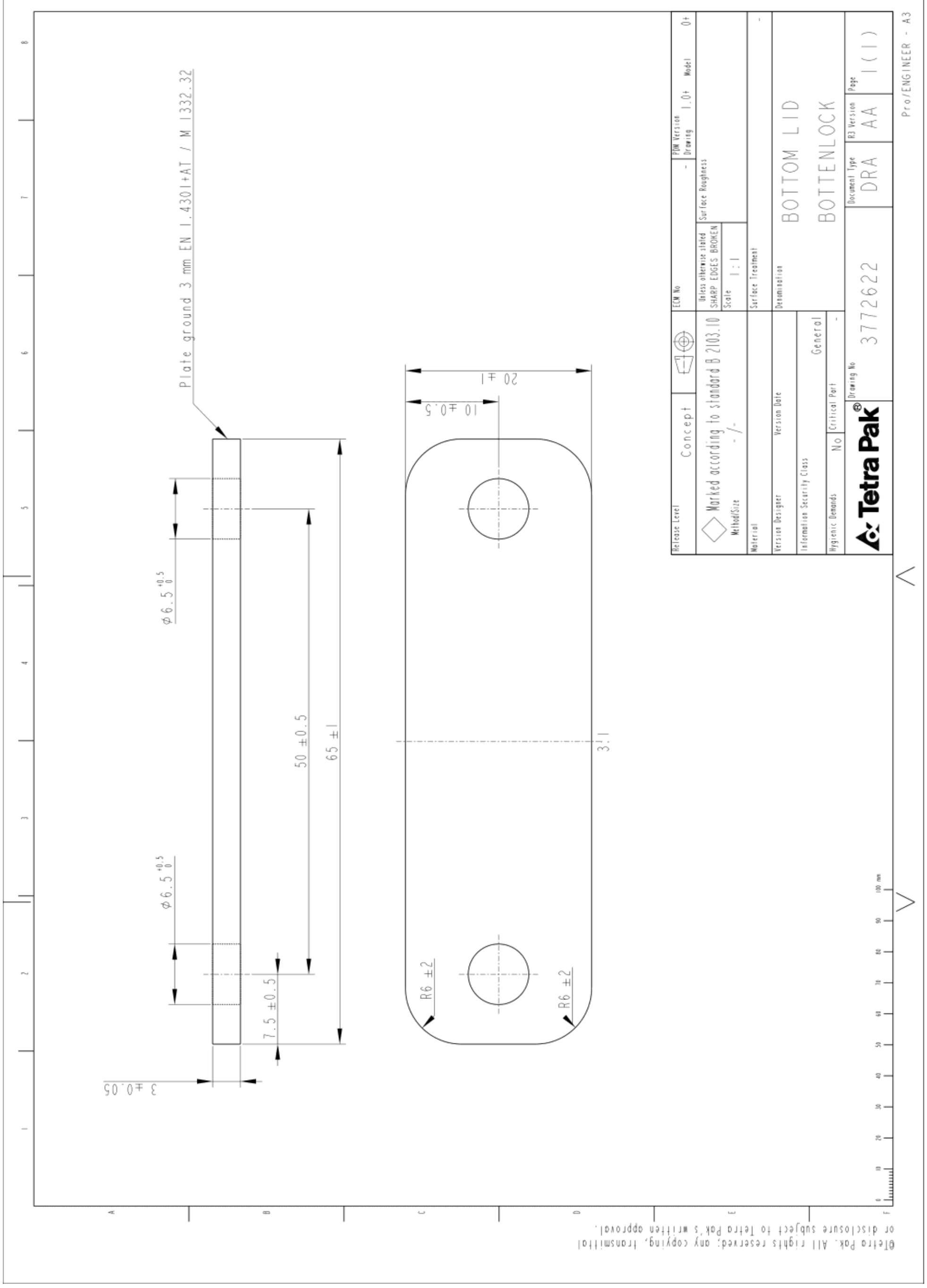
Plate ground 3 mm EN 1.4301+AT / M 1332.32
Ø6.5 +0.5 0
Ø6.5 +0.5 0
50 ±0.5
65 ±1
7.5 ±0.5
3 ±0.05
20 ±1
10 ±0.5
R6 ±2
R6 ±2
Release Level
Concept
Marked according to standard B 2103.10
Unless otherwise stated
SHARP EDGES BROKEN
Scale 1:1
Surface Roughness
Material
Surface Treatment
Denomination
BOTTOM LID
BOTTENLOCK
Version Designer
Version Date
Information Security Class
General
Hygienic Demands
No
Critical Part
Tetra Pak
Drawing No
3772622
Document Type
DRA
R3 Version
AA
Page
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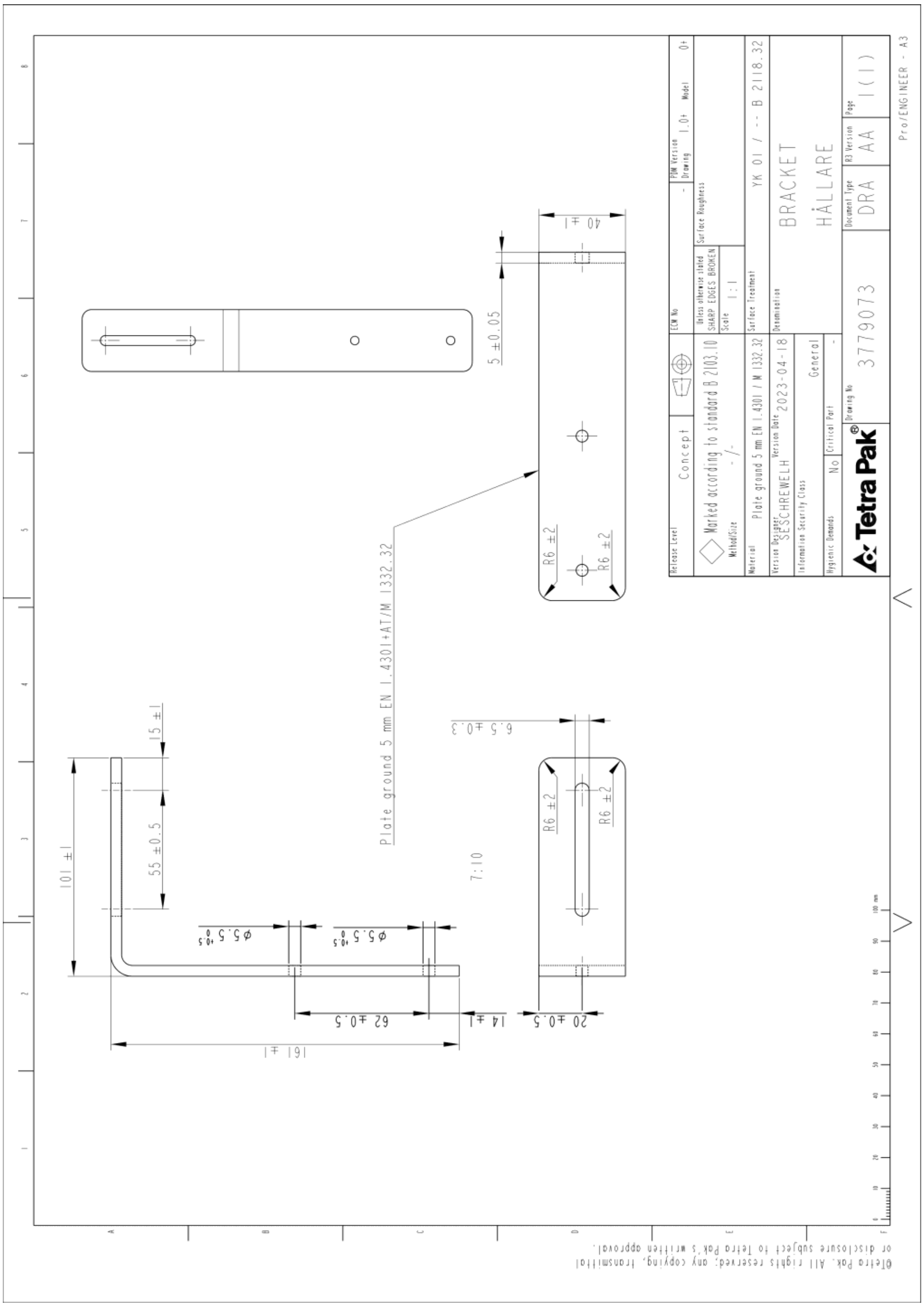
Plate ground 5 mm EN 1.4301+AT/M 1332.32
Concept
Marked according to standard B 2103.10
Plate ground 5 mm EN 1.4301 / M 1332.32
SESCHREWELH
2023-04-18
General
YK 01 / -- B 2118.32
BRACKET
HÅLLARE
3779073
DRA
AA
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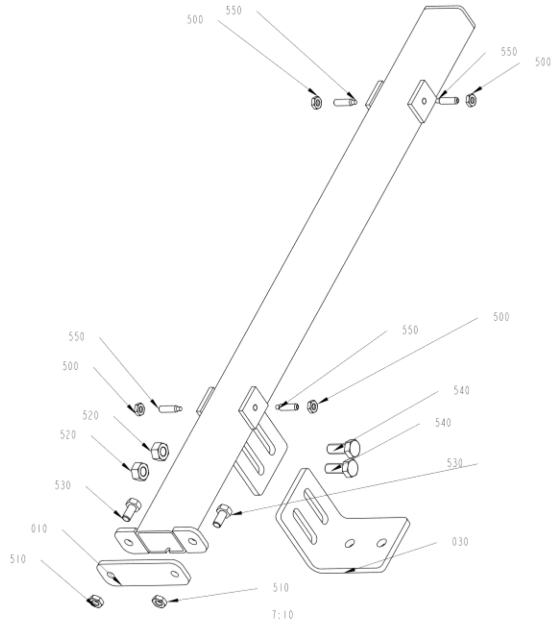
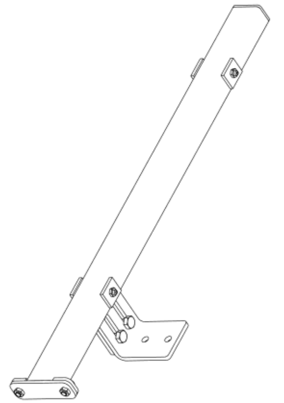
A.1.2 TCA Drawings

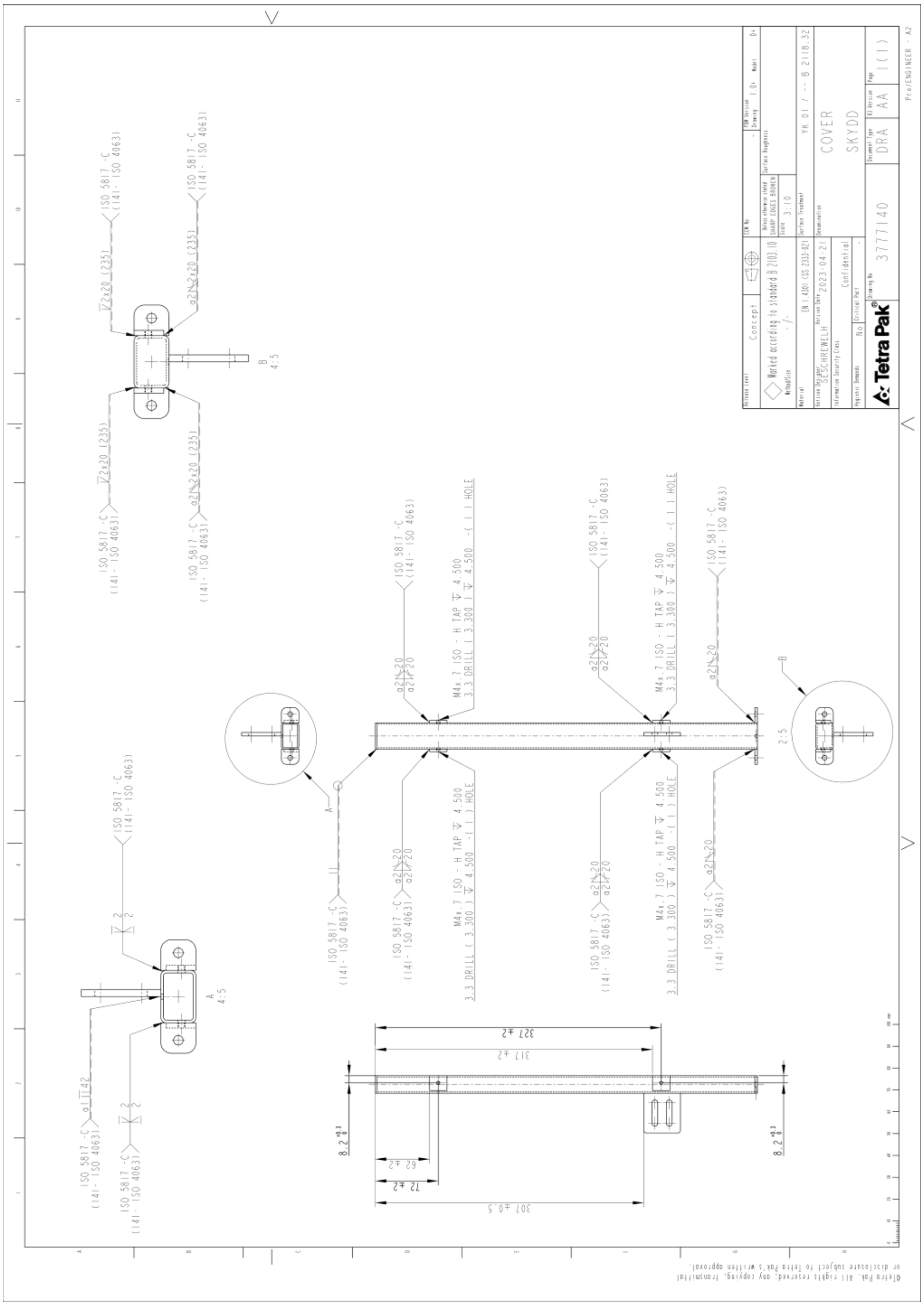
Bill of Material for 3777155-0101						
Pos No	Model Name	Identity	Rev	Description	Qty.	Units
010	3772622	3772622	.0+	BOTTOM LID	1	
020	3777140	3777140	.0+	COVER	1	
030	3778485	3778485	.0+	BRACKET	1	
500	312625-0312	312625-0312	1.16	HEX.NUT ISO 4035 M4	4	
510	312625-0314	312625-0314	1.16	HEX.NUT ISO 4035 M5	2	
520	312607-0316	312607-0316	1.10	HEXAGON NUT A4-M6M-80 M6	2	
530	312105-0325	312105-0325	4.4	SCREW ISO 4017 M5X10	2	
540	312105-0368	312105-0368	4.3	SCREW ISO 4017 M6X16	2	
550	344324-0293	344324-0293	1.1	Set screw ISO 4028 M4X16	4	

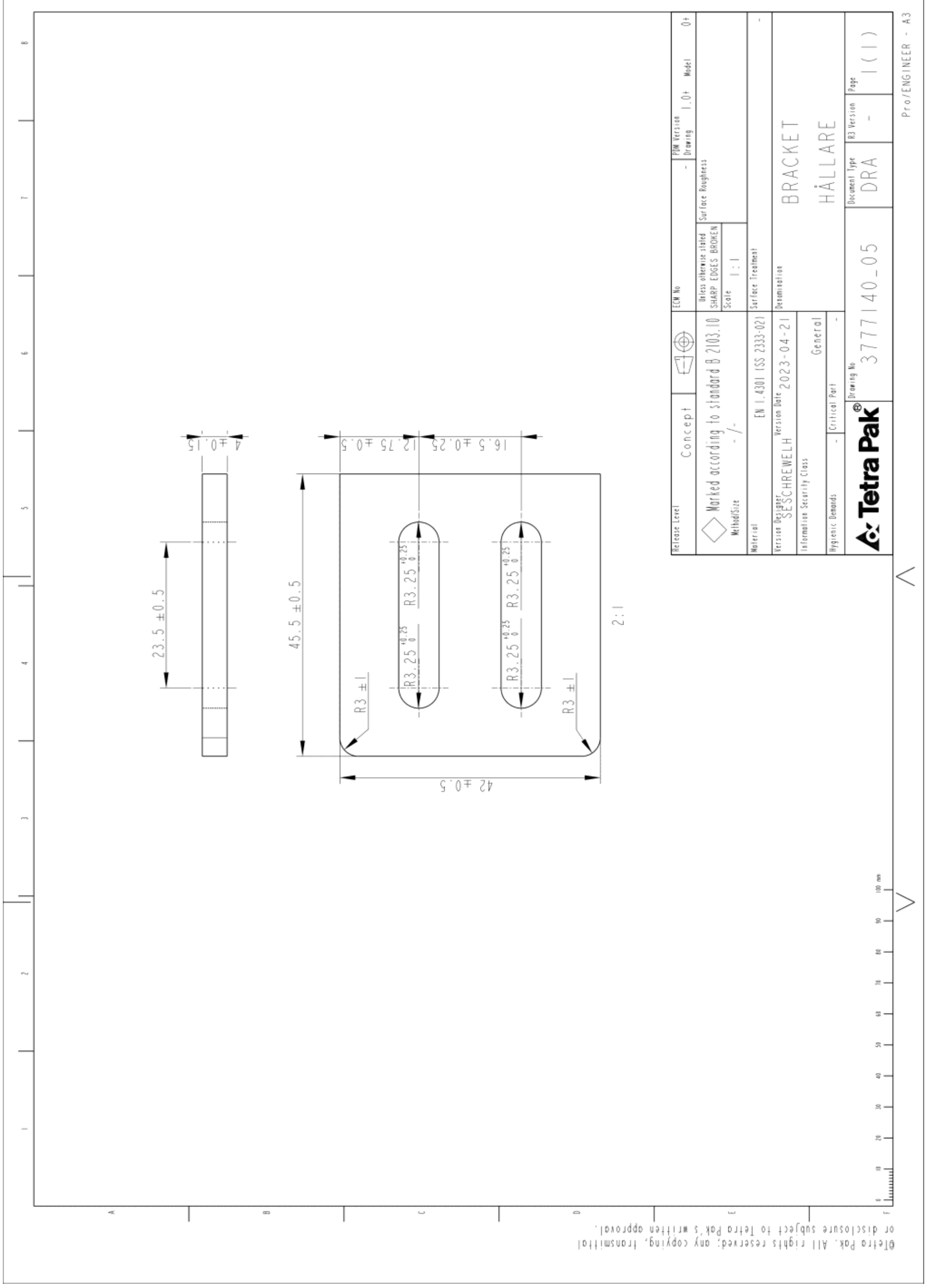




Release Level: Concept
ECN No: -
PDM Version: Drawing 1.0+ Model 0+
Version Designer: SESCHREWELH
Version Date: 2023-04-21
Information Security Class: General
Denomination: BRACKET HÅLLARE
Tetra Pak®
Drawing No: 3777155-1
Document Type: ASS
R3 Version: AA
Page: 1(1)

Pro/ENGINEER - AA2


COVER
SKYDD
3777140
DRA
AA
Tetra Pak


4 ±0.15
12.75 ±0.5
16.5 ±0.25
23.5 ±0.5
45.5 ±0.5
R3.25
R3 ±1
42 ±0.5
2:1
Concept
Marked according to standard B 2103.10
SHARP EDGES BROKEN
Scale 1:1
EN 1.4301 ISS 2333-021
SESCHREWELH
2023-04-21
General
BRACKET
HÅLLARE
Tetra Pak
3777140_05
DRA
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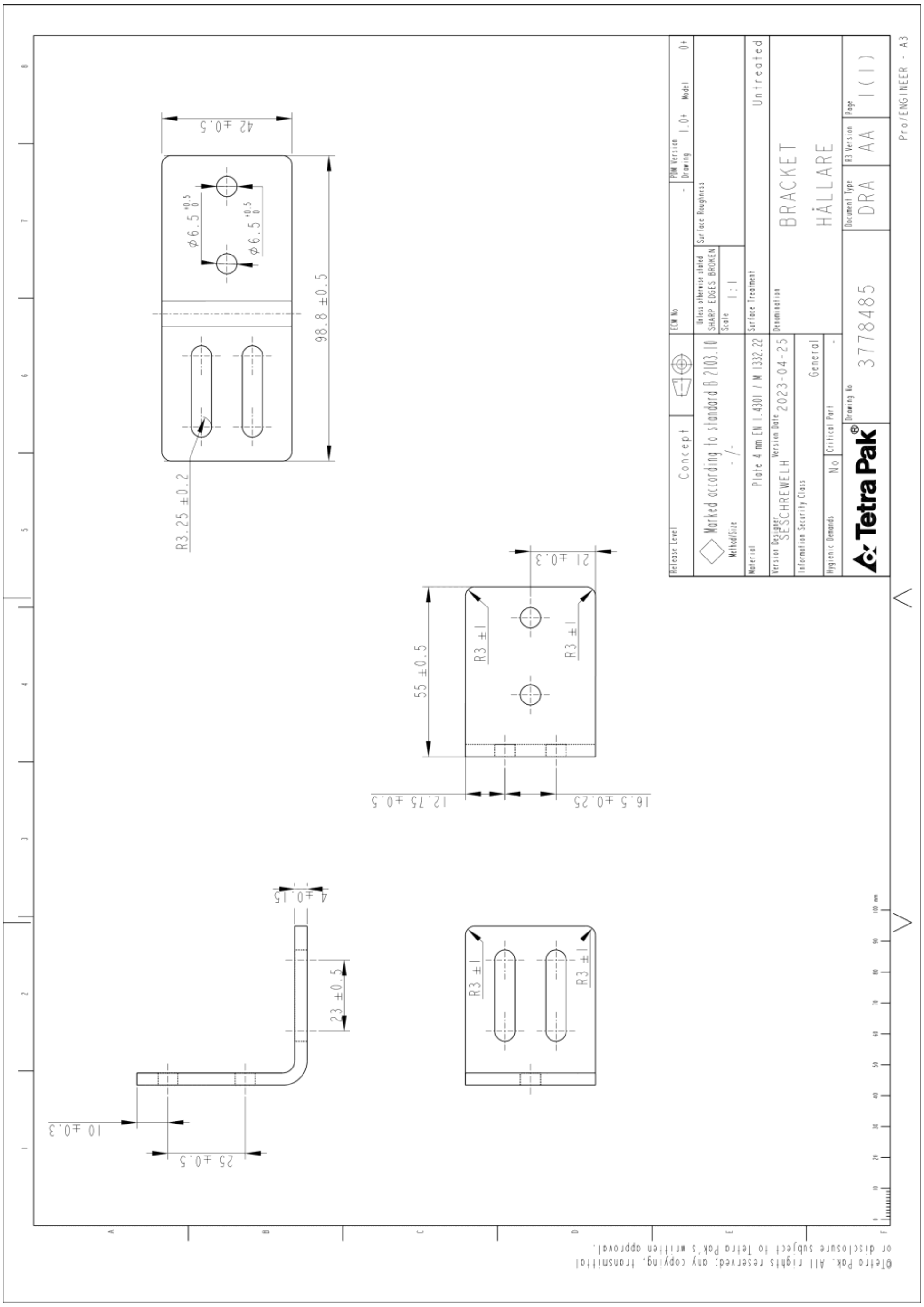
42 ±0.5
98.8 ±0.5
R3.25 ±0.2
55 ±0.5
21 ±0.3
12.75 ±0.5
16.5 ±0.25
R3 ±1
4 ±0.15
23 ±0.5
10 ±0.3
25 ±0.5
Concept
Marked according to standard B 2103.10
SHARP EDGES BROKEN
1:1
Plate 4 mm EN 1.4301 / M 1332.22
Untreated
SESCHREWELH
2023-04-25
General
No
BRACKET
HÅLLARE
3778485
DRA
AA
1(1)
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