Soap Level Monitoring System

Level monitoring system for the SCA Tork S4 foam soap system

Master of Science Thesis

BJÖRN ARENDAL
JACOB CEDULF

Department of Product and Production Development
Division of Product Development
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden, 2012

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Chalmers University of Technology
Department of Product and Production Development
SE-41296 Göteborg
Sweden
Telephone: +46(0)31-772 10 00

Preface

This Master of Science thesis is the final project for us, Björn Arendal and Jacob Cedulf, in our postgraduate studies at the Department of Product and Production Development at Chalmers University of Technology. It has been carried out at SCA Hygiene Products in Gothenburg during the spring of 2012.

We would like to thank everyone who has been involved for their much appreciated help throughout the project. Special thanks go to our SCA supervisors Björn Larsson and Gunilla Himmelmann for all your guidance and support. We would also like to thank our supervisor from Chalmers University of Technology, Dr. Erik Hulthén, for help with academic issues. Last but not least we would like to thank our fellow thesis workers at SCA for the collaboration and many laughs shared.

Gothenburg, May 2012

Björn Arendal
Jacob Cedulf

Abstract

SCA (Svenska Cellulosa Aktiebolaget) is a global hygiene and paper company. Among many other areas, SCA develop products for public washrooms and the purpose of this project was to create an inexpensive yet reliable electronic soap level measurement system that would add value to SCA's soap dispenser products. All prototypes and tests in this project have been based on the SCA Tork S4 foam soap system.

To provide the best possible hygiene, the S4 soap refills are designed as a closed system. This means the surrounding air is kept from entering the refill, also when soap is being dispensed. To achieve this, the refills collapse and often in an unpredictable manner. To find a level measurement method for a refill that collapses unpredictably was the main challenge in this project.

Three main methods based on capacitance, mass, and optical properties respectively were prototyped and tested. The "winning" concept measures the weight of the soap by a load cell placed so that it is subjected to the moment with which the dispenser wants to rotate around its lower attachment points.

Initial tests show a promising linear relationship between soap level and sensor readings. Future work is recommended to be aimed at increasing the system's accuracy for the 0% soap level and at upgrading the software with features such as refill change detection and adaptive sleep duration between measurements.

Sammanfattning

SCA (Svenska Cellulosa Aktiebolaget) är ett globalt hygien- och pappersföretag. Ett av många områden som SCA utvecklar produkter för är offentliga toalettutrymmen. För att potentiellt höja kundvärdet hos SCA:s tvåldispensrar har detta projekt haft som syfte att ta fram ett elektroniskt mätsystem som på ett pålitligt och billigt sätt mäter tvålnivå. Alla prototyper och tester i det här projektet har baserats på SCA Tork S4 skumtvålsprodukter.

För att uppnå bästa möjliga hygien är tvålrefillerna hos S4-serien byggda som slutna system. Detta innebär att luft förhindras från att komma in i refillen, även när tvål pumpas ut. För att uppnå detta kollapsar refillerna ihop vid användning, ofta på ett oregelbundet vis. Att hitta ett system som kan mäta nivån i en kollapsande behållare har varit den huvudsakliga utmaningen i detta projekt.

Prototyper gjordes av tre huvudsakliga lösningsmetoder som baserades på kapacitans, massa och optiska egenskaper. Efter att dessa prototyper testats kunde en ”vinnare” utses som använder sig utav en lastcell som ersätter de två övre skruvarna i dispensern och mäter där kraften med vilken dispensern försöker rotera kring sin nedre infästning.

Tidiga tester visar på ett nära linjärt samband mellan tvålnivå och mätvärden från lastcellen. Rekommendationer för framtida arbete är bland annat att förbättra mätsystemets prestanda kring nollnivå samt att uppgradera mjukvaran till att adaptivt justera tiden mellan mätningar och hantera refillbyten.

Contents

Chapter 1

Introduction

1.1 Background

SCA (Svenska Cellulosa Aktiebolaget) is a global hygiene and paper company offering a wide range of products and brands. Amongst these is the global brand Tork, most common to be found on products like toilet paper, paper towels, napkins and soap. In order to make these products available to the end-user, the Tork brand also offers dispensers developed specifically for a variety of sites and environments.[1] An example is soap dispensers adapted for high traffic washrooms like those found on airports, hospitals and shopping malls (Figure 1.1).

Figure 1.1: Tork dispensers in a high traffic washroom.[1]

For high traffic washrooms current trends point in the direction of better hygiene by increased hand wash compliance and decreased risk for cross contamination. To comply with these needs it is necessary to provide automatic and touch free dispensers as well as always make sure that the dispensers are supplied and ready to use. This is where an electronic soap level measurement system comes into the picture. The cost and acceptance of implementing the necessary technology have reached levels where SCA find it interesting and feasible to test it on their automatic soap and towel dispensers. The idea is to have the dispensers indicating their level of soap and towels respectively, in order to let the responsible staff know when it is time for refill. The potential benefits generated by implementing this technology are many. For example the usage of soap and towels could be monitored more easily and cleaning staff, responsible for keeping dispensers stuffed, could rationalize their work.[2]

The circumstances described above demands a reliable and inexpensive soap and towel level measurement system. As far as soap dispensers are concerned, some of the present solutions for satisfying these needs implement a counting functionality. This makes it possible to keep track of the number of doses dispensed and to compare this number with an average maximum capacity of a refill, a method which has proven to be unreliable in some cases.

1.2 Purpose

The purpose is to make sure to stay ahead of competitors in the development of public washroom technology by providing an inexpensive and reliable solution for soap level measurement which adds value to SCA's soap dispenser products. This will be achieved by developing a level measurement system for an electronic foam soap dispenser.

1.3 Objective

The objective is, during the time from January to June 2012, to develop an electronic soap level measurement system which makes it possible to present the soap level in a dispenser. The project is to result in one or several functional prototypes.

1.4 Scope

Current automatic dispensers already have batteries, circuit board and microcontroller. Because of this the scope of this project is restricted to the level measurement system only, excluding power supply to the system and design of the soap dispenser itself. However, minor modifications of the soap dispenser can be made in order to facilitate level measurement. Therefore, the power supply, circuits and processor used in combination with the level measurement prototypes will not be adapted for usage in a final product. The project is based on the manual S4 soap dispenser, but the resulting system shall be possible to use in future soap dispensers.

Chapter 2

Methods and materials

This chapter presents the methods and materials that have been used to take this project from pre-study to final prototype. The information given is categorised by using the different phases of the project as sections. A product development process similar to the ones presented in many influential textbooks has been used to ensure that the methods are proven and risks minimised.[3][4][5]

2.1 Pre-study

During the pre-study phase emphasis was put on understanding the product context and characteristics of the soap dispenser. Efforts were also made to find existing solutions on the market and patented measurement techniques relevant to dispenser products.

Literature studies - was carried out using mainly on-line sources. Reports on a variety of sensor technologies were studied both for learning purposes, i.e. to get familiar with limitations and possibilities of relevant sensors, and to extract ideas from previous experiments and tests.

Benchmarking - Information about SCA's and competitors' soap dispensers was gathered from on-line sources provided by each company. Specifications, key performance indicators and geometrical dimensions were compiled in tables. Disassembly of some competitors' dispensers was also done to further examine the internal components and features.

Patent searches - took place using the Espacenet patent database. Due to the fact that the patent database contains a very large amount of patents some sort of adapted search method had to be applied. In this case the search was focused on certain categories where the most interesting patents were believed to be found. The search results were compiled in a list and by using this list some patents were chosen for further investigation. The categorisation tree was as follows:

1. PHYSICS
   (a) MEASURING
      i. MEASURING VOLUME FLOW, VOLUME FLOW, MASS FLOW OR LIQUID LEVEL; METERING BY VOLUME
         A. LEVEL INDICATORS

The hits given by these search restrictions could then be evaluated manually for further actions. All relevant patents which were further investigated are presented and briefly explained in Appendix B.

Interviews - took place both at Chalmers University of Technology (Chalmers) with a professor of electrical measurements and with various people at SCA. A semi-structured interview method was used which allows for more spontaneous follow up questions and sidetracks which is suitable when the interviewee has a good understanding of the subject.[6]

List of specifications - was established early in the project. At this stage it was desirable to keep most of the specifications general and non-quantitative. There is little knowledge available for this type of product and no known existing references on the market which otherwise could have provided an indication of performance parameters and other important criteria. Instead the list, which is presented in Appendix C, was based on information given by SCA. A selection of the most important specifications was later used in the concept evaluation stage as reformulated criteria in the evaluation matrices.

2.2 Concept generation

In the initial stage of the concept generation all possible ideas were desired. A large amount of ideas would then be possible to decrease by excluding ideas and concepts with poor performance, i.e. applying a development funnel.

Brainstorming - was conducted in various groups and environments. External input during brainstorming sessions was provided in the form of ideas and suggestions from SCA employees, consultants and other experts. The theme of the sessions was to come up with ideas of different ways to measure soap level.

Idea provoking tools - like the TRIZ matrix were used to get a different point of view when trying to generate new concepts. TRIZ is a Russian acronym for a theory which is usually called *The theory of inventive problem solving* in English. The essence of this theory has been compiled in a matrix which states several common contradictions between features and suggestions for how to work around these contradictions.[7]

Categorisation - made it possible to handle all the generated ideas in a systematic way. The categorisation was based on concepts and ideas which shared certain features and the degree of modifications needed of the current dispenser and refill. The categories were:

- No modifications
- Dispenser modifications only
- Modifications to refill or both

2.3 Concept evaluation and selection

In this stage of the project the aim was to start excluding poor concepts and eventually identify strengths in certain concepts and use them to improve the weaknesses in others.

Evaluation matrices - were created based on guidelines given by Ulrich & Eppinger [3]. Concept screening was done using Pugh matrices. Evaluation criteria, presented in Table C.2 in Appendix C, were chosen from the list of specifications and all concepts were then compared to chosen reference concept by deciding if the performance was better than, worse than or same as the reference. Weaknesses in some concepts could be identified and concepts with high score could be further improved. Furthermore, poor concepts could be revised or excluded and others were combined to create new better ones. In the final part of the evaluation and selection process several tests had been done and more knowledge had been gained. This made it possible to identify the most relevant criteria, presented in Table C.3 in Appendix C, when selecting which concepts that would make it through to the last part of the concept development stage.

External decisions - a number of interim meetings were held with SCA representatives to follow up on the status of the project. Feedback was given on concepts' performance and potential based on test results and calculations. In some cases decisions were made whether a concept should be excluded.

2.4 Concept development and testing

In this stage all promising concepts were refined. Focus was on being able to build prototypes which later were to be used in tests. After these tests a selection of concepts were further developed and tested again. Some concept were to be refined several times while others only were tested once.

CAD tools - were used for everything from concept visualisation to detailed engineering. Three dimensional models were created to evaluate and improve various constructions. The models were also used to create prototypes or parts of prototypes through Selective Laser Sintering.

Tests - In the beginning of the test phase there were a large number of concepts to be examined and a restricted amount of time. To test a concept by manually emptying a soap refill, which lasts for approximately 2500 doses, would take too long. Hence, a fast and easily accessible test was needed which could be performed many times but still be able to indicate how well a certain concept would perform in a real environment. Later, when some of the concepts had been excluded, a new test was used which was allowed to take more time so as to get closer to a real usage situation. The new test procedure was possible thanks to a machine which emptied the refill by pushing the dispenser automatically. When only the most promising concepts were left a manual and time consuming but realistic test could be used. The aim was to simulate random pushes which the measurement system would not be subjected to in the pumping machine. The last test was carried out in a restroom at SCA's office to get a genuine real environment.

2.5 Materials

All hardware and software used in this project and their functions are listed in Table 2.1. For more details about the project specific prototyping platform, see Appendix A. As both the micro and beam load cells have been taken from commercially available kitchen scales there are no specifications or further details about them.

Table 2.1: A list of software and hardware used.

Function	Means
Prototyping platform 1	Project specific (ATMega324PA)
Prototyping platform 2	Arduino Uno
Computer Aided Design	Autodesk inventor 2012
Patent database	Espacenet
Calculation and plotting 1	Matlab
Calculation and plotting 2	Excel 2012
AVR programming 1	AVR Studio 4
AVR programming 2	IAR Workbench
Donut load cell	Futek LTH300
Button load cell	Honeywell FSS load sensor
IR distance sensor	Everlight Electronics ITR 8307
Hall effect sensor	Allegro A1324
Micro load cell	N/A
Beam load cell	N/A

Chapter 3

Dispensers and refills

In order to better understand what design problems that have been faced and how the concepts are supposed to work, some important information about the S4 dispenser and refill is required. This information can be found in this chapter. To get a better overview of the product context and other dispensers more information can be found in Appendix E and Appendix F, which present Tork products and competitors' products respectively.

3.1 The S4 dispenser

The S4 dispenser is one of many products of the Tork Elevation series. It is made of ABS plastic and weighs 317 grams without refill.[17] It is basically comprised by the following components:

- Back part mounted onto the washroom wall holding up all other parts
- Lockable lid
- Push handle for dispenser activation
- Refill locking mechanism

Figure 3.1 shows the back part and its holes that enable wall mounting. It is also possible to mount the dispenser onto the washroom wall by a sticky label. A solid mounting is required to ensure that the dispenser feels firm when used.

Figure 3.1: The back part viewed from behind showing the four mounting holes.

The lower part of the dispenser lid is transparent to provide visual information about the content, like a viewing glass. However, it can be difficult to determine how much soap is left in the refill due to the limited size of the transparent area. In Figure 3.2 the dispenser is presented by a picture and a rendered image of a CAD model. In the model the pump has been highlighted with green and blue colours to illustrate how it is supposed to fit inside. It should be noted that in reality the pump is always attached to a refill.

Figure 3.2: **Left:** Front view of a black S4 dispenser with the transparent part barely visible. **Right:** A CAD-model of the S4 dispenser with hidden lid and push handle, the pump has been highlighted with green and blue colours to illustrate how it is supposed to fit inside.

The S4 dispenser is designed to fit Tork Premium foam soap refills which have a special pump attached to them. The interface between pump and dispenser is illustrated in Figure 3.3. The pump is held up by a circular support which is split up in a front and back part covering approximately 45 degrees each of a complete circle. The locking mechanism, which is partly visible, is held in a non lock state by a spring. The spring pushes the mechanism to the right in Figure 3.3 but when the lid is being closed, it pushes the mechanism to the left into a locking position and the spring will be compressed again. The locking mechanism, in combination with the dispenser interface geometry, will lock the refill in five degrees of freedom, i.e. translation in X, Y and Z axis as well as rotation around the X and Y axis. Rotation around the Z axis is still possible. It should be noted that small gaps due to tolerances may allow for the refill to tilt slightly back and forward around the Y axis upon dispenser usage.

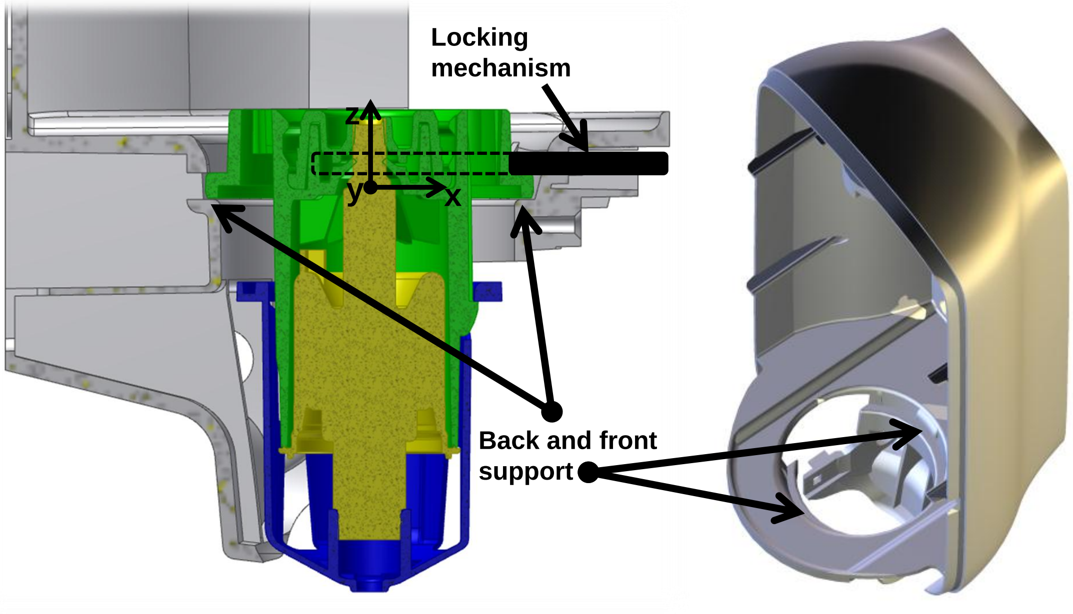

Figure 3.3: **Left:** A half section view of the S4 dispenser and pump without refill. **Right:** Another view of the dispenser where the front and back supports are visible.

3.2 The S4 refill

The S4 refill is currently available with three variants of Tork premium foam soap, i.e. soap which is in a liquid state while inside the refill and comes out as foam. The alternatives are mild, extra mild and antimicrobial and are presented in Figure 3.4.

Figure 3.4: The S4 refill containing mild, extra mild and antimicrobial foam soap respectively. While the antimicrobial foam soap is transparent, the other two foam soaps are light yellow in colour.

The refill and pump is designed to be a closed system which means that the pump is always attached to the refill, from delivery to disposal. When soap is pumped out of the refill no air comes in and the refill will collapse over time. By letting the back of the refill have a smaller material thickness than the the front, it will move towards the front when the refill is collapsing. Ideally this will give an empty refill the shape similar to the one of a cylindrical shell sliced in half from top to bottom. However, variations in the refill production often cause unpredictable collapsing behaviour. The refill may twist, rotate and bend during collapse. In Figure 3.5, a number of refills with different amounts of soap are presented to give an example of how the collapse may look like.

Figure 3.5: Four S4 refills with soap levels ranging from almost empty to full.

A vital part of the refill system is the pump which is presented in Figure 3.6. When the handle of the dispenser is pushed the moveable part of the pump will move upwards. A spring, placed between the movable and the yellow part of the pump, will in turn act on the refill in an upward movement. This can make the refill move inside the dispenser in an unpredictable way, as explained in Section 3.1.

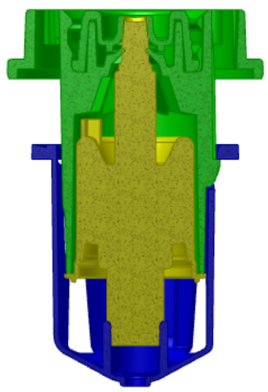

Figure 3.6: **Green colour:** the part of the pumps which rests against the dispenser and is held in place by the locking mechanism. **Yellow colour:** the part where soap in liquid state is collected and later extruded through, as a foam, upon pump activation. **Blue colour:** the moving part which is manoeuvred by the push handle.

3.3 System characteristics

By analysing the information about the refill from Section 3.2, a number of characteristics covarying with soap level could be determined. These characteristics were then used to facilitate idea and concept generation. Properties of the dispenser and refill system that vary or might vary depending on soap level:

Mass - Decreases with decreasing soap level.

Volume - Refill volume decreases when the dispenser is used and the volume of the surrounding air increases accordingly.

Visual soap level (height in refill) - Due to the refill's collapse, the visual soap level does not decrease linearly with the amount of soap. However, the visual soap level is a good sign of how much is left when the refill is nearly empty.

Natural frequency/frequency response - Depending on soap level, the refill will have different shape and mass and therefore it should react differently to various frequencies, both mechanically and sonically.

Geometry/shape - The rear half of the soap bottle approaches the front half when being used.

Centre of mass - Due to the refill's geometry change when collapsing, the centre of mass of the refill moves.

The internal pressure - The internal pressure at the bottom of the bottle should decrease with decreasing soap level.

3.4 Summary of existing products and competitors

The competitor study was focused on some of the biggest competitors and examples of their automatic dispensers. Most information was accessed through the respective company's web page. For some dispensers information was gathered during disassembly of the actual product, see Appendix F for more details. No dedicated level measurement system could be found in any of the examined dispensers. However, some dispensers implement a soap level warning light which suggests that some sort of counting is done to keep track of the total number of doses dispensed. Switches are commonly used to monitor if the lid of the dispenser is closed and if there is a refill inside. The information provided by these switches could be used to guess if there is a refill change and if so reset the dose counter. Some dispensers also have a reset button which could serve the same purpose. Based on the information gathered about automatic soap dispensers a function diagram was created for better overview, see Figure 3.7.

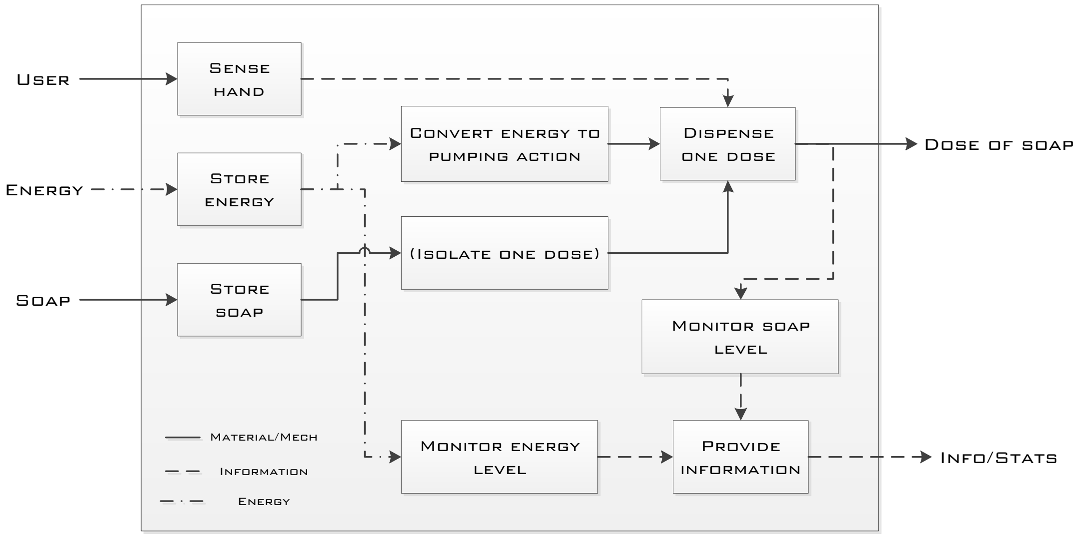

Figure 3.7: A diagram of an automatic soap dispenser showing its functions and how they relate to each other.

Chapter 4

Sensors and physics

This chapter gives an introduction to the physics and sensors utilised in the most interesting concepts and their tests. The purpose is to make it easier to understand the function of the concepts presented in Chapter 5 and the tests described in Chapter 6.

4.1 Reaction forces

In a non-accelerating system, the net sum of all forces and the net sum of all moments are both zero. By looking at the moments acting on the two dispenser attachment points (the screw pairs), the reaction forces generated by the dispenser weight can be determined, see equations 4.1 and 4.2. The parameters are shown in Figure 4.1.

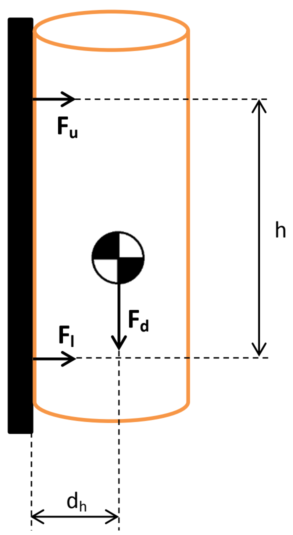

Figure 4.1: Important forces and dimensions.

$$F_l = \frac{d_h}{h} F_d \tag{4.1}$$

$$F_u = -\frac{d_h}{h} F_d \tag{4.2}$$

4.2 Strain gauges and load cells

The most common way to measure strain is to use one or more strain gauges. One-dimensional strain, ε, in a material is the fraction between change in length, ΔL, and the total (relaxed) length in that direction, L.

$$\varepsilon = \frac{\Delta L}{L} \tag{4.3}$$

The material can be seen as a spring, the more loaded the material is, the longer it gets and the greater the strain. Strain gauges are constructed in such a way that their electric resistance changes with their length. They are carefully glued to the material on which the measurements will be taken so that the strain of the material and the strain gauge will be the same. [9] [10]

Strain gauges are often the sensing elements in so called load cells. Load cells measure force or torque and have built-in elastic mechanical components on which the strain gauges are mounted. The load cells are often built in such a way that the measurement is proportional to the force applied to them. This makes them convenient to use and they are common in many types of applications such as kitchen and bathroom scales, industrial force measurements etc. [9] [10]

4.2.1 Load cells used in this project

Beam load cell

As the name suggests, the beam load cell is shaped like a beam. Often holes have been drilled through the middle of the beam where the strain gauges are mounted to make it weaker. One strain gauge is usually mounted on either side of the beam perpendicular to the load so that one of them is contracted and the other one stretched when the beam is loaded. The beam is fixed in one of its ends and loaded in the other. A photo of the beam load cell used in this project is shown in Figure 4.2.

Figure 4.2: The beam load cell used in this project.

Donut load cell

The donut load cell has a flat cylindrical shape with a hole in the middle as seen in Figure 4.3. It is designed in such a way that the outer ring of the load cell can be supported by a surface but still leave the inner ring, centered around the hole, unsupported. This means that the inner ring can make small translations relative to the outer ring along the axial direction of the load cell. In this way force on the inner ring can be measured, as long as it does not exceed the maximum load. An example of where it could be used is for measuring how tightly fastened a bolt or screw is.

Figure 4.3: The donut shaped load cell used in this project.

Micro load cell

Since the micro load cell's flexible component is a punched out piece of sheet steel, it can be made very flat. The cell is designed in such a way that it has an outer ring that is to be held fixed and an inner beam for bending, on which one or two strain gauges are mounted. In this project micro load cells were taken from a kitchen scale and had therefore a rather large plastic part attached to them which had acted as one of the scale's feet, see Figure 4.4.

Figure 4.4: The micro load cell used in this project.

Button load cell

The smallest type of load cell used in this project is the button load cell shown in Figure 4.5. Its flat rear is fixed and the load is placed on the metallic "ball" on its front.

Figure 4.5: The button load cell used in this project.

4.3 Capacitance

The ability of a capacitor to store charge in an electric field is called capacitance. An example of capacitor is the one with two parallel metallic plates of equal area, A, separated at a distance, d, by a dielectric medium (any medium or combination of mediums that electrically separates the two plates). If the distance between the plates is short compared to other dimensions (so that the electric field is nearly uniform), the following is approximately true:

$$C = \varepsilon_r \varepsilon_0 \frac{A}{d} \tag{4.4}$$

Here, C stands for capacitance, ε_r is the dielectric constant of the material between the plates, and ε_0 is the electric constant (approx. $8.854 \cdot 10^{-12} Fm^{-1}$). [9] [10]

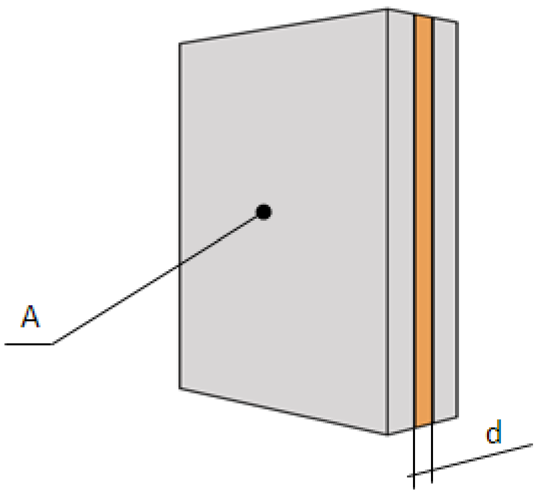

Figure 4.6: Illustration of a parallel plate capacitor.

There are several ways to measure capacitance. It is possible to either use a dedicated capacitance meter device or construct a circuit suitable for the problem at hand. The methods are all based on how a capacitor affects an electric circuit:

$$I(t) = C \frac{dV}{dt} \tag{4.5}$$

where I is the displacement current through the capacitor, C is the capacitance, V is the voltage across the capacitor and t is the time. [9] [12]

4.4 Proximity and distance sensors

4.4.1 IR distance sensor

Infrared (IR) light is electromagnetic radiation with wavelength greater than that of visible light. It can be used in electronic circuits for several purposes, one of which is distance measurement. An IR distance sensor has a light emitting diode (LED) that sends out infrared light and a phototransistor that measures the strength or amount of the reflected light coming back. If the sensor is analogue, then the output voltage will vary with the distance to the sensed object. Please note however that for a certain distance, the output will depend also on the properties of the object such as its colour, texture etc. IR distance sensors are often one of the more inexpensive options when it comes to distance measurements.[10]

4.4.2 Hall effect sensor

Hall effect sensors respond to the flux density of a magnetic field. They exist both as digital (ON/OFF) and as analogue sensors. If using an analogue sensor it is possible to e.g. determine the distance to a magnet or detect variations in the magnetic field between the sensor and a magnet. For example, the flux density, B, at a distance, x, from a rectangular magnet can be described as:

$$B(x) = \frac{B_r}{\pi}\left(atan\left(U(x)\right) - atan\left(V(x)\right)\right) \tag{4.6}$$

$$U(x) = \frac{WL}{2x\sqrt{4x^2 + W^2 + L^2}} \tag{4.7}$$

$$V(x) = \frac{WL}{2(x+T)\sqrt{4(x+T)^2 + W^2 + L^2}} \tag{4.8}$$

where W, L and T are the width, length and thickness of the magnet and B_r is the remanence of the magnetic material[10] [11]. A plot of the relation between flux density and the distance from a rectangular magnet made of neodymium is presented i Figure 4.7. The figure shows that the useful measurement range in this type of application is limited to small distances only.

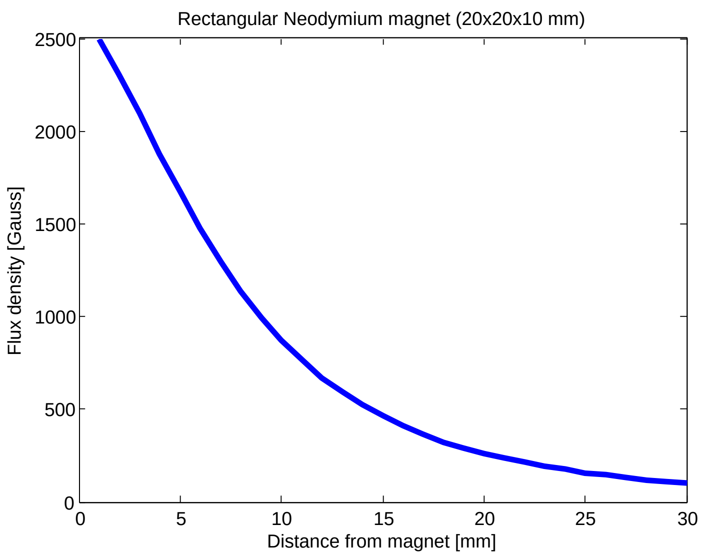

Figure 4.7: The relationship between flux density and distance.

The digital configuration is often called a Hall switch and can be found in many applications, e.g. on bicycles for speed measurement where the sensor is fixed to the frame and a magnet passes by for each revolution of the wheel.

Chapter 5

Concepts and prototypes

Several measurement methods were prototyped and tested to facilitate concept evaluation. The concepts called ”Back plate” and ”Donut” were seen as the most interesting and they were therefore prototyped more than once. The last prototypes had a commercially more viable design. Only the concepts that were taken all the way to testing are described in this chapter. Sketches of these and all other ideas are found in Appendix G.1. The evaluation and selection process is described in Chapter 7. Concepts involving sensors whose output need to be amplified have been used together with an externally developed circuit board based on the ATmega324PA microcontroller. Sensors that do not need amplification have been used with an Arduino Uno prototyping platform.

5.1 Back plate

5.1.1 Description

The dispenser is attached to a slider that makes vertical translation possible, see Figure 5.1. Either a spring or a load cell is then placed between two horizontal components, one of which is fixed and the other mounted on the dispenser. This type of construction makes it possible to weigh the dispenser at the same time as it seems to be firmly mounted against the washroom wall. A load cell measures directly the weight put on it whereas various distance sensors are combined with a spring to measure translation. The idea is simple, the more soap the dispenser contains, the more it will weigh and the more it will affect the sensor. The spring used made the dispenser differ in position a few millimetres (less than 5 mm).

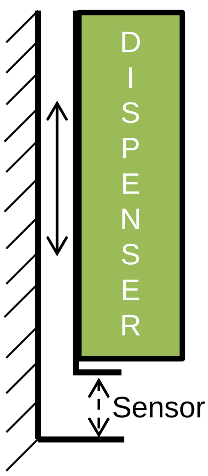

Figure 5.1: The dispenser can move freely in the vertical direction and the sensor measures its weight.

5.1.2 First prototype

The initial prototype of the back plate concept was made from 10 mm thick polymethyl methacrylate (PMMA). Two L-shaped components were made and mounted together via a metallic slider, see Figure 5.2. The idea with this prototype was to make a quick and sturdy construction that could provide a good platform for testing a number of different sensors.

Figure 5.2: Left: Front view of the first back plate prototype. Right: Angled view.

5.1.3 Second prototype

The second prototype is aesthetically more viable and customised for a micro load cell. It consists of two components, one male component mounted to the wall and one female component attached to the dispenser. The two components are shaped so that they form an extension of the rear side of the dispenser. The wall mounted part has a holder for the load cell, on which the dispenser rests. A computer model of the prototype is shown in Figure 5.3. The real prototype was made from three components. The dispenser part and the lower element of the wall mounted part are 3D printed, whereas the rest of the wall mounted part is milled out from plexiglass. The two elements belonging to the same part were then glued together.

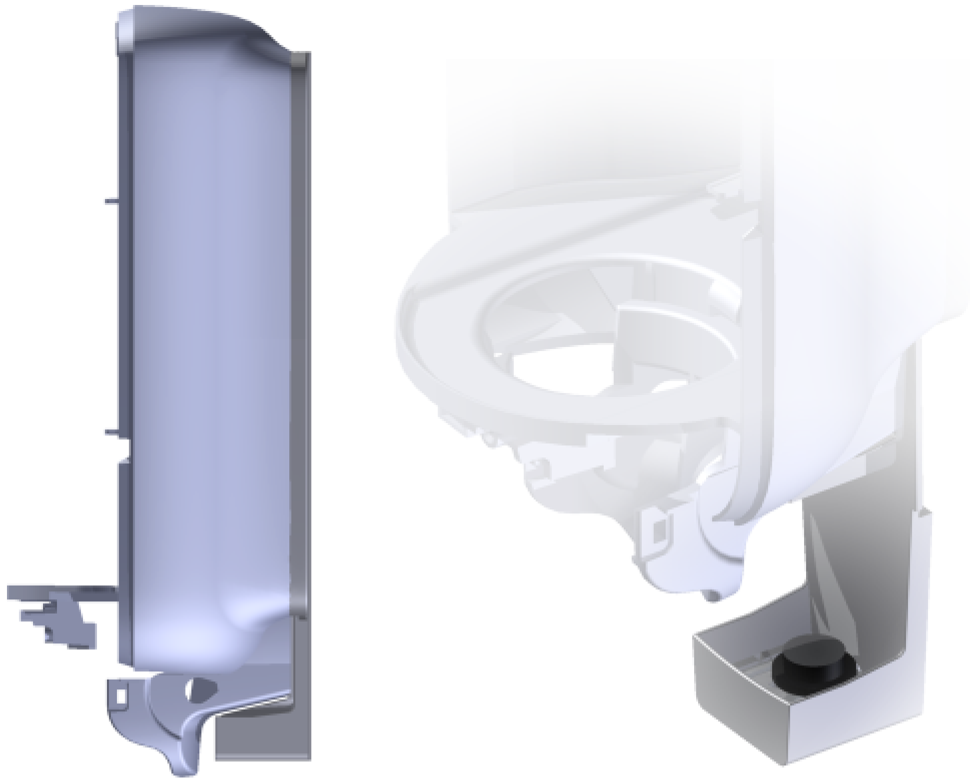

Figure 5.3: **Left:** Side view of the back plate concept. **Right:** The load cell is held by a "shelf" on the wall mounted part.

5.2 Donut

5.2.1 Description

A load cell is placed so that it is subjected to the force F_u in Figure 4.1. For the first prototype a donut shaped load cell was used (thereof the concept name). The second and third prototype make use of a less expensive micro load cell. The principle behind the donut concept is further decribed in Figure 5.4.

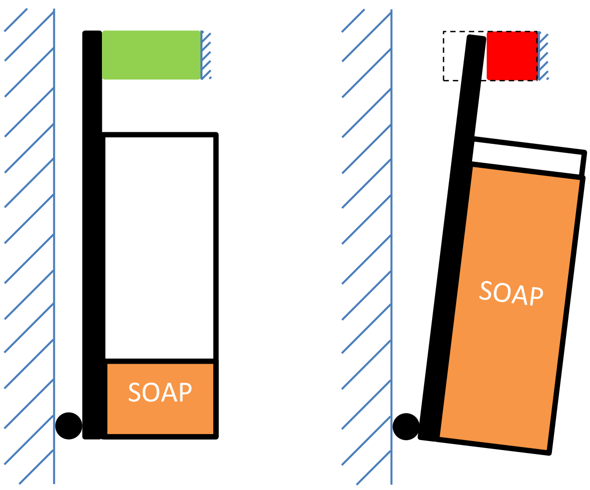

Figure 5.4: An exaggerated view of how the donut concept works. The more soap, the higher the load on the sensor.

5.2.2 First prototype

The very first prototype of the donut concept was to squeeze a donut shaped load cell between a screw head and the inner wall of the dispenser. The two upper screws were replaced with one single screw (used for the load cell) between the two previous holes, see Figure 5.5. To enable the dispenser to wobble slightly, a flexible plastic distance was placed between the wall and the lower part of the dispenser.

Figure 5.5: The first prototype of the donut concept. A donut shaped load cell was mounted with a screw and washer.

5.2.3 Second prototype

For the second prototype of the donut concept, a micro load cell taken from a kitchen scale was used. This load cell was mounted on the inner wall of the dispenser between the two upper screw holes. Before the screws were put into place they were connected by an aluminium plate which had the task of pushing against the load cell, see Figure 5.6. To make sure the refill always rests on its front end, a support was added to both inner side walls of the dispenser, forcing the refill to lean slightly forward.

Figure 5.6: In the second prototype of the donut concept, the donut load cell was replaced by a more affordable micro load cell.

5.2.4 Third prototype

The third and last prototype of the donut concept consists of a plastic part (Fig. 5.7) holding a micro load cell against the inner wall of the dispenser. To avoid it being dependant on the force with which the screws are fastened, the plastic part touches the washroom wall and the screws are mounted through it, see Figure 5.9. The upper screw holes on the dispenser are replaced by two larger, elongated holes so that the dispenser will not be able to touch the load cell holder.

Figure 5.7: A 3D computer model of the load cell holder.

The prototype was first tested without a pivot support. Instead it only had an inward leaning surface on the dispenser below the screw holes. However, the attempt did not perform very well and a pivot support was reintroduced in the form of washers between the wall and dispenser. As in the previous prototype, support for the refill was glued to the upper inner walls of the dispenser so that the refill would remain slightly forward leaning. The reason for having the refill leaning slightly forward is that it will always rest on its frontmost resting point, so that the dispenser's centre of mass will only vary with the weight of the refill, not its geometry. The least collapsing perimeter of the refill is the upper corners, which motivates the placement of the added supports. The prototype was made in a 3D printer and is shown in Figure 5.8.

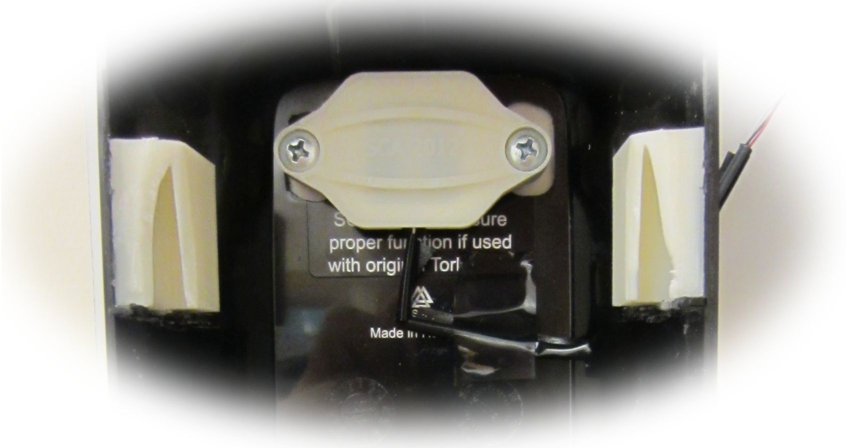

Figure 5.8: The 3D printed prototype mounted in a dispenser. The refill supports were made slightly too big and had to be cut off for the refill to fit.

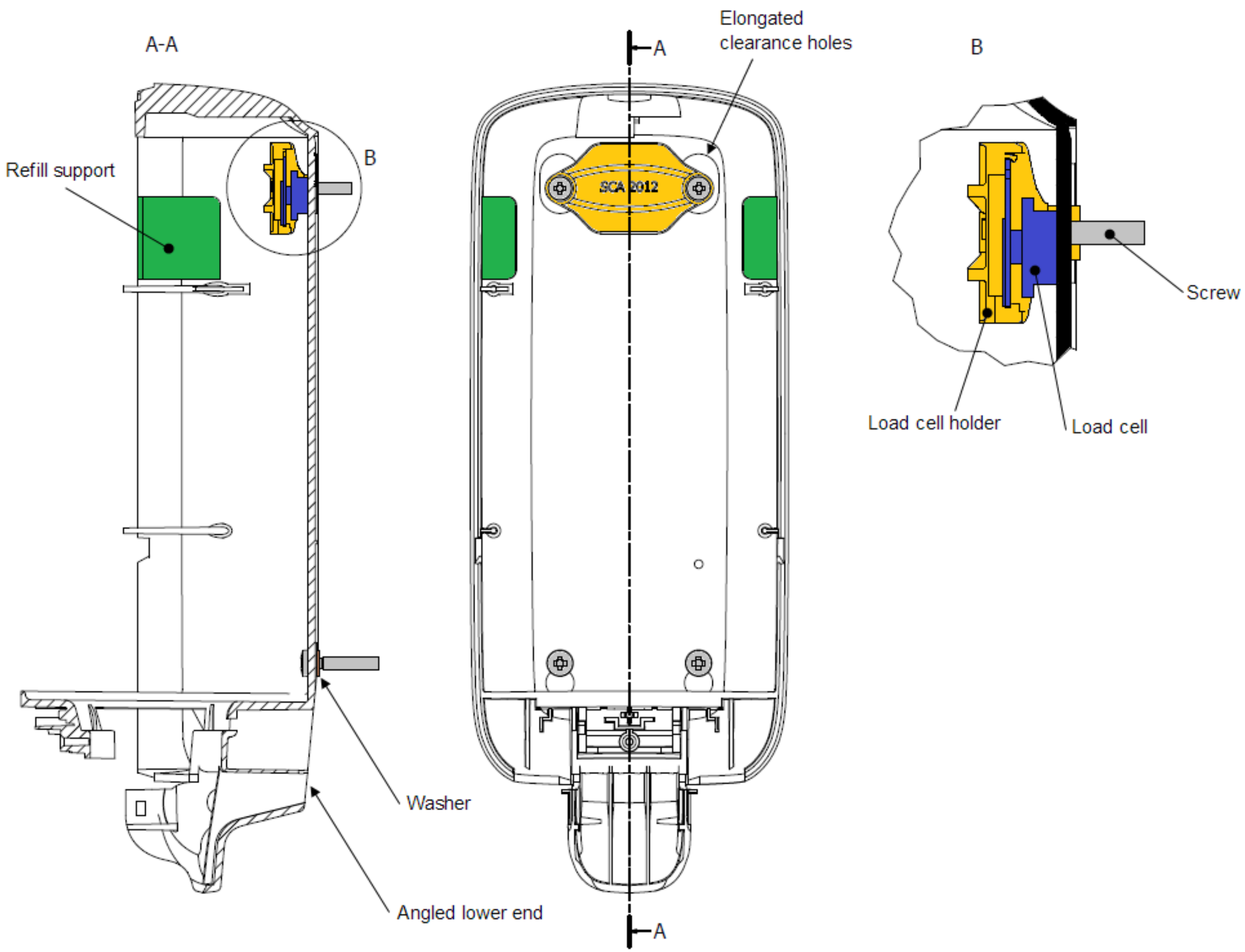

Figure 5.9: The third and final prototype of the donut concept.

5.3 Swing

This concept uses a load cell placed at the lower back side of the dispenser, so that it is squeezed between the washroom wall and the dispenser and thereby subjected to the force F_l in Figure 4.1. To make this work the dispenser is only mounted to the washroom wall with its upper screw pair, so that the dispenser can ”rotate” around these screws. The concept is further clarified in Figure 5.10. The load cell used in the prototype was a small so called button load cell.

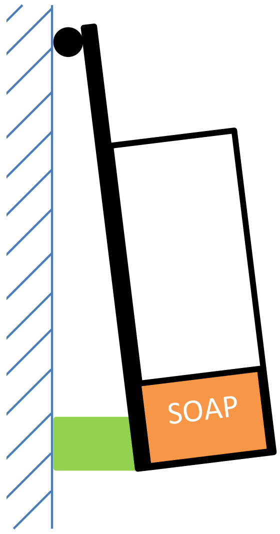

Figure 5.10: An exaggerated view of how the swing concept works. The more soap, the higher the load on the sensor.

5.4 Optical sensing

The idea here is to detect the different visual properties between an empty and soap covered area of the refill. It has been discovered that the reflectivity of the refill changes depending on if there is soap inside or not. By using an appropriate optical sensor this change of reflectivity can be detected. Analogue IR distance sensors were attached by tape at various places on a refill. In order to obtain the desired functionality from the sensors, a circuit and sensor like the ones presented in Figure 5.11 were used. Test results are shown in Section 6.5.

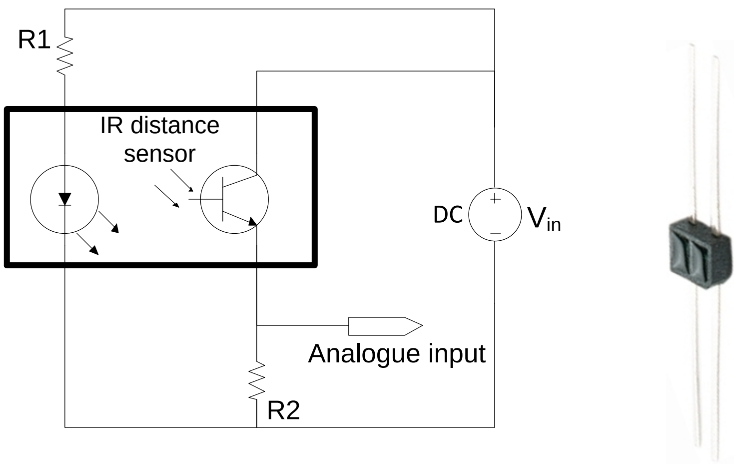

Figure 5.11: **Left:** The IR sensor circuit used in the tests. **Right:** The IR distance sensor used in the tests (not actual size).

5.5 Capacitance

One way to use capacitance as a means for measuring soap level is to use the soap as the dielectric medium between the plates (for theory, see Section 4.3). The dielectric constants for air and various plastics are about 3 or less and for water (soap) about 80. In other words there should be a significant difference in capacitance between plates when soap is present and when it is not [13].[1]

Simple prototypes were made where thin sheets of aluminium were placed at the inner front wall and inner back wall of the dispenser. The entire refill was used as dielectric medium.

5.5.1 The RC circuit

To be able to measure capacitance one must include the capacitor in some sort of electronic circuit. The one used in this project was the simplest form of resistor - capacitor (RC) circuit, see Figure 5.12.

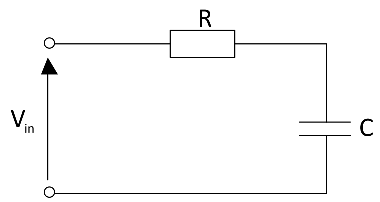

Figure 5.12: RC series circuit schematics.

Since the capacitor and resistor are connected in series, the current flowing through the components has to be the same for both the capacitor and the resistor, hence

$$C\frac{dV_c}{dt} + \frac{V_c}{R} = 0 \tag{5.1}$$

where V_c is the voltage across the capacitor. Solving this for V_c yields

$$V_c(t) = V_0 e^{-\frac{t}{RC}} \tag{5.2}$$

where V_0 is the voltage at time $t = 0$. The time it takes for the voltage to drop to $\frac{V_0}{e}$ is called the RC time constant and is given by $\tau = RC$. For a given resistance, the time it takes for the voltage to drop to a certain level depends on the capacitance and this time and the corresponding voltages can be monitored by a microcontroller. This was the approach taken in the tests described in Section 6.6.

5.6 Seal

The dosage pump mechanism of the refill is made from several components where one is a circular seal. The seal has direct contact with the soap and since soap is conductive whereas air is not, one idea was to test the conductivity between two opposing sides of the seal to see if it was possible to detect when the refill becomes totally empty. Unfortunately a thin layer of conductive soap remained on the seal walls and this concept had to be discarded.

[1] If placing a soap refill between two plates that are about as large as the refill itself, the distance between the plates cannot be seen as small and equation 4.4 will lose accuracy. However, the variables should still relate to each other in a similar way.

Chapter 6

Tests and test results

This chapter presents the test results obtained for the concepts described in Chapter 5. For each concept and prototype, their dedicated section starts by showing graphs of the test results, followed by some comments about the result or the test in general. Where suitable, the data has been scaled so that the largest value is set to one (1) and the smallest value zero (0).

6.1 Test procedures

TP1 - Seven refills were prepared so that their contents ranged from full to empty. These refills were then placed inside a prototype one at a time and discrete values were obtained and plotted against the actual soap level to create an approximate emptying curve.

TP2 - The sensors and their readings were continuously monitored as a machine emptied the refill dose by dose. The total number of doses dispensed was noted when the refill became empty. In this way thousands of measurement points were taken which gave a detailed picture of concept performance and characteristics.

TP3 - Approximately 50 ml of soap was manually emptied in intervals and between each interval the dispenser was left at rest until the software accepted incoming sensor readings, read more about the software in Chapter 8. Allowed emptying speed k_{min} was set rather high; 18 grams per minute. In other words the whole refill was emptied in about an hour.

TP4 - The fourth test was carried out during several days in a restroom at SCA's office. The system updated its status each minute and the readings were saved to a log file for later analysis. Three times during the test the system was paused and the actual weight of the refill was measured using a calibrated scale.

6.2 Back plate

6.2.1 First prototype

Spring and Hall effect sensor

A magnet was placed on the moving part and a Hall effect sensor was placed on the non-moving part of the slider. The closer the two parts are, the stronger is the magnetic field the sensor experiences and the measurable output changes accordingly. A spring was used between the two parts to create the distance difference between full and empty refill. Test results are shown in Figure 6.1.

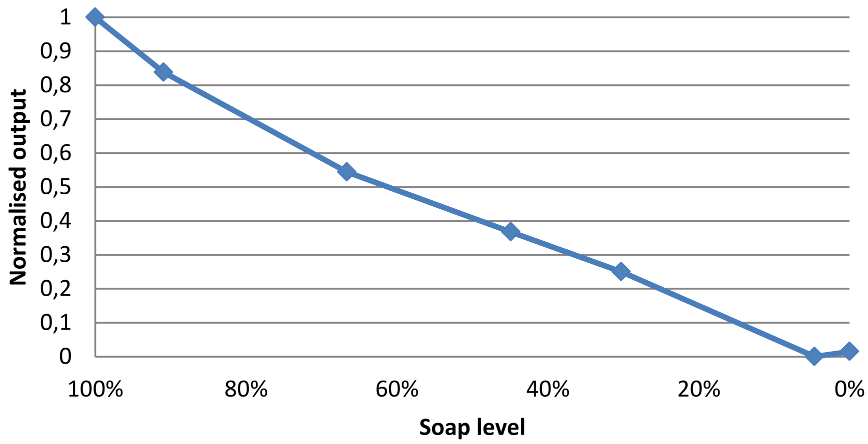

Figure 6.1: Spring and Hall effect sensor test results. TP1.

Spring and IR distance sensor

The distance between the two parts of the slider was measured by an IR distance sensor. The sensor was used together with a spring. See Figure 6.2 for results.

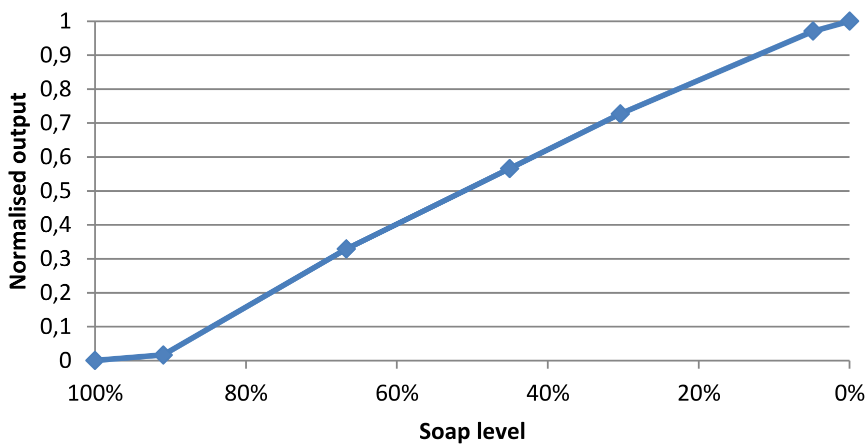

Figure 6.2: Spring and IR distance sensor test results. TP1.

Beam load cell

A beam load cell taken from an electric kitchen scale was placed between the two parts of the slider. The deflection of the beam in this test is not visible to the human eye. The plot in Figure 6.3 shows a steadily decreasing curve generated by the output from the load cell.

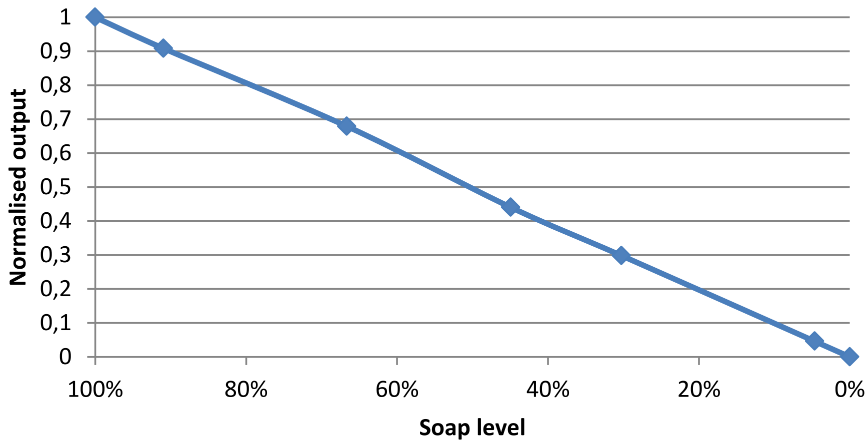

Figure 6.3: Beam load cell test results. TP1.

Micro load cell

A micro load cell taken from an electric kitchen scale was placed between the two parts of the slider. The deflection of this load cell is small but possible to see. According to Figure 6.4-6.6 the micro load cell (being significantly weaker than the beam) seems to be able to handle the weight giving a slightly less steady curve.

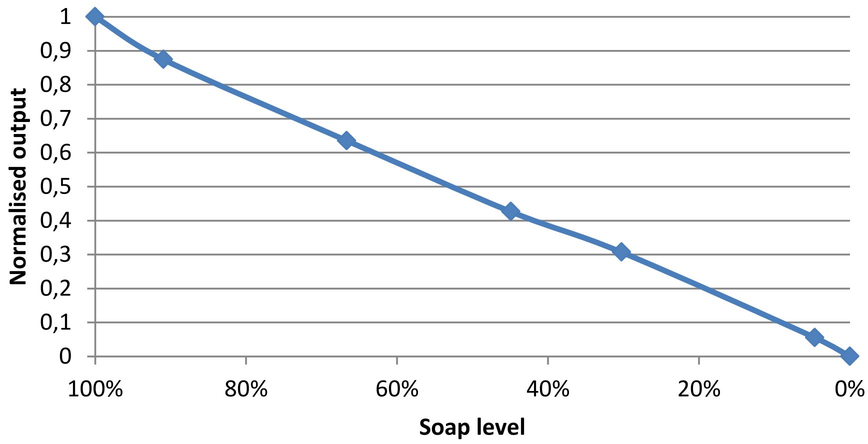

Figure 6.4: Micro load cell non-continous test results. TP1.

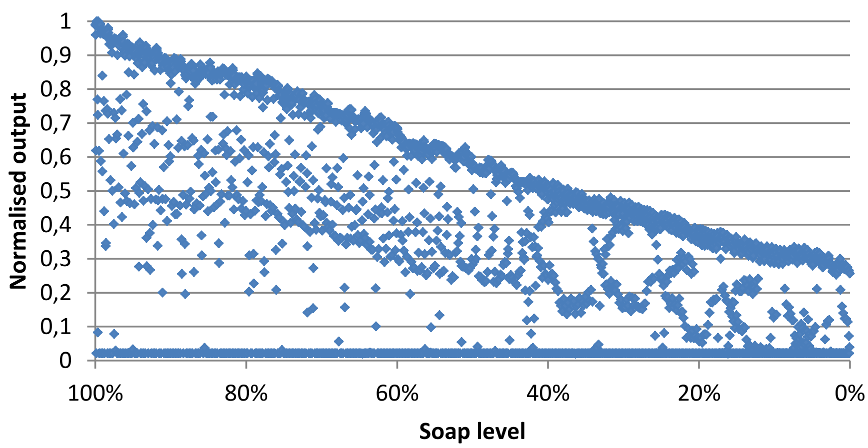

Figure 6.5: Results from a machine test of the back plate using a micro load cell. TP2.

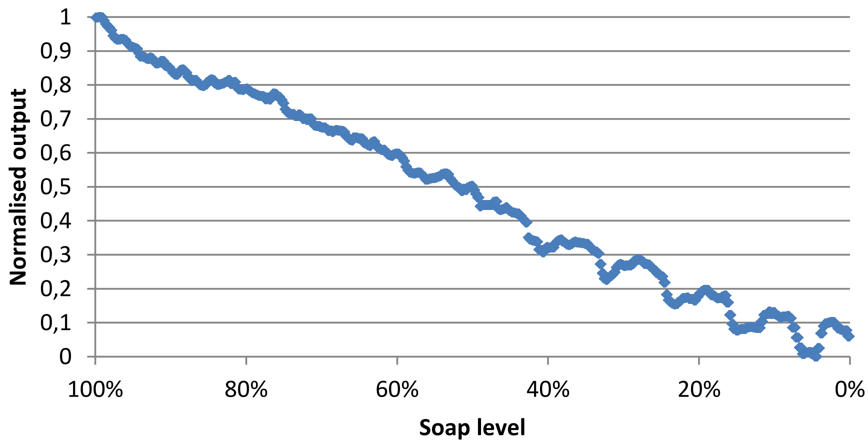

Figure 6.6: Median filtered results from the machine test of the micro load cell. TP2.

Comments

All of the back plate concepts have proven to be rather accurate at tests. One problem however appears with the first prototype and the spring used. The problem is that the system can find more than one stable condition. The dispenser can often be lifted a (tiny) bit and then stay in that new position due to friction etc. which yields a sensor reading different from the previous, despite that the weight of the dispenser has not changed. In Figure 6.5, several measurement values are below the approximately linear level curve and some are equal to zero. The explanation is that these values have been measured while the machine was pushing against the lever which lifted the dispenser marginally.

6.2.2 Second prototype

The red line in Figures 6.7 and 6.8 marks where the system is calibrated for empty refill. The green line marks full refill. The sensor readings were noted at the time where the programme accepted them, read more about the software in Chapter 8.

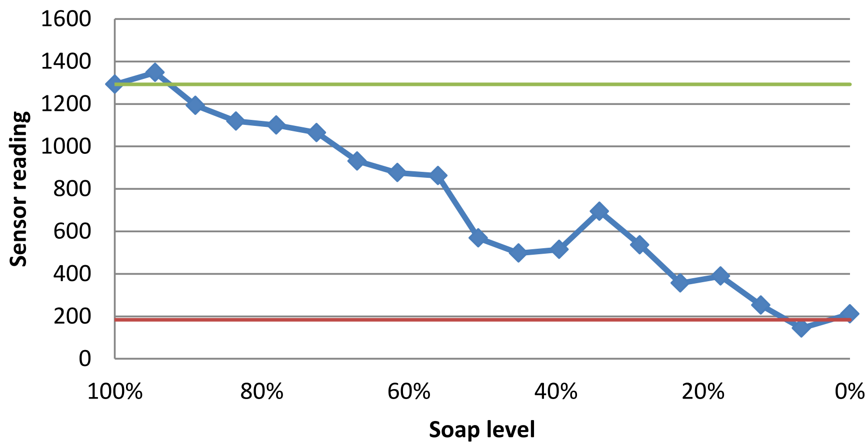

Figure 6.7: Back plate results (second prototype, test 1). TP3.

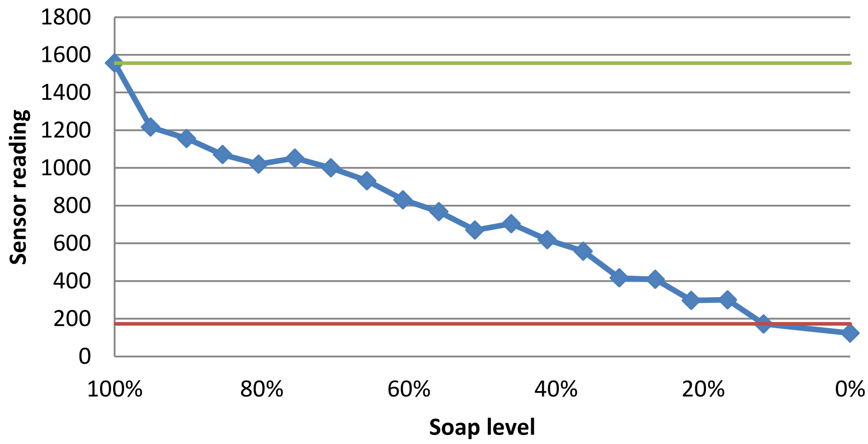

Figure 6.8: Back plate test results (second prototype, test 2). TP3.

Comments

In steady state when the dispenser was at rest the sensor gave very stable readings. However, the prototype proved to be very sensitive to how the dispenser was positioned on the load cell. Since usage causes the dispenser to move slightly this sometimes affected the readings rather strongly, especially in the first test. To allow for the dispenser to move up and down there needs to be a certain gap between the two parts that move relative to each other. This gap was reduced in the second test (Figure 6.8) by adding a few paper strips between the parts. As can be seen in the results, the second test showed more linearity than the first. The programme showed empty slightly before reality, which is due to a difference between calibrated zero reading and what the system senses when the refill has been emptied.

6.3 Donut

6.3.1 First prototype

The test results of the first prototype of the donut load cell is presented in Figure 6.9.

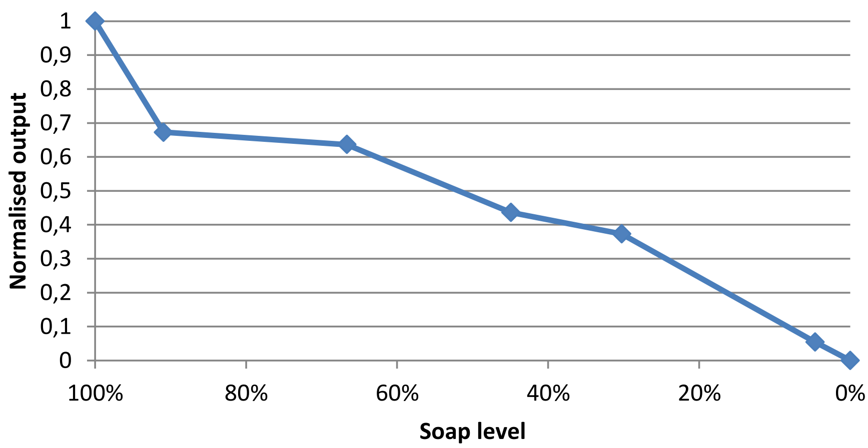

Figure 6.9: Donut load cell test results (first prototype). TP1.

Comments

The output from the sensor gives, apart from the fluctuating values to the left in Figure 6.9, good indications of the soap level and it is possible to distinguish a completely empty refill from an almost empty one.

6.3.2 Second prototype

Figures 6.10 - 6.12 show the test results of the second donut prototype.

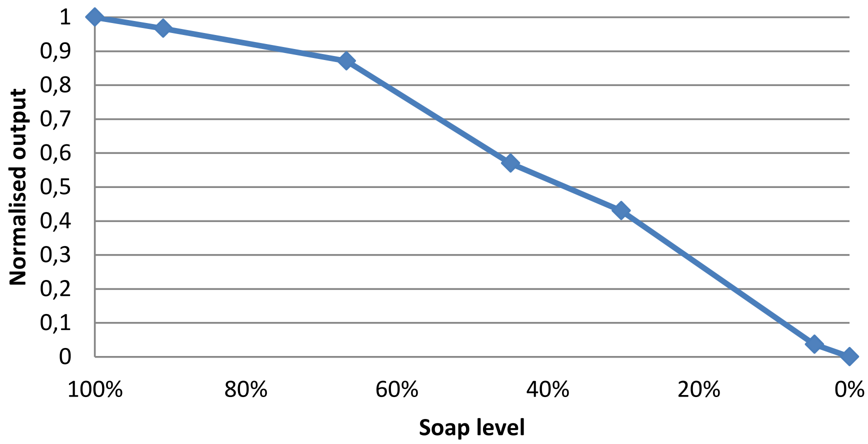

Figure 6.10: Results of a discrete test of the second donut prototype. TP1.

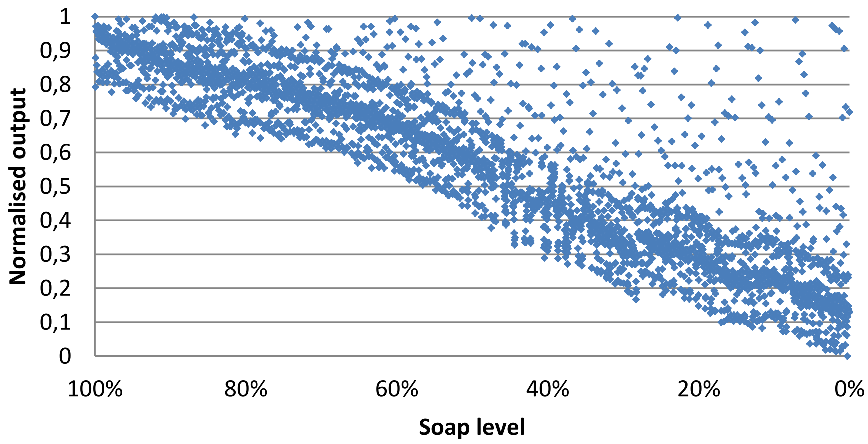

Figure 6.11: Machine test results for the second donut prototype. TP2.

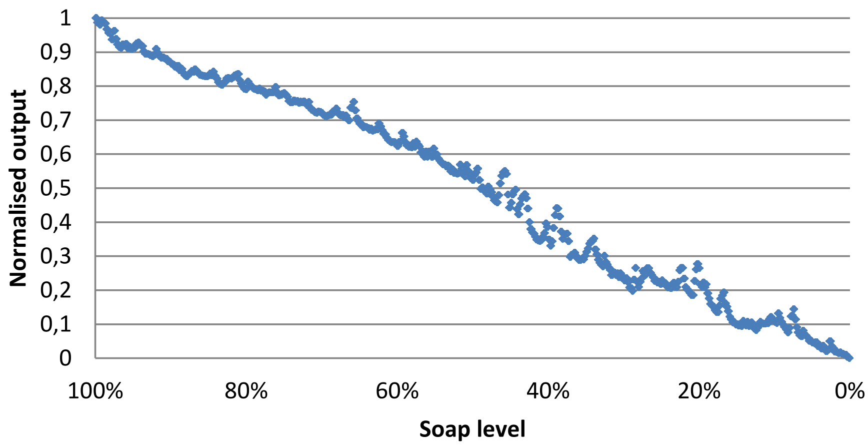

Figure 6.12: Median filtered machine test results for the second donut prototype. TP2.

Comments

The second prototype showed a stable trend in readings between full and empty refill. The perhaps most interesting shown in the graphs is the three bands of readings in Figure 6.11. The reason for these has not been figured out, luckily outer bands had no or little effect on the filtered result. The reason why readings can be seen above the main cluster is because measurements were sometimes taken while the machine was pushing against the lever and generated thereby a spike in readings while doing so.

6.3.3 Third prototype

The red line in Figures 6.13 and 6.14 marks where the system is calibrated for empty refill. The green line marks full refill. The sensor readings were noted at the time where the programme accepted them, read more about the software in Chapter 8. Figures 6.15, 6.16 and Tables 6.1 and 6.2 present the results from the final tests which took place in a real washroom environment. The fourth test (Fig. 6.16) was carried out using a punctured, non-collapsing refill. It should be noted that these graphs contain a large number of data points on a small area. For more details and larger graphs, see Appendix H.

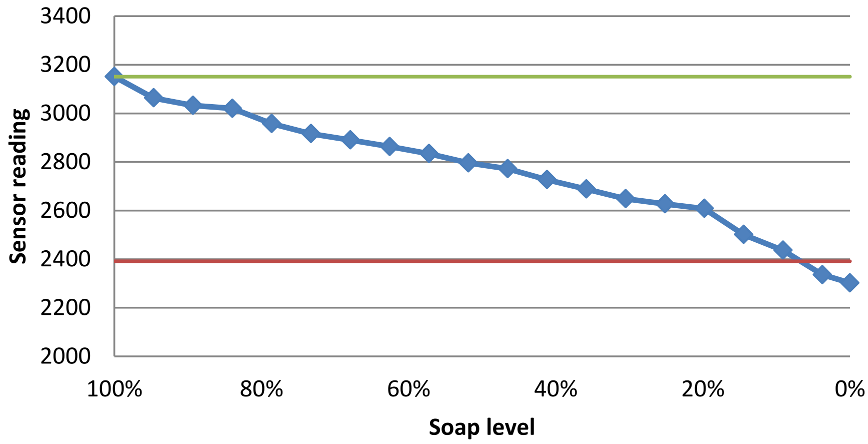

Figure 6.13: Donut test results (third prototype, test 1). TP3.

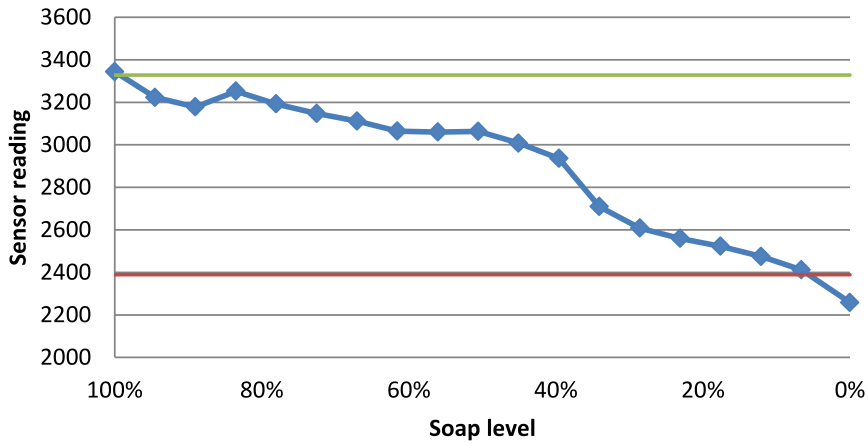

Figure 6.14: Donut test results (third prototype, test 2). TP3.

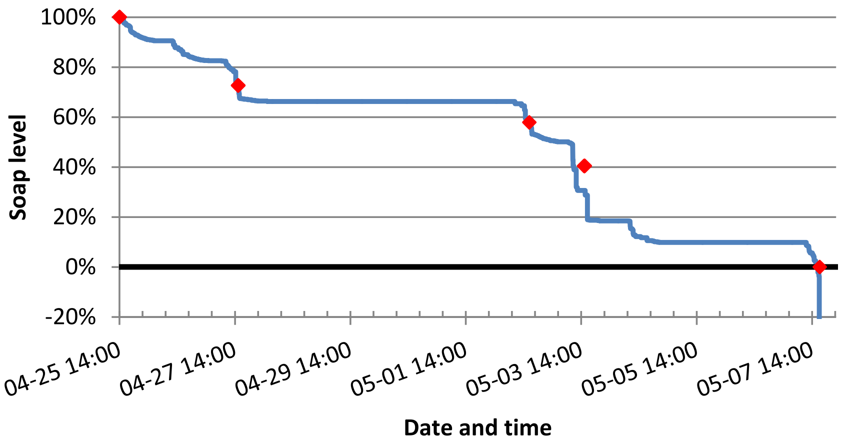

Figure 6.15: Donut test results (third prototype, test 3). TP4. The blue line represents the measurement system's soap level estimation while the red diamonds show the actual soap level.

Table 6.1: Donut test results (third prototype, test 3). TP4

Mass (g)	Est. mass (g)	Diff. (g)	Actual %	Est. %	Doses diff.	Day
1090	1089	1	100.0	99.9	2.5	0
810	815	-5	72.6	73.1	-12.5	2
659	673	-14	57.8	59.2	-35	7
481	387	94	40.4	31.2	235	8
68	-198	266	0.0	-26.0	665	12

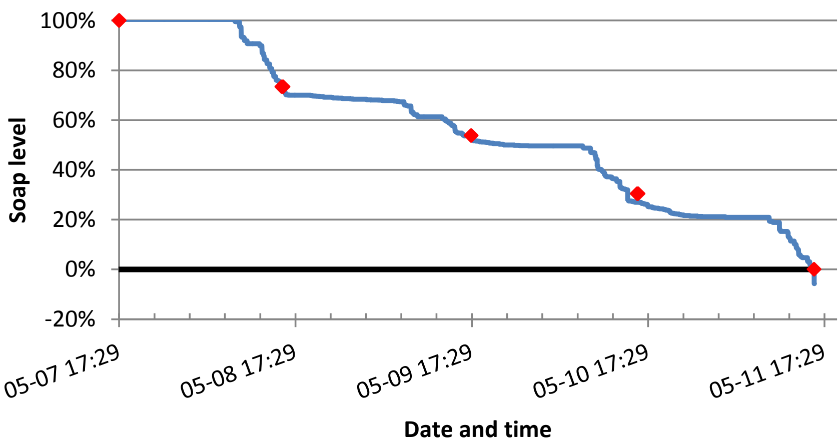

Figure 6.16: Donut test results (third prototype, test 4). TP4. The blue line represents the measurement system's soap level estimation while the red diamonds show the actual soap level.

Table 6.2: Donut test results (third prototype, test 4). TP4

Mass (g)	Est. mass (g)	Diff. (g)	Actual %	Est. %	Doses diff.	Day
1105	1106	1	100.0	100.1	2	0
830	837	7	73.4	74.1	18	1
626	631	5	53.7	54.2	13	2
385	349	-36	30.4	27.0	-89	3
70	11	-59	0.0	-5.7	-147	4

Comments

The third prototype has sometimes showed tendencies of measurement offset. The sensor readings have here seemed to, for a while, be too high or too low for a given soap level. Within the time span of a test the system has usually however corrected itself and returned to be in the proximity of the expected reading. An example of a shifting curve is seen in Figure 6.14. Figure 6.13 on the other hand shows an example of when there are few surprises and a good linearity in readings.

The accuracy of the measurements seem to become worse with decreasing soap level. In the end of the last test, presented in Figure 6.15, the system's readings are far from the expected values and indicate a 0% soap level when there still is a considerable amount of soap left. When the dispenser lid was opened after having emptied all soap, one could see that the refill had twisted away from one of the upper supports. This makes it likely that the refill's weight distribution had shifted slightly from being almost entirely on the front to having put weight also on its rear resting point. A shift in weight distribution between the two resting points has a very large impact on the measurements. If the refill starts to put weight on the rear resting point, the dispenser's centre of mass moves closer to the wall and the moment the sensor measures drops. Since the magnitude of the readings decrease, the system thinks the soap level has decreased and this is what could have happened near the end of the third test shown in Figure 6.15. A clearer, larger graph is found in Appendix H.

6.4 Swing

The dispenser is fixed to the wall with only the two upper screws loosely tightened. A button load cell is mounted on the lower part of the dispenser so that, except for the uppermost part of the dispenser, only the load cell touches the wall, see Figure 6.17.

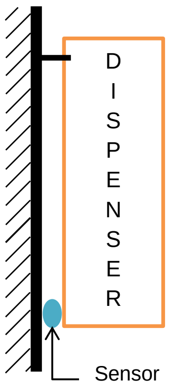

Figure 6.17: Swing setup.

Results

The output from the sensor gives good indications of the soap level and it is possible to distinguish a completely empty refill from an almost empty one, see Figure 6.18.

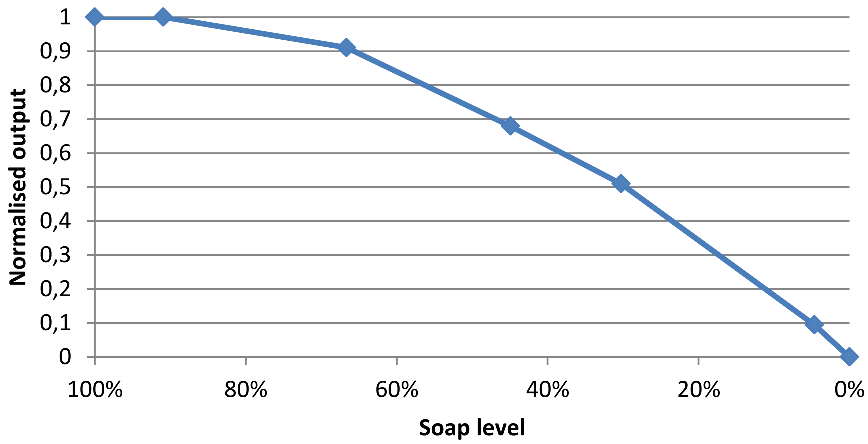

Figure 6.18: Swing test results. TP1.

Comments

The swing concept and the button load cell gives good results but the problem with overload must be solved (the load cell must be protected against the additional forces occurring when a user pushes the lever). Moreover, the dispenser cannot be loosely mounted in a real situation.

6.5 Optical

Prior to the tests the optical concept was meant to use one sensor placed at the best possible spot on the refill. In order to make the test more effective three distance sensors were mounted closely against the surface of the refill according to Figure 6.19, all measuring the closest adjacent surface. The sensor placed at the top and against the thick part of the refill is called "Upper". The one that is attached down to the left is called "Neck". The third and last sensor down to the right and against the thick part of the refill is called "Middle". The test was carried out in a machine.

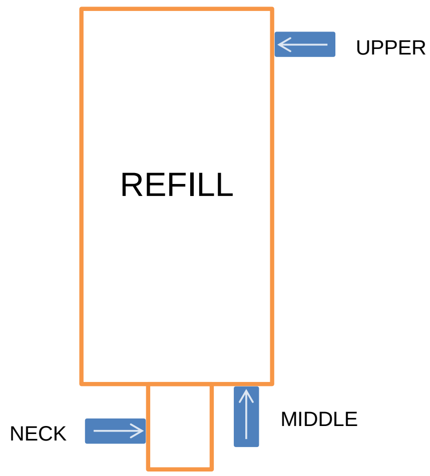

Figure 6.19: Optical test setup.

Results

As can be seen in Figure 6.20, the upper sensor was the first to begin covarying with soap level. The middle sensor starts to indicate changes when the level is lower than 15% and there is a distinct decrease when the refill starts to become empty. The neck sensor gives a steep decrease in signal when the refill is virtually empty.

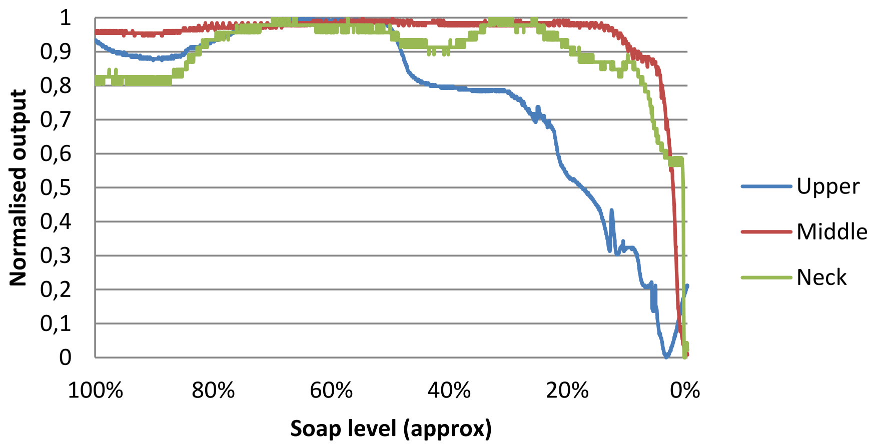

Figure 6.20: Optical test results. TP2.

Comments

Optical sensing is an interesting method that seems to have potential of giving good readings for certain soap level intervals. Important is to find a construction that makes it possible for the sensor to come in direct contact with the soap refill. One must also make sure that this construction will not hinder a refill change.

Another thing to keep in mind is that in this test the refill was emptied quickly so that bubbles formed inside the refill. Bubbles affect a sensor's output quite strongly and how the same sensors would react in a situation where the refill is emptied much slower so that bubbles go away is difficult to say.

Preliminary tests indicate that optical sensing works with different kinds of soap, including soaps that are not transparent.

6.6 Capacitance

6.6.1 Single plate sensing

Thin sheets of aluminium are placed on both sides of the refill inside the dispenser. These two sheets form two capacitor plates, one being constantly connected to ground whereas the other plate is charged and discharged. The grounded plate is placed at the back of the dispenser and the sensing plate at the front.

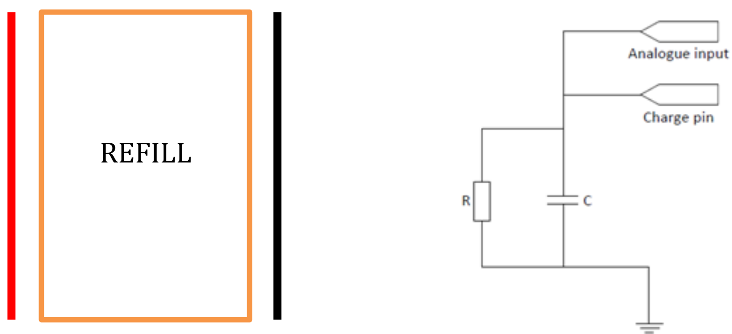

Figure 6.21: **Left:** Single plate sensing setup. **Right:** RC circuit used for single plate sensing.

Measurement procedure

Charge the sensing plate → Turn off charging → Sample voltages during discharge → Estimate RC time constant.

Results

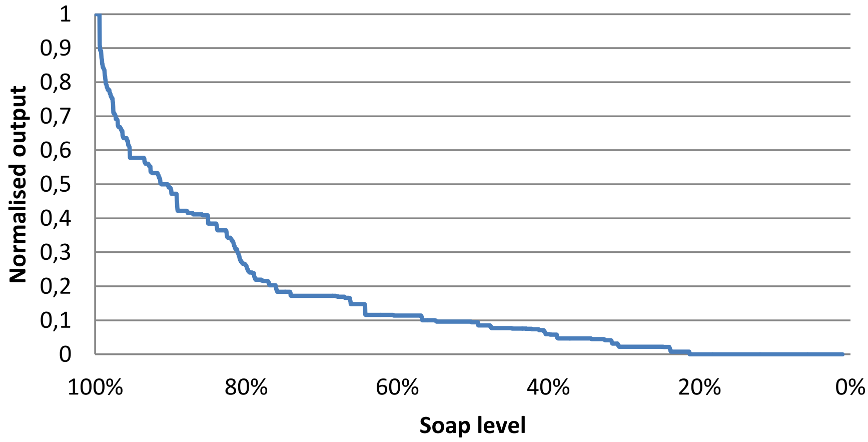

Figure 6.22: Single plate results from continuous test in machine. TP2.

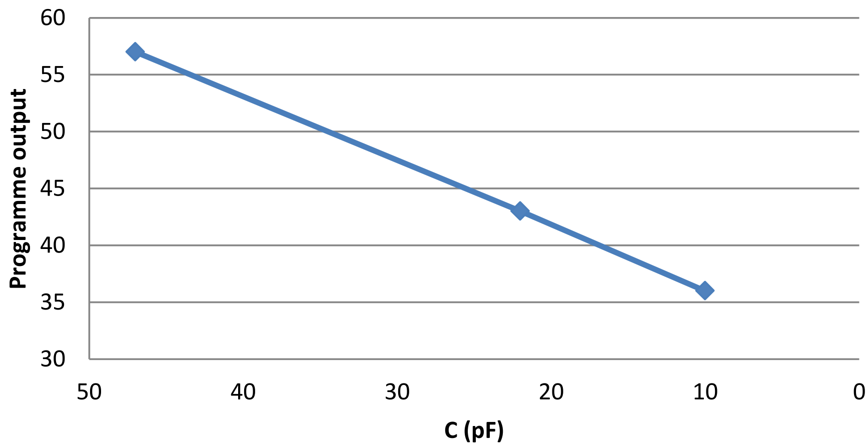

Figure 6.23: Programme output for known capacitances. Resistor used: 680 kΩ.

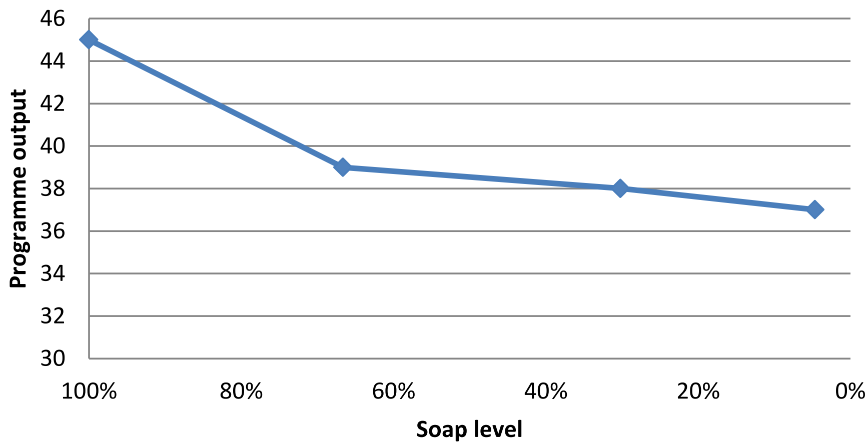

Figure 6.24: Programme output for various soap levels. Resistor used: 680 kΩ. TP1.

Comments

It seems like the capacitance changes most rapidly when the refill is nearly full. From a soap level of around 70% down to 0% the capacitance changes only by a few picofarads. Such a small change is very difficult to measure with the used circuit and setup.

How much better other circuits are at measuring these small changes is not known. Another question mark is how well the plates can be shielded from the surroundings. In the tests, a hand placed on the front of the dispenser made the output reach levels of the same magnitude as a full refill.

All in all, the single plate setup should be fairly accurate at sensing whether a refill is changed to a full one. However, only the simplest forms of microcontroller based capacitance measurements have been tested in this project and more sofisticated methods might prove to be successful in the entire usage cycle of the refill.

6.6.2 Triple plate sensing

An idea is to split the sensing plate into three and thereby get three readings that combined could be more precise than a single reading. Another possible advantage from segmenting the sensing plate is that the readings become more local to the upper, mid, and lower sections of the refill. Therefore, three thin sensing plates of aluminium were placed at the front of the dispenser. A single plate was used as ground at the back of the dispenser, see Figure 6.25. The circuit that was used is shown in Figure 6.26.

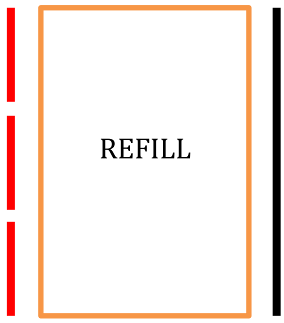

Figure 6.25: Triple plate sensing setup.

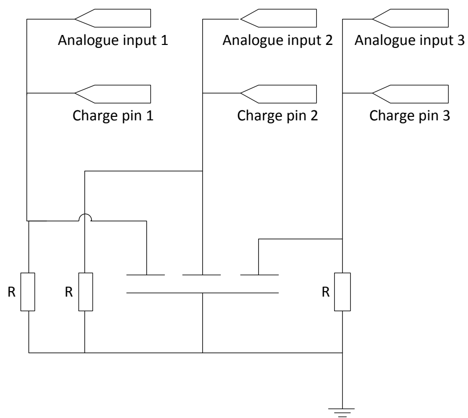

Figure 6.26: Circuit used for triple plate sensing.

Measurement procedure

P1: For each plate: Charge the sensing plate → Turn off charging → Sample voltages during discharge → Estimate RC time constant.

P2: For each plate: Charge the sensing plate → Turn off charging → Measure the time it takes for the voltage to drop to a certain level.

Results

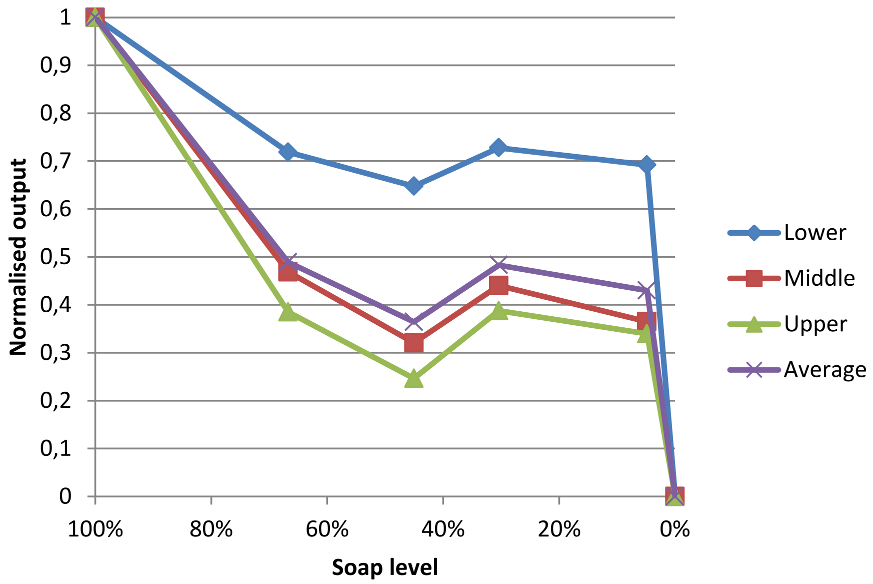

Figure 6.27: Test results for programme P1. TP1.

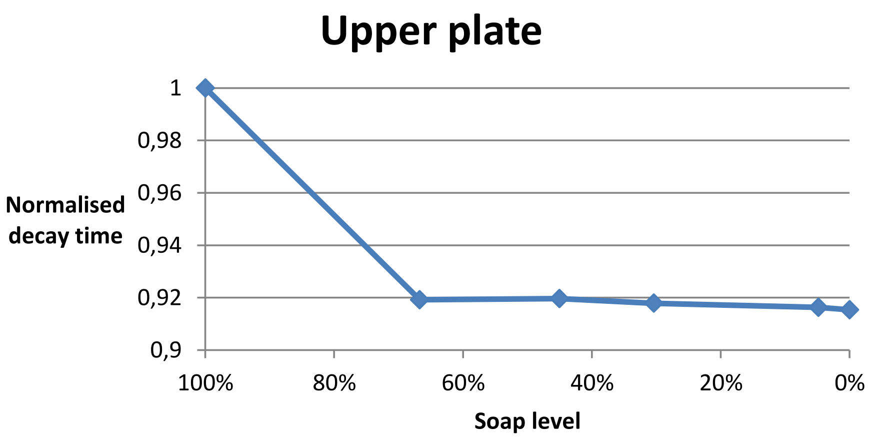

Figure 6.28: Test results for the upper plate with programme P2. TP1.

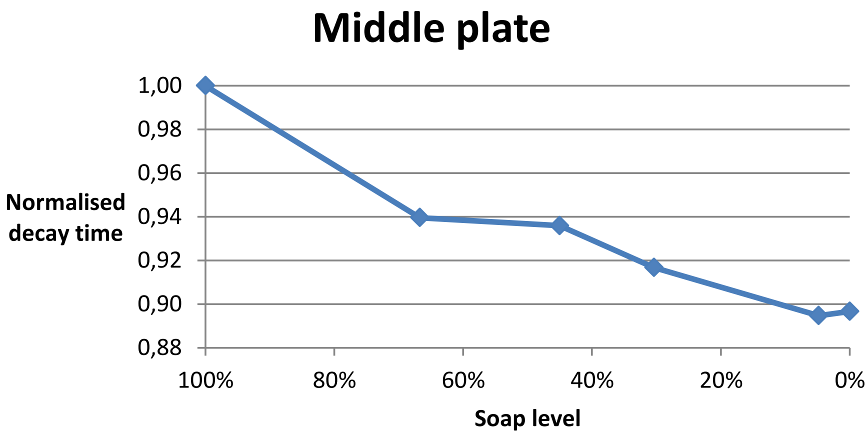

Figure 6.29: Test results for the middle plate with programme P2. TP1.

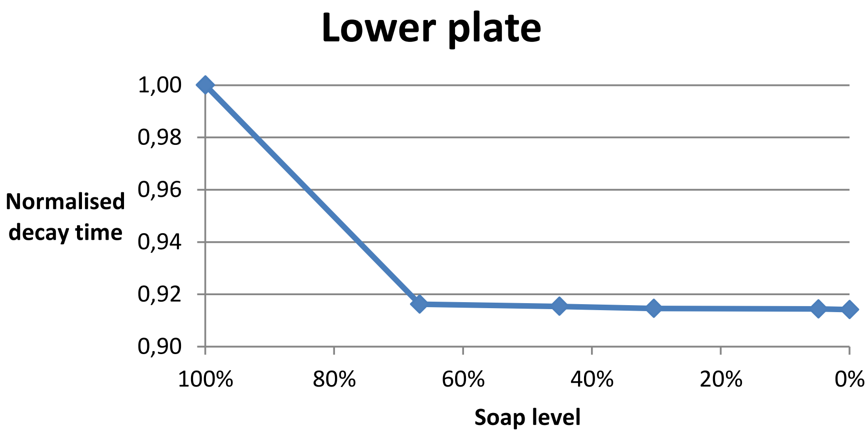

Figure 6.30: Test results for the lower plate with programme P2. TP1.

Comments

The triple plate concept shows the same behaviour as the single plate. The resolution is good for a nearly full refill but the soap level gets difficult to derive at lower levels. The sudden drop close to 0% in Figure 6.27 is interesting but seems to be due to the shape of that particular empty refill.

6.6.3 Tube sensing

Two thin and narrow sheets of aluminium were attached to a 12ml, 8 cm test tube. The tube was then filled with soap, one ml at a time, generating the results shown in Figure 6.31. The difference between maximum and minimum absolute reading in this test was very small.

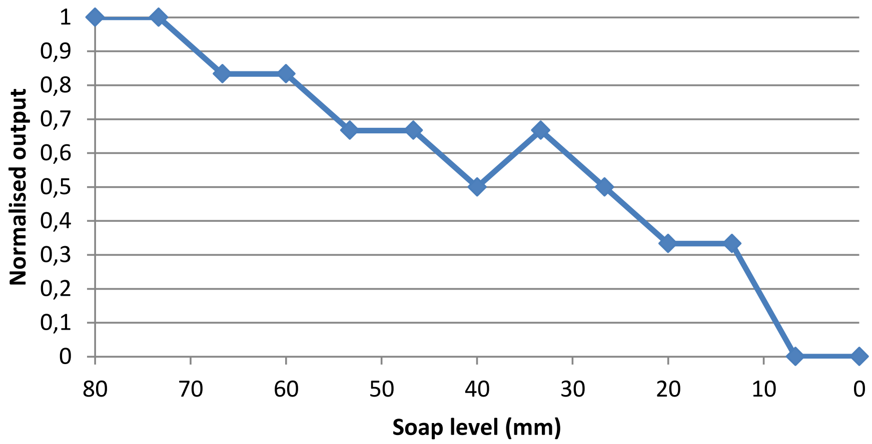

Figure 6.31: Test results for test tube measurement.

Comments

Unfortunately the capacitance differences seemed to be so small in this test that the used equipment could barely detect the changes.

6.6.4 Comments on capacitive sensing

If the system can be shielded in a good way and a suitable circuit for detecting capacitance changes of a few picofarads magnitude can be found, then using a capacitive sensor might be interesting for soap level measurement.

If the above cannot be accomplished then capacitance could still be a good way to detect whether a full refill is inserted into the dispenser. This also works without a grounded plate, i.e. only a single thin sheet of metal would be enough.

Recommended is to try out more sophisticated hardware (often based on alternating current, AC) to see if the soap level can be derived more easily with these. Except from the circuit board, the capacitive sensor only needs two thin sheets of metal and should be possible to produce at very low cost.

Chapter 7

Concept evaluation and selection

After the concept generation 24 different ideas were to be funneled down to one or two ”winners”. The initial approach was to narrow down similar concepts and keep the best one or two of each type. Furthermore, concepts with uncertain performance that were easy to test were kept and concepts that would be time consuming or difficult to test were eliminated unless they had an obviously higher potential than other remaining concepts. All initial sketches can be found in Appendix G.1.

7.1 First screening: Categorisation

The ideas were categorised according to what kind of modifications they would make to the present S4 system. Three main categories were created. The number of concepts belonging to each category is shown in brackets:

- No modifications (5)
- Dispenser modifications only (10)
- Modifications to refill or both (9)

The concepts within each category were then compared to each other on a number of criteria, see Appendix C. The criteria were:

- Quality of visual signal
- Performance in measurement
- Durability
- Resistance against disturbances
- ”Foolproof-ness”
- Energy consumption
- Ease of manufacture
- Generality
- Economic potential

The way this was done was to put concepts belonging to the same category in a table and use one concept as reference and then, for each criterion, hand out pluses and minuses for all other concepts to denote if they were thought as being better or worse compared to the reference. Also zeros and question marks were put into the table. Zeros meaning a concept was seen as equally good as the reference at a criterion and a question mark meant that no credible estimation could be made. The pluses, minuses, zeros and question marks were then summed up and gave a rough idea of which concepts had a high potential, which that were poor and which that were uncertain. The main result from the comparison was however not the table itself, rather it was the insight gained after discussing the criteria for each concept. After these discussions, a total of 11 concepts were eliminated. The tables, also known as Pugh matrices, can be found in Appendix D.

The now remaining concepts are shown in Table 7.1.

Table 7.1: Remaining concepts after initial screening.

No.	Name (Swedish)	Name (English)	Category	Main sensor
1	Kateterinvers	Water bed	No modifications	Pressure, capacitance
2	Bakplatta med fjäder 1	Back plate with spring	No modifications	Position
3	Elektronisk bakplatta	Electronic back plate	No modifications	Load cell
4	Endast TT-givare	Strain gauge(s) only	Dispenser mod. only	Strain gauge
5	Donut	Donut	Dispenser mod. only	Load cell
6	Yttre gunga	Swing	Dispenser mod. only	Load cell
7	Rätt tonläge	Audio	Dispenser mod. only	Microphone
8	Kondensator	Capacitor	Dispenser mod. only	Capacitor, metal
9	Direkt nivåavläsning	Colour or reflection	Dispenser mod. only	IR
10	Tätning	Seal	Mod. refill or both	Switch
11	Magnetisk baksida	Magnetic rear label	Mod. refill or both	Hall effect
12	Solid nivådel	Stiff tube	Mod. refill or both	IR, capacitor
13	Icke-kollapsande tillägg	Non-collapsing piece	Mod. refill or both	IR

7.2 Step two: Testing

The relative performance and viability of the remaining concepts were difficult to estimate and therefore it was decided to test as many as possible.

Concepts 9, 12 and 13 could share a common test/prototype (see Section 6.5) and were therefore seen as one until the results of this test had been evaluated. Similarly, concepts 2 and 3 could be tested with a shared prototype, see Section 6.2.1. The rest of the concepts were prototyped individually and tested except the following four:

1: Water bed. Was too difficult too construct a reliable prototype without taking valuable time from other concepts. Also, it was uncertain it would be possible to keep a product 100% waterproof year after year. A ready to build prototype is presented in Appendix I.

4: Strain gauge(s) only. Uncertainty whether strain gauges would work properly on a plastic material. Many other strain gauge based concepts were still remaining and therefore it was decided to let this concept go.

7: Audio. This was seen as an interesting but time consuming concept. The time needed along with a big portion of uncertainty led to the elimination decision. A brief explanation of how this concept were supposed to work can be found in Appendix J.

11: Magnetic rear label. Having a magnetic label on the refill means customers would have to pay extra for each refill and since this concept was mostly seen as reliable in a digital (soap / no soap) mode it was believed that it would never come out as a winner.

All in all, nine concepts were taken further for testing. The results from the tests are shown in Chapter 6.

7.3 Step three: After tests

Concept 10, ”Seal”, could be eliminated since a thin layer of soap remained on the inner surfaces of the refill even when it was considered being empty. The seal was therefore conductive at all times and the concept did not work. The other tested concepts did work and their status after testing was compiled into Table 7.2.

Using the test results and Table 7.2 as background, the remaining concepts were discussed with SCA representatives and it was decided to focus on concepts 3 and 5, electronic back plate and donut. These two concepts had a good chance of being able to measure a continuous level and could use the same sensor and practically also the same software.

Table 7.2: Remaining concepts after initial screening.

	Electronic back plate	**Back plate with spring**	**Optical/IR**	**Capacitor**	**Donut**	**Swing**
Concept no.	3	2	9, 12, 13	8	5	6
Can measure continuous level	+++	+++	+	+	++	++
Can clearly see when the refill is empty or when the soap passes a certain level	++	++	+++	+	++	++
Uncertainty in upcoming work	-	-	- -	- - -	- -	- - -
Estimated relative cost	- - -	- - -	-	-	- -	- -

7.4 Step four: Evaluation of the two final concepts

New prototypes were made of the final two concepts. The main modification to both concepts was an improved aesthetic appearance. Test results for the electronic back plate are shown in Section 6.2.2 and for the donut concept in Section 6.3.3. Evaluations of the two prototypes are found in sections 7.4.1 and 7.4.2 below.

7.4.1 Electronic back plate

For a sliding construction it was immediately noticed how sensitive the geometry was. Large tolerances for the gaps between the parts would make them move quite freely, but would also mean the dispenser was not always positioned in the same way on the load cell. Similarly, tight tolerances would make the dispenser lie centered on the load cell at all times, but could lead to friction disturbances in measurements. A future prototype or product also needs to become stiffer in rotation around the vertical axis.

This prototype had low measurement drift but was prone to measurement offset. One of the reasons for sudden changes in readings after dispenser usage is believed to be the possibility for the dispenser to move slightly in the horizontal direction. This yields a situation where the dispenser does not rest equally on the load cell at all times. How much of a problem this is for another type of load cell is not known. A disadvantage with the used load cell might be that if the dispenser moves horizontally it also bends the load cell slightly in a non-vertical direction, giving unpredictable readings.

To prevent someone from lifting the whole dispenser a snap fit between the two parts could be designed, so that one would have to open the lid before being able to dismantle the dispenser.

7.4.2 Donut

The donut concept gave a more sturdy feeling when using the dispenser. Another good thing about the donut concept is that it is completely hidden inside the dispenser body. The largest concern is about mounting. The current prototype is sensitive to screw holes that are not drilled perpendicularly to the wall and parallel to each other. A refinement of the prototype should however be able to deal with these issues.

The idea with having the load cell holder touching the wall onto which the dispenser is mounted is to make the system as insensitive as possible to how tightly the screws are fastened. This has not worked as well as intended but a 3D printed prototype is quite soft and fragile. Another thing affecting this is the evenness of the wall onto which the dispenser is mounted. Many washroom walls are tiled and there is often a level difference between tiles and at the intersection between tiles.

The measurements from the donut concept have shown more drift than what has been observed for the back plate. However, it has been less disturbed by usage and the reading drift and offset have been approximately equally frequent above and below the true value.

7.4.3 Winner

Based on the experience from the last two prototypes it was the donut prototype that performed best and was therefore mounted in a restroom at SCA for deeper analysis. Results from this test are shown in Section 6.3.3.

Chapter 8

Software

The software interpreting the analogue signal received from the load cell in the donut and electronic back plate concepts is described by a flow chart, see Figure 8.1 below.

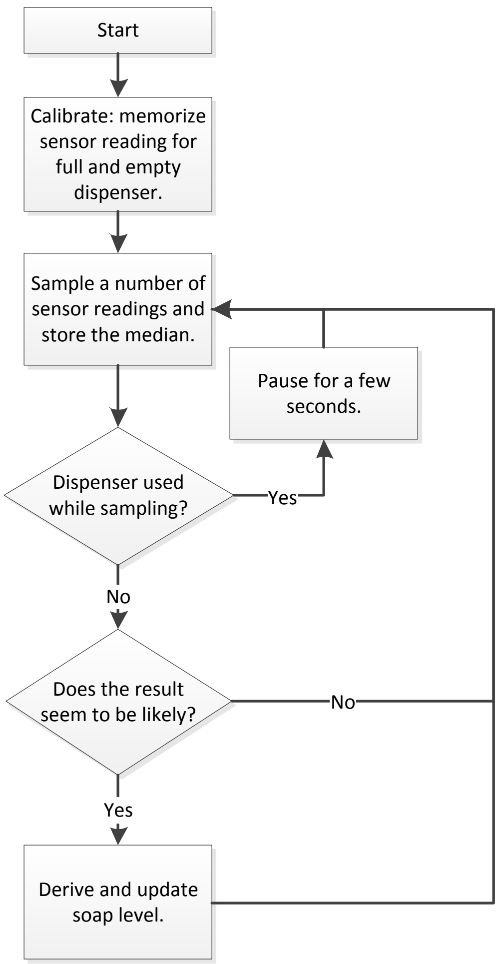

Figure 8.1: Flow chart describing the main features of the software.

Calibration

The system is calibrated by the following procedure:

1. A button is pushed when the dispenser is completely empty. A median filtered sensor reading is stored for ”empty dispenser”.

2. The button is pushed again, now with a full refill inserted into the dispenser. A median filtered sensor reading is stored for "refill max".
3. The system assumes a linear relationship between refill weight and sensor reading and sets the expected reading for an empty refill to a point on the line between full and completely empty dispenser. This reading is denoted "refill min".
4. The system is now calibrated and enters its main state, where readings are compared to the straight line between refill min and refill max.

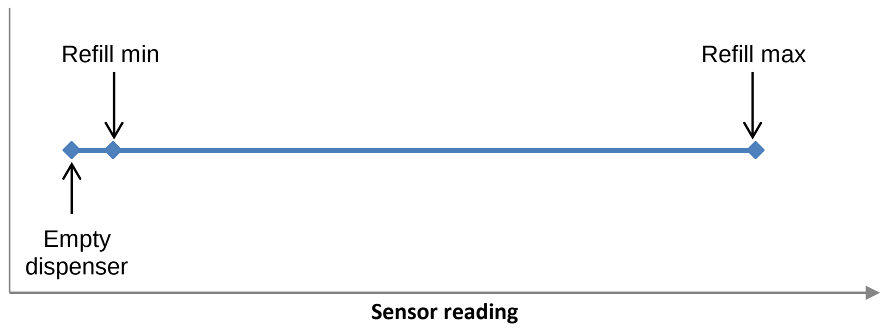

Figure 8.2: Points of interest during calibration. Refill min is placed between the reading for empty dispenser and a full refill.

Sensor sampling and disturbances

The microcontroller reads the sensor nine times at 200 millisecond intervals.[1] The result is then given as the median of these readings. Furthermore, during the sampling the maximum and minimum readings are stored and later compared. If these two readings differ too much the system is not at rest (someone is using the dispenser) and the sampling is restarted after a five seconds long pause. If the system needs to restart the sampling many times in a row, it will eventually accept the result anyway to avoid freeze.

Analysis of a new sensor reading

Every time the system accepts a sensor reading, it stores the value of the new reading together with the time at which the measurement was taken. When a new measurement is made, the reading and its corresponding time are compared to the last accepted measurement as follows:

$$k = \frac{reading_{new} - reading_{lastOK}}{time_{new} - time_{lastOK}} \tag{8.1}$$

The result is accepted if $k < 0$ and $k > k_{min}$. In other words, the result is accepted if the soap level has decreased and it has decreased at a rate no quicker than what is allowed by k_{min}.

[1] Nine readings at 200 ms intervals have proven to work fairly well. These parameters are however set without any deeper analysis.

Chapter 9

Discussion

9.1 Project execution

This section will bring forward how some important parts of the project were executed with emphasis on what was good and what could have been done better. To start up the project with a thorough patent search gave plenty of ideas and indications on good practises. At the same time the risk of making unintentional patent violations was reduced. To be able to navigate through the world of patents it is necessary to have access to a well functioning database and search tool. Furthermore, a thorough investigation of competing companies' automatic soap dispensers was done which clearly showed that there was no explicit solution to the soap level measurement problem.

Over all the project has been focused on practical work through extensive testing and trying of different sensors and set ups. A prerequisite to make this possible is to focus on components which are commonly used and easily accessible. This way of working resulted in further development of promising concepts which otherwise would have been excluded due to uncertainties and lack of time for testing.

When it was time to create prototypes especially one action was taken that certainly avoided costly mistakes and bad prototype performance; a close communication with the prototype manufacturer was established early. By doing so, valuable feedback was given on construction details that made it possible to further improve the performance of the prototypes. An example of this is a decision that had to be made whether a prototype was to be produced in a workshop or by rapid prototyping. In this case performance uncertainties were discussed and decided to be too big for rapid prototyping. Instead, the construction could be elaborated in a workshop to ensure satisfying performance. It should also be noted that as much knowledge as possible must be gained before ordering vital parts for the future stages of the project. A certain level of knowledge makes it possible to predict future needs that must be satisfied later on. When the circuit board and microprocessor were about to be ordered this prediction failed in some aspects. For example there could have been better prerequisites for connection to an external display and more space for code, factors that later would limit software development and additional functions.

The focus during this project has been on a stand alone system which meant a lot of effort was put into making one well functioning solution. However, the result could possibly have been even better if a combination of solutions had been pursued. It is likely that some sort of synergy effect could have been achieved if weighing the dispenser would have been combined with a counting function. Maybe there also would have been more interesting concepts.

9.2 Measurements

9.2.1 Expensive sensors

Some costly sensors that would never be commercially viable to use in an end product were used in tests. The reason for this is that it was primarily the principles of the concepts that were to be tested. Knowing that the sensors themselves were of good quality meant that the principles could be judged in a fair way and good references were available when it came to developing the less expensive solutions. Sensors used that can be seen as expensive are the button and donut load cells.

9.2.2 Drift and offset

The unfiltered measurement data given from the micro load cell while mounted in all the load cell utilising prototypes showed a drift phenomenon in a state of rest, i.e. values were sometimes slowly decreasing or increasing without any obvious explanation. For example, a measurement from the load cell (u_{noload}) could be taken when there was no refill placed inside the dispenser. Subsequently a full refill was put inside the dispenser and a new value ($u_{maxload}$) was given. Without touching or affecting the system in any way the sensor value then started to decrease slowly, i.e. the dispenser seemed to get lighter and lighter, for example giving a value 2% lower than $u_{maxload}$ after 10 - 15 minutes. Furthermore, u_{noload} may now show a false value if the offset is not taken into consideration. This will of course affect the performance of the soap level measurement system and thus makes it important to understand why the phenomenon arises and what can be done to avoid it or decrease its negative influence.

Another behaviour that was observed while taking measurements was something resembling an offset that often occurred after the dispenser had been used. If, for example, $u_{maxload}$ was set according to the previous text and, immediately after that, a person pushed the dispenser a value greater than $u_{maxload}$ could be observed. This was often followed by a drift. Figure 9.1 shows an example where initially a stable voltage is observed. The crack indicates that the dispenser has been affected by an external force. Immediately after this, when the external force has been removed, another voltage is measured offset from the previous one and drifting marginally for a short time.

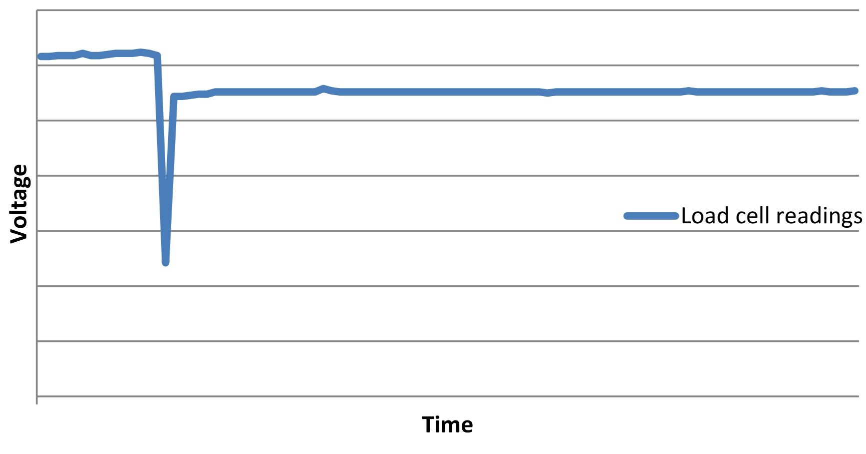

Figure 9.1: An example of how an offset and drift can be preceded by dispenser usage.

While it is common for all sensors to drift it should be noted that the drift affecting the prototype tests could not be reproduced when the load cell was loaded with a weight only as in Figure 9.2. It was clear that this drift was not related to the properties of the load cell itself but rather had something to do with the design and material of the prototypes. It is possible that friction and microscopic lock-ups could cause a situation with a positive drift, i.e. slowly increasing values. Accordingly more and more of the total dispenser weight is transferred from unwanted stress points to the load cell itself over time. The other way around, illustrated by the example given in the first paragraph of this section, is harder to explain and understand.

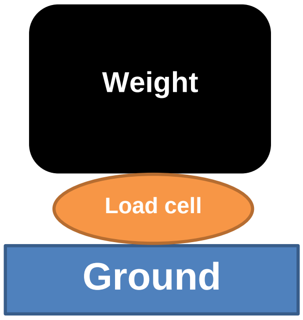

Figure 9.2: A simple set up to test the inherent drift of the load cell.

The major problem caused by the drift and offset phenomena is that the calibrated maximum and minimum values may become unreliable immediately after the dispenser has been used. An analogy could be a jamming spring mechanism which needs a push to reach its true end position. As there has not been enough time to test a variety of constructions there are no safe advices as how to construct a prototype with less drift and offset. Only assumptions on necessary improvements can be made.

9.2.3 Refill resting point, donut

Since the donut concept practically measures the centre of gravity of the dispenser, it is crucial that this property behaves in an expected way. In the S4 dispenser the refill has two points on which its weight can be supported, see Figure 9.3.

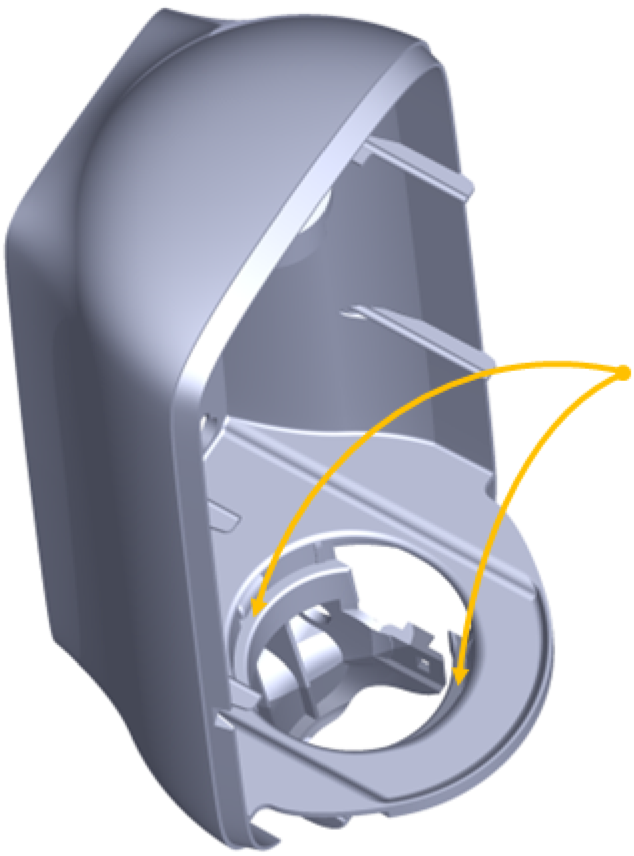

Figure 9.3: The two places where a refill can rest in the manual S4 dispenser.

For a given weight of the refill, the donut concept's sensor will give different readings depending on how the refill's weight is distributed between the front and rear support. The way this has been dealt with in the prototypes has been to add two support points on the upper inner walls of the dispenser so that the refill has been forced to lean slightly forward and thereby put approximately all its weight on the front support. This has worked fairly well but should not be trusted completely.

9.3 Level indication

The issue of how to visually present the soap level for a dispenser has been given little focus in this project. The reason for this is that modifications to the dispenser and/or refill so that one can directly see the refill's content is seen as superior to all indirect electronic solutions such as LEDs, displays etc. Electronic level monitoring has however one major advantage; it enables remote monitoring of dispensers.

If, despite this, an electronic level indicator is preferred on the dispenser itself, it is vital that the power consumption is minimised. To both give a clear visual signal and to minimise power consumption may be contradictory. Primarily two different approaches to deal with this have been thought of. The first approach is to only indicate the level when cleaning staff is inside the washroom. The cleaning staff could e.g. carry an electronic identification or push a button to let the washroom and its dispensers know that cleaning staff is in the room. The dispensers could then start to "glow" red or green depending on if they soon will be empty or not (or give any other form of indication).

The second approach is to let an indicator switch between two stable conditions, i.e. the system only draws current when the indicator changes state. This could probably be accomplished in many different ways, one of which could be to move something mechanically e.g. by the use of magnets or a small motor.

9.4 Counting in software

If the system continuously monitors incoming sensor readings it can detect whether the dispenser is being used or not. By counting the number of pushes the accuracy of the soap level determination could be further increased. Suggested is then to use some sort of weighting between the counting and the weight estimation. A common filter for this type of process (primarily for events with gaussian distribution) is the Kalman filter.

9.5 Other promising concepts

The donut concept was chosen as the winner but there were other promising concepts which deserve to be mentioned in this chapter. It is believed that these concepts still have much potential which, due to the limited time for the project, is yet to be discovered.

9.5.1 Capacitance

While being inexpensive and elegant this concept is also one of the more technically advanced ones. More knowledge about electric fields is required in order to be able to fully understand what actions need to be taken to improve its performance. The concept in its current state is able to detect if a refill is present in the dispenser or not. A reason to why it did not succeed in this project is believed to be that the circuit and equipment used during experiments were not correctly used. A method for system shielding is necessary for additional functionality. In this project only one measurement method using DC has been examined but there are many other methods, mainly including AC, being used for liquid level measurements. However, it is likely that this concept works best for rigid tanks, which do not move and are more suitable for attachment of a measurement device, rather than soap refills which are flexible and volatile.

9.5.2 Optical

Yet another inexpensive concept which, by using IR distance sensors, can indicate when the soap has reached a certain level but lacks performance over the total soap level range. More experiments with different sensor placements as well as different types of soap should be conducted. The concept in its current form should be suitable to combine with another solution, with a wider range, in order to achieve increased performance. A good match would be to combine this concept with keeping track of the number of doses dispensed.

9.5.3 Back plate

As well as in the winning donut concept the weight of the refill is central for this concept. It has been showing good results in tests but there are problems with gaps in the construction and material flexibility which sometimes cause unreliable sensor readings mainly due to offset. It is suggested that further development of this concept should consider the beam load cell as sensor instead of the micro load cell. By doing so it is believed that the system will be less sensitive to offset and drift.

9.6 Other product improvements

This section will explain some ideas of how a future dispenser and refill, better adapted for soap level indication and measurement, should be designed. The ideas and suggestions are based on experience from tests and knowledge about the soap level measurement system gathered during the project.

9.6.1 The refill

In order to make it easier for optical soap level measurement methods the refill should be as transparent as possible. This would also make it easier for a person to visually assess the soap level.

If a collapsing refill must be used then there are some important details to keep in mind. The collapse should be predictable and as identical as possible for each refill. Furthermore, many concepts in this project, and perhaps a majority of all measurement methods, would benefit from a symmetrical collapse, i.e. if the center of gravity only changes in height and not backwards, forwards or sidewards inside the dispenser. An example could be if the top of the refill would move towards the bottom, not only being powered by a lowered internal pressure but also gravity, instead of the back towards the front as it currently does.

The refill should not only collapse symmetrically but also be symmetrical in shape and geometry. This would make it impossible to insert it into the dispenser the wrong way and if it were to rotate during usage it would not change any important measurement parameter. A concept idea during the course of this project was to add ”ears” on the refill that would be locked in place by the dispenser lid and be visible from outside, see Figure 9.4. This would give a clear visual indication of the soap level and a stable refill.

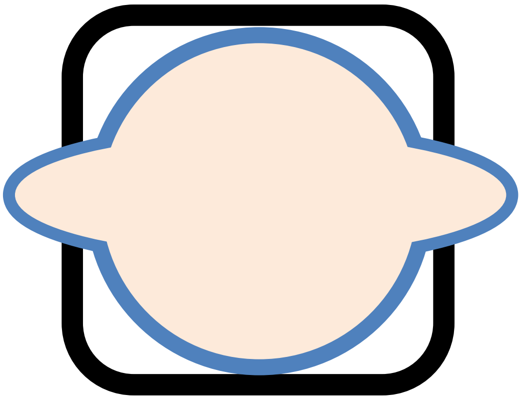

Figure 9.4: An illustration of how an improved refill could look in a cross section viewed from above. The black line represents the dispenser walls and the blue line the transparent refill with soap inside.

9.6.2 The dispenser

An improved dispenser should have a larger transparent window or, in the ideal case, be completely transparent everywhere. The main challenge is to make the refill clearly visible at the same time as the dispenser is appealing in its design. Furthermore, the design should communicate the correct way of usage and mounting and also make these as easy as possible. As far as mounting is concerned, the current solution with four holes and screws may easily become misaligned.

Some sort of reserve tank could be added in order to have a back-up during the time from when the refill gets empty until it is replaced. If the reserve tank is rigid it would be easier to implement a system that signals a warning when a certain level is reached, for example by using an optical sensor. Optimum would be if there was no refill at all but instead a large central tank which several dispensers could be supplied by concurrently through pipelines. For large solid tanks there are several well-tried and accepted level measurement systems.

Chapter 10

Conclusions and recommendations

10.1 Conclusions

A soap level measurement system has been developed and prototyped. The current status of the product is a functional prototype which has been successfully tested in real conditions. The system is able to monitor soap level and present this level to anyone near the soap dispenser by a display. Furthermore, the list of specifications is met but the system has shortcomings which should be improvable. The current design has drift and offset problems which are believed to be caused by the current mechanical construction of the prototype. These problems mainly affect the calibration procedure.

No other solution with similar functionality has been discovered in the hygiene sector during the course of this project. This means this system could put SCA ahead of competitors if it were to be implemented as a commercial product.

More concepts, other than the chosen donut concept, have proven to be promising. Tests have confirmed that concepts within areas such as optical and capacitive sensing might be interesting for use in soap dispensers.

The objective has been accomplished within time schedule and recommendations have been given for further development.

10.2 Donut: The winning concept

Features

- Completely hidden inside dispenser
- Continuous level monitoring
- Insensitive to how a refill collapses

Possibilities

- The concept can be used also for other types of dispensers
- Measurement frequency can be made adaptive in software to save energy
- Has potential to be developed into a stand alone product
- Can be programmed to count the number of doses

Requirements

- Requires a dispenser system having a fixed centre of gravity or one that only moves in the vertical direction. (The system is sensitive to if the centre of gravity shifts in the direction perpendicular to the wall).
- Larger, elongated holes instead of the original upper holes on the dispenser
- A power supply

10.3 The next version of the donut concept

10.3.1 Hinge component

If the weight of the dispenser could be supported by a hinge component, then there would be no need for the rather uncertain type of pivot support used in the current prototype. Furthermore, if the pivot line could be placed behind the lever then the user's effect on measurements would be minimised since the moment the user creates around the hinge would be very small, see Figure 10.1.

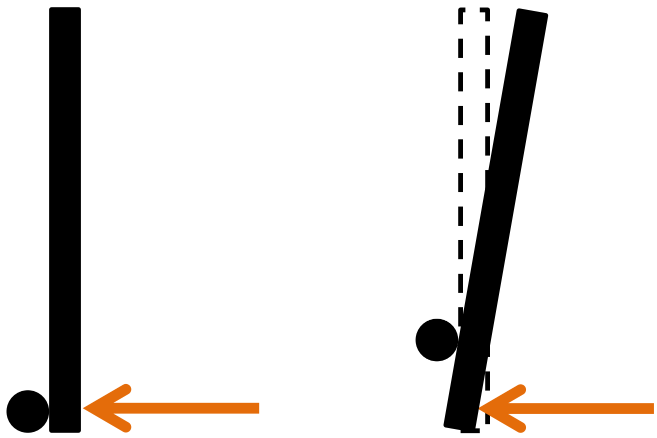

Figure 10.1: The placement of the pivot line affects how much the user will be able to disturb the system.

If having a hinge component, the lower rear end of any dispenser, not just soap, could be modified to be compatible with the new measurement system. Ideally the dispenser body should be made so that the same dispenser body could be used both for customers wanting monitoring and for those who do not.

10.3.2 Stand alone product

It might be interesting to redesign the load cell holder so that it would contain necessary electronics for wirelessly transmitting the sensor readings to a receiving central unit. The receiving unit could then use the sensor readings and perform whatever computations and actions desired.

Figure 10.2: An illustration of a futuristic idea where a tablet is used to ”read” a washroom.

10.3.3 Improved mounting

The current prototype is sensitive to if the holes drilled in the washroom wall are not parallel. Recommended is to use through holes that are as large as possible. It might also be a good idea to make the holes slightly tapered, so that the diameter increases going from the screw head to the washroom wall. Moreover, the space dedicated to the screw heads needs to be increased.

10.3.4 Load cell with two strain gauges

If choosing to keep the current load cell design, one of the more important changes to make is to introduce a second strain gauge to the load cell. This second strain gauge should be placed opposite the first one, on the other side of the metal. This will make the two strain gauges experience the same environment and measurement errors due to temperature etc. will be strongly reduced. Furthermore, since they are placed on opposite sides of the metal, one gauge will be compressed whereas the other one will be stretched when the cell is loaded. This means their electrical resistances will change in different directions. One of the gauges' resistance will increase whereas the other strain gauge's resistance will decrease, creating a more sensitive load cell with greater range and accuracy. A more sensitive load cell comes with two possibilities:

1. Use the higher sensitivity to generate a higher resolution in measurements, so that different soap levels differ more in sensor reading. An example of a load cell having a strain gauge configuration as described above is the beam load cell that was tested for the back plate concept. Its test result was very pleasing and is shown in Figure 6.3.
2. A higher resolution makes it interesting to build the load cell from a thicker sheet of metal. The load cell would then become stronger, stiffer and more durable. Since the load cell becomes stiffer, the dispenser will wobble less and the whole system becomes more sturdy.

10.3.5 Calibration procedure

In the current prototype, the system is calibrated through the use of an ON/OFF switch. It is plausible that there are more suitable ways to handle the calibration. Important is to make it user friendly at the same time as users should not be able to calibrate the dispenser out of curiosity (meddlesomeness). One idea is to make use of the already existing IR receiver present in automatic dispensers by using it also for communication purposes. Calibration could then be performed by using a remote control that sent out a modulated IR pulse to the dispenser. The person calibrating the system also needs to receive some sort of feedback, e.g. from LEDs that mark the progress of the calibration procedure.

10.3.6 Design for X

The current design is 3D printed and few thoughts have put on draft angles etc. needed for other manufacturing methods, such as injection moulding. The general design of the current prototype should however not need to be changed. For environmental and assembly aspects it is recommended to, as in the current prototype, implement some sort of snap fit between the load cell and the load cell holder. That way the two parts will be easy both to assemble and disassemble. Since the load cell is made mainly of metal and the load cell holder is plastic, disassembly might be of interest.

10.3.7 Software updates

The current prototype is not programmed to detect when a new refill has been inserted into the dispenser. This should however be a fairly straightforward task due to the clear difference in sensor reading between a full and empty dispenser. Some special cases that might be interesting to look at are:

- When a refill change occurs that does not go from empty to full
- When a refill is inserted that does not contain the same type of soap as the previous refill

Ideally the system should be able to update its parameters so that it automatically handles the above situations. If that is not possible, it would be advantageous if the system could at least detect that something has happened and notify the responsible staff.

In general, the system needs to be programmed in such a way that it becomes ”self-aware”. That is, the system must understand when it needs to be recalibrated or in any other form maintained by staff.

Adaptive measurement frequency

To save energy, the system could enter a sleep mode between measurements. It is recommended to make the duration of this sleep adaptive to how fast the soap level is decreasing. If the dispenser is used very frequently, it will measure often. Likewise, if the dispenser is used less frequently it will measure more seldom and spend more time sleeping.

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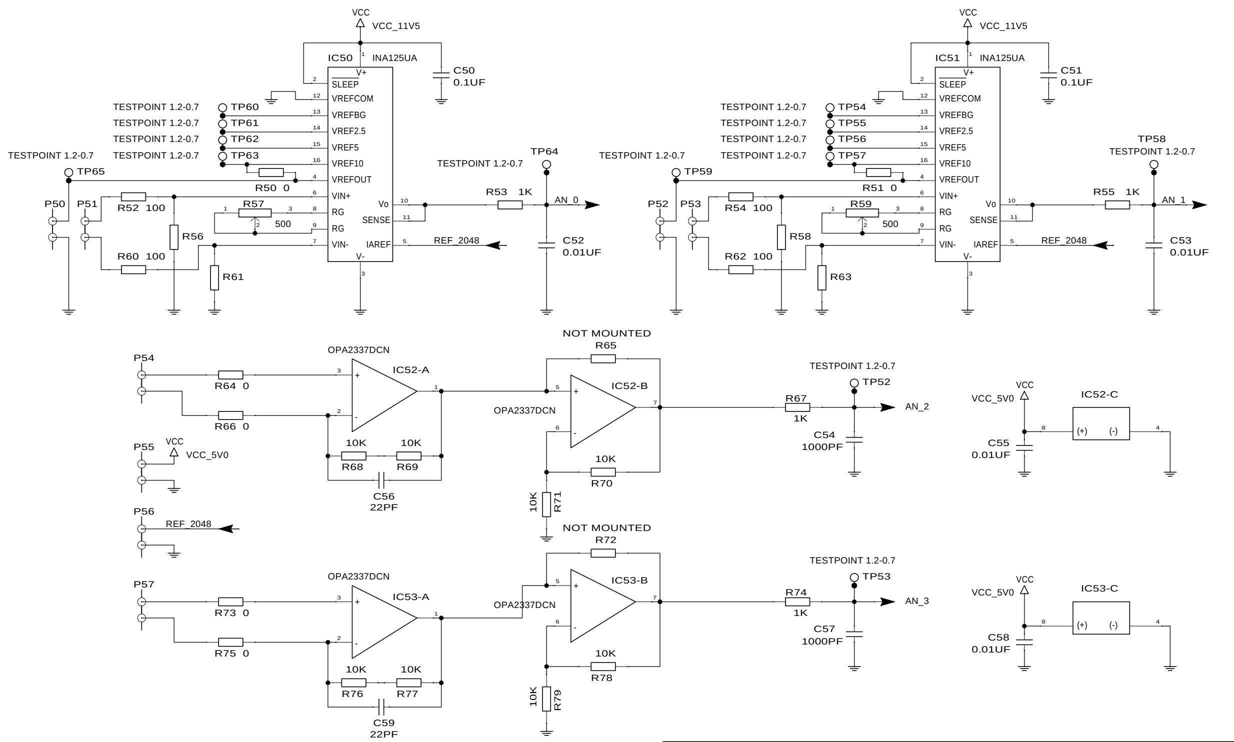
Appendix A

Prototyping platform

Rev.no:	Specification	Account	Date



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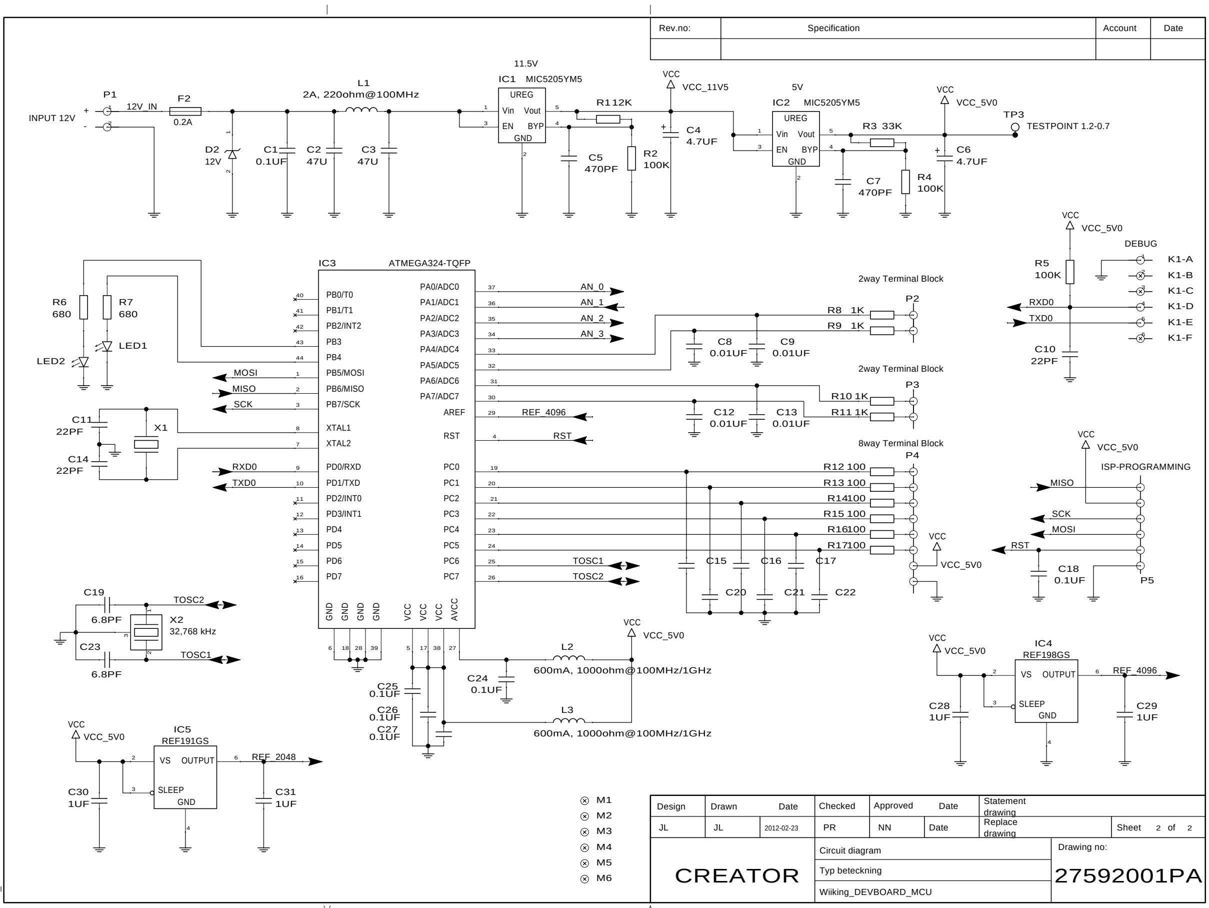
CREATOR	Circuit diagram	Drawing no:
	Typ beteckning	27592001PA
	Wiiking_DEVBOARD_ANALOG	

A3_CREATOR

A3_CREATOR


Rev.no:
Specification
Account
Date
P1
INPUT 12V
12V_IN
F2
0.2A
L1
2A, 220ohm@100MHz
D2
12V
C1
0.1UF
C2
47U
C3
47U
11.5V
IC1 MIC5205YM5
UREG
Vin
Vout
EN
BYP
GND
R1 12K
C5
470PF
R2
100K
VCC
VCC_11V5
C4
4.7UF
5V
IC2 MIC5205YM5
R3 33K
C7
470PF
R4
100K
VCC_5V0
C6
4.7UF
TP3
TESTPOINT 1.2-0.7
IC3
ATMEGA324-TQFP
PB0/T0
PB1/T1
PB2/INT2
PB3
PB4
PB5/MOSI
PB6/MISO
PB7/SCK
XTAL1
XTAL2
PD0/RXD
PD1/TXD
PD2/INT0
PD3/INT1
PD4
PD5
PD6
PD7
PA0/ADC0
PA1/ADC1
PA2/ADC2
PA3/ADC3
PA4/ADC4
PA5/ADC5
PA6/ADC6
PA7/ADC7
AREF
RST
PC0
PC1
PC2
PC3
PC4
PC5
PC6
PC7
GND
VCC
AVCC
AN_0
AN_1
AN_2
AN_3
REF_4096
RST
TOSC1
TOSC2
R6
680
R7
680
LED2
LED1
MOSI
MISO
SCK
C11
22PF
X1
C14
22PF
RXD0
TXD0
2way Terminal Block
P2
R8 1K
R9 1K
C8
0.01UF
C9
0.01UF
P3
R10 1K
R11 1K
C12
0.01UF
C13
0.01UF
8way Terminal Block
P4
R12 100
R13 100
R14100
R15 100
R16100
R17100
C15
C16
C17
C20
C21
C22
DEBUG
R5
100K
K1-A
K1-B
K1-C
K1-D
K1-E
K1-F
C10
22PF
ISP-PROGRAMMING
C18
0.1UF
P5
C19
6.8PF
X2
32,768 kHz
C23
6.8PF
L2
600mA, 1000ohm@100MHz/1GHz
L3
600mA, 1000ohm@100MHz/1GHz
C24
0.1UF
C25
0.1UF
C26
0.1UF
C27
0.1UF
IC4
REF198GS
VS
OUTPUT
SLEEP
C28
1UF
C29
1UF
IC5
REF191GS
REF_2048
C30
1UF
C31
1UF
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M2
M3
M4
M5
M6
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Checked
Approved
Date
Statement drawing
JL
JL
2012-02-23
PR
NN
Date
Replace drawing
Sheet 2 of 2
CREATOR
Circuit diagram
Typ beteckning
Wiiking_DEVBOARD_MCU
Drawing no:
27592001PA

Appendix B

Patents

B.1 Method and device for indicating future need for product replacement of random use dispensing

In order to reduce waste and maintain hygiene it is important that dispensers with disposable refills in some way can predict when it is time for replacement. If the replacement is made too early there will still be some product left which will go to waste and if it is made too late the user won?t be able to use the dispenser. This patented invention states that it is possible to foresee the time for replacement even if the dispenser is used at random and there is a varying amount of refill placed in it. By letting the maintenance personnel enter service interval and amount of product (which can also be received through a RFID tag) and an activation switch count the number of times the dispenser has been activated it is possible to program a controller to predict if a replacement must be performed prior to the next service interval.

B.2 Dispenser and method

The background for the problem this invention wants to solve is the same as the previous example. The product level is monitored by counting the activation of the dispenser only by using a lever connected to the dispenser activation handle. When the activation handle is pushed the lever turns a gear by sprockets and the gear activates the counter which keeps track of every dispensing event. In order for this to work the system must be programmed with the product amount in every refill as well as an average amount of product in every dispensed dose.

B.3 Apparatus for hands-free dispensing of a measured quantity of material

Describing in more general terms a touch less dispenser this invention also tries to keep track of how much product that is still left in the container by counting, and will stop when a predetermined number of actuations has been reached, typically 95% of total amount. As previous invention also this controller require manual input from the user about total volume of the product as well as the volume of every dispensed dose to calculate when to signal for refill.

B.4 Electronically keyed dispensing systems and related methods of installation and use

This invention identifies the need for keyed dispensers and refills in order to ensure that only a proper refill is installed in a certain dispenser. If a refill from a competitor is used instead of the proper one the dispenser manufacturer will experience economic damage due to the fact that dispenser often are sold at cost or less. Instead, the dispenser manufacturer will rely on the refill sales to provide profit. The invention for solving this problem includes communication devices on both the refill and the dispenser preferably using RFID tags. If unauthorized use is detected the dispenser will be disabled by a controller.

B.5 Dispensing machine

The inventors of this machine states that it is hard to keep track and control the amount of cleaning products that is used in larger facilities like hotels, hospitals and offices. This particular machine keeps track of and sums up the total amount, weight or volume of products that has been dispensed. It can also prevent dispense of more products than a preset number during a certain timeframe but denying unauthorized usage.

B.6 System and method for measuring, monitoring and controlling washroom dispensers and products

Patent: WO2005065509 (A1)
About sensing the product used with the dispenser to update the dispenser's parameters accordingly. Ways mentioned to identify the product are: an RFID reader, a barcode reader, a printed label reader, a magnetic strip reader, a smart tag reader a hologram reader, a luminescence reader and/or a fluorescence reader.

B.7 Dispenser with warning device for the level of the content

Patent: EP0940110 (A1) Has one fixed and one moveable part/assembly of the dispenser. When it is used the moveable part moves relative to the fixed component. The dispenser counts the number of displacements of the movable relative to the fixed component and gives a warning signal when the number of trips counted reaches a predetermined value.

Technical solution: A sensor detects every movement of the movable relative to the fixed element, and a microcontroller totals the number of trips and generates a signal when the amount of displacement reaches or exceeds a predetermined threshold value.

"Preferably, the sensor consists of a magnet and reed switch (ILS), respectively fixed to the movable and the fixed component."

"For example, a short press on the handle can be an ?application? of the user who wishes to obtain an object or one-dose product, and a long press to reset the counting device, when replacing or filling the tank by maintenance personnel."

B.8 A liquid receptacle of "bag-in-box" type

Patent: WO2009064232 (A1)
The idea here is to in a bag-in-box product let the bag have a stiff upper part or ?ceiling? that can be seen through the outer box. When the content of the bag decreases the height of the bag will also decrease and thus the position of the ?ceiling? will change. The upper part?s dimensions are just slightly smaller than the outer box? cross-sectional area.

Appendix C

Specifications and criteria

C.1 List of specifications

Table C.1: A list of specifications.

No.	Requirements	Demand/Wish
1	Monitor soap level	D
2	Enable soap level forecasting	W
3	Function without regular service	D
4	Resolution of at least 10 ml	D
5	Maximum manufacturing cost of 10 euro	D
6	Manufacturing cost less than 5 euro	W
7	Low sensitivity for external disturbance	D
8	Should be easy to use	D
9	Minimal need for user configuration	W
10	Automatic reset	W
11	Visual indication of soap level	D
12	Low energy consumption	D
13	Simple construction	W

Explanations:

1. The main function of the system. Means that it shall be able to measure some quantity that is proportional to the amount of soap that is left in the refill and provide an output signal that can be used to indicate the soap level.

2. If the measurements can be used to forecast when the refill will be empty it will be regarded as an advantage.

3. It will be too expensive if the system needs more attention by a technician than a soap dispenser normally would. An unreliable and sensitive system is not acceptable.

4. If the resolution is too bad then there is not benefit of using the system. To be able to see steps of at most 10 ml should be enough.

5. The customers' cost acceptance is limited and a maximum cost of 10 Euro has been set.

6. A lower cost is an advantage because it makes it more likely that a customer would by the product.

7. If it is easy to manipulated the measurements by external disturbance then there is a risk of scepticism from users and customers.

8. With easy to use it is meant that one shall be able to mount and initiate the system by using simple instructions and tools.

9. This requirement is related to number seven and emphasises that for example the software must be smart to avoid complicated calibrations manoeuvres.

10. Replacing an empty refill should not require a recalibration. The system should automatically reset on refill change and start over with new measurements.
11. Some sort of visual indication is needed in order to communicate the soap level to users and cleaning staff.
12. Minimum energy consumption must be strived for as a limited battery supply is the most common power source for soap dispensers.
13. If the system is easy to produce it will be cheaper and most likely more popular on the market.

C.2 First evaluation matrix criteria

Table C.2: Concept screening criteria.

No.	Criteria
1	Quality of visual signal
2	Performance in measurement
3	Durability
4	Resistance against disturbances
5	"Foolproof-ness"
6	Energy consumption
7	Ease of manufacture
8	Generality
9	Economic potential

Explanations:

1. If the system is able to provide a visual soap level signal without extra electronics it is regarded as an advantage. No need for extra components to present the soap level.
2. The anticipated performance of the measurements should be good enough to be used for soap level estimation.
3. It is important the system is able to handle rough usage without breaking or prolonged decreased performance.
4. Temporary disturbance for example during usage must be handled and is not allowed to make the system useless.
5. The system must be easy to set up and minimise the risk for mistakes when operated.
6. The lower the consumption the better. Batteries is the most common power source.
7. It is an advantage if the system can be used in other dispensers regardless of its content.
8. The cheaper the system is and the more value it is likely to provide the product the better.

C.3 Second evaluation matrix criteria

Table C.3: The criteria chosen for the final concept evaluation.

No.	Criteria
1	Can measure continuous level
2	Can clearly see when the refill is empty or when the soap passes a certain level
3	Uncertainty in upcoming work
4	Estimated relative cost

Explanations:

1. The system should be able to continuously follow the soap level from full to empty as it will provide more value to the product than for example just being able to tell when it is nearly empty.

2. A reliable system should be able to tell when the refill is empty with as high certainty as possible. Even if the level measurement is not exact over the full range of the soap level it can still be an advantage if it is precise for a range close to nearly empty.

3. If a concept is believed to be hard to develop further and if it is uncertain how to improve the current status of the concept then it should be considered as a disadvantage. Instead a concept that is straight forward to improve should be favoured as it will require less development time and still provide a satisfying final result.

4. The estimated cost for a concept should be as low as possible. A higher cost must be motivated by better performance.

Appendix D

Pugh matrices

D.1 No modifications

	Kateterinvers	Block (referens)	Bakplatta med fjäder 1	Elektronisk bakplatta	Motvikt
Quality of visual signal	**0**	**0**	**0**	**-**	**-**
Performance in measuren	**0**	**0**	**0**	**+**	**-**
Durability	**0**	**0**	**0**	**+**	**0**
Resistance against disturb	**0**	**0**	**0**	**0**	**0**
Foolproof-ness	**0**	**0**	**0**	**0**	**0**
Energy consumption	**0**	**0**	**0**	**0**	**+**
Ease of manufacture	**f**	**0**	**+**	**+**	**+**
Generality	**0**	**0**	**0**	**0**	**0**
Economic potential	**0**	**0**	**+**	**-**	**0**
Number of pluses	0	0	2	3	2
Number os zeros	8	9	7	4	5
Number of minuses	0	0	0	2	2
Plusminus	0	0	2	1	0
Question marks	1	0	0	0	0
Comment	Through	Put on hold since it does not feel like it is commercially viable.	Good if a decent feeling at usage can be guaranteed (damper?). If not: eliminate. (Through)	Through	Put on hold due to greater potential among other back plates.
+/-	0	0	2	1	0
Potential	1	0	2	1	0
Uncertainty [%]	11	0	0	0	0

D.2 Dispenser modifications only

	Endast TT-givare	Donut-lastcell vid skruv	Yttre gunga	Inre gunga	Balansvåg	Bra vibrationer	Öga för detaljer (REF)	Rätt tonläge	Kondensator	Direkt nivåavläsning
Quality of visual signal	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Performance in measurement	**+**	**f**	**+**	**+**	**f**	**f**	**0**	**f**	**f**	**f**
Durability	**0**	**0**	**-**	**f**	**-**	**-**	**0**	**0**	**+**	**0**
Resistance against disturbances	**0**	**f**	**0**	**+**	**+**	**f**	**0**	**-**	**-**	**0**
Foolproof-ness	**+**	**0**	**+**	**0**	**0**	**+**	**0**	**0**	**0**	**0**
Energy consumption	**+**	**+**	**+**	**+**	**+**	**0**	**0**	**0**	**f**	**0**
Ease of manufacture	**f**	**+**	**-**	**-**	**-**	**0**	**0**	**0**	**0**	**0**
Generality	**+**	**+**	**+**	**-**	**0**	**0**	**0**	**0**	**0**	**-**
Economic potential	**-**	**f**	**-**	**-**	**-**	**0**	**0**	**0**	**-**	**f**
Number of pluses	4	3	4	3	2	1	0	0	1	0
Number os zeros	3	3	2	2	3	5	9	7	4	6
Number of minuses	1	0	3	3	3	1	0	1	2	1
Plusminus	3	3	1	0	-1	0	0	-1	-1	-1
Question marks	1	3	0	1	1	2	0	1	2	2
Comment	Through	Through	Through	Eliminated, Swing is seen as a better alternative. This one is similar but more advanced.	Put on hold until simpler concepts have failed.	Put on hold. Too many uncertain parameters. The valuable test time is given to other concepts.	Eliminated if not modified to perform better when the refill is nearly empty.	Through	Has potential but also great uncertainty. Needs to be tested.	Combine with "Öga för detaljer" to get better performance when the refill is rather full?
+/-	3	3	1	0	-1	0	0	-1	-1	-1
Potential	4	6	1	1	0	2	0	0	1	1
Uncertainty [%]	11	33	0	11	11	22	0	11	22	22

D.3 Modifications to refill or both

	Sluten krets	Tätning	Magnetisk baksida	Färgjämförelse	Solid nivådel	Icke-kollapsande tillägg	Nivårör med koppling	Vattensäng	Fjädrande hals
Quality of visual signal	**-**	**-**	**0**	**-**	**+**	**0**	**0**	**0**	**-**
Performance in measurem	**0**	**f**	**-**	**f**	**f**	**f**	**0**	**f**	**f**
Durability	**+**	**+**	**0**	**+**	**+**	**+**	**0**	**+**	**+**
Resistance against disturb	**f**	**0**	**0**	**-**	**0**	**0**	**0**	**0**	**f**
Foolproof-ness	**+**	**+**	**0**	**0**	**+**	**+**	**0**	**+**	**+**
Energy consumption	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Ease of manufacture	**f**	**+**	**+**	**f**	**+**	**+**	**0**	**0**	**f**
Generality	**0**	**-**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Economic potential	**0**	**+**	**+**	**0**	**+**	**+**	**0**	**0**	**0**
Number of pluses	2	4	2	1	5	4	0	2	2
Number os zeros	4	2	6	4	3	4	9	6	3
Number of minuses	1	2	1	2	0	0	0	0	1
Plusminus	1	2	1	-1	5	4	0	2	1
Question marks	2	1	0	2	1	1	0	1	3
Comment	The other switch concept"Tätning" is given higher priority.	Through	Through	At the moment inferior to "Direkt nivåavläsning". Remember the idea of having a reference area.	Through	Through	Eliminated due to its complexity compared to similar concepts.	Eliminated as original. Through as back plate.	Put on hold due to uncertainties whether it can be manufactured and give accurate measurements.
+/-	1	2	1	-1	5	4	0	2	1
Potential	3	3	1	1	6	5	0	3	4
Uncertainty [%]	22	11	0	22	11	11	0	11	33

Appendix E

Tork dispensers and refills

E.1 S1 - manual liquid soap system

Material: ABS
Dimensions: 112 x 291 x 114 mm (W x H x D)
Mass: 350g/511g (with/without lever)

Compatible with all SCA Tork soap refills except foam soap.
Available in black, white and with or without armlever. Also available in a different exterior made partly from aluminium. The aluminium version has the dimensions 105 x 297 x 102 mm (W x H x D).[14] The S1 dispensers are shown in Figure E.1.

E.2 S2 - manual liquid soap system small

Material: ABS
Dimensions: 112 x 206 x 114 mm (W x H x D)
Mass: 263 g

Same as S1 but smaller. Available in black and in white.[15] (Figure E.2).

E.3 S3 - automatic foam soap system

Material: ABS, PP and aluminium
Dimensions: 129 x 293 x 125 mm (W x H x D)
Mass: 916 g

Automatic IR sensor activated dispenser compatible with the Tork Premium Luxury Foam Soap refill. It has an SCA aluminium exterior separated from an externally developed electronic dispensing module. The module runs on four C-cell batteries, indicates low battery and estimated refill level by light or sound, senses whether a refill is inserted and if the lid is closed or open. When the lid is opened it assumes a new refill is inserted and then counts the number of activations to estimate the remaining level.[16] The S3 dispenser is shown in Figure E.3.

E.4 S4 - manual foam soap system

Material: ABS
Dimensions: 113 x 286 x 105 mm (W x H x D)
Mass: 371 g

This dispenser (Figure E.4) is yet another product of the Tork elevation series. The main difference between the S4 and the S1 is a different interface to the refill; the S4 is to be used with the Tork Premium foam soap refills.[17]

Figure E.1: A White, black and aluminium S1 liquid soap dispenser.

Figure E.2: White and black S2 liquid soap dispenser.

Figure E.3: S3 automatic foam soap dispenser.

Figure E.4: A white, black and open S4 foam soap dispenser.

E.5 Tork Refills

All of the Tork refills are collapsible. The front half of the bottle is stiff and the rear half is flexible. This makes the rear approach the front as more soap/content is pumped out. This solution has a number of benefits. A fully closed system prevents the contents of the refill of becoming contaminated. The collapsing bottle also makes it more difficult to refill by pouring in competitors' soap. Lastly the collapsible bottle takes up less space than a rigid one when being empty which means that the waste will take less space.

Two sizes: 1000 ml and 475 ml.

The Tork Premium *foam* soap refills are equipped with a dosage pump, see Figure E.5. This pump lathers the foam soap liquid and gives a dose of approximately 0.4 ml per full pump action. The other Tork refills have a tube that opens when being pressed against.

Figure E.5: To the left a foam soap refill, followed by a standard and small one.

Appendix F

Existing products and competitors

This chapter presents the result from the benchmarking which was focused on some of the biggest competitors and an example of their automatic dispensers. Most information was accessed through the respective company's online sources. For some dispensers information was gathered during disassembly of the actual product. A compilation of product specific data can be found in Table F.1 for a better overview.

F.1 Deb group

The Deb groups is a global company with 65 years experience from skincare in automotive, private and public sector, medical care and food industry. They were first to introduce a foam soap cartridge that collapses and aim to be cost effective and hygienic. An example of their touch free dispensers are marketed under the name InstantFOAM TouchFREE. This product offers level monitoring by transparent cover, i.e. no electronic indication, and has accessories like drip collectors and floor stands. The InstantFOAM dispensers are primarily mounted on a wall by four screws and anti-microbial material mixed in the plastic gives better hygiene properties. Marketing focus on hygiene and lower costs due to less waste and controlled dosing.[18]

Figure F.1: The InstantFOAM TouchFREE dispenser manufactured by Deb group[18]

F.2 Georgia Pacific

Georgia Pacific is one of the world's leading manufacturers and marketers of tissue, packaging, paper, pulp and building products and related chemicals. The company has more than 40 000 employees at approximately 300 locations in North America, South America and Europe. An automatic dispenser is manufactured and sold under the name enMotion. The dispenser comes with a mounting plate for easy removal and it has a transparent cover to show soap level. The design makes it slim against the wall.[19] Disassembly showed that there were two switches connected to the circuit board, one for maintenance and one for detecting whether the cover is shut or open. The logic runs on a PIC16F610.

Figure F.2: The enMotion dispenser manufactured by Georgia Pacific[19]

F.3 GOJO

GOJO started 65 years ago and is now a global producer of skin health and hygiene solutions for the away from home market. They are currently making touchless soap dispensers called TFX Touch Free Dispenser which comes with 1200 or 1000 ml refills. A function called Skylight, in practice a transparent window, indicates when it is time to reload. GOJO states that hand washing compliance increases generally by 20% when a touch free dispenser is introduced.[20]

Figure F.3: The TFX Touch Free dispenser manufactured by GOJO[20]

F.4 Hagleitner

Started in 1971 this actor is striving to be the most innovative and provide the best service within hygiene. Hagleitner is currently developing and producing all products by them selves. Based in Austria there are around 600 employees working within the group. XIBU is the premium line of products offered including an automatic foam soap dispenser. There is a reserve tank system providing a buffer if a refill change would be delayed, but at the same time it makes the foam soap vulnerable for contamination.[21] During disassembly it was clear that XIBU senseFOAM distinguishes itself from other dispensers not only by build quality but also a sophisticated foam pumping system. An electrical motor pumps the soap by a pressing roller action at the same time as a servo motor drives an air pump which provides air which mixes with the soap and creates foam. Anti theft protection is provided by a lock which is opened by a special opening tool.

Figure F.4: The Xibu senseFOAM dispenser manufactured by Hagleitner[21]

F.5 Kimberly-Clark

Kimberly-Clark is a global company with approximately 57 000 employees and 140 years of history and they are present in family and personal care, medical care and professional sector. Kimberly-Clark is marketing their automatic soap dispenser as "the electronic touchless skin care system" through the brand Kleenex, focusing on hygiene, touchless technology and luxury. The electronic skin care dispenser holds 1200 ml of soap and the three D-cell alkaline batteries last for 60 000 single uses. The cassette is easy to change and recycle.[22] Features that were found after disassembly included two switches for detecting when a refill is inserted, electronics module separated from exterior/cover and an accessible programming interface.

Figure F.5: The Kleenex dispenser manufactured by Kimberly-Clark[22]

F.6 Ophardt Hygiene

As a German company founded in 1962, Ophardt Hygiene is a producer of dispensing systems for disinfection and hygiene in the medical area, as well as multifaceted dosage applications in the industrial and sanitation sectors. The company has an automatic soap dispenser in the so called Ingo-man series called IMP T Touchless which distinguishes itself from competition by having the pump and nozzle on top, making it possible to place the dispenser on tables and prevents dripping. It also has a manual operation of pump in case of sensor system failure. They also have a conventional touch free dispenser called Neptune which apart from most other competitors supports individual printings on the cover. Marketing focus on suitability for hospitals due to good hygiene features like material choice and touch free operation. Also easy to use concerning dosage selection, pump removal and high quality.[23]

Figure F.6: The IMTP Touchless dispenser manufactured by Ophardt Hygiene[23]

F.7 Technical concepts / Rubbermaid

In April 2008 Rubbermaid, a manufacturer of injection moulded products, acquired Technical Concepts, a manufacturer of washroom hygiene and fragrance products. Rubbermaid Commercial Products specializes in manufacturing products for the cleaning, safety, waste management, materials handling and catering industries. The acquisition consolidated Rubbermaid′s position in the commercial washroom sector and added a range of products to Rubbermaid?s portfolio of washroom solutions. The Autofoam dispenser has a 1100 ml refill and is marketed as a good looking product. The battery life of 120,000 handwashes or 3 years is claimed to be industry-leading. Among the features are yellow and red light blinks for low battery and refill level respectively, and a beep tone if an object is in field for more than 10 seconds.[24]

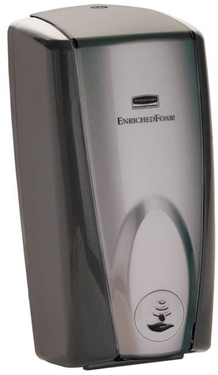


Figure F.7: The Autofoam dispenser is manufactured by TC / Rubbermaid[24]

F.8 UltraClenz

UltraClenz started in 1995 with an ambition to increase hand wash compliance in areas like hospitality, health care, food and beverage, processing plants and infection prevention laboratories. They have a range of products related to communication between dispensers and monitoring stations and are currently producing two types of touch free soap dispensers. The Simplicity plus is claimed to be a rugged and reliable dispenser which can take most so called Bag n' Box containers. External power supply is possible. The Proclenz PCS has proprietary nozzle and locking pump assemblies that orientate nozzle into correct position and has optional drip tray and stand. It also offers modularity that makes it possible to modify a dispensers from manual to automatic functionality. The IR sensor is adjustable as well as the 2-speed motor and range selector.[25]

Figure F.8: The Proclenz PCS dispenser manufactured by UltraClenz[25]

F.9 Summary of competing products

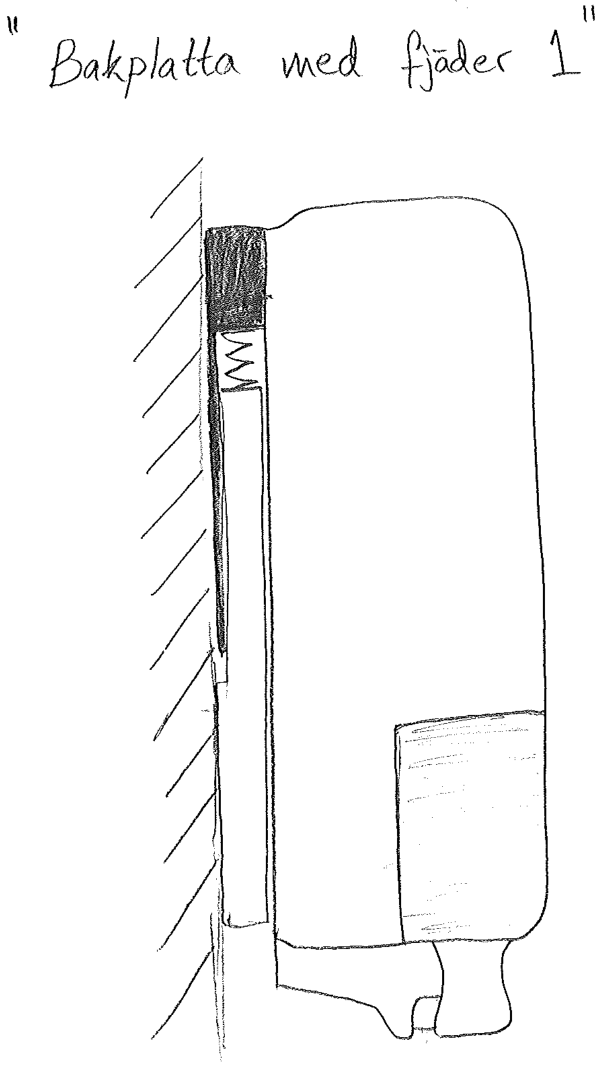
Table F.1: Examples of existing products

Brand	Model	Dimensions (HxWxD mm)	Batteries	Capacity (ml)	Battery indication	Refill level
Deb group	InstantFOAM TouchFREE	277 x 170 x 100	4 (D-cell)	1000	Light	Transparency
Georgia Pacific	enMotion	281 x 170 x 99	4 (D-cell)	1200	Light	Window
GOJO	TFX Touch Free	267 x 152 x 102	3 (C-cell)	1200	Light	Window
Hagleitner	Xibu senseFOAM	277 x 136 x 108	3 (C-cell)	1200	Light	Light
Kleenex	Electronic skin care	292 x 184 x 102	3 (D-cell)	1200	Light	Light
Ophardt Hygiene	IMP T Touchless	330 x 92 x 210	5 (D-cell)	1000	Light	No
Ophardt Hygiene	Neptune Touchless	398 x 188 x 101	4 (C-cell)	1000	Light	Add-on system
TC/ Rubbermaid	Autofoam	276 x 132 x 133	4 (C-cell)	1100	Light	Light
UltraClenz	Simplicity plus	273 x 171 x 121	4 (D-cell)	1500	Light	Transparency
UltraClenz	Proclenz PCS	267 x 171 x 102	4 (D-cell)	1250	Light	Add-on sys.
SCA Tork	S3	293 x 129 x 125	4 (C-cell)	1000	Light	No
SCA Tork	S4 (manual)	286 x 113 x 105	N/A	1000	N/A	N/A

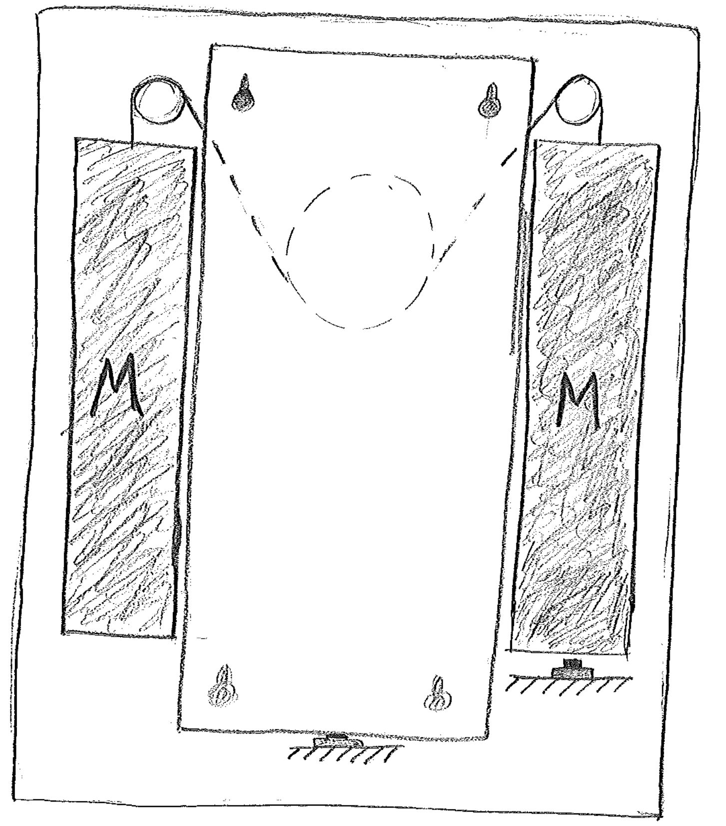
Appendix G

Concept sketches

G.1 No modifications

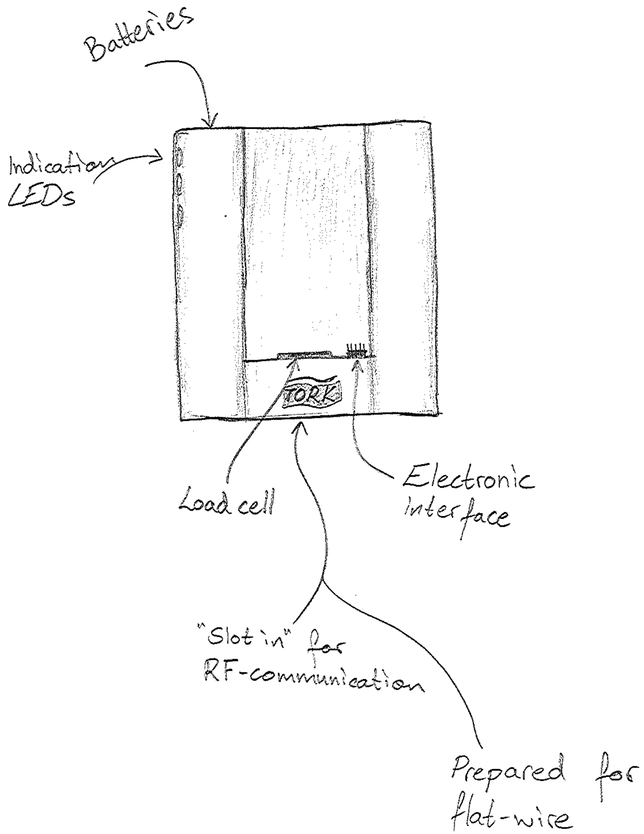


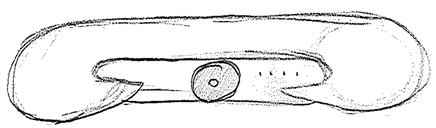
"Motvikt"



Alt. en ensam motvikt.
Alt. koppla in fjädrar eller liknande för kalibrering.

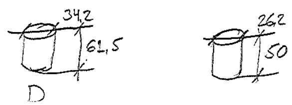
"Elektronisk bakplatta"



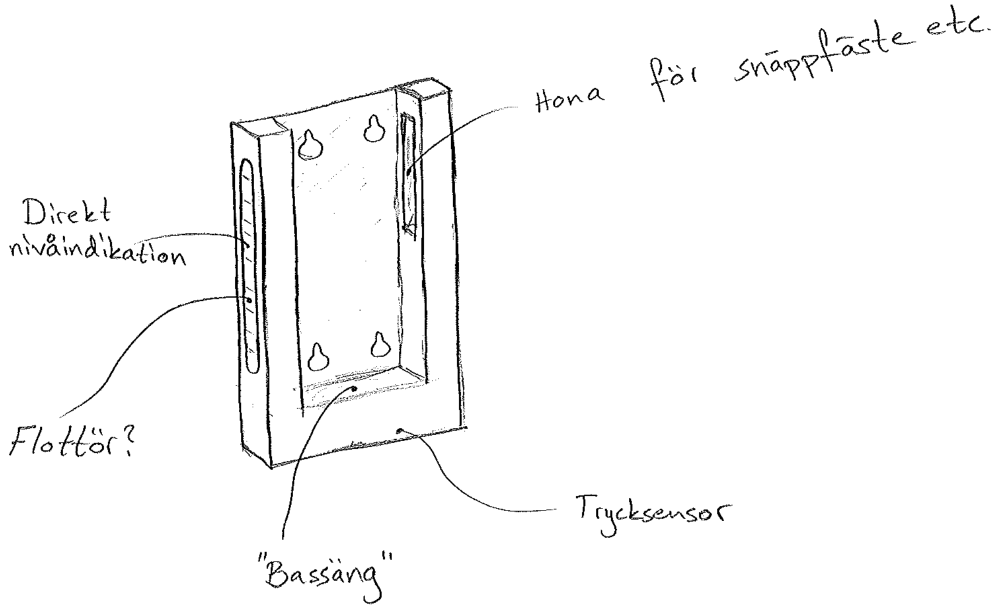


- Electronic interface for communication with the dispenser
  - counting
  - it's dark → shut down
- The batteries can be a counterweight.
- How to prevent theft and how to change batteries easily?

Batteries



"Kateter^{-1}"



+ Visuell indikering
+ Generell
+ Kan göras smal

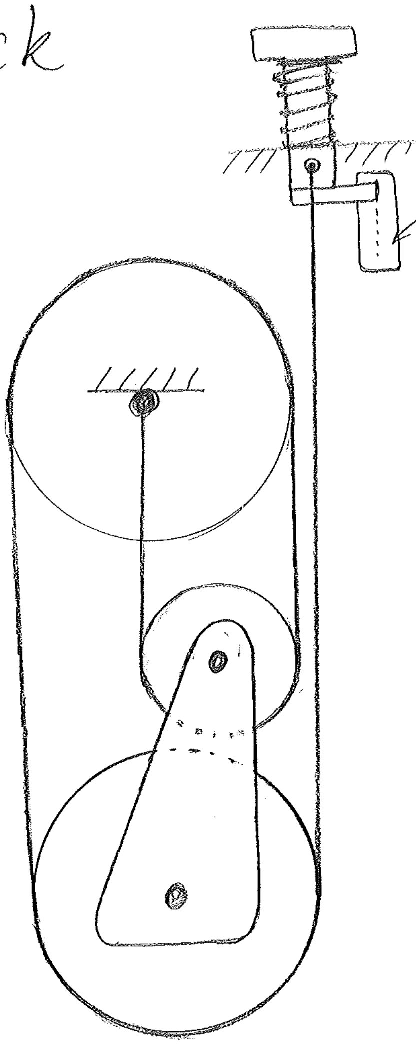
– Kommer ut från väggen.

? Beteende vid tryckning/pumpn

? Hur göra med vattenbehållaren/påsen?

! Aquachange

"Block"

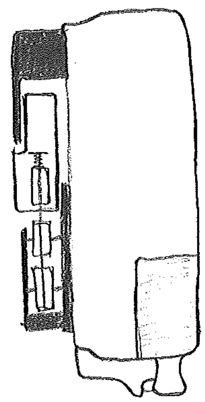


POT/POSITIONSSENSOR

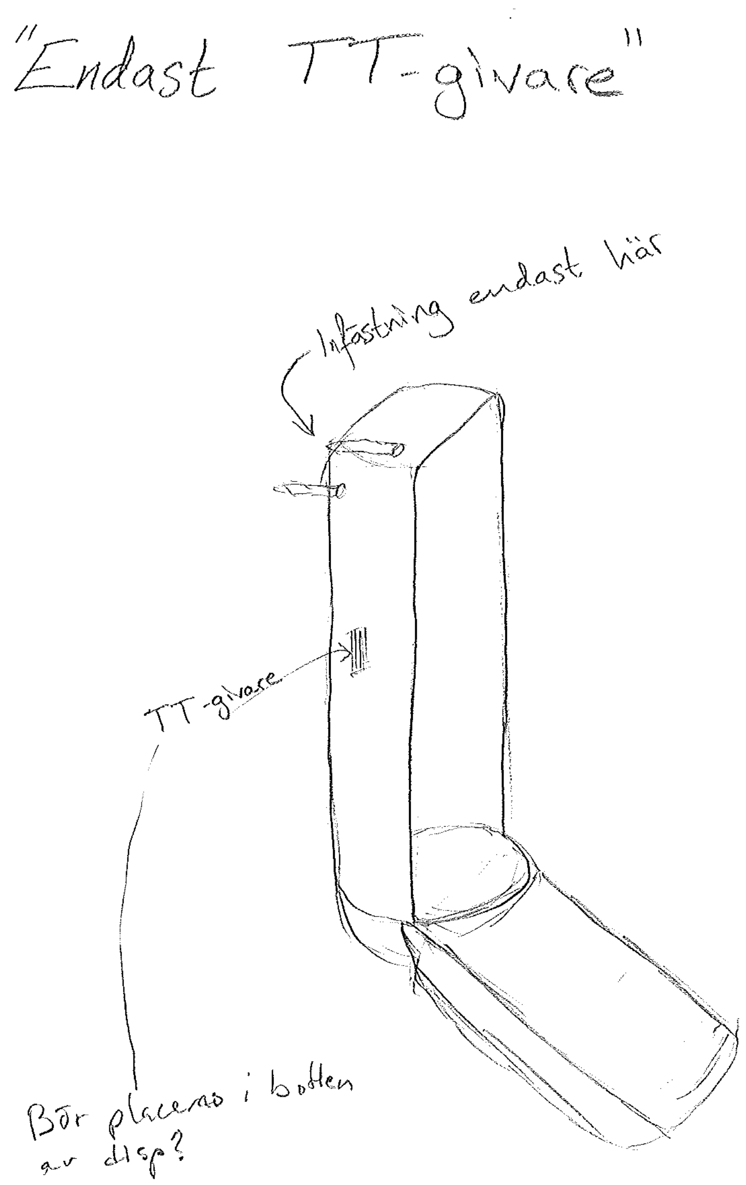
- \+ Bör vara relativt smal
- \+ Viss möjlighet till mekanisk nivåvisning
- \+ Antingen switch eller analog.
- − Många delar

? Hur skall gränssnitten se ut? Speciellt mot väggen.

? Räkna på fjäderns dim.



G.2 Dispenser modifications - Load cells and strain gauges



II "Balansvåg"

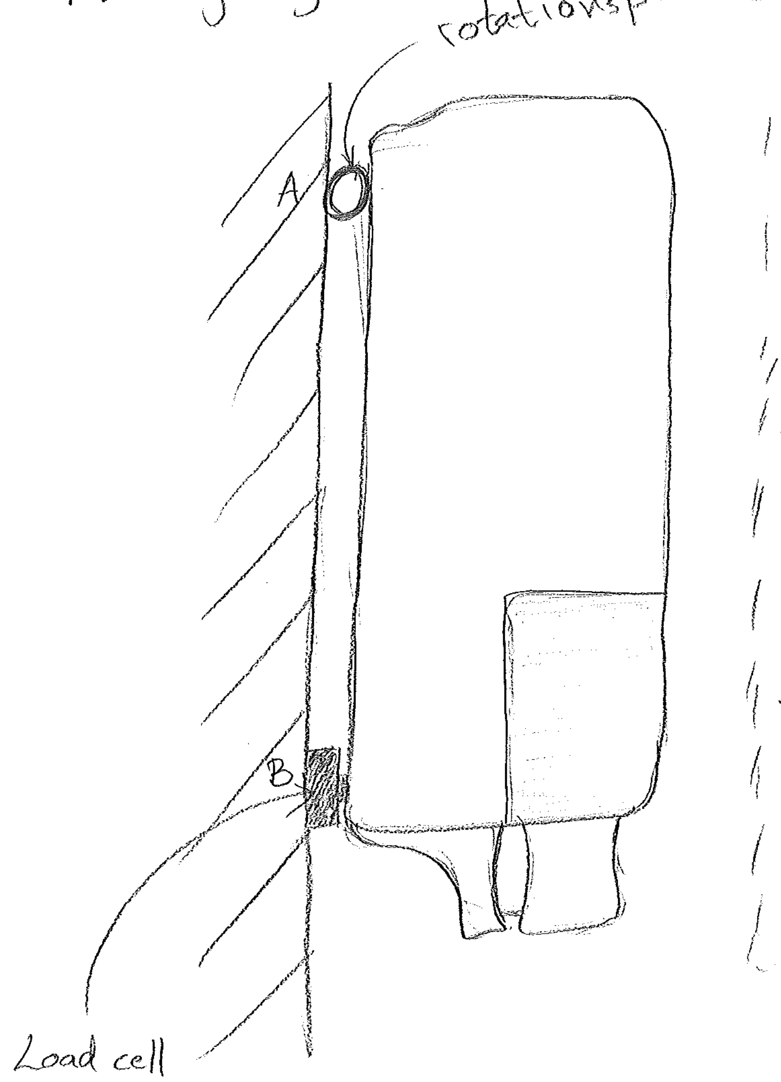
+ Liknande lösning finns i prototypstadie

- Stora modifikationer krävs
- Avancerad konstruktion

? För dyr ?

Kopiera prototyp med inbyggd våg och anpassa för en lastcell

"Yttre gunga"



+ endast små modifikationer på dispensern.

+ Principiellt generell lösning.

+ Möjlighet till mekanisk justering

− Kommer ut från väggen.

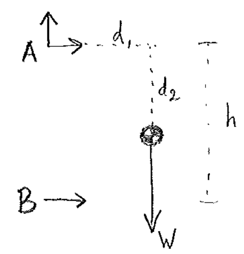
− Känslig för yttre påverkan.

? Rotation utan skranglighet

Kalibrera genom att förskjuta cellens position h.

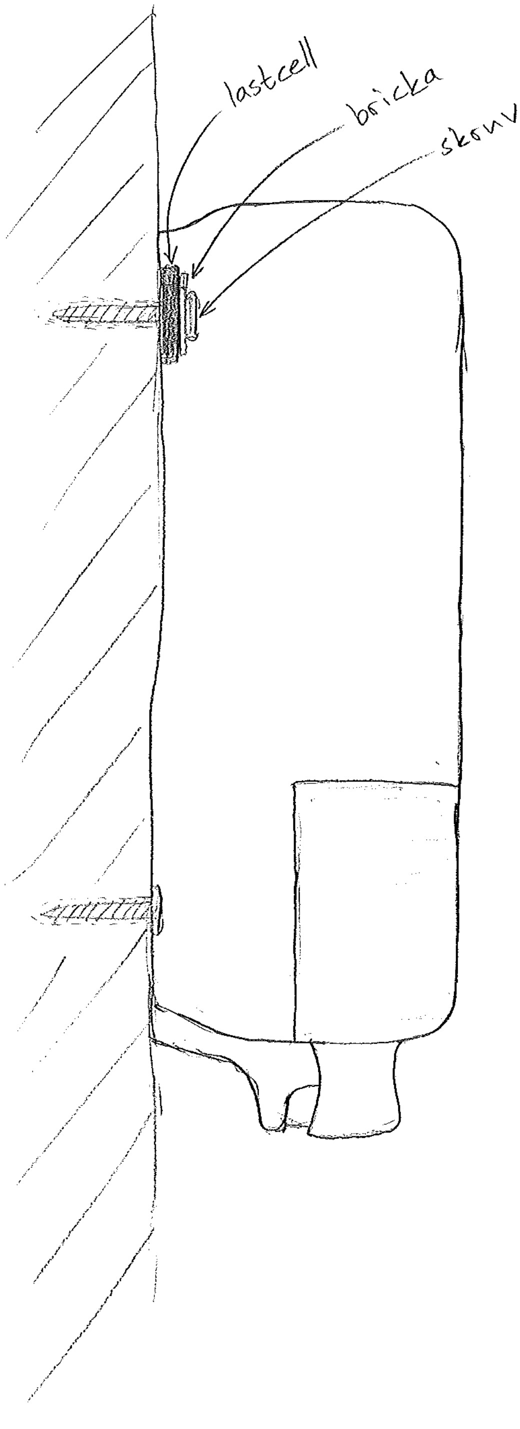
Kolla upp var TP sitter.

Kan användas som räknare!



$d_1 W = R_B h$

"Donut-lastcell vid skruv"



+ Inga modifikationer

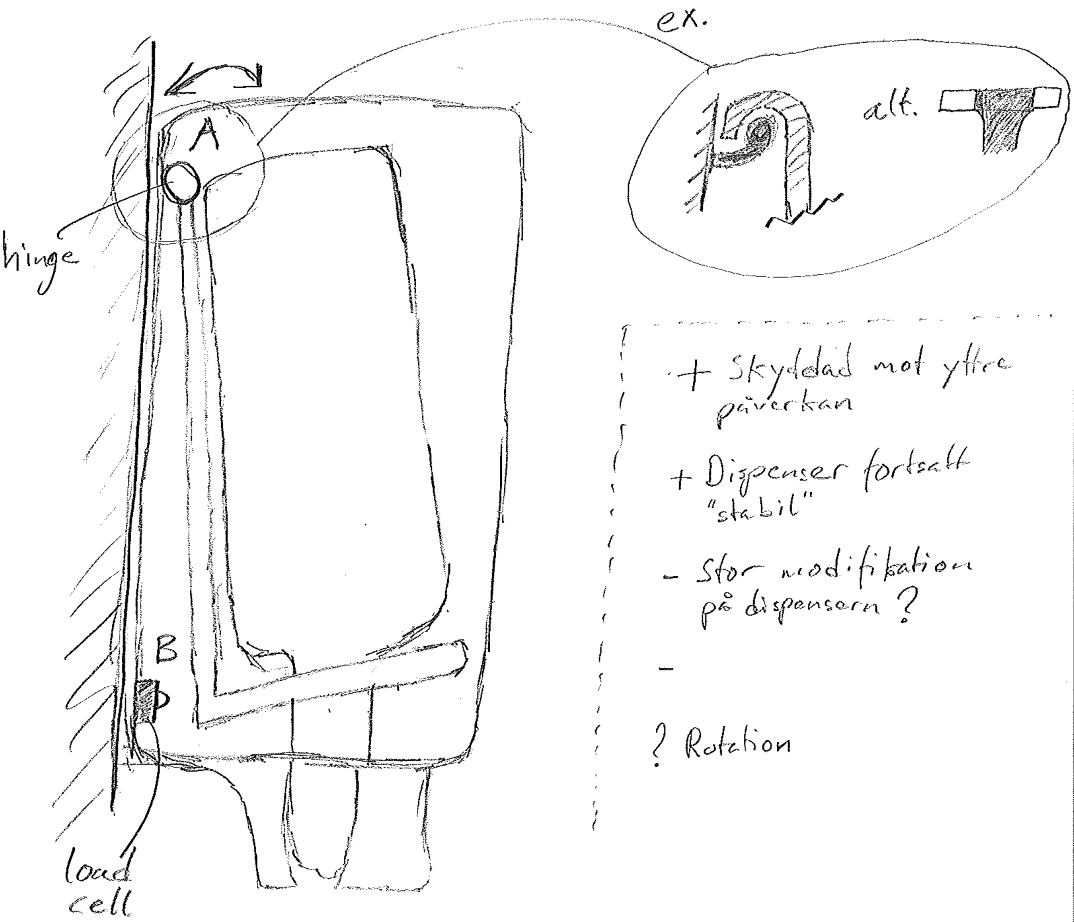
+ Generell lösning

– Känslig för montering

? Fungerar?

? Billig?

Inre gunga



\+ Skyddad mot yttre påverkan

\+ Dispenser fortsatt "stabil"

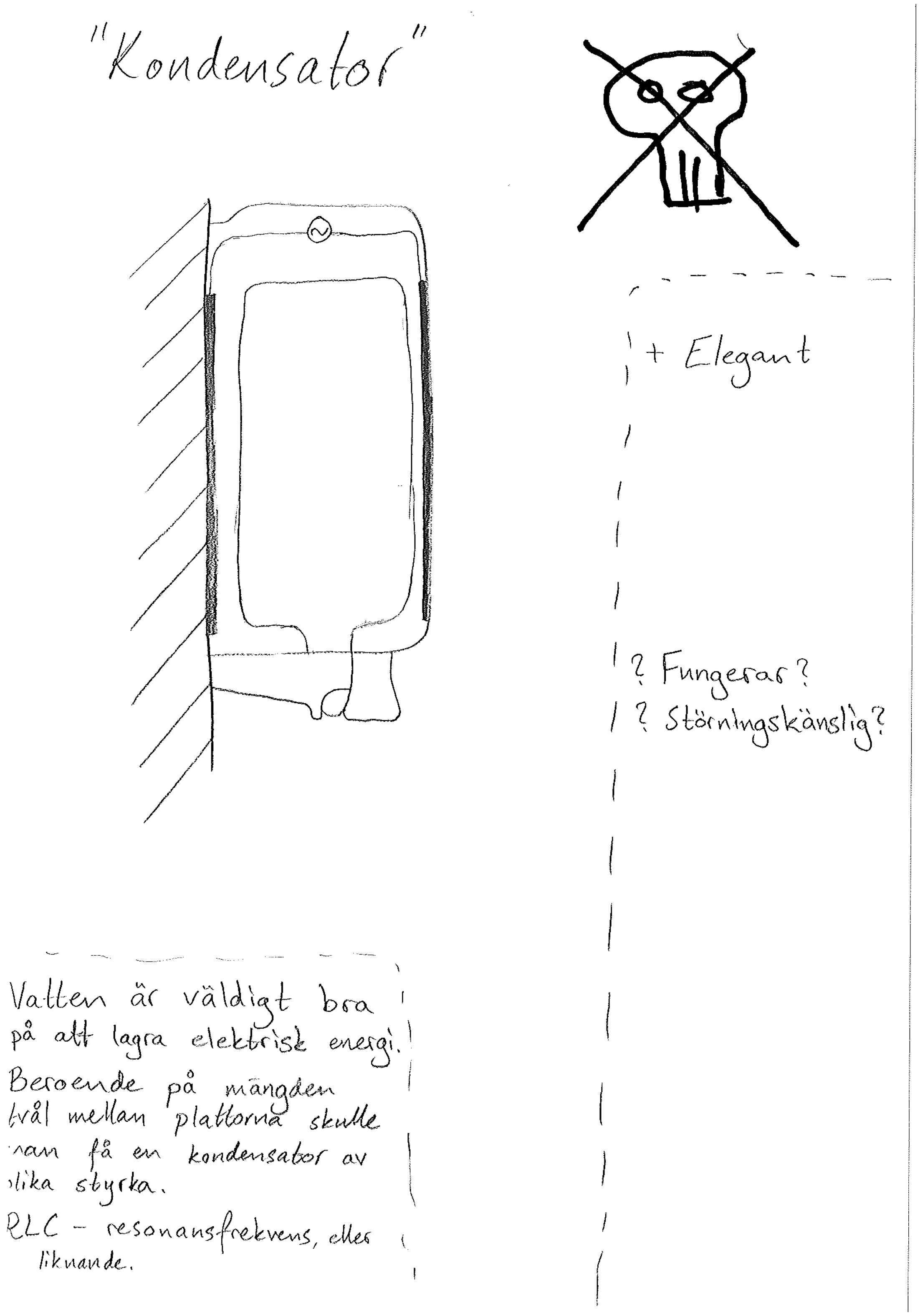
\- Stor modifikation på dispensern?

\-

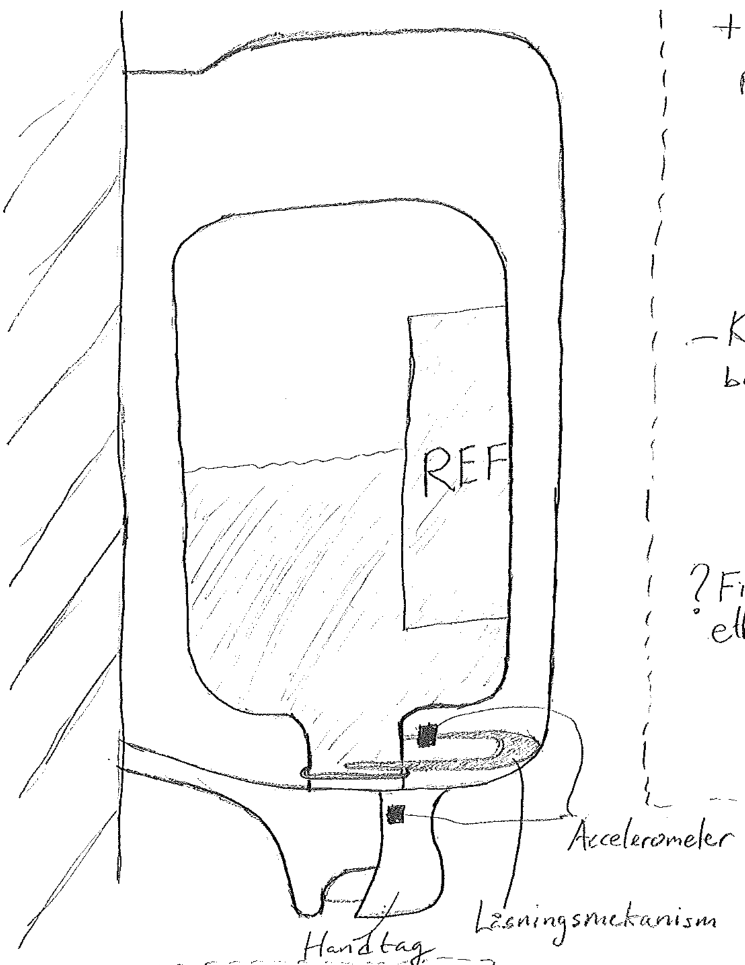
? Rotation

Gungan kan stabiliseras med styrskenor och snäppfäste

G.3 Dispenser modifications - Other



"Bra vibrationer"

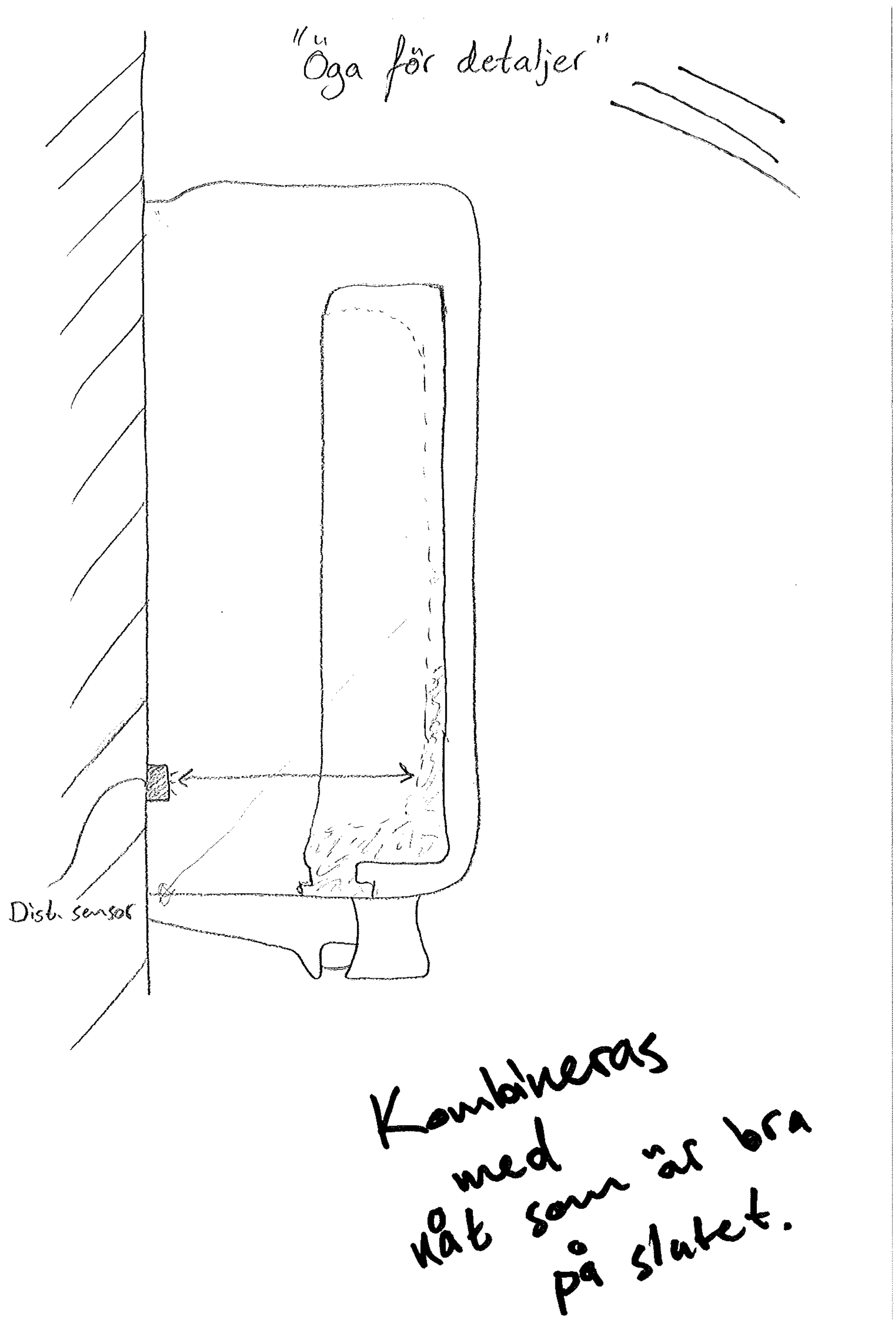


+ Inga modifikationer på refill eller dispenser (?)

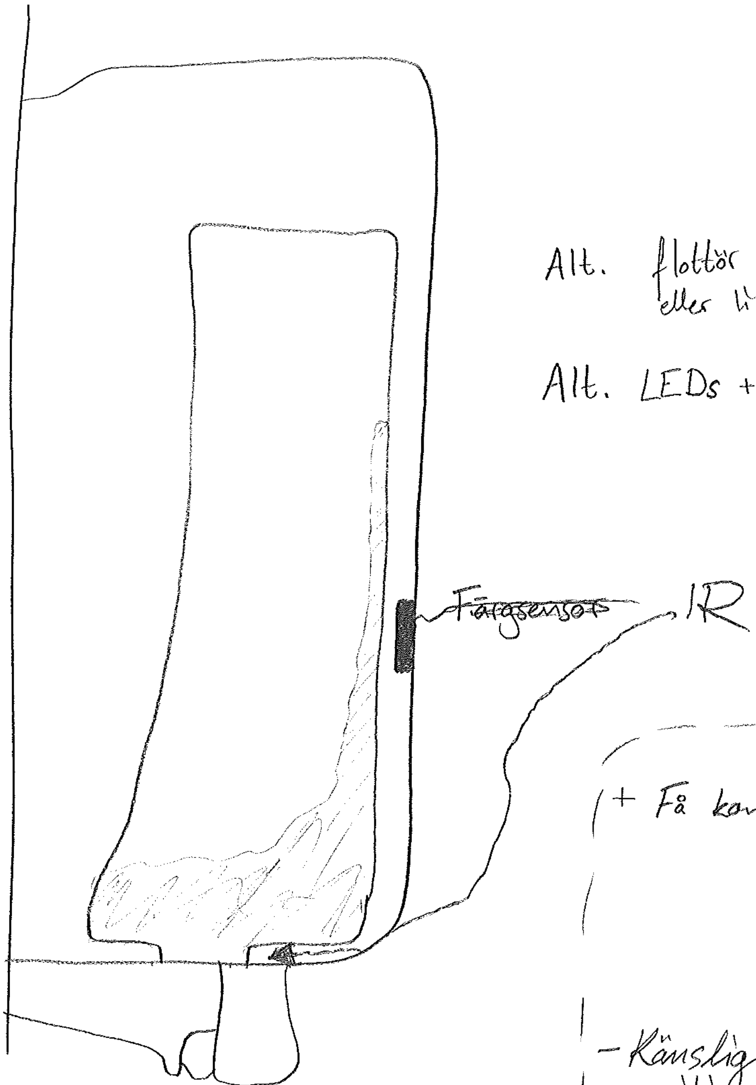
– Kräver viss beräkningskapacitet

? Finns det verkligen ett samband?

lär dispensern aktiveras uppkommer
ibrationer i låsningsmekanismen som
eror på hur hårt man trycker och
ur mycket tvål som återstår i
lispensern.
enom att jämföra värden från
åde handtag och låsning borde
ivån kunna uppskattas.


"Öga för detaljer"
Dist. sensor
Kombineras med nåt som är bra på slutet.

"Direkt nivåavläsning"



Alt. flottör + hallswitch eller liknande

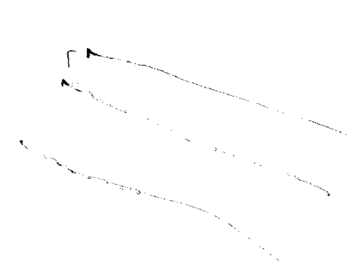
Alt. LEDs + självlysande tvål

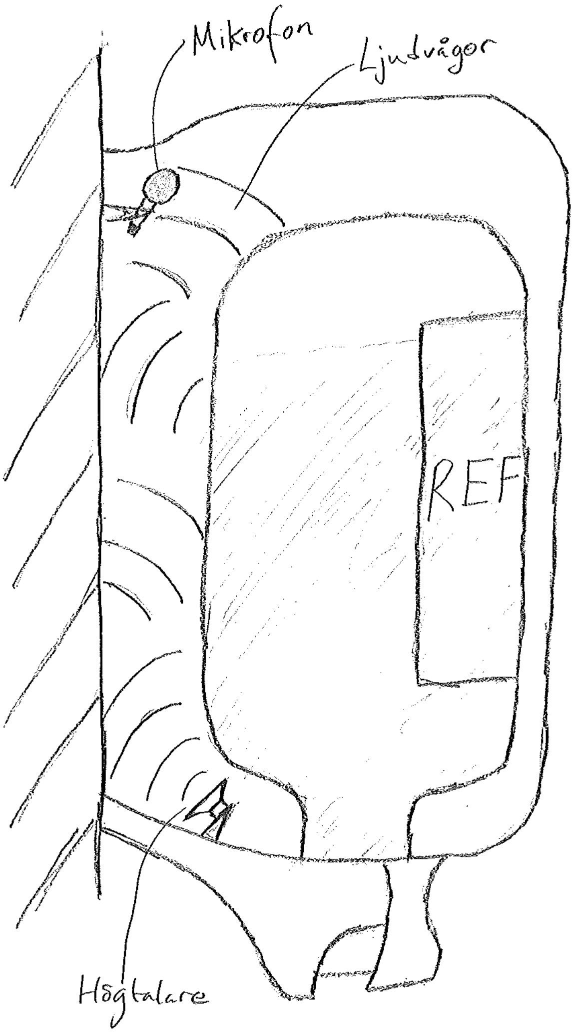
+ Få komponenter

– Känslig för refillens position!

! Tydlig färgskillnad krävs mellan tvål och inte tvål.

"Rätt tonläge"





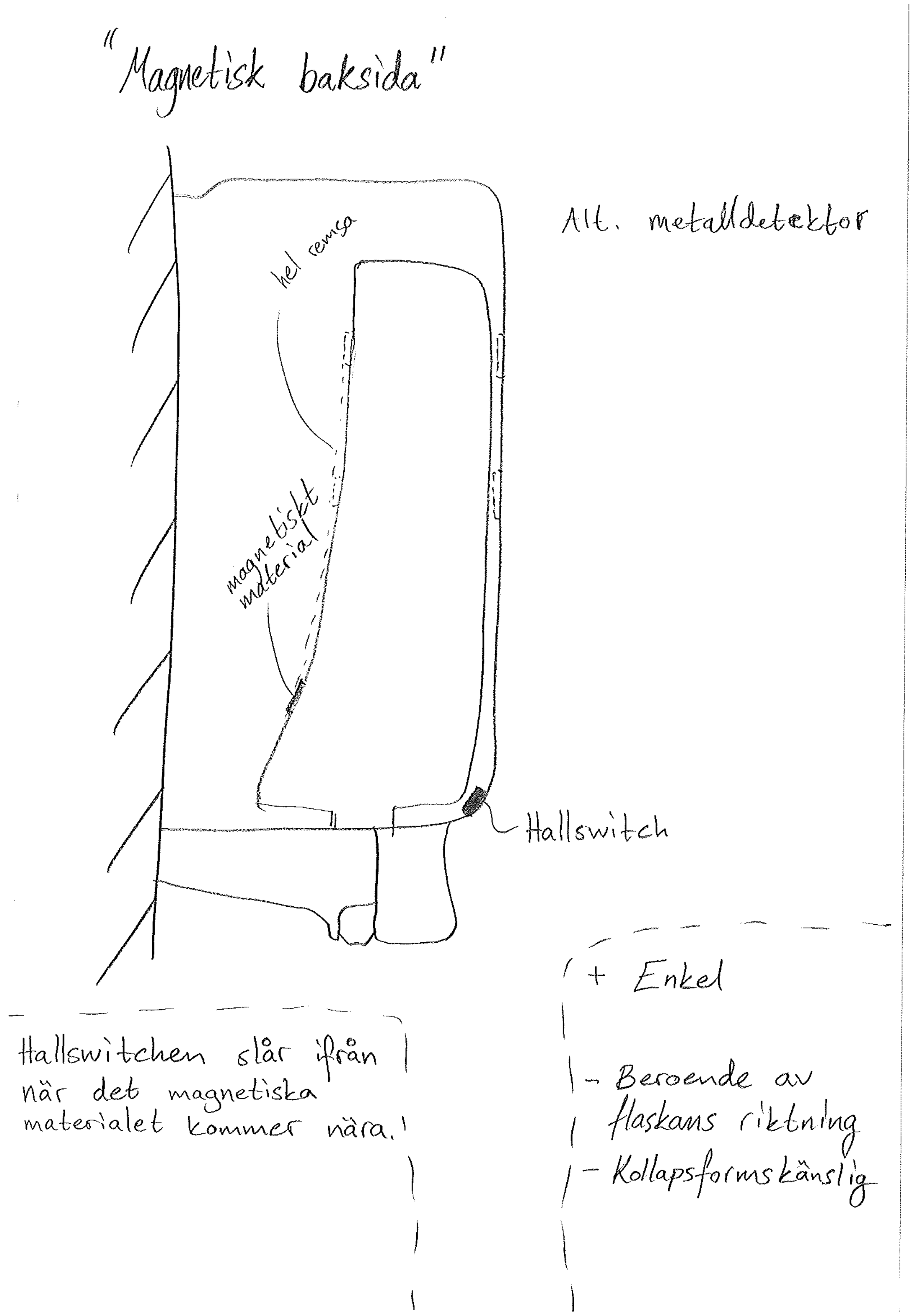
+ Endast små modifikationer på dispenser

– Känsligt för montering (?)

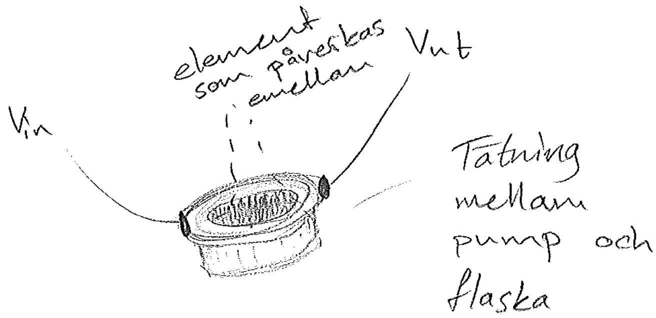
? Finns det ett samband?

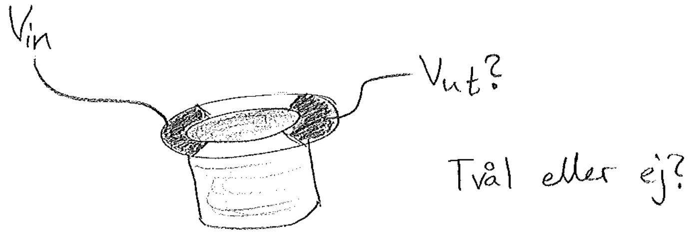
Högtalare sänder ut en anpassad ljudvåg som tas upp av en mikrofon.
Refillen volym påverkar akustiken och därmed borde vätskenivå kunna uppskattas.

G.4 Refill (and dispenser) modifications - Direct electronics

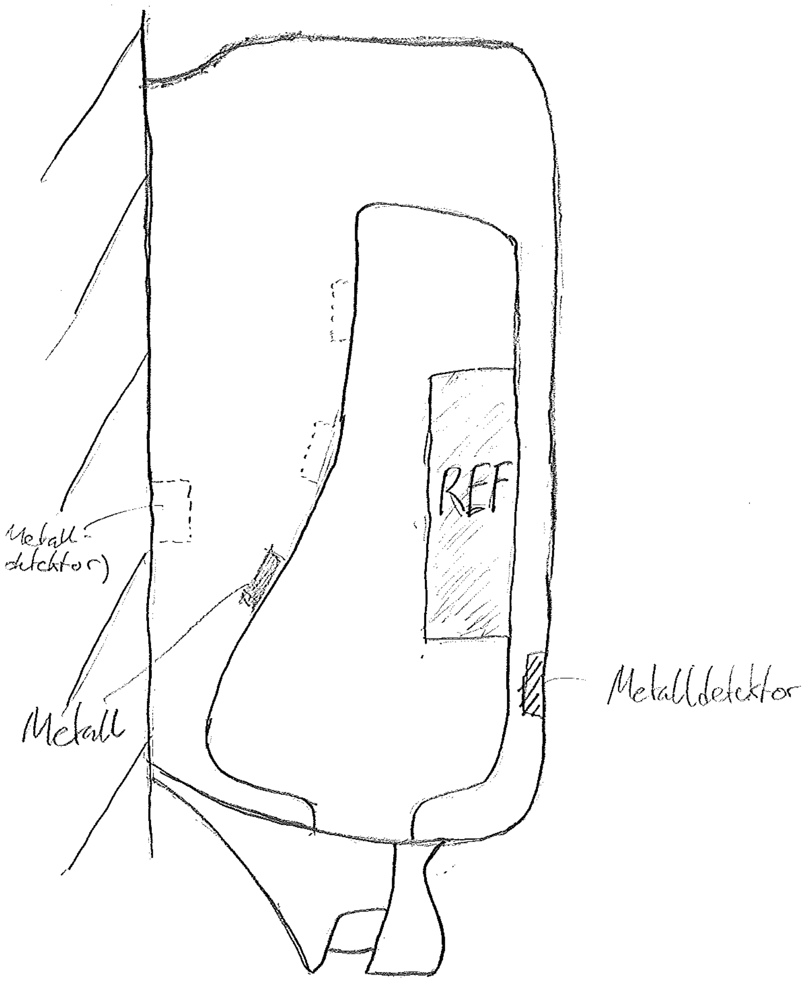


"Tätning"


element som påverkas emellan
Vut
Vin
Tätning mellan pump och flaska

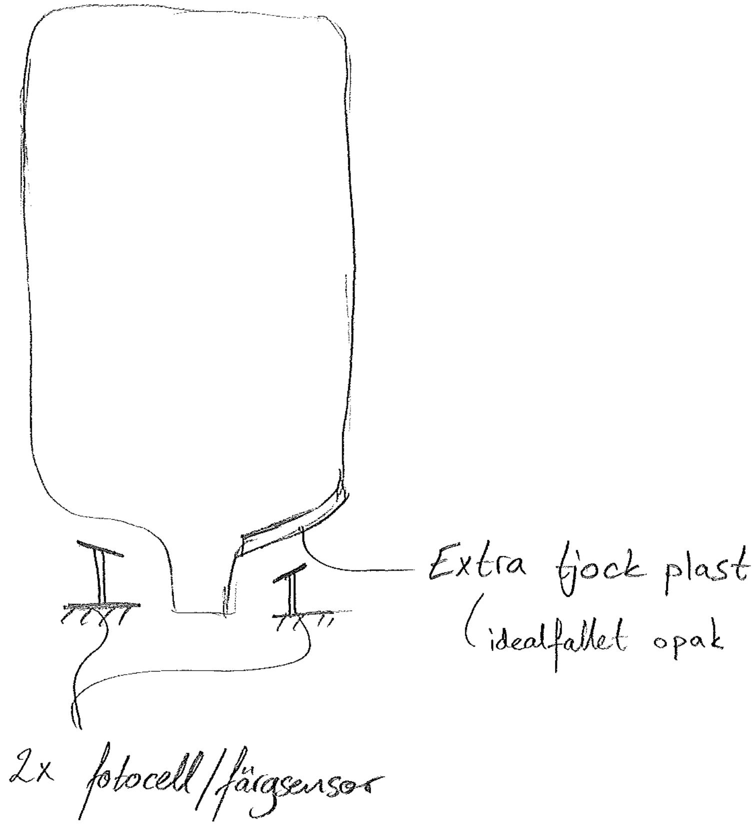

Vin
Vut?
Tvål eller ej?

"Metalldetektor"



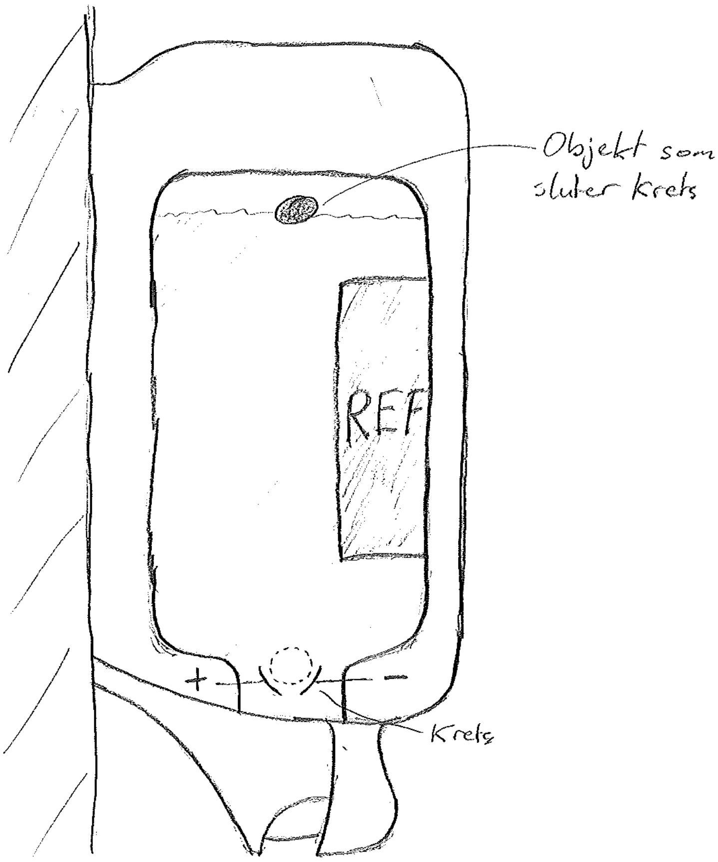
letalldetektorn känner av
ärhet till metallen som sitter
å refillens kollapsande baksidan

"Färgjämförelse"



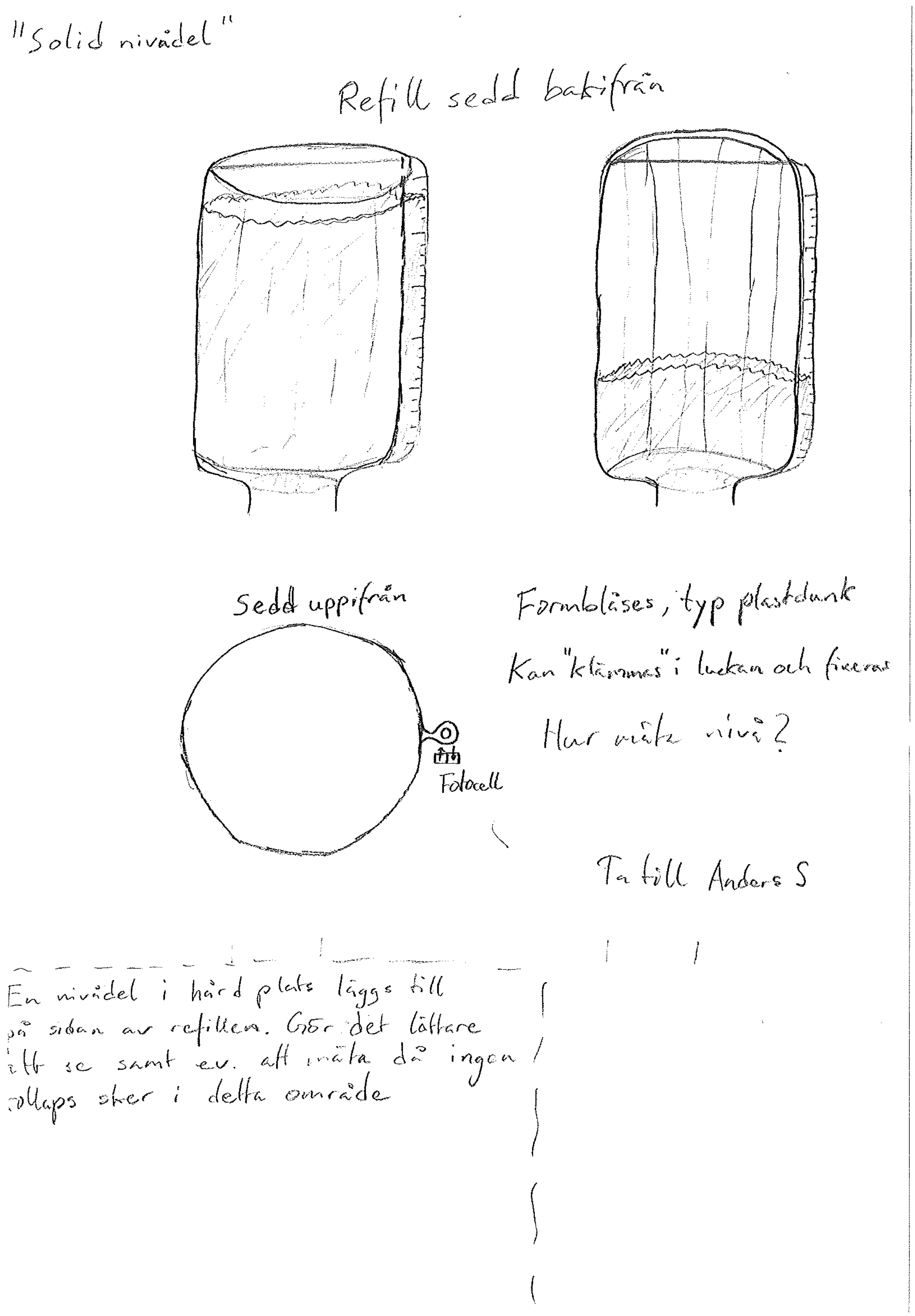
När slut på tvål vid mätpunkten ser båda sensorerna samma färg.

"Sluten krets"

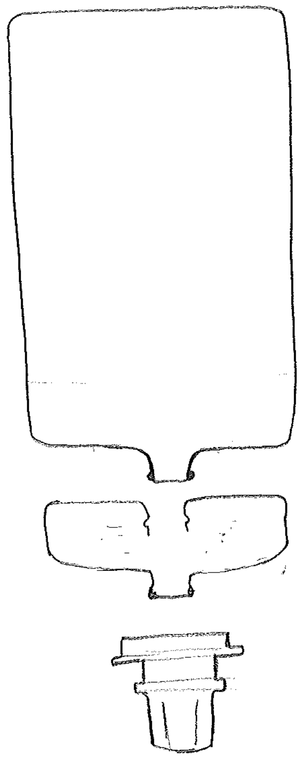


Ett flytande, ledande objekt
tillsätts i tvålen. När nivån
är låg kommer objektet att sluta
en krets som ger larm om
låg nivå

G.5 Refill (and dispenser) modifications - Indirect electronics



"Icke-kollapsande tillägg"



Alt. Hård plast i flaskans nedre bakkant.

Alt. Fjäder i tillägg som lyfter flaskan när tom.

+ Hamnar i fönstret.

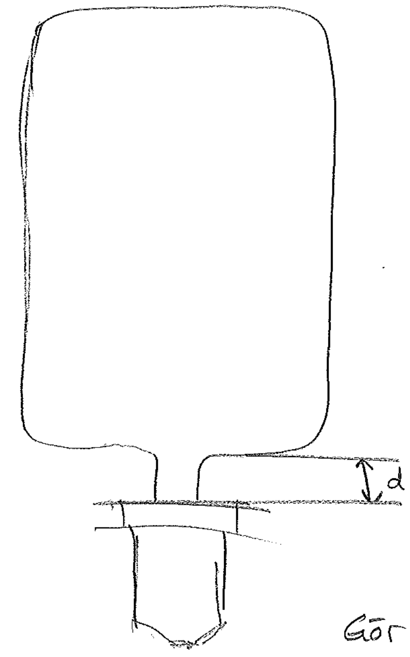
Hur mäta nivå?

? Form på tillägget?

? Tryckbilden?

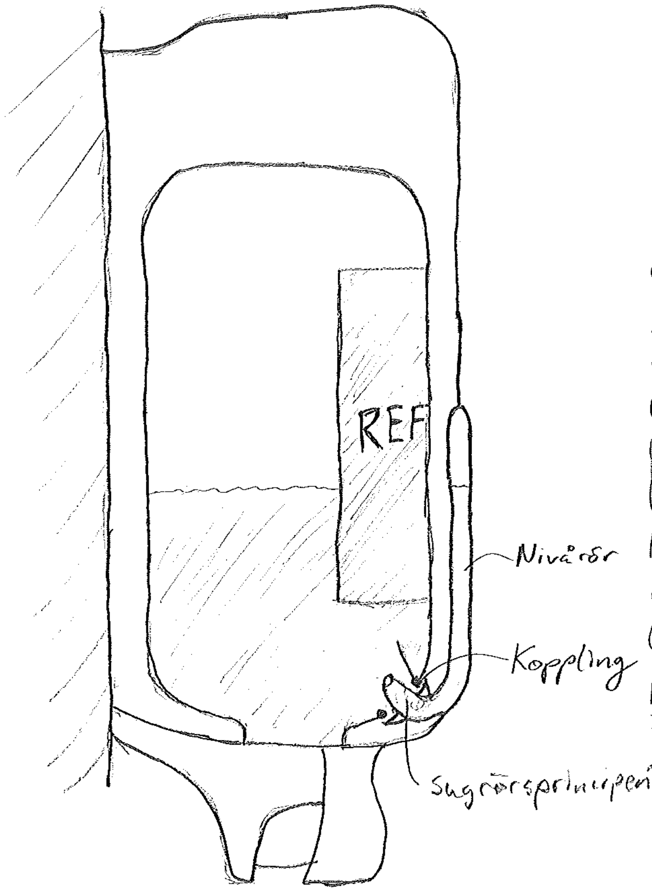
! Aquachange

"Fjädrande hals"



Gör d beroende av flaskan/tvålens vikt.

"Nivårör med koppling"



+ Ger visuell indikering

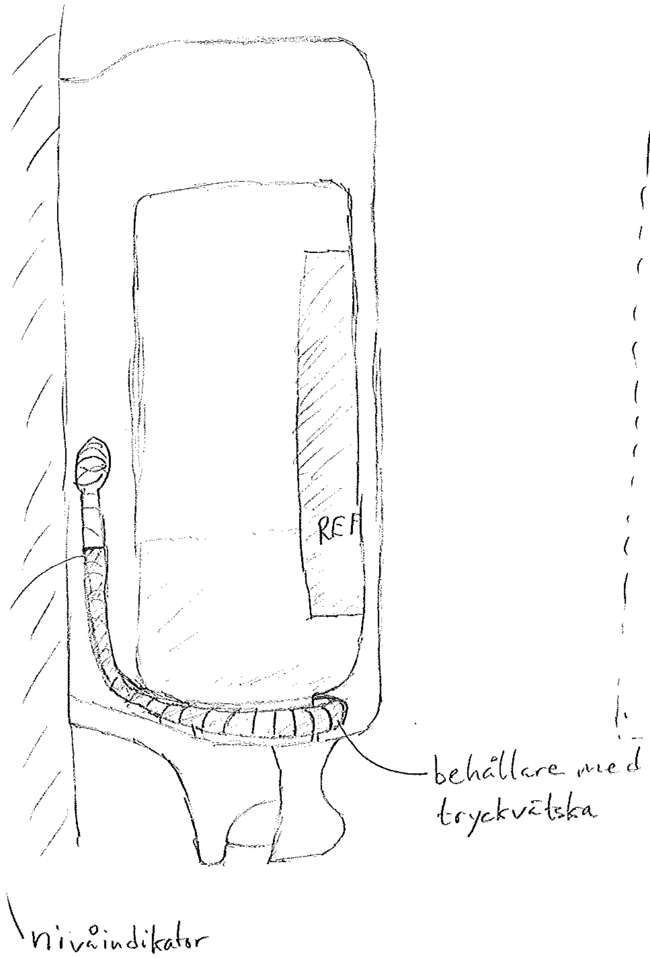
– Kräver modifikation av dispenser och refill

? Hur länge håller det?

? Finns billig och enkel koppling?

[N]ivåröret är en solid del [a]v dispensern som med [h]jälp av en koppling ansluter [t]ill refillen

"Vattensäng"

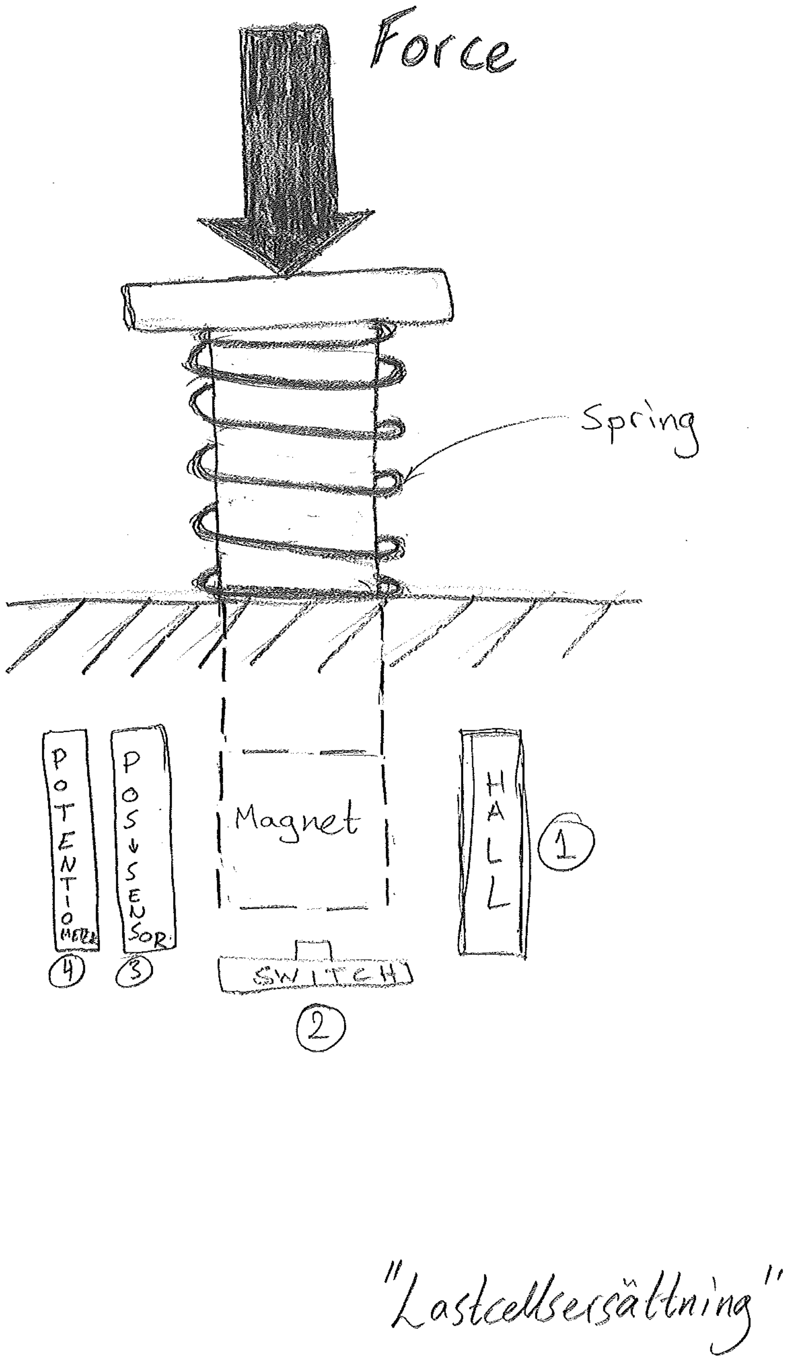


+ Ger visuell indikering

– Stora modifikationer krävs

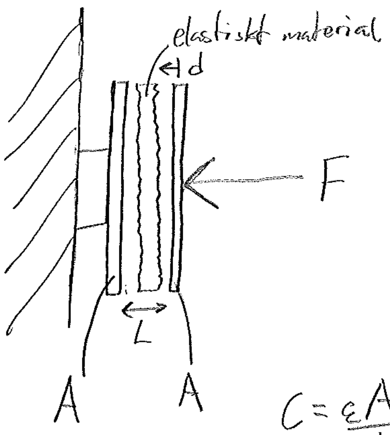
? Lösas på annat sätt?

G.6 Features



Force
Spring
POTENTIOMETER
POS SENSOR
Magnet
HALL
SWITCH
1
2
3
4
"Lastcellsersättning"

"Kapacitiv sensor istället för lastcell"

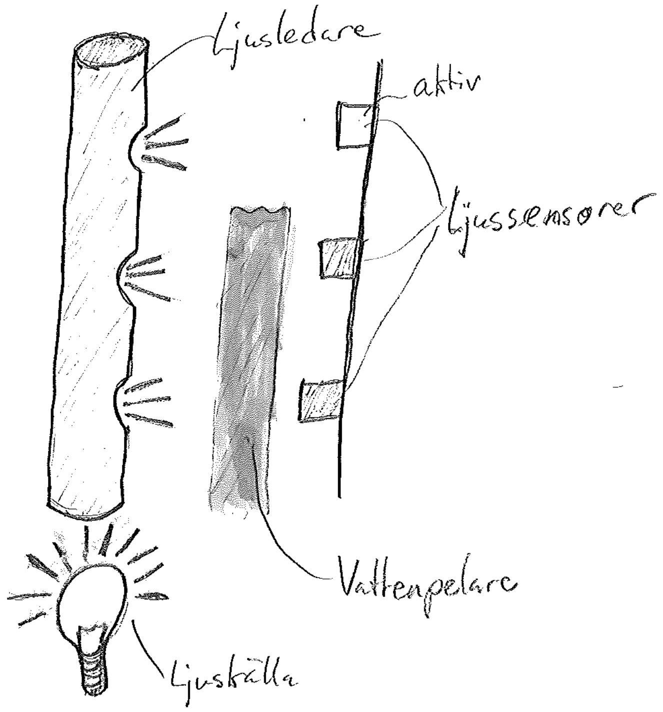


$$F = \frac{dEA}{L^2} \quad (1)$$

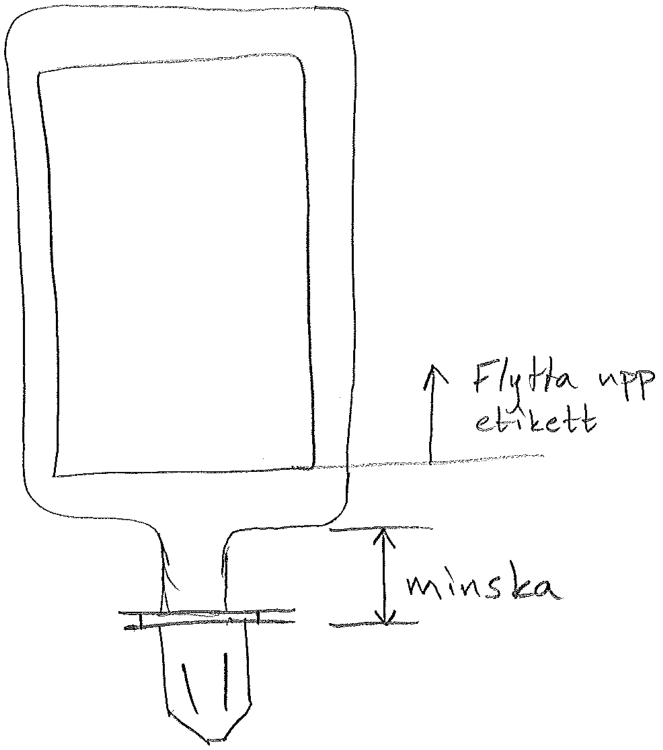
$$C = \frac{\varepsilon A}{L-d} \Rightarrow d = L - \frac{\varepsilon A}{C} \quad (2)$$

$$1,2 \Rightarrow F = \frac{EA}{L^2}\left(L - \frac{\varepsilon A}{C}\right)$$

"Optisk ljusledare"



"Uppvisning"



Appendix H

Donut test results (TP4)

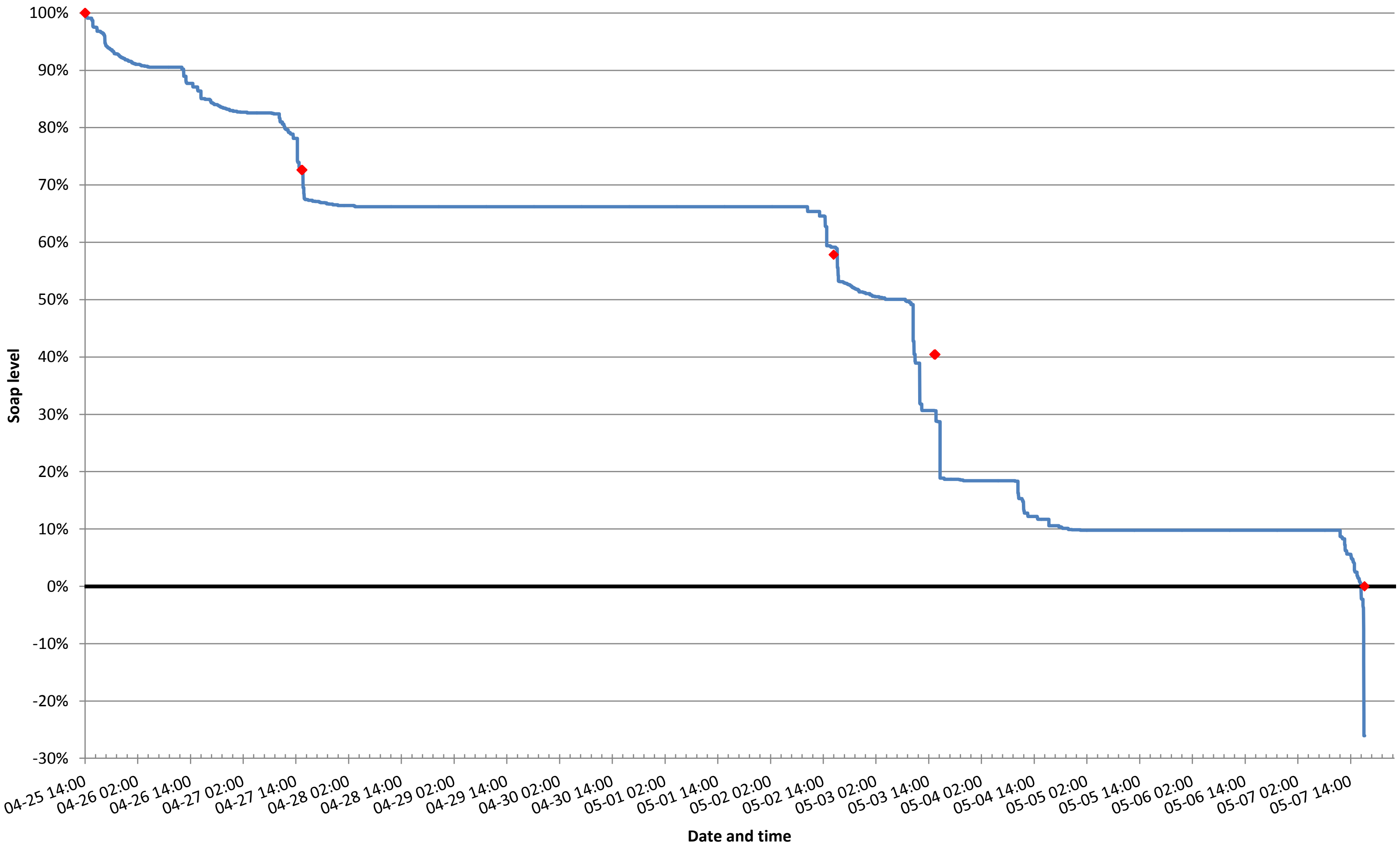


Figure H.1: Donut test results (third prototype, test 3). TP4. The line represents the measurement sytem's soap level estimation while the diamonds show the actual soap level.

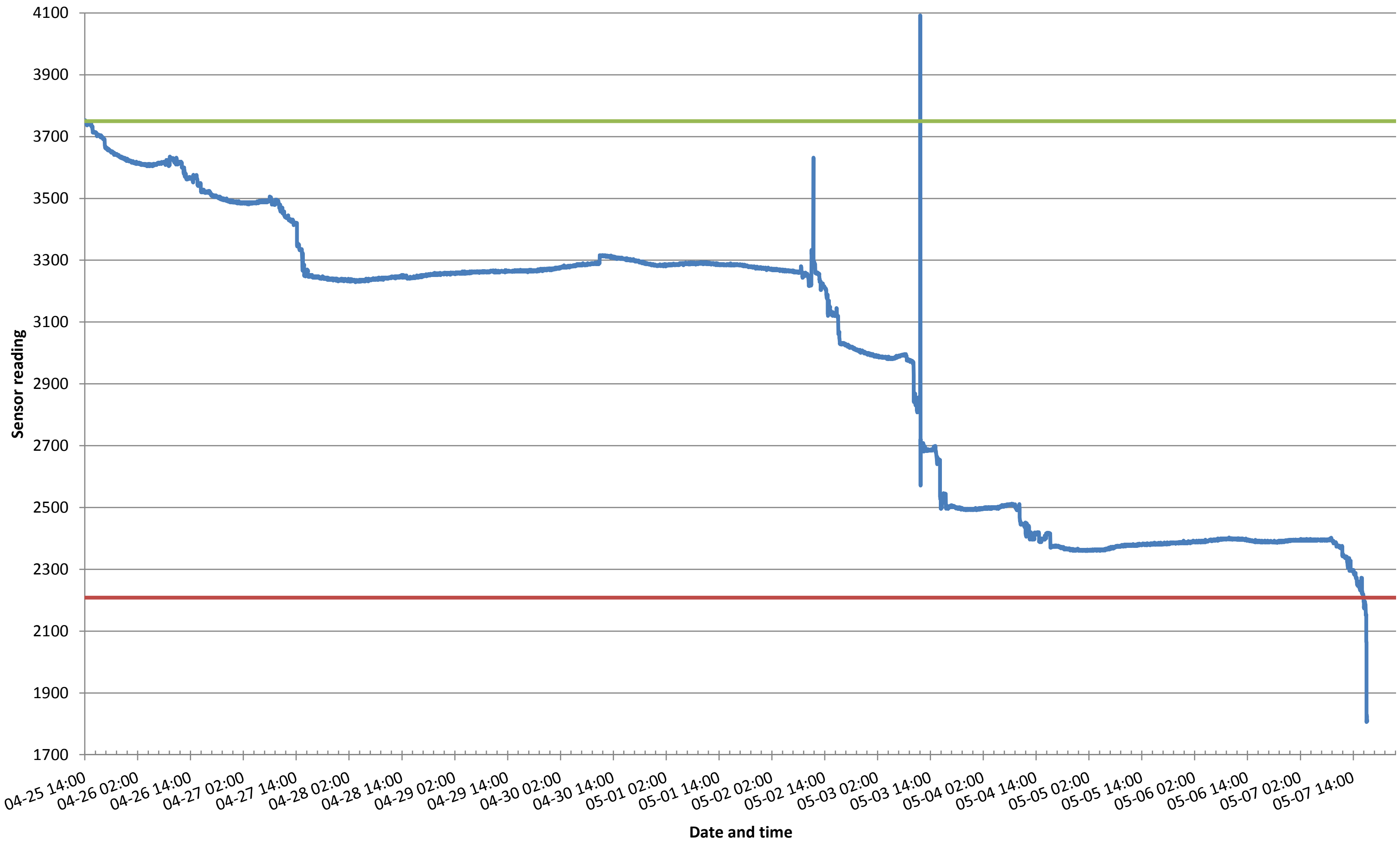


Figure H.2: Donut test results (third prototype, test 3). TP4. The red line marks where the system is calibrated for empty refill. The green line marks full refill.

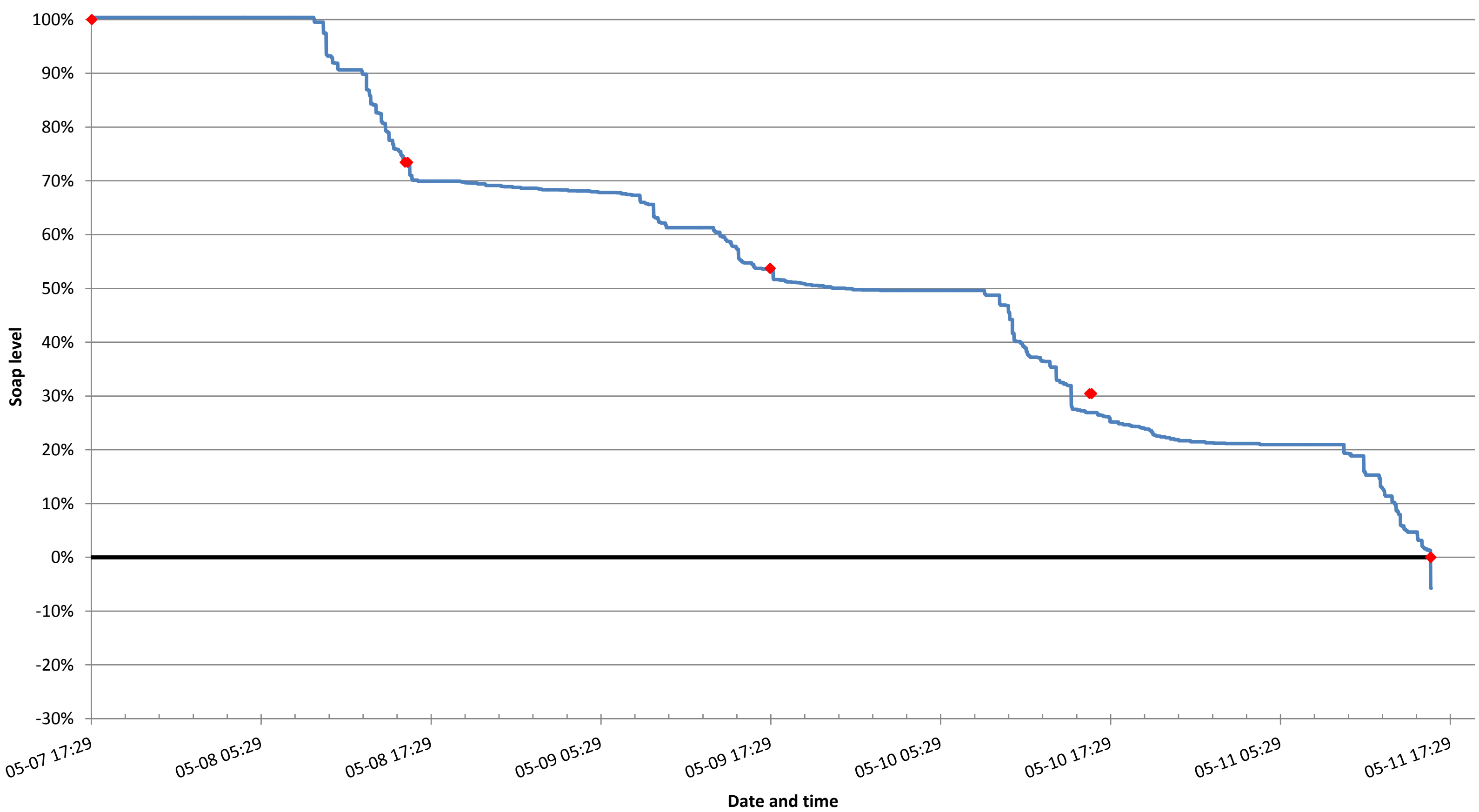


Figure H.3: Donut test results (third prototype, test 4). TP4. The line represents the measurement sytem's soap level estimation while the diamonds show the actual soap level.

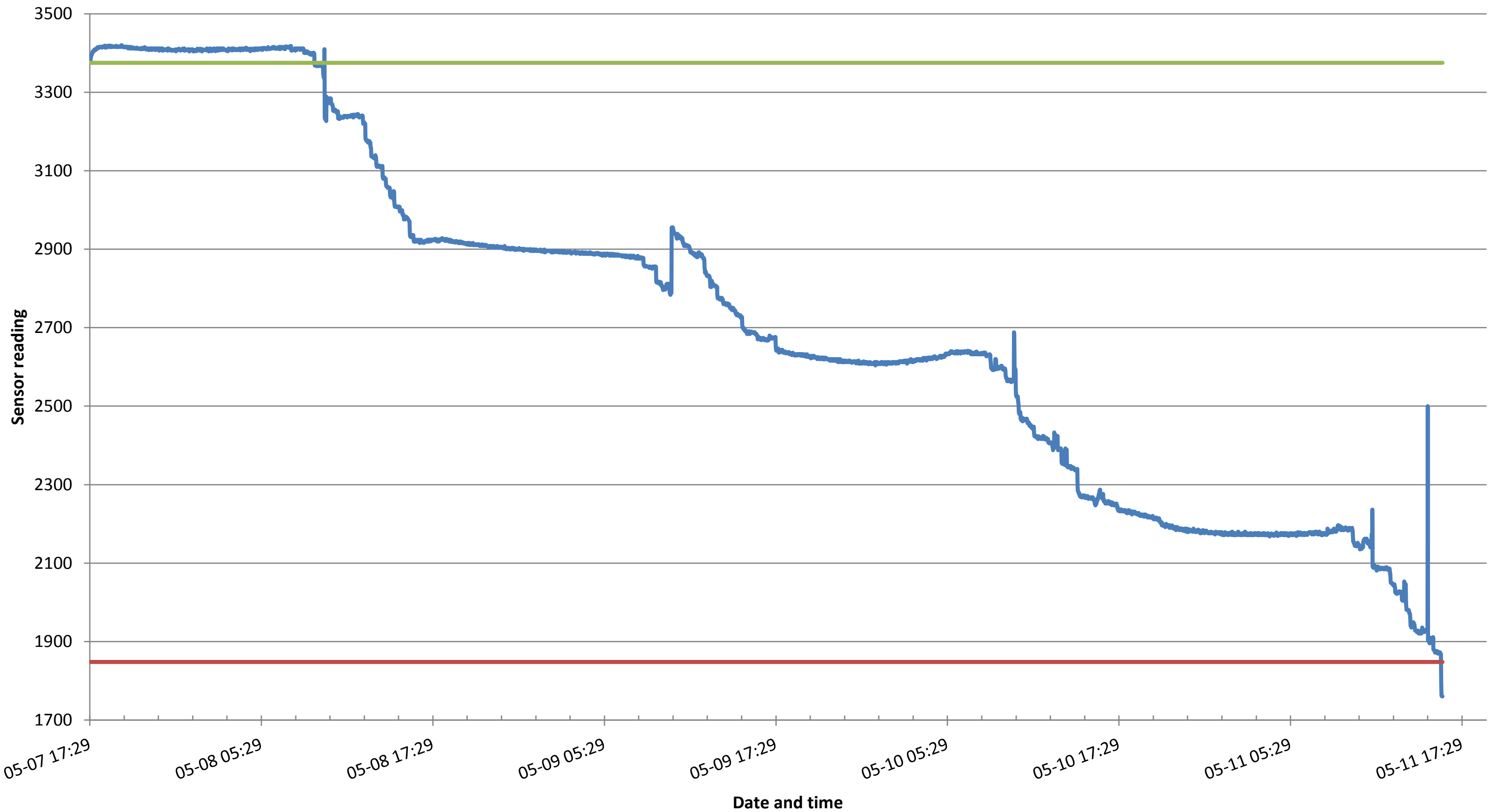


Figure H.4: Donut test results (third prototype, test 4). TP4. The red line marks where the system is calibrated for empty refill. The green line marks full refill.

Appendix I

The Water Bed concept

The design of the planned prototype can be seen in Figures I and I. The dispenser is attached to a back plate which enables it to move slightly in the vertical direction and the weight of the dispenser is thereby put on the "water bed". In the planned prototype this means the weight is put on a balloon that leads the pushed away liquid into a closed-end pipe. The air pressure at the top of the pipe increases until the weight of the dispenser is completely counteracted. A sensor could either measure the pressure inside the liquid system, or sense the height of the liquid pillar.

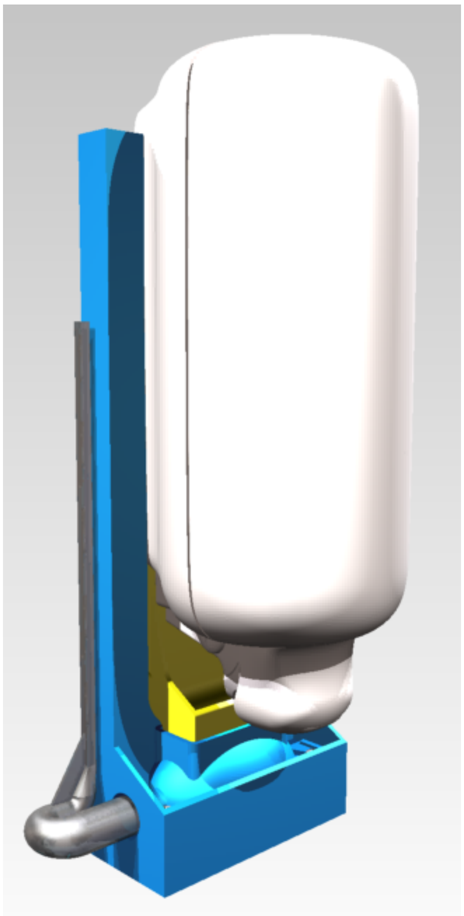


Figure I.1: A computer model of the planned Water Bed prototype.

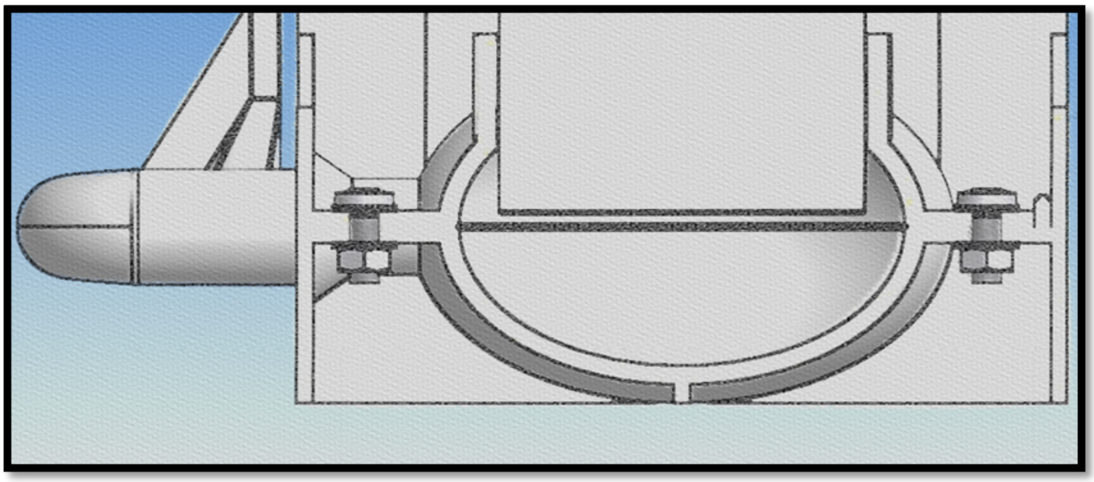


Figure I.2: A close up of the thought Water Bed prototype. The piston pushes against a balloon and the pushed out liquid enters a narrow pipe on the side.

Appendix J

The Audio concept

One way to know how the volume of the refill changes within the dispenser could be to measure the acoustical properties inside the system. A full refill, compared to an empty refill, will take up more of the inside volume of the dispenser and thus create a certain environment for sound waves. An analogy could be an acoustic guitar where the volume of the hollow body determines how it will sound. In this case less volume will result in a tone which will ring for a shorter time and with less intensity. An example of how this can work for a soap dispenser is shown in Figure J.1.

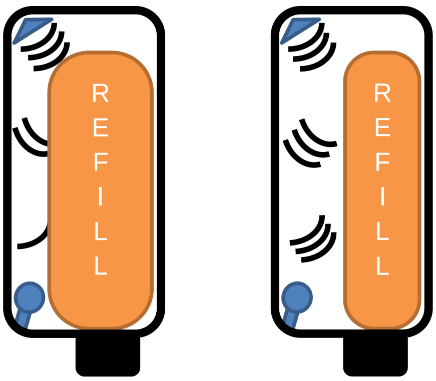


Figure J.1: An illustration of two dispenser with different amount of soap left seen from the side. Inside them there is a speaker and a microphone.

Another method which could be able to measure the volume of the refill is to use one speaker, two microphones and one reference chamber. This method is based on how change in pressure and volume is related in a closed chamber:

$$\frac{\Delta P}{P_0} = \gamma \frac{\Delta V}{V} \tag{J.1}$$

Where P_0 is the pressure in the chamber (preferably atmospheric pressure), V is the volume of the chamber and γ is the ratio of specific heat. The suggested measurement method is as follows:

- Place one microphone in a reference chamber and the other one inside the dispenser.
- Assemble the reference chamber with the dispenser by an open intersection and mount the speaker in this intersection.
- The speaker emits a sinusoidal wave signal and the ratio of the amplitude of the microphone outputs is measured.
- Calibrate the system using an object inside the dispenser with a known volume.

For more details, see the source where this idea was taken from.[26]