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Lifa Air Secure Box method for chilled beam cleaning

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The objective of this Bachelor's Thesis was to introduce a chilled beam cleaning method and to develop an improved version for the prototype introduced in 2011. This thesis was commissioned by Lifa Air Ltd. The company itself is specialized in improving Indoor Air quality and offers a wide range of products meant for ventilation cleaning. The aim for the development work was to fill the requirements and needs set by the company based on the research done, and to construct a working and improved prototype.

The research was started by gathering information from the previous versions of the product. All data was obtained by interviewing and studying all the research. This was followed by brainstorming and sketching which were finally modelled with a Solidworks 3D software. Once a preliminary version was modelled, the construction of a prototype could be started. While the prototype was under construction, all needs for improvements were noted and updated in 3D model. This method ensured that the prototype would be close enough to the production version. The testing of the prototype was performed as it was constructed.

As a result a 3D model, technical drawings and a working prototype were achieved. Based on the model and drawings, the production version for the final product can be manufactured. The project worked also as a learning process for understanding the steps and challenges of a product development process.

Keywords	Chilled beam, Convector, Ventilation hygiene, Secure Box, IAQ,

Contents

Metropolia

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List of Abbreviations

VTT	Finnish government research center
TAYS	Tampere University Hospital
IAQ	Indoor Air Quality
ppm	Particles per million, where 10000 ppm is same than 1%
pa	SI Unit, pressure
InH2O	Imperial unit, pressure
HEPA	High efficiency particulate air filter
3G	Filter developed by Lifa Air Ltd. Filter efficiency up to 99.99%
HC1100	HEPA Clean 1100, product of Lifa Air Ltd
PC	Polycarbonate, plastic
AISI 304	Austenitic stainless steel according North-American standard
kg	Weight (kilogram)
m	Dimension (meter)
mm	Dimension (millimeter)
µm	Dimension (micrometer)
DS SW	SolidWorks is a program developed by Dassault System. Program is used for making dimensional drawings out from 3D models created.
3D	Three dimensions

1 Introduction

This chapter is a walk through for the study and why it was made. This will also explain the aims, objectives and scopes for the project, and give general understanding for the problem studied.

1.1 Background

As technology improves, the awareness of poor indoor air quality and its health effects increases. For years there have been studies about how hospital environment air quality affects directly to the possibility for getting infections. Hospitals have daily routines for using disinfectants in the rooms where sick people have been held. The reason for the surface disinfecting hasn’t been so effective is the bacteria and pollutants spreading through the ventilation system. The main problem are the chilled beams, which will gather dust and moisture from the ventilation and surrounding room. This will act as a perfect breeding ground for bacteria (Työterveyslaitos, 2011).

Lifa Air Ltd has already invented a way to clean these beams while hospital departments can be open during the cleaning session, and there is no need for removing these beams from their places. The invention has been called as a Secure Box. This thesis will concentrate on the methods the chilled beam have been cleaned, and especially for the Secure Box method. The goal is to manufacture updated and more user-friendly product of the Secure Box, and test it on the field.

1.2 Aims & objectives

Aim of the project is to construct a working prototype of Lifa Secure Box and taking into account the shortcomings of the previous prototype.

The objectives are:

- to analyze the theory behind chilled beam cleaning,
- to investigate and compare methods for chilled beam cleaning,
- to design and manufacture working prototype of the final product and
- to evaluate constructed product.

1.3 Project scope

The scope of this project was to construct a working prototype within the allocated time. In addition to the time limitation there were other limitations to be taken into account, from which the majority concerned construction limitations. These were weight and height limitations and physical width versus length to match most elevators and vans.

1.4 Methodology

To achieve the aims and objectives, following methodology was used:

1. Perform a literature review concerning information regarding Lifa Secure Box product. Including comparison of chilled beam cleaning between new Lifa and the previous methods,
2. perform analysis of the theory involved with Secure Box, and determine best practice approach for the design from physical and economical aspect,
3. to design product according to the limitations set by the company and
4. to construct final product and check its functionality by testing.

It was projected that by using this methodology the goals for this project would be accomplished.

2 Literature review

During time and use, building ventilation system will gather dust and impurities. When into this combination is added the moisture, due to temperature fluctuation, the indoor air quality will drop considerably. Due to the moisture, the dust and impurities will gather inside the ventilation system and pollute the room air.

In hospital environment the dust and moisture will work as a breeding ground for bacteria allowing pathogenic germs travel from room to room. In the worst case scenario this can cause a spreading hospital bacterium. (Työterveyslaitos, 2011)

Finnish institute of Occupational Health has drawn up instructions for cleaning procedure.

2.1 Ventilation and air quality

According the construction regulations in Finland, the ventilation system must be designed and constructed in order to produce good conditions for healthy indoor air regardless the outdoor weather conditions. The ventilation system is designed to purify indoor air resulting no chemicals microbes or unpleasant smells are migrated indoors.

Mechanical ventilation is mostly used in new buildings. It provides good opportunity for controlling the airflow, filtration and distributing of supplied air as per need of each space and for a good heat recovery, thus minimizing energy consumption.

When machined ventilation is used, opening windows in the purpose of venting should be avoided. Thus the transition of dust and impurities from outdoor air can be prevented. (Työterveyslaitos, 2011)

Finnish construction regulations part D2 gives instructional and target values for good IAQ, according to which carbon dioxide ratings should be lower than 1200 ppm. According to best classification of IAQ (S1) the carbon dioxide ratings should be lower than 750 ppm. The S1 classification gives also more accurate limit-values for ammonia, formaldehydes, particles and radon. All concentration of the particles is originating partially from outdoors and partially from activities and people indoors. (RakMK D2, 2012)

Hospital environment causes additional requirements for air ventilation and hygiene of ventilation system. Patients can have reduced immunity and this will make them more sensitive for certain pathogens and infections. Therefore air distribution should be designed to prevent unnecessary germs to spread between departments and hallways. (Työterveyslaitos, 2011)

2.2 Importance of hospital IAQ

Due to the range of operation, the quality requirement for hospital IAQ is more demanding than in many other buildings. Researches shows that more than 50,000 hospital infections occur in every year, which contributes the mortality for two to five thousand patients. All methods for preventing the spread of infections is based on knowledge how microbes are moving inside room environment. There is no exact knowledge about infections which are transmitted through the air. The most frequent estimated value used is 10 percentages from overall infections. (Työterveyslaitos, 2011)

Figure below shows importance of good IAQ in numbers

Costs of bad quality air

	Euros / year	Included in calculations
Deterioration of existing allergies, new allergies	1.18 billion	30 % of the cost of all allergic diseases
Sick leaves	0.8 billion	In terms of office work, 600.000 employees, 15 % of absences caused by indoor air
Drop in work efficiency	0.2 billion	Office employees' drop 10 %
Hospital infections	84 million	Total cost of hospital infections 170 million, half caused by indoor air
Lung cancers caused by radon	34 million	450 cases per year, cost of one case 75.000 euros

Figure 1. Costs of bad air quality (www.lifa.net, 2014)

Infections from airborne spreading microbes are prevented by following so called air insulation instructions, where the patient with serious airborne transmitting disease is placed in a room which is set on negative pressure. Instead of circulating the polluted negative pressure air in hospital, it is filtered and directed out. Biggest challenge for hospital IAQ is almost constant need for the building maintenance. (Työterveyslaitos, 2011)

2.3 Infection risks due to cleaning of ventilation

When ventilation and chilled beam cleaning is performed, microbes and small particles are released in the air. The quantities of these particles can exceed the normal state by multiple times. While performing the cleaning it is observed that especially particles sized 1-5 µm had significant variation. Also the quantity for particles sized less than 1 µm is increased. The quantity of these particles can stay above normal for many hours after the cleaning has been performed.

The impurities should not have harmful effects on patients nor hospital personnel. It is recommended that cleaning is done when hospital departments is emptied and isolated. This way the departments can be set on a negative pressure, and all particles can be filtrated through HEPA filter. Nevertheless, excessive negative pressure can induce the particles and microbes to travel between hospital wards trough structures.

During the cleaning work the impurities falling from chilled beams and ventilation surface can reach high amounts quickly. Therefore negative pressure and proper filtration is advised throughout the operation. All particle samples from the air are taken while the cleaning operation is on. Before cleaning work is started, it should be examined if the work can be done during the department is open, or if it ought to be closed. (Työterveyslaitos, 2011)

2.4 Maintaining the purity and proper working condition

Ventilation system consists of air handling units, ducts and various components inside. The ventilation unit and ducts must be clean and the air flowing in rooms should be balanced as intended use requires. Service and maintenance of the ventilation system will affect straight to the IAQ.

Maintenance program of ventilation system must be followed according to the plan. Carefully followed maintenance program of the ventilation system ensures the appropriate air condition. Excessive fouling of ventilation system typically happens because of inadequate maintenance. (Työterveyslaitos, 2011)

2.5 Need for chilled beam cleaning

According to Finnish fire safety law, the owner or operator of the building must ensure that building ventilation system and ducts are cleaned to minimize the risk of fire. At the moment there is no regulation regarding scheduled inspection and cleaning. The ventilation system that circulates room air gathers dust and impurities while in use. Therefore cleanliness of chilled beams should be paid special attention to. In general convectors should be checked and cleaned in every two to three years, while interval for chilled beam check is from one to two years. (Pelastuslaki, 29.4.2011/379)

Depending from the season, the condition of chilled beams and convectors can get in bad condition in a short term. The microbe levels of chilled beam increases considerably right after cleaning procedure has been done. (Lifa Air Ltd, 2012)

In the figure below it is demonstrated into what condition chilled beams get when two to three years have passed since the last cleaning has been performed.

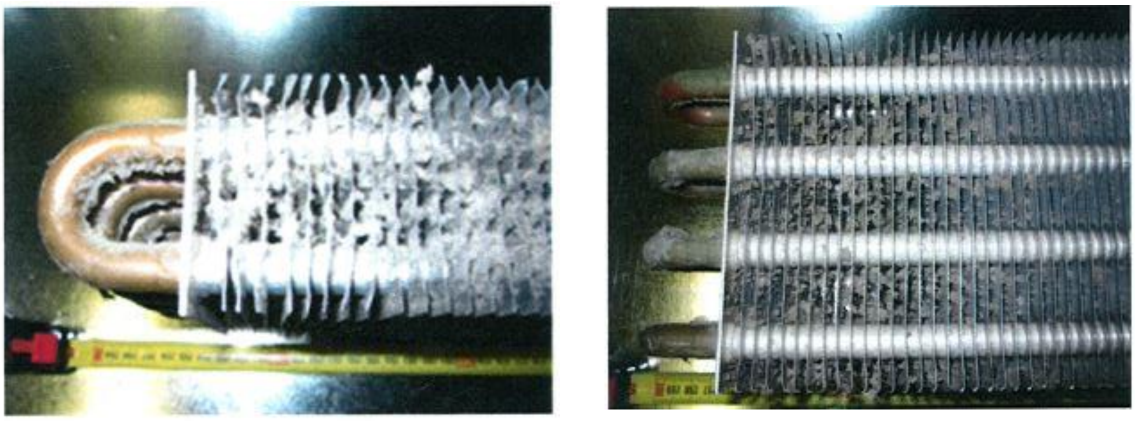

Figure 2. Last cleaning for this chilled beam was done 2009. Picture taken 2012 (Lifa Air Ltd, 2012)

2.6 Methods for cleaning chilled beams

Old-established way for cleaning chilled beams and convectors is mixed use of dry and wet cleaning equipment. Ventilation cells, heat exchangers and other parts including surfaces are usually cleaned with compressed air and vacuum cleaner. Ventilation ducts are cleaned by using special brushing machines. During cleaning operation, all workers on area must use respiratory protective equipment.

Method for the deep-cleaning of chilled beam and convectors uses following pattern:

1. Opening of the grill/ diffuser
2. Visual inspection
3. Setting negative pressure to the area cleaned if possible
4. Vacuuming of chilled beam or convector
5. Removal of the beam
6. Cleaning with use of solvent- or alcohol based disinfectant
7. Installing the chilled beam or convector back to its place
8. Closing of the grill/ diffuser
9. Inspection of the successful sanitation / disinfection by taking samples

Method that Lifa Air has developed and tested with in co-operation of VTT and TAYS simplifies the cleaning and disinfection process. In Lifa Air method the chilled beam or convector is isolated with box that is under negative pressure throughout the process. Consequently the cleaning is done while closing the whole hospital departments can be avoided. The negative pressure inside the box is gained with negative pressure unit. The unit itself has a HEPA or Lifa 3G filtration in it. Vacuumed air can be directed out from hospital, which will improve the final result.

Testing of the Secure Box method was done in Tampere University Hospital. Test results showed that using of Lifa Secure Box method is more efficient than old-established best practice. In addition the method would improve working conditions when cleaning of chilled beams or convectors is done. As the Figure 3 shows Secure Box itself is used to insulate the chilled beam from its surrounding.

Lifa method uses following steps:

1. Lifting the Secure Box up in order to cover whole chilled beam or convector. Manual lifting device is included with the product. When Secure Box is on its place, negative air unit can be started. Use of Lifa HC1100 is suggested.
2. Opening of the grill / diffuser
3. Vacuum surface of chilled beam with HEPA rated vacuum cleaner
4. Applying compressed air to chilled beam or convectors
5. Cleaning with use of solvent- or alcohol based disinfectant
6. Closing of grill / diffuser
7. Inspection of the successful sanitation / disinfection by taking samples

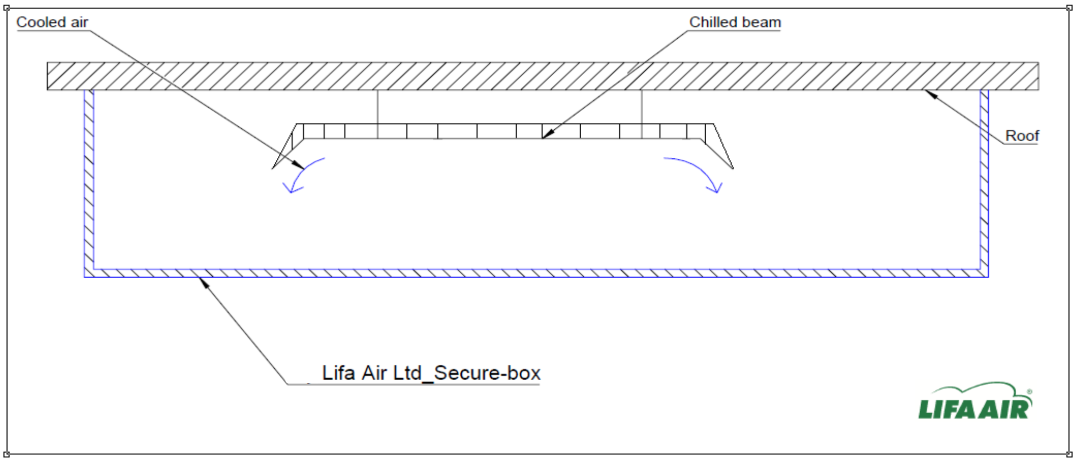

Figure 3. Secure Box method (Lifa Air Ltd, 2014)

2.6.1 Comparison of methods

Using Lifa Air Secure Box sectioning method for cleaning process, it allows comprehensive cleaning and disinfection for chilled beam and convectors without any disassembling. The need for prolonged planning process is redundant, this will save time and money for the purification company. Most importantly Lifa Air Secure Box method will save time needed for hospital rooms being cleaned and unnecessary closing of hospital departments is avoided.

Developed method can be used for prolonging the time gap needed in completing the sanitation and disengaging the chilled beam or convectors. This way the saving in overall costs can be significant. (Lifa Air Ltd, 2011)

3 Design

This chapter describes the different stages of the design process from the draft to the decisions made, and how the construction of the product was finalized. Designing the final prototype was a process of learning from the very beginning to the end.

3.1 Studying first prototype

Lifa Air had made a preliminary version of Secure Box based on studies and requirements related to hospital chilled beam cleaning. This method was introduced on 2011.

Product itself was a fixed structure and this worked as restrictive factor. Length for the box was approximately 400 cm and width 70 cm, meaning that the only chilled beams or convectors less than four meters were possible to clean by using this method. The main reason for making revised prototype of already existing version was the movability of Secure Box construction. Due to construction being fixed, it was impossible to transfer it in normal sized van. In addition to its customizability one of concerns was the sealing of the access doors of the Secure Box itself, even though the sealing was studied to be sufficient. The product itself worked in way it was intended. This was to be taken account when designing the improved version.

Figure 4. First version of Lifa Secure Box (Lifa Air Ltd, 2011)

3.2 Designing

Designing the Secure Box and the improvements wanted started first looking at photos and then drawing rough drafts to graph paper. This way the visualization for the problems was easier. (Appendices 1, 2, 3)

Conceptual drawings made were compared with each other. After visual studies and discussion, the best and most suitable idea was started to work on.

Before the construction of prototype could have been started, the idea was to be sketched with 3D tooling program. 3D designing program used was DS SolidWorks 2014.

3.3 Material selection

When selecting materials for the structure, the practical and easy usage for the product has to be considered. Final weight for product was desired to be as small as possible, value limited by the lifter was to be taken into account.

Main wall material, for the previous version was transparent PC sheet. The PC sheet was chosen due to its easy use and fairly good properties. Thickness for PC sheet was decided to be 10mm. This would ensure the durability of the construction against formed negative pressure, and minor strains from environment while transport and at actual use.

Aluminium L- profile was used on the seams of the PC sheet. Industrial glue was selected as addition for strengthening the seam. Glue worked also as a seal for the structure.

In order to obtain telescopic behaviour for the product, practical solution was found to be two C-profiles sliding in each other. For its corrosive protective properties AISI 304 stainless steel was chosen the C-profile material. The material will allow various disinfectants to be used.

A drywall lifter was used as a base for the construction. The drywall lift used, was chosen from company called ABC- Kärry Oy. Maximum load for this specified model is 35 kg, and the lifter material was also AISI 314 stainless steel. Surface of the lifter could be used as the strongest part for the frame. As for being most expensive single part for the product, different type of drywall lifters were compared and studied. The best suitable lifter was chosen based on its price, properties and formability.

3.3.1 Material suppliers

Most of the materials needed for constructing the prototype could be found from company's warehouse. None the less some material had to be ordered from different companies. Biggest and the main supplier for these materials is ETRA Oy. Other suppliers are such companies as WÜRTH Oy, ACB- Kärry Oy and LVI-Dahl Oy.

3.4 Design progression

Progression for designing the prototype of the Lifa Secure Box was begun by making 3D sketch. Once the preliminary model was done, the construction of the prototype itself could have been started. Because the processed prototype was wanted to be as close production version as possible, the best way for making prototype that works as wanted, was found to be constructing product from first drawings. The 3D model and drawings are easy to change once the need for improvements is identified.

3.5 Working on prototype

The first couple of weeks were spent by thinking and sketching different solutions for making the parts slide without too much friction or constraints. After the first draft was made the base material for the frame was decided to be AISI 304 C-profile. The two different size C-profiles allow telescopic behaviour for the final product. Profiles were planned to slide on each other and excess friction would be taken off by using Vaseline or other appropriate lubricant. All materials for Lifa Secure Box was chosen by taking into account the weight restrictions brought by handling.

The main material for the secure Box was polycarbonate plate, which is used particularly in greenhouse solutions. In the first prototype made by Lifa Air, the material properties were proven to be sufficiently strong enough for the suction made inside the box. The Secure Box will be used with Lifa HC1100 which will give 750 pa (3.01 InH_2O) negative pressure inside the box.

Week after the construction started to become in designed form. In this stage the weight of the product was approximately 35 kg, which was slightly more than planned. Secure Box itself was meant to be attached on drywall lifter which can carry 35 kg's in maximum. Drywall lifter was modified to have the size that won't restrict the movability. At this stage the weight of Secure Box laid on the top limit for the lifter, consequently modifications were necessary.

Next step was to plan the weight reductions. Best way for reducing weight was to remove unnecessary components from the product and change some material for lighter option if available. Other significant defects noticed at this stage were the dimensions of the Secure Box. Width of the product was found to be 1- 2 cm too wide. This would cause problems with fitting the product through "normal" 80 cm door. However, it was observed that the current width wouldn't be a problem in hospital environment. As final decision for these noted problems- after first constructed version, was to rebuild upgraded version. This would be closer to the actual production version. Prior to any permanent changes for this version all potential errors and defects were considered carefully through.

On the following week all missing components, including drywall lifter, rails for sliding parts and sealing materials arrived. The first decision made regarding to the framework of the Secure Box was to integrate the base of the drywall lifter in it. The base of drywall lifter would also strengthen the structure, meaning that most steel frame supports could be taken off. This would also reduce the weight of the final product. The dimensions for new version of the Secure Box would make the product easier to transport between job sites. Determined dimensions for updated prototype were 70 cm in width and minimum height of 200 cm. With these dimensions the product is easy to move in elevators and through doors. The quantity of C-profiles was dropped to half. By making this modification the expected weight drop would be at least 5 kg.

All components and material from previous version will be reused to keep the expenses in minimum. Generally the revision of first prototype will consider weight and dimension improvements and will be closer to the production version.

Figure 5.   3D model from final version of prototype (Lifa Air Ltd, 2014)

4 Product testing

The operation of the prototype was tested against any leaks. The test environment was chosen in a way that stability of conditions could have been ensured. For increasing particle amount, fogging machine was placed inside the Secure Box. Machine itself was operated from a distance with remote control.

Testing was carried out in five stages. All five stages included different types of filtration for negative pressured air. Measurements were performed three times per stage to ensure that errors would be at minimum.

- Stage 1: Normal conditions + HC1100 + Lifa 3G filter
- Stage 2: Applying fog + HC1100 + Lifa 3G filter
- Stage 3: Applying fog + HC1100 + Lifa 3G filter + G4 pre filter
- Stage 4: Applying fog + HC1100 + G4 pre filter + HEPA filter
- Stage 5: Applying fog + HC1100 + G4 pre filter + HEPA filter + F7 bag filter for exhaust air

Figure below shows filtration classes according to standard EN 779:2012

Classification of air filters[1)]

Group	Class	Final pressure drop (test) Pa	Average arrestance (Am) of synthetic dust %	Average efficiency (Em) for 0.4 µm particles %	Minimum efficiency[2)] for 0.4 µm particles %
Coarse	G1	250	50≤Am<65	-	-
	G2	250	65≤Am<80	-	-
	G3	250	80≤Am<90	-	-
	G4	250	90≤Am	-	-
Medium	**M5**	450	-	40≤Em<60	-
	M6	450	-	60≤Em<80	-
Fine	F7	450	-	80≤Em<90	**35**
	F8	450	-	90≤Em<95	**55**
	F9	450	-	95≤Em	**70**

NOTE
[1)] The characteristics of atmospheric dust vary widely in comparison with those of the synthetic loading dust used in the tests. Because of this, the test results do not provide a basis for predicting either operational performance or service life. Loss of media charge or shedding of particles or fibres can also adversely affect efficiency.
[2)] Minimum efficiency is the lowest of any of the following three values: initial efficiency, discharged efficiency or efficiency throughout the test's loading procedure.

Figure 6. Classification of air filters (www.Camfil.co.uk, 2014)

4.1 Equipment used

Equipment used for testing:

- Secure Box + HC1100 + accessories (figure 7)
- ARTI HHPC – 6, airborne particle counter (figure 8)
- ELECTRO GEN 2000 fogging machine (figure 9)
- Flexible hose from Secure Box to HC1100 (figure 7)

Figure 7. The final product in compact pack

Figure 8. The particle counter used for testing

Figure 9. Picture of fogging machine used for raising amount of the particles inside Secure Box.

4.2 Testing

First the fogging machine was to be placed inside the Secure Box and 3G filter inside negative pressure unit. Because of its weight, the fogging machine had to be placed in middle of the box (figure 10).

Figure 10. Placement of Electro gen fogging machine and HC1100 with 3G filter

Next the negative pressure unit was to be started. Before taking any readings it was important to wait in minimum two minutes until the unit worked in its optimum range. Once the optimum working range was reached, it was possible to take readings. When adding filtration between stages, the negative air unit had to be turned off.

Figure 11. On final stage the F7 class exhaust filter was added to negative pressure unit.

4.3 Taking readings

Readings were taken with ARTI particle counter. All values were written up to following tables 1-5. Time gap between each measurement change was 15 minutes. In this time the particle amount drops to match the readings before testing. At the end of each section is presented a brief explanation which explains the result of the particle counter. The particle counter gave readings within +/- 10 % accuracy.

Table 1. Readings from stage 1. See listing from chapter 4.

Particle size	Quantity / liter			Other information
	Test 1.	Test 2.	Test 3.	3 tests in row
0.3 µm	8642	8567	8649	
0.5 µm	1474	1428	1487	Humidity 27 %
0.7 µm	506	469	498	Temperature: 24 ºC
1.0 µm	200	196	191	Quantities in 1.0 L of air
2.0 µm	56	56	45	
5.0 µm	1	5	1	

Table 1 shows the figures of particle counts at normal conditions. In other words no extra fog had been added inside Secure Box. Readings show that IAQ at test area is very good, even better than it was expected. This will facilitate to see the difference between all the tests done. The reading for normal office room air is typically at both sides of 30.000 particles sized of 0.3 µm in Scandinavia. (Haapalainen, K. 2014)

Table 2. Readings from stage 2. See listing from chapter 4.

Particle size	Quantity / liter			Other information
	Test 1.	Test 2.	Test 3.	3 min between tests
0.3 µm	38509	19973	16106	
0.5 µm	5624	2924	2452	Humidity 25 %
0.7 µm	1366	791	674	Temperature: 25 ºC
1.0 µm	443	321	221	Quantities in 1.0 L of air
2.0 µm	84	87	66	
5.0 µm	7	5	4	

Table 2 shows readings after fog was applied. When comparing table two for the starting conditions, it is possible to see how the amount of particles is increased dramatically. At this stage the vacuum unit was using only Lifa 3G filtration. The reason for such high particle count was found to be too high face velocity for this type of filter. Because of the properties of the liquid vaporized and too high airflow, 3G filter didn't have time to process all particles going through. It was noticed that particle quantity dropped almost at the normal level after 10 minutes.

Table 3. Readings from stage 3. See listing from chapter 4.

Particle size	Quantity / liter			Other information
	Test 1.	Test 2.	Test 3.	3 tests in row
0.3 µm	12678	12765	12327	
0.5 µm	2175	2075	2004	Humidity 25 %
0.7 µm	765	678	639	Temperature: 25 ºC
1.0 µm	395	333	313	Quantities in 1.0 L of air
2.0 µm	207	147	121	
5.0 µm	38	21	11	

On stage 3 the negative pressure unit was fitted with Lifa 3G filter, and as addition G4 pre filter was fitted inside the suction hose / duct in front of the negative air unit. All test results were taken in a row and approximated time spent for this stage was 15 minutes in. The results show that additional G4 pre filter boosted 30 % of the efficiency for 3G filter by giving the maximum amount of 0.3 µm particles approximately 1/3rd, from previous stage.

Table 4. Readings from stage 4. See listing from chapter 4.

Particle size	Quantity / liter			Room conditions
	Test 1.	Test 2.	Test 3.	3 tests in row
0.3 µm	6643	6505	5722	
0.5 µm	1289	1326	1149	Humidity 25 %
0.7 µm	539	548	484	Temperature: 24 ºC
1.0 µm	317	313	272	Quantities in 1.0 L of air
2.0 µm	159	149	117	
5.0 µm	24	9	12	

Stage 4 testing was performed by changing HEPA filter in to negative pressure unit. Tests show that HEPA filter is actually making the room air quality better, while negative pressure unit is powered on. This stage shows also what difference it makes once filtration is improved.

Table 5. Readings from stage 5. See listing from chapter 4.

Particle size	Quantity / liter			Room conditions
	Test 1.	Test 2.	Test 3.	3 tests in row
0.3 µm	6025	5883	5723	
0.5 µm	1129	1132	1129	Humidity 25 %
0.7 µm	492	493	489	Temperature: 24 ºC
1.0 µm	312	282	275	Quantities in 1.0 L of air
2.0 µm	121	102	94	
5.0 µm	23	12	5	

On this stage there was F7 classification bag filter added to block the rest of particles that went through HEPA filter. After that, the filtration combination is G4 pre filter, HEPA filter and F7 bag filter. The bag filter would also block the airflow from blowing dust and particles from floor to the air. Tests also showed that small improvements were gained by adding filtration for exhaust air. This filtration method would increase the quality of indoor air on area where cleaning process is held on.

5 Final evaluation and conclusions

This research for IAQ and especially how it has an direct effect on the spread of infections, with the data presented in this report, it can be concluded that the need for easier and faster ways for cleaning chilled beams and convectors needs to be found. It has been proved that the developed Lifa Air Ltd method reduces time spent for cleaning these beams by removing unnecessary work steps. Method will improve working conditions on the processed area too.

From the previous research done by Lifa Air and VTT it can be seen that Secure Box method gave same results as old-established way, leaving as the main differentiating and beneficial factor to be fast way to clean ventilation equipment. With the new design the product fits easily inside the normal sized van. This way Secure Box method can save great amount of money and time from companies operating on sanitation business. The method would also make cleaning thoroughly possible more often than it has been before.

Testing in chapter 4 was done mainly to prove that the construction does not have any leaks and sealing is sufficient. As the test results indicate the constructed version of Secure Box don’t have any leakage and the negative pressure inside the box is sufficient for controlling the particle amount inside the box. Test results show that filtration and combination of different filters have an influence on particle amount on area processed.

The project was successful. Project goals were achieved and the prototype meets the requirements set by the company. In addition the project worked as a learning process and will work as a base for future projects. The method how this project was carried out, allowed small changes to be done throughout the process and defects of product could be seen easily.

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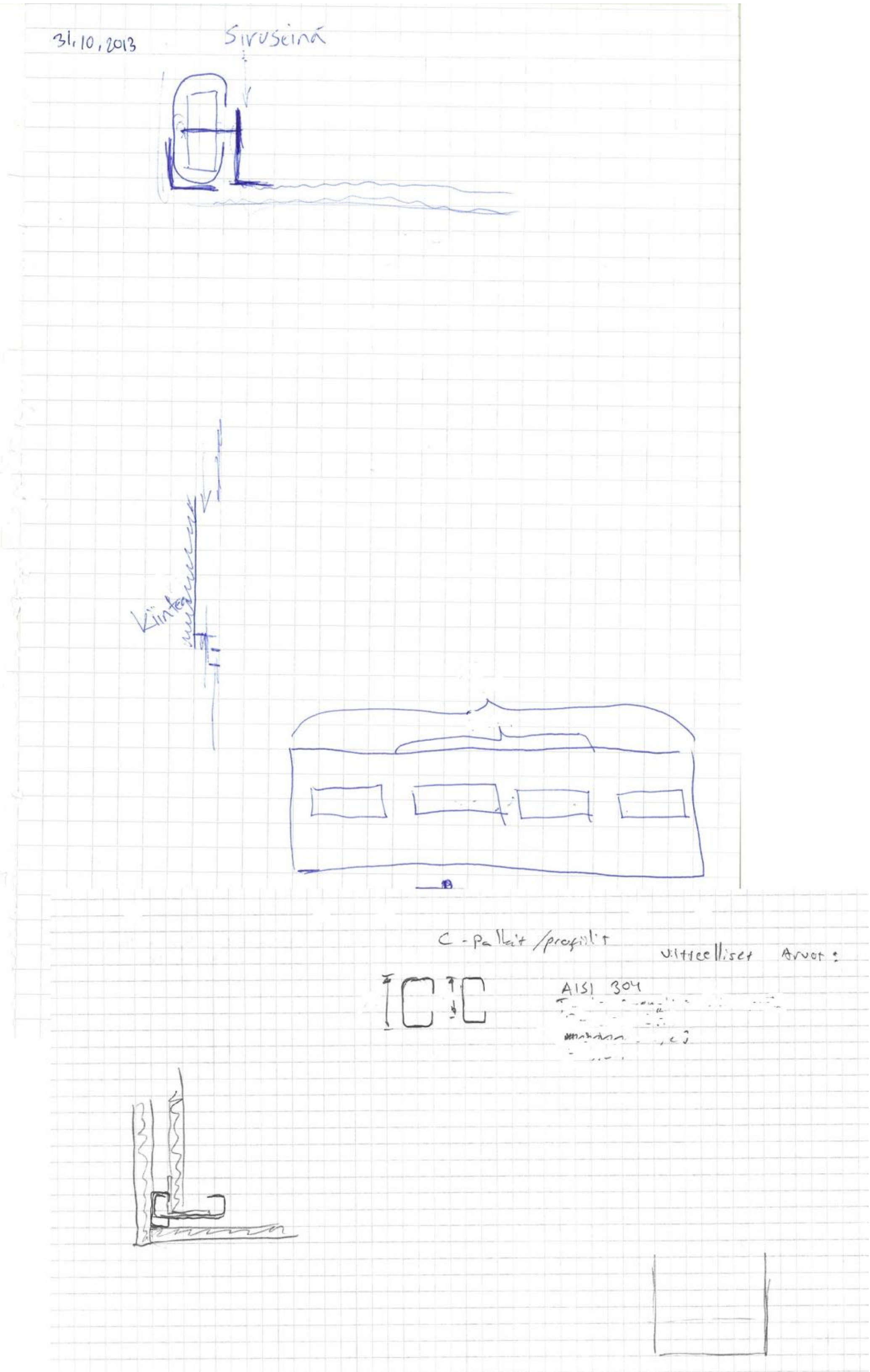
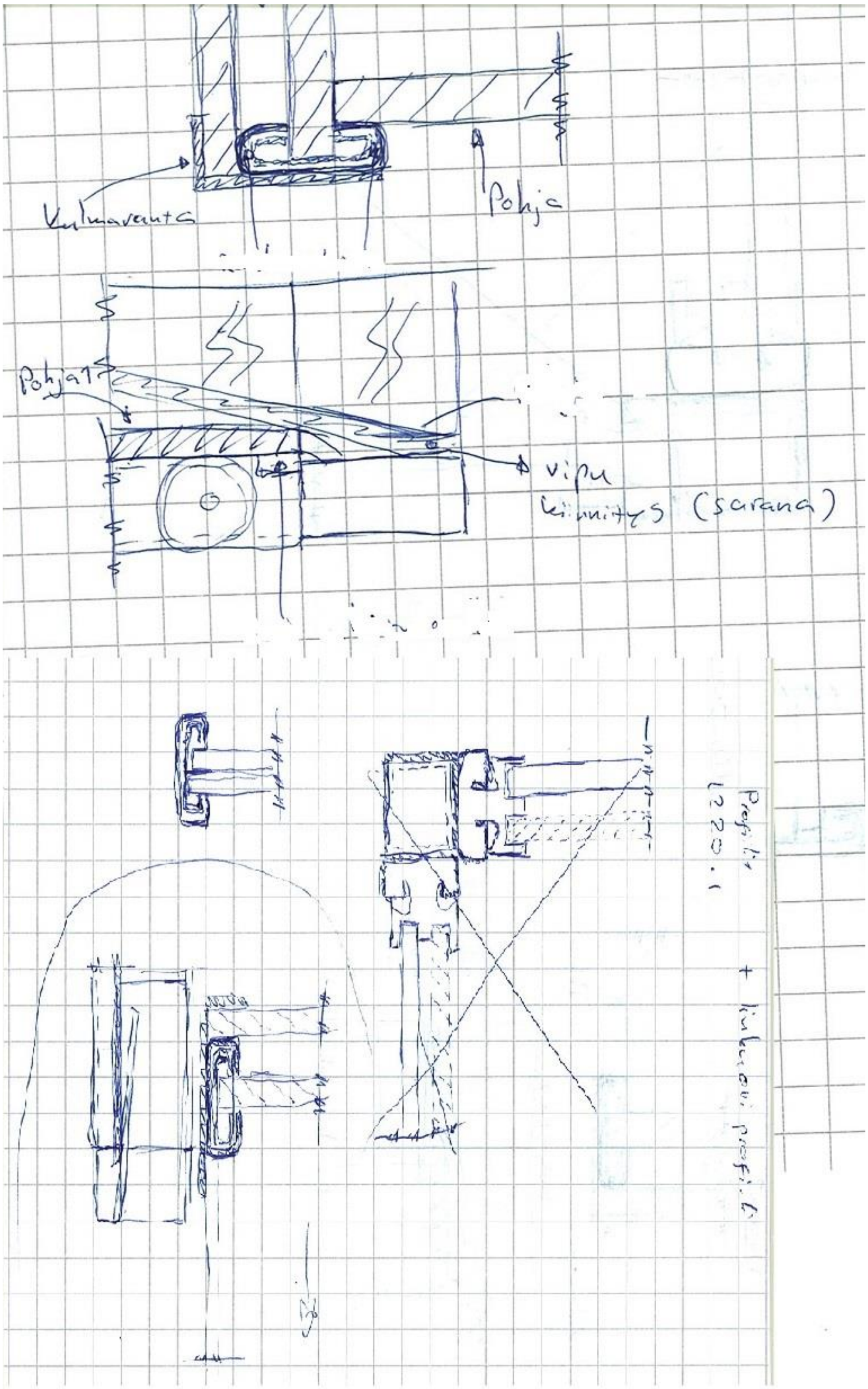
Appendices

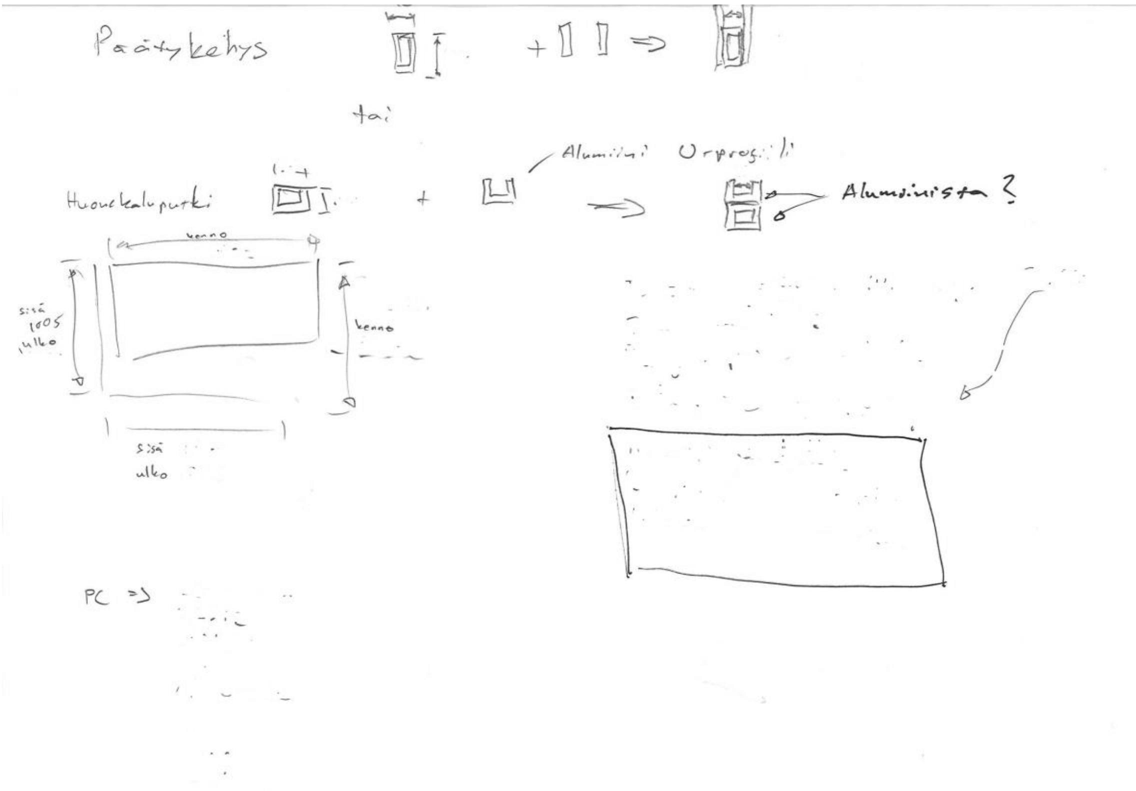
Appendix 1: Sketching method for sliding profiles

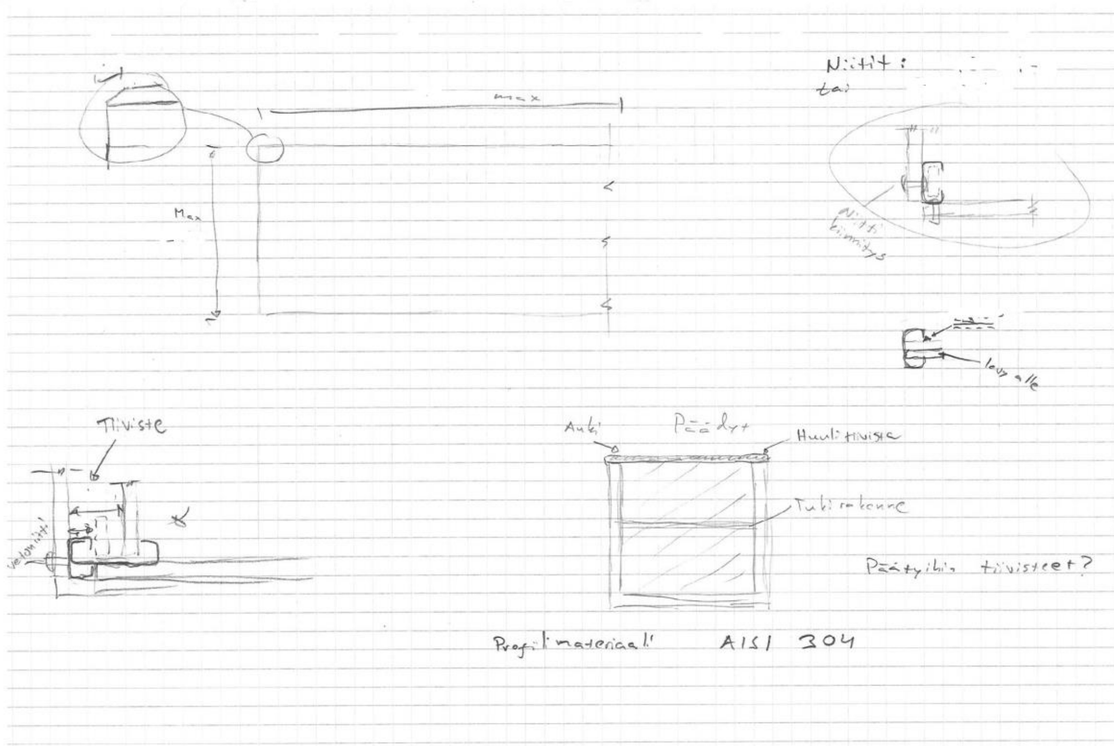


Appendix 2: Sketching of product telescopic properties

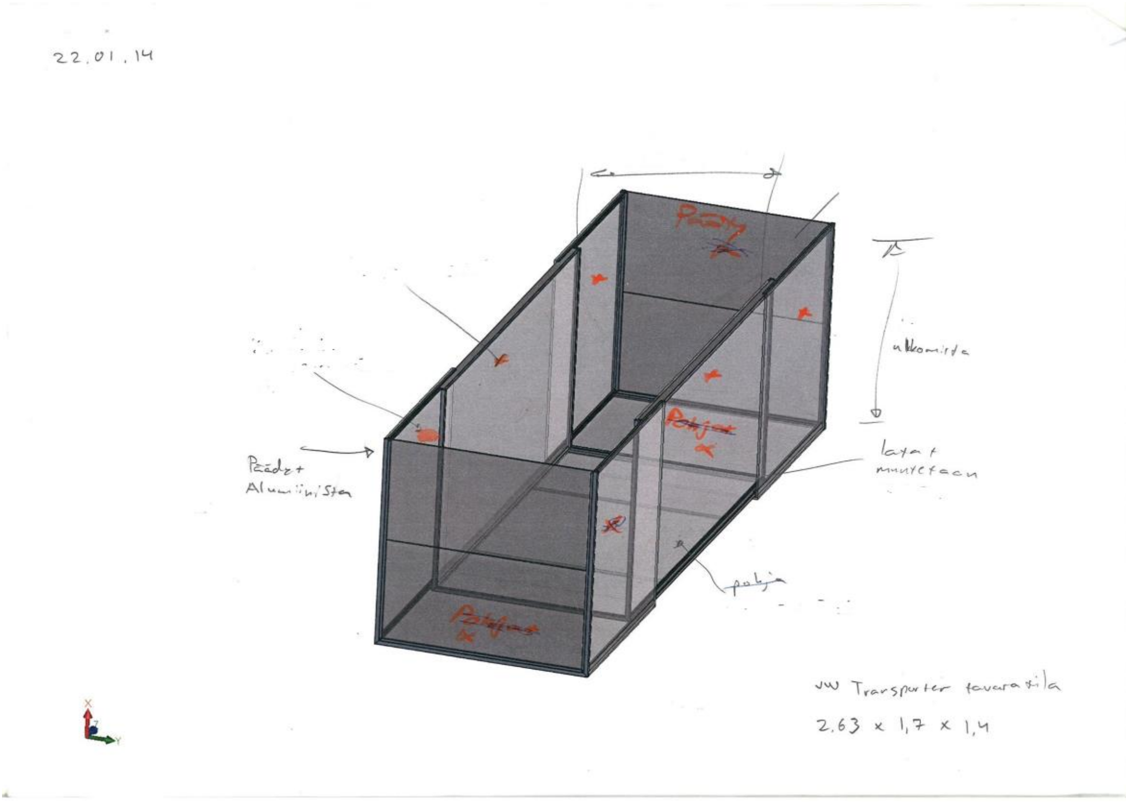


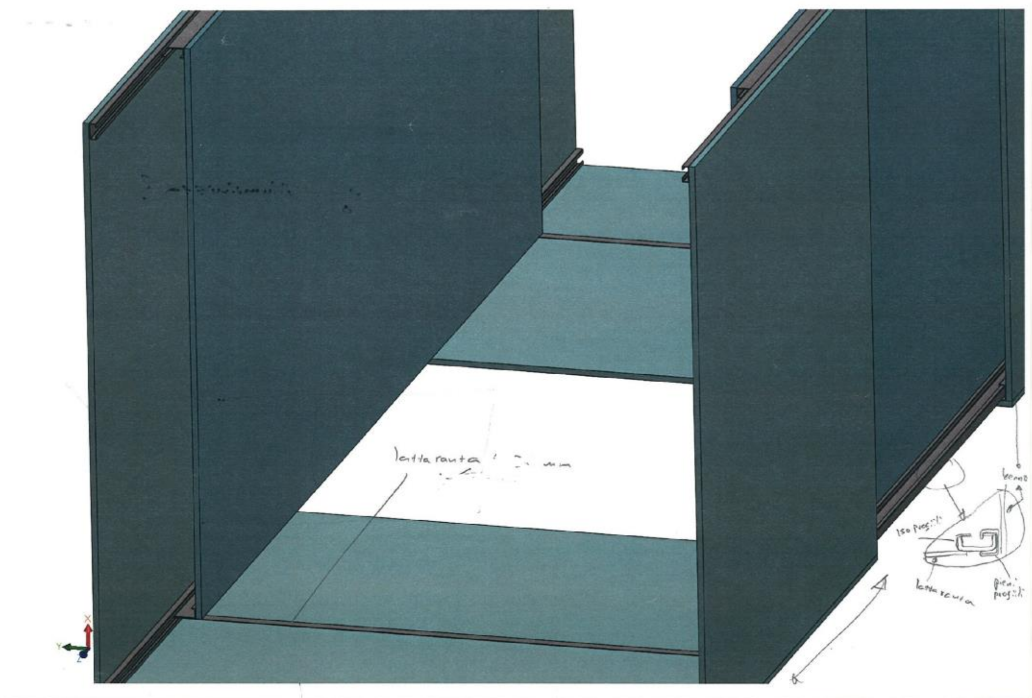
Appendix 3: Sketching improvements during construction





Appendix 4: Preliminary 1 3D design from construction





Appendix 5: Decided drywall lift

ABC KÄRRY OY

LEVYHISSI 4,5M

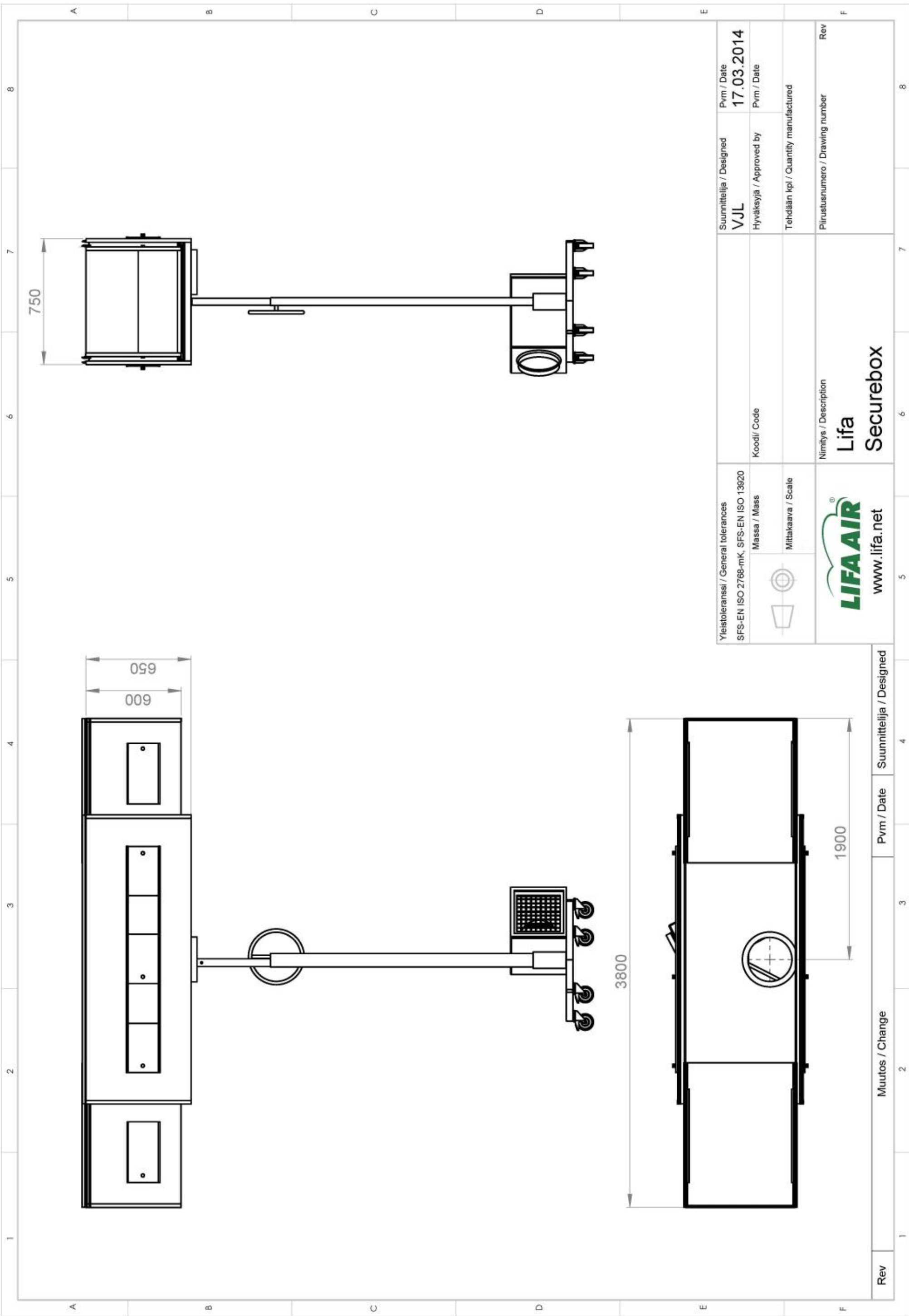
415155 Levyhissi 4,5 m ketjulla

- **Suurin nostokorkeus 4,5 m**
- **Levyhissi tarkoitettu kipsilevyjen sekä sisustuslevyjen nostamiseen**
- **Hississä on 100mm pyörät, joten sen liikuttaminen on helppoa**
- **Hissin saa kolmeen osaan kuljetuksen ajaksi, helppo kasata**
- **Runkoputket on galvanoitu ja kaikki liikkuvat osat saa vaihdettua tarvittaessa uusiin**
- **Levyhissin suurin sallittu nostomäärä ei saa ylittää 35 kg**
- **Tuote täyttää CE98/37/EC mukaisen koneturvallisuus direktiivin**
- **Tuotenumero: 91415155**

415151 Levyhissi 3,0 m ketjulla

- **Suurin nostokorkeus 3,0 m**
- **Levyhissi tarkoitettu kipsilevyjen sekä sisustuslevyjen nostamiseen**
- **Hississä on 100mm pyörät, joten sen liikuttaminen on helppoa**
- **Hissin saa kolmeen osaan kuljetuksen ajaksi, helppo kasata**
- **Runkoputket on galvanoitu ja kaikki liikkuvat osat saa vaihdettua tarvittaessa uusiin**
- **Levyhissin suurin sallittu nostomäärä ei saa ylittää 35 kg**
- **Tuote täyttää CE98/37/EC mukaisen koneturvallisuus direktiivin**
- **Tuotenumero: 91415151**

Appendix 6: Assembled product drawing



Appendix 7: Detailed C-profile drawing