Design parameters for powder removal from crushed glass in a gravity separator

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In cooperation with

Abstract

Mercury is one of the most dangerous elements that exist on this earth and can cause serious damage to both humans and nature. Therefore it is crucial that it does not get spread out in the environment but is recycled in a safe manner when used in consumer products. Fluorescence lamps that are coated with mercury contaminated fluorescence powder still exist today. Therefore it is crucial that the mercury contaminated fluorescence powder is separated from the glass so the fluorescence powder can be reused and the mercury can be sent to final deposal.

This thesis has been done as a compulsory part of the program Master of Science in Mechanical Engineering at Blekinge Institute of Technology and in collaboration with MRT System International AB. The purpose of this thesis was to develop a prototype of a gravitational separation unit to separate fluorescence powder from the glass on fluorescents light trying to increase the efficiency of the separation process at MRT. The work began by making a detailed project plan to get an overview of the different parts of the thesis and how they should be implemented. A requirement specification was made as a ground to make sure that the developed prototype would meet the requirements set for the prototype.

After the requirement specification had been made a study of air classifiers began to get a perception of the alternatives that are offered today and to see how they work. Research was made to get ideas and a better knowledge of the different methods of separating two different materials. The information collected from the study formed the basis of the different concept proposals that was been generated. Tools were then used to decide which of the concepts that later would become the final one to be built. When the prototype was built, measurements were made to see how efficient the separation was.

Keywords: Mercury, fluorescence powder, prototype, innovation, recycling, concepts

Sammanfattning

Kvicksilver är ett av de farligaste ämnena som finns på jorden och kan orsaka stor skada på både människor och i naturen. Därför är det viktigt att det inte sprids i naturen utan återvinns på ett säkert sätt då det används till exempel i konsumtionsprodukter. Lampor som innehåller kvicksilverkontaminerat lyspulver används fortafarande. Det är därför vitkigt att separera det kvicksilverkontaminerade ljuspulvret från glaset så att lyspulvret kan återanvändas och kvicksilvret kan skickas till slutförvaring.

Examensarbetet är en obligatorisk del av programmet Civilingenjör i Maskinteknik på Blekinge Tekniska högskola och har gjorts i samarbete med MRT System International AB. Arbetet syftar till att ta fram en prototyp av en separationsutrustning som använder luft och gravitation för att separera lyspulver från glaskrosset från lysrör och få en mer effektiv separationsprocess hos MRT. Examensarbetet började med att ta fram en genomgående projektplan för att få en bra översikt över vilka delar projektet ska innehålla samt hur de ska genomföras. En kravspecifikation baserad på MRTs önskemål upprättades och låg senare till grund för den prototyp som togs fram och testades.

När kravspecifikationen hade upprättats började en teoristudie för att få en uppfattning om vad det redan fanns för alternativ på marknaden idag och hur de fungerade. Detta gjordes för att få en idéer och för att få bättre kunskap på de olika metoderna när man separerar två olika material. Information som togs fram under studien låg sedan till grund för de koncept som har genererats. Olika verktyg användes sedan för att bestämma vilket koncept som skulle bli det slutgiltiga och resultera i en färdig prototyp. När prototypen var utvecklad utfördes tester för att kunna mäta hur effektivt prototypen separerade de två materialen.

Nyckelord: Kvicksilver, lyspulver, prototyp, innovation, återvinning, koncept

Acknowledgement

This thesis has been done as a compulsory part of the program Master of Science in Mechanical Engineering at Blekinge Institute of Technology and in collaboration with MRT System International AB. Magnus Nilsson has been the supervisor at MRT System and Stefan Sjödahl has been the supervisor at BTH.

I would like to take this opportunity and express my gratitude to everyone at MRT for the possibility to write the thesis and all the support and help I have received during the work. Not only regarding the thesis but also the insight given of the line of business has been interesting and educational and I have learned a lot how the company works to meet a more sustainable future.

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Notations

NOTATIONS	
BTH	Blekinge Institute of Technology
MRT	MRT System International AB
WEEE	Waste Electrical and Electronic Equipment
CRT	Cathode Ray Tube, a type of display
Existing System	The system MRT use for extracting mercury
Air classifier	Separation unit using air to separate materials
SEK	Swedish currency
CAD	Computer Aided Design
Solid Works	CAD program that has been used during the thesis
h	Hour
L	Lift power
p	Density
m	Meter
F	Force
N	Newton
s	Seconds
g	Gravity force
m^2	Square meter
m^3	Cubic meter
g	Gram
kg	Kilogram

1 Introduction

Mercury is one of the most dangerous elements that exist on this earth and can cause serious damage to both humans and nature [1]. Therefore it is crucial that it does not get spread out in the environment but is recycled in a safe manner. The fluorescence powder is coated on the inside of lamps, both to give the fluorescence lamp a visible light and a specific color of the light depending on the mixture of the powder. By having the possibility to mix fluorescence powder and creating different colors fluorescence lamps can be created for many different applications [2].

During this thesis a new prototype for separating mercury contaminated fluorescence powder from crushed glass from lamps was developed. This was done by studying the market today to see how the problem was solved and how it could be done differently. This study resulted in different concepts which were compared with the requirement specification that was set both from MRT and from the study. One concept was chosen to be built and tested to see how efficient the separation process was and if it was the right option for MRT to go pursue in order to meet the increased demand of the efficiency of the output of mercury from the recycling process.

1.1 Problem

To maintain the leading positon MRT has today, there is a need for a constant development to improve their machines. The posibility of having a dry separation method that could make the recycling process more effective will be examined in this report.

1.2 Purpose

The purpose with this thesis is to study different existing air classifiers to receive the knowledge to develop a physical prototype. The information gathered from the study will form a basis to the brainstorming sessions which will generate different concepts. Tools will determine a proposition for a final concept. From this final concept a prototype will be built and tested to see if there is any improvement compared to the machine that MRT uses today.

1.3 Definition of problems

During this thesis different existing separation air classifiers will be examined to receive a better understanding of what competitors there are and how their products work. This information will later be used to see how a new type of air classifier can be designed to meet the requirements that have been set by MRT. The questions below will be answered during this thesis:

1. Can the two materials that MRT want to separate be separated by means of an air classifier?
2. How can a prototype be designed to fit the required design measures?
3. Can a prototype be made to fit the existing system that MRT offers today?
4. Can a prototype be made within the production costs set by MRT?
5. Can a prototype be developed to have better separation efficiency than the machine that MRT uses today?

1.4 Boundaries

This thesis will only consider the development of a new concept and only air classifiers that are using a dry separation method of air and gravity to separate the two materials will be considered.

The concept will be built into a prototype and tested. The results given during these tests will be analyzed. Future adjustments and redesigns will not be considered during this thesis. The prototype will not be installed into an existing system that MRT is using today but instead tested with a type of vacuum cleaner that MRT is using when they are testing their equipment.

To fit the existing system that MRT is using today the connectors to the prototype will be 100mm and therefore no consideration will be taken to this.

1.5 Background

We are constantly reminded by the alarming truth of how we are affecting the environment and our planet by overusing resources, the overuse is still increasing which makes us have to rethink how we are using products [3]. We have to recycle more and use less dangerous materials to start reversing this trend. Therefore the process of recycling products has become one of our daily routines.

MRT System has since 1979 developed equipment for recycling mercury contaminated waste [4]. Because of the laws and regulations that were introduced in the beginning of year 2000, lamps are systematically collected and recycled.

1.5.1 MRT System International AB

MRT System International AB is a world leading company of developing complete solutions for WEEE recycling such as mercury recovery systems, lamp recycling equipment, CRT separation systems and equipment's for recycling flat panel displays [5]. The main office is located in Karlskrona but MRT is established around the world through collaboration with skilled personnel at other companies.

1.5.2 History

It all started in 1975 when it was discovered that a work force at a lamp manufacturer had high levels of mercury in their blood. After the production process was investigated a distiller was installed to isolate the mercury and to reduce the risk for the workers of being exposed to it. This was the first step in the history of MRT System International AB [5].

In 2005 a new directive of collecting, recycling and recovering of waste electrical and electronic equipment, WEEE, was introduced. This was to reduce waste and to begin to reuse and use other forms of recycling. The goal was to make customers hand in WEEE which would generate more work for MRT [5].

1.5.3 Today

Today MRT deliver a large amount of machines all over the world and almost all of the sales are sold for export. MRT can offer complete solutions for mercury recovery from any fluorescence lamps and they also have recycling machines for mercury batteries, medical waste, LCD-Screens, CRT-Screens, Televisions and other electrical waste [4].

1.5.4 Products

MRT have different standard products that they are offering for their customers. Since most of the customers have different wishes of how they want the machine to work; many of the machines that MRT are selling are custom made to fit their needs [4]. MRT have products to fit both big and small scale recycling, from simple manual machines to fully automatic ones; this is to cover a wide market as possible. The machines can be very complex and are made from order to avoid storages of machines.

After establishing contract with the customer a study is made to ensure that the customer will get what they are asking for. If the customer is requesting a custom made product a study is made to see what has to be done to reach the requirements set by the customer. The product is then assembled and tested in Karlskrona to see if it the requirements are met. If it fulfills the requirements it is disassembled, delivered and installed at the customer. After a while a follow-up is made to confirm that everything is working as expected[1].

1.6 Specification of goals

To be able to evaluate the different concepts, specifications were set to make sure that the final prototype would fulfill the requirements that were set.

Environment
The air classifier shall not contribute to a systematic increase of any of the four sustainable principles that "The Natural Step" has developed (Chapter 3.1).

Ergonomic
The prototype should be easy to use and no complex actions should be necessary to operate the prototype. The prototype shall be designed so that anyone will be able to operate it, no extra education and no excessive strength should be necessary.

The residence time, the time for separation, shall not be so long that it will generate a hold up in the system. It would be preferable if the residence time could be adjusted to fit the existing system that the prototype shall be installed in, since there are different systems there are different residual times.

Economics
The limit for the production cost is 50.000 SEK. This includes materials and a fixed hour price that is standard for the employee who will build it. It is

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[1] Daniel Gunnarsson, Project Manager, MRT System International AB, Interview, 8/5 - 2014

important that the price of the finished product is competitive and the payback time short.

The maintenance cost should be kept at a minimum and not be more expensive than any other part in the system. The maintenance should also be fast and easy to perform

Maintenance

The intervals between the services should preferable coincide so that the maintenance can be done at the same time as the other machines in the system the prototype is installed in.

Chemicals

No hazardous substances or chemicals should be used during production, use or when it is being recycled.

Requirement Specification

In order to make sure that the prototype would fulfill MRT's specifications a requirement specification was established (Table 1.1). The requirement specification was especially of great assistance when the final concept was decided.

Table 1.1 - Requirement Specification from MRT

[illegible]	
Specifications	Requirements
Feed capacity	200-600 kg/h
Goal value of Hg	< 5ppm
Production cost	< 50.000 SEK
Maximum height	2 meters
Durability	> 30 years
Weight	< 100 kg
Air inlet	Minimum of one
Air-flow	Adjustable

2 Method

For the thesis to be successful the work has followed the product development method *Ulrich & Eppinger – Product Development Process* [6]. The advantage of this method is that it offers a structured working process when developing a product; it includes all the important parts of the development process. Another advantage is that if there is a discovery that something needs to be changed it is easy to go backwards to fix the problem earlier in the process.

The picture (Figure 2.1) describes the process that has been used throughout the thesis:

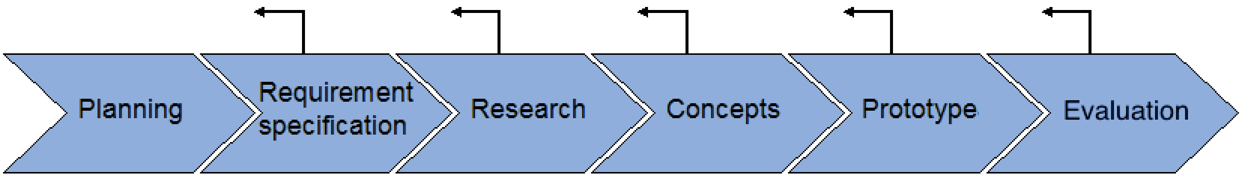


Figure 2.1 - Shows the workflow of the thesis

As shown in the picture the work process is not always a straight line, sometimes it is necessary to go backwards to be able to make adjustments to assure that the required specifications set by MRT is fulfilled.

Since the method does not fit all development projects it had to be modified to fit this thesis. There are some restrictions, for example resources and time that had to be reconsidered. In the following section, the different parts of the development process that will be used during this thesis will be explained.

2.1 Planning

During the first week a plan was established to provide a good overview of the work that need to be done. This plan included the different parts that would be covered and how they would be executed. Time frames were set to assure that the thesis was following a good pace so that the thesis could be finished in time.

2.2 Study

A thorough study was made to examine how the market looked today, what machines that were available and how they worked. This study would be the basis for the brainstorming process for generating concepts for the prototype.

2.3 Concepts

From the information gathered during the study, several concepts were generated. As a first selection the concepts was matched with the requirement specification8. Further on, to decide which concept that would be the final two different decision tools, PUGH-matrix and SWOT-analysis was used. The concept that was chosen as the final one was designed in Solid Works from where drawings were made.

2.4 Prototype

From the drawings a prototype was built. When the prototype was finished, tests with different mixtures of material were made to see how efficient and how well it performed when separation the two materials.

2.5 Evaluation

In order to see how the results that have been collected during the thesis are relative for the separation unit that MRT is using today an evaluation was made.

3 Theoretical foundation and research

3.1 Sustainability Aspects

Environmental scientists all over the world have worked together to create the four system conditions which are important to meet for stopping the increasing effect on the environment and hopefully move towards a more sustainable society [7].

To make the prototype both more attractive for potential customers and to make an effort for the environment, the sustainable aspect has to be considered. The concepts will therefore be looked at from a sustainable point of view using the four system principles that are developed by The Natural Step [7]. The earth is a sustainable system but over the last centuries, we, the humans are having a greater impact on the environment and the earth's sustainability is threatened. Today we are using one and a half of the planet we are living on [8]. We have to change our way of thinking on how we are using products and not throw them away as soon as they do not work or when we do not like them anymore. We also have to choose products that are not contributing to an increase of unsustainability.

The goal of these principles is not to stop the increasing level of unsustainability, but to reduce the amount of overuse of rare materials, dangerous substances and hopefully start to decrease the systematically level of unsustainability. If the impact were small compared to the planet there would not be a problem, however since the impact is getting larger serious problems to the environment will arise [7].

When developing concepts, the four sustainable principles will be considered to make sure that the finished product will be sustainable. This will be a separate column in the PUGH-matrix to assure that the concept that is considering the sustainable principles will be rewarded with extra points. Offering more sustainable products is important to continue the work towards a better future for both the environment and for the human race.

The four sustainable principles are explained by the figure (Figure 3.1) and the following text:

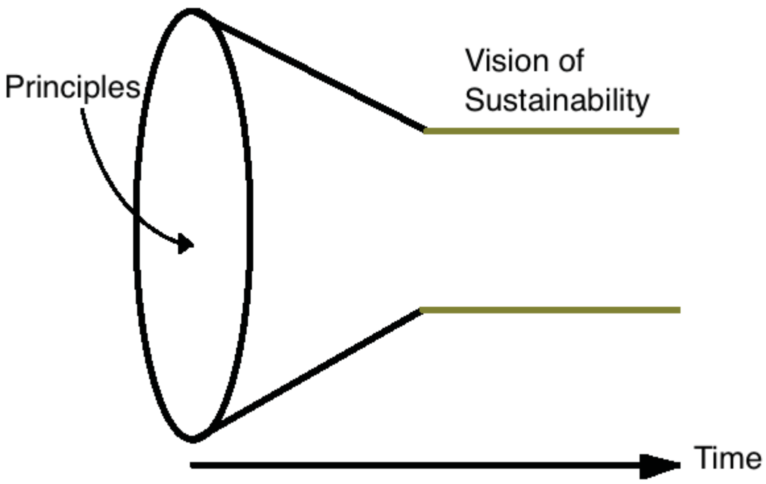


Figure 3.1 - Funnel showing how create a sustainable society

By applying the sustainable principles we can decrease the overuse that exists today and create a state of a sustainability society.

1. **A systematic increase of concentrations of substances extracted from the earth's crust.**
   The material that the prototype will built of should not be from substances extracted from the earth's crust and the prototype shall not be dependent of fossil fuels [7].

2. **A systematic increase of concentrations of substances produced by the society.**
   The prototype should not contribute to a systematic increase of substances that is produced by the society, for example plastics, PCBs or DDT [7].

3. **The systematic degradation of nature and natural processes.**
   The prototype should not contribute to a systematic degradation of nature and natural processes for example, over harvesting forests or destroying habitats [7].

4. **Conditions that systematically undermine people's capacity to meet their basic human needs.**
   The basic human needs for the employee's that are building the prototype should not be undermined, for example, dangerous working conditions and/or abuse of power [7].

3.2 Fluorescence powder

The fluorescence lamp is filled with gas at low pressure and works by the principle of *Low pressure gas discharge principle*, when the light is lit the temperature rises making the mercury evaporate [2].

On the inside of fluorescence lamps there is fluorescence powder coated which is white and highly volatile. An electrical field is created inside the lamps where the gas is discharged by two electrodes which make the mercury to emit UV rays. When the UV rays hits the fluorescence powder it is converted into visible light. By having a special mixture of different fluorescent powders it will give the light the color that is wanted [2]. The difference between the fluorescence powders is that they are giving different levels of blue, red and green when hit by UV-light.

The primary size of the glass that will be separated are between 5-10mm but there can be fractions of glas that are around the same size as the fluorescens powder. These small fractions will however be so small that it will not have any affect on the result and will be considered as fluorescens powder. To make the results easier to understand an assumption is made that all fractions above 200 µ is considered glass and everything below 200 µ meter is considerd fluorescence powder[2].

At MRT there are three different fluorescence powders with different specifications that the lights that are being recycled are coated with. The

[2] Magnus Nilsson, Technical Manager, MRT System International AB, Interview 18/3 2014

following information data have been found from the different security data sheets which can be found under the appendixes:

3.2.1 NP-340

This fluorescens powder will provide a red light to the fluorescence lamp. (Appendix 1)
Main substances: Ytrium Oxide
Density: 5,05 kg/m^3

3.2.2 NP-107

The NP-107 fluorescence powder till provide a blue light to the fluorescence lamp. (Appendix 2)
Main substances: Aluminium, barium and magnesium oxide
Density: 3,83 kg/m^3

3.2.3 NP-220

The NP-220 fluorescence powder will provide a green light to the fluorescence lamp. (Appendix 3)
Main substances: Phosphor acid, lanthanum salt, cerium and terbium-doped
Density: 5,20 kg/m^3

3.3 Mercury

One of today´s most dangerous material is mercury which makes a threat for both living organisms and nature. The main parts of the body that are affected by mercury are the nervous system, kidneys and cardiovascular systems which mercury is causing serious health effects on [1]. An exposure of mercury is especially dangerous for humans with developing organ systems, therefore infants, children and women in child-bearing age are considered as the most vulnerable groups [9].

Although mercury deposition has decreased in recent decades there is still extensive deposition over Sweden despite the considerable efforts that have been made to reduce the use and emissions of it. In 2011 the estimated deposition of mercury in Sweden was four tons and the main reason for the still large deposition is that the mercury travels long distances from other countries in the world [9]. The main source for mercury emission is burning of coal, but emissions also come from industries, dumps and drains that will sour the environment are contributing [9].

Mercury cannot be broken down without being accumulated, once it has been released into the environment it stays there circulating between air, water, sediments, soil and living organisms [9]. It is especially the most common fishes in Sweden such as perch, pike and walleye species that have elevated mercury levels [1]. To achieve tolerable concentrations of mercury in fish in Sweden the deposition must decrease with 80% [1].

In Sweden the municipalities have the responsibility for collection of hazardous waste, which includes mercury. To make the collection easier the municipalities are collaborating with companies who manufacture electrical components and batteries regardless if they contain hazardous material or not. As mentioned before when mercury has been collected it cannot be destroyed, it will continue to circulate in the environment. The only way to reduce the impact of the environmental is to remove it from the circulation in the environment. Therefore when the mercury has been collected in Sweden it will not be recycled or reused but instead stored in a safe manner [9].

At MRT, when mercury is separated from the glass in the recycling process it is still bounded to the fluorescence powder. After the mercury has been separated from the glass the powder and mercury are transported away from the recycling system by the ventilation system. At the end of the ventilation system, any free vaporized mercury is captured in a carbon filter. Mercury captured in the fluorescence powder is removed in a distillation process. In the distiller the powder is heated to 675 Celsius where the mercury is vaporized, condensed and separated from the fluorescence powder. The separated mercury is sent to final storage as hazardous waste. The fluorescence powder that is made from rare earth elements is collected from the recycling process is taken care of and is either sold or reused.[3]

3.4 Study

In this study existing air classifiers has been studied. The study gave a better knowledge of the different air classifiers design and how they separate materials. The information in this chapter is a summary of the sources and has been found by searching websites, brochures and scientific reports.

3.4.1 Air classifiers

Separation of two materials can be seen as a quite complex process and there are many different ways to do it. Mainly there are two categories for separation of two materials, dry and wet. In Sweden it is preferable to use a dry separation method, both for climate reason and to reduce the need for drying the finished product. A dry method is also preferable where water is a scarce product [10].

In this study only dry separation solutions will be studied, they are both simpler and cheaper to maintain since there are no moving parts. *From here on when air classifier is mentioned it is referring to a dry air classifier.* There are many different types of dry air classifiers but one thing they all have in common is that they are only using gravity and air to separate materials. The two materials that will be separated need to have different densities for the separation to work. The bigger difference in density the two materials have the easier they are to separate.

[3] Magnus Nilsson, Technical Manager, MRT System International AB, Interview 17/3 2014

3.4.2 Zig-Zag air classifier

In a Zig-Zag air classifier air is flowing through a vertical channel. The air enters the channel on the bottom and is sucked up through the channel and exits on top of the air classifier. The materials that are going to be separated are fed into the Zig-Zag channel via a feeding inlet which preferably is located on the middle of the air classifier. Having the feeding inlet located in the middle makes space for the material to travel some stages up and down without exiting the channel. Depending if it is coarse or the fine material, it will either fall down against the upwards going air-flow or get caught by it and follow it upwards and exit the channel at the top and be collected in a filter. [12]

The coarse material will fall down through the channel with help of gravity and be collected in a bin underneath the air classifier. Depending on the properties of the materials that will be separated; the strength of the air-flow and the amount of materials that are being fed into the channel can be adjusted. These parameters are the ones that have the biggest impact on how efficient the separation will be [10].

The Zig-Zag channel has a special pattern to optimize the separation efficiency [12]. Because of the Zig-Zag design there will be areas with turbulent air when the main air-flow breaks of at the bottom of each stage (Figure 3.2). It is in this turbulent air where the main part of the separation will take place [11]. By having different angles between the stages in the channel the strength of the turbulence will be changed resulting in different efficiency of the separation [13].

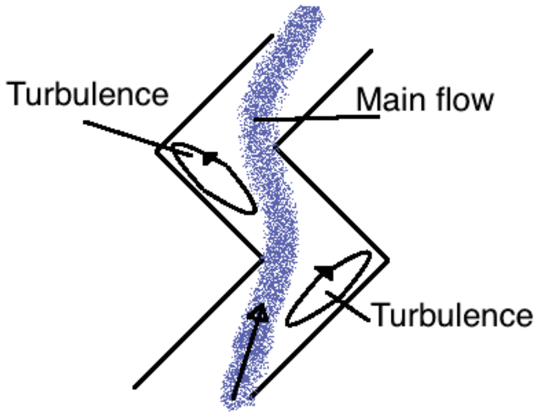


Figure 3.2 – Showing the turbulence created in the Zig-Zag channel.

3.4.3 Recirculation air classifier

Another type of air classifier for separating materials is a recirculation air classifier. It is using a recirculation chamber to increase the separation efficiency by making the material go through the separation process several times. Below two different air classifiers with a recirculation chamber have been studied; the first one being a single stage with one air inlet and the second one being an air classifier with two stages and three air inlets.

3.4.3.1 Single stage air classifier

The main advantage by having a recirculation chamber is that the material can go through the separation process several times. The feeding inlet is located on top of the air classifier and the materials enter the channel at the same place as the material that has been recirculated is exiting the recirculation chamber. The air inlet is located just beneath the exit of the fine particles and will push the material that have not exit through the fine particle making the fine particles exit into the recirculation chamber (Figure 3.3). The material will go through the separation process again. Experiments have shown that by letting the material be recirculated the amount of fine particles exiting with the coarse material reduced from 7,61% to 0,61% [14].

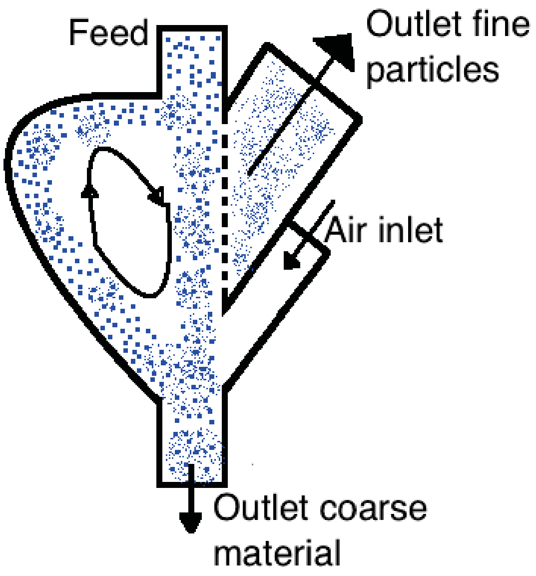


Figure 3.3 - Showing a single stage recirculation air classifier

3.4.3.2 Different designs of air inlet

Additional studies have been done with both the air inlet as well as the circulation chamber to see if different designs on these parts had any impact of the separation efficiency. Two different designs of the air inlet were studied in addition to the standard design, one horizontal and one that was directed upwards (Figure 3.4). Results showed that the horizontal design provided a higher air velocity into the recirculation chamber and brought more coarse material with it. When the coarse material entered the separation zone again there would be more material, increasing the particle to particle collision and disturbing the air-flow in the separation zone decreasing the separation efficiency [14].

The third design with the upward going air inlet did not result in any recirculation since the air just went upward and out with the fine particles [14]. Regarding the design of the circulation chamber there was not any improvement when using the new design compared to the standard design. Instead the new design increased the air velocity with the result of disturbing the air-flow in the separation zone and the separation efficiency was decreased [14].

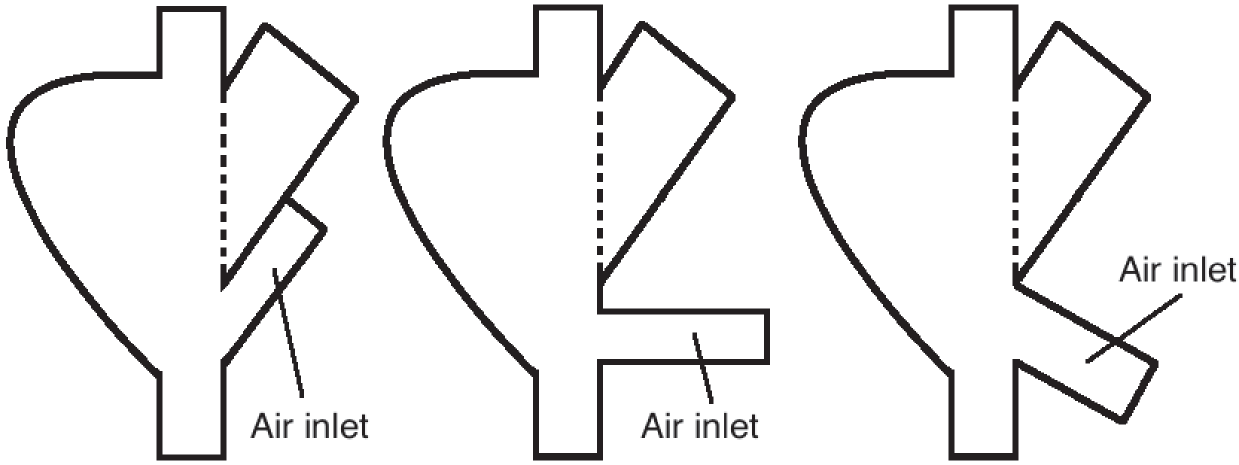


Figure 3.4 – Different design of the air inlet

3.4.4 Double stage air classifier

This study was done with a two-stage air classifier with three air inlets (Figure 3.5). To see how big impact the different air inlets had on the separation efficiency; eight tests were made with the different air inlets open and close to cover all possibilities [10].

Experiments showed that the secondary air inlet in stage one had a huge influence on the separation efficiency how well the materials were separated on both stages. The primary inlet did not have any or low effect on the separation efficiency on the fine particles but it had the ability to control amount of coarse material that was exiting stage one. Because it can control the amount of the coarse material exiting the first stage it is the most important parameter in the air classifier.

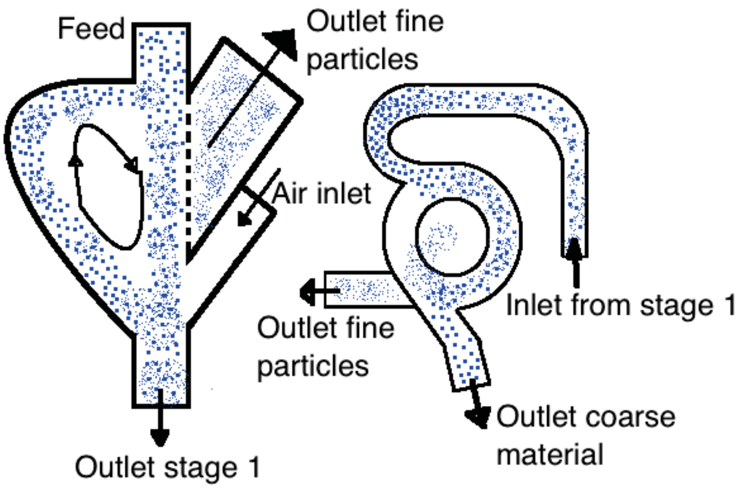


Figure 3.5 – Shows the two stages of the two stage air classifier

3.4.5 Cross- and counter-flow zone air classifiers

These kinds of gravitational air classifiers are using the same parameters as the other air classifiers that have been described above. But these are using the two parameters in a different way since the designs of these air classifiers is not like the other air classifiers have that have been shown in this report. The picture of the different air classifiers can be seen in the end of this chapter (Figure 3.6).

3.4.5.1 Gravitational counter-flow zone (a)

In this air classifier the air is going upwards and out on the top of the air classifier and takes the light particles with it. At the same time the heavier particles are falling down with the gravity and exit the air classifier at the bottom [15]. It works by the same principle as the air classifiers described above but does not have any pattern or recirculation chamber.

3.4.5.2 Gravitational cross-flow zone (b)

In this air classifier a horizontal air-flow is going through the air classifier. The materials that are going to be separated are dropped into the air-flow and will be caught in the cross-flow. The coarse material will fall down through the cross-air flow and land at the bottom of the air classifier. Fine particles do not land in the air classifier at all and exits the air classifier with the air-flow on the other side of the inlet [15].

3.4.5.3 Centrifugal counter-flow zone (c)

In this air classifier a flat air vortex in a cylindrical chamber with a tangential inlet where the materials are fed. An outlet is located in the center of the air classifier and it is where the main part separation is performed. By using the tangential inlet the centrifugal forces where the heavier particles will be thrown out to the side wall and fall down while the lighter particles will continue in the air-flow and continue upwards. The air classifier should be constructed so it keeps a constant tangential air velocity to keep the cut size along the radial direction [15].

3.4.5.4 Centrifugal cross-flow zone (d)

In this air classifier there are two outlets for the course materials on each side of the bottom of the zone. The material is fed straight from the bottom with whirl blades together with the air, which creates a screw-type flow inside the cylindrical chamber. The material will follow the whirl upwards where the coarse material will start falling when the pressure decreases when entering the bigger cylinder. The lighter particles will follow the air-flow up and exit on top of the air classifier [15].

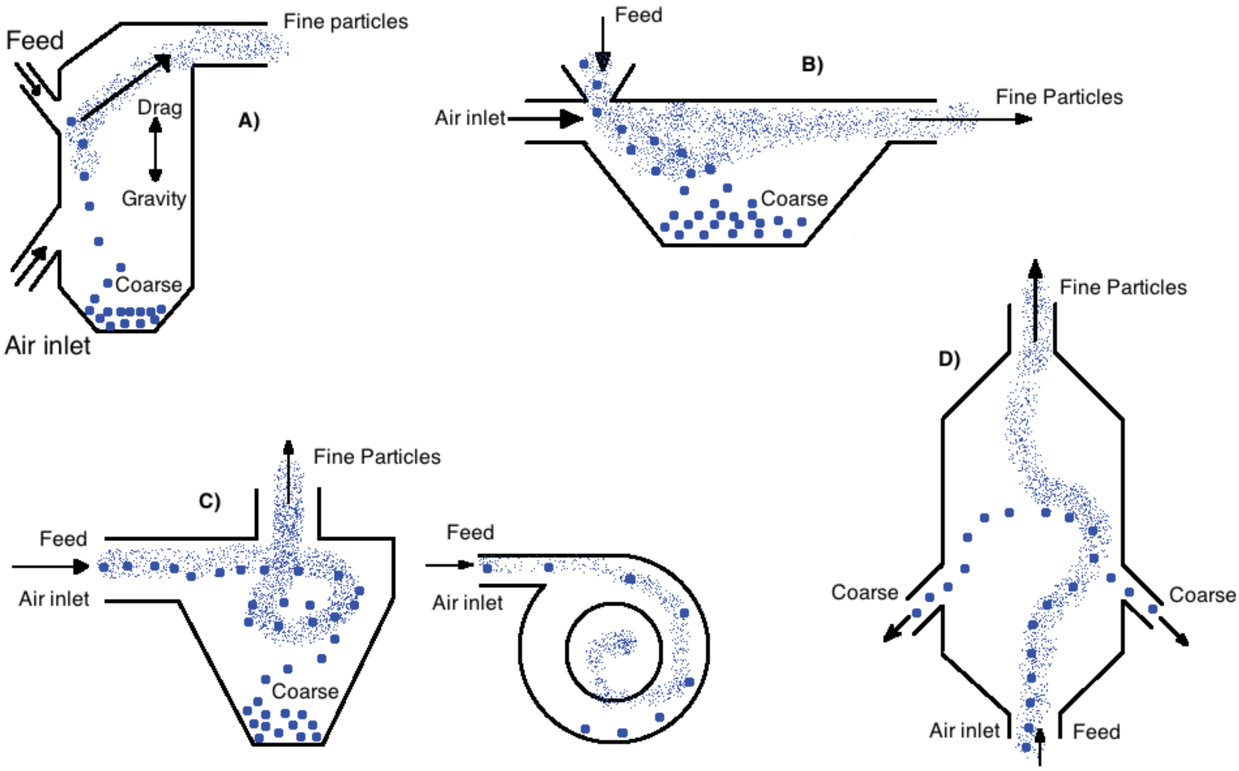


Figure 3.6 - Shows cross-flow and counter-flow air classifiers

4 Ideas – Choise of concepts

In this chapter the concepts that have been generated through brainstorming be described. There are a total of seven concepts that are using air and gravity in different ways to separate the two materials.

4.1 Brainstorming

The information gathered through the study has been used during the brainstorming sessions, which were done to generate different concepts. The concepts have been analyzed with a PUGH-matrix and a SWOT-analysis and the winning concept out of these analyses will be the concept that later will be built into a prototype.

The concepts ideas that have been generated are mainly from the study but also previous experiences and input from MRT staff has been considered. One of the brainstorming sessions was done together with persons that do not have any insight in the thesis or has any experience of this kind of processes before and one session was made with people with some experience of this kind of subject. This resulted in many different ideas that were very innovative and could be potential solutions for the air classifier. There were also ideas that were very innovative but not relevant for this thesis. Mostly the ideas that came up were not considering the design of the air classifier but functions that could be added to the air classifier [16].

Concept 1 – Lower Zig-Zag

This concept is a Zig-Zag model but with fewer sections than what is normally used when making a Zig-Zag. Air will enter the model at the lower part of the model and the material will be fed through an inlet in the middle of the air classifier. Coarse fractions will fall down with the gravity and fine fractions will move with the air that is going upwards through the channel and exit the air classifier at the top. Just to lower the height will result in that the air classifier will be below the two meters that have been set as the maximum height. The downside with the lower height is that it will probably provide a worse separation efficiency since there will be fewer stages in the channel where the material can go through a turbulence zone.

Concept 2 – Recirculation with pattern

Concept two is a version of an air classifier with a recirculation chamber. The difference is that it will have small bumps along the chamber making it look like a Zig-Zag pattern. This pattern will result in areas with turbulence inside the chamber which should make the separation efficiency increase. There will however be a need for higher air velocity through the chamber so that the air can move the material through the channel. Having a higher air velocity entering the chamber will also result in a higher velocity out of the chamber. When the material exits the chamber it will return to where the materials separate which will increase the number of collisions and may affect the separation efficient negatively.

Concept 3 – Two air classifiers

Using two different air classifiers and combing these into one small system of separation will provide better separation efficiency. Letting the material first go through a centrifugal counter cross-flow and then into and through a Zig-Zag will make the material go through a two stage air classifier with the result that the materials will be separated two times. Having two different air classifiers connected to each other will require more space, which can be a challenge; however it is the height that is the most critical parameter when talking about space needed for the air classifier. Since the concept suggests that the counter cross-flow air classifier will be installed next to the Zig-Zag it will not have any effect of the height of the Zig-Zag.

Concept 4 – Module based Zig-Zag

As mentioned, the height is one of the most critic parameters on the air classifier; this concept main advantage is that it can change height depending on what height is requested by the customer. Making the air classifier in different modules the height can easily be changed depending on the situation. To make it easy; one stage of the air classifier should be equal to one module and the feed and the air inlet should be a separate module. This concept will be very easy to modify by just adding a module with the type of stage that is wanted. If there is a new type of stage that needs to be developed it can be installed between two modules, which facilitate the process of developing the air classifier.

Concept 5 – High air velocity

This is another version of a Zig-Zag air classifier, but instead of having a pattern that creates turbulence which separates the two materials a stronger velocity will be used. This will make all the materials go up with the air-flow and get stuck in a fine filter on the top of the air classifier. The fine fractions will go through the filter while the glass will get stuck and fall down when the air is stopped. The glass will be collected in a bin and the fine fractions will continue with the air-flow and be collected in a filter further down the ventilation system.

Concept 6 – Heat and filtrate

This is also a version of a Zig-Zag channel. In this air classifier the material will be heated before the material enters the Zig-Zag. Heating the material will make the mercury change into a gas state. When the material enters the channel it will go through the same process as when going through a standard Zig-Zag channel. The light material will exit on top and the coarse material will exit in the bottom.

By having mercury in a different shape it will make it easier to remove from the fluorescence powder and it will not be necessary with a high air velocity. Weaker air velocity will generate less turbulence in the Zig-Zag channel and there will not be the same wear of the channel as with a higher air velocity where there is a lot of turbulence.

Concept 7 – Cross-counter air classifier

When looking at the study, ideas came up to combining two designs with each other. The two designs, which should be combined, were the gravitational cross-flow zone and the centrifugal counter-flow air classifiers. Having these two working together would both give the advantage of having two separation processes and save height. Having the gravitational cross-flow zone to separate the biggest particles and then letting the smaller fractions fly into the centrifugal counter-flow to go through a second separation process could result in good separation efficiency.

The fine particles would then exit on the top of the second air classifier and continue out with the ventilation system. There would be one bin beneath both of the air classifier to collect the coarse material.

4.2 SWOT-analysis of each concept

The first step of making the selection of the concepts will be through a SWOT-analysis. A SWOT-analysis will point out the Strengths, Weaknesses, Opportunities and Threats of each and one of the concepts [17]. Some concepts are more advanced than other, which explains why the descriptions of the concepts vary; the SWOT-analysis will however bring a more detailed knowledge of the different concepts.

Concept 1 – Lower Zig-Zag

Strength
The biggest strength with the first concept is that is a proven air classifier with good results making it easy to build and maintenance. There have also been studies showing that it is a good method for separating two different materials similar to the ones that are going to be separated with the prototype.

Weakness
Because of the lower height of the air classifier, the channel of the Zig-Zag is shorter which can result with a shorter residual time for the separation and the separation efficiency may be affected negatively.

Opportunities
Since it has a regular Zig-Zag design but is shorter it can be fitted into an existing system more easily than if it is higher making it more attractive for a wider customer segment. Depending on what separation efficiency and separation time that is requested the angle between the stages can be set to different values.

Threats
Because of the lower height, the air classifier may not be getting the required separation efficiency and the separation time will be shorter since the material will fall through the channel faster.

Concept 2 – Recirculation with pattern

Strength
Recirculation of the material can increase the efficiency of the separation of the materials. Both because the material can be separated several times and because the pattern inside the chamber will create more turbulence making the material crash into each other more times. It also has compact design, which can fit into the height requirements of the air classifier.

Weakness
It will be harder to build because of the more complex design. Since there are pattern inside the circulation chamber it will require a stronger air-flow to make the materials go through the recirculation chamber. A negative effect of the increased air-flow is that there will be more coarse material recirculated. More coarse material will cause disturbance at the exit of the recirculation chamber where the material will enter the air classifier when fed into the channel. This will make the air-flow uneven and the separation in the first part of the air classifier can be affected negatively.

Opportunities
By having a recirculation chamber together with a pattern the opportunity to create really good separation efficiency increases. There are possibilities of developing the air classifier with different sizes of the pattern inside the circulation chamber. Development can also be made with different air-flows and angles in the chamber to see if there is any difference in the efficiency.

Threats
The concept has a quite complex design so the production costs may increase. If the material is worn down or if a part inside the circulation chamber will break it will be hard to replace or repair it.

Concept 3 – Two air classifiers

Strength
Having two air classifiers will make the material go through the separation process twice which can increase the separation time and improve the separation efficiency which in the end would result in a cleaner glass.

Weakness
Since the air classifier already takes a lot of space it will be hard to modify and to add other functions to it without making it even bigger. It also requires more connections to the system ventilation and two bins for collection of the coarse material since there will be two outputs for the coarse material.

Opportunities
By having two air classifiers the air-flow and speed can be set individually. Having the first one with a stronger air-flow and air-speed and the second one with a slower air- speed and flow they can focus on different separation stages in the process. Since the inlet is on the bottom and the exit of the coarse material is on top it will most likely fit the already existing system

Threats
Even though the Zig-Zag air classifier is quite low an additional air classifier will require more floor space to be able to operate. Two air classifiers will

require more material for being built and it will take longer time building it which will make the production cost increase. The extra connections for the ventilation system and an extra bin will also contribute with an increasing cost.

Concept 4 – Module based Zig-Zag

Strength

Building the air classifier in different modules makes the height adjustable upon what is requested by the customer and the existing system. The design of the concept can be adjusted after how it is wanted to be, if it is necessary to have the inlet higher up in the concept it is easy to change by moving the sections.

Weakness

The modules need to be well attached to each other since the channel needs to be dense and not leak. If mercury is let out there will be a huge security risk for the person operating the system. By changing place of the different parts the air classifier may not work as intended.

Opportunities

Different designs of the channel and sections can be tested without doing any major changes to the air classifier. If a new design is under development it can easily be installed and tested which facilitates the development process and the time for developing new sections can be reduced significantly.

Threats

The stability of the air classifier can be adversely affected since the sections are not built as one piece. Depending on how the sections will be put together the stability may be affected negatively. If too few sections are used the height will be very low and there may not be enough stages for the material to be separated properly.

Concept 5 – High air velocity

Strength
This concept has very simple design, which will keep the air classifier and maintenance costs low. It does not require much space and can be constructed to be a very low air classifier making it easier to be fitted in an existing system.

Weakness
It needs to be shut down regularly to separate the glass from the filter and put back on again to repeat the separation process. When the glass is stuck at the filter it is blocking the outlet of the powder, which can result in that powder gets stuck on the glass, which is stuck in the filter. When the air classifier is turned off and the glass is falling down the powder will follow it.

Opportunities
Because of the very easy design the production will go quick and because of the very low height it can be modified with other functions and add-ons to improve the separation efficiency.

Threats
Putting it on and off regularly will result in an increase of wear on the air classifier and the filter where the glass is collected. It can cause a stop in the existing system making the whole recycling process less effective and more time consuming.

Concept 6 – Heat and vibration

Strength
Heating up the fluorescence powder and turning the mercury into a gas-shape will make the separation process much easier since the materials will not be as tight fixed to each other. Therefore a slower air- flow and speed must be used since the material will not be needed to be in the turbulence as long as if the material was not pre heated.

Weakness

This concept requires an additional heating section before the Zig-Zag which is space demanding and needs additional electricity or other way of heating.

Opportunities
Since the primary idea of this concept is the heating and filtering it can be installed on almost any other air classifier.

Threats
The air classifier requires some kind of heating device installed to heat up the mercury which requires more energy for the air classifier to work which will increase the operation cost. Having a piece of the air classifier heated up to almost 400 degrees of Celsius it will be a more dangerous environment for the people operating the air classifier.

Concept 7 – Cross-Counter air classifier

Strength
Having two different air classifiers combined will increase the separation efficiency since the material will go through a separation process twice. It is a very low construction and will pass the requirement of two meters without any problem.

Weakness
It will take up more floor space since the two air classifiers are not built on top of each other as the other concepts. It can be more complex to fit into the rest of the system because it is very low built and adjustments have to be done to the existing system.

Opportunities
The two air classifiers are not placed on top of each other and modifications can therefore be built on the height if it is increasing the separation efficiency, this can also make it easier to fit into an existing system.
Threats

The production costs will increase since there are two air classifiers that needs to be built, it will also need two bins, which also will increase the costs of the air classifier.

4.3 PUGH - Matrix

The PUGH-matrix [18] (Appendix 4) is used to compare the seven different concepts to each other. The matrix will give a more visible comparison between the concepts. Since there is not a possibility for building each of the concept assumptions have been made from the study.

There is one concept that will be used as a reference concept, which the rest of the concept will be weighed against. The reference concept, *Concept 1*, has the standard value of 0. The other concepts are the compared to the reference concept and a number is set to mark if the concept is better or worse as the list below shows:

- Worse: -1
- Much worse: -2
- Neutral: 0
- Better: +1
- Much Better: +2

The criteria's from which the concepts are looked upon are:

Height – 7
The height of the air classifier is the most important criteria to consider since it has to fit the existing system. Therefore it has been given the highest weight so it will have the biggest impact on the final score. The lower the height is the higher number the air classifier will get.

Production cost – 5
Even though the production cost is not the most important criteria it is still an important question since it has to be competitive and the payback time short. Since there is a limit of 50.000 SEK to build the air classifier it has got the weight point of 5. The cheaper the air classifier will be to build the higher number it will get in the matrix.

Weight – 1
The weight of the air classifier is not highly prioritized but it has to be able to be moved if necessary. There is no requirement of a maximum weight but it has to be considered and is therefore given the lowest criteria number. The number have been given from how big the concept is and an assumption on how much material that would be needed for building it was the main factor for the number for this criteria.

Environmental effect – 3
The environmental effect is of big interest as described in chapter 3.1. The number given to the air classifier is considered from what material is used and how much of that material that will be needed for building the concept. If there is any need of using hazardous substances when building, using and recycling the air classifier that will also be considered. Using less material and substances will give the concept a higher number.

Maintenance – 4
If there is some part that breaks or is worn down when the air classifier is in use the maintenance has to be easy and quick so there will not be a long stop. Looking at existing air classifiers assumptions have been made to make the decision on what number that will be given for this concept. The easier the air classifier is to maintenance the higher number it will get.

Separation time – 2
The time for the two materials to be separated inside the air classifier is not considered as an important factor and will therefore be given a low number. This is related to the amount of material that can be fed into the system since there cannot be too much material in the channel at the same time. Because all

of the concepts cannot be built estimation has to be taken for the time, the study will be to assistance here. The faster separation the higher number the air classifier will be given.

Separation efficiency – 6

Separation efficiency is one of the more important criteria's. It is important that the separation efficiency is high and that the materials are separated properly so the mercury can be collected and taken care of. The efficiency cannot be measured at this stage and there is no possibility to build each concept. Therefore knowledge from the study has been studied to make the decision on what number each concept will get for this criteria. The better efficiency that the air classifier has the higher number it will get.

4.3.1 Criteria impact

When the numbers have been set for each of the concepts they are multiplied with the specific criteria number for each criteria which generates a new number. These numbers for each concept are then added to get the total score. This is done so that the more important criteria´s will have a bigger impact on the final score.

4.4 Final Concept

The result from the PUGH-matrix shows that the concept that got most points is concept number 4 – Module based Zig-Zag. This concept is built from several different parts that are put together to one assembled construction. The main advantages of this concept is that it has an easy design and can easily be disassembled and assembled again if there is any need of maintenance or modification needed to be done quickly.

The height was the most important criteria and because the height can easily be adjusted in this concept is was the main reason that this concept became the one with highest score. The module section that is the main part of the concept can be turned up-side-down which means that only one type of the module section is necessary and it do not need to be modified to fit the section above or below. This saves cost, makes production easier and it also makes a module easier to replace.

The dimensions that will be used have been inspired from the study where similar Zigzag's have been made. The channel will be 200x200x100 millimeters in all section modules.

Even though the production time probably would be longer because each section has to be built separate it would be advantageous in the long run.

4.5 CAD

The finished concept has been drawn as a 3D-model in Solid Works. The different modules and parts will be built separately and then put together as a final concept in an assembly. This will make it easier to meet the height that is requested by adding and removing sections and to modify it if necessary. All of the parts have been made as drawings (Appendix 5) to be able to build the prototype.

4.5.1 Module Section

This Module section (Figure 4.1) is the main section of the prototype and the most common part. It is an assembly of three different parts with the total of five parts. The different parts are two plates, two flanges and one box. The two plates that are forming a channel through the part are mounted in an angle of 60 degrees which together with the section will be mounted above or below create an angel of a total 120 degrees.

The two flanges that are mounted on the top and bottom will help to stabilize the section. The flanges have eight holes drilled through so that the module section can be steadily mounted with another section. All of the parts used in this prototype have the same holes patterns so that all different parts can be put together.

Since the module sections are using the same type of flange on the top and bottom it can be turned upside down and used on the other side. This reduces the production cost since the same module can be used over the whole prototype. It is only the module section that can be turned upside down and since it does not have any inlets or modifications to it.

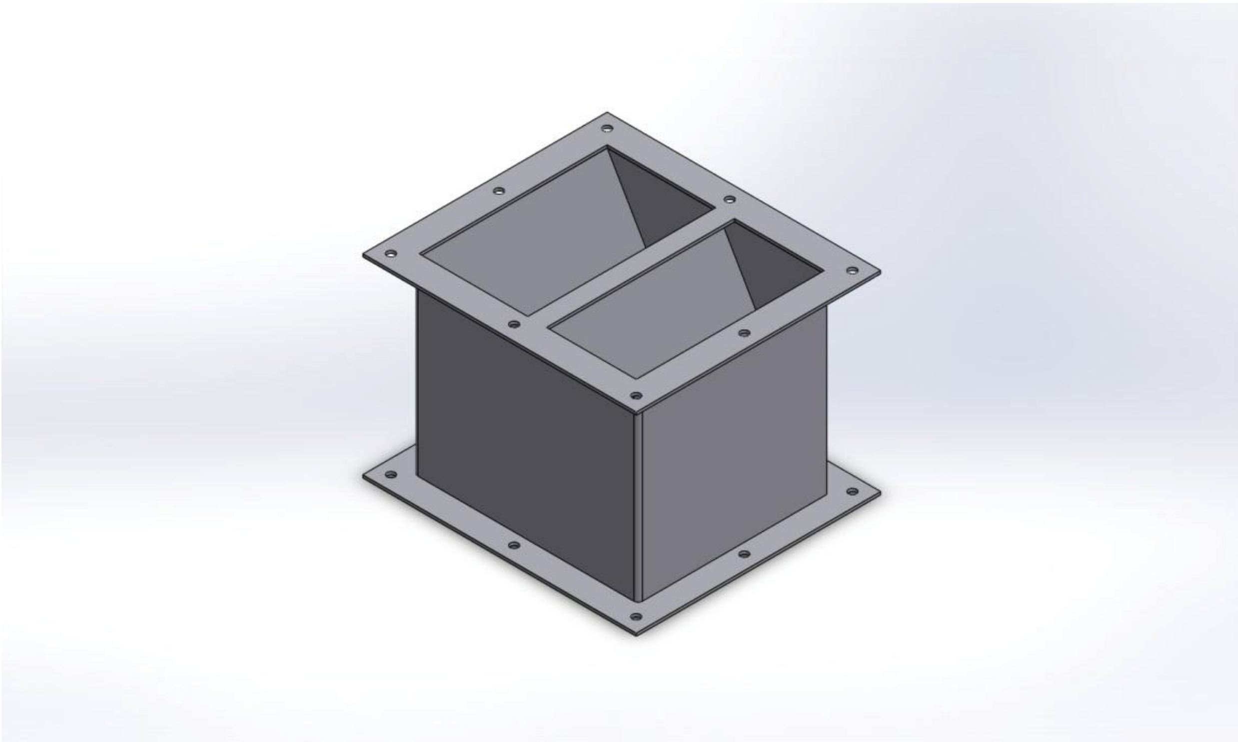


Figure 4.1 - Shows the Module Section

4.5.2 Material Feed Section

The material feed (Figure 4.2) is where the materials are fed into the channel. It is a modified version of the Module Section where a hole has been cut through the outside box and one plate so that the feed inlet can be mounted and the material can enter the main channel easy. For the material to “hit” the air as hard as possible the feed was mounted in the steepest angle possible so that the material will have a high velocity when it enters the channel and meets the upward moving air stream. The width of the feed is 182 millimeters, the depth is 300 millimeters and the height is 143 millimeters.

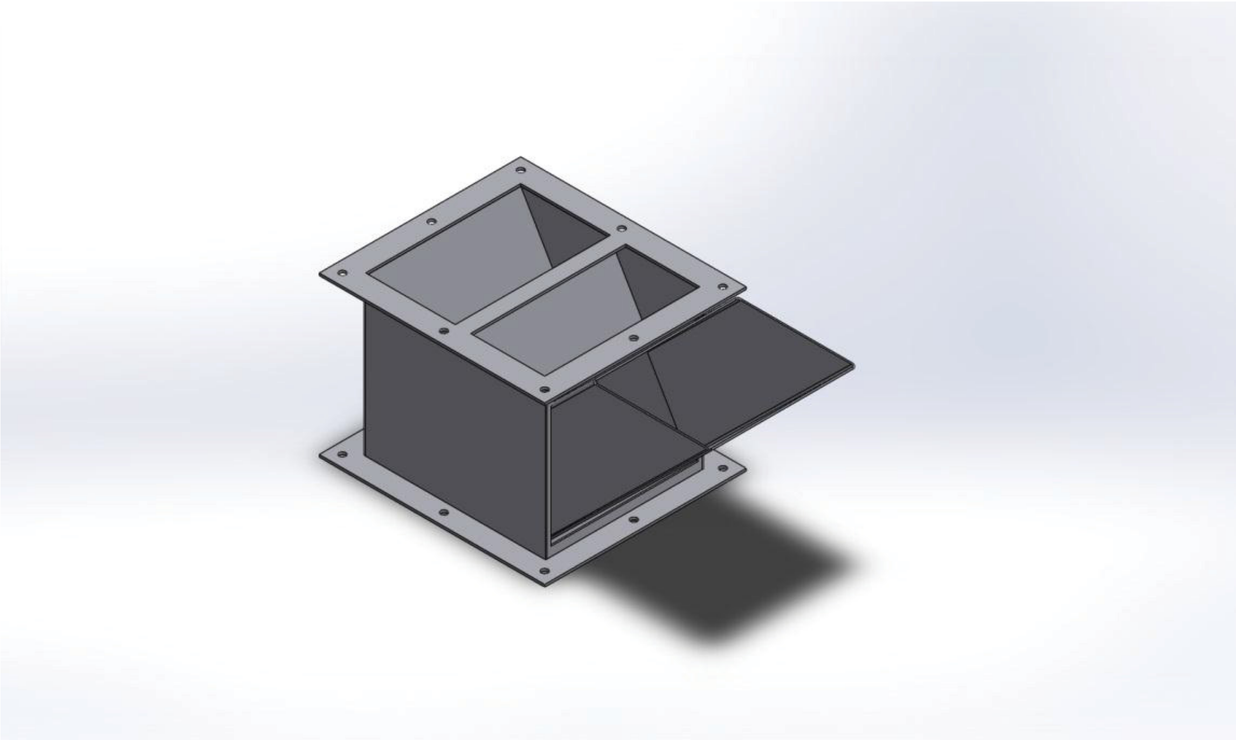


Figure 4.2 - Shows the Material Feed Section

4.5.3 Air Inlet Module

The air enters the channel through the air inlet section (Figure 4.3). The air inlet section will help to guide the air through the whole channel since it is placed in the bottom of the air classifier. The section is like the material feed also a modified version of the module section. There is a hole from one of the short sides which goes into the channel. Between these holes there is a straight tube where the air will be sucked in and go through the channel. The holes has an inside diameter of 100 millimeters which is the same as all the other holes in the prototype to keep the same pressure within the whole channel.

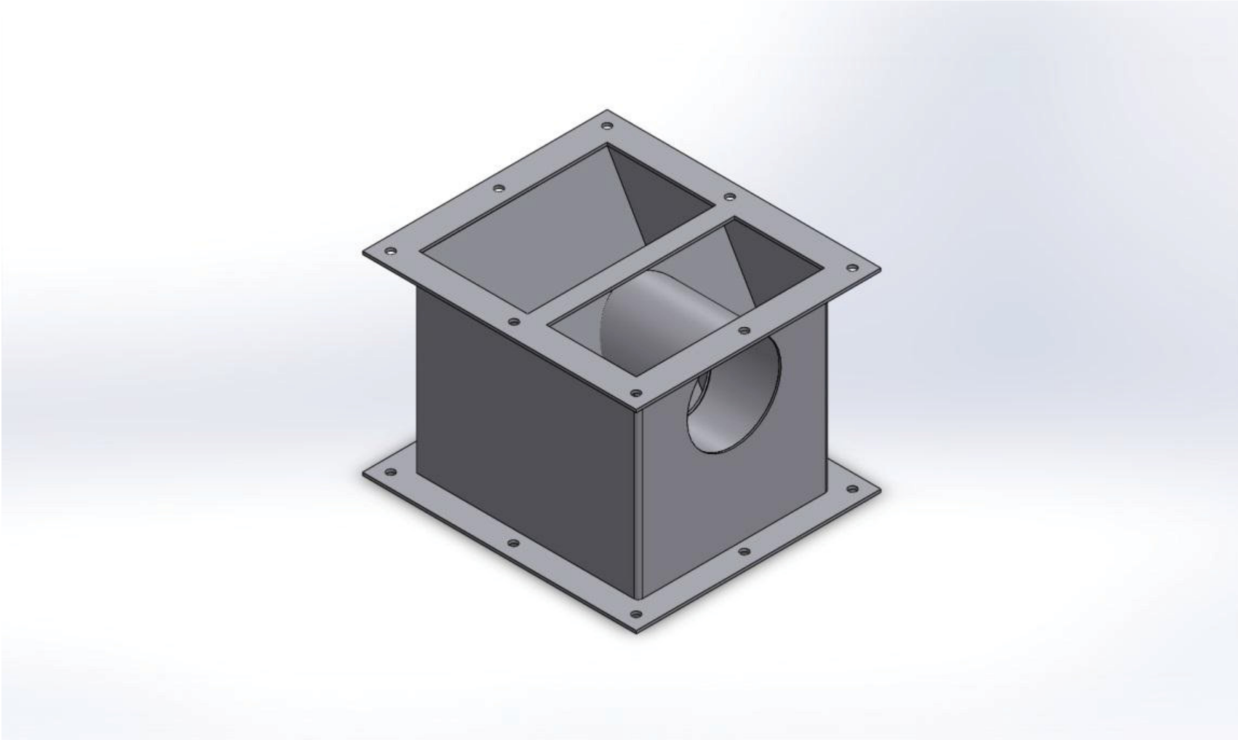


Figure 4.3 - Shows the air inlet module

4.5.4 Funnel

Since the channel is rectangular and the connectors to the ventilation system are circular it will not fit without some kind of modification. Therefore one funnel is mounted on the top and one on the bottom to go from the rectangular shape to a 100 millimeter hole. The hole is 100 millimeters both to keep the same pressure within the whole channel and the connectors to the ventilation system is also 100 millimeters. The distance from the flange to the top of the funnel is 200 millimeters which is the same as the other section modules in the prototype. The funnel is assembled from three parts, to half funnels and one flange. The funnels are made in half because the construction will be easier to build; these will later be welded together as one funnel. The final funnel will be welded onto a flange so that it can be connected to the other sections (Figure 4.4).

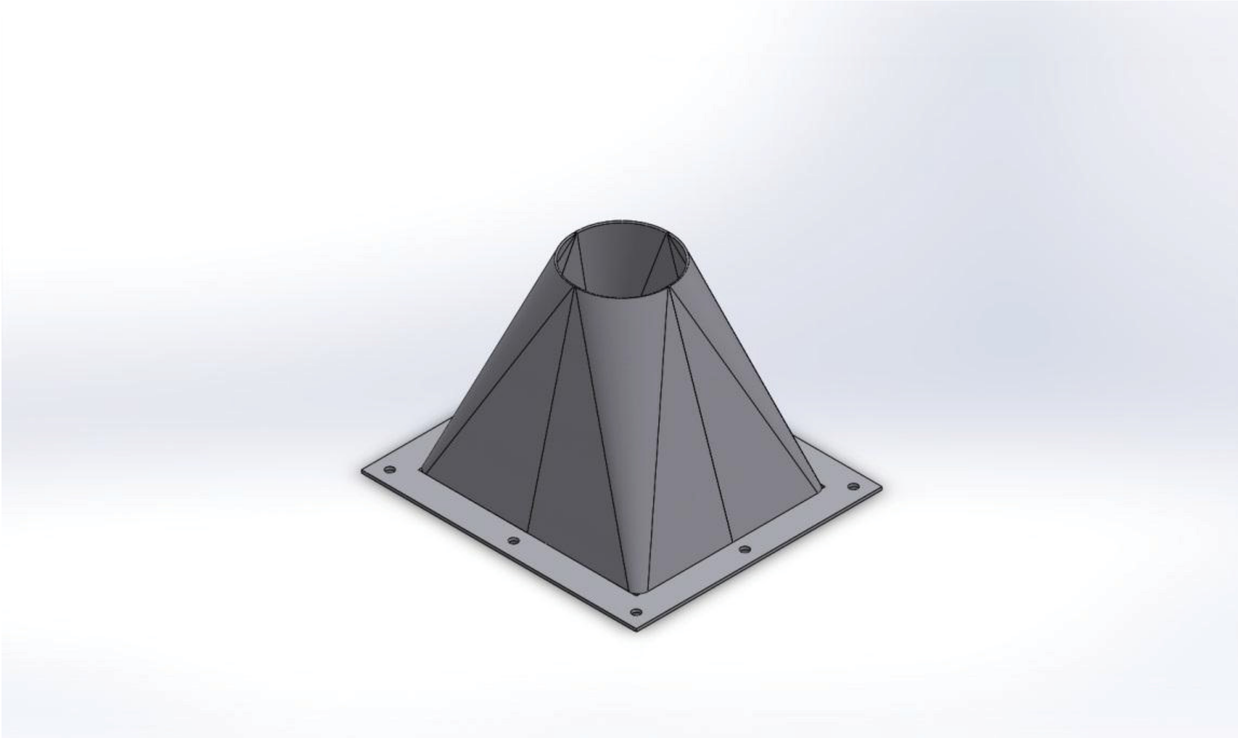


Figure 4.4 - Shows the funnel

4.5.5 Stand

For the prototype to be stable a stand has been made where the prototype will be mounted on (Figure 4.5). The stand has the dimensions of (length X width) 1000x800 millimeters and is 1000 millimeters high. This makes it possible to have a bin beneath the prototype to collect the glass that has been separated. In the middle of the stand are two profiles going across the stand and in the middle of these two are smaller profiles welded creating a square where the prototype will be mounted. There are eight holes so that the flange can be screwed properly and sit tight. On the bottom of each leg is a flat plate where the stand can be screwed to the floor increasing the stability and to make sure it is stationary.

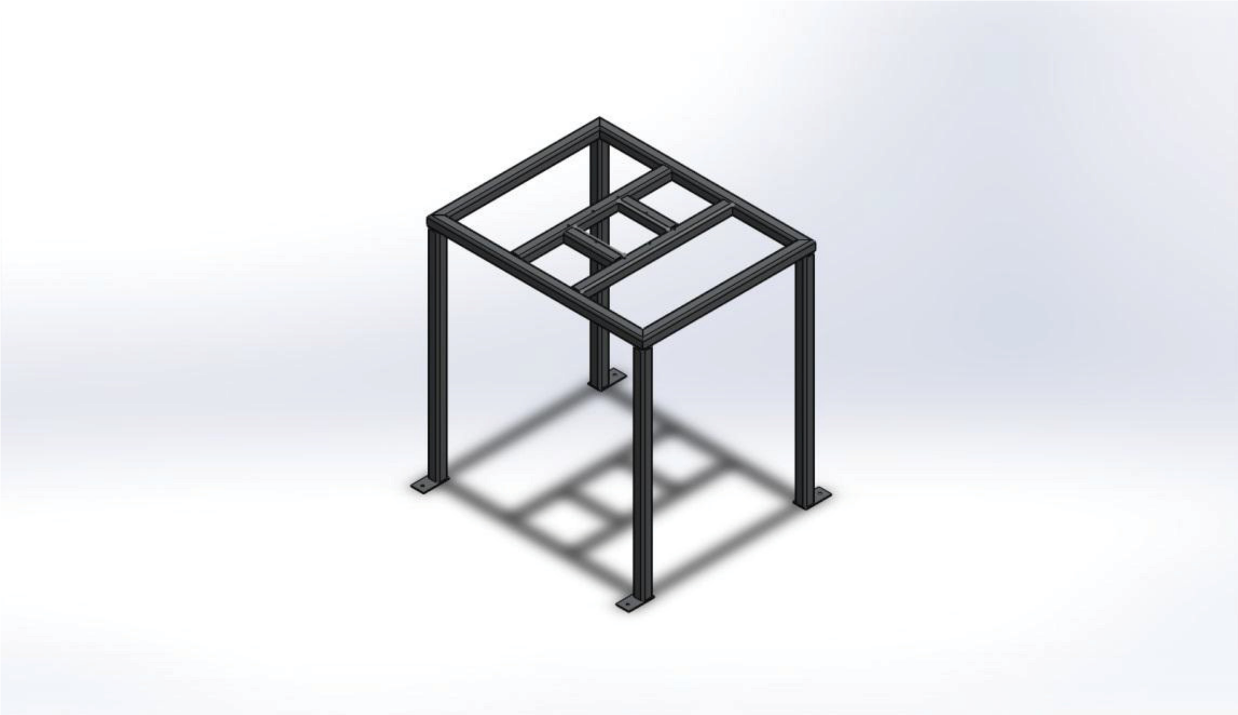


Figure 4.5 - Shows the stand that the prototype will be mounted on.

4.5.6 Assembled Concept

When the sections are assembled they will be mounted on the stand creating the final prototype (Figure 4.6). The parts that are in this assembly are:

- 4 Module Sections
- 1 Material Feed
- 1 Air inlet
- 2 Funnels
- 1 Stand

This will make a total of seven Zig-Zag patterns in the channel. The study showed that the material feed should be mounted in the middle of the channel to able the material to move up- and downwards in the channel without exiting the channel.

For the air to pass through the whole channel the air inlet is located on the section in the bottom just before the funnel section. This will make the air to go through the whole channel and the separation will take place at all sections. Because of the shorter channel it is necessary to use the whole channel for separation, even though the main part of the separation will take place just after the materials have entered the channel.

The total height of the prototype is 1,64 meters without the stand and 2,49 meters with the stand. Even though it is higher than two meters with the stand it can be used without the stand and directly mounted on for example a bin, it should then be attached to something on the top to make it stable.

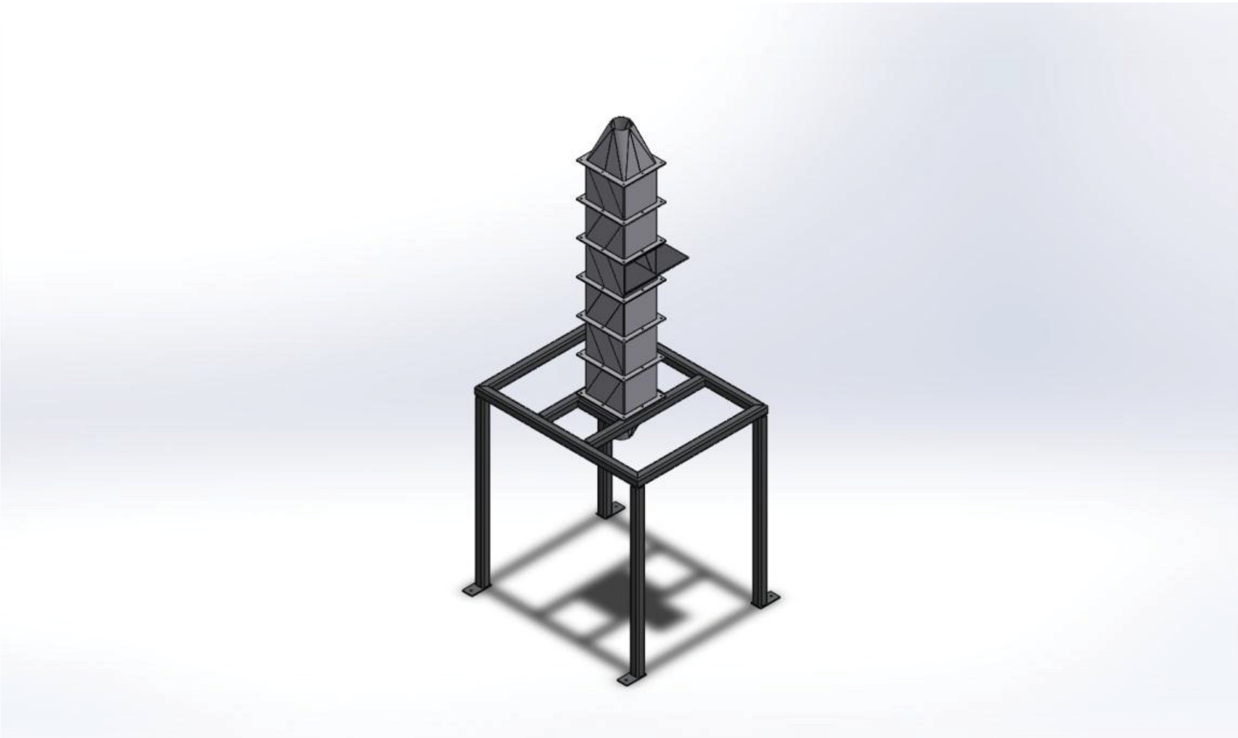


Figure 4.6 - Shows the complete prototype

5 Prototype

The main material that was used for building the prototype is two millimeter thick sheet metal; this was used for plates, boxes, feed inlet and air inlet.

There were adjustments from the original drawings making it easier and faster to build which also facilitated if there was any need for adjustments or further development when after it was built. Two module sections was built as one and both of these had one side open so a plastic glass could be mounted on that side to provide a clear view of the inside of the channel. This made it possible to see how the material moved inside the channel and to see if there was any need of adjustments or improvements to increase the separation efficiency.

As shown on the final prototype (Figure 5.1) the material feed was placed between the two double sections and the air inlet was located below the lower of the two double sections making it possible for the air to go through the whole channel.

Because of the lack of time the material for the flanges was made out of two millimeter sheet metal since they could be made at MRT. The funnels had to be bent by hand to give the correct measurements and therefore one millimeter sheet metal was used for these. Using only sheet metal for all the different part did not have any effect on the final results, it could have effect on the durability of the prototype but since it was only for test purposes and since the prototype was not installed in an existing system it did not matter.

The stand was made of 30x30x3 millimeter square profiles since MRT already had this material at home and it was decided to use theses to make the production time shorter.

Figure 5.1 – Picture of the developed prototype

5.1 Calculations

The crushed glass and the fluorescence powder have very different densities and was therefore easier to separate than two materials with similar densities. To know how strong air-flow that was required to lift the fluorescence powder without bringing the glass with it calculations was made to give an estimation of the strength of the air- flow and speed. The calculations were made with a channel dimension of 200x100 millimeters with the area of 0,02 m^2. To be able to calculate the lift power of the air and what maximum air-flow was needed before the glass would follow the air stream the force from the air stream on the glass needed to be calculated.

Glass that already had been separated from fluorescence powder was weighed and this weight was then used in the calculations. Since the glass with fluorescence powder weighed more, the lowest weight of the glass was used.

The values that have been used in the calculations are presented below:

Channel depth: d_t = 0,2 m
Channel with: W_c = 0,1 m
Mass (one piece): 0,075 g
Density glass: p = 2470 kg/m^3
Area channel: 0,02 m^2
Area (one piece): $1 \cdot 10^{-4}\ m^2$

$$F_{glass} = m \cdot g \rightarrow 0{,}075 \cdot 9{,}82 = 0{,}7365\ N\ =\ \mathbf{0{,}74\ N} \qquad (5.1)$$

The maximum lifting force according to the calculations that can be used before the glass will be lifted up with the air stream is L = 0,74 N.

$$L = 0{,}5\ \cdot\ p\ \cdot\ v^2\ \cdot\ A\ \rightarrow\ v = \sqrt{\frac{L}{0{,}5 \cdot p \cdot A}} = \sqrt{\frac{0{,}74}{0{,}5 \cdot 1{,}224 \cdot 0{,}1}} =$$
$$3{,}5\ \text{m/s} = \mathbf{252\ m^3/h}\ \ [19] \qquad (5.2)$$

As the calculations above shows the maximum air-flow through the channel can be 252 m^3/h. This is before the glass will follow the air-flow up and exit the air classifier. Looking at the specifications of the ventilation system that is installed at MRT, it is possible to use their system since the maximum air-flow through their system is 2260 m^3/h.

5.2 Observations during tests

The tests of the prototype were performed at MRT in Karlskrona. A large vacuum cleaner was fitted to the prototype to suck air from the top to simulate the ventilation system that normally would be connected to the prototype if it were fitted in an existing system.

Before any material was tested an instrument was used to see how the air-flow and air speed was moving inside the channel. This was be performed at different places in the channel to see if there was any variations depending on where in the channel the air- flow and speed was measured. To be able to adjust the air-flow through the channel a valve was installed on the air inlet this was to see how the air inlet would affect the air-flow through the channel.

When the initial tests had been done tests with material was started. The materials that were tested were crushed glass with sizes between 5-10mm and are coated with powder. The material was fed with small amounts and was gradually increased over time until test was done. The maximum capacity that the prototype can handle was also tested.

First tests

The first tests of the prototype it showed that it got too much air and had difficulties of getting the glass to stay in the channel and be separated. Adding a metal plate over the material feed inlet helped but was not good enough and there was still air leaking in trough that inlet. After talking with the man who built the air classifier is was discussed that the best and easiest way to solve the problem was to use an airlock with two manual locks with a container between them where the material would be collected before it was fed into the channel.

This was built on the spot with trial and error technique. Tests after this modification was installed showed an improvement of the circulation of glass particles. Initial tests were also made to see how much material that could be fed without any complications. This showed that when feeding too much material into the channel the air was not be strong enough to stop all of the material to from being stuck in the turbulence and circulate; instead the majority of the material just fell right through the channel. When having a slower feeding rate the results were much better and almost all of the material stayed inside the channel and was going through the turbulence zone. The first tests were made with an air speed of approximately 7 m/s.

Air inlets/locks

If the prototype was to be installed in an existing system the bin beneath the prototype would be sealed, therefore a manual sluice was installed on the outlet on the bottom of the prototype. Having this closed, the air-flow through the channel could be determined by adjusting the valve which is located on the air inlet. This gave a better flow through the channel and a lower air-flow and speed could be used to reach the same values as when not having a lock on the air outlet. The air-flow through the channel became more concentrated and there was not any noticeable air-flow in the material feed, hole 3 (Figure 5.2) and therefore no measurements were taken from that location.

Setting the correct air speed/flow

For the final test to be as good as possible the right air speed and air-flow has to be determined before the final test would begin. This was made with glass pieces that already have been separated from fluorescence powder with the same sizes as the material that would later be used. By using an instrument that measured both air speed and air-flow the correct values could be decided with visual control through the plastic glass when the circulation of the glass reached a good separation level.

The air-flow and air speed have been tested in three locations on the prototype (Figure 5.2). This is to see how the air- speed and flow varies throughout the prototype to be able to make adjustments if necessary. There were four different setting on the vacuum cleaner that generated different sucking power; all different settings were tried at the different locations. On the machine the different settings on how powerful the suction force should be was in Hertz, Hz.

The test instrument gave a maximum and a minimum value which was used to calculate an average value. This average value was used to decide what speed that should be used when using crushed glass with powder. The result from the three different locations with the four different settings is shown below:

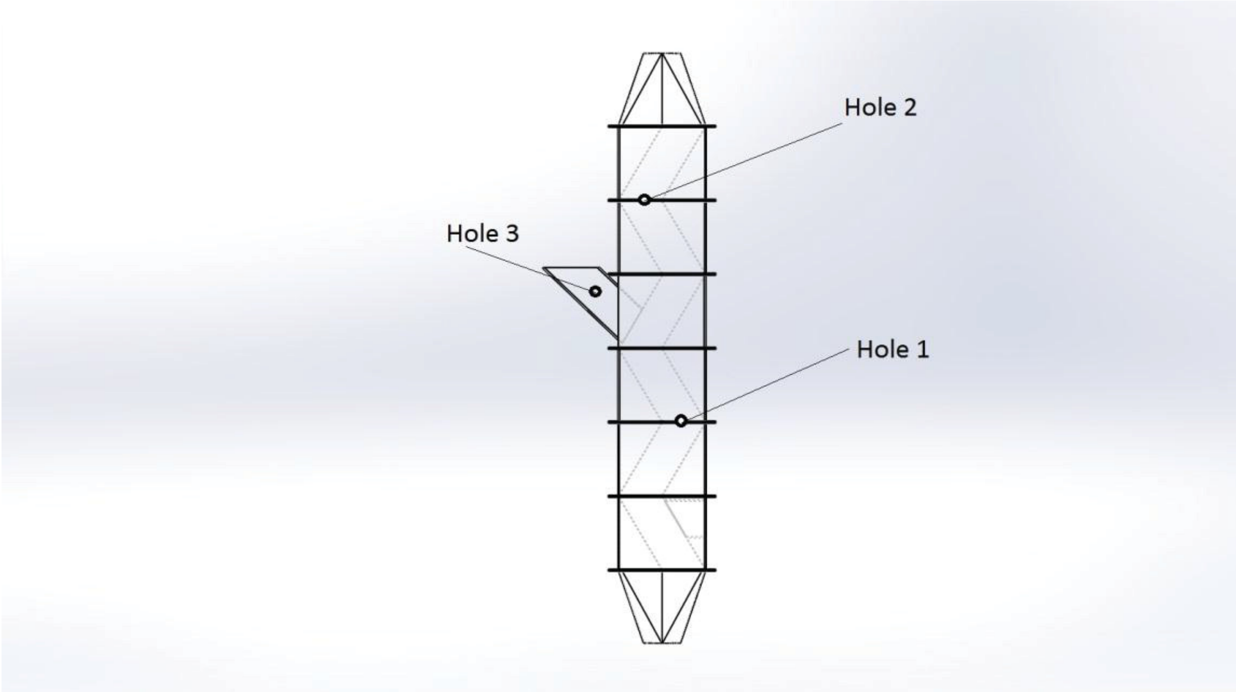


Figure 5.2 - Picture of hole locations on the prototype where air-flow and speed was measured

Test on location 1

On location 1, hole 1, the following results were taken (Table 5.1 & 5.2). In the first table the maximum and minimum values that were recorded are shown and in the second table the average results from the tests are shown.

Table 5.1 - Show Max/Min values from location 1

Location 1 – Min/Max Values				
[illegible]	[illegible]		[illegible]	
	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	3,5	6,6	254	476
[illegible]	6,1	8,5	441	617
[illegible]	6,6	9,1	476	661
[illegible]	8,1	12,8	590	922

Table 5.2 - Show mean values from location 1

Location 1 – Average Values		
[illegible]	[illegible]	[illegible]
[illegible]	5,1	365
[illegible]	7,3	529
[illegible]	7,9	569
[illegible]	10,5	756

Test on location 2

On the location 2, where hole 2 is located the following results were measured (Table 5.3 & 5.4). In the first table the maximum and minimum values that were recorded are shown and in the second table the average results from the tests are shown.

Table 5.3 - Show Max/Min values from location 2

Location 2 – Max/Min Values				
[illegible]	[illegible]		[illegible]	
	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	3,5	6,1	254	441
[illegible]	5,5	7,7	402	555
[illegible]	6,6	8,0	476	583
[illegible]	7,2	9,3	525	673

Table 5.4 - Show mean values from location 2

Location 2 – Average Values		
[illegible]	[illegible]	[illegible]
[illegible]	4,8	348
[illegible]	6,6	479
[illegible]	7,3	530
[illegible]	8,3	599

Test on location 3

When using the locks to make the air only go through the air inlet on the bottom side of the air classifier the feeding inlet and the bottom outlet did not contribute to any air leaking in to the channel. The air that was going in through the air inlet travelled the fastest way up and out through the top resulting in that there was none or very little air going around at hole 3.

Therefore there were no results when measuring the air speed and air-flow at the location of hole 3. Having no air activity here is preferable since it is wanted for the material to start the separation when entering the channel and not before that. This can, during unlucky circumstances, create a disturbance in the air-flow and have a negative effect on the separation efficiency.

Visual tests with glass

To see how the material is affected by the different settings of the vacuum cleaner, glass that already has been separated from fluorescence powder was used. This was only to give and idea how it moves around in the channel at different air- speeds and flows. It was clear that at 40 Hz, the air- flow and speed was too weak to keep the circulation of the material that is needed to reach the separation efficiency that is requested.

When increasing the speed to 45 Hz the circulation of the glass was better but still not satisfying; there was still a lot of glass going right through the channel right after it had been fed into the channel. Increasing the speed up to 50 Hz resulted with an increase of the air circulation in the channel and there were very little material falling right through the channel, only material that came in a big lump was falling straight through. When increasing the speed to maximum at 55 Hz the material was circulation very good and there was even material going upwards in the channel indicating that the speed was a bit too strong. There was not much material going straight through the channel unless it came in a big lump after it had been fed.

Conclusion first tests

To get a good separation, the first thing to think about is to feed the material with an even volume (kg/h) across the whole channel so it will not be any big lumps entering the air-flow. After the tests of the air speed and flow it showed that the best speed to use is 50 Hz, this will give an air- speed and flow of approximately 7,3 m/s and 529,5 m^3/h at location two. These settings gave the best circulation when feeding the material with an even pace. There will not be any glass following the air-flow upwards and at the same time the circulation of the material was satisfying.

5.3 Final Tests

The tests were made with tree different fluorescence powders at three different speeds this to give a good understanding of what happened to the different mixes at different air- speeds and flows. This was to get various results and to see how well the prototype could perform at optimized speeds and how the results differed at different settings.

All the materials was weighed and photographed before and after it was tested to visually give a look of how good the separation was (Appendix 6). This was to give and estimation how much material the prototype had separated.

To give an even more specific analysis of how well the separation was, the recycled material was sent to ALS Scandinavia a company who carries out sample analysis for companies. ALS Scandinavia analyzed the samples and gave a result in how many parts per million (mg/kg) that was left on the glass. A sample from the sieve from MRT was also sent as a reference to see how well the prototype performed compared to the sieve which has the same purpose as the prototype would have in an existing system.

5.3.1 Tested materials

Material 1
This material is from lightning tubes which is collected after the glass crush and is also the material that will be compared to with the sieve from MRT.

Material 2
Material 2 comes straight from crushed CFL-lamps.

Material 3
The third material is the output from a LP 200 system that has been mixed with pure fluorescence powder. Because it is only mixed it is not bonded as tight as the other two materials that are tested.

5.3.2 45 Hz

Material 1
During this test the air-flow and speed was not enough to completely separate the two materials from each other. The feed rate of the material into the channel was good and there was not much material that was just falling trough. However the fractions did not reach the circulation that was satisfying enough and the time that the material was in turbulence was too short.

Material 2
Like material 1 the air-flow was not strong enough to separate the materials to a level that was satisfying. However there were some separation and one could see a difference from the in- and output. The feed rate of the material was good but the weak air-flow could not keep up with the feed rate and there were material falling right through the channel.

Material 3
The majority of the powder was separated, mostly because the binding between the powder and glass was very loose. The powder was separated from the glass easily and there was a lot of powder going up at the same time making it visible to see through the glass how the air stream was moving upwards although the slowest setting was used.

5.3.3 50 Hz

Material 1

When having stronger air-flow and speed the difference was noticeable from the lower air- flow and speed, 45 Hz. The separation was good and there was some material falling right through when there was an even feeding rate.

Material 2

As with material 1 there was a noticeable difference from 45 Hz. The separation between the materials was good and there was only some material that fell straight through the channel.

Material 3

Like at the 45 Hz setting, the glass and fluorescence powder was just a mix and was not combined in the same way as the other material making the separation was much better and visible. Right after the material had been fed into the channel one could see on the top of the channel that the fluorescence powder was going right up, creating a white layer on the plastic glass on the air classifier. There was a very big difference from the material that had been fed and the output material.

5.3.4 55 Hz

Material 1

With this speed there was a good separation and there was no material that fell right through the channel when feeding at an even rate. The air- flow and speed was strong and there were even some glass pieces that followed the air upwards and exited the channel on top with the fine particles.

Material 2

When feeding the prototype with material 2 at 55 Hz there was, like with material 1, a good separation efficiency and there was no material falling right through the channel when feeding at an even pace and across the whole channel. However there were some glass pieces going up with the air stream and exited the channel where the powder should. There was a clear difference between of the material before and after the separation.

Material 3

With the loose powder there was, as with 50 Hz, a visible separation of the fluorescence powder and the glass. The powder going up with the air created a white layer on the inside of the plastic glass. The difference between the material that was fed into the channel and the material that exited the channel was clear with almost no powder left on the glass. There was however some material going up with the air and exited on top.

6 Results

In this section the results of the thesis will be explained, how the outcome of the different parts turned out and if they are satisfying or not. The questions that are defined in the beginning of the thesis will also be answered here.

6.1 Answering the defined questions

Can the two materials that MRT want to separate be separated by means of an air classifier?
The two materials that MRT wants to separate are lamps coated with fluorescence powder that are crushed into pieces. The glass and fluorescence powder have very different density which makes them ideal to separate from each other in an air classifier.

The bigger difference in density the two materials have the easier they are to separate from each other. During the study there were no tests found using similar materials that MRT will use for separation.

How can a prototype be designed to fit the required design measures?
The most crucial design requirement from MRT was that the maximum height of the prototype should not exceed two meters. With the prototype built as it is the height is 1.64 meters without the stand which is well below the required maximum height. The other dimensions had no other restrictions regarding the final prototype and since the developed prototype has been approved by MRT the following measurements are used:

With stand:
Width: 1000 mm
Depth: 260 mm

Without stand:
Width: 469 mm (Feeding inlet)
Depth: 260 mm

To see full specifications of the final concept see chapter 4.5 or drawings in Appendix 5.

Can a prototype be made to fit the existing systems that MRT offers today?

MRT has many different systems that they are offering to their customers and many of these systems are custom made to meet the needs of the customer. This opens up the possibility to make the prototype fit the different systems that they have, depending on how well the separation needs to be and how much height that are available the prototype designed to fit the existing system.

Can a prototype be made within the production costs that have been set from MRT?

By using material that is common by steel dealers both the time getting the material and the cost for it can be reduced. The most expensive part in the prototype is the flange where the holes are cut out by water, this is however not a unit price since several units can be cut at the same time reducing the cost. The cost for the prototype ended at 23.362 SEK where material cost is 2.962 SEK making the hourly price of the staff building the prototype the bigger part of the production cost. The maximum production cost for the prototype was set to 50.000 SEK which was reached.

Can a prototype be developed to have better separation efficiency than the machine MRT uses today?

After the tests that was made with the different materials at different air-speeds and flows the glass was sent in for analyses at ALS Scandinavia. Looking at the materials after they had been separated the material at 50 Hz was the one that looked most promising. The decision was made to send the 50 Hz tests in for analyze.

For comparison material that had gone through the sieve from MRT was sent with the material from the prototype for the purpose to see if the prototype could be a potential replacement for the sieve in the future. The results showed that the prototype performed better that the separation unit that MRT is using. The prototype had 0,396 mg/kg and MRT’s separation unit had 0,105 mg/kg mercury left on the glass.

6.2 Meeting the requirements

In this chapter the prototype will be looked at from the requirements that have been set for it. Each of the requirements will be described from the prototype perspective and how it is or not met. Since the prototype was not entirely build as the drawings specified but was simplified, the prototype will be looked from the perspective as it should be built according to the drawings.

6.2.1 Environment

Looking at the concept from the environmental point of view with the four sustainability principles in mind the prototype manages well. Sheet metal that is used for the concept is made from steel has a very low impact on the environment and can be used on many different applications [20]. The other parts in the prototype are made of steel as well but are either thinner or thicker.

6.2.2 Ergonomic

During the tests of the concept there were two locks mounted on the air classifier, one on the feed inlet and one in the outlet on the bottom. The air locks that were installed were not easy to operate, requiring a lot of strength and were installed in a bad way, making it hard to operate. However if the air classifier would be installed in an existing system the feeding inlet would be connected and sealed with the previous stage of the system and the lock would not be necessary since there would be a constant feed. The outlet would go into a sealed bin and no lock would be necessary. Removing these two locks there would not be anything to operate on the concept making the ergonomic pleasant since it would be a standalone prototype.

6.2.3 Economics

Looking at the cost calculations (Appendix 7), the production costs for the air classifier would be 23.362 SEK making it pass the limit for the cost requirement, set to 50.000 SEK. The easy design of the prototype makes every section of the concept easily reachable and the maintenance costs should not be expensive either.

6.2.4 Maintenance

The maintenance cost is low, however since glass have not before been tested and depending on how much the prototype will be used the life of the sheet metal is hard to determine and may vary. There are no moving parts that can break leaving the only tear of the prototype to the glass. However the prototype should last at least 30 years but the two sections below the feed inlet may be worn faster but because of the simple design they can easily be replaced.

6.2.5 Chemicals

There are no chemicals used for either building or using the concept. If wanted the concept can be painted but it is not necessary.

6.2.6 MRT Requirement specification

Looking at the requirement specification table (Table 6.1) the prototype manages well. Almost the entire requirement specification table has been fulfilled with only two requirements marked with yellow.

Table 6.1 - Shows if the requirement specifications are met

[illegible]		
Specification	Requirement	Result
Feed capacity	200-600 kg/h	> 120 kg/h
Goal value of Hg	< 5ppm	—
Production cost	< 50.000 SEK	23.363 SEK
Maximum height	2 meters	1,63 m
Durability	> 30 years	> 30 years
Weight	< 100 kg	103,1 kg
Air inlet	Minimum of one	One
Air-flow	Adjustable	Adjustable

If the result is marked green the requirement is met, if it is marked yellow it is uncertain or nearly met.

The reason why the feed capacity is lower is because it was hard to adjust the material to be fed evenly over the channel. The case during the tests was that the material that was fed came in a lump where the air could not carry all the material which made some material fall straight through the turbulence. This was the main reason for the material to fall straight through the channel. If there would be an even volume of material entering the channel the results may have been different.

The value of mercury, Hg, was hard to determine since it depended on the start value which was not measured. The results only showed indications on how well the prototype performed in comparison to the sieve the MRT is using. To get a more correct value and to make a better comparison of how well the prototype is performing it has to be installed in an existing system and be running for a while. This was however not possible during the period of thesis due to time restrictions.

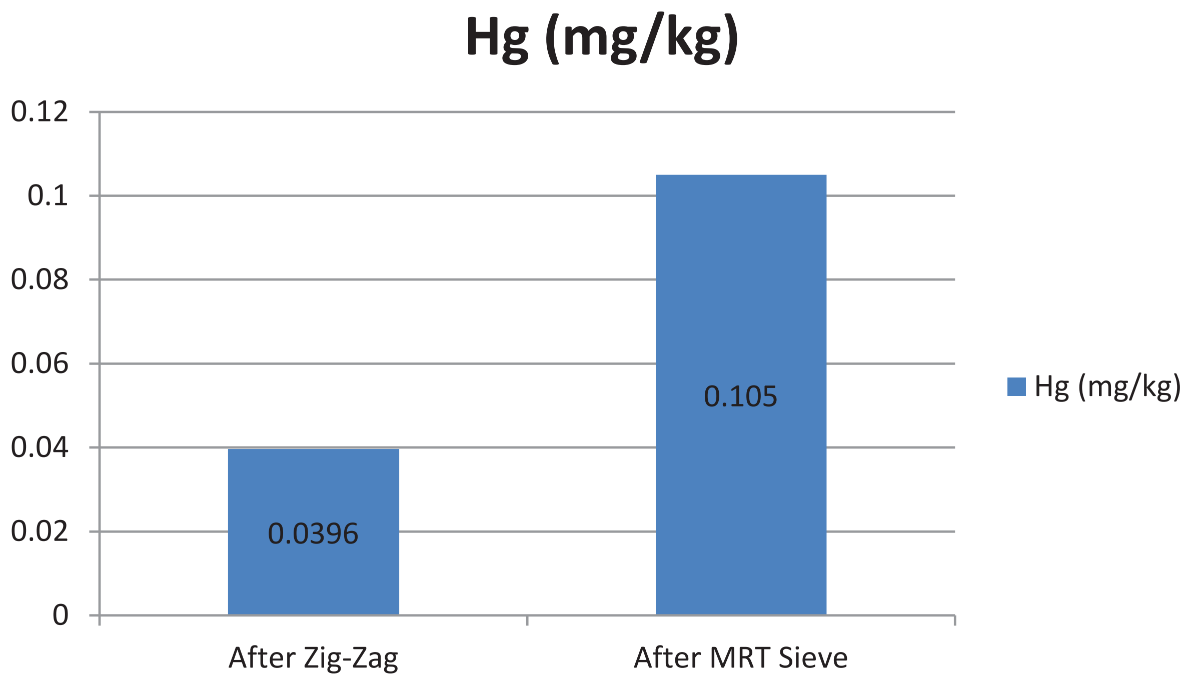
6.3 Have the goals been met?

By examining different air classifiers in the study and using methods to determine and develop a functional prototype the goal for this thesis was achieved.

The goal with this thesis was to through a study come up with a prototype to reduce the mercury contaminated fluorescence powder that had been coated on the inside of fluorescence lamps. In this thesis different existing alternatives that separate two materials from each other only by using air and gravitation have been studied and described. From the study existing alternatives were studied and concepts were developed through different brainstorming sessions. Looking at the requirement specifications and how the different existing alternatives were designed; one final concept was chosen which best met the requirement that was posed.

The concept developed was later built into a prototype which was tested with different mixes of materials at different air- flows and speeds to get a good base for comparison. Material that was taken from the sieve from MRT that is filling the same purpose as the prototype was sent to analysis together with material from the prototype to see the difference of separation efficiency.

Table 6.2 - Shows the amount of mercury on the glass after analysis



The table (Table 6.2) shows that there is a difference between the two materials, material 1 from the prototype and the material from the MRT sieve that have gone through the separation process. Both of the materials are taken from the same source, just after the material have been crushed and are therefore good for comparison on how well the prototype is preforming against the sieve MRT is using. However, since the levels of mercury is very low these results should only be used as an indication on how the different separations units preforms and not be taken as a final result.

7 Discussion

The final concept is much like a regular Zig-Zag that was studied during the study but with the advantage of the adjustability of the height depending on what situation it is going to be used in. This kind of modular system was not found during the study and is a good solution that is a result of the brainstorming sessions.

When deciding the final design of the concept the material that was going to be used was discussed with the personnel at MRT. It was decided to build the whole prototype with sheet metal to shorten the production time so tests could be made before the end of the thesis. The difference from the original concept was foremost that the flanges should be thicker and made out of flat steel to give a more stable construction to guarantee the life time of the air classifier. The prototype that was built had no stability issues or did not suffer from any effects of the changes material specifications. The concept may be using stronger material than what is needed for its purpose, making it more expensive than what is necessary. Looking at the production cost for the concept that was developed and not the prototype that was built, the material cost ended at 2.962 SEK and together the hourly price of the employee building it the cost ended at 23.362 SEK. This is well below the 50.000 SEK that was set as the maximum production cost for the prototype.

The two materials that MRT need to have separated from each other are different from what the materials that is commonly in an air classifier. No air classifier that was studied during the study used glass and powder as separation materials, the materials that were used with the studied air classifiers was granulating with different kind of powders. The big difference between granulate and glass is the density and that glass is harder than granulate. With a heavier material the air- flow and speed needs to be stronger and therefore calculations was made to get an estimation of how strong the air- flow and speed needed to be. With harder material circulating the channel the wear of the channel will be increased which also needs to be considered before any full scale use will begin. In the study there was slim to none information on what strength of air- speeds and flows that was used during the tests and therefore there were a lot of the trial and error technique used to determine the correct values.

The air- flow and speed was also measured with a tool to see the actual values. When comparing the calculations with the measured values they were consistent with measurement at the lowest speed of the vacuum cleaner, 40 Hz. This speed later turned out to not be strong enough to give the separation efficiency requested by the requirement specification. Errors in the calculation can be that it is calculated that the air- flow and speed are consistent over the whole channel. This is not the case since the main air-flow takes the strongest way through the channel and weaker air- flow and speed are created closer to the channel walls. The air- flow and speed is also stronger higher up in the channel, one reason for this can be that there is a leakage in the material feed. If the prototype will be installed in an existing system this will not happen because the material feed will be sealed.

After the tests was made with the air- flow and speed, crushed glass was used to see how it was moving in the channel and to give an feeling for which speed that was going to be used when the final tests were made. The results were that the 40 Hz was too weak and it was decided to use 45, 50 and 55 Hz with three different materials tested at each setting to give a more varied result.

The material was weighed before and after the tests and together with the visual comparison that was made between the materials it was decided that three materials from 50 Hz was going to be sent for analysis to measure the amount mercury left on the glass. With the tests a bag with the same amount of material from the sieve that MRT is using was packaged. This was done to later be able to compare how well the prototype was performing looking at the sieve from MRT.

The results were good and the glass from the prototype contained less mercury than the glass from MRT's sieve. However since the mercury levels were so low the results should only be seen as an indication and therefore cannot be used to see final result of the amount of mercury on the glass. To get a real comparison, the prototype should be installed in an existing system and be running for a while to get a better basis for comparison and a more precise measurement. It should also be tested with fewer and more sections installed to see how the performance would be affected.

The prototype developed is fulfilling all of the specifications except for two, *Feed capacity* and *Goal value of Hg* on the requirement specification that was set for the final prototype. The two specifications that were not met were hard to measure and needs more testing to be determined, preferable in an existing system to simulate a real process as possible. The material had to manually be fed into the system but it will be automatic if the prototype is installed in an existing system which will result with a more even feeding pace and a better spread over the channel.

The biggest advantage with the developed prototype is that the height can be adjusted depending on what height that is required for the prototype to fit, this opens the opportunities for more customers that would be interested. It also facilitates the possibility for developing new sections with new designs since it is easy to install new sections.

This thesis will hopefully contribute to a wider knowledge of how a dry air classifier works and increase the efficiency of removing mercury contaminated fluorescence powder from lamp glass so there will be less mercury in use in the future.

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Appendix 1 - Material safety data sheet for NP-340

SÄKERHETSDATABLAD NP-340

Utfärdat: 2003-02-07 Versionsnummer:2 Omarbated: 2003-03-03 Sida:1/3

1. NAMNET PÅ PRODUKTEN OCH FÖRETAGET

NP-340

Användningsområde / Funktion: Fluoriserande lampor
Levrantör: Nichia Chemical Europe GmbH, Südwestpark 60, D-90449 Nürnberg, Tyskland
Telefon: +49-911-996-8621
Telefax: +49-911-996-8611
www address: www.nichia.de
Utfärdat av: Alexandra Beedman e-mail: beeman@nichia.de
Nödtelefonnummer:
Giftinformationscentralen 112

2. SAMMANSÄTTNING / ÄMNENAS KLASSIFICERING

Kemist ämne	EG-No.	CAS-No.	Halt/konc.	Symbol(er):	R-fras(er):
Yttriumoxid, europium-doped	271-591-2	68585-82-0	100%	-	-

3. FARLIGA EGENSKAPER

BETYDELSEFULLASTE RISKER:
Ej märkningspliktig produkt

4. FÖRSTA HJÄLPEN

GENERELL REKOMMENDATION
Visa detta varuinformationsblad för jourhavande läkare.
FÖRTÄRING
Ge genast ett par glas mjölk eller vatten att dricka om den skadade är vid fullt medvetande.
Till läkare/sjukhus om en större mängd förtärts.
INANDNING
Frisk luft och vila.
Eventuell andningsjälp.
Kontakta läkare om besvär kvatstår.
HUDKONTAKT
Tag genast av nedstänkta/förorenade kläder/skor.
Tvätta huden med tvål och vatten.
Kontakta läkare om besvär uppstår.
ÖGONKONTAKT
Skölj genast med vatten i flera minuter. Håll ögonlocken brett isär.
Kontakta läkare om besvär kvarstår.
ALLMÄN INFOMATION
Vid minsta osäkerhet eller om besvär kvarstår, kontakta läkare. Ge aldrig vätska eller framkalla kräkning om pesonen är medvetslös.

5. ÅTGÄRDER VID BRAND

LÄMPLIGA BRANDSLÄCKNINGSMEDEL
Släckmedel väljs med hänsyn till brandtyp.
ÖVRIG INFORMATION
Kyl utsatta förpackningar med vatten och avlägsna om möjligt från brandhärden.

SÄKERHETSDATABLAD NP-340

Utfärdat: 2003-02-07 Versionsnummer:2 Omarbated: 2003-03-03 Sida:2/3

6. ÅTGÄRDER VID SPILL / OAVSIKTLIGA UTSLÄPP

FÖSRSIKTIGHETSÅTGÄRDER BETRÄFFANDE MILJÖN

Undvik förorening av vattendrag och avlopp.

ÅTGÄRDER VID OMHÄNDERTAGANDE AV SPILL

Valla in spill absorberande material, såsom t ex sand, torr jord, vermikulit eller annat lämpligt. Samla upp och destruera.

7. HANTERING OCH LAGRING

FÖREBYGGANDE SKYDDÅTGÄRDER

Hälsofarlig vara bör förvaras svårkomligt för små barn och avskilt från produkter som är avsedda att ätas.

REKOMMENDATION FÖR SÄKER HANTERING

Normal industrihygien skall iakttagas. Ingen särskild hanteringsförskrift är nödvändigt.

LAGRING

Förvaras svalt i väl ventilerat utrymme borta från starka syror och oxiderande ämnen.

8. BEGRÄNSNING AV EXPONERING / PERSONLIGA SKYDDSÅTGÄRDER

ANDNINGSSKYDD

Sörj för god ventilation.
Använd andningsskydd när damm alstras.

SKYDDSHANDSKAR-GENOMBROTTSTID

Skyddshandskar är rekommenderade.

ÖGONSKYDD

Använd skyddsglasögon

ÅTGÄRDER BETRÄFFANDE HYGIEN

Normal industrihygien skall iakttagas. Byt förorenade kläder och tvätta händerna efter arbetes slut.

9. FYSIKALISKA OCH KEMISKA EGENSKAPER

Form	Pluver
Färg	Vit
Densitet	5.05
Löslighet i vatten	Olöslig
Lukt	Luktlös

10.STABILITET OCH REAKTIVITET

STABILITET

Stabil vid normala förhållanden.

FÖRHÅLLANDEN SOM SKALL UNDVIKAS

Undvik kontakt med starka syror.
Yttriumoxid absorberar koldioxid och ammoniak från luft.

11.TOXIKOLOGISK INFORMATION

AKUT TOXICITET

Inga uppgifter finns om ämnet

LOKALA EFFEKTER(inandning, förtäring, ögon-och hudkontakt)

Inga uppgifter finns om ämnet

SÄKERHETSDATABLAD NP-340

Utfärdat: 2003-02-07 Versionsnummer:2 Omarbated: 2003-03-03 Sida:3/3

12.EKOTOXIKOLOGISK INFORMATION

RÖRLIGHET

Olöslig i vatten.

EKOTOXICTET

Produkten har inga kända.

13.AVFALL

AVFALL FRÅN ÖVERSKOTT/OANVÄNDA PRODUKTER

Destrueras i enlighet med myndigheternas rekommendationer och gällande lagstiftning.

RESTAVFALL/OANVÄNDA PRODUKTER

Avafalls kod: 10 03 05; Andra metalloxider än de som anges i 06 03 15.

14.TRANSPORT INFORMATION

Ej klassad som farligt gods enligt ADR/RID/IMO/DGR.

15.GÄLLANDE BESTÄMMELSER

Ej märkningspliktig produkt

16.ÖVRIG INFORMATION

KÄLLOR

KIFS 2001: 3, KIFS 2001 : 4, www.kemi.se,

REFERENSER TILL YTTERLIGARE INFORMATION

Denna information är ett komplement till annan information. Användaren måste själv avgöra om informationen är tilläcklig. Ansvarig för produktsäkerhet och fakta är Nichia Chemical Europe GmbH. Säkerhetsdatabladet har upprättats under medverkan av Amasis Konsult AB, Solna.

Appendix 2 - Material safety data sheet for NP-107

SÄKERHETSDATABLAD NP-107

Utfärdat: 2003-02-07 Versionsnummer:2 Omarbated: 2003-03-03 Sida:1/3

1. NAMNET PÅ PRODUKTEN OCH FÖRETAGET

NP-107
Användningsområde / Funktion: Fluoriserande lampor
Levrantör: Nichia Chemical Europe GmbH, Südwestpark 60, D-90449 Nürnberg, Tyskland
Telefon: +49-911-996-8621
Telefax: +49-911-996-8611
www address: www.nichia.de
Utfärdat av: Alexandra Beedman e-mail: beeman@nichia.de
Nödtelefonnummer:
Giftinformationscentralen 112

2. SAMMANSÄTTNING / ÄMNENAS KLASSIFICERING

Kemist ämne	EG-No.	CAS-No.	Halt/konc.	Symbol(er):	R-fras(er):
Barium,magnesium,Aluminat: (Europium)	264-456-4	63774-55-0	100%	-	-

3. FARLIGA EGENSKAPER

BETYDELSEFULLASTE RISKER:
Ej märkningspliktig produkt

4. FÖRSTA HJÄLPEN

GENERELL REKOMMENDATION
Visa detta varuinformationsblad för jourhavande läkare.
FÖRTÄRING
Ge genast ett par glas mjölk eller vatten att dricka om den skadade är vid fullt medvetande.
Till läkare/sjukhus om en större mängd förtärts.
INANDNING
Frisk luft och vila.
Eventuell andningsjälp.
Kontakta läkare om besvär kvatstår.
HUDKONTAKT
Tag genast av nedstänkta/förorenade kläder/skor.
Tvätta huden med tvål och vatten.
Kontakta läkare om besvär uppstår.
ÖGONKONTAKT
Skölj genast med vatten i flera minuter. Håll ögonlocken brett isär.
Kontakta läkare om besvär kvarstår.
ALLMÄN INFOMATION
Vid minsta osäkerhet eller om besvär kvarstår, kontakta läkare. Ge aldrig vätska eller framkalla kräkning om pesonen är medvetslös.

5. ÅTGÄRDER VID BRAND

LÄMPLIGA BRANDSLÄCKNINGSMEDEL
Släckmedel väljs med hänsyn till brandtyp.
ÖVRIG INFORMATION
Kyl utsatta förpackningar med vatten och avlägsna om möjligt från brandhärden.

6. ÅTGÄRDER VID SPILL / OAVSIKTLIGA UTSLÄPP

FÖSRSIKTIGHETSÅTGÄRDER BETRÄFFANDE MILJÖN

Undvik förorening av vattendrag och avlopp.

ÅTGÄRDER VID OMHÄNDERTAGANDE AV SPILL

Valla in spill absorberande material, såsom t ex sand, torr jord, vermikulit eller annat lämpligt. Samla upp och destruera.

7. HANTERING OCH LAGRING

FÖREBYGGANDE SKYDDÅTGÄRDER

Hälsofarlig vara bör förvaras svårkomligt för små barn och avskilt från produkter som är avsedda att ätas.

REKOMMENDATION FÖR SÄKER HANTERING

Normal industrihygien skall iakttagas. Ingen särskild hanteringsförskrift är nödvändigt.

LAGRING

Förvaras svalt i väl ventilerat utrymme borta från starka syror och oxiderande ämnen.

8. BEGRÄNSNING AV EXPONERING / PERSONLIGA SKYDDSÅTGÄRDER

ANDNINGSSKYDD

Sörj för god ventilation.
Använd andningsskydd när damm alstras.

SKYDDSHANDSKAR-GENOMBROTTSTID

Skyddshandskar är rekommenderade.

ÖGONSKYDD

Använd skyddsglasögon

ÅTGÄRDER BETRÄFFANDE HYGIEN

Normal industrihygien skall iakttagas. Byt förorenade kläder och tvätta händerna efter arbetes slut.

9. FYSIKALISKA OCH KEMISKA EGENSKAPER

Form	Pluver
Färg	Vit
Densitet	3.83
Löslighet i vatten	Olöslig
Lukt	Luktlös

10.STABILITET OCH REAKTIVITET

STABILITET

Stabil vid normala förhållanden.

FÖRHÅLLANDEN SOM SKALL UNDVIKAS

Undvik kontakt med starka syror.

11.TOXIKOLOGISK INFORMATION

AKUT TOXICITET

Inga uppgifter finns om ämnet

LOKALA EFFEKTER(inandning, förtäring, ögon-och hudkontakt)

Inga uppgifter finns om ämnet

SÄKERHETSDATABLAD NP-107

12.EKOTOXIKOLOGISK INFORMATION

RÖRLIGHET

Olöslig i vatten.

EKOTOXICTET

Produkten har inga kända ekotoxikologiska effekter.

13.AVFALL

AVFALL FRÅN ÖVERSKOTT/OANVÄNDA PRODUKTER

Destrueras i enlighet med myndighetemas rekommendationer och gällande lagstiftning.

RESTAVFALL/OANVÄNDA PRODUKTER

Avafalls kod: 10 03 05; Aluminiumoxidavfall

14.TRANSPORT INFORMATION

Ej klassad som farligt gods enligt ADR/RID/IMO/DGR.

15.GÄLLANDE BESTÄMMELSER

Ej märkningspliktig

16.ÖVRIG INFORMATION

KÄLLOR

KIFS 2001: 3, KIFS 2001 : 4, www.kemi.se,

REFERENSER TILL YTTERLIGARE INFORMATION

Denna information är ett komplement till annan information. Användaren måste själv avgöra om informationen är tilläcklig. Ansvarig för produktsäkerhet och fakta är Nichia Chemical Europe GmbH. Säkerhetsdatabladet har upprättats under medverkan av Amasis Konsult AB, Solna.

Appendix 3 - Material safety data sheet for NP-220

SÄKERHETSDATABLAD NP-220

Utfärdat: 2003-02-07 Versionsnummer:2 Omarbated: 2003-03-03 Sida:1/3

1. NAMNET PÅ PRODUKTEN OCH FÖRETAGET

NP-220

Användningsområde / Funktion: Fluoriserande lampor
Levrantör: Nichia Chemical Europe GmbH, Südwestpark 60, D-90449 Nürnberg, Tyskland
Telefon: +49-911-996-8621
Telefax: +49-911-996-8611
www address: www.nichia.de
Utfärdat av: Alexandra Beedman e-mail: beeman@nichia.de
Nödtelefonnummer:
Giftinformationscentralen 112

2. SAMMANSÄTTNING / ÄMNENAS KLASSIFICERING

Kemist ämne	EG-No.	CAS-No.	Halt/konc.	Symbol(er):	R-fras(er):
Fosforsyra, lantansalt, cerium, terbium-dopad	-	95823-34-0	100%	-	-

3. FARLIGA EGENSKAPER

BETYDELSEFULLASTE RISKER:
Ej märkningspliktig produkt

4. FÖRSTA HJÄLPEN

GENERELL REKOMMENDATION
Visa detta varuinformationsblad för jourhavande läkare.

FÖRTÄRING
Ge genast ett par glas mjölk eller vatten att dricka om den skadade är vid fullt medvetande.
Till läkare/sjukhus om en större mängd förtärts.

INANDNING
Frisk luft och vila.
Eventuell andningsjälp.
Kontakta läkare om besvär kvatstår.

HUDKONTAKT
Tag genast av nedstänkta/förorenade kläder/skor.
Tvätta huden med tvål och vatten.
Frätskada skall vehandlas av läkare.

ÖGONKONTAKT
Viktigt! Skölj genast med vatten i flera minuter. Håll ögonlocken brett isär.

FÖRTÄRING
Ge genast ett par glas mjölk eller vatten att drivka om den skadade är vid fullt medbetande.
Framkalla ej kräkning.
Till läkare/sjkhus.

ALLMÄN INFOMATION
Vid minsta osäkerhet eller om besvär kvarstår, kontakta läkare. Ge aldrig vätska eller framkalla kräkning om pesonen är medvetslös.

SÄKERHETSDATABLAD NP-220

Utfärdat: 2003-02-07 Versionsnummer:2 Omarbated: 2003-03-03 Sida:2/3

5. ÅTGÄRDER VID BRAND

LÄMPLIGA BRANDSLÄCKNINGSMEDEL

Använd Koldioxid och pulver som släckmedel.

BRANDSLÄCKNINGSMEDEL SOM AV SÄKERHETSSKÄL INTE FÅR ANVÄNDAS

Använd ej vatten som släckmedel.

ÖVRIG INFORMATION

Kyl utsatta förpackningar med vatten och avlägsna om möjligt från brandhärden.

6. ÅTGÄRDER VID SPILL / OAVSIKTLIGA UTSLÄPP

FÖSRSIKTIGHETSÅTGÄRDER BETRÄFFANDE MILJÖN

Undvik förorening av vattendrag och avlopp. Ämnet får inte släppas ut så att det kan skada grundvattnet.

ÅTGÄRDER VID OMHÄNDERTAGANDE AV SPILL

Valla in spill absorberande material, såsom t ex sand, torr jord, vermikulit eller annat lämpligt. Samla upp och destruera.

7. HANTERING OCH LAGRING

FÖREBYGGANDE SKYDDÅTGÄRDER

Hälsofarlig vara bör förvaras svårkomligt för små barn och avskilt från produkter som är avsedda att ätas.
Ämnet får inte släppas ut så att det kan skada grundvattnet.
Tillståndspliktiga verksamheter med miljörapporten (NFS 2000:13 bil 2).

REKOMMENDATION FÖR SÄKER HANTERING

Arbetsplasten bör ha nöddusch och möjligheter till ögonspolning.

LAGRING

Förvaras svalt i väl ventilerat utrymme borta från starka syror och baser.

8. BEGRÄNSNING AV EXPONERING / PERSONLIGA SKYDDSÅTGÄRDER

ANDNINGSSKYDD

Sörj för god ventilation.
Använd andningsskydd Partikefilter P2.

SKYDDSHANDSKAR-GENOMBROTTSTID

Skyddshandskar är rekommenderade.

ÖGONSKYDD

Använd öganskydd vid risk för direktkontakt eller stank.

ÅTGÄRDER BETRÄFFANDE HYGIEN

Normal industrihygien skall iakttagas. Byt förorenade kläder och tvätta händerna efter arbetes slut.

9. FYSIKALISKA OCH KEMISKA EGENSKAPER

Form	Pluver
Färg	Vit
Densitet	5.20
Löslighet i vatten	Olöslig
Lukt	Luktlös

10.STABILITET OCH REAKTIVITET

STABILITET

Stabil vid normala förhållanden.

FÖRHÅLLANDEN SOM SKALL UNDVIKAS

Undvik kontakt med starka syror och baser.

11.TOXIKOLOGISK INFORMATION

AKUT TOXICITET

Inga uppgifter finns om ämnet

LOKALA EFFEKTER(inandning, förtäring, ögon-och hudkontakt)

Inga uppgifter finns om ämnet

12.EKOTOXIKOLOGISK INFORMATION

RÖRLIGHET

Olöslig i vatten.

EKOTOXICTET

Produkten på grund av sin låga pH-värde, kan skada miljön och grundvattnet.

13.AVFALL

AVFALL FRÅN ÖVERSKOTT/OANVÄNDA PRODUKTER

Destrueras i enlighet med myndigheternas rekommendationer och gällande lagstiftning.

RESTAVFALL/OANVÄNDA PRODUKTER

Avafalls kod: 06 01 06; Andra syror.

14.TRANSPORT INFORMATION

Ej klassad som farligt gods enligt ADR/RID/IMO/DGR.

15.GÄLLANDE BESTÄMMELSER

Ej märkningspliktig produkt

16.ÖVRIG INFORMATION

KÄLLOR

KIFS 2001: 3, KIFS 2001 : 4, www.kemi.se,

REFERENSER TILL YTTERLIGARE INFORMATION

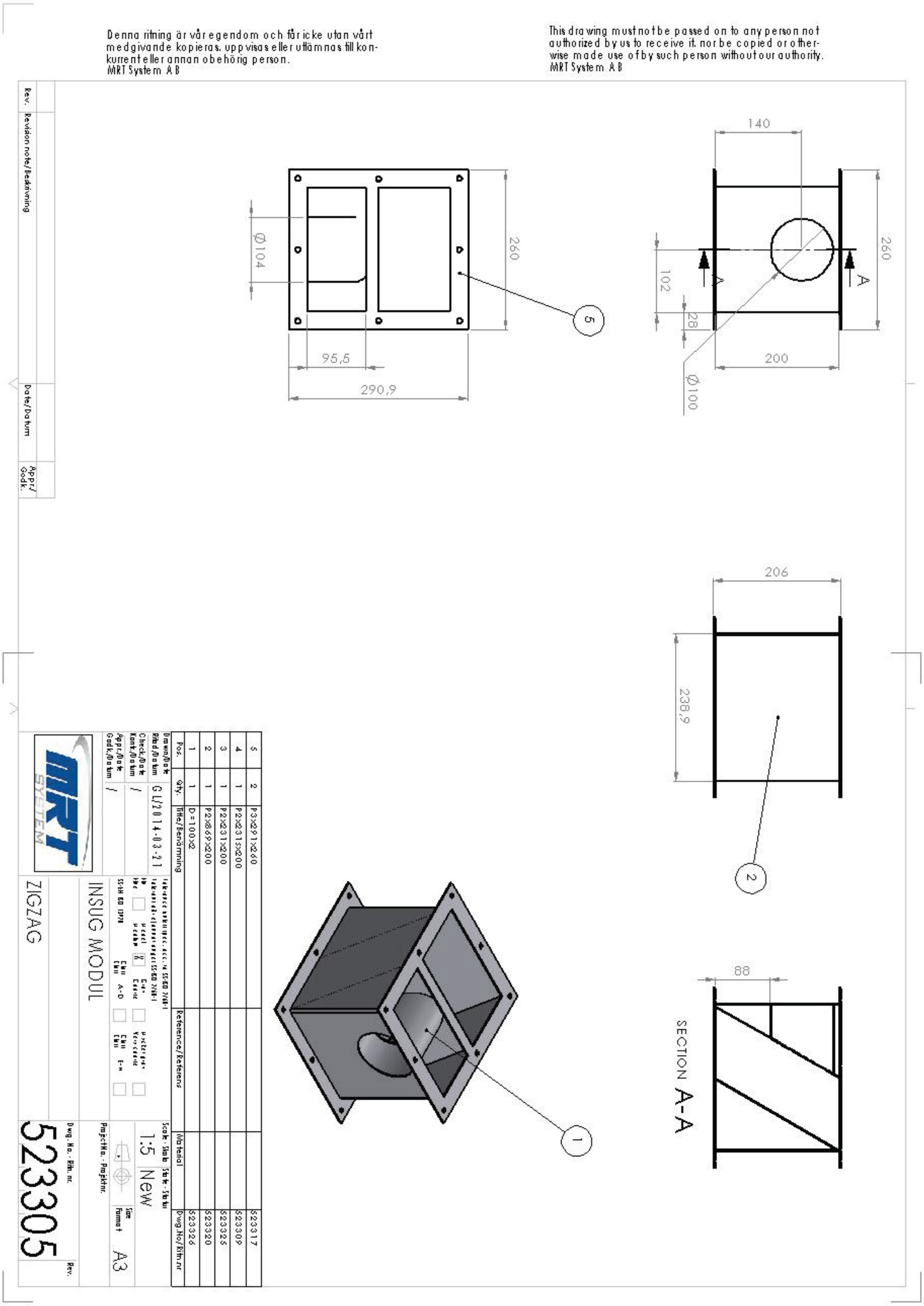
Denna information är ett komplement till annan information. Användaren måste själv avgöra om informationen är tilläcklig. Ansvarig för produktsäkerhet och fakta är Nichia Chemical Europe GmbH. Säkerhetsdatabladet har upprättats under medverkan av Amasis Konsult AB, Solna.

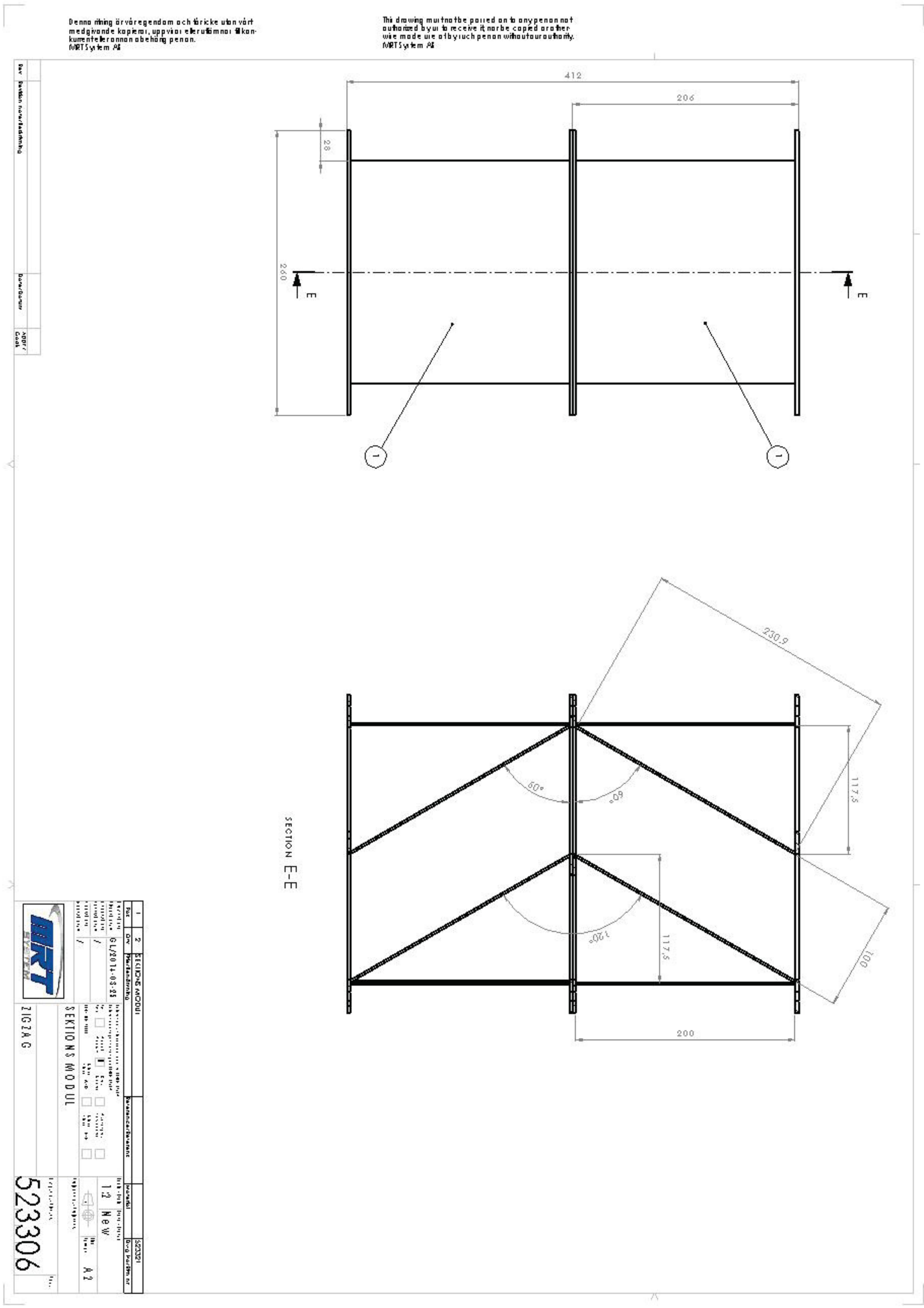
Appendix 4 - Pugh-Matrix

PUGH - MATRIX

	Weights	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5	Concept 6	Concept 7
Height	7	0	+1	0	+1	+1	0	+2
Production cost	5	0	-1	-1	-1	+1	-1	-1
Weight	1	0	-1	-1	0	+1	-1	-1
Environmental effect	3	0	0	-1	0	0	-1	0
Maintenance	4	0	-1	-1	+2	+1	-1	-1
Separation time	2	0	-1	-1	0	+1	-1	-1
Separation efficiency	6	0	+1	+1	0	-2	+2	+1
Totalt	– – –	0	-2	-4	+2	+3	-3	-1
Weighed	– – –	0	1	-9	10	7	-1	8

Appendix 5 - Drawings




Denna ritning är vår egendom och får icke utan vårt medgivande kopieras, uppvisas eller utlämnas till konkurrent eller annan obehörig person.
MRT System AB
This drawing must not be passed on to any person not authorized by us to receive it, nor be copied or otherwise made use of by such person without our authority.
MRT System AB
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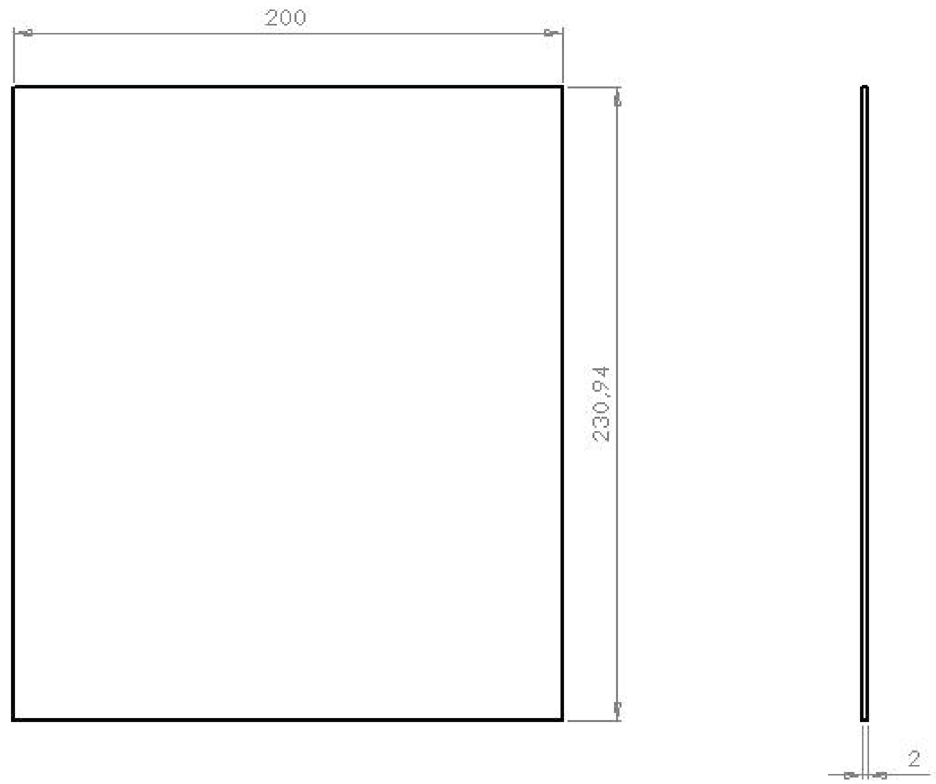
523306

Rev.	Revision note/Beskrivning	Date/Datum	Appr/ Godk.



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Check/Date Kontr./Datum	/
Appr./Date Godk./Datum	/
Scale - Skala	1:2
State - Status	New
Size Format	A4
ProjectNo. - Projektnr.	
Dwg. No. - Ritn. nr.	523308
Rev.	

P2x231x200

PLATTA

ZIGZAG

MRT SYSTEM

Rev.	Revision note/Beskrivning	Date/Datum	Appr./Godk.

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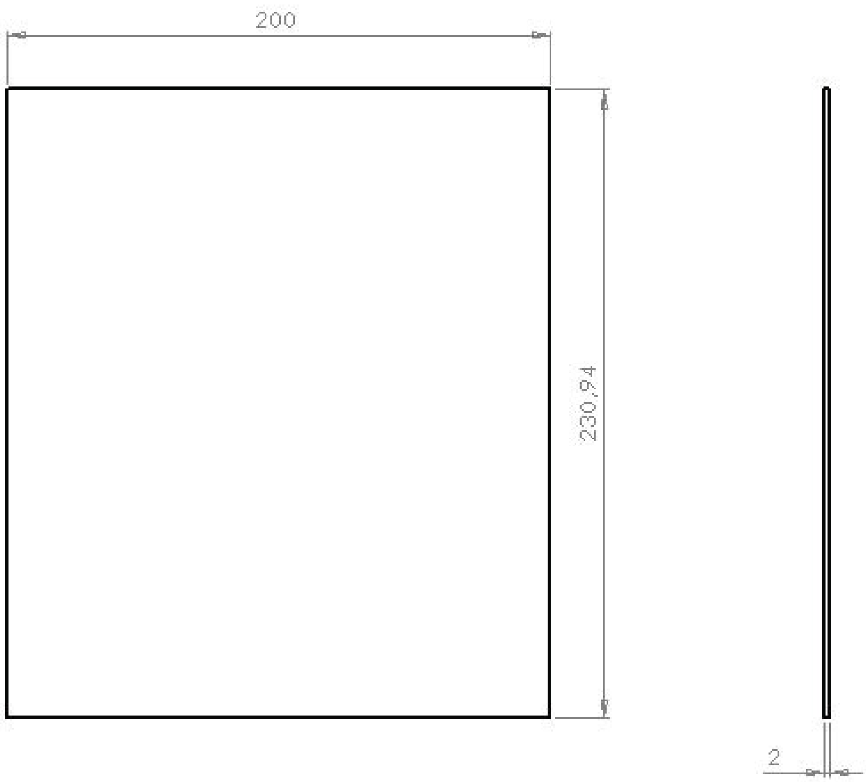

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Check./Date Kontr./Datum	/	State - Status: New
Appr./Date Godk./Datum	/	Size Format: A4
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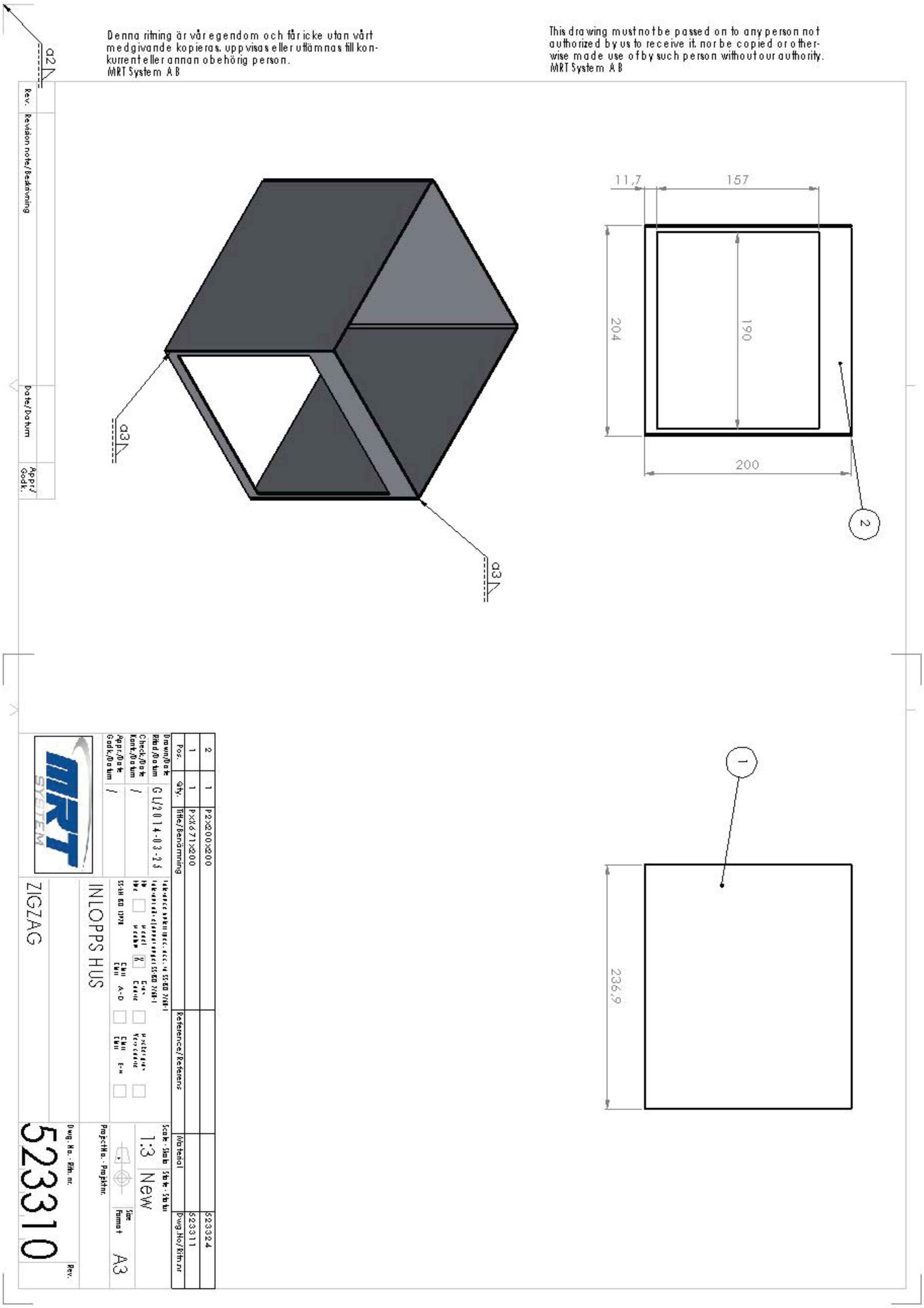
	PLATTA	Dwg. No. - Ritn. nr.: 523309
	ZIGZAG	Rev.

MRT SYSTEM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MRT System AB
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MRT System AB
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Revision note/Beskrivning
Date/Datum
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Dwg. No. - Ritn. nr.
523310
Rev.

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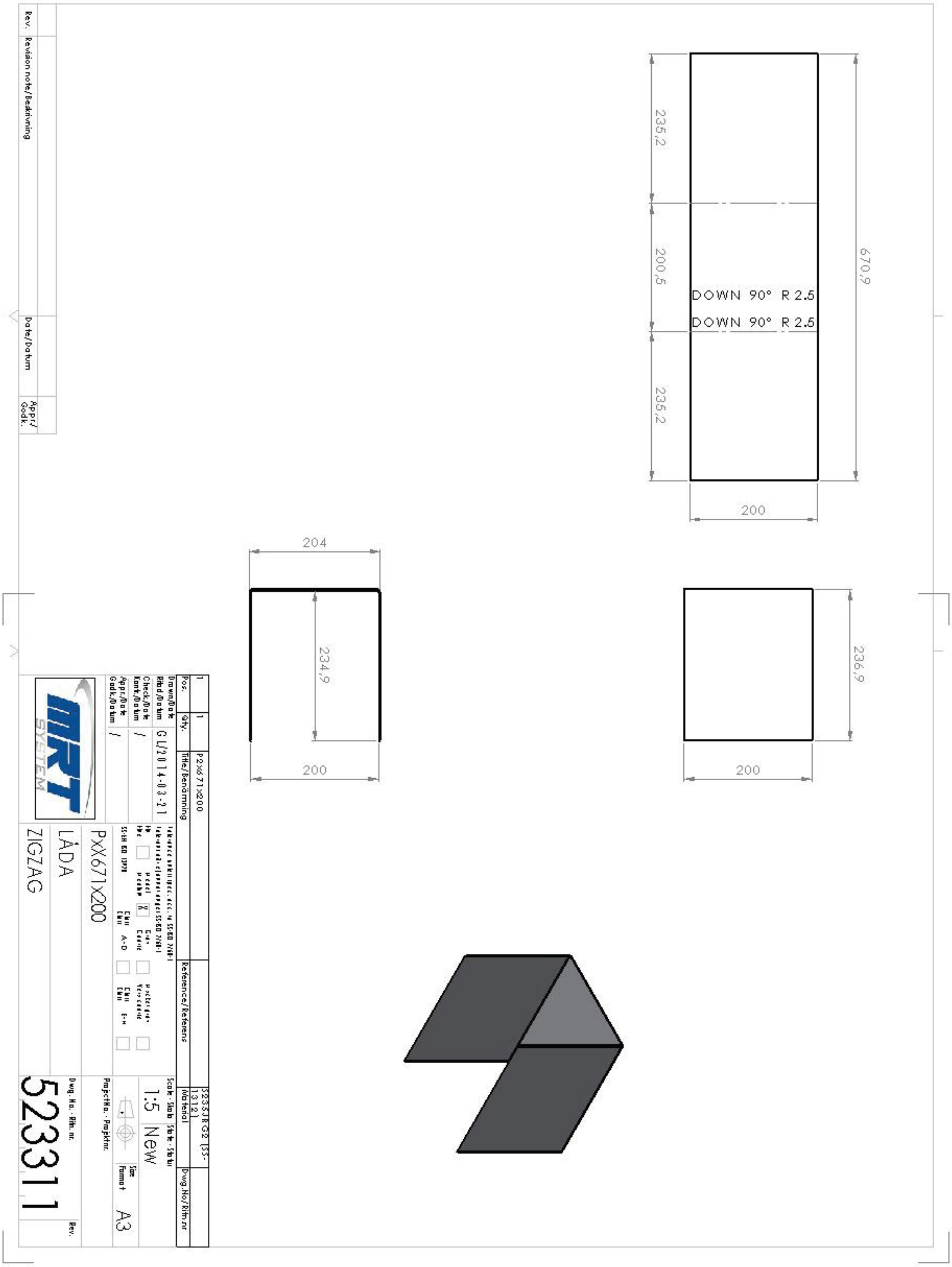
MRT System AB



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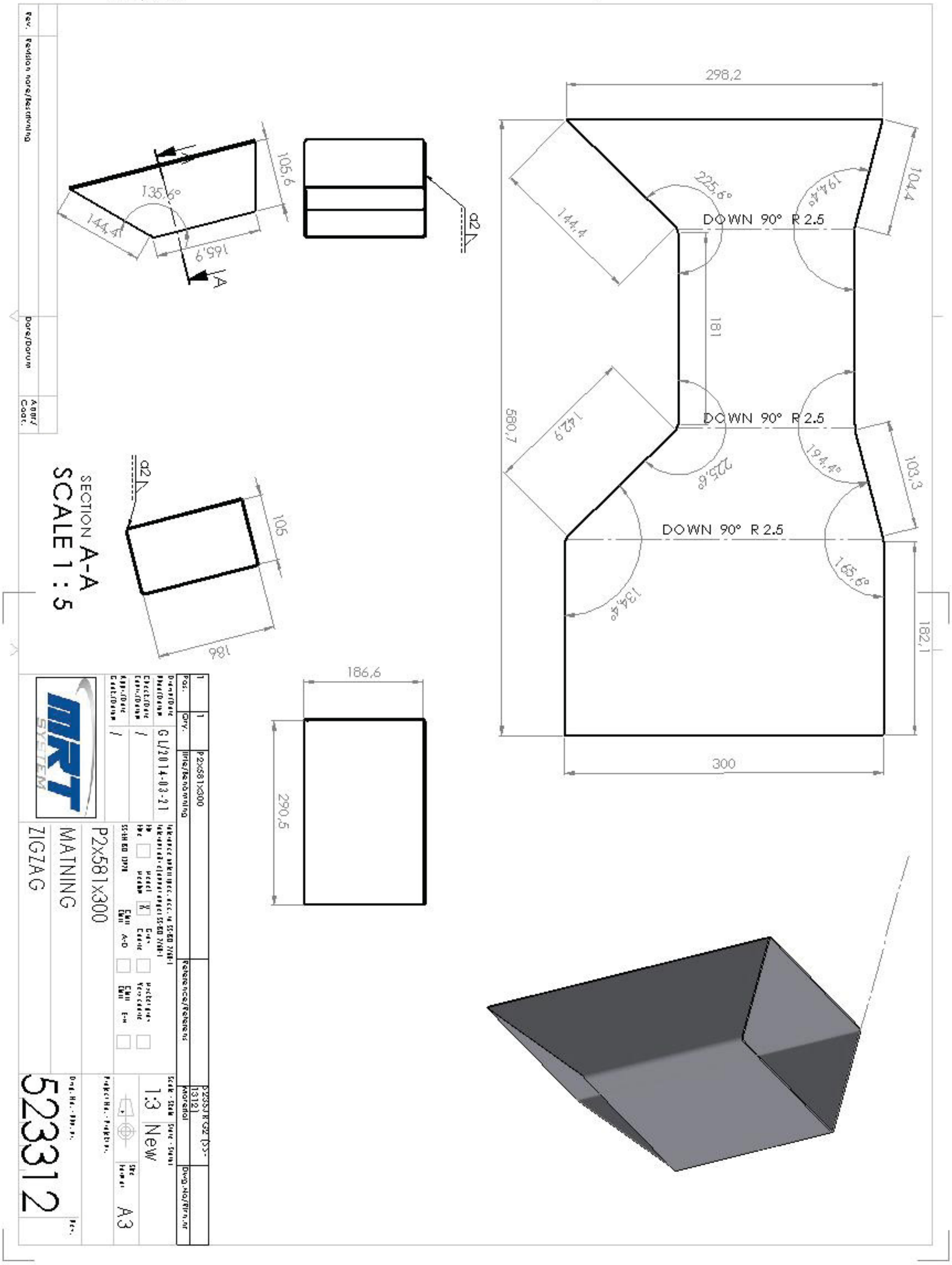
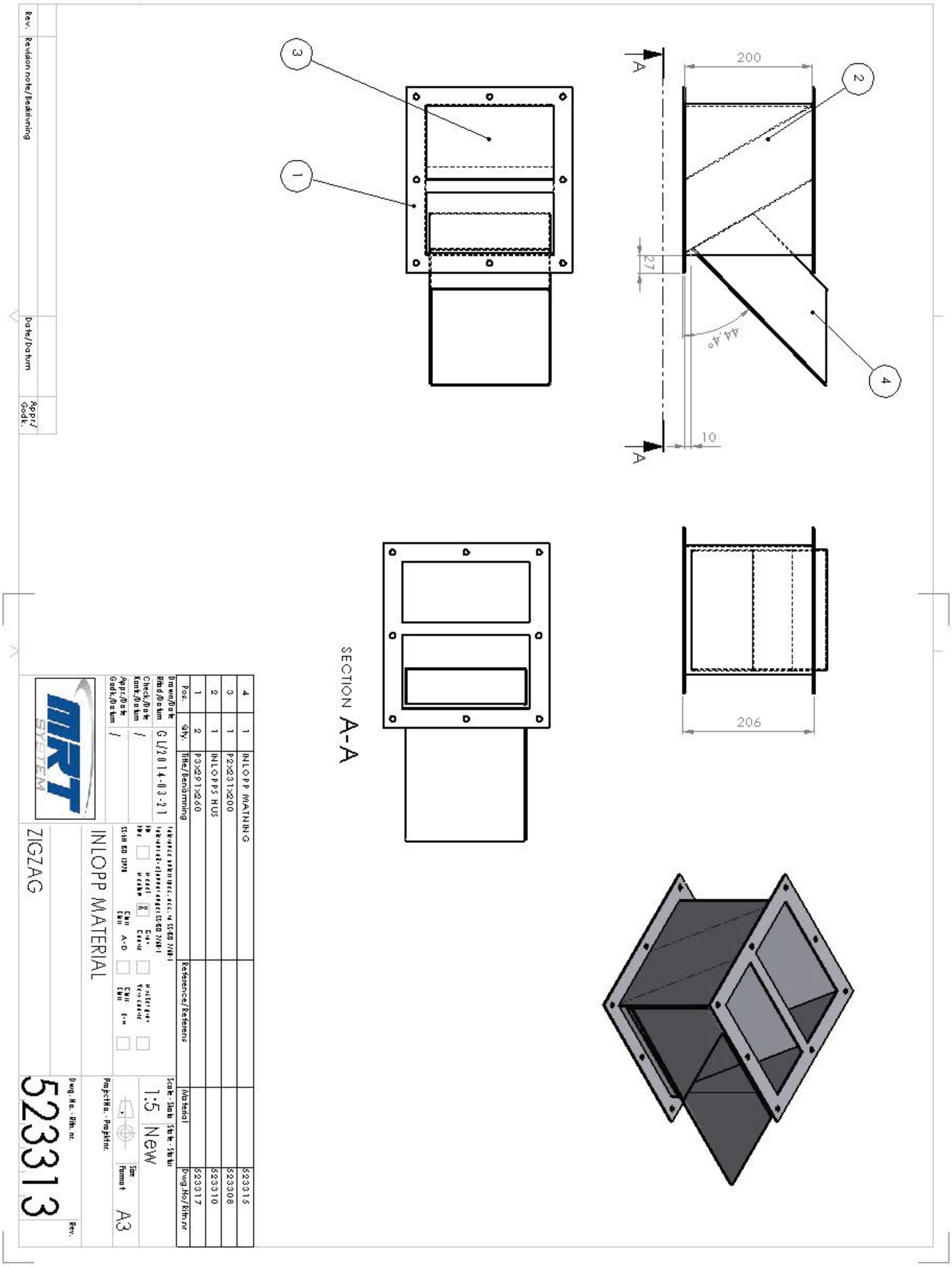
MRT System AB




Rev.
Revision note/Beskrivning
Date/Datum
Appr/Godk.
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3 1 P2X231X200 S23308
2 1 INLOPPS HUS S23310
1 2 P3X291X260 S23317
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Drawn/Date Ritad/Datum GL/2014-03-21
Check/Date Kontr./Datum /
Appr./Date Godk./Datum /
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Status - Status New
Size Format A3
ProjectNo. - Projektnr.
INLOPP MATERIAL
ZIGZAG
Dwg.No. - Ritn.nr. 523313
Rev.

Rev.	Revision note/Beskrivning	Date/Datum	Appr/ Godk.

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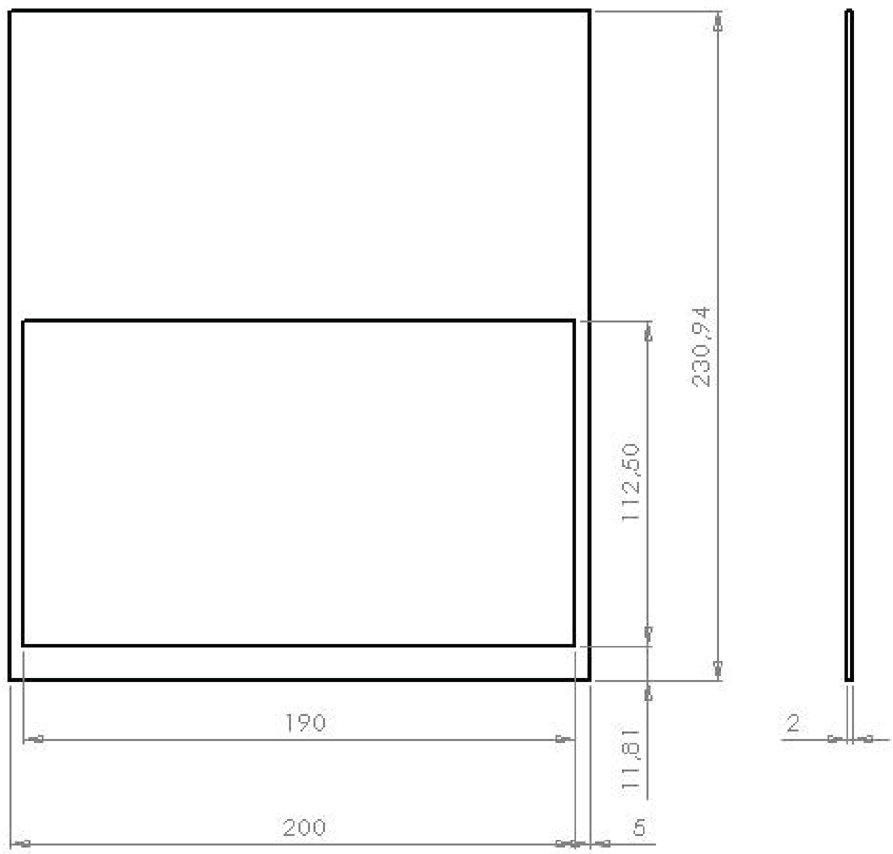

Denna ritning är vår egendom och får icke utan vårt medgivande kopieras, uppvisas eller utlämnas till konkurrent eller annan obehörig person. MRT System AB

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Pos.	Qty.	Title/Benämning	Reference/Referens	Material	Dwg.No/Ritn.nr

Drawn/Date Ritad/Datum	GL/2014-03-24	[illegible]	Scale - Skala 1:2 / State - Status New
Check/Date Kontr./Datum	/	[illegible]	Size Format A4
Appr./Date Godk./Datum	/	SS-EN ISO 13920 [illegible]	
MRT SYSTEM		P2x231x200	Project No. - Projektnr.
		PLATTA INMATNING	Dwg. No. - Ritn. nr. 523314 / Rev.
		ZIGZAG	

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MRT System AB

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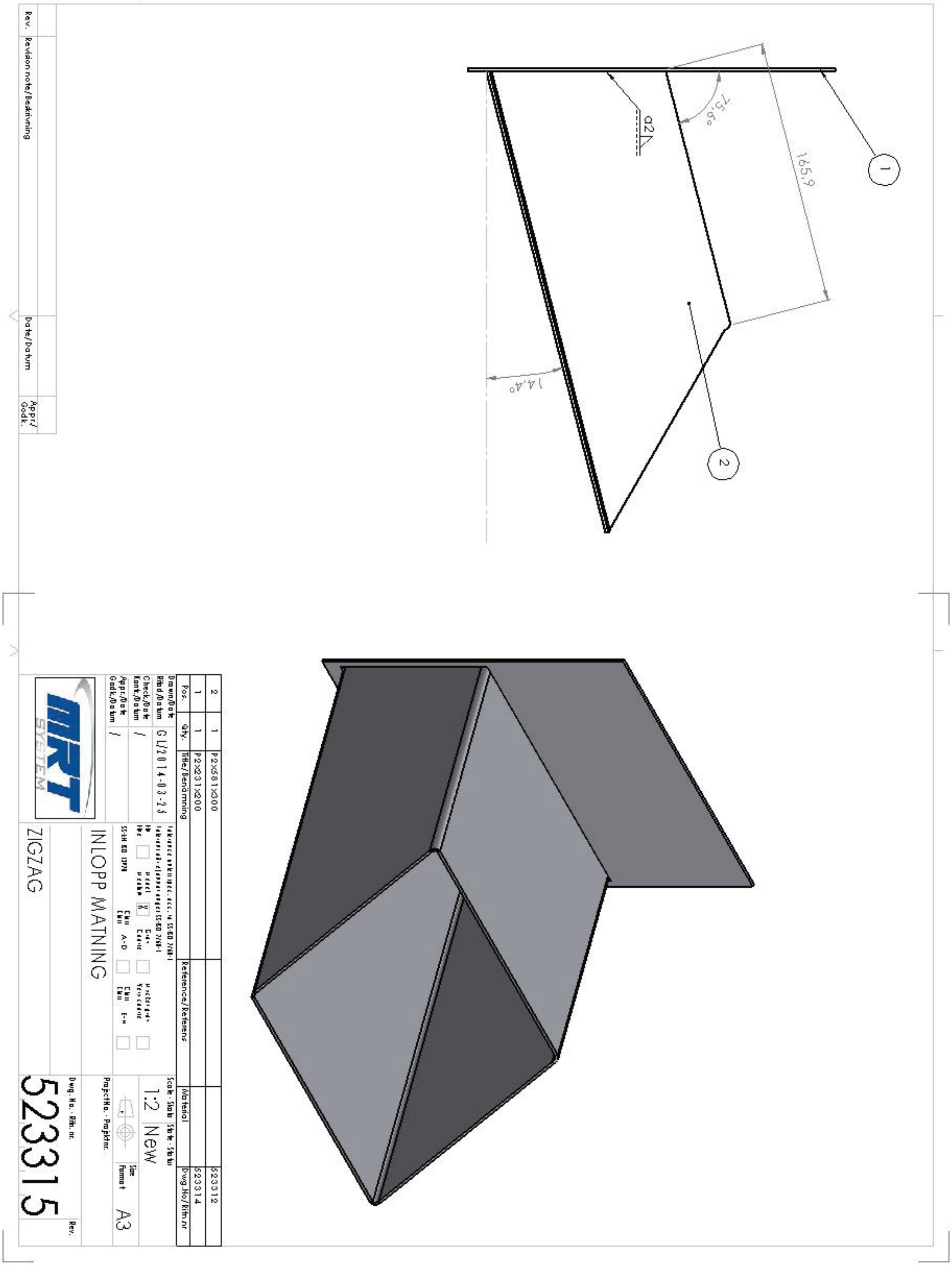
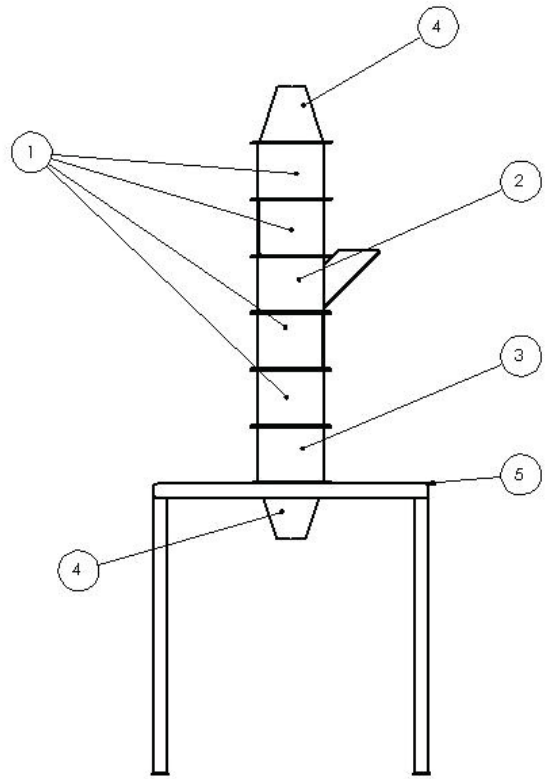
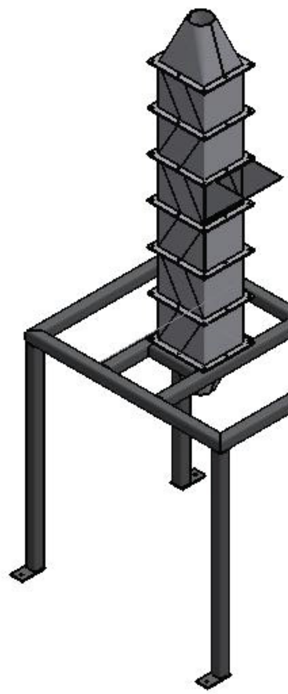
MRT System AB



Denna ritning är vår egendom och får icke utan vårt medgivande kopieras, uppvisas eller utlämnas till konkurrent eller annan obehörig person.
MRT System AB

This drawing must not be passed on to any person not authorized by us to receive it, nor be copied or otherwise made use of by such person without our authority.
MRT System AB





Pos.	Qty.	Title/Benämning	Reference/Referens	Material	Dwg.No/Ritn.nr
5	1	STÄLL			523327
4	2	TRATT			523322
3	1	INSUG MODUL			523305
2	1	INLOPP MATERIAL			523313
1	2	SEKTIONS MODUL			523306

Drawn/Date Ritad/Datum	GL/2014-03-25
Check/Date Kontr./Datum	/
Appr./Date Godk./Datum	/
Scale - Skala	1:15
State - Status	New
Size Format	A3
Project No. - Projektnr.	
Dwg. No. - Ritn. nr.	523316
Rev.	

Rev.	Revision note/Beskrivning	Date/Datum	Appr./Godk.

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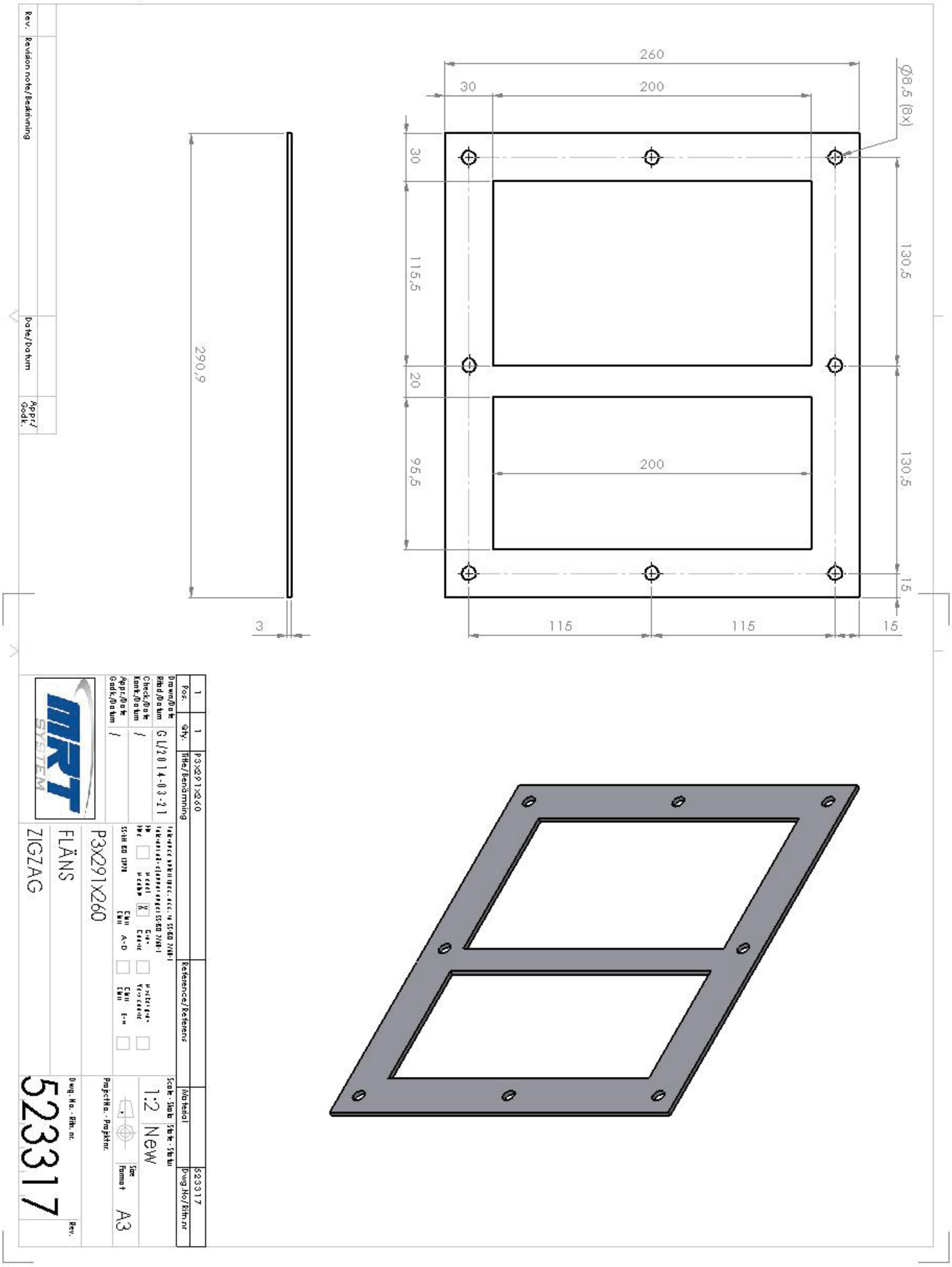
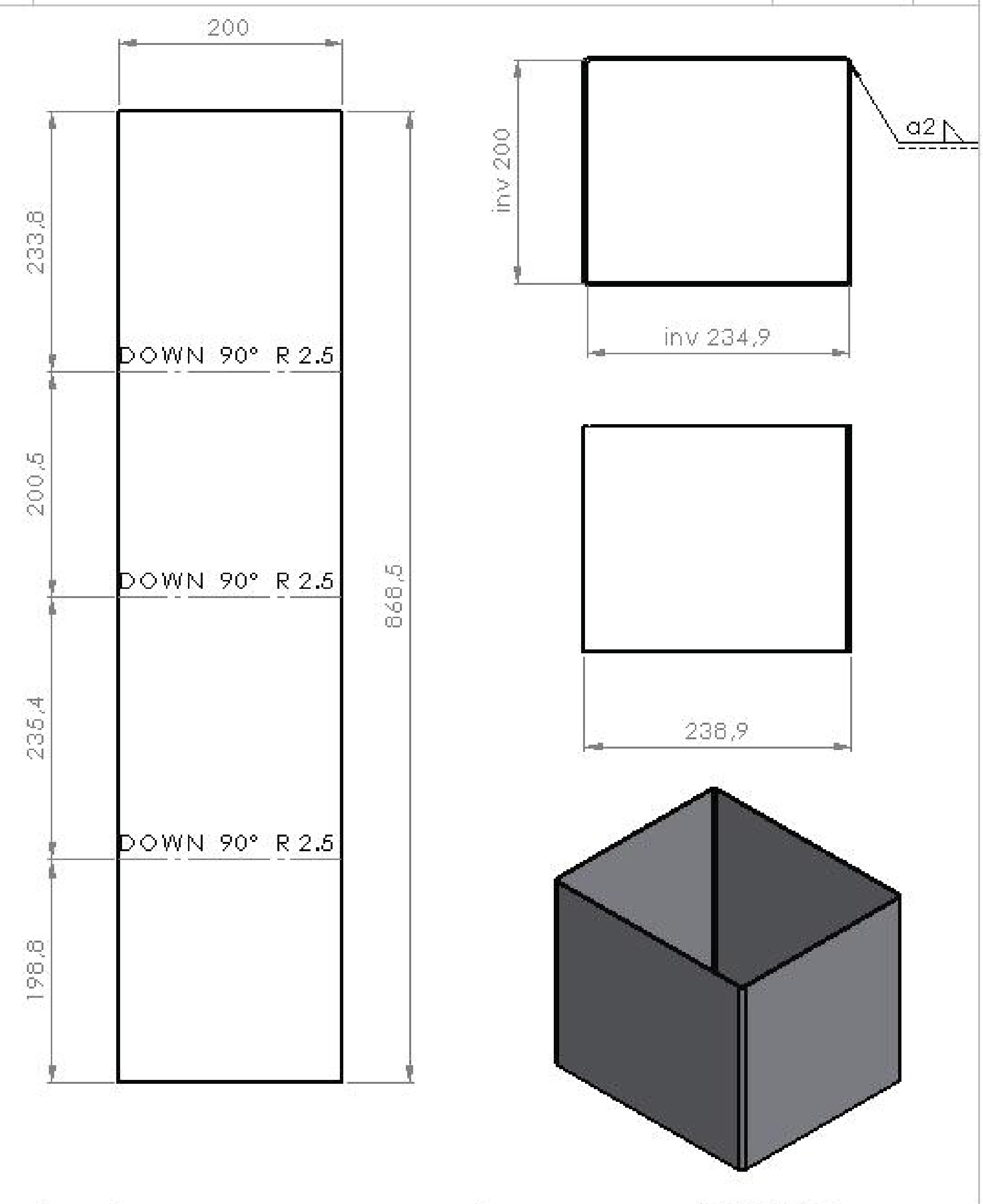


Rev.	Revision note/Beskrivning	Date/Datum	Appr./Godk.



Pos.	Qty.	Title/Benämning	Reference/Referens	Material	Dwg.No/Ritn.nr
1	1	P2x869x200		S235JRG2 (SS-1312)	

Drawn/Date Ritad/Datum: GL/2014-03-24

Check./Date Kont./Datum: /

Appr./Date Godk./Datum: /

Scale - Skala: 1:5

State - Status: New

Size Format: A4

Project No. - Projektnr.

P2x869x200

LÅDA

ZIGZAG

Dwg. No. - Ritn. nr. 523319

Rev.

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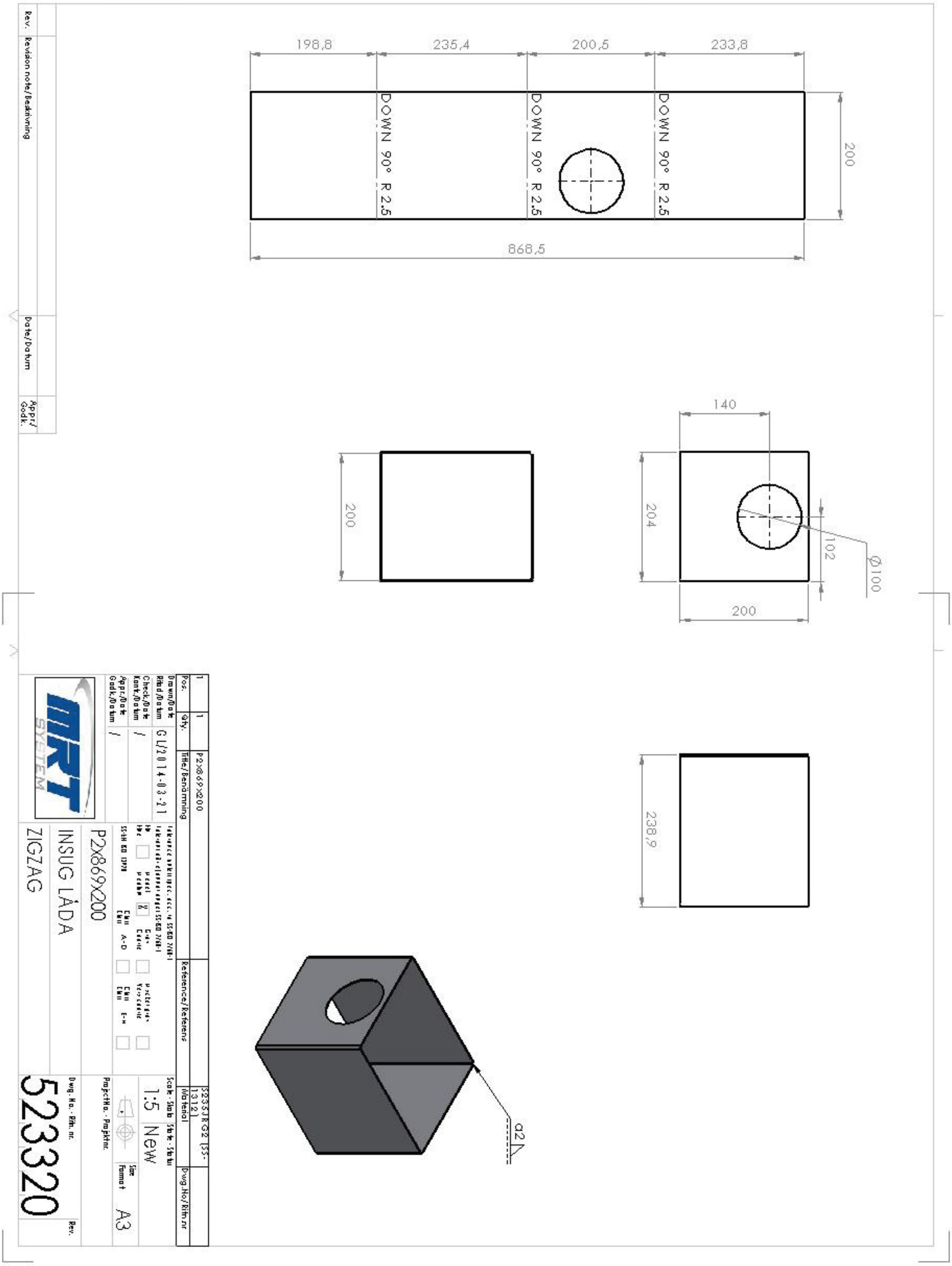

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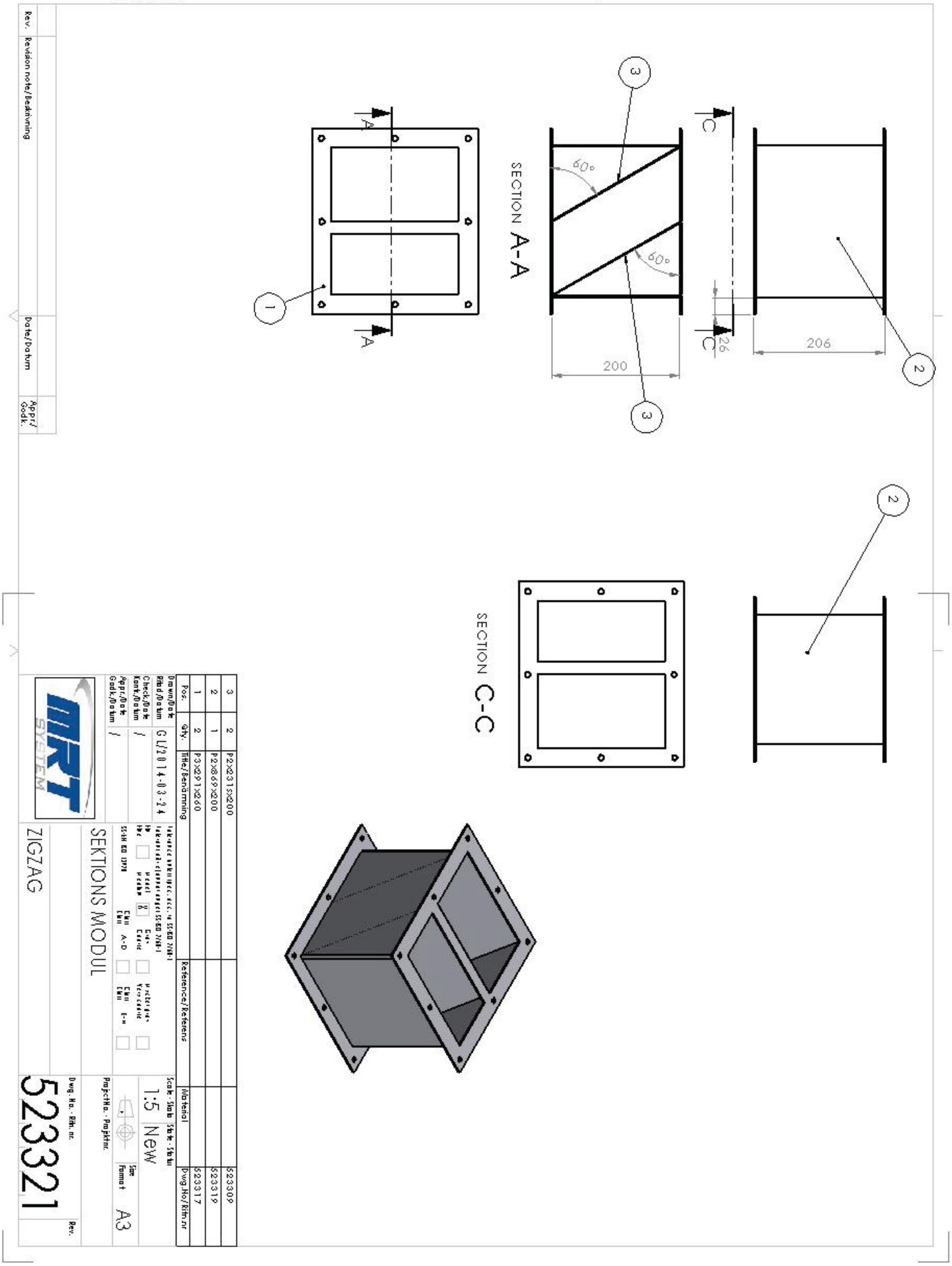

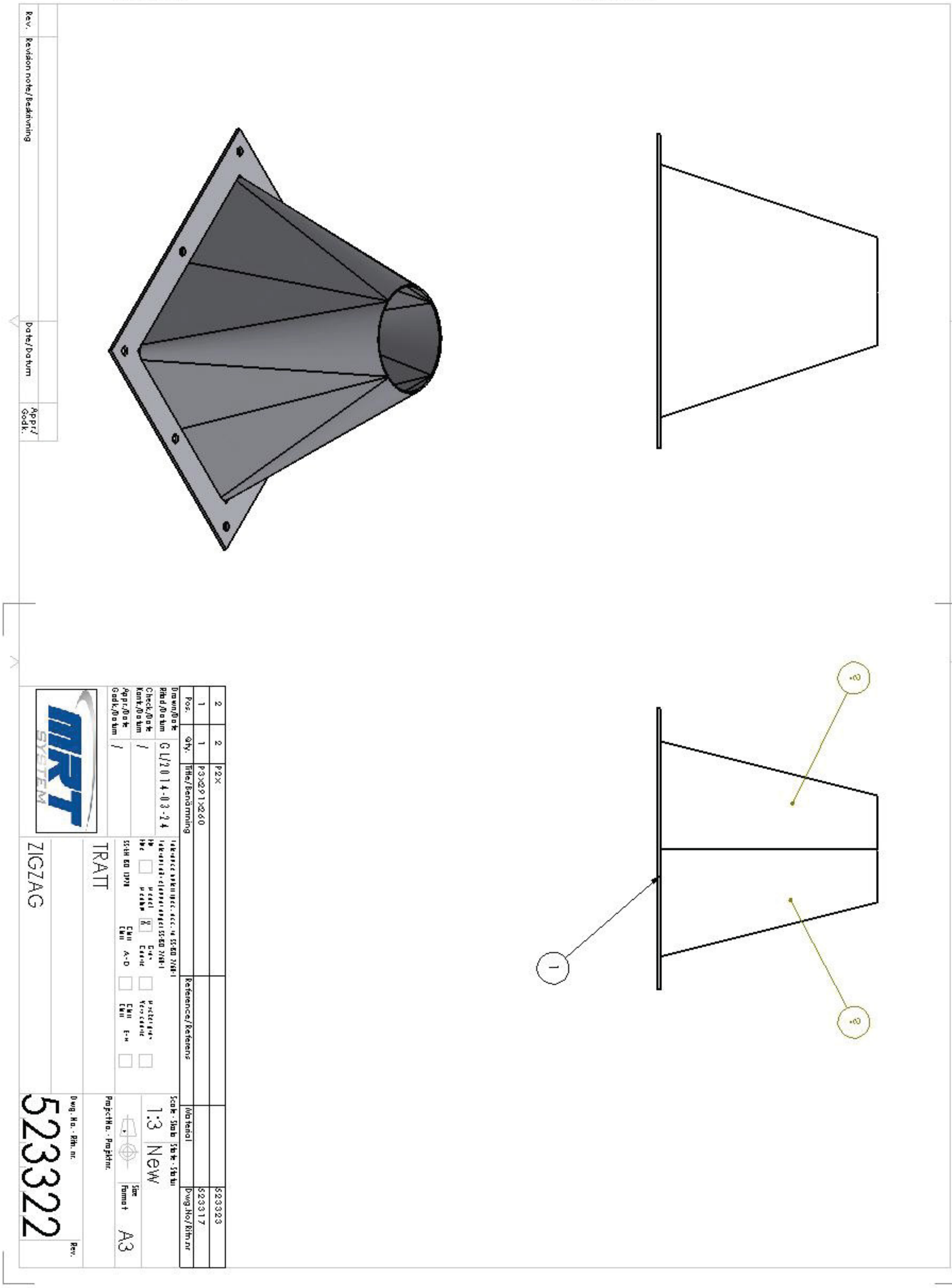
Rev.
Revision note/Beskrivning
Date/Datum
Appr/ Godk.
1
2
2
2 | 2 | P2X | 523323
1 | 1 | P3x291x260 | 523317
Pos. | Qty. | Title/Benämning | Reference/Referens | Material | Dwg.No/Ritn.nr
Drawn/Date Ritad/Datum GL/2014-03-24
Check/Date Kontr./Datum /
Appr./Date Godk./Datum /
Scale - Skala 1:3
State - Status New
Size Format A3
Project No. - Projektnr.
TRATT
ZIGZAG
Dwg. No. - Ritn. nr. 523322
Rev.

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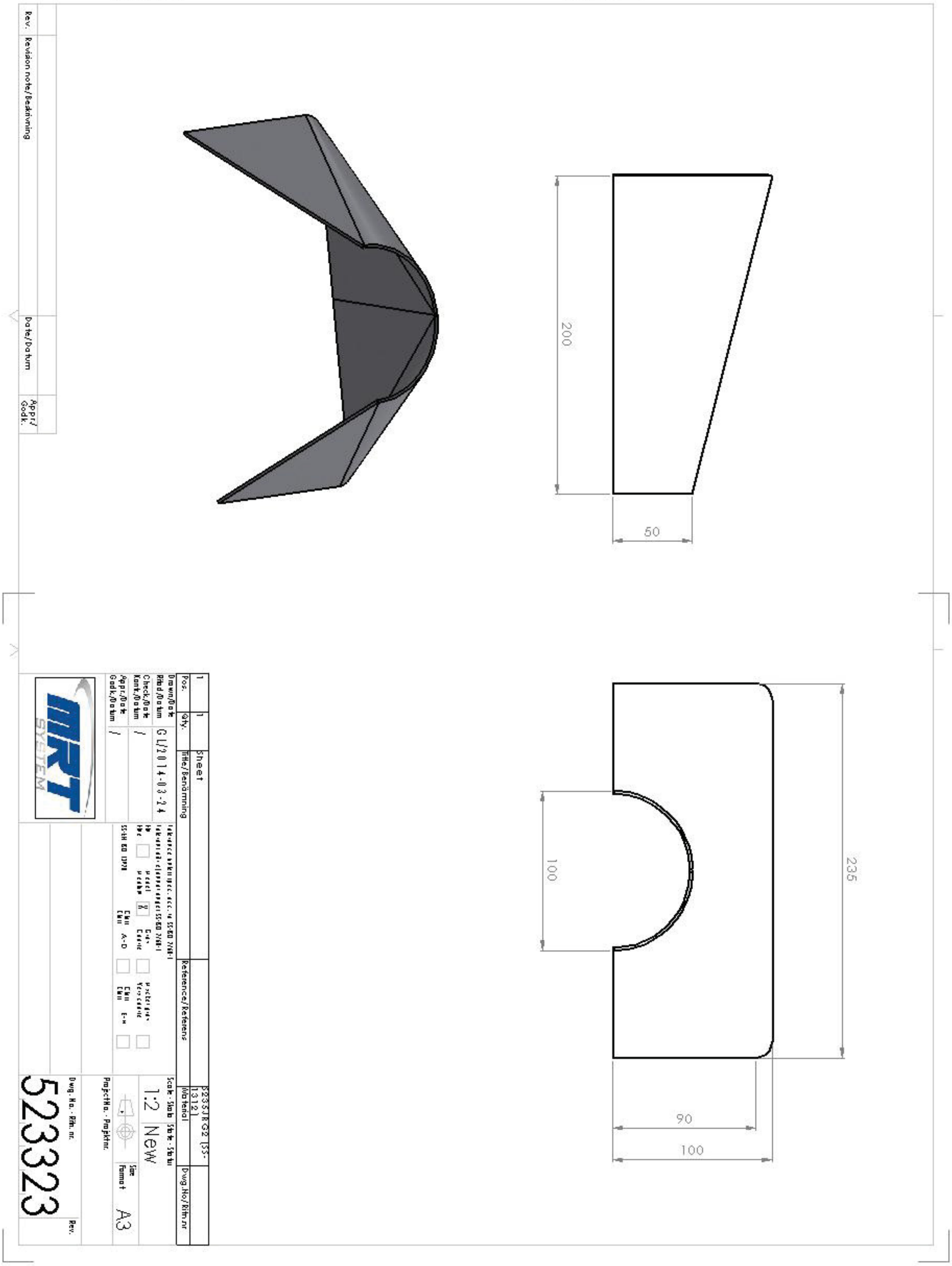
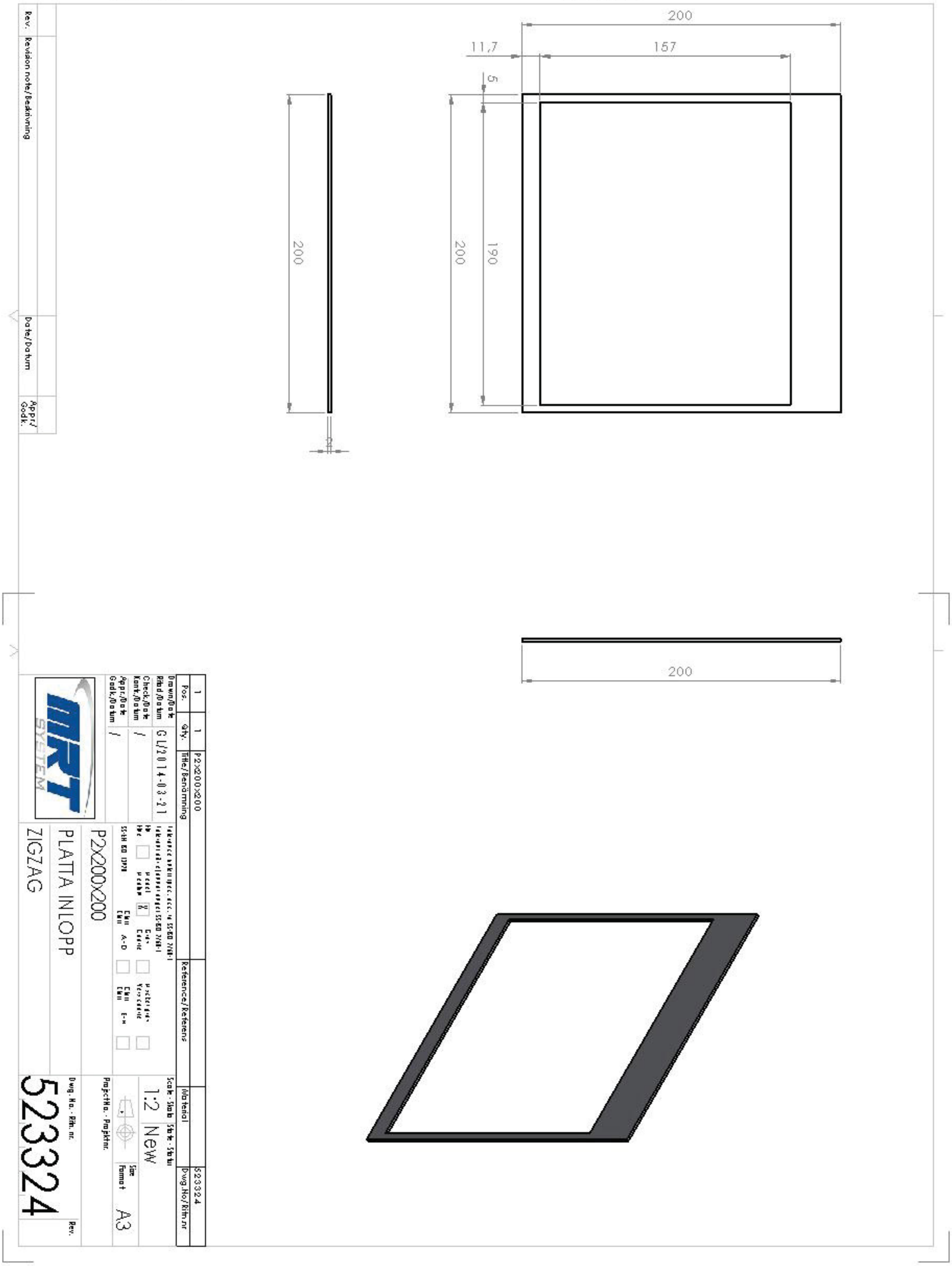
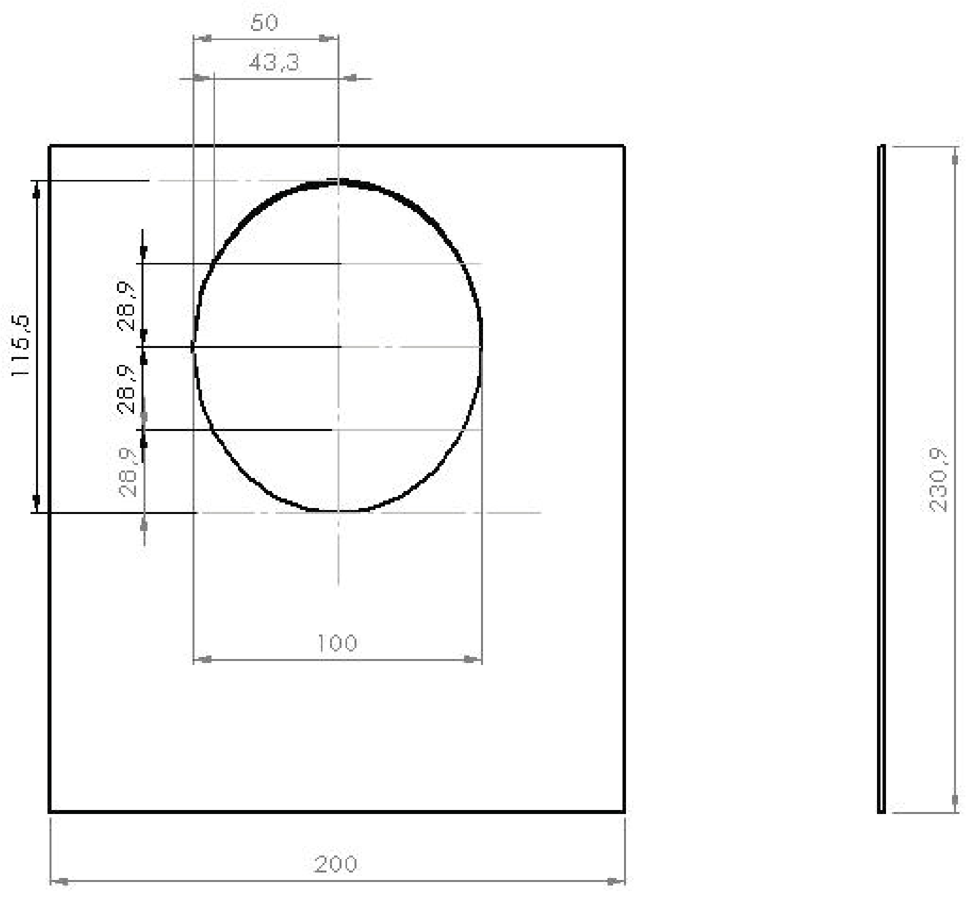



200
11,7
157
5
200
200
190
200
Rev.
Revision note/Beskrivning
Date/Datum
Appr/
Godk.
1
1
P2x200x200
Pos.
Qty.
Title/Benämning
Reference/Referens
Material
Drwg No/Ritn.nr
523324
Drawn/Date
Ritad/Datum
G L/2014-03-21
Check./Date
Kont./Datum
/
Appr./Date
Godk./Datum
/
Scale · Skala
State · Status
1:2
New
Size
Format
A3
Project No. · Projektnr.
P2X200X200
PLATTA INLOPP
ZIGZAG
Dwg. No. · Ritn. nr.
523324
Rev.

Rev.	Revision note/Beskrivning	Date/Datum	Appr/ Godk.



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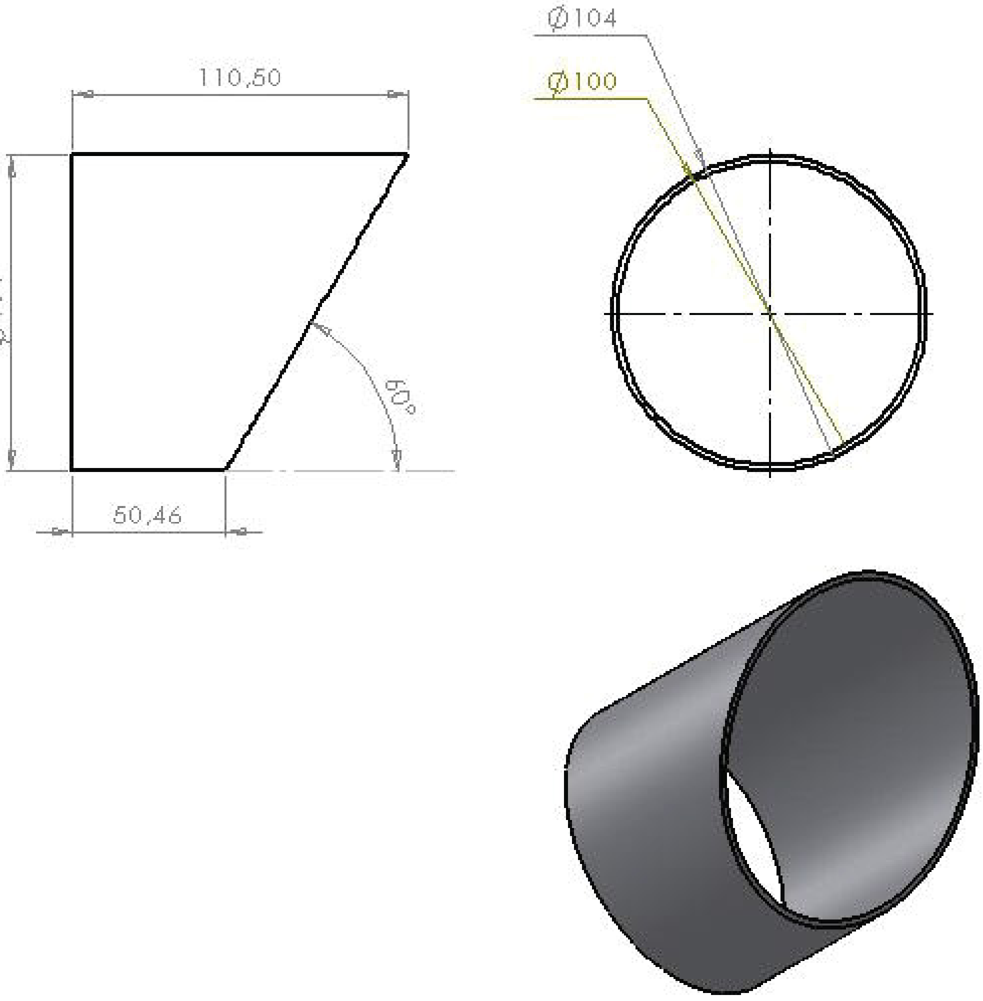
Pos.	Qty.	Title/Benämning	Reference/Referens	Material	Dwg.No/Ritn.nr
1	1	P2x231x200			523325

Drawn/Date Ritad/Datum	GL/2014-03-21
Check/Date Kont./Datum	/
Appr./Date Godk./Datum	/
Scale - Skala	1:2
State - Status	New
Size Format	A4
Project No. - Projekt nr.	
Title	P2x231x200
	PLATTA INSUG
	ZIGZAG
Dwg. No. - Ritn. nr.	523325
Rev.	

Rev.	Revision note/Beskrivning	Date/Datum	Appr/ Godk.



1	1	D=100x2			523326
Pos.	Qty.	Title/Benämning	Reference/Referens	Material	Dwg.No/Ritn.nr

Drawn/Date Ritad/Datum	GL/2014-03-21	Scale - Skala: 1:2	State - Status: New
Check/Date Kontr./Datum	/		Size Format: A4
Appr./Date Godk./Datum	/	Project No. - Projektnr.	

D=100x2

RÖR INSUG

ZIGZAG

Dwg. No. - Ritn. nr. 523326

Rev.

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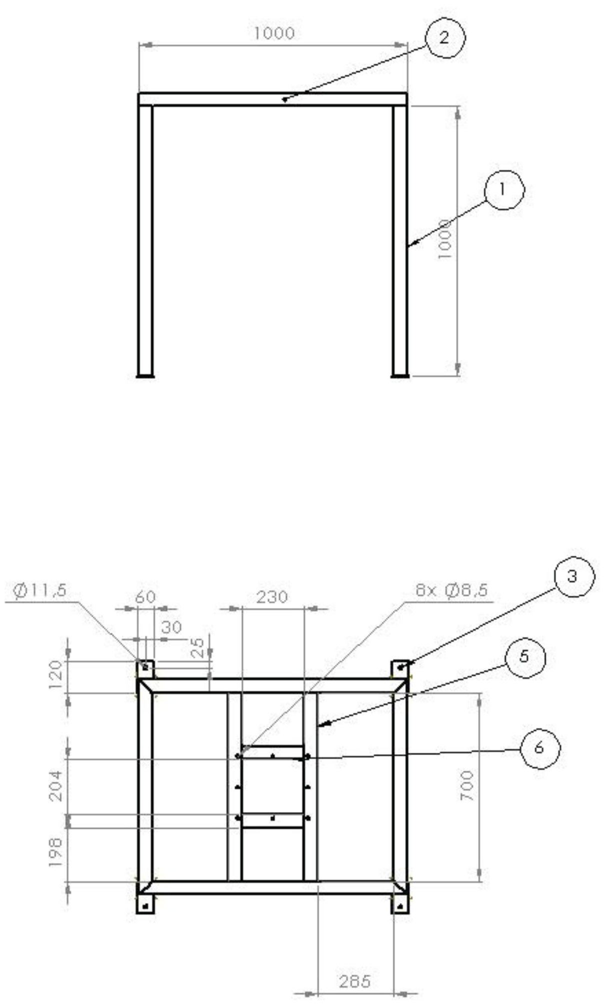

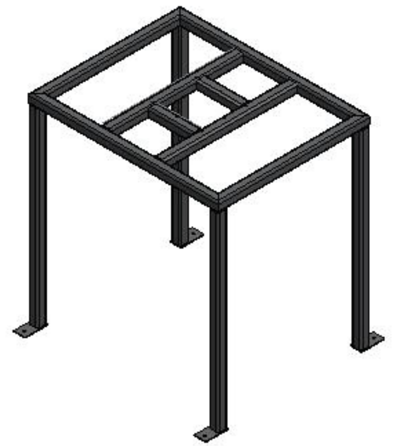

Målas
1 x Grund
1 x Täck RAL 7032 Kisel Grå

Generell svets

Pos.	Qty.	Title/Benämning	Reference/Referens	Material	Dwg.No/Ritn.nr
6	2	Fyrkantrör 50x50x5	230	S355J2G3 (SS-2134-01)	
5	2	Fyrkantrör 50x50x5	700	S355J2G3 (SS-2134-01)	
4	2	Fyrkantrör 50x50x5	800	S355J2G3 (SS-2134-01)	
3	4	pls60x6	120	S355J2G3 (SS-2134-01)	
2	2	Fyrkantrör 50x50x5	1000	S355J2G3 (SS-2134-01)	
1	4	Fyrkantrör 50x50x5	1000	S355J2G3 (SS-2134-01)	

Drawn/Date: GL/2014-03-24
Check./Date: /
Appr./Date: /
Tolerance enl. SS-ISO 2768-1
SS-EN ISO 13920
Scale: 1:15
Status: New
Size: A3
STÄLL
ZigZag
Dwg. No.: 523327
Rev.

Rev.	Revision note/Beskrivning	Date/Datum	Appr./Cont.

MRT SYSTEM

Appendix 6 - Before and after pictures

Here under will picture before and after it has gone through the Zig-Zag air classifier be shown. There are nine different materials three different materials at three different speeds.

The photos are taken on the same place with the same lightning on the same cardboard with less than five minutes difference from each other. However in some pictures it is hard to see the difference.

Material 1 at 45 Hz

Before:

After:

Material 2 at 45 Hz

Before:

After:

‘

Material 3 at 45 Hz

Before:

After:

Material 1 at 50 Hz

Before:

After:

Material 2 at 50 Hz

Before:

After:

Material 3 at 50 Hz

Before:

After:

Material 1 at 55 Hz

Before:

After:

Material 2 at 55 Hz

Before:

After:

Material 3 at 55 Hz

Before:

After:

Appendix 7 - Calculation

[illegible]			
[illegible]			
[illegible]			
	[illegible]	[illegible]	[illegible]
	50x50		
	1	6	6
	0,700	4	2,8
	0,230	2	0,46
[illegible]			9,26
Price SEK / m			74
Total m			10
Total Price (SEK):			740
[illegible]			
[illegible]			
	0,120	4	0,48
[illegible]			0,48
Price SEK / m			40
Total m			1
Total Price (SEK):			40
[illegible]			
[illegible]			
	0,2x0,869	6	0,6952
			0,6952
[illegible]			
	0,229x0,389	4	0,36

			0,36
[illegible]			
	0,2x0,231	12	0,5544
			0,5544
[illegible]			
	0,581x0,299	1	0,1737
			0,1737
[illegible]			1,7833
Pris SEK / m			200
Total sq.m,			2
Total Price (SEK):			400
[illegible]			
[illegible]			
	Waterjet	14	14
[illegible]			
Price SEK			1516,25
Total			1516,25
Total Price (SEK):			1516,25
[illegible]			
[illegible]			
	0,111	1	0,111
[illegible]			0,111
Price SEK / m			265
Total m			1
Total Price (SEK):			265

[illegible]			[illegible]
[illegible]			
		40	40
[illegible]			40
Price SEK / hour			510
Total hours			40
Total Price (SEK):			20400
[illegible]			[illegible]