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Enhancement of Industrial Horizontal Rubber Injection Moulding Machine Feeding System

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ENHANCEMENT OF INDUSTRIAL HORIZONTAL RUBBER INJECTION MOLUDING MACHINE FEEDING SYSTEM

Master's Thesis in the Master's Programme in Mechanical Engineering

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Preface

The following study is a Master's Thesis in Mechanical Engineering at Halmstad University associated with the HGF rubber factory located in Halmstad. The work aimed to design a setup to enhance the rubber injection scheme through an automated guided path roller conveyor for the HGF company. The project helps to gain more knowledge in the mechanical field of production and development.

We extend our gratitude towards all our professors and experts who provided timely guidance to the form and completion of this thesis.

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- Dr. Håkan Petersson, professor and examiner of the master program in the mechanical engineering department at Halmstad University.

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In addition, we want to thank our opponents, fellow students, friends, and families for all their support during our studies.

Minchin John and Krishnakumar Balakrishnan

Abstract

This study aims to improve the design of the feeding system of industrial horizontal rubber injection moulding machines. There are many ways to implement this research. Still, the suitable design is to implement such a mechanism that will help reduce the operator intervention in the feeding system of the injection moulding machine. The FEM analysis is used to understand the real-world situation on the feed part or assembly. This analysis also provides the ability to detect the potential issues in the design, including the tension area of design and the weak spots. In the industrial horizontal rubber injection moulding machine, the same technique is used to evaluate the feeding system and based on it, the roller conveyor is designed. The 3D model is implemented using Cad software. The selection of motor for the roller conveyor and the power transmission system is also extracted to maintain the quality and enhance the feeding system's productivity. In the research, a design is presented to improve the feeding system in which the conveyor belt is designed, which provides complete support for the feeding system.

Key words: Feeding system, Industrial horizontal rubber injection moulding machine, FEM analysis of feeding system.

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List of Abbreviations

HGF: Halmstad Gummifabrik

TBDA: Template Based Design Analysis

FEA: Finite Element Analysis

CBDA: Computer-based design analysis

QFD: Quality Function Deployment

1 Introduction

At the Halmstad GummiFabrik, there is an existing process for the rubber feeding system, and the client wants to improve the feeding system. The rubber comes in the ribbon roll form, and the ribbon is pushed into the rubber moulding metal cavity; rubber moulding produces shaped rubber pieces. The required quantity of heat is provided to these blocks, causing a chemical reaction. According to (Chelopo, 2020) there are different types of methods use to mould the rubber. All rubber manufacturing companies use heat and pressure methods to make moulded rubber products. In the rubber moulding process, the three most prevalent approaches are rubber injection moulding, transfer moulding, and compression moulding. In this research, injection moulding is discussed.

The injection method involves a hopper, pin, and barrel, and a hypodermic needle. This method permits and escorts the rubber through the eating, compressing, degassing, melting, injection, and packaging procedures. This injection moulding is the advanced process of moulding the products of rubber. It is the reciprocating machine having a screw, and the specific compound feeds the screw as the continuous strip, and it could also be fed from the hopper. This screw is also forced backward and forward; however, when this screw is pushed back, it prepares the shot. The screw's rotation is stopped, and then this screw is moved forward for the injection process, and a specific amount of rubber is injected into the closed mould. Initially, the screw is placed in the injection position, which use to maintain the predetermined pressure which uses for consolidating the stock. The screw is rotated again to refill the barrel, and in this way, the mould is opened for the removal part.

In this process, it is highly essential to maintain the feeding part of the injection method in which the rubber is moulded before the injection process. For this purpose, the roller conveyor will be used to eliminate the operator intervention. This feeding part will be designed in the form of the roller conveyer using Cad software, and its 3D modeling will be represented in this research. The FEM analysis of this feeding method is also implemented to evaluate the quality of the complete functionality (Zhang et al., 2021).

1.1 HGF Background

HGF (Halmstads Gummifabrik) is a very successful and developing manufacture, they are specialized in moulded products made of rubber and thermoplastic elastomers (TPE). HGf was founded in 1947, it is under Swedish corporation. The headquarter of the company is located in Halmstad, by mid of 2000, the company builds its second production unit in Latvia. In May 2016, HGF becomes a strong partner to customers in sectors like automotive, mining, and energy industries have also taken a step by switching to the Jeevas enterprise resource planning system HGF now operates in six business segments: automotive, industrial products, marine and offshore, mining and construction, sealing, and sports. HGF received the Hallands award in 2009, second place in the "Swedish Lean Prize" in 2011, and the "Honda Excellent Overall Performance" award in 2015. Christian is the current CEO of HGF, and Jakob Frank is our Industrial supervisor.

At HGF, the feeding system will be enhanced which will help to reduce the human effort during the moulding of rubber. Cylindrical-shaped rollers are used in these roller conveyors. They are made from ERW steel pipes with a cast that is used to adjust the antifriction bearings. These rollers are also known as the idler rollers. There are three types of rollers, cylindrical, double tapered, and wheel. Roller axles are fixed on the frame.

The frame also helps the roller axles to rest. These roller axles are placed in the slots cut in the flanges of the frame. In the end, these rollers are flat. In this way, the roller axles do not rotate in the slots. For using the axles in the heavy rollers, the axles are fixed on the frame with the help of the clamps (Jawale, 2020).

Trestles are also known as stands and help in supporting the conveyor frames with the roller assemblies, fixing to the ground. The height of the stands depends on the convenience level of the conveyor such as small conveyors the stand has telescoping legs.

1.2 Aim of project

The primary objective is to design the roller conveyor, which improves the feeding system for the injection moulding machine. The project will cover the feeding system for horizontal injection rubber moulding machine, Designing of conveyor roller, FEM analysis of feeding system, Selection of motor and Power transmission calculations for the conveyor roller.

1.2.1 Problem definition

In the manufacturing process at HGF, products have to be moved from one point of development to another. Materials handling devices allow quick, inexpensive, and easy loading and unloading with minimal human support. For example, in terms of weight and height, the roller conveyor device can be used for easy handling of items beyond human capability. This paper examines the design considerations and measurements of the roller conveyor device for rubber raw material in terms of height, weight, rpm, diameter, strength, idler spacing, mechanism and angle of rotation, control mode, intended application, a commodity to be treated, and its maximum load limit to ensure effectiveness and speed, continuous and effective movement of rubber raw material during fed into the injection moulding machine. This project will bring in a rubber feeding system that is inexpensive, efficient, and optimized.

1.3 Limitation of project

Measuring tools and sensors are not incorporated in the design. The observations from the sensors are only required to analyze the system in a better way, and it does not hinder the design process. Another limitation of the project is that a practical experiment is required to observe the quality of the design and final product.

1.4 Study environment

The final year thesis will be submitted at the University of Halmstad. The study environment of the institute is also effective, which helps us during our research. We visited the HGF and found its environment extremely comfortable.

2 Method

2.1 Alternative method

Today, many different engineering design processes are available. These methods are adopted to use as a platform in companies for product development by tailoring them based on their specific conditions. Some of the processes followed by the company Ullman's, stage gate, Freddy Olson, otto and wood, Eggert are the other well-known engineering design processes or product development processes (Olivia and Marina, 2017; Petersson, 2016) . This report's methodologies and chosen method almost share the same set of stages and substages in the process. Like Task: with scope of market, company, and environment, requirement list: it is with design specification, principle solution: it is with concept generation, preliminary layout: checking for the weak spots and eliminating the errors, definitive layout: it is in relation with detail drawing and part list, then product documentation and solution.

In this report, we have considered Ullman's product development process as an alternative method as a reference because it states that regardless of the design problem, we have to focus on five basic steps. While, during the designing process based on: how to solve the problem, understand the problem, generating alternative solutions, evaluate the alternatives, and selecting the final solution. All these are not followed in their line of orders. They are often interrupted and re-thought due to solution generation and evaluation that improves the understanding of the problem(Ullman, 1991). We followed the quality function deployment matrix in this process, also called the house of quality and generic product development which is shown in Appendix-I. QFD is used to interpret the voice of the customer and their requirement, which will help determine what area we have to focus on and eliminate the unnecessary parts conditions during the initial phase of the project comparing with the existing models and it is shown in Appendix-I. Process design aims to establish an integrated process that addresses all internal and external consumer expectations while ensuring quality and efficiency standards. Protection, expense, variability, efficiency, environmental effects, "green" production, measurement capacity, and equipment maintainability are all considerations to consider when developing a process. Method designs must be viewed in comparison to other systems that affect them because processes frequently cut through conventional organizational roles and seldom run-in isolation.

2.2 Chosen methodology of the project

This project was developed and formatted based on Ulrich and Eppinger's approach based on the seventh edition of the book product design and development written by Karl T Ulrich, Steven D. Eppinger, and Maria C Yang. This methodology was chosen because of previous personal experience working with Ulrich and Eppinger's approach for designing mechanically operated lifting platform (Ulrich et al., 2020). The information of the design process, studies carried out, and detailed description of the Ulrich and Eppinger design process method are followed in chapter 3 of this thesis report.

2.3 Preparations and data Collection

The preparation and data collection for this report was performed using the listed below:

Literature review and other sources: The relevant data for this project is captured from various research papers, publications, instructional videos, datasets, and material obtained in a participative Mechanical Design Process, suitable Design for moulding rubber, Intensive Material and Manufacturing Techniques, metaphor, zoom meetings, phone calls, company visits, suggestions from supervisors to improve performance to generate ideas

Observation and company visit: Along with former supports, the company visit was crucial in determining what sort of solution would be more adaptable to the situation and the challenges involved in real-time; for that, we made 12 visits to the company total of 36 hours. During this time, it helped us interact with operators who handled the machines in different shifts and great help from the company supervisor who shared informative data, problems they face, and challenges involved.

Pugh matrix: It used to rank the design concept and helps in attain the desired solution.

CAD Software: CATIA, an acronym of computer aided three-dimensional interactive application and Solidworks and AutoCAD are three software used for computer-aided design (CAD) These three platforms were used for the CAD modelling of the different models created during this thesis.

FEM analysis: It is an engineering simulation software which was used to carry out the stress analysis

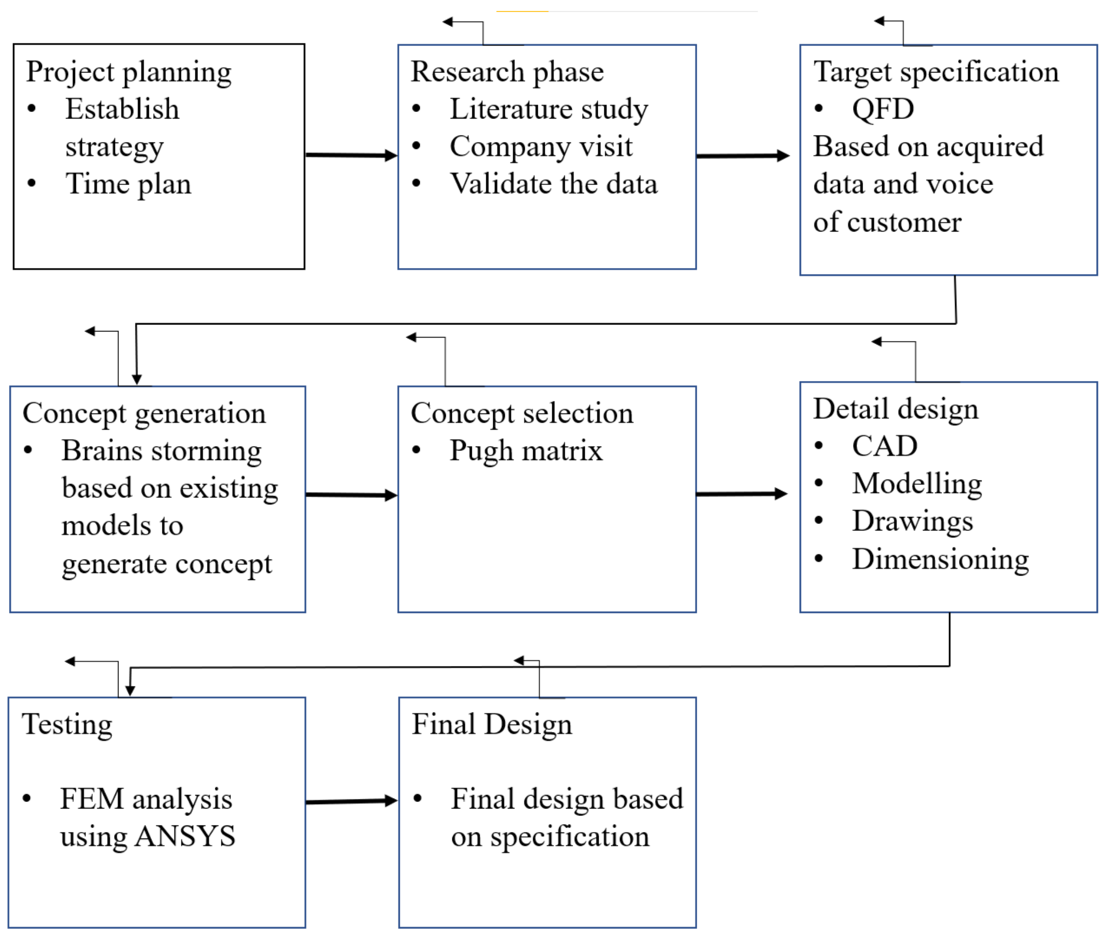

Figure 2-1Work flow of the project

3 Theoretical Framework

3.1 Summary of the literature Study

3.1.1 Ulrich and Eppinger Design Process Method

Ulrich & Eppinger (2020) describes the very simple and comprehensive manner in which product design processes were developed to put together the advertisement, design, and industries manufacturing functions. And product creation is a series of activities that starts with knowledge of business prospects and concludes with product design, selling, and distribution. In product production, there is a multisectoral activity involving inputs from the firms in all functions. There are three different categories of functions that are nearly at the core of the project of product development, including market launch, design, and manufacturing. However, the design component plays a leading role in all three roles, which are defined in the functional nature of a product that better suits the consumer's needs. As of now, we’re concerned about product preparation. Product preparation provides insight into the product line produced by any company and the launching time of the product into the market. And the product strategies that are designed with the purpose, capacity, competitive climate, and constraints of the business in mind. Product preparation includes, in the eight-step phase, identifying opportunities, evaluating and prioritizing tasks, allocating resources and scheduling of plans, completing the planning of pre-project, and reflecting on process and outcomes. Besides, future product growth programmers are dependent on the organization’s competitive approach, technology pathways, and product network strategies. When talking about understanding the needs of the consumer, which describes the desires of the customer in terms of product creation and exactly how the employer or industry meets their demands.

The idea selection provides details on the method of assessing concepts concerning consumer requirements and the other factors measuring the relative weaknesses and strength of concepts and selecting either single or more concepts for further testing, investigation, and production (Ulrich et al., 2020).

i. **Project planning**: The first stage of the process consists of the thorough definition of the task, the establishment of the process that will be followed –its stages and substages–, the time plan, and the resources available. In this phase a work breakdown structure of the process will be created well as a Gantt chart showing the duration of each of the stages and substages that make up the process
ii. **Research phase**: In this part of the process the literature review and data set validated, which then filtered and focused into generation of ideas for reaching to the desired solution.

iii. **Set target specifications**: The requirements that the product should fulfil are set on this stage. Numerical values will be assigned to the different metrics that will define the characteristics of the product. This set of specifications will be carefully followed during the process, and design decisions will be made according to them.
iv. **Concept generation phase**: In this phase the information collected based on the literature study and existing models and observed information from the company visit which then is filtered, brainstormed and discussed, are used to generate the design concept for reaching into the desired solution.
v. **Concept selection**: One of the concepts from the previous phase will be selected for further development. This will be done employing a Pugh's matrix, in which the concepts will receive a score ─out of an established scale─ by comparing it to another design according to different variables with varying levels of importance.
vi. **Detail design**: This stage encompasses, defining preliminary dimensions of the product, and a CAD model will be developed.
vii. **Testing**: FEM analysis is carried using ANSYS for finding the weak spots and reworking on the design for getting an improved design.
viii. **Set final specifications**: In this phase based on the calculation and analysis a final design is developed which can then be used by the client.

The following sections in this report describe each stage of Ulrich and Epinger engineering design processes involved in this project.

3.2 Project planning

This is the first stage of the Ulrich and Eppinger method which consist of task, the establishment of the process to be followed, their stages and substages based on a time plan which is then represented by Gantt chart and finally looking up for the resources available.

3.3 Research and concept Generation Phase

In this part of the process the literature review and data set validated, which then filtered and focused into generation of ideas for reaching to the desired solution. The following are the literature research steps carried out and explained for the generation of concept.

Rubber Moulding Method

Due to its unique combination of processes, injection moulding is the most sophisticated moulding technique, especially for producing rubber goods. The equipment is frequently used in small and large work spaces, including workshops, warehouses, parking lots, warehouses, and work yards. Typically, the compound is delivered to the screw in the form of pellets through hopper channels or a continuous strip (Iris et al., 2015).

Injection moulding is the most consistent moulding method, with the lowest cycle durations and the least amount of flash. The primary drawback is the expensive cost of the machine, moulds, and ancillary equipment. The method is best suited for high-volume manufacturing. Injection Moulding requires fluor elastomers with low viscosity (less than 30 on the Mooney viscometer at 121°C). It is critical to apply one or more process aids to improve mould flow during injection and facilitate easy release of pieces from the mould after curing.

Research on Stress Analysis

Dynamic stress causes fatigue strength functions in shear loading of fabric conveyor belts. Cheng & Du (2011) dealt with functions fatigue strength in shear loading of fabric conveyor belts. They concluded that the fatigue phenomenon of belts is explained by the decrease of shear strength, which is determined as an ultimate angle initiating the lamination failure of the central rubber layers (Cheng and Du, 2011).

Cheng & Du (2011) investigated the force condition of the belt conveyor even during the horizontal turning segment in order to increase the conveyor belt designing level using horizontal turning (Cheng and Du, 2011). (Kumar and Mandloi, 2013) reviewed belt conveyor design modifications and the most recent technologies or approaches used in various applications to decrease failures, maintenance expenses, and equipment-related fatal incidents that arise during services. The finite element approach has proven helpful for the static response of conveyor belts (FEM). The study done by (Fedorko and Ivančo, 2012) used FEM numerical modelling stress-strain state in conveyor belts. In (Li and Pang, 2018), a novel technique is provided for calculating dynamic stress distributions on large conveyor belts using a viscous-damping model. Pang was the second author to address the prospects of FEM application within the context of a full investigation of the conveyor belt issue. Fedorko & Ivanco (2012) investigated the force ratios in conveyor belts of conventional belt conveyors using FEM. One of the most important aspects of using FEM for belt conveyor research is determining the suitable material characteristics of conveyor belts (Fedorko and Ivančo, 2012). Mazurkiewicz's (2010) work was crucial in resolving this issue. The conveyor belt is particularly vital for belt conveying operators in terms of both economy and efficiency. As a result, considerable emphasis must be paid to studying the causes of its deterioration (Mazurkiewicz, 2010). Kasztelewicz & Szymanski (2018) addressed the ability to adjust the drive acceleration torque, resulting in a smooth soft start while keeping belt tensions below specified safe limits, which is crucial for belt conveyor performance. They discuss failure analysis in the context of condition monitoring (Kasztelewicz and Szymanski, 2008). Mazurkiewicz (2010) also addressed the issue of conveyor belt deterioration. The tension induced by the impact of lumpy material is one of the primary causes of conveyor belt wear. Material impact on the conveyor belt causes not just wear but also conveyor belt damage in many circumstances. This issue has already been addressed not only in theory but also via laboratory testing (Mazurkiewicz, 2010). In (Fedorko et al., 2013) the authors' efforts are aimed at developing mathematical models to explain the features of conveyor belts. Until recently, mathematical machinery for determining the dependability of belt conveyors using renewal theory has been presented. Only weakly solved regression models in the field of conveyor belt failures. FEM mathematical modelling receives the greatest attention. Damaged conveyor belt research may be carried out immediately during the operation of belt conveyors, which is sometimes difficult or impossible to do, or it is feasible to utilize specific test machines. (Blazej et al., 2017) investigated the causes of belt conveyor deterioration in laboratory circumstances. Conveyor belt damage leads to its slow deterioration, and as a result, we may observe massive economic losses for users. As a result, the author's efforts are focused on producing, while consumers' interests are focused on purchasing conveyor belts with the highest damage resistance. The article contains a technique that may be employed by conveyor belt testing to examine their damage resistance and breakdown creations in severe instances. (Zhang et al., 2021) used machine vision and kernel approaches to do an online analysis of coal on a conveyor belt.

Template Based Design Analysis

In the modern period of industries, to enable developers to take part in a range of analysis of their design solutions. The key theme defined as the participation of engineering designers in the CBDA (computer-based design analysis) is one aspect of the TBDA (template-based design analysis) (Petersson, 2016) and is an integral component of the design system of the engineering method.

The primary application of structural analysis on computer-based techniques like the Finite Element Analysis (FEA) and structural optimization of a computer-based system, which has primarily difficult geometry, and a requirement to use sophisticated constructive modeling of some design kind. In the present condition in industries, the involvement of engineering designers to take up an active role in the study of design strategies in several various businesses and industries around the world. Furthermore, the key goal of the model-based concept review was to promote the successful commitment of the engineering designer to the success of the computer-based design analysis in a particular individual or some other organizational environment by utilizing the TBDA methodology. Along with a unified component of the operation in the engineering phase of design (Petersson, 2016). Through the usage of template-based design analysis, it is of the utmost importance that it is possible to define the engineering design performance in addition to the CBDA method for the creation of an engineering designer who is developing to carry out the computer-based design analysis process on a stand-alone basis or in some organizational environment. The FEM (Finite Element Method) is a computational method used to solve various problems in mathematical physics and engineering

The method is like unexplained functions in the field. However, if we are to address this issue, if we subdivide a larger structure into lesser, simpler bits, called a finite element. The ultimate objective of product production and approach of engineering design is to improve both productivity and efficiency in the creation of designing the product, and it would be difficult to eliminate the equally productive and successful convergence between the phase of engineering design and the design research activities to adhere to the CBDA (Petersson et al., 2015).

Design Analysis Clarification Task

Many new product development programs utilize computer-assisted engineering systems to evaluate product ideas. It is also a necessary activity to properly implement the research activities in the creation phase product. Computer-based concept evaluations of products and the machinery are carried out in a vast variety of product preparations to ascertain the feasibility of the proposed approach (Petersson et al., 2012). And the research operation is carried out by each of the professionals who understand each move excellently, employed by any business or consultancy firm. Besides, various repetitions usually happen, and the engineer need to design is analyst's model suggestion and utilizes the findings to improve and develop the ideas that become the latest subjects of the study. There have still been several other elements that needed to be undertaken into consideration. When we talk about background analysis, the complexity of this method of design research only protects observable analysis triggers needing and the usage of specialized computer-assisted engineering design analysis techniques (Petersson et al., 2012).

In the current sense, some of the key goals of the design review are as follows (1) to ascertain the feasibility of the experiments and the quantification criteria in favor of detection and planning practices. (2) To carry out exploratory surveys to promote a combination of practices. (3) Measure the attributes of the commodity under the terms of the lifecycle of a product. (4) Separate the techniques of verification and confirmation of the research carried out. In comparison, various concept research techniques and strategies are utilized in different styles of solutions with different degrees of specificity in analysis. The whole method and role of analyzing the design relevant to the design requirements, suggestions, revision, and prior research. Subsequently in the detection of the challenge was identified as a consideration of the importance of the task concerning the project, the analyst, and the customer.

The preparation and contracts of the task provide brief detail on the negotiations and the consensus on the review of the task, and later the material between the researcher of the project leader and the leader (Eriksson and Burman, 2005; Petersson, 2016).

Feeding Mechanism

Rubber extruders are classified as hot-feed or cold-feed extruders based on their feeding configuration. Hot-feed extruders are typically fed prewarmed milled strips, whilst cold-feed extruders generally fed pellets or strips at room temperature (Hietala et al., 2013). The Cold-feed extruders are becoming increasingly popular owing to their cheaper capital investment and production costs, as well as their short heat history (Choton et al., 2020). Several screw designs, as described by (CEMA and ANSI, 2019), were presented to introduce the complicated flow patterns necessary to produce high dispersion levels and thermal uniformity of the rubber compound component. An extensive study has been conducted on the logical design of screw extruders for processing thermoplastics that integrate the non-Newtonian flow of molten polymers (Mård, 2019). This research has been conducted on the phenomena that occur inside the screw channel during the extrusion of rubber compounds. These experiments were carried out by removing the screw from the barrel and observing the flow patterns and rubber distribution in the screw channel. This study has also been used and applied to rubber injection-moulding machines, where identical tugging trials on the injection unit have been undertaken. The lack of a pellet/powder conveying and melting zone distinguishes rubber extruders from thermoplastic extruders. There is simply metering in rubber extrusion, albeit a portion of the metering zone near the hopper mimics melting and solid-conveying zones. This greatly simplifies the extruder design scenario. However, the rheological qualities of rubber compounds complicate screw design even more.

Process, material, and function

The material choice, as well as method, is inextricably related to the choice of design. The term “form” refers to both the exterior, macro-shape and the internal micro-shape, as in a cellular structure. To achieve the ideal shape, the substance is placed through a set of processes that refer to as manufacture: main shaping processes (such as casting and forging), material removal processes (such as machining and drilling), finishing processes (such as polishing) and joining processes (e.g., welding). Interactions between feature, substance, form, and method. The purpose determines both the material and the form. The material has an effect on the process: formability, machinability, weldability, heat-treatability, and so on (Ashby, 2005).

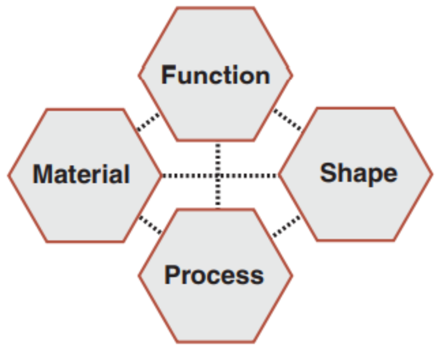

Figure 3-1: Selection of design (Ashby, 2005)

Vibrating hopper

The vibratory hopper is placed in the feeder in a feeding device, and its use is suggested in many applications because it is the autonomy element that enables the parts to be processed and dosed to the vibratory bowl feeder. It also ensures that parts are present in the bowl if the latter lacks adequate ability to house the number of parts needed to attain the necessary autonomy period. It is needed in certain applications due to the type of product to feed, especially in terms of load weight (Han et al., 2013).

Single self-loading tube

The single Tube Filling System is designed especially for filling and sealing rubber and shielded tubes. High efficiency, low energy usage, easy and secure function, low expense, high stability, and ease of maintenance are all essential features of this machine. On malfunction or abnormal function, the computer supplies an automated alert (Audio-visual Notification Annunciation System). To stop wastage, the plant is set to auto tube feed service with a solid-state no tube or no filling system mechanism (Miloradović et al., 2018). Tube washing (pneumatic) and feeding, labeling recognition, filling, folding, wrapping, code writing, and finished product production are all done by the built-in systems.

Rotating hopper

The hoppers are designed to supply material to conveyors at varying speeds. Speeding up or slowing down feeder conveyors (or growing or decreasing the size of the feeder gate opening) can raise or decrease the rate of material flowing on the feeder conveyor. These two examples demonstrate the stone is processed in hoppers and removed by hopper feeder conveyors. Each conveyor is powered by a VFD attached to an ultrasonic probe (Miloradović et al., 2018).

Alternative methods for the feeding

In a rubber injection moulding machine different feeding method are used, one of which is the conveyor system. It plays a significant role in injection moulding machines by providing feeding of raw rubber to the hoppers. At hoppers, the raw rubber is heated and moulded into the desired shape. The feeding of raw rubber to the injecting nozzle is particularly important and it depends on speed efficiency, flow rate, timing, and synchronization. The decline conveyor rollers work on gravity. They are economical and commonly used in feeding and loading systems. These conveyor rollers are mounted at a slight decline angle hence uses gravity to feed rubber to the machine for longer distances. These decline conveyor rollers are preferred because highly standardized rollers are used (Nada, 2019).

Hydrostatic bar feeding method

Hydrostatic bar feeding is another method that could be used for rubber injection moulding. It receives a large batch rather than one by one. This system feeds the rubber into the machine and removes the excess material from the machine. This feeding system has a cycle of less than 30 for feeding. Truly little maintenance is required as many lubricants are used. Easy to use and operate. Numeric controllers are used for setup positions. The main disadvantage regarding this method is that it is expensive, and few safety precautions are needed in the surrounding (Chiang et al., 2005).

Feeding method with the help of gears

Gears have been used in power and motion transfer under various loads and speeds for over three thousand years. The market for plastics in the gearing sector is considerably higher and will undoubtedly continue to grow because of the fiscal and realistic benefits. Plastic gears have many benefits compared to metal gears, such as lightweight, noiseless run, rust-resistant, lower rubber coefficients, and the capacity to run without lubrication.

Plastic gears may be created by hobbing or moulding, these gears are the alternative method for injection moulding. With persistent technological development, plastic injection moulding is becoming an even more cost-effective mass manufacturing method to satisfy the increasingly increasing requirement of the industry for plastic equipment in many applications. Plastic injection moulded gears were successfully used in the automobile, office and household equipment, food and garment equipment, and several other applications. In the rubber industry, carbon black is the primary reinforcing agent. More than a dozen standards and grades have been produced to satisfy the production needs of the rubber industry. Previously, others were categorized according to machine rules, while some were classified according to roles, which resulted in a very chaotic situation. Later, ASTM-1765, a new classification system, was established. The advent of this approach ends the previous disorderly grouping and lack of empirical characterization of carbon black; however, it has the downside of not reflecting the composition of carbon black(Mehat et al., 2013).

3.4 Product development

The Pugh matrix is selected from the specific book name “The mechanical design process” which will help understand the problem and analyze the effective ideas and other concepts. Product development is often used to apply to all steps involved in taking a product from prototype or idea to commercial introduction and beyond. In other terms, product manufacturing encompasses the whole life cycle of a product (Ullman, 1991). For achieving a complete product definition, the QFD tool was implemented to help to understand the feeding mechanism that needed to be designed. A complete explanation of the QFD tool and the procedure followed to implement it in this thesis can be found in Appendix I.

4 Results

4.1 Concept selection

4.1.1 Pugh matrix

In this thesis, the extension of the feeding system with break-free rubber injection is required, there are multiple options to achieve this design including the vibrating hopper, single self-loading conveyor, Multiple self-loading tubes, decline roller, and the rotating hopper. The primary concern of the Pugh matrix is to select the best possible method from all the given matrices. In this matrix, the distinctive characteristics of all these methods are defined including the performance analysis, life of these methods, ease of use, physical attributes. These characteristics are compared against the weightage of each method. As it is already discussed that the guided path is required for the feeding system and as per the Pugh matrix the weightage of these methods is shown below. In this Pugh matrix, the number is given against each attribute. Regarding performance, the speed, power use, accuracy repeatability as well as noise is given. In this matrix, the specific weightage is given to each characteristic from the range between -3 to 3 and this weightage is given to each attribute according to the given standards and performance. In the life section, the bearing capacities of these methods are elaborated which includes the jamming, maintenance, range of temperature, the expectancy of life, durability as well as reliabilities. In this section, the methods of declined roller conveyor obtained the maximum number than the other methods. In this selection criteria, the feeding method should provide ease to use. To check this criterion, the startup time, controlling and Maneuverability should be measured in which the weightage of the rotating hopper and decline roller conveyor both are equal. This weightage of this section provides an overview of the functionality of this extension which will be added to the feeding system for the horizontal rubber injection moulding machine. The physical attributes are the most important factor in the designing of this method which includes the size, weight, attractiveness, manufacturing, and cost of this method.

Table 4-1 Pugh Matrix of Feeding system for horizontal rubber injection moulding machine feeding system

Critical Quality	Pugh Concept Selection Matrix	Weight	Design Concept 1	Design Concept 2	Design Concept 3	Design Concept 4	Design Concept 5
Performance	Speed	2	1	3	3	3	2
	Power Usage	2	-3	3	3	2	-2

	Accuracy	1	*	*	*	*	*
	Noise	2	-3	3	3	3	2
	Repeatability	2	1	3	3	3	3
Life	Jamming	3	-2	3	3	3	3
	Maintenance	3	-2	3	3	2	2
	Temp Range	3	3	3	3	3	3
	Life Expectancy	2	2	3	3	3	2
	Durability	3	3	3	3	3	3
	Reliability	3	2	3	3	3	2
Ease of use	Loading	3	3	-3	-3	-3	3
	control	2	3	3	3	3	3
	Maneuverability	3	-1	2	1	-1	3
	Start uptime	1	2	3	3	3	2
Physical Attributes	Size	3	2	-2	2	1	2
	Weight	3	-2	3	3	2	-1
	Safety	2	1	3	3	2	1
	Manufacturability	3	-2	1	3	2	-3
	Attractiveness	2	2	2	-2	2	3
	cost	3	-2	3	3	2	-3
	Total +		25	50	51	46	39
	Total-		-17	-5	-5	-4	-9
	Total Score		8	45	46	42	30
	Weighted Total +		61	123	126	108	97
	Weighted Total -		-45	-15	-13	-12	-25
	Weighted score		16	108	113	96	72

The total number of weights is determined after the submission of all positive signs that are written in the total + section and the submission of all negative signs are written in the total – section. The total submission of the weightage is also written in the weighted total +. The primary decision is taken based on the total weighted score which provides the best method from all the given methods. After analyzing the Pugh matrix, it is found that the decline roller conveyor is the best method for extended this feeding system for the horizontal rubber injecting moulding machine. This method is selected because its score is 113 in number. The second-best method is the single self-loading tube because its total weightage is 108 in the Pugh matrix. The vibrating hopper is the least efficient method as per the weightage of the matrix.

4.1.2 Selection of conveyor system

The setting in which the feeding system can improve in the rubber injection moulding machine is a crucial aspect to remember when choosing a conveyor system. High humidity, temperature, friction, strain, delicate or dangerous components are also to be considered. The flammable goods can be addressed with a conveyor manufacturer to assess any possible hazards and the appropriate countermeasures and workarounds. Evaluate the system's scale compared to the amount of room available in the workspace and how it can interact with current equipment. Due to their broad sizes and incorporation into numerous rubber moulding operations, conveyor systems are also relatively complicated in their architecture and layout (Nada, 2019). Also, long and complicated structures are feasible due to the flexible design of several conveyor components. Manufacturers of such systems may aid with design so that the conveyor fits into the usable space. Figure 4-1shows the basic design of a conveyor belt.

By studying the above feeding methods and ranking with pugh matrix as discussed in section 4.1.1 the conveyor belt system is chosen. The different parts of the system are given below:

4.1.3 Conveyor belt system

To comprehend the application of disc brakes on a conveyor system, it is essential first to grasp the morphology of the belt conveyor device, as the belt conveyor is the most prevalent and widely utilized continuous bulk material transportation technology in mining, materials manufacturing, and power generation industries. This is largely due to the benefits associated with expense, operational protection, dependability, flexibility, and environmental compliance. As belt conveyors get longer and conveyor networks become more sophisticated, engineers must consider and apply advanced design concepts to maintain durable, efficient, and cost-effective material handling systems. Conveyor belts are classified as dynamic structures since they are interdependent with all other subsystems and parts in a finished unit.

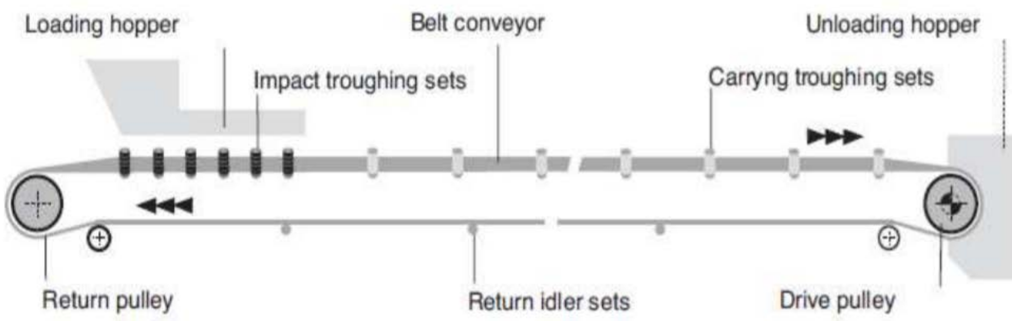

Figure 4-1: Basic design of conveyor belt (Nada, 2019)

Different conveyor designs can necessitate disc brakes to stop an overloaded conveyor belt and keep it from running away from an excessive coasting situation since unnecessary coasting would result in even more material being discharged than could be managed by the received conveyor or processing silo. Belt conveyor systems' complex behavior during the starting and braking processes is dictated by their drive and brake units. The optimal configuration of large-capacity and long steeply declined belt conveyors should consider the values and variations between the drive torque ratio and the peripheral forces of the powered or brake pulleys, and therefore the belt tension and also the belt conveyor's acceleration and deceleration.

Principle operation of conveyor belt

Conveyor belt instruments, configuration, and part placement may be tailored to the implementation of material transportation within a given scenario and conveyor area.

The main components of conveyor belt which are used for transporting high pitched payload include the

- Pulley's conveyor
- Idler's conveyor
- Elastic belt conveyor
- Drive unit conveyor
- Tensioning the devices

Conveyor pulley

Conveyor pulleys are fabricated and manufactured in various sizes, with a continuous rim and two end discs equipped with compression hubs. To reinforce the body, an intermediate pulley shell stiffening disc is welded within the bottom. Specific application pulleys are equipped with strength in the rim, disc, shaft, and mounting bearings to prevent component loss and eliminate movement of the pulley to shaft setup. Pulley diameter is primarily due to belt length, friction, bending stress caused in the belt's outer plies, and face pressure between the pulley drum shell and the belt.

Conveyor idlers

Conveyor idlers are used to reinforce the belt between the head and tail pulleys, which are located a few meters or even kilometers away. Conveyor idlers' primary function is to move the longitudinal load onto the supporting structure and the mass of a conveyor belt and the material transported. A typical belt conveyor route includes a transporter, normally in the form of a trestle, braces, and idler rolls designed to support, lift, and shape the hollows of the conveyor belt. The belt movement imparts rotary motion to the roller at the matching peripheral rpm, which rolls without slipping on supporting rollers.

4.2 Conceptual Designs

The framework is designed, and the calculations for the conveyor belt are given below. There were different iterations going back and forth between the stages, design and estimate calculations several times for improvements to check technical feasibility. Of course, several functions respecting the applied methods obeyed, such as safety, size, standards, scale, etc. As mentioned before, economic issues do not cover by this project.

4.2.1 Systematic design of declined roller conveyor

The first picture is designed to get the model body of the system which provides ease in the planning and development in the other designing parts. The dimensions of all parts were not designed according to the existing size of raw material and the conceptual design was provided in this perspective. In this design, all parts were not designed however, this design only has the conveyor itself and cage made of protective inflation.

Not all the parts of the system were made in this version, and it only had the conveyor itself and the protective inflation cage. It was determined that none of the other add-ons would be developed further for this selection of design since the connections and technological solutions would vary in the final product. Later, the same rolls were utilized in many other models. Because they would be outsourced, they were basic models with no features, and multiple kinds of rolls could be utilized in the same frame. The only dimensions that matter to them are the length and diameter of the axle and cylinder.

The guided path of the conveyor is designed that is used to push or carry the required material use to feed the machine's mouth. This path is powered by the motor that is mounted towards the existing roller after fixing the roller part powered with the help of the same motor for the guider conveyor and that roller which use to pull the material from the tray and path towards the conveyor then this conveyor carries it to the feed mouth of the machine. Three conveyors function together to present the pieces to the assembly work cell. The first conveyor, under servo power, is positioned at an angle of decline and is used to lift sections from a bulk hopper.

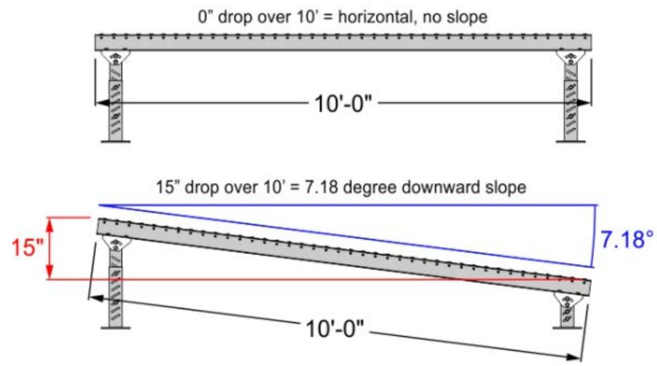

Figure 4-2: Declining of the conveyor (Irfan Ahmed Halepoto, 2016).

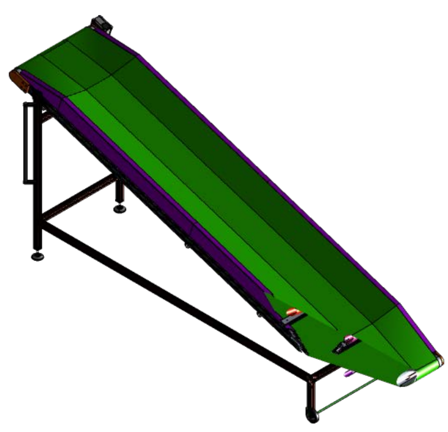

Figure 4-3: 3D model of Decline Roller Conveyor

4.2.2 Systematic design of enclosed conveyor

The design of version 2 was thought more thoroughly than its predecessor. In this version, DFMA was used, and the components were fabricated from inventory steel profiles (Figure 4-2). In addition, practically all of the connections were redesigned since the earlier solutions were far from suitable, according to the QFD chart. The legs' ends would fit within the frame and be tightened in place with a bolt in this form. The conveyor structure was completely rebuilt; however, some of the legs and the safety cage may be re-fitted with minor modifications.

In this version, the other add-ons were also included for assembly, inflation robot mounts, tool walls, as well as an air hose holder. The stand for a bead mounter as well as its balancer was left out of this version because it was deemed to be better as a distinct entity rather than a permanent element of the conveyor. The hose return mechanism is the most noticeable distinction between this version and other manufacturers' goods or prior prototypes. Other variations often include a standard hose that does not automatically return or a hose within spring that pulls it back after usage. Because these methods were ineffective for this item, a hanging spiral hose was tested (Figure 4-3).

4.2.3 Design of roller tube

Additional elements were constructed to replicate the full product to have a better visual sense of the concept. Although they are not part of the real project, a Tyre, air hoses, and inflation robots were added to the assembly. Unlike the earlier version, this version was also submitted to the client for evaluation. This version was further developed using QFD, DFMA, as well as customer input, resulting in the final version of the software.

The roller tube is designed to provide a strong support system to the conveyor belt of the rubber injecting feeding method as shown in Figure 4-4.

Figure 4-4: Isometric view of the roller tube

Determine Incline for Helix Curves

The steepness of a helix belt curve is limited, just as it is with straight belt conveyors. A decent rule of thumb is that the inclination angle at the inner radius will not be more than 22 degrees. According to the kind of belt used and physical features of the product are handled, this number may increase or decrease. The AutoCAD design of the roller tube is given in the appendix.

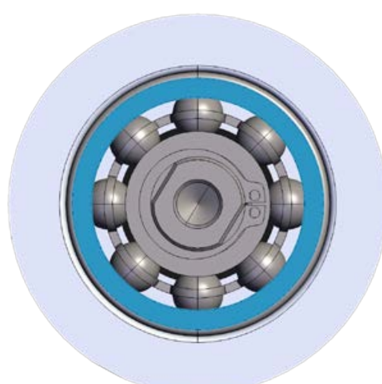

Figure 4-5: Front view of roller conveyor

The third and final model of the roller conveyor was created from the ground up. In this version, only certain old pieces from the inflation cage, as well as the hose stand, were used, and these were also changed. The logic in this iteration remained the same: use stock-sized steel components to assure availability and low production costs. The focus in this version has been on keeping the pieces simple and detachable for efficient packaging and production (Figure 4-5), yet functioning remained the most important objective.

4.3 Final Design of Guided Path Roller Conveyor for Rubber Injection Moulding

4.3.1 Designing of conveyor belt and selection of motor

The required parameters of the conveyor belt are designed including the calculation of the belt speed and its width (see Figure 4-6). The gear box is also selected that would help to manage the specification of the motor. The drive pulley selection and its calculations are also covered in this section. The absorbed power is also calculated and the results of the design are also given in the result section.

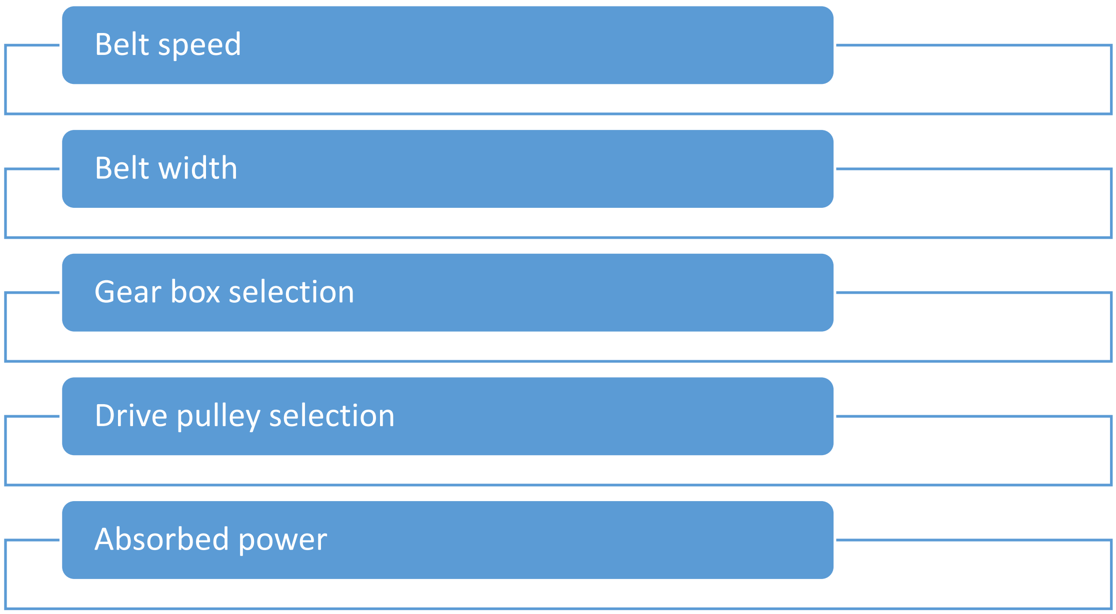

Figure 4-6: Parameters for designing conveyor belt

Calculations for the conveyor belt and input data.

The conveyor belt plays a primary role in this design because it will help to pass the material towards the hopper which will reduce the human's effort. This design will help in the selection of the conveyor belt as per the requirement of the feeding system.

Data Input

Bulk density = 1.7 T/m^3

Lump size=0-10mm

Width of belt =B=185mm

Bearing Capacity=C=800-900 TPH

Lift of material =H= 5.112 meter

Center Length=L=29m

Speed of belt=v=1.2 $\frac{m}{s}$

Troughing angle=35 degree

Inclination Conveyor= 10.36 degree

Travel takes up =600mm

The calculation of motor

The motor will be mounted on the existing roller stand, and the guider path will resemble an extended arm similar to a belt conveyor that can be folded. The motor will be the source of power for the pulling and pushing action of the rollers, which will then lead to the conveyor, which will also be powered by the same motor. This guide path conveyor will keep the material flowing into the machine even if the material breaks during the procedure, allowing the machine to continue the process without the operator's intervention.

If the shaft of the conveyor can be moved at 20 rpm, then the torque can be determined with the help of the given formula

$$T = r * F \quad (4\text{-}1)$$

r= Conveyor diameter using for driving pulley= 1 inch= 2.54 cm

The torque can be determined with the help of the below formula which includes the

T= (2.54/100) (450) =11.43 Nm

The power required to drive the shaft can also be calculated with the help of the below formula

P=T*rpm (4-2)

P= 11.43* 20= 23.028 W

The design of the conveyor belt

The conveyor belt model should conduct a thorough analysis of the conveyed material's characteristics, especially the angle of repose and the angle of surcharge. The response angle of a substance also recognized as the "natural friction angle," is the angle with which the material takes up to the horizontal plane when imposed loosely onto a horizontal surface. The response angle is also shown below which can explain the important part of the conveyor belt.

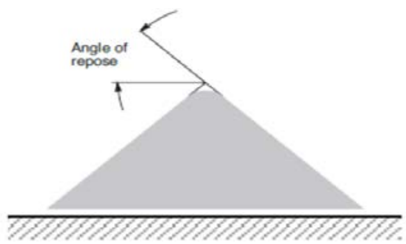

Figure 4-7: Angle response (Ananth, Rakesh, & Visweswarao, 2013)

The surcharge angle is also calculated which is also mentioned in the Figure 4-8;

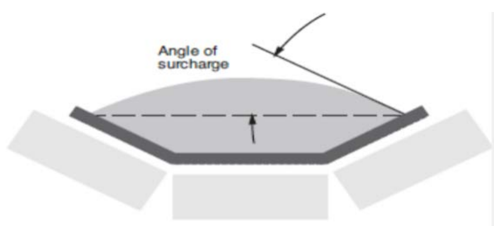

Figure 4-8: Angle of surcharge (Ananth, Rakesh, & Visweswarao, 2013)

The conveyed volume value can be calculated with the below formula;

$S = \frac{Ivt}{3600}\ m^2$ (4-3)

When this volume at given at the specific conveyor speed of $1\frac{m}{s}$.

Table 4-2: Surcharge Angle for different shape is given at specific angle response (Anath and Rakesh, 2013)

Frequency	Surcharge angle	Response angle
Very high	5	0-19
High	10	20-29
Medium	20	30-34
Medium	25	35-39
Low	30	40 and more

Belt speed

Quite fast speeds also resulted in a significant rise in the volume conveyed. As compared to the overall load, the weight of conveying material per linear meter of conveyor is reduced, and hence the structure cost in the toughing set frames and the belt itself are reduced. The physical properties of the transmitted content are used to calculate the belt speed. As the scale of a substance lump, its abrasiveness, or the particular weight increases, the conveyor belt speed must be reduced.

Table 4-3 Belt speed based on size (Ananth et al., 2013)

Lump size-Maxi. dimension		Belt minimum width	Max speed		
Uniform up to mm	Mixed up to mm	mm	A	B	C
50	100	400	2.5	2.3	2
75	150	500			
125	200	650	3	2.75	2.38
170	300	800	3.5	3.2	2.75
250	400	1000	4	3.65	3.15
350	500	1200			
400	600	1400	4.5	4	3.5
500	700	1800	5	4.5	3.5
550	750	2000			
600	800	2200	6	5	4.5

We may infer from the variables that restrict the overall conveyor speed: Because as the inclination of the belt leaving the loading point is considered, the larger the inclination, the greater the volume of friction when the material rotates on the belt. This condition is a restricting factor in determining the optimum belt speed since it causes the belt surface to excessively wear out. The repetitive abrasive activity on the belt material caused by frequent loadings into a certain segment of the belt underneath the loading hopper is proportional to the belt speed and inversely proportional to its volume (Chelopo, 2020).

Width of the belt.

The appropriate belt speed and belt width are primarily determined by the quantity of conveyed content, which is shown by the conveyer belt's design (Zhang et al., 2021). In reality, the most cost-effective troughing range is one that meets the necessary loaded volume by utilizing a belt of the smallest diameter.

Belt width calculation

The load volume of the conveyor capacity can be expressed in the form of load volume IVT and this value is calculated in the form of $\left[\frac{m^3}{h}\right] per\ v = 1\ m.second$. The angle of troughing is also defined between 20 to 45 degrees. The troughing is set at between 40 to 45 degrees which will be used in special cases.

Absorbed power

The power required for the drive pully (Pa) after considering drive pulleys loss, Pdp.

$$Pdp = \frac{((Rwd+Rbd)V)}{1000}\ KW \qquad (4\text{-}4)$$

In the above formula the

$Rwd\ is\ the\ wrap\ resistance\ which\ has\ the\ primary\ resistance\ 230\ N.$

Rbd= Resistance of Pulley bearing for drive pulley 100 N.

$$Power\ absorbed, Pa = P + Pdb \qquad (4\text{-}5)$$

Where,$power\ absorbed, Pa = 23.028 + ((230 + 100) * 1.2)/1000$

$$Pa = 23.4\ KW$$

Motor power

The output power of the motor can be determined

$$Pm = \frac{Pa}{\eta}$$

η = efficiency of gearbox after taking power losses as well as couplings=0.94 The output power can be determined as

$$Pm = \frac{23.424}{0.9} = 24.4\ KW.$$

Selection of motor

The motors having 1500 rpm are selected which has a nominal power of 37kw/1500 rpm.

The gearbox selection

It is the ratio between the input rpm as well as output rpm.

$$Reduction\ ratio = \frac{Input\ rpm\ of\ motor}{Output\ rpm\ of\ motor}$$

The rpm of the motor is 1500 rpm. The rpm of the motor at the output side can be determined with the help of the below formula

$$V = \frac{pi * D * N}{60}$$

In the above D is the pulley diameter which is 654 mm for the driving pully and this diameter is feasible for those motor which has less power than the 50kw and 24 mm extra diameter that is provided due to lagging pulley.

$$1.2 = \frac{pi * 0.65 * N}{60}$$

$$N = \frac{60 * 12}{pi * 0.654} = 35.04\ rpm\ at\ the\ output\ side$$

Guided Path Roller Conveyor calculated result for the selection of motor required for the belt and pulley.

The absorbed power of the pulley (Pa)=23.028kw

The motor power (pm)=24.49kw

The pulley speed N=1500 rpm however at the input side the rpm is 35.043 rpm

4.3.2 Belt Roller Support Design

Angled merges and strip merges are two types of customized belt conveyors that we explore. They are widely used in the airport terminal for baggage handling and also parcel as well as package management. The goal is to construct goods at an angle to a transfer point to make the transition easier. The angles at which they are commonly created are 45 degrees, 30 degrees, and 20 degrees, however, this does not preclude alternative angles from being accomplished. The conventional angles are followed because creating a new variant requires a pretty high degree of engineering and is usually not justifiable. The angled merging is accomplished by wrapping a single flat belt at an inclination around a nose bar. The belt travels in the same manner as a conveyor belt that has been flipped inside out at one end and twisted in the center. The nose bars may be as tiny as 1 inch in diameter or as big as 4 inches in diameter. Therefore, the closer the angled face could go to another conveyor, the smaller the nose bar. The disadvantage is that as the nose bar lowers in size, so does the friction and wear on the belt, thus there is still a trade-off. Irrespective of the nose bar, it is critical to remember that it is a serviceable part that should be changed, and the conveyors selected must account for that change. Angled merging is often offered in 30- and 45-degree forms.

The strip merge does the same thing, except it uses a succession of narrow belts instead of a single flat belt. The strip merging is more costly, but it eliminates the need to deal with a nose bar. The secret to strip merges is that each belt is controlled and has its tensioning system. There are several designs available, and it is critical to choose one that is both functional and appropriate for the purpose. It is very inconvenient to have to remove the complete conveyor to replace a single belt if it becomes broken. Strips merges are normally only supplied when an angled merging would not operate properly due to their high cost. Strip merges are often found in 20- and 30-degree forms.

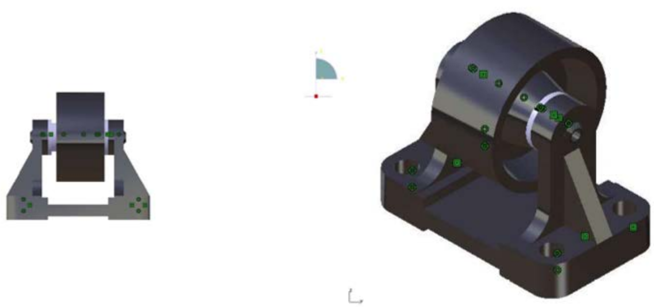

Figure 4-9 Belt Roller support; Front View (Left) Isometric View (Right)

Conveyor belts in curves form are normally delivered as entire pieces. Curves may be built in many portions for logistical reasons. The uniqueness of these demands does not differentiate between driving and intermediate parts. As a result, we describe belt curves as whole units. Based on the outer radius of the carrying surface, belt curve conveyors are classified into many size groups as shown in Table 4-4.

Many manufacturers provide just a limited number of outer radii as well as belt width options. For example, they might provide a 1,500 mm outer radius with belt widths of 600 mm, 800 mm, or 1,000 mm. Mostly every radius or belt width combination is possible, based on the manufacturer. There are several geometric constraints, including the pulley diameter, which will be explained later.

Table 4-4 Belt curve conveyor classification (Deformation in mm)

Groups	Sizes
A	Maximum of 1,200 mm (47 in.) 1,201 mm to 1,500 mm
B	59-inch 1.501 mm to 2.200 mm
C	(87 in.)
D	over 2,200 mm (87 in.)

4.3.3 Frame Construction

Different types of frames can be used in the construction of the design including the roller bed, belt curves that can be used in the concept of slider bed, and the slider bed. The surface that is in sliding form is extremely low friction and made of steel that is not painted. This sliding surface can be made of galvanized steel and phenolic impregnated wood. For instance, within heavy load applications, friction is extremely desirable. The wheels and rollers are also used in the conjunction with the slider bed. The prominent frame has various designs including the frame made with welded steel. There are many manufacturers who use this kind of frame because such frames are extremely easy to install and can be manufactured with the help of welding from the top plate side and this welding help to make the 3 sides frame. The different parts of the frames are shown in the appendix The steel box structure is made of stainless steel. The frame design is also open which can be seen in the below image. The open frame is also welded as well as extruded aluminum. The design that is opened also allows to provide the ease for visual inspection as well as provide the access to various service parts.

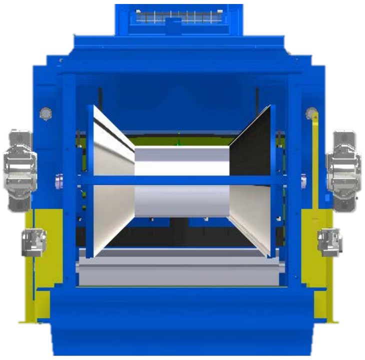

Figure 4-10: Pulley

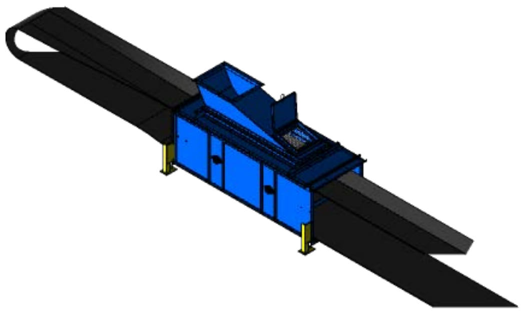

Figure 4-11: Conveyor assembly

4.3.4 Belt Drives

When choosing a belt curvature, you will have three different choices of main drive types to choose from: Friction drives, ancillary drives, and pinch drives. This is particular to the fact that the belt is connected to the motor drive rather than either the front or the back of the conveyor. In this scenario, all of these individual models specifies where the drive is positioned on the bend. The friction drive propels the conveyor directly, much as a straight belt conveyor does. Conveyors with friction drives are designed with pulleys that are trimmed to fine specifications to guarantee optimum "belt traction". They are capable of providing high rotational and linear speed, such as 600 FPS (Faster Than Normal Speeds). Since the belt's low coefficient of friction bottom contains the roller, the weight that the friction motor can handle is limited. A guiding element is placed on the circumference of the belt to expand the area that will receive torque as well. A set of bearings or a guide bead might serve as this guiding element. As opposed to the ball bearings, which create a great deal of noise, the guide bead tends to be sewed or bolted in. Although it is not the best way to go about it, friction belts may be used to force the belt to curve than to go through it by tugging. The belt is squeezed between two revolving wheels by the pinch drive. Because the tapered pulleys are only needed to monitor the belt, this drive allows for looser tolerances on them. can be operated with the minimum amount of pressure on the hardest tolerance of the three devices Thus, as in the friction drive pulley, belts, guiding elements are present on the outside circumference of belt pulleys. The only alteration that is required to the pinch drive is to be able to use it in a conveyor is the reversal of the gear. The pinch-to-wheel is often found on the outer arc, with its needles (puck joints) set to go away from the belt, so when they have pushed the two away it does not pinch the belt. Secondary pulleys are used in applications where in addition to the main pulleys, which causes a belt to spin to an operational belt or a secondary belt to turn the secondary devices as well as the former does the main devices (see Figure 4-12). Additionally, the drive supports the tapered pulley, which allows a wider range of different ancillary pulley tolerances in certain instances, the secondary drive (often non-driven) slip device may pull far more than the friction or pinch devices, operating at rates up to and above 600 feet per minute (500+). To be used effectively, a pneumatic ancillary device requiring side bow chains and keeping it lubricated requires a chain, sprocket, and chain guide maintenance would keep their activity going at a constant level to reduce wear. Although a secondary drive might be used to push a belt, it is more useful in high-volume/low-speed/low-loading applications depending on the chain design and belt tension, the side-sprockets may jump the sprocket teeth and cause them to wear faster. To a certain extent, the chain becomes noisy with time, according to the level of maintenance it is performed.

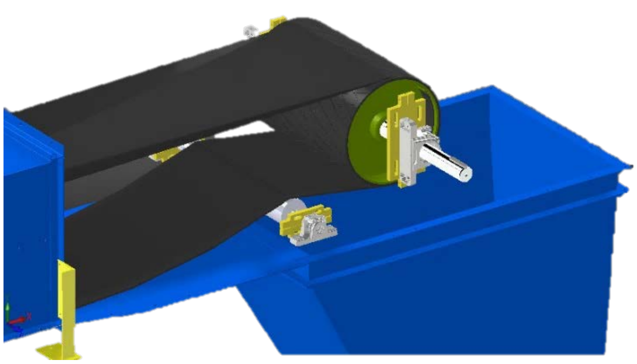

Figure 4-12: Motor Driven Belt Drive (isometric view)

4.3.5 Belt Design

Ideally, the belt is tight throughout the breadth of the conveyor on straight belt conveyors so that the product does not come beneath the edges of the belt. According to the construction of these belts, A multifilament warp and a monofilament weft are used in these belts. Belt type is referred to as being ‘curved’ because of the shape rather than texture; this sort of belt requires a ‘balanced’ weave. Whenever a curved belt is sliced from a wrap of belting, both weft and warp points are oriented in various directions across the belt’s curvature arc.

The monofilament weft will stretch more than the multifilament warp to attain a proportion in the weave, therefore a balanced weave is usually using both the weft and the warp sets. When it comes to the belt, it is rigidly connected to the framing and the type of drive. Due to the inherent basic concepts of a belt curvature, the belt naturally wants to pull toward the middle. One essential aspect of the belt layout is to consider is where the belt is fastened. One of the basic belt design possibilities is beading, the other is chain drive, and the third is the chain & sprocket. Beading uses an extruded urethane-spun polyurethane (polyurethane) belt, which is stitched to the belt’s outside edge. This is usually employed in designs for pinch or friction drives. The beading is done by holding the various bearers in place to the exterior of the frame. There is a strong connection between both the belt and the beading in this design scheme; the belt must have balanced tracks and weave as well along with the curve. The chain is linked to the belt using a series of rivets; a depiction of “ancillary drive design”. The chain is guided by a guide track that maintains the right radius. To the belt around the outside side of the unit, there are also a series of rollers, the third style of which is known as race-expand. The bearings are typically fastened to the sprockets on each side of the chain by either rivets or grommets. This is a kind of tap shoe with beading; you will usually see this utilized with friction or pinch drive designs. Although these embroideries with beads offer the quietest embroidery, you may still have limits on how much it can carry. The chain design may have the best load-carrying capability, but it is noisier at high speeds. The primary function of the expandable belt design is to keep the belt in place, and its additional one which is reliant on belt tracking is dependent, thus it is very vital for the secondary and bearing and guide structures to be able to be sturdy. There are unlimited possibilities when it comes to belts that have vulcanized splices or have self-splicing clasps. the machine provides more versatility and fewer places of friction while fastening the belt, which results in a perfectly flat surface belt that can be maintained over time.

4.3.6 Pulleys

On belt turns, the pulleys are often tapered to fit the curve radius. The taper is intended to keep the belt in place. The pulley may be constructed in several techniques and materials. Pulley structures may be divided into the following categories:

- Rolling form tapered steel
- Tapered steel in cold form

- Urethane cast
- Urethane Machined
- Turned wood

For drive pulleys in the case of steel pulleys, a rubber and urethane lagging may be applied for greater traction on friction-driven rotations. Chain drives need the addition of a sprocket to a similar shaft as the pulley to drive the associated chain or even other power transmission devices.

The prototype functioning and schematic are provided above via email to customer HGF. There were many flaws in the design. Further improvement is required to enhance all the designing parameters. The C profile steel is used in the manufacturing of the structure which is not against the requirement of the customer. The reason for changing the frame profile was that it's easier to install any kind of rolls on an open frame profile. The frame also has two distinct end pieces, one taller than the other to prevent a rolling Tyre. The buyer also requested that the central support beam be detachable so that everything could be packed into a smaller area in the IKEA pattern. The stopper at the bottom of the frame was replaced with the final roll to be lifted. This makes it easy to remove a Tyre from the conveyor and eliminates the possibility of damaging the rims. Because they were accessible, the rolls utilized for the prototype were the same ones that the client had previously used to build their autonomous warehouse. Any other rolls that fit within the frame and have an axle diameter of less than 8-15 mm might have sufficed.

4.4 FEM Analysis

A simpler 3D model was developed in the software Solid Works program by adopting the frame as the study object to determine the dynamic properties of the framework of the "horizontal conveyor rubber injection moulding machine". With ANSYS Work, the six natural frequencies were identified for the frame and its associated modal shape was measured, in addition to the functioning state of the injection machine, the modal vibration on each part was also investigated. The findings of this investigation may help in formulating the design and optimizing the injection. This finding is based on the analysis of the motion and shows that the excitation frequency for the middle seat is smaller than the frequency without any resonance effects. Finally, using optimal control assessment of the ejection machine's headstock, the thickness of the head-stock was lowered by 10 mm, and also the weight was lowered from 374.2 kg to 356.3 kg, achieving the materials savings and cost reduction goals.

Tensile Stress

σ=FA

In the above equation, the σ is the tensile stress and force can be representing by F however, the A is showing the cross-sectional area. The bending stress is representing below in which the

$$\sigma b = \frac{M}{A.e}\left[\frac{y}{Rn-y}\right] \quad (4\text{-}6)$$

In the above equation, the A is representing the cross-sectional area, e is the distance of the centroid axis, R is the curvature radius, Rn is the neutral axis radius, and y is the distance from the neutral axis. All the figures related to the stress analysis carried out using ANSYS is given in the appendix.

This roller is designed after observing the thickness of ropes including 1 liter or 2 liters depending upon the pressing. The flow rate of the feed takes 10 to 60 seconds regarding the blue material comprising upon the detail. The thickness of the ropes is between 8 to 15 mm and the width of the rope is 30 to 85 mm. The maximum operating temperature falls in between the 80 to 90 C used for the injection screw. This system is designed for the feeding system and the FEA analysis is checked.

Table 4-5 Tensile stress at the roller

Designing	Force applied (Max) (N)	Compressive Stress(N/mm^2)	Tensile stress (N/mm^2)
Existing roller	350	3	15.1
Optimization of roller	350	2.739	13.4

Table 4-6 Deformation in mm

Designing	Von mises stresses	Deformation (mm)
Existing roller	11.57	0.032
Optimization of roller	10.24	0.019

In the above model, the stress analysis is done with the help of Ansys software and the results of FEM analysis are obtained. The compressive stress of the existing and customized roller is provided above.

5 Conclusion

In this report, the guided path of the conveyor is designed that is used to push or carry the required material feed to the machine's mouth. This path is powered by the motor that is mounted towards the existing roller after fixing the roller part. This part is powered with the help of the same motor for the guider conveyor. The roller which uses to pull the material from the tray and path towards the conveyor then this conveyor carries it to the feed mouth of the machine. The power requirement of the motor is determined including the bandwidth, belt width as well as the speed of the conveyor system.

The dissertation is an excellent example of a product design process within the context of a wider product development cycle. The development process began with the client identifying market potential, researching it, as well as eventually creating their prototypes. The commencement of this process comes at an ideal time since the concept phase with prototypes was coming to a conclusion, and the next logical step was to create precise production documentation. The project is quite similar to a real-world professional job. It was interesting and aided in the development of professional abilities and preparation to begin working as an engineer. The topics covered in the project are prevalent in many technology firms. Product design, outsourcing, global production, and online sales are all commonplace in today's commercial and industrial environments.

The project's execution followed the timeline reasonably well and resulting in a working prototype for the client's usage. The prototype improves safety and efficacy, is simple to construct and disassemble, employs simple and inexpensive technology, and needs a small variety of tools. Also, it meets the requirements established by the client at the start of the project. During implementation, the client's voice has become the most significant guiding aspect of the process.

Although Solid Works, AutoCAD, QFD, and FMEA were valuable tools, prioritizing them above the client would have been insufficient. Although new methods had to be explored with the client, no major concerns arose throughout the process. The development process might be continued by doing practical testing to see what practical concerns might arise in the prototype as a result of user experience. Following testing, the blueprints should be revised depending on user input, and these updated solutions tested as well. Finding an appropriate manufacturer for mass manufacturing may also be difficult, and the customer's own contacts and expertise may be quite helpful in this regard.

6 Critical Review

6.1.1 Ethical and social

This system can fulfill the requirement of the feeding system effectively. The section of the motor is also selected to operate the conveyor that is used to carry the material. This conveyor can feed the mouth of the rubber moulding machine in the way it desired to function. In the making of the machinery, we have followed the EU legislation based on the regulations, safety and standards this is an important aspect which we have to follow if not the design of machinery is not applicable in the EU market. We have followed the rules and regulations while collaborating with the company. The project helps in making no operator intervention during the production cycle and the company also focus on ecofriendly process and methods. The company also got good commitment with society around which is clear from the products and the demand of their goods.

6.1.2 Health and Safety Hazards

Steel rollers are wrapped with rubber and polyurethane sheet to offer a regulated level of resilience. After that, they are sterilized in autoclaves. Aside from the health dangers, then there's the potential of fire or explosion from the fine cured rubber dust created while grinding the covered roller to shape. The vast majority of recorded rubber factory fires include finely split vulcanized rubber and dust.

Depending on the particle size, extraction at rubber grinding machines will normally need to be developed and fitted for usage with potentially explosive dust. Consider where the dust collecting unit is positioned, and especially where the explosive relief vents are positioned. A subsequent dust explosion may be avoided by practicing good housekeeping. If the operator makes too deep a cut, the rubber will overheat, increasing the danger of a fire.

6.1.3 Mechanical Hazards

Entanglement between the revolving mandrel as well as the supplied material is a severe risk. These have resulted in severe injuries to operators, especially when cable and ropes are used. In addition, there is a flowing nip between the material as well as the mandrel. Operators must always wear close-fitting clothes with cuffs or short sleeves, and long hair should be tied back. This equipment is particularly difficult to secure, and expert assistance may be required when creating solutions.

For relatively small lengths of hose, less than 3 meters, one alternative is to offer a hinge guard of horizontal lines down the mandrel's length, linked with a DC injection brake system, by which the different materials are injected.

When making wire-reinforced tubing, operators (wearing a leather waistcoat and leather gloves) would wrap the wire around their back and through their gloved hands before feeding it onto the mandrel. They can adjust the tension in the wire by leaning away from the mandrel, but the chance of entanglement is considerably increased. A trolley-mounted reel or an automated winding head that travels the length of the machine should be utilized as an alternate means of feeding the wire.

6.1.4 How to avoid mechanical hazards

More common are semi-automatic or fully automatic machines where conveyors remove the moulded product. Injection moulding machines tend to operate at faster speeds and on shorter cycle times than compression/transfer moulding, which effectively increases the potential risk to the operator from mechanical hazards.

6.1.5 Economic

This is not in the project scope but in considering the general aspects the it is not a satisfactory. But if it is to be considered to be in larger quantities then the price can be lowered. The materials involved like motor conveyor fabrication process and there is also challenge with space so the complexity of parts in order to install in the required space and man hours involved.as said if considering in greater number it can lower the prices.

6.1.6 SWOT Analysis

Table 6-1SWOT Analysis of the Project

Strengths - knowhow - 3D design proficiency - customer's experience and passion	**Weaknesses** - Author's inexperience - a long distance to try out prototypes
Opportunities - gaining professional experience - getting a good product as an outcome - prepare for future possibilities on modular design	**Threats** - time limits (schoolwork at the same time) - not finding suitable solutions - blueprints too hard to manufacture properly

The SWOT analysis of this project is represented above in the strength, weaknesses, opportunities and threats are mentioned. In the strengths, the customer show professionalism in collecting the data for this topic including the background, knowledge about the CAD program. The experience of the customers and passion both are explained.

Weaknesses: Weaknesses include the author's lack of expertise functioning at the engineering level and producing relevant data for a corporation. This is not a difficult challenge to overcome, although it may cause some swings inefficiency in the initial process ***Opportunities***: The most promising aspect of this idea is its opportunities. If all goes well, the author will obtain valuable product design expertise, and the buyer will get a high-quality product at a fair price for their sales catalog. This also opens the door for better implementation of a similar sort of system to make use of modularity.

6.1.7 Environment

According to the project, there are several aspects to follow environment friendly such as ***1***. Use of lighter materials with adequate strength and less energy consumption. ***2***. considering motors and belts which is efficient and compatible with the company atmosphere in terms noise and feed material. ***3.*** Fabricating standard parts to save manufacturing energy. ***4.*** Using fewer components accordingly, fewer interfaces, and less material. ***5.*** Paying attention to the life cycle of the project.

6.1.8 Recommended Amendments in Final Design

This design requires further improvement including the extension of legs which can fit in the new frame and that frame should be taken apart. The DFMA is compromised because of the fewer bolts connected in the assembly phase. The buyer said that the legs would not be installed and disassembled often enough to cause an issue. Separable pieces may also be put in smaller boxes, which better meet QFD requirements. In concept, the height-control mechanism remained the same, but the measurements needed to be adjusted to accommodate new components.

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Appendices

Appendix-I QFD

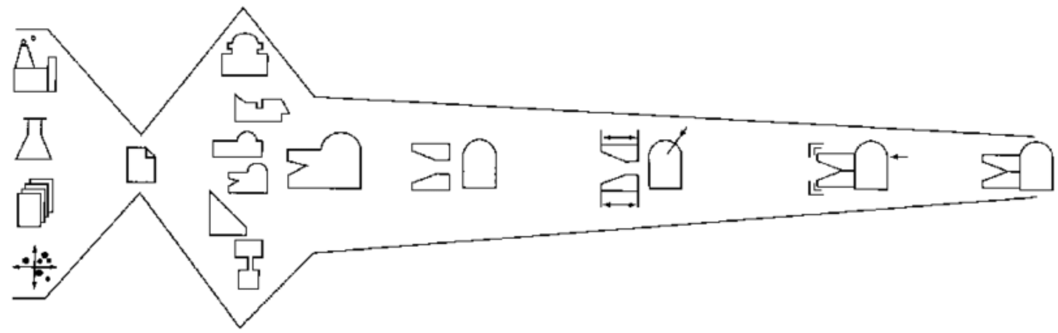


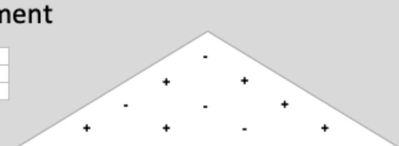
Figure A-1 Generic product development-process chart (Ulrich et al., 2020)

QFD

Quality Function Deployment

Project Title: ENHANCEMENT OF INDUSTRIAL HORIZONTAL RUBBER INJECTION MOLDING MACHINE FEEDING SYSTEM
Project Leader:
Date:

You need only to fill the white and blue cells.



Correlation:	+	.	-	
	Positive	No correlation	Negative	
Relationships:	9	3	1	
	Strong	Moderate	Weak	None

Customer importance rating (1: low, 5: high)	Customer Requirements - (What) ↓ / Functional Requirements (How) →	Design and Manufacture Cost	Efficient Feeding	Ease to assemble	Torque Capacity	high durability	Weighted Score	MY Satisfaction rating (O)	HGF rating (A)	INSTITUTION rating (B)	
	Desired direction of improvement (↑,0,↓)	↓	↑	↑	↑	↑					
5	Continuous and effective movement of rubber raw material during fed into the injection molding machine	9	9	3	3	9	165	12	12	12	
1	Roller Conveyor Design	9	1	9	1	9	29	10	10	10	
5	FEM analysis of designed roller	3	3	1	9	9	125	9	9	9	
5	Automated Function - computer controlled	9	9	3	1	9	155	8	11	11	
5	Design Calculations for motor design	1	1	1	9	3	75	7	8	8	
1	Injection Volume=1 Liter or 2 Liter depending on the press	1	9	3	3	9	25	2	6	6	
1	Flow rate of the feed for 10-60 seconds	1	9	3	1	9	23	1	5	5	
1	Feed Size	9	9	3	3	9	33	11	4	4	
5	Thickness of the ropes 8-15mm	3	9	9	1	9	155	3	3	3	
5	Width of the ropes 30-85mm	3	9	9	1	9	155	4	2	2	
5	Maximum Operating Temperature 80-90°C for the injection screw	1	3	3	3	9	95	5	1	1	
5	Power Transmission System Calculation	1	3	3	3	9	95	6	7	7	
	Technical importance score	170	258	178	158	366	1130				
	Importance %	15%	23%	16%	14%	32%	100%				
	Priorities rank	4	2	3	5	1					
	Current performance	A	A	B	C	C					
	Target	A	A	A	A	A					
	Benchmark	A	A	A	A	A					
	Difficulty	5	5	5	1	1	1: very easy, 5: very difficult				
	Cost and time	5	5	5	1	1	1: low, 5: high				
	Priority (=1)	1	1	1	1	1					

Competitive evaluation (1: low, 5: high)

Comments/Conclusion:

PROJECT REQUIREMENTS gathering is the first step. After gathering requirements, EU regulations are collected and documented to extract "how" functional requirements out of them.

Figure A-2 QFD based on voice of customer

Appendix II FEM analysis

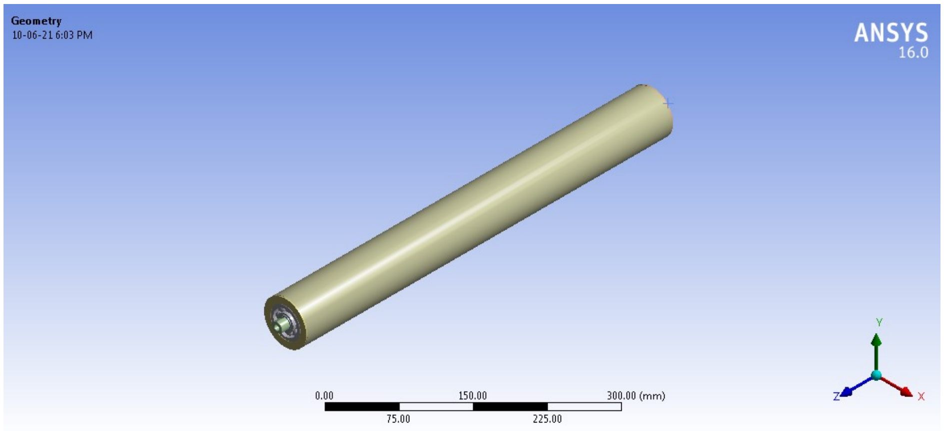


Figure A-3 Geometry

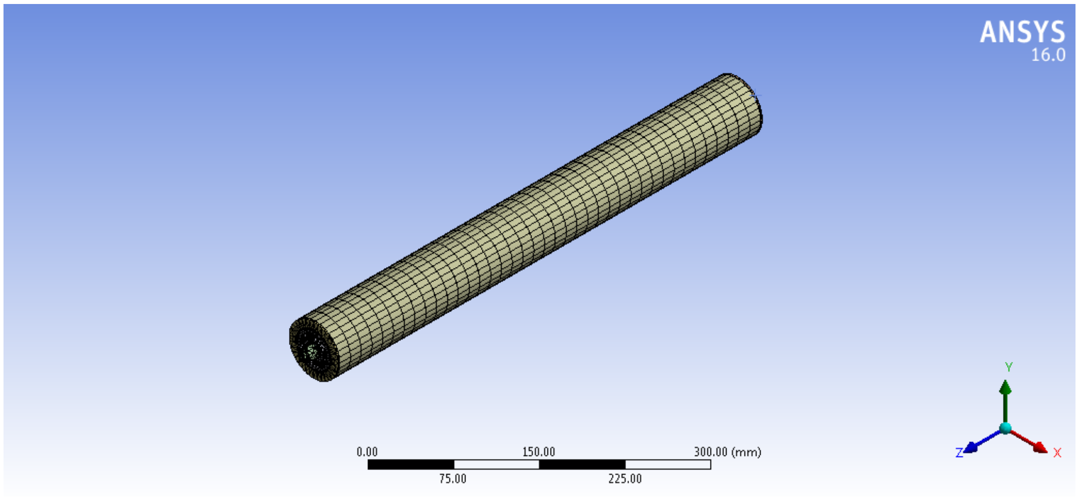


Figure A-4 mesh

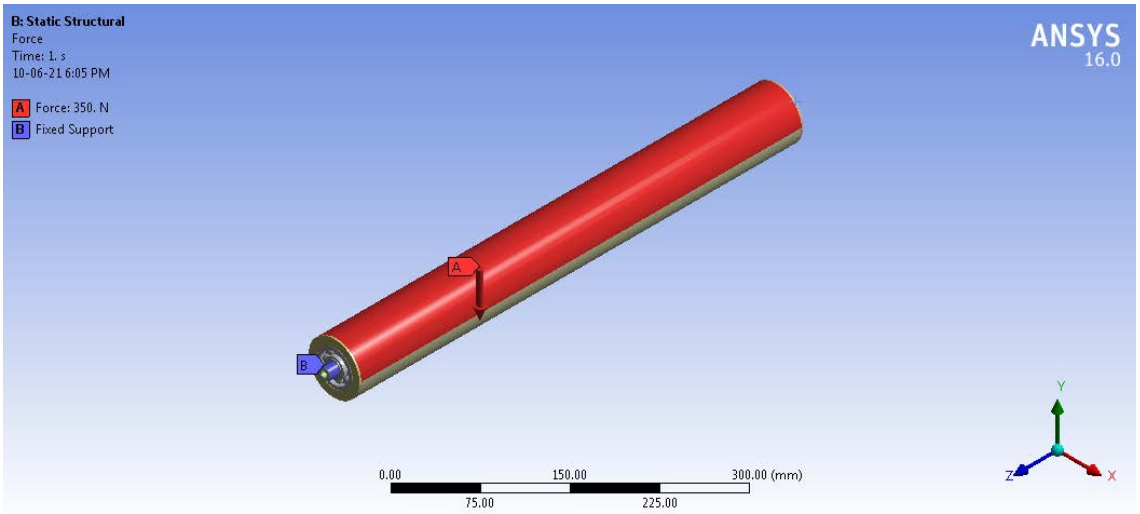


Figure A-5 Static structural

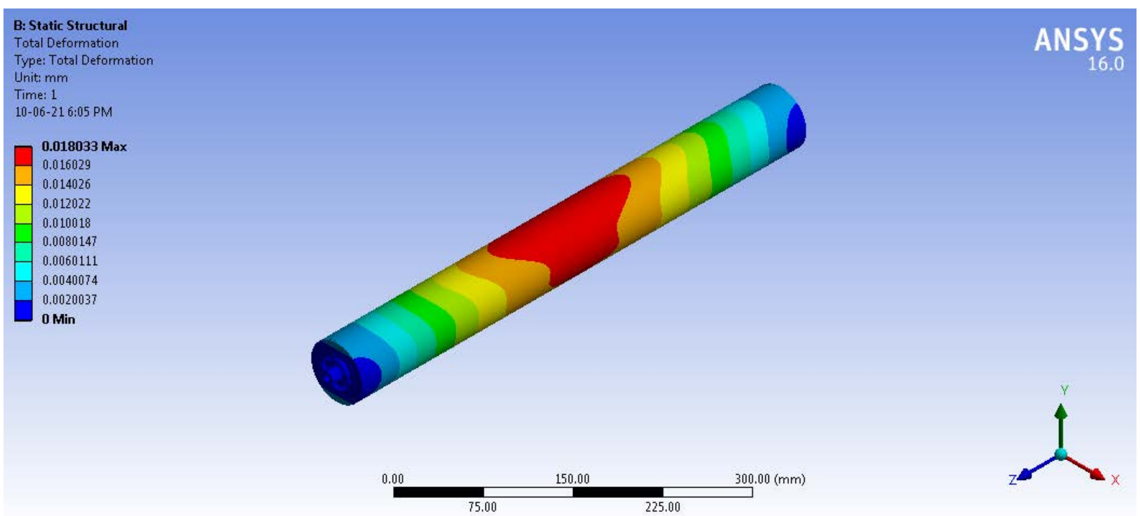


Figure A-6 Static structural total deformation

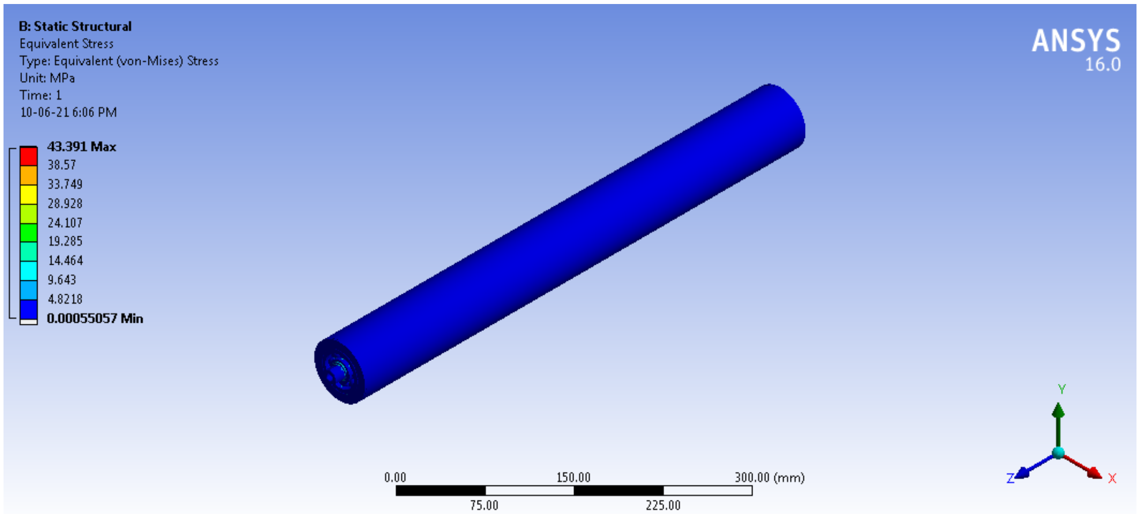


Figure A-7 Static structural (Von-Mises)

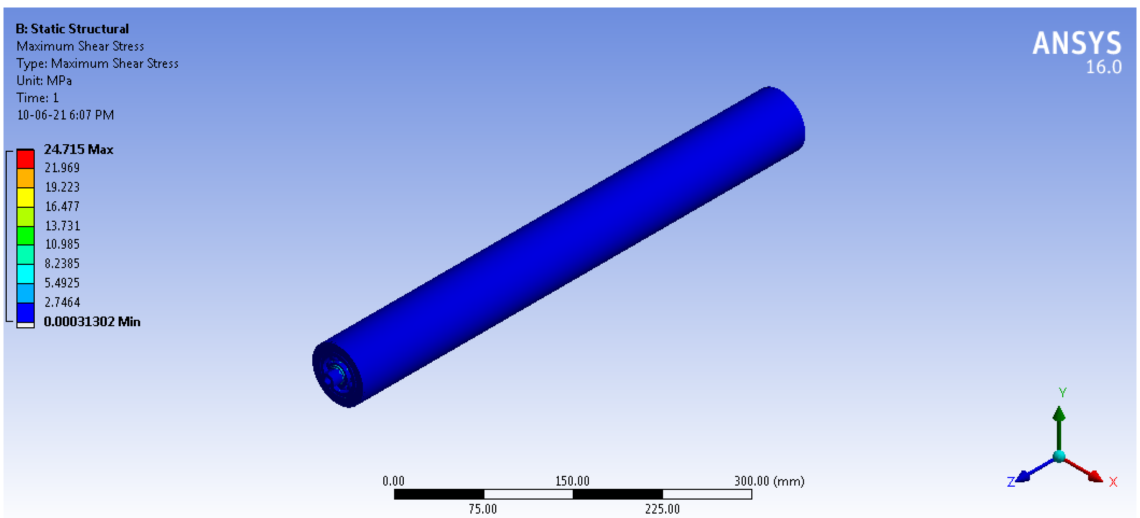


Figure A-8 Static structural maximum shear stress

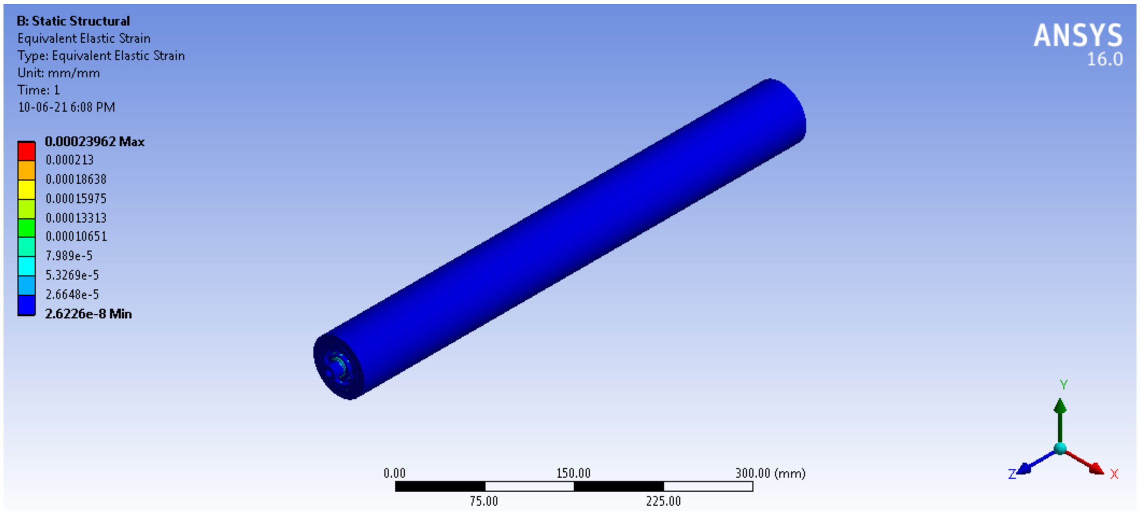


Figure A-9 Static structural equivalent elastic strain

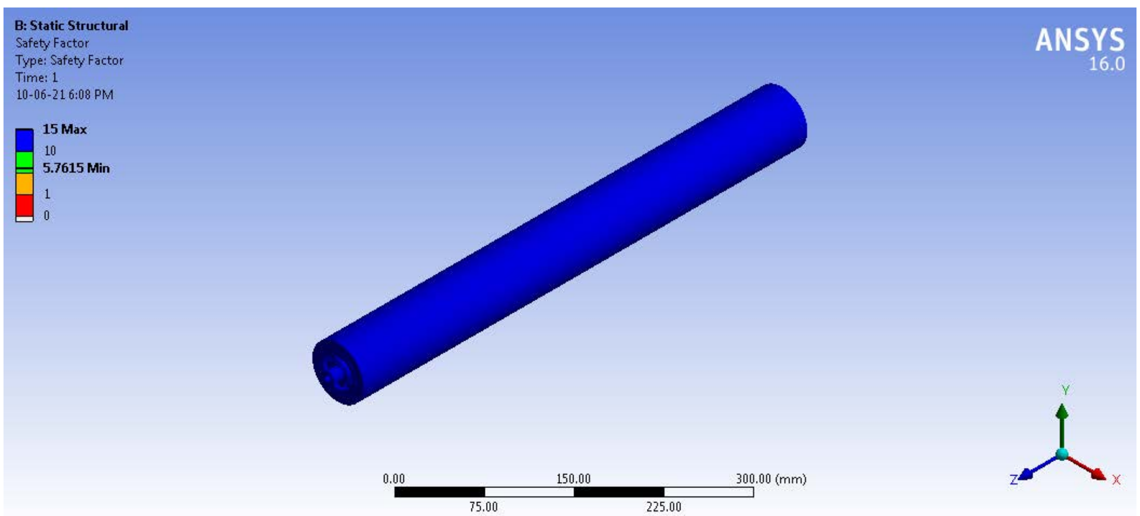


Figure A-10 Static structural safety factor

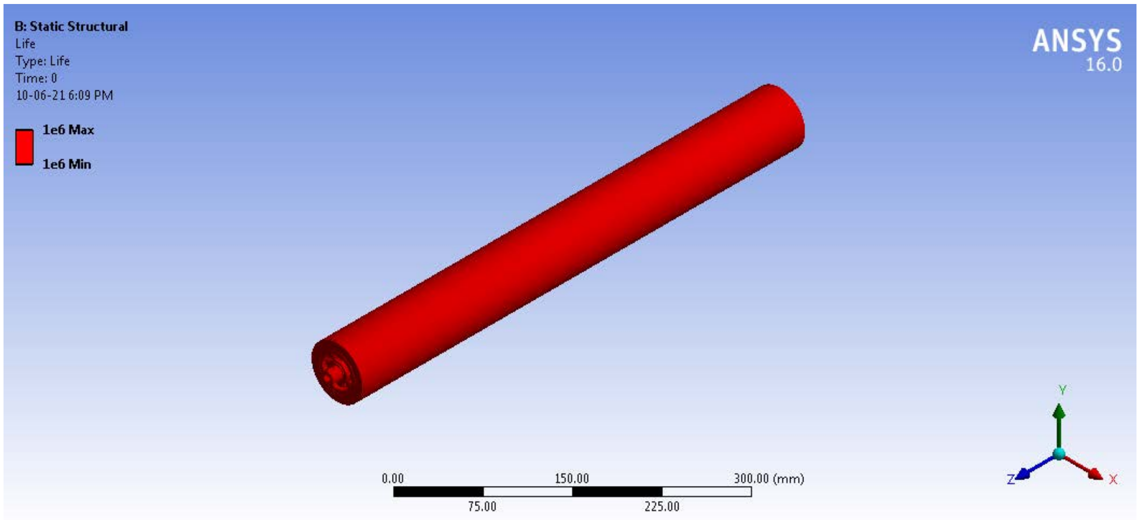
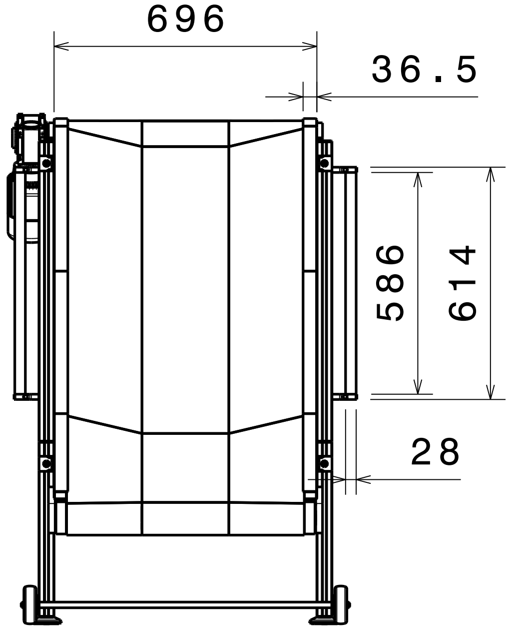
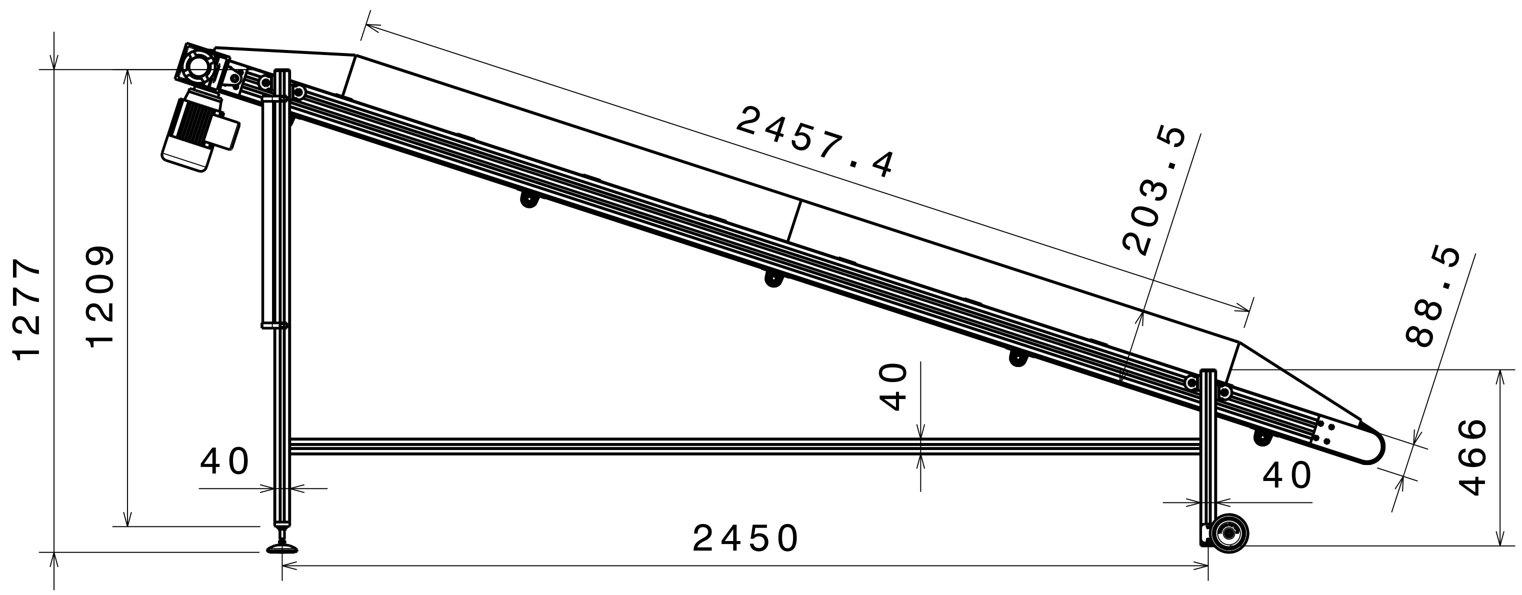


Figure A-11 Static structural life cycle

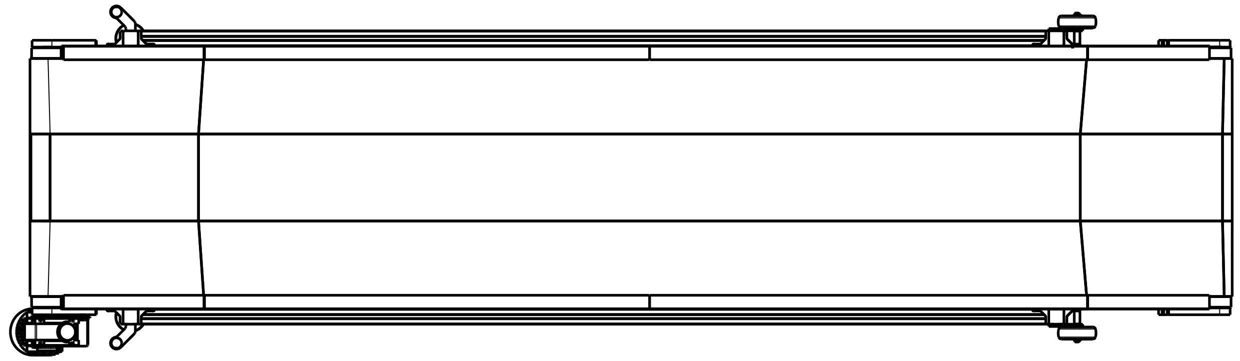
Appendix III – Detailed drawings of declined roller conveyor



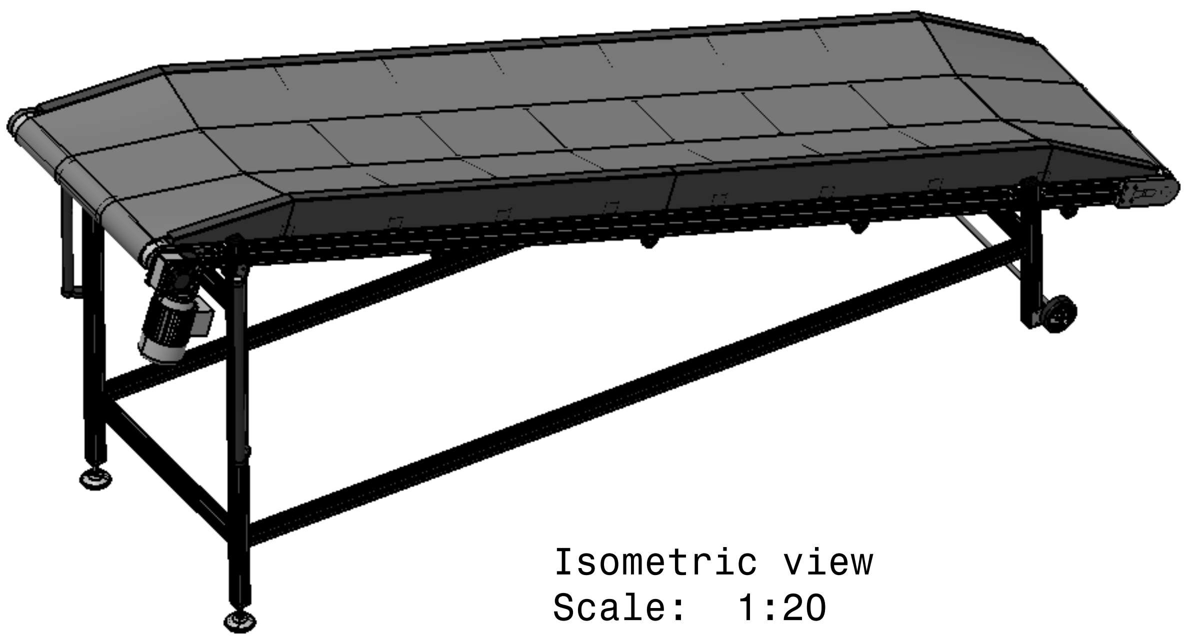
Right view
Scale: 1:20



Front view
Scale: 1:20



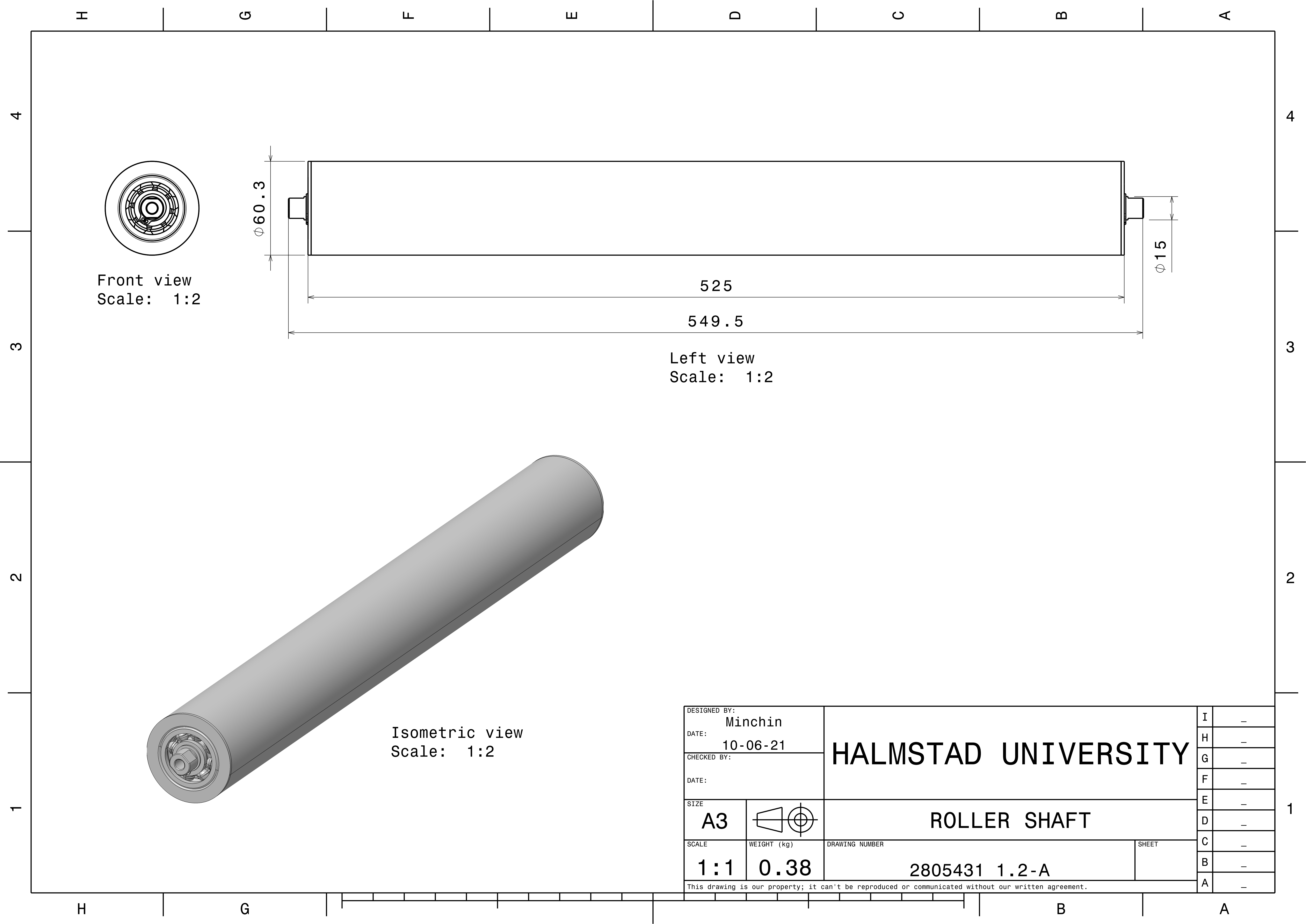
Top view
Scale: 1:20



Isometric view
Scale: 1:20

DESIGNED BY: Minchin DATE: 10-06-21 CHECKED BY: DATE:	HALMSTAD UNIVERSITY		
SIZE A3		ROLLER CONVEYOR	
SCALE 1:1	WEIGHT (kg) 38.01	DRAWING NUMBER PTD.00 Conveyor	SHEET

I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_



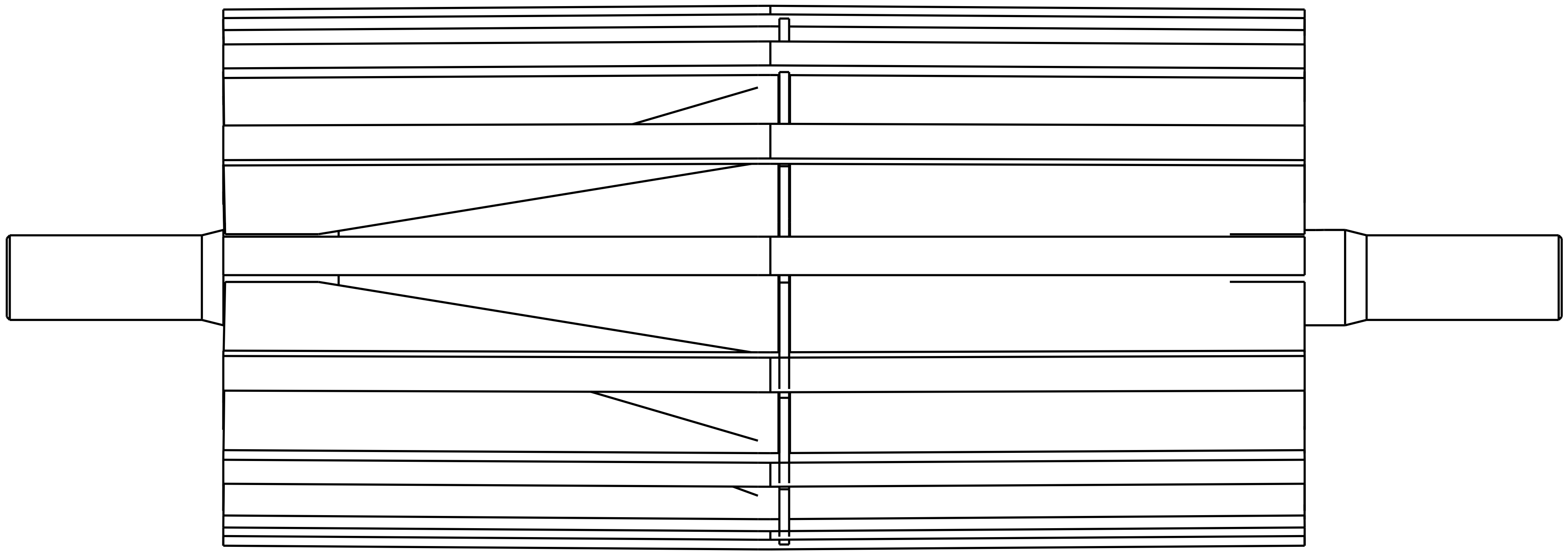
Front view
Scale: 1:2

Left view
Scale: 1:2

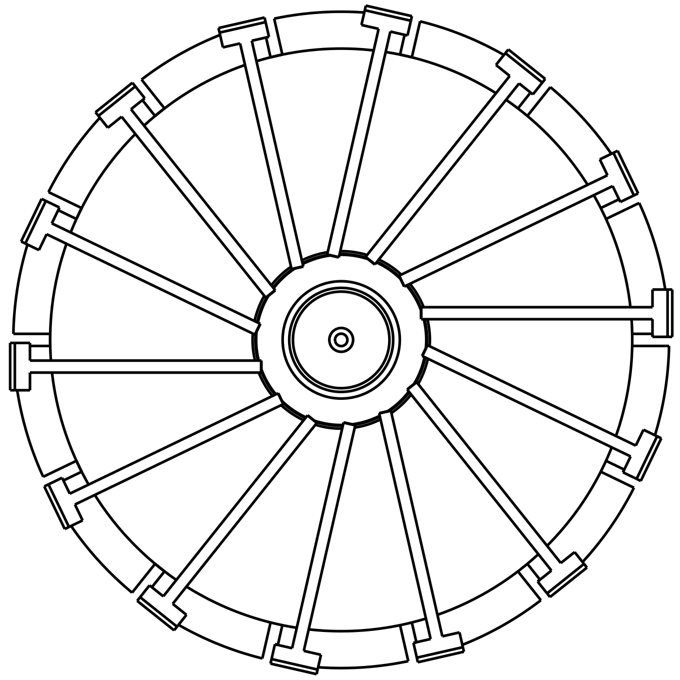
Isometric view
Scale: 1:2

DESIGNED BY: Minchin DATE: 10-06-21 CHECKED BY: DATE:		HALMSTAD UNIVERSITY	
SIZE A3		ROLLER SHAFT	
SCALE 1:1	WEIGHT (kg) 0.38	DRAWING NUMBER 2805431 1.2-A	SHEET

I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_



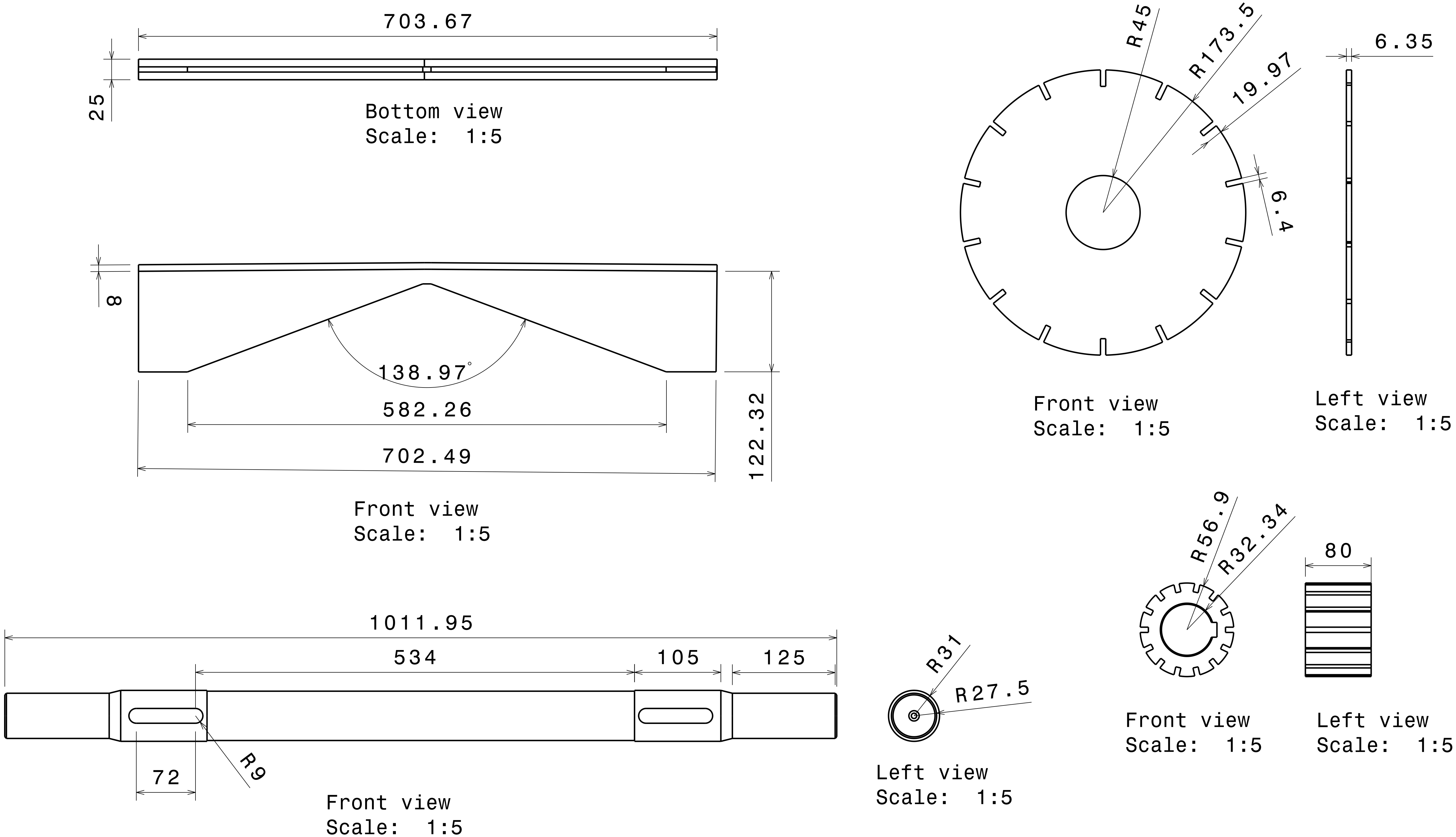
Front view
Scale: 1:4



Left view
Scale: 1:4

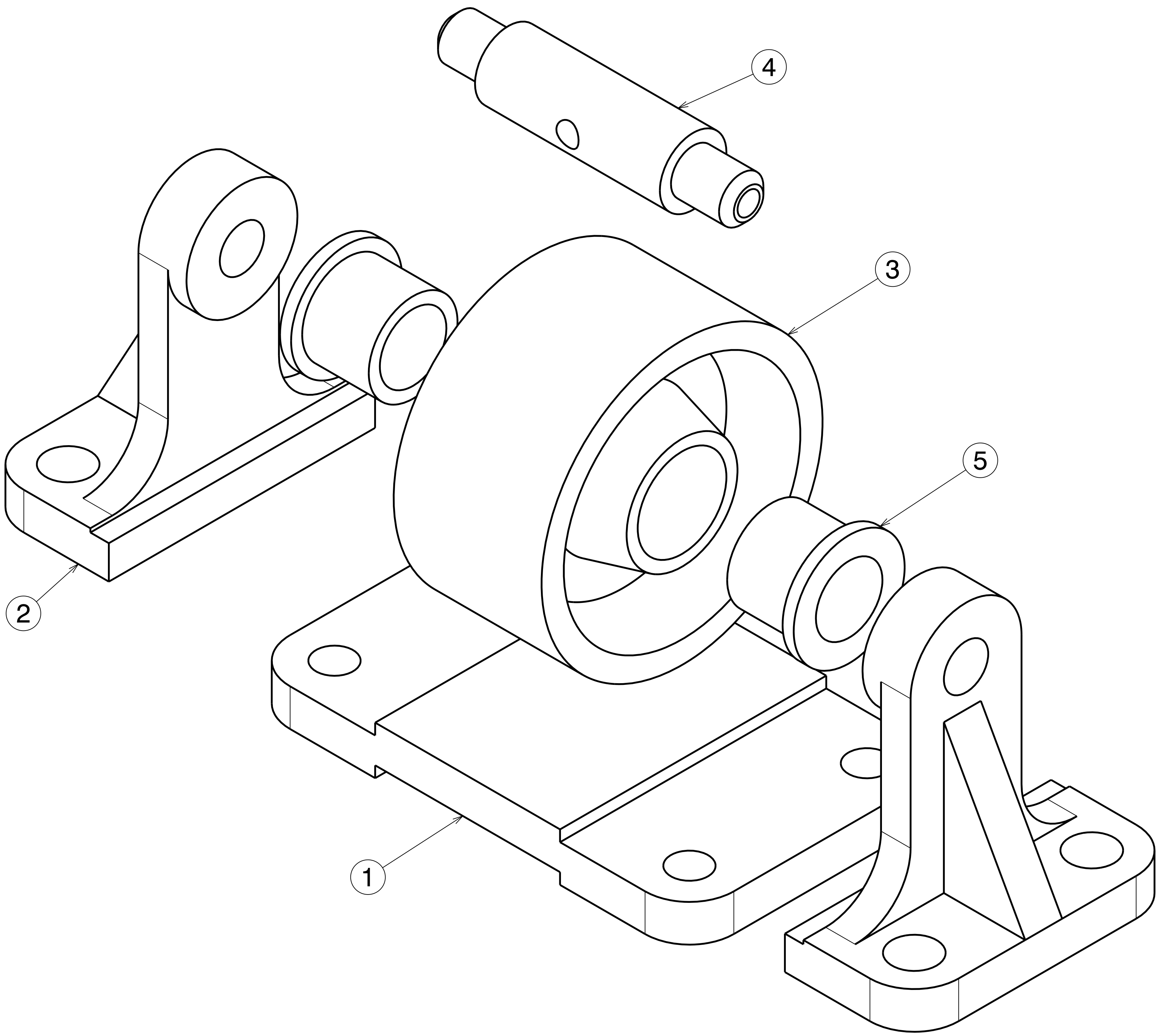
DESIGNED BY: Minchin DATE: 16-06-21	HALMSTAD UNIVERSITY		
CHECKED BY: DATE:			
SIZE A3		Tensioned Roll	
SCALE	WEIGHT (kg)	DRAWING NUMBER tensioner roll assembled	SHEET

Revision	
I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_



DESIGNED BY: Minchin	HALMSTAD UNIVERSITY		
DATE: 16-06-21			
CHECKED BY:			
DATE:			
SIZE A3	COMPONENTS		
SCALE	WEIGHT (kg)	DRAWING NUMBER tensioner roll assembled	SHEET

I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_

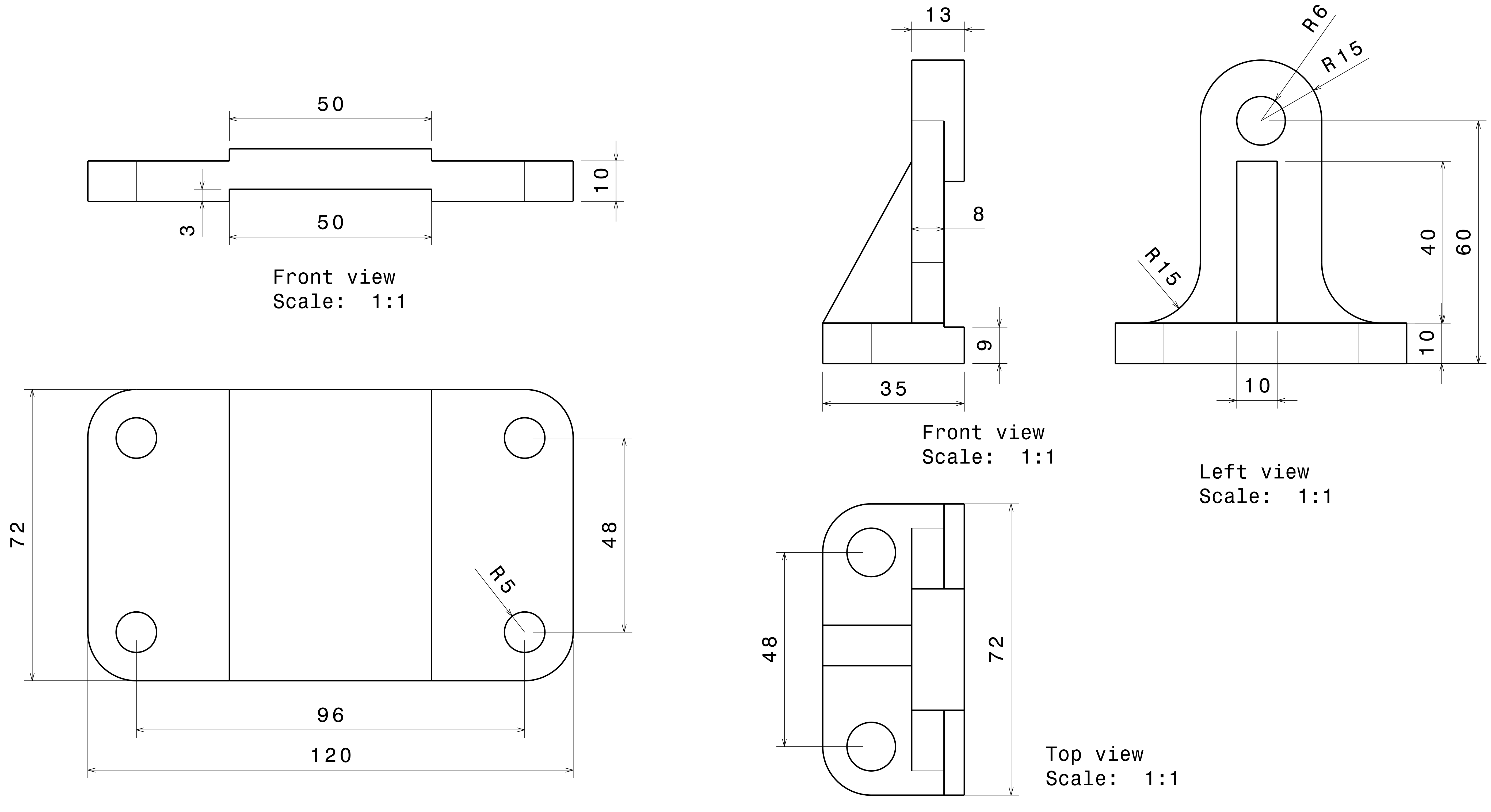


SL.NO	PART NAME	QTY
1	BASE	1
2	BRACKET	2
3	ROLLER	1
4	SHAFT	1
5	BUSH	2

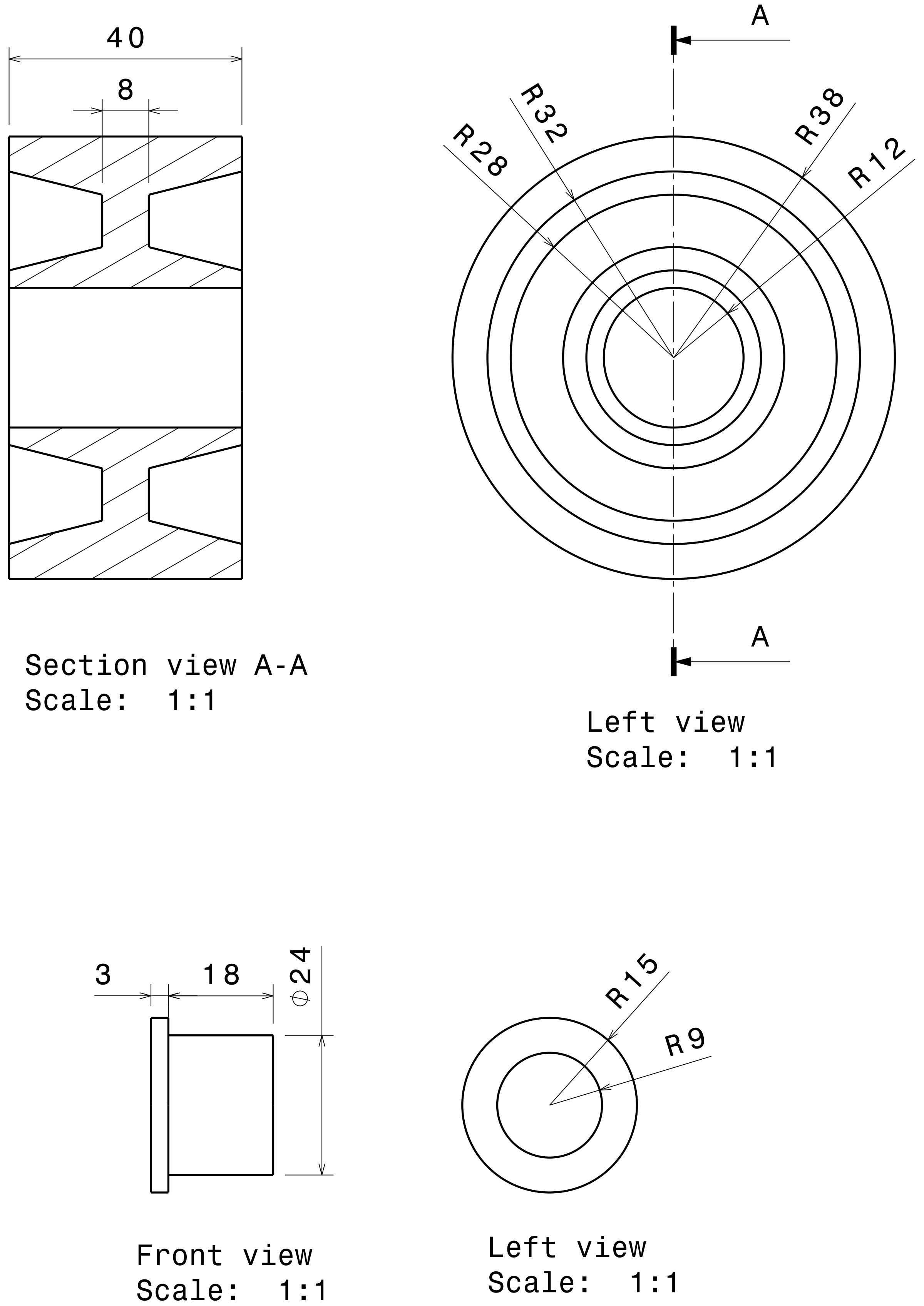
Isometric view
Scale: 1:1

DESIGNED BY: Minchin	HALMSTAD UNIVERSITY		
DATE: 16-06-21			
CHECKED BY:			
DATE:			
SIZE A3		ROLLER ASSEMBLY	
SCALE	WEIGHT (kg) 0.30	DRAWING NUMBER Product1	SHEET

I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_



DESIGNED BY: Minchin DATE: 16-06-21		HALMSTAD UNIVERSITY		I _
CHECKED BY: DATE:				H _ / G _ / F _
SIZE A3		BASE & BRACKET		E _ / D _
SCALE	WEIGHT (kg)	DRAWING NUMBER Product1	SHEET	C _ / B _ / A _

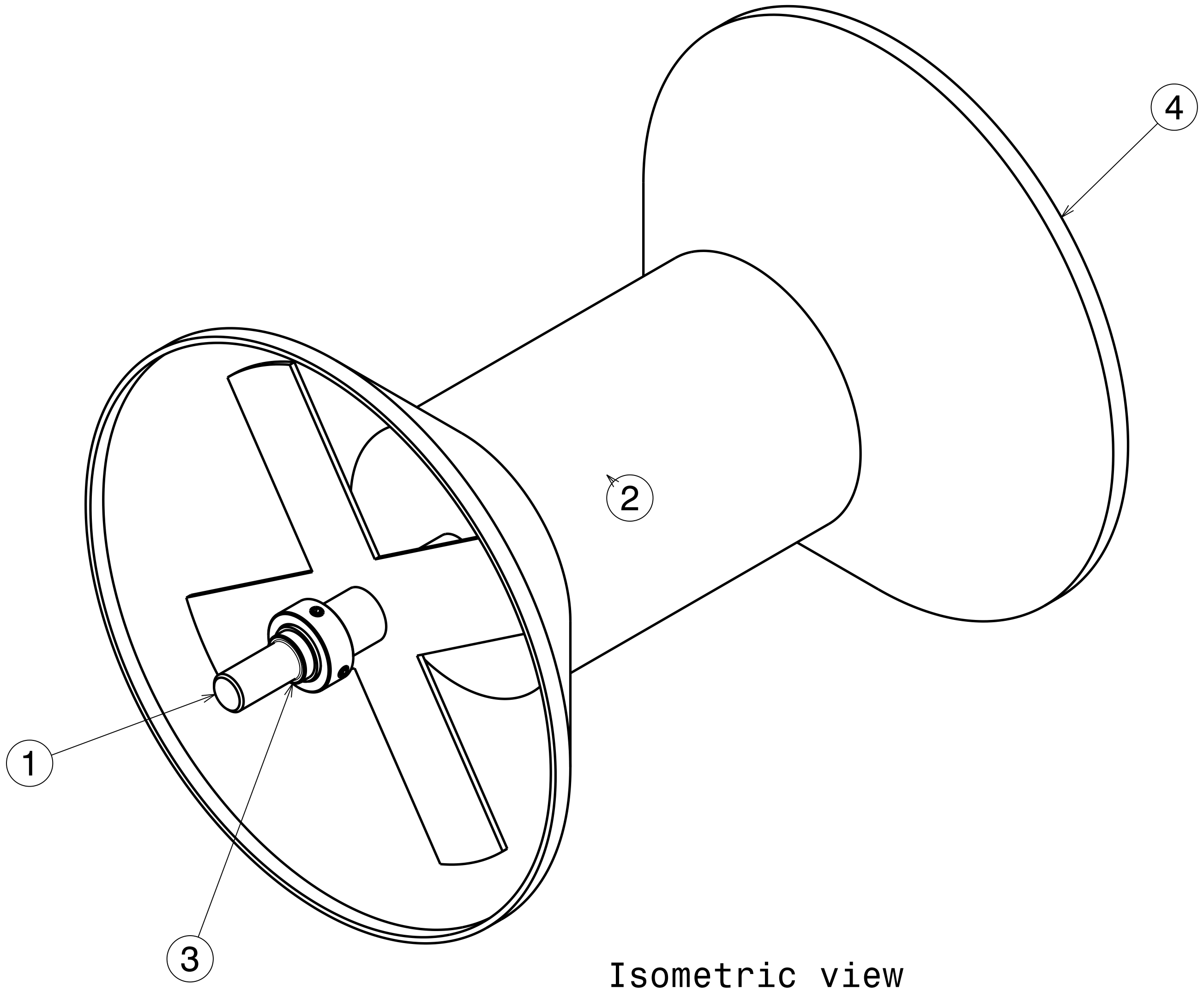


DESIGNED BY:	Minchin
DATE:	16-06-21
CHECKED BY:	
DATE:	
SIZE	A3
SCALE	
WEIGHT (kg)	
DRAWING NUMBER	Product1
SHEET	

HALMSTAD UNIVERSITY

ROLLER, SHAFT & BUSHING

I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_



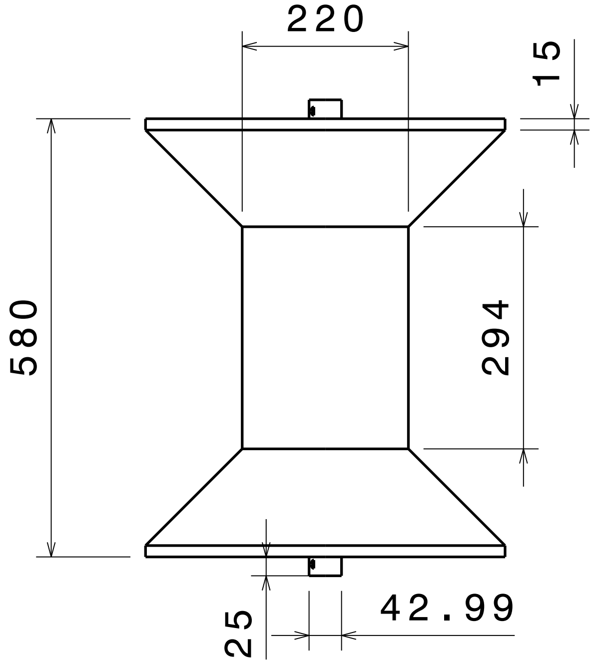
Isometric view
Scale: 1:5

Bill of Material: roller armed

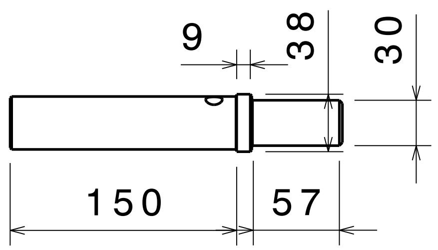
Quantity	Part Number
2	roller shaft end
4	socket set screw cone point_ai_SSCONESKT 0.375-16x1-HX-N
2	stop
1	roller 01

DESIGNED BY: Minchin	HALMSTAD UNIVERISTY
DATE: 17-06-21	
CHECKED BY:	
DATE:	
SIZE A3	ROLLER ARMED ASSEMBLY
SCALE	WEIGHT (kg)
DRAWING NUMBER	roller armed
SHEET	

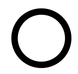
I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_



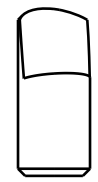
Front view
Scale: 1:10



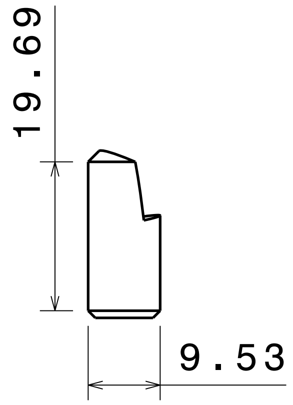
Front view
Scale: 1:5



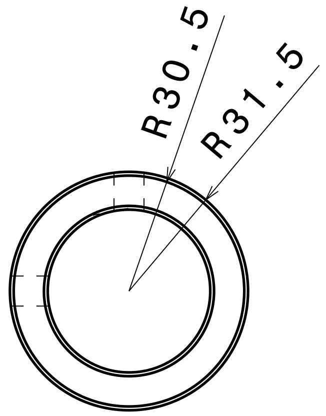
Left view
Scale: 1:5



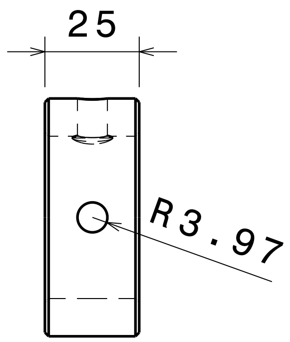
Right view
Scale: 1:1



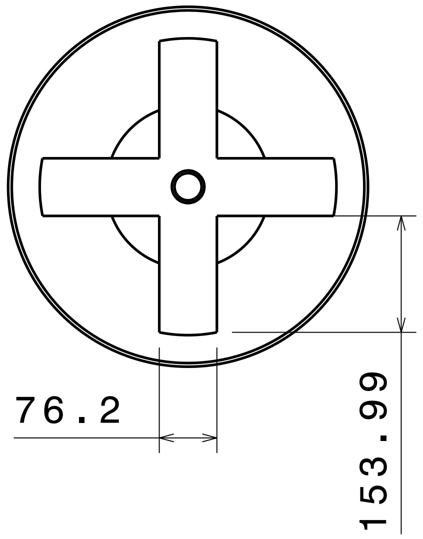
Front view
Scale: 1:1



Front view
Scale: 1:2



Left view
Scale: 1:2



Top view
Scale: 1:10

DESIGNED BY: Minchin
DATE: 17-06-21
CHECKED BY:
DATE:

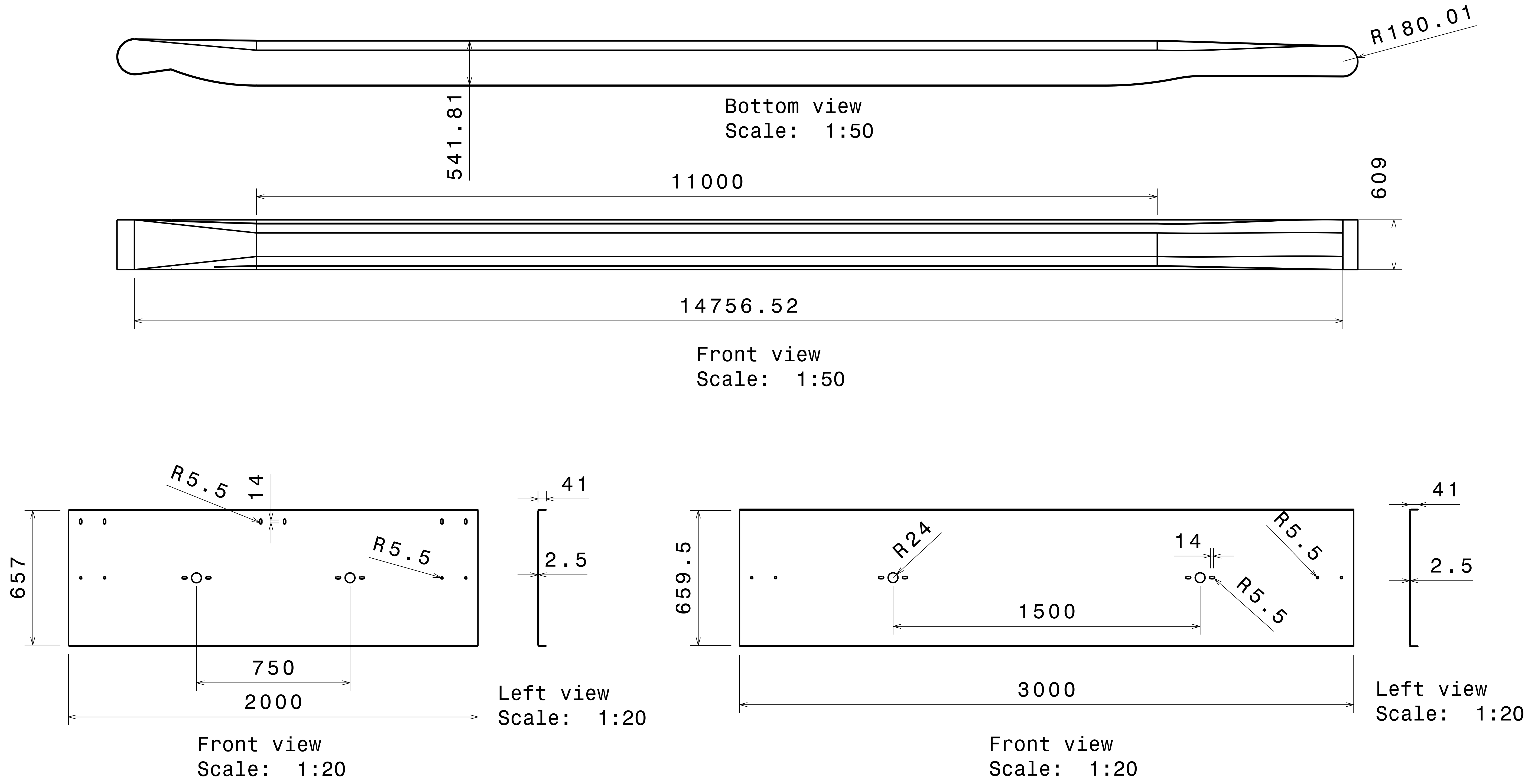
HALMSTAD UNIVERISTY

SIZE A3

COMPONENTS

SCALE
WEIGHT (kg)
DRAWING NUMBER: roller armed
SHEET

I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_



DESIGNED BY: Minchin

DATE: 17-06-21

CHECKED BY:

DATE:

HALMSTAD UNIVERISTY

SIZE A3

COMPONENTS

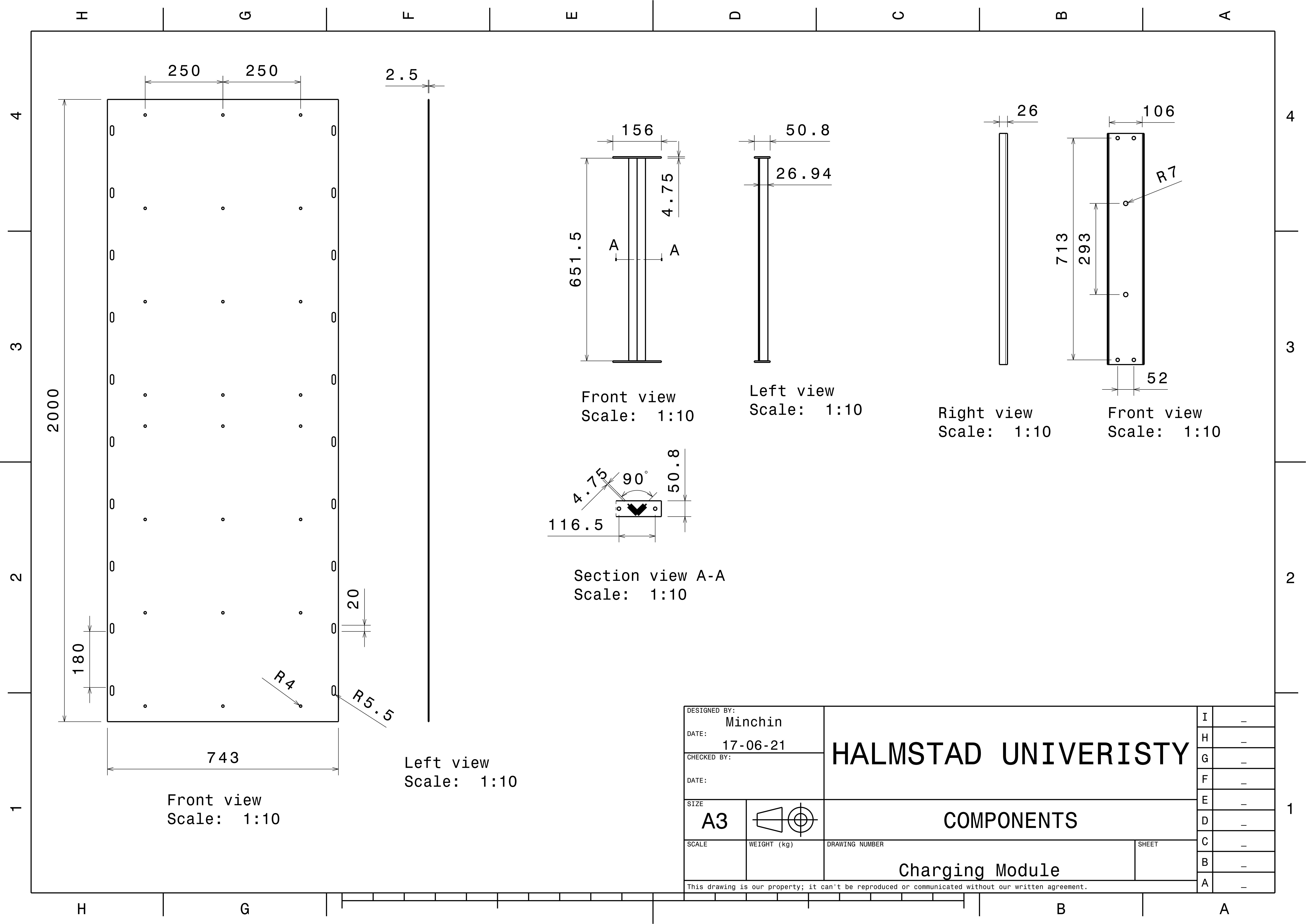
SCALE

WEIGHT (kg)

DRAWING NUMBER: Charging Module

SHEET

I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_



250
250
2.5
2000
180
743
R4
R5.5
20
Front view
Scale: 1:10
Left view
Scale: 1:10
156
4.75
651.5
A
A
Front view
Scale: 1:10
50.8
26.94
Left view
Scale: 1:10
4.75
90°
50.8
116.5
Section view A-A
Scale: 1:10
26
Right view
Scale: 1:10
106
R7
713
293
52
Front view
Scale: 1:10
DESIGNED BY:
Minchin
DATE:
17-06-21
CHECKED BY:
DATE:
HALMSTAD UNIVERISTY
SIZE
A3
COMPONENTS
SCALE
WEIGHT (kg)
DRAWING NUMBER
Charging Module
SHEET
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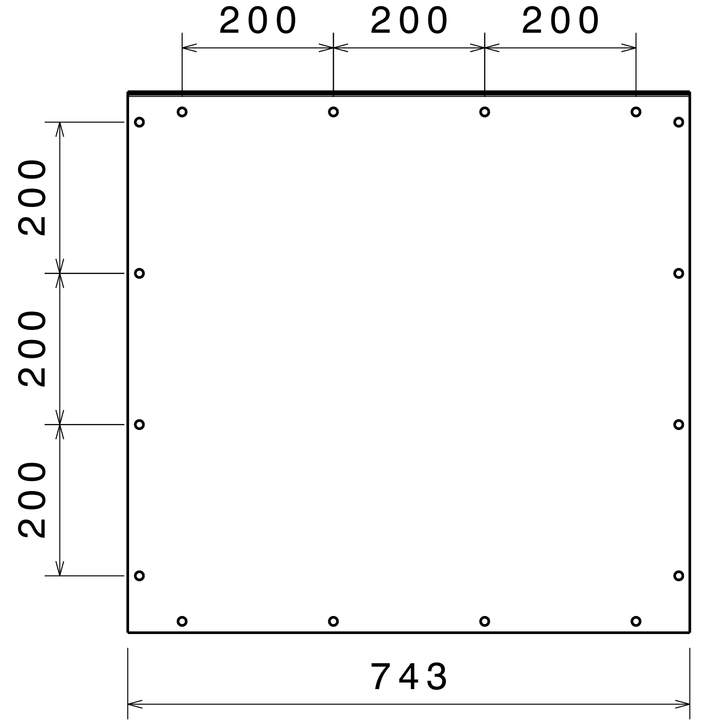
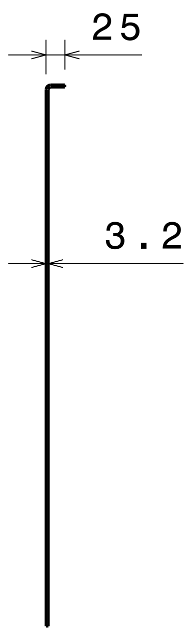
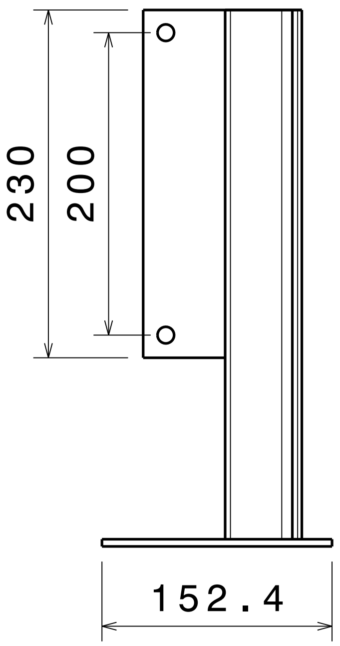


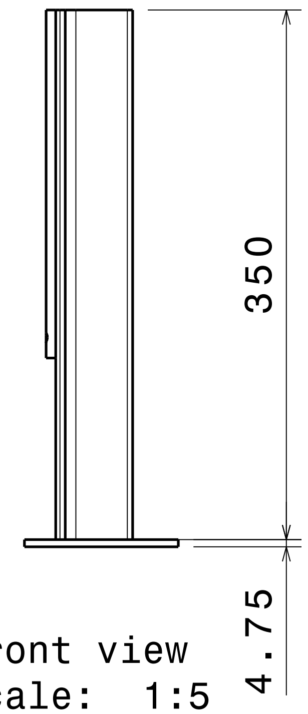
Front view
Scale: 1:10



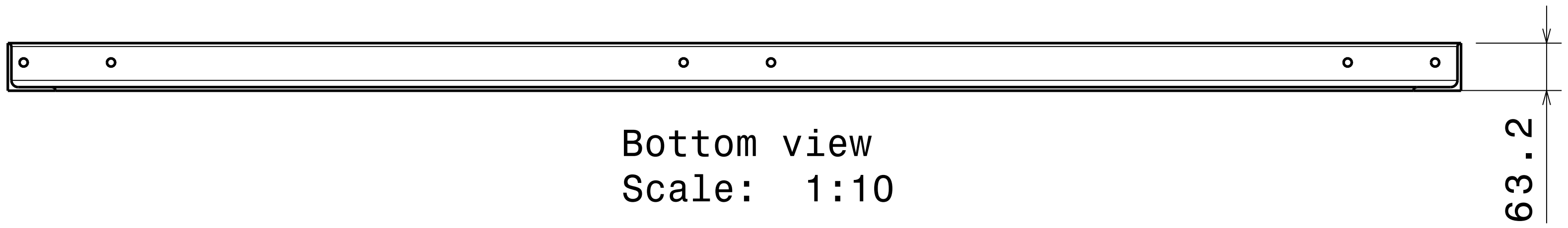
Left view
Scale: 1:10



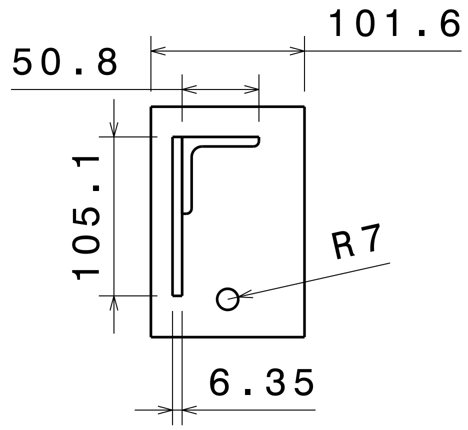
Right view
Scale: 1:5



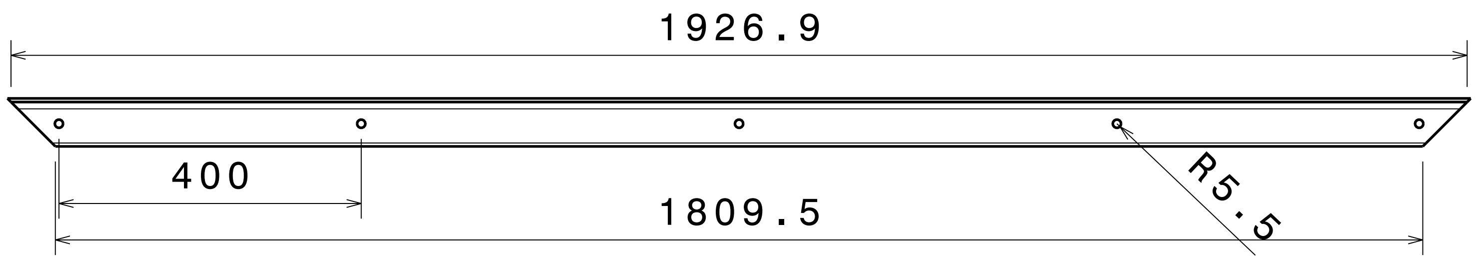
Front view
Scale: 1:5



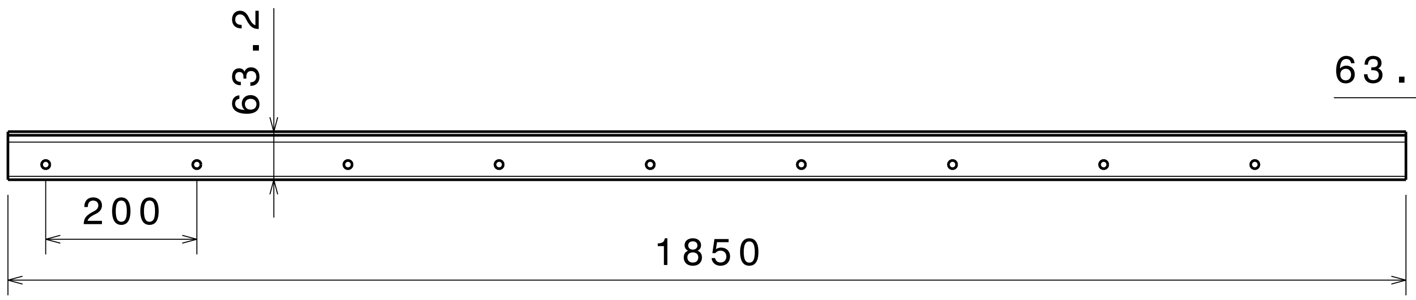
Bottom view
Scale: 1:10



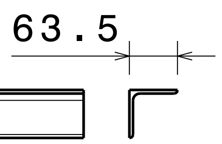
Top view
Scale: 1:5



Front view
Scale: 1:10



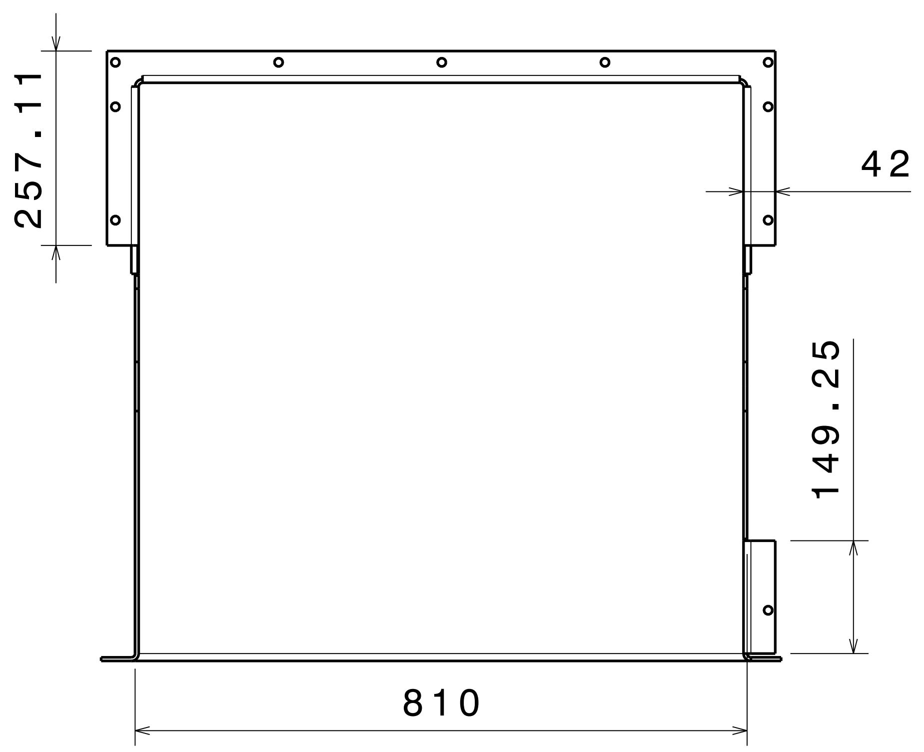
Front view
Scale: 1:10



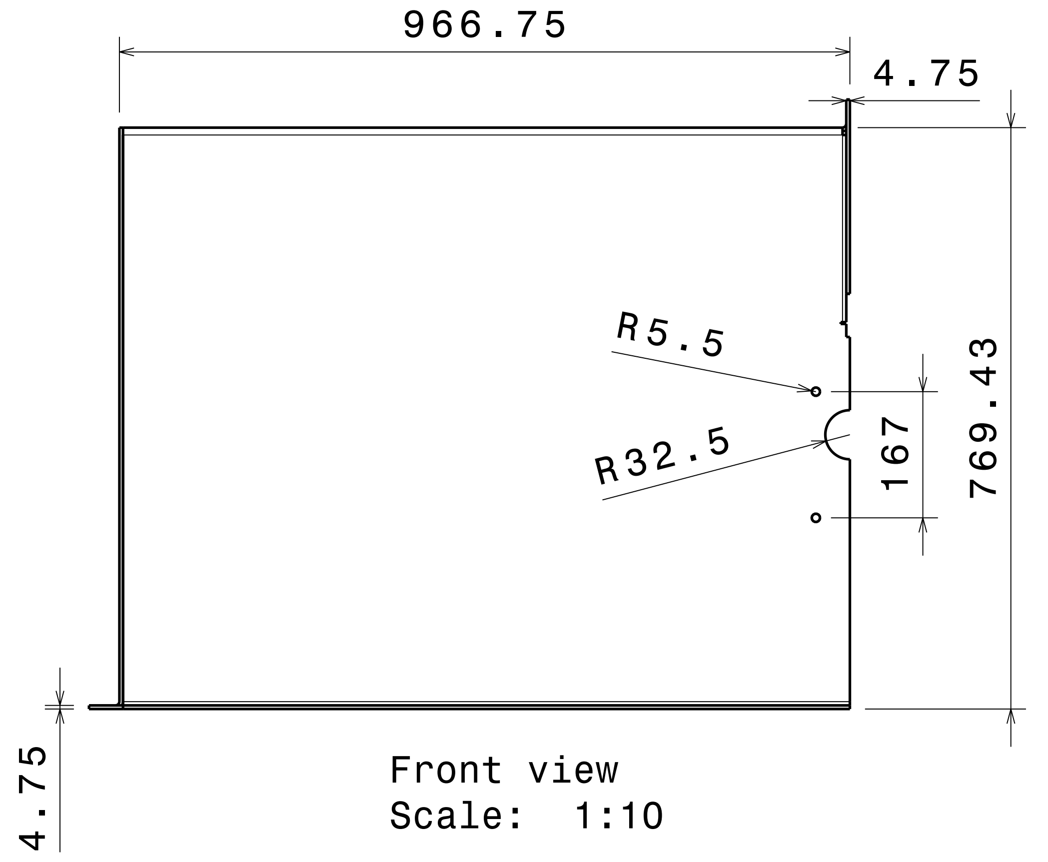
Left view
Scale: 1:10

DESIGNED BY: Minchin	HALMSTAD UNIVERISTY	
DATE: 17-06-21		
CHECKED BY:		
DATE:		
SIZE A3	COMPONENTS	
SCALE	WEIGHT (kg)	DRAWING NUMBER Charging Module	SHEET

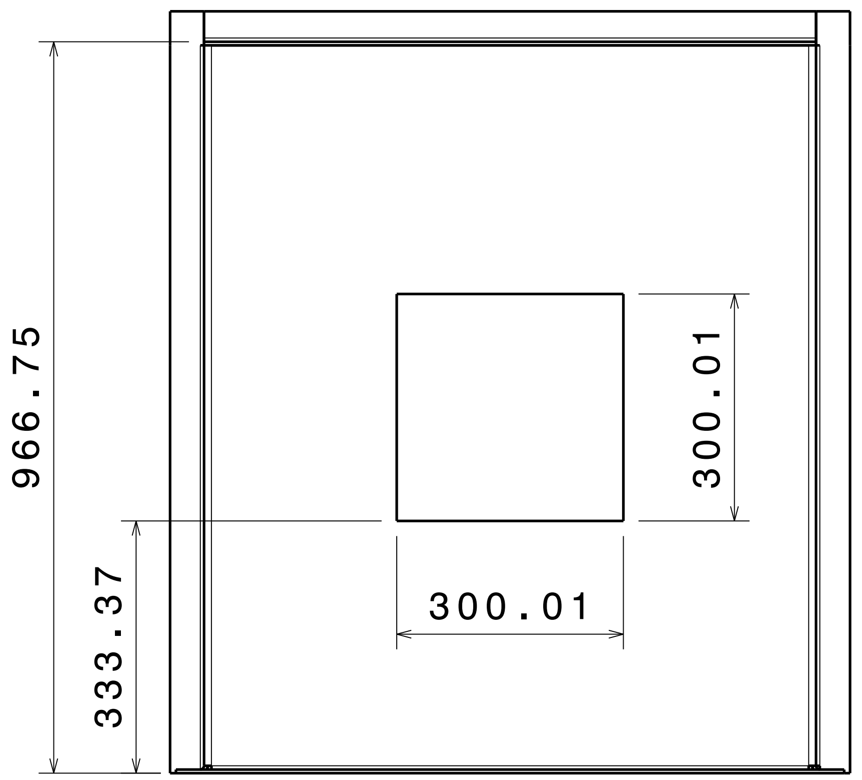
I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_



Right view
Scale: 1:10



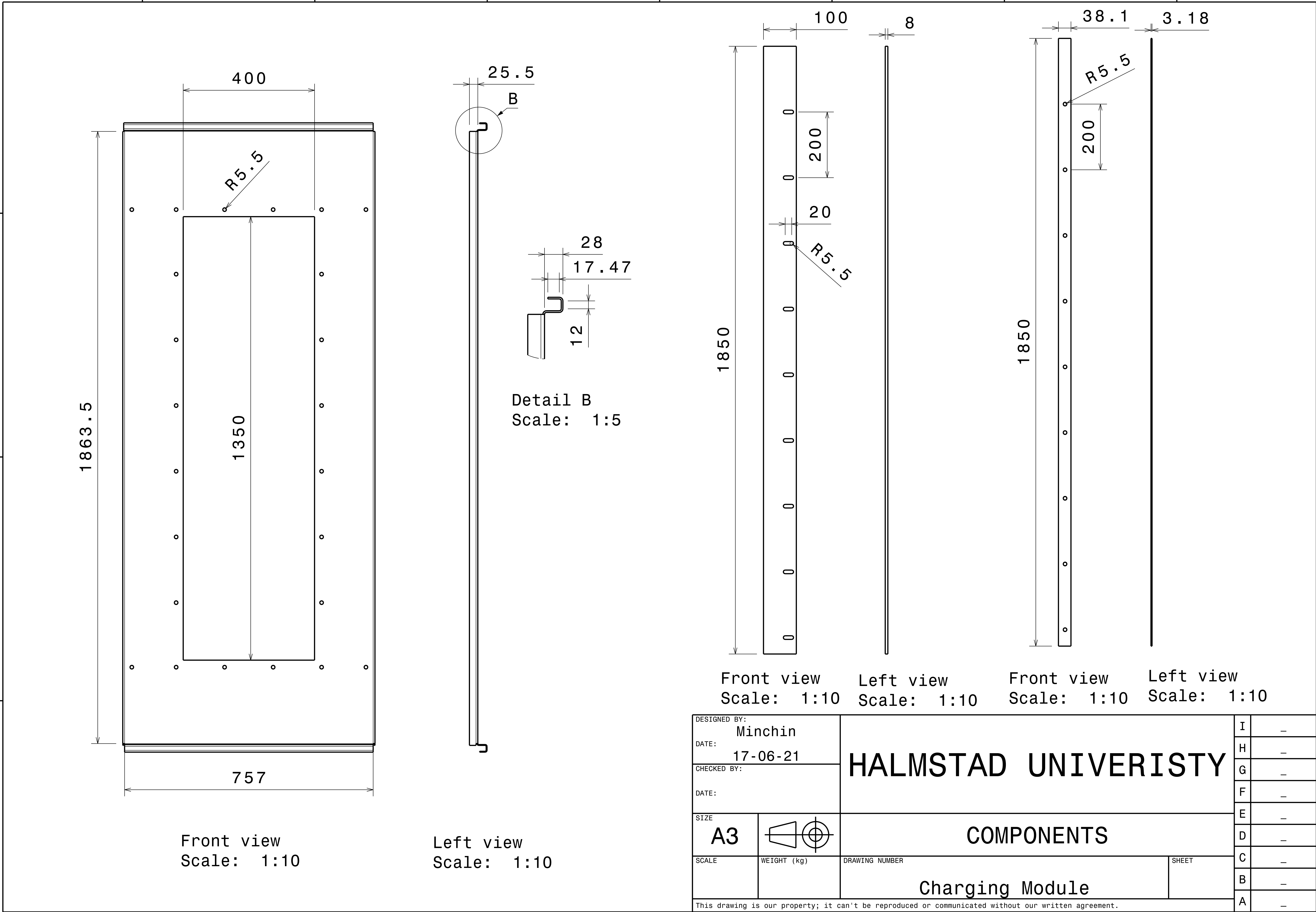
Front view
Scale: 1:10



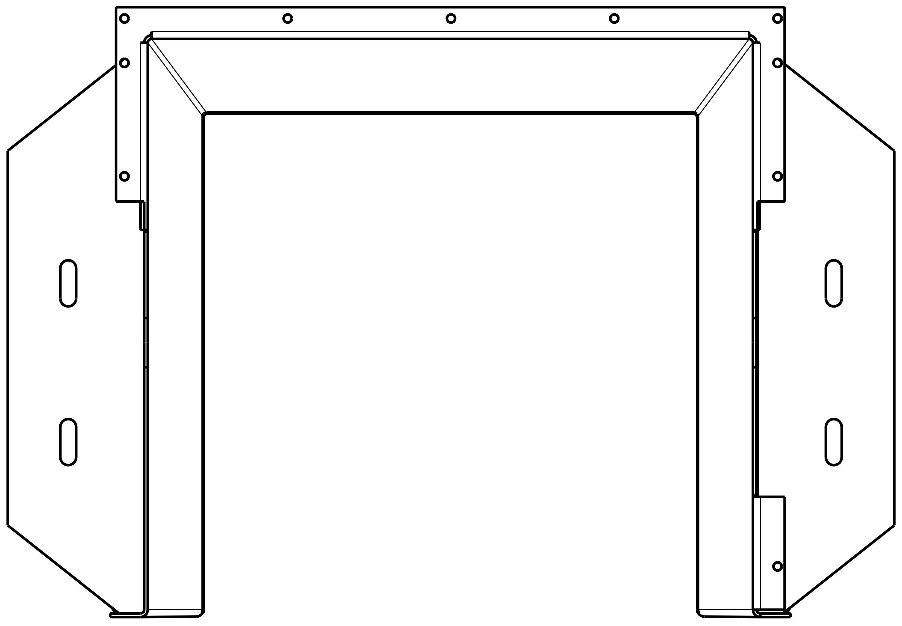
Auxiliary view A
Scale: 1:10

DESIGNED BY: Minchin	HALMSTAD UNIVERSITY		
DATE: 16-06-21			
CHECKED BY:			
DATE:			
SIZE A3		CABINET	
SCALE	WEIGHT (kg) 13.95	DRAWING NUMBER cab 1	SHEET

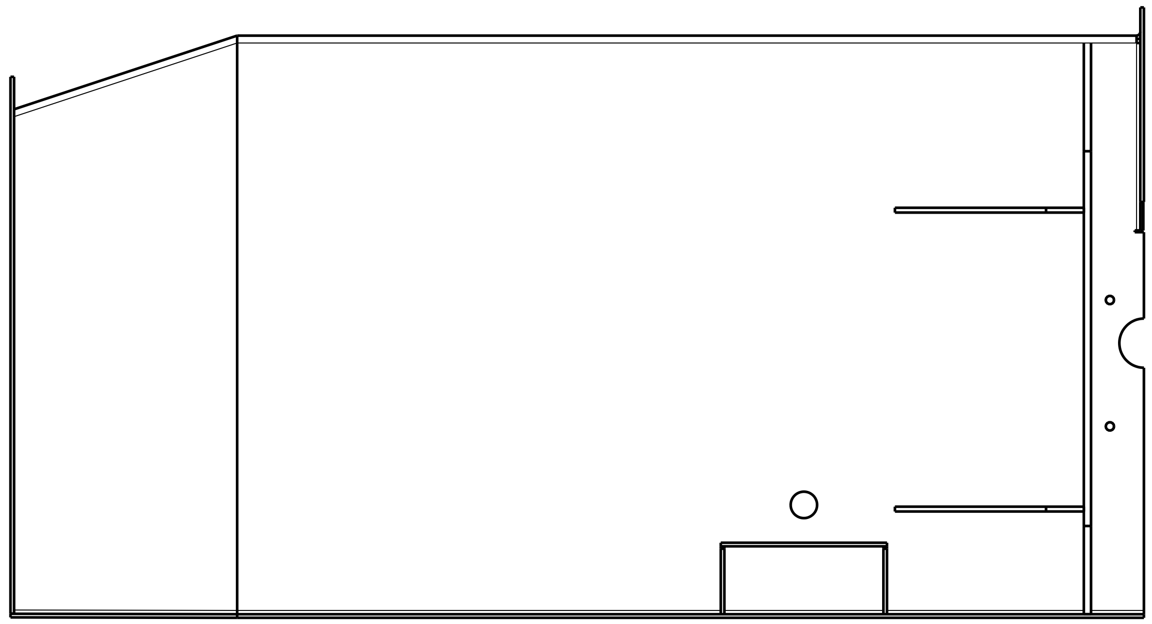
I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_



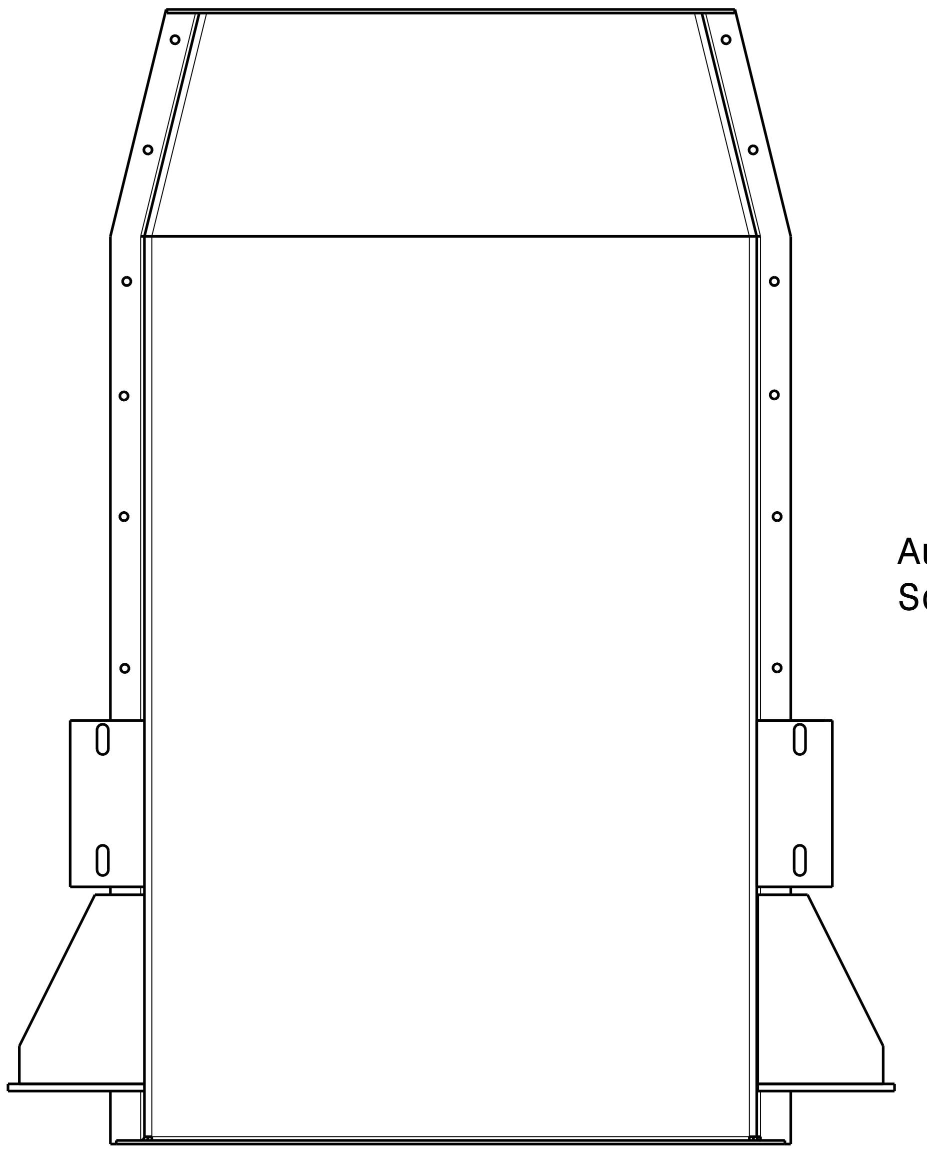
DESIGNED BY: Minchin DATE: 17-06-21	HALMSTAD UNIVERISTY			I _
CHECKED BY: DATE:				H _ / G _ / F _ / E _
SIZE A3		COMPONENTS		D _
SCALE	WEIGHT (kg)	DRAWING NUMBER Charging Module	SHEET	C _ / B _ / A _



Right view
Scale: 1:10



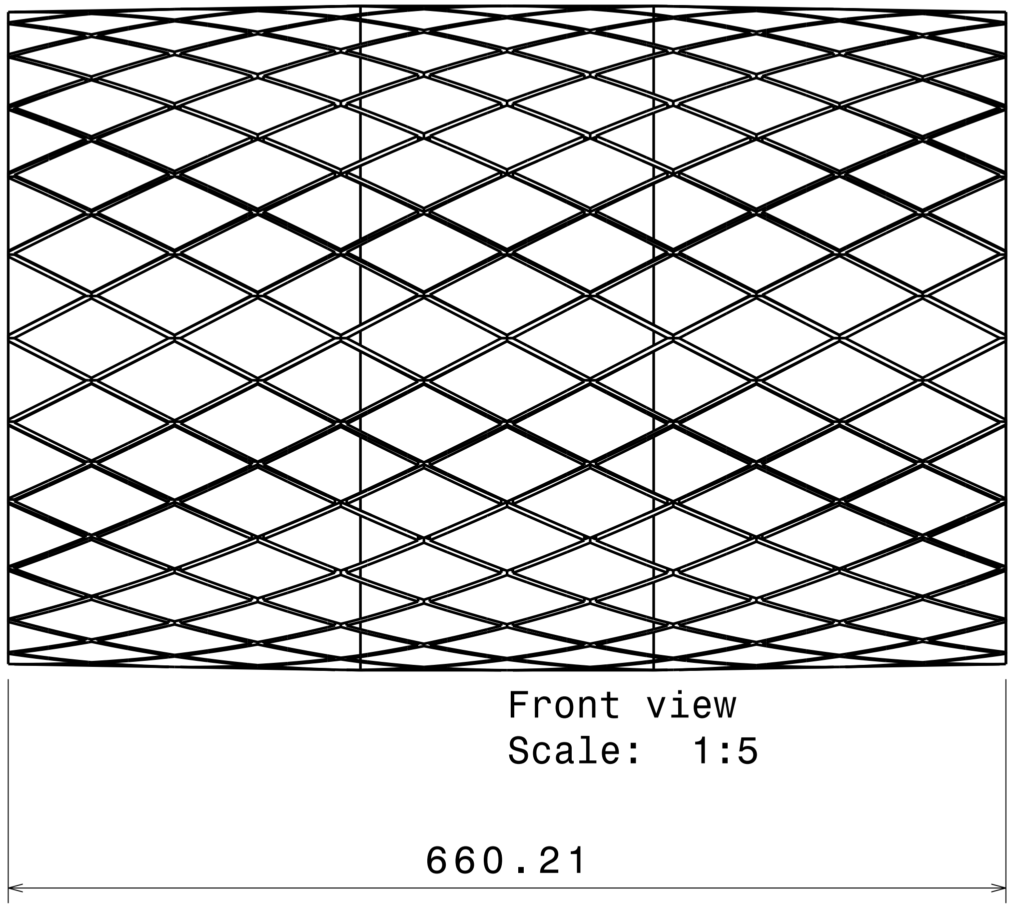
Front view
Scale: 1:10



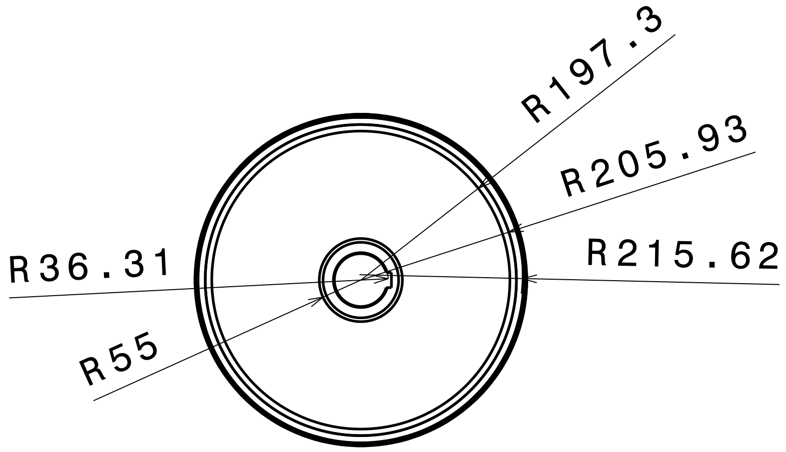
Auxiliary view B
Scale: 1:10

DESIGNED BY: Minchin DATE: 16-06-21 CHECKED BY: DATE:	HALMSTAD UNIVERSITY		
SIZE A3		CABINET 2	
SCALE	WEIGHT (kg) 0.00	DRAWING NUMBER cab 2	SHEET

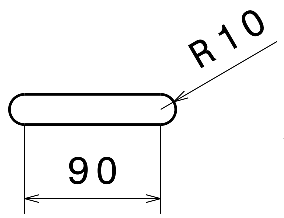
I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_



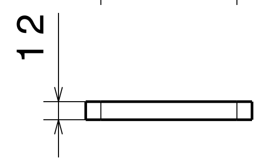
Front view
Scale: 1:5



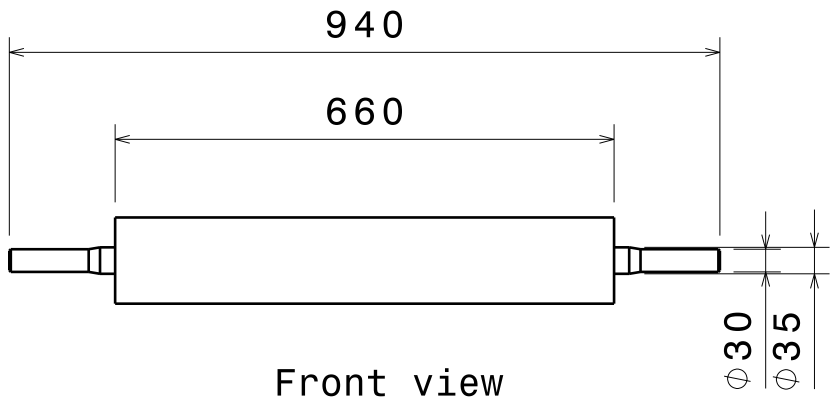
Left view
Scale: 1:10



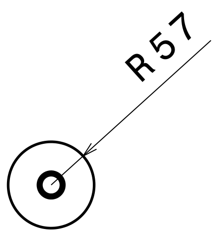
Front view
Scale: 1:5



Top view
Scale: 1:5



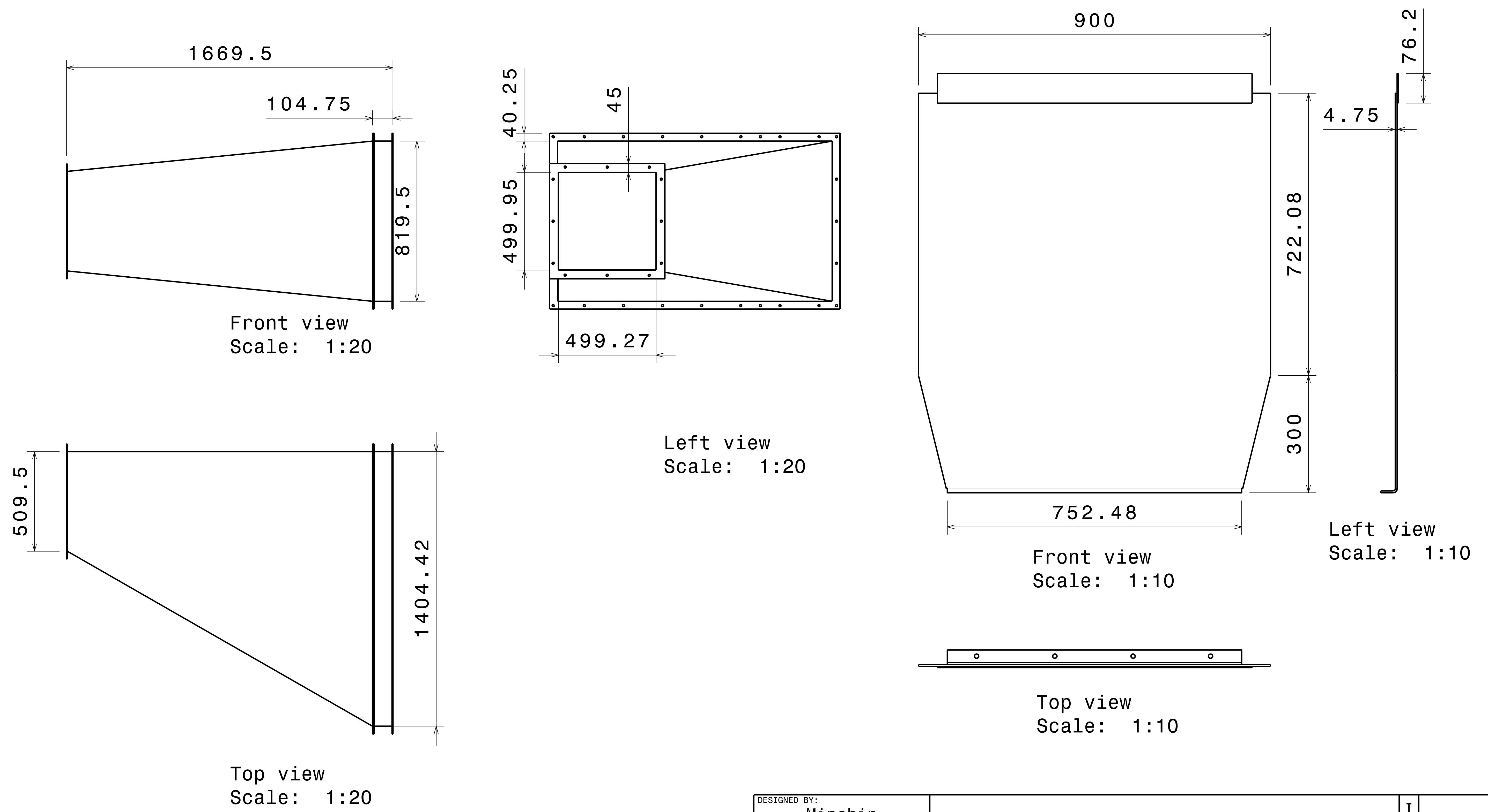
Front view
Scale: 1:10



Left view
Scale: 1:10

DESIGNED BY: Minchin	HALMSTAD UNIVERSITY
DATE: 16-06-21	
CHECKED BY:	
DATE:	
SIZE A3	DRIVING ROLLER
SCALE	WEIGHT (kg) 20.96
DRAWING NUMBER	driving roller
SHEET	

I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_



DESIGNED BY: Minchin	HALMSTAD UNIVERSITY			I _
DATE: 16-06-21				H _
CHECKED BY:				G _
DATE:				F _
SIZE A3		FLANGE & HEAD FLOOR		E _
				D _
SCALE	WEIGHT (kg) 29.97	DRAWING NUMBER flange down	SHEET	C _
				B _
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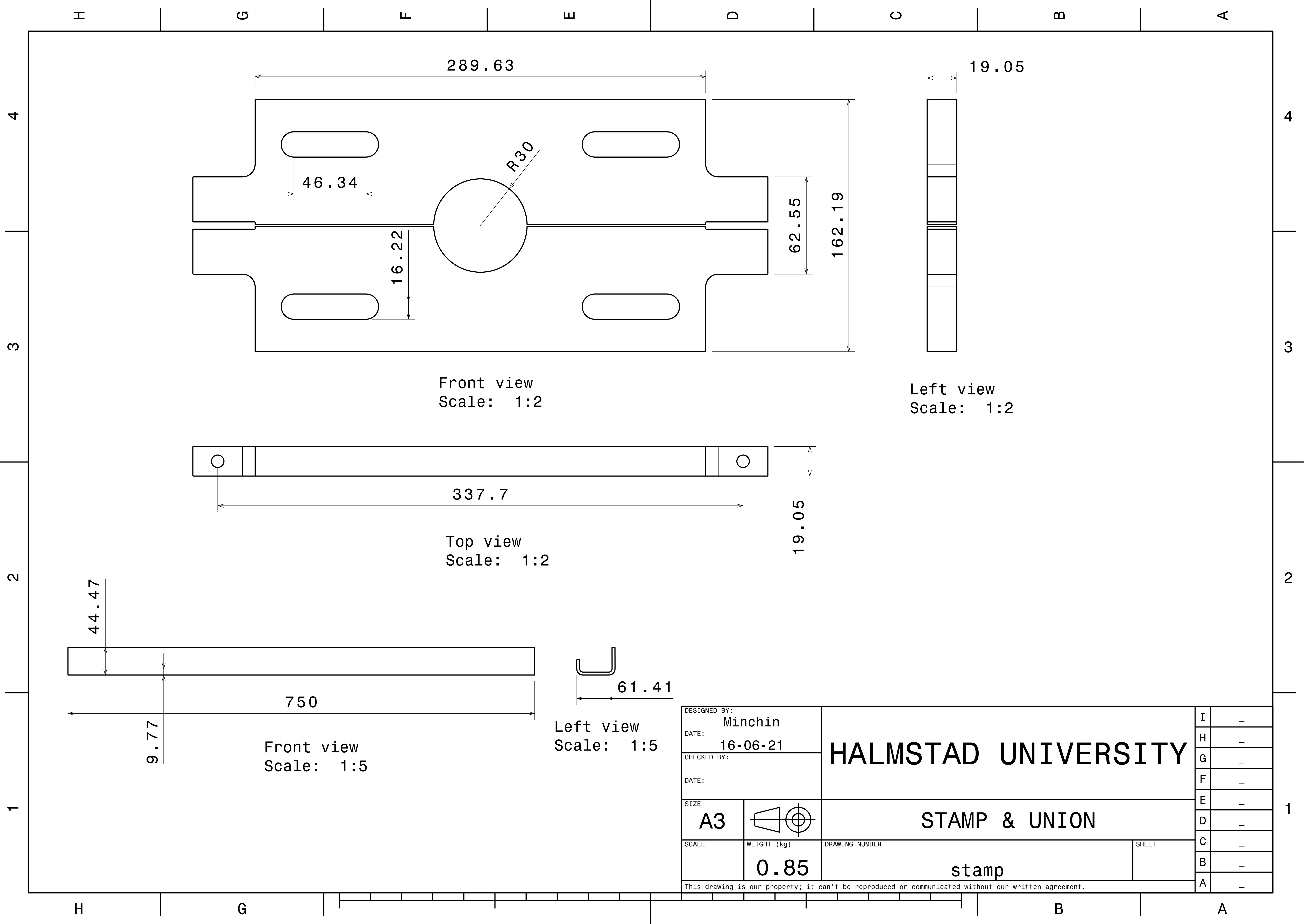
289.63
19.05
R30
46.34
62.55
162.19
16.22
Front view
Scale: 1:2
Left view
Scale: 1:2
337.7
19.05
Top view
Scale: 1:2
44.47
750
9.77
Front view
Scale: 1:5
61.41
Left view
Scale: 1:5
DESIGNED BY:
Minchin
DATE:
16-06-21
CHECKED BY:
DATE:
HALMSTAD UNIVERSITY
SIZE
A3
STAMP & UNION
SCALE
WEIGHT (kg)
0.85
DRAWING NUMBER
stamp
SHEET
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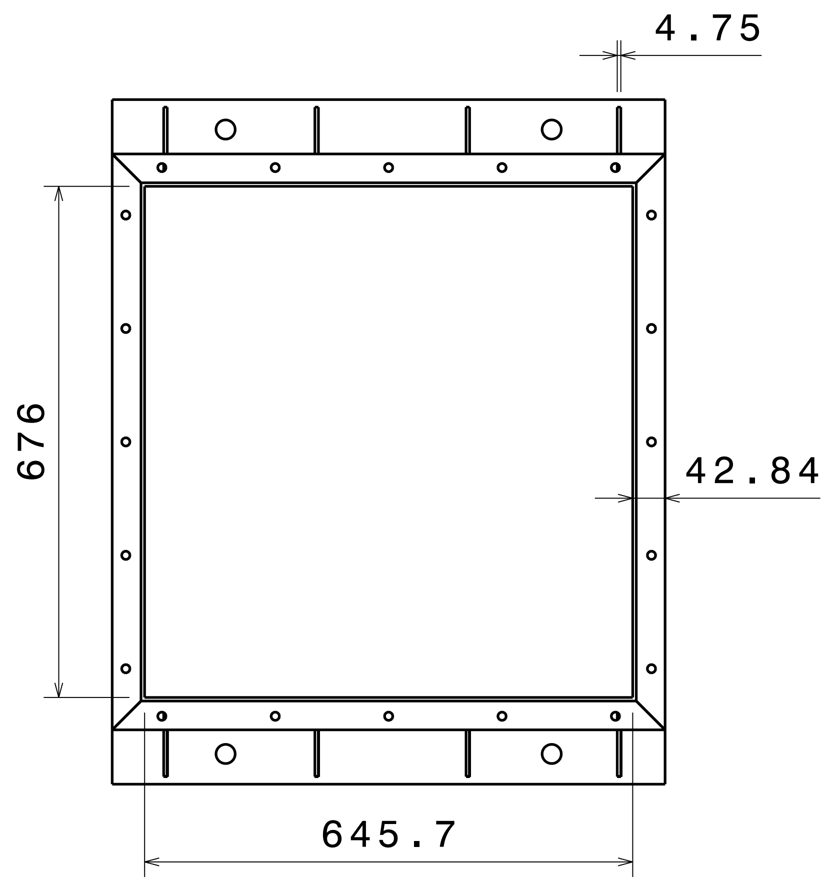
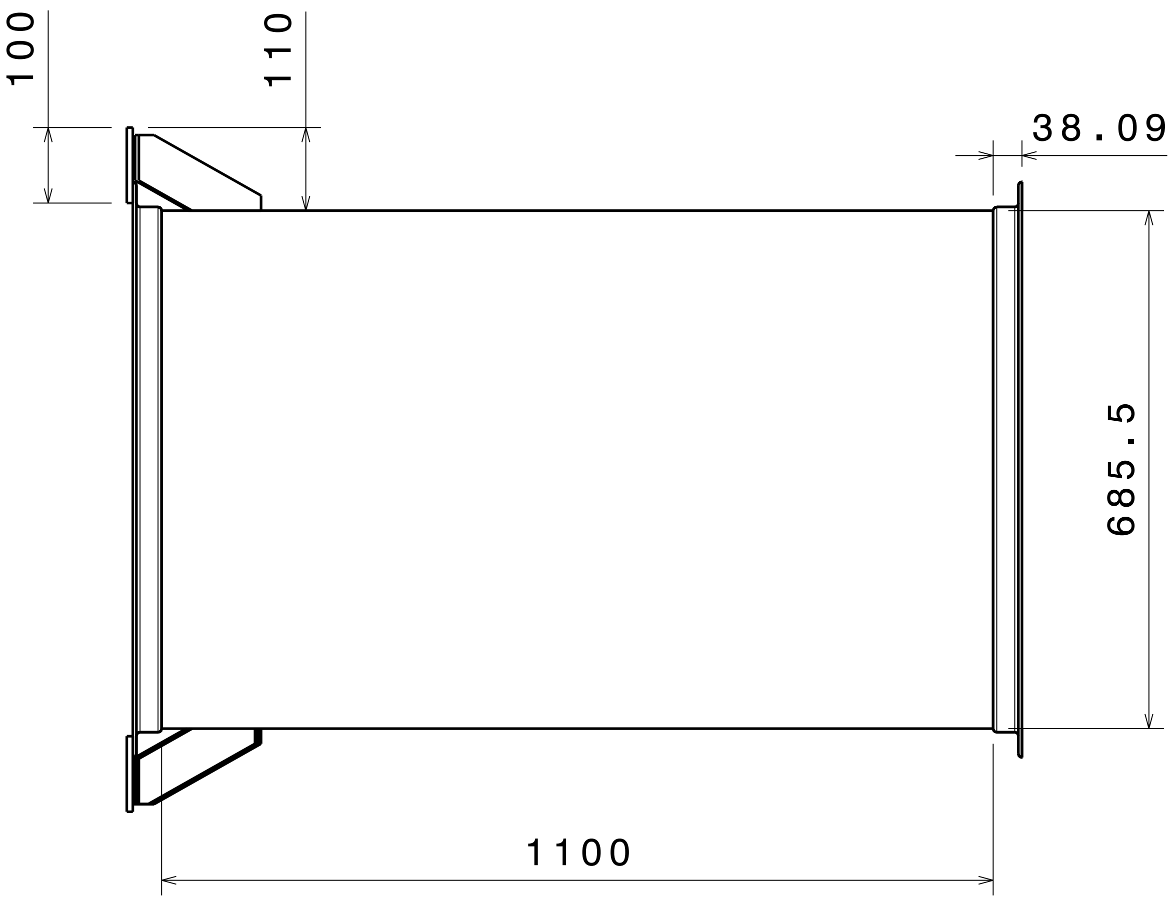
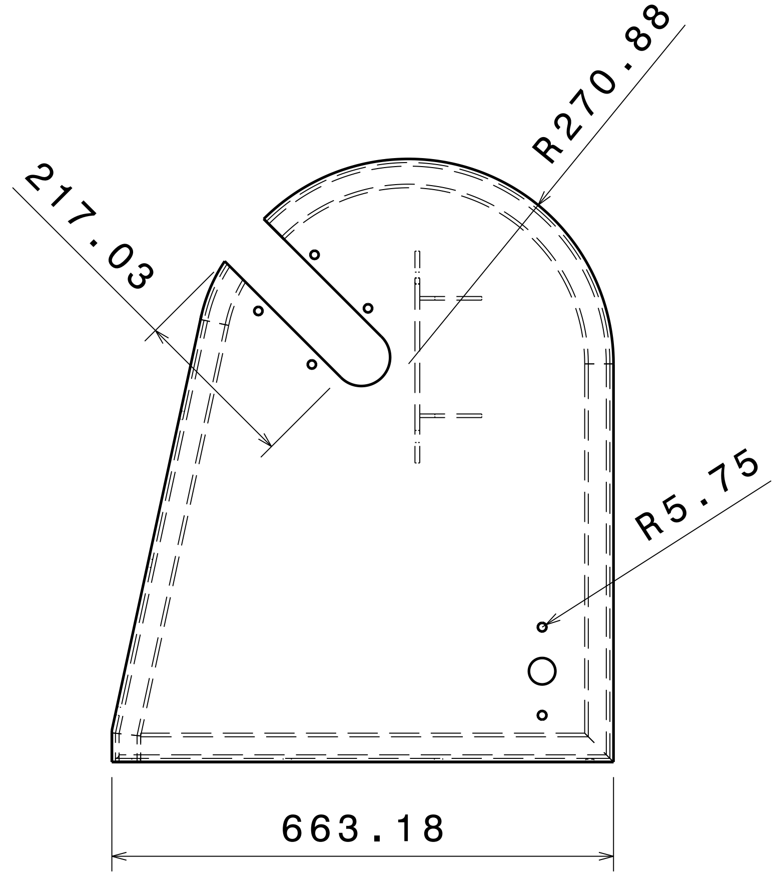


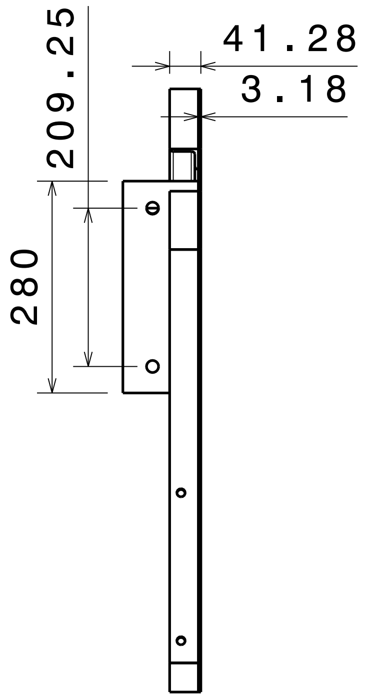
Right view
Scale: 1:10



Front view
Scale: 1:10



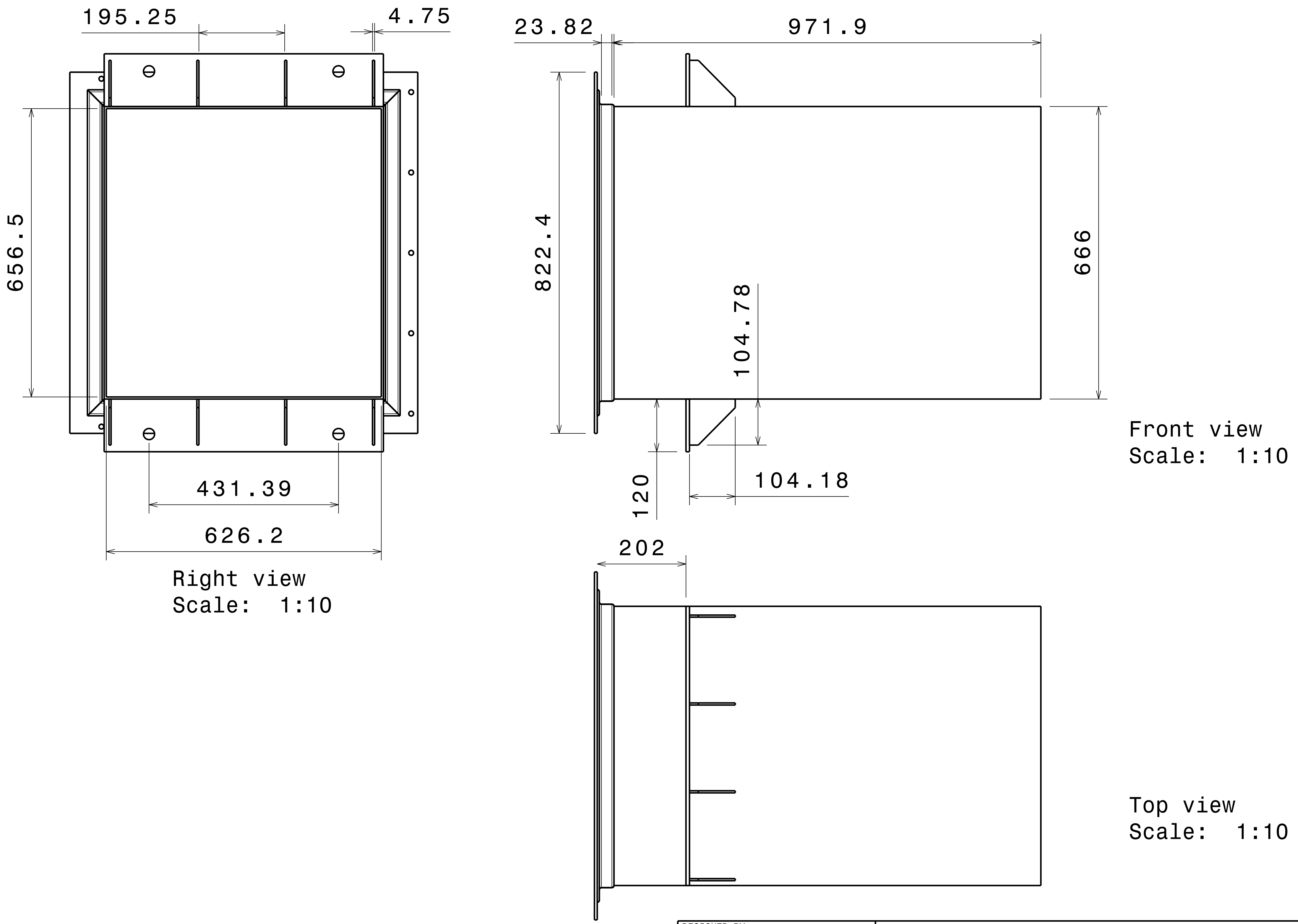
Front view
Scale: 1:10



Left view
Scale: 1:10

DESIGNED BY: Minchin DATE: 16-06-21 CHECKED BY: DATE:		HALMSTAD UNIVERSITY	
SIZE A3		COMPONENTS	
SCALE	WEIGHT (kg)	DRAWING NUMBER Tensioning Head	SHEET

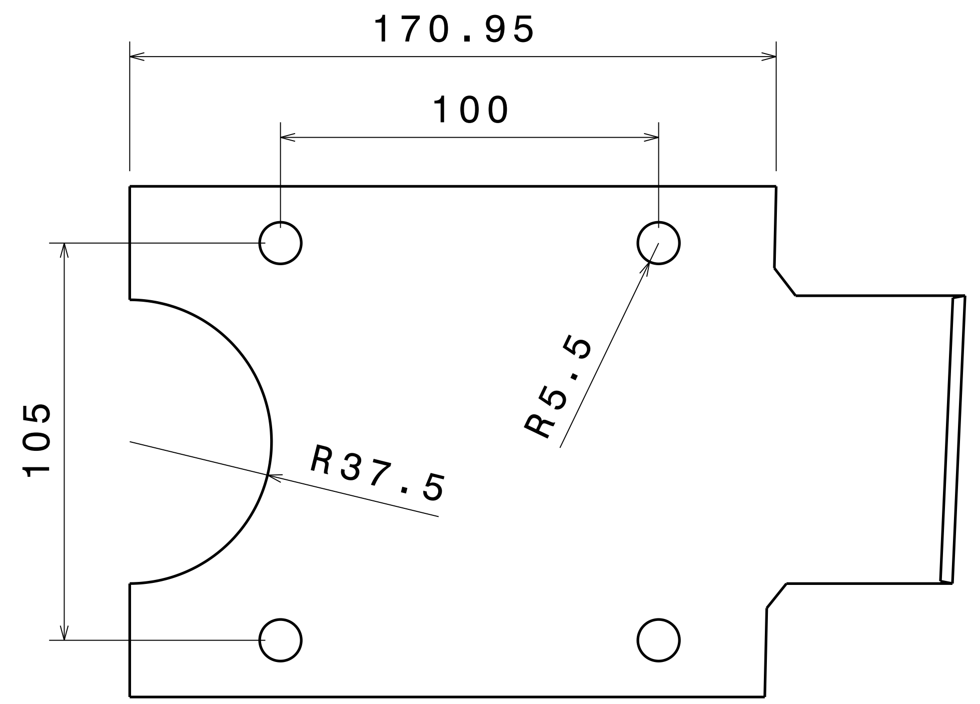
I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_



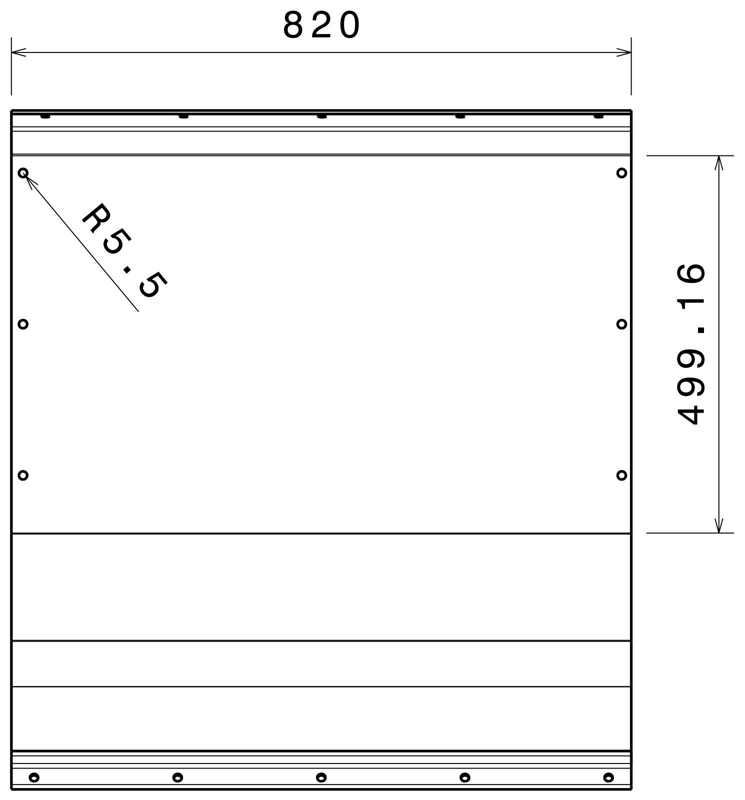
DESIGNED BY: Minchin	HALMSTAD UNIVERSITY
DATE: 16-06-21	
CHECKED BY:	
DATE:	
SIZE A3	COMPONENTS
SCALE	WEIGHT (kg)
DRAWING NUMBER	Tensioning Head
SHEET	

Rev	
I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_

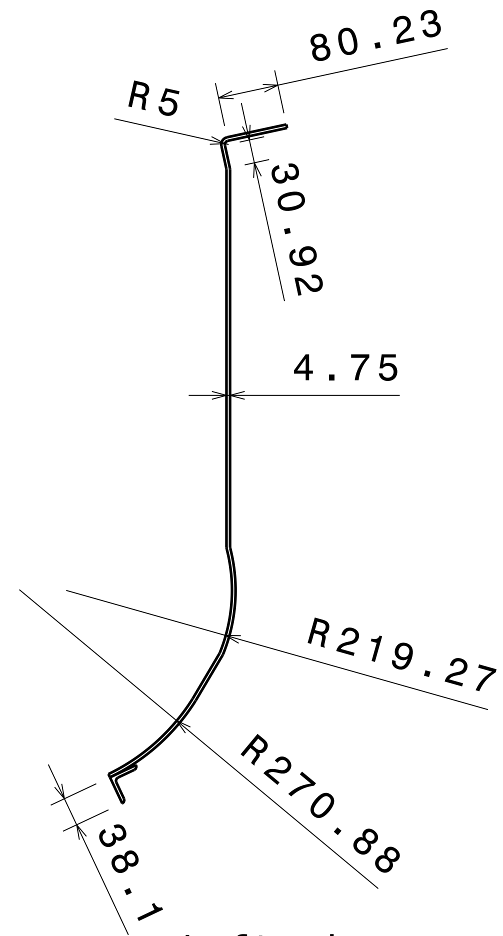
Bottom view
Scale: 1:2



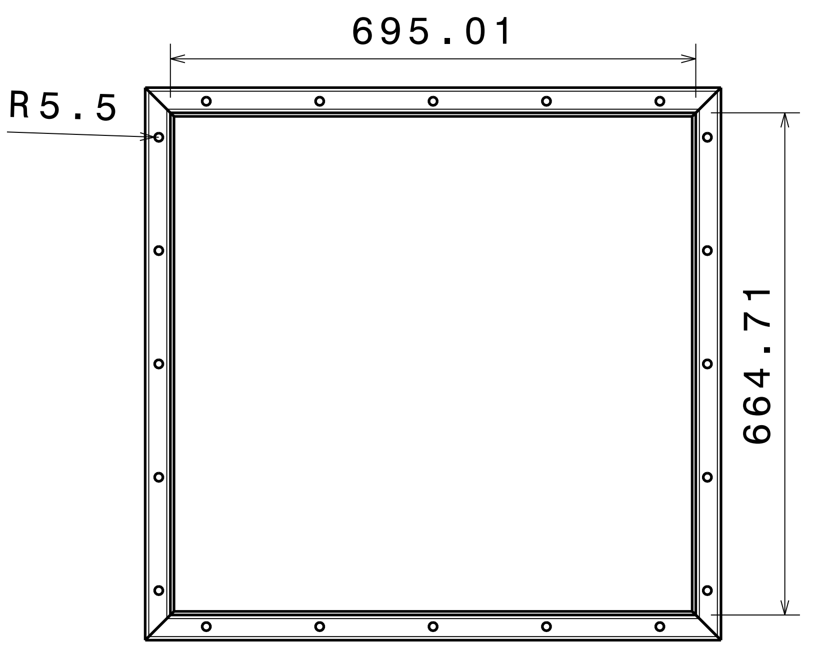
Front view
Scale: 1:2



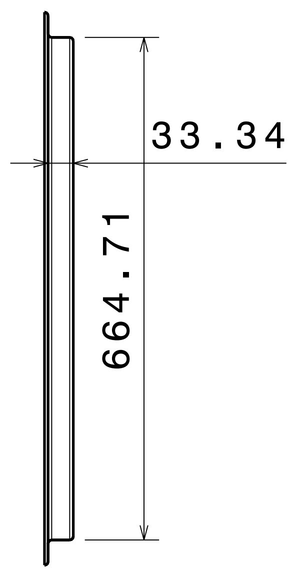
Front view
Scale: 1:10



Left view
Scale: 1:10



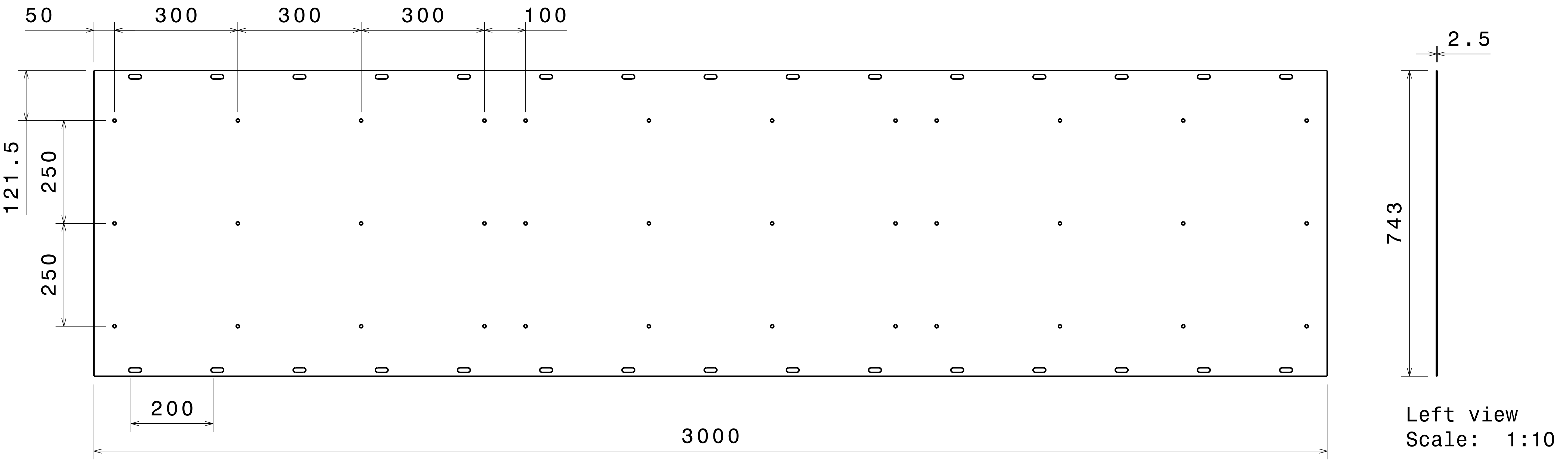
Front view
Scale: 1:10



Left view
Scale: 1:10

DESIGNED BY: Minchin	HALMSTAD UNIVERSITY	
DATE: 16-06-21		
CHECKED BY:		
DATE:		
SIZE A3	COMPONENTS	
SCALE	WEIGHT (kg)	DRAWING NUMBER Tensioning Head	SHEET

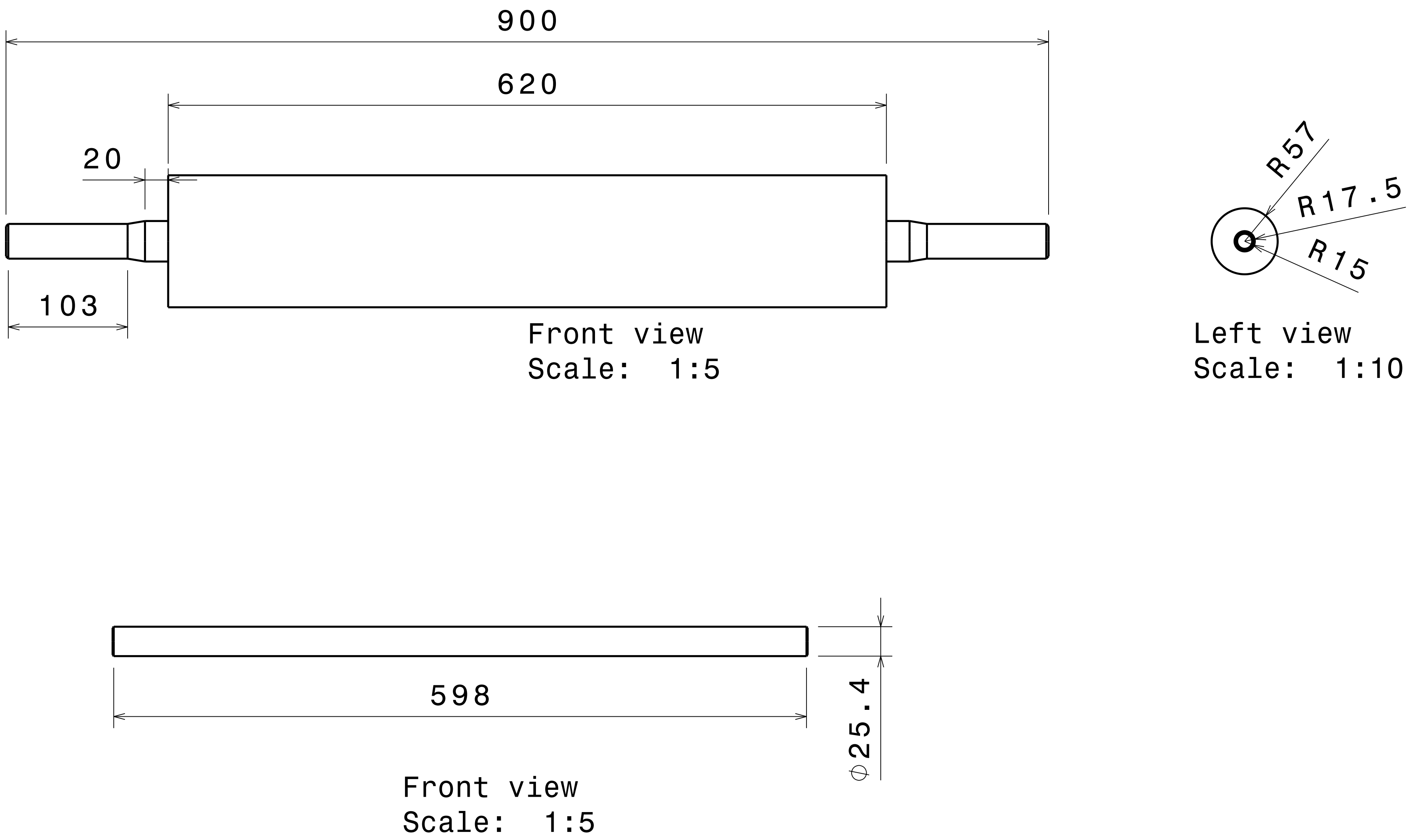
I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_



Front view
Scale: 1:10

Left view
Scale: 1:10

DESIGNED BY: Minchin	HALMSTAD UNIVERSITY		I	_
DATE: 17-06-21			H	_
CHECKED BY:			G	_
DATE:			F	_
SIZE A3	COMPONENTS		E	_
			D	_
SCALE	WEIGHT (kg)	DRAWING NUMBER Module	SHEET	C _
			B	_
			A	_

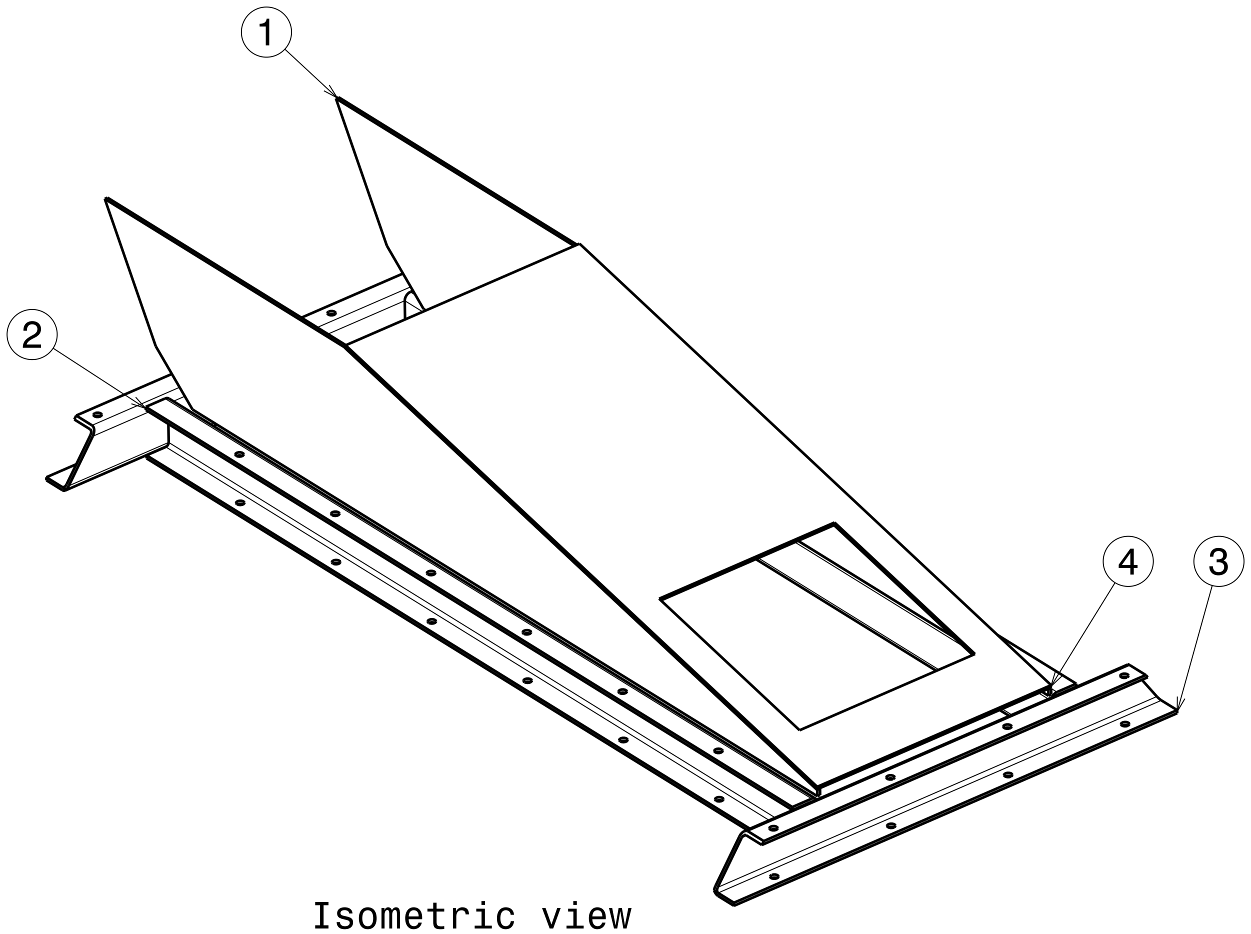


DESIGNED BY:	Minchin
DATE:	16-06-21
CHECKED BY:	
DATE:	
SIZE	A3
SCALE	
WEIGHT (kg)	
DRAWING NUMBER	Tensioning Head
SHEET	

HALMSTAD UNIVERSITY

COMPONENTS

Rev.	
I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_

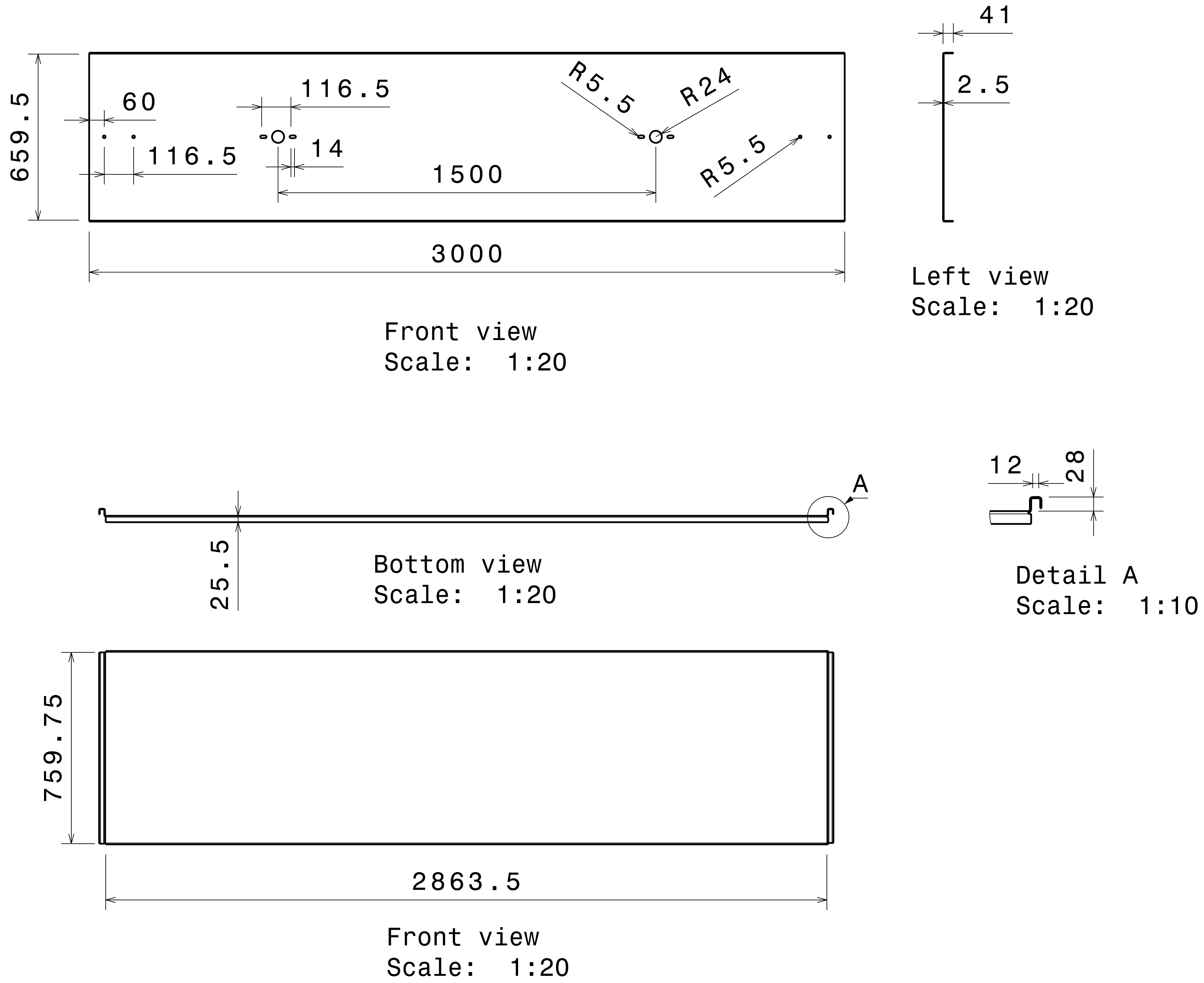


Isometric view
Scale: 1:10

Bill of Material: loading mouth

Quantity	Part Number
2	lat
2	Pleg 1
2	Pleg 2
1	sup

DESIGNED BY: Minchin	HALMSTAD UNIVERSITY	I	_
DATE: 17-06-21		H	_
CHECKED BY:		G	_
DATE:		F	_
SIZE A3	LOADING MOUTH ASSEMBLY	E	_
		D	_
SCALE	WEIGHT (kg)	C	_
DRAWING NUMBER loading mouth	SHEET	B	_
		A	_



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DATE: 17-06-21

CHECKED BY:

DATE:

HALMSTAD UNIVERSITY

SIZE: A3

COMPONENTS

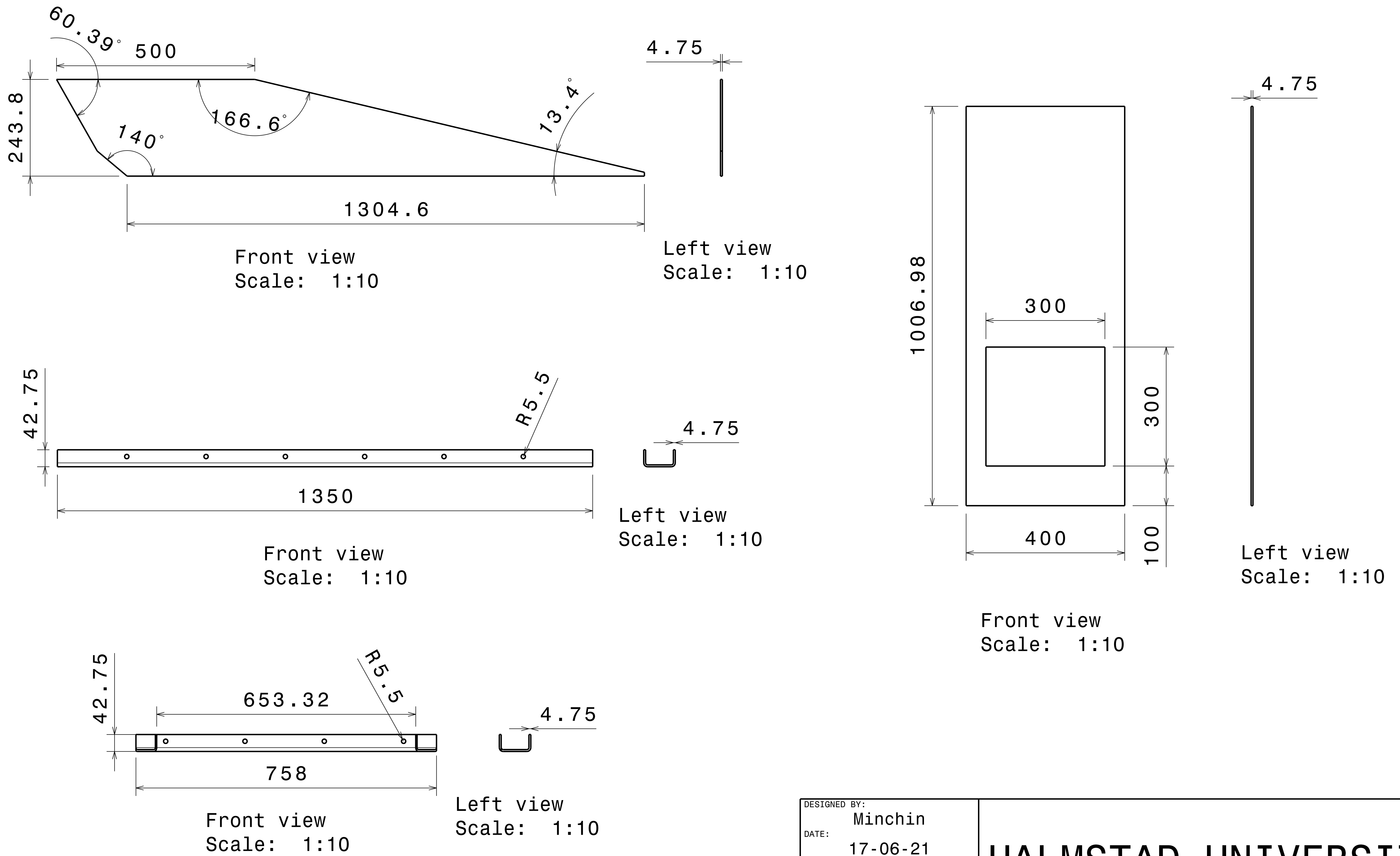
SCALE

WEIGHT (kg)

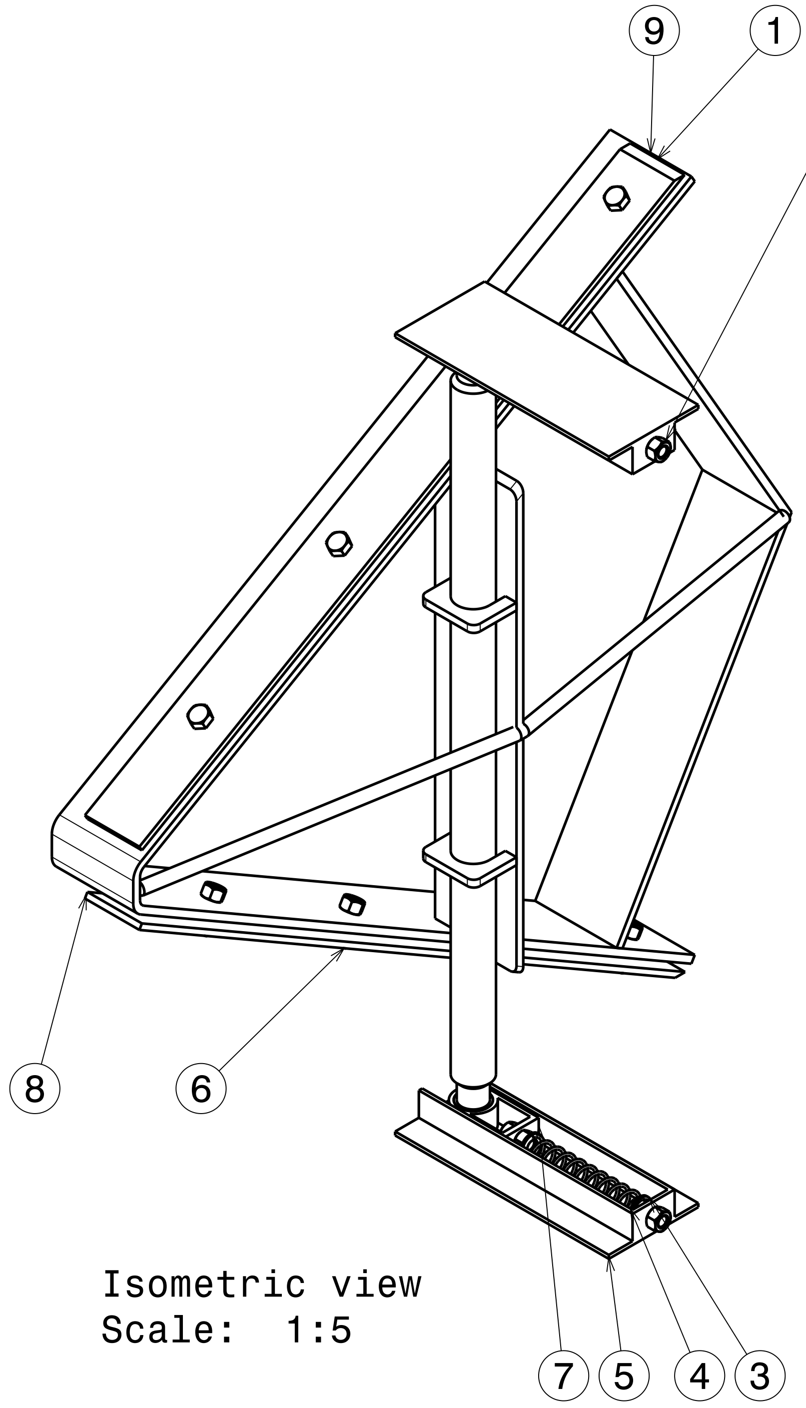
DRAWING NUMBER: Module

SHEET

I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_



DESIGNED BY: Minchin	HALMSTAD UNIVERSITY			I –
DATE: 17-06-21				H –
CHECKED BY:				G –
DATE:				F –
SIZE A3		COMPONENTS		E –
				D –
SCALE	WEIGHT (kg)	DRAWING NUMBER loading mouth	SHEET	C –
				B –
This drawing is our property; it can't be reproduced or communicated without our written agreement.				A –

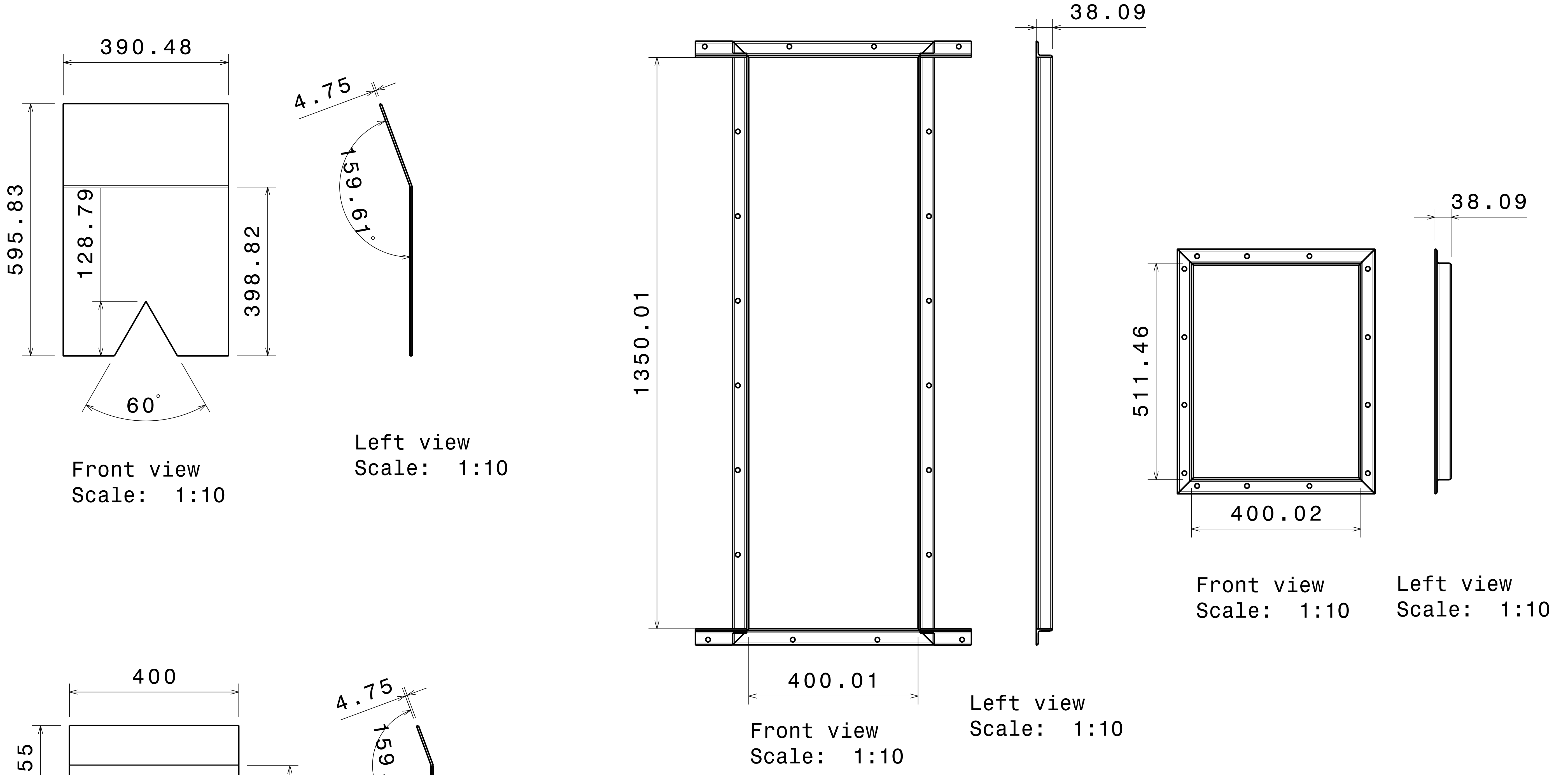


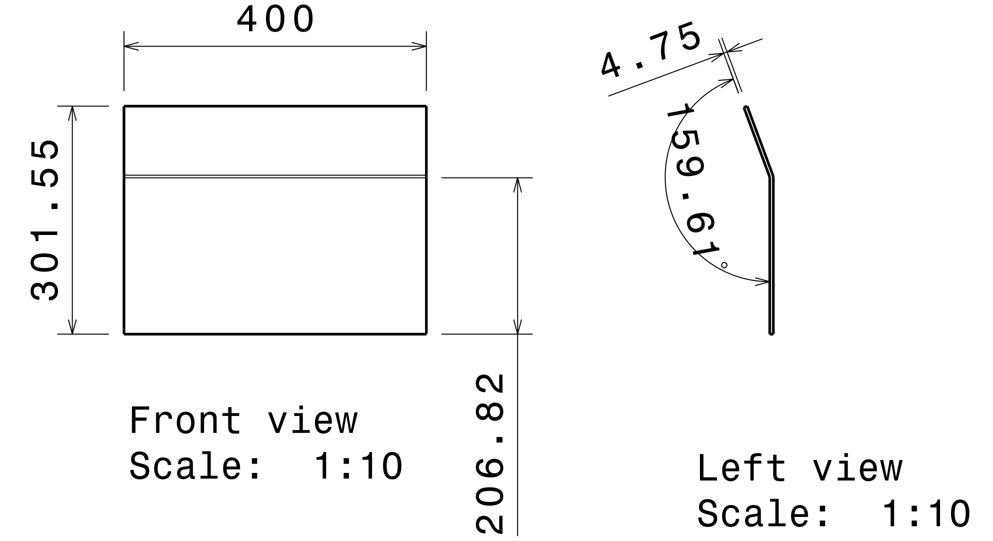
Isometric view
Scale: 1:5

Bill of Material: scraper assembled

Quantity	Part Number
1	scrap 2_1
16	hex nut_ai_HNUT 0.3750-16-D-N
4	flat washer type a selected narrow_ai_Selected Narrow FW 0.375
2	guide spring
2	lateral guide2
8	hex bolt_ai_HBOLT 0.3750-24x1x1-N
2	lateral guide 1
1	scrap 2
1	scrap 1

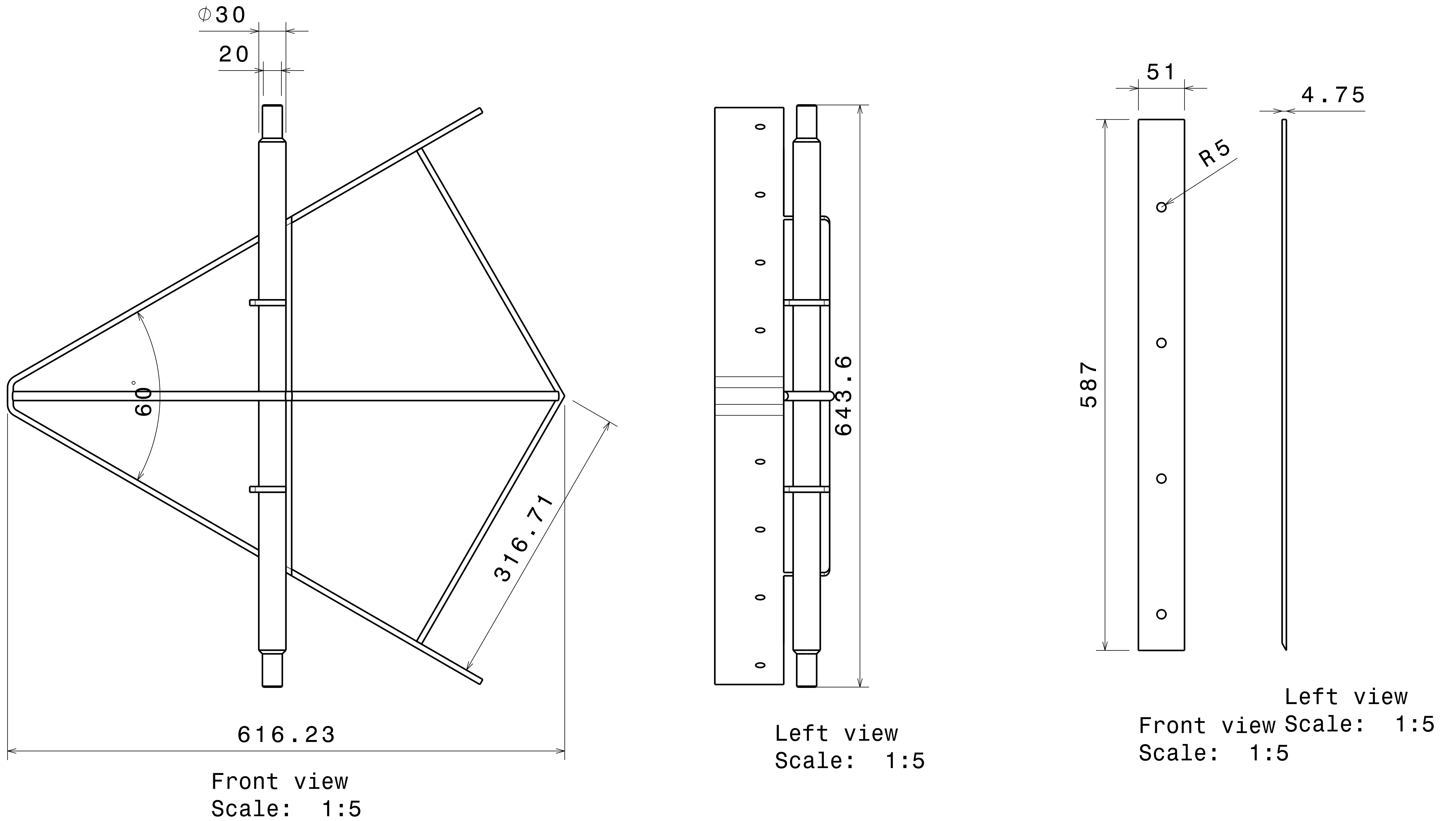
DESIGNED BY: Minchin DATE: 16-06-21		HALMSTAD UNIVERSITY		I _
CHECKED BY: DATE:				H _ / G _ / F _
SIZE A3		SCRAPER ASSEMBLY		E _ / D _
SCALE	WEIGHT (kg)	DRAWING NUMBER scraper assembled	SHEET	C _ / B _





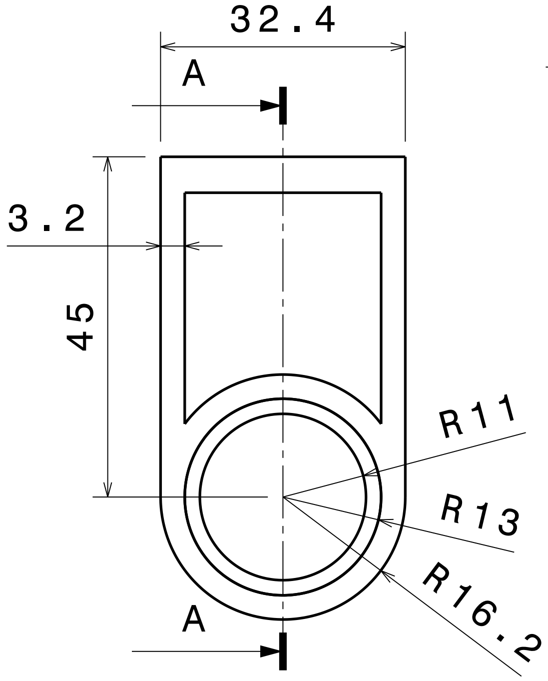
DESIGNED BY: Minchin DATE: 17-06-21 CHECKED BY: DATE:	HALMSTAD UNIVERSITY		
SIZE A3		COMPONENTS	
SCALE	WEIGHT (kg)	DRAWING NUMBER loading mouth	SHEET

I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_

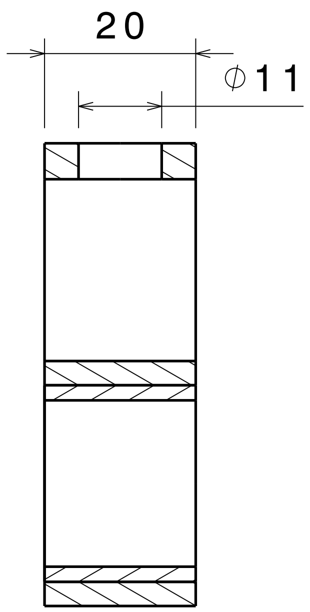


DESIGNED BY: Minchin	HALMSTAD UNIVERSITY		
DATE: 16-06-21			
CHECKED BY:			
DATE:			
SIZE A3		COMPONENTS	
SCALE	WEIGHT (kg)	DRAWING NUMBER scraper assembled	SHEET

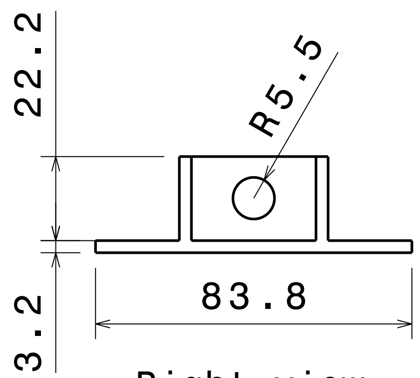
Rev	
I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_



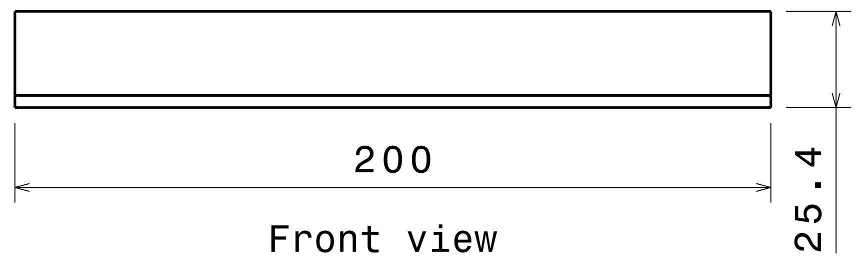
Front view
Scale: 1:1



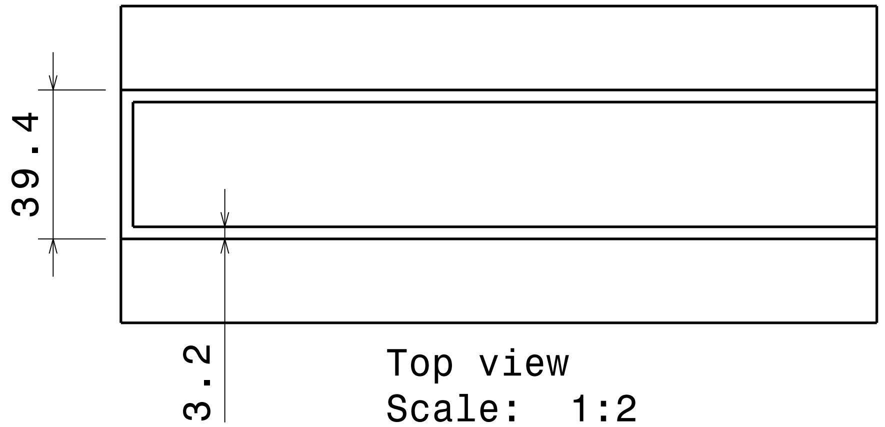
Section view A-A
Scale: 1:1



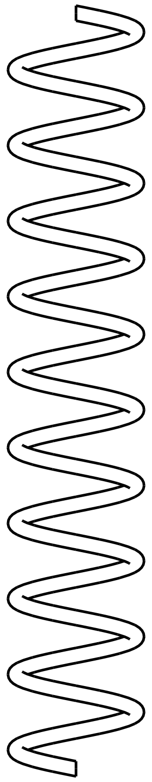
Right view
Scale: 1:2



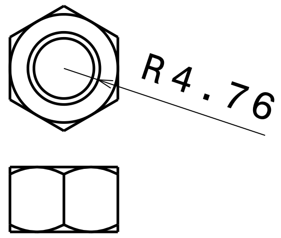
Front view
Scale: 1:2

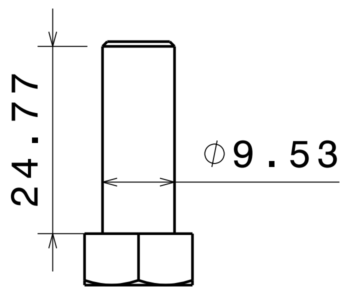


Top view
Scale: 1:2

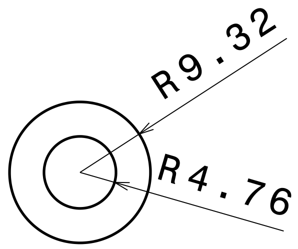


Front view
Scale: 1:1





Front view
Scale: 1:1



Front view
Scale: 1:1

DESIGNED BY: Minchin	HALMSTAD UNIVERSITY	
DATE: 16-06-21		
CHECKED BY:		
DATE:		
SIZE A3	COMPONENTS	
SCALE	WEIGHT (kg)	DRAWING NUMBER SCRAPER ASSEMBLED	SHEET

I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_

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