COMILLAS
UNIVERSIDAD PONTIFICIA

ICAI

MASTER'S DEGREE IN INDUSTRIAL ENGINEERING

MASTER'S THESIS

DEVELOPMENT OF A BATTERY THERMAL MANAGEMENT UNIT FOR ELECTRICAL VEHICLES

Author: Gonzalo Muñoz Díaz

Director: Jan Rennies

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Madrid

I declare, under my own responsibility, that the Project submitted under the title

Development of a battery thermal management unit for electrical vehicles

at the ETS de Ingeniería - ICAI of the Universidad Pontificia Comillas in the academic year 2022/23 is my own, original, and unpublished work, and

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Gonzalo Muñoz Díaz

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The delivery of the project has been authorised

THE PROJECT MANAGER

D.F.: Jan Rennies   Date: ..03../ ..07../ 23..

J. Rennies

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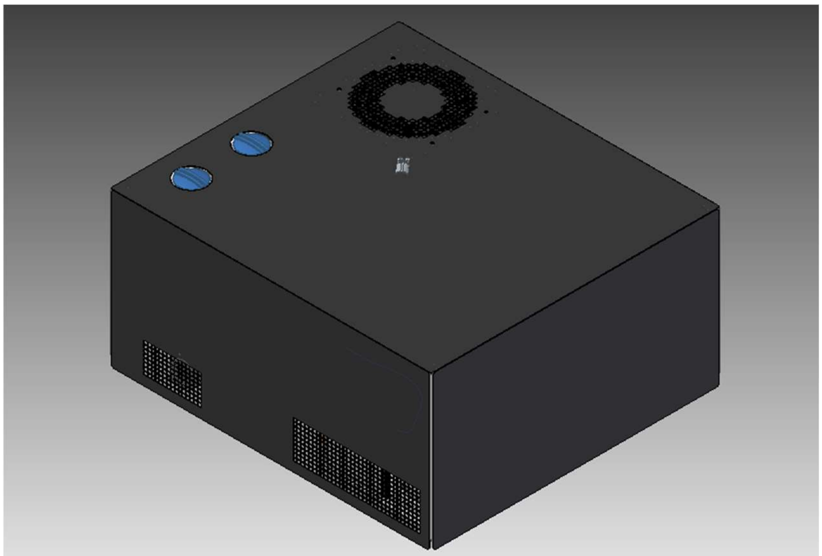

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DESARROLLO DE UNA UMTB

Autor: Muñoz Díaz, Gonzalo.
Director: Rennies, Jan.
Entidad Colaboradora: Sanz Clima

RESUMEN DEL PROYECTO

Introducción

En este proyecto industrial mecánico, se recoge la información necesaria para el desarrollo y futura producción de una unidad de mantenimiento térmico de baterías para coches eléctricos.

La razón por la que se ha realizado este proyecto es para suplir la necesidad actual de mejorar el rendimiento de vehículos impulsados por una betería eléctrica, concentrándose específicamente en vehículos pesados. El rendimiento de la batería es óptimo cuando esta se encuentra dentro de un rango, por lo que el equipo tendrá una doble función climatizadora, la de enfriar y calentar dependiendo de las características tanto externas como de funcionamiento.

El objetivo final es crear un producto competitivo que con sus ventas genere ingresos para Sanz Clima, empresa colaboradora en el desarrollo de este Trabajo de Fin de Máster.

Definición del proyecto

La unidad climatizadora para vehículos de baterías eléctricas debe contener la temperatura de la batería entre quince y veinticinco grados centígrados para que el rendimiento de esta sea óptimo. Además, el cliente medio exige unos requerimientos de capacidad térmica, flujo y de tamaño, que marcarán los límites mínimos del producto. Al ir equipado en un vehículo eléctrico, su fuente de energía será también la batería de este.

El presente proyecto consta de varios documentos de cálculos y diseños a ejecutar para la producción de la unidad. Entre otros están los cálculos de ciclo de refrigeración, lista de materiales del producto, y el código de programación para su funcionamiento.

Características generales

Las características del proyecto que se van a desarrollar en este documento deben cumplir con los requerimientos del cliente. Este producto utilizará como fuente de energía la propia batería del vehículo o una secundaria de menos voltaje.

El dispositivo tendrá dos circuitos. Uno cerrado, que es el circuito de refrigeración (Rankine), que tanto para enfriar como calentar la batería eléctrica el gas refrigerante circulará en el mismo sentido. Y luego un circuito de agua, con la que se climatizará la batería, que tiene cuatro válvulas para variar el flujo del agua dependiendo de si queremos bajar o subir la temperatura de la batería. Estas válvulas y otros componentes electrónicos se coordinarán a través de un microcontrolador.

Uno de los aspectos de innovación es la elección del gas propano (R290) como refrigerante, ya que sus propiedades hacen que cumpla tanto con las características termodinámicas como con las obligaciones medioambientales de la actualidad.

Metodología y desarrollo

La primera tarea del proyecto fue buscar la normativa actual sobre gases refrigerantes y normas de atmosferas explosivas para el uso de propano en este equipo, ya que en Europa todavía no está permitido de momento, pero la tendencia actual es que en el futuro los climatizadores que actúan como una bomba de calor usen el propano como refrigerante. Tras indagar se han realizado los cálculos termodinámicos para conocer las características que se deben cumplir y así elegir los componentes necesarios concorde a las mismas.

La segunda parte ha sido el diseño del prototipo, empezando por el mecánico. Se han seleccionado varios componentes, como los intercambiadores de calor o el evaporador, después se ha elegido la colocación de los componentes, el tamaño de las chapas de metal que serán el esqueleto del producto. Después se hace una leve mención a los componentes eléctricos de unidad climatizadora para baterías eléctricas, y por último se ha diseñado un código para la implementación electrónica.

La tercera parte es el estudio de producción y de coste del material, donde se analiza cuánto cuesta el producir una unidad, para luego ponerle un precio de venta con el que obtener un margen de beneficio.

En línea con los Objetivos de Desarrollo Sostenible, hay un documento en el que se habla de los beneficios para el medio ambiente que este proyecto incluye en su desarrollo.

Cálculos y resultados

Se han realizado cálculos teóricos para el ciclo de refrigeración que confirman la posibilidad de lograr un producto competitivo, y faltaría una confirmación experimental para ver si realmente este producto es viable, ya que a pesar de ser un trabajo de diseño por razones de normativa y tiempo el producto no ha podido ser probado antes de finalizar este documento. Además, uno de los impedimentos para producir una unidad climatizadora de baterías eléctricas con propano actualmente es la inexistencia de un compresor cerrado con el tamaño y precio que concuerde con los requerimientos de este proyecto.

Para los cálculos se ha utilizado la herramienta CoolPack, y para el diseño mecánico el programa Solid Edge, con el que se han dibujado varios planos y se ha sacado la lista de materiales. La gran mayoría de información y recursos utilizados para este trabajo son propiedad de Sanz Clima Dreiha.

DEVELOPMENT OF A BTMU

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Collaborating Entity: Sanz Clima.

ABSTRACT

Keywords: cooling, electric battery, vehicle, propane

Introduction

In this industrial mechanical project, the information necessary for the development and future production of a battery thermal maintenance unit for electric cars is collected.

The reason for this project is to address the current need to improve the performance of vehicles powered by an electric battery, with a specific focus on heavy duty vehicles. The performance of the battery is optimal when the battery is within a range, so the equipment will have a dual function of cooling and heating depending on both external and operating characteristics.

The final objective is to create a competitive product whose sales will generate income for Sanz Clima, a collaborating company in the development of this Master's thesis.

Definition of the Project

The air conditioning unit for electric battery vehicles must contain the temperature of the battery between fifteen and twenty-five degrees centigrade for optimum performance. In addition, the average customer's thermal capacity, flow and size requirements will set the minimum limits for the product. As it is equipped in an electric vehicle, its energy source will also be the vehicle's battery.

This project consists of several calculation and design documents to be executed to produce the unit. Among others are the refrigeration cycle calculations, product bill of materials, and the programming code for its operation.

General characteristics

The characteristics of the project to be developed in this document must meet the customer's requirements. This product shall use the vehicle's own battery or a secondary battery of lower voltage as a power source.

The device will have two circuits. A closed one, which is the cooling circuit (Rankine), that both for cooling and heating the electric battery the refrigerant gas will circulate in the same direction. And then a water circuit, with which the battery will be heated, which has four valves to vary the flow of water depending on whether we want to lower or raise the temperature of the battery. These valves and other electronic components will be coordinated via a microcontroller.

One of the innovative aspects is the choice of propane gas (R290) as the refrigerant, as its properties mean that it meets both thermodynamic characteristics and current environmental obligations.

Methodology and development

The first task of the project was to search for the current regulations on refrigerant gases and explosive atmosphere standards for the use of propane in this equipment, as in Europe it is not yet allowed at the moment, but the current trend is that in the future air conditioners acting as a heat pump will use propane as a refrigerant. After some research, thermodynamic calculations were carried out to determine the characteristics that must be fulfilled and to choose the necessary components accordingly.

The second part was the design of the prototype, starting with the mechanical design. Several components were selected, such as the heat exchangers or the evaporator, then the placement of the components and the size of the metal sheets that will be the skeleton of the product were chosen. Then a brief mention is made of the electrical components of the air-conditioning unit for electric batteries, and finally a code has been designed for the electronic implementation.

The third part is the study of production and cost of the material, where we analyse how much it costs to produce a unit, in order to then set a selling price with which to obtain a profit margin.

In line with the Sustainable Development Goals, there is a document that talks about the benefits for the environment that this project includes in its development.

Calculations and results

Theoretical calculations have been made for the refrigeration cycle that confirm the possibility of achieving a competitive product, and an experimental confirmation would be needed to see if this product is really viable, since despite being a design work, for regulatory and time reasons, the product could not be tested before finalising this document. In addition, one of the impediments to producing an electric battery air conditioning unit with propane at present is the non-existence of a closed compressor with the size and price that matches the requirements of this project.

For the calculations, the CoolPack tool was used, and for the mechanical design, the Solid Edge program was used, with which several drawings were made, and the bill of materials were extracted. Most of the information and resources used for this work are the property of Sanz Clima Dreiha.

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1. GENERAL DESCRIPTION

1.1 INTRODUCTION

In this mechanical industrial project, the design of a new product is going to be developed to carry out its manufacture and subsequent sale. The device is a battery thermal management unit (BTMU), which will be used to maintain the battery temperature of an electric vehicle (EV) in an optimal range.

Nowadays there are different manufacturers which are designing BTMU to fulfil the actual demand of electrical vehicles. The EV battery is becoming a key differentiating factor among automobile brands since the car's autonomy depends on it. On the following image appears the EV sales of 2022 according to EV-Volumes (Irle, 2022).

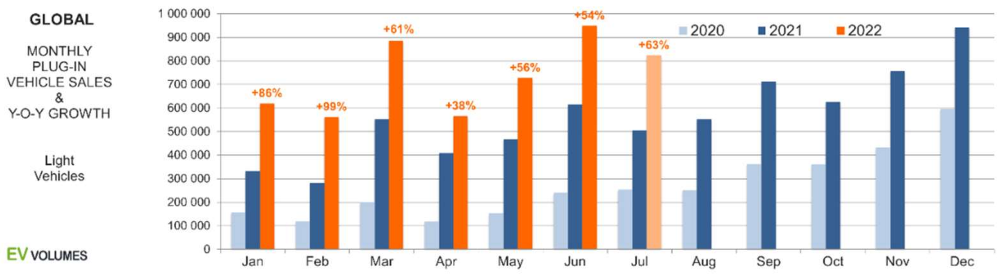

Figure 1.EV sales (EV-Volumes).

The growth in sales of these vehicles is remarkable, brands such as Tesla are now in the top sellers of luxury cars due to the current climate requirements and therefore the big companies in the transport sector are adapting to the market. New companies such as "Nikola" are joining this adaptation, focusing on more specific vehicles such as trucks, which need higher energy storage capacity, better performance, and high efficiency.

To achieve this efficiency, it is very important that the electric battery has an optimal performance and for this the working conditions must be almost ideal. The performance of an electric car battery is influenced by several factors, which most important are:

- Battery capacity: The amount of energy stored in the battery affects the vehicle range and overall performance. In cars it is usually 40 kWh (Car and Driver, 2021) while in heavy vehicles it can be up to 500 kWh (Science Direct, 2019).
- Battery technology: Different battery chemistries have different energy densities and charging/discharging efficiencies. In the automotive sector, the most used is the lithium battery.
- Operating temperature: High temperatures can affect the performance and lifespan of the battery, while low temperatures can reduce the range and efficiency of the vehicle.

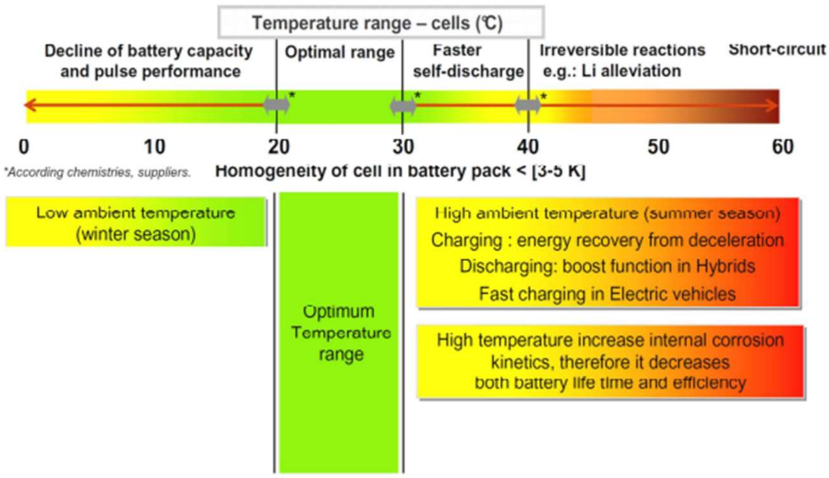

Figure 2. Optimal temperature range (Sanz Dreiha).

The previous image shows how the temperature range affect the battery performance, especially when it gets over forty degrees.

Depending on the country, the ambient temperature can reach values of -30°C as in Norway or Denmark (Granda, 2023), or on the other hand values of 40°C as in Spain (Ecoavant, 2022). The appliance must therefore have a dual function, as a cooler and as a heater. These states will alternate with the help of a controller as required. It is worth noting that although this temperature control unit consumes energy from the battery itself, the performance is higher than without it.

This is the reason for the life of the project, the next chapters will explain how to develop equipment that can maintain the car battery temperature in the ideal range.

1.2 STATE OF ART

It is important to clarify how a thermal unit works. In a thermal unit, heat exchanges occur between two bodies (usually fluid-gas or fluid-fluid). These heat exchanges are based on the refrigeration cycle, which has a component in a closed circuit called refrigerant, which is responsible for subtracting heat from the other component. Refrigerants are used in refrigeration systems that maintain a pressure much higher than atmospheric pressure, so the boiling points of these components in such system would be much higher than outdoors.

The boiling point of a refrigerant refers to the temperature at which it changes from a liquid to a gas. The boiling point depends on the pressure of the refrigerant, with lower pressures resulting in lower boiling points. Some examples of refrigerants with their boiling points (at atmospheric pressure) are (The engeniering ToolBox, 2023):

Refrigerant	Boiling temperature (°C) at 1 bar
R134a	-15
R22	-41,3

Table 1. Boiling point examples.

In the last decade two factors, Global Warming Potential (GWP) and Ozone Depletion Potential (ODP), have been added in order to measure the climate impact of the refrigerants (Science Direct, 2023).

GWP measures the potential of a refrigerant to contribute to global warming by trapping heat in the atmosphere. It is expressed as a ratio of the heat trapping capacity of a given amount of the refrigerant to that of CO2 over a specified period of time, typically 100 years. For example, R134a has a GWP of 1.430, which means that it is 1.430 times more potent at trapping heat in the atmosphere than CO2. In contrast, R32 has a GWP of 675, making it a much more environmentally friendly alternative.

The ODP measures the potential of a refrigerant to deplete the ozone layer. Ozone depletion occurs when Chlorofluorocarbons (CFCs) and other ozone-depleting substances release chlorine and bromine molecules into the stratosphere, which react with and destroy ozone molecules. The ODP is expressed as a ratio of the ozone-depleting capacity of a given amount of refrigerant to that of CFC-11 over a specified period. CFCs have an ODP of 1, while most Hydrofluorocarbons (HFCs9, such as R134a, have an ODP of 0, making them a safer alternative for the ozone layer.

R290 (propane) will be used as the refrigerant for this device. This refrigerant has a GWP of 3 and an ODP of 0. This means that it has a relatively low potential to contribute to global warming and does not pose a threat to the ozone layer.

R290 is a natural, low-GWP alternative to many high-GWP synthetic refrigerants and is widely used in refrigeration and air conditioning systems. However, it is flammable and requires careful handling and storage to ensure safety. For this purpose, the Atmospheres Explosible (ATEX) regulation and the EN-378 standards will be complied with.

Also, plate heat exchangers will be used to make the equipment safer, as they allow fluid-fluid and fluid-vapour heat transfer. For this project the fluid to be cooled will be water, which could be heated in other function of the device. The different components whose performance matches the requirements will be discussed in the following chapters.

In the refrigeration cycle (Rankine, 1850) there are four elements, which can be seen in the following diagram:

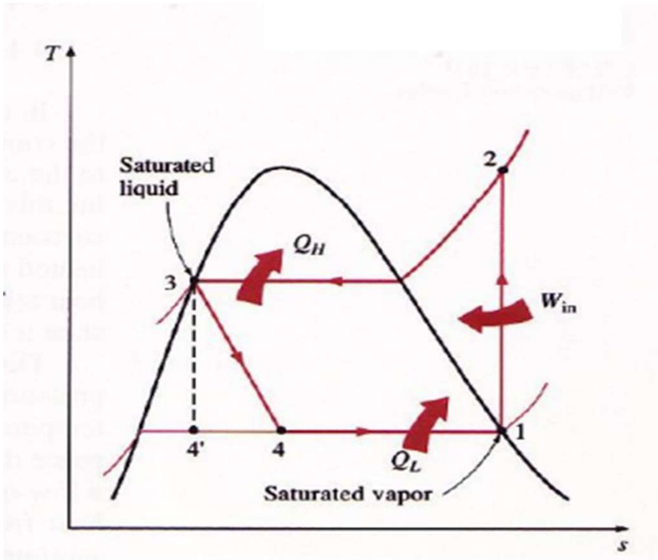

Figure 3. Refrigeration cycle (ICAI).

- Compressor (1-2): the refrigerant enters in a gaseous state and is compressed to increase its enthalpy and it is sent to the condenser.
- Condenser (2-3): the refrigerant is cooled in a heat exchanger to liquefy it.
- Expansion device (3-4): usually a valve that creates a pressure drop after the refrigerant leaves the condenser, causing rapid boiling in the refrigerant.
- Evaporator (4-1): the refrigerant absorbs the heat of the other component, in another heat exchanger and it is sent to the compressor again.

An important factor of cooling units or air conditioners it's the Coefficient of performance (COP). The COP of a refrigeration cycle is a measure of the efficiency of the system, representing the amount of cooling produced per unit of energy consumed (Connor, 2023). The compressor is a key component that affects the COP of a refrigeration cycle as it consumes a significant portion of the energy input. A more efficient compressor will have a lower power consumption, leading to a higher COP. Conversely, a less efficient compressor will consume more energy, lowering the COP. Improving the efficiency of the compressor can result in a higher COP, making the refrigeration system more energy-efficient.

There is an example by the web (Energy education):

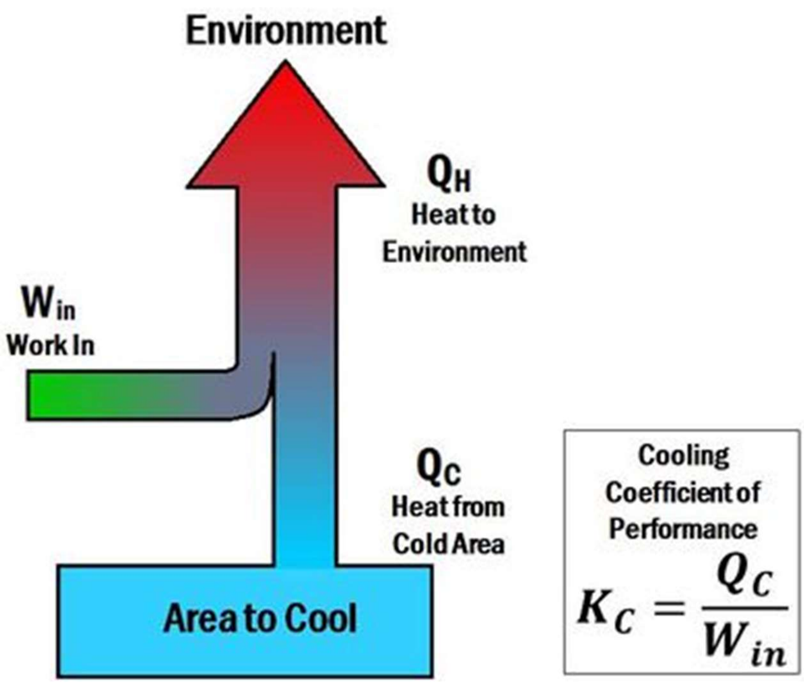

Figure 4. COP example

1.3 CUSTOMER REQUIREMENTS

The purpose of designing the BTMU is to sell it to a customer in the transport sector, in this case electric buses or trucks. Project such us the manufacture of a truck are quite complex and require synergies between several companies, so it is essential to indicate the characteristics of the product before its development. On the one hand, the coachbuilder is limiting the size of the BTMU. On the other hand, the product must meet cooling and heating capacities, which is part of the motor design. The customer wants to start assembly of its product in November 2023, so the design phase must be completed a few months earlier and the prototype has to be tested. In the final product could be some minor variations.

1. Size requirements:

Length	≤ 1000 mm
Width	≤ 900 mm
Height	≤ 500 mm
Weight	≤ 100 kg

Table 2. Size requirements.

2. Project deadline:

Date:	15/07/2023

Table 3. Project deadline.

3. Refrigerant circuit requirements:

Refrigerant	R290
Cooling capacity	≥ 9 kW at 35 °C temp. ambient ≥ 6 kW at 40 °C temp. ambient
Cooling efficiency (COP/EER)	≥ 3 at 35 °C temp. ambient
Heating capacity	≥ 6 kW at -10 °C temp. ambient
Heating efficiency (COP)	≥ 2
Compressor voltage	450-800 V DC
Compressor control	Pulse width modulation (PWM)
Condenser type	Plate heat exchanger
Evaporator type	Plate heat exchanger
Other electronic devices control	PWM
Other electronic devices voltage	24 V DC

Table 4. Refrigerant circuit requirements

The choice of "R290" as the refrigerant for this air-conditioning unit is a climate-sensitive innovation, as its Global Warming Potential (GWP) and Ozone Depletion Potential (ODP) are beneficial to the environment. The data sheet can be found in the annexes. The compressor voltage will be connected directly to the vehicle's battery, although in some cases it can be connected to a 24 V DC auxiliary battery. Blower, fans, electronic valves are examples of other electronic devices used in this unit.

2. PROTOTYPE DESIGN

This project consists of a mechanical design, an electrical design, and a software design, that will be developed in this chapter. For the design of the device, the guides of the company Sanz Dreiha will be used. These guidelines include standardised parts according to "Deutsche Institut für Normung" (DIN) or International Organization for Standardization (ISO) standards. In addition, EN-378 for the cooling circuit and ECE-10 for the EMC design shall be followed.

2.1 *MECHANICAL DESIGN*

2.1.1. REFRIGERANT

In this section, the mechanical elements of the equipment will be described. As this is a project for a thermal control unit, the first part to be designed is the cooling circuit. As already mentioned, the refrigerant to be used in the BTMU will be R290. Its properties will be shown in the annex, some of them are (INTARCON, 2023):

Chemical formula	HgC_3
Molecular mass	44 gr/mol
Boiling temperature	-42 ºC
Critical temperature	96,7 ºC
Latent heat (-10ºC)	375 kJ/kg
Density saturated liquid (-10ºC)	542 kg/m^3
Volumetric capacity (-10ºC)	1846 Kg/m^3
COP (-10/+45ºC)	3,7
GWP	3
Class	A3
Lower flammability limit	0,038 kg/m^3
Combustion heat	2200 kJ/mol
Auto-ignition temperature	470 ºC
Practical limit	8 gr/m^3

Figure 5. R290 properties

When using R290 (propane) as a refrigerant in a cooling circuit, it is recommended to use materials and components that are compatible with its flammable nature.

- Copper or steel tubing: These materials are commonly used for the refrigerant lines in R290 systems, as they are compatible with propane and can withstand the higher pressures required for R290 operation.
- Explosion-proof electrical components: Due to the flammable nature of R290, all electrical components (such as compressors, motors, and switches) must be rated for use in hazardous locations and designed to prevent sparking.

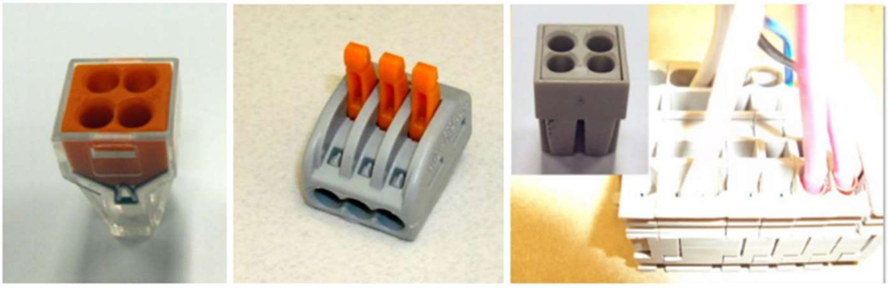

Figure 6. Electrical connectors for the R290

- Pressure relief valves: These valves are designed to release pressure in the event of an overpressure condition in the system, which can help prevent equipment damage or rupture.
- For the assembly of the equipment, the operators must follow the ATEX regulations when inserting the R290. For this purpose, they will have to take an informative course and will be equipped with the necessary safety elements.

Since 2008, the regulations allowed a maximum quantity of 150g of propane in the circuit. But just this month there has been a change in the law IEC 60335-2-89 (Danfoss), which now sets the maximum limit at around 500g. It is true that this law refers to air conditioners in enclosed spaces, but there is nothing written about this feature in the automotive sector. It will therefore be used as a legal reference, as it is a product of research and innovation.

"New charge limits for flammable refrigerants:
In early 2019, the International Electrotechnical Commission (IEC) revised its safety standard IEC 60335-2-89 and raised the charge limit for flammable refrigerants in stand-alone commercial refrigeration equipment.
This news is important because the transition to low global warming potential (GWP) refrigerants will lead to the increasing use of flammable refrigerants such as propane (R290) and isobutane (R600a) in commercial refrigeration.
However, the change has the potential to cause some confusion. For example, the new charge limits come into effect at different times in different countries, applying to some but not all applications. They also depend on the size of a room in which the unit can be used." (Danfoss)

To find out how much propane we need in this device, we will use the CoolPack tool. The parameters of the "requirements" section have been entered. The customer has ordered a cooling capacity of 8 kW at an ambient temperature of 35 °C, and a heating capacity of 6 kW at an ambient temperature of -10 °C. For the other parameters, such as efficiency, typical values have been chosen.

Cooling mode

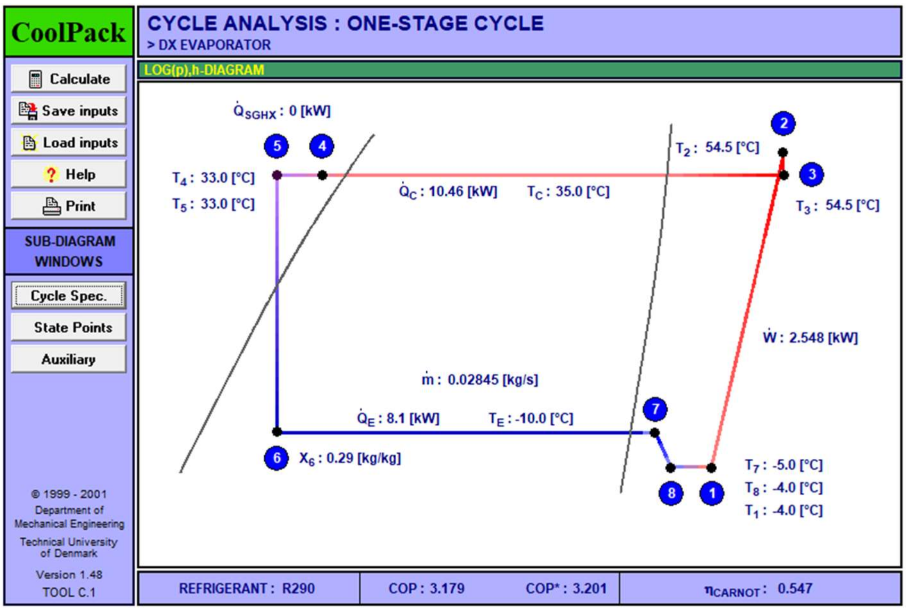

Figure 7. Cooling analysis

STATE POINTS

STATE POINT	TEMPERATURE [°C]	PRESSURE [kPa]	ENTHALPY [kJ/kg]	DENSITY [kg/m³]
1	-4.0	342.0	474.9	7.3
2	54.5	1232.7	555.5	23.6
3	54.5	1218.3	555.9	23.2
4	33.0	1218.3	188.2	479.3
5	33.0	1218.3	188.2	479.3
6	-10.0	347.7	188.2	-----
7	-5.0	347.7	473.0	7.5
8	-4.0	342.0	474.9	7.3

Additional information
Pressure ratio (p_2 / p_1): 3.605
$T_{2,IS}$: 46.0 [°C] $T_{2,IS}$ is the temperature of the discharge gas assuming reversible and adiabatic compression
$T_{2,W}$: 58.8 [°C] $T_{2,W}$ is the temperature of the discharge gas assuming real and adiabatic compression

Figure 8. Cooling state points.

This first analysis refers to the typical use of a refrigeration cycle, where the evaporator is the main exchanger, and its function is to cool. This appliance is designed to heat as well, so it acts as a heat pump. In the case of heating, the condenser is the main heat exchanger. Its analysis is as follows:

Heating mode

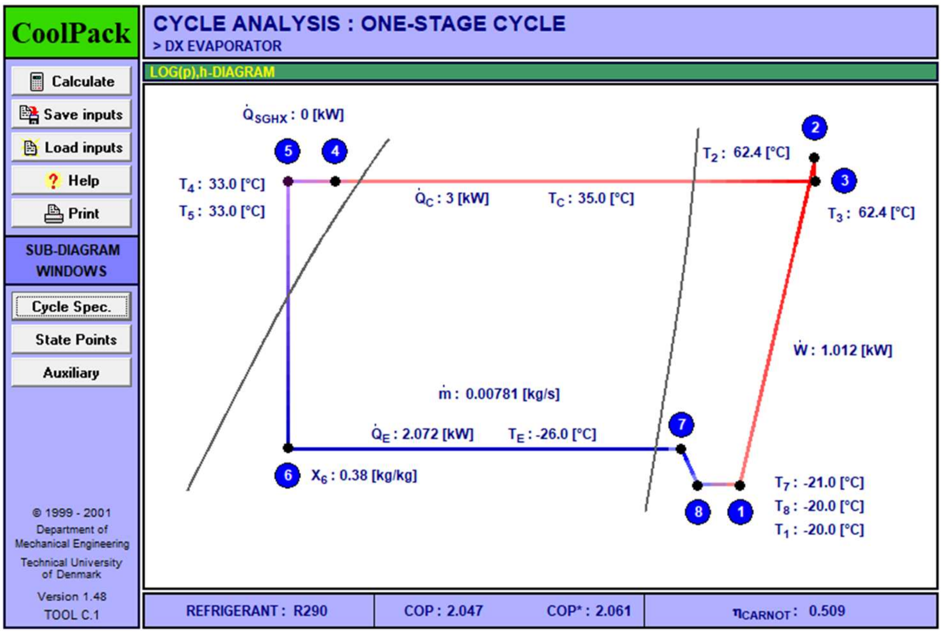

Figure 9. Heating analysis

STATE POINT	TEMPERATURE [°C]	PRESSURE [kPa]	ENTHALPY [kJ/kg]	DENSITY [kg/m^3]
1	-20.0	192.8	455.3	4.3
2	62.4	1232.7	572.0	22.7
3	62.4	1218.3	572.4	22.4
4	33.0	1218.3	188.2	479.3
5	33.0	1218.3	188.2	479.3
6	-26.0	196.6	188.2	-----
7	-21.0	196.6	453.6	4.4
8	-20.0	192.8	455.3	4.3

Additional information
Pressure ratio (p_2 / p_1): 6.393
$T_{2,IS}$: 50.0 [°C] $T_{2,IS}$ is the temperature of the discharge gas assuming reversible and adiabatic compression
$T_{2,W}$: 68.5 [°C] $T_{2,W}$ is the temperature of the discharge gas assuming real and adiabatic compression

Figure 10. Heating state points.

2.1.2. COMPRESSOR

This component is the heart of the refrigerant circuit. The compressor generates an enthalpy increase by increasing the pressure of the refrigerant which enters at low temperature but in a gaseous state. As mentioned above, this equipment must be enclosed to prevent the escape of propane and must not produce sparks. Nowadays many manufacturers produce equipment specifically designed for the R290. The main characteristics for compressor selection are the vehicle battery voltage, evaporator cooling capacity with respect to temperature and mass flow rate obtained in the previous section. "QPE34-850" made by "TCCi" is a suitable option for the BTMU.

Figure 11. TCCi high voltage compressor

Displacement (cc/rev)	Cooling power (kW)	Speed (rpm)	Voltage (V)
34	8,5	1000-8500	400-850

Table 5. Compressor features

The compressor chosen does not comply with ATEX safety regulations. This is because it is an open compressor, so the flammable gas could escape to the outside. As it is an innovation project, it will be used only to check whether the characteristics of the project meet the client's requirements. For actual production an analogue compressor has to be used but closed instead of open.

Today's closed compressors on the market do not meet the characteristics required for this project for two reasons:

- Price: closed compressors are much more expensive than open compressors, especially for the range of features required for this BTMU.

- Size: for the same features the size's difference between closed and open compressor is striking, being the closed one the biggest. Due to this device will be on the top of big vehicles, this is a problem for the shape characteristics of the BTMU, and for the weight limit too. The following model has a size of 250x246x438 mm (emerson.com, 2023), which it is a half of the total space to be filled.

The analogue closed compressor of the project choice would be ZB*KU (Emerson)

Figure 12. Emerson compressor

In the future there will probably be closed compressors that meet the requirements for the cooling of electric heavy vehicles. Countries such as China, are developing new heat pumps based on the R290 gas (Haroldsen, 2023). This is due to the performance of this gas outweighs the disadvantages of being flammable.

In the conclusions section will be discussed if the production of the BTMU is profitable or not.

2.1.3. HEAT EXCHANGER PLATES

Since this equipment will act as a heat pump, the secondary cooling circuit fluid will be water. It been chosen 70 plates for this device.

Therefore, the heat exchangers must be plate heat exchangers, since in this case there is no air exchange. "SWEP B10TS- All Stainless" will be purchased for both the condenser and the evaporator. Some of the features can be seen below:

Figure 13. Evaporator plate

Basic specifications

Maximum number of plates (NoP)	140
Max flow	9 m^3/h (39.63 gpm)
Channel volume	0.061/0.061 dm^3 (0.0022/0.0022 ft^3)
Material	316 Stainless Steel Plates, Stainless Steel Brazing
Weight excl. connections	1.24+(0.121*NoP) kg 2.73+(0.267*NoP) lb
Max Particle Size (mm)	1

Figure 14. Heat exchanger plate features.

2.1.4. EXPANSION VALVE

An expansion valve is a metering device that regulates the flow of refrigerant from the high-pressure side to the low-pressure side in a refrigeration or air conditioning system. It does this by creating a pressure drop in the refrigerant, which causes it to expand and cool as it enters the low-pressure side of the system.

The expansion valve achieves this by utilizing a small orifice that restricts the flow of refrigerant, causing it to expand and cool as it passes through. The chosen component is the "Danfoss TD1/ TDE1" expansion valve.

Figure 15. Expansion valve.

2.1.5. WATER PUMP AND TANK

For the secondary circuit the coolant will be a water-glycol mixture (up to 50%), to prevent freezing. The following tanks will be used to store the mixture.

Figure 16. NRF water tank

The water pump shall generate the water flow in the secondary circuit. The electric motor driving the water pump shall have a voltage of 24 V DC and with a PWM or CAN controller. The chosen one is "eCP80" by "Avid Technology", because of its features.

Figure 17. Water pump

2.1.6. WATER HEAT EXCHANGER

A water-air heat exchanger works by transferring heat between water and air. Cold water flows through a set of tubes, while hot air flows over the tubes, absorbing heat from the water. The cold water is then pumped out of the exchanger and the hot air is distributed throughout the space. This device is to be used only when the water entering the condenser plate is to be cooled. The chosen one is from the company "Thermokey".

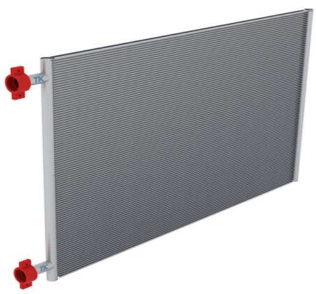

Figure 18. Water Heat Exchanger

To improve the performance of this heat exchange, a fan will be added to produce forced convection.

2.1.7. PIPES AND OTHER COMPONENTS.

In the BTMU there are two circuits.

- The first one is the propane circuit. Its pipes will be made of copper, having solder fitting as joints. In this circuit, a collector filter drier, which goes downstream of the condenser, is also needed to remove the moisture and contaminants from the refrigerant. This component and others such us the sight glass, pressure sensors, venting mechanism, will be purchased from "Danfoss".
- The second one is the water circuit. Its pipes will be of PVC, and the other components will be purchased from "Danfoss" too.

2.1.8. SHEET METAL PARTS

The material used for the metal sheets will be Aluminium, with a thickness of 1.5 mm. Drawings of the metal sheets to be used are given in the annexes. In the following picture you will see the metal sheets and components assembled.

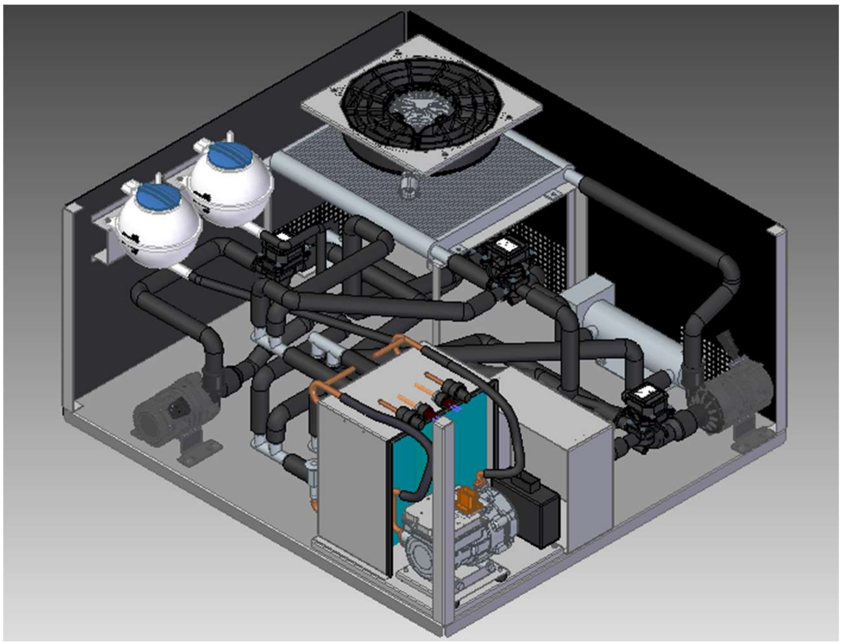

Figure 19. BTMU view

2.1.9. HYDRAULIC DIAGRAM

This battery thermal management unit will operate as a heat pump. On one hand, when cooling is required, the water that goes to the electric battery exchanges heat in the evaporator. On the other hand, when heating is required, the water that goes to the battery exchanges heat in the condenser, with the aid of an electric heater. For this purpose, a circuit with three-way valves has been designed, depending on their position, the water flow will pass through the required path.

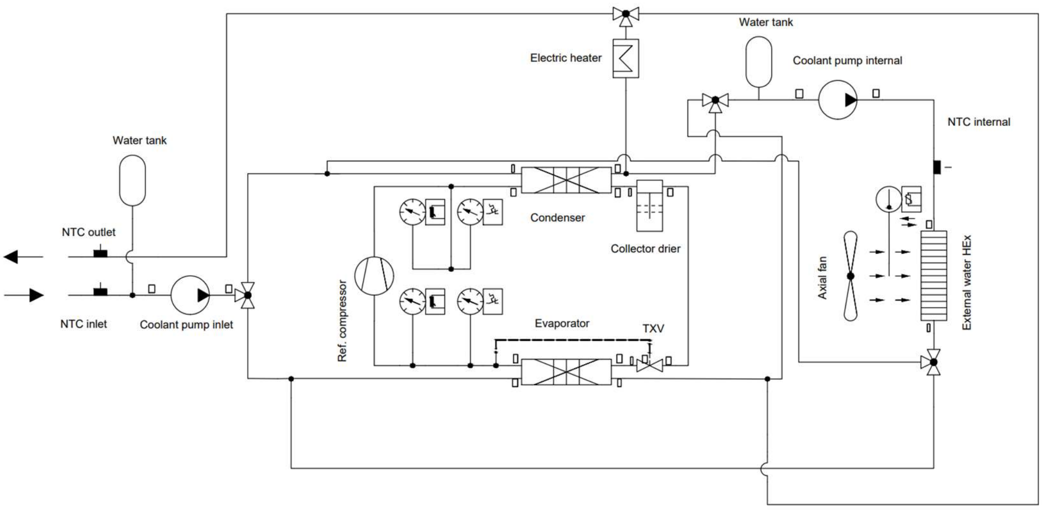

Figure 20. BTMU hydraulic diagram

2.2. *ELECTRICAL DESIGN*

In this section, the elements that form part of the electrical design, such as cables, resistors, transformers, etc., will be developed. This device is to be installed in heavy vehicles such as buses or tractors, so it must be considered that the voltage of these batteries is much higher than electric cars (in this case 800 V DC). However, considering that this is a prototype, it is assumed that the power supply for the various electrical components will be 24 V DC, except for the microcontrollers, which will be 12 V DC.

2.1.1 WIRING

To reduce the risk of explosion, the cables must follow the ATEX norm. For this project there will be used Intrinsically Safe (Exi) cables. These cables are suitable for use in hazardous areas where the energy levels need to be limited to prevent ignition. They are designed to restrict electrical energy and prevent sparks or excessive heat from occurring.

Figure 21. Exi cable example

2.1.2. CURRENT AND VOLTAGE

As mentioned above, we will assume that the voltage to which this equipment will be connected is 24 V DC. The maximum current will be controlled with a fuse to avoid overheating and possible short circuits.

2.2 CONTROL UNIT DESIGN

In this section, the different control processes of the BTMU will be developed, and it will be explained which components act according to the working mode. As discussed above, depending on the temperature of the electric battery this device will have three modes of operation. To measure the temperature a sensor will be used which will be developed in the hardware part. To understand these modes, it has to be kwon that the valves also have three positions, closed, open one, and open two. The three modes are:

- Idle (0): the temperature is in the optimal range 15 °C to 25 °C. In this mode all four valves are closed, position 0, the compressor, pumps and heater are switched off. In theory, consumption in this mode should be zero.
- Cooling Mode (1): the temperature is over 25 °C. In this situation, there are two valves in position 1 and two valves in position 2. This causes water from the electric battery to flow into the evaporator and returns cooled. The condenser circuit is cooled by a forced air flow through the heat exchanger. It can be seen in the next picture.

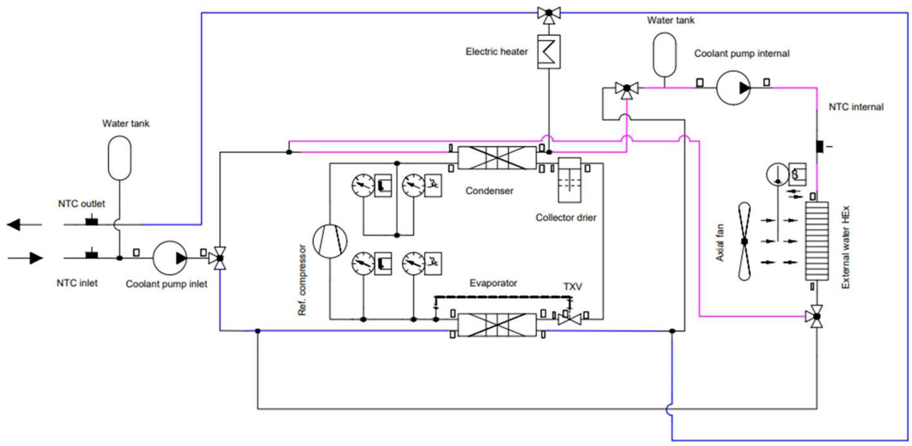

Figure 22. Cooling mode circuit

The pumps, fan and the compressor will be acting according to the temperature difference from the optimal range, using for this a proportional integral derivative control (PID) controller. The electric heater will be off.

- Heating Mode (2): the battery temperature is below 15°C. In this situation, there are two valves in position 1 and two valves in position 2. This causes water from the electric battery to flow into the condenser and returns heated and flows to the electric heater too. The evaporator circuit is cooled by a forced air flow through the heat exchanger. It can be seen in the next picture.

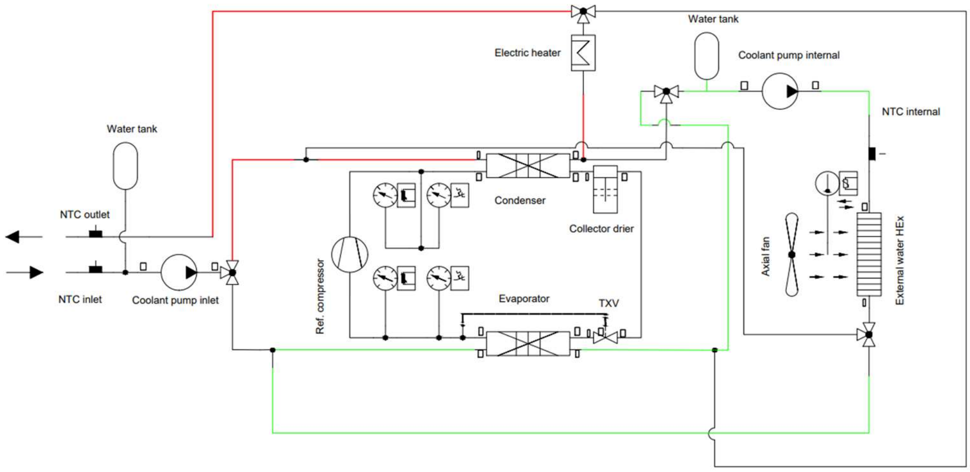

Figure 23. Heating mode circuit

The pumps, fan and the compressor will be acting according to the temperature difference from the optimal range, using for this a PID controller. The electric heater will be on.

2.2.1 MICROCONTROLLER

A microcontroller "dsPIC33FJMC202/204" of the brand "MICROCHIP" will be used for this equipment.

Figure 24. dsPIC33FJMC202/204

2.2.2 DEVELOPMENT BOARD

The motherboard to be implemented in this prototype is the "PicTrainer v3.0", for the industrial production product a simpler and cheaper model will be sought. power supply to the board is 7 to 9.5 V DC.

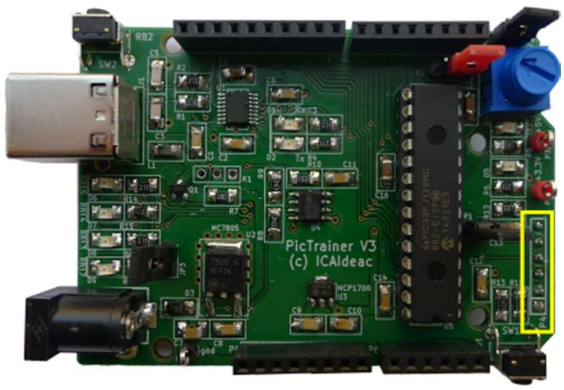

Figure 25. ICAI development board.

2.2.3 SOFTWARE

This section will give an overview of how the electronic control system for this equipment works. The program, which will appear in the Annexes, is written in "C" with the tool "MPLAB X IDE". First, the inputs and outputs will be defined.

- **Inputs:** Three temperature sensors shall be used to control the BTMU, two placed at the inlet and outlet of the refrigeration circuit and the third placed at the inlet of the water-air heat exchanger. The water quantity levels of the tanks will not be considered for this prototype, but for series production it should be considered, to avoid recurrent revisions.

An analog-to-digital conversion driver will be created, whose file is called "adc.c". With this driver the signal from the temperature sensors will be converted to digital, giving 0 at low temperatures and 1023 at high temperatures. The microcontroller analog ports shall be used.

- **<u>Outputs:</u>** four relays that activate the three-way valves, two hydraulic pumps, a compressor, an electric heater, and a heating resistor, protected by transistors. In addition, an LED will be installed that will light up when the BTMU is not working properly.

For rotating equipment, a driver called "pwm.c" will be used to configure the pins with a PWM signal. This signal will be treated with a PID according to the temperature variation. For timing requirements, a driver will be defined to act as a clock called "timer.c".

The state machine programmed for the BTMU would be as follows:

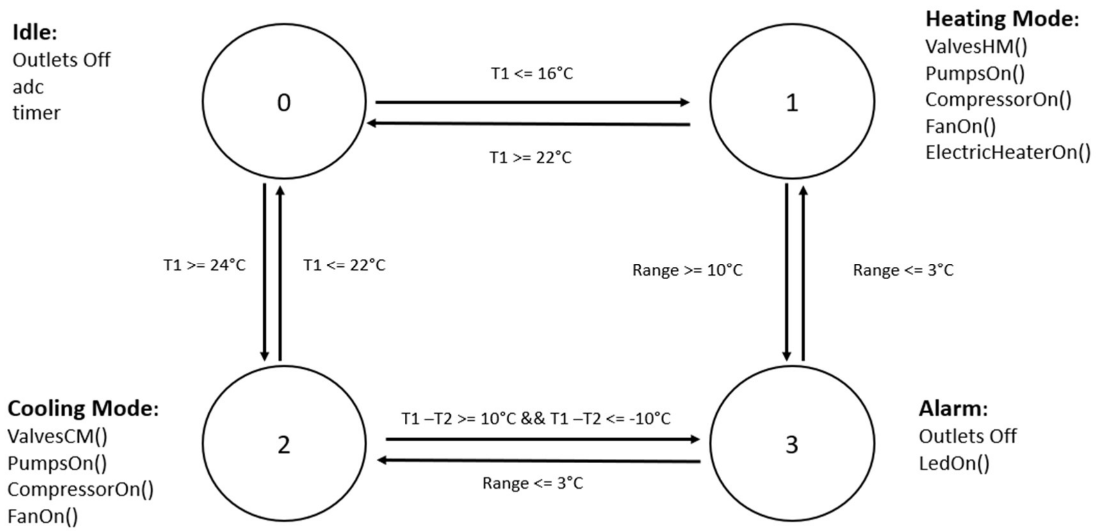

Figure 26. BTMU State machine

3. COST AND PRODUCTION

In this section, the cost of production of the BTMU will be calculated. To do this, we will first study the cost of the materials needed for the prototype. With this study we will know the cost of the materials, and then we will have to calculate how much it would cost to produce one unit. For this calculation it is necessary to know the manufacturing route of the material.

3.1 COST OF MATERIALS

The following "Excel" table lists the materials to be used, with several columns showing the material reference, the material description, the quantities required, the unit price and the total price.

Summary of Atomic Parts For BTMU_Gonzalo							
Item	Title	Subject	Category	Quant./ size	**Unit price**	**Measure**	**Total**
1	Water tank	7		2	15.75	€/ Unit	31.5
2	Water tube			4.3	4.75	€/ m	20.425
3	Tank cap	6		2	1.05	€/ Unit	2.1
4	BG0004317		Cap screw ISO 14579 M5x35 A4	4	0.03	€/ Unit	0.12
5	KN0003330	69-2098.A	Cable gland M20x1,5 Br	5	0.2	€/ Unit	1
6	BG0012043	79-0564.Z	Hexagon nut ISO 4032 M5 A2	20	0.02	€/ Unit	0.4
7	Coolant T pipe	8		1	0.3	€/ Unit	0.3
8	Electric heater	9		1	0.4	€/ Unit	0.4
63	Main sheet	Sheet 001	Main sheet	1.4	1	€/ m	1.4
52	E-Box	Sheet 002	E-Box	0.2	1	€/ m	0.2
15	Cover left	Sheet 003	Cover left	0.4	1	€/ m	0.4
12	KD0033095		Axial Fan 24V D280	1	87.6	€/ Unit	87.6
13	BG0007745	79-0576.Z	Flat head screw M5x16 ISO14583 A4 TX	16	0.02	€/ Unit	0.32
14	Cover front A	Sheet 004	Cover front A	1.2	2	€/ m	2.4
51	Cover front B	Sheet 005	Cover front B	1.2	1	€/ m	1.2
53	Angle	Sheet 006	Angle	0.1	1	€/ m	0.1
17	KN0000066	69-1835.A	Cable gland M16x1,5 Br	6	6.54	€/ Unit	39.24
18	Pipe TXV to Evap			1	0.5	€/ Unit	0.5
19	TXV			1	12.8	€/ Unit	12.8
20	DMC			1	14.8	€/ Unit	14.8
21	Pipe cond. to drier			1	6.78	€/ Unit	6.78
22	Evaporator plate	11		1	360	€/ Unit	360
16	Plate for pipes	Sheet 007	Plate for pipes	0.5	1	€/ m	0.5
24	Emerson			2	16.77	€/ Unit	33.54
25	Pipe clamp			2	5.75	€/ Unit	11.5

Table 6. Cost of materials 1

Item	Title	Subject	Category	Quant./ size	Unit price	Measure	Total
26	Sensor			2	60.8	€/ Unit	121.6
27	Pipe Clamp			2	5.75	€/ Unit	11.5
10	Anlge B	Sheet 008	Anlge B	0.5	1	€/ m	0.5
29	Pipe Drier to TXV			4	19.78	€/ Unit	79.12
30	Driere bracket			1	35.98	€/ Unit	35.98
31	Elko			4	13.66	€/ Unit	54.64
32	BG0010482	79-0515.Z	Lock Washer Sk S 8 A4	2	0.02	€/ Unit	0.04
33	79-0682.Z		Hexagon screw ISO4017 M8x100 A4-70	2	0.06	€/ Unit	0.12
34	BG0003931	79-0636.Z	Blind rivet nut M5 A2	4	0.02	€/ Unit	0.08
35	Compressor	10		1	290.99	€/ Unit	290.99
54	Angle C	Sheet 009	Angle C	0.1	1	€/ m	0.1
9	Cover fan	Sheet 010	Cover fan	0.1	1	€/ m	0.1
38	Outlet pipe compressor			1	2	€/ Unit	2
39	Outlet pipe evaporator			1	2	€/ Unit	2
40	Inlet pipe compressor			1	2	€/ Unit	2
41	Edge protection			1	1	€/ Unit	1
42	Compressor control unit			1	45.88	€/ Unit	45.88
43	Inlet pipe condenser			1	1	€/ Unit	1
44	Condenser plate	12		1	320.75	€/ Unit	320.75
45	Coolant F pipe	2		4	3.75	€/ Unit	15
46	Inlet water pipe	3		1	2	€/ Unit	2
47	GB0036548		Microchannel HEx for water-glycol	1	160.66	€/ Unit	160.66
48	KG0010007	7.137.200.10	Motor	4	38.9	€/ Unit	155.6
49	LABEL		LABEL	4	1	€/ Unit	4
50	BG0020345	79-0523.Z	Screw M6	12	0.01	€/ Unit	0.12
11	Fan bracket	Sheet 011	Fan bracket	1.2	1	€/ m	1.2
37	Compressor bracket	Sheet 012	Sheet 012	0.7	1	€/ m	0.7
28	Sheet metal	Sheet 013	Sheet metal	0.2	1	€/ m	0.2
23	Plate HEx bracket	Sheet 014		0.2	1	€/ m	0.2
55	Oulet water pipe	4		1	1	€/ Unit	1
56	Hose pump	5		2	0.02	€/ Unit	0.04
57	BG0023123	79-0555.Z	Nut M6	4	0.02	€/ Unit	0.08
58	Torx M5x14_13_15_0.par			16	0.02	€/ Unit	0.32
59	BG0098716	79-0123.Z	Lock Washer M6	4	0.02	€/ Unit	0.08
60	Kepler pump			2	260.75	€/ Unit	521.5
61	Outlet hose			1	3	€/ Unit	3
62	Inlet hose			1	3	€/ Unit	3
36	Compressor bracket 2	Sheet 015	Sheet 015	2	1	€/ m	2
64	BG0077877	79-0556.Z	Screw M8	4	0.02	€/ Unit	0.08
65	BG0074878	79-0524.Z	Nut M8	12	0.01	€/ Unit	0.12
66	BG0075879	79-0223.Z	Lock Washer M8	4	0.02	€/ Unit	0.08
67	BG0077880	79-0235.Z	Screw M8	4	0.02	€/ Unit	0.08
68	BG0077966	79-0522.Z	Nut M8	4	0.02	€/ Unit	0.08
69	BG0096882	79-0599.Z	Lock Washer M8	4	0.02	€/ Unit	0.08
70	BG0057883	79-0623.Z	Screw M16	4	0.02	€/ Unit	0.08
						Total	€ 2,470.23

Table 7. Cost of materials 2

As can be seen, the cost of the electric battery thermal maintenance unit reaches the figure of 2,470.23 €, which is approximately 2,500 €.

3.2 ROUTE DESIGN AND PRODUCTION COSTING

The manufacturing route for this product passes through three zones, where different machines are used, and there are different workers specialised in their task. The preparation time and the working time at each stage will be considered to calculate the production cost. The working areas are:

- Pre-production: in this area, the tasks of manufacturing the metal sheet that will later serve as a shell for the final product are carried out. The following table shall be used to calculate the production times.

Material					
Sheet 001		Setup	Labour	Machine	
Main sheet	CNC	5	-	0.3	min
	Bending machine	7	-	0.5	min
	Press	-	-	-	min
			Total	12.8	min

Table 8. Example task time control

Material					
Sheet 001		Setup	Labour	Machine	
Main sheet	CNC	5	-	0.3	min
	Bending machine	7	-	0.5	min
	Press	-	-	-	min
			Total	12.8	min
Material					
Sheet 002		Setup	Labour	Machine	
E-Box	CNC	7	-	1	min
	Bending machine	6	-	1.5	min
	Press	-	-	-	min
			Total	15.5	min
Material					
Sheet 003		Setup	Labour	Machine	
Cover left	CNC	5	-	1	min
	Bending machine	-	-	-	min
	Press	20	-	1	min
			Total	27	min
Material					
Sheet 004		Setup	Labour	Machine	
Cover front A	CNC	2	-	1	min
	Bending machine	-	-	-	min
	Press	-	-	-	min
			Total	3	min

Material					
Sheet 005		Setup	Labour	Machine	
Cover front	CNC	5	-	1	min
	Bending machine	7	-	0.5	min
	Press	25	-	4	min
			Total	42.5	min
Material					
Sheet 006		Setup	Labour	Machine	
Angle	CNC	5	-	0.1	min
	Bending machine	4	-	0,2	min
	Press	-	-	-	min
			Total	9.1	min
Material					
Sheet 007		Setup	Labour	Machine	
Plate-pipes	CNC	5	-	0.1	min
	Bending machine	3	-	0.5	min
	Press	-	-	-	min
			Total	8.6	min
Material					
Sheet 008		Setup	Labour	Machine	
Anlge B	CNC	5	-	0.1	min
	Bending machine	3	-	0.5	min
	Press	-	-	-	min
			Total	8.6	min

Table 9. Production time control 1

Material					
Sheet 009		Setup	Labour	Machine	
Angle C	CNC	5	-	0.2	min
	Bending machine	3	-	0.5	min
	Press	-	-	-	min
			Total	8.7	min
Material					
Sheet 010		Setup	Labour	Machine	
Cover fan	CNC	5	-	1	min
	Bending machine	-	-	-	min
	Press	25	-	4	min
			Total	35	min
Material					
Sheet 011		Setup	Labour	Machine	
Fan bckt.	CNC	5	-	1	min
	Bending machine	3	-	0.5	min
	Press	-	-	-	min
			Total	9.5	min
Material					
Sheet 012		Setup	Labour	Machine	
Compr. br.	CNC	6	-	0.7	min
	Bending machine	10	-	1.2	min
	Press	-	-	-	min
			Total	17.9	min

Material					
Sheet 013		Setup	Labour	Machine	
	CNC	1	-	0.1	min
	Bending machine	5	-	0.2	min
	Press	-	-	-	min
			Total	6.3	min
Material					
Sheet 014		Setup	Labour	Machine	
Plate HEx	CNC	5	-	1	min
	Bending machine	7	-	1.5	min
	Press	-	-	-	min
			Total	14.5	min
Material					
Sheet 015		Setup	Labour	Machine	
Compr. Br. 2	CNC	5	-	0.8	min
	Bending machine	7	-	0.5	min
	Press	-	-	-	min
			Total	13.3	min
Total Time	232.3	min			
	3.87	h			

Table 10. Production time control 2

The final calculation gives about 3 hours and 47 minutes of sheet metal production, 4 hours approximately.

- Electrical assembly: this task is carried out by a specialised worker, so all the tasks will be grouped together in a single production order.

BTMU cables		Setup	Labour	Machine	
	Elect. Asm.	10	30	-	min
			Total	40	min

Table 11. Electrical Assembly Prod. Control

- Assembly: this task is reflected in the ADR assembly plan, the worker must assemble the components, join the plates, and assemble the cooling circuits that are integrated in the equipment.

Material					
BTMU asm		Setup	Labour	Machine	
	Assembly	10	65	-	min
			Total	75	min

Table 12 BTMU Assembly

With the data that has been obtained, the total production time of 7 hours, with the average hourly cost of the worker being around €30/hour, the following equation would apply.

n°		Unit cost	Time	€/hour	Cost (€)
1	Total Prod. hours		5.79	30	173.65
1	Material Costs	2470.23			2470.225
				Total	€ 2,643.88
				Per unit	€ 2,643.88

Table 13. Production cost

In conclusion, the total cost of manufacturing one BTMU is 2,643.88 €. To reduce production costs, it would be possible to make batches of larger quantities, for example if 50 were made in a row. This is because the setup time is the same for 1 unit as it is for 50 units. Furthermore, the price of materials would be more negotiable. The unit price would be as follows:

n°		Unit cost	Time	€/hour	Cost (€)
50	Total Prod. hours		104.85	30	3145.5
50	Material Costs	2470.23			123511.25
				Total	€ 126,656.75
				Per unit	€ 2,533.14

Table 14. Production batch cost

4. ANNEXES

A. ALIGNMENT WITH THE SDG:

The first SDG to be achieved will be innovation. The BTMU to be developed will be an innovation project with technology that was in disuse until the advent of climate policies. Electric vehicles are part of the future of transportation, especially in last mile transport, so any improvement in their performance is a step forward on the road to energy efficiency, which is one of the most important current engineering problems.

The second SDG to be pursued will be climate action. A refrigerant will be used that is environmentally benign while meeting the necessary thermodynamic characteristics. Therefore, CFCs and HFCHs will be avoided. In addition, it will be designed so that parts of the equipment are recyclable or reusable.

Following the SDGs is crucial for ensuring a habitable planet for future generations. Scientific consensus underscores the urgent need to mitigate climate change, conserve biodiversity, and manage natural resources sustainably. The SDGs emphasize the necessity of transitioning towards clean energy, implementing responsible consumption and production patterns, and fostering resilient ecosystems.

Additionally, scientific studies highlight the economic benefits of adhering to the SDGs. Sustainable practices, such as investing in renewable energy, promoting circular economy principles, and enhancing social inclusivity, can drive innovation, create jobs, and stimulate economic growth. In summary, scientific evidence overwhelmingly supports the adoption of the SDGs. Following these goals enables societies to address interconnected global challenges, promote sustainability, and safeguard the well-being of current and future generations. By aligning policies, practices, and investments towards the SDGs, nations can create a resilient and prosperous future for all.

B. PROGRAMING CODE

Config.H

```
#ifndef _CONFIG_H
#define _CONFIG_H


#define FCY 39613750UL

void inicializarReloj(void);

#endif
```

BTMU.H

```
#ifndef BTMU_H
#define BTMU_H

void tareaBTMU(void);
void resetTiempo(void);
void inicializarPuertos(void);

#endif
```

Adc.H

```
#ifndef ADC_H
#define ADC_H

void configurarPinADC(unsigned char pin_analogico);
void inicializarADC(void);
unsigned int getMedidaADC(unsigned char pin_analogico);
#endif
```

Timer.H

```
#ifndef _TIMER_H
#define _TIMER_H
void timer(unsigned int dms);
#endif// in
```

Pwm.H

```
#ifndef _PWM_H
#define _PWM_H
// -----------------------------------------------------
///
//* @param bitmap Los bits a 1 serán salidas digitales. */
void inicializarPWM(unsigned int bitmap);

/**
* Establece el valor del periodo de un pin.
*
* @param pin Índice del pin [0, 15].
* @param dms Periodo en décimas de milisegundo. */
void periodoPWM(unsigned char pin, unsigned int dms);
// -----------------------------------------------------

/**
* Establece el valor del factor de servicio de un pin. *
* @param pin Índice del pin [0, 15].
* @param dms Factor de servicio en décimas de ms. */
void dcPWM(unsigned char pin, unsigned int dms);
// -----------------------------------------------------

#endif
```

Config.c

```
#include <xc.h>  // Incluye el microcontrolador seleccionado en el proyecto
#include "config.h"

// --------------------------------------------------------------------------
// -------------------------- BITS DE CONFIGURACIÓN --------------------------
// --------------------------------------------------------------------------

// FBS
#pragma config BWRP = WRPROTECT_OFF  // Permitir la escritura del segmento de arranque
flash
#pragma config BSS = NO_FLASH        // Eliminar el segmento de arranque flash

// FGS
#pragma config GWRP = OFF            // No proteger la memoria de programa contra
escritura
#pragma config GSS = OFF             // No proteger el código

// FOSCSEL
#pragma config FNOSC = FRC           // Utilizar el oscilador interno (FRC) en el
arranque
#pragma config IESO = OFF            // Arrancar directamente con el oscilador
seleccionado

// FOSC
#pragma config POSCMD = NONE         // Desactivar el oscilador primario
#pragma config OSCIOFNC = ON         // Utilizar el oscilador secundario como entrada
y salida digital
#pragma config IOL1WAY = OFF         // Permitir múltiples remapeos de los pines
#pragma config FCKSM = CSECMD       // Permitir la conmutación del reloj y deshabilitar
el control de fallos

// FWDT
#pragma config FWDTEN = OFF          // Watchdog timer controlado por software
(Inicialmente deshabilitado)
#pragma config WDTPOST = PS32768     // Postescalado del watchdog (1:32,768)
#pragma config WDTPRE = PR128        // Preescalado del watchdog (1:128)
#pragma config WINDIS = OFF          // Permitir resetear el watchdog en cualquier
momento

// FPOR
#pragma config FPWRT = PWR128        // Esperar 128 ms y resetear el microcontrolador
al enchufar la alimentación
#pragma config ALTI2C = OFF          // Utilizar los pines estándar (SDA1 y SCL1) para
el I2C
```

```
#pragma config LPOL = ON             // Los pines PWM low están activos a nivel alto
#pragma config HPOL = ON             // Los pines PWM high están activos a nivel alto
#pragma config PWMPIN = ON            // Controlar los pines de PWM desde el registro
PORTx al arrancar

// FICD
#pragma config ICS = PGD1            // Programar y depurar a través de los pines PGEC1
y PGED1
#pragma config JTAGEN = OFF          // Desactivar la interfaz para JTAG

// ----------------------------------------------------------------------------
// ---------------------------- FUNCIONES PÚBLICAS ----------------------------
// ----------------------------------------------------------------------------

void inicializarReloj(void) {
    CLKDIVbits.PLLPRE  =  0;  // Preescalado del PLL:   N1 = 2
    PLLFBD             = 41;  // Multiplicador del PLL: M = PLLFBD + 2 = 43
    CLKDIVbits.PLLPOST =  0;  // Postescalado del PLL:  N2 = 2

    // Funciones para desbloquear la escritura del registro OSCCON
    __builtin_write_OSCCONH(0x01);           // Nuevo reloj: FRC w/ PLL
    __builtin_write_OSCCONL(OSCCON | 0x01);  // Iniciar el cambio de reloj

    while (OSCCONbits.COSC != 1);  // Esperar al cambio de reloj
    while (OSCCONbits.LOCK != 1);  // Esperar a que se sincronice el PLL
}
```

Adc.c

```c
#include <p33FJ32MC202.h>
#include "adc.h"
// -----------------------------------------------------
#define NUM_PINES_AD 6 // Número de pines A/D

// -----------------------------------------------------
// ------------ VARIABLES GLOBALES AL MÓDULO ------------
// -----------------------------------------------------
static unsigned int medida_adc[] = {0, 0, 0,
    0, 0, 0};
static unsigned char pin_configurado[] = {0, 0, 0,
    0, 0, 0};
static unsigned char pin_ad = 0;
// -----------------------------------------------------
// -------- PROTOTIPOS DE LAS FUNCIONES PRIVADAS --------
// -----------------------------------------------------
/**
 * Rutina de interrupción del conversor A/D.
 *
 * Declaración opcional. Se incluye con p33FJ32MC202.h
 */
void __attribute__((interrupt, no_auto_psv))_ADC1Interrupt(void);

// -----------------------------------------------------
// ----------------- FUNCIONES PÚBLICAS -----------------
// -----------------------------------------------------

void configurarPinADC(unsigned char pin_analogico) {
    // Comprobar que el argumento es válido
    if (pin_analogico >= NUM_PINES_AD)
        return;
    // Configurar como entrada
    if (pin_analogico <= 1)
        TRISA |= 1 << pin_analogico;
    else
        TRISB |= 1 << (pin_analogico - 2);
    AD1PCFGL &= ~(1 << pin_analogico); // Pin analógico
    pin_configurado[pin_analogico] = 1;
}

void inicializarADC(void) {
    AD1CON3 = 0x0105; // Muestreo: 1 ciclo, ADCS = 5
    IFS0bits.AD1IF = 0; // Borrar la bandera
```

```
    IEC0bits.AD1IE = 1; // Habilitar interrupciones
    IPC3bits.AD1IP = 1; // Prioridad interrupciones
    AD1CON1 = 0x80E0; // ON, conversión automática
    // Seleccionar el primer pin analógico configurado
    unsigned char i = 0;
    for (i = 0; i < NUM_PINES_AD; i++) {
        if (pin_configurado[i] == 1) {
            pin_ad = i;
            break;
        }
    }
    AD1CHS0 = pin_ad;
    AD1CON1 |= 1 << 1; // Empezar a muestrear
}

// -----------------------------------------------------

unsigned int getMedidaADC(unsigned char pin_analogico) { //mirar si esto esta bien

    int temperatura = 0;

    if (pin_analogico >= NUM_PINES_AD)
        return 0;
    else

         temperatura = medida_adc[pin_analogico]*50/1023; // sensor diseñado para dar
valores entre 0 y 50ºC

    return temperatura;

}


void __attribute__((interrupt, no_auto_psv))_ADC1Interrupt(void) {
    IFS0bits.AD1IF = 0; // Borrar la bandera
    medida_adc[pin_ad] = ADC1BUF0; // Guardar la medida
    do{


        pin_ad++;
        if (pin_ad >= NUM_PINES_AD)
            pin_ad = 0;
    }while(pin_configurado[pin_ad] == 0);
    AD1CHS0 = pin_ad; // Seleccionar el nuevo pin AD
    AD1CON1 |= 1 << 1; // Empezar a muestrear
}
```

Pwm.c

```
#include <p33FJ32MC202.h>
#include "pwm.h"
// -----------------------------------------------------
#define NUM_PINES_PWM 16 // Número de pines
// ------------------------------------------------------ // ------------ VARIABLES
GLOBALES AL MÓDULO ------------ // ---------------------------------------------------
---
static unsigned int periodo[] = {0, 0, 0, 0, 0, 0, 0, 0,
    0, 0, 0, 0, 0, 0, 0, 0};
static unsigned int dc[] = {0, 0, 0, 0, 0, 0, 0, 0,
    0, 0, 0, 0, 0, 0, 0, 0};
static unsigned int ticks[] = {0, 0, 0, 0, 0, 0, 0, 0,
    0, 0, 0, 0, 0, 0, 0, 0};

// -------- PROTOTIPOS DE LAS FUNCIONES PRIVADAS --------

void __attribute__((interrupt, no_auto_psv))
_T2Interrupt(void);

// ---------------- FUNCIONES PÚBLICAS ----------------

void inicializarPWM(unsigned int bitmap) {
    // Configurar los pines como salidas digitales
    AD1PCFGL |= (bitmap & 0xF) << 2;
    TRISB &= ~bitmap;

    // Configurar el Timer 2 con interrupciones
    T2CON = 0x0000;
    PR2 = 3961;
    TMR2 = 0;
    IFS0bits.T2IF = 0; // Borrar la bandera
    IEC0bits.T2IE = 1; // Habilitar interrupciones
    IPC1bits.T2IP = 4; // Prioridad interrupciones
//    T2CON |= 1 << 15;
}

void periodoPWM(unsigned char pin, unsigned int dms) {
    // Comprobar que el pin es válido
    if (pin > 15)
        return;
    periodo[pin] = dms;
}
// -----------------------------------------------------
```

```
void dcPWM(unsigned char pin, unsigned int dms) {
    // Comprobar que el pin es válido
    if (pin > 15)
        return;
    dc[pin] = dms;
}

// ----------------- FUNCIONES PRIVADAS -----------------

void __attribute__((interrupt, no_auto_psv))
_T2Interrupt(void) {
    IFS0bits.T2IF = 0; // Borrar la bandera
    unsigned char i;
    for (i = 0; i < NUM_PINES_PWM; i++) {
        // Generar solo las señales con periodo no nulo, es
        // decir, las que se han configurado explícitamente,
        // para dejar libres los demás pines para otros usos.
        if (periodo[i] > 0) {
            if (ticks[i] < dc[i])
                PORTB |= 1 << i;
            else
                PORTB &= ~(1 << i);
            ticks[i]++;
            if (ticks[i] >= periodo[i])
                ticks[i] = 0;
        }
    }
}
```

Timer.c

```
#include <stdio.h>
#include <stdlib.h>
#include <p33FJ32MC202.h>
#include "config.h" // Incluye la función InicializarReloj()

void timer(unsigned int dms) {

    int preesc;

    double aux1;

    double aux2;

    double aux3;



    if (dms <= 17){

        preesc=1;

        T1CON = 0x0000; // Timer 1 OFF / Preescalado 1:1

    }else{

        if(dms <= 132){

            preesc=8;

            T1CON = 0x0010; // Timer 1 OFF / Preescalado 1:8

        }else{

            if(dms <= 1059){

                preesc=64;

                T1CON = 0x0020; // Timer 1 OFF / Preescalado 1:64

            }else{

                preesc=256;
```

```
                T1CON = 0x0030; // Timer 1 OFF / Preescalado 1:256
            }
        }
    }

    //Configuramos el Timer 1

    aux1 = dms/10000.0;

    aux2 = aux1*40000000.0;

    aux3= aux2/preesc;

    PR1 = aux3;

    TMR1 = 0; // Inicializamos la cuenta

// Inicializar interrupciones
IFS0bits.T1IF = 0; // Borrar la bandera
IEC0bits.T1IE = 1; // Habilitar interrupciones
IPC0bits.T1IP = 3; // Prioridad interrupciones

T1CON |= (1 << 15); // Timer 1 ON

       return;
}
```

Btmu.C

```
#include <p33FJ32MC202.h>
#include "adc.h"
#include "pwm.h"
#include "btmu.h"


#define AN_TEMP1 2
#define AN_TEMP2 3
#define AN_TEMP3 4
#define DIG_TEMP1 0
#define DIG_TEMP2 1
#define DIG_TEMP3 2
#define DIG_V1 6
#define DIG_V2 7
#define DIG_V3 8
#define DIG_V4 9
#define DIG_RES 10
#define DIG_P1 11
#define DIG_P2 12
#define DIG_COMPRESSOR 13
#define DIG_FAN 14
#define DIG_LED 15

#define lim_temp_max 24 //24ºC
#define lim_temp_min 16 //16ºC
#define rango_lim 10 //rango de temperatura máximo permitido entre salida y entrada


#define CONSIGNA1 20 // [ºC]
#define CONSIGNA2 27 // [ºC]
#define K_P 12.4 // [ %] / [ºC]
#define K_I 5.3 // [ %] / ([ºC] * [s])
#define K_D 1.5 // [ %] * [s] / [ºC]
#define T_S 0.06 // [s]

static unsigned int ticks_control_1 = 0;
static unsigned int ticks_control_2 = 0;
static unsigned int ticks = 0;
static unsigned int segundos = 0;


static unsigned int ticks_pumps = 0;
static unsigned int ticks_fan = 0;
static unsigned int ticks_compressor = 0;
```

```
static unsigned int dc_pumps = 0;
static unsigned int dc_fan = 0;
static unsigned int dc_compressor = 0;

void EquiposOff(void);
void HeatModeValves(void);
void CoolModeValves(void);

void resetTiempo(void) {
    ticks_control_1 = 0;
    ticks_control_2 = 0;
    ticks_pumps = 0 ;
    ticks_fan = 0;
    ticks_compressor = 0;
    ticks = 0;
    segundos = 0;
}

void inicializarPuertos(void) {

    AD1PCFGL = 0xFFFF; // inicialmente todos digitales
    TRISB |= 1 << DIG_TEMP1 | 1 << DIG_TEMP2 | 1 << DIG_TEMP3;
    TRISB &= ~(1 << DIG_V1 | 1 << DIG_V2 | 1 << DIG_V2 | 1 << DIG_V3 | 1 << DIG_RES |
1 << DIG_P1| 1 << DIG_P2| 1 << DIG_COMPRESSOR | 1 << DIG_FAN | 1<< DIG_LED);
    PORTB &= 0x0000;

    configurarPinADC(AN_TEMP1);
    configurarPinADC(AN_TEMP2);
    configurarPinADC(AN_TEMP3);

    inicializarPWM(DIG_P1);
    periodoPWM(DIG_P1, 200); // periodo de 20 ms

    inicializarPWM(DIG_P2);
    periodoPWM(DIG_P2, 200); // periodo de 20 ms

    inicializarPWM(DIG_FAN);
    periodoPWM(DIG_FAN, 200); // periodo de 20 ms

    inicializarPWM(DIG_COMPRESSOR);
    periodoPWM(DIG_COMPRESSOR, 200); // periodo de 20 ms

}

void tareaBTMU(void) {
```

```
    static unsigned char estado = 0;

    unsigned int valorTemp1 = 0;
    unsigned int valorTemp2 = 0;
    unsigned int valorTemp3 = 0;


    valorTemp1 = getMedidaADC(AN_TEMP1); //tomamos valor entrada de agua en el circuito
    valorTemp2 = getMedidaADC(AN_TEMP2); //tomamos valor salida de agua del circuito
     valorTemp3 = getMedidaADC(AN_TEMP3); //tomamos valor entrada de agua en el
intercambiador aire-agua forzado


//     dcPWM(DIG_SERVO, ticks_servo);
    if(valorTemp1 >= 24){
        estado = 2;
    }else if (valorTemp1<= 16){
        estado = 1;
    } else {
        estado = 0;
    }

    if ((valorTemp1-valorTemp2) >= rango_lim || (valorTemp1-valorTemp2) <= -rango_lim){
        estado = 3;
    }
    switch (estado) {

        case 0: //Estado de espera

            EquiposOff();

            break;

        case 1: //HEAT MODE

            controlPID1(valorTemp1);
            controlPID2(valorTemp2);

            PORTB |= 1 << DIG_RES // electric heater resistor
            HeatModeValves();

            // pumps and compressor set up
            if (ticks_pumps < dc_pumps)
                PORTB |= 1 << DIG_P1 | 1 << DIG_P2;
```

```
        else
            PORTB &= ~(1 << DIG_P1 | 1 << DIG_P2);

        if (ticks_fan < dc_fan)
            PORTB |= 1 << DIG_FAN;
        else
            PORTB &= ~(1 << DIG_FAN);

        if (ticks_compressor < dc_compressor)
            PORTB |= 1 << DIG_COMPRESSOR;
        else
            PORTB &= ~(1 << DIG_COMPRESSOR);

        break;


    case 2: //HEAT MODE

        controlPID1(valorTemp1);
        controlPID2(valorTemp3);

        PORTB &=~(1 << DIG_RES );// electric heater resistor
        CoolModeValves();

        // pumps and compressor set up
        if (ticks_pumps < dc_pumps)
            PORTB |= 1 << DIG_P1 | 1 << DIG_P2;
        else
            PORTB &= ~(1 << DIG_P1 | 1 << DIG_P2);

        if (ticks_fan < dc_fan)
            PORTB |= 1 << DIG_FAN;
        else
            PORTB &= ~(1 << DIG_FAN);

        if (ticks_compressor < dc_compressor)
            PORTB |= 1 << DIG_COMPRESSOR;
        else
            PORTB &= ~(1 << DIG_COMPRESSOR);

        break;

    case 3: //alarma

        if(segundos >= 20){
            PORTB &=~(1<<DIG_LED);
```

```
            }
        }
}

// ------------------------------------------------------
// ----------------- FUNCIONES PRIVADAS -----------------
// ------------------------------------------------------


void EquiposOff (void){
        PORTB |= 0x0000;
    }

void HeatModeValves(void){
    int portb;
    portb = PORTB;
    portb |= (1 << DIG_V1);
    portb |= 1(1 << DIG_V2);
    portb &= ~ << DIG_V3;
    portb  << DIG_V4;
    PORTB = portb;
}

void CoolModeValves(void) {
    int portb;
    portb = PORTB;
    portb &= ~(1 << DIG_V1);
    portb &= ~(1 << DIG_V2);
    portb |= 1 << DIG_V3;
    portb |= 1 << DIG_V4;
    PORTB = portb;
}

void controlPID1(float valorTemp1) {
    if (ticks_control_1 >= 100) {
        ticks_control_1 = 0;
        static float integral_error = 0.0;
        static float error = 0.0;
        float derivada_error;
        float error_ant = error;
        float mando;
        error = CONSIGNA1 - valorTemp1;
        integral_error += error * T_S;
        derivada_error = (error - error_ant) / T_S;
        mando = K_P * error + K_I * integral_error + K_D * derivada_error;
```

```
        // Saturar el mando
        if (mando > 100) {
            mando = 100;
            integral_error -= error * T_S; // Anti-windup
        } else if (mando < 0) {
            mando = 0;
            integral_error -= error * T_S; // Anti-windup
        }
        dc_pumps = (unsigned int) (mando / 2 + 0.5);
         dc_compressor = (unsigned int) (mando / 2 + 0.5); // en este PID se controla
las bombas y el compresor
    }
}

void controlPID2(float valorTemp2) {
    if (ticks_control_2 >= 100) {
        ticks_control_2 = 0;
        static float integral_error = 0.0;
        static float error = 0.0;
        float derivada_error;
        float error_ant = error;
        float mando;
        error = CONSIGNA2 - valorTemp2;
        integral_error += error * T_S;
        derivada_error = (error - error_ant) / T_S;
        mando = K_P * error + K_I * integral_error + K_D * derivada_error;
        // Saturar el mando
        if (mando > 100) {
            mando = 100;
            integral_error -= error * T_S; // Anti-windup
        } else if (mando < 0) {
            mando = 0;
            integral_error -= error * T_S; // Anti-windup
        }
        dc_fan = (unsigned int) (mando / 2 + 0.5);
    }
}
void __attribute__((interrupt, no_auto_psv)) _T1Interrupt(void) {
    IFS0bits.T1IF = 0; // tick cada 0,005 segundos

    ticks_control_1 ++;
    ticks_control_2++;
    ticks++;
    if (ticks++ >= 200) {
        segundos++;
```

```
        if (segundos >= 30) {
            segundos = 0;
        }
    }

    if (++ticks_pumps >= 100) // tick cada 0,5 segundos
        ticks_pumps= 0;
     if (++ticks_fan >= 100)
        ticks_fan = 0;
     if (++ticks_compressor >= 100)
        ticks_compressor = 0;
}
```

Main.c

```
#include <p33FJ32MC202.h>
#include "btmu.h"
#include "adc.h"
#include "timer.h"
#include "config.h"
#include "pwm.h"


int main(void) {

    resetTiempo();
    inicializarPuertos();
    inicializarADC();
    inicializarReloj();
    timer(500); // 0,005 segundos
    while (1) {
        tareaBTMU();
    }
    return 0;
}
```

C. CALCULATIONS

All equations used in the calculations are taken from the slides of the ICAI university course on "Climatización".

Cooling mode.

Ideal refrigerant circuit calculations table from CoolPack:

Point	Description	Absolute pressure	Temperature	Enthalpy (h)	Density (ρ)
		bar	°C	kJ/kg	kg/m^3
1	Compressor inlet	3,42	-4	474,9	7,3
2	Compressor output	12,32	54,5	555,5	23,6
3	Condenser output	12,32	33	188,2	-
4	Evaporator inlet	3,42	-10	188,2	-

Table 15. Cooling cycle ponts

If the machine is to give a cooling capacity of 8 kW, then the mass flow rate must be:

$$\dot{m} = \frac{Cooling\ capacity}{h_1 - h_4} = \frac{8}{474{,}9 - 188{,}2} = 0{,}0279 \frac{kg}{s}$$

The volumetric flow rate of vapours sucked in is:

$$Q = \frac{\dot{m}}{\rho_1} = \frac{0{,}0279}{7{,}3} = 0{,}0038 = 13{,}76 \frac{m^3}{h}$$

If the compressor is the one selected:

Displacement (cc/rev)	Cooling power (kW)	Speed (rpm)	Voltage (V)
34	8,5	1000-8500	400-850

Table 16. Compressor data

$$\dot{w} = \frac{Q}{Disp} = \frac{13{,}76}{34} \cdot \frac{100^3}{60} = 6745\ rpm$$

It falls within the speed range of the compressor. It is also noted that the cooling power required is lower than the maximum possible compressor power.

The absorbed power of this machine with an ideal compressor would be:

$$Pa_{ideal} = \dot{m} \cdot (h_2 - h_1) = 0{,}0279 \cdot (555{,}5 - 474{,}9) = 2{,}25\ kW$$

The real power of this machine with an 90% efficiency compressor would be:

$$Pa_{real} = \frac{Pa_{ideal}}{\eta} = \frac{2{,}25}{0{,}85} = 2{,}5\ kW$$

Therefore, the effective COP of the machine is:

$$COP = \frac{C_{cap}}{Pa_{real}} = \frac{8}{2{,}5} = 3{,}2$$

The calculated COP is slightly above the required COP, so a refrigerant cycle very close to the ideal one will have to be achieved, or a better compressor performance will have to be achieved.

Heating mode.

Ideal refrigerant circuit calculations table from CoolPack:

Point	Description	Absolute pressure	Temperature	Enthalpy (h)	Density (ρ)
		bar	°C	kJ/kg	kg/m^3
1	Compressor inlet	1,93	-20	455,3	4,3
2	Compressor output	12,32	62,4	572,4	22,7
3	Condenser output	12,32	33	192,8	-
4	Evaporator inlet	1,93	-26	192,8	-

Table 17. Heating cycle points

If the machine is to give a heating capacity of 6 kW, then the mass flow rate must be:

$$\dot{m} = \frac{Heating\ capacity}{h_2 - h_3} = \frac{6}{572{,}4 - 192{,}8} = 0{,}0158\,\frac{kg}{s}$$

The volumetric flow rate of vapours sucked in is:

$$Q = \frac{\dot{m}}{\rho_1} = \frac{0{,}0158}{4{,}3} = 0{,}0036 = 12{,}96\,\frac{m^3}{h}$$

If the compressor is the one selected before:

$$\dot{w} = \frac{Q}{Disp} = \frac{12{,}96}{34} \cdot \frac{100^3}{60} = 6350\ rpm$$

It falls within the speed range of the compressor.

The absorbed power of this machine with an ideal compressor would be:

$$Pa_{ideal} = \dot{m} \cdot (h_2 - h_1) = 0{,}0158 \cdot (572{,}4 - 455{,}3) = 1{,}85\ kW$$

The real power of this machine with an 65% efficiency compressor would be:

$$Pa_{real} = \frac{Pa_{ideal}}{\eta} = \frac{1{,}85}{0{,}65} = 2{,}85\ kW$$

The Cooling capacity will be:

$$C_{capacity} = \dot{m} \cdot (h_1 - h_4) = 0{,}0158 \cdot (455{,}3 - 192{,}8) = 4{,}15\ \ kW$$

Therefore, the effective COP of the machine is:

$$COP = \frac{C_{cap}}{Pa_{real}} = \frac{6}{2{,}85} = 2{,}1$$

The calculated COP is slightly above the required COP, so a refrigerant cycle very close to the ideal one will have to be achieved, or a better compressor performance will have to be achieved.

D. BIBLIOGRAPHY

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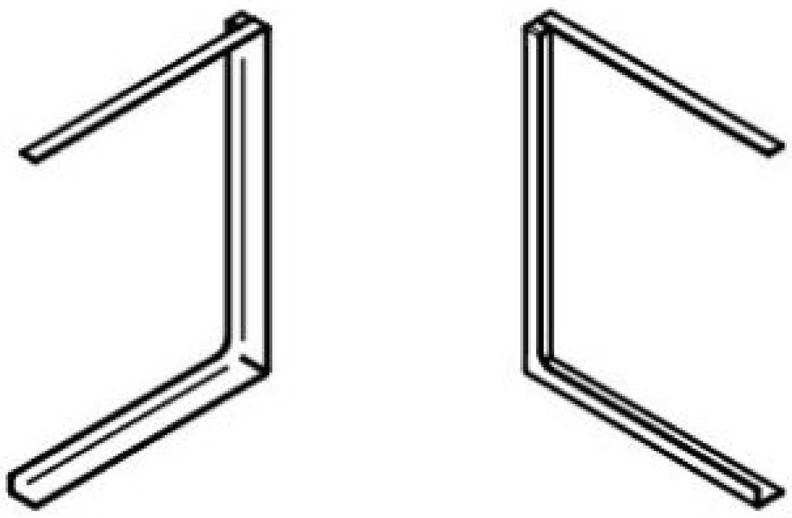
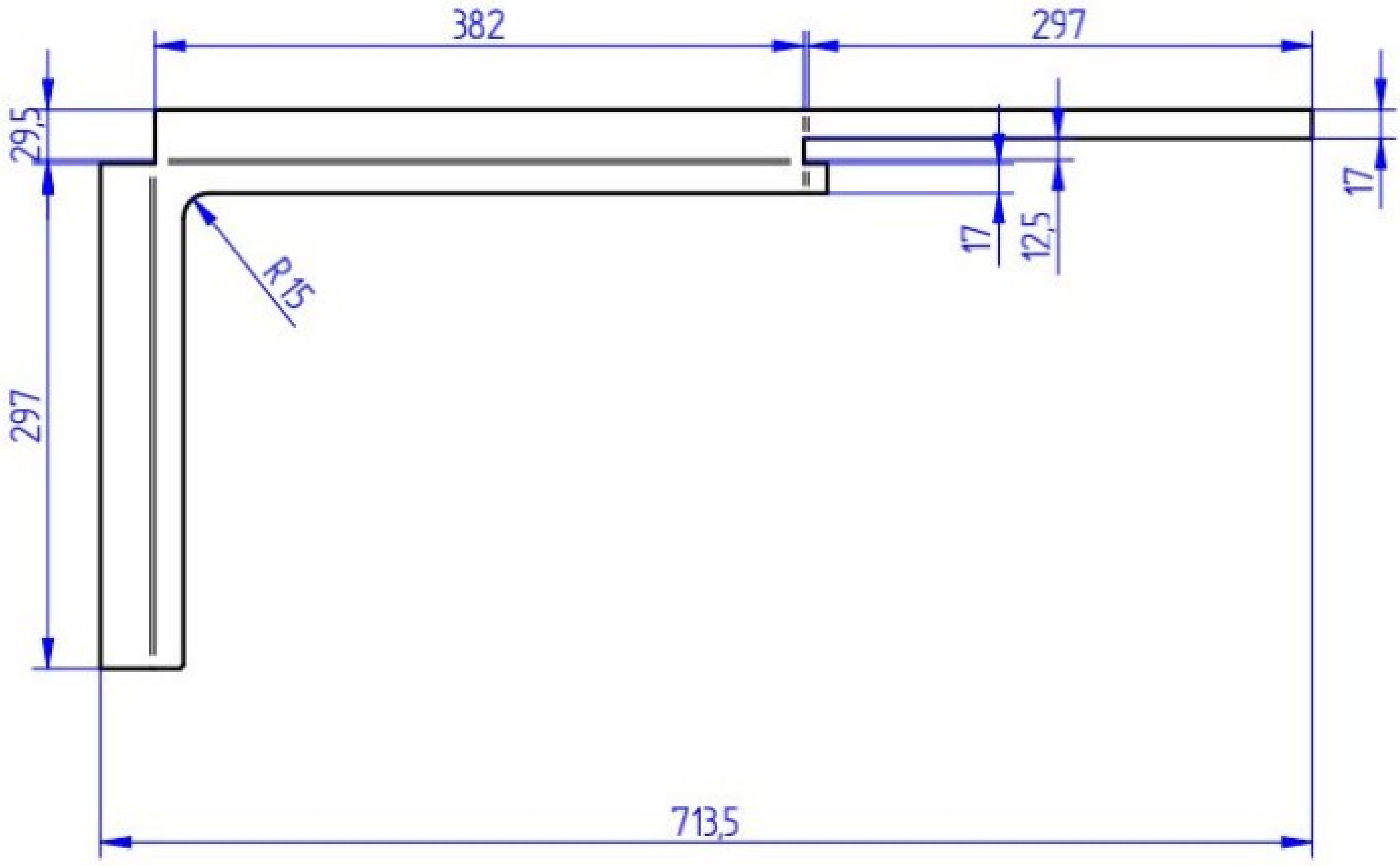
E. DRAWINGS

1. *Sheet metal pre-production drawings.*
2. *Assembly drawings and list of materials.*
3. *Conceptual schemes.*





Part-No.: Anlge B
Former Dreiha P/N: Sheet 008

Index	No.	Revision record	Date	Name	Index	No.	Revision record	Date	Name

Welding dimensions limits according to DIN EN ISO 13920-B
Welding information according to DIN EN 2553
Thermal cutting dimension limits according to DIN EN ISO 9013-1
Edges according to DIN ISO 13715
Plastic parts according to DIN 7715 T5 | Adhesion according to TR 208
Surfaces according to DIN ISO 1302
Bending tolerances according to DIN 6935 | Press tolerances according to DIN 6930-m
Dimensions checked during inspection

Material: BB0002618

Weight (calculated): 0.210 kg | Area:

Unfolded dimensions

	Date	Name
created by:	25/04/2023	gmunoz
checked by:	25/04/2023	Name Prüfer
approved by:		
substitutes:		

Unspecified dimensions according to ISO 2768-1: Toleranzklasse

Tolerance class	more than 0,5 to 3	more than 3 to 6	more than 6 to 30	more than 30 to 120	more than 120 to 315	more than 315 to 1000	more than 1000 to 2000	more than 2000 to 4000
fine	±0,05	±0,05	±0,1	±0,15	±0,2	±0,3	±0,5	±0,8
medium	±0,1	±0,1	±0,2	±0,3	±0,5	±0,8	±1,2	±2
coarse	±0,2	±0,3	±0,5	±0,8	±1,2	±2	±3	±4
very coarse	-	±0,5	±1	±1,5	±2,5	±3	±6	±8

Surfaces:	Ø Hole: H13 Ø Axis: h13 Thread: 6H-8	Hole distance:	Hole position
√AA		± 0.4	± 0.2

- Computer Aided Design -
Only change this drawing in the CAD-System.
No revision without referring to model: Anlge B

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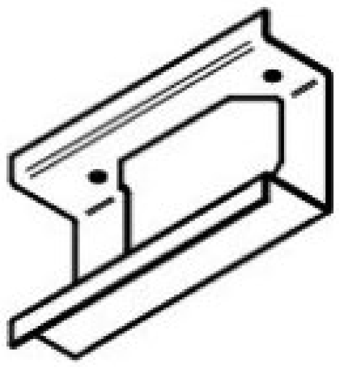
First application: Erstverwendung

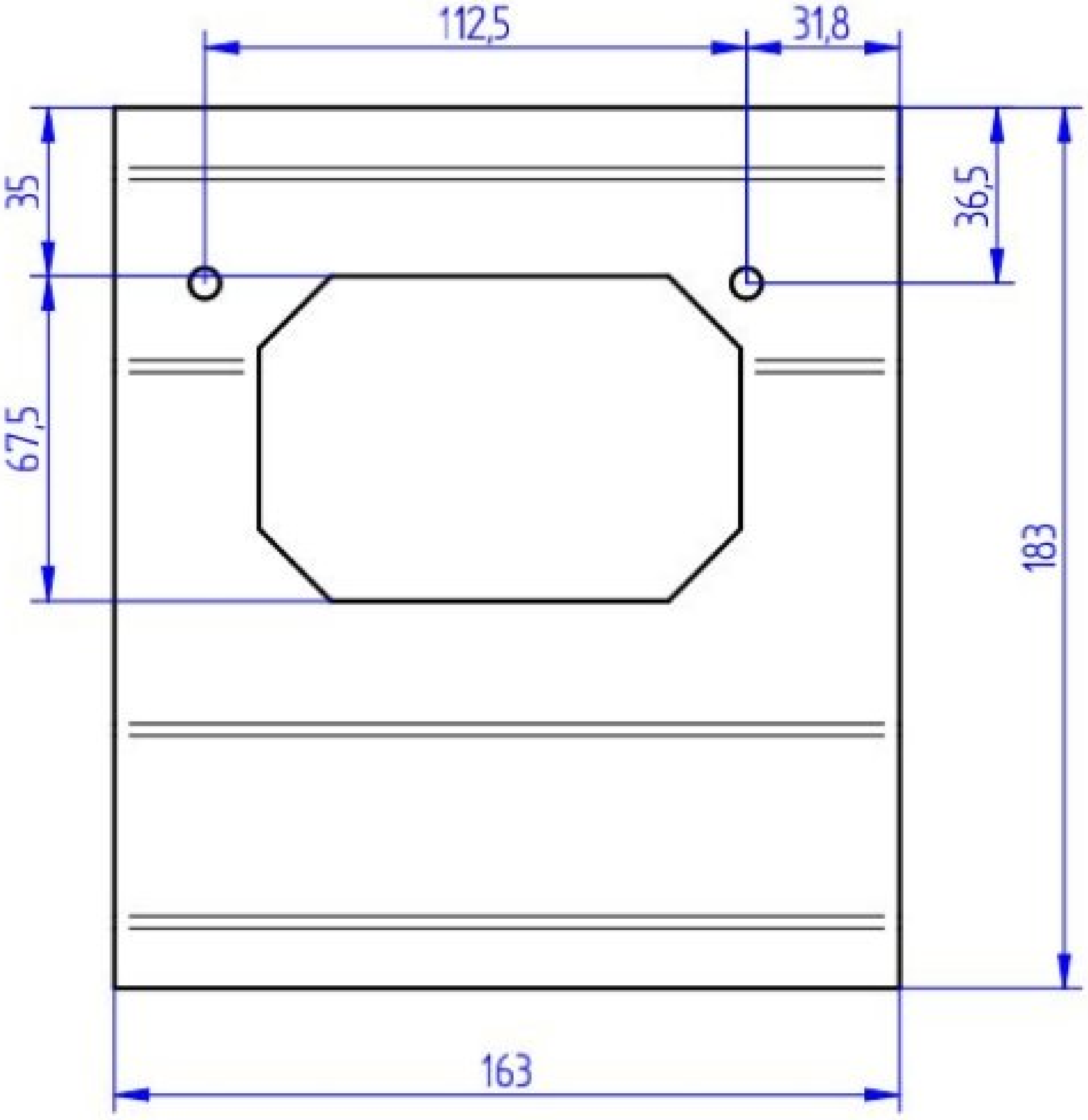
Title: Anlge B

Drawing No.: Zeichnungsnummer

Sheet: 1 of: 1

Size: A4 Scale: 1:5





Part-No.: Angle C
Former Dreiha P/N: Sheet 009

Index	No.	Revision record	Date	Name	Index	No.	Revision record	Date	Name

Welding dimensions limits according to DIN EN ISO 13920-B
Welding information according to DIN EN 2553
Thermal cutting dimension limits according to DIN EN ISO 9013-1
Edges according to DIN ISO 13715
Plastic parts according to DIN 7715 T5 | Adhesion according to TR 208
Surfaces according to DIN ISO 1302
Bending tolerances according to DIN 6935 | Press tolerances according to DIN 6930-m
Dimensions checked during inspection

Material: BB0006683
Weight (calculated): 0.096 kg
Area:
Unfolded dimensions

	Date	Name
created by:	20/04/2023	gmunoz
checked by:	20/04/2023	Name Prüfer
approved by:		
substitutes:		

Unspecified dimensions according to ISO 2768-1: Toleranzklasse

Tolerance class	more than 0,5 to 3	more than 3 to 6	more than 6 to 30	more than 30 to 120	more than 120 to 315	more than 315 to 1000	more than 1000 to 2000	more than 2000 to 4000
fine	±0,05	±0,05	±0,1	±0,15	±0,2	±0,3	±0,5	±0,8
medium	±0,1	±0,1	±0,2	±0,3	±0,5	±0,8	±1,2	±2
coarse	±0,2	±0,3	±0,5	±0,8	±1,2	±2	±3	±4
very coarse	-	±0,5	±1	±1,5	±2,5	±3	±6	±8

Surfaces:	Ø Hole: H13 Ø Axis: h13 Thread: 6H-8	Hole distance:	Hole position
√AA		± 0.4	± 0.2

- Computer Aided Design -
Only change this drawing in the CAD-System.
No revision without referring to model: Angle C

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First application: Erstverwendung

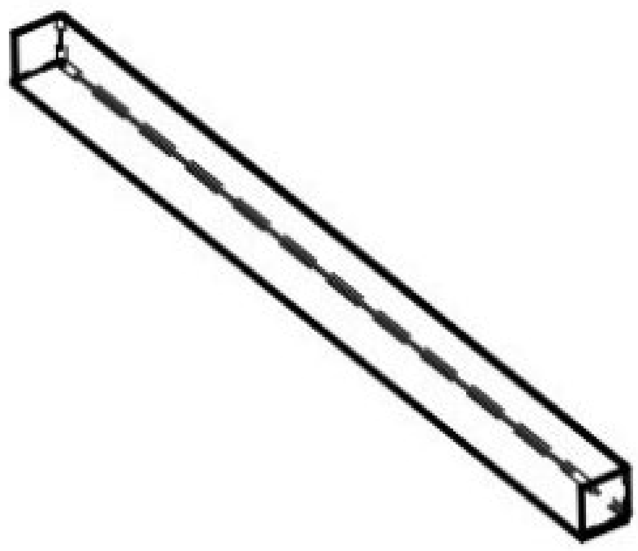
Title: Angle C

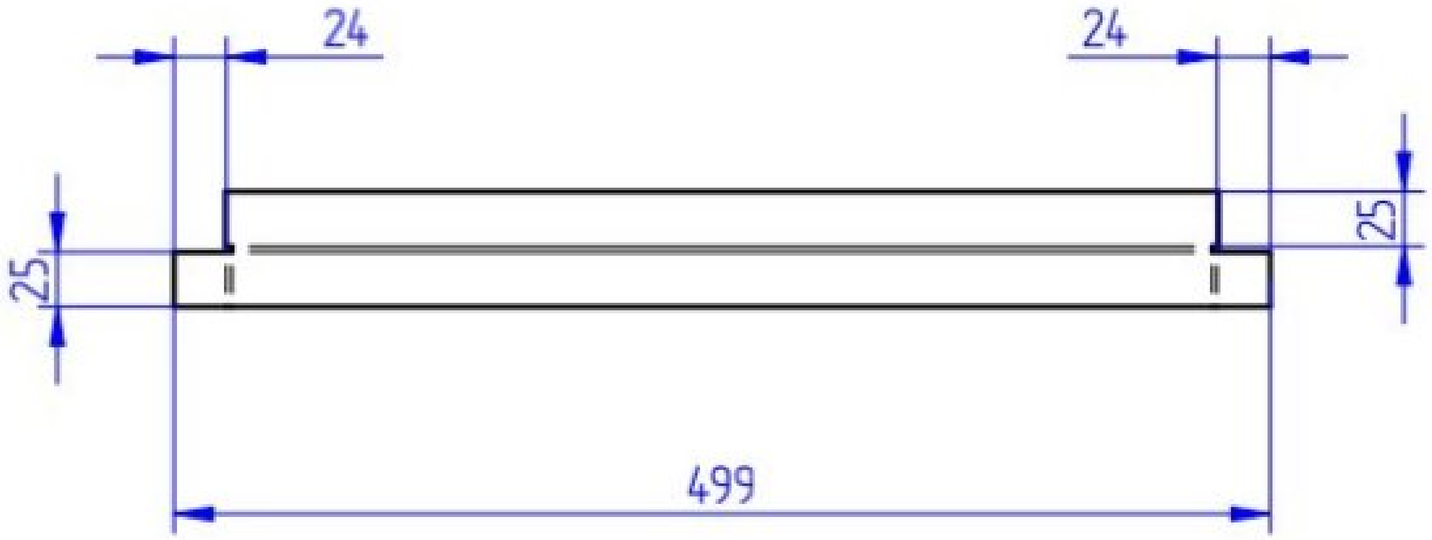
Drawing No.: Zeichnungsnummer

Sheet: 1 of: 1

Size: A4 Scale: 1:2

Escaneado con CamScanner





Part-No.: Angle
Former Dreiha P/N: Sheet 006

Index	No.	Revision record	Date	Name	Index	No.	Revision record	Date	Name

Welding dimensions limits according to DIN EN ISO 13920-B
Welding information according to DIN EN 2553
Thermal cutting dimension limits according to DIN EN ISO 9013-1
Edges according to DIN ISO 13715
Plastic parts according to DIN 7715 T5 | Adhesion according to TR 208
Surfaces according to DIN ISO 1302
Bending tolerances according to DIN 6935 | Press tolerances according to DIN 6930-m
Dimensions checked during inspection

Material: BB0002618

Weight (calculated): 0.136 kg | Area:

Unfolded dimensions

	Date	Name
created by:	20/04/2023	gmunoz
checked by:	20/04/2023	Name Prüfer
approved by:		
substitutes:		

Unspecified dimensions according to ISO 2768-1: Toleranzklasse

Tolerance class	more than 0,5 to 3	more than 3 to 6	more than 6 to 30	more than 30 to 120	more than 120 to 315	more than 315 to 1000	more than 1000 to 2000	more than 2000 to 4000
fine	±0,05	±0,05	±0,1	±0,15	±0,2	±0,3	±0,5	±0,8
medium	±0,1	±0,1	±0,2	±0,3	±0,5	±0,8	±1,2	±2
coarse	±0,2	±0,3	±0,5	±0,8	±1,2	±2	±3	±4
very coarse	-	±0,5	±1	±1,5	±2,5	±3	±6	±8

Surfaces:	Ø Hole: H13 Ø Axis: h13 Thread: 6H-8	Hole distance:	Hole position
√AA		±0.4	±0.2

- Computer Aided Design -
Only change this drawing in the CAD-System.
No revision without referring to model: Angle

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First application: Erstverwendung

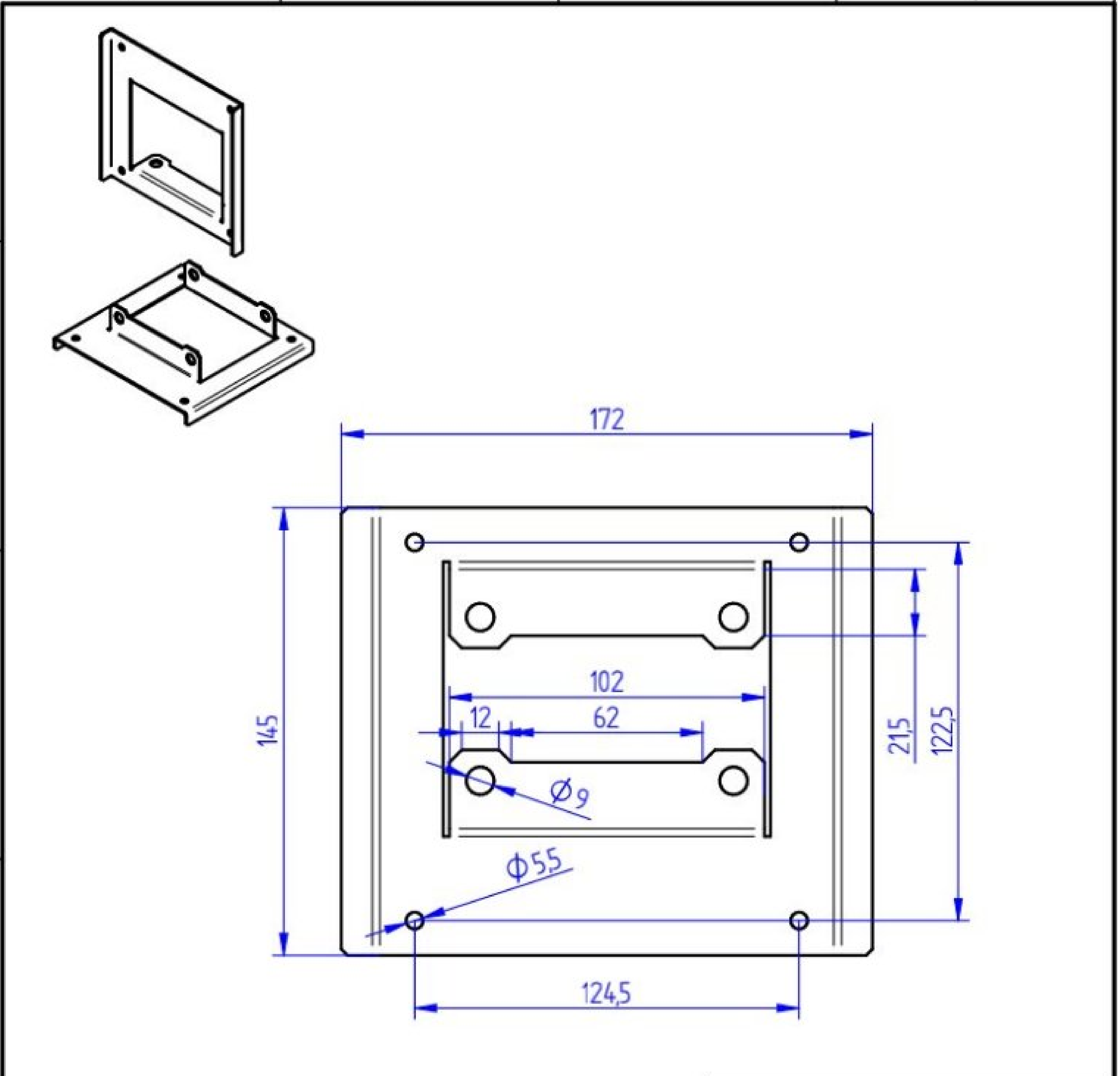
Title: **Angle**

Drawing No.: Zeichnungsnummer

Sheet: 1 of: 1

Size: A4 Scale: 1:5

Escaneado con CamScanner



Part-No.: Compressor bracket
Former Dreiha P/N: Sheet 012

Index	No.	Revision record	Date	Name	Index	No.	Revision record	Date	Name

Welding dimensions limits according to DIN EN ISO 13920-B
Welding information according to DIN EN 2553
Thermal cutting dimension limits according to DIN EN ISO 9013-1
Edges according to DIN ISO 13715
Plastic parts according to DIN 7715 T5 | Adhesion according to TR 208
Surfaces according to DIN ISO 1302
Bending tolerances according to DIN 6935 | Press tolerances according to DIN 6930-m
Dimensions checked during inspection

Material: BB0006683

Weight (calculated): 0.083 kg | Area:

Unfolded dimensions

	Date	Name
created by:	26/04/2023	gmunoz
checked by:	26/04/2023	Name Prüfer
approved by:		
substitutes:		

Unspecified dimensions according to ISO 2768-1: Toleranzklasse

Tolerance class	more than 0,5 to 3	more than 3 to 6	more than 6 to 30	more than 30 to 120	more than 120 to 315	more than 315 to 1000	more than 1000 to 2000	more than 2000 to 4000
fine	±0,05	±0,05	±0,1	±0,15	±0,2	±0,3	±0,5	±0,8
medium	±0,1	±0,1	±0,2	±0,3	±0,5	±0,8	±1,2	±2
coarse	±0,2	±0,3	±0,5	±0,8	±1,2	±2	±3	±4
very coarse	-	±0,5	±1	±1,5	±2,5	±3	±6	±8

Surfaces:	Ø Hole: H13 Ø Axis: h13 Thread: 6H-8	Hole distance:	Hole position
√AA		±0.4	±0.2

- Computer Aided Design -
Only change this drawing in the CAD-System.
No revision without referring to model: Compressor bracket

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First application: Erstverwendung

Title: Sheet 012

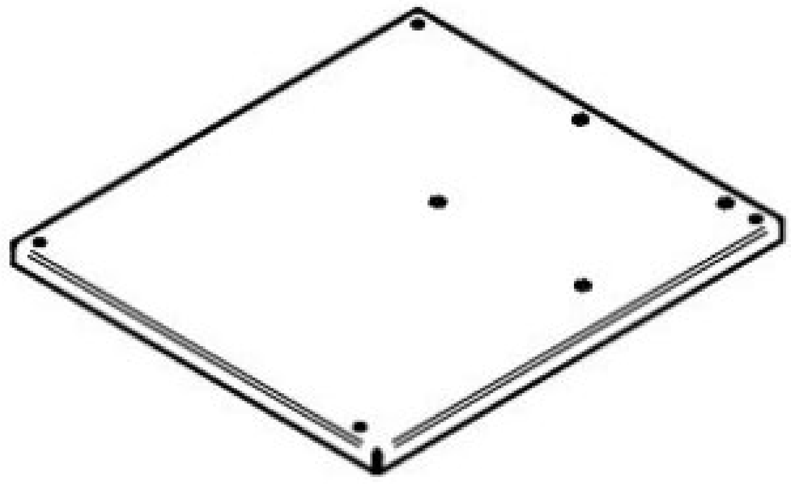
Drawing No.: Zeichnungsnummer

Sheet: 1 of: 1

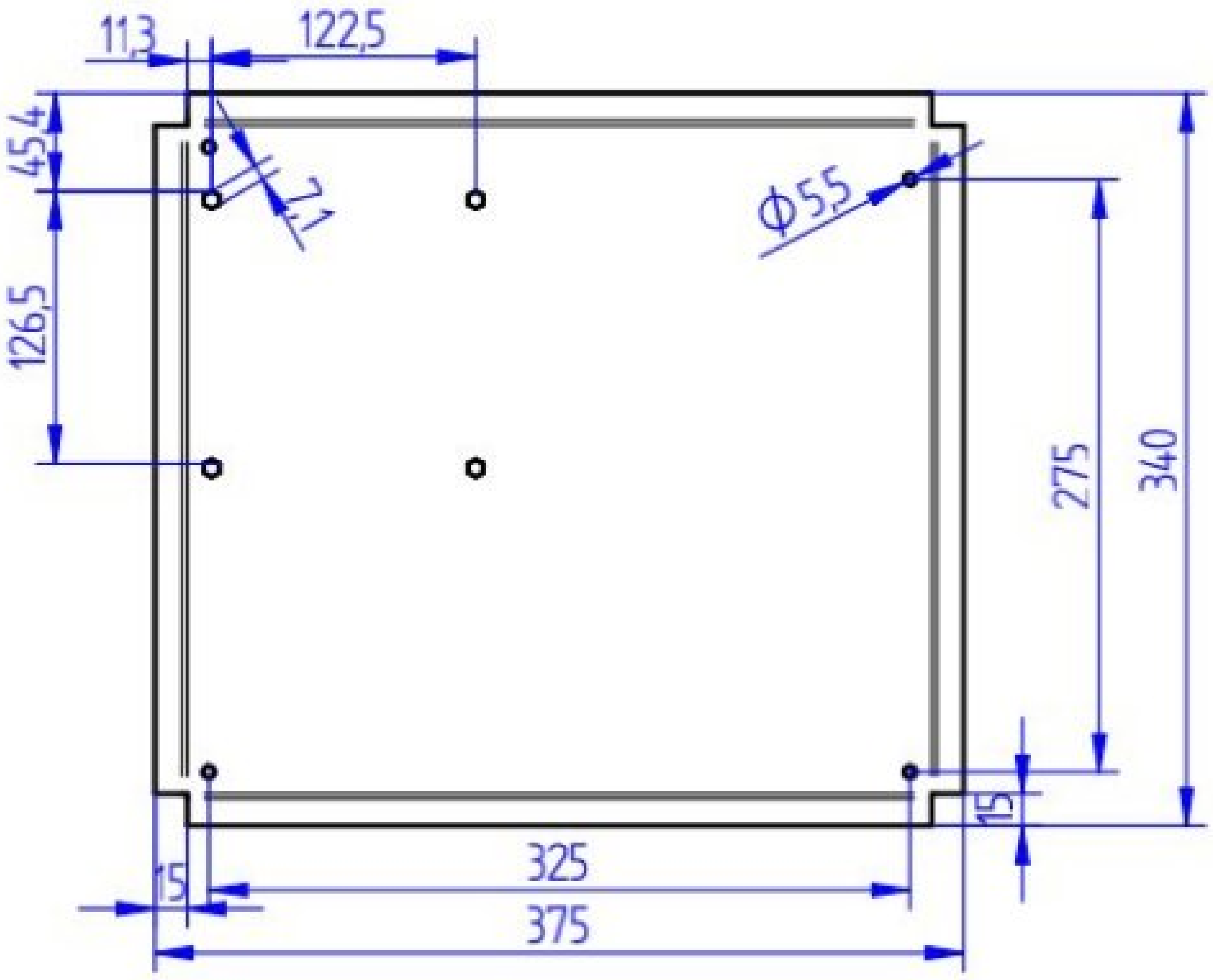
Size: A4 Scale: 1:2

1	2	3	4

A



B



C

D

Part-No.: Compressor bracket 2
Former Dreiha P/N: Sheet 015

E

Index	No.	Revision record	Date	Name	Index	No.	Revision record	Date	Name

F

Welding dimensions limits according to DIN EN ISO 13920-B
Welding information according to DIN EN 2553
Thermal cutting dimension limits according to DIN EN ISO 9013-1
Edges according to DIN ISO 13715
Plastic parts according to DIN 7715 T5 | Adhesion according to TR 208
Surfaces according to DIN ISO 1302
Bending tolerances according to DIN 6935 | Press tolerances according to DIN 6930-m
Dimensions checked during inspection

Material: BB0006683

Weight (calculated): 0.513 kg | Area:

Unfolded dimensions

	Date	Name
created by:	26/04/2023	gmunoz
checked by:	26/04/2023	Name Prüfer
approved by:		
substitutes:		

Unspecified dimensions according to ISO 2768-1: Toleranzklasse

Tolerance class	more than 0,5 to 3	more than 3 to 6	more than 6 to 30	more than 30 to 120	more than 120 to 315	more than 315 to 1000	more than 1000 to 2000	more than 2000 to 4000
fine	±0,05	±0,05	±0,1	±0,15	±0,2	±0,3	±0,5	±0,8
medium	±0,1	±0,1	±0,2	±0,3	±0,5	±0,8	±1,2	±2
coarse	±0,2	±0,3	±0,5	±0,8	±1,2	±2	±3	±4
very coarse	-	±0,5	±1	±1,5	±2,5	±3	±6	±8

Surfaces:	Ø Hole: H13 Ø Axis: h13 Thread: 6H-8	Hole distance:	Hole position
√AA		±0.4	±0.2

- Computer Aided Design -
Only change this drawing in the CAD-System.
No revision without referring to model: Compressor bracket 2

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First application: Erstverwendung

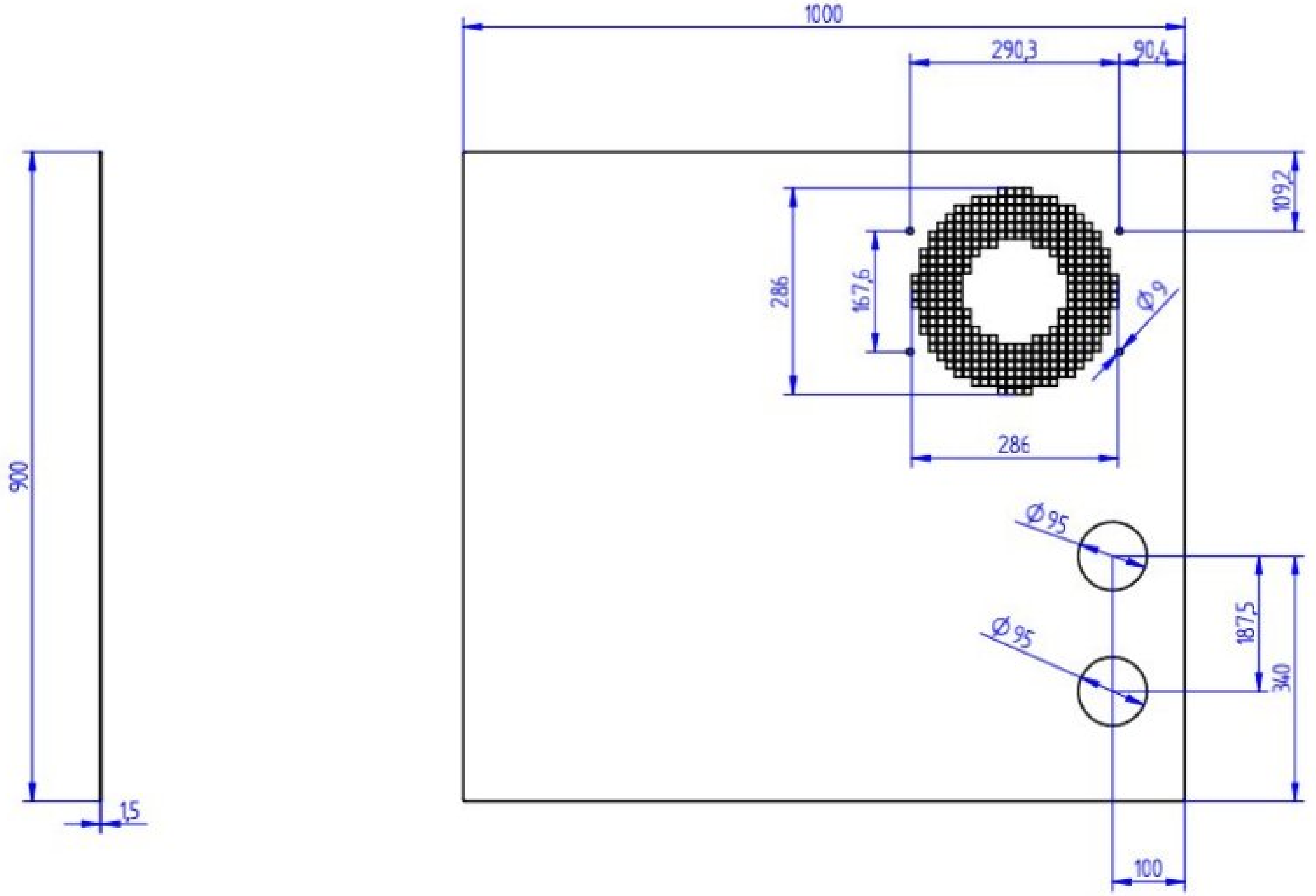
Title: Sheet 015

Drawing No.: Zeichnungsnummer

Sheet: 1 of: 1

Size: A4 | Scale: 1:5

Escaneado con CamScanner



Part-No.: Cover fan
Former Dreiha P/N: Sheet 010

Index	No.	Revision record	Date	Name	Index	No.	Revision record	Date	Name

Welding dimensions limits according to: DIN EN ISO 13920-B		Date	Name
Welding information according to: DIN EN 2553	created by:	03/04/2023	gmunoz
Thermal cutting dimension limits according to DIN EN ISO 9013-1	checked by:	03/04/2023	Name Prüfer
Edges according to DIN ISO 13715	approved by:		
Plastic parts according to DIN 7715 T5 / Adhesion according to TR 208	substitutes:		
Surfaces according to DIN ISO 1302	General tolerances: [illegible]		
Bending tolerances according to DIN 6935 / Press tolerances according to DIN 6930-m			
Dimensions checked during inspection			
Material: BB0006683			
Weight (calculated): 3.457 kg / Area:	Surfaces: √Aa	Ø Hole H13, Ø Axis h13, Thread 6H/6g [illegible]	Hole distance: ±0.[illegible] / Hole position: ±0.[illegible]
Unfinished dimensions	- Computer Aided Design - Only change the drawing in the CAD-System. No revision without referring to model: Cover fan		

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mail@dreiha.de Phone +49 421 [illegible] Fax +49 421 [illegible]

First application: Erstverwendung

Title: Cover fan

Drawing No.: Zeichnungsnummer

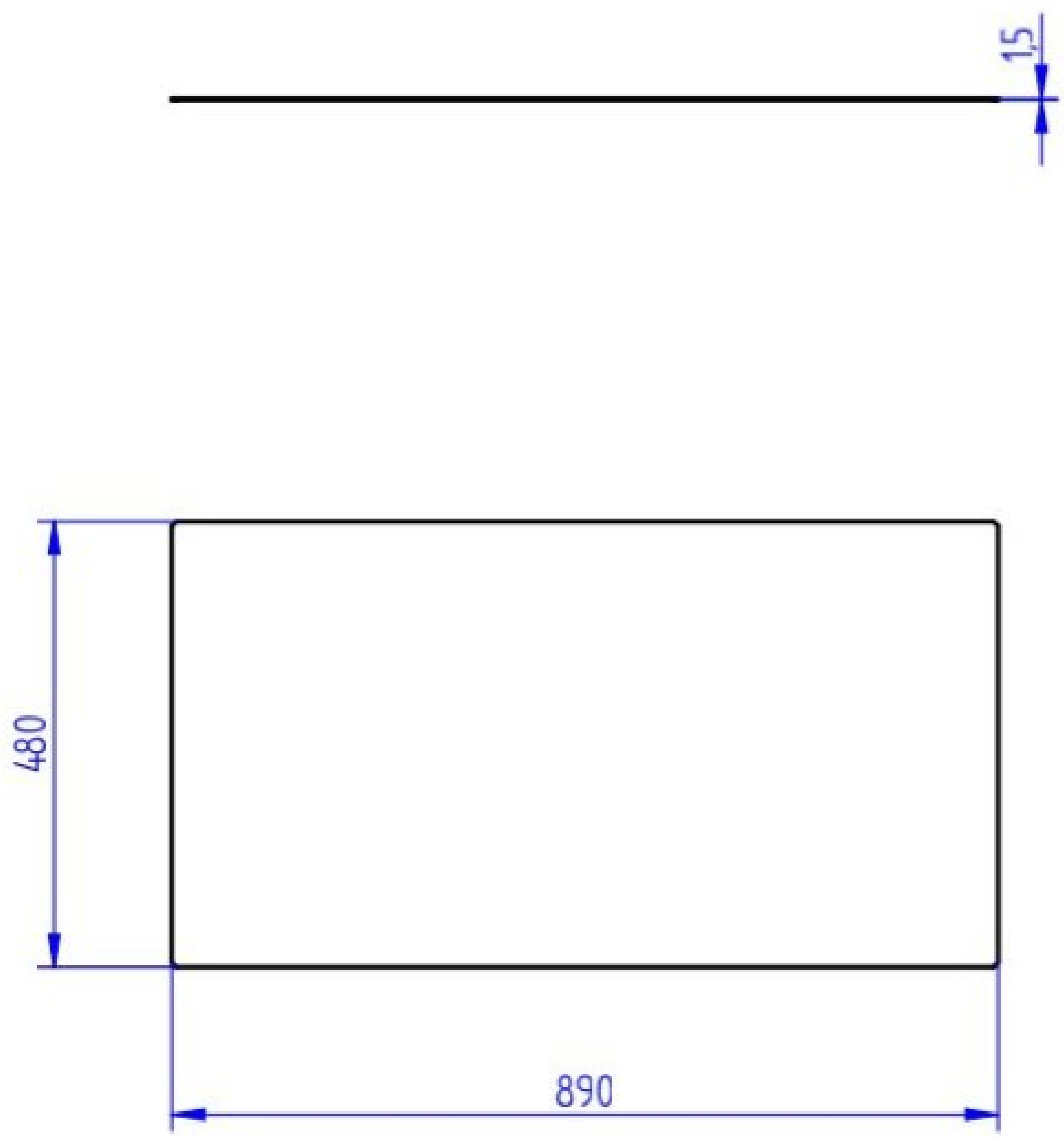
Sheet: 1 of 1

Size: A3 Scale: 1:1

Escaneado con CamScanner

1	2	3	4

A B C D E F



Part-No.: Cover front A
Former Dreiha P/N: Sheet 004

Index	No.	Revision record	Date	Name	Index	No.	Revision record	Date	Name

Welding dimensions limits according to DIN EN ISO 13920-B
Welding information according to DIN EN 2553
Thermal cutting dimension limits according to DIN EN ISO 9013-1
Edges according to DIN ISO 13715
Plastic parts according to DIN 7715 T5 | Adhesion according to TR 208
Surfaces according to DIN ISO 1302
Bending tolerances according to DIN 6935 | Press tolerances according to DIN 6930-m
Dimensions checked during inspection

Material: BB0006683

Weight (calculated): 1.730 kg | Area:

Unfolded dimensions

	Date	Name
created by:	03/04/2023	gmuncz
checked by:	03/04/2023	Name Prüfer
approved by:		
substitutes:		

Unspecified dimensions according to ISO 2768-1: Toleranzklasse

Tolerance class	more than 0,5 to 3	more than 3 to 6	more than 6 to 30	more than 30 to 120	more than 120 to 315	more than 315 to 1000	more than 1000 to 2000	more than 2000 to 4000
fine	±0,05	±0,05	±0,1	±0,15	±0,2	±0,3	±0,5	±0,8
medium	±0,1	±0,1	±0,2	±0,3	±0,5	±0,8	±1,2	±2
coarse	±0,2	±0,3	±0,5	±0,8	±1,2	±2	±3	±4
very coarse	-	±0,5	±1	±1,5	±2,5	±3	±6	±8

Surfaces:	Ø Hole: H13 Ø Axis: h13 Thread: 6H-8	Hole distance:	Hole position
√AA		±0.4	±0.2

- Computer Aided Design -
Only change this drawing in the CAD-System.
No revision without referring to model: Cover front A

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First application: Erstverwendung

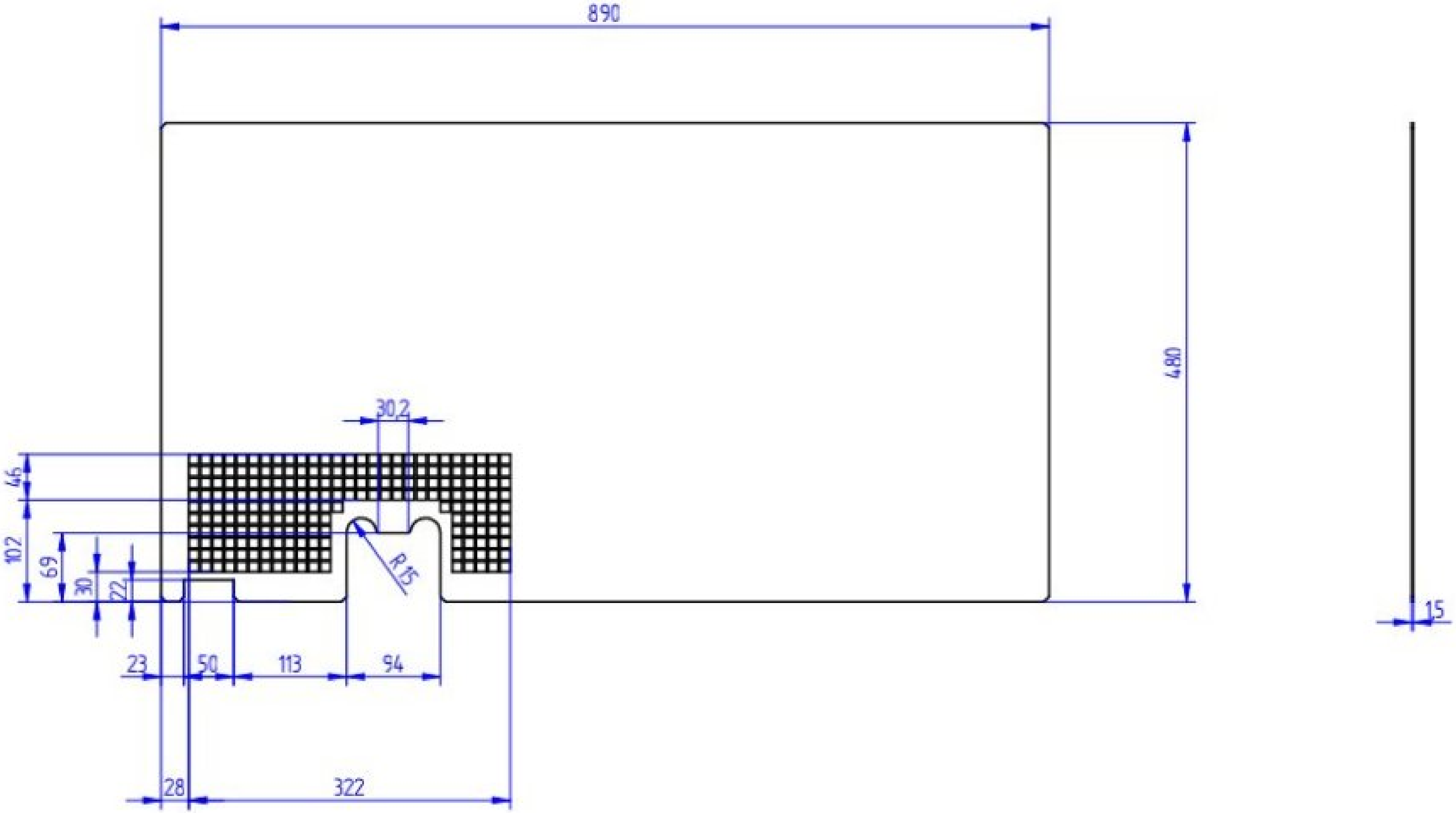
Title: Cover front A

Drawing No.: Zeichnungsnummer

Sheet: 1 of: 1

Size: A4 Scale: 1:1

Escaneado con CamScanner



Part-No.: Cover front B
Former Dreiha P/N: Sheet 005

Index	No.	Revision record	Date	Name	Index	No.	Revision record	Date	Name

		Date	Name
Welding dimensions limits according to: DIN EN ISO 13920-B			
Welding information according to DIN EN 2553	created by	03/04/2023	gmunoz
Thermal cutting dimension limits according to DIN EN ISO 9013-1	checked by	03/04/2023	Name Prüfer
Edges according to DIN ISO 13715	approved by		
Plastic parts according to DIN 7715 T5 / Adhesion according to TR 308	substitutes		
Surfaces according to DIN ISO 1302			
Dimensions checked during inspection			
Material: BB0006683			
Weight (calculated): 1.610 kg / Area:			
Unlisted dimensions			

Surfaces: AA; Ø Hole H13, Ø Axis h13, Thread 6H/6g; Hole distance: ± 0.4; Hole position: ± 0.2

– Computer Aided Design –
Only change the drawing in the CAD-System
No revision without referring to model: Cover front B

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First application: Erstverwendung

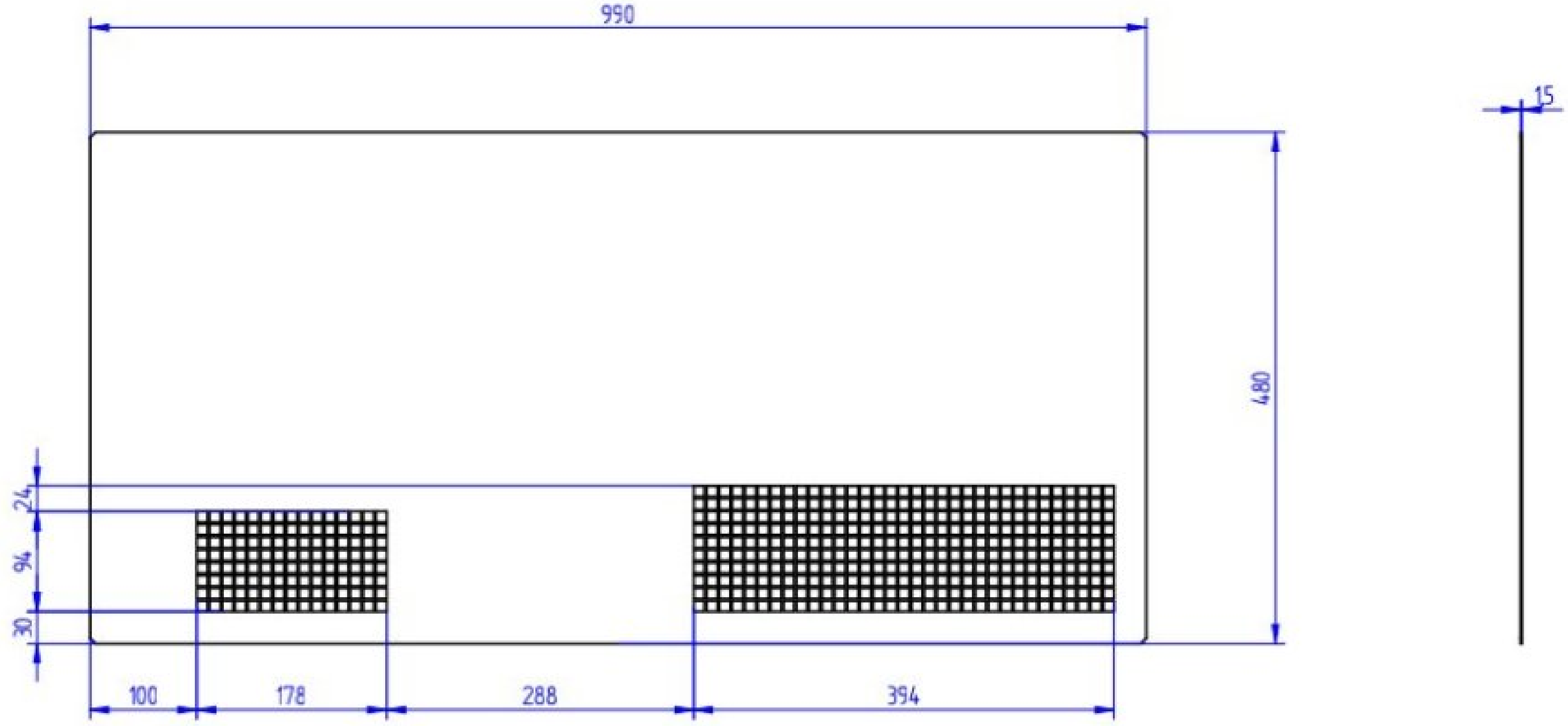
Title: Cover front B

Drawing No.: Zeichnungsnummer

Sheet: 1 of 1

Size: A3 Scale: 1:1

Escaneado con CamScanner



Part-No.: Cover left
Former Dreiha P/N: Sheet 003

Index	No.	Revision record	Date	Name	Index	No.	Revision record	Date	Name

		Date	Name
Welding dimensions limits according to: DIN EN ISO 13920-B		Date	Name
Welding information according to: DIN EN 2553	created by:	03/04/2023	gmunoz
Thermal cutting dimension limits according to DIN EN ISO 9013-1	checked by:	03/04/2023	Name Prüfer
Edges according to DIN ISO 13715	approved by:		
Plastic parts according to DIN 7715 T5 / Adhesion according to TR 308	substitutes:		
Surfaces according to DIN ISO 1302	Unspecified dimensions according to ISO 2768-1 Toleranzklasse		
Bending tolerances according to DIN 6935 / Press tolerances according to DIN 6930-m			
Dimensions checked during inspection			
Material: BB0006683			
Weight (calculated): 1.742 kg / Area:	Surfaces: Ra	Ø Hole H13, Ø Axis h13, Thread 6H8 / Hole distance: ± 0.4	Hole position: ± 0.1
Unfinished dimensions	- Computer Aided Design - Only change the drawing in the CAD-System. No revision without referring to model: Cover left		

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First application: Erstverwendung

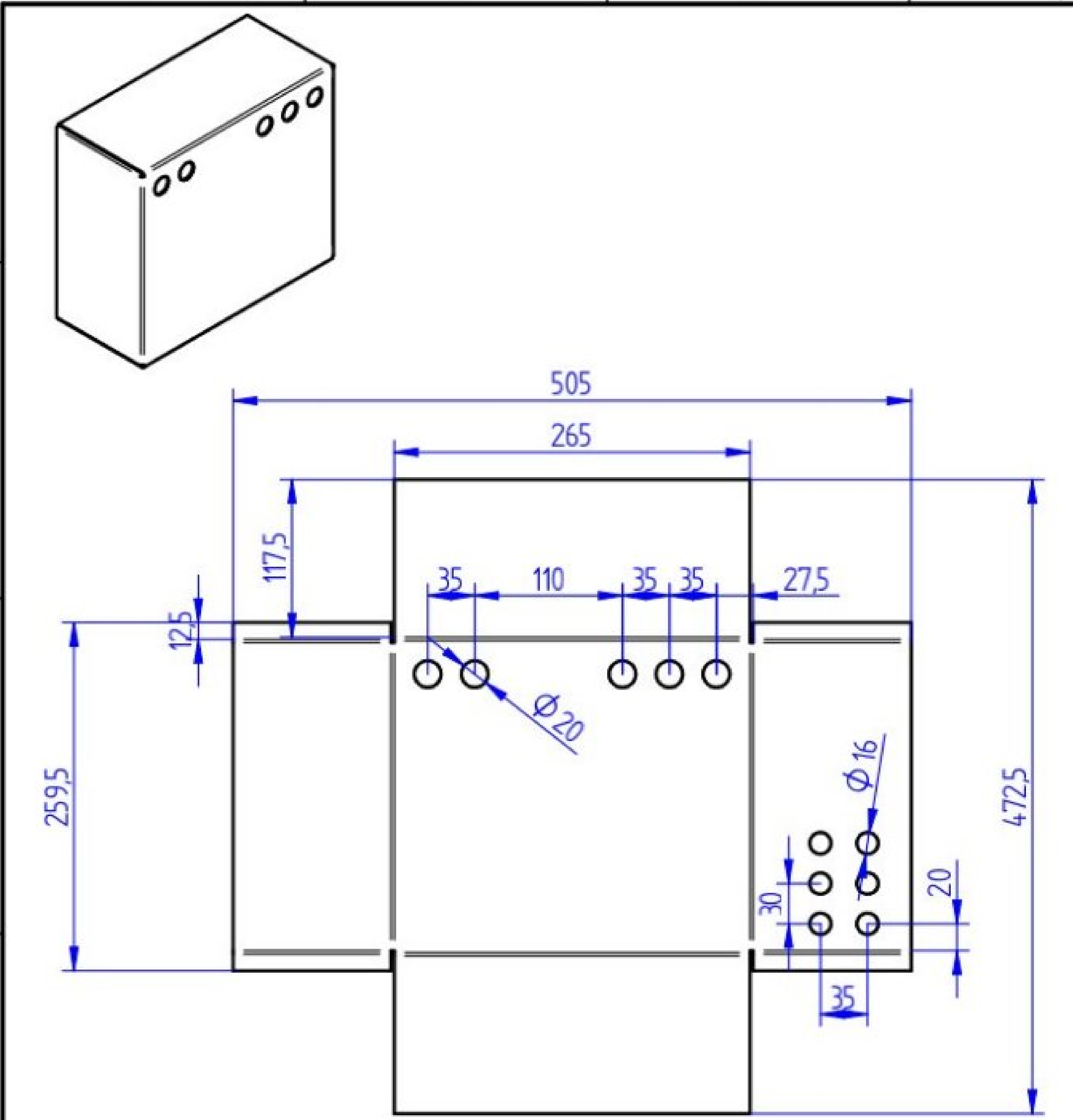
Title: Cover left

Drawing No.: Zeichnungsnummer

Sheet: 1 of 1

Size: A3 Scale: 1:1

Escaneado con CamScanner



Part-No.: E-Box
Former Dreiha P/N: Sheet 002

Index	No.	Revision record	Date	Name	Index	No.	Revision record	Date	Name

Welding dimensions limits according to DIN EN ISO 13920-B
Welding information according to DIN EN 2553
Thermal cutting dimension limits according to DIN EN ISO 9013-1
Edges according to DIN ISO 13715
Plastic parts according to DIN 7715 T5 | Adhesion according to TR 208
Surfaces according to DIN ISO 1302
Bending tolerances according to DIN 6935 | Press tolerances according to DIN 6930-m
Dimensions checked during inspection

Material: BB0006683

Weight (calculated): 0.749 kg | Area:

Unfolded dimensions

	Date	Name
created by:	26/04/2023	gmunoz
checked by:	26/04/2023	Name Prüfer
approved by:		
substitutes:		

Unspecified dimensions according to ISO 2768-1: Toleranzklasse

Tolerance class	more than 0,5 to 3	more than 3 to 6	more than 6 to 30	more than 30 to 120	more than 120 to 315	more than 315 to 1000	more than 1000 to 2000	more than 2000 to 4000
fine	±0,05	±0,05	±0,1	±0,15	±0,2	±0,3	±0,5	±0,8
medium	±0,1	±0,1	±0,2	±0,3	±0,5	±0,8	±1,2	±2
coarse	±0,2	±0,3	±0,5	±0,8	±1,2	±2	±3	±4
very coarse	-	±0,5	±1	±1,5	±2,5	±3	±6	±8

Surfaces:	Ø Hole: H13 Ø Axis: h13 Thread: SH8	Hole distance:	Hole position
√AA		±0.4	±0.2

- Computer Aided Design -
Only change this drawing in the CAD-System.
No revision without referring to model: E-Box

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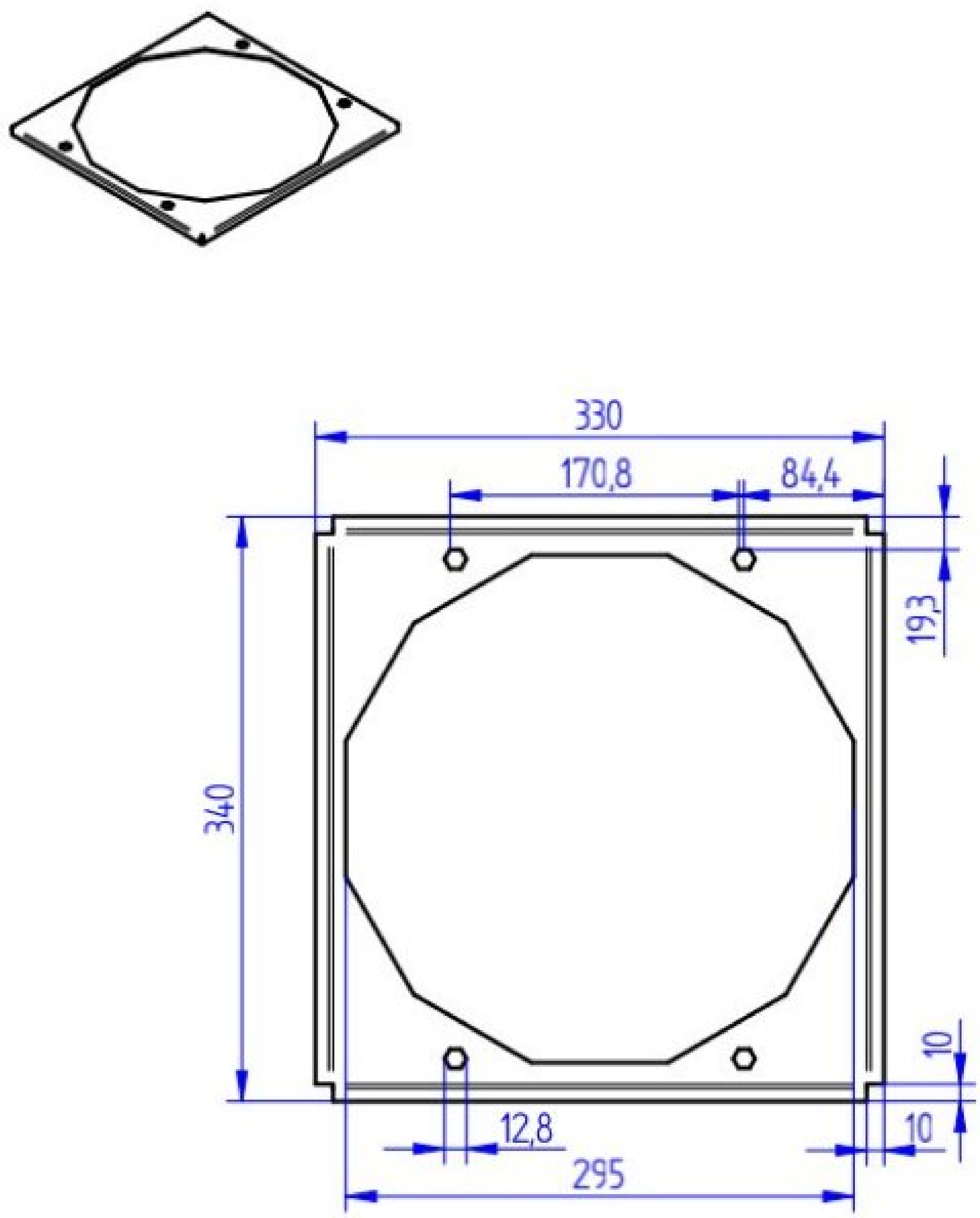
First application: Erstverwendung

Title: E-Box

Drawing No.: Zeichnungsnummer

Sheet: 1 of: 1

Size: A4 | Scale: 1:5



Part-No.: Fan bracket
Former Dreiha P/N: Sheet 011

Index	No.	Revision record	Date	Name	Index	No.	Revision record	Date	Name

Welding dimensions limits according to DIN EN ISO 13920-B
Welding information according to DIN EN 2553
Thermal cutting dimension limits according to DIN EN ISO 9013-1
Edges according to DIN ISO 13715
Plastic parts according to DIN 7715 T5 | Adhesion according to TR 208
Surfaces according to DIN ISO 1302
Bending tolerances according to DIN 6935 | Press tolerances according to DIN 6930-m
Dimensions checked during inspection

Material: BB0006683

Weight (calculated): 0.169 kg | Area:

Unfolded dimensions

	Date	Name
created by:	26/04/2023	gmuncz
checked by:	26/04/2023	Name Prüfer
approved by:		
substitutes:		

Unspecified dimensions according to ISO 2768-1: Toleranzklasse

Tolerance class	more than 0,5 to 3	more than 3 to 6	more than 6 to 30	more than 30 to 120	more than 120 to 315	more than 315 to 1000	more than 1000 to 2000	more than 2000 to 4000
fine	±0,05	±0,05	±0,1	±0,15	±0,2	±0,3	±0,5	±0,8
medium	±0,1	±0,1	±0,2	±0,3	±0,5	±0,8	±1,2	±2
coarse	±0,2	±0,3	±0,5	±0,8	±1,2	±2	±3	±4
very coarse	-	±0,5	±1	±1,5	±2,5	±3	±6	±8

Surfaces:	Ø Hole: H13 Ø Axis: h13 Thread: 6H-8	Hole distance:	Hole position
√AA		± 0.4	± 0.2

- Computer Aided Design -
Only change this drawing in the CAD-System.
No revision without referring to model: Fan bracket

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First application: Erstverwendung

Title: Fan bracket

Drawing No.: Zeichnungsnummer

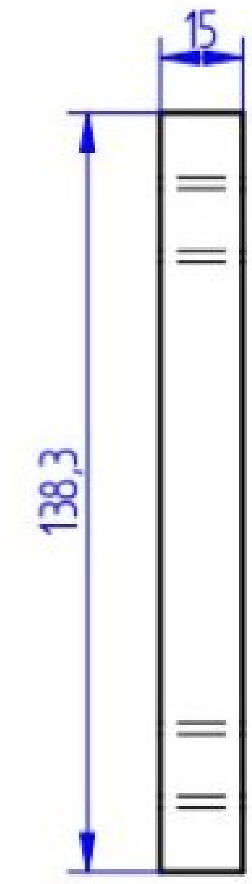
Sheet: 1 of: 1

Size: A4 | Scale: 1:5

Escaneado con CamScanner

1 2 3 4

A B C D E F



Part-No.: Sheet metal
Former Dreiha P/N: Sheet 013

Index	No.	Revision record	Date	Name	Index	No.	Revision record	Date	Name

Welding dimensions limits according to DIN EN ISO 13920-B
Welding information according to DIN EN 2553
Thermal cutting dimension limits according to DIN EN ISO 9013-1
Edges according to DIN ISO 13715
Plastic parts according to DIN 7715 T5 | Adhesion according to TR 208
Surfaces according to DIN ISO 1302
Bending tolerances according to DIN 6935 | Press tolerances according to DIN 6930-m
Dimensions checked during inspection

Material: BB0006683

Weight (calculated): 0.008 kg | Area:

Unfolded dimensions

	Date	Name
created by:	26/04/2023	gmunoz
checked by:	26/04/2023	Name Prüfer
approved by:		
substitutes:		

Unspecified dimensions according to ISO 2768-1: Toleranzklasse

Tolerance class	more than 0.5 to 3	more than 3 to 6	more than 6 to 30	more than 30 to 120	more than 120 to 315	more than 315 to 1000	more than 1000 to 2000	more than 2000 to 4000
fine	±0,05	±0,05	±0,1	±0,15	±0,2	±0,3	±0,5	±0,8
medium	±0,1	±0,1	±0,2	±0,3	±0,5	±0,8	±1,2	±2
coarse	±0,2	±0,3	±0,5	±0,8	±1,2	±2	±3	±4
very coarse	-	±0,5	±1	±1,5	±2,5	±3	±6	±8

Surfaces:	Ø Hole: H13 Ø Axis: h13 Thread: 6H-8	Hole distance:	Hole position
√AA		± 0.4	± 0.2

- Computer Aided Design -
Only change this drawing in the CAD-System.
No revision without referring to model: Sheet metal

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First application: Erstverwendung

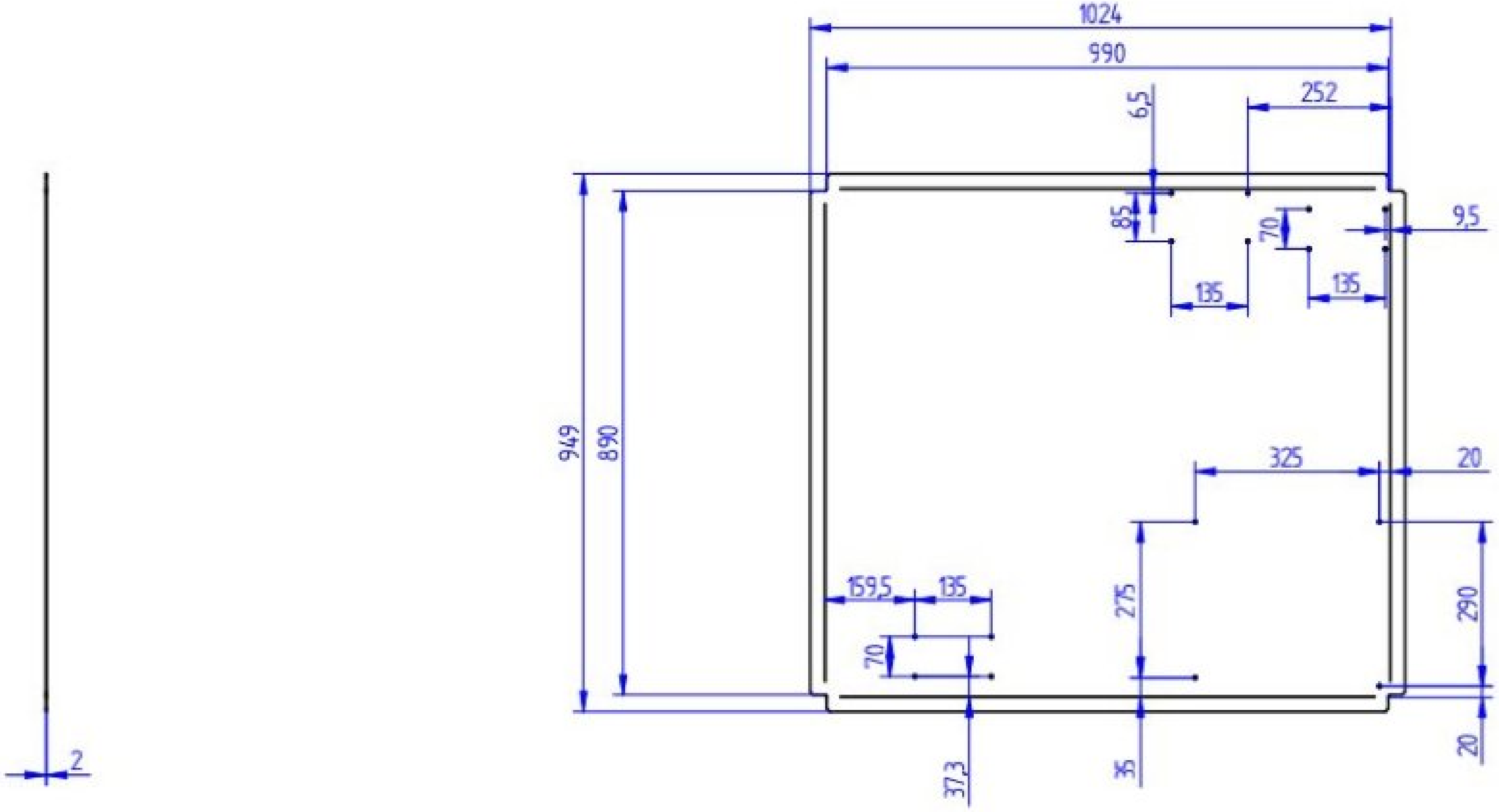
Title: Sheet metal

Drawing No.: Zeichnungsnummer

Sheet: 1 of: 1

Size: A4 Scale: 1:2

Escaneado con CamScanner



Part-No.: Main sheet
Former Dreiha P/N: Sheet 001

Index	No.	Revision record	Date	Name	Index	No.	Revision record	Date	Name

Welding dimensions limits according to: DIN EN ISO 13920-B
Welding information according to: DIN EN 2553
Thermal cutting dimension limits according to DIN EN ISO 9013-1
Edges according to DIN ISO 13715
Plastic parts according to DIN 7715 T5 | Adhesion according to TR 208
Surfaces according to DIN ISO 1302
Bending tolerances according to DIN 6935 | Press tolerances according to DIN 6930-m
Dimensions checked during inspection

Material: BB0002618

Weight (calculated): 5.367 kg | Area:

Unfinished dimensions

	Date	Name
created by	03/04/2023	gmunoz
checked by	03/04/2023	Name Prüfer
approved by		
substitutes		

Surfaces: √AA | Ø Hole H13, Ø Axis h13, Thread 6H6 | Hole distance ± 0.4 | Hole position ± 0.2

– Computer Aided Design –
Only change the drawing in the CAD-System
No revision without referring to model: Main sheet

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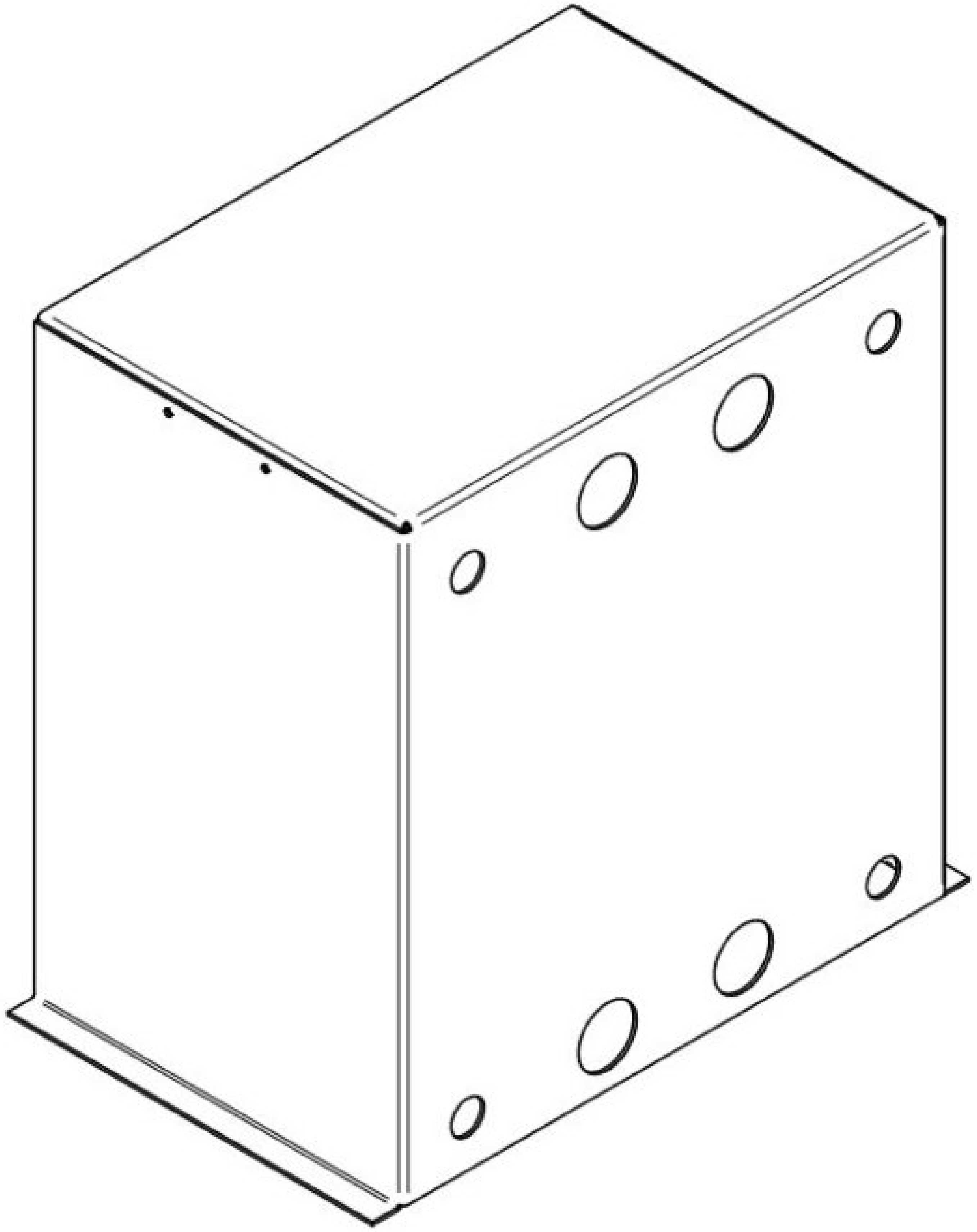
First application: Erstverwendung

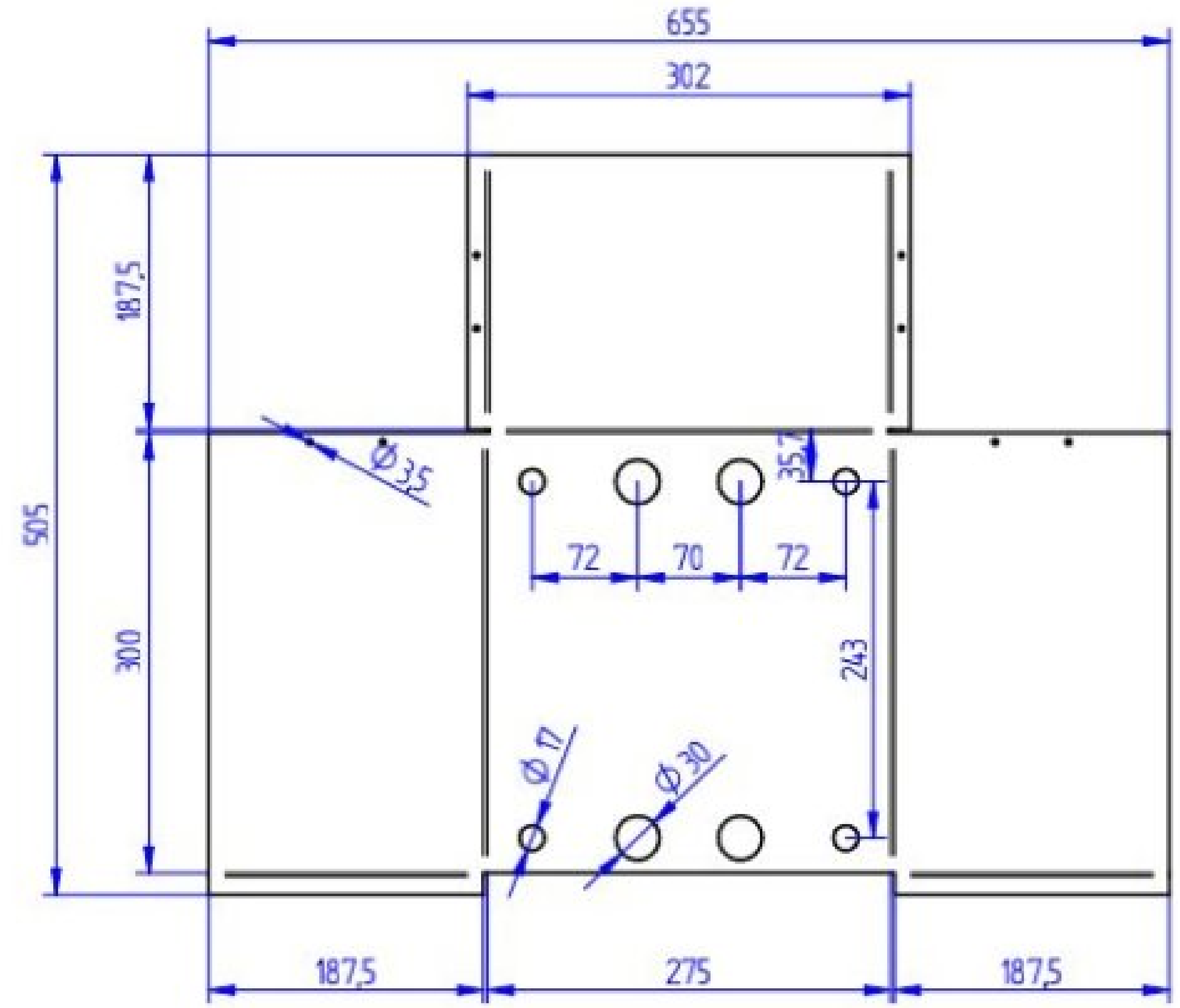
Title: Main sheet

Drawing No.: Zeichnungsnummer

Sheet: 1 of 1

Size: A3 | Scale: 1:1





Part-No.: Plate HEx bracket

Former Dreiha P/N: Sheet 014

Index	No.	Revision record	Date	Name	Index	No.	Revision record	Date	Name

Welding dimensions limits according to: DIN EN ISO 13920-B		Date	Name
Welding information according to: DIN EN 2553	created by:	20/04/2023	gmunoz
Thermal cutting dimension limits according to DIN EN ISO 9013-1	checked by:	20/04/2023	Name Prüfer
Edges according to DIN ISO 13715	approved by:		
Plastic parts according to DIN 7715 T5 / Adhesion according to TR 308	substitutes		
Surfaces according to DIN ISO 1302	Linear-not-dimensions according to ISO 2768-1	Tolerance class	
Bending tolerances according to DIN 6935 / Press tolerances according to DIN 6930-m	[illegible]		
Dimensions checked during inspection	[illegible]		
Material: BB0006683	[illegible]		
Weight (calculated): 1.037 kg / Area:	Surfaces: Ra	Ø Hole H12, Ø Axis h13, Thread 6H6	Hole distance: ± 0.4 / Hole position: ± 0.3
Untoleranced dimensions	– Computer Aided Design – Only change the drawing in the CAD-System. No revision without referring to model: Plate HEx bracket		

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First application: Erstverwendung

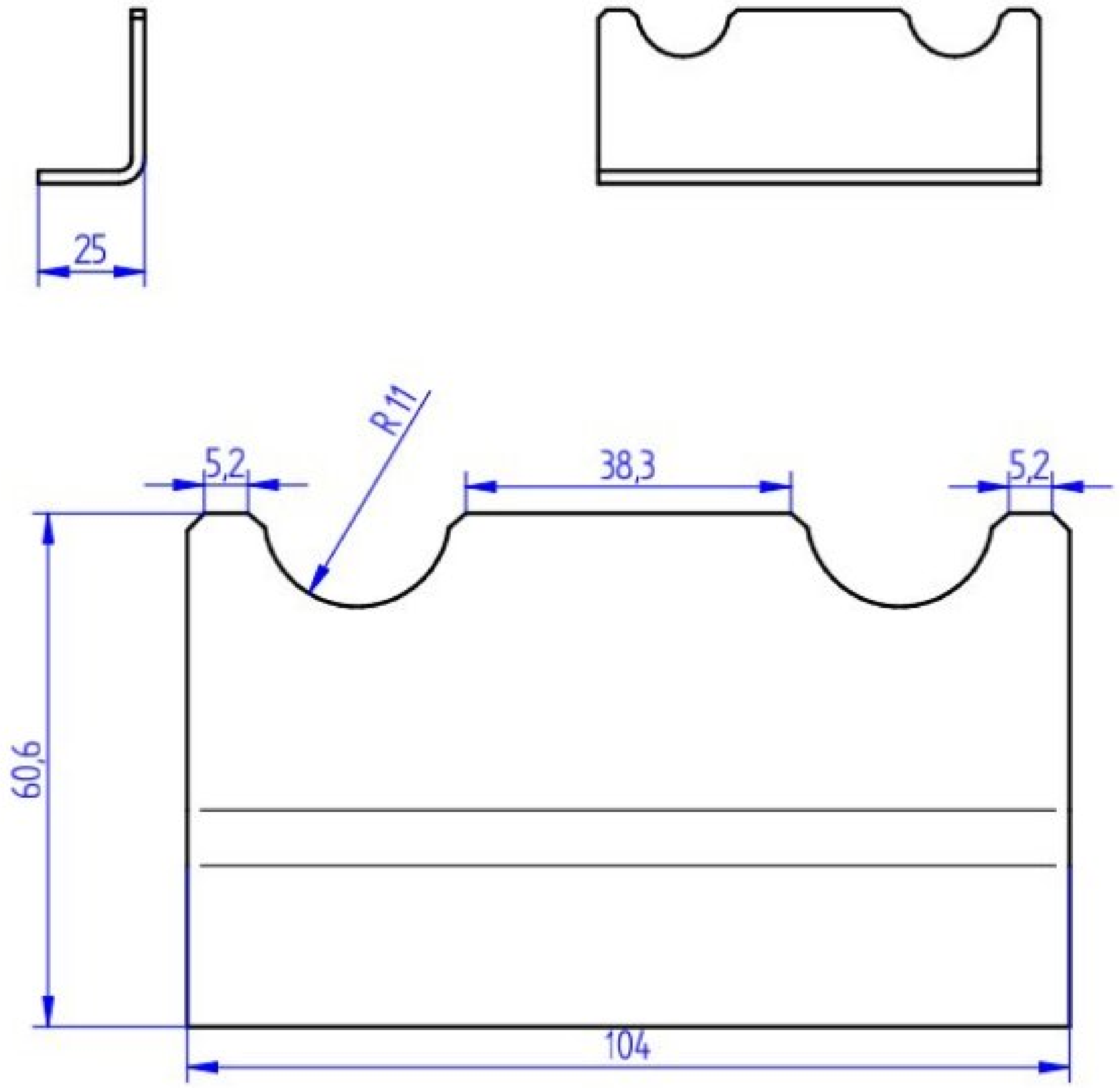
Title:

Drawing No.: Zeichnungsnummer

Sheet: 1 of 1

Size: A3 Scale: 1:5

Escaneado con CamScanner



Part-No.: Plate for pipes
Former Dreiha P/N: Sheet 007

Index	No.	Revision record	Date	Name	Index	No.	Revision record	Date	Name

Welding dimensions limits according to DIN EN ISO 13920-B
Welding information according to DIN EN 2553
Thermal cutting dimension limits according to DIN EN ISO 9013-1
Edges according to DIN ISO 13715
Plastic parts according to DIN 7715 T5 | Adhesion according to TR 208
Surfaces according to DIN ISO 1302
Bending tolerances according to DIN 6935 | Press tolerances according to DIN 6930-m
Dimensions checked during inspection

Material: BB0006683

Weight (calculated): 0.048 kg | Area:

Unfolded dimensions

	Date	Name
created by:	26/04/2023	gmunoz
checked by:	26/04/2023	Name Prüfer
approved by:		
substitutes:		

Unspecified dimensions according to ISO 2768-1: Toleranzklasse

Tolerance class	more than 0,5 to 3	more than 3 to 6	more than 6 to 30	more than 30 to 120	more than 120 to 315	more than 315 to 1000	more than 1000 to 2000	more than 2000 to 4000
fine	±0,05	±0,05	±0,1	±0,15	±0,2	±0,3	±0,5	±0,8
medium	±0,1	±0,1	±0,2	±0,3	±0,5	±0,8	±1,2	±2
coarse	±0,2	±0,3	±0,5	±0,8	±1,2	±2	±3	±4
very coarse	-	±0,5	±1	±1,5	±2,5	±3	±6	±8

Surfaces:	Ø Hole: H13 Ø Axis: h13 Thread: SH8	Hole distance:	Hole position
√AA		±0.4	±0.2

- Computer Aided Design -
Only change this drawing in the CAD-System.
No revision without referring to model: Plate for pipes

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First application: Erstverwendung

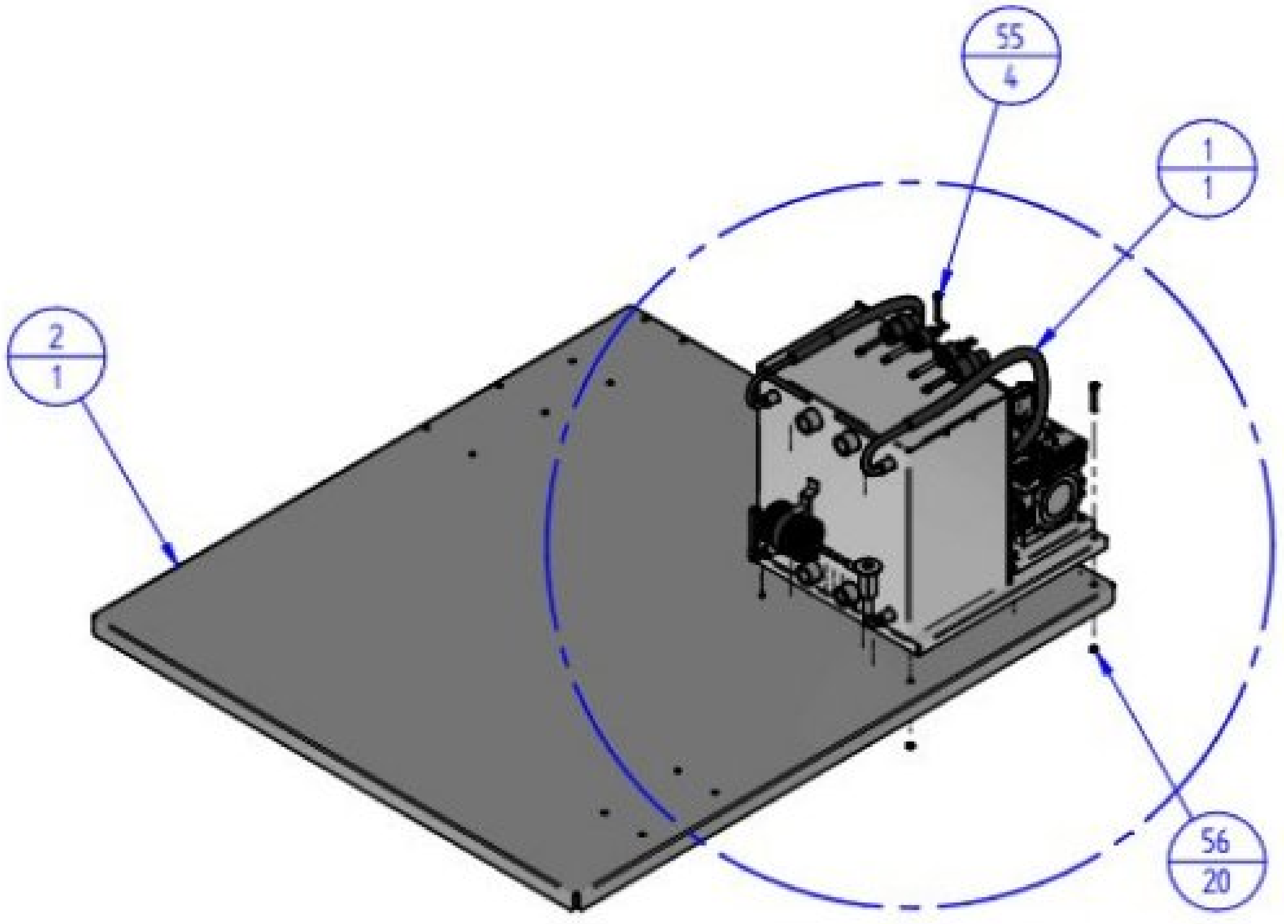
Title: Plate for pipes

Drawing No.: Zeichnungsnummer

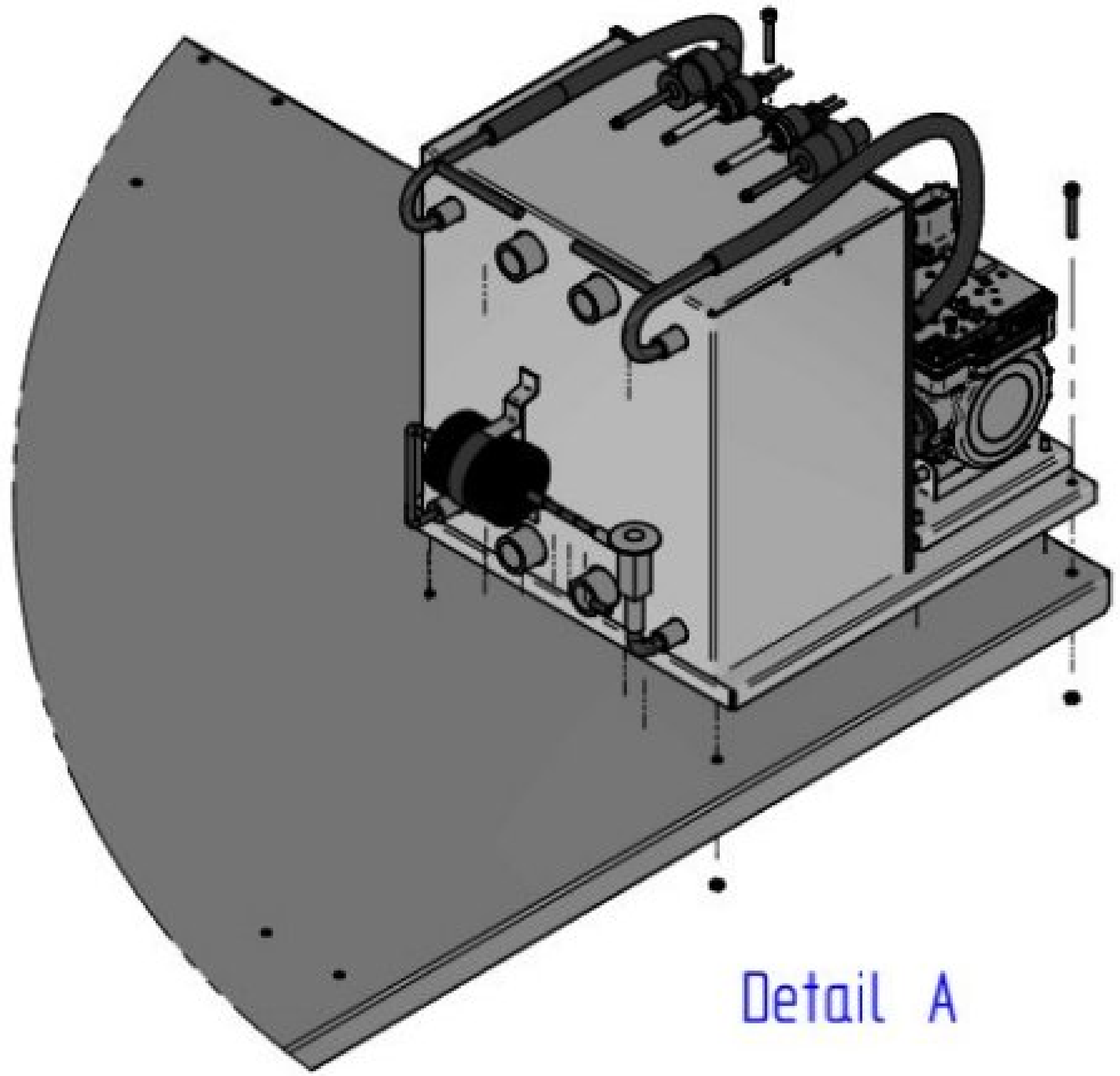
Sheet: 1 of: 1

Size: A4 | Scale: 1:1

Escaneado con CamScanner



A



Detail A

Part-No.:	BTMU
Former Dreiha P/N:	BTMU

- Place the pre-assembled compressor on the base plate.
- Tighten the screws with washers and nuts.

Index	No.	Revision record	Date	Name	Index	No.	Revision record	Date	Name

		Date	Name
Welding dimensions limits according to DIN EN ISO 13920-B			
Welding information according to DIN EN 2553	created by	27/04/2023	gmunoz
Thermal cutting dimension limits according to DIN EN ISO 9013-1	checked by	27/04/2023	Name Prüfer
Edges according to DIN ISO 13715	approved by		
Plastic parts according to DIN 7715 T5 / Adhesion according to TR 308	substitutes		
Surfaces according to DIN ISO 1302	Unspecified dimensions according to ISO 2768-1		
Bending tolerances according to DIN 6935 / Press tolerances according to DIN 6930-m			
Dimensions checked during inspection			
Material:			
Weight (calculated): 0.000 kg / Area:	Surfaces: Ra	Ø Hole H13, Ø Axis h13, Thread 6H/6g	Hole distance: ± 0.4 / Hole position: ± 0.2
Unfinished dimensions	– Computer Aided Design – Only change this drawing in the CAD-System. No revision without referring to model: BTMU		

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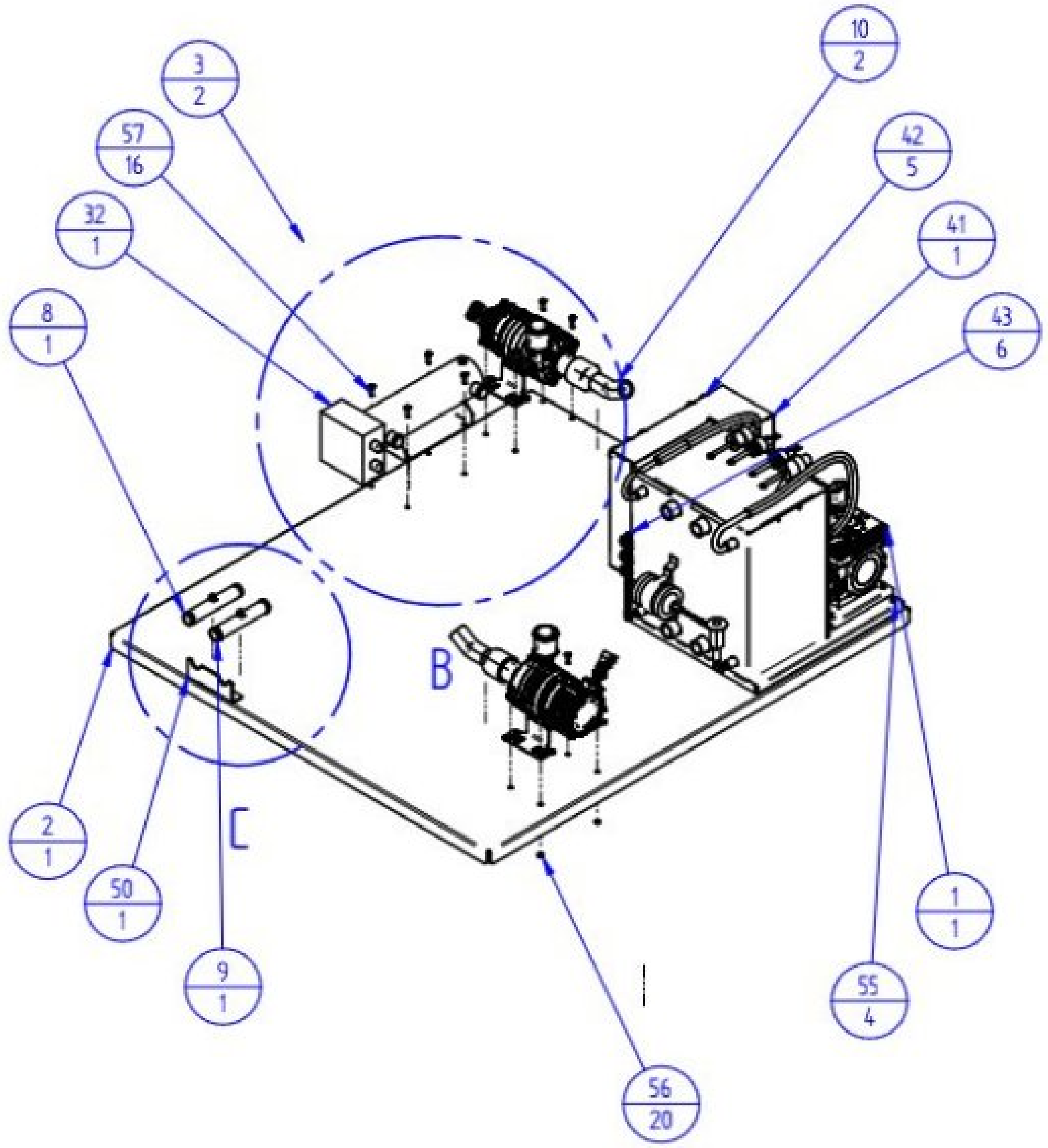
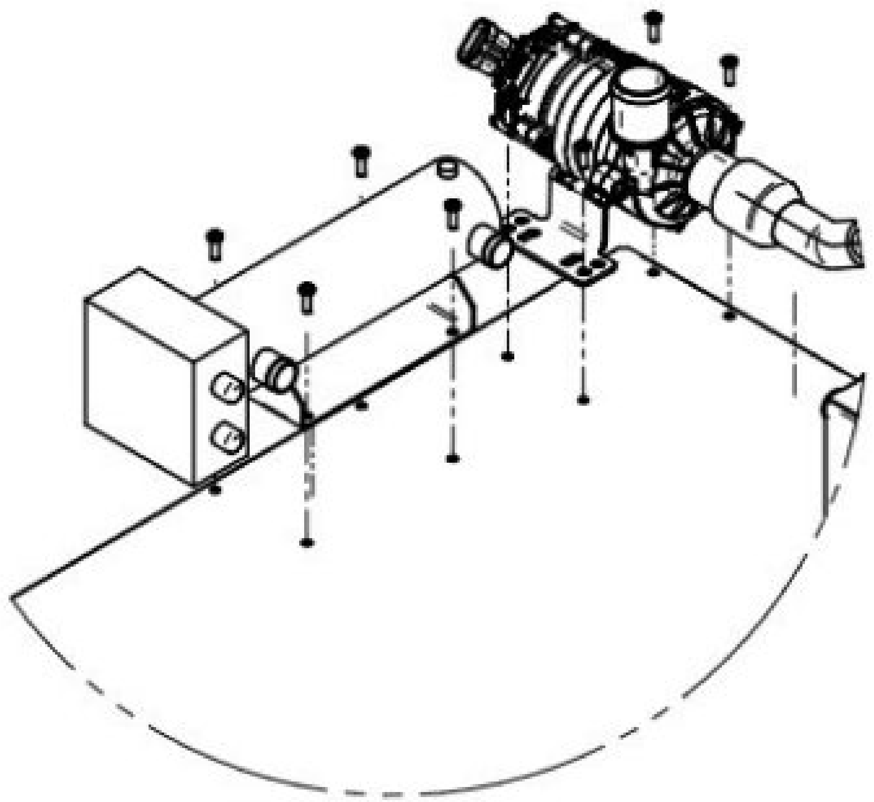
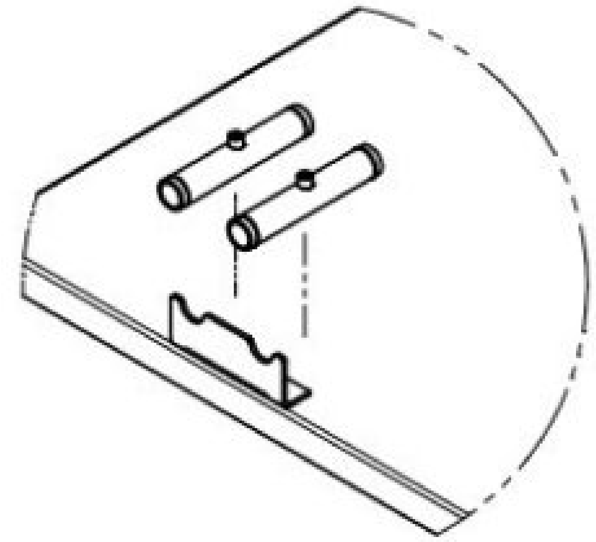
First application:	Erstverwendung
Title:	BTMU
Drawing No.:	Zeichnungsnummer
Sheet:	1
of	4
Size:	A3
Scale:	1:10

Escaneado con CamScanner





Detail B



Detail C

Part-No.: BTMU
Former Dreiha P/N: BTMU

- Material 41 and 50 are welded to the based plate. As it can be seen in Detail C.
- Place the pumps and electric heater and tighten the screws with washers and nuts (Detail B).

Index	No.	Revision record	Date	Name	Index	No.	Revision record	Date	Name

		Date	Name
Welding dimensions limits according to: DIN EN ISO 13920-B			
Welding information according to: DIN EN 2553	created by:	27/04/2023	gmunoz
Thermal cutting dimension limits according to DIN EN ISO 9013-1	checked by:	27/04/2023	Name Prüfer
Edges according to DIN ISO 13715	approved by:		
Plastic parts according to DIN 7715 T5 / Adhesion according to TR 208	substitutes:		
Surfaces according to DIN ISO 1302			

Dimensions checked during inspection

Material:

Weight (calculated): 0.000 kg | Area:

Unfinished dimensions

Surfaces: √AA | Ø Hole H13, Ø Axis h13, Thread 6H/6g | Hole distance: ± 0.4 | Hole position: ± 0.1

– Computer Aided Design –
Only change this drawing in the CAD-System
No revision without referring to model: BTMU

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First application: Erstverwendung

Title: BTMU

Drawing No.: Zeichnungsnummer

Sheet 2 of 4

Size: A3 | Scale: 1:10

Escaneado con CamScanner

Item Number	File Name (no extension)	Author	Quantity
1	BTMU_Compressor assembly	LLeuker	1
2	BTMU_002_Main sheet	gmunoz	1
3	BTMU_056_Hepler EP80	jrennies	2
4	CD0006295_Water valve 3-way (24V)	rgrojo	4
5	CB0036548_Microchannel HEx for water-glycol	LLeuker	1
6	2_tube_water	gmunoz	1
7	BTMU_039_Coolant F pipe	LLeuker	4
8	BTMU_034_Inlet water pipe	LLeuker	1
9	BTMU_035_Outlet water pipe	LLeuker	1
10	BTMU_105_Hose pump ext 3 way	LLeuker	2
11	5_tube_water	gmunoz	1
12	7_tw	gmunoz	1
13	8_tw	gmunoz	1
14	9_tw	gmunoz	1
15	10_tw	gmunoz	1
16	11_tw	gmunoz	1
17	12_tw	gmunoz	1
18	14_tw	gmunoz	1
19	15_tw	gmunoz	1
20	16_tw	gmunoz	1
21	17_tw	gmunoz	1
22	18_tw	gmunoz	1
23	BTMU_019_Tank cap	LLeuker	2
24	BTMU_018_Water tank	LLeuker	2
25	BTMU_040_Coolant T pipe with tank connection	LLeuker	1
26	23_wt	gmunoz	1

Item Number	File Name (no extension)	Author	Quantity
27	24_wt	gmunoz	1
28	24_tw	gmunoz	1
29	25_wt	gmunoz	1
30	26_wt	gmunoz	1
31	27_wt	gmunoz	1
32	BTMU_088_Electric heater	LLeuker	1
33	29_wt	gmunoz	1
34	31_tw	gmunoz	1
35	33_wt	gmunoz	1
36	34_wt	gmunoz	1
37	38_wt	gmunoz	1
38	40_wt	gmunoz	1
39	MD0033095_Axial fan D280 24V PWM brushless	LLeuker	1
40	41_wt	gmunoz	1
41	BTMU_020_E-Box	LLeuker	1
42	Mh0003330_Cable_gland_M20x1,5_Br	JSchuldt	5
43	Mh0000066_Cable gland M16x1,5 Br	LLeuker	6
44	BTMU_024_Cover left	LLeuker	2
45	28_wt	gmunoz	1
46	28_wt2	gmunoz	1
47	BTMU_025_Cover front	gmunoz	1
48	BTMU_026_Cover front	LLeuker	1
49	BTMU_006_Angle	LLeuker	3
50	BTMU_045_Plate for inlet outlet pipes	LLeuker	1
51	BTMU_086_Angle	LLeuker	2
52	BTMU_127_Sheet	LLeuker	2

Item Number	File Name (no extension)	Author	Quantity
53	BTMU_022_Cover fan	gmunoz	1
54	BTMU_049_Fan bracket sheet	LLeuker	1
55	BC0004317_Cap screw ISO 14579 M5x35 A4	bcimen	4
56	BC0012043_Hexagon Nut ISO4032 M5 A2	jrennies	20
57	BC0007745_Flat head screw M5x16 ISO14583 A4(Torx)	jrennies	16
58	tube_203	gmunoz	1
59	t_204	gmunoz	1
60	t_205	gmunoz	1
61	t_206	gmunoz	1
62	t_207	gmunoz	1
63	t_208	gmunoz	1
64	t_209	gmunoz	1
65	t_211	gmunoz	1
66	t_213	gmunoz	1
67	t_2015	gmunoz	1
68	t_216	gmunoz	1
69	t_217	gmunoz	1
70	t_2018	gmunoz	1
71	t_12223	gmunoz	1

Part-No.: BTMU
Former Dreiha P/N: BTMU

Dreiha

	Date	Name
created by	27/04/2023	gmunoz
checked by	27/04/2023	Frank Prüfer

First application: Erstverwendung

Title: BTMU

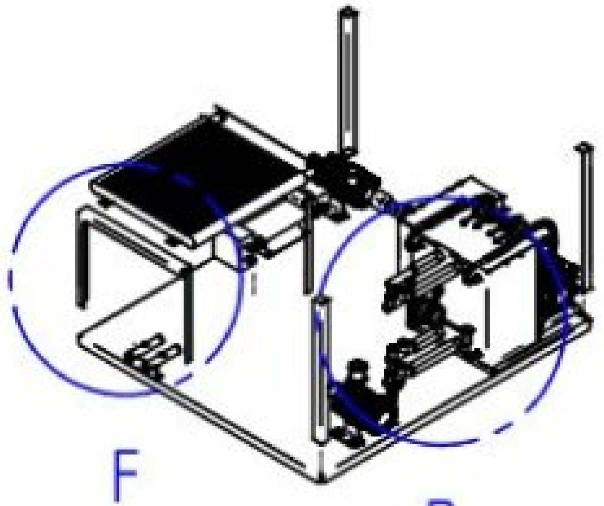
Drawing No.: Zeichnungsnummer

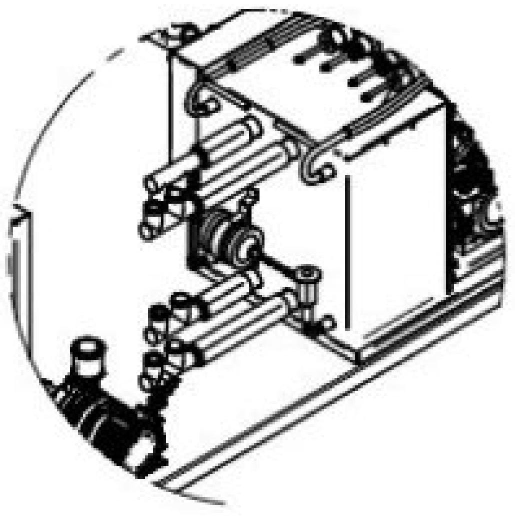
Sheet 3 of 4

Size: A3 | Scale: 1:20

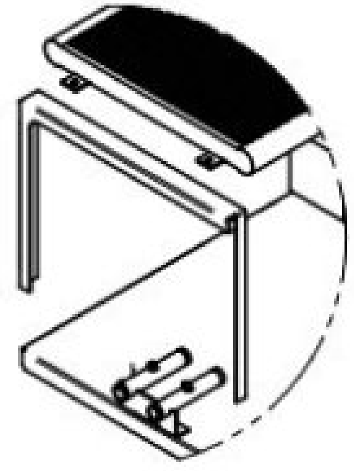
Weight: 0.000 kg

Escaneado con CamScanner





Detail D



Detail F

Part-No.: BTMU
Former Dreiha P/N: BTMU

- Put the plates exchangers rubber hoses with the "T" connectors (Detail D)
- Weld the sheet metal brakets to the sheet based plate.
- Weld the heat exchanger to the brackets Detail F.

Index	No.	Revision record	Date	Name	Index	No.	Revision record	Date	Name

		Date	Name
Welding dimensions limits according to DIN EN ISO 13920-B			
Welding information according to DIN EN 2553	created by	27/04/2023	gmunoz
Thermal cutting dimension limits according to DIN EN ISO 9013-1	checked by	27/04/2023	Name Prüfer
Edges according to DIN ISO 13715	approved by		
Plastic parts according to DIN 7715 T5 / Adhesion according to TR 208	substitutes		
Surfaces according to DIN ISO 1302			
Bending tolerances according to DIN 6935 / Press tolerances according to DIN 6930-m			
Dimensions checked during inspection			
Material:			
Weight (calculated): 0.000 kg / Area:			
Unlisted dimensions			

Unspecified dimensions according to ISO 2768-1 — Toleranzangabe: [illegible]

Surface: √AA — Ø Hole H13, Ø Axis h13, Thread 6H/6g — Hole distance ± 0.4 — Hole position ± 0.2

– Computer Aided Design –
Only change the drawing in the CAD-System
No revision without referring to model: BTMU

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First application: Erstverwendung

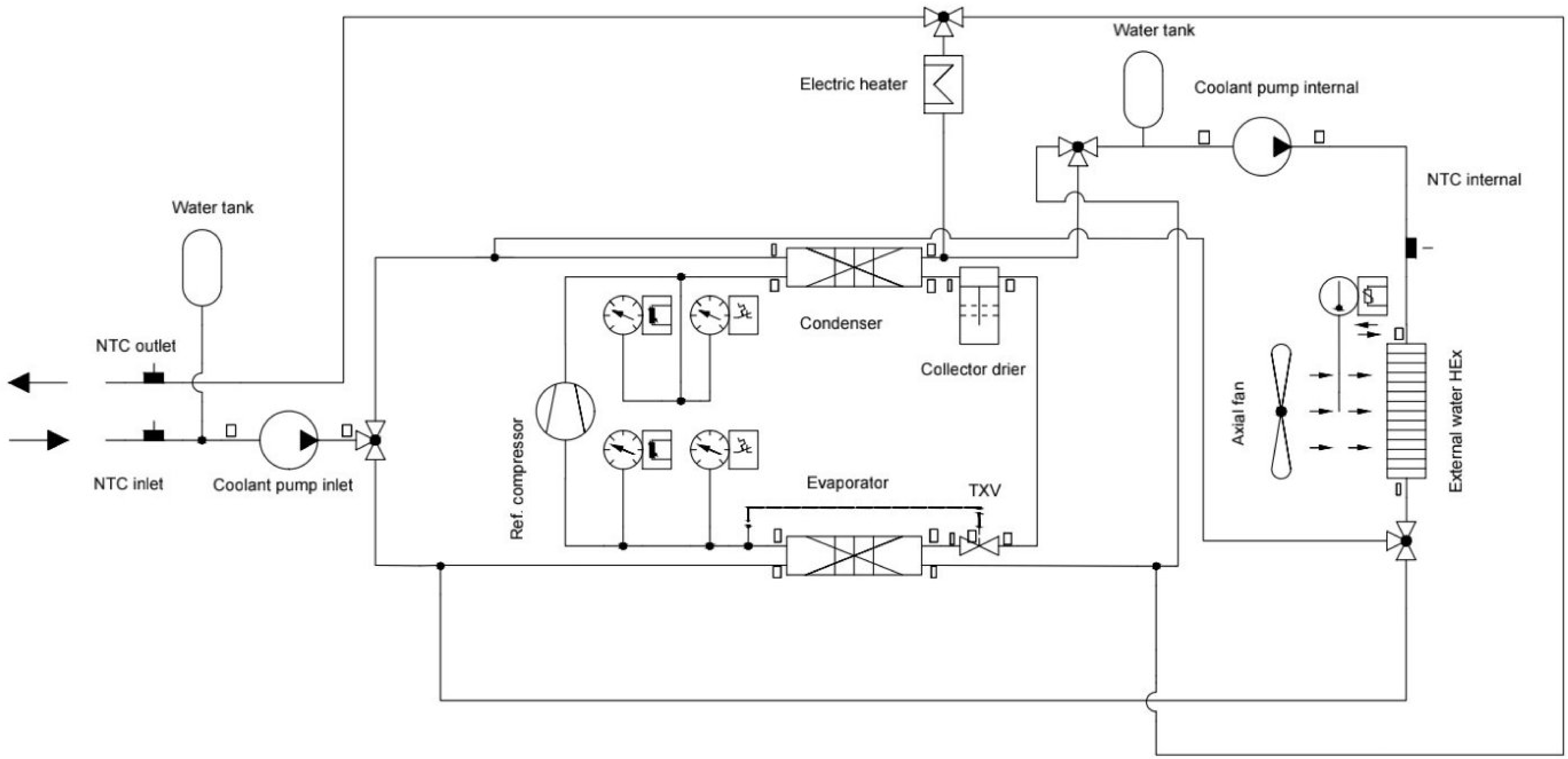
Title: BTMU

Drawing No.: Zeichnungsnummer

Sheet: 4 of 4

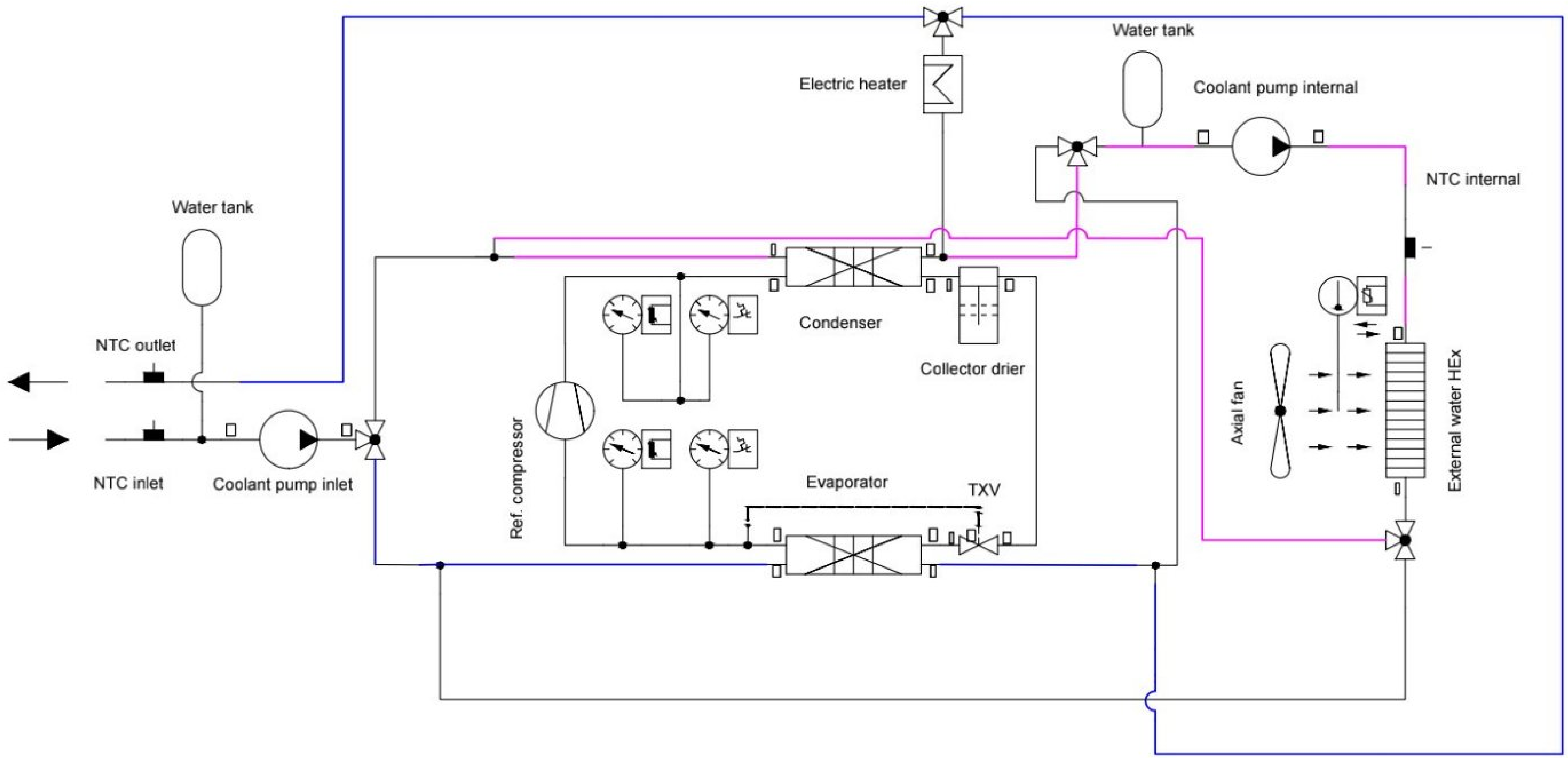
Size: A3 Scale: 1:20

Escaneado con CamScanner



Designer	DATE	Concept Scheme	
GMD	9/04/23		
FIRMA:	BTMU		DRAW Nº: 1

Escaneado con CamScanner

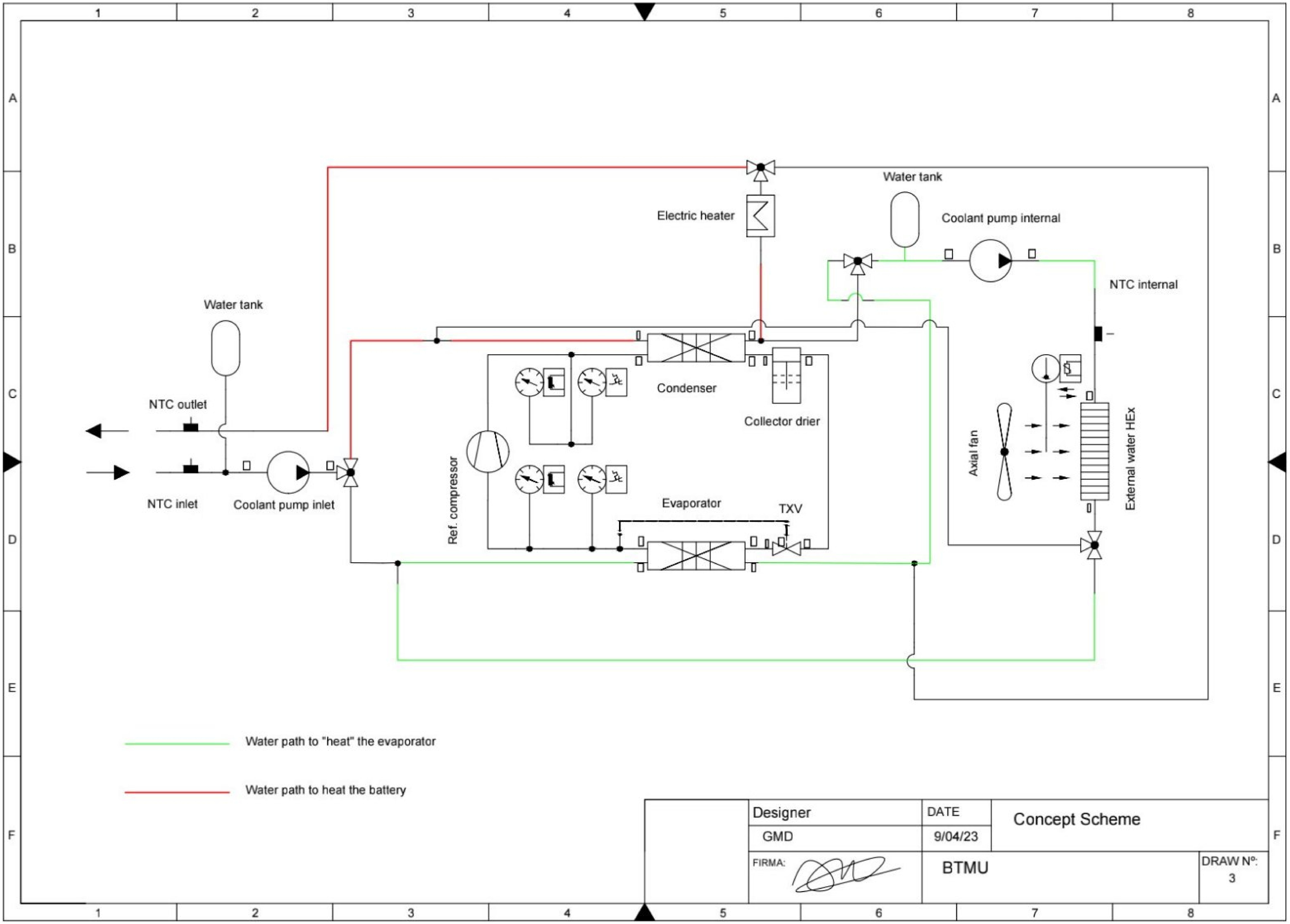


Water path to cool the condenser

Water path to cool the battery

Designer	DATE	Concept Scheme	
GMD	9/04/23		
FIRMA:		BTMU	DRAW Nº: 2

Escaneado con CamScanner



Escaneado con CamScanner