Design and Fabrication of Automatic Welding Manipulator for Oil and Gas Pipeline Welding

By

Ahmad Syahiq bin Aminuddin
16733

Dissertation submitted in partial fulfillment of
the requirement for the
Bachelor of Engineering (Hons)
(Mechanical)

MAY 2015

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridz

CERTIFICATION OF APPROVAL

Design and Fabrication of Automatic Welding Manipulator for Oil and Gas Pipeline Welding

by

Ahmad Syahiq bin Aminuddin
16733

A project dissertation submitted to the
Mechanical Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfillment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(MECHANICAL)

Approved by,

____

(Dr Srinivasa Rao Pedapatti)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
May 2015

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified I the references and acknowledgement, and that the original work contained herein have not been undertaken or done by unspecified sources or person.

____

AHMAD SYAHIQ BIN AMINUDDIN

ABSTRACT

Welding is a familiar process in oil and gas industry however, the shortage of man power with the expertise is decreasing. In order to prevent loss due to poor quality of weldment, manipulators has been implemented most of the oil and gas company. Still, there were none manipulators that have been established as for the purpose of oil and gas pipeline welding. This project present a welding manipulator that is designed especially for the purposed of oil and gas pipeline welding, included in this report also the mechanical structure design and the mechanism of the manipulators. The drawing and the design will be performed by using SOLIDWORK 2015 where proper geometric relation such as the material specification and dimension.

ACKNOWLEDGEMENT

Inspiration and guidance are invaluable in every aspects of life, especially in the fields of academics, which we have received from the Mechanical Department of University Teknologi Petronas (UTP). I would like to thank them as they are responsible for the complete presentation of my project and also for the endless contribution of time, effort valuable guidance and encouragement given by Dr Srinivasa Rao Pedapatti project work.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS AND NOMENCLATURES

1. PLC	Programmable logic controller	6
2. HMI	Human machine interface	6
3. TIG	Tungsten inert gas	8
4. MIG	Metal inert gas	8
5. GMAW	Gas Metal Arc Welding	10
6. SAW	Submerged Arc Welding	10
7. GTAW	Gas Tungsten Arc Welding	10
8. 2D	2 dimension	16
9. 3D	3 dimension	16
10. AISI	American Iron and Steel Institute	27
11. F_H	Horizontal Force	30
12. F_V	Vertical Force	30
13. P_R	Force to raise the load	31
14. P_L	Force to lower the load	31
15. T_R	Torque to raise the load	31
16. T_L	Torque to lower the load	31
17. P_W	Power of the motor	33

CHAPTER 1: INTRODUCTION

1.1 Background Study

The term welding is used to cover a wide range of bonding techniques. Currently, a lot of welding processes has been established especially for industrial purposes. Arc welding is one of the welding processes. The welding process can be performed either manually or automatically. Usually in industries, most of the part will be produced in mass production. Therefore, in order to achieve a good outcome, implementation of automation in the process should be done.

In the twenty first century, most of the process involved in the industry will be automated. In addition to that, variety of tasks such as complex assembly, part and material handling, hazardous and monotonous task can be executed repeatedly without sacrificing the precision and quality, thus increasing the productivity of a company and reducing the manufacturing time and cost. With the advance technology applied to the system, such as the electronic analog or digital sensor and complex control system, the machine can cope itself in various working condition.

In oil and gas pipe line welding, most of the welding process are performed by automated welding machines. The machine operate automatically based on the programs and the parameters defined by the welders and can perform dedicated movements on a weld joint that is highly repeatable in shapes such as circle, arc and longitudinal seams. As mentioned before, the machine can cope with various type of working condition and welding application. The weld equipment operations are positioned normally fixed to perform a basic geometric welding application. In general, the main character of welding automation are the machine systems and the welding position equipment. Some of the components are welding lathes, turn tables positioners, circle welders, and longitudinal seam welders. Whether the machine is large or small, the same concept and principle for positioning are used.

The applications of automatic manipulator has increased from time to time. This is due to the significant increase of the need for a precise and uniform quality part from a mass production. However, in some industries especially when there is chemical process involved, employers hiring laborers such as children to work in dangerous, hazardous and highly risky polluted environment. Machine can be employed instead of human in those harmful situations.

1.2 Problem Statement

In general, welding can be the hardest and difficult in manufacturing process and in term of understanding. Due to this condition, the shortage of man power specialized in the field occur. For example, the demand for welders in the Metro-Detroit area is very high. Even if there is an individual with such skill, it is still going to be expensive to find, train and retain them. Instead of spending a lot of money to find and train several number of welders, why not just hiring one great welders that can monitor the weldment or work quality of several welding machines.

Regarding the quality, it is impossible for the human to have the same weldment quality throughout each product. A lot of factors are taking part in this condition such as the fatigue, emotions and boredom due the welds in the same spots for a many times.

The possibility of the part to be damaged, scrapped and being hold due to quality notification are high. Thus increasing the cost of the production and increasing the total time to market. Welding can be dangerous and hazardous towards the welders if no proper precautions are taken. Some may cause a severe injury and even death. Examples of the safety issues related to welding are:

I. **Electric shock.** Electric shock happens when welders touch two pieces of metal that have a voltage between them, along these lines embedding themselves into the electrical circuit.

II. **Fumes and Gases.** Welding smoke contains possibly unsafe complex metal oxide mixes from consumables, base metal, and the base-metal coatings, so it's critical to keep your head out of the exhaust and utilize enough ventilation and/or fumes to control your exposure to substances in the smoke, contingent upon the kind of pole and base metal being utilized.

III. **Fire and explosions.** The welding arc will produce a very high temperatures and may represent a critical blaze and blast risk if safe practices are not implemented.

IV. **Injuries from Insufficient PPE**. Personal protective equipment helps to keep welding operators free from injury, such as burns--the most common welding injury--and exposure to arc rays. The right PPE takes into account opportunity of development while even now giving satisfactory security from welding hazards.

1.3 Objectives

The project are identified to have the following objectives:

1. To establish the hardware design, material and motor sizing for the automated welding manipulator that is specialized for oil and gas pipeline welding.
2. To simulate the automatic fixture movement using 3D modelling software.

1.4 Scope of Study

The main part of this project is to design the automatic welding manipulator for oil and gas pipeline. The machine should be able to weld a pipe from with the diameter range from ½ inch to 6 inch. The design should include the positioner for the pipe. In addition, positioner for metal plate can also be included. At the end of the project, the machine should be able to be operate and can perform the welding whether on pipeline or metal plate. The weldment quality should be measure on certain standard.

CHAPTER 2: LITERATURE REVIEW

2.1 Arc Welding

One of the common method in joining metals is arc welding. This is done by melting the metal with a high intense heat between two parts. This will cause them to intermix - directly, or more commonly, with an intermediate molten filler metal. A metallurgical bond will be created during the cooling and solidification process. The final might have different properties such as strength and chemically since the joining is an intermixture of metals.

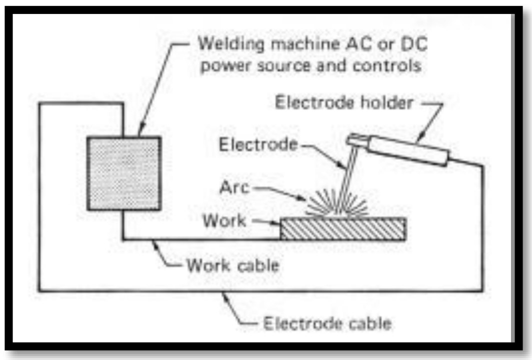


Figure 1: Arc welding circuit

2.2 Manipulator

In general, manipulator is a device used to manipulate materials or object without making any physical contact. A manipulator can handle variety of jobs that is beyond the capabilities of human right from material handling and complex assembly tasks. In welding, manipulator mainly used for handling and controlling the torch movement.

Table 1: Summary of literatures on welding manipulator

Author/Year	Objective of the paper	Parameters studied	Summary
Md. Anisul Haque (2013)	1. Establish hardware design of a robotic manipulator for arc welding 2. Establish a circuit and program (C language) for the operated designed manipulator.	1. Work envelop geometry 2. Motion control technology 3. Working mechanism of manipulator.	1. The manipulator can move in linear and vertical motion within the specified velocity. 2. The motion control of the manipulator is established by controlling the motors using the H-bridge circuit through parallel port of the computer.
Ai-min Li (2011)	1. Establish mechanical design used for the carbon dioxide gas welding. 2. Integrate human machine interface into the control system.	1. Mechanical design of the automatic welding machine. 2. Control system of the welding machine which consist of programmable logic controller (PLC) and	1. PLC control is simple, easy to maintain and can increase the efficiency for circular weld.

		human machine interface (HMI).	
Y.D. Patel (2011)	1. The applications of parallel manipulators for industry.	1. Comparison between parallel and serial manipulator. 2. Classification of parallel manipulators.	1. One of the basic features of parallel mechanisms like Stewart platform, Hexaglides, hexa-pods and delta robots consist of suitable behavior for dynamical applications where high speed operation makes important the dynamics of the system
Richard W. (1962)	1. Six axis manipulator.	1. This invention relates to a machine having 6 degree of freedom for positioning a work head such as a spot welder in universal work processing relationship with respect to articles moving past the machine.	1. 6-ais manipulator is suitable for digital programmed control movement to achieve universal work processing relationships.

Figure 2: Column and boom manipulator

In welding area, the most common manipulators used are the column and boom manipulator and robotic arm manipulator. Nowadays, a lot of fabrication industries such as petrochemical, submarine manufacture, nuclear and conventional power generation plant, on shore and offshore has implemented the column and boom manipulators for their automated welding process. The columns usually will be installed on two types of base which**:** a steel fabricated base where the column is stationary, the other is a traversing base or bogie to allow it to move along a suitable track way. In order to enable the column to rotate 360 degree, it will be installed together with the slewing rings. The main purpose of the column and the boom is to hold the automatic welding head to carry automatic welding heads which could be TIG, Plasma, MIG or submerged arc welding heads to weld either longitudinal seams or circumferential seams with rotators. Usually, column and boom manipulators are used together with welding rotators in order to performed longitudinal and circumferential welding at the best position of down hand welding. They can also be used with welding positioners for automatic circumferential welding.

Figure 3: Robotic manipulator

The main part of robotic manipulator is the robot arm. Robotic manipulator can handle two types of welding which is spot and arc welding. For spot welding, the robot arm will be programmed for a specific coordinate's series. The robot arm should also should have wrist with good dexterity and large degree of freedom since the parts that will be joined might be complex or irregular. This will allow the end tool to align properly to the programmed coordinate without crashing with the other portion of the parts.

Arc welding using robotic manipulator was also has been massively implemented especially in automobile industry. Cartesian robotic manipulator (which can move in linear motion) which is specifically made for this single application is most usually the choice. If the part needed to be positioned and hold accurately at a certain parameters, the complex two-dimensional path can be pre-taught and no external sensors are needed.

2.3 Positioners

Positioners are one of the main elements in the process of production. They are required in almost all of the manufacturing, assembly and inspections process. Welding positioners is an advanced implement that helps perform welding [1]. It functions by keeping the work piece in place when being welded. the work piece need to be positioned and supported in proper position and location in order to prevent the work piece from being distorted during the welding process. The work piece needs to be place carefully and the clamping need to be light in order to prevent any damage occur to the work piece but still, it is need to be firm. The placement of the clamping elements must be clear from the welding area. The positioner also need to be stable and rigid enough to withstand the welding process. In addition, it also provide some relative, progressive, smooth movement between the torch of a fusion welding head and the joint to be welded [1]. Since the elements is moving in a simple lines, it is considered as relative movement. In conventional welding methods, a welding table is used. Although a welding table is very useful in certain ways, the limitation of no intrinsic movement has make it fall shorts on the above definition. Welding positioners is a must have tool for a highly productive mechanically assisted manual welding for those different process that supply filter filler metal continuously from a spool (GMAW,SAW) or for GTAW with thin sections if filler metal is not required [1].

Weld positioners available in a lot of design and features with the objective to help in producing the best output in the welding working area. In addition, in can reduce the risk and hazard for the welders that are working with heavy machinery. However, weld positioner are not meant to be used by only in the heavy machinery sectors, others such as automotive, heavy construction, oil and pipe, and defense industries also utilized it. In addition, it is also being applied by the agricultural industry as well.

Since weld positioners has been well known as a tool that can help increase the productivity rate, many manufacturing company has established variety of design and features for welding positioners such as sliding tailstock trunnions, ferris wheel positioners, five-axis positioners, L-hook positioners, and dual trunnion turntables.

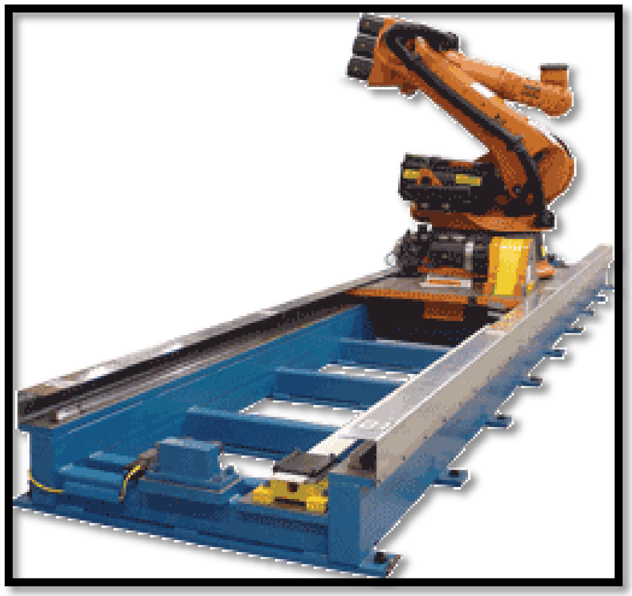


Figure 4: Sliding tailstock trunnions

Sliding tailstock trunnions consists of a floor-mounted headstock utilizing precision-bearing, high-quality alloy pinion and large tool mounting plates. It can handle multiple payloads quickly and precisely by aligning the tailstock attached to a servo-driven rack and pinion slide. These positioners are coordinated with a robot by means of the robot's auxiliary axis.

Figure 5: A drop center positioner

A drop center positioner can handle extremely heavy and long parts. Nowadays, a drop center positioners commonly used in the agricultural industry for GMAW applications. It is also have been proven that drop center positioners are reliable for use on any kind of weld in any industry.

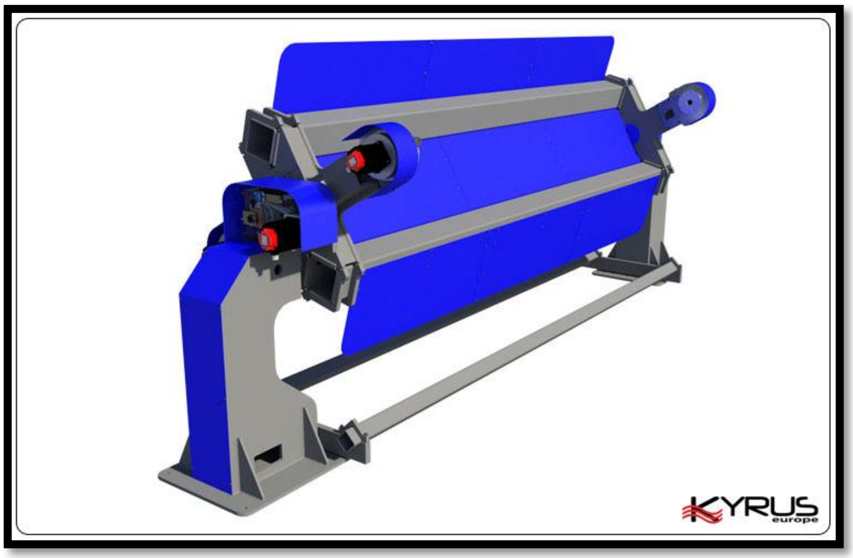


Figure 6: Ferris wheel positioners

Ferris wheel positioners normally already integrate with the robot arm purchased. Ferris wheel positioners consist of 16-ft-long horizontal exchange axis to reduce station footprint while accommodating longer parts. To protect the welders or operator from the arc flash, a barrier from the metal arc scree is created. Ferris wheel positioners are very convenient as they can handle longer parts in a small work space area.

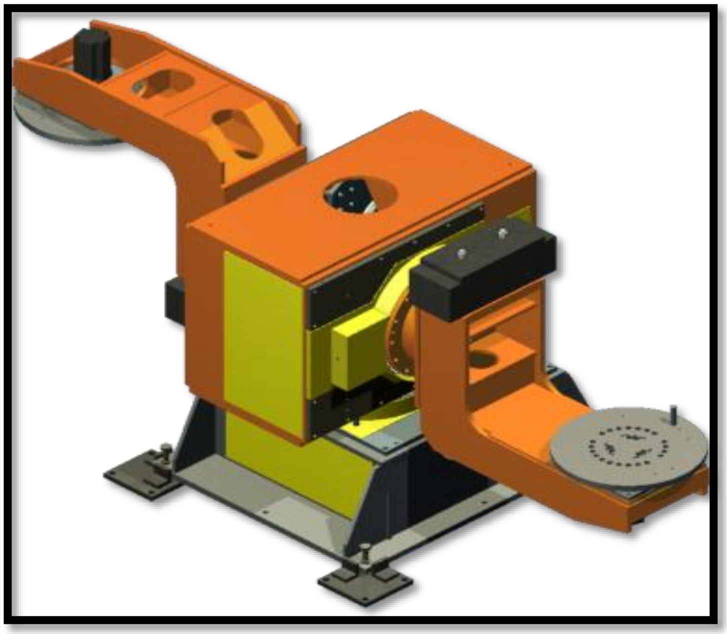


Figure 7: L-hook positioners

L-hook positioners are two-axis positioners that consists a robust, four-point contact with a ball radial bearing and pinion with 360-deg rotation on both the main and the table axis [2]. L-hook positioners are mostly used for agricultural equipment.

Author/Year	Objective of the paper	Parameters studied	Summary
Ranjeet Mithari (2014)	1. Design of Multi-Axis welding positioner with auto indexing	1. Auto indexing	1. Multi axis welding positioner with auto indexing reduces operator fatigue considerably. Because of this automation we achieved rise in production. 2. Reduce in rejected part.
Prof. S. N. Shinde (2014)	1. Provide a supporting structure having greater capabilities and not only being used more expediously but also of handling structural assemblies which are bulky to be handled manually.	2. Center of gravity	1. A few other considerations for calculations that would ultimately improve the quality of the welding fixture are stress analysis and cost benefit analysis. 2. Stress analysis and friction analysis would both help in the selection of material to be used for each part of the machine

Prof. N. B. Totala	1. Design, manufacturing and testing of circular welding positioner.	1. System design 2. Components of system 3. Chances of failure 4. Weight of machine	1. Multiple indexer positions, enables to make staggered welded joints.

Table 2: Summary of literatures on welding positioners

CHAPTER 3: METHODOLOGY

3.1 Literature review

The analysis was mainly done on the type of manipulators and positioners. To be more details on the matter, the author would like to study the main characteristics of manipulators and positioners which include the degree of freedom of the manipulator, the eases of the positioners and mechanism of both manipulators and positioners. Resources that was obtained from the journals, books, articles and web pages from the internet has help the author a lot in the analysis.

3.2 Drawing, Modelling and Simulation

The drawing and modelling for this project will be done using SolidWorks 2015. The technique used in developing this model are sketch and extrude. Sketch is use to create basic dimension of the 2D drawing. Then, that 2D drawing is develop into 3D geometry by using extrude. In conceptual design, two designs have been develop and proposes.

3.2.1 SolidWorks 2015

SolidWorks is a solid modeler, and utilizes a parametric feature-based approach to create models and assemblies [3]. The software is written on Parasolid-kernel [3].

Parameters can be defined as the constraints value that will determine the geometric shape of the model or assembly. It can exists either in numeric parameters for example, length of a line or diameter of a circle, or geometric parameters such as tangent, parallel and concentric. Usually, geometric parameters are used in assembly drawing. Numeric parameters can be associated with each other by the use of relation, which allow them to capture design intent [3].

Design intent can be define as the design or shape that is intended to be created by the creator. For example, the creator want to extrude a cylindrical shape on the side of a box and stay at the box, regardless of the height or size of the box, even after some alterations. Solidworks will allow the user to specify the cylindrical shape at the side of a box, and will then honor their design intent no matter what height they later assign to the can [3].

Features can be refer as the building block of the part that has been created. The part is constructed by the shapes and operations programmed by the creator. Shape-based features usually started with a 2D sketch of the shapes such as holes or boxes [3]. The sketched shape will be extruded or cut forming a 3D model. Operation-based features are not sketch based. In order to use the operation based features such as fillet or chamfer, a 3D model needed to be construct first.

For beginners, it is advised that they start to build a model by using 2D sketch. From the sketch, few parameters geometry need to be define such as points, lines, arc and circle. Dimension will be added to the sketch using the Smart Dimension features. The location of the sketch of the sketch can also be determined. The parametric nature of SolidWorks means that the dimensions and relations drive the geometry, not the other way around [3]. The dimensions in the sketch can be controlled independently, or by relationships to other parameters inside or outside of the sketch [3].

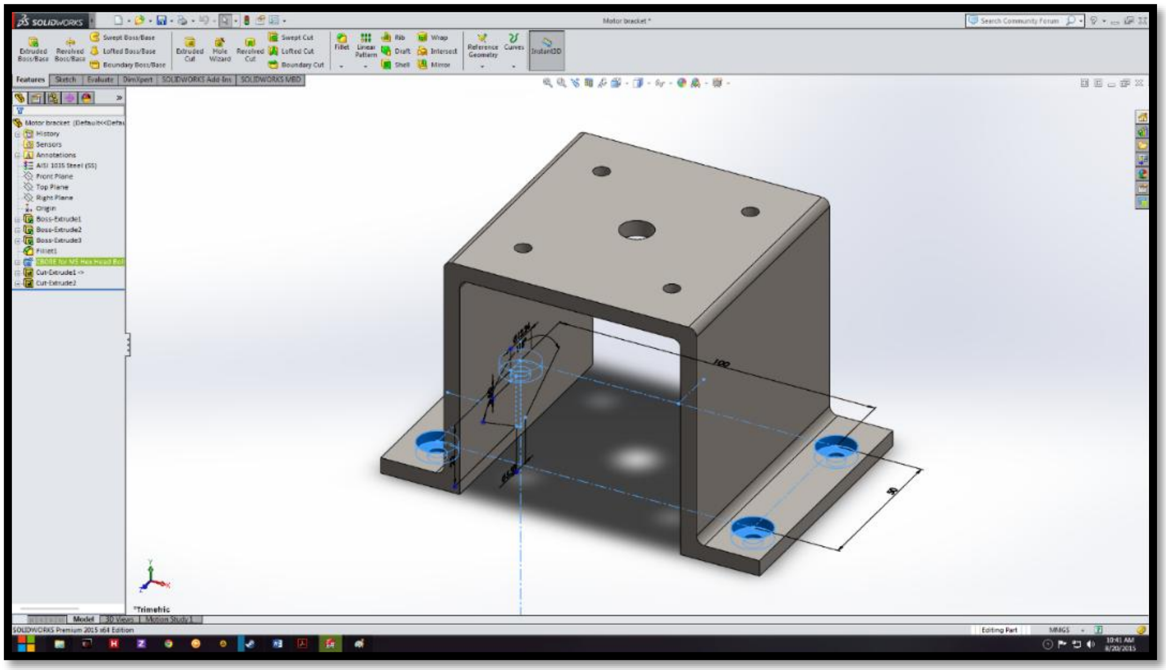


Figure 8: Part drawing

In as assembly, the relations needed to be defined are called mates. Mates relations consists of several conditions such as tangency, parallelism, and concentricity with respect to sketch geometry. Assembly mates define equivalent relations with respect to the individual parts or components, allowing the easy construction of assemblies [3]. There is also advance matting features included in the software such as the matting of rack and pinion, gear, train and cam and follower.

Finally, 2D drawing can be generated either form parts or assembly. The views are automatically generated from the solid model, and notes, dimensions and tolerances can then be easily added to the drawing as needed [3].

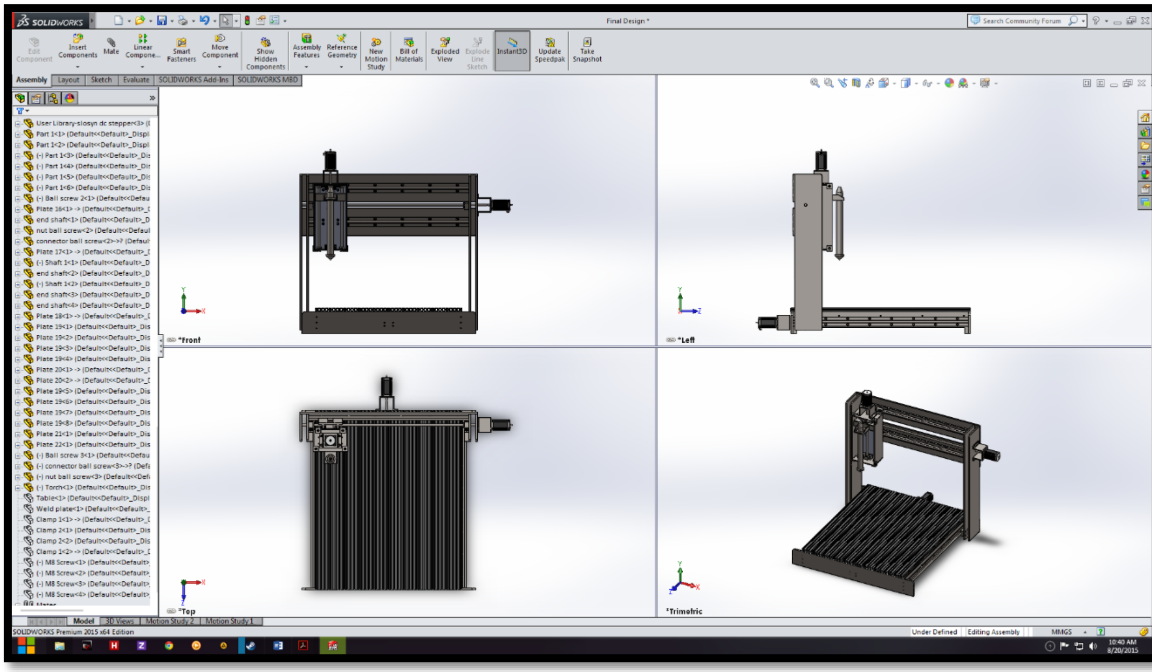


Figure 9: Assembly drawing

3.3 Conceptual Design

A few conceptual design for the welding manipulator has been established throughout the project time period. The design has been established by referring to the currently existing and prototype found on the research paper, journal and catalogue of manipulators company. All of the design are built in SolidWorks 2015 software.

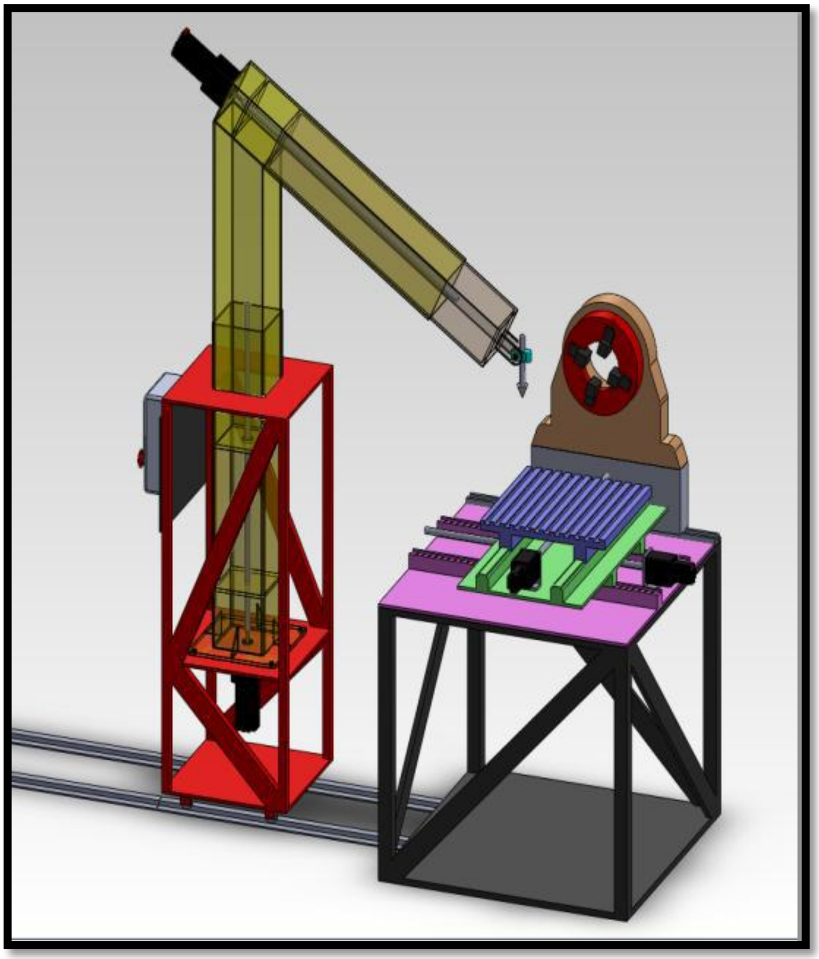


Figure 10: Conceptual design 1

For conceptual design 1, the main concept is referred to the design that has been established by . The design is more to the robotic arm concept but with less degree of freedom. The curved beam's angle is 45 degree and it is moved by the power screw that is driven by the servo motor. This will helps to achieve the linear motion of the whole curved beam in the vertical direction accurately. The total displacement of the beam is 800m. Similar to the beam, the telescopic arm can also in linear motion in the direction of the 45 degree. The telescopic arm is moved by a power screw which is driven by another servo motor. The stroke of the telescopic arm, is 600m. Between curved beam and the chassis, and between the telescopic arm and curved beam there are connections by the rail of sliding block keeping a smooth and accurate linear motion movement. Four truckles, two of them are universal wheel that can rotate in 360 degree with plane brake, while the other two are common truckles. The welding chassis can be removed before the welding process begin. The aligning of the torch to the welding line can be easy by the help of the two linear movement and the movement of the truckles.

The positioners consists of a chuck and table. The table can travelled in x-axis and y-axis direction. It is moved by a power screw driven by two servos motors. Both of the axis can travel 300m in each direction. The chuck is can handle the pipe with the diameter ranging from ½ inch to 6 inch.

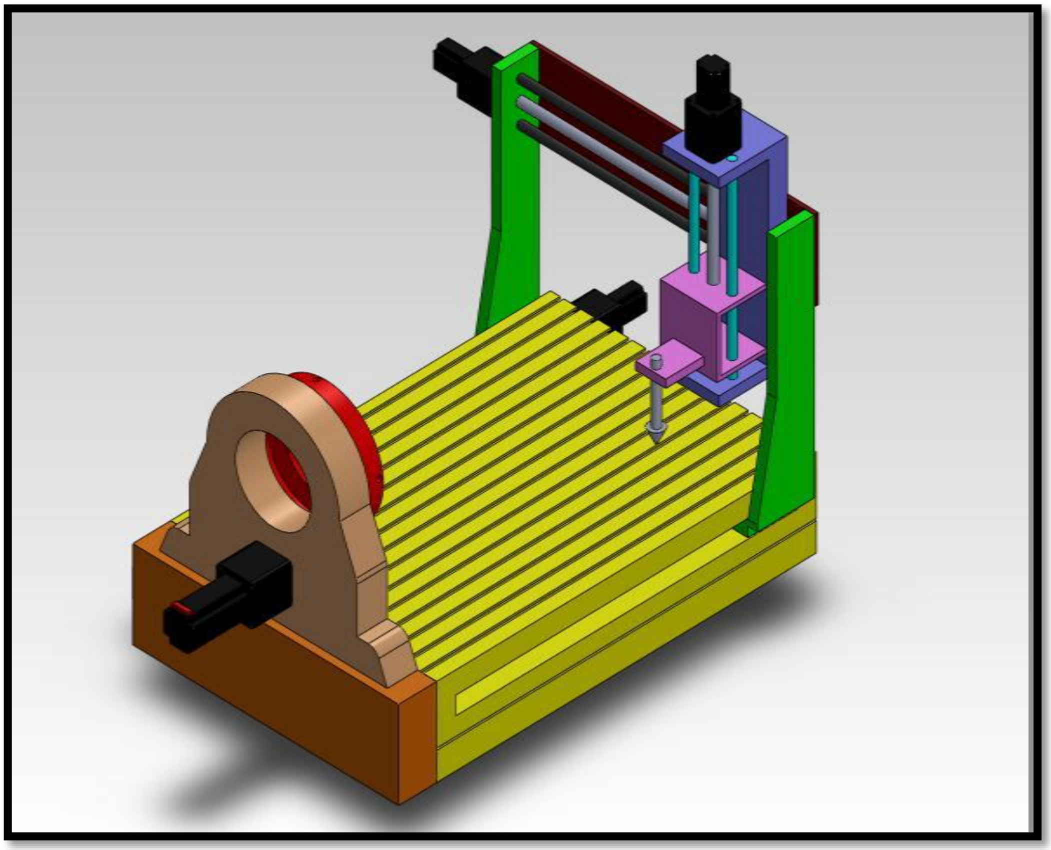
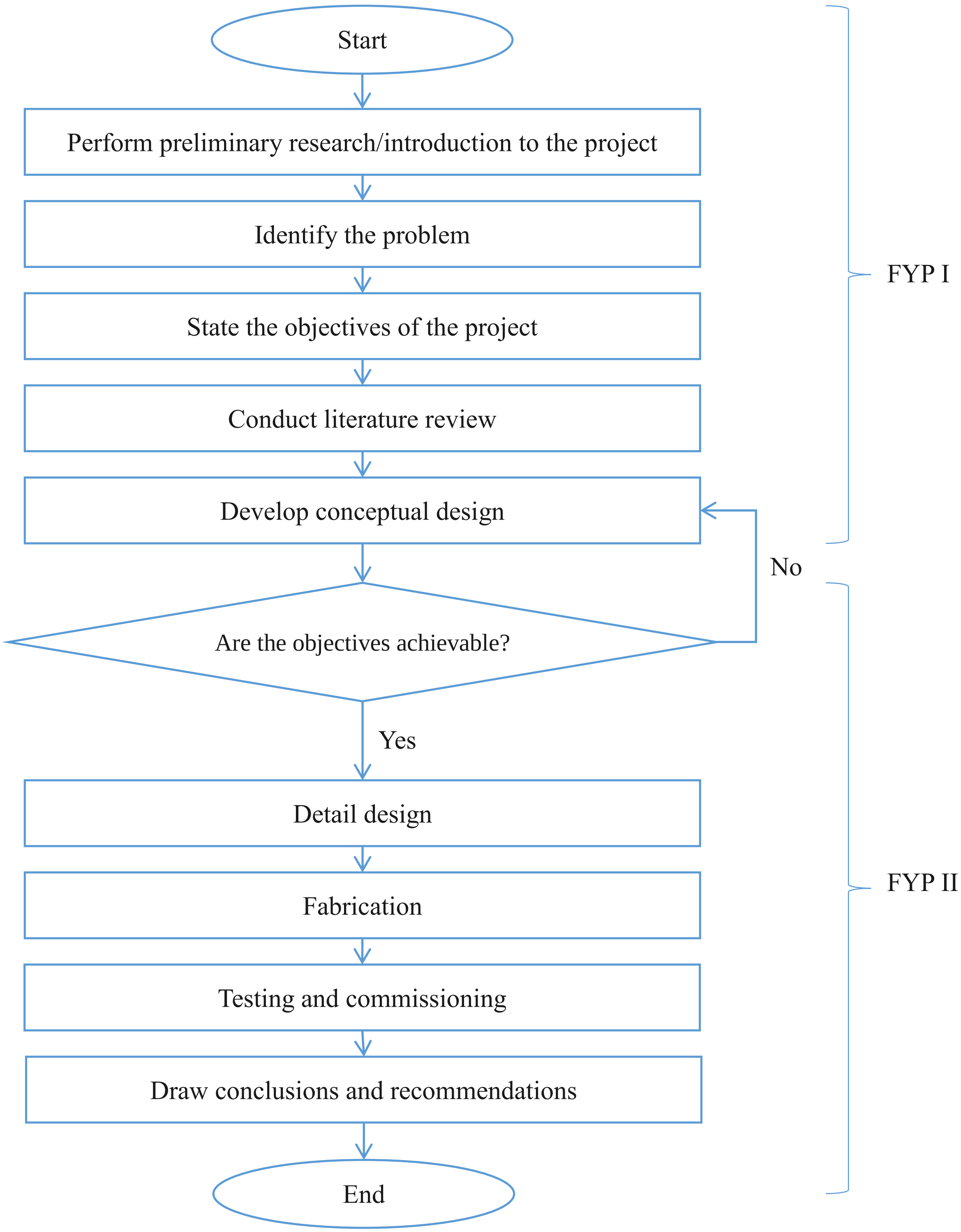


Figure 11: Conceptual design 2

The mechanism for the movement of manipulators mostly are linear motion. The concept of the manipulators are much more like gantry design. There will be 4 motors in the design, 3 motors will be controlling the movement of the welding torch while the other one will be use to rotate the positioners. Motor 1 can move the bracket in x-axis direction. The travel distance of the bracket along the x-axis direction is 0.7 meter. In a similar way, Motor 2 can move the smaller bracket in y –axis direction. The travel distance of the bracket along the y-axis direction is 0.5 meter. Motor 3 will control the height of the weld torch which is z-axis. The torch can travel in the height distance of 0.2 meter. Motor 4 will rotate the chuck. The chuck can handle pipe with a diameter ranging from ½ inch to 6 inch. The table is fixed and cannot be moved. For flat metal welding process, chuck is not needed. If the torch cannot reach the metal, another table will be use to increase the height of the metal plate.

3.3 Project Flowchart

A proposed project workflow is as illustrated below:



3.4 Project Gantt chart

3.4.1 FYP 1

No	Activities/week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Tittle selection														
2	Weekly meeting with supervisor														
3	Literature review study														
4	Extended proposal submission														
5	Conceptual design														
6	Proposal defence														
7	Detail design														
	i. Material selection														
	ii. Motor and part sizing														
8	Interim report submission														

Table 1: Gantt chart for FYP 1

3.4.2 FYP 2

No	Activities/week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Submission to vendor for fabrication														
2	Weekly meeting with supervisor														
3	Fabrication														
4	Testing and commissioning														
5	Submission of progress report														
6	Pre-SEDEX														
7	Submission of draft final report														
8	Submission of dissertation														
9	Submission of technical paper														
10	Viva presentation														
11	Submission of project dissertation														

Table 2: Gantt chart for FYP 2

3.5 Key Milestones

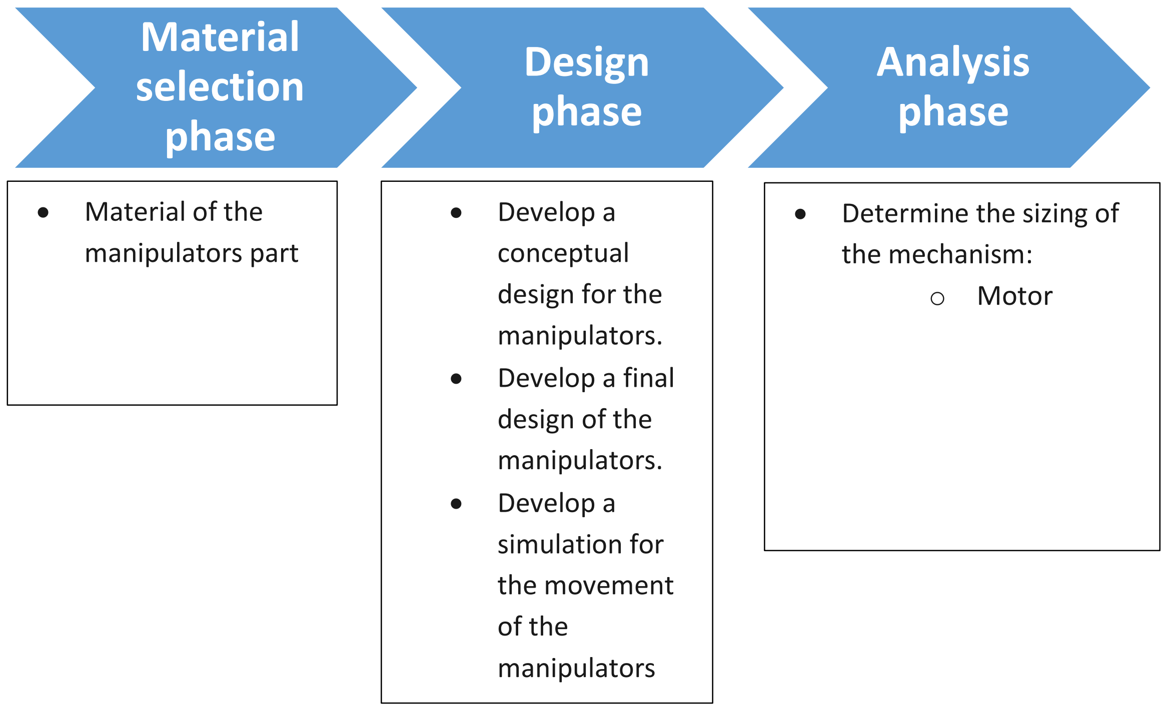


Figure 12: Key milestone

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Material

The material that is suitable to make the part of the machine are AISI 1035 steel. 1035 steel is most commonly characterized as a medium carbon grade, and as such is a popular "work horse" grade of steel. 1035 steel is often supplied in hot rolled, cold drawn, turned & polished, annealed and or coated conditions; both in bar lengths or packaged into wire rod. AISI 1035 steel is a relatively low cost, medium strength steel and is common in a wide variety of general purpose applications. AISI 1035 steel is higher in strength and hardness than low carbon steel.

Table 13: Mechanical properties of AISI 1035 steel

Properties	Metric	Imperial
Tensile strength, ultimate	585 MPa	84800 psi
Tensile strength, yield	370 MPa	53700 psi
Modulus of elasticity	190-210 GPa	29700-30458 ksi
Bulk modulus (typical for steel)	140 GPa	20300 ksi
Shear modulus (typical for steel)	80 GPa	11600 ksi
Poisson's ratio	0.27-0.30	0.27-0.30
Elongation at break (in 50 mm)	30%	30%
Reduction of area	53%	53%
Hardness, Brinell	183	183
Hardness, Knoop (converted from Brinell hardness)	204	204
Hardness, Rockwell B (converted from Brinell hardness)	89	89
Hardness, Vickers (converted from Brinell hardness)	192	192
Machinability (based on AISI 1212 steel. as 100 machinability)	65	65

Table 14: Thermal properties of AISI 1035 steel

Thermal Properties	Metric	Imperial
Thermal expansion co-efficient (@20°C/68°F)	11 µm/m°C	6.11 µin/in°F
Thermal conductivity	51.9 W/mK	360 BTU in/hr.ft^2.°F

4.2 Design Justification

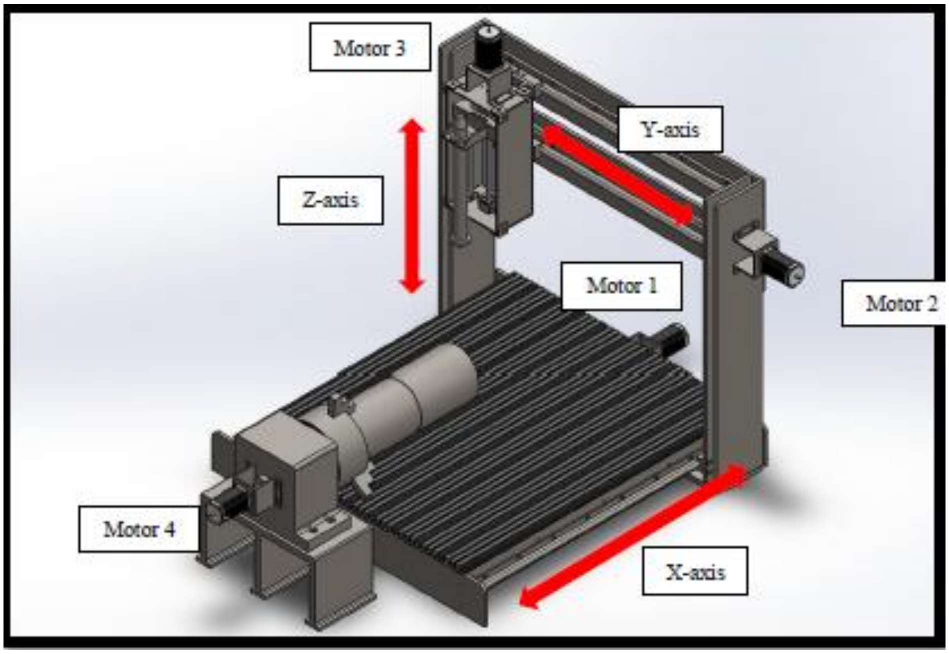


Figure 13: Final design (pipeline welding)

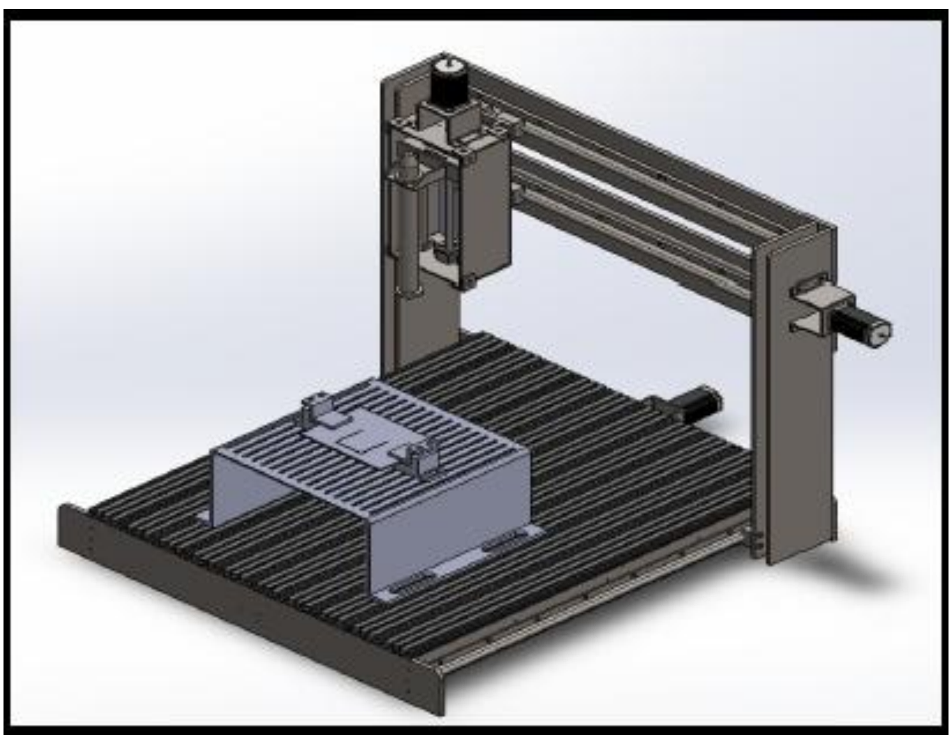


Figure 14: Final design (Plate welding)

The mechanism for the movement of manipulators mostly are linear motion. The concept of the manipulators are much more like gantry design. There will be 4 motors in the design, 3 motors will be controlling the movement of the welding torch while the other one will be use to rotate the positioners. Motor 1 can move the bracket in x-axis direction. The travel distance of the bracket along the x-axis direction is 0.8 meter. In a similar way, Motor 2 can move the smaller bracket in y –axis direction. The travel distance of the bracket along the y-axis direction is 0.75 meter. Motor 3 will control the height of the weld torch which is z-axis. The torch can travel in the height distance of 0.3 meter. Motor 4 will rotate the chuck. The chuck can handle pipe with a diameter ranging from ½ inch to 6 inch. The table is fixed and cannot be moved. For flat metal welding process, chuck is not needed. If the torch cannot reach the metal, another table will be use to increase the height of the metal plate.

4.3 Motor

4.3.1 Motor Sizing

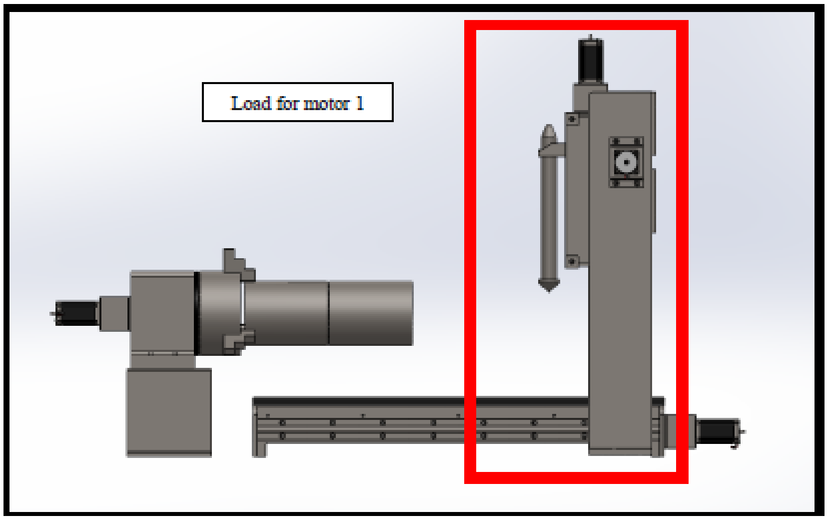


Figure 15: Motor 1 calculation diagram

From the software, we will obtain the approximate load of the parts by determining the type of material. For motor 1, the load that need to move by the motor is approximately 56.12 kg. Based on calculation:

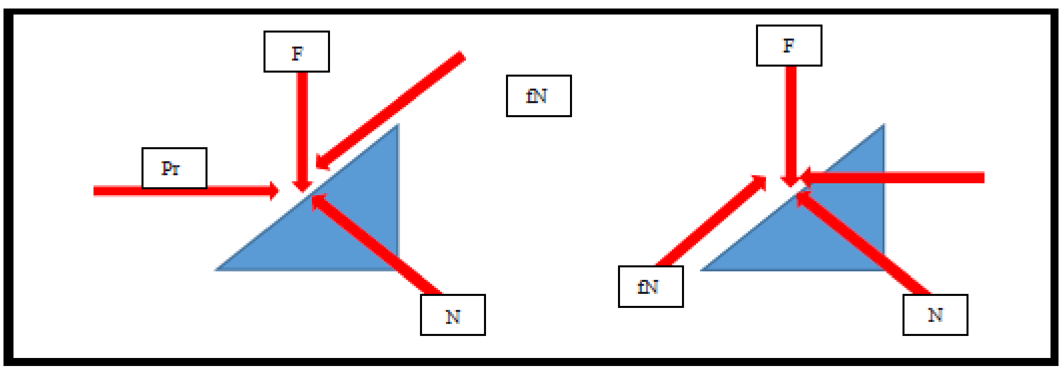


Figure 16: Free body diagram of power screw

To raise the load, a force Pr acts to the right. To lower the load, Pl acts to the left. For raising the load we have:

$$\sum F_H = P_R - N\sin\lambda - f\,N\cos\lambda = 0$$

$$\sum F_V = F + f\,N\sin\lambda - N\cos\lambda = 0$$

In a similar manner, for lowering the load, we have:

$$\sum F_H = -P_L - N\sin\lambda + f\ N\cos\lambda = 0$$
$$\sum F_V = F - f\ N\sin\lambda - N\cos\lambda = 0$$

Since we are not interested in the normal force *N*, we eliminate it from each of these sets of equations and solve the result for P. For raising the load, this gives:

$$P_R = \frac{F(\sin\lambda + f\cos\lambda)}{\cos\lambda - f\sin\lambda}$$

and for lowering the load:

$$P_L = \frac{F\times(f\cos\lambda - \sin\lambda)}{\cos\lambda + f\sin\lambda}$$

Next, divide the numerator and the denominator of these equations by cos k and use the relation tan k = *l* /o *dm*. We then have:

$$P_R = \frac{F\left[(l/\pi\,d_m) + f\right]}{1 - (f\ l/\pi\,d_m)}$$

$$P_L = \frac{F\times\left[f - (l/\pi\times d_m)\right]}{1 + (f\times l/\pi\times d_m)}$$

Finally noting that the torque is the product of the force *P* and the mean radius dm / 2, for raising the load we can write:

$$T_R = \frac{Fd_m}{2}\times\left(\frac{l + \pi\ f\ d_m}{\pi\ d_m - f\ l}\right)$$

Where *TR* is the torque required for two purposes; to overcome thread friction and to raise the load. The torque required to lower the load:

$$T_L = \frac{Fd_m}{2}\left(\frac{\pi\ f\ d_m - l}{\pi\ d_m + f\ l}\right)$$

Load, F	= 140 kg = 1373.4N
Power screw major diameter	= 13mm
Pitch	= 4mm
Collar diameter	= 20mm
Collar friction, fc	= 0.08

$$d_m = d - \frac{p}{2} = 13 - \frac{4}{2} = 11mm$$

$$l = np = 4(2) = 8mm$$

For safety factor, the value of F is time by 2, therefore, F = 2746.8N

To raise the load, the force required is:

$$P_R = \frac{F\left[\left(\frac{l}{\pi d_m}\right) + f\right]}{1 - \left(\frac{fl}{\pi d_m}\right)} = \frac{2746.8\left[\frac{8}{\pi(11)} + (0.08)\right]}{1 - \frac{(0.08)(8)}{\pi(11)}} = 873.0847N$$

To lower the load, the force required is:

$$P_L = \frac{F\left[f - \left(\frac{l}{\pi d_m}\right)\right]}{1 + f\left(\frac{l}{\pi d_m}\right)} = \frac{2746.8\left[0.08 - \frac{8}{\pi(11)}\right]}{1 + 0.08\left(\frac{8}{\pi 11}\right)} = -416.135N$$

The torque required to raise and lower the load are:

$$T_R = \frac{Fd_m}{2}\left[\frac{l + \pi f d_m}{\pi d_m - fl}\right] + \frac{Ff_c d_c}{2}$$

$$T_R = \frac{(2746.8)(11)}{2}\left[\frac{8 + \pi(0.08)(11)}{\pi(0.018) - (0.08)(8)}\right] + \frac{873.0847(0.08)(20)}{2}$$

$$T_R = 6992.529Nm$$

$$T_L = \frac{Fd_m}{2}\left(\frac{\pi f d_m - l}{\pi d_m + fl}\right) + \frac{Ff_c d_c}{2}$$

$$T_L = \frac{(2746.8)(11)}{2}\left[\frac{\pi(0.08)(13) - 8}{\pi(13) + (0.08)(8)}\right] + \frac{873.0847(0.08)(20)}{2}$$

$$= 470.6642Nm$$

$$T = \frac{P_w 9.554}{n}$$

Where Pw is the power of the motor = watts

Speed of the motor, n = revolution per minute (rpm)

In this case, the max value of torque which is the raise torque will be used and the value of motor speed is 100 rpm.

Therefore,

$$T = \frac{P_w 9.554}{n}$$

$$P_w = \frac{Tn}{9.554}$$

$$P_w = \frac{6992.529Nm(100)}{9.554}$$

$$P_w = 7.32kW$$

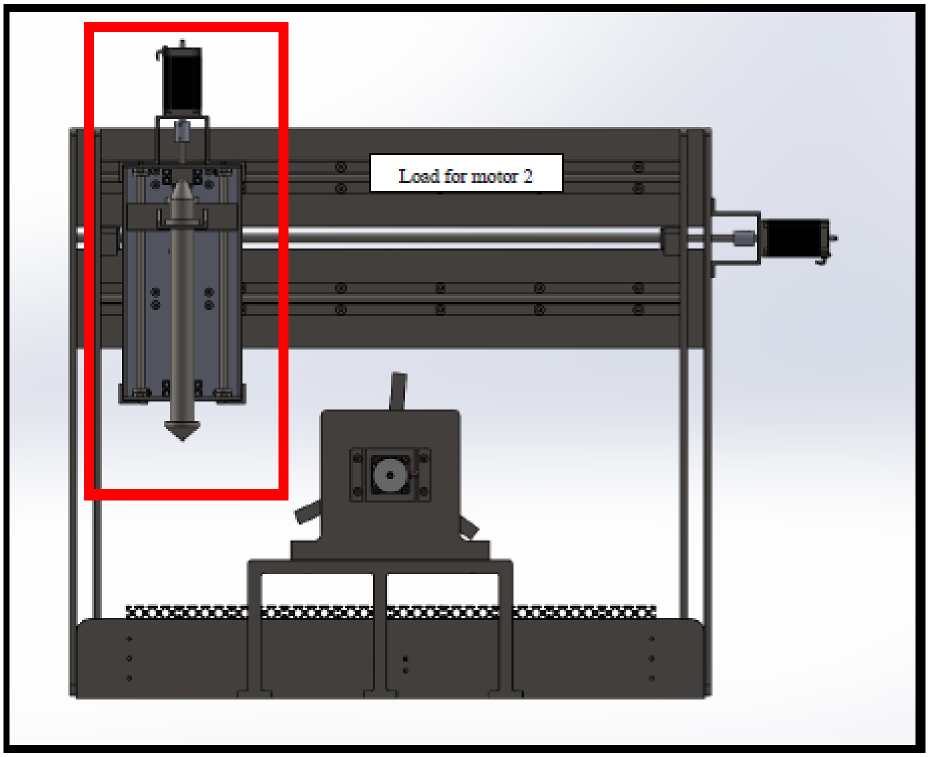


Figure 17: Motor 2 calculation diagram

Load, F	= 25 kg = 245.25N
Power screw major diameter	= 13mm
Pitch	= 4mm
Collar diameter	= 20mm
Collar friction, fc	= 0.08

$$d_m = d - \frac{p}{2} = 13 - \frac{4}{2} = 11mm$$

$$l = np = 4(2) = 8mm$$

For safety factor, the value of F is time by 2, therefore, F = 490.5N

To raise the load, the force required is:

$$P_R = \frac{F\left[\left(\frac{l}{\pi d_m}\right) + f\right]}{1 - \left(\frac{fl}{\pi d_m}\right)} = \frac{490.5\left[\frac{8}{\pi(11)} + (0.08)\right]}{1 - \frac{(0.08)(8)}{\pi(11)}} = 155.908N$$

To lower the load, the force required is:

$$P_L = \frac{F\left[f - \left(\frac{l}{\pi d_m}\right)\right]}{1 + f\left(\frac{l}{\pi d_m}\right)} = \frac{490.5\left[0.08 - \frac{8}{\pi(11)}\right]}{1 + 0.08\left(\frac{8}{\pi 11}\right)} = -72.9586N$$

The torque required to raise and lower the load are:

$$T_R = \frac{Fd_m}{2}\left[\frac{l + \pi f d_m}{\pi d_m - fl}\right] + \frac{Ff_c d_c}{2}$$

$$T_R = \frac{(2746.8)(11)}{2}\left[\frac{8 + \pi(0.08)(11)}{\pi(0.018) - (0.08)(8)}\right] + \frac{327.85(0.08)(20)}{2}$$

$$T_R = 1248.666Nm$$

$$T_L = \frac{Fd_m}{2}\left(\frac{\pi f d_m - l}{\pi d_m + fl}\right) + \frac{Ff_c d_c}{2}$$

$$T_L = \frac{(2746.8)(11)}{2}\left[\frac{\pi(0.08)(13) - 8}{\pi(13) + (0.08)(8)}\right] + \frac{327.85(0.08)(20)}{2} = 470.6642Nm$$

$$T = \frac{P_w 9.554}{n}$$

Where Pw is the power of the motor = watts

Speed of the motor, n = revolution per minute (rpm)

In this case, the max value of torque which is the raise torque will be used and the value of motor speed is 100 rpm.

Therefore,

$$T = \frac{P_w 9.554}{n}$$

$$P_w = \frac{Tn}{9.554}$$

$$P_w = \frac{1248.666Nm(100)}{9.554}$$

$$P_w = 1.31kW$$

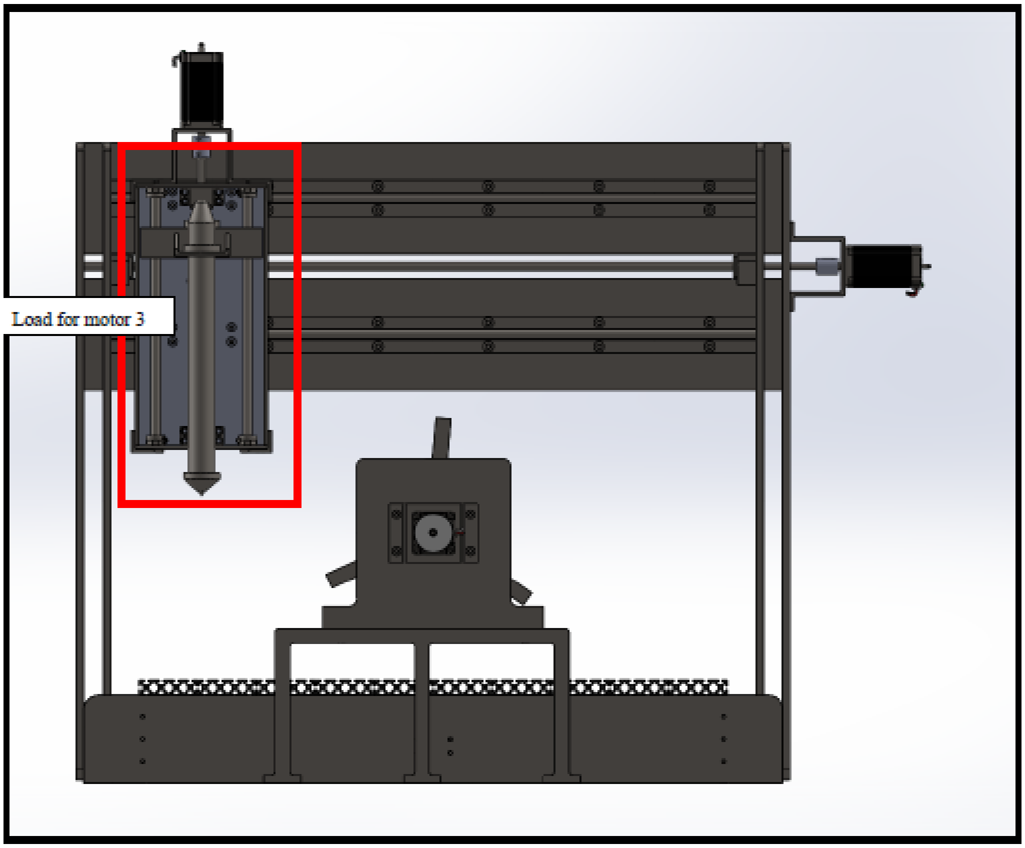


Figure 18: Motor 3 calculation diagram

Load, F	= 10 kg = 98.10N
Power screw major diameter	= 13mm
Pitch	= 4mm
Collar diameter	= 20mm
Collar friction, fc	= 0.08

$$d_m = d - \frac{p}{2} = 13 - \frac{4}{2} = 11mm$$

$$l = np = 4(2) = 8mm$$

For safety factor, the value of F is time by 2, therefore, F = 196.20N

To raise the load, the force required is:

$$P_R = \frac{F\left[\left(\frac{l}{\pi d_m}\right) + f\right]}{1 - \left(\frac{fl}{\pi d_m}\right)} = \frac{196.20\left[\frac{8}{\pi(11)} + (0.08)\right]}{1 - \frac{(0.08)(8)}{\pi(11)}} = 62.3632N$$

To lower the load, the force required is:

$$P_L = \frac{F\left[f - \left(\frac{l}{\pi d_m}\right)\right]}{1 + f\left(\frac{l}{\pi d_m}\right)} = \frac{196.20\left[0.08 - \frac{8}{\pi(11)}\right]}{1 + 0.08\left(\frac{8}{\pi 11}\right)} = -29.1835N$$

The torque required to raise and lower the load are:

$$T_R = \frac{Fd_m}{2}\left[\frac{l + \pi f d_m}{\pi d_m - fl}\right] + \frac{F f_c d_c}{2}$$

$$T_R = \frac{(2746.8)(11)}{2}\left[\frac{8 + \pi(0.08)(11)}{\pi(0.018) - (0.08)(8)}\right] + \frac{196.20(0.08)(20)}{2}$$

$$T_R = 499.5663Nm$$

$$T_L = \frac{Fd_m}{2}\left(\frac{\pi f d_m - l}{\pi d_m + fl}\right) + \frac{F f_c d_c}{2}$$

$$T_L = \frac{(2746.8)(11)}{2}\left[\frac{\pi(0.08)(13) - 8}{\pi(13) + (0.08)(8)}\right] + \frac{196.20(0.08)(20)}{2} = 33.6188Nm$$

$$T = \frac{P_w 9.554}{n}$$

Where Pw is the power of the motor = watts

Speed of the motor, n = revolution per minute (rpm)

In this case, the max value of torque which is the raise torque will be used and the value of motor speed is 100 rpm.

Therefore,

$$T = \frac{P_w 9.554}{n}$$

$$P_w = \frac{Tn}{9.554}$$

$$P_w = \frac{499.5663Nm(100)}{9.554}$$

$$P_w = 0.52kW$$

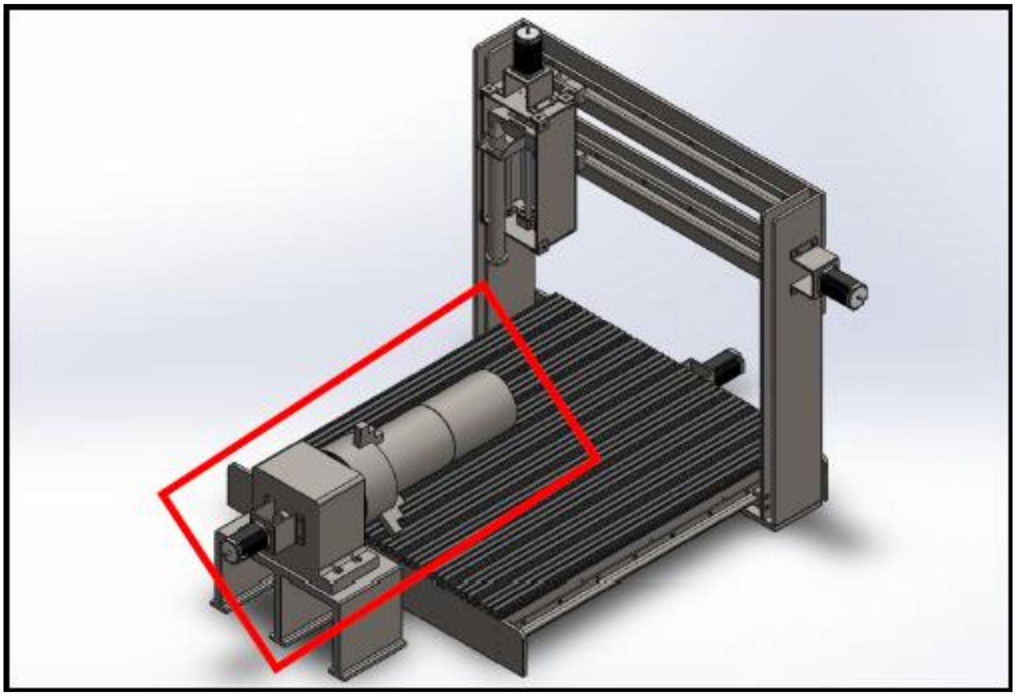


Figure 19: Motor 4 calculation diagram

Load = 98.75kg = 968.7375 N

Radius of motor shaft = 10.30 mm

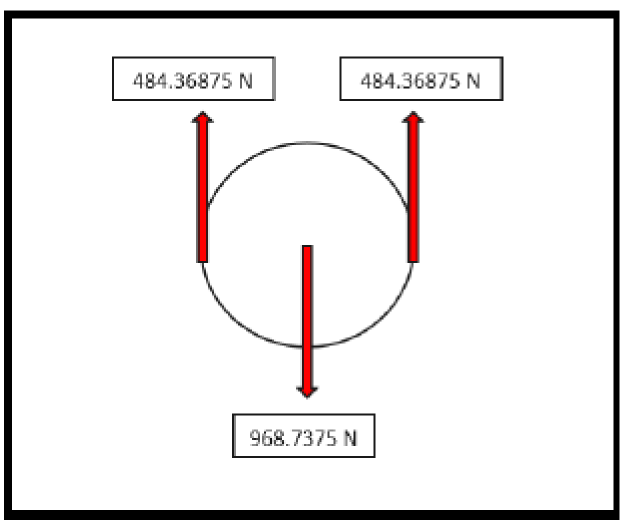


Figure 20: Motor 4 calculation free body diagram

$$T = Fr$$

$$T = (484.36875N)(10.3mm)$$

$$T = 4.9Nm$$

$$T = \frac{P_w 9.554}{n}$$

Where Pw is the power of the motor = watts

Speed of the motor, n = revolution per minute (rpm)

In this case, the max value of torque which is the raise torque will be used and the value of motor speed is 1000 rpm.

Therefore,

$$T = \frac{P_w 9.554}{n}$$

$$P_w = \frac{Tn}{9.554}$$

$$P_w = \frac{4.9Nm(1000)}{9.554}$$

$$P_w = 512.8W$$

4.3.2 Motor Selection

Servo motors are self-contained electric devices that rotate or push parts of a machine with great precision [4]. A servo system made up from three main elements which is - a controlled device, an output sensor and a feedback system. Servo system is an automatic closed loop system. A dc motor will operate by applying variable input signals. Differs from DC motor, Servo motor operates by receiving feedback signal and compare it with the input and output signal. When an input signal is generated to the system, a sensor will detect it and compare the signal thus producing a third signal which is the feedback system. The third signal will acts as the input signal of controlled device. This input signal to the device presents as long as there is a logical difference between reference input signal and output signal of the system [4]. When the system already achieved the desired output, the logical difference between reference input signal and reference output signal of the system is eliminated. Later, the comparison between third signal and the above said signals will not be sufficient enough to operate the system further and to produce further output of the system until the next reference input signal or command signal is applied to the system [4]. Therefore, the main task of the servomechanism is to maintain the output of a system at the desired value in the presence of disturbances.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

By doing the research regarding the process related to welding and positioners, a better knowledge and understanding is achieved. This helps a lot in the effectiveness of the project. From the design, it is believed to have a potential as a finished product. Nowadays, automating a process played a big role in especially in oil and gas industry. However, even the demand is highly extensively, there is still some room for improvement. It is essential that the design satisfies all of the requirements and design parameters which were outlined at the start of the project.

From the above design calculations, it is proven to be applicable to be used in real life. The process of conducting operations related to welding fixtures and positioners helps in gaining a deeper understanding as well as effective project process. From finding a resource for research material to design updates of the part causes the task of accurately prototyping the real design difficult. It is important that the design satisfies all of the functional requirements and design parameters which were outlined at the start of the project. In order to meet the requirements of the fixture customization is done by making the clamping system very practical for various sizes and geometries. By also knowing the material selection a cost benefit analysis could be conducted to determine how cost effective the product is.

For recommendation, stress analysis and friction analysis can be conducted. It would both help in the best material selection to be used for each part of the machine. The calculation can be simulated using the ANSYS software however it is afraid that the rendering time will take too long since there will be a lot of part that need to be simulated. All of these calculations would greatly add to the significance of the research already conducted.

REFERENCES

[1] Prof. N.B.Totala, Sarang S. Bhutada, Nakul R. Katruwar, Rachan R. Rai, Ketan N. Dhumke. (2014). Design, Manufacturing and Testing of Circular Welding Positioner. *International Journal of Engineering Research and Development*.

[2] Ai-min Li, C.-h. Z.-l.-y.-h.-l.-w. (2011). Design of Automatic Welding Machine Based on PLC. *2011 Fourth International Conference on Intelligent Computation Technology and Automation*.
Retrieved from IEEE Xplore Digital Library: http://ieeexplore.ieee.org/

[3] *Wikipedia*. (2015, July 31). Retrieved from Wikipedia Solidworks: https://en.wikipedia.org/wiki/SolidWorks

[4] *Introduction to Servo Motors*. (2012). Retrieved from Science Buddies: http://www.sciencebuddies.org/science-fair-projects/project_ideas/Robotics_ServoMotors.shtml

[5] Cooper, C. N. (1970). Manipulator For Welding Or Cutting Apparatus. *United States Patent*.

Retrieved from: http://www.google.tl/patents/US3543989

[6] Favareto, M. (1982). Manipulator. *United States Patent*.

Retrieved from: http://www.google.com.ar/patents/US4312622

[7] John. P. Fabel, D. N. (1940). Welding Manipulator. *United State Patent Office*.

Retrieved from: http://www.google.tl/patents/US2224958

[8] Md. Anisul Haque1, T. T. (27-28 December, 2013). Design and Development of a Robotic Manipulator for Automatic Arc Welding.

Retrieved from: http://www.gistconpro.com/705-Anisul.pdf

[9] Paul P. Wuesthoti, S. L. (April 24, 1962). Welding Manipulator With Reciprocating Boom. *United State Patent Office*.

Retrieved from: https://www.google.com/patents/US1991128

[10] Prof. S.N.Shinde, S. K. (August-September, 2014). Design of Welding Fixtures and Positiners.

Retrieved from International Journal of Engineering Research and General science: http://ijergs.org/Archives

[11] Ranjeet Mithari, A. P. (3 February 2014). Design of Multi-Axis Welding Positioner with. *International Journal of Innovations in Engineering and Technology (IJIET)*.

Retrieved from International Journal of Innovations in Engineering and Technology: http://ijiet.com/wp-content/uploads/2014/03/9.pdf

[12] Richard W. Yasenchak, F. (1972). Six-axis Manipulator. *United States Patent*.

Retrieved from: http://www.google.com/patents/US3665148

[13] Valentine, L. T. (1975). Welding Manipulator. *United States Patent*.

[14] Y. D. Patel1*, P. M. (2012). Parallel Manipulators Applications—A Survey. *Modern Mechanical Engineering,*.

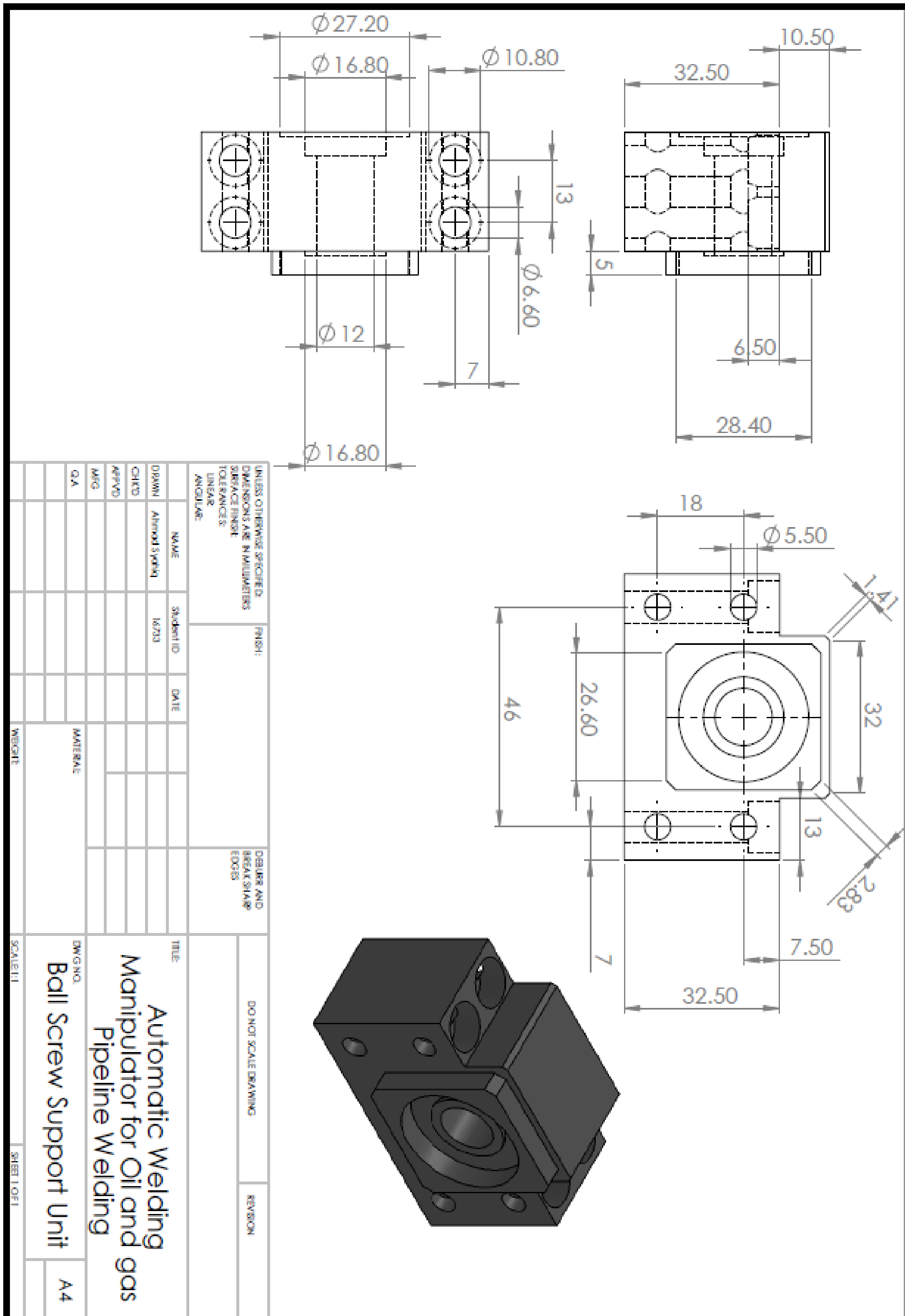
[15] II, D. H. (n.d.). Retrieved from What Can a Welding Positioner Do for You?: http://www.fabtechexpo.com/what-can-a-welding-positioner-do-for-you

[16] Robert, G. (2013, February 20). *Robotiq.* Retrieved from Emerging Applications in Robotic Industrial and Service Blog: http://blog.robotiq.com/bid/63115/Top-5-Advantages-of-Robotic-Welding

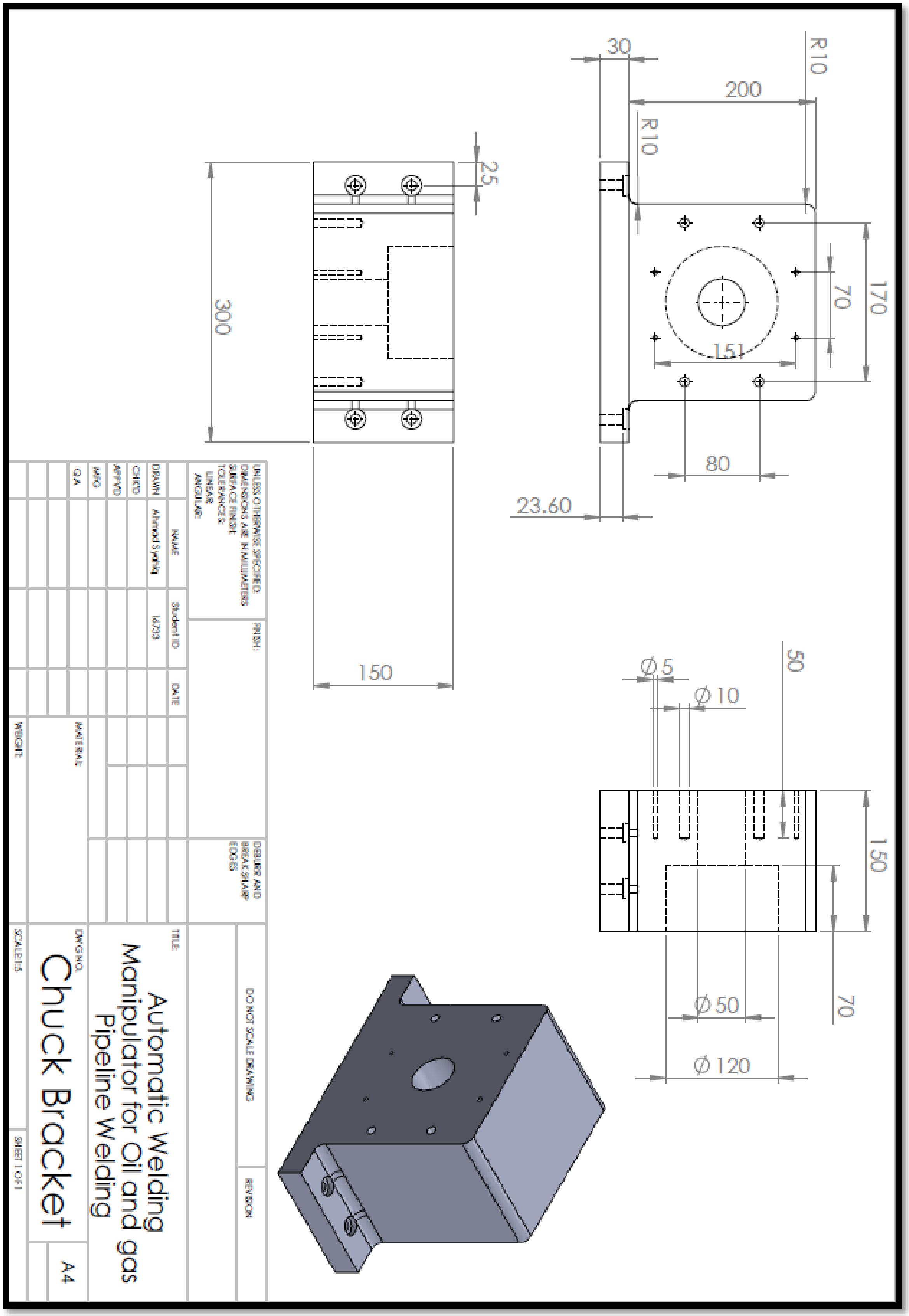
[17] Petkovsek, J. (n.d.). *Be Prepared: Five Potential Welding Safety Hazards to Avoid.* Retrieved from Lincoln Electric Welding Expertise:

http://www.lincolnelectric.com/en-us/support/welding-solutions/Pages/Five-potential-welding-safety-hazards.asp

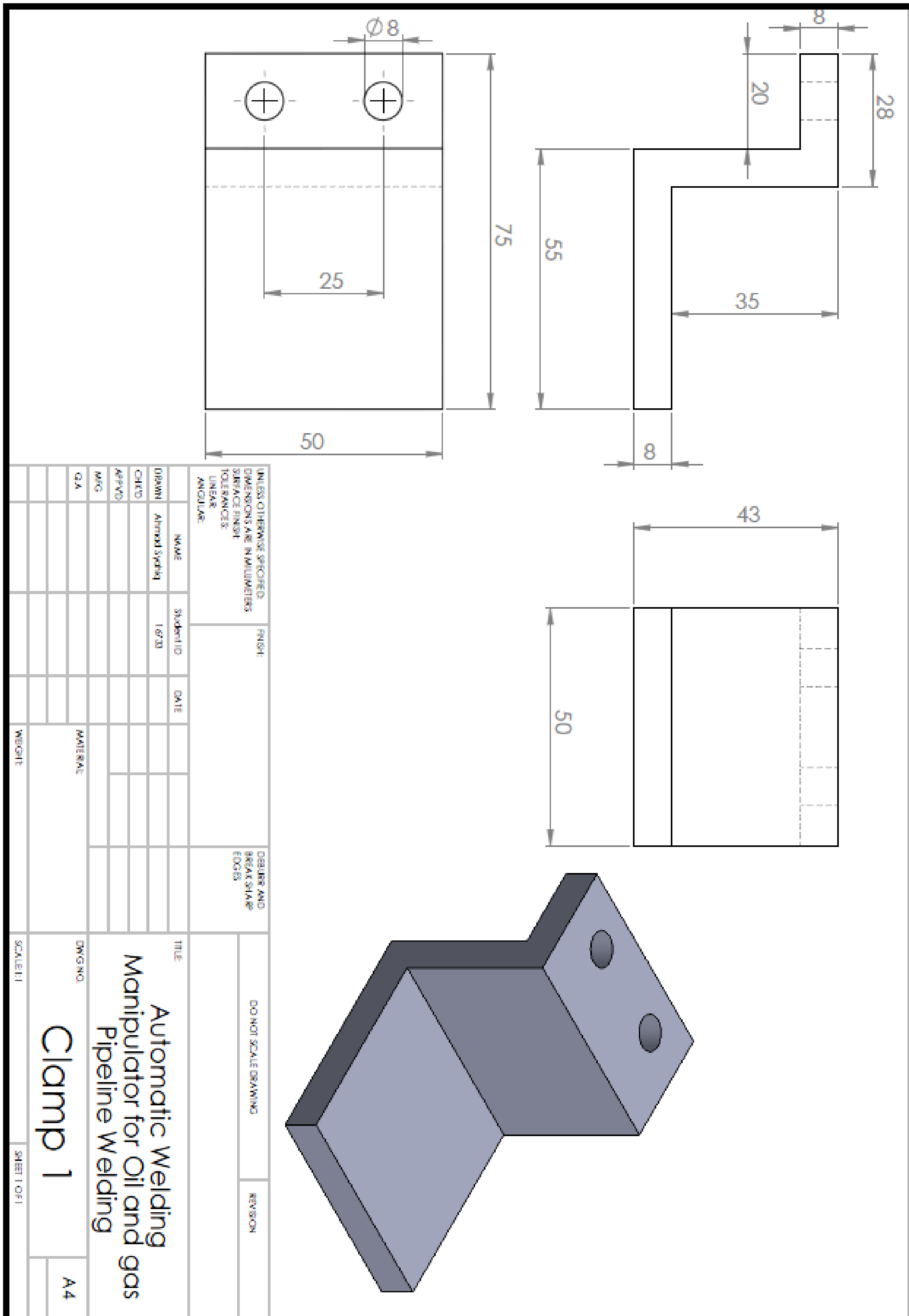
APPENDICES

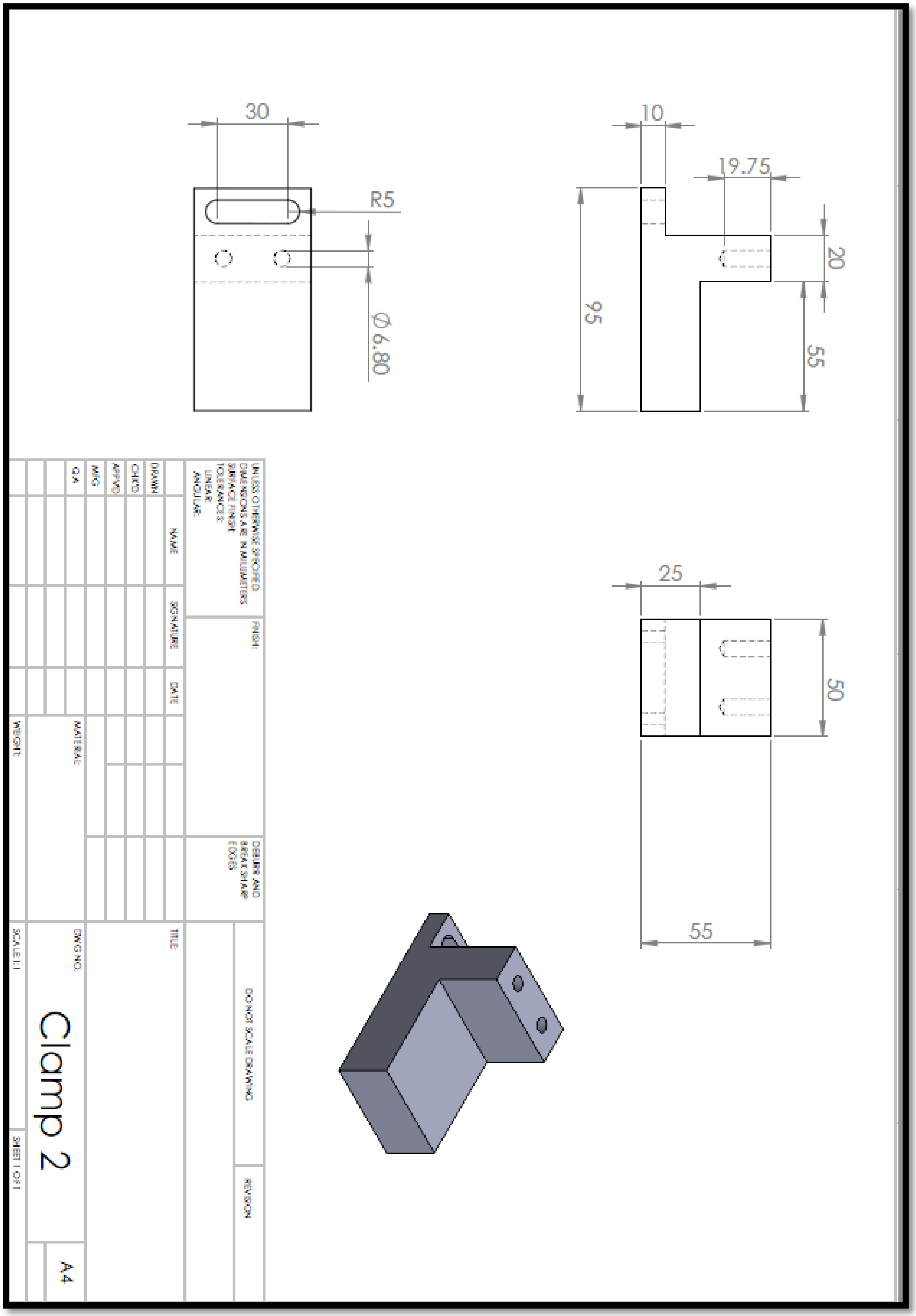


Ø27.20
Ø16.80
Ø10.80
10.50
32.50
13
5
Ø6.60
Ø12
7
6.50
28.40
Ø16.80
18
Ø5.50
1.41
46
26.60
32
13
2.83
7
7.50
32.50
DO NOT SCALE DRAWING
REVISION
TITLE:
Automatic Welding Manipulator for Oil and gas Pipeline Welding
DWG NO.
Ball Screw Support Unit
A4
SCALE:1:1
SHEET 1 OF 1

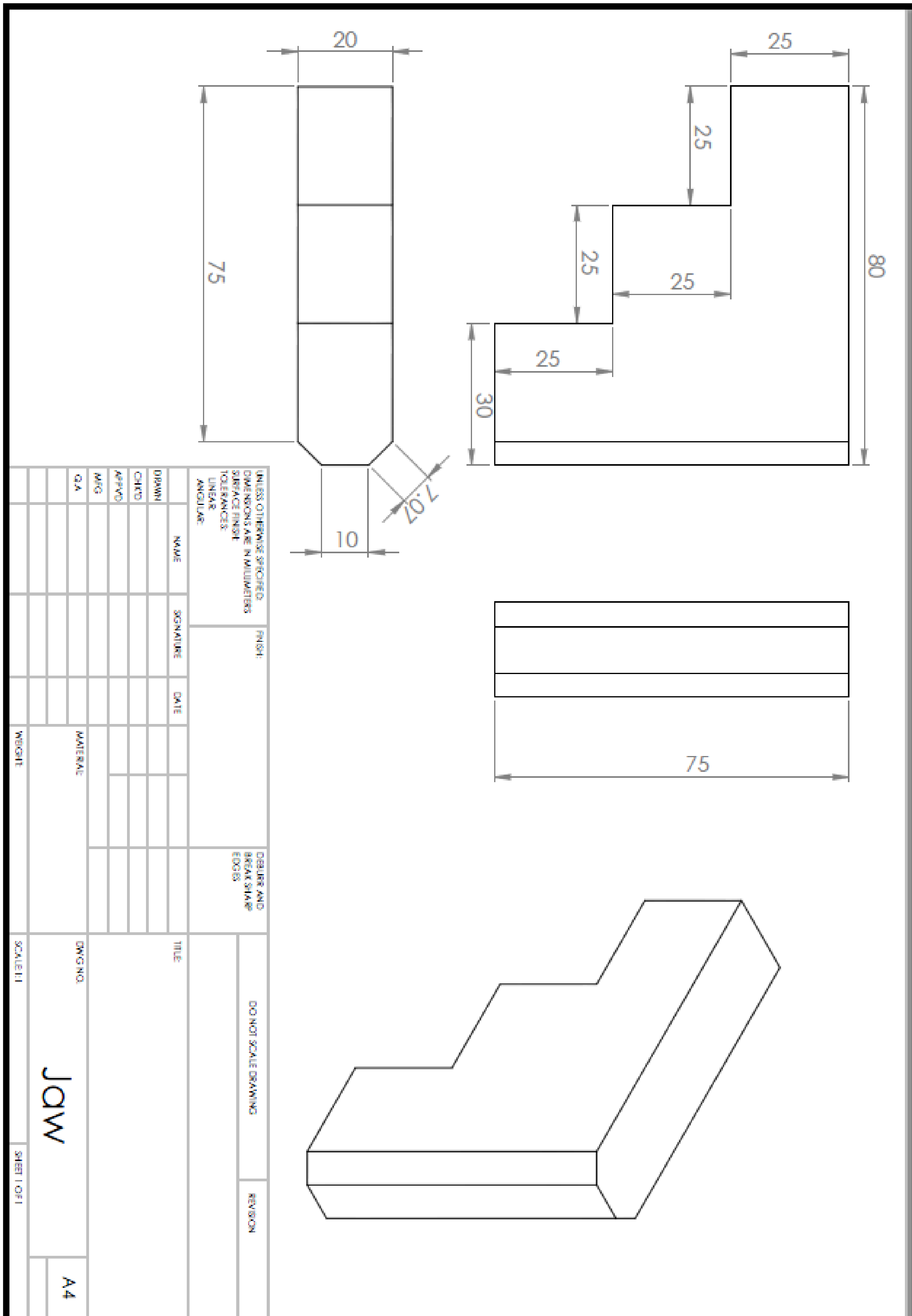


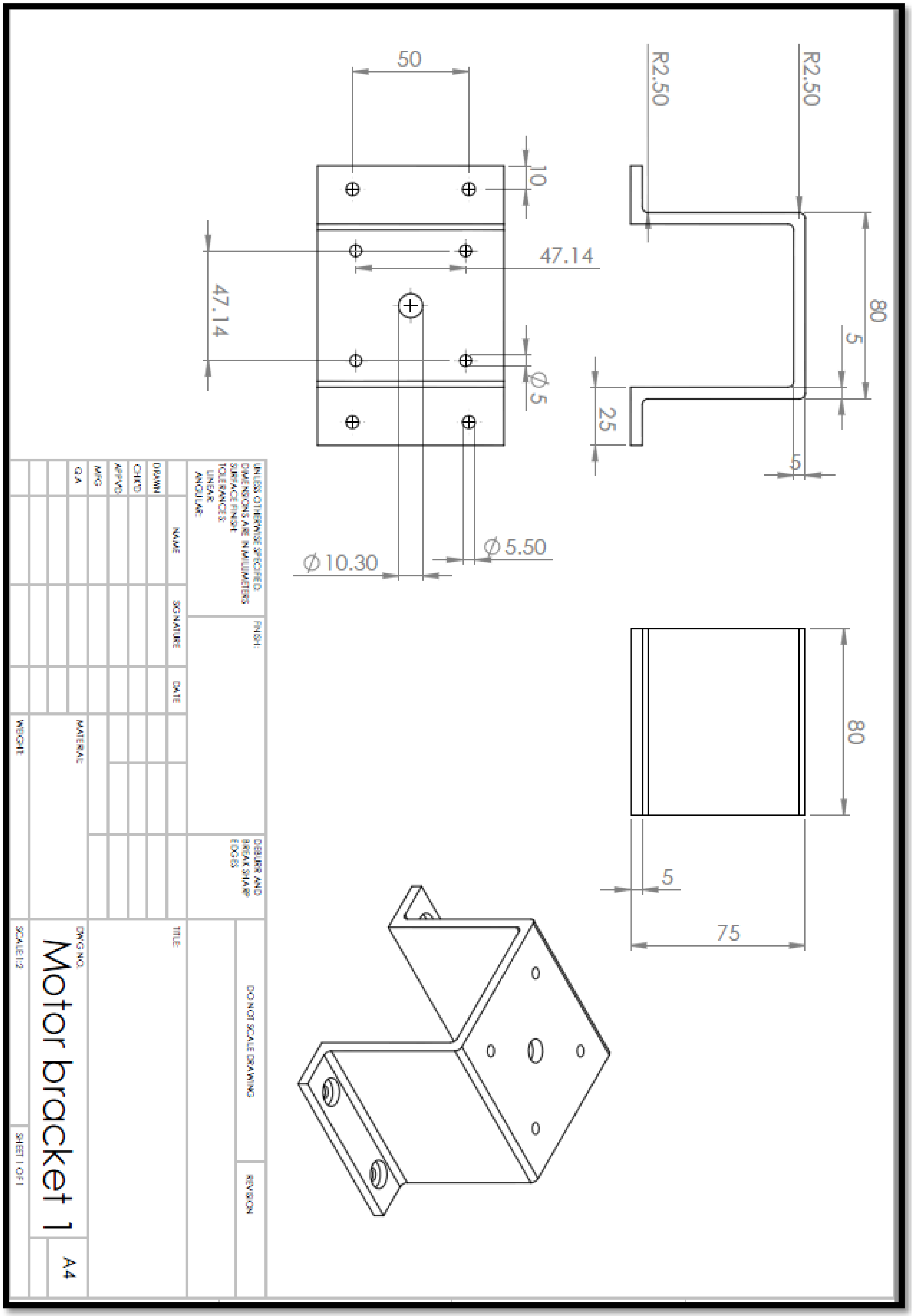
30
R10
200
R10
25
300
170
70
151
80
23.60
150
Ø5
Ø10
50
150
70
Ø50
Ø120
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
Student ID
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
Automatic Welding Manipulator for Oil and gas Pipeline Welding
DWG NO.
Chuck Bracket
A4
SCALE:1:5
SHEET 1 OF 1

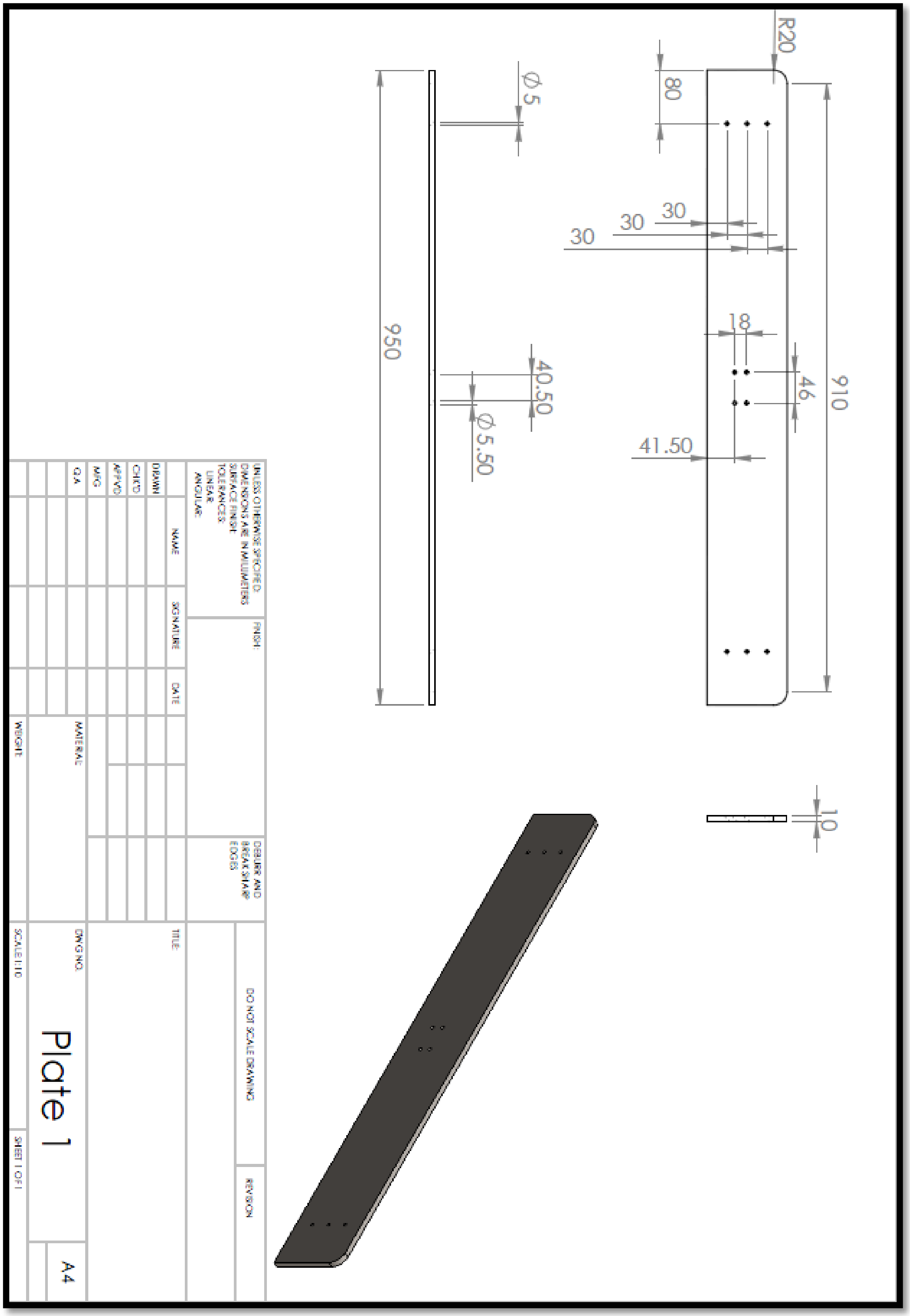

Ø8
8
20
28
75
55
25
35
50
8
43
50
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
Automatic Welding Manipulator for Oil and gas Pipeline Welding
DWG NO.
Clamp 1
A4
SCALE:1:1
SHEET 1 OF 1

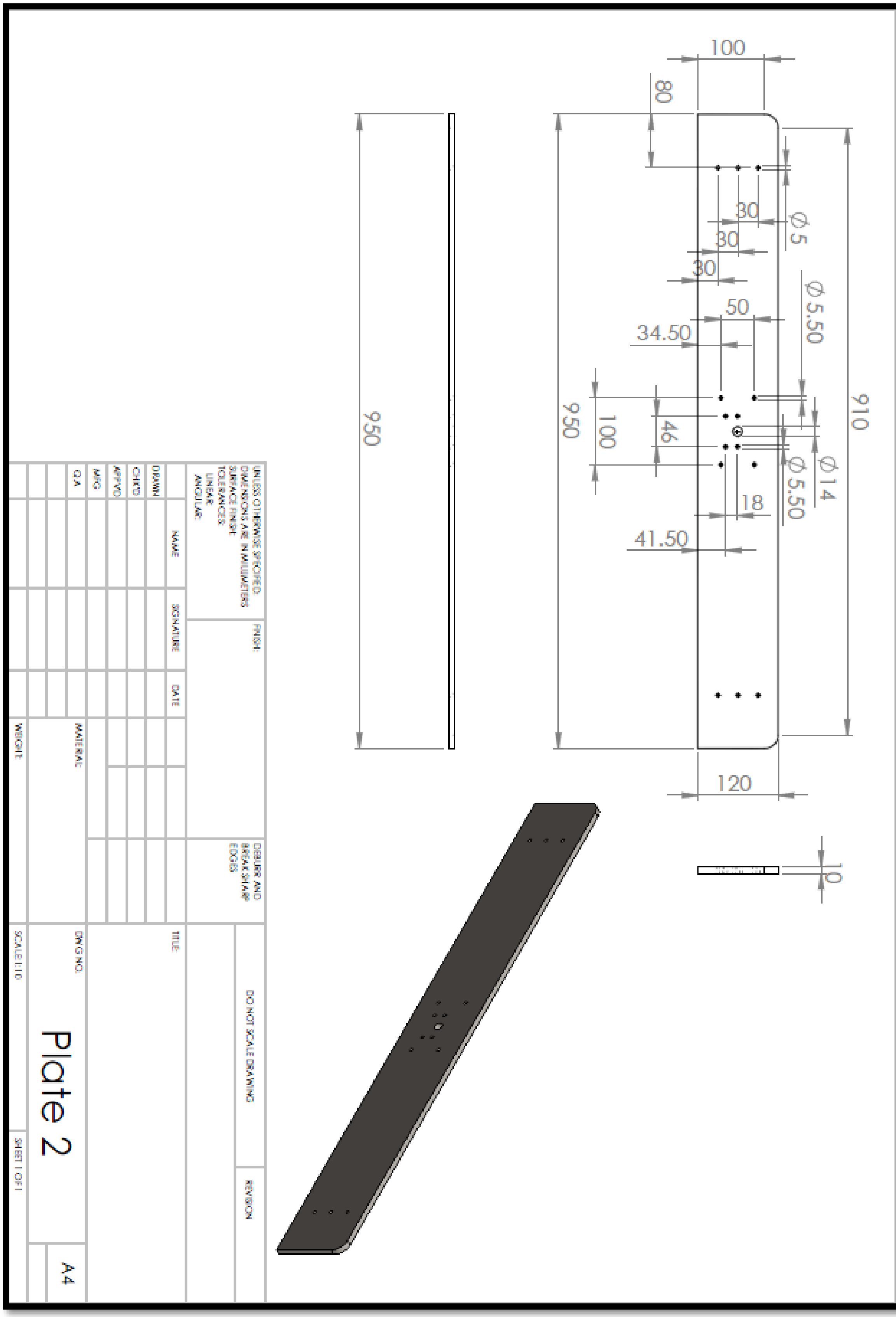


30
R5
Ø6.80
10
19.75
20
95
55
25
50
55
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
DWG NO.
Clamp 2
A4
SCALE:1:1
SHEET 1 OF 1

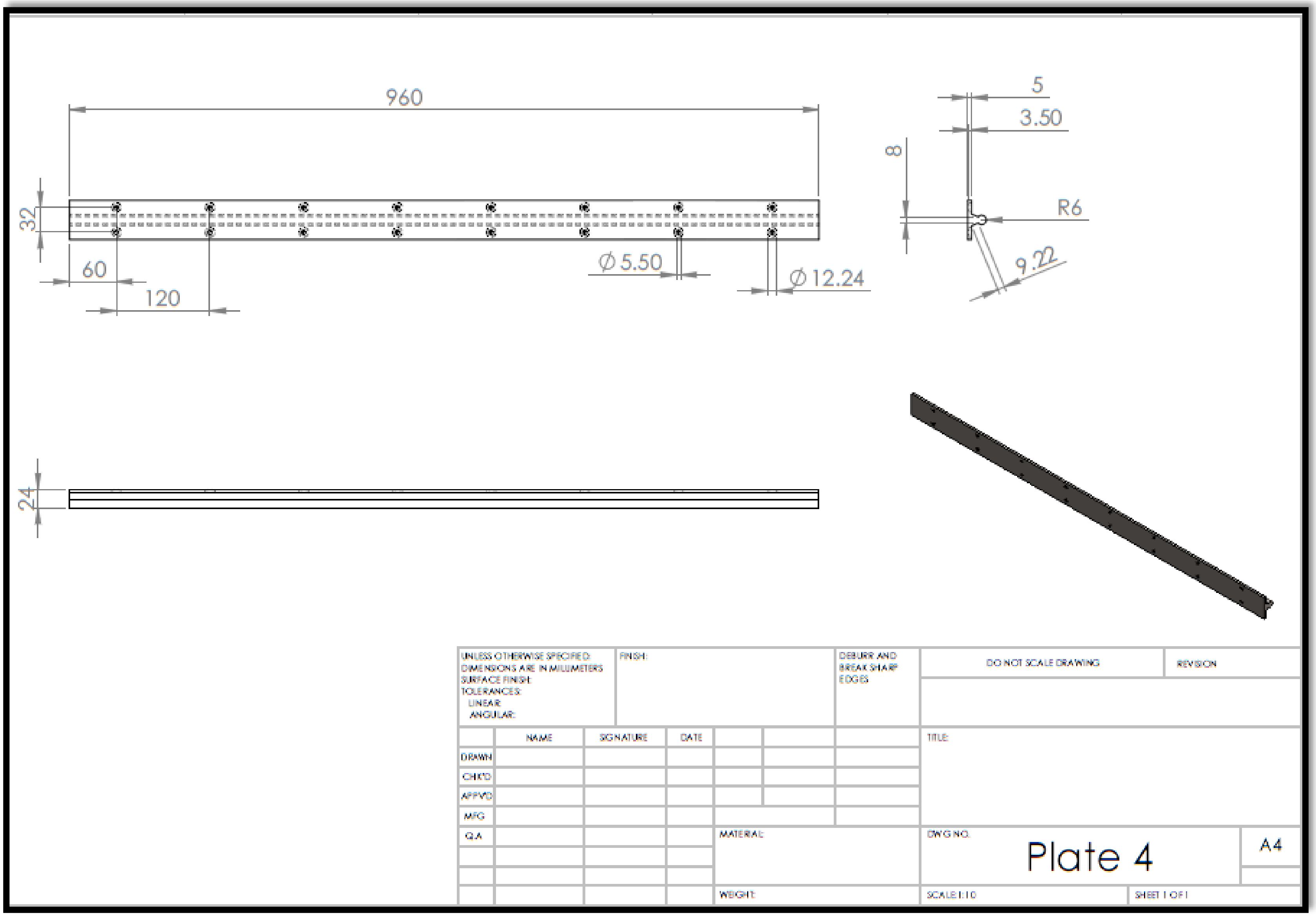

20
75
10
7.07
25
25
25
25
25
80
30
75
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
DWG NO.
Jaw
A4
SCALE:1:1
SHEET 1 OF 1

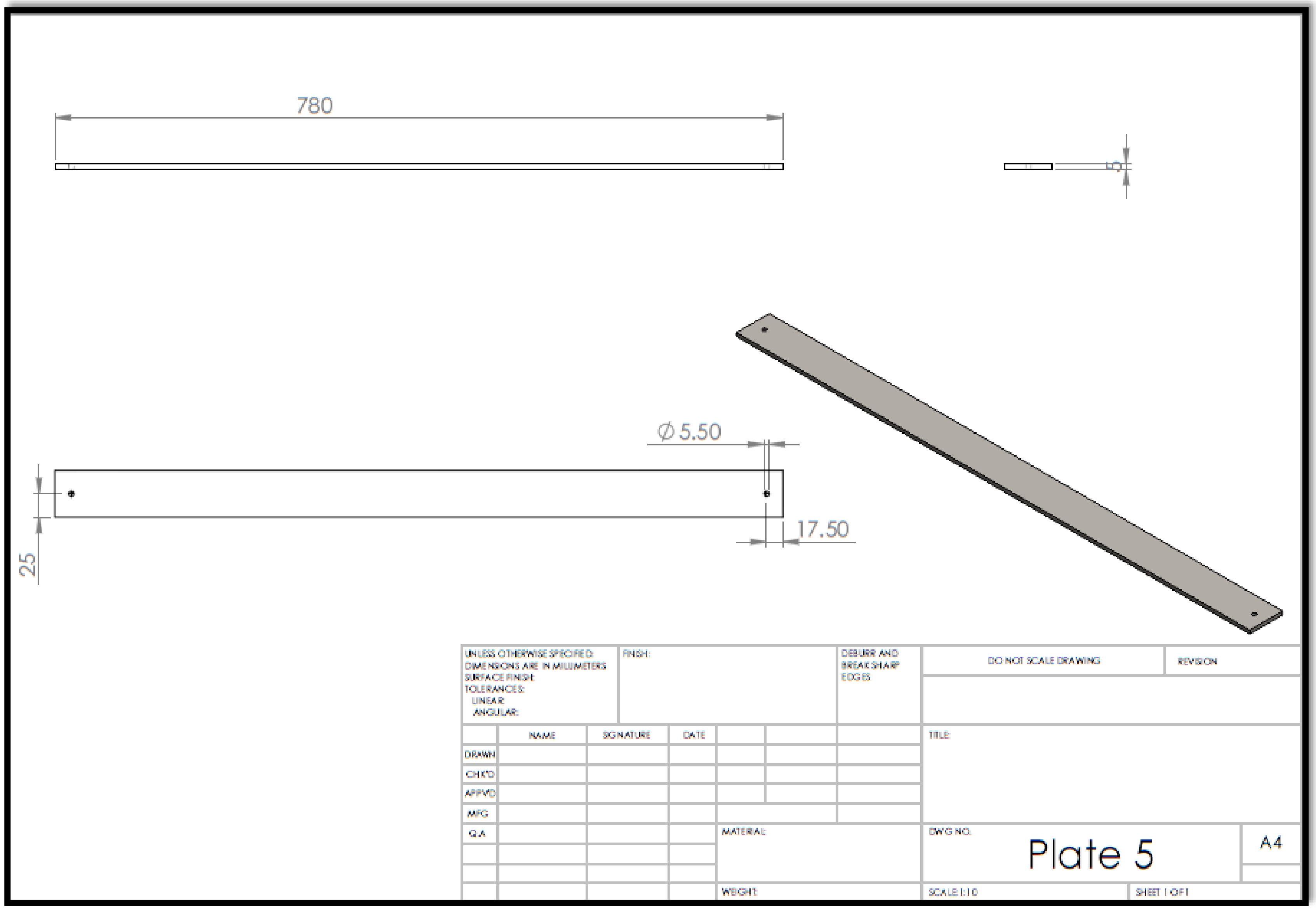

Motor bracket 1
A4
DWG NO.
TITLE:
SCALE:1:2
SHEET 1 OF 1
WEIGHT:
MATERIAL:
DO NOT SCALE DRAWING
REVISION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
50
10
47.14
47.14
Ø5
Ø5.50
Ø10.30
R2.50
R2.50
80
5
25
5
80
5
75


R20
80
30
30
30
18
46
910
41.50
10
950
Ø5
40.50
Ø5.50
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
DWG NO.
Plate 1
A4
SCALE:1:10
SHEET 1 OF 1

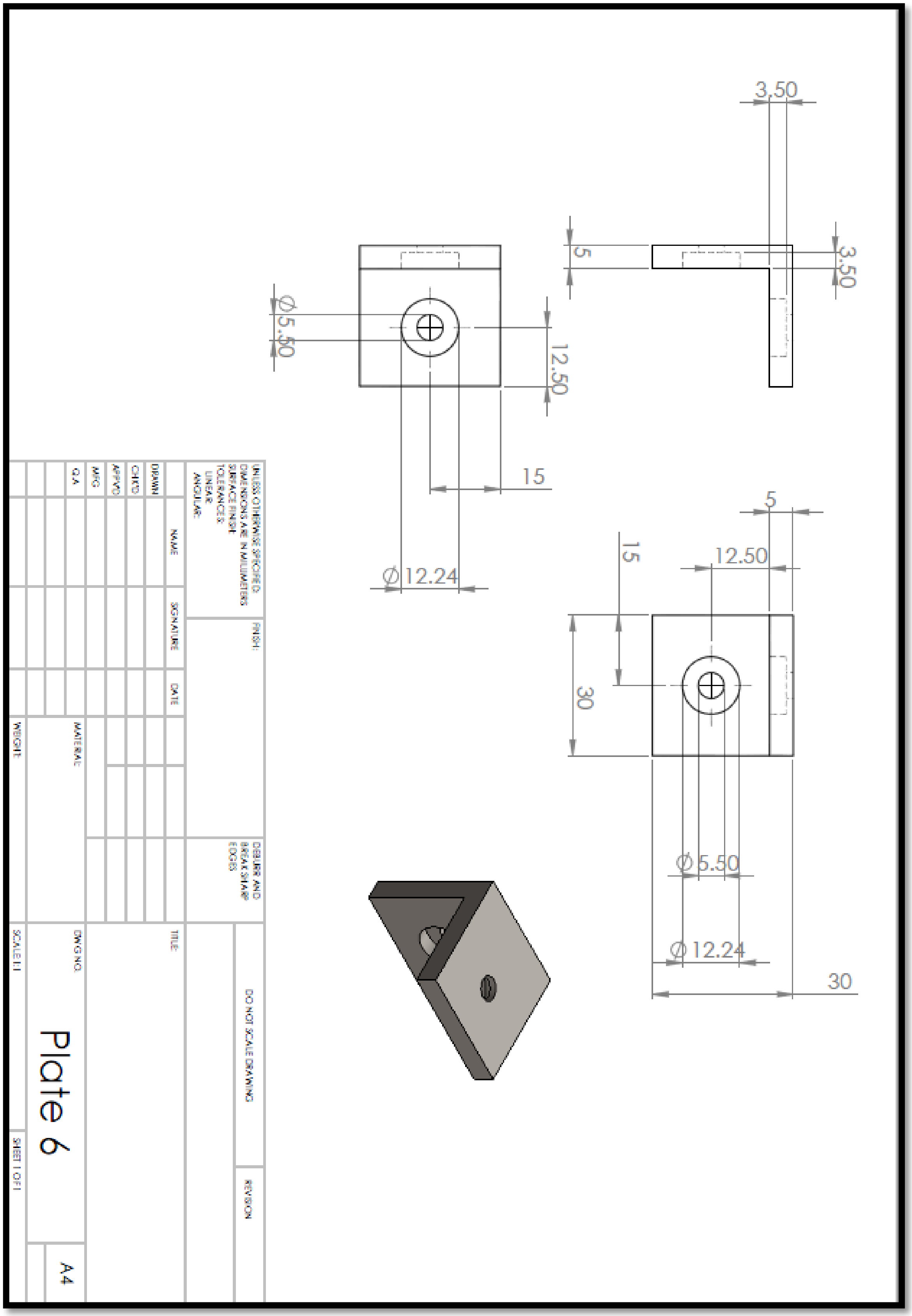


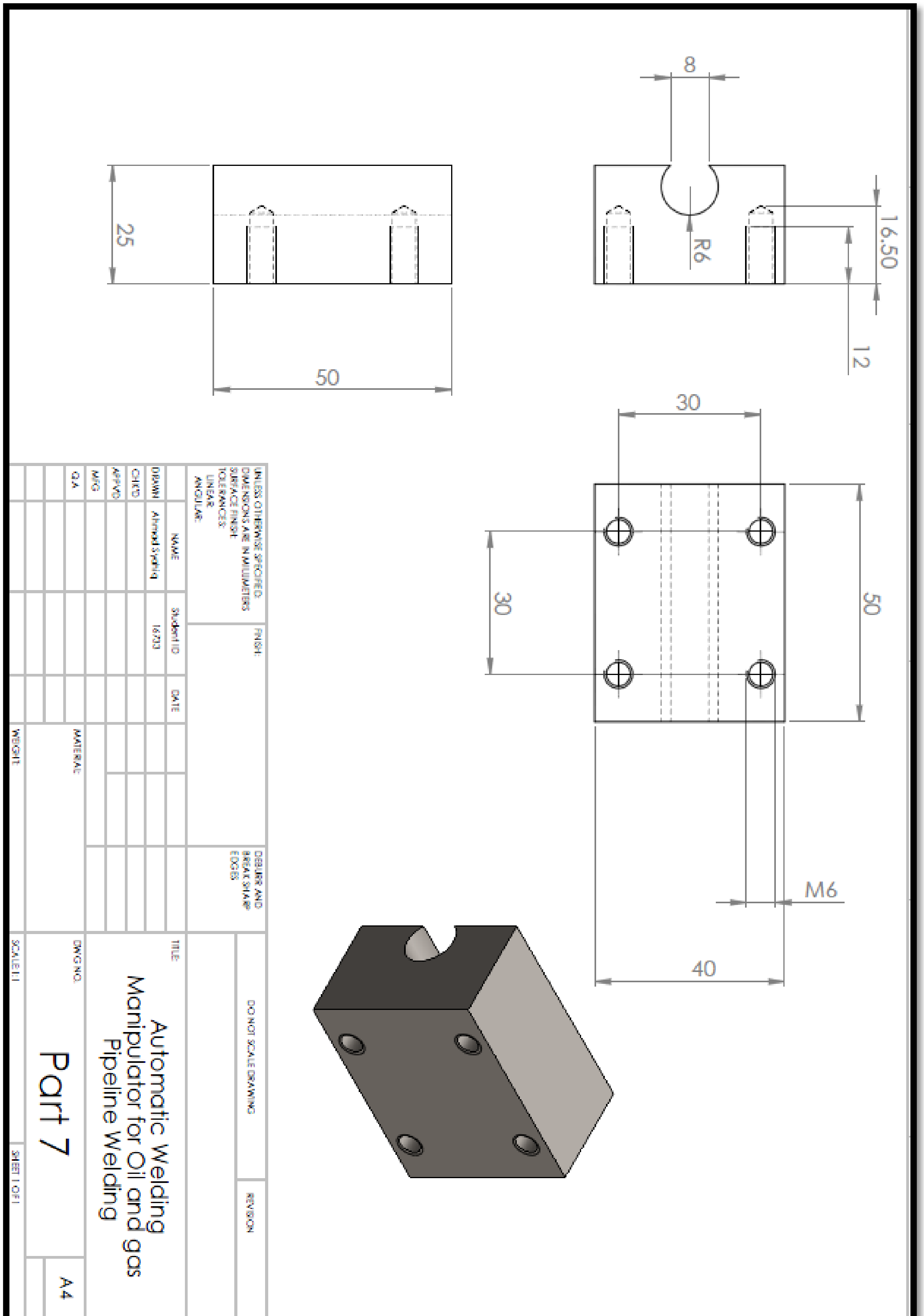
100
80
950
950
910
30
30
30
Ø5
50
34.50
Ø5.50
100
46
Ø14
Ø5.50
18
41.50
120
10
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
DWG NO.
Plate 2
A4
SCALE:1:10
SHEET 1 OF 1


960
32
60
120
Ø 5.50
Ø 12.24
24
5
3.50
8
R6
9.22
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND
BREAK SHARP
EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
TITLE:
MATERIAL:
DWG NO.
Plate 4
A4
WEIGHT:
SCALE:1:10
SHEET 1 OF 1


780
5
Ø 5.50
25
17.50
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND
BREAK SHARP
EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
DWG NO.
Plate 5
A4
SCALE:1:10
SHEET 1 OF 1

J


UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
TITLE:
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
DWG NO.
Plate 6
A4
WEIGHT:
SCALE:1:1
SHEET 1 OF 1
3.50
5
3.50
Ø5.50
12.50
15
Ø12.24
5
12.50
15
30
Ø5.50
Ø12.24
30


8
16.50
R6
12
25
50
30
30
50
M6
40
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
Automatic Welding Manipulator for Oil and gas Pipeline Welding
DWG NO.
Part 7
A4
SCALE:1:1
SHEET 1 OF 1

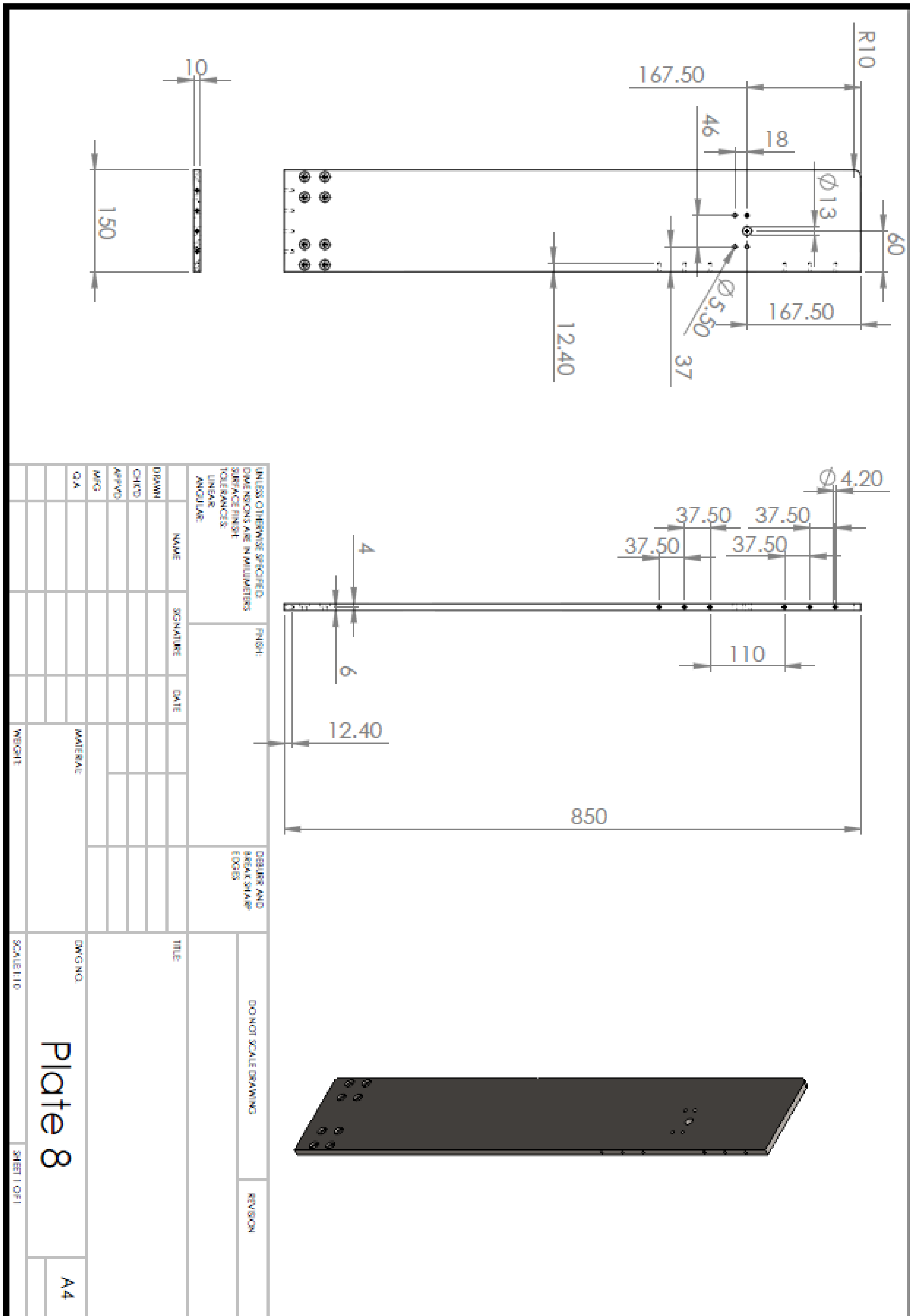
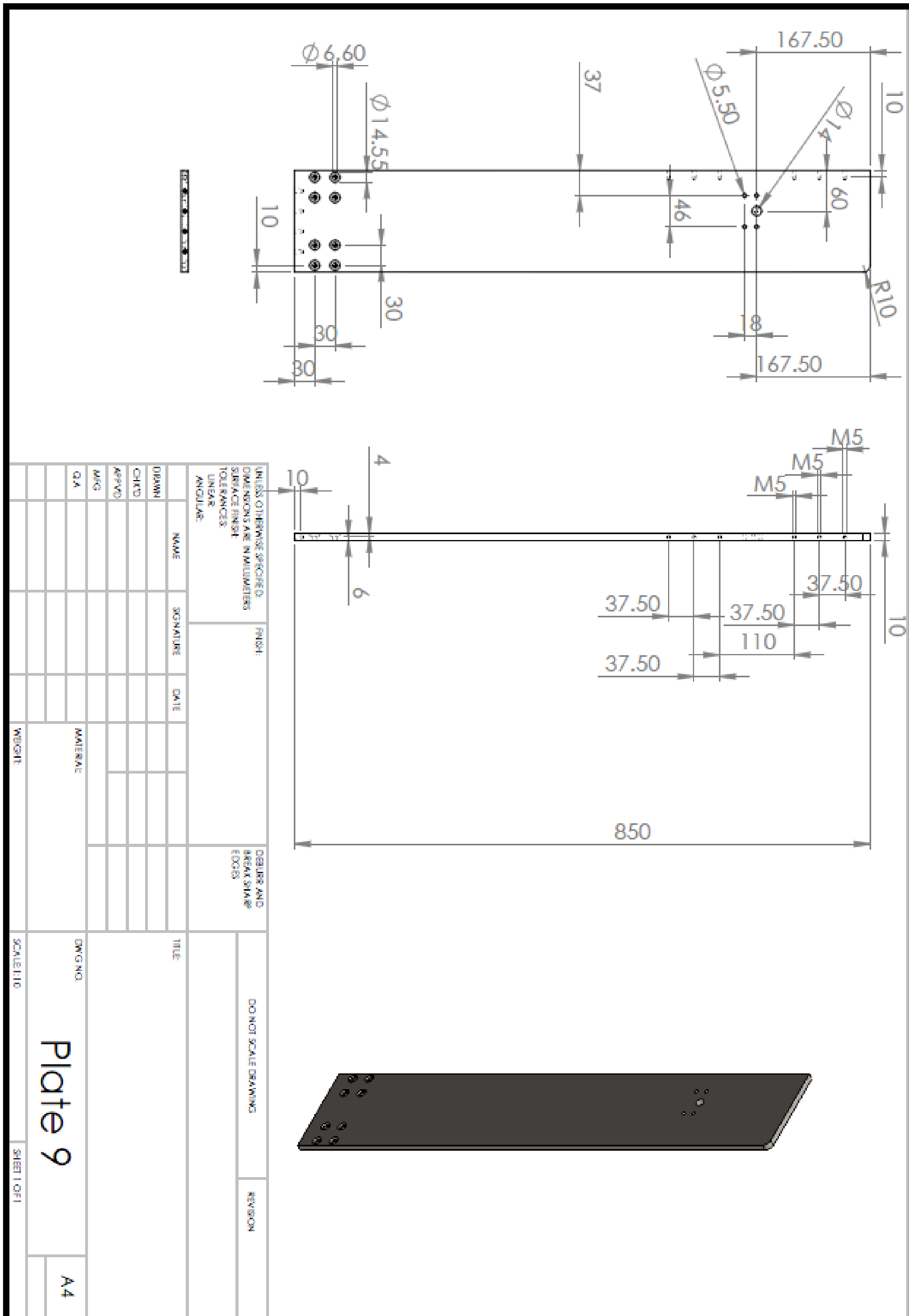
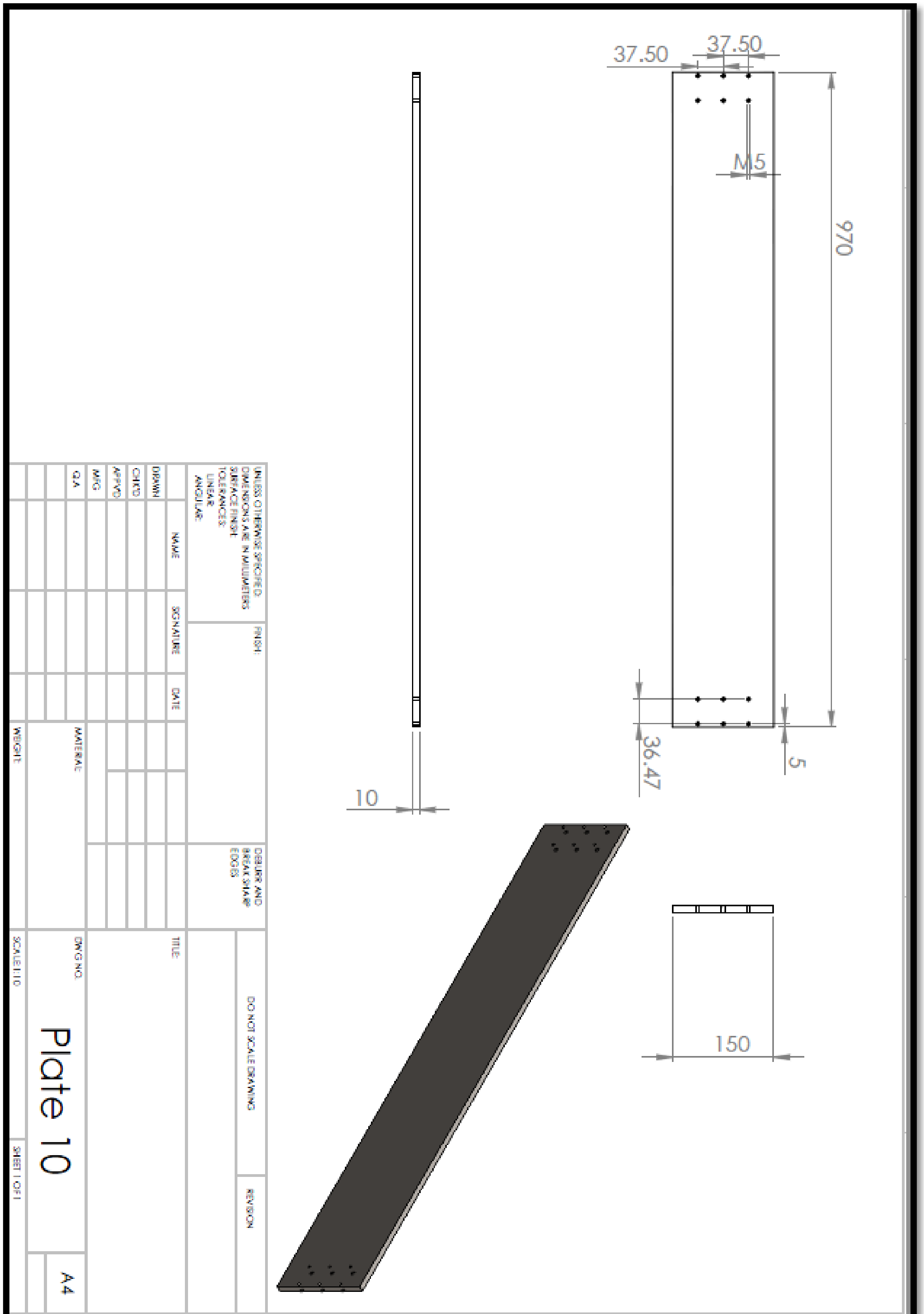


Plate 8
A4
DWG NO.
TITLE:
SCALE:1:10
SHEET 1 OF 1
DO NOT SCALE DRAWING
REVISION
WEIGHT:
MATERIAL:
DEBURR AND BREAK SHARP EDGES
FINISH:
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
10
150
167.50
R10
46
18
Ø13
60
Ø5.50
167.50
12.40
37
Ø4.20
37.50
37.50
37.50
37.50
4
6
110
12.40
850


Ø6.60
Ø14.55
37
Ø5.50
Ø14
167.50
10
46
60
R10
18
167.50
10
30
30
30
4
10
M5
M5
M5
6
37.50
37.50
37.50
110
37.50
10
850
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
DWG NO.
Plate 9
A4
SCALE:1:10
SHEET 1 OF 1


37.50
37.50
M5
970
36.47
5
10
150
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
DWG NO.
Plate 10
A4
SCALE:1:10
SHEET 1 OF 1

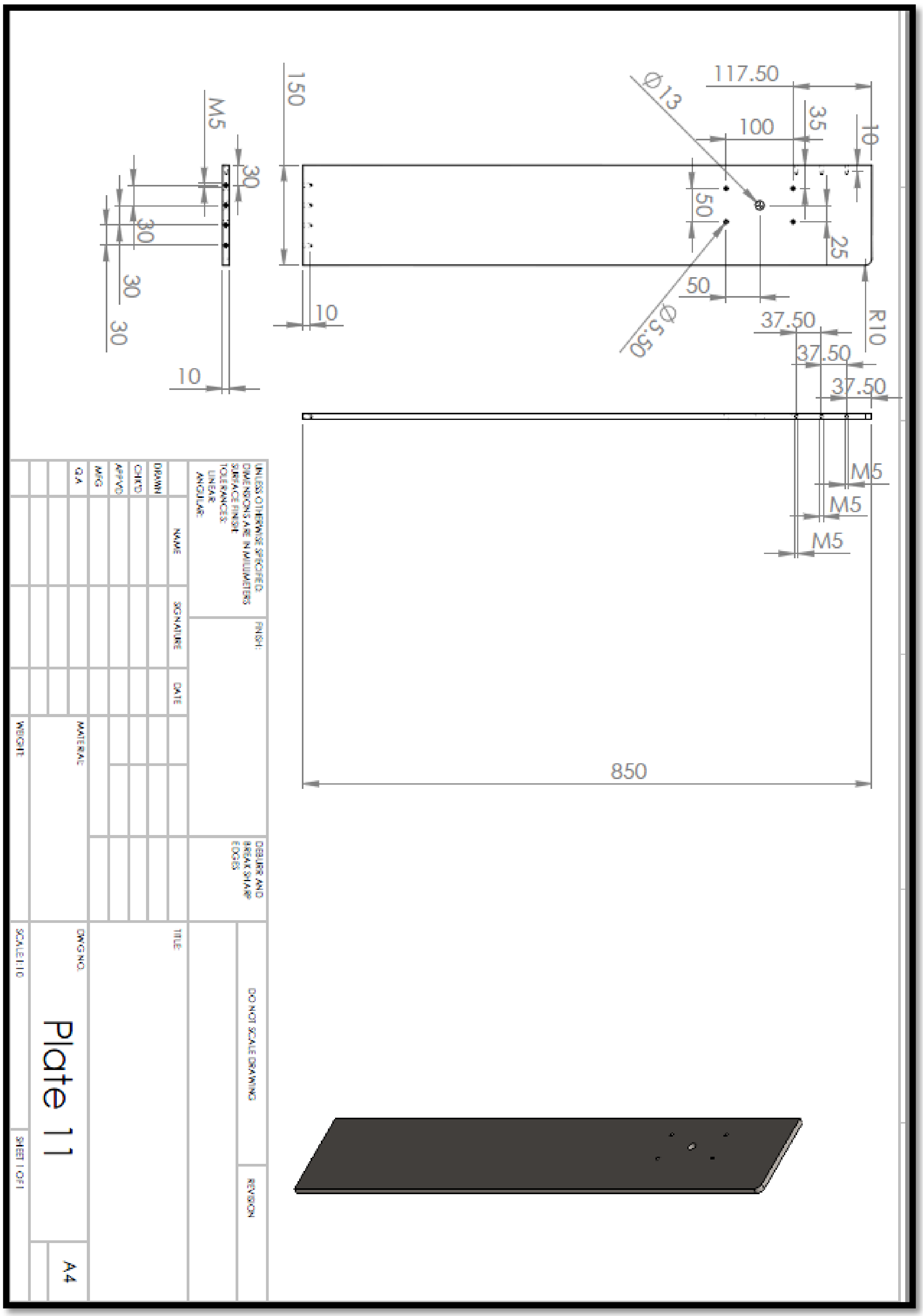
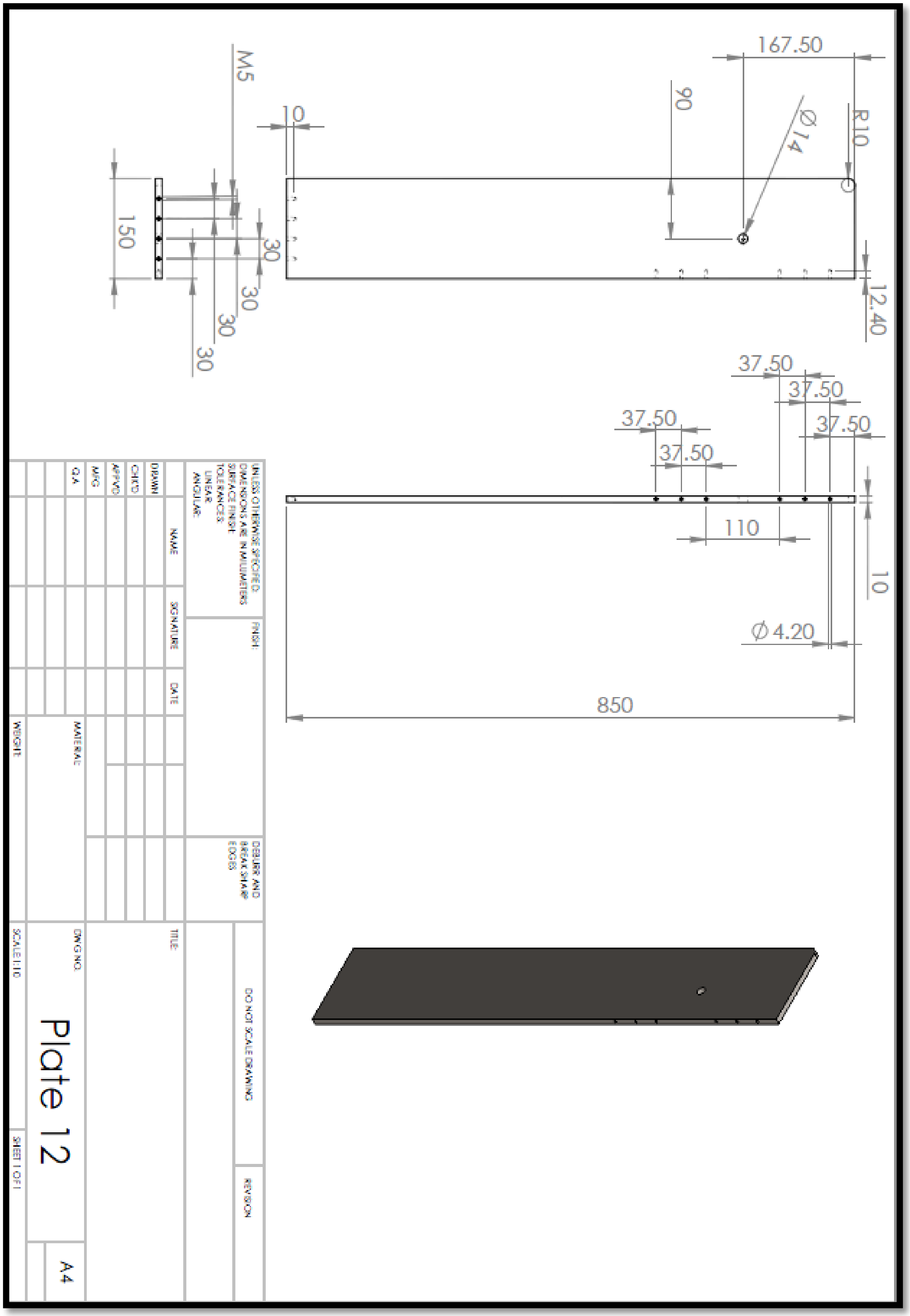
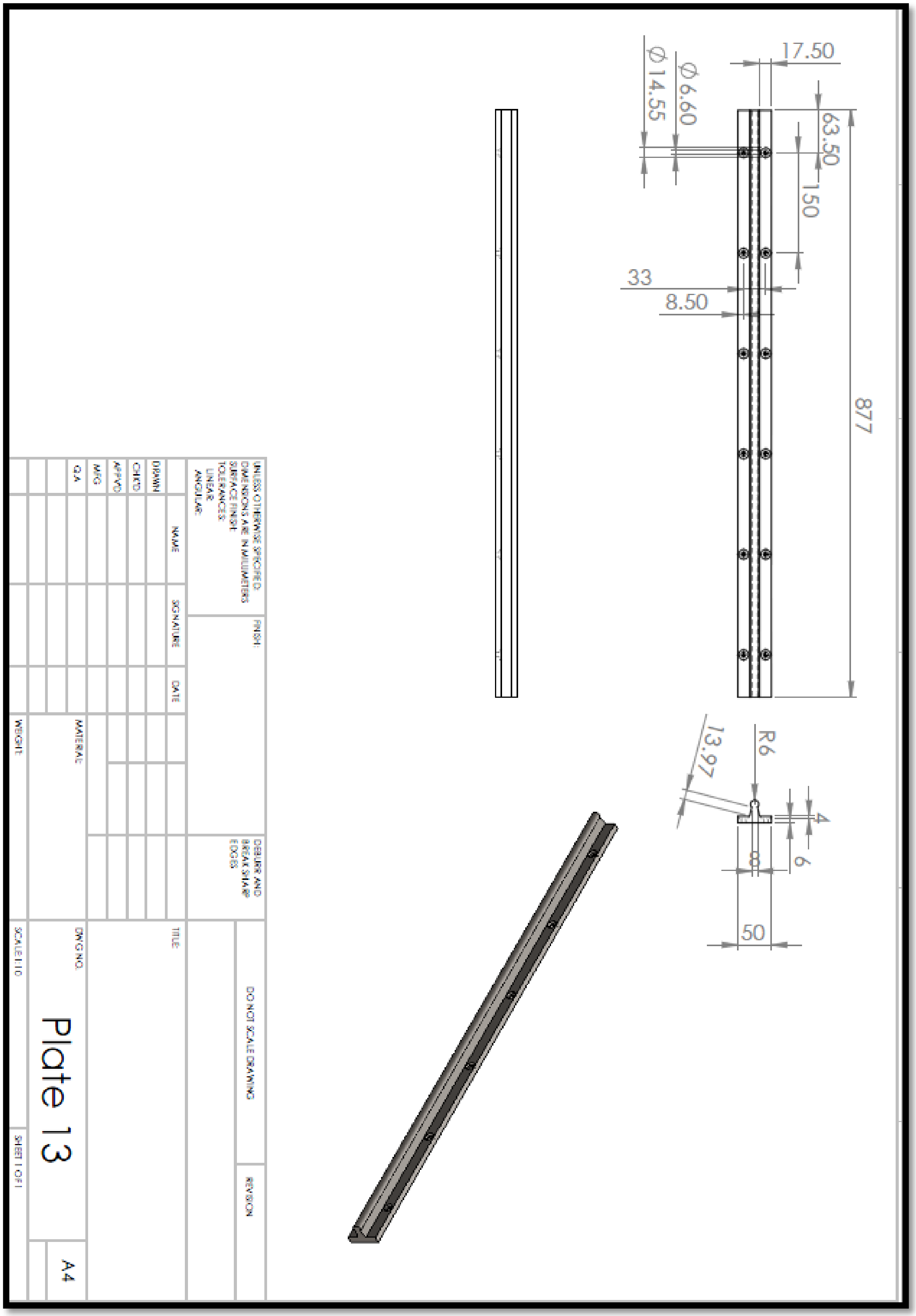
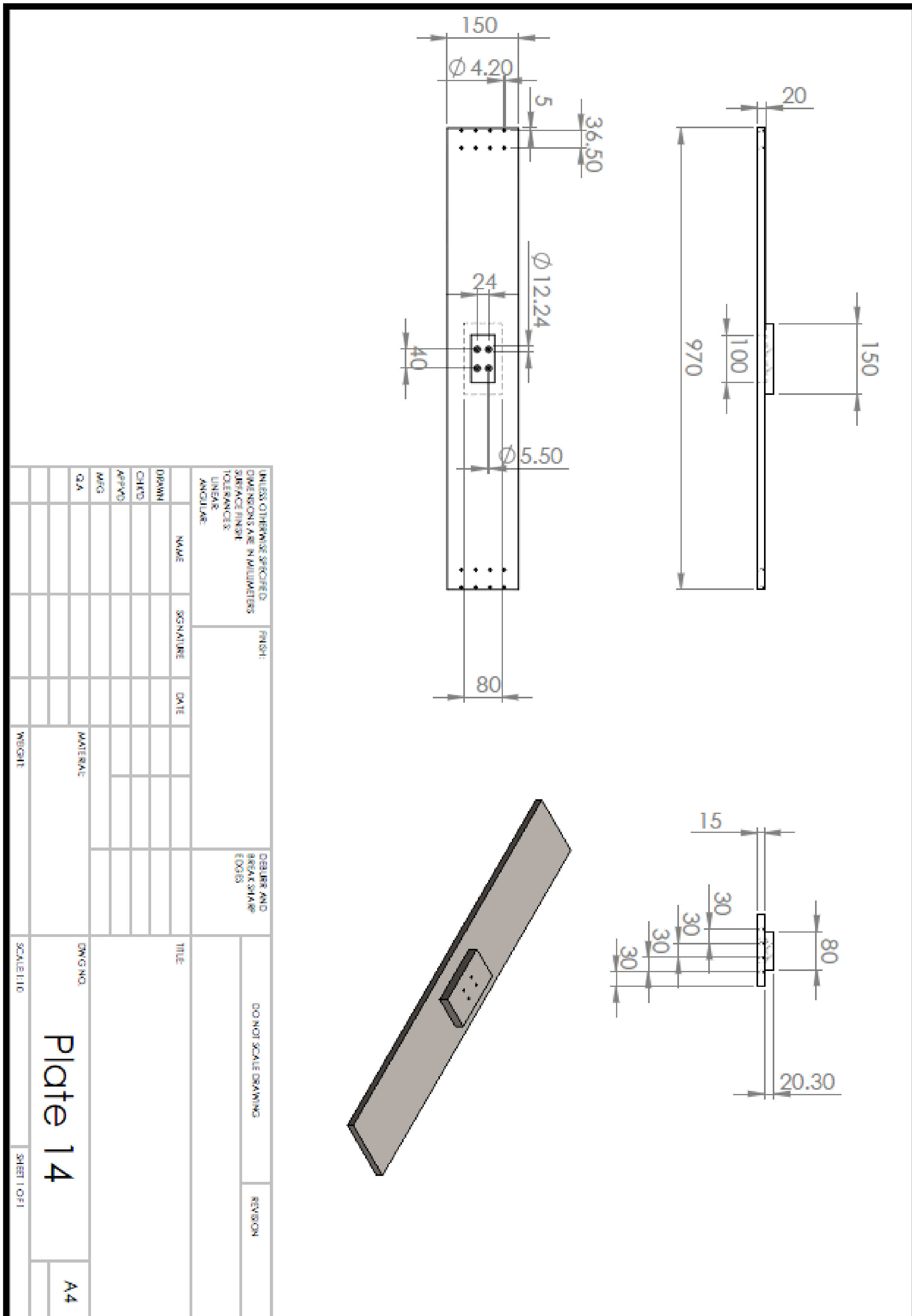


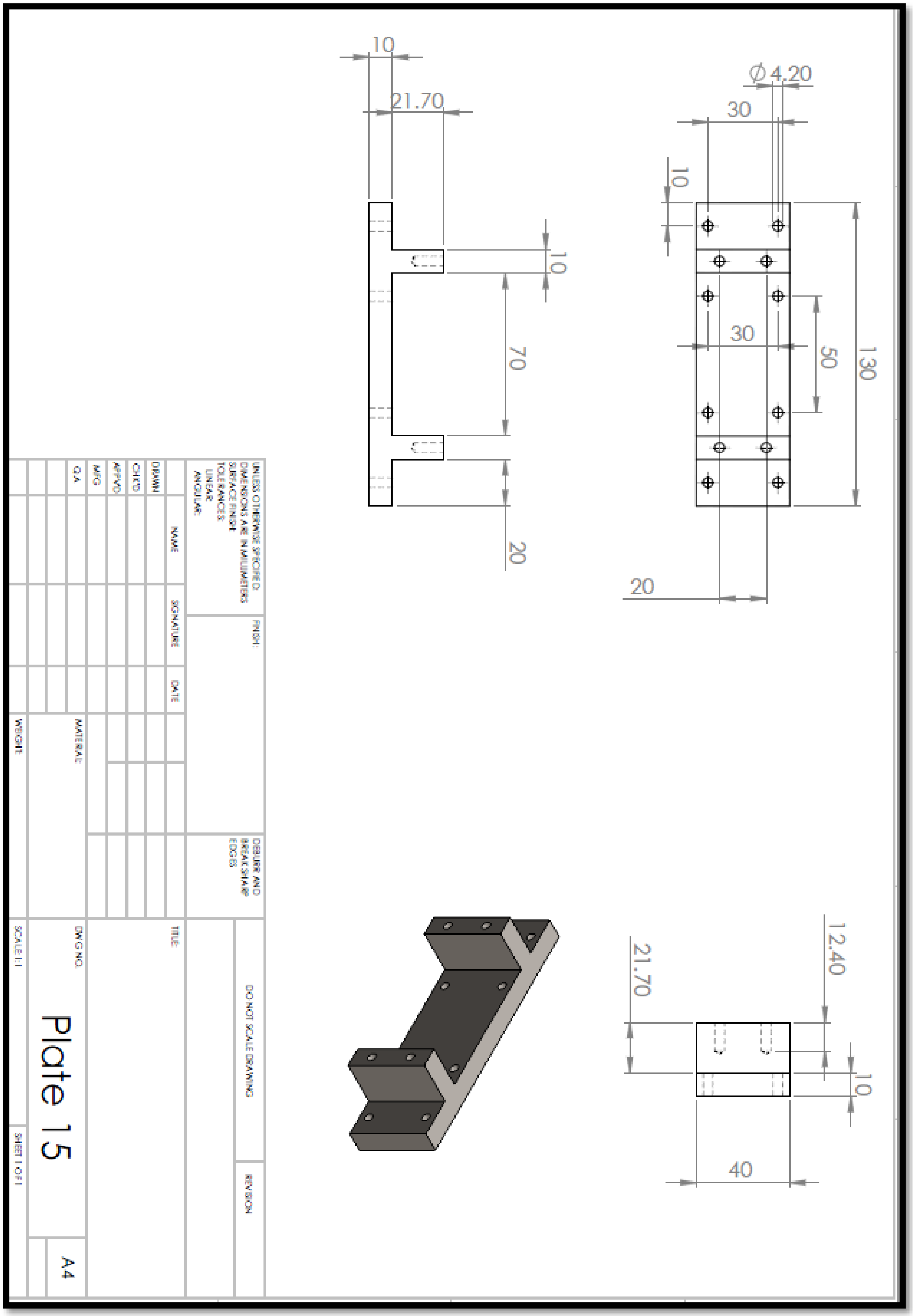
Plate 11
A4
SCALE 1:10
SHEET 1 OF 1
DWG NO.
TITLE:
DO NOT SCALE DRAWING
REVISION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
117.50
Ø13
100
35
10
50
25
R10
50
Ø5.50
37.50
37.50
37.50
150
10
M5
30
30
30
30
10
M5
M5
M5
850


167.50
90
Ø14
R10
10
M5
150
30
30
30
30
12.40
37.50
37.50
37.50
37.50
37.50
37.50
110
10
Ø 4.20
850
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
DWG NO.
Plate 12
A4
SCALE:1:10
SHEET 1 OF 1

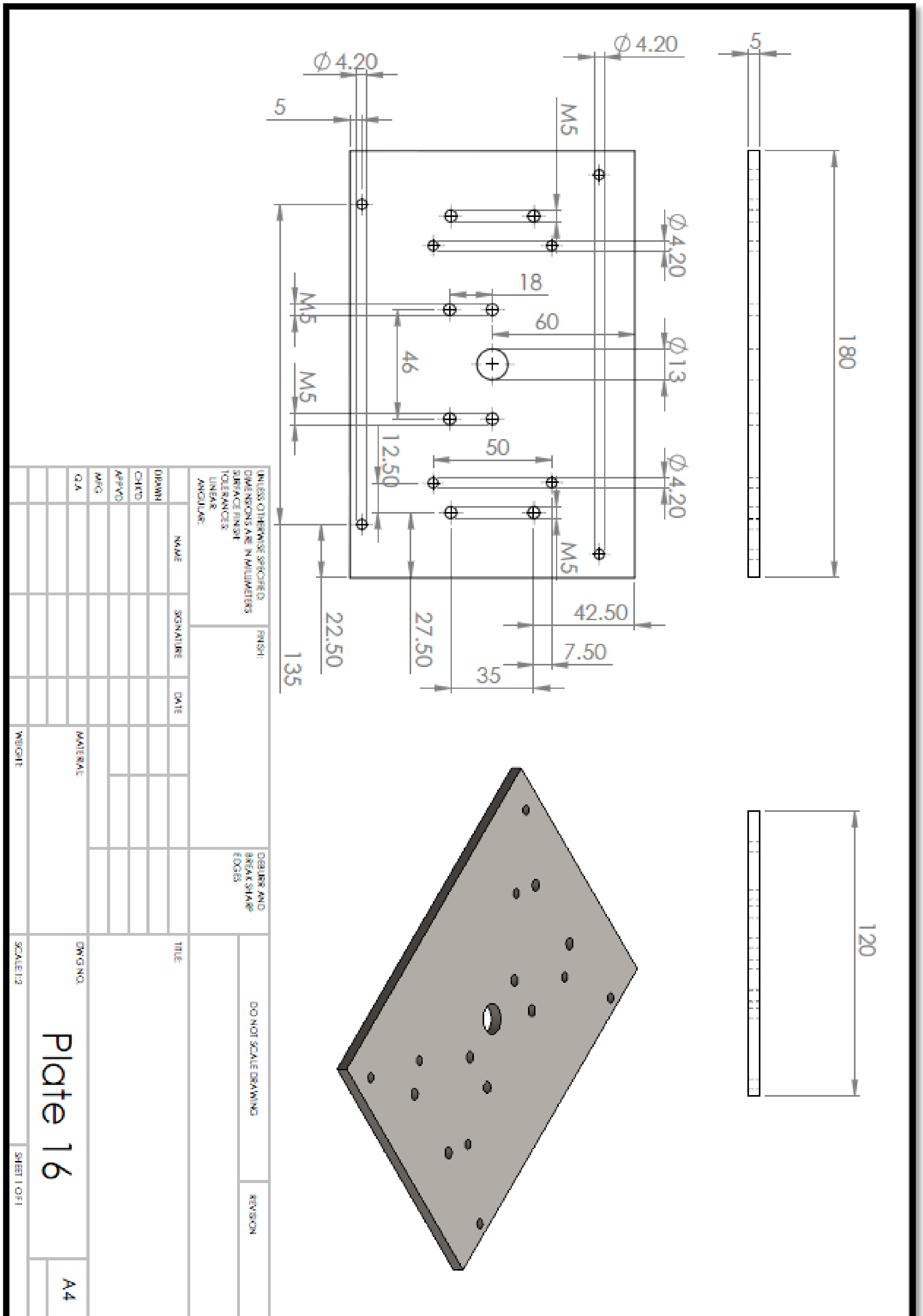

17.50
Ø 6.60
Ø 14.55
63.50
150
33
8.50
877
R6
13.97
4
6
8
50
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
DWG NO.
Plate 13
A4
SCALE:1:10
SHEET 1 OF 1

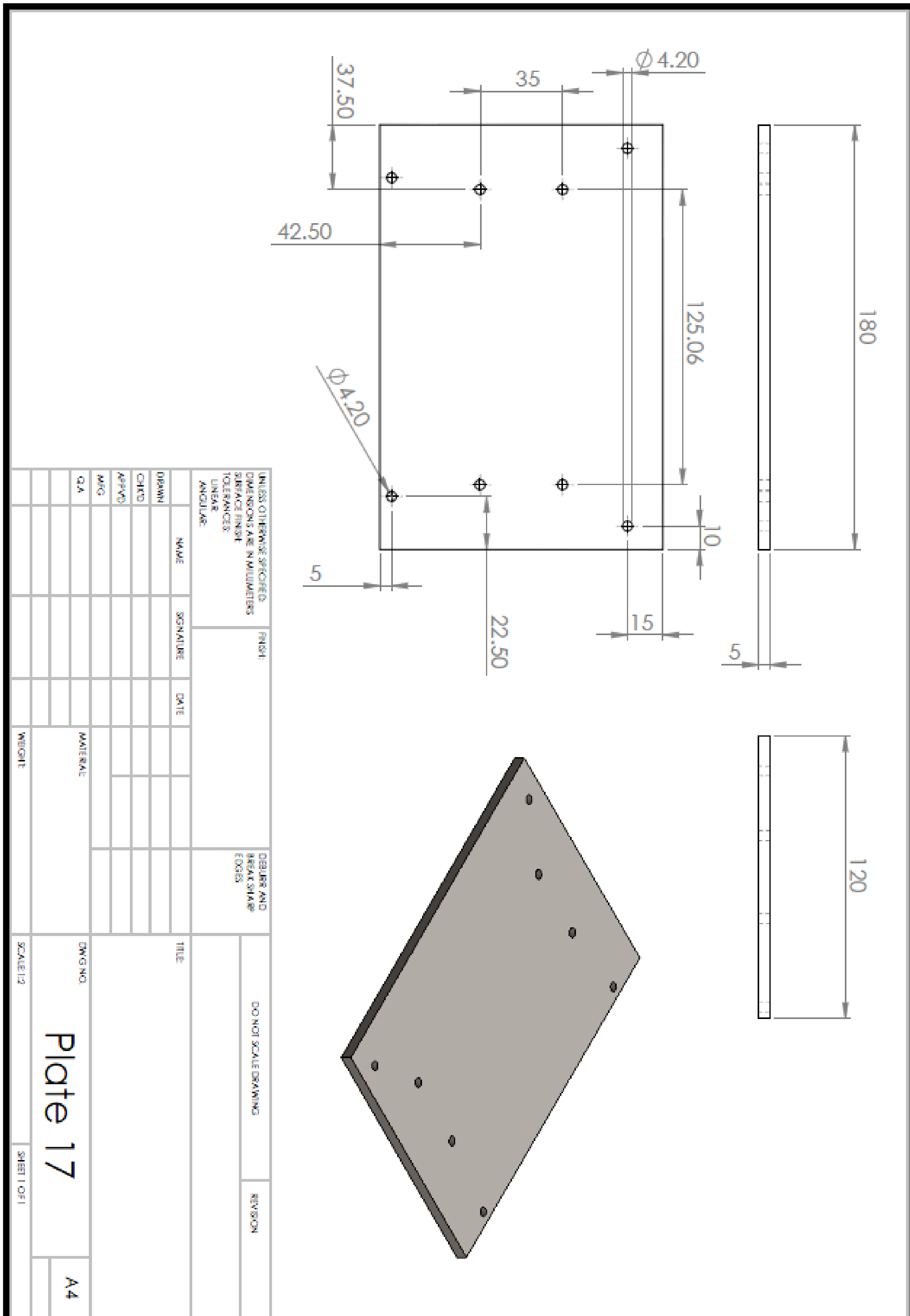
R


150
Ø 4.20
5
36.50
Ø 12.24
24
40
Ø 5.50
80
20
970
100
150
15
30
30
30
30
80
20.30
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
DWG NO.
Plate 14
A4
SCALE:1:10
SHEET 1 OF 1

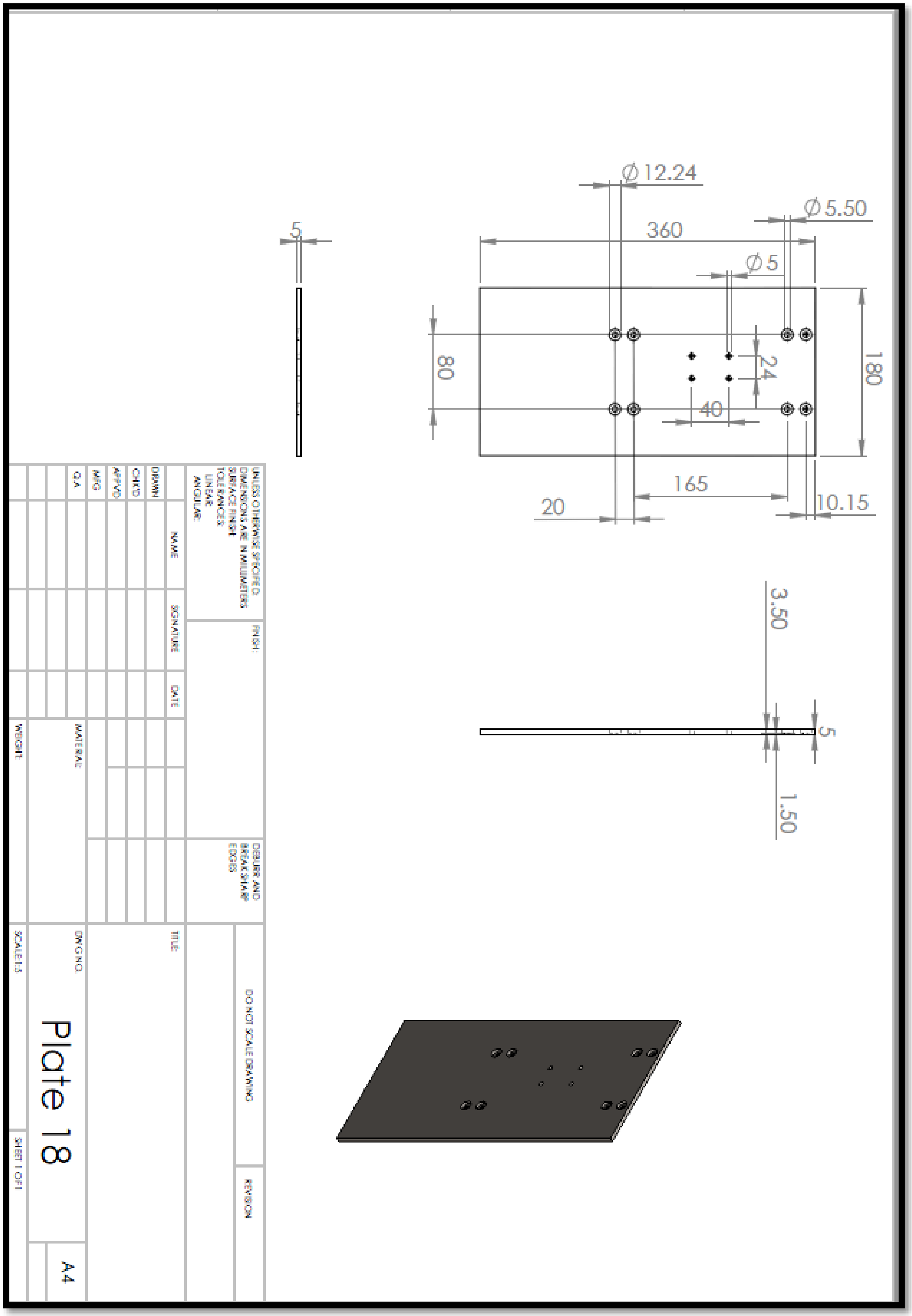

10
21.70
10
70
20
Ø 4.20
30
10
30
50
130
20
21.70
12.40
10
40
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
TITLE:
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
DWG NO.
Plate 15
A4
WEIGHT:
SCALE:1:1
SHEET 1 OF 1

T


Ø 4.20
5
M5
Ø4.20
18
60
Ø13
46
50
12.50
180
120
42.50
7.50
35
22.50
27.50
135
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
DWG NO.
Plate 16
A4
SCALE:1:2
SHEET 1 OF 1

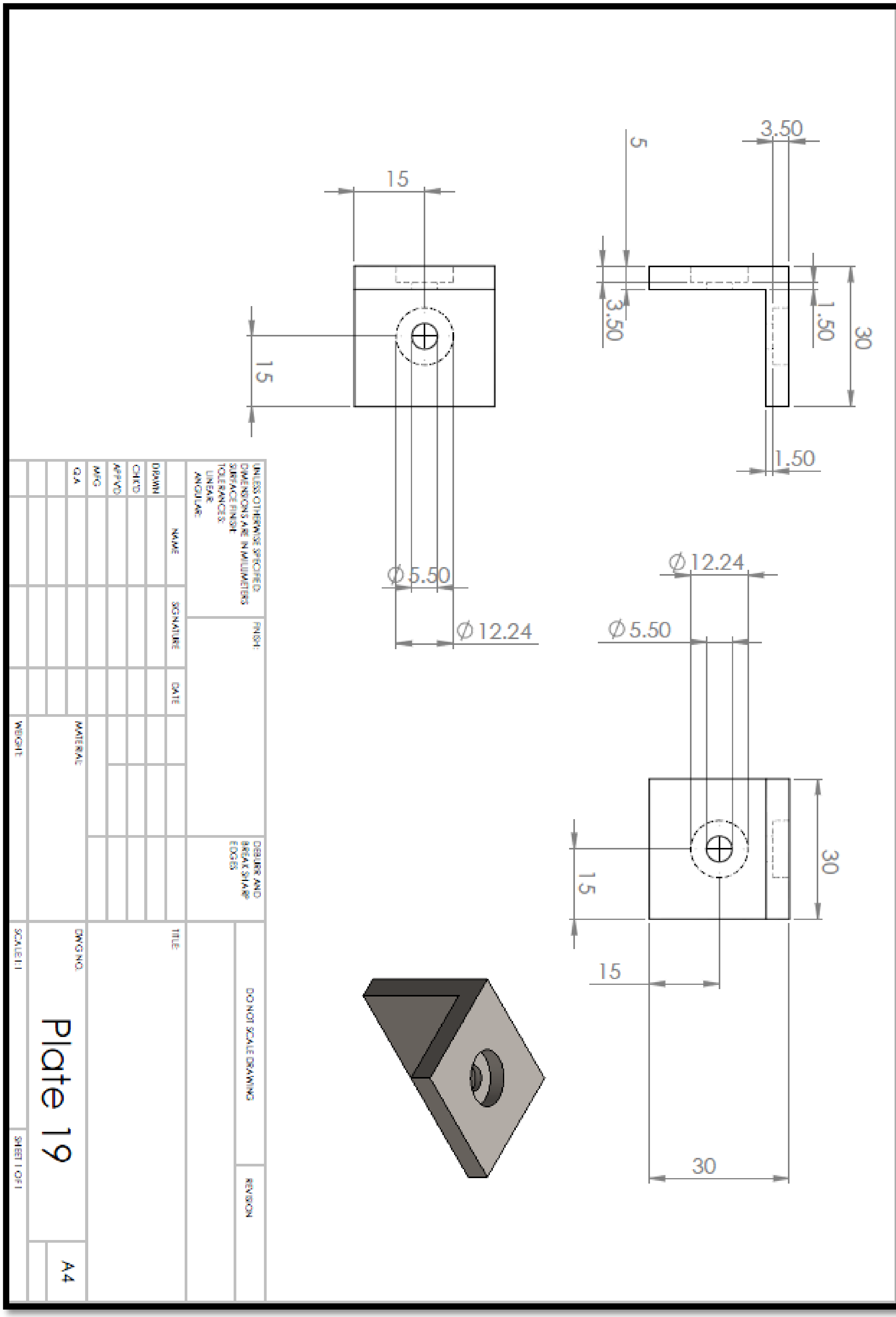


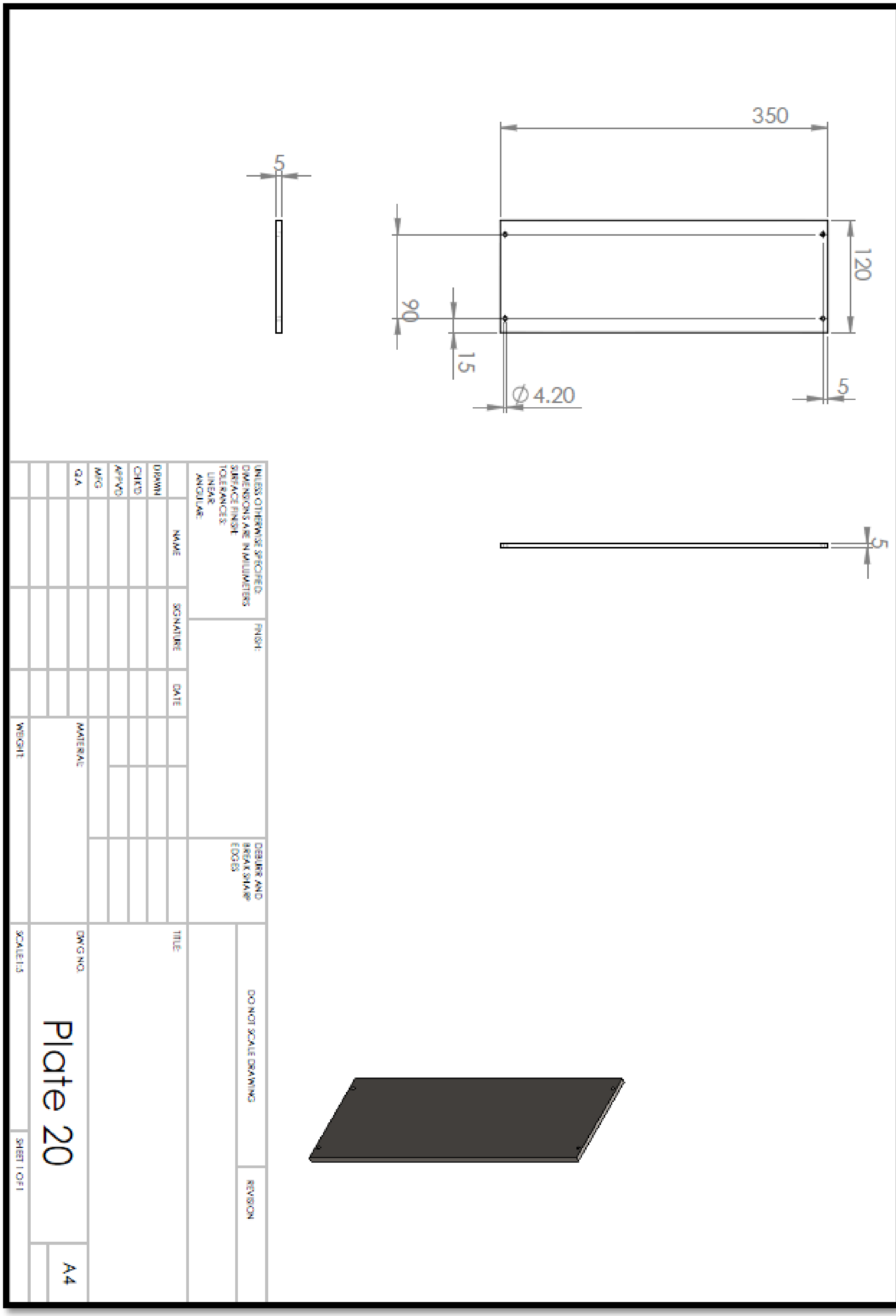
Ø 4.20
35
37.50
42.50
125.06
180
Ø 4.20
5
22.50
15
10
5
120
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
DWG NO.
Plate 17
A4
SCALE:1:2
SHEET 1 OF 1



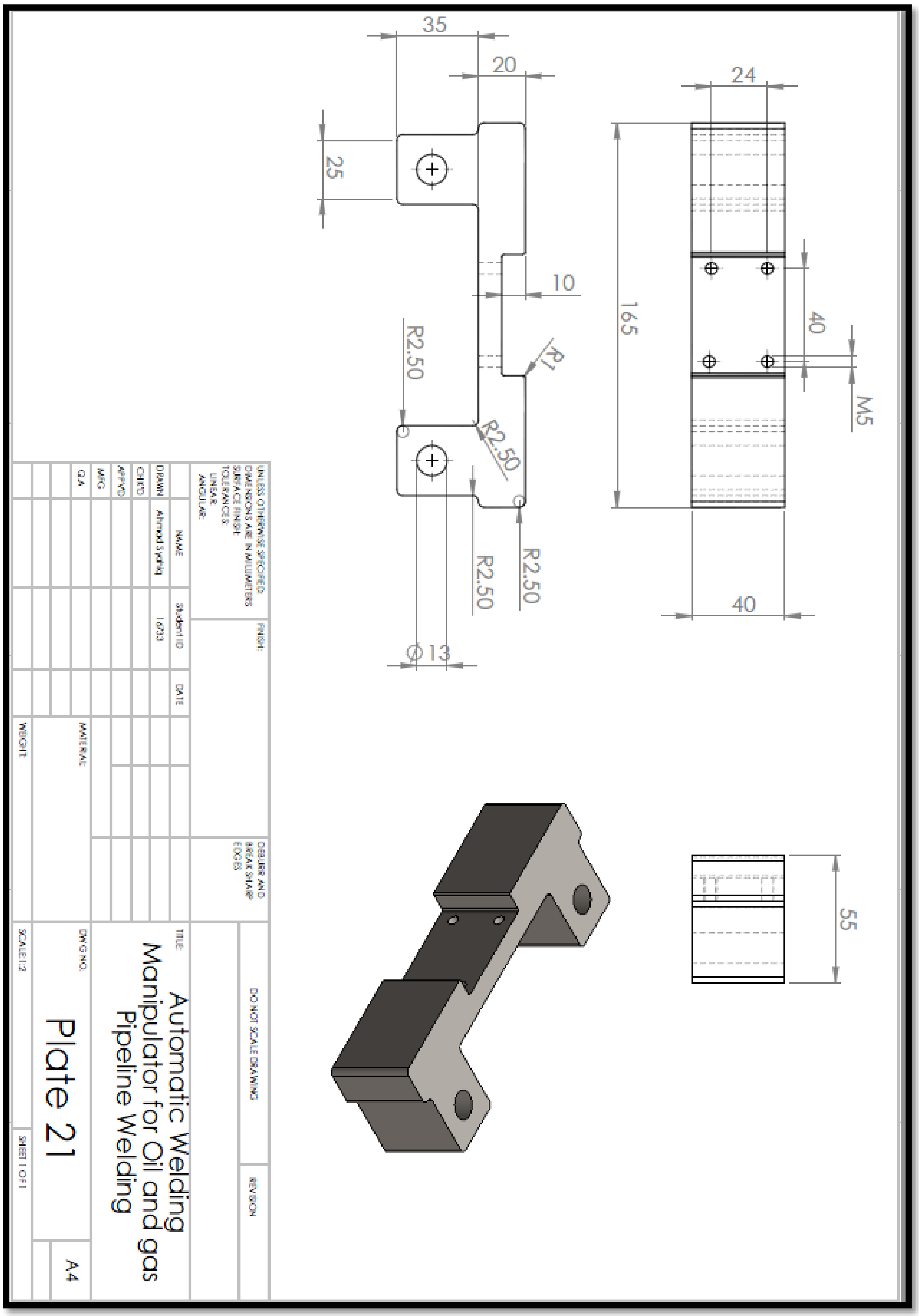
Ø 12.24
Ø 5.50
360
Ø 5
180
80
24
40
165
20
10.15
5
3.50
5
1.50
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
DWG NO.
Plate 18
A4
SCALE:1:5
SHEET 1 OF 1

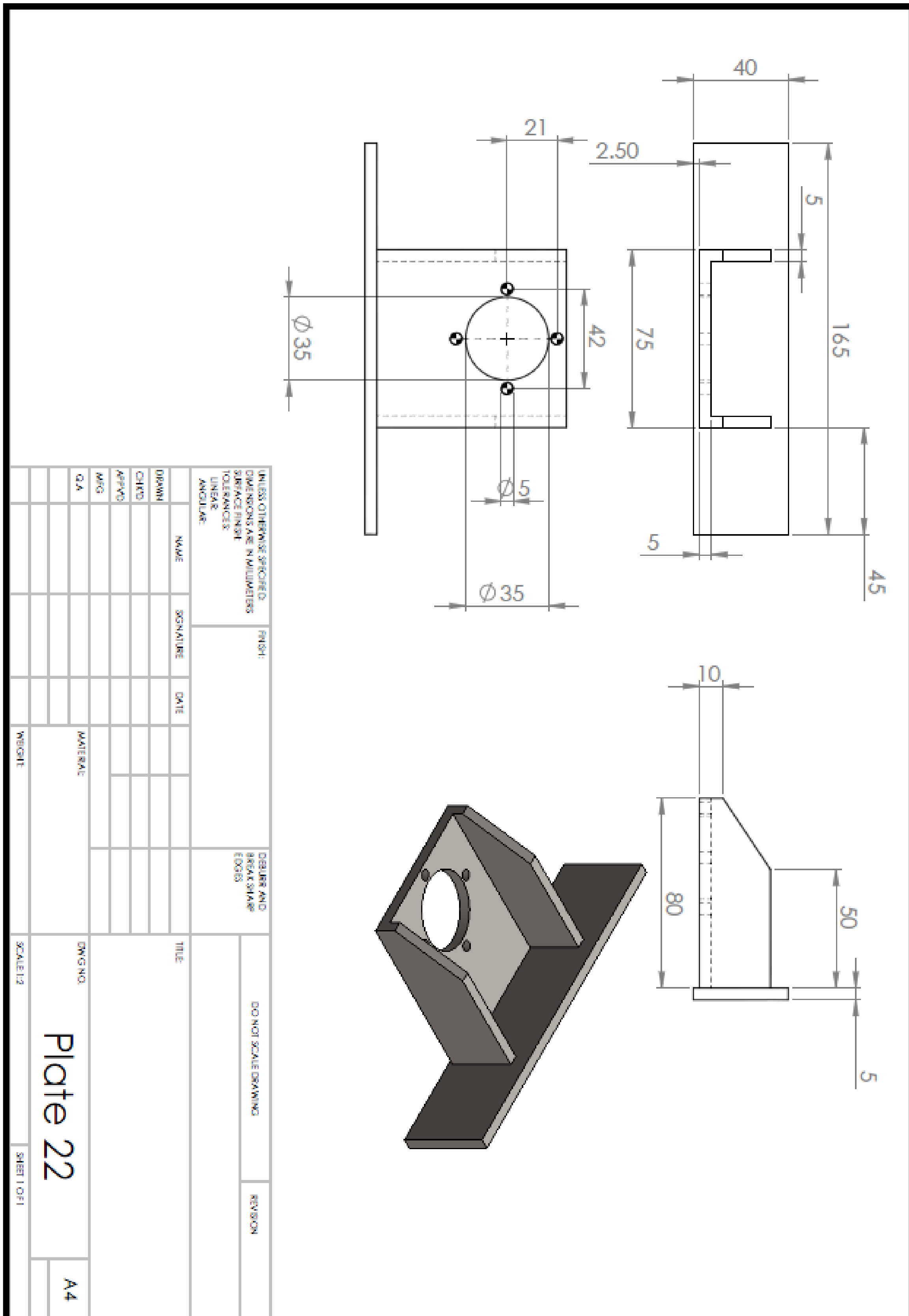
w

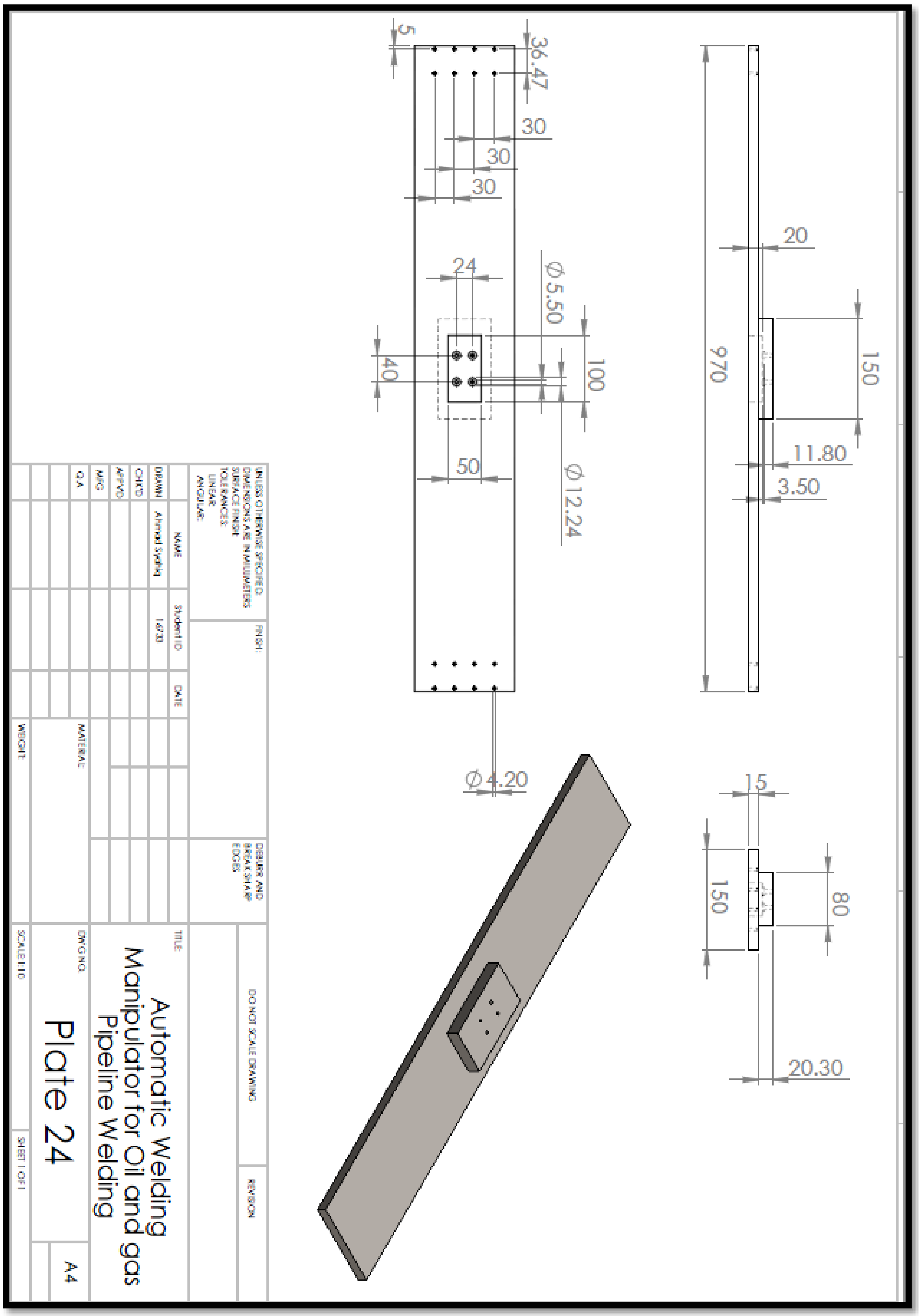

15
15
3.50
5
3.50
1.50
30
1.50
Ø5.50
Ø12.24
Ø12.24
Ø5.50
30
15
15
30
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
TITLE:
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
DWG NO.
Plate 19
A4
SCALE:1:1
SHEET 1 OF 1

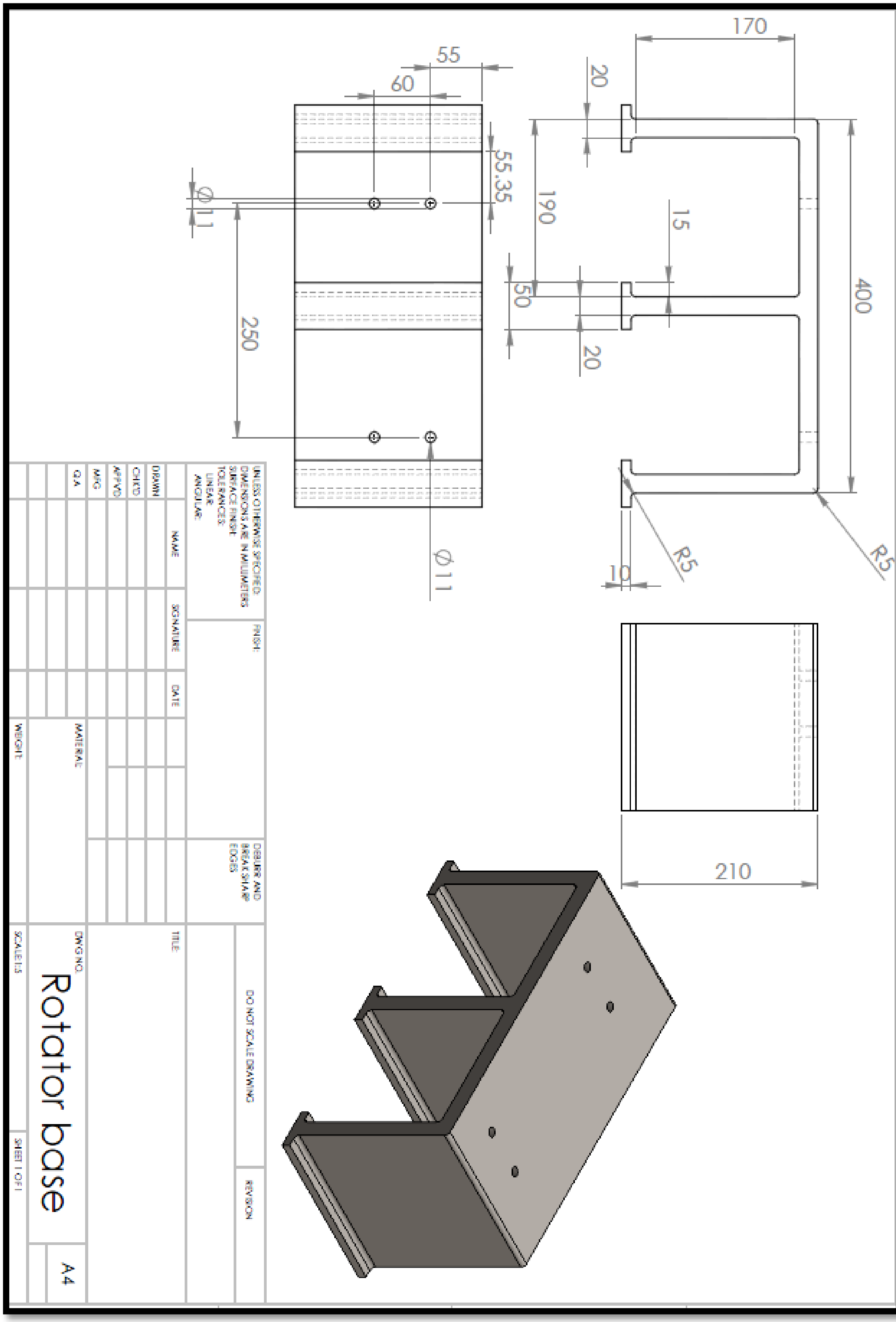

350
120
90
15
5
Ø 4.20
5
5
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
DWG NO.
Plate 20
A4
SCALE:1:5
SHEET 1 OF 1

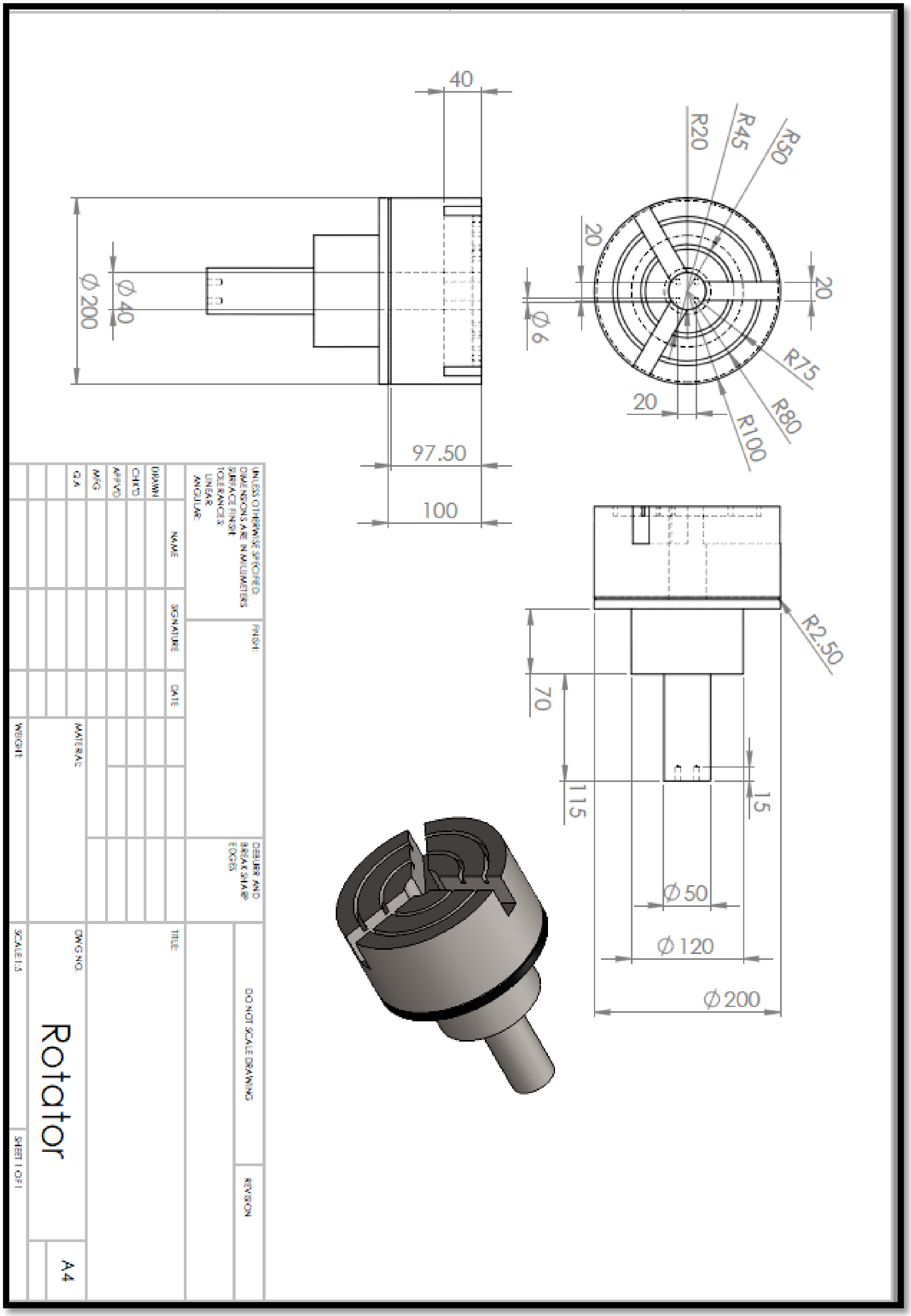
Y


35
20
25
10
R2.50
R1
R2.50
R2.50
R2.50
Ø13
24
165
40
M5
40
55
DO NOT SCALE DRAWING
REVISION
TITLE:
Automatic Welding Manipulator for Oil and gas Pipeline Welding
DWG NO.
Plate 21
A4
SCALE:1:2
SHEET 1 OF 1
WEIGHT:
MATERIAL:
FINISH:
DEBURR AND BREAK SHARP EDGES
NAME
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A

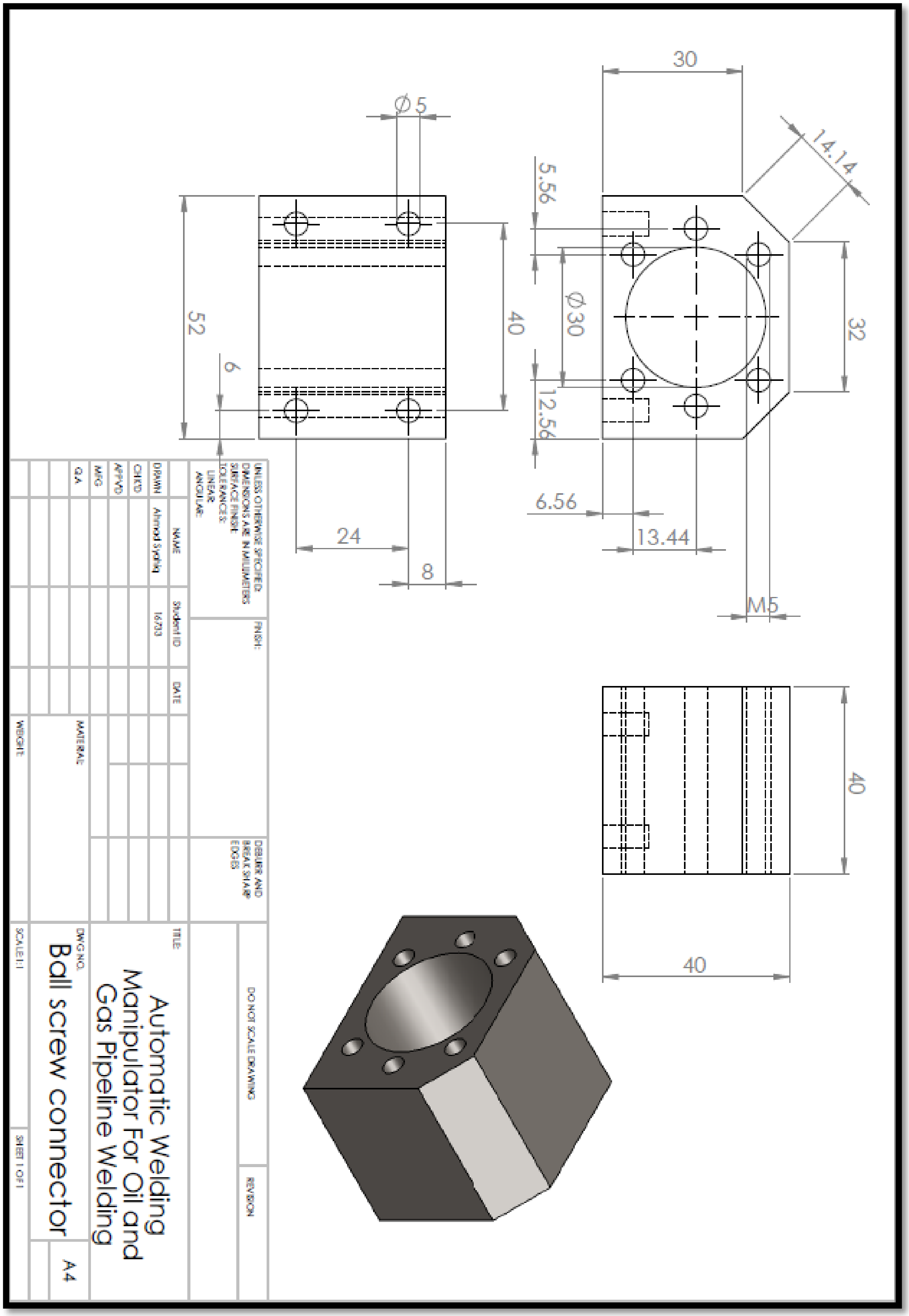

40
21
2.50
5
165
42
75
Ø35
Ø5
5
Ø35
45
10
80
50
5
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
DWG NO.
Plate 22
A4
SCALE:1:2
SHEET 1 OF 1


Automatic Welding Manipulator for Oil and gas Pipeline Welding
Plate 24
A4
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
Student ID
DATE
DRAWN
Ahmad Syafiq
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
DWG NO.
SCALE:1:10
SHEET 1 OF 1
970
150
20
11.80
3.50
15
80
20.30
5
36.47
30
30
30
24
Ø5.50
40
100
50
Ø12.24
Ø4.20

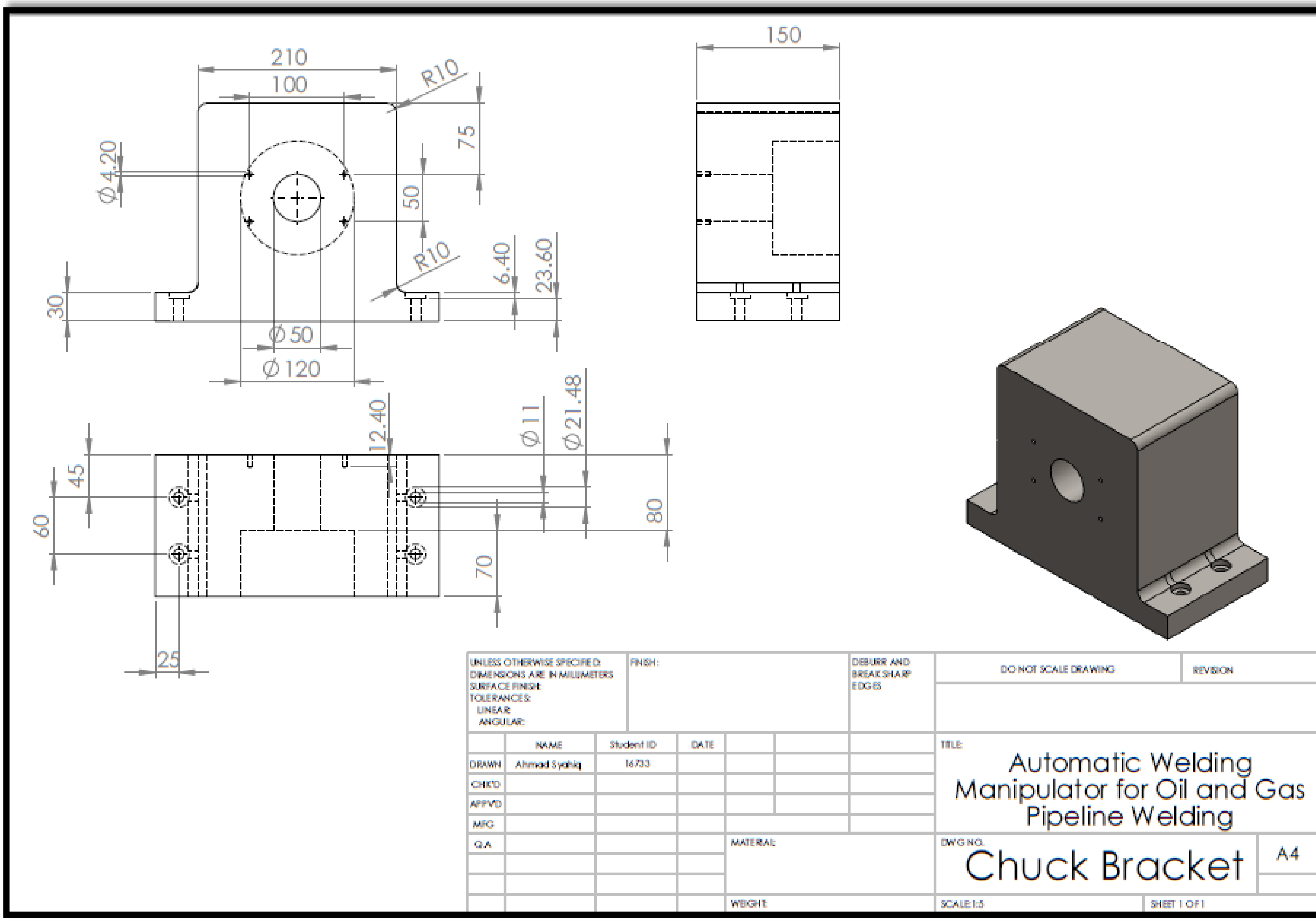

170
55
60
20
55.35
190
15
400
Ø11
250
50
20
R5
10
210
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
DWG NO.
Rotator base
A4
SCALE:1:5
SHEET 1 OF 1

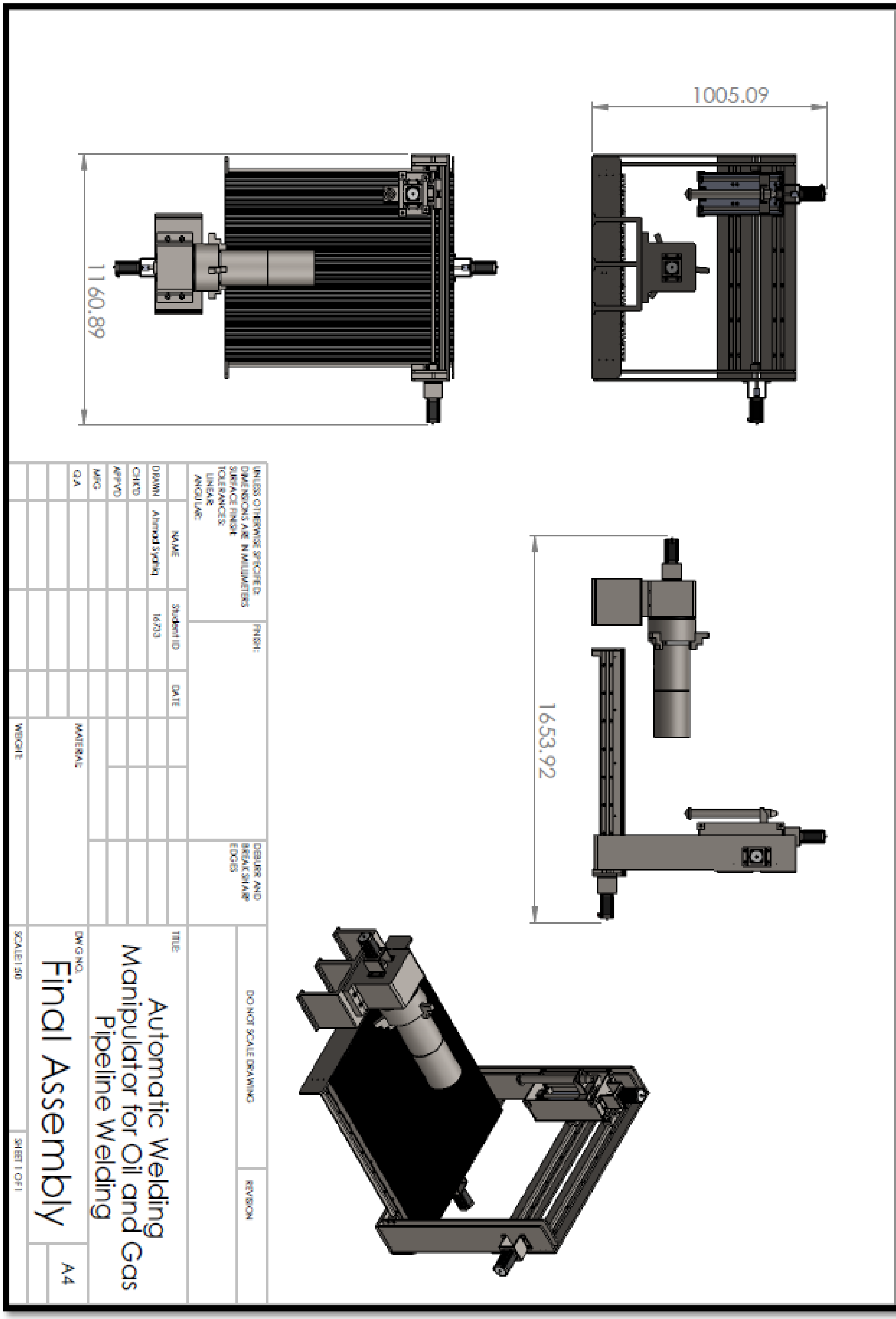


40
R20
R45
R50
20
20
Ø6
R75
R80
R100
20
Ø 200
Ø 40
97.50
100
R2.50
70
115
15
Ø50
Ø120
Ø200
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
DWG NO.
Rotator
A4
SCALE:1:5
SHEET 1 OF 1



30
14.14
Ø5
5.56
52
40
Ø30
32
6
12.56
6.56
24
13.44
8
M5
40
40
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
Student ID
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
Automatic Welding Manipulator For Oil and Gas Pipeline Welding
DWG NO.
Ball screw connector
A4
SCALE:1:1
SHEET 1 OF 1


210
100
R10
75
Ø4.20
50
R10
6.40
23.60
30
Ø50
Ø120
150
12.40
Ø11
Ø21.48
45
60
80
70
25
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
Student ID
DATE
DRAWN
Ahmad Syahiq
16733
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
Automatic Welding Manipulator for Oil and Gas Pipeline Welding
DWG NO.
Chuck Bracket
A4
SCALE:1:5
SHEET 1 OF 1


1005.09
1653.92
1160.89
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND
BREAK SHARP
EDGES
DO NOT SCALE DRAWING
REVISION
NAME
Student ID
DATE
DRAWN
Ahmad Syahiq
16733
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
Automatic Welding
Manipulator for Oil and Gas
Pipeline Welding
DWG NO.
Final Assembly
A4
SCALE:1:50
SHEET 1 OF 1