University of Southern Queensland

Faculty of Health, Engineering and Sciences

Bucking Units – A More Effective Approach

A dissertation submitted by

Jackson Gould

In fulfilment of the requirements of

ENG4111 and ENG4112 Research Project

towards the degree of

Bachelor of Engineering (Honours) (Mechanical)

Submitted 14th October 2021

University of Southern Queensland

Faculty of Health, Engineering and Sciences

ENG4111/ENG4112 Research Project

Limitations of Use

University of Southern Queensland

Faculty of Health, Engineering and Sciences

ENG4111/ENG4112 Research Project

Certification of Dissertation

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

Jackson Gould

Student Number: [redacted]

Principal Supervisor: Steven Goh

[redacted]

Signature

08/10/21

____

Date

Abstract

Oil and Gas has been a major contributor to Australia's economy for over a century, boasting a GVA of over $31.4 billion and ensuring over 17,600 jobs for Australians in exploration alone (L. Granwal, 2020). With 22 million tonnes of liquified natural gas being exported from Queensland alone during the 2019 to 2020 financial year, generating $11.1 billion in gross capital gains via the industry during the year (Energy Information Australia, 2021), it is clear that there is a large demand for the services and products created from liquified natural gas.

It is common knowledge that the oil and gas industry is not overly sustainable for future generations, therefore, it is crucial that services within this industry are the most practical and efficient during operation, ensuring not only a thriving economy due to the impact of the industry, but assuring the workers of this generation have a smooth transition of work capabilities, providing everyone with the same opportunities.

This project allowed for the design of a bucking unit which is transportable. This was achieved by reducing the overall weight and size of the unit, amongst other dimensional parameters. Utilising a strict design criteria along with rigorous finite element analysis, a design was achieved. Unfortunately due to time restrictions, however, the design is not complete and ready for testing nor manufacturing. The critical elements of the design identified within this report were shown to be successful and to all relevant standards.

This project provides implications on methods of allowing this industry to thrive for its natural course through the values and principles of design incorporated. These are seen to be promoting sustainability, efficiency and safety in design, a standard all engineers and workers are encouraged to uphold throughout their working career.

Acknowledgements

I would like to firstly thank my friends and family who have supported me throughout my academic career at USQ. Without their support none of what I have achieved at USQ would be possible.

Thank you to all my lecturers who supported me academically throughout my courses, providing help where possible to ensure I thrived at USQ. A very special thanks to Dr. Steven Goh for providing me with a variety of support and resources throughout my project, enabling me to envision and realise the best project possible.

– Jackson Gould

Table of Contents

Table of Figures

Table of Tables

Nomenclature

Table 0. 1 Nomenclature Used

Term Used	Description
OD	Outside Diameter
ID	Inside Diameter
FEA	Finite Element Analysis
NCXX	Thread Type – Numbered Connection (##) e.g. NC50
Drill String	Series of Drill Pipe with Casing
CNC	Computerised Numerical Control
HPU	Hydraulic Powered Unit
FOS	Factory of Safety

Chapter 1 – Introduction

1.1 Introduction

This study aims to identify the critical elements of the bucking unit and improve upon them for cost and weight reduction where applicable and appropriate. A bucking unit is a machine that makes-up and breaks-out pipe in a safe and effective manner (Universe Machine Corporation, 2021). The pipe being discussed in this dissertation will be drill pipe, generally used to transport coal seam gas at very high pressures. There are multiple types of pipes with differing governing dimensions such as inside diameter, outside diameter, consequent wall thickness and length. Along with this, it must be understood that there are a large variety of connections, however, threaded connections will be the focus in this report. These are generally identified by their connection number (N.C.) followed by a set of digits, such as NC38. These are used within the API standard to easily and quickly identify which type of threaded connection is used within a pipeline, helping to understand the working conditions of pipe. By reviewing the current literature and discussing critical elements of the design, the optimal design for the bucking unit will be proposed. This will be supported with the use of finite element analysis (Solidworks based) ensuring the design is fit and suitable to last an appropriate life cycle safely and effectively.

1.2 The Problem

The issue with conventionally designed bucking units is that due to torque requirements and sizing of the drill pipes along with previous designs, bucking units were typically secured into the ground for ease of resistance against the high forces exerted. There is a large push for devices such as bucking units to become mobile and easily transportable. This is due to the large expenditure that comes with closing down coal seam gas drilling operations for multiple days. It is clear that the large price associated with drilling downtime is great and impacts the business severely every day it occurs. It is widely known and understood that prevention is preferred over fixing a machine, especially when related to downtime. Using devices that can be transported on-site to perform routine maintenance or repairs on drilling equipment, as discussed above, can reduce downtime costs.

Downtime costs can come in many forms, such as:

- Operator wages – Not being able to work until the specified equipment is fixed
- Transportation – Paying for road transport for equipment to be moved to the location of repair and back
- Fitting/testing – Costs associated with the time taken to fit the new equipment and ensure it is running as intended
- Contractors/hired workers – Having to pay callout fees for onsite welders and engineers
- Loss of production – The largest cost by far, being the drilling operation not able to continue as required, thus losing large amounts of profit

Identifying these issues is key in understanding and idealising a modern design for the bucking unit for modern problems. With these issues at the forefront of the report, solving the issues at hand within the improvement of the current bucking unit design will undoubtedly resolve most of these above identified financial loss associated with drilling operation downtime.

1.3 Project Objectives and Research Question

It is well understood that coal seam gas, oil and energy-based companies are striving for more effective and sustainable technologies, methods and processes of conducting their work, for the benefit of future generations alongside the workers of today. This report will investigate how to improve the effectiveness of the bucking unit design to reduce lead time and overhead costs. Ultimately, this report aims to do the following;

- Review the design of the current common bucking unit
- Investigate the processes in which the machine works and understand ways to improve the effectiveness of the design
- Identify critical components of the design to make potential improvements or adjust them for transportation
- Reduce the overall size of the design to be suitable to be locked onto a shipping container or other similar tiedown method to be transportable via truck
- Conduct a rigorous design methodology supported by FEA to ensure the design is feasible and reliable
- Compare materials that are able to be used in regard to availability, ease of manufacturing and weldability
- Conduct research into the current design methodology and determine if any gaps in the market can be assumed

Using the knowledge acquired through an extensive literature review and rigorous 3D model testing and FEA, a design suitable for these applications that will aid in reducing the costs of drill pipe repairs and maintenance will be created. Using these methods described, the following research question will be answered;

How can a bucking unit (bucking machine) be designed such that it is transportable, providing on-site servicing and repairs of drilling pipe?

1.4 Ethical Issues and Consequences

Identifying ethical issues in design are key when discussing a potential future design. It is the responsibility of not only the designers but the approvers and stakeholders to ensure the design achieved does not cause any significant negative impacts to any one community or group. It is clear that engineers hold a certain role in ensuring the designs created are sustainable, efficient and have a net positive impact on the environment and communities in which it affects. Below all identifiable ethical issues and relevant consequences will be identified.

The design aimed for this project is to create a bucking unit that is suitable for transport, reducing overhead costs and lead time experienced with off-site drill pipe repairs and maintenance. This solves one issue, as stated above, but it is recognised that other issues of ethical concern must be addressed and considered when undertaking a design project such as this.

The main ethical concern with this project is seen that any company or business that relies solely on the work provided by this pipe repairs and maintenance would inherently suffer due to the lack of required work. It is true that this could certainly be an issue, however, it is seen as quite rudimentary to assume there are many companies that merely incorporate one of the many forms of fabrication and trade work involved within the oil and gas industry. Furthermore, it is quite fair to assume that many businesses will not notice any change in work, purely due to the fact that this design is not being created for mass production, rather, it is suited for incorporation into one company in which it is designed for.

Engineers Australia Code of Ethics outlines many ethical issues within all elements of the engineering profession, the main focus being sustainability. This can be related to sustainability for the environment and the communities within, ensuring the current and future generations are able to experience the same opportunities as the current and previous (Code of Ethics and Guidelines on Professional Conduct, 2019). The four main points within this Code of Ethics are to demonstrate integrity, practise competently, exercise leadership and promote sustainability (Code of Ethics and Guidelines on Professional Conduct, 2019). This project aims to utilise all of the above stated ethical guidelines to the fullest extent.

1.5 Project Outline

As previously stated, this report aims to design a bucking unit that is easily transportable whilst providing appropriate torque to sufficiently make up and break out threaded connections on drill pipes. Due to the design being relatively similar for years, there is very limited literature sources available on such devices, as it is not ground-breaking technology nor is there a large user market. Along with this, it is assumed that companies that have successful designs of such equipment do not wish to discuss their findings and shortcomings of their design methodology. Companies that require these services generally outsource the work to companies that are in possession of such a machine, as purchasing or building one is too expensive to justify the money saved via outsourcing. This, however, is not the purpose of the report, being to propose a design that would allow Obadare Group to excel in the energy sector locally and provide yet another service to their customers.

To identify what literature will be of potential benefit to this report and its readers, keywords must be established. This allows for the identification of useful pre-existing information to be digested and relayed, laying the foundation for the reports design methodology and, findings and relevant discussion. The table below identifies what keywords will be used throughout this literature review, paired with an explanation of reasoning into its choice. Keywords may be used in conjunction, separately or as a combination of many.

Table 1. 1 Definitions and Key Search Terms

Term	**Explanation**
Drill	This is a broad term that will return many results related to the oil, gas and energy sectors. This will provide a broad explanation of the field to inexperienced readers, allowing for insight into the current moves of companies in the space
Pipe	This term will narrow the search to drilling pipe, providing a more accurate set of results and articles in regard to filed and sector
Bucking Unit	This will provide very specific information on the related field, attempting to discover any pre-existing written material on these machines
Overhead costs	These terms will allow me to review reports on overhead costs and investigate reputable methods of reducing overhead costs within a business and how they can relate directly to my design choices
Lead time	These terms will allow me to review articles that discuss lead time within business with regard to certain devices and services offered by companies, and ways in which to reduce them
Oil and Gas	These keywords allow for results directly within the intended industry, providing results more accurate and reputable for the research to be undertaken

Due to there being very little literature on bucking units and their services, processes and requirements, literature will be reviewed on multiple areas of discussion surrounding the potential design and how to make an effective device. These include:

- Similar devices or machinery in the field – understanding what steps the author or designer has taken to ensure that their design is successful in the oil and gas industry
- API standards – review what the current needs are for this product defined by API Q1 and ISO 9001, understanding the differences in each standard and how they relate directly to my design process
- Material choices – investigate recent and previous established literature surrounding material choices
- Critical components – Review multiple weighted grading methods, identifying the most appropriate to use for the decision of critical components

Using the above identified fields of discussion, justifications towards design choices can be made effectively and backed by reputable sources.

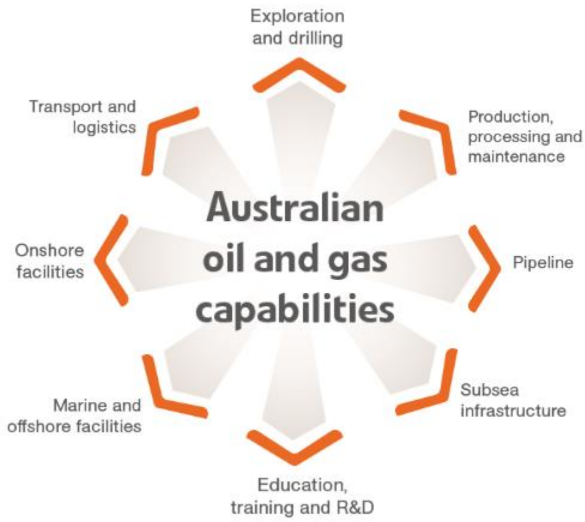
1.6 Industry and Field Overview

Oil and coal seam gas has been a major supply of energy for Australia for over one hundred years. Since 1907, Australia has been drilling onshore wells for crude oil production to be used as a form of energy (Australian Government, 2014). Currently, coal seam gas is considered much more environmentally friendly than traditional oil and coal (WA Museum, 2017). As coal seam gas is drawn from the wells via the drilling process, it is then stripped of impurities and cooled, changing the state from gas to liquid, thus the formation of LNG (liquified natural gas) (Queensland Government, 2016). With 22 million tonnes of liquified natural gas being exported from Queensland alone during the 2019 to 2020 financial year, generating $11.1 billion in gross capital gains via the industry during the year (Energy Information Australia, 2021), it is clear that there is a large demand for the services and products created from liquified natural gas. This also helped see Australia become the second largest exporter of liquified natural gas worldwide. Examples of products that use oil and CSG during production are medicines, electronics, toiletries, vehicles, petrol, paint and much more (Energy Information Australia, 2019). For years, workers and pioneers during the ‘coal seam gas boom’ have been searching for ways to reduce costs, wherever possible, to allow for more profits, as any business model deems reasonable.

Whilst oil and gas throughout the energy sectors has laid the foundation for future generations regarding opportunities for work along with the commercialised products that benefit from oil and CSG, it is clear that the industry faces many challenges in its road ahead. Ensuring that the many jobs invested into this sector are secure for years to come will allow Australia’s economy to thrive for many years to come. Some issues that will be faced in the future are due to the high-cost environment, regarding exploration and development of new potential sites. Another issue is the fluctuating price of oil and gas, affecting jobs around Australia, especially for operators (CSIRO, 2017). Continual development and innovation of new technologies is essential for this sector to see growth and ensure the workforce directly and indirectly related to these processes thrive.

The oil and gas industry has also allowed for accelerated innovation for many other technologies that are transferrable between industries and professions. These are seen in the figure below.

Figure 1. 1 Australian Oil and Gas Capabilities, AusTrade, 2016



This cannot have been done without the innovation and constant improvements made to drilling rigs. A drilling rig is a combination of multiple large pieces of machinery, such as the crown, drill string, top drive, doghouse, blow off prevention, mud pumps, skids and pits, pipe racks and much more. Every device listed and many more serve a specialised purpose within the drilling operation, allowing for an effective removal of oil or gas from their natural seams all the way through to the refinement stage. These rigs are used onshore and offshore, with layouts and machinery changing depending on location and intended use. It is estimated that the demand for natural gas to generate energy will increase by 50% between 2017 and 2040 (Oil and Gas - A Roadmap for unlocking future growth opportunities for Australia, 2017), and that CSG will remain a dominant provider of energy within the sector for many years. The Australian Government stated, however, that it aims to reduce the amount of CO_2 emissions by at a minimum of 70% from 209.5 MT (mega tonnes) to approximately 63 MT (Timperley, 2019). Oil and gas has been a major contributor to Australia's economy for over a century, boasting a GVA of over $31.4 billion and ensuring over 17,600 jobs for Australians (L. Granwal, 2020).

With an oil refinery capacity of 72 million litres per day, it is no wonder the oil and gas has seen such success. Australia sits as the world's largest exporter of LPG (liquified petroleum gas), whilst exporting 105 billion cubic metres of LNG (liquified natural gas) in 2019 (L. Granwal, 2020). The table below describes the amount of energy consumed by Australia during the FY (financial year) of 2018-2019.

Figure 1. 2 Energy Consumption in Australia, Department of Industry, Science, Energy and Resources (2020

	2018–19		Average annual growth	
	PJ	share (per cent)	2018–19 (per cent)	10 years (per cent)
Oil	2,402.1	38.8	1.3	1.7
Coal	1,801.6	29.1	-2.5	-2.3
Gas	1,592.7	25.7	2.2	2.7
Renewables	399.6	6.4	4.6	3.9
Total	**6,196.0**	**100.0**	**0.6**	**0.7**

The diagram below describes the uses of LNG during the 2018-2019 FY.

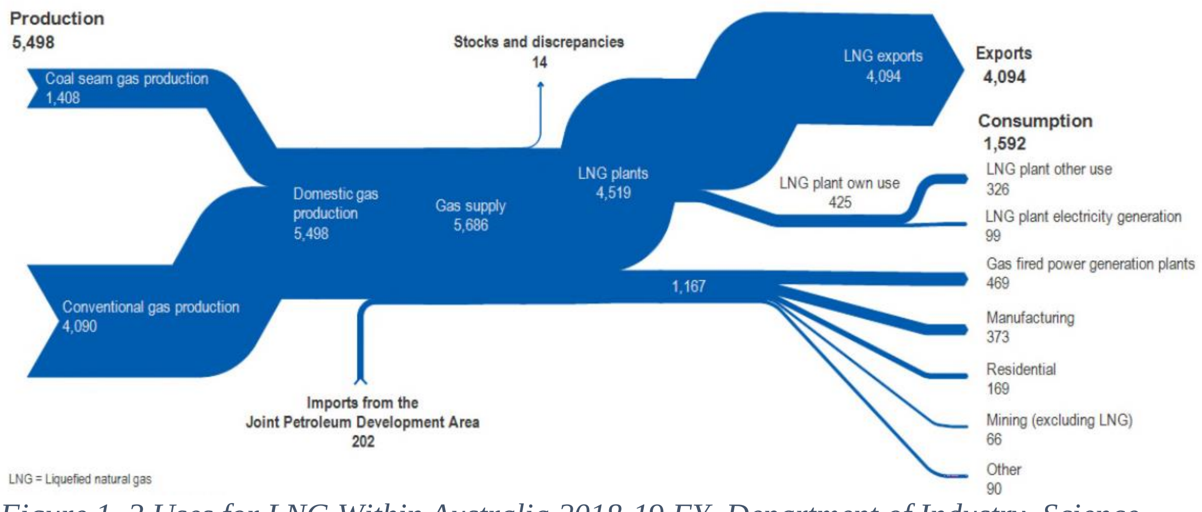


Figure 1. 3 Uses for LNG Within Australia 2018-19 FY, Department of Industry, Science, Energy and Resources (2020)

The data here suggests that a large portion of the LNG produced within Australia is sold off and exported to other countries. This provides grounds to assume that the oil and gas energy sector provides a multitude of opportunities for work and economical value within Australia. It is clear, however, that other forms of energy use are on the rise and aim to replace oil and gas as major energy providers. This will take a long time and thus the oil and gas industry must ensure the projects undertaken by these companies are effective and efficient as ever, providing a sustainable future for workers.

It is with the constant development and refining of these devices that the industry can remain profitable and allow Australia to maintain a dominance in the market for energy for years to come.

It is seen within *Section 1* that there is an incessant need for a design such as this bucking unit that provides a much easier method of delivering these services on-site, aimed at benefiting the companies in use of these units throughout Australia.

1.7 Chapter Outlines

Chapter two of this report outlines all literature surrounding the design of a mechanical system. Some features of this chapter include but are not limited to material comparison, engineering principles relating to the topic, industry specific components and more. Chapter three outlines different forms of design methodology available to use, comparing these from trustworthy and reputable sources, to identify the most effective methodology to utilise during the design process within Chapter four. Chapter four also details the design process, initial and FEA testing along with revisiting models ensure FEA results are appropriate. Chapter five details a concise evaluation of the final design, discussing which project objectives were achieved and which of them were not due to time restrictions and resource limitations. Chapter six details the conclusion of the report, discussing what happened successfully and what was not satisfactory throughout the design process. Following this are the appendices, featuring detailed drawings, project timelines and budgets/resources, along with the risk management plan (RMP).

1.8 Conclusions

This report has highlighted the requirement for the values and principles of design surrounding sustainability and effective service within the oil and gas industry. This is not limited to this industry alone, however, emphasising the importance of these values within design for all engineers across many industries and sectors. The design seen was successful at reaching the intended goals set out for the project. More work is required, however, to get this design to be approved for manufacturing. This involves technical drawings, hydraulic force measuring gauges and more. The design was seen to be successful, however, with all but one of the project objectives being completed. The last project objective was not completed due to being a case of time permittance, which was not available throughout this project.

Chapter 2 – Literature Review

As previously stated, the question posed for this dissertation is as follows:

How can a bucking unit (bucking machine) be designed such that it is transportable, providing on-site servicing and repairs of drilling pipe?

In order to understand the processes and reasoning involved with answering this question, it is imperative that current literature is discussed, analysed and reviewed regarding the field and the intended use of the product. This way, the design is ensured to be based around informed decisions derived from a multitude of reputable sources and data. This chapter serves as the location of information aimed to provide a richer understanding of drilling rig equipment, in particular drill pipe (and drill string) and how repairs can be made on-site, reducing many costs associated with these repairs, such as lead time. Initially some facts about the industry and its positive impact on the world must be stated to understand the important role the oil and gas industry has had. The graph below presents the amount of energy consumption in Australia per type of energy.

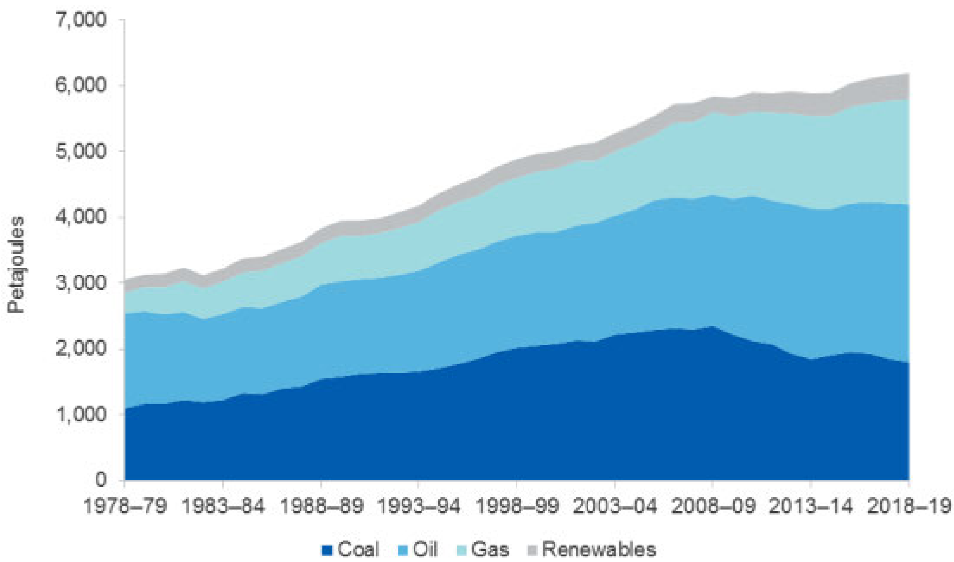


Figure 2. 1 Energy Consumption in Australia vs Year, Department of Industry, Science, Energy and Resources (2020)

It is abundantly clear that whilst other forms of energy usage are increasing every year, it will be many years before it is at the point where Australia aims to be gaining a vast majority of energy generation from renewables, as compared to oil, gas and coal. The information presented in this article is highly reputable, being government statistics from 2020.

This allows for transparency with the data and no tampering or incorrect data being used, providing insight into the state of energy production and consumption within Australia currently, allowing the reader to derive future trends.

For years, companies within the oil and gas energy sector have strived to use superior technologies and processes every step of the way. This is shown throughout the history of the drilling rig and its constant requirement for improvement and competitive edge, sparking the current designs seen today all around Australia. Table 2.1 below describes a timeline that depicts the evolution of drilling rig technology and the benefits seen by them.

Table 2. 1 Drilling Technology Evolution (Eustes, 2007)

Year	**Improvement**	**Benefit**
1901	Combined use of drill-mud and rotatory drill-bit	Easier access to deep underground wells, provides deeper drilling access
1924	First blow off prevention system designed	Reducing risk and hazards associated with blowoff from drilling rigs due to high pressure release
1933	First design of tricone drill-bit	Used with drill-mud allowing for much quicker digging for rigs
1978	Measurement devices used while drilling	Allows for use of failure prevention detection methods to be used while operating
2006	Drill rigs are now placed onto ‘pads’	Reduces effect on the surrounding land and environment
2012	Hydraulic skid implementation	Allows rigs to be transported much more quickly and efficiently

It is seen through the report that whilst improvements to machinery and the way in which drilling is now conducted compared to previous designs and methods, that a clear development of the technology has occurred. In saying this, the article fails to mention any form of future intended study relating to these beneficial improvements, thus leaving the reader open-ended as to where the field and industry are at currently with research and development of this machinery and related procedures. Along with this, the article does not state any lacks in research identified by the author.

The reliability of the article is not questioned, rather the authors lack of identification of potential future issues within the industry. In recent years, drilling rigs and equipment have been used for more than just drilling operations. China and other countries on the forefront of drilling and mining operations have been utilising drilling rig equipment to remove and help ventilate underground coal mining operations (Hungerford, Ren and Aziz, 2013).

Using an operation called in-seam drilling, drilling rig equipment has been utilised to minimise risk of gas blowout during mining, improving the safety for all miners and the surrounding environment and its inhabitants (Hungerford, Ren and Aziz, 2013). This also allowed for the continual improvement of surveying techniques along for mining and drilling operations.

It is critical to discuss and outline some key features of a drilling rig, providing insight into the operations of each type of machine. Drilling rig components are generally categorised into two types, being surfaced and down-well systems. Surfaced systems consist of everything above the well, such as generators, top drive, pipe handling and hydraulics systems, whereas down-well systems consist of drill string, drill-bit, measurement devices and more (Brakel, Tarr, Cox, Jorgensen and Straume, 2015). The article further states that there are three types of time measurements used to categorise and identify approaching performance statistics, being non-productive, productive and invisible lost time. Non-productive time, contrary to the name, means time spent indirectly preparing for the well to be drilled, whereas productive time is classified as time spent drilling the wells. Invisible lost time is described as extra time required during a drilling operation due to inefficiencies (Brakel, Tarr, Cox, Jorgensen and Straume, 2015).

As previously stated, there have been many developments with regard to drill pipe and drill strings, allowing them to be more robust for use and fatigue resistant than previous designs. Approximately 30% of all time required setting up drilling rigs and wells is accounted for by the setup of tubular goods, such as drill string (Kinzel and Pietras, 2011). This would amount to millions of dollars every time the operation must come to a halt for the maintenance and repairs of these connections and pipes (Kinzel and Pietras, 2011). Using this information, another need for a design for transportable, on-site drill pipe makeup and breakout operations can be identified.

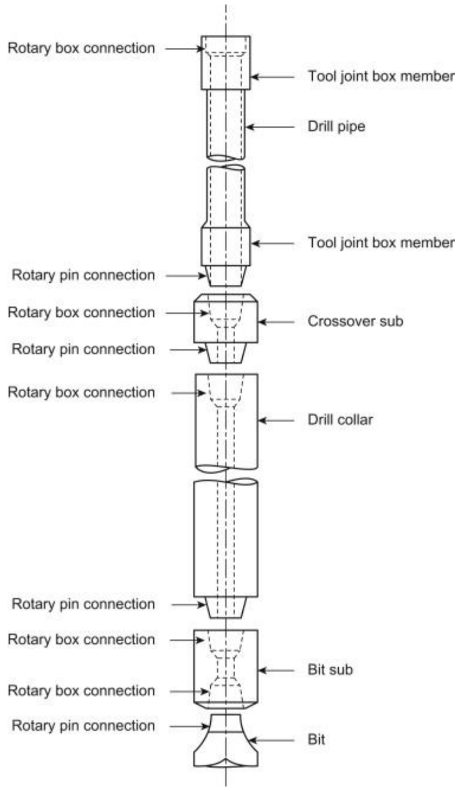
This is due to not only the materials chosen but the connections and other design choices made, providing longevity and safety during drilling operations. There are many factors to consider when designing choosing drill pipe for the required purpose. These include reflection from API and ISO standard requirements, connections, joints, pipe grade, torsional strength and more. The table below describes the types of drill pipe grades and their respective yield strength.

Horizontal onshore drilling, perhaps considered one of the most effective and beneficial developments within the coal seam gas industry, has allowed well operators to attain much more CSG per lifetime of a well relative to traditional drilling operations. This has called for a large development of drill pipe (drill string) technology, as it is now required to be used horizontally for more effective practice.

Drill pipe has, in recent years, been a constant source of innovation and development, much like the rest of the equipment used in drilling rigs. This is due to an increase in demand for energy and the biproducts associated with oil and gas (Liu, Guan, Zhang and Zhang, 2016).

Innovation in drill pipe has, as previously stated, allowed for the extended exploration of new drill sites with new technologies, such as horizontal hydraulic fracking and drilling. Investigations into using different types of materials for pipe have been underway for many years now, showing promising results. Discussions and testing of certain other materials such as composites or titanium and carbon fibre blends have been posed, being a much more effective solution to directional drilling using conventional steel pipe, with strength to weight ratios 101% and 34.8% higher respectively (Leslie, 2008). It is also seen that composite pipes are able to extend nearly three times that of conventional steel pipe for directional drilling. However, it is seen that there are major cost issues involved with using such materials for drill pipe, being approximately three to five times the cost of generic steel pipe (S-135), providing investors and implementors a good reason for not yet adopting this technology. The design and manufacturing of a drill string is not as simple believed, however, having multiple joints and pin and box connections. This can be seen in the figure below.

Figure 2. 2 Typical Components of Drilling Equipment, Sankara Papavinasam (2014)



It is clear that the design of a drill string in its entirety is a large and complex system that has been evolved from the original design to meet modern day requirements placed onto the equipment with rising populations and this increasing energy usage. This outlines the necessity for ever improving and updated technologies and forms of maintenance for these drilling rigs and the equipment used within. One of the most expensive forms of maintenance seen within the lifetime of drilling operations, is, with no surprise, shutting down wells for maintenance and repairs; not to be confused with decommissioning; where companies must make the harsh decision of incurring a large loss for repairs or decommission the well. The costs companies are subjected to not only come from pausing production but also come from resuming production, costing the average well approximately $400,000 to $500,000 USD for stopping and restarting useful production of the drilling rigs (Gauthier, 2020).

These costs generally come in the form of overhead costs, lead time pending for resuming production and labour, along with the parts and chemicals required for the maintenance or repairs. It is clear that there is a large amount of pressure on companies to find ways in which these costs can be reduced, as the costs not only affect the company and business model but the jobs in which they provide nationwide.

Some costs that are foreseeable and manageable within reason are lead time and overhead costs associated with these repairs. These costs are identified as foreseeable within reason as they are a guarantee when drilling rigs and wells need routine maintenance or repairs. Lead times are a very important factor to consider when organising these types of halts on drilling operations. They are directly related to customer satisfaction, inventory supply and pricing of these operations short and long term. Lead time grows exponentially when some material, part or device must be removed from the system on-site and taken to another location for fixing, testing or maintenance.

This is seen with drill pipe within the drill string. As the pipe is under large angled frictional forces and dynamic vibrations throughout the lifetime of the well, it is common practice to perform routine checks and maintenance if required. If repairs are required, generally these services cannot be offered on site, due to many reasons such as the machinery used to be too large to transport.

There are four main areas in which a drill pipe is most likely to fail or show signs of premature failure, being:

1. Irregularities in surface condition
2. Pipe upset; volume of pipe that reduces/increases in cross sectional area
3. Corrosion pitting
4. Threaded connections

(Zamani, Hassanzadeh-Tabrizi and Sharific, 2016)

Accompanying these issues, constant dynamic loads and vibrations that the pipes endure are also very frequent modes of failure. These are described in the figure below.

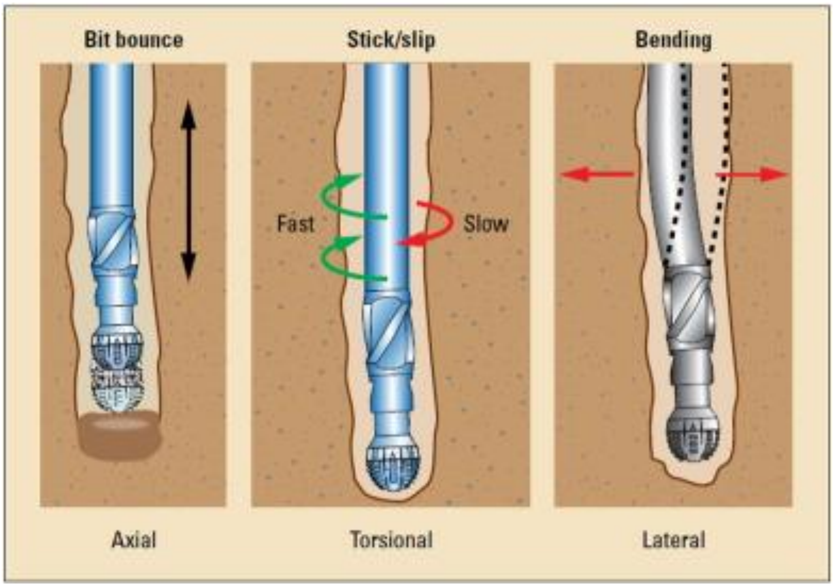


Figure 2. 3 Effects of Vibrations on Drill Strings, Zamani, Hassanzadeh-Tabrizi and Sharific (2016)

The most prevalent mode of failure is fatigue, caused by frictional heating combined with incredibly high pressures of fluid and gas pumping through the pipes, causing up to 68% of all failures within piping (Zamani, Hassanzadeh-Tabrizi and Sharific, 2016). Due to the many forms of failure that drill pipe and drill strings are subject to, it is clear as to why there is an incessant need for on-site repairs and routine maintenance within reason.

Grade	Minimum Yield (MPa)
E-75	517.1
X-95	655.0
G-105	723.9
S-135	930.8
Z-140	965.3
V-150	1034.2
U-165	1137.6

Table 2. 2 Drill Pipe Grades and Strengths (MPa), IADC (2015)

IADC also lists certain types of connections (weld on tool joints), seen in the table below.

Code	Description
IF	Internal Flush
XH	Extra Hole
SH	Slim Hole
OH	Open Hole
SL – H-90	Slim Line – Hughes-90
FH	Full Hole
H-90	Hughes-90
WO	Wide Open
NC	Numbered Connection

Table 2. 3 Connection Codes and Descriptions

These different types of connections allow for different types of applications, but the most common by far is seen to be the numbered connection, as it allows quick identification of the type of joint, allowing for interchangeability between many different parts with the same code. These are generally listed NC23 through to NC77 pipe (API, 2002).

There is no doubt on the reliability of the data provided by IADC (International Association of Drilling Contractors), being a non-profit association. Along with this, the values presented appear consistently throughout other sources where external referencing has occurred, thus this source is reliable and reputable.

The maximum torque to makeup a threaded connection is 60% of the minimum yield strength for a pin or box connection (whichever is weakest in the connection) (Specification for Drilling and Well Servicing Structures, 2016). It is understood that numbered connections (NC38 for example) are the most common due to their adaptability and strength within many use cases, therefore these connections will be used for the standard of this report. As outlined within API 5B, it is seen that for 6-5/8 OD pipe, the maximum recommended make-up torque is 19500 N.m. API states, however, that the minimum makeup torque for an NC50 connection on a 6-5/8 inch pipe is 40300 N.m.

Material choices are crucial to ensuring a design meets the criteria set out for it in the beginning stages of the design process. Material choices are determined by many factors, some of which include:

- Cost
- Availability
- Weldability
- Mass
- Strength

Some components within this design will not need a heavy review of materials to ensure the success of the design. This includes components such as the base frame, tongs and more. For this, a very simple approach will be taken, discussing two popular materials for use in steel construction. These are GR350 steel and AISI 1020. Both are very common forms of steel within Australia for their availability and low costs relative to other forms of materials.

The table below compares many factors that have an impact on the choice of material to be used. Weldability and availability are removed from this comparison as they are both equally available and weldable as a parent material. Cost will be based off a 10mm thick plate.

Parameter	**GR350**	**AISI 1020**
Base Metal Price (Relative) (%)	1.8	39
Density (kg/m^3)	7900	8200
Strength (Nominal) (MPa)	350	830-2300

Table 2. 4 Material Comparisons (BestBuySteel (2014), BlueScope Distribution (n.d.), Makeitfrom.com(n.d.))

It is clear that these metals offer much different services as intended, however, being two very common materials, a comparison was made to provide assurance that the chosen material was suitable for the structural design of the above listed components. It is seen that AISI 1020 is incredibly expensive compared to grade 350 steel, due to the amount of pre-treatment the material requires (Kelly et al., 2019). Therefore, it is seen that the material choice of grade 350 steel is appropriate. Furthermore, the material choices for critical components that require a more in-depth analysis and review will therefore require a more comprehensive and thorough method of comparison. Using Pugh's Method, this will be done within *Section 5 – Design and Testing*. This will ensure that the material choices made for components not able to be made of grade 350 steel will be suitable for their intended application, such as higher stresses induced from high torque outputs.

Another innovation within the design of drill pipe is presented in the article below, describing multiple approaches taken when discussing and reviewing drill pipe, stating that the design of drill pipe has not evolved at the rate in which other technologies in the same space have, thus creating a lack on research within the field that is starting to be recognised and discussed.

The forces that drill pipe must withstand when under operation are large, with examples being frictional forces due to high angle curvature, tension upon the drill string when deep underground, high pressure of the drilling mud and gas within the pipes along with the large torque forces between the drilling components and the land. After the tests on certain drill pipe materials and compositions were completed, the data attained suggested that regulations on drill pipe were below what is now understood to be critical in the design of drill string (Shepard, 2014). This article was spoken at a conference for offshore technology, thus an argument can be made questioning the validity of the report, however, it must be noted that the trials conducted within the report appear to be valid with appropriate results, thus this resource is seen as noteworthy.

It is seen that there are many elements involved within the design of the drill pipe alone, let alone drill string and other components. This is all a clear derivation of company's efforts within the oil and gas industry to ensure maximum efficiency of drilling rigs optimising business models for minimal related costs. An example of this is seen below within the case study, where the company involved designed an open head bucking unit, a first for the industry. The company claims this design has reduced not only pipe-process time but has allowed for the minimising of non-productive time delivering precise results, all on site (Hulke, Habetz, 2016). This is repeated within the article *Preventive Maintenance and the Drilling Contractor* (Shepard, 2012), stating that one of the very few areas in which the oil and gas industry has not extensively reviewed as part of cost savings is within the maintenance of machinery and operations. This could come down to a multitude of reasons, such as capital or overhead costs being too high to justify the analysis of these departments and forms of mitigation in the sort-term (Shepard, 2012).

One main issue seen within the oil and gas industry is that, due to the operation and industry being so vast, when discussing the large-scale supply chain, that the connections made between these are generally different companies. This creates many opportunities for communication defects and an unnecessary increased lead time for the refinement of goods, delivery of materials or services, etc. It is clear that creating a much tighter supply chain with increased communication and collaboration allows for the industry to thrive exponentially (Chima, 2011).

It is suggested that this can be addressed by ensuring any step of the supply chain above the issue that arises is able to respond quickly and rectify the issue in the shortest timeframe as reasonably possible. It is clear that when even one of the companies veer off course when regarding these goals set for the supply chain, whether it is due to acting in the best interest for profits, etc., that the customer satisfaction levels decrease exponentially with a decrease in quality service and timing (Chima, 2011). Tubulars are one of the most commonly supplied and sought after products within the oil and gas industry, being critical to the supply chain in an overview, whether it be casing, tubing or piping.

It is clear that managing this major element within the supply chain is essential to realising larger profits and an increased customer satisfaction rate with every business transaction (Chima, 2011).

Supply chain management is easily discussed in three separate sections, being configuration, coordination and improvement. The configuration is a type of adaptive planning seen within the supply chain, containing pre-communications between companies, allocation resources to certain areas and departments and more, ensuring a swift delivery of the intended service or product. Coordination follows, reviewing the processes and transactions between businesses as they take place and confirming that these practices are safe, profitable and effective for the companies involved (Chima, 2011). Improvement involves a review (for example, at the end of a large project) to discuss any concerns that were raised throughout the project, identifying key areas for improvement. This source is peer reviewed and contains many references to reputable government statistics and sources, thus the information provided is proof of experience and trustworthy.

It is clear that the oil and gas industry is leaning to high automation of products and services, as this will reduce overhead costs, lead time and potential human error, where people are not required to contact each other for the most part.

However, automation does not need to come in the form of reducing man-hours. An example of this is utilising a transportable model of a pre-existing device, such as the bucking unit. Whilst the service remains similar, it serves a purpose that cannot be solved any other way. On-site repairs and maintenance of tubular goods is an effective form of cost saving and profit realisation for many companies invested in oil and gas wells (Macmillan, 2019).

Whilst the design of the hydraulic motor will not be undertaken in this project, information on the devices will be provided, allowing insight into the choice to use this motor type. Hydraulic motors convert high levels of fluid pressure into kinetic rotary energy used to power mechanical components (Zhang, 2010). There are three types of hydraulic motors, being piston, vane and gear motors (Daniel and Paulus, 2019). Gear motors, whilst not being the most efficient, have a very high tolerance for oil contamination, making them ideal for dirty work environments that are constantly changing (Daniel and Paulus, 2019).

Piston motors come in variable and fixed volumetric versions, and come in many types, the most popular being axial piston motors. These are seen as ideal for variable loading conditions where the power and force required from these motors is constantly changing (Daniel and Paulus, 2019). These are generally seen as the most expensive to buy and operate. Vane motors, on the other hand, are efficiently sized and extremely reliable, with one limiting factor; low speed capabilities (Daniel and Paulus, 2019). This is confirmed by Zhang, also stating that these motors are effective when the motor is required to start under immense load. Soft starters are also available for use, allowing for automatic control on the use of the hydraulic motor, i.e., if the motor is under no load for a certain period of time, it will automatically shut down. These sources are reliable as they are from leading industry experts.

There are two commonly seen gearboxes paired with hydraulic motors, being chain and sprocket reduction and planetary gearboxes. Chain and sprocket gearboxes will not be considered for this design for two main reasons. Firstly, they are large in size and quite heavy when a mount and the surrounding cage is built for them (Kent, 2018). Secondly and more importantly, chain and sprocket gears are very unsafe, and have been known to snap and injure workers nearby, even with the appropriate protection. The alternative is planetary gearboxes. These are very safe in comparison to the former mentioned (Kent, 2018), and are much smaller and lightweight than the required mass of all components for chain and sprocket gears. They use a series of gears within the gearbox that can be changed at any time to achieve the desired torque output, controllable by the rotational velocity of the gears and the gear reduction currently used (Strmčnik and Majdič, 2019).

We see that there is a strong foundation of articles and peer reviewed literature that can be used to identify the critical elements of this design, using these to support and justify the future decisions made towards the design. Using the above sources in conjunction with the design methodology below, the following is to be determined:

1. How can the design of the bucking unit be achieved whilst reducing the size of the base frame?
2. How can the bucking unit be easily removed from and placed onto a truck for transportation?
3. How can the bucking unit be accessed from the truck?

4. What materials are the most effective for certain areas of the design which are high stress?
5. Can the overall design withstand the large torque and clamping forces whilst being reduced in size and weight?

The information discussed above not only provides a variety of context for the units implications into the field and the benefits that would be seen by utilising these, but allows insight into the industry as a whole, depicting the need for ever-increasing productivity. Using the above stated questions, we can base the design methodology and process around these, ensuring the design meets the requirements as per the design requirements and goals identified in *Chapter 4 – Design Methodology* below and as described in the introduction.

Chapter 3 – Design Methodology

Outlining the processes and tools used in for this device to be designed will provide a clear understanding of the methods in which the design was achieved, providing validity and justification for the choices made. The design methodology chosen will not only align with Australian standards of design but API (American Petroleum Institute), allowing for a comprehensive and rigorous design methodology to be attained and provided. The process of design will adhere to the following standards:

- AS1170.0 and 1170.1 (Structural design actions) – These standards are crucial for identifying general procedures and criteria for the design of structures. It incorporates actions (and combinations of actions) along with methods of analysis and confirmation of the design, providing a firm basis for which the design will be tested and justified with.
- AS/NZS 1100.101 Technical drawing: General principles – This standard is used to produce effective technical drawings for the production, procurement and assembly of complicated designs. This standard provides information regarding line thickness, appropriate dimensioning, tolerances and more.
- AS/NZS 1554.1:2014 Structural steel welding: Welding of steel structures – This standard compares and discusses the requirements of certain steel structures and related welding specifications.
- API Q1 – Specification for Quality Management System Requirements for Manufacturing Organizations for the Petroleum and Natural Gas Industry – Following guidelines from the American Petroleum Institute, this standard provides information key to ensuring the product is certified to be used for the generation of oil and gas.
- ISO 9001: Quality Management Systems – This standard is used in conjunction with API Q1 to ensure the design proposed is safe and effective for use. It discusses risks and forms of mitigation, amongst other quality management systems.

For this system a thorough review of the mechanical design process has been undertaken. With reference to *The Mechanical Design Process* (Ullman, 2010), the design process has been broken down to find the most optimal method in which to pursue this project. As this project aims to not only produce a design that is fit for the market and useful within the oil and gas industry, it is clear that a rigorous review of the design process must be undertaken for this to be realistically achievable.

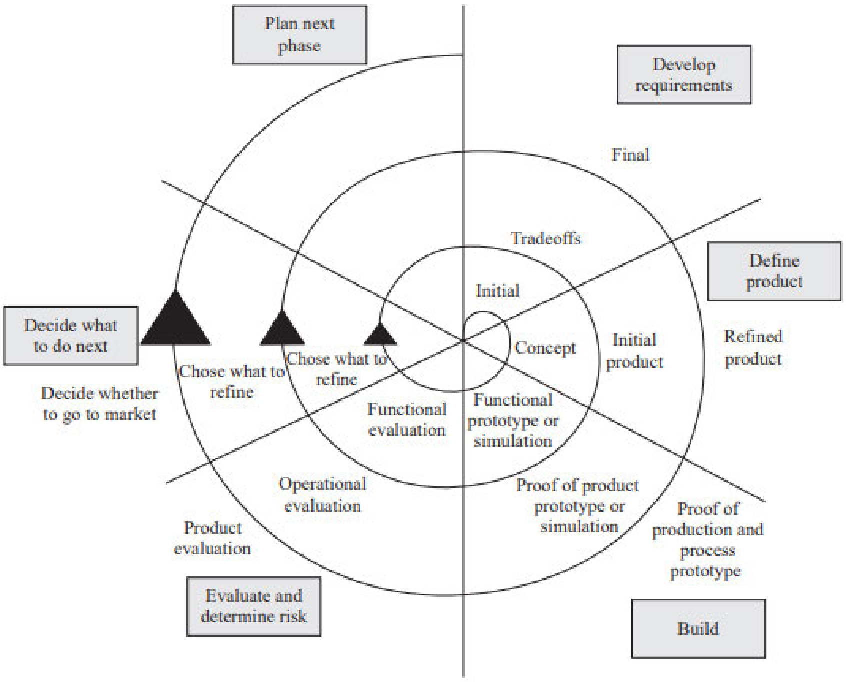
Ulman describes three effective methods to attempting design, being the following:

- Stage-gate process
- Spiral development
- Waterfall model

Inherently, all three methods of design aim to achieve one goal in common – propose the most effective design possible within an appropriate timeframe whilst remaining cost effective. The use of time within the design process is comparable to that of large expenditures for materials and other costly products and services (Ulman, 2010). Further investigation into these different methods will provide the allocation of the most optimal methodology. The stage-gate process is simple, stage one identifying the product in which must be designed, stage two is developing concepts and the third is to evaluate concepts, following through until the final design is achieved. This method identifies its critical benefit as utilising time for these stages in 'parallel' (Ulman, 2021), rather than simultaneously. This method is deemed effective yet not all features of the method are beneficial to this project design.

The second design methodology discussed is the spiral development methodology, where the designer begins at the 'centre' as seen below in the figure.

Figure 3. 1 Spiral Design Methodology, Ulman, The Mechanical Design Process (2010)

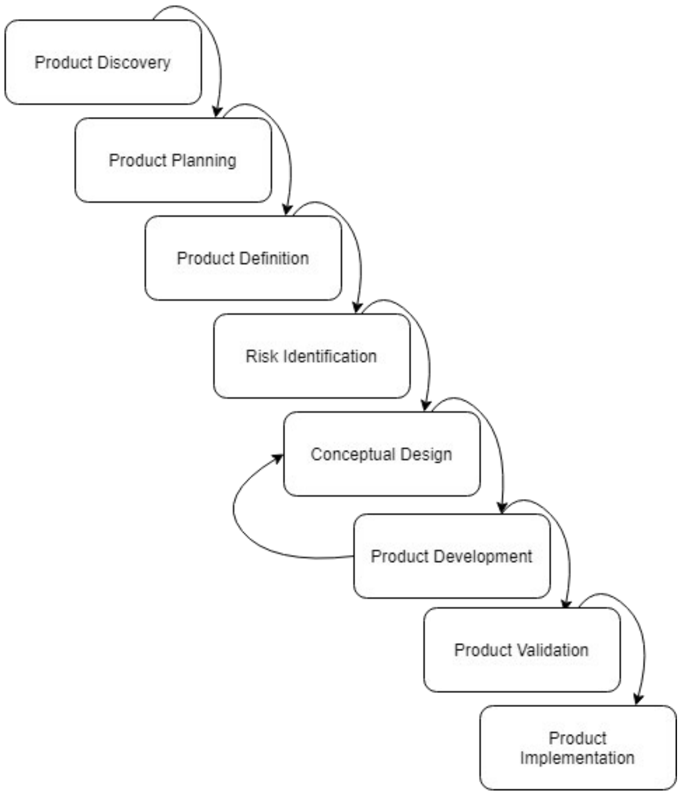


The primary defining features of the spiral process are iterative approaches, revisiting each task every cycle, reassessing requirements, prototypes and elaborations, clear decision point in each cycle, each cycle identifies objectives, constraints, alternatives, risks etc. for each stage, amongst many others. The spiral design process, however, is best suited to the design of things such as software and coding packages, due to the heavy iterations and recycling nature of the process.

The third method, being the waterfall model, is the most commonly used, and is a similar yet separate version of design methodology to that of the stage-gate method. This method identifies the product intended for design, beginning with heavy brainstorming and discussion around possible designs. This is followed up with the product definition and conceptual design of the product, allowing the designer to visualise and get a better grasp on the design constraints. This step is repeated multiple times until a final design is achieved through the validation of hand calculations and FEA testing, providing a numerical foundation for reputability. Proceeding this, product support is offered, with a discussion on the potential of the design for future models, along with maintenance and upkeep considerations.

Upon review, it is clear that a combination of all three methods will be adopted, using the waterfall model as the basis for the methodology. Elements from the stage-gate process will be utilised as they imitate the design process seen within most engineering firms in the industry, as the ‘stage-gates’ serve as design reviews at each major milestone of the design (Ulman, 2010). The focus of the spiral method will be utilised as well, due to its ability for reconsideration of the design and discuss potential areas of issue relating to other elements within the design. Using a combination of these processes, it is seen that the most optimal methodology is determined. In the figure below, a modified version of the waterfall model is constructed, visualising the tasks and steps necessary in creating the proposed design.

Figure 3. 2 Modified Waterfall Chart



The first stage of the design begins with the product discovery. This involves the identification of the needs that have allowed for this project to be justified and valid.

As discussed within the introduction of this report, the discovery of the project is founded upon the basis of the potential time and cost savings available to frequent users of this product. The overhead costs, lead time costs and labour costs associated with the use of bucking units are high due to the common design.

Due to torque requirements and utility, it was previously understood that the pipes in which maintenance and repairs are operated on were required to be operated on off-site. This is no longer the case due to technological advancements, providing the discovery of this product.

The product planning as seen in the figure allows for the designer and or company to allocate resources to the project to ensure viability. This is seen within a project timeline, describing the steps required for this project to be successful and the methods in which to achieve these. It is perhaps the most important of steps, as without the planning of the project, time can interchange between steps and a ‘lag’ of resources, such as increased lead times, may occur.

Product definition is key to outlining the task at hand, ensuring a swift delivery of the product for its intended purpose. The customers of this product are well understood, being companies that operate and service oil and gas well, due to their constant pipe maintenance schedule. Thus, the customer requirements must be established. This is conducted via discussing with relevant members of Obadare Group, such as Evan Maunder (Machine Specialist) and Jiel Case (Engineering Manager), gaining invaluable information on what Obadare would like to see from the design outputs. These can be outlined as follows:

- Must be transportable
- Weight must be inclusive within the safe loading and unloading of a forklift
- Must be able to break out and make up connections on 6-5/8 inch outside diameter (OD) pipe

With these requirements understood, we must now identify the targets for performance. These are outlined below:

- Length and width requirements must be met to ensure the design fits onto shipping container locks for transport
- Design must meet requirements by legal and safe work practices standards

- Torque required for the break out and make up of 6-5/8" size pipe is 19500 N.m., therefore must meet this minimum value

Another key element of the product definition stage is to identify critical components. These are components in which the dimensions, material choices and other choices regarding design are required to be accurate within the allowable tolerances, otherwise the component may be subject to premature failure or usage defects. This will be discussed further in the design stage, and the critical components will be identified and reviewed for justification behind the classification.

Understanding these requirements and their inherent performance goals and targets, the risks related to the design can be clearly identified. An example of this is the torque output requirements associated with making up and breaking out drill pipe, as seen above, and the risks that are implied from using machinery capable of generating such torque. This is a small part of the design process with large implications and adverse effects if not conducted correctly and thoroughly.

Once the risks are identified, conceptual design processes must be undertaken to compare multiple potential designs, all of which are fit to suit the requirements of the design. It is clear that some concept designs will be more appropriate for the desired application than other initial designs, whilst others will need to be changed heavily to suit.

Product development will occur once the concepts have been generated. These will become the refined products formed from the initial designs and will be generated using the Solidworks 3D modelling package. There are four main elements of design that will be evaluated during this stage:

- Availability of materials
- Ease of manufacturing
- Cost of manufacturing and implementation
- Performance with regard to specifications

No prototypes will be built for this design due to time limitations and funding availability, however the products will be communicated through Solidworks modelling and possible drafting of the final designs.

Following this will be the final step regarding the design of the component, being the design validation. This will be seen through initial calculations for critical values, whether they be dimensions, torque, power, mass, etc. The other form of product validation seen will be to use Solidworks Simulation add-in, allowing for effective finite element analysis (FEA) results. This will be realised by applying appropriate mass, torque and other force values to the components and discussing the results in the sections below. This will provide a level on confidence and justification for implementation into the design, ensuring safe and effective components are generated for the final product.

Whilst these steps are imperative to the design process, it is understood that the design must follow certain Australian Standards of design and manufacturing. These are briefly discussed above and will be covered in-depth. AS 1554.1 provides details on welding specifications for steel structures. Using sections 2 and 3 of this standard, the materials available to be welded together along with the details of welded connections are acquired. This will allow the identification of appropriate parent and backing materials to be used when welding connections are required, along with the relevant weld types best suited for each application and with the subjected stress values. Calculations from these sections will be used to identify whether a certain weld type or size may be suitable for the application.

The design process stated above will be the guideline for which the idealisation and creation of critical components in the design will be formed. This will be discussed further in *Section 4 – Design and Testing* below. It is noted, however, that design consideration will not be given to elements of the design outside the scope of this report. These for example include, but are not limited to:

- Hydraulic systems
- Power system
- Transportation forms (such as trucks)
- Electrical components and systems
- Gearbox/reduction system

The focus of this project involves the design of a bucking machine fit for transport and easy access to on-site locations, thus the critical components identified will relate to tackling the issue of size, transportability and weight.

These include, but are not limited to the following:

- Jaws
- Tong assembly
- Base frame
- Tong movement system
- Transportation connection

Using AS 1170.0 and AS 1170.1, the dynamic and permanent loading variables can be determined for each load case subject to the design. This provides the design with a margin of safety required for production and safe and effective use. Using Section 3 of the standard, determining the lifetime of the design is possible, along with Section 6 allowing for the determination of the load paths and Section 4 to determine the effects of the cyclic action of applying and removing high torque concentrations on the jaws.

AS 1100.101 provides information on how to appropriately and effectively communicate all designs and related information (such as connections, materials, geometry, etc.) within the technical drawings for the components. This will also provide the knowledge necessary for creating technical drawings of the final assembly of the drawing.

This design, whilst not bound by any certain API requirements, will benefit from being subject to some restrictions from the API Q1 standard. This will allow for a more effective implementation of the design into the industry, along with ensuring the design complies with appropriate and common quality assurance guidelines. Furthermore, if the design were ever to need API certification, e.g., to be used for API certified work, the design would not require as much modification to reach this certification. The above identified critical standards and methodology will be utilised throughout the design process to form a design that is effective and successfully integrates into the industry, providing the aimed services.

Chapter 4 – Design and Testing

Market Research

To outline the potential design parameters required within the critical components, an interview with Jiel Case (Obadare Group Engineering Manager) was conducted. Jiel provides years of industry experience and understands the required outputs of this design. The discussion comprised of multiple half hour sessions due to limited time resources, with a summary of the discussion and inherent choices made throughout these meetings below.

- Base frame to suit container locks for a 20ft shipping container
- Must fit maximum of 6-5/8" API Full Hole pin box connection
- Must fit maximum of 8.5" outside diameter pipe
- Must fit minimum of 2.5" outside diameter pipe
- Must have forklift socks to allow for removal and placement off and on truck
- Will use hydraulic press setup for jaws/tongs
- Will use National Transport Commission (NTC) guide for restraining forms and standards

Using these parameters, the design will have a clearly identifiable scope in which the parameters of the build will involve and consist of.

Design Parameters

We will first identify the critical components of the design in which the scope of this report will entail. These are:

- Tong dies
- Pipe stands
- Tong assembly
- Base frame
- Tong movement system
- Transportation connection
- Spacing required for all non-critical components
    - Hydraulic systems
    - Power system
    - Transportation forms
    - Electrical components and systems
    - Gearbox/reduction system

Tong Dies

The tong dies will not be designed, but rather are a bought in item. Therefore, some preliminary designs will be shown to compare the different forms of tong dies available on the market.

Pipe Stands

There is two designs required for the pipe stands for this bucking unit. The first is a translating pipe stand with rollers, allowing for axial movement of the pipe and a second design featuring a rotating pipe stand that allows the pipe that is broken out to rotate whilst the other side remains stationary.

Tong Assembly

The tong assembly must suit the geometry of the design, meeting all dimensional parameters. It must be able to fit the jaws and be able to resist and withstand the forces in which it is exposed to whilst operating.

Tong Movement System

This system must be able to safely and effectively move the tong assembly in a linear motion along the drill pipe for clamping where it is required. Furthermore, this system must be easily repairable and low on maintenance.

Base Frame

The base frame must suit fitment to a 20 foot shipping container, thus must be within the dimensions of the shipping container (6100mm x 2440mm x 2590mm).

It must also contain a way for a forklift to remove it from the truck, such as a form of forklift sock integrated into the frame, for safe and efficient placement of the system.

Transportation Connection

The connection system is aimed to utilise shipping container locks, as seen in the figure below. This will allow for easy loading and unloading onto the truck for transportation, along with a safe transportation on-site.

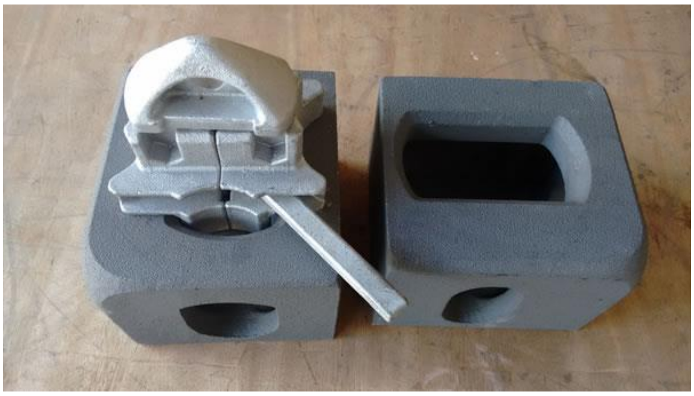


Figure 4. 1 Transverse Double Ended Shipping Container Twist Lock Unlocked, twistlocks.com.au (2021)

Figure 4. 2 Transverse Double Ended Shipping Container Twist Lock Locked, twistlocks.com.au (2021)

Concept Designs

Jaws

Before initiating the design phase of this report, an analysis of what is actually required from this machine must be performed. As seen in the *Design Parameters* above, the jaws must be designed to withstand the stress that 150 kNm of torque (approximate maximum) will exert onto the parts. With this in mind, it is clear that hydraulics are the only practical solution. This is due to the following factors:

- Deliver a smooth application of pressure
- Provides a smooth pressure removal
- The pressure/force can be applied at any part of the stroke limit within the ram
- It is common practice to use hydraulic rams within industrial and agricultural environments where the force exerted needs to be measured and controlled safely

Due to the application of the torque required within this system, it is clear that a strong yet controllable medium is required to be used. Thus, a hydraulic press (ram) is the ideal choice for the requirements.

It is not yet decided what form design of tong dies will be utilised, however, these are off the shelf items with specific load ratings for applications such as this, therefore, these are not a concern for FEA.

Figure 4. 3 Jaw Tong Preliminary Sketch 1

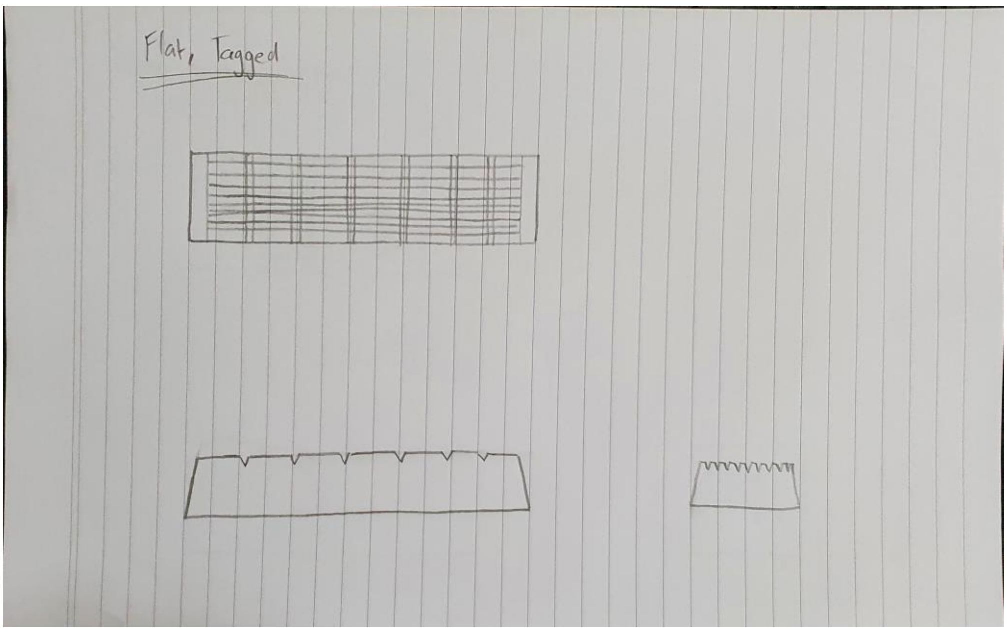
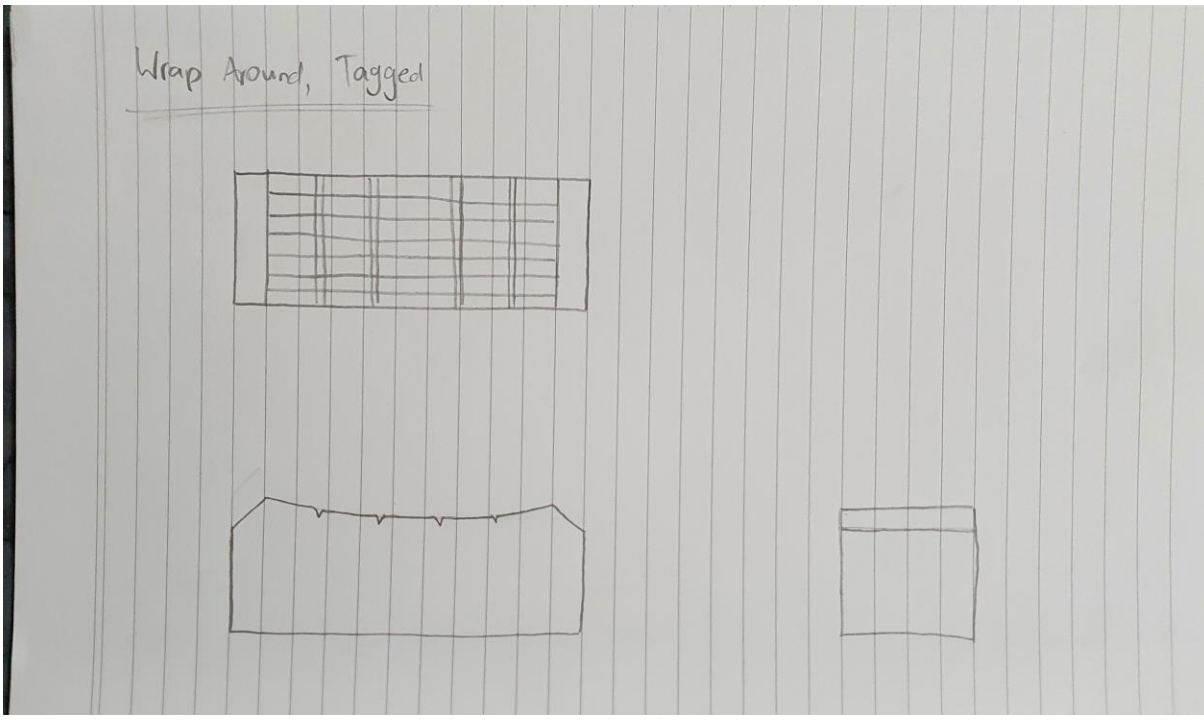


Figure 4. 4 Jaw Tong Preliminary Sketch 2



The two designs above will be compared in further detail later in this report, allowing an informed decision to be made regarding choice of design.

Tong Assembly

When the operator of the bucking unit will begin to lay the pipe into the machine, two things must be decided; how far the translating tong assembly must be from the rotating tong and whether another support is required to hold the selected drill pipe without bowing of the pipe. It is understood that there are two series of design for this part that could be viable options, being either a series of hydraulic rams acting as presses, similar to a hydraulic chuck, or to

Some preliminary sketches of the proposed design are shown below.

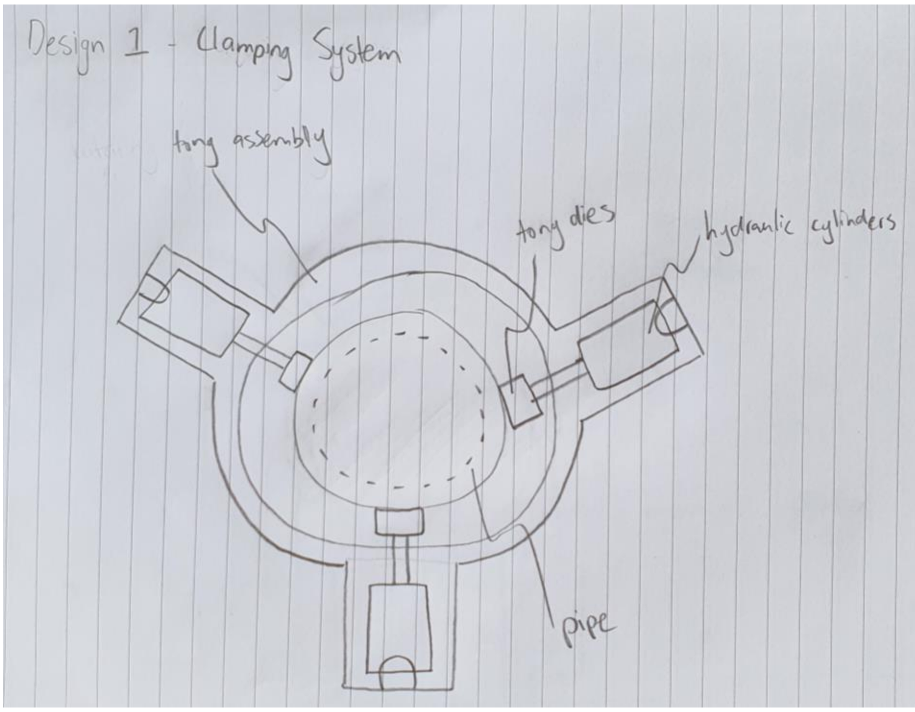


Figure 4. 5 Clamping System Preliminary Sketch 1

The above design shows a set of hydraulic rams that will be integrated into the rotating (and stationary) tong assembly. Pipes or folded profiles will be welded onto the outside of the major pipe as seen above, allowing the hydraulic rams to be connected to this part as a separate, isolated clamping system. A currently undetermined connection method will provide the tong dies with placement onto the hydraulic rams, most likely to be guided through these pipes.

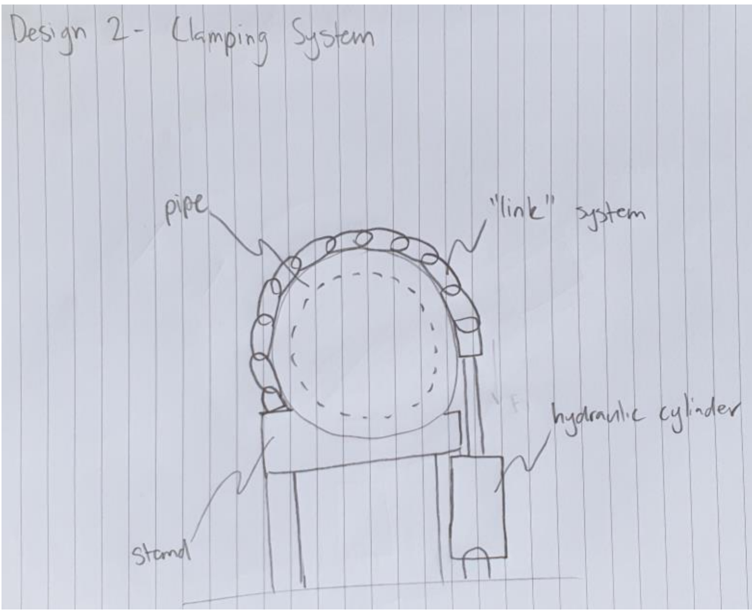


Figure 4. 6 Clamping System Preliminary Sketch 2

The above design depicts a "link" system, comprised of particularly designed industrial strength links that, once the hydraulic pressure is applied, will tighten around the pipe. These links have smaller tong dies on the surfaces in contact with the pipe providing grip. This will provide the connection necessary to grip and hold the pipe in place whether this be for the rotating or stationary tong assembly.

It is seen that the design of the link system would be complicated and quite possibly expensive to produce compared to the simpler hydraulic ram clamping system (Design 1), thus, design one will be used as the basis for design and improved upon.

Tong Movement System

To move the translating tong assembly along the base of the bucking unit, a motor must be used for safe and precise movement. Due to the load of moving the translating tong assembly being quite low, an electric motor will be used for quick and accurate results. The system used to lock the tong assembly in place whilst in operation must be considered, ideally being a simple design that provides a variety of distances in which the tongs can be separated between. This will be adapted throughout the design to suit dimensional parameters and simplicity of design. Initially, it is understood that a pin or spring bolt will be used.

Some preliminary sketches of the proposed design are shown below.

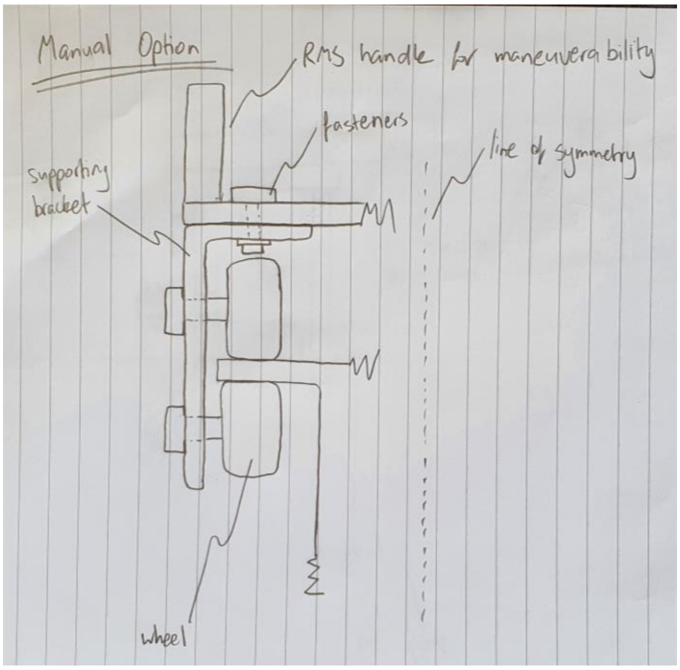


Figure 4. 7 Tong Movement System Preliminary Sketch 1

The design above shows a PFC guide with wheels allowing the manual translation of the tong assembly via the RMS (round mild steel) handle.

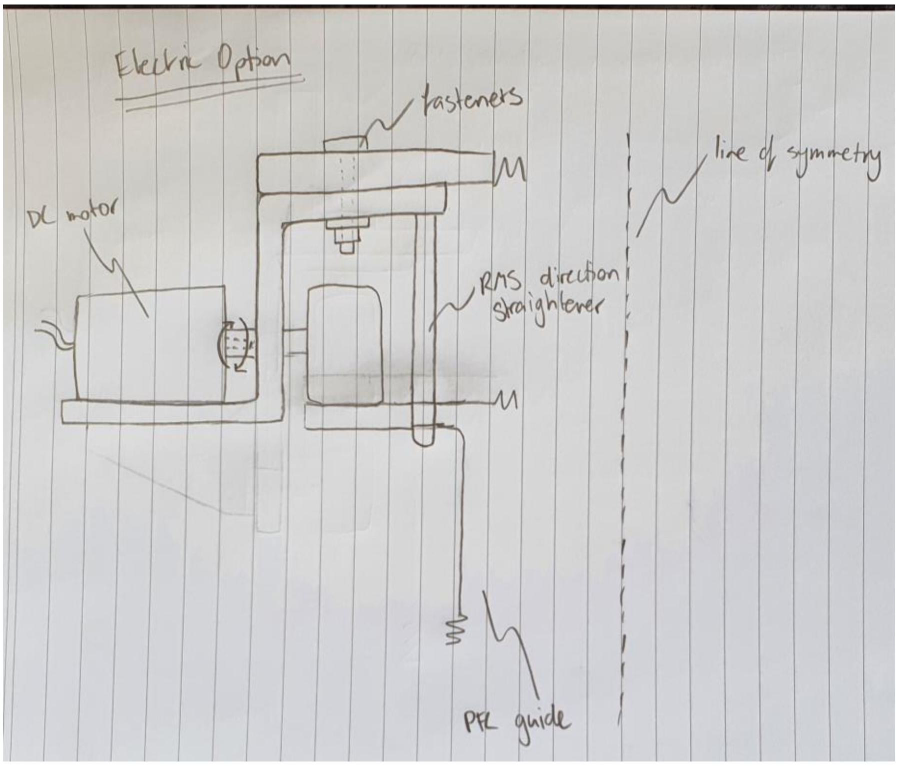


Figure 4. 8 Tong Movement System Preliminary Sketch 2

The electric option seen for the translating tong assembly above features a DC motor (or another electric drive equivalent) to turn the wheels. For the translating tong assembly, it is understood that the weight of the tong assembly may become quite heavy, thus proving to be a strenuous task to manoeuvre it. Therefore, the electric option will be explored in depth further.

Base Frame

As previously discussed, it is known that the bucking unit must be transported in the footprint of a 20ft shipping container as this is a very common industry standard practice to transport heavy machinery. An analysis on whether the base frame of the bucking unit is to suit these dimensions or whether a bottom frame (skid) will be used to connect the base frame to the 20ft shipping container locks on the desired truck for transport.

Some preliminary sketches of the proposed design are shown below.

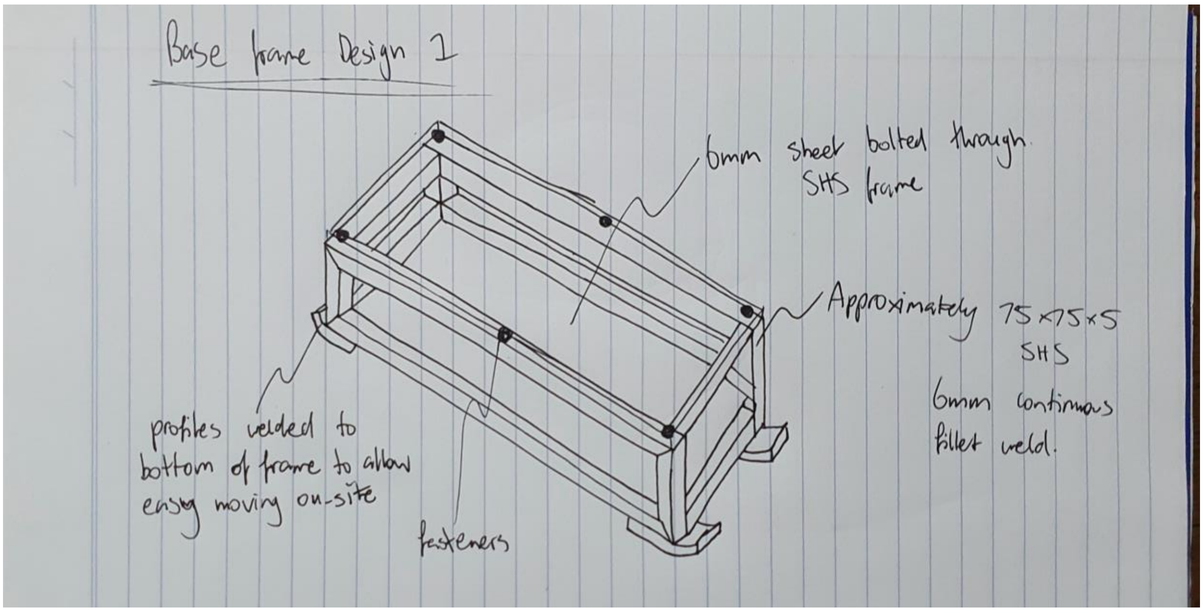


Figure 4. 9 Base Frame Preliminary Sketch 1

The first base frame comprises of welded SHS members to make the skeleton of the frame, with a 6mm steel plate fastened through the top to provide a landing for the parts.

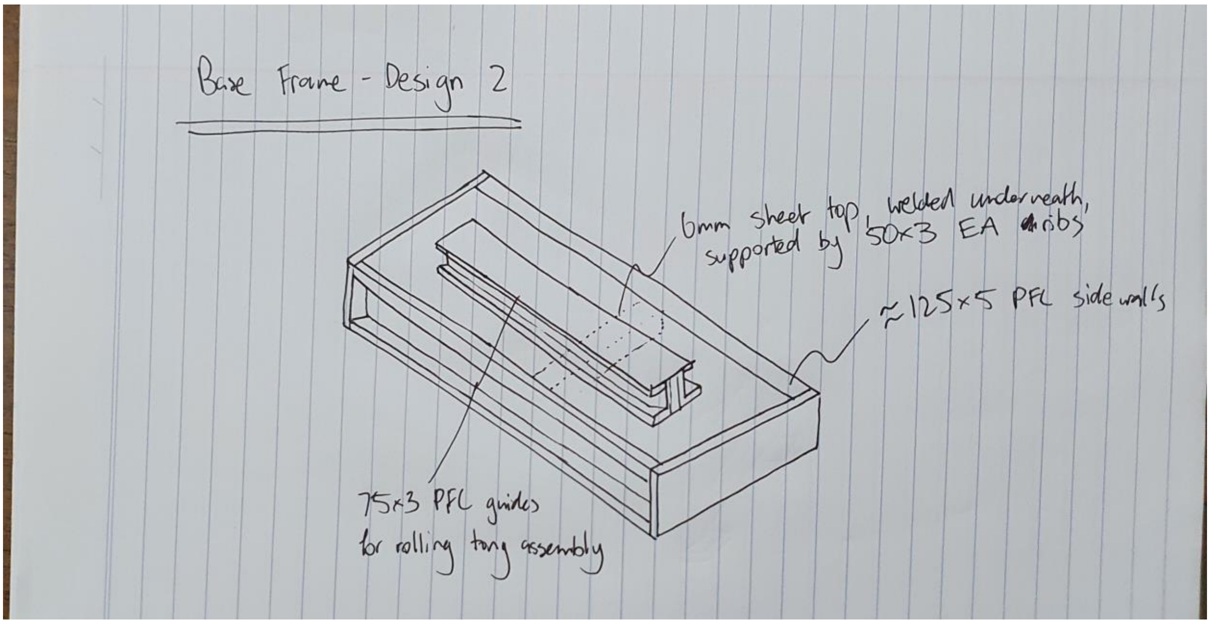


Figure 4. 10 Base Frame Preliminary Sketch 2

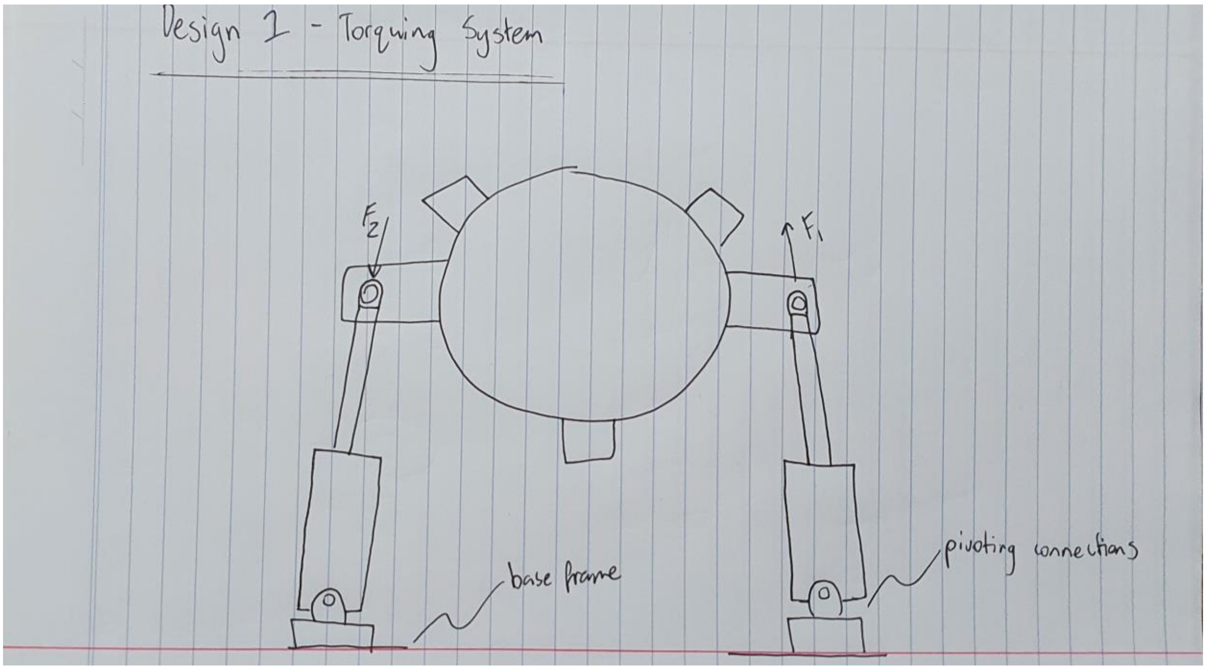
The second base frame is made of PFC (parallel flange channel) members on the sides with a 6mm plate welded underneath to provide a landing. The PFC guides as seen on top of the landing are for the translating tong assembly to guide along. Furthermore, the second option has EA (equal angle) members welded underneath to acts as ribs for the landing to provide rigidity and strength.

Torquing Mechanism

The mechanism used for torquing up or breaking out pipe whilst in operation must be analysed. For this, much like the jaws, the force applied must be easily controllable, measurable and considerable. As previously discussed, this machine must output an approximate maximum of 150 kNm. For this to be applied, a large amount of force must be output from the hydraulic rams to meet this requirement.

A preliminary sketch of the proposed design is shown below.

Figure 4. 11 Torquing Mechanism Preliminary Sketch 1



Some calculations into the required force output of the rams, and thus, the ram size are shown below.

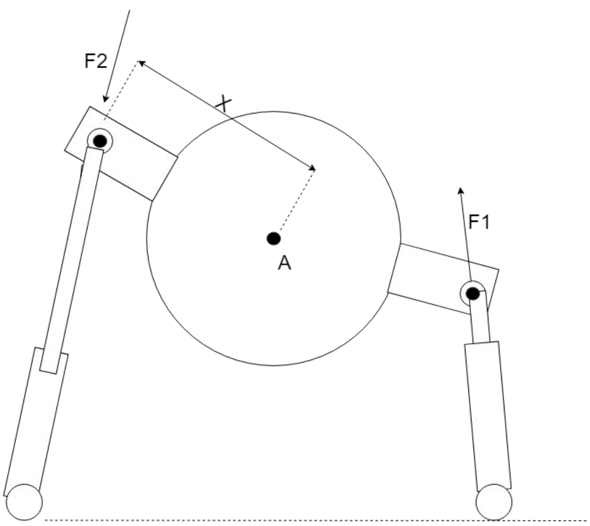


Figure 4. 12 Torquing Mechanism Diagram

First some assumptions are made:

$$x = 400mm = 0.4m, T_{applied} = 150\ kNm = 150 * 10^3\ Nm, F1 = F2$$

$$\Sigma M_A = 150 * 10^3 = F_{total} * d = F_{total} * x$$

(Beer, FP, Johnston, ER, DeWolf JT & Mazurek, DF, 2015)

$$150 * 10^3 = F * 0.4$$

$$F_{total} = \frac{150 * 10^3}{0.4}$$

$$F_{total} = 375 * 10^3 N$$

$$But\ there\ are\ 2\ points\ of\ force\ application, thus:$$

$$F1 = F2 = \frac{375 * 10^3}{2}$$

$$F1 = F2 = 187.5 * 10^3\ N\ for\ the\ given\ conditions$$

Therefore, a significant amount of force is required to push and pull the rotating tong assembly. Using this, a preliminary calculation for the stress the handle at F1 and F2 (same result) will be subjected to is done below.

$$Assuming\ the\ hole\ in\ which\ the\ rams\ will\ lock\ into\ are\ \varnothing 40mm,$$

$$a\ 60°\ surface\ contact\ angle\ and\ 20mm\ thickness:$$

$$Perimetre = 2\pi r = 2\pi * 20 = 125.7mm$$

$$Thus, Area = 125.7 * \frac{60°}{360°} * 20 = 418.9mm^2$$

$$\sigma = \frac{F}{A} = \frac{187.5 * 10^3}{418.9} = 447.6\ MPa$$

(Beer, FP, Johnston, ER, DeWolf JT & Mazurek, DF, 2015)

It is seen that this stress is very high, and for this certain area, the design must be revised from the initial calculations and validated via FEA results to ensure the design will perform safely without yielding the material. Using the value of required force from above, the size of the hydraulic rams can be calculated, as seen below.

$$P = \frac{F}{A}, \qquad \therefore A = \frac{F}{P}$$

Most companies use the imperial system when designing and sizing hydraulic cylinders, thus, a conversion of inches for sizing and mm for the calculations must be performed. Nordon Cylinders will be used for this application due to being reliable and effective, proven within the industry, however the website also provides greater detail on cylinder dimensions, connections, standard operating pressures, etc.

The required size of the cylinder is calculated via the safe operating pressure of Nordon Cylinders hydraulic cylinders of 3000 PSI (approximately 20.68 MPa).

$$A = \frac{187.5 * 10^3}{20.68 * 10^6} = 9.067 * 10^{-3} m^2 = 14.054 in^2$$

$$A = \pi r^2, \qquad \therefore r = \sqrt{\frac{A}{\pi}} = \sqrt{\frac{14.054}{\pi}} = 2.115''$$

$$\therefore \emptyset_{BORE} = 2 * r = 4.23''$$

From this value, we know that the diameter of the bore must be an approximate minimum of 4.23”, so we must round up to a nominated 5” bore diameter to meet this minimum. This will provide a level on adjustment of possible force exerted by the cylinders, thus not limiting the value to the preliminary calculation above. Using this new diameter, the full safe force of the hydraulic cylinder can be calculated.

$$F = P * A = 20.68 * \pi * \left(\frac{5 * 25.4}{2}\right)^2 = 261.97\ kN$$

(Beer, FP, Johnston, ER, DeWolf JT & Mazurek, DF, 2015)

Using this formula, the force exerted by the rod side of the cylinder is attained. The area in this case, however, is the bore area subtracted by the rod area, hence leaving the effective rod side area of the cylinder.

According to Nordon Cylinders, the 5” bore cylinders come with an accompanying 2.25” and 2.5” rod size. Using these values returns the following force figures.

$$For\ 2.25''\ rod; F = 208.92\ kN$$

$$For\ 2.5''\ rod;\ F = 196.48\ kN$$

Thus, it is seen that utilising a smaller rod will provide a higher rod side output force. For this design, a 2.25” rod size will be used. If the cylinder size changes, using Nordon Cylinders available sizes, the smallest rod size will be attained and used.

Model Refining

Using the above preliminary sketches above, the following design was attained. It is still at a very rudimentary stage with more detail and parts required to be added.

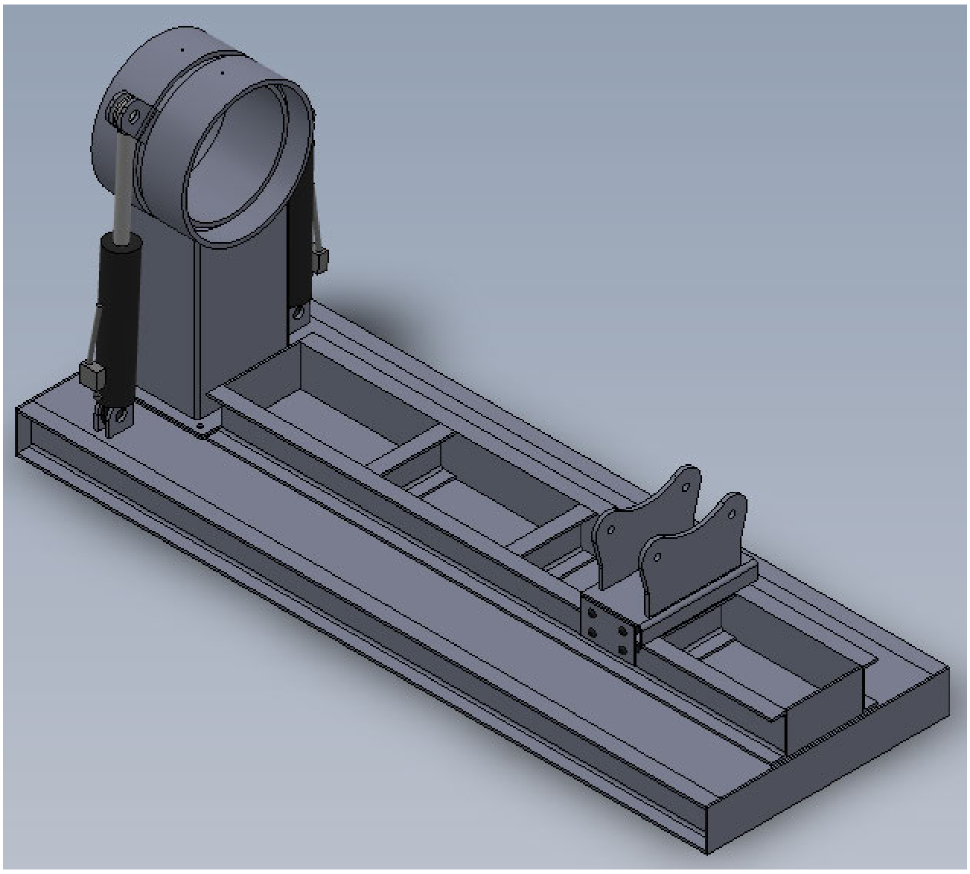
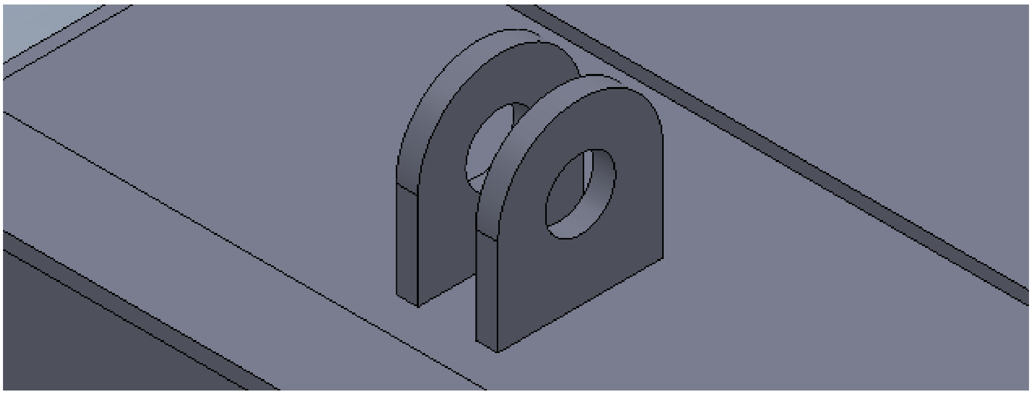


Figure 4. 13 Initial Design Model

It is seen that the translating tong assembly does not have the tong designed and placed inside yet. More research must be conducted into the design of these parts and how it is intended to work. The main elements of the design have already been previously discussed, thus, a special consideration will be taken into analysing the lugs welded onto the top of the base frame. The design is seen below.

Figure 4. 14 Base Frame Lug



These are made of 16mm plate currently. This thickness is subject to change as required per the stresses experienced by the hydraulic ram operation. A sample calculation of the stresses expected to be experienced is seen below. As per above, the maximum force required is approximately 187.5 kN per side to breakout the pipes intended for use.

$$P = \frac{F}{A} \; where \; F = 187.5 * 10^3 N$$

Assuming a 60° surface contact angle, we have the following area.

$$\mathrm{A} = 2\pi\mathrm{r} * \mathrm{L} * \frac{60°}{360°} = 2\pi * 25.5mm * 16mm * \frac{60°}{360°}$$

$$A = 427.26mm^2$$

$$P = \frac{187.5 * 10^3}{427.26} = 438.85 \; MPa$$

But there are two lugs in which the hydraulic ram is connected to, therefore;

$$P_{per\;lug} = \frac{438.85}{2} = 219.42 \; MPa$$

We can see from this that these lugs are more than capable of withstanding the stresses experienced for the given load case as above. These are preliminary calculations, however, and serve only as quick checks for values. The values used to create informed decisions about materials and other design choices will be finite element analysis, as this is a formative validation process.

Upon reviewing the design shown above, it appears that some parts of this design can be reviewed to change some factors, such as weight and size of the pieces. This is seen below.

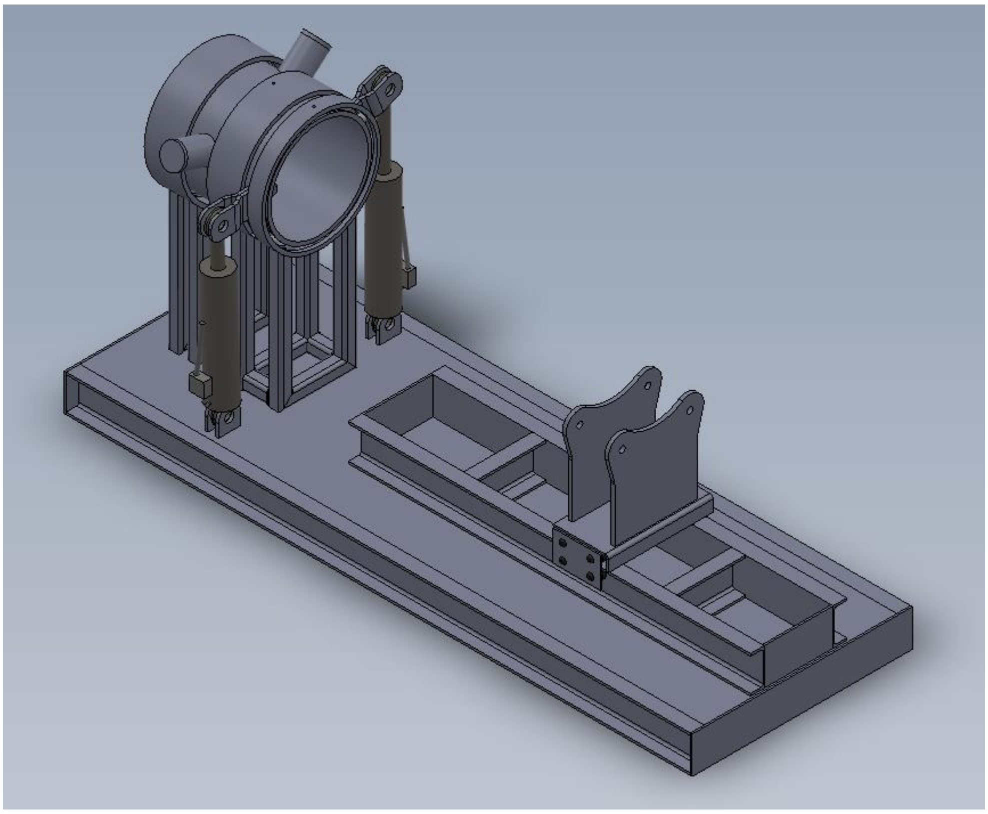


Figure 4. 15 Initial Design Model with Hydraulic Cylinders

Two main changes are made to this design from the previous revision, being that the stands for the rotating tong assembly are now made of SHS members (approximately 75 x 5) and the tong assembly has been redesigned to include connections for the hydraulic rams to be used as clamps. Currently the method for attaching the hydraulic rams to the freely rotating assembly point is via welded lugs inside the pipe, such as seen with the base frame connections and the torquing mechanism. This is shown below.

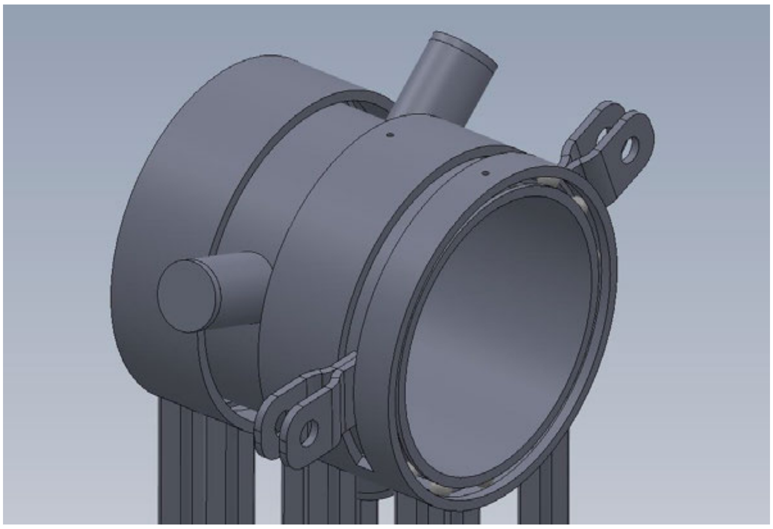


Figure 4. 16 Torquing Mechanism Initial Model

During the design phase, a discussion with Obadare Group and team was had revisiting the details of the size pipe and connection the bucking unit was required to breakout and torque up. It was found that the maximum sized connection required to operate on was an API Full House 6-5/8” connection with a pipe outer diameter of 8.5”. A pipe fitting this description requires a minimum breakout torque of 68,000 ft. lb (92.2 kNm) (Evolution Drilling, n.d.).

It is understood now that the force required to be exerted from the hydraulic cylinders must be recalculated for this new value of torque. This is seen in the following table, utilising the same equations as identified above.

Torque Required

Torque Output	100000	Nm
Distance (x)	465.7	mm
	0.4657	m
Force Required	214730.5132	N
	214.7305132	kN
	107.3652566	kN/side

Thus, the new calculated force required is 214.73 kN approximately. Using this, we can recalculate the size of the rods as seen below.

$$P = \frac{F}{A}, \qquad \therefore A = \frac{F}{P}$$

$$A = \frac{100 * 10^3}{20.68 * 10^6} = 4.8356 * 10^{-3} m^2 = 7.4952 in^2$$

$$A = \pi r^2, \qquad \therefore r = \sqrt{\frac{A}{\pi}} = \sqrt{\frac{7.4952}{\pi}} = 1.545''$$

$$\therefore \emptyset_{BORE} = 2 * r = 3.089''$$

Thus, round up to 4” bore for an increased safety factor and less required working pressure. Nordon Cylinders has only an option for a 4” bore and 2” rod, thus, use this. The force exerted by this hydraulic cylinder is seen tabulated below.

Cylinder Capacity

	inches	mm
Bore:	4	101.6
Rod:	2	50.8

Area:		mm^2
Bore:		8107.3
Rod:		2026.8
Eff. Rod:		6080.5

System Details

System Pressure	3000	PSI
	20.68	MPa
Force Capacity Bore Side	167694	N
	17094	kg
Force Capacity Rod Side	125770	N
	12821	kg
Total Complimentary Force	293464	N
	29915	kg

Therefore, this cylinder provides a very reasonable and appropriate value of force. Initially the design was produced to include a translating support along the base, in which more hydraulic cylinders were to provide clamping, to resist the torsion placed by the rotation of the connected pipes, thus, breaking out and torquing up these pieces. It is seen, however, that this is not only unnecessary, but also proves to be more components required for the design. This goes against the design methodology of this design, aiming to provide a unit that required the least amount of maintenance and lowest production cost possible. An example of this can be seen below.

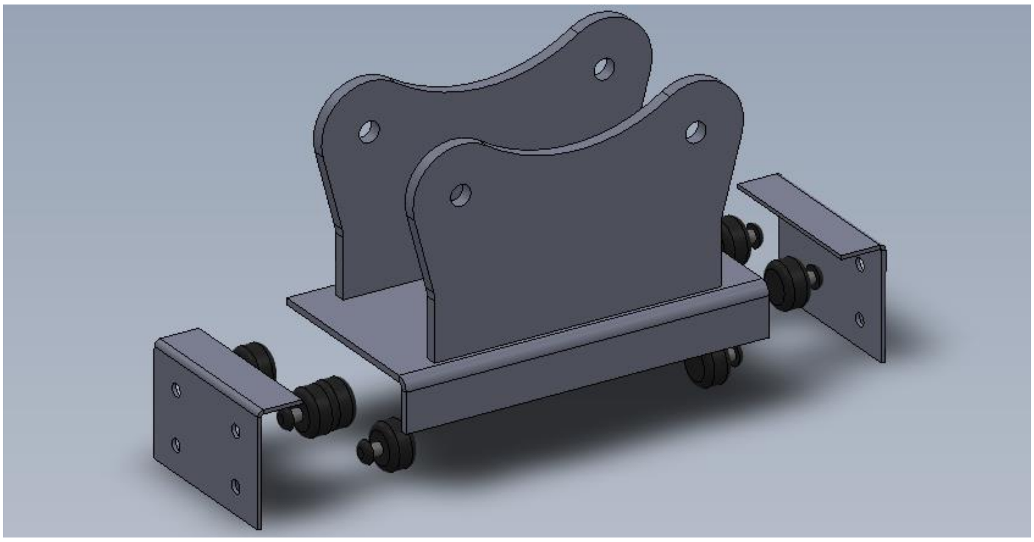


Figure 4. 17 Translating Tong Movement System Model

It is clear that this sub-assembly of the translating tong was not complete when this was discovered, however, the exploded view above shows the simple design. As per the preliminary sketches above, this design was to have an electric motor rotating the wheels of this design, allowing the translation of the tongs. The tong nor the electric drive motor is not shown in this assembly currently. This design will be re-envisioned to be stationary closer to the rotating tong assembly. This will provide two benefits;

- Less moving parts, therefore reducing the overall cost, along with preventative maintenance and repairs costs
- Will reduce torsional stress placed upon the pipe as the distance between the point of rotation and clamping is reduced

After reassessing the purpose and functionality of this tong system, a new design was created. This is shown below.

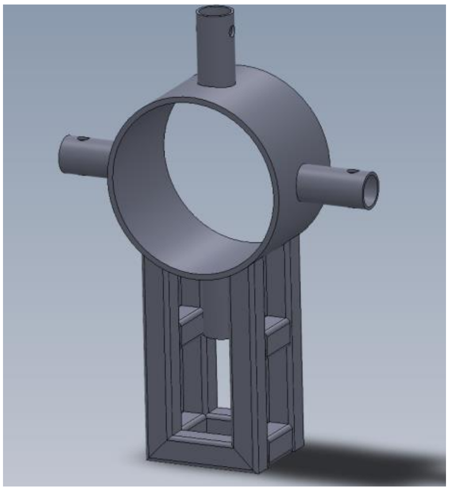


Figure 4. 18 New Clamping Tong Design Model

The current design consists of the following key features;

- 100 x 6 SHS frame
- DN650, XS pipe
- Approximately DN125, XXS pipe for hydraulic cylinder guides
- Connected via trunnion mounts (see below)

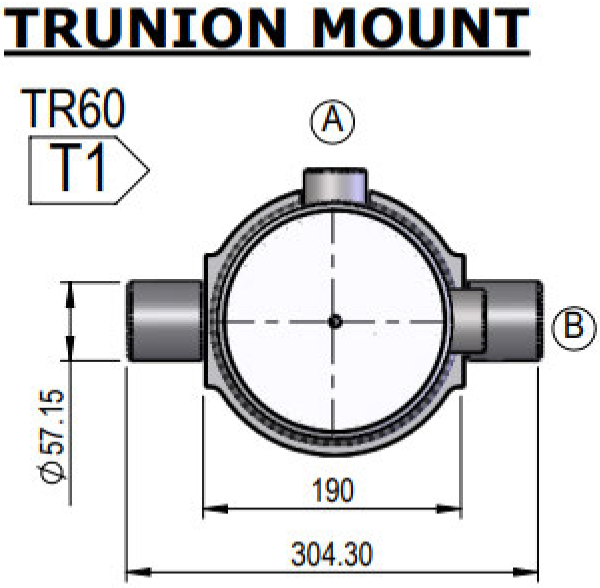


Figure 4. 19 Trunnion Mount Connection Details and Dimensions (Nordon Cylinders, 2015)

The 100 x 6 SHS frame provides a fair footprint for the counter-torquing support. This will allow the structure to resist the torsional forces applied to the frame during the clamping operation. FEA will need to be conducted into this to ensure the welds holding the DN650 pipe to the frame will be sufficient to avoid failure of the piece. The DN650 XS pipe contains a wall thickness of 12.7mm, allowing stresses experienced within the pipe to disperse evenly and appropriately. The (approximated) DN125 XXS pipe seen to contain the trunnion connections is aimed to be quite thick. The essential need for thick, strong material at this location is due to the counter torque being placed upon the pipes being operated on. The calculations below show a rough estimate of force required by the hydraulic cylinders to oppose and overcome the torque placed within the rotating tong assembly during operation. A simple free body diagram is used for ease of understanding.

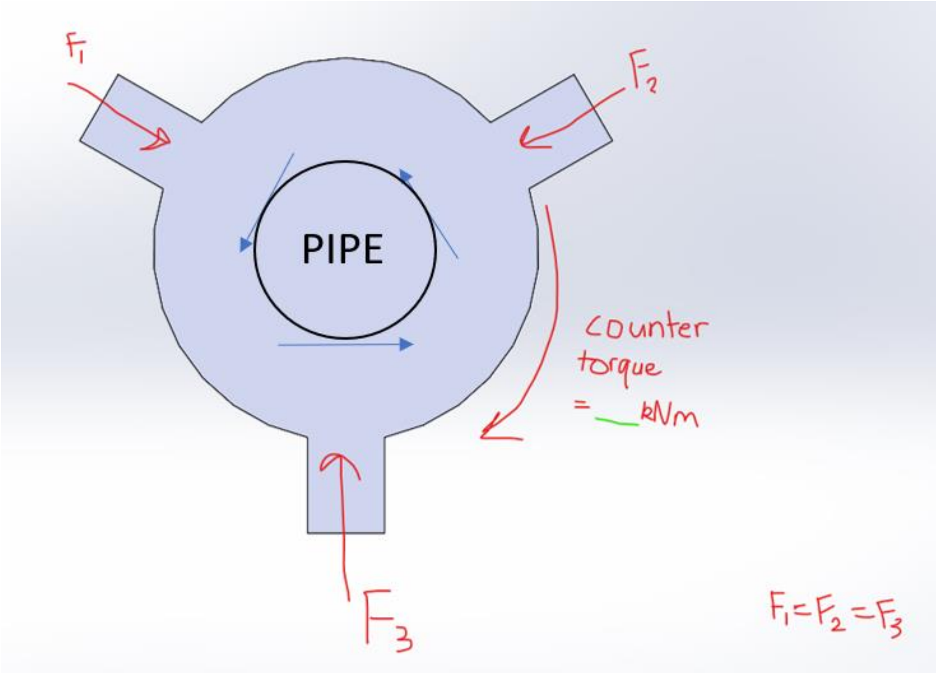


Figure 4. 20 Counter Torque FBD

The force applied by the intended hydraulic cylinders will be normal at these points to the moment created by the rotation of the pipe through the opposing tong assembly. Thus, the force normal to this application must be found to overcome the rotational forces. Using the following parameters, the force required to oppose the torque is found:

- Pipe outer diameter of 8.5” (for API full hole 6-5/8” connections)
- Torque applied to break out is 92kNm, round up to 100kNm for safety factor

$$Pipe\ \text{Ø} = 8.5" = 215.9mm$$

$$Therefore\ radius, r = \frac{215.9}{2} = 107.95mm$$

$$Force = \frac{100 * 10^3}{107.95} = 926.35kN$$

But this is assuming 100% friction, which is not the case in real world applications, thus, the coefficient of friction for hard steel on hard steel was attained to be 0.78 (Dudley Fuller, 1984). Using this, we can now find the minimum force that is required to resist the torque applied via the rotating tong assembly.

$$Force_{applied} = \frac{926.35kN}{0.78} = 1187.63kN$$

But there is a minimum of three tong dies to apply this force around the pipe, therefore the force required per tong die (and thus, hydraulic cylinder) is 395.88kN.

It is seen that this is a very large amount of force to apply from just one hydraulic cylinder through one tong die, thus, the number of cylinders used and tong dies will be increased to a minimum of four, reducing the stresses experienced within not only the tong dies but the DN125 pipe used to support these. When recalculating, this value is seen to be 296.9kN. The number of clamping cylinders installed on the tong assemblies may need to increase to a possible six to reduce stress. Nordon Cylinders do not have cylinders this size that are compact enough for a smooth integration into this design, thus Berendsen Cylinders is used. The current optimal hydraulic cylinder design offered is seen to be a 160mm (approximately 6.3") bore with a 110mm (approximately 4.3") rod. This cylinder provides a max bore side force of 415.9kN, being more than enough for the current required application. A model of this cylinder is seen below.

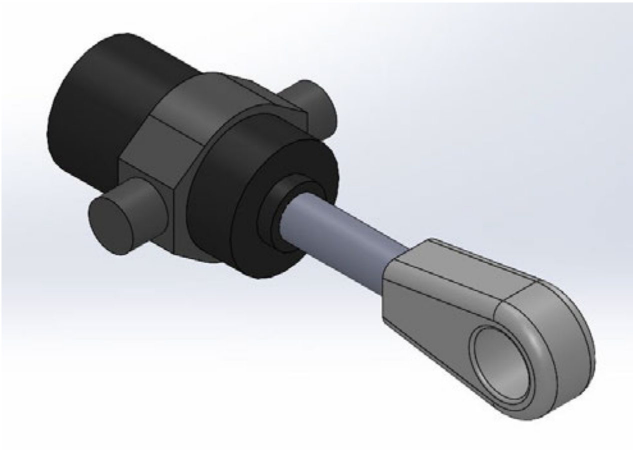


Figure 4. 21 Berendsen Cylinder Model

Inherently by removing the need for the translating tong assembly, the length of the base frame was reduced from 3.5m to 2.4m. The base-frame is still subject to change in its entirety regarding dimensions and design. This is seen below.

Figure 4. 22 Base Frame Model Side View

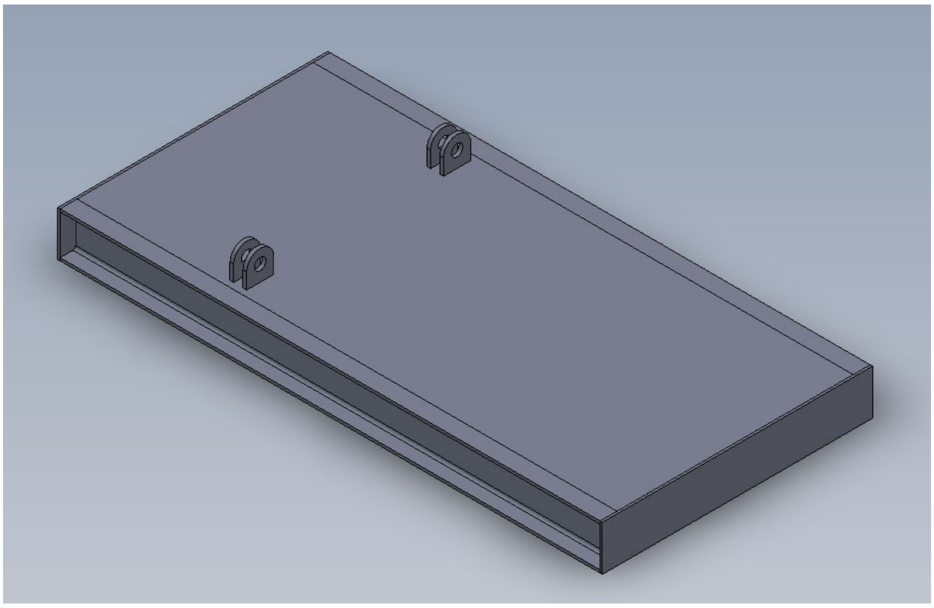


Figure 4. 23 Base Frame ISO View

It is seen that the base frame utilises a simple pair of lugs welded on to support the hydraulic cylinders, connected with a spherical bearing, such as seen below.

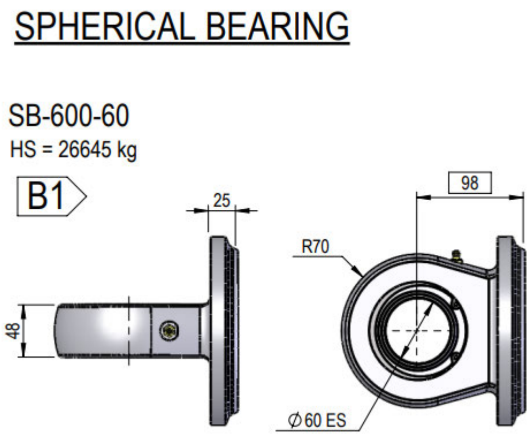


Figure 4. 24 NORDON Spherical Bearing Dimensions

The lugs and spherical bearing connection are tied together via a 2” pin.

As discussed above, the minimum number of hydraulic cylinders used to apply to torque (and counter torque) will be 4 for each tong assembly. The tong assembly is a more complex design feat than the other parts as there is the requirement of a freely rotating clamping system that must be torqued up. This is shown below in the following screenshots.

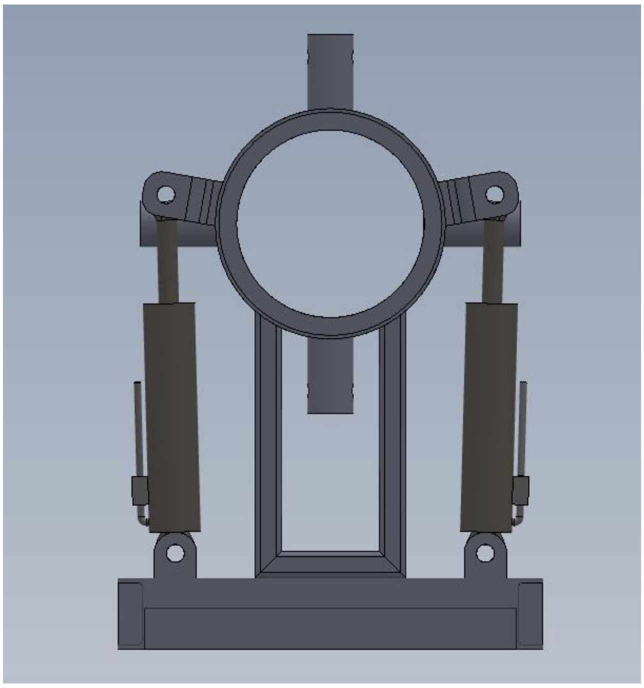


Figure 4. 25 Bucking Unit Assembly Front View

Above is a screenshot of a sectioned view of the design (along the YZ plane). This shows the hydraulic cylinders attached to the base frame and the welded lugs attached to the rotating clamping tong. Below is an isometric view of the design in its entirety.

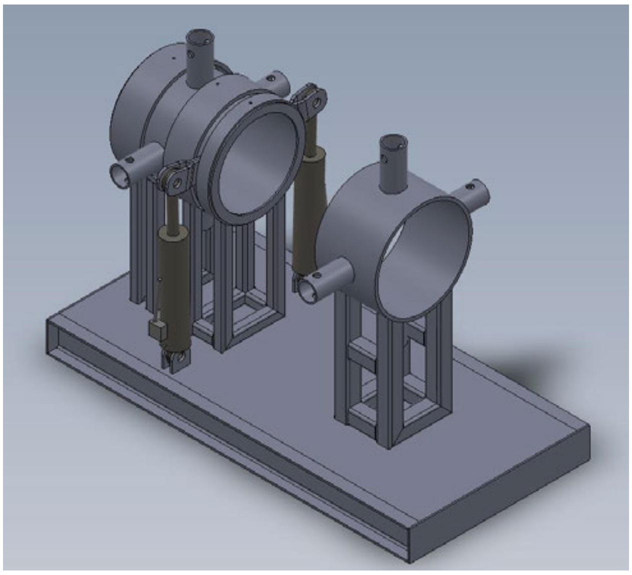


Figure 4. 26 Bucking Unit Assembly Model ISO View

Currently, there are no hydraulic cylinders placed in the model for the clamping, as more research is yet to be conducted onto the availability of cylinders with the correct size and stroke that can output such high forces. When removing the supports, base-frame and cylinders from the model, the following is shown.

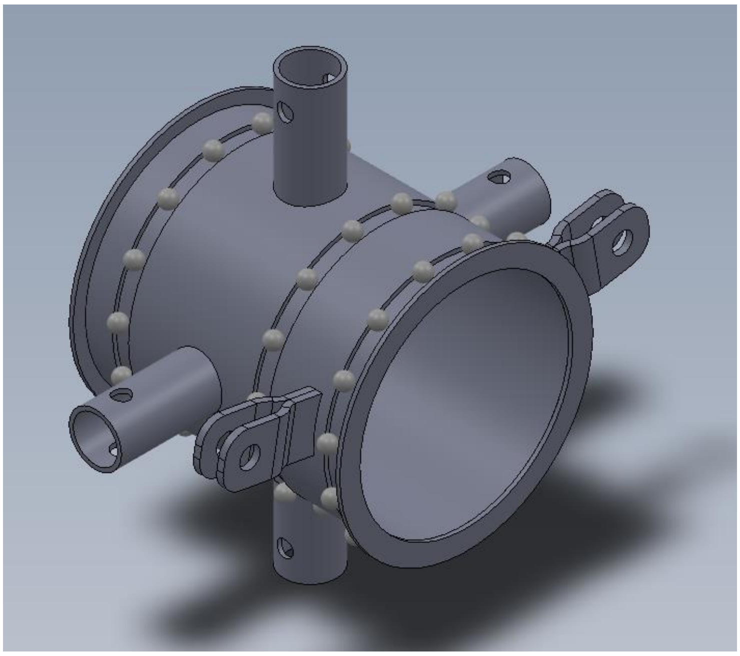


Figure 4. 27 Rotating Tong ISO View

It is seen that the connection of the rotating cylinders to the inner rotating tong assembly consists of two folded 16mm profiles to be laser cut, which are welded onto the outside of the cylinder. Inside the grooves are seen to be 20mm steel and chrome plated balls. These will act as a ball bearing, being the main method of allowing the inner guide to rotate freely and with minimal friction. On the outer support, as seen below, there are ½" BSP threads aimed to allow a grease nipple for insertion and use during operation to reduce friction further.

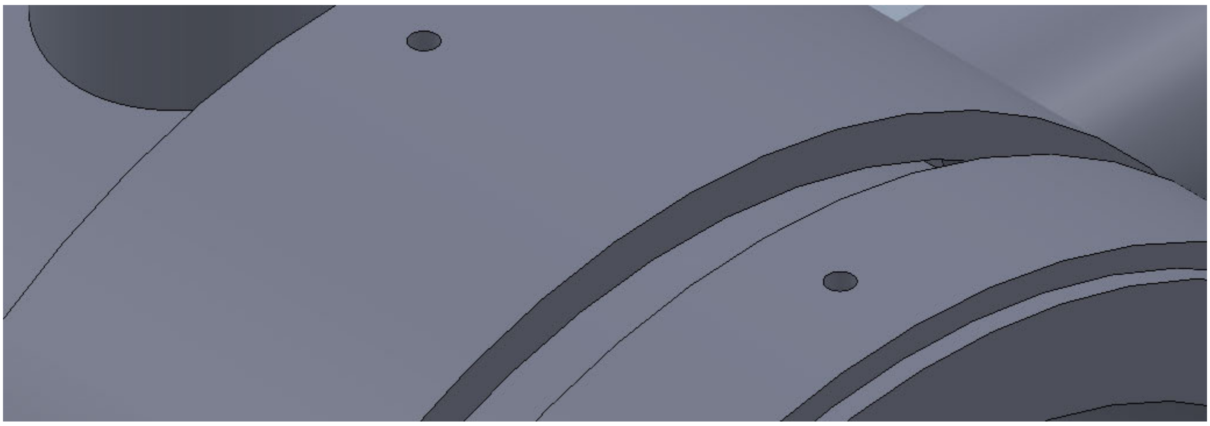


Figure 4. 28 Rotating Tong Assembly Closeup

Thus, the tong can rotate freely within between the pair of supports. The support seen at the back of the rotating tong assembly is used to provide vertical force along pipes placed within tong assembly at the rear of the unit. This is shown below.

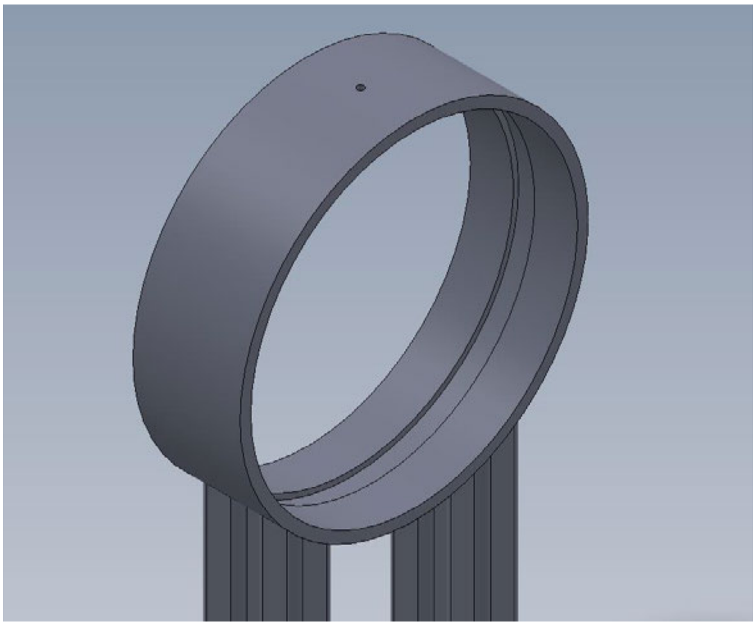


Figure 4. 29 Rotating Tong Frame

The design is seen to be quite similar to the other support on the front of the freely rotating tong assembly, utilising the same ball bearing technique to allow minimum friction of the rotating components during operation.

Sizing of the hydraulic cylinders for clamping, as previously discussed, provided an estimate of the size of hydraulic ram required. A major challenge was ensuring that 4-6 of these hydraulic cylinders could be implemented into the design effectively. More work must be undertaken into finding the optimal amount (and hence, size) of hydraulic cylinders for clamping, to reduce overall stresses whilst not increasing the cost of production to a rate that does not align with the fundamental principles of this design.

As the Berendsen cylinders connect to the tong frame via a spherical bearing type connection, the following design will be used as the frame.

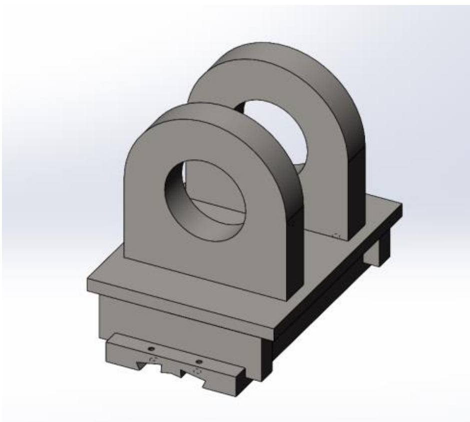


Figure 4. 30 Berendsen Cylinder Tong Die Connection

It is seen that two sets of tong dies will be placed into the frame for extra grip and stress reduction. A screenshot of the selected tong die model is seen below.

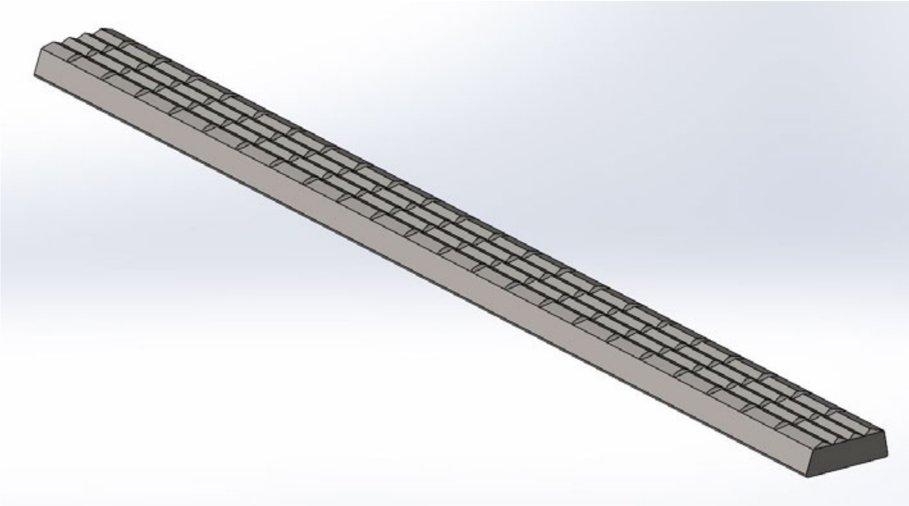


Figure 4. 31 Tong Die Model

These tong dies are purchased from many various stores that service the oil and gas industry, such as Oil baron. Oil Baron provides a range of dies suited for multiple lengths and insert shapes/sizes. The model is cut to length of 344mm.

The weldable container locks are added to the base-frame as shown below.

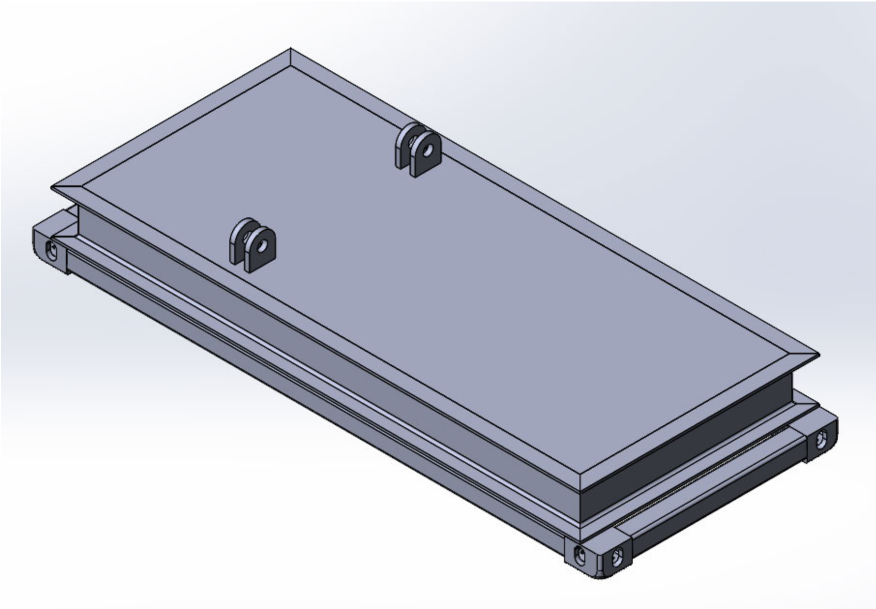


Figure 4. 32 Base Frame With Skid

It is seen that members of 100 x 5 SHS with container locks are welded onto the corners of the base frame for easy transportation of the unit. The final elements of the design stage are complete, adding a rotating pipe stand for the side of the drill pipe that will need to twist whilst the unit is under operation. This is shown below.

Figure 4. 33 Rotating Drill Pipe Stand

The opposing pipe stand required by this design is a translating pipe stand that features sliders. This allows the drill pipe to slide in and out of the machine effortlessly. This is shown below.

Figure 4. 34 Translating Tong Pipe Stand

The two above pipe stands feature a three leg design of 40NB H CHS with 60 x 5 FMS landing flats. This allows the stands to dig into the ground and stabilise utilising the surroundings.

The height is adjustable via the RMS handles seen in the screenshots, via twisting the inner rod that is threaded to match the ID of the CHS (also threaded), allowing the height to be changed to suit each OD of pipe required for operation (up to 6-5/8”). The rotating pipe stand features custom rubber wheels that allow the easy rotation of the pipe under torsion from the hydraulic cylinders, whilst the translating pipe stand allows for the easy rolling of pipe via custom rolling pins into the unit to the desired positioning. This marks the end of the design process. The final assembly is seen below.

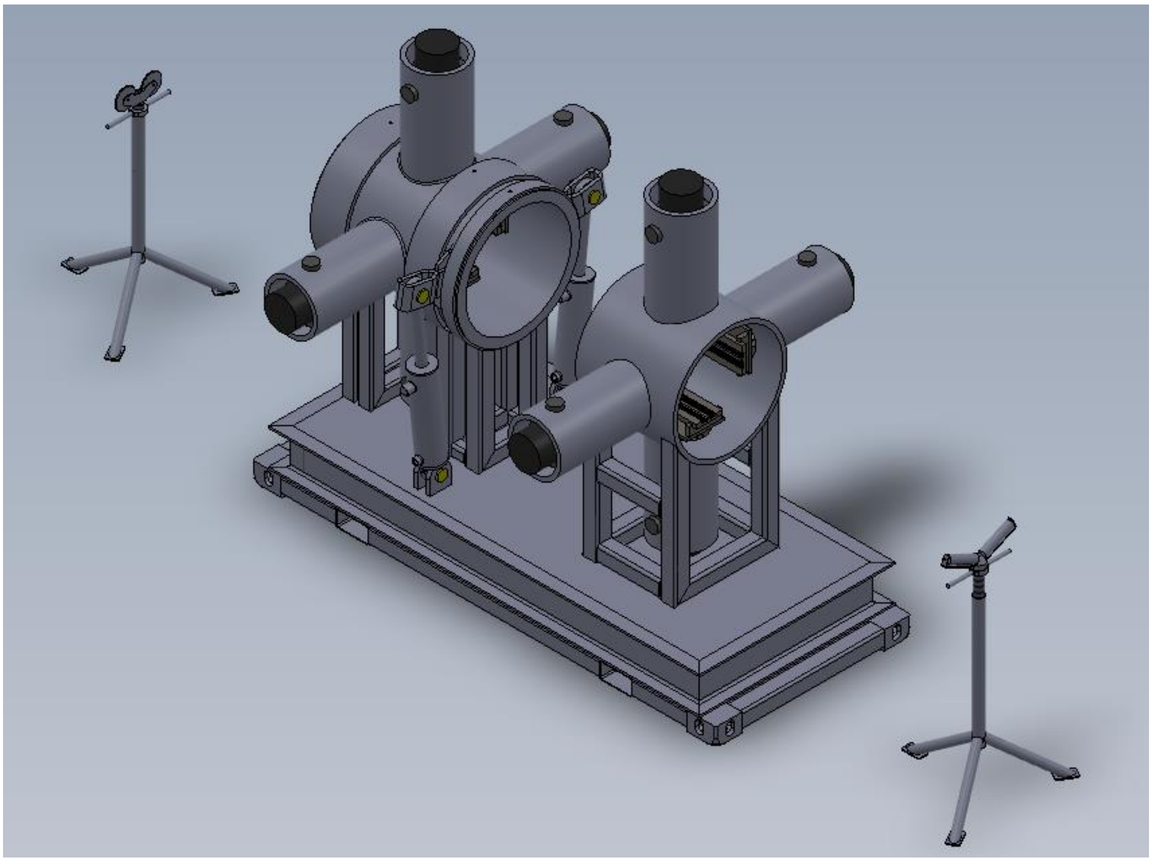


Figure 4. 35 Final Model ISO View

This screenshot shows the relative positioning of all components within the design.

It is seen within Appendices A through E, technical drawings are created. These generally highlight the assembly design and describe the use of the unit with regard to other parts. Secondly, the technical drawings allow for the identification of critical dimensions and assist in manufacturing.

Initial FEA Testing

With the design being refined and appropriate thus far as operational requirements is concerned, some initial finite element analysis will be conducted to determine how the design will withstand the forces exerted upon it by the hydraulic cylinders. There are three main areas of interest identified as critical locations that FEA will be required to create informed design decisions for future revisions. These are seen below.

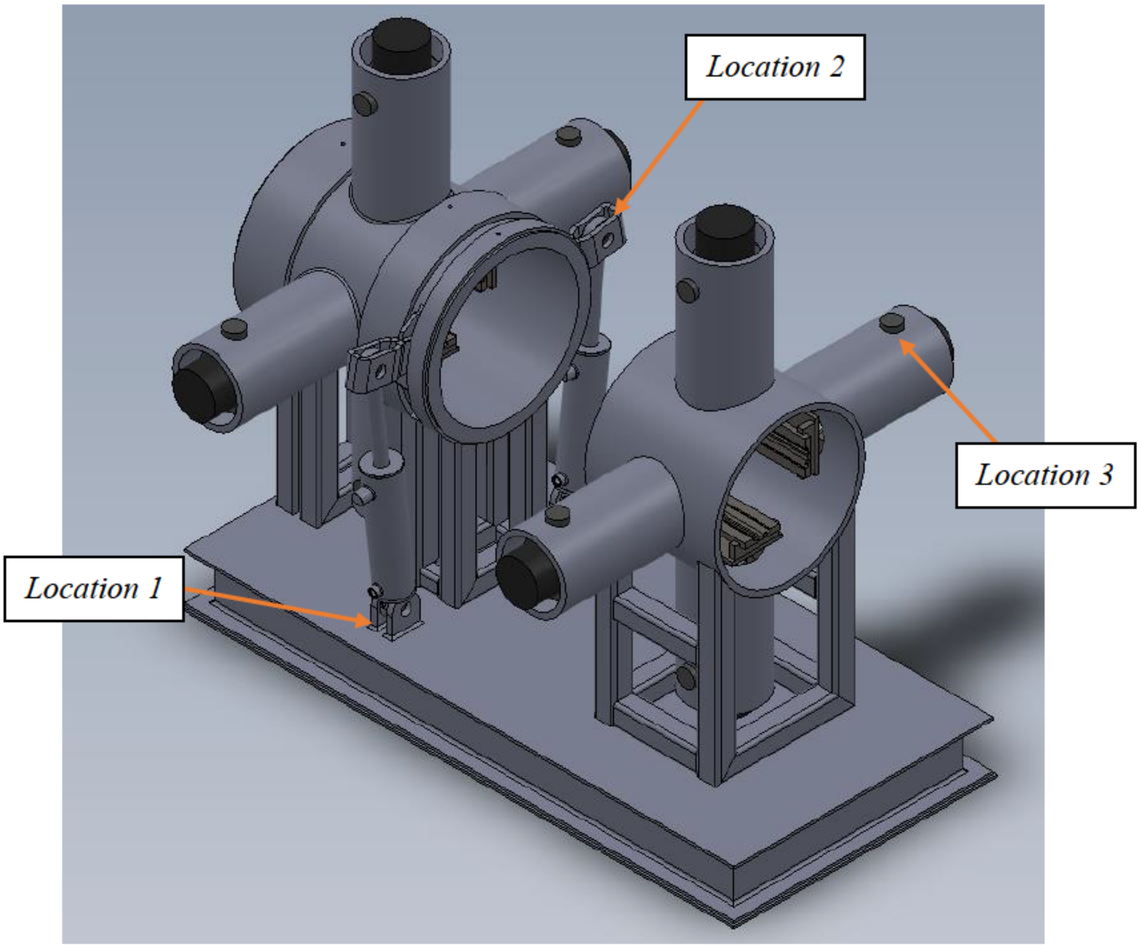


Figure 4. 36 FEA Locations

Location 1 identifies the connection between the hydraulic cylinders and the base frame connection via the welded lugs. *Location 2* identifies the extended lugs welded to the rotating tong assembly in which the aforementioned hydraulic cylinders will connect to, twisting the assembly. *Location 3* identifies the connection between the clamping hydraulic cylinders and the welded pipes on the tong assemblies.

Location 1

For the initial FEA run of the welded lugs on the base frame, there are some key points we aim to achieve through this run as per AS3990:

- Withstand forces of 1.5 x max load
- Results must be within 0.66 x yield strength of material

The current dimensions of the welded lug is shown below.

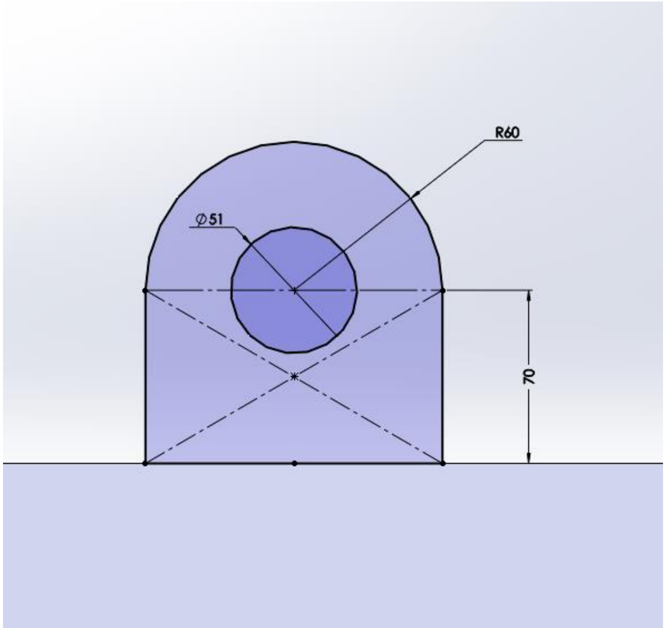


Figure 4. 37 Lug Dimensions

First, some parameters must be set for the FEA analysis. Initially, the model is combined using the "Combine" feature in Solidworks. This allows the FEA results to be accurate and modelled as one body. Points are added to the middle of the holes, then, using these as references, a new coordinate system is added on these, with the Z axis being the concentric axis through the lug holes. This is required as the force will be applied using a bearing load application to accurately simulate the force application to the holes on the lugs. Creating a new configuration for the load case, LC01-01 (meaning Load Case 01 – Parameter 1), this allows editing of the base part without affecting the base model. An extruded boss must be added to the bottom of the part to simulate the ground where it will be placed. Applying a fixture to the bottom section of the ground piece will provide the most accurate results specifically on the lugs. Applying the bearing load to circular holes, it is known that the force required is 106.4kN, thus 1.5 x 106.4kN = 159.6kN. Thus, a force of 160kN is applied to each lug. It is assumed that the welds and the lugs will experience a large amount of stress, thus mesh controls are applied to these faces.

After running the mesh (detailing a curvature based mesh), the details are seen below.

Mesh Details

Study name	LC01-01 (-LC01-01<As Machined>-)
Mesh type	Solid Mesh
Mesher Used	Curvature-based mesh
Jacobian points for High quality mesh	16 points
Mesh Control	Defined
Max Element Size	20 mm
Min Element Size	4 mm
Mesh quality	High
Total nodes	664905
Total elements	359789
Maximum Aspect Ratio	19.71
Percentage of elements with Aspect Ratio < 3	86.8
Percentage of elements with Aspect Ratio > 10	0.0384
Percentage of distorted elements	0
Number of distorted elements	0
Time to complete mesh(hh:mm:ss)	00:00:28
Computer name	IT006744

Figure 4. 38 Initial Mesh Details

The percentage of elements with an aspect ratio < 3 is 86.8%. This value is okay for now, but in future meshing this value will be aimed to increase to a minimum of 95%. The ratio of elements with an aspect ratio > 10 is 0.0384. This value is okay for this run, but similar to before, it will be aimed to reduce even further (Logan and Chaudhry, 2012). Using an aspect ratio mesh plot we see the quality of the mesh.

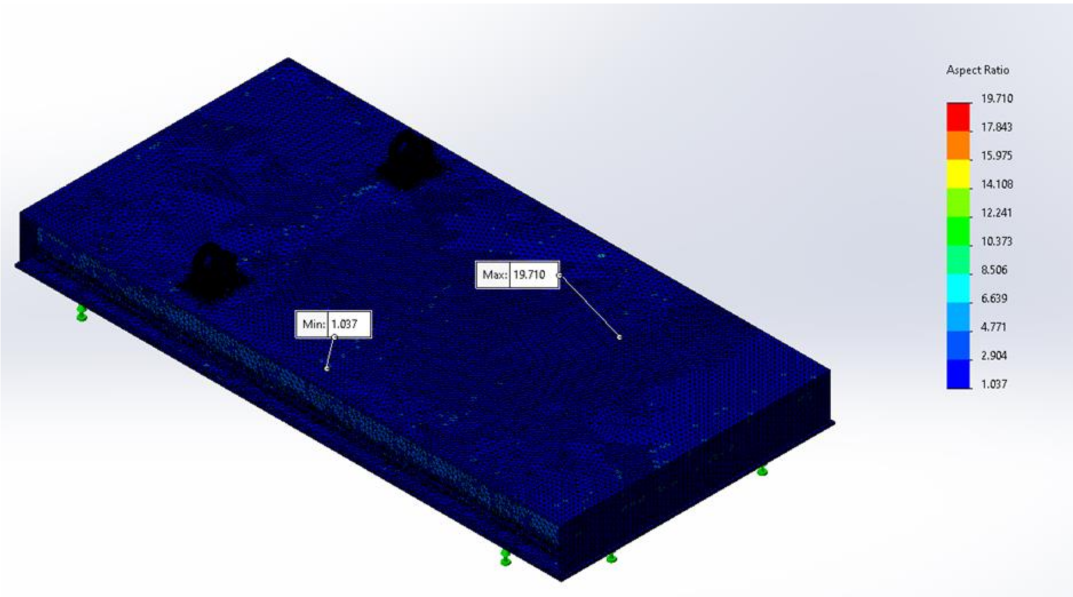


Figure 4. 39 Aspect Ratio Plot

The max value seen is 19.71. Being lower than 30 ensures a quality mesh, however, this will be aimed to reduce much lower in further meshes.

Next the Jacobian ratio mesh plot is reviewed.

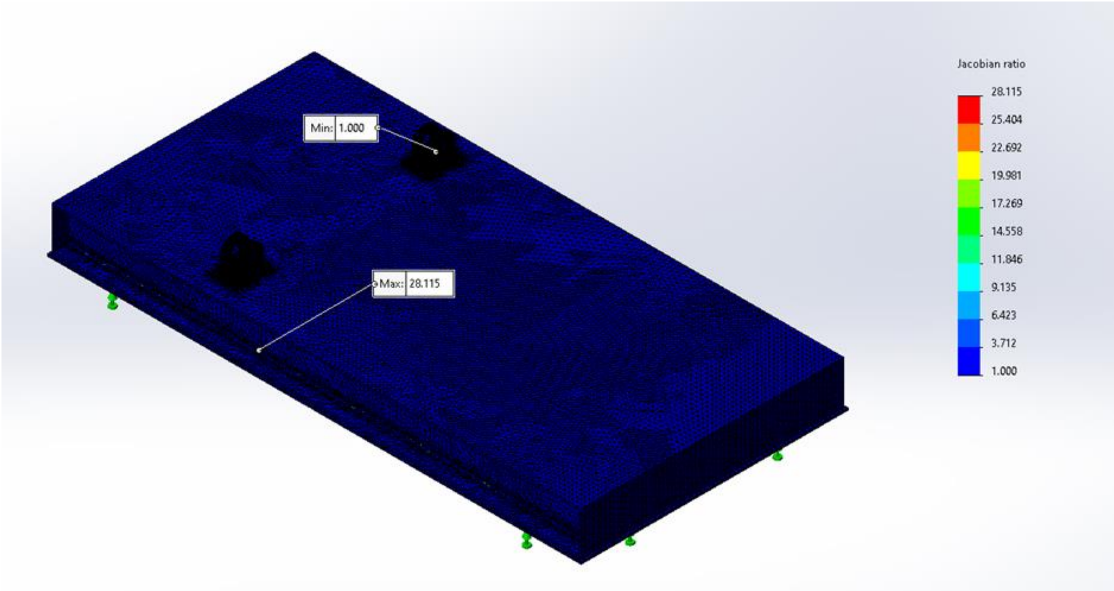
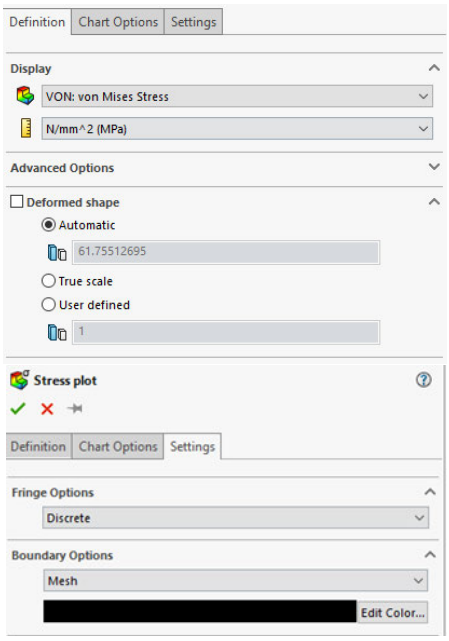


Figure 4. 40 Jacobian Ratio Plot

The minimum value of this plot is 1. This shows that our mesh quality is high, and there are no negative Jacobian tetrahedrons.

Applying a material is the final step before running the study. The material Grade 350 metal is applied, as this is the base material aimed to be used in this design. The study is run, however, some changes to the chart setups must be made for the results to be shown in a convenient form. These are seen below.

For the definition of the stress, the following options were chosen.



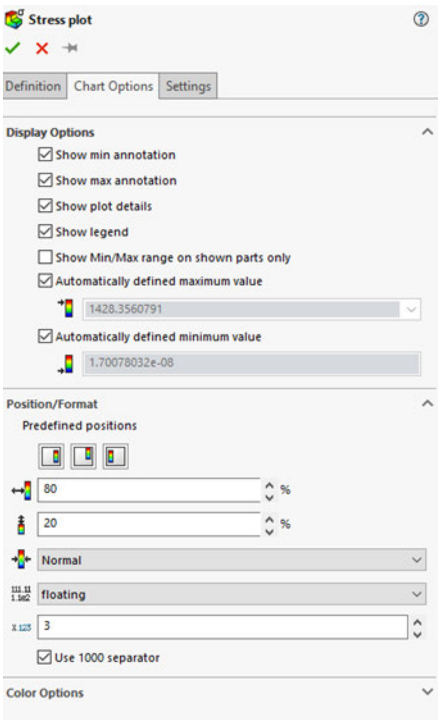


Figure 4. 41 FEA View Settings

The main changes are identified below.

- Show minimum and maximum annotations – Shows the min and max stress values throughout the weldment
- Change number format to floating – Provides base numbers for stress, no scientific or engineering notation utilised
- Change fringe options to discrete – Applies discrete shading to mesh
- Change boundary options to mesh – This provides a uniform stress within each tetrahedron compared to smoothing the contour

This will be common practice for all FEA analyses throughout this report.

Upon completing these steps, the stress contours are ready for viewing. A screenshot of the stress distribution is shown below.

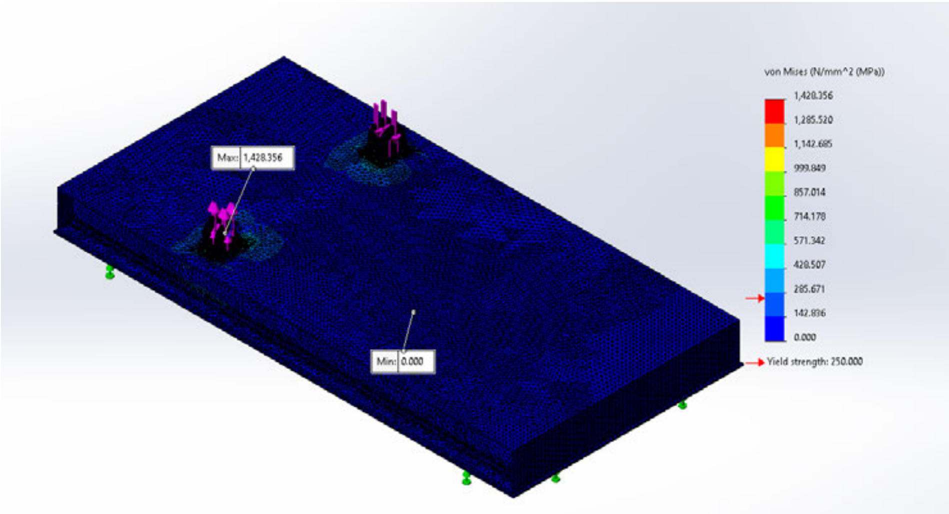


Figure 4. 42 FEA Initial Result Location 1

The result of maximum stress is seen below.

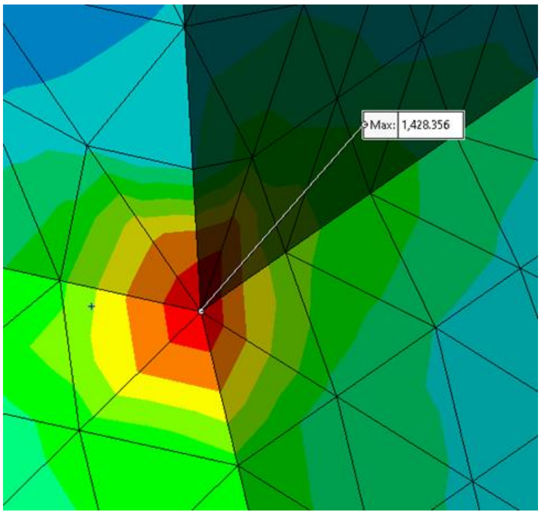


Figure 4. 43 FEA Singularity

It is understood that this is likely a singularity due to the location of the stress, and the small size of the impacted area. Iso-clipping for a 0.66 x yield stress (231 MPa for 350 Grade Steel) returns the following results.

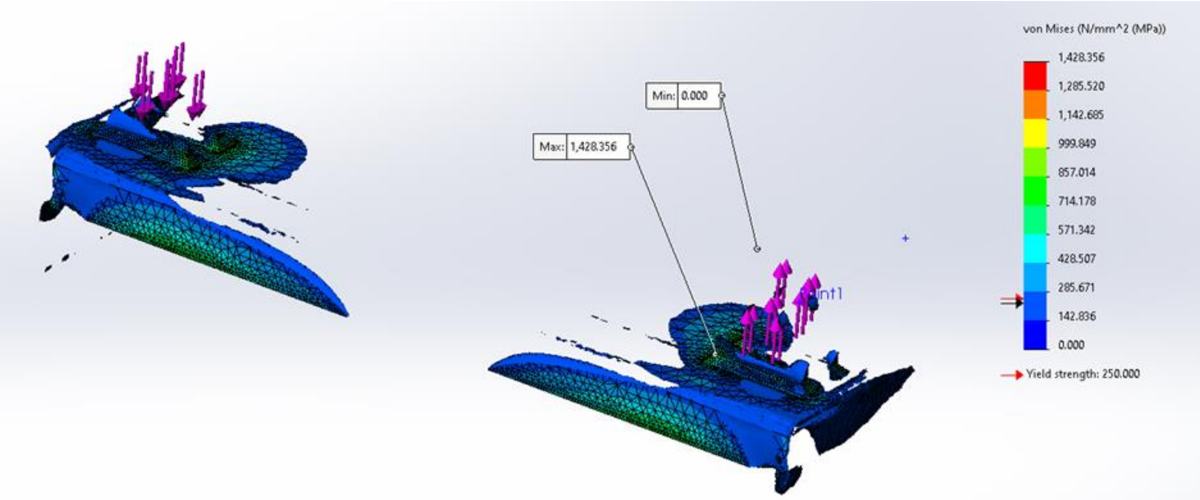


Figure 4. 44 FEA Iso-Clipped

A considerable load path is identified. It is understood that due to not utilising Solidworks Premium Simulation software, the values of stress are infinite as the program only allows for the plastic deformation region data of each material. It is clear that the material thickness of the steel plates on the base frame must be increased, along with the thickness of the lugs and the weld sizes. Other stiffeners may need to be added to withstand these forces.

Location 2

Now that the initial FEA setup parameters have been defined as per above, FEA must be run for the second location identified, being the welded lugs on the outside of the rotating tong assembly. It is assumed that the stresses on these welds will be very high due to the distance of the force application and the direction of the force, being perpendicular to the surface of the tong. Using the same setup parameters as before and running the mesh, the details are shown below.

Study name	LC01-01 (-LC01-01<As Welded>-)
Mesh type	Solid Mesh
Mesher Used	Standard mesh
Automatic Transition	Off
Include Mesh Auto Loops	Off
Jacobian points for High quality mesh	16 points
Element size	20 mm
Tolerance	4 mm
Mesh quality	High
Total nodes	79482
Total elements	41496
Maximum Aspect Ratio	7.9722
Percentage of elements with Aspect Ratio < 3	98.4
Percentage of elements with Aspect Ratio > 10	0
Percentage of distorted elements	0
Number of distorted elements	0
Time to complete mesh(hh:mm:ss)	00:00:09
Computer name	IT006744

Figure 4. 45 Location 2 Mesh Details

It is seen that the percentage of elements with an aspect ratio < 3 is 98.4%, whereas the percentage of elements with an aspect ratio > 10 is 0. This provides confidence in the current mesh quality; however, mesh control may have to be applied to the welds and lugs to provide an accurate stress value (Logan and Chaudhry, 2012). Below is a screenshot of the Aspect ratio mesh quality plot.

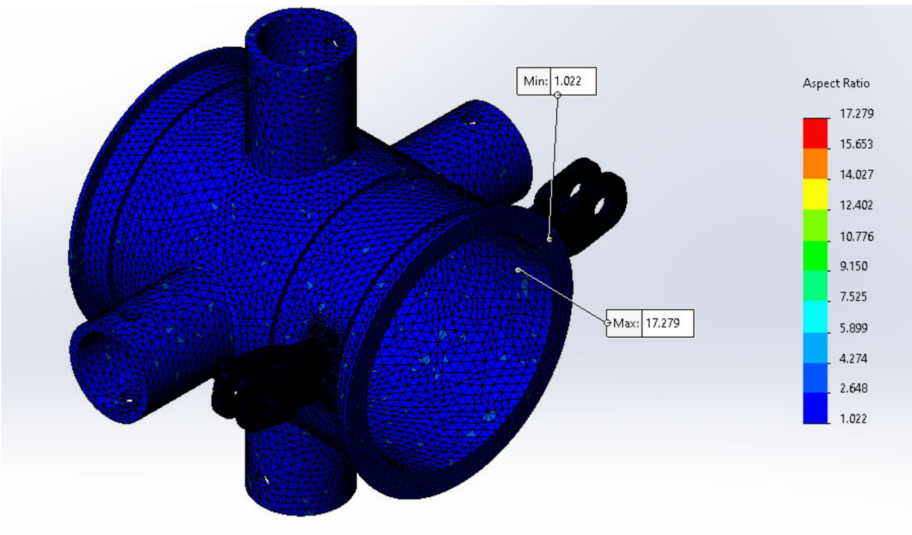


Figure 4. 46 Location 2 Aspect Ratio Plot

It is shown that the maximum value in the above plot is 17, being well under 30. Below is a screenshot of the Jacobian ratio plot.

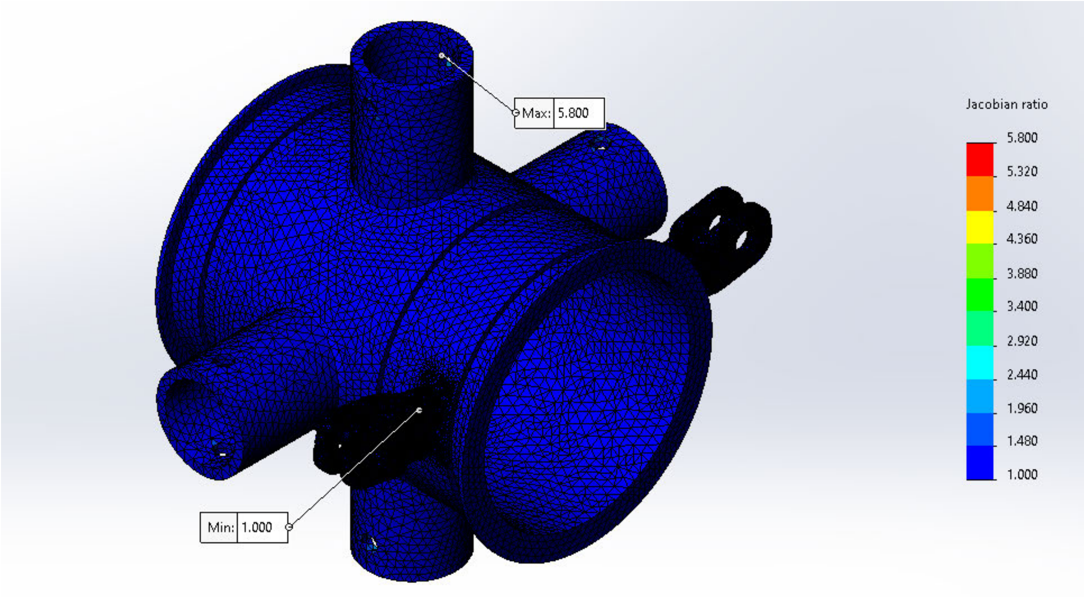


Figure 4. 47 Location 2 Jacobian Ratio Plot

The same values of 160kN are applied to each lug, opposing the forces applied to the base frame lugs as per the operational use of this device. The Von Mises stress contour is seen below. Rotational constraints are applied to the inside of the smaller welded pipes as seen below. This is due to the location of the clamping hydraulic rams that will be analysed later in this report.

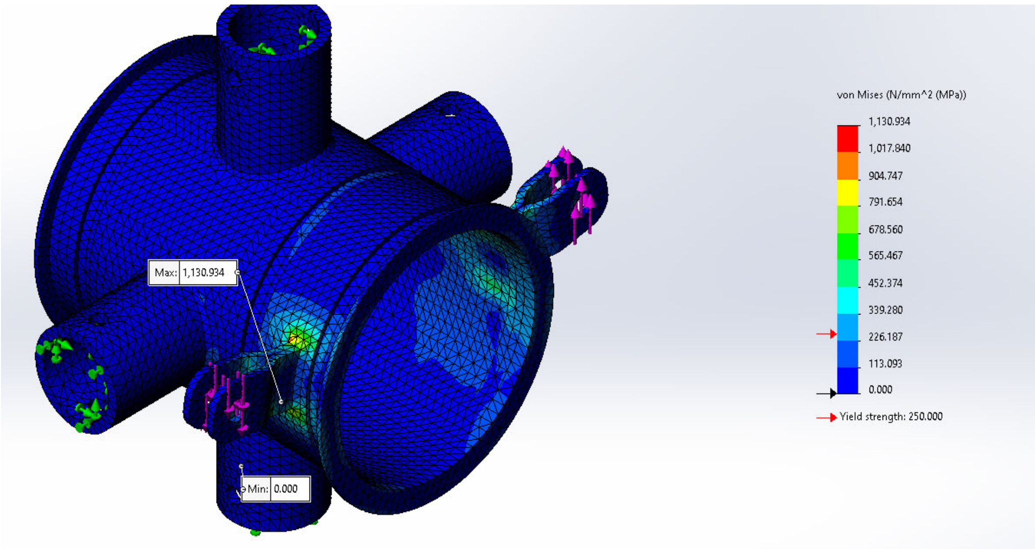


Figure 4. 48 Location 2 Initial FEA Results

It is seen that the stresses are very high, much like the first pass on the base frame welded lugs. A maximum stress of 1130.9MPa is identified at the corners of the welds.

Applying a mesh control around these areas, it will become clear whether the mesh needs further refining for more accurate results or if the model needs stiffeners and other reinforcing applied to assist in distributing the stresses.

Using Iso-Clipping with a minimum limit of 231MPa (0.66 of the Yield strength for 350 grade steel), the following contour is attained.

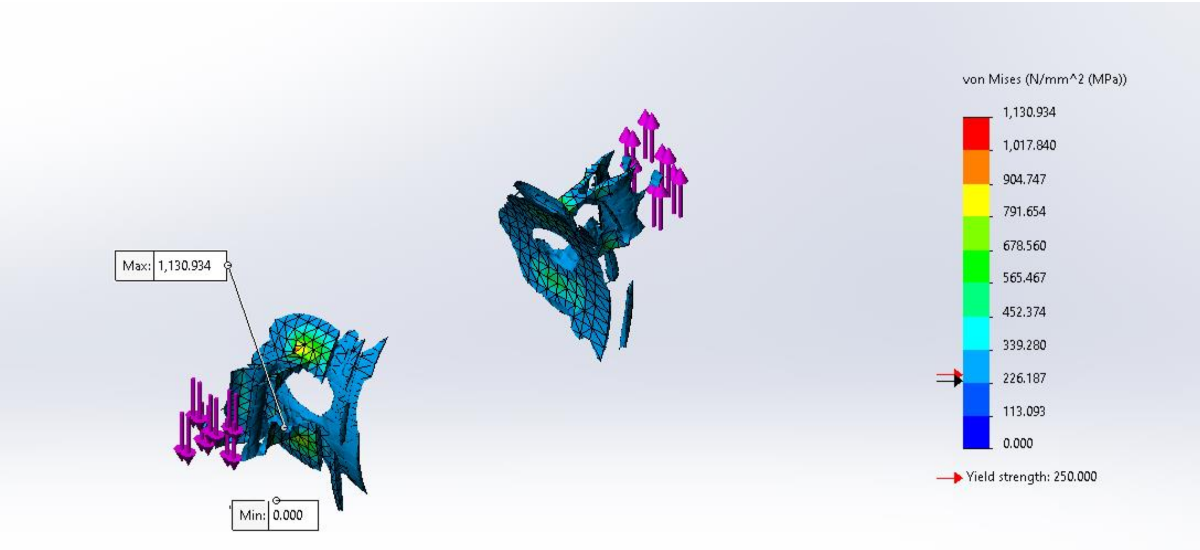


Figure 4. 49 Location 2 Initial FEA Iso-Clipped

A mesh control with the following parameters is applied to the selected surfaces (lugs and welds) to ensure the mesh is satisfactory for analysis, with a maximum element size of 4mm (Logan and Chaudhry, 2012). Details are shown below.

Study name	LC01-02 (-LC01-02<As Welded>-)
Mesh type	Solid Mesh
Mesher Used	Curvature-based mesh
Jacobian points for High quality mesh	16 points
Mesh Control	Defined
Max Element Size	20 mm
Min Element Size	6.6666 mm
Mesh quality	High
Total nodes	558845
Total elements	367559
Maximum Aspect Ratio	17.279
Percentage of elements with Aspect Ratio < 3	99.6
Percentage of elements with Aspect Ratio > 10	0.0019
Percentage of distorted elements	0
Number of distorted elements	0
Time to complete mesh(hh:mm:ss)	00:00:16
Computer name	IT006744

Figure 4. 50 Location 2 Mesh Details

The resulting Von Mises stress contour is shown below.

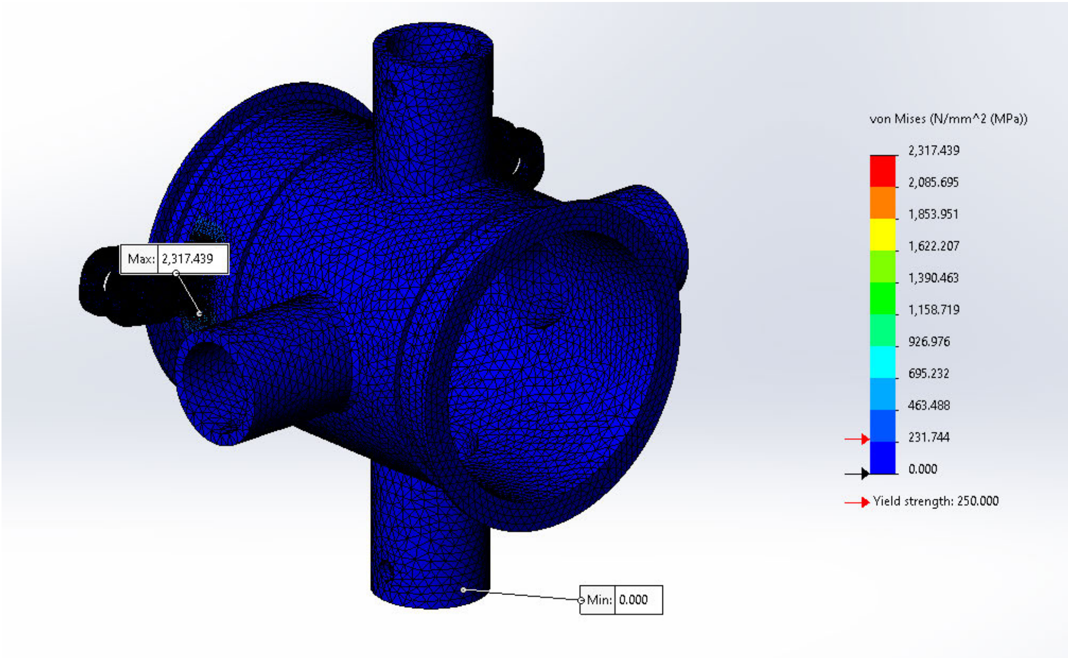


Figure 4. 51 Location 2 FEA Results

It is seen that the maximum stress has increased drastically from 1131MPa to 2317MPa. Therefore, further mesh refinement must occur along with stiffening of the design.

Location 3

Using the initial FEA parameters as identified above, a series of runs must be performed for the welded pipe locations where the clamping hydraulic cylinders impose force. The values of stress here are assumed to be quite high for this region as the forces exerted into the material are very large. The mesh details for this run are the same as the initial details for *Location 2* as it is run on the same part. A fixture is applied in the centre of the part to simulate the parts inability to rotate or translate about the centre (in the closed system that is being analysed). The force applied was applied at a total of an 80° contact surface angle area (Bathe, 2014) as the bearing load application does not work for holes that intercept multiple planes.

Using this mesh, we attain the following Von Mises stress contour.

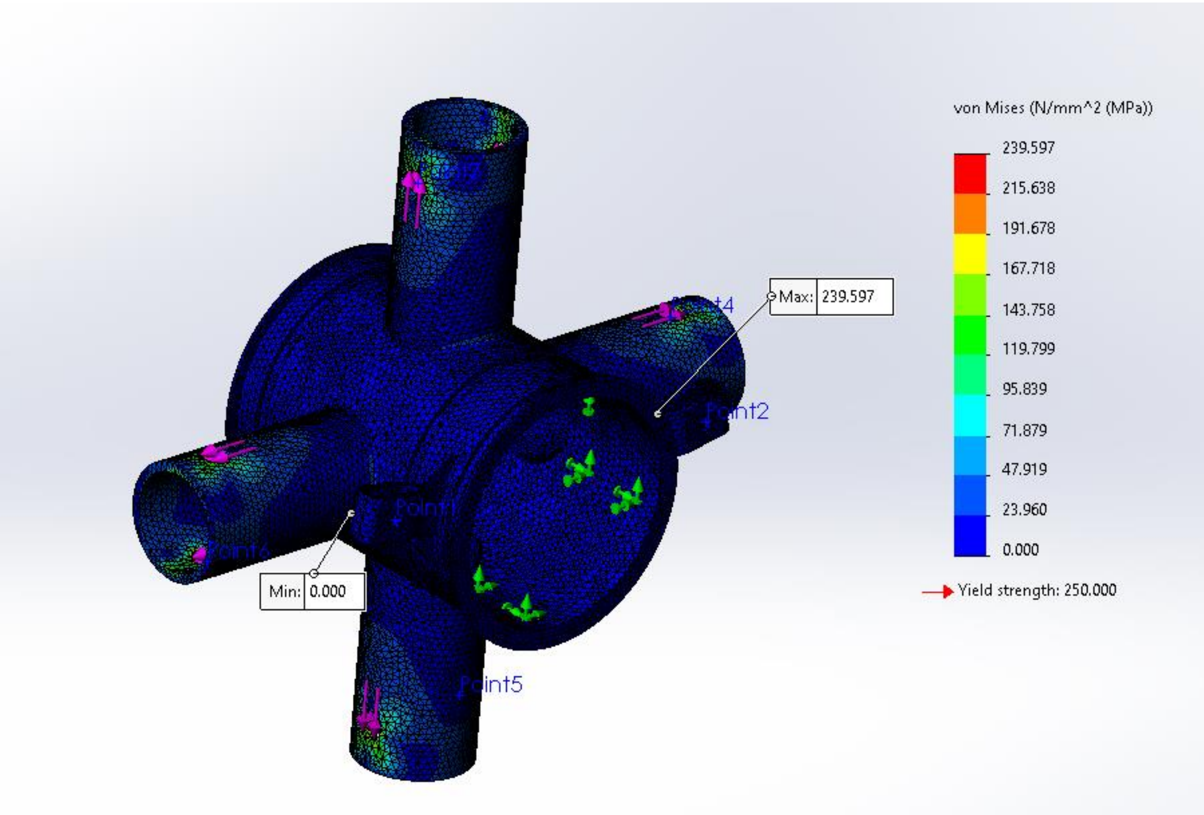


Figure 4. 52 Location 3 FEA Initial Results

The maximum stress is seen to be 239.6MPa, much lower than expected. Upon further inspection of the affected zone, the mesh appears to be very large for this area, as seen below.

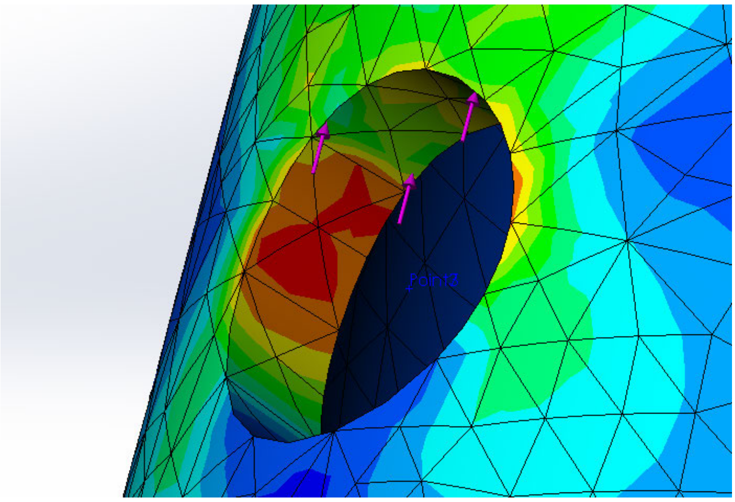


Figure 4. 53 Location 3 FEA Stress Concentration

Therefore, a mesh control is applied to this area of a maximum element size of 2mm. The following mesh details are shown below.

Study name	LC02-02 (-LC02-02<As Welded>-)
Mesh type	Solid Mesh
Mesher Used	Curvature-based mesh
Jacobian points for High quality mesh	16 points
Mesh Control	Defined
Max Element Size	20 mm
Min Element Size	6.6666 mm
Mesh quality	High
Total nodes	1017726
Total elements	659746
Maximum Aspect Ratio	97.952
Percentage of elements with Aspect Ratio < 3	99.7
Percentage of elements with Aspect Ratio > 10	0.00349
Percentage of distorted elements	0
Number of distorted elements	0
Time to complete mesh(hh:mm:ss)	00:00:40
Computer name	IT006744

Figure 4. 54 Location 3 Initial FEA Mesh Details

The percentage of elements with an aspect ratio < 3 is 99.7%, whilst the percentage of elements with an aspect ratio > 10 is 0.00349%. These values are satisfactory.

The aspect ratio contour plot is seen below.

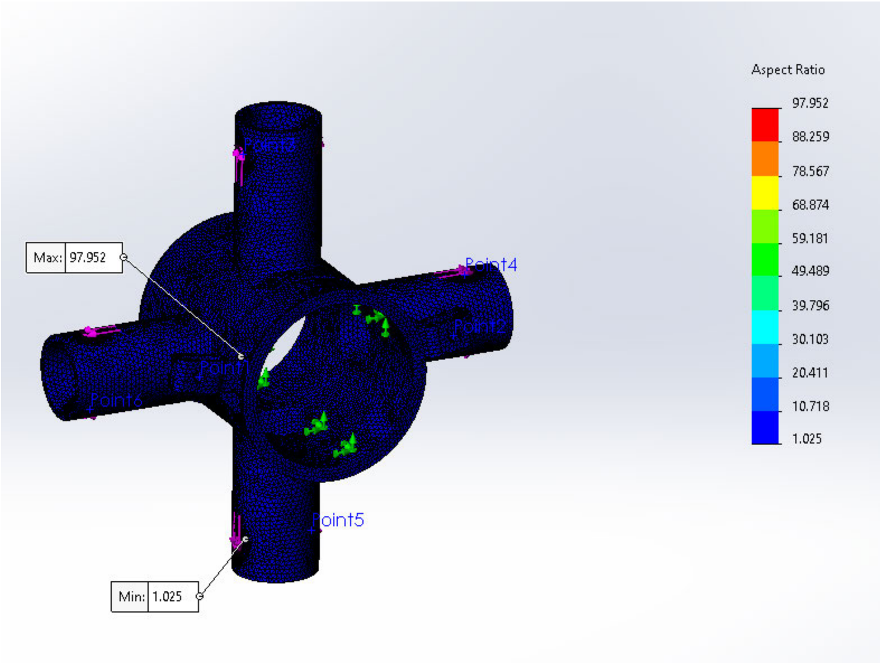


Figure 4. 55 Location 3 Initial FEA Aspect Ratio Plot

This aspect ratio seen above is quite high, however the maximum value is seen to be in an area (being the weld on the lugs) that previously required mesh control as the element size seen is too large for the weld. This is ignored as this will not affect the current study. The screenshot below shows the Jacobian ratio of the mesh.

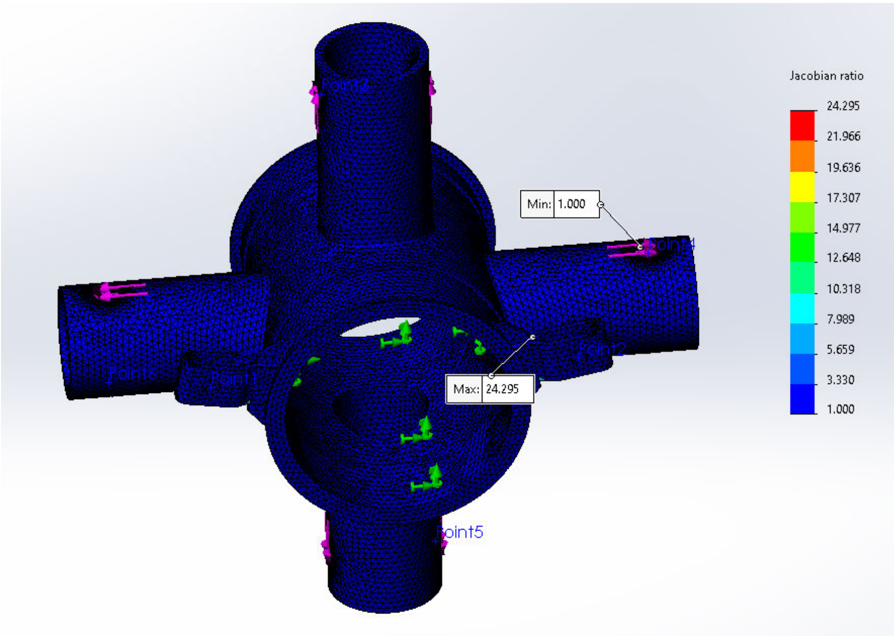


Figure 4. 56 Location 3 Initial FEA Jacobian Ratio Plot

A repeat of the last mesh quality plot is seen within this too. The key information to take from this plot, however, is that the Jacobian ratio is 1.00, therefore trust this mesh.

This provided the following Von Mises stress contour.

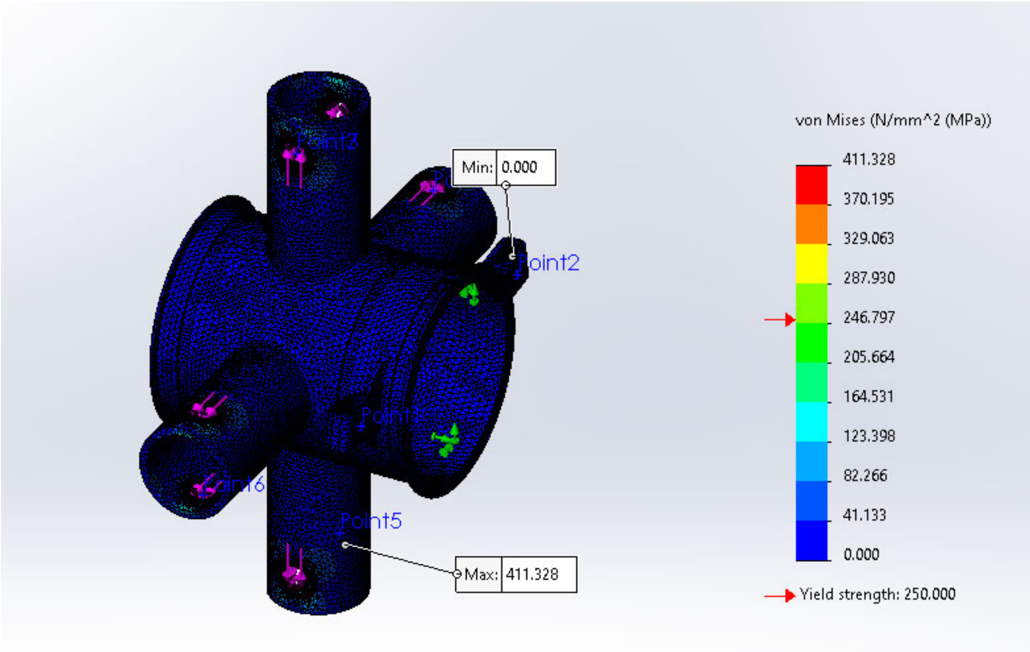


Figure 4. 57 Location 3 FEA Stress Results

The face that features this slice of the surface to apply the force is seen to be the reason for this very large stress value, as seen below.

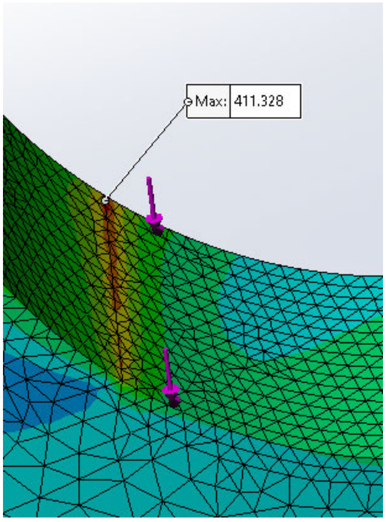


Figure 4. 58 Location 3 FEA Stress Concentration

Iso-clipping at 0.66 Yield of A106B (most common pipe material) at 159MPa reveals the following results (Van Leeuwen, n.d.).

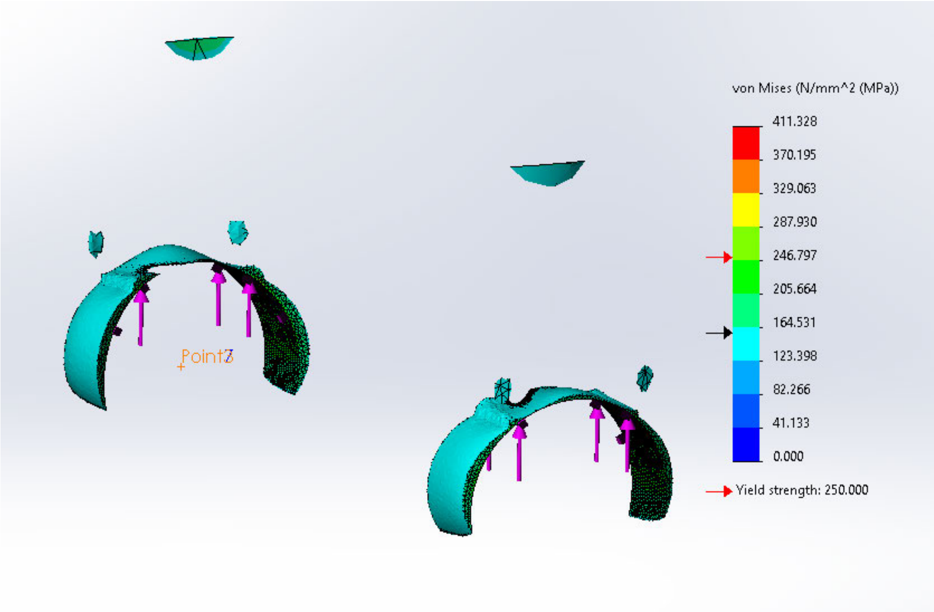


Figure 4. 59 Location 3 FEA Results Iso-Clipped

The concentrations of stress appear to be much more formed than what can be disregarded as artificial stresses. It is deemed suitable that instead of adding more weight and trying to add stiffeners for each piece of pipe to help alleviate these stresses, that a more suitable material choice will be made. This is seen to be grade X65 PSL2 steel pipe that has a yield strength of 450 MPa(Van Leeuwen, n.d.). Iso-clipping at the 0.66 Yield of this material (297 MPa) is seen below.

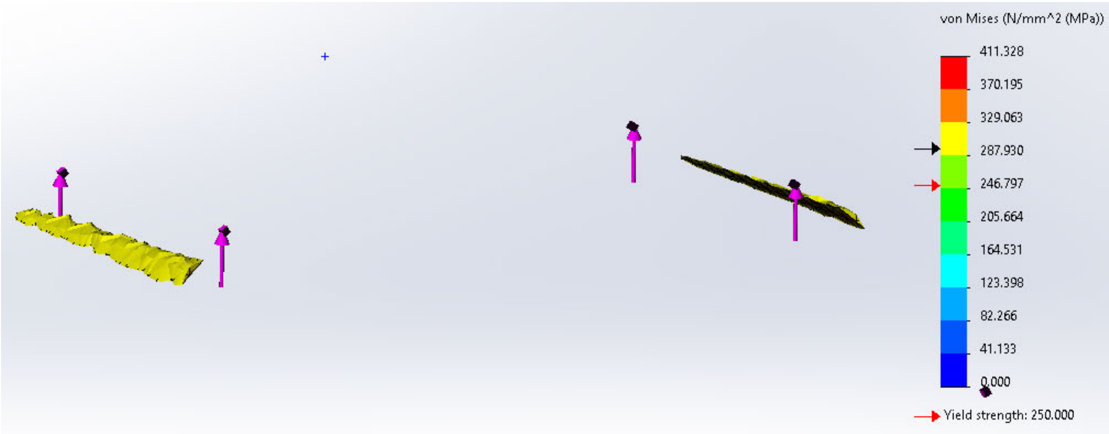


Figure 4. 60 Location 3 FEA Stress Concentration Iso-Clipped

Therefore, this stress concentration is seen to be much less formed than the previous material choice. It is understood that this is an artificial singularity, thus it will be ignored. This model, hence, will not require revisiting.

Revisiting Models

Location 1

Initially the steel plate was removed, making all sides of the base frame 200 PFC. Along with this, the EA stiffeners underneath the top plate were changed to 200 UB stiffeners for extra material thickness. The Von Mises stress results are shown below.

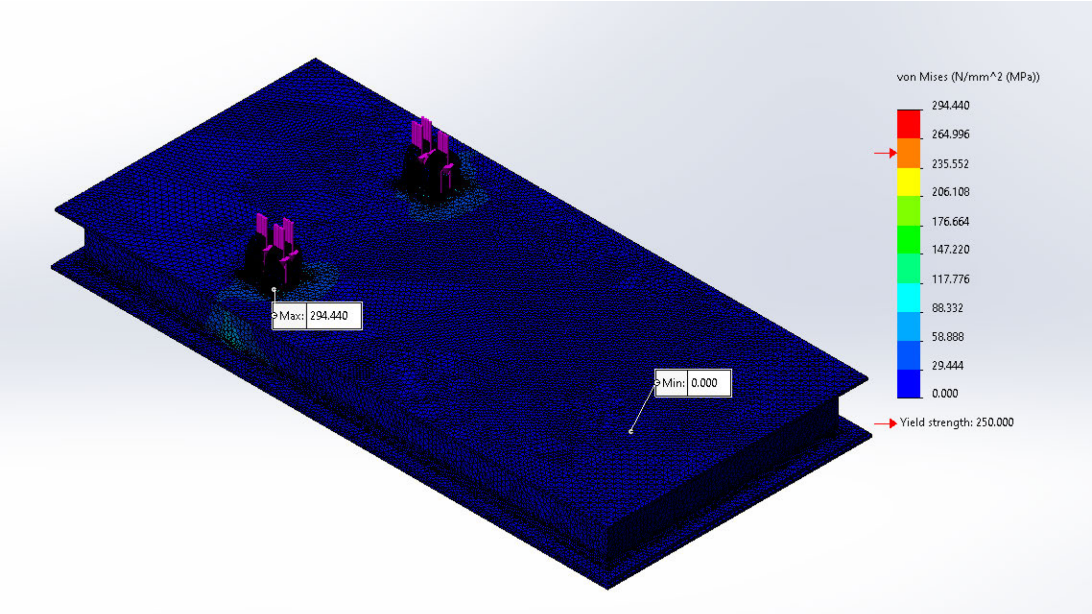


Figure 4. 61 Base Frame Final FEA

Iso-clipping with a limit of 213MPa, the following plot is returned.

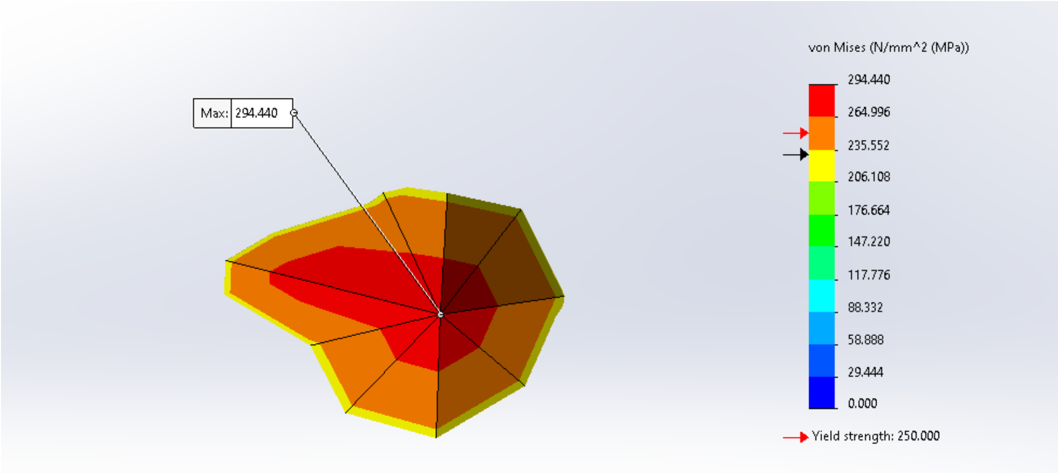


Figure 4. 62 Base Frame Final FEA Iso-Clipped

It is seen that this value is a singularity. This is apparent by the location of the stress concentration, being a corner of the weld. Furthermore, the load path is not shown when iso-clipped. Stress in other locations, such as the stiffeners under the top plate do not exceed 150MPa (approximately).

Location 2

As seen in the section above, the maximum stress experienced within the part is 2317MPa. Initially the design of the connecting "ears" is changed to be one piece that wraps around the top, as shown below.

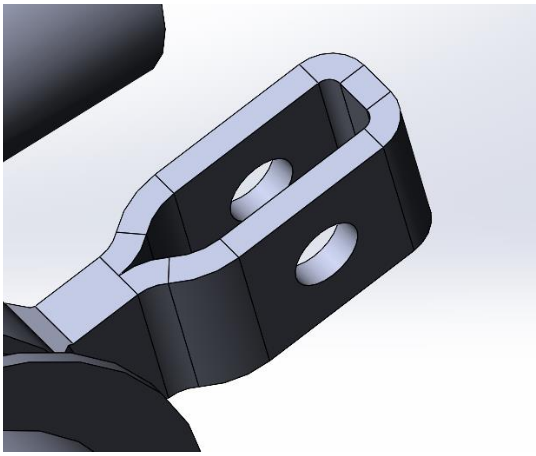


Figure 4. 63 FEA Location 2 Closeup

The maximum Von Mises stress has increased to 2503MPa, as seen below.

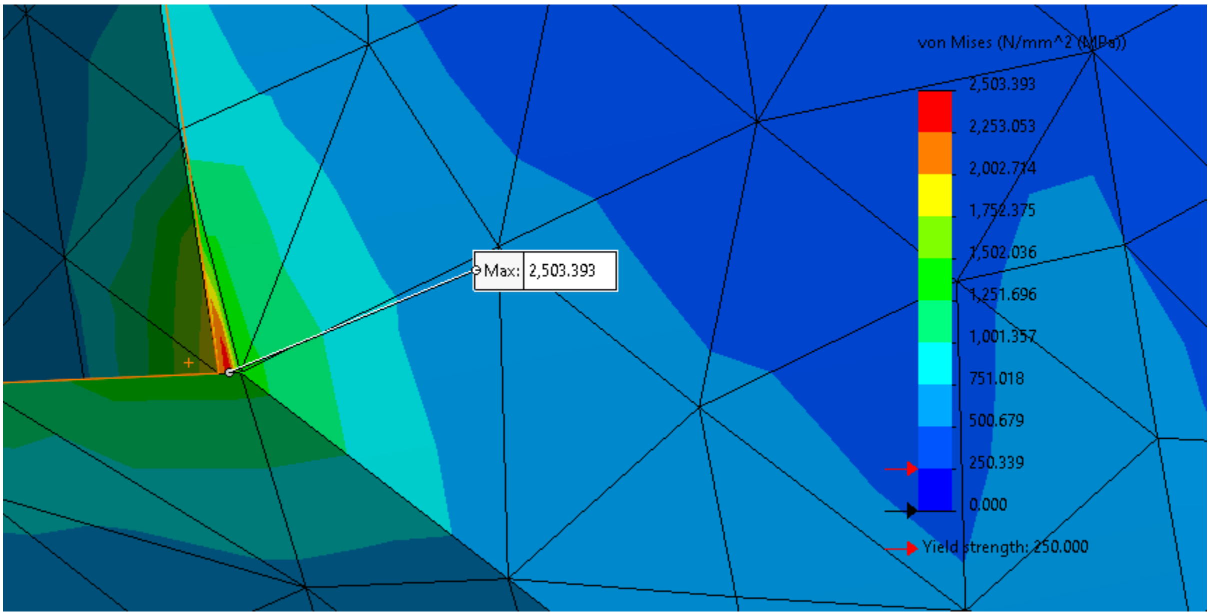


Figure 4. 64 Location 2 FEA Result

Therefore, it is seen that the model needs further refining. This is realised by adding some stiffeners to the sides of the ears, as seen below.

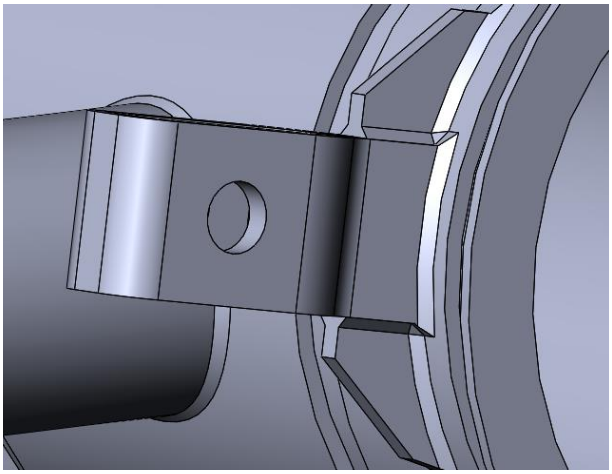


Figure 4. 65 FEA Location 2 Closeup Revised

This provided the following Von Mises stress contour.

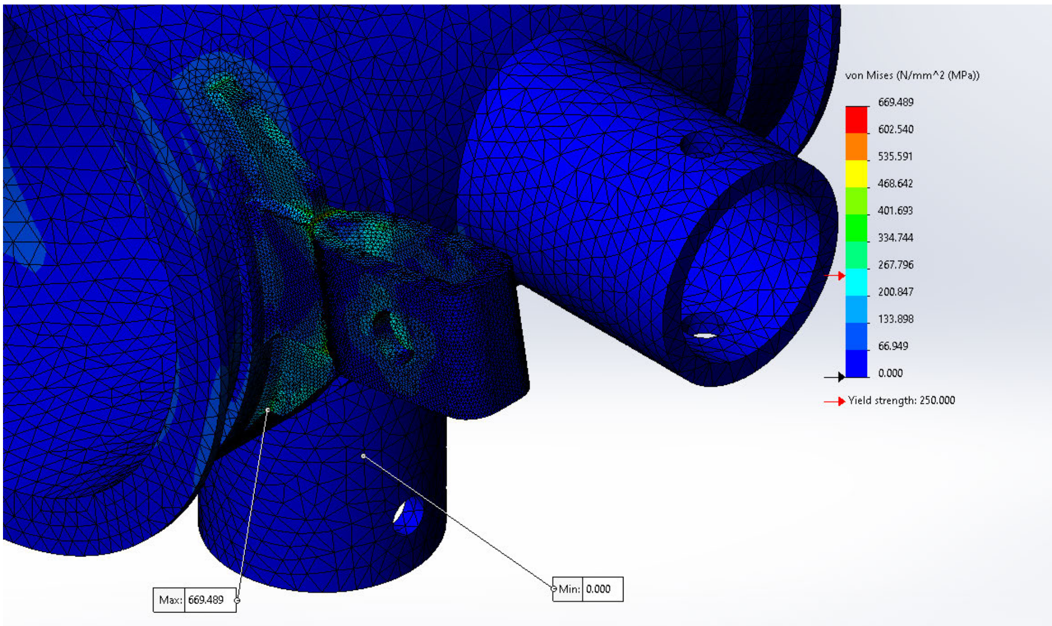


Figure 4. 66 FEA Location 2 Stress Results

The stress has decreased drastically from the previous run. It is shown that there is now a maximum stress of 669MPa. Iso-clipping these results, as seen below, provides the following contour.

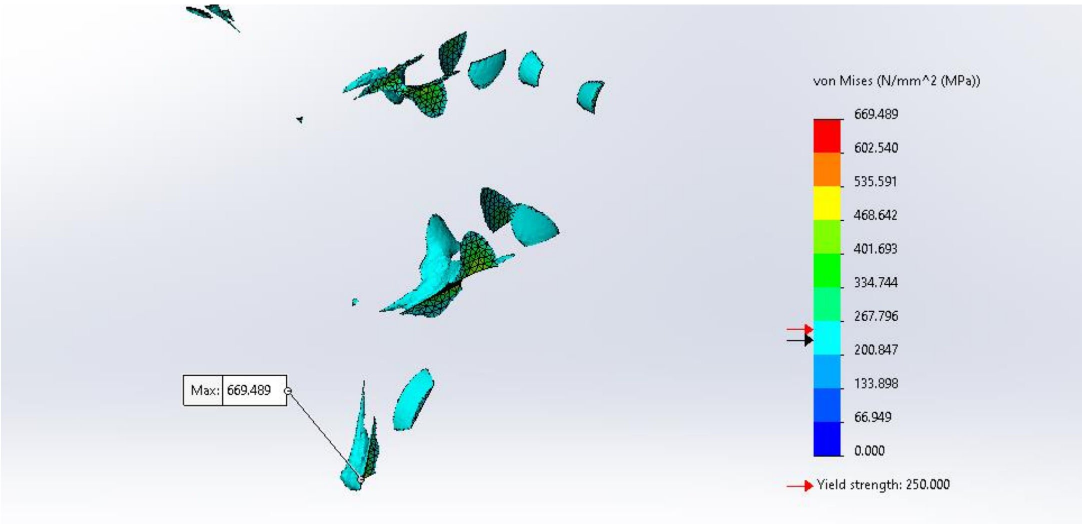


Figure 4. 67 FEA Location 2 Iso-Clipped

This shows the stress above 231MPa on one ear of the tong assembly. A stress hotspot diagnostics is run to determine if this value of stress (maximum value above) is a singularity or an expected value (not artificial) (Logan and Chaudhry, 2012). The results are shown below.

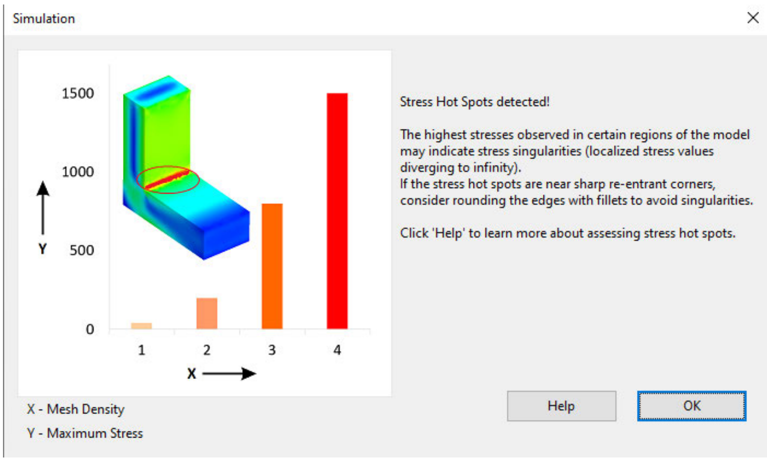


Figure 4. 68 Solidworks FEA Hot-Spot Detector

Solidworks states there are hot spots detected within this analysis. The screenshot below depicts an area of the fillet weld on the ear that has not meshed optimally, therefore, this stress is much higher than what is truly expected.

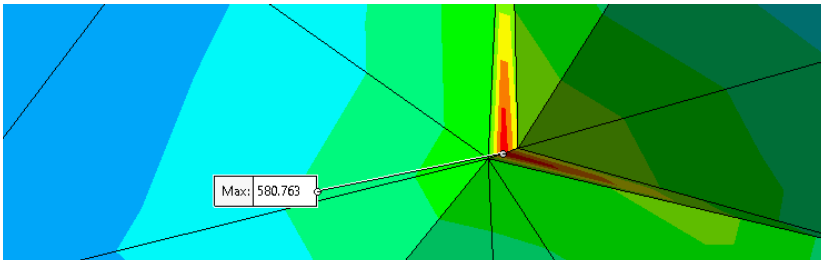


Figure 4. 69 Location 2 Stress Hot Spot

It is estimated that no real validated stresses are over the 0.66 x yield strength of 700 grade steel (462MPa). Via iso-clipping at this value, the following results are shown.

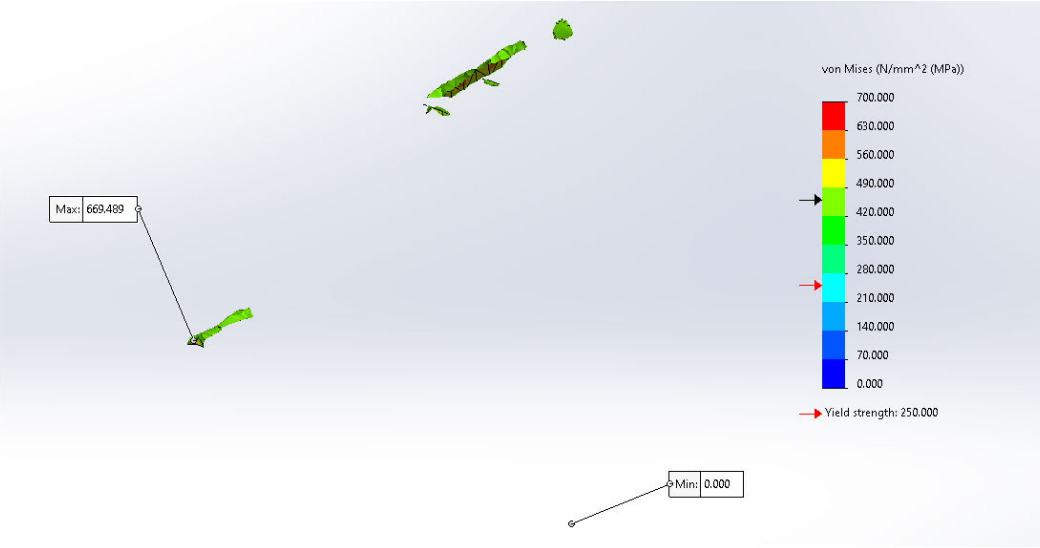


Figure 4. 70 Location 2 Stress Iso-Clipped

These results are similar for both ears, showing that there are clear singularities on the lines of the welds. Further model refining may find that this design can be compliant and safe using 350 grade steel, however, it is determined that this is not worth the time investment. It is also clear that this will have to be welded with a high carbon steel, such as AWS E71T-1C carbon steel wire, with a yield strength of approximately 652MPa (FP Beer, ER Johnston, JT DeWolf & DF Mazurek, 2015).

Final FEA Results

Location 1

It is shown above that the final FEA results for location one are satisfactory in regard to meeting Australian standards of Mechanical equipment – Steelwork (AS3990). By applying mesh controls and editing the model to include stiffeners underneath the lugs, along with the increased weld sizes around the lugs, it was seen that the highest non-artificial stress was under 200MPa. Two stress singularities are seen on corners of the welds, clearly being artificial stresses due to location and the very small load path of the stress, hence, these values are ignored in the analysis.

Location 2

The final FEA results for this location on the rotating tong assembly are shown above, meeting the Australian standards of Mechanical equipment – Steelwork (AS3990). Similarly, by applying a refined mesh control to the location of the lugs and welds, along with placing ribs (stiffeners) along the axial force application, the deign gained a large amount of rigidity. The final results show multiple stress hotspot locations (singularities) as identified by Solidworks. With the stress experienced within these lugs, due to the distance between the force application and the welds, the material choices for the lugs and welds were identified above to be 700 grade steel and a high carbon steel weld wire. This would allow for a much higher minimum stress value of 462MPa to meet the above standard discussed. The iso-clipping at this value provided detail on stress locations above this, identified as being on the edges of two welds, with a minimal load path. This indicates that these values are artificial stresses and thus can be ruled out as real possible stress to be experienced.

Location 3

The final FEA results for this location on the tong assemblies are shown above, meeting the Australian standards of Mechanical equipment – Steelwork (AS3990). By refining the mesh around the connection of the trunnion mount and the pipes, it was seen that the expected real maximum stress was well under the 0.66 yield of X65 PSL2 pipe (297MPa). This pipe may be more expensive due to its more desirable mechanical properties; however, it is a worthy investment for this area of such high stresses.

All three locations above are seen to have a safety factor of 2 or more, making these elements of design safe.

It is seen that the design process utilised the design methodologies stated above, allowing for an effective design to be produced within the scope of the project. This is validated predominantly through the use of FEA alongside the research conducted into the required materials and design concepts.

FEA Results

The final FEA results are tabulated below, providing a clear comparison between the allowable stress limits and the experienced stress of each location.

Table 4. 1 Stress Value Comparison

Stress Type	Location 1	Location 2	Location 3
Allowable (MPa)	231	462	297
FEA Result Max (MPa)	≈150	≈300	≈250

It must be noted, however, that there is no real maximum value of stress experienced within each location during these simulations, rather, these serve as a guide to assist in comparison between the allowable stresses and the finite element analysis result. Generally, as previously stated, the minimum FOS is seen to be 2, realistically providing a FOS approximately around 2.5-3 in most cases.

Chapter 5 – Design Evaluation

Project objective one was to review the current design of the bucking unit. This was achieved through a rigorous evaluation identifying negative elements of the design that were needed to change for this project to be successful, such as the weight of the bucking unit, footprint of the unit and more. It is seen within the design methodology and preliminary design stages of this report that this was achieved. Using a critical analysis of the unnecessary parts of a bucking unit, this project objective was found to be very useful for the design stage as setting these boundaries and limitations of design allowed for a reasonable scope and product to be idealised.

Project objective two was to investigate the processes in which the machine works and hence provide an understanding of methods of improving the effectiveness of the design. This is directly related to the first project objective as reviewing the design provided insight into the ways in which the traditional design cold be altered as per the needs of this project to be not only successful but improve upon the shortcomings of the previous design methodology used for other units. It is seen that this was done effectively within the market research section in conjunction with the background information to provide a product that met all needs of design. It was found during these processes that utilising a smaller maximum outer diameter of pipe was the most effective way of reducing all governing design parameters as identified above.

Project objective three was to identify the critical components of the design to make potential improvements or adjust them for transportation. The critical components of design were identified during the design methodology and initial design sections, allowing for a progression of these parts with changing requirements due to many factors. This report succeeded in doing this, allowing for an effective scope of design and research.

Project objective four was to reduce the overall size of the design to be suitable to be locked onto a shipping container or other similar tiedown method to be transportable via truck. The design methodology allowed for a simple connection of shipping container locks and weldable twist locks to be utilised to transport the unit with ease from any location. Furthermore, the incorporation of RHS forklift slippers allows the easy manoeuvrability of the unit to wherever deemed appropriate by workers on-site. The size of the unit was reduced to an overall size of 2850mm x 1930mm x 2313mm.

This is seen to be much smaller than most other units on the market, however, there are some limitation to this design. As previously stated, by reducing the maximum outer diameter of pipe that is able to be broken out and made up, the unit is required to withstand less stress and force than usually required by conventional machines. This was done as the most common sizes of pipes this machine is intended to be operating on is approximately 5”, but pipe that was 6-5/8” OD is used often enough that this could be included into the design methodology without changing the design criteria too harshly.

Project objective five was to conduct a rigorous design methodology supported by FEA to ensure the design is feasible and reliable. As referenced above, the design methodology utilised was not only rigorous but aided in defining an appropriate scope of design for this project. During the design and testing chapter, the initial design was conceived, then altered via the feedback provided by the use of FEA. All design elements were affected by FEA, whether it was a simple design change such as additional stiffeners to increase strength or more complex alterations such as moving parts around to fit the footprint of the unit. All elements that had FEA conducted are within required API and Australian standards of design, having a safety factor over 2 for all parts. During the FEA iterations, it was seen that much of the stress causing a value to exceed the usual expected limit was due to singularities. This was countered by using the provided mesh quality plots (aspect ratio and Jacobian ratio) along with the mesh details including aspect ratio parameters to ensure the mesh used was effective and safe, then designing around this to ensure the model, and thus built product would be safe for operation.

Project objective six outlined a comparison of materials to be used for each element of design, providing options into availability, ease of manufacturing and weldability. Predominantly the design was aimed to consist of 350 grade steel as this is the most abundant steel, with reasonable mechanical properties and comes at a sufficient price. This material is also easily weldable, a key feature as this design features many welds.

During the design stage, the material selection was based around the FEA simulation results, indicating as to whether the initial chosen material was sufficient for the application. This was not the case in some instances, hence utilising 700 grade steel (for example) on areas of large stress such as the lugs welded to the base frame was a minimum requirement of the design to ensure safety and reliability for a sufficient lifecycle of the unit.

Project objective seven was to conduct research into the current design methodology and determine if any gaps in the market can be assumed. This was a project objective set to be accomplished if time permitted. Unfortunately, no time is available for this to occur, however this would help strengthen this report by identifying more operations or elements of the traditional design that are not required for this specific design.

The design overall is seen to meet all of the above project objectives except objective seven due to time restrictions.

Chapter 6 – Conclusion

The final design is shown again below.

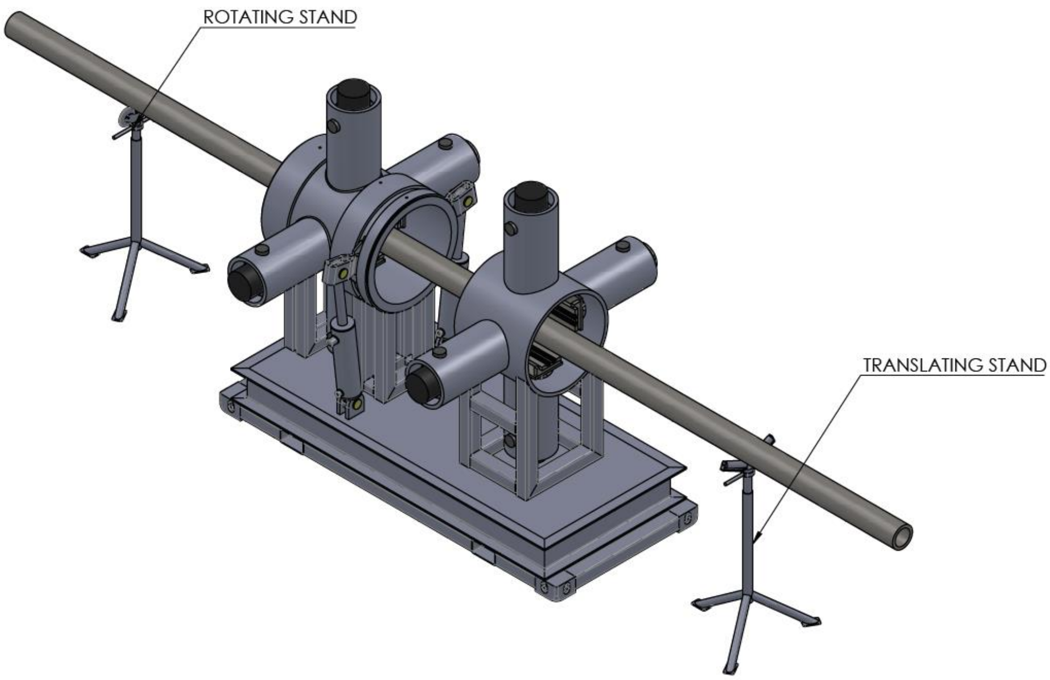


Figure 6. 1 Final Model

The project undertaken was successful for the most part in constructing a design suitable for the stated project aims and objectives, as previously discussed. It is seen that six out of seven project objectives were clearly met through the rigorous design methodology backed by supporting research via the literature review, amongst the other sections. The design methodology, being established around the waterfall method in conjunction with beneficial elements of the stage gate and spiral development processes, allowed for a critical yet efficient method of design. The design overall is quite effective at its intended use case indicated from the data gathered throughout this report. Some changes to be made to the design, however, if time permitted, are the following;

- Increase the number of hydraulic units per tong assembly – this would allow a reduction of size of the hydraulic cylinders due to less required force per cylinder. Furthermore, this would allow stress to be more affectively dispersed throughout the connections and the dies, thus different materials may be able to be used.

- Design a simpler method for allowing the rotating tong assembly to freely rotate – Whilst the current design is sufficient, more time would allow the exploration of other methods of rotating the assembly, such as designing a large hydraulic chuck (for example).
- Perform an investigation into the required power input of this unit and its components (hydraulic cylinders) and determine an effective method of powering the unit away from power sources. This could be a HPU connected to the frame or a separate system all together. Similarly, this design could utilise a power unit on-site, however, the details of these power units vary per site, thus the optimal solution would be to spec up a HPU for this unit to use.

The material choices are appropriate for all but one part of the design. This is seen to be the pipes welded to the tong assemblies for the trunnion mount connections of the clamping hydraulic cylinders. This material was chosen due to the high stresses experienced due to designing to standard to ensure a safety factor over two, creating a safe and sustainable design. With the aforementioned design changes, this material may be able to be changed to a more available and cost effective material such as a common A106B pipe. All other material choices are deemed the most effective for the design in regard to availability, weldability, cost and ease of manufacturing, as required by the project objectives.

The project took the expected amount of time, finishing prior to the submission date. This provides two pieces of information, being that the scope of the design was correct and accurate for a project of this type given the time period and that the project timeline was managed effectively and conducted with rigour to ensure the most effective solution was attained as per the scope.

More work is required for this design to become ready for manufacturing. The first of these steps is to conduct more FEA and testing on parts that may see stresses, such as the tong dies and perhaps other elements of the tong assemblies. Along with this, the possible design changes as previously mentioned must be explored. This would provide a professional assurance that this particular design of the bucking unit is as in-depth as competently possible within reason. Following this, testing of parts using load cells would be a very effective method of ensuring that the data attained from FEA is accurate and precise.

Additional work is required to provide technical drawings of the parts and assemblies to a reasonable level where they are able to be used for production, however, this is more likely to be of benefit once the design has been improved upon by the notes previously mentioned. Furthermore, additional work is needed to implement a force measuring gauge into the hydraulic line. This work is relatively simple, however, it would take more time than available to specify the correct items to incorporate, thus it is out of scope for this project.

The solution is deemed to be safe with a minimum safety factor of 2, as identified above within the *Final FEA Results* section. Using the above mentioned techniques, however, this safety could be increased to possibly 2.5 or 3, ensuring a higher lifecycle along with inherent safety benefits.

As discussed in the *Ethical Issues and Consequences* section above, there is no real cause for concern regarding the impact a product like this would have on the current workplace and environment within this industry. Furthermore, this product already exists within the Oil and Gas industry, therefore this product is not revolutionary and the negative impacts will be minimal at most, in comparison to the benefits this design offers. The benefits of this design, as previously discussed, are the reduction of overhead costs involved in transporting pipe away from the worksite to a workshop able to breakout and makeup the connections. These are;

- Operator wages
- Fitting and testing costs
- Transportation costs
- Contractors and hired workers costs
- Loss of production (such as invisible time)

Understanding the benefits of this design reemphasises the incessant need for this portable unit within the industry. These value and principles of design are not only limited to the bucking unit, of course. The need for design methodology to be established around the ideology of ensuring sustainability, ease of usability and a potential reduction unnecessary costs as listed above. There is a constant requirement for this to be considered within the Oil and Gas industry as it is to this day still a major provider of energy for Australia and worldwide, hence it is not going to disappear nor transition to other, more sustainable practices anytime soon. This creates urgency for engineers to design in such a way that promotes sustainability for the duration of this industry, as many workers and practices rely on these services.

References

1994. *Technical drawing*. Homebush, N.S.W.: Standards Australia (Standards Association of Australia), pp.5-43.

2004. *Structural steel welding*. Sydney, N.S.W.: Standards Australia International, pp.5-17.

2015. *Quality management systems*. Sydney, N.S.W., pp.5-22.

2017. *Oil and Gas - A Roadmap for unlocking future growth opportunities for Australia*. [ebook] Available at: <https://www.csiro.au/-/media/Do-Business/Files/Futures/RoadmapOilGasFull.pdf> [Accessed 9 March 2021].

A BRIEF HISTORY OF OFFSHORE DRILLING RIGS 2020, petroleumclub.org.au, viewed 22 April 2021, <https://petroleumclub.org.au/april-2020-enewsletter-pages/a-brief-history-of-offshore-drilling-rigs>.

Agarwal, NA 2008, 'Modified V-Door Position(s) — New Technique for Lifting and Mechanical Handling on Drilling Units', *IPTC 2008: International Petroleum Technology Conference*.

American Petroleum Insitute 2001, *Specifications for Rotary Drill Stem Elements*, November, viewed 23 April 2021, <https://www.api.org/~/media/Files/Certification/Monogram-APIQR/0_API-Monogram-APIQR/Advisories-Updates/Addenda-Errata/API_7-1_1st-Edition_Addendum-1_March-2007.pdf>.

API Q1 – Specification for Quality Management System Requirements for Manufacturing Organizations for the Petroleum and Natural Gas Industry

Australia Oil & Gas Industry Outlook Report 2020, appea.com.au, Wood Mackenzie, viewed 17 March 2021, <https://appea.com.au/wp-content/uploads/2020/06/Australia-Oil-and-Gas-Industry-Outlook-Report.pdf>.

Australian Government 2019, *Oil and Gas Products and You, Energy Information Australia*, p. 1, viewed 20 March 2021, <https://energyinformationaustralia.com.au/wp-content/uploads/2019/10/Petroleum-and-You-Final.pdf>.

Bathe, K., 2014. *Finite element procedures*. 2nd ed. Watertown (MA): K. J. Bathe.

Beer, FP, Johnston, ER, DeWolf JT & Mazurek, DF 2015, Mechanics of materials, 7th edn, McGraw-Hill, New York. (in SI units.)

Berendsen. n.d. *Cylinder Catalogue*. [online] Available at: <https://www.berendsen.com.au/wp-content/uploads/2017/08/Cylinder_Catalogue.pdf> [Accessed 28 August 2021].

Bestbuysteel.com.au. n.d. *Buy Steel Australia*. [online] Available at: <https://bestbuysteel.com.au/php/webstore/ecom/index.php?option=search&search=grade+350+and+aisi+1020> [Accessed 02 May 2021].

BlueScope Distribution. n.d. *Steel Plate - BlueScope Distribution*. [online] Available at: <http://www.bluescopedistribution.com.au/products/steel-plate/> [Accessed 02 May 2021].

Bottani, E & Rizzi, A 2008, 'An adapted multi-criteria approach to suppliers and products selection—An application oriented to lead-time reduction', *International Journal of Production Economics*, vol. 111, no. 2, pp. 763–781, viewed 12 April 2021, <https://reader.elsevier.com/reader/sd/pii/S0925527307001636?token=C9D06575DB626DD46264077FA58D771C04452A8F212F53FE305CF041BF7962384E0351BE3F00F6BAFDBBA364E1E608D9&originRegion=us-east-1&originCreation=20210424085238>.

Bucking Units n.d., umcorp.com, viewed 11 March 2021, <http://umcorp.com/products/bucking-units>.

Chima, C., 2011. Supply-Chain Management Issues In The Oil And Gas Industry. *Journal of Business & Economics Research (JBER)*, [online] 5(6). Available at: <https://www.clutejournals.com/index.php/JBER/article/view/2552/2598>.

Cook, RD, Malkus, DS, Plesha, ME & Witt, RJ 2002, *Concepts and applications of finite element analysis*, 4th edn, Wiley, New York.

CSG And Water 2019, Australian Government, viewed 25 March 2021, <https://energyinformationaustralia.com.au/wp-content/uploads/2019/10/Myth-Vs-Fact-CGS-and-Water.pdf>.

Culley, SJ 1994, 'The mechanical design process', *Design Studies*, vol. 15, no. 1, pp. 23–147.

Cummins, T, Sinnott, A & Forestier, D 2012, *Increased Tubular Running Efficiency on Drilling Rigs*, onepetro.org, OnePetro, viewed 12 April 2021, <https://onepetro.org/SPEAPOG/proceedings-abstract/12APOG/All-12APOG/SPE-156235-MS/155803>.

Daniel, R & Paulus, T 2019, *Hydraulic Motor - an overview | ScienceDirect Topics*, www.sciencedirect.com, viewed 25 April 2021, <https://www.sciencedirect.com/topics/engineering/hydraulic-motor>.

Drill Pipe Selection Guide | Engineering360 n.d., www.globalspec.com, viewed 23 April 2021, <https://www.globalspec.com/learnmore/specialized_industrial_products/mining_equipment/drill_pipe>.

Drill Pipe Selection Guide | Engineering360 2006, www.globalspec.com, viewed 25 March 2021, <https://www.globalspec.com/learnmore/specialized_industrial_products/mining_equipment/drill_pipe>.

DRILL STRING DS-1 n.d., viewed 25 April 2021, <https://www.iadc.org/wp-content/uploads/2015/08/preview-drst.pdf>.

Drilling 101 2019, Energy Information Australia, viewed 10 February 2021, <https://energyinformationaustralia.com.au/oil-and-gas-explained/formation-and-extraction/drilling-101/>.

Enerpac. n.d. *Hydraulic Pressure and Force Gauges*. [online] Available at: <https://www.enerpac.com/en-au/system-components/AUGauges> [Accessed 3 August 2021].

Engineers Australia 2019, *Code of Ethics and Guidelines on Professional Conduct*, viewed 27 April 2021, <https://www.engineersaustralia.org.au/sites/default/files/resource-files/2020-02/828145%20Code%20of%20Ethics%202020%20D.pdf>.

Eustes, AW 2007, *The Evolution of Automation in Drilling*, onepetro.org, OnePetro, viewed 25 April 2021, <https://onepetro.org/SPEATCE/proceedings-abstract/07ATCE/All-07ATCE/SPE-111125-MS/143259>.

Gauthier, P 2020, *Shutting Down Oil Wells, a Risky and Expensive Option*, Resilience, viewed 12 April 2021, <https://www.resilience.org/stories/2020-05-28/shutting-down-oil-wells-a-risky-and-expensive-option/>.

Glide, R 2019, *All About Drill Pipes: What are They & What are They Used For? | Texas International Oilfield Tools LTD*, TIOT, viewed 24 March 2021, <https://www.texasinternational.com/all-about-drill-pipes/>.

Grade 350 Maraging Steel vs. SAE-AISI 1020 Steel :: MakeItFrom.com n.d., www.makeitfrom.com, viewed 25 April 2021, <https://www.makeitfrom.com/compare/Grade-350-Maraging-Steel/SAE-AISI-1020-S20C-G10200-Carbon-Steel>.

Hossain, ME & Al-Majed, AA 2015, *Fundamentals of Sustainable Drilling Engineering*, *Google Books*, 1st edn, John Wiley & Sons, viewed 22 April 2021, <https://books.google.com.au/books?hl=en&lr=&id=Ug99BgAAQBAJ&oi=fnd&pg=PP1&dq=drilling+rig+technology+advancements&ots=U5nyKGfv4C&sig=5TfP90MDcWcYby1BnA0goYgNIeM#v=onepage&q&f=false>.

Hulke, M & Habetz, J 2016, *Collaboration with Client: Industry's First Open- Head, Full Rotating High-Torque Bucking Unit Enables Makeup of Tubulars on Pipe Deck*, onepetro.org, OnePetro, viewed 17 April 2021, <https://onepetro.org/OTCONF/proceedings-abstract/16OTC/3-16OTC/D031S031R002/84592>.

Hungerford, F 2013, 'Evolution and application of in-seam drilling for gas drainage', *International Journal of Mining Science and Technology*, vol. 23, no. 4, pp. 543–553, viewed 12 May 2021, <https://www.sciencedirect.com/science/article/abs/pii/S2095268613001122>.

Immerse | The History of Offshore Oil and Gas Production | Below The Seabed | Western Australian Museum 2020, www.museum.wa.gov.au, viewed 12 March 2021, <http://www.museum.wa.gov.au/immerse/panel/12.html#:~:text=In%20Australia%2C%20the%20first%20oil>.

Industry Capability Report - Oil and Gas 2020, www.austrade.gov.au, Australian Government | Australian Trade Commissions.

J.V.Bjuneb, KAMacdonald 2007, 'Failure analysis of drillstrings', *Engineering Failure Analysis*, vol. 14, no. 8, pp. 1641–1666, viewed 19 April 2021, <https://www.sciencedirect.com/science/article/pii/S1350630706002251?casa_token=6THjM3XxSAsAAAAA:TyE2ocvJvurWdeJW2AWkhcLzCDPdZbggQLj1BYoJbM9fxEyeP-b3kL79VNFK6JpHie4swfyRT53t>.

Jellison, M 2009, *Ultra-high-strength drill pipe may meet demands of ERD, critical deep drilling CURRENT AND FUTURE*, *drilling contractor.org*, pp. 1–7, viewed 01 May 2021, <http://drillingcontractor.org/dcpi/2009/mar-apr/DC_Mar09_GrantPrideco.pdf>.

Kelly, M., Schmid, S., Adams, D., Fletcher, J. and Heard, R., 2019. Experimental investigation of linear friction welding of AISI 1020 steel with pre-heating. *Journal of Manufacturing Processes*, 39, pp.26-39.

Kent, R., 2018. Services. *Energy Management in Plastics Processing*, [online] pp.105-210. Available at: https://www.sciencedirect.com/science/article/pii/B9780081025079500040 [Accessed 21 May 2021].

Kinzel, H. and Pietras, B., 2011. The Designing and Building of an All-Purpose Automatic Torque-Wrenching Machine for Drilling Rigs. *IADC/SPE Drilling Conference*,.

Leslie, JC 2008, *Development and Manufacture of Cost-Effective Composite Drill Pipe*, www.osti.gov, viewed 16 April 2021, <https://www.osti.gov/servlets/purl/1034754>.

Liu, Y, Guan, Z, Zhang, H & Zhang, B 2016, 'Development and Application of the Downhole Drilling String Shock-Absorption and Hydraulic Supercharging Device', *Shock and Vibration*, vol. 2016, pp. 1–10, viewed 23 April 2021, <https://downloads.hindawi.com/journals/sv/2016/2041671.pdf>.

Logan, DL 2016, A first course in the finite element method, SI 6th edn, Cengage Learning, Stamford, CT.

Macmillan, R 2019, *Drilling Machines and Equipment*, *dsaroadmap.org*, 31 March, pp. 2–10, viewed 25 March 2021, <http://dsaroadmap.org/wp-content/uploads/2019/06/8-of-14-Drilling-Machines-Equipment-190531.pdf>.

Nordon Cylinders. n.d. *NI Series: Industrial Cylinders*. [online] Available at: <https://www.nordoncyl.com.au/ni-series-industrial-cylinders> [Accessed 28 August 2021].

Nordon Cylinders. n.d. *NI-50 SERIES*. [online] Available at: <https://www.nordoncyl.com.au/sites/default/files/images/NI-50.PDF> [Accessed 16 July 2021].http://www.evolutiondrilling.com/uploads/1/0/3/4/103400562/drill_collar_make_up_torque.pdf

Nordon Cylinders. 2015. *Agricultural & Industrial Hydraulic Cylinder Range 2015*. [online] Available at: <https://www.nordoncyl.com.au/sites/default/files/images/2015%20Catalogue.pdf> [Accessed 24 August 2021].

Obadare Group | Certified Manufacturing, Maintenance and Inspection Specialists - Obadare Group 2021, www.obadare.com.au, viewed 03 March 2021, <https://www.obadare.com.au/>.

Queensland Oil and Gas Benefits 2010, *energyinformationaustralia.com.au*, October, pp. 1–3, viewed 21 March 2021, <https://energyinformationaustralia.com.au>.

Queensland Oil and Gas Benefits 2021, *Energy Information Australia*, March, pp. 1–4, viewed 07 March 2021, <https://energyinformationaustralia.com.au/wp-content/uploads/2021/03/Queensland-Oil-and-Gas-Benefits-Factsheet_Update.pdf>.

Redlinger, TM, Griggs, PS, Odell, A & Bergo, S 2012, *Comprehensive Review of Damages and Repairs on Drill Pipe Connections*, onepetro.org, OnePetro, viewed 15 April 2021, <https://onepetro.org/conference-paper/SPE-151253-MS>.

Ronalds, BF 2006, ‘Features, challenges and opportunities in Australian gas and oil technology’, *Journal of Constructional Steel Research*, vol. 62, no. 11, pp. 1184–1191, viewed 2 June 2020, <https://www.sciencedirect.com/science/article/pii/S0143974X06001404?casa_token=LfhngJkdLgYAAAAA:QMoFLjZfpHnlO_6jJ-_Ye5o0_ZFaJy9CKc8q8Z4Zj_CfO8-dvXaYOoXROmzGPCGpTrgSjDtWIVF7>.

Sinnott, A 2013, ‘Evolution of Tubular Handling Brings Big Safety, Efficiency Gain’, *Journal of Petroleum Technology*, vol. 65, no. 11, pp. 28–31.

Specification for Quality Management System Requirements for Manufacturing Organisations for the Petroleum and Natural Gas Industry 2015, Q1, API, Sydney.

Stall, JC & Blenkarn, KA 1962, *Calculated Allowable Hook Load and Torque Combinations for Stuck Drill Strings*, onepetro.org, OnePetro, viewed 15 April 2021, <https://onepetro.org/APIDPP/proceedings-abstract/API62/All-API62/API-62-038/51337>.

Strmčnik, E. and Majdič, F., 2019. Analytical, numerical and experimental approaches to improving the performance indices of an orbital hydraulic motor. *Positive Displacement Machines*, [online] pp.399-422. Available at: https://www.sciencedirect.com/science/article/pii/B9780128169988000145 [Accessed 21 May 2021].

Timperley, J., 2019. *The Carbon Brief Profile: Australia*. [online] Carbon Brief. Available at: <https://www.carbonbrief.org/the-carbon-brief-profile-australia> [Accessed 10 March 2021].

Toutounchian, S, Abbaspour, M, Dana, T & Abedi, Z 2018, ‘Design of a safety cost estimation parametric model in oil and gas engineering, procurement and construction contracts’, *Safety Science*, vol. 106, pp. 35–46.

Van Leeuwen. n.d. *Seamless and Welded Pipes and Tubes Catalogue*. [online] Available at: <https://www.vanleeuwen.com/en/products/round-tubes/> [Accessed 9 August 2021].

Wedel, J & Lumsden, K 1995, ‘The influence of lead-time reductions on decisions and rules in the production planning process’, *International Journal of Production Economics*, vol. 41, no. 1-3, pp. 399–404, viewed 1 March 2020, <https://reader.elsevier.com/reader/sd/pii/0925527395000399?token=7A757B283E6E131654675DCBCBAD0114E8351BD7FFBCF452DE436F6BEB3AC93B1C4492CDD4B6FE5C32B4CC27D082D2D7&originRegion=us-east-1&originCreation=20210424085308>.

Weiyong, Q 1999, *Effect of Drill Pipe/Coiled Tubing Initial Configuration on Contact Force*, onepetro.org, OnePetro, viewed 25 April 2021, <https://onepetro.org/SPEOKOG/proceedings-abstract/99MCOS/All-99MCOS/SPE-52189-MS/60512>.

What are drilling rigs used for? - Drilling Rigs | Excavator Hire - DrillPower QLD 2021, www.drillpowerqld.com.au, viewed 19 March 2021, <http://www.drillpowerqld.com.au/What-are-drilling-rigs-used-for-bgp3687.html>.

Zamani, SM, Hassanzadeh-Tabrizi, SA & Sharifi, H 2016, 'Failure analysis of drill pipe: A review', *Engineering Failure Analysis*, vol. 59, pp. 605–623, viewed 2 February 2021, <https://www.sciencedirect.com/science/article/pii/S1350630715301138?casa_token=ZixVbex1mvEAAAAA:E_ZqjDt0GkzmeuSQAD3-ufL0IO73COit_xXBOcUyI9OcI7NWsH6Cdb2MzbZGhtl785pd8460pwc_>.

Zhang, P 2010, *Chapter 3 - Sensors and actuators*, in P Zhang (ed.), ScienceDirect, William Andrew Publishing, Oxford, pp. 73–116, viewed 21 April 2021, <https://www.sciencedirect.com/science/article/pii/B9781437778076100038>.

Appendix A – Project Specification

ENG4111/4112 Research Project

Project Specification

For: Jackson Gould

Title: Bucking Units – A More Effective Approach

Major: Mechanical

Supervisors: Steven Goh

Enrollment: ENG4111 – EXT S1, 2021

ENG4112 – EXT S2, 2021

Project Aim: This project aims to review the current design of the bucking unit, used to makeup and breakout threads on drill pipe, casing and tubing. This dissertation will investigate the processes below and review which can be expanded upon and changed to make the conceptualization of bucking units more effective:

- Current design and discuss which areas can be improved upon
- API 4F standards (5 ed.) ensuring all changes are appropriate and meet requirements per this standard
- Material choices and procurement methods
- Design changes that do not affect implementation or usability
- Review training required for operators and users

Programme: Version 1, 17th March 2021

Objectives/Method: The method of the thesis proposal are listed below:

1. Review the current design of the bucking unit commonly used and investigate in which areas the design can be improved upon.
2. Review company (Obadare Group) guidelines ensuring the design meets all API 4F standards and requirements per the latest edition.
3. Conduct initial background research into the bucking unit utility processes and design process to identify which areas are critical.
4. Investigate and review supply chain options to determine the most effective method of material procurement.
5. Discuss material choices in comparison to current selections to determine whether the design can be optimised more effectively.
6. Closely review the design of the bucking unit and see which areas are possibly over-engineered or can change drastically for a more effective use of the bucking unit, with investigations into more versatile and portable options.

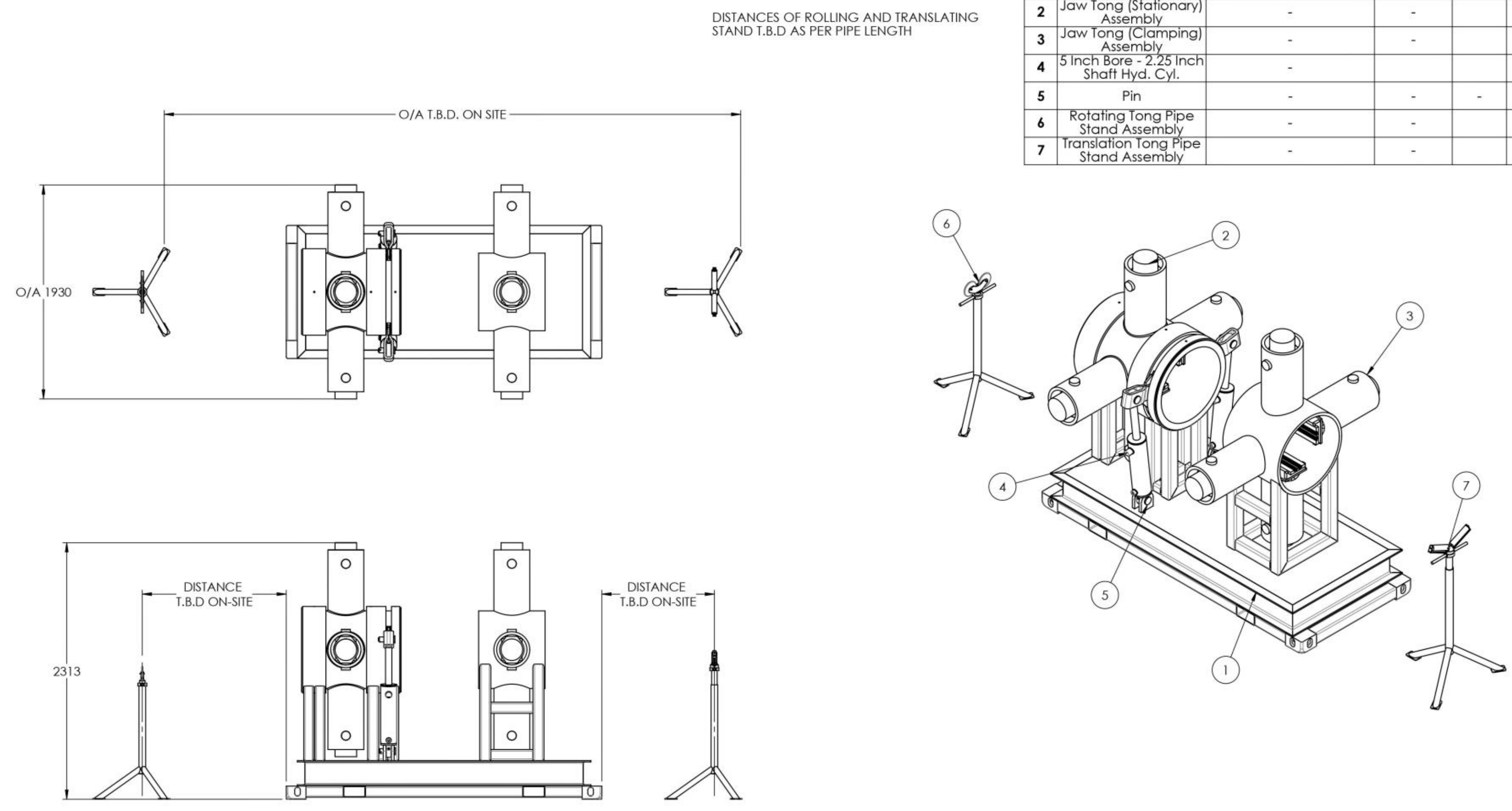
7. Outline in detail the requirements of the bucking unit and where the design can be changed without major impact to current implementation.
8. Begin design alterations and changes to manufacturing processes (if any).
9. Run FEA and other required simulations to determine if the achieved design is viable and effective as a proposed solution.
10. Consider training required for new upgrades (if any).
11. Identify and discuss outcomes and compile into a report that is clear, concise and detailed, bale to be understood by academics and others that are not technically minded nor in the field.

If time and resources permit:

12. Use Obadare resources to create prototypes of certain elements of the design intended on being changed to test realistically how these elements interact and affect productivity along with effectiveness of the overall design.
13. Discuss with operators within the field as to their concerns with the current and future designs and how to ensure a safe design for the users.

Appendix B –Assembly Drawings

ITEM	PART # / REF.	DESCRIPTION	MATERIAL / GRADE	LENGTH	QTY
1	Base Frame	-	-	-	1
2	Jaw Tong (Stationary) Assembly	-	-		1
3	Jaw Tong (Clamping) Assembly	-	-		1
4	5 Inch Bore - 2.25 Inch Shaft Hyd. Cyl.	-			2
5	Pin	-	-	-	4
6	Rotating Tong Pipe Stand Assembly	-	-		1
7	Translation Tong Pipe Stand Assembly	-	-		1



APPROX. MASS: 1750.0kg | JOB No.: - | WELD STANDARDS: - | FINISH: -

TOLERANCES UNLESS OTHERWISE SPECIFIED
FABRICATION: DIM. +/- 2; ANGULAR +/- 1°; HOLE CTRS. +/- 0.5
MACHINING: DIM. +/- 0.05; ANGULAR +/- 0.05°; FINISH 6.4 µm
BLAST GRADE MIN. SA2.5
PRIMER COAT 60 - 175µm DFT
TOP COAT 60 - 75µm DFT

REMOVE ALL SHARP EDGES AND DEBUR ALL HOLES UNLESS OTHERWISE SPECIFIED
ALL DIMENSIONS IN mm UNLESS OTHERWISE SPECIFIED
MATERIAL CERTIFICATION IS REQUIRED FOR ALL COMPONENTS
ALL WELDS TO COMPLY WITH AS1554.1 CATEGORY G.P. U.N.O.
C.F.W. LEG LENGTH AND C.B.W. THROAT THICKNESS TO BE EQUAL TO THE THINNEST SECTION BEING JOINED U.N.O.

DRAWN BY:	CHECKED BY:	APPROVED BY:
JG		
DWN DATE: 10/09/21	CHKD DATE:	APPD DATE:

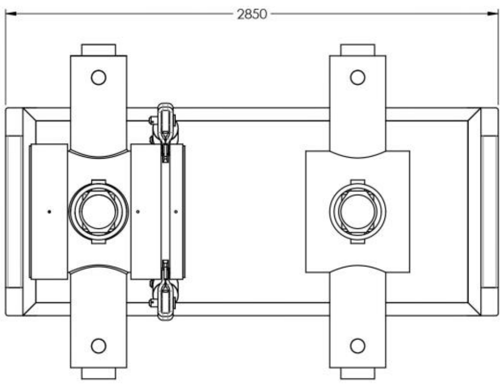
TITLE: -

SCALE: 1:50
DO NOT SCALE
SHEET 1 OF 3

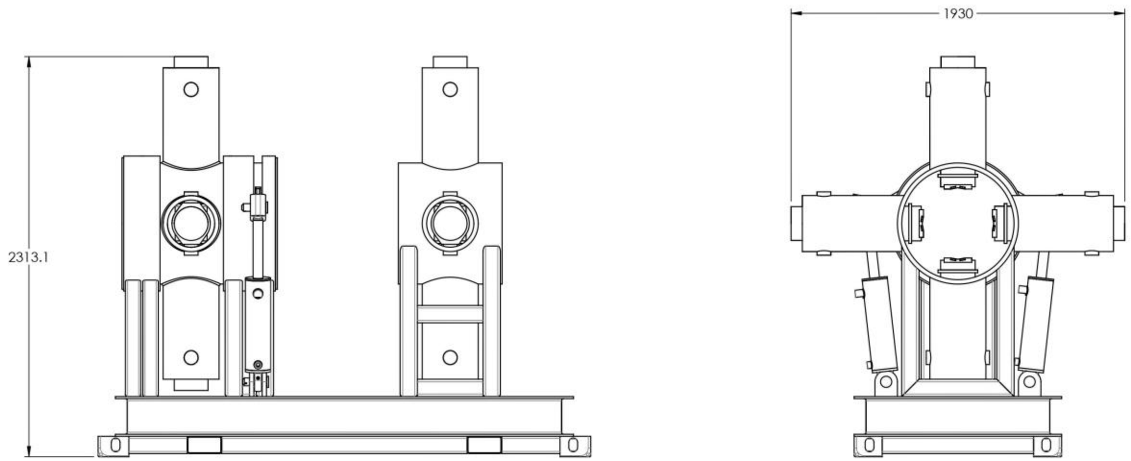
DWG No.: **Bucking Unit**

SIZE: A3
REV. P0

REV.	DESCRIPTION	DATE	REVISED BY	APPROVEDBY
	REVISION			



STANDS MUST BE SECURED BY MEANS BEST SUITED
PER COMPANY DURING TRANSPORTATION



TRANSPORT

APPROX. MASS: 1750.0kg	JOB No.: -	WELD STANDARDS: -	FINISH: -

TOLERANCES UNLESS OTHERWISE SPECIFIED

FABRICATION		MACHINING	
DIM.	+/- 2	DIM.	+/- 0.05
ANGULAR	+/- 1°	ANGULAR	+/- 0.05°
HOLE CTRS.	+/- 0.5	FINISH	6.4 μm

BLAST GRADE MIN. SA2.5
PRIMER COAT 60 - 175μm DFT
TOP COAT 60 - 75μm DFT

REMOVE ALL SHARP EDGES AND DEBUR ALL HOLES UNLESS OTHERWISE SPECIFIED
ALL DIMENSIONS IN mm UNLESS OTHERWISE SPECIFIED
MATERIAL CERTIFICATION IS REQUIRED FOR ALL COMPONENTS
ALL WELDS TO COMPLY WITH AS1554.1 CATEGORY G.P. U.N.O.
C.F.W. LEG LENGTH AND C.B.W. THROAT THICKNESS TO BE EQUAL TO THE THINNEST SECTION BEING JOINED U.N.O.

DRAWN BY: JG	CHECKED BY:	APPROVED BY:
DWN DATE: 10/09/21	CHKD DATE:	APPD DATE:

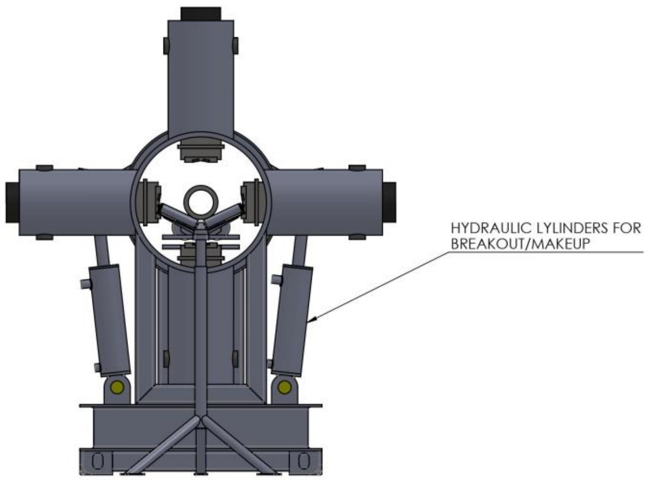
TITLE: -

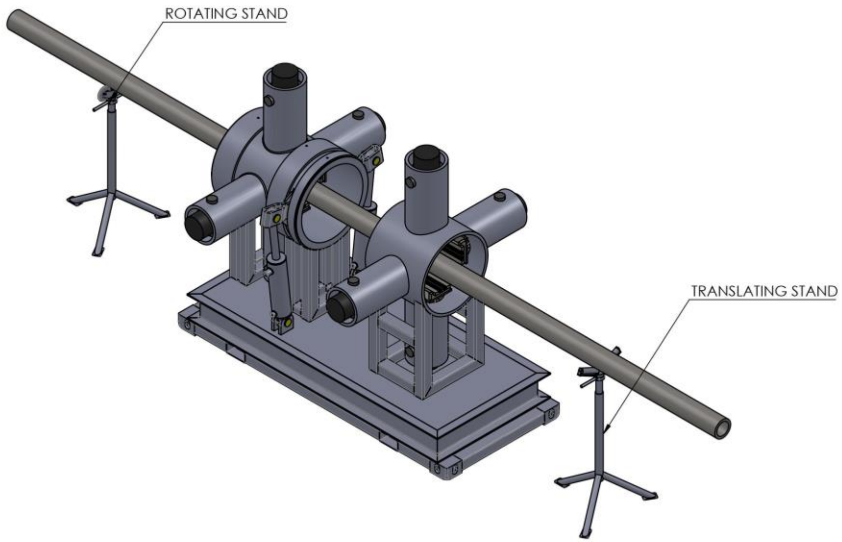
SCALE: 1:50
DO NOT SCALE
SHEET 2 OF 3

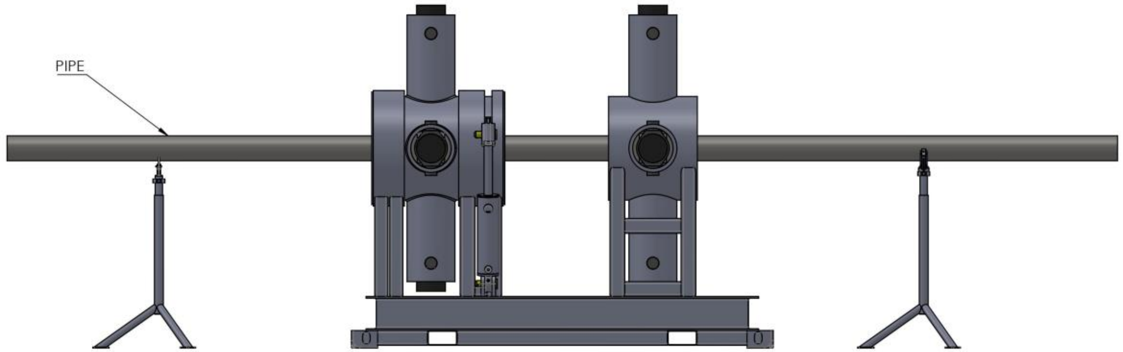
DWG No.: **Bucking Unit**

SIZE: A3

REV. P0







OPERATION

APPROX. MASS: 1750.0kg | JOB No.: - | WELD STANDARDS: - | FINISH: -

TOLERANCES UNLESS OTHERWISE SPECIFIED
FABRICATION — DIM. +/- 2; ANGULAR +/- 1'; HOLE CTRS. +/- 0.5
MACHINING — DIM. +/- 0.05; ANGULAR +/- 0.05'; FINISH 6.4 µm
BLAST GRADE MIN. SA2.5
PRIMER COAT 60 - 175µm DFT
TOP COAT 60 - 75µm DFT

REMOVE ALL SHARP EDGES AND DEBUR ALL HOLES UNLESS OTHERWISE SPECIFIED
ALL DIMENSIONS IN mm UNLESS OTHERWISE SPECIFIED
MATERIAL CERTIFICATION IS REQUIRED FOR ALL COMPONENTS
ALL WELDS TO COMPLY WITH AS1554.1 CATEGORY G.P. U.N.O.
C.F.W. LEG LENGTH AND C.B.W. THROAT THICKNESS TO BE EQUAL TO THE THINNEST SECTION BEING JOINED U.N.O.

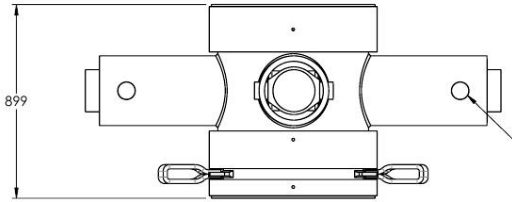
DRAWN BY: JG | CHECKED BY: | APPROVED BY:
DWN DATE: 10/09/21 | CHKD DATE: | APPD DATE:

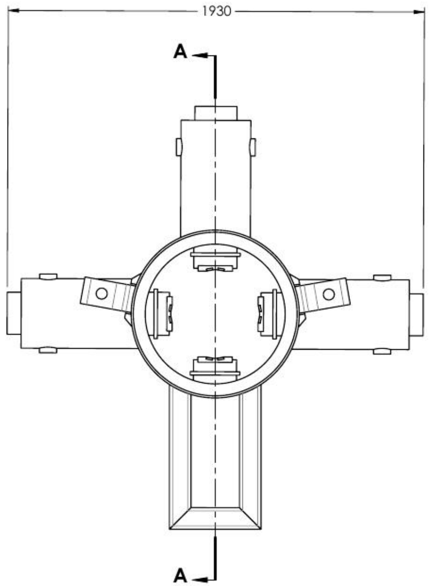
TITLE: -

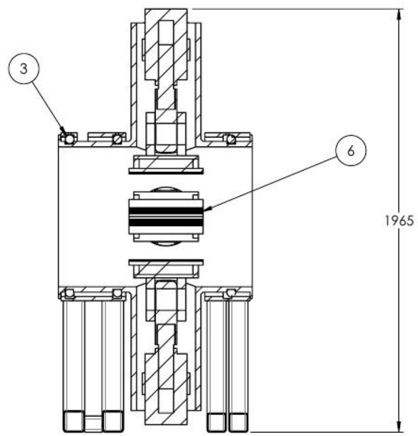
SCALE: 1:50
DO NOT SCALE
SHEET 3 OF 3

DWG No.: Bucking Unit
SIZE: A3
REV. P0

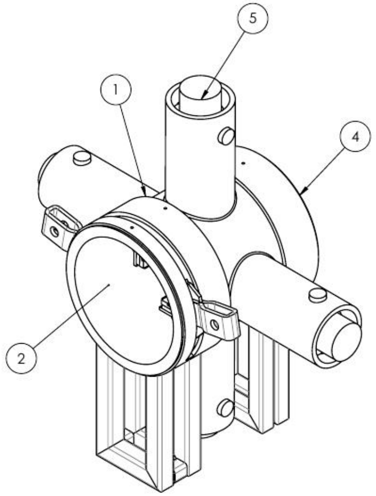
ITEM	PART # / REF.	DESCRIPTION	MATERIAL / GRADE	LENGTH	QTY
1	Jaw Tong (Stationary)	-	-	-	1
2	Jaw Tong (Stationary) Inner	-	-	-	1
3	Ball Bearing Ball	-	-	-	45
4	Jaw Tong (Stationary) Support	-	-	-	1
5	Berendsen Heavy Duty Cylinder	-	-		4
6	Tong Die	-	-	-	8







SECTION A-A



REV.	DESCRIPTION	DATE	REVISED BY	APPROVEDBY
	REVISION			

APPROX. MASS: 353.2kg
JOB No.: -
WELD STANDARDS: -
FINISH: -

TOLERANCES UNLESS OTHERWISE SPECIFIED
FABRICATION — DIM. +/- 2; ANGULAR +/- 1°; HOLE CTRS. +/- 0.5
MACHINING — DIM. +/- 0.05; ANGULAR +/- 0.05°; FINISH 6.4 μm
BLAST GRADE MIN. SA2.5
PRIMER COAT 60 - 175μm DFT
TOP COAT 60 - 75μm DFT

REMOVE ALL SHARP EDGES AND DEBUR ALL HOLES UNLESS OTHERWISE SPECIFIED
ALL DIMENSIONS IN mm UNLESS OTHERWISE SPECIFIED
MATERIAL CERTIFICATION IS REQUIRED FOR ALL COMPONENTS
ALL WELDS TO COMPLY WITH AS1554.1 CATEGORY G.P. U.N.O.
C.F.W. LEG LENGTH AND C.B.W. THROAT THICKNESS TO BE EQUAL TO THE THINNEST SECTION BEING JOINED U.N.O.

DRAWN BY: JG
DWN DATE: 10/09/21
CHECKED BY:
CHKD DATE:
APPROVED BY:
APPD DATE:

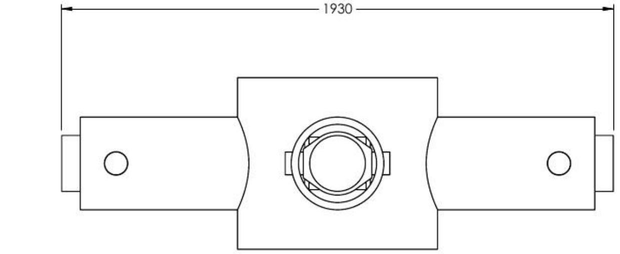
SCALE: 1:20
DO NOT SCALE
SHEET 1 OF 1

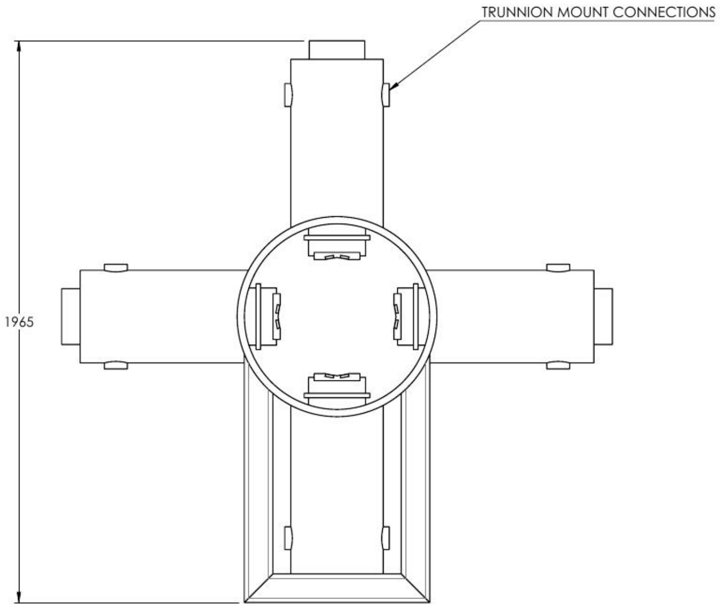
TITLE: -

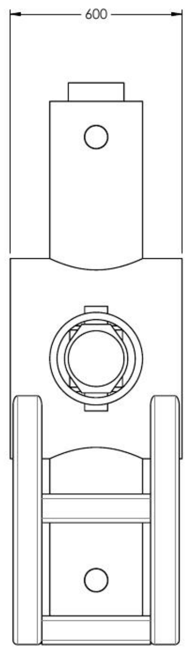
DWG No.: **Jaw Tong (Stationary) Assembly**

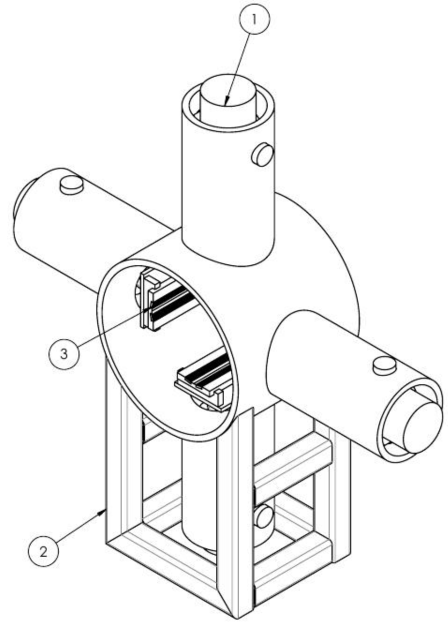
SIZE: A3
REV. P0

ITEM	PART # / REF.	DESCRIPTION	MATERIAL / GRADE	LENGTH	QTY
1	Berendsen Heavy Duty Cylinder	-	-		4
2	Jaw Tong (Clamping)	-	-	-	1
3	Tong Die	-	-	-	8









REV.	DESCRIPTION	DATE	REVISED BY	APPROVEDBY

REVISION

APPROX. MASS: 314.6kg

JOB No.: -

WELD STANDARDS: -

FINISH: -

TOLERANCES UNLESS OTHERWISE SPECIFIED

FABRICATION		MACHINING	
DIM.	+/- 2	DIM.	+/- 0.05
ANGULAR	+/- 1°	ANGULAR	+/- 0.05°
HOLE CTRS.	+/- 0.5	FINISH	6.4 μm

BLAST GRADE MIN. SA2.5
PRIMER COAT 60 - 175μm DFT
TOP COAT 60 - 75μm DFT

REMOVE ALL SHARP EDGES AND DEBUR ALL HOLES UNLESS OTHERWISE SPECIFIED
ALL DIMENSIONS IN mm UNLESS OTHERWISE SPECIFIED
MATERIAL CERTIFICATION IS REQUIRED FOR ALL COMPONENTS
ALL WELDS TO COMPLY WITH AS1554.1 CATEGORY G.P. U.N.O.
C.F.W. LEG LENGTH AND C.B.W. THROAT THICKNESS TO BE EQUAL TO THE THINNEST SECTION BEING JOINED U.N.O.

DRAWN BY:	CHECKED BY:	APPROVED BY:
DWN DATE:	CHKD DATE:	APPD DATE:

TITLE: -

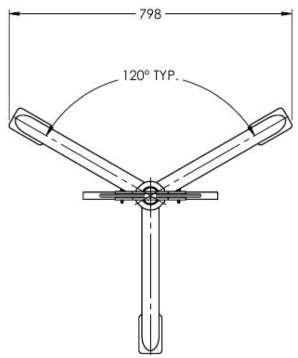
SCALE: 1:20
DO NOT SCALE

SHEET 1 OF 1

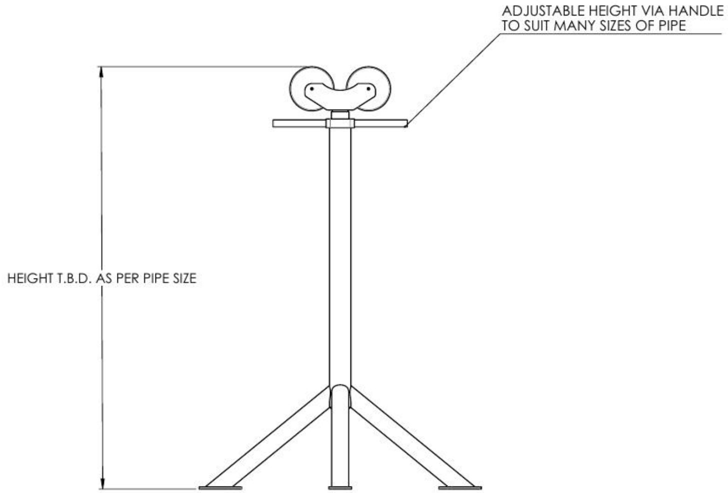
DWG No.: **Jaw Tong (Clamping) Assembly**

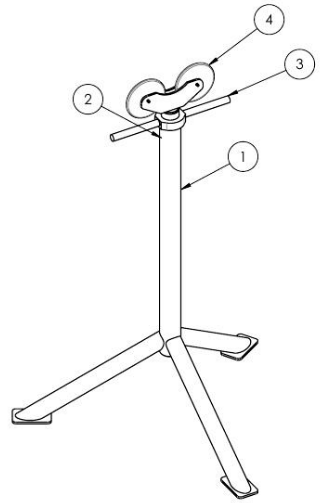
SIZE: A3

REV.



ITEM	PART # / REF.	DESCRIPTION	MATERIAL / GRADE	LENGTH	QTY
1	Rotating Tong Pipe Stand	-	-	-	1
2	Rotating Tong Pipe Stand Insert	-	-	-	1
3	Rotating Tong Pipe Handle	-	-	-	1
4	Rotating Pipe Roller	-	-		1





APPROX. MASS: 2.3kg | JOB No.: - | WELD STANDARDS: - | FINISH: -

TOLERANCES UNLESS OTHERWISE SPECIFIED
FABRICATION
DIM. +/- 2
ANGULAR +/- 1°
HOLE CTRS. +/- 0.5
MACHINING
DIM. +/- 0.05
ANGULAR +/- 0.05°
FINISH 6.4 μm
BLAST GRADE MIN. SA2.5
PRIMER COAT 60 - 175μm DFT
TOP COAT 60 - 75μm DFT

REMOVE ALL SHARP EDGES AND DEBUR ALL HOLES UNLESS OTHERWISE SPECIFIED
ALL DIMENSIONS IN mm UNLESS OTHERWISE SPECIFIED
MATERIAL CERTIFICATION IS REQUIRED FOR ALL COMPONENTS
ALL WELDS TO COMPLY WITH AS1554.1 CATEGORY G.P. U.N.O.
C.F.W. LEG LENGTH AND C.B.W. THROAT THICKNESS TO BE EQUAL TO THE THINNEST SECTION BEING JOINED U.N.O.

DRAWN BY:	CHECKED BY:	APPROVED BY:
DWN DATE:	CHKD DATE:	APPD DATE:

TITLE: -

SCALE: 1:20
DO NOT SCALE
SHEET 1 OF 1

DWG: **Rotating Tong Pipe Stand Assembly**

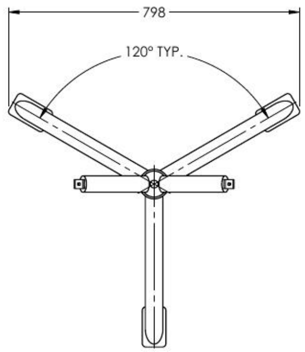
SIZE: A3

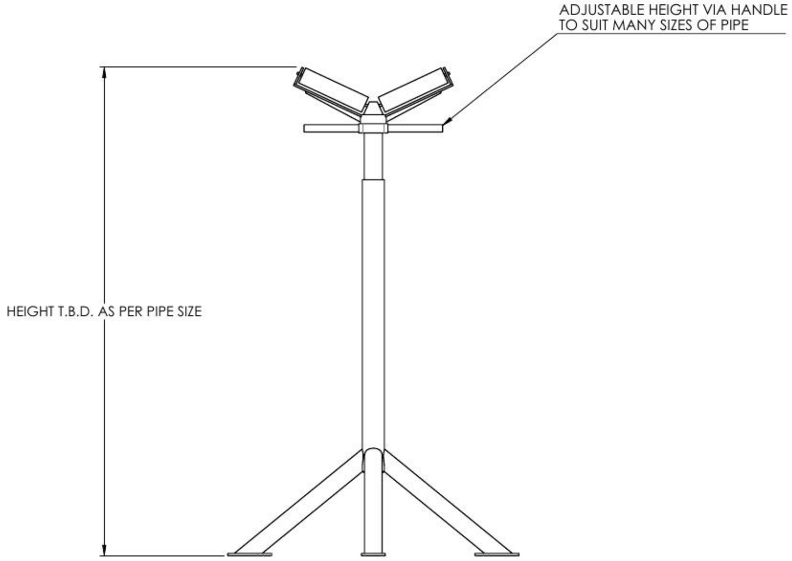
REV.

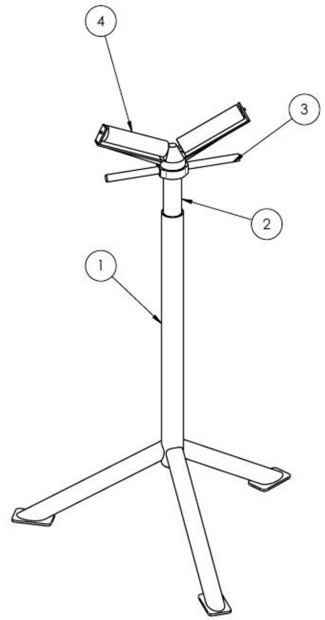
REV.	DESCRIPTION	DATE	REVISED BY	APPROVEDBY

REVISION

ITEM	PART # / REF.	DESCRIPTION	MATERIAL / GRADE	LENGTH	QTY
1	Rotating Tong Pipe Stand	-	-	-	1
2	Rotating Tong Pipe Stand Insert	-	-	-	1
3	Rotating Tong Pipe Handle	-	-	-	1
4	Rotating Pipe Slider	-	-		1







APPROX. MASS: 2.8kg

JOB No.: -

WELD STANDARDS: -

FINISH: -

TOLERANCES UNLESS OTHERWISE SPECIFIED

FABRICATION		MACHINING	
DIM.	+/- 2	DIM.	+/- 0.05
ANGULAR	+/- 1°	ANGULAR	+/- 0.05°
HOLE CTRS.	+/- 0.5	FINISH	6.4 μm

BLAST GRADE MIN. SA2.5
PRIMER COAT 60 - 175μm DFT
TOP COAT 60 - 75μm DFT

REMOVE ALL SHARP EDGES AND DEBUR ALL HOLES UNLESS OTHERWISE SPECIFIED
ALL DIMENSIONS IN mm UNLESS OTHERWISE SPECIFIED
MATERIAL CERTIFICATION IS REQUIRED FOR ALL COMPONENTS
ALL WELDS TO COMPLY WITH AS1554.1 CATEGORY G.P. U.N.O.
C.F.W. LEG LENGTH AND C.B.W. THROAT THICKNESS TO BE EQUAL TO THE THINNEST SECTION BEING JOINED U.N.O.

DRAWN BY: | CHECKED BY: | APPROVED BY:
DWN DATE: | CHKD DATE: | APPD DATE:

TITLE: -

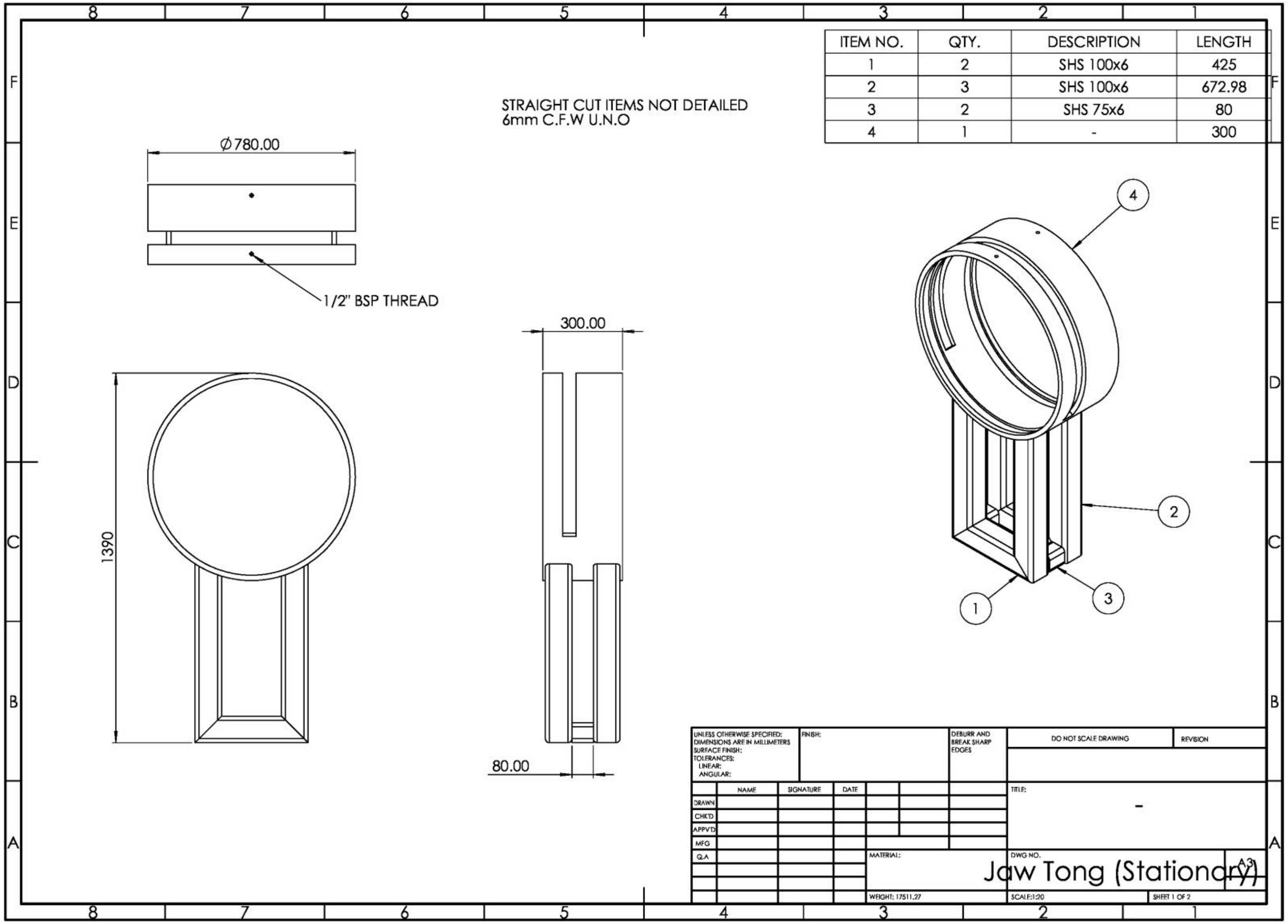
SCALE: 1:20
DO NOT SCALE
SHEET 1 OF 2

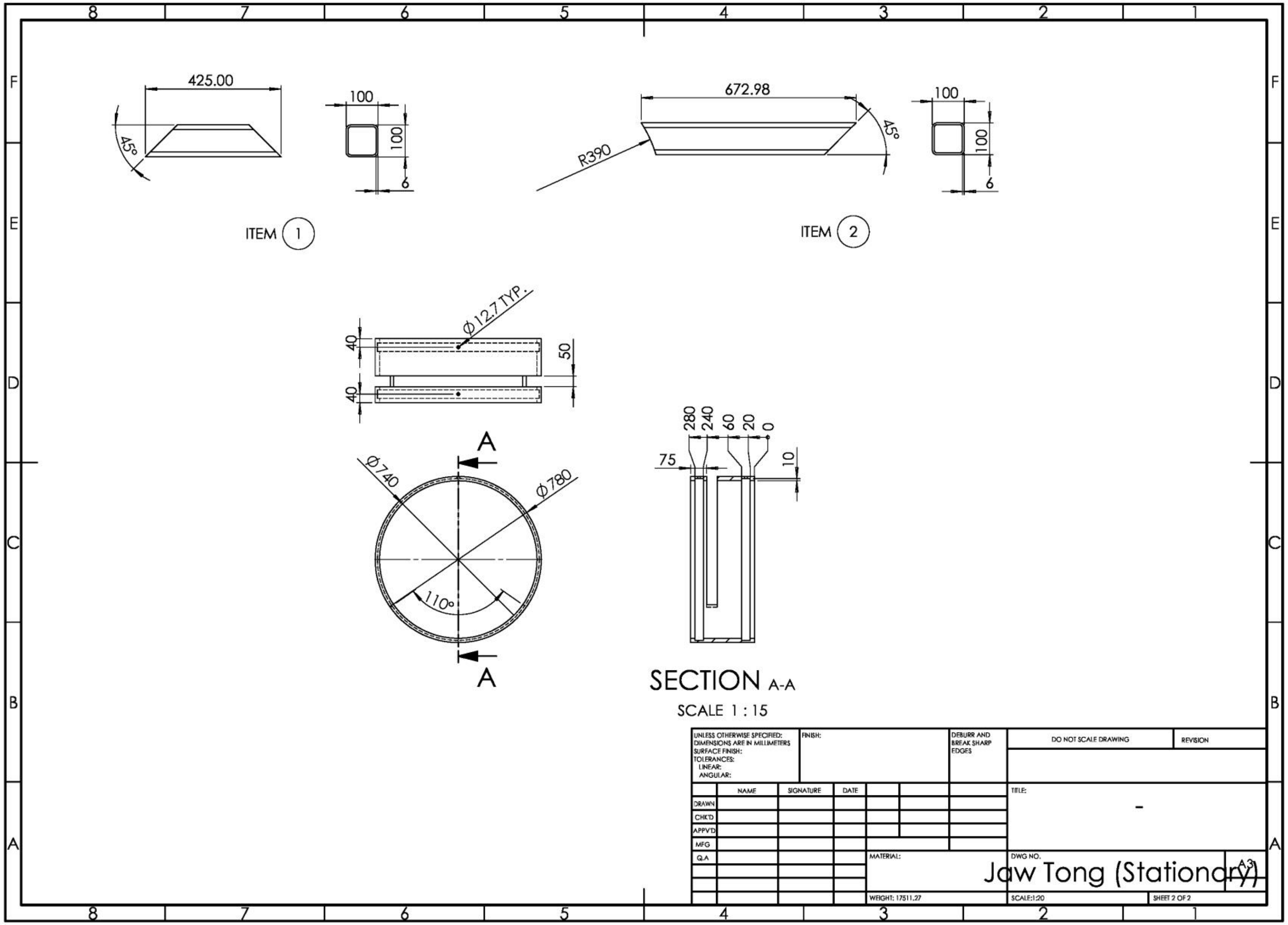
Translation Tong Pipe Stand Assembly

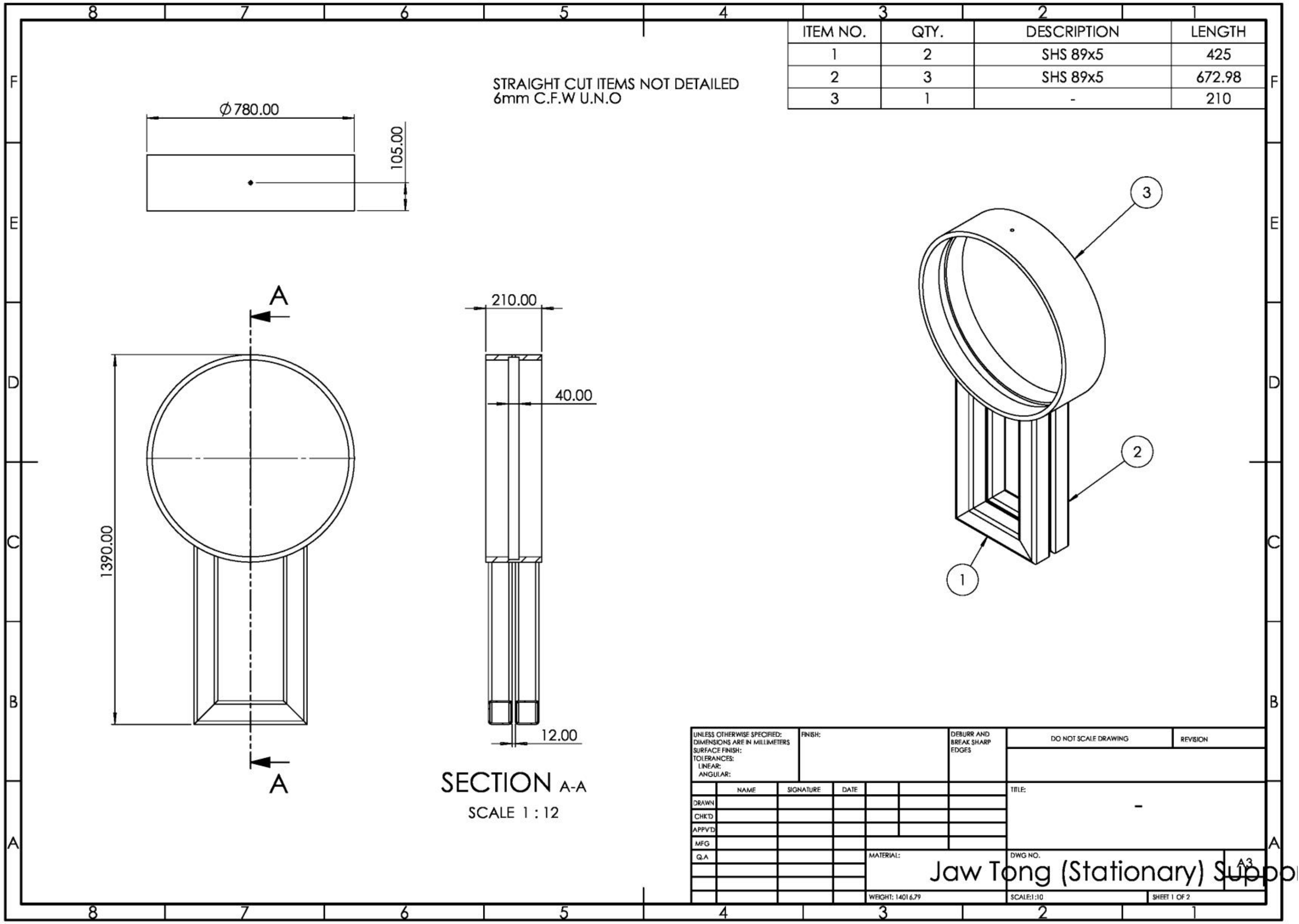
SIZE: A3
REV.

REV.	DESCRIPTION	DATE	REVISED BY	APPROVEDBY
	REVISION			

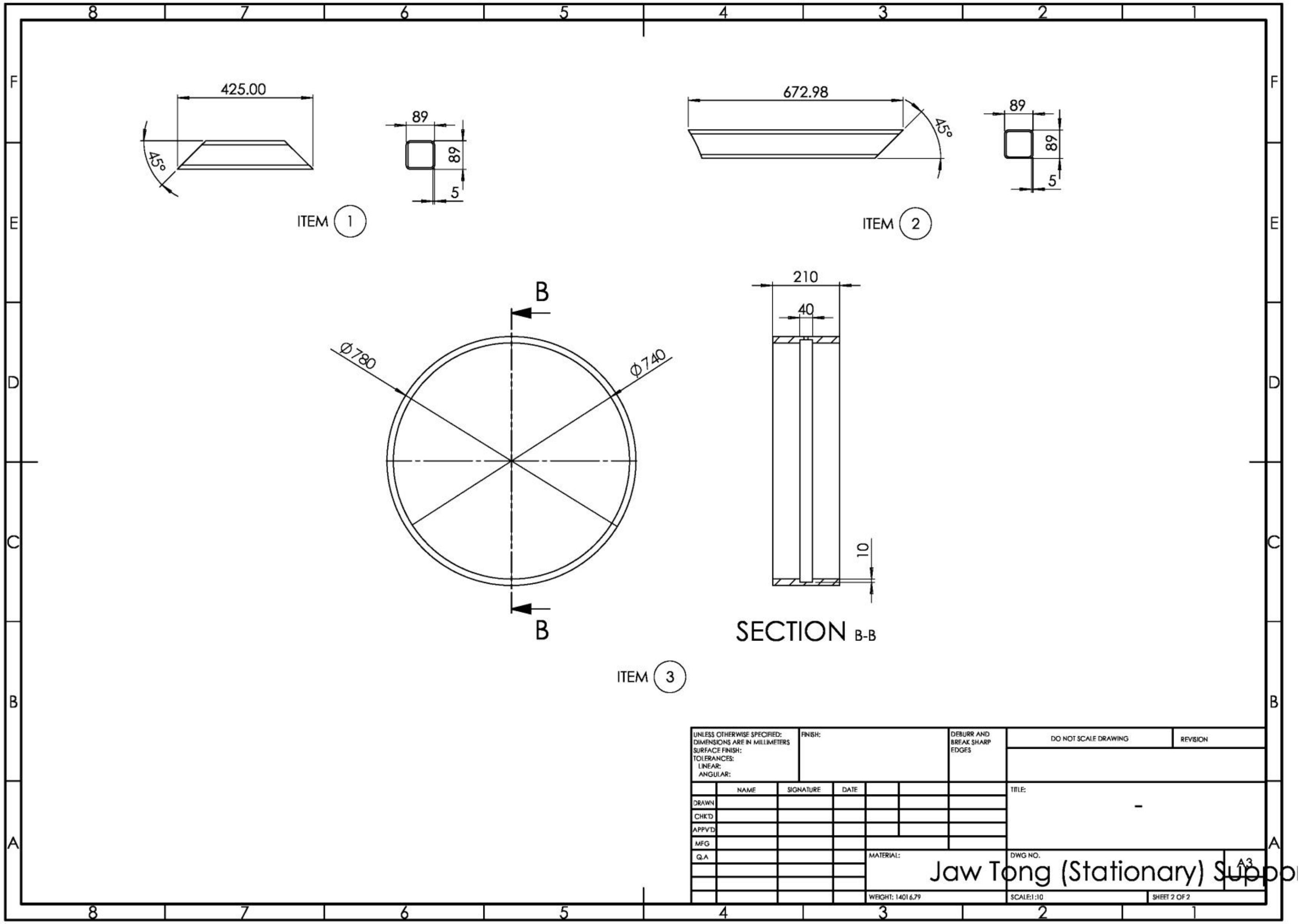
Appendix C – Technical Drawings




425.00
100
45°
6
ITEM 1
672.98
R390
ITEM 2
Ø12.7 TYP.
40
50
Ø740
Ø780
110°
A
280 240 60 20 0
75
10
SECTION A-A
SCALE 1 : 15
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.
Jaw Tong (Stationary)
A3
WEIGHT: 17511.27
SCALE:1:20
SHEET 2 OF 2

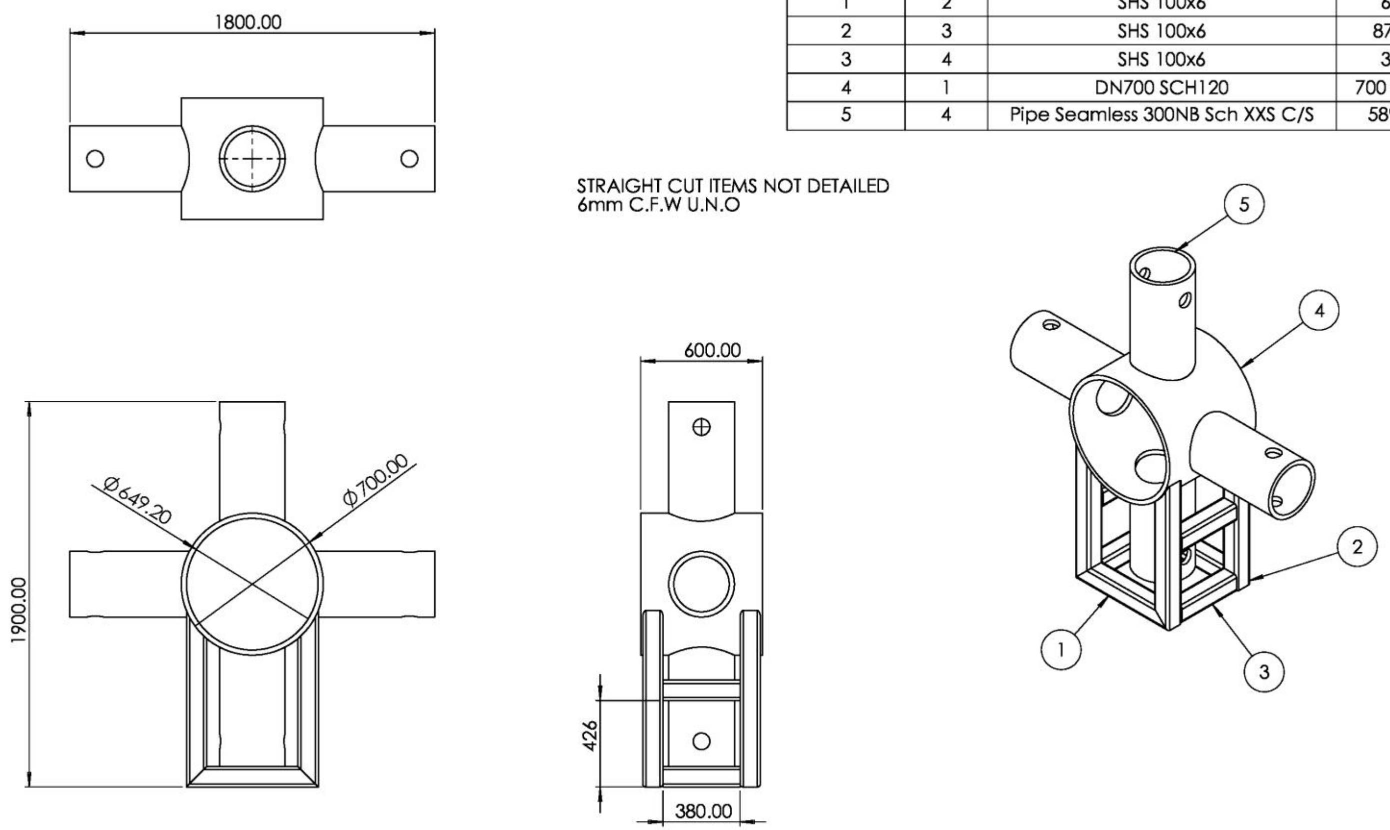


ITEM NO.	QTY.	DESCRIPTION	LENGTH
1	2	SHS 89x5	425
2	3	SHS 89x5	672.98
3	1	-	210


425.00
45°
89
89
5
ITEM 1
672.98
45°
89
89
5
ITEM 2
B
Ø780
Ø740
B
210
40
10
SECTION B-B
ITEM 3
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.
Jaw Tong (Stationary) Suppo
A3
WEIGHT: 14016.79
SCALE:1:10
SHEET 2 OF 2

ITEM NO.	QTY.	DESCRIPTION	LENGTH
1	2	SHS 100x6	650
2	3	SHS 100x6	870.1
3	4	SHS 100x6	380
4	1	DN700 SCH120	700 x 700
5	4	Pipe Seamless 300NB Sch XXS C/S	589.72

STRAIGHT CUT ITEMS NOT DETAILED
6mm C.F.W U.N.O



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.

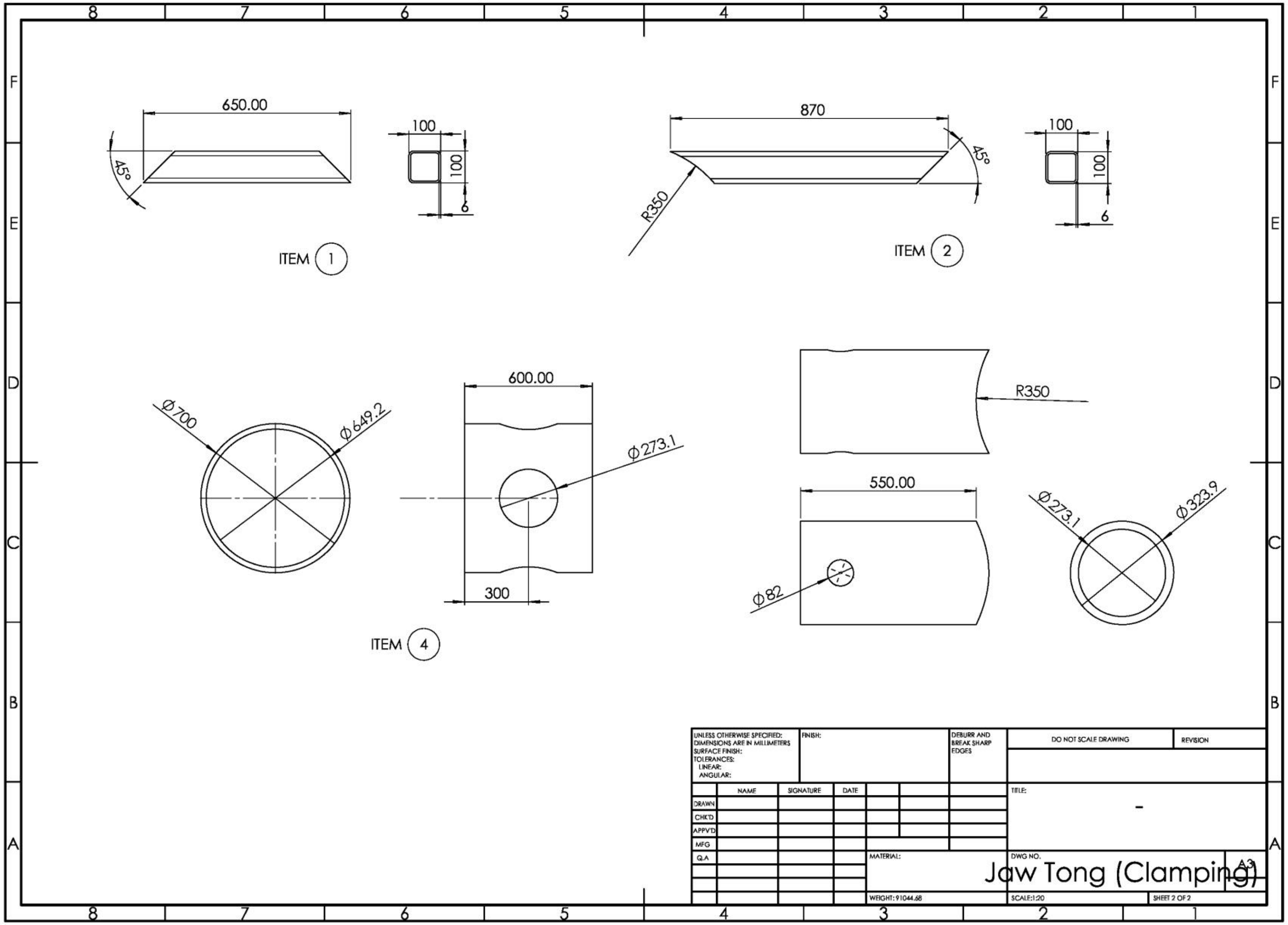
Jaw Tong (Clamping)

A3

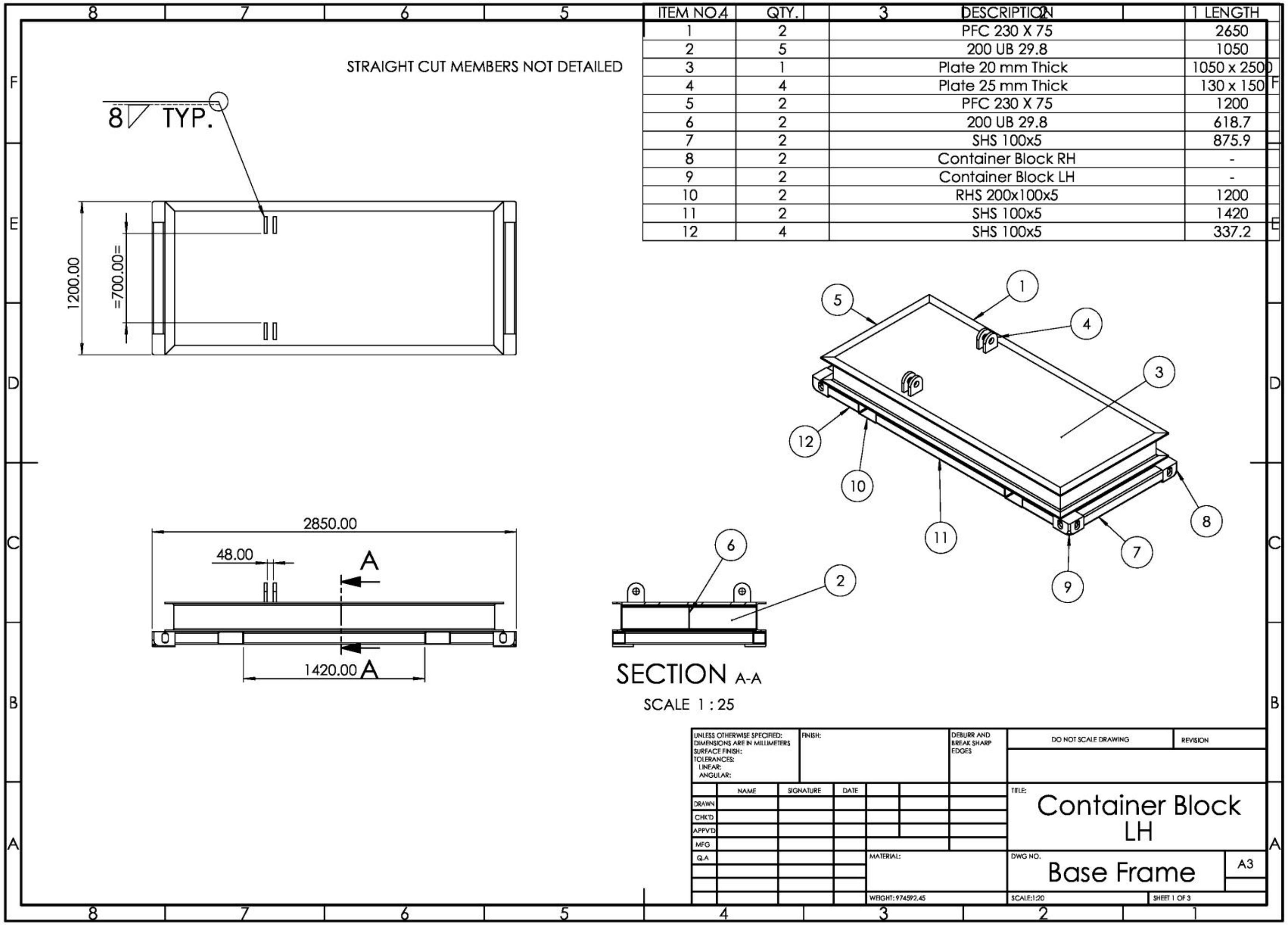
WEIGHT: 91044.68

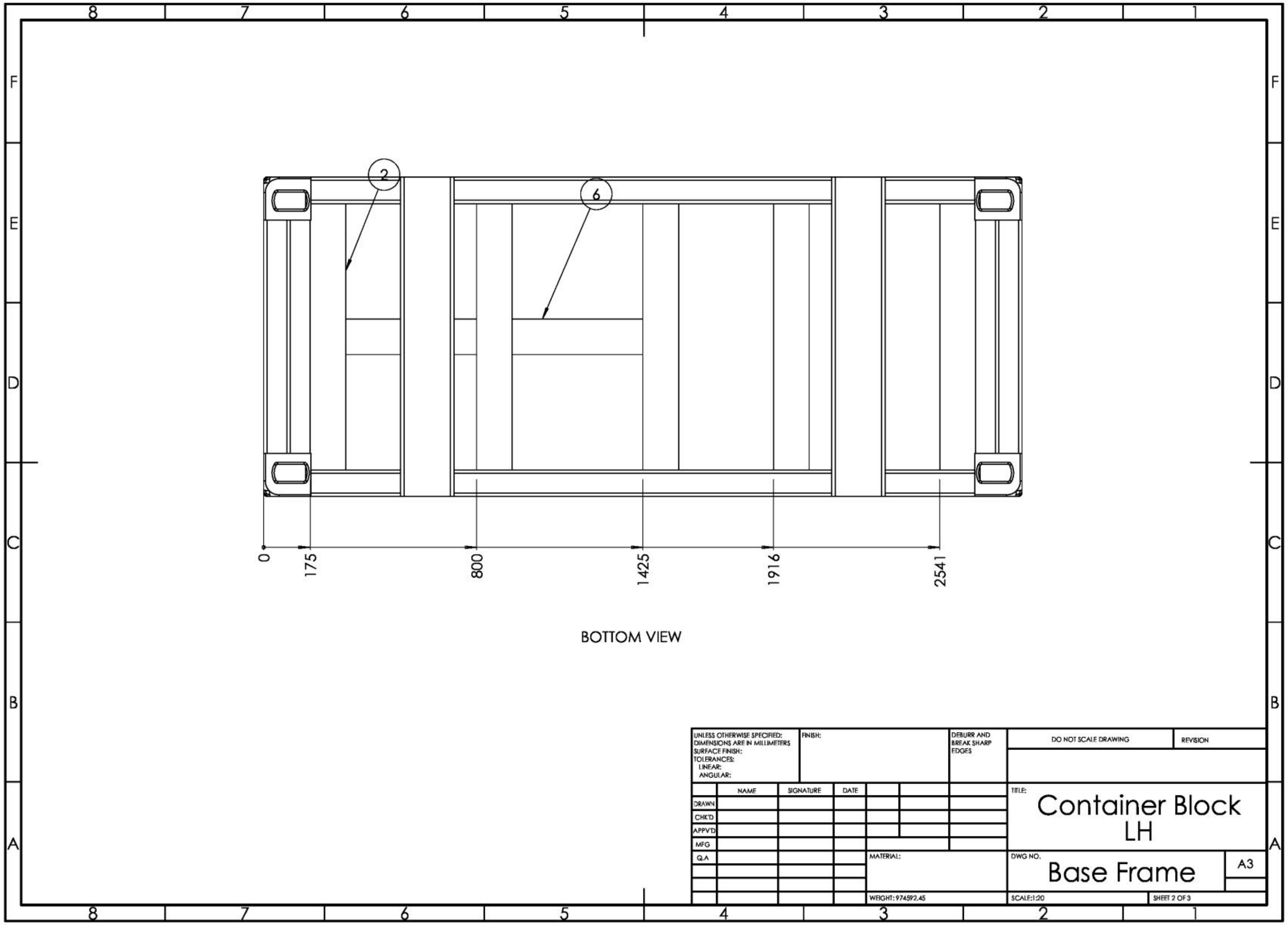
SCALE:1:20

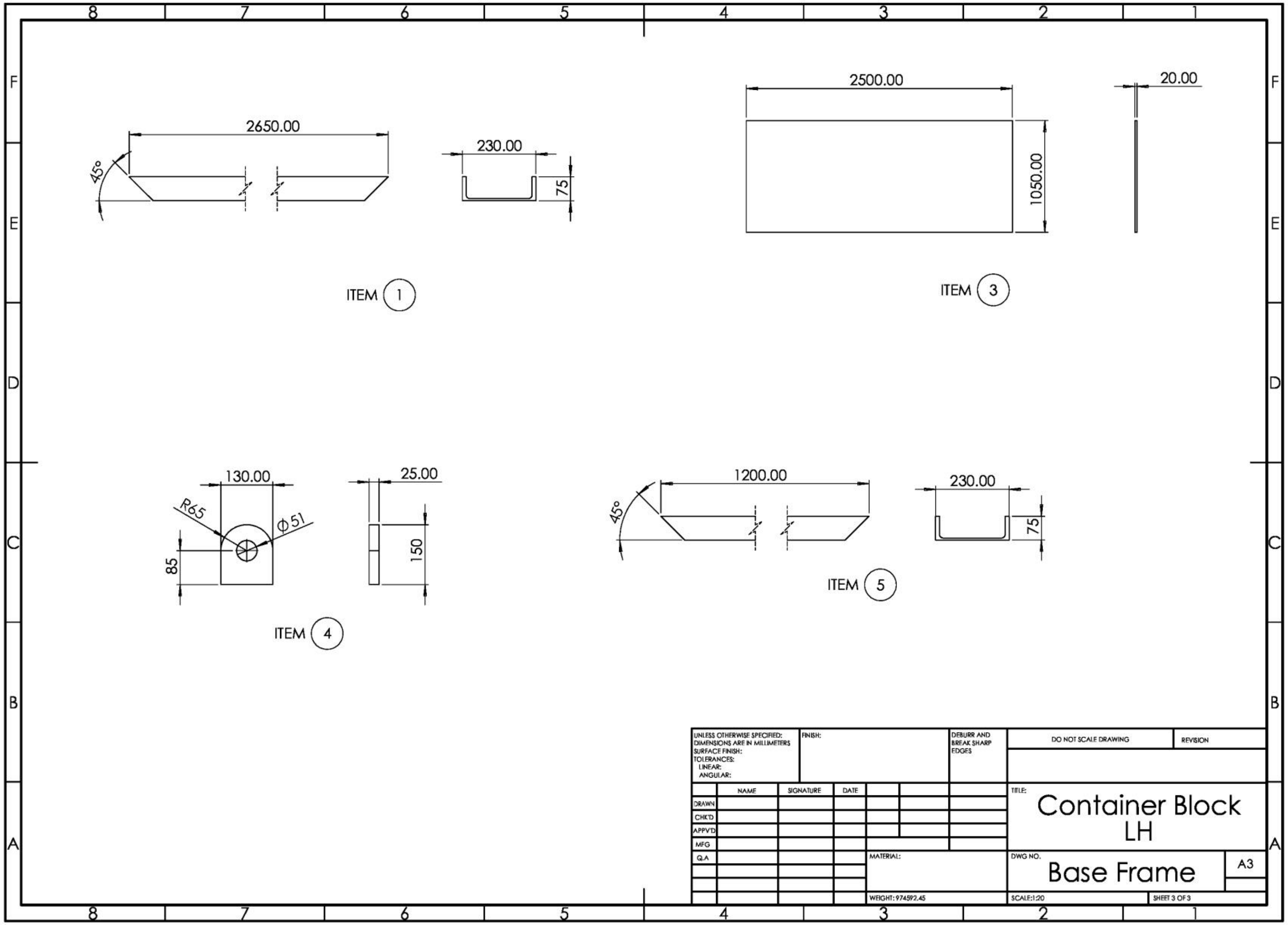
SHEET 1 OF 2

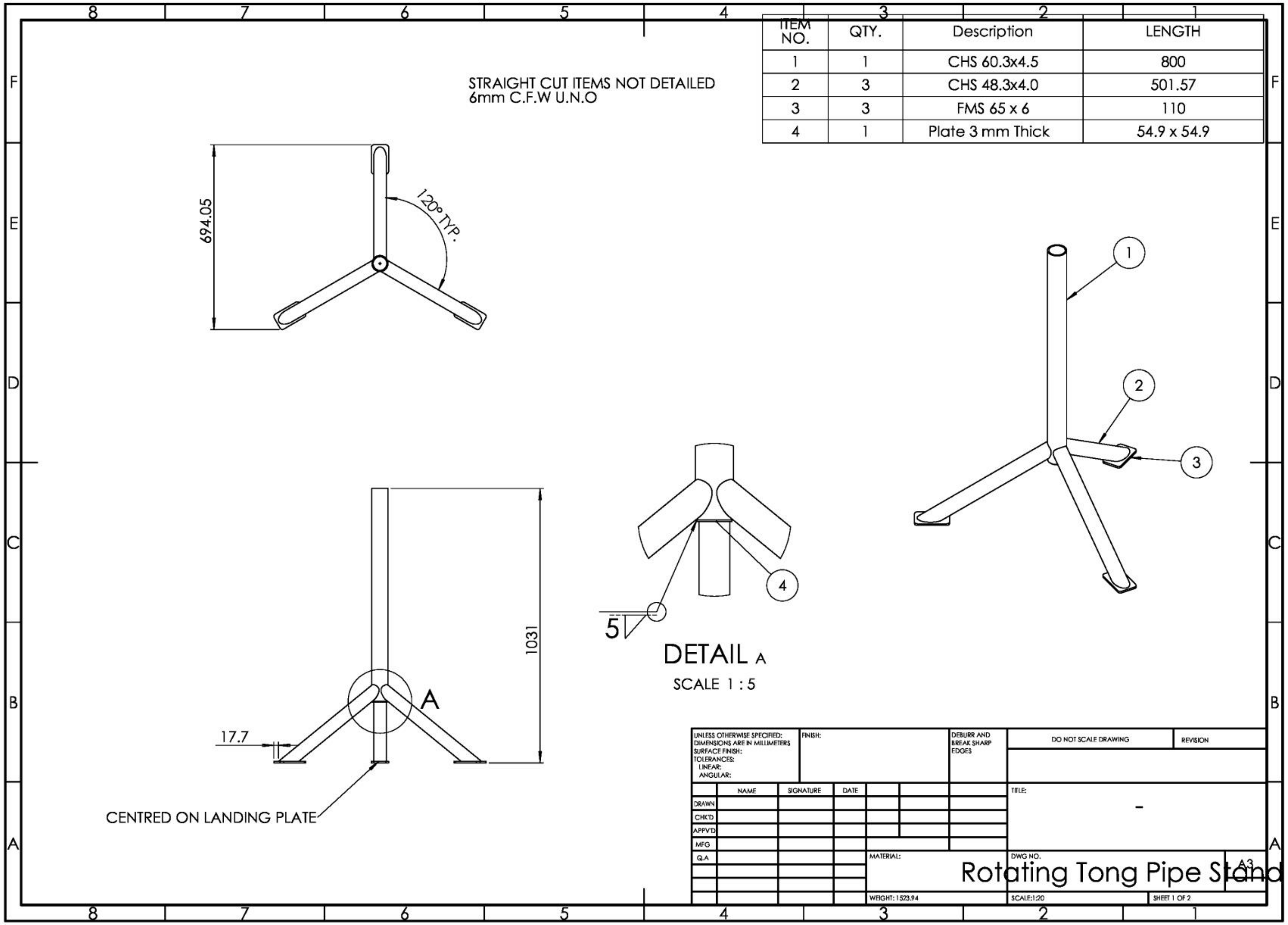

650.00
45°
100
100
6
ITEM 1
870
45°
R350
100
100
6
ITEM 2
Ø700
Ø649.2
600.00
Ø273.1
300
ITEM 4
R350
550.00
Ø82
Ø273.1
Ø323.9
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
TITLE:
-
MATERIAL:
DWG NO.
Jaw Tong (Clamping)
A3
WEIGHT: 91044.68
SCALE:1:20
SHEET 2 OF 2

ITEM NO.	QTY.	DESCRIPTION	LENGTH
1	2	PFC 230 X 75	2650
2	5	200 UB 29.8	1050
3	1	Plate 20 mm Thick	1050 x 2500
4	4	Plate 25 mm Thick	130 x 150
5	2	PFC 230 X 75	1200
6	2	200 UB 29.8	618.7
7	2	SHS 100x5	875.9
8	2	Container Block RH	-
9	2	Container Block LH	-
10	2	RHS 200x100x5	1200
11	2	SHS 100x5	1420
12	4	SHS 100x5	337.2

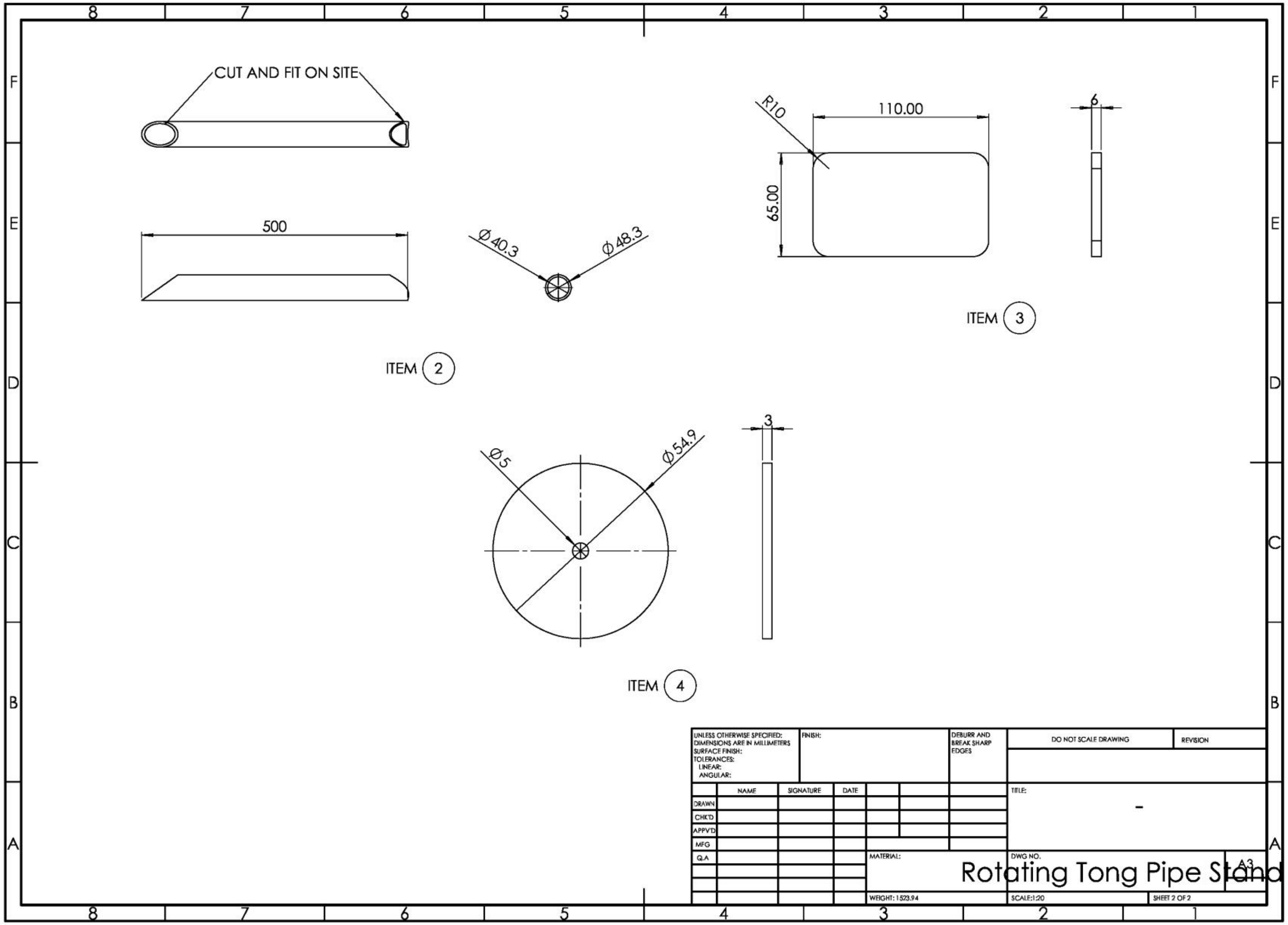


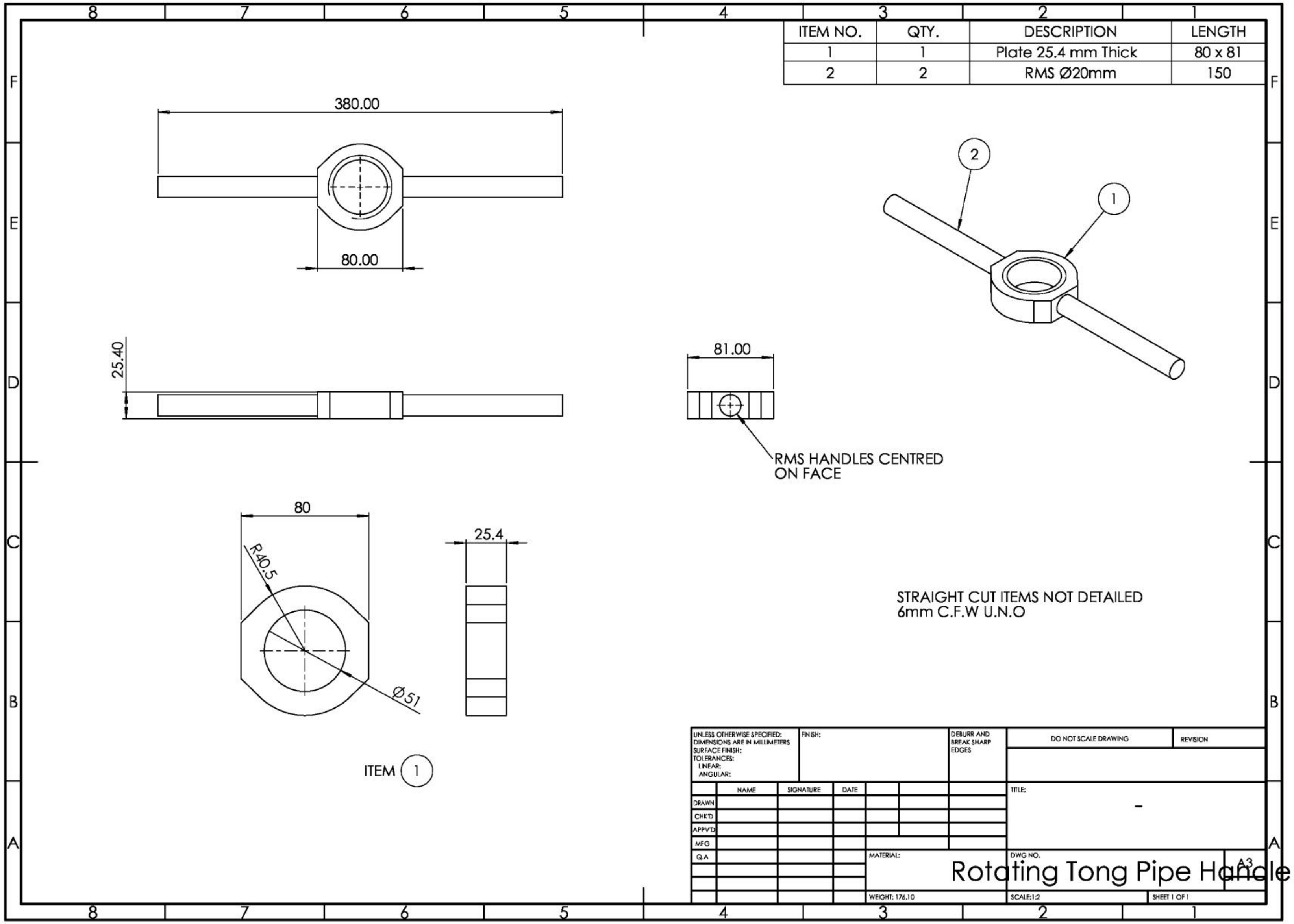

2
6
0
175
800
1425
1916
2541
BOTTOM VIEW
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT: 974592.45
TITLE:
Container Block LH
DWG NO.
Base Frame
A3
SCALE:1:20
SHEET 2 OF 3


2650.00
45°
230.00
75
ITEM 1
2500.00
20.00
1050.00
ITEM 3
130.00
R65
Ø51
85
25.00
150
ITEM 4
1200.00
45°
230.00
75
ITEM 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
TITLE:
Container Block LH
MATERIAL:
DWG NO.
Base Frame
A3
WEIGHT: 974592.45
SCALE:1:20
SHEET 3 OF 3



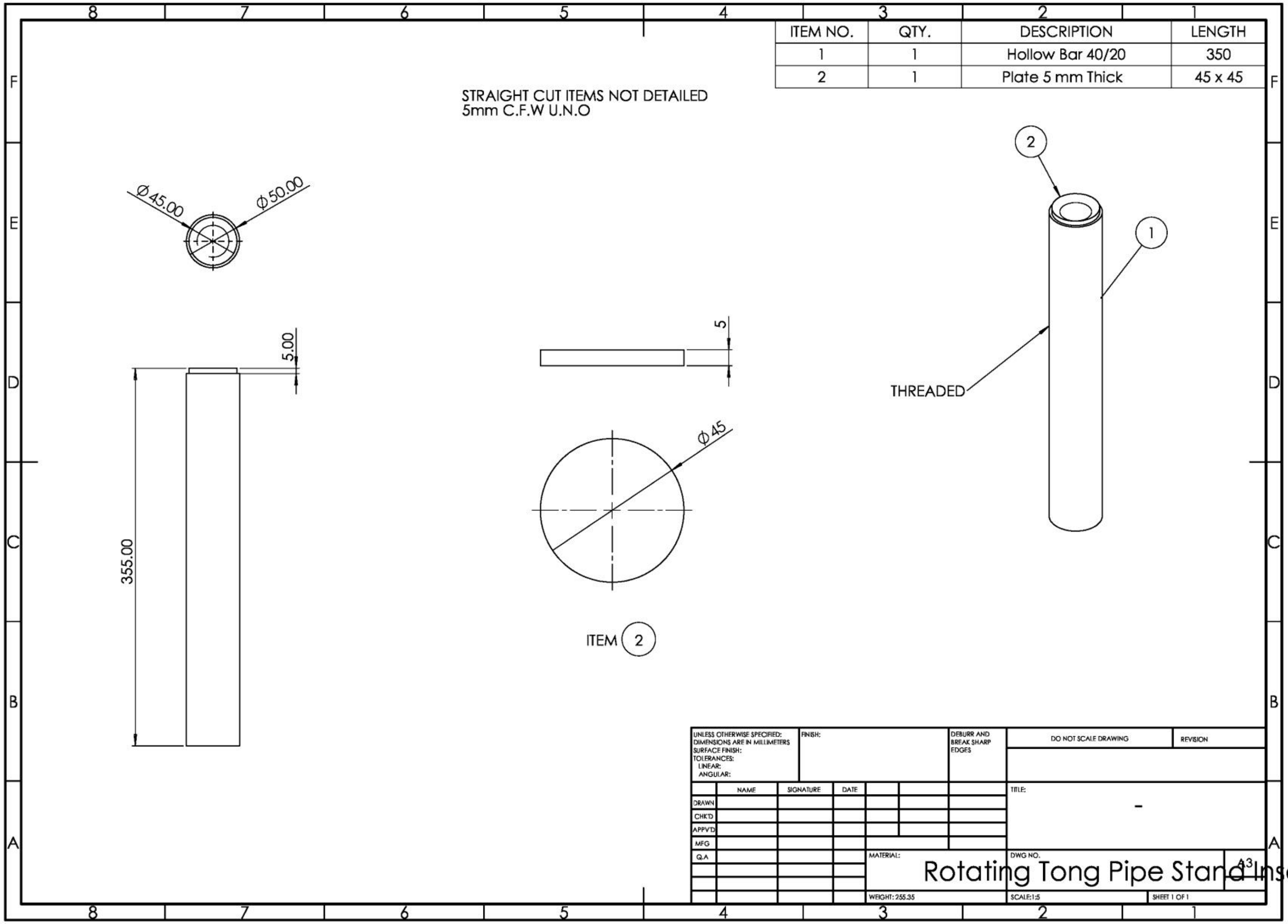
ITEM NO.	QTY.	Description	LENGTH
1	1	CHS 60.3x4.5	800
2	3	CHS 48.3x4.0	501.57
3	3	FMS 65 x 6	110
4	1	Plate 3 mm Thick	54.9 x 54.9

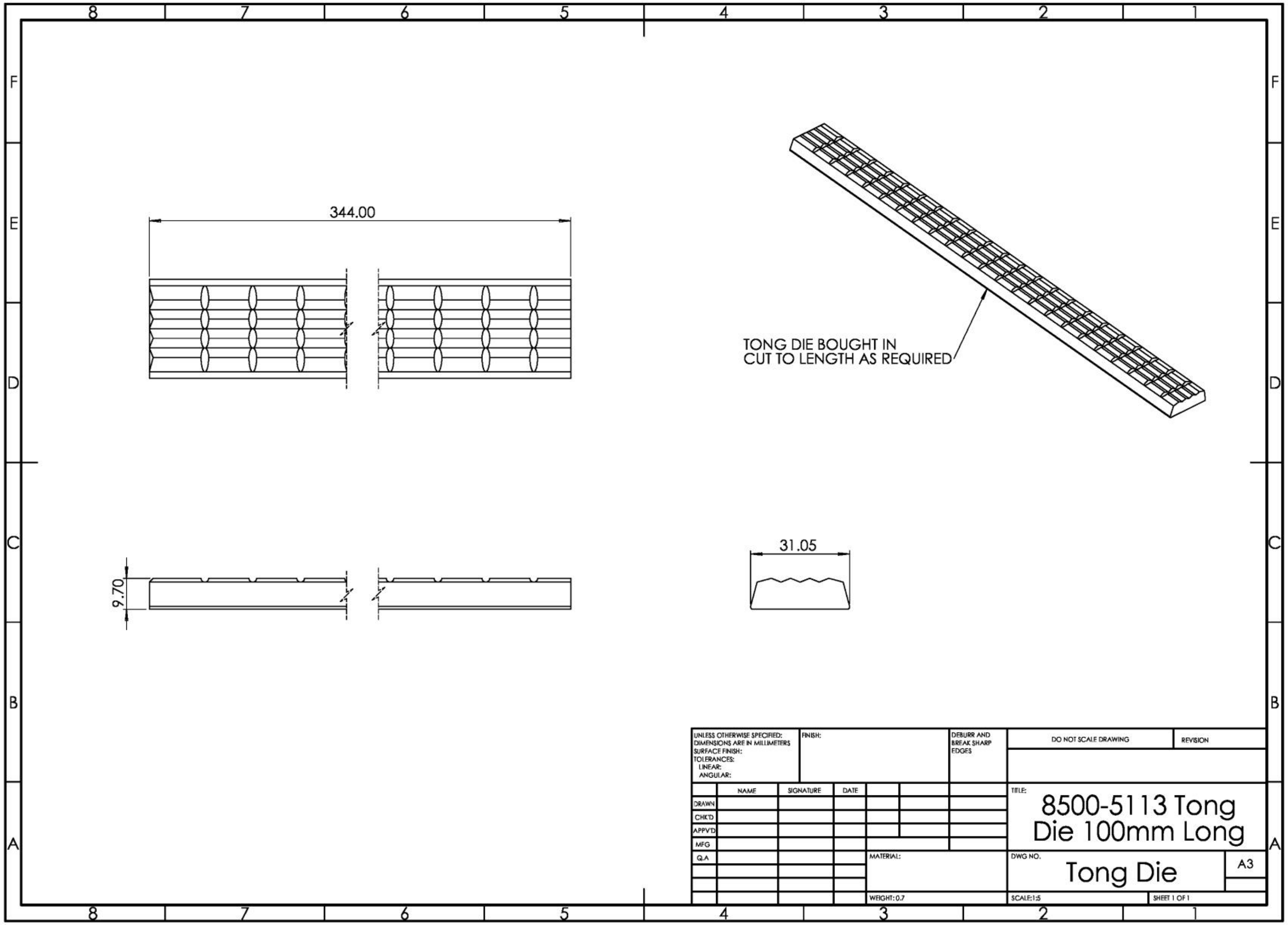

CUT AND FIT ON SITE
500
Ø 40.3
Ø 48.3
ITEM 2
R10
110.00
65.00
6
ITEM 3
Ø5
Ø 54.9
3
ITEM 4
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
TITLE:
-
MATERIAL:
DWG NO.
Rotating Tong Pipe Stand
A3
WEIGHT: 1523.94
SCALE:1:20
SHEET 2 OF 2



ITEM NO.	QTY.	DESCRIPTION	LENGTH
1	1	Plate 25.4 mm Thick	80 x 81
2	2	RMS Ø20mm	150

ITEM NO.	QTY.	DESCRIPTION	LENGTH
1	1	Hollow Bar 40/20	350
2	1	Plate 5 mm Thick	45 x 45




344.00
TONG DIE BOUGHT IN
CUT TO LENGTH AS REQUIRED
9.70
31.05
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: 0.7
TITLE:
8500-5113 Tong Die 100mm Long
DWG NO.
Tong Die
A3
SCALE:1:5
SHEET 1 OF 1

Appendix D – Project Timeline

The methodology of the proposed project can be further and more simply understood by breaking down the events of the dissertation into stages and tasks. These can be seen below.

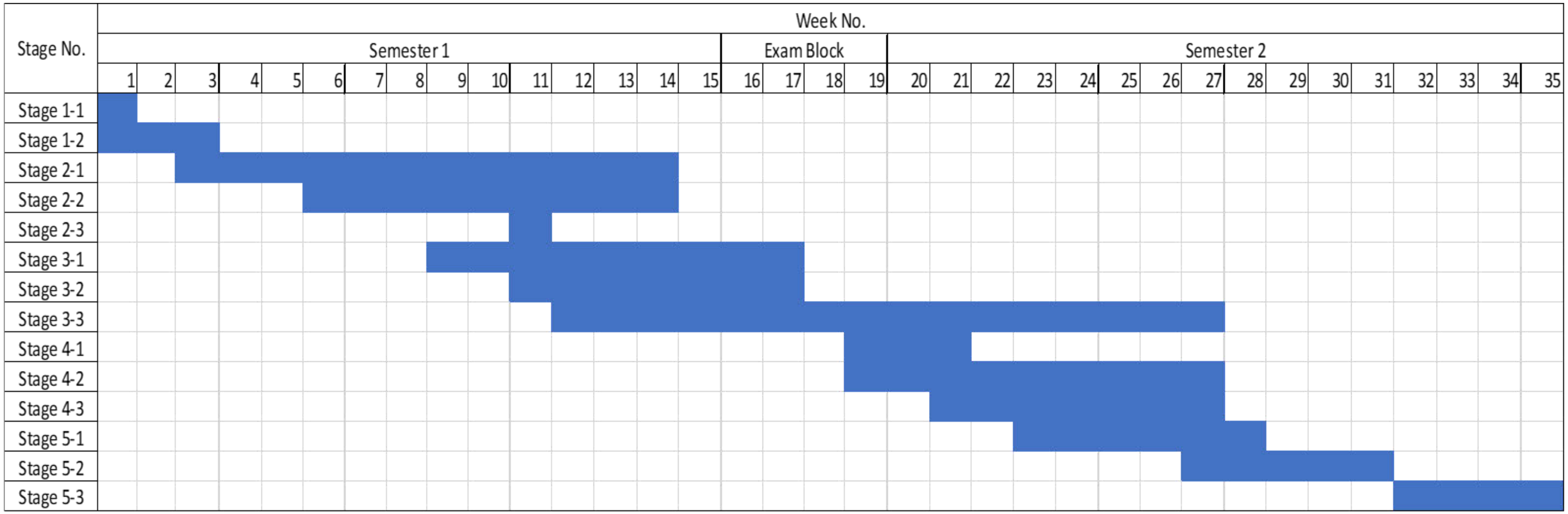
Stage 1	Conducting initial research and brainstorming to identify complete structure and required information of the report
Stage 2	Conduct extensive literature review to attain all relevant and up to date information on bucking units and all factors relating to these processes. Identify critical elements of the design.
Stage 3	Using Solidworks, create the idealised design. Run FEA to ensure the design is equipped to perform safely and effectively for a satisfactory life cycle.
Stage 4	Run FEA to ensure the design is equipped to perform safely and effectively for a satisfactory life cycle.
Stage 5	Collate and finalise project/report

The stages above merely serve as a guide and the tasks within each stage are subject to change. They are outlined above to provide a close to accurate step by step guide of the project for the duration, and the separate tasks are explained in depth below.

Stage 1-1	Brainstorm possible routes of investigation to undertake and how to effectively and efficiently conduct all further stages of the project
Stage 1-2	Identify then conduct initial research on bucking units, identifying key issues
Stage 2-1	Using prior research, conduct extensive literature review to attain reliable and near conclusive data on these methods and issues
Stage 2-2	Collate information into dissertation report and identify the most appropriate factors that must be considered
Stage 2-3	Using a weighted grading matrix (possibly Pugh Method), identify the critical elements of the design (as per API 4F)
Stage 3-1	Begin initial designing of elements
Stage 3-2	Ensure design will meet safety requirements (as per API 4F)
Stage 3-3	Get a revision of design that is satisfactory for testing in Solidworks
Stage 4-1	Identify the forces and stresses that will be prevalent on the design and create an FEA
Stage 4-2	Commence FEA, record results
Stage 4-3	Adapt design to the requirement as seen by the FEA and improve the elements
Stage 5-1	With all previous steps finalised, the dissertation will be collated in appropriate structure

Stage 5-2	Outline objectives that were achieved and if the outcomes attained were desirable towards the common goal of the project
Stage 5-3	Attend conference and present findings thus far; describe further action to take before deadline

On the following page is a graph that portrays this on a weekly basis, helping to realise and achieve goals.


Stage No.
Week No.
Semester 1
Exam Block
Semester 2
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
Stage 1-1
Stage 1-2
Stage 2-1
Stage 2-2
Stage 2-3
Stage 3-1
Stage 3-2
Stage 3-3
Stage 4-1
Stage 4-2
Stage 4-3
Stage 5-1
Stage 5-2
Stage 5-3

Appendix E – Project Budget and Resources

Resources

For the intended report to be written as part of ERP 2021, it is required to outline the allocated resources and budget of the extended research and design.

The resources are defined as follows:

- Access to USQ library during/after hours when working on report writing
- Access to work facilities (Obadare Group) such as;
    - Computers
    - Software (Solidworks and related programs)
- USQ eLibrary
- Possible access to pre-existing bucking unit (if available)

Budget

The budget of the report is not relevant as monetary value will not be spent, and if it is, will be very limited. This includes:

1. Certain standards pertaining to API 4F and Australian/New Zealand manufacturing standards

Monetary value: Nil

2. Access to possible websites that provide data and informative reports, but require to access through a paywall (oneptro.org)

Monetary value: Approximately $270 AUD ($200 USD)

3. Work resources, such as work computers

Monetary value: Nil

TOTAL **$ 270 AU**

Appendix F – Risk Management Plan (RMP)

UNIVERSITY OF SOUTHERN QUEENSLAND

University of Southern Queensland

USQ Safety Risk Management System

Print View

Version 2.0

Safety Risk Management Plan

Risk Management Plan ID:	Status:	Current User:	Author:	Supervisor:	Approver:
RMP_2021_5568	Approve	[redacted]	[redacted]	[redacted]	[redacted]

Assessment Title:	Bucking Units - A more Effective Approach	Assessment Date:	24/05/2021
Workplace (Division/Faculty/Section):	204010 - Faculty of Health, Engineering and Sciences	Review Date:	(5 years maximum)

Approver: *Steven Goh*	*Supervisor: (for notification of Risk Assessment only)* *Steven Goh*

Context

DESCRIPTION:

What is the task/event/purchase/project/procedure?	Design Task		
Why is it being conducted?	Project for Obadare Group		
Where is it being conducted?	Assessment COnductors House		
Course code (if applicable)	ENG411 and ENG4112	Chemical Name (if applicable)	

WHAT ARE THE NOMINAL CONDITIONS?

Personnel involved	Jackson Gould
Equipment	Computer, Software
Environment	Indoor Housing
Other	
Briefly explain the procedure/process	Using computer software, design a bucking unit suitable for transport

Assessment Team - who is conducting the assessment?

Assessor(s):	Steven Goh
Others consulted: (eg elected health and safety representative, other personnel exposed to risks)	

Risk Matrix

Probability	Consequence: Insignificant No Injury 0-$5K	Minor First Aid $5K-$50K	Moderate Med Treatment $50K-$100K	Major Serious Injury $100K-$250K	Catastrophic Death More than $250K
Almost Certain 1 in 2	M	H	E	E	E
Likely 1 in 100	M	H	H	E	E
Possible 1 in 1,000	L	M	H	H	H
Unlikely 1 in 10,000	L	L	M	M	M
Rare 1 in 1,000,000	L	L	L	L	L

Recommended Action Guide

Extreme:	E= Extreme Risk – Task ***MUST NOT*** proceed
High:	H = High Risk – Special Procedures Required (Contact USQSafe) Approval by VC only
Medium:	M= Medium Risk - A Risk Management Plan/Safe Work Method Statement is required
Low:	L= Low Risk - Manage by routine procedures.

Risk Register and Analysis

Step 1	Step 2	Step 2a	Step 2b	Step 3	Step 4

Risk Register and Analysis

	Step 1	Step 2	Step 2a	Step 2b	Step 3				Step 4			
	Hazards: From step 1 or more if identified	**The Risk:** What can happen if exposed to the hazard without existing controls in place?	**Consequence:** What is the harm that can be caused by the hazard without existing controls in place?	**Existing Controls:** What are the existing controls that are already in place?	**Risk Assessment:** Consequence x Probability = Risk			**Additional Controls:** Enter additional controls if required to reduce the risk level	**Risk assessment with additional controls:** Has the consequence or probability changed?			
					Probability	Risk Level	ALARP		Consequence	Probability	Risk Level	ALARP
	Example											
	Working in temperatures over 35⁰ C	*Heat stress/heat stroke/exhaustion leading to serious personal injury/death*	*catastrophic*	*Regular breaks, chilled water available, loose clothing, fatigue management policy.*	*possible*	*high*	*No*	*temporary shade shelters, essential tasks only, close supervision, buddy system*	*catastrophic*	*unlikely*	*mod*	*Yes*
1	Constant use...	Eye strain	Insignificant	Regular Breaks	Possible	Low	☑					☐
2	Power surge	Computer battery fries, ruining electrical components	Minor	Power surge resistant powerpoint outlet	Rare	Low	☑					☐
3	Multiple wire...	Tripping and hurting myself	Minor	Organising cables in clean and effective manor	Rare	Low	☑					☐
4	Driving to an...	Car accident	Minor	Drive safely, abide by all road rules as outlined by QLD and Australian Government	Unlikely	Low	☑					☐
5	Electricity ov...	Causes harm to myself, equipment	Moderate	Surge protected board	Rare	Low	☑					☐
6	Ergonomics ...	Sore muscles and strain	Insignificant	Use posture correcter on chair, take small walks every hour to stretch muscles	Possible	Low	☑					☐
7	Ergnomics of...	Sore muscles and bad neck	Insignificant	Always use correct posture, take frequent breaks	Possible	Low	☑					☐

Step 5 - Action Plan (for controls not already in place)

	Additional Controls:	*Exclude from Action Plan: (repeated control)*	*Resources:*	*Persons Responsible:*	*Proposed Implementation Date:*

Supporting Attachments

jpg2pdf.pdf
5.42 MB

thumbnail_20210525_134507.jpg
322.39 KB

thumbnail_20210525_134512.jpg
236.1 KB

Step 6 – Request Approval

Drafters Name: *Jackson Gould*

Draft Date: *24/05/2021*

Drafters Comments: *No outstanding risks that are cause for concern, no manual labour or physical work being conducted, nor any use of dangerous or otherwise harmful chemicals or materials, thus the risks are extremely low. Attached are images of some of the devices being used to minimmise risk further.*

Assessment Approval: **All risks are marked as ALARP** 0

Maximum Residual Risk Level: **Low - Manager/Supervisor Approval Required** 1

Document Status: *Approve*

Step 6 – Approval

Approvers Name: *Steven Goh*

Approvers Position Title: *Academic Project Supervisor*

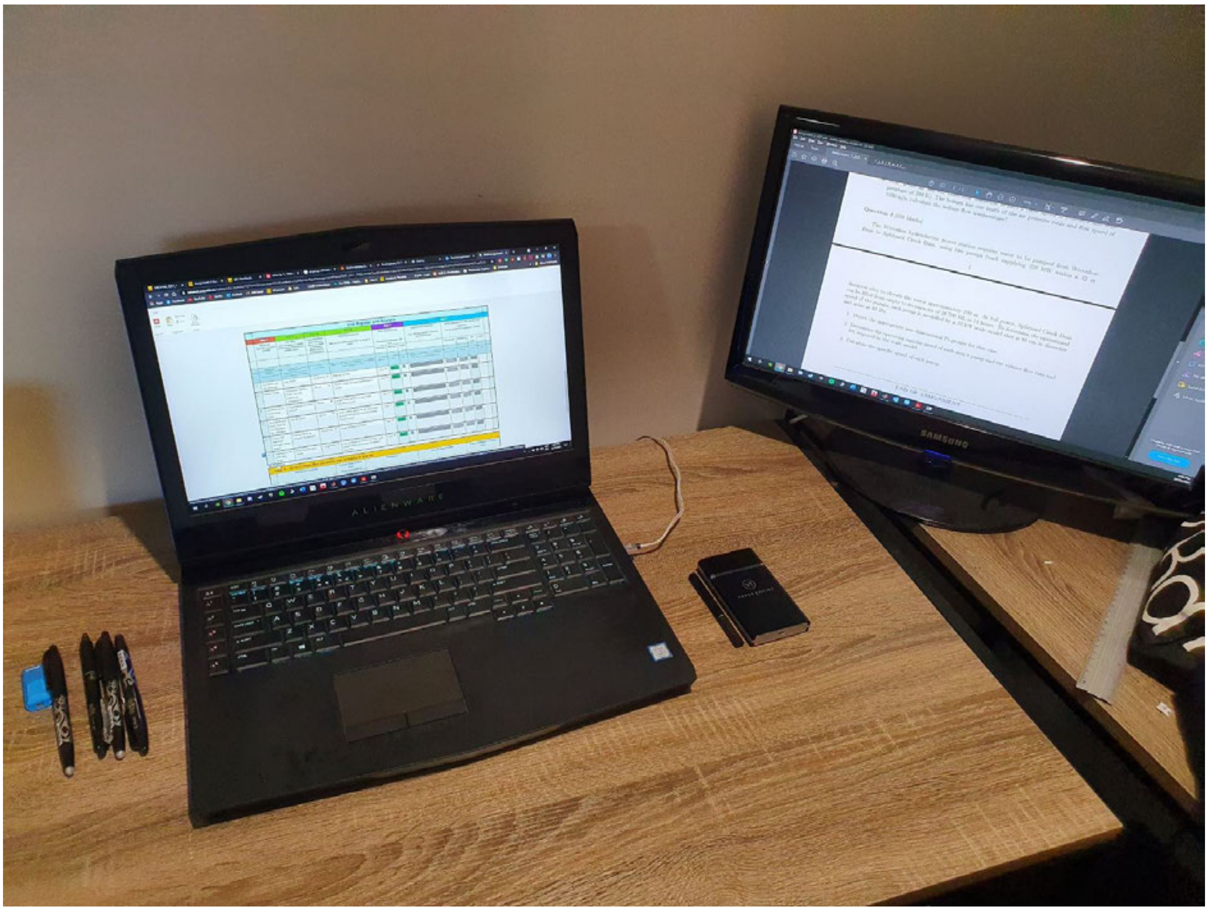
Approvers Comments: *desktop project on designing mechancial components using solid-modelling and FEA*

I am satisfied that the risks are as low as reasonably practicable and that the resources required will be provided.

Approval Decision: Approve

Approve / Reject Date: *27/05/2021*

Document Status: *Approve*


ALIENWARE
SAMSUNG