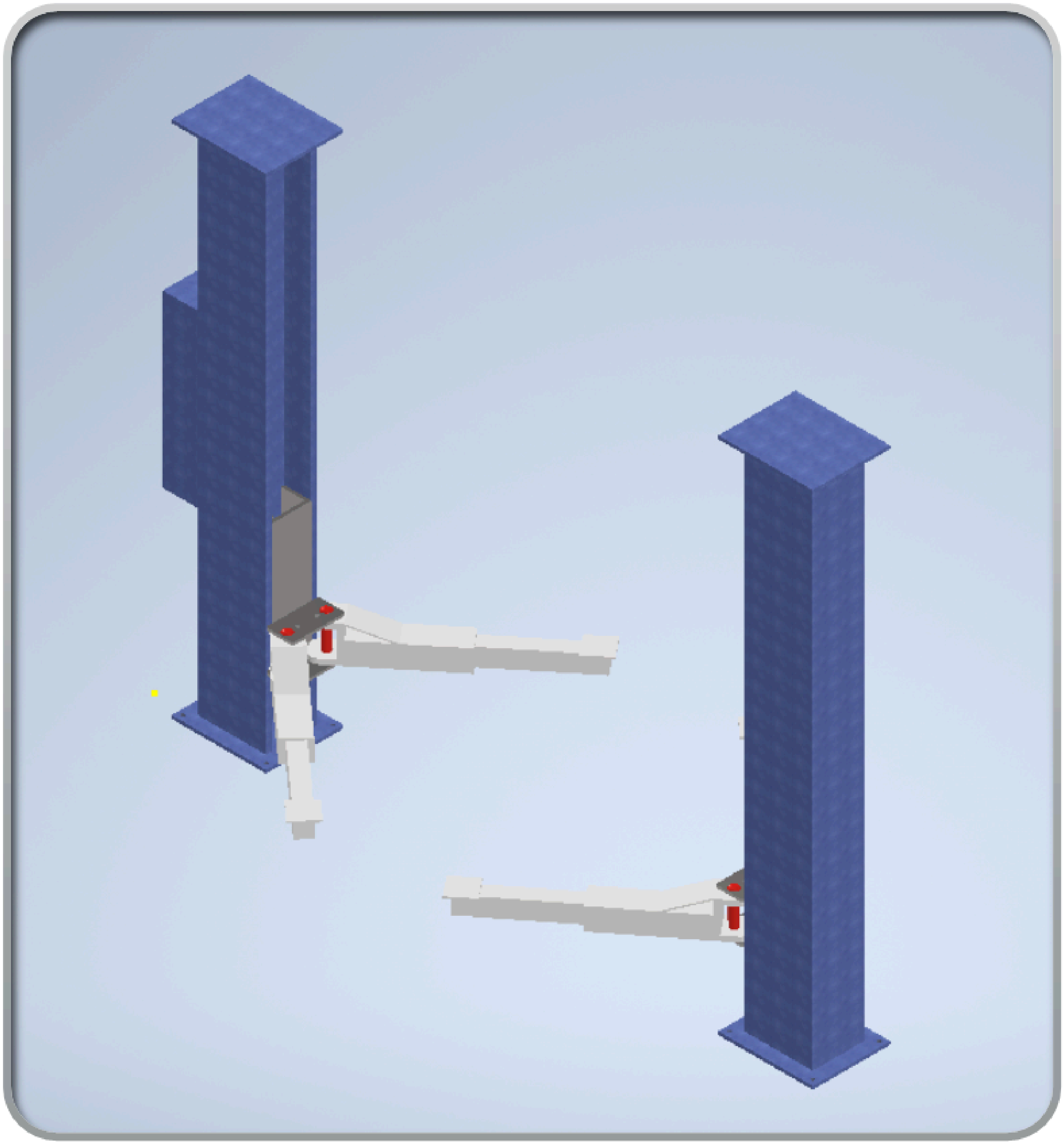
Hydraulic Car Lift

HND Mechanical Engineering Graded Unit



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Summary

Simpson Fabrications was assigned the task of creating a hydraulic car lift that is capable of lifting 3 tonnes off the ground by 2m and be completed within a timeframe of 18 weeks. A brief was written and a schedule constructed to help keep the project on track.

Objectives were set so that both the engineers and the client were aware of the expected outcome in terms of the hydraulic car lifts' capabilities and project projection. Three designs were produced and working to the clients specifications, a justification of the final design was agreed.

Constant communication was maintained with the client to make sure that they were satisfied with the design and the choices made throughout the project. Any changes that were made were to ensure complete customer satisfaction.

Drawings were then produced and from those drawings 3d models were created to give a visual aid on how the final product was going to look.

Once the design was finalised materials were chosen for the car lift's construction and calculations were performed to determine whether or not the material could withstand the forces acting upon it. All of this information was then presented in a powerpoint presentation showcasing the specifications of the project in order to give the client an understanding of the costs involved and the safety features provided. All of this was then finalised into a report for the client.

Introduction

In early 2021, a mechanic approached Simpson Fabricators with a request to design and install a hydraulic car lift capable of lifting 3 tonnes off the ground by around 2m. Simpson Fabricators were chosen because of their track record in successfully completing similar projects and we were confident that a good outcome could be achieved.

The design team was given 18 weeks to complete the task.

Initial designs for the car lift were drawn up to understand how the project would play out before final design was picked by both the client and the engineers. A project brief, specifications and schedule, which was to be altered at 5 week intervals, was designed. Once the initial design process was complete the focus shifted onto research, manufacturing and testing. These were all key points for the project, and were done under compliance with all of the current, relevant health and safety regulations.

Brief

A mechanic at a local garage has requested an engineer to produce a hydraulic car lift to inspect and service cars. The lift must have a capacity of 3 tonnes, extend to a maximum height of 2 metres, and be fixed to the ground for support. The time allocated to this project is 18 weeks and the budget set out by the customer and engineer is £10,000.00. All work must comply with current health and safety regulations.

Specification

The parameters for this project will be checked throughout the design phase since they instruct the operator as to the physical limitations of the lift. The specifications will detail all relevant properties that are needed for the car lift.

- General information
    - 2 post lift - posts will be fabricated
    - 4 arms will be fabricated
    - 2 Mounting plates to be fabricated
    - 4 pins for arms to be fabricated
    - Pump will be sourced
    - Hydraulic cylinders will be sourced

- Physical Properties
    - Maximum height - 3m tall
    - Maximum internal width - 2.8m wide
    - Working area of $15m^2$ (not including vehicle length as it will vary from differing vehicles)
    - Maximum ceiling height of 5m (2m underneath + 2m of vehicle height + 1m of clearance)

- Mechanical Properties
    - Lifting capacity - 3 tonnes
    - Lifting height - 2 metres
    - Post anchored to ground with zinc yellow-chromate plated grade 5 steel anchor bolts
    - Arms connected by spring loaded steel pins

- Electrical Properties
    - Supply voltage of 220V, 50Hz
    - Power requirement of 2.2Kw

- Environmental Properties
  Vehicle lift will be in a garage at all times, protected from most of the elements, however Air is still able to interact with it.
    - Hydraulic fluids are to be disposed in an acceptable place
    - Lubricants are to also be disposed in an acceptable place
    - Life expectancy of both frame and pump unit has a life expectancy of 20-30 years
    - Paint to protect steel frames from oxidation

- Health and safety
  When manufacturing this hydraulic car lift, health and safety regulations are to be followed as set by local governments and the health and safety executives (HSE), the regulations required to follow are:
    - Health And Safety At Work Act 1974
    - Provision of Use of Work Equipment Regulations 1998
    - Lifting Operations and Lifting Equipment Regulations 1998
    - Personal Protective Equipment at Work Regulations 1992
    - Control Of Substances Hazardous to Health 2002

- Maintenance
    - Electrical cables to be replaced every 5 years
    - Rails to be lubricated every 3 years
    - Scheduled examination must take place every 6-12 months for the hydraulic pump by a trained person
    - Fresh coat of paint reapplied every 1-2 years

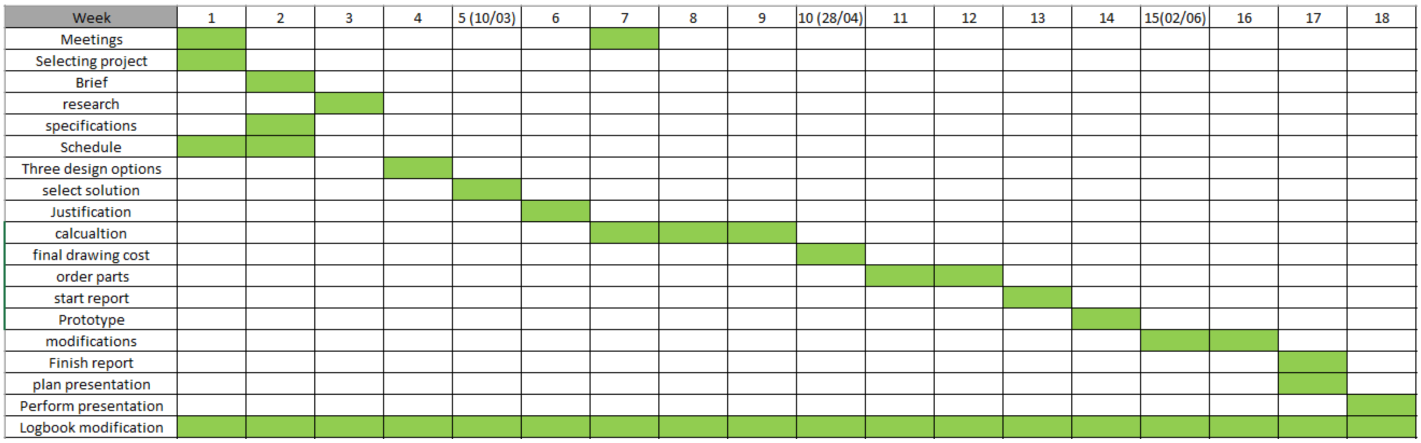
Objectives

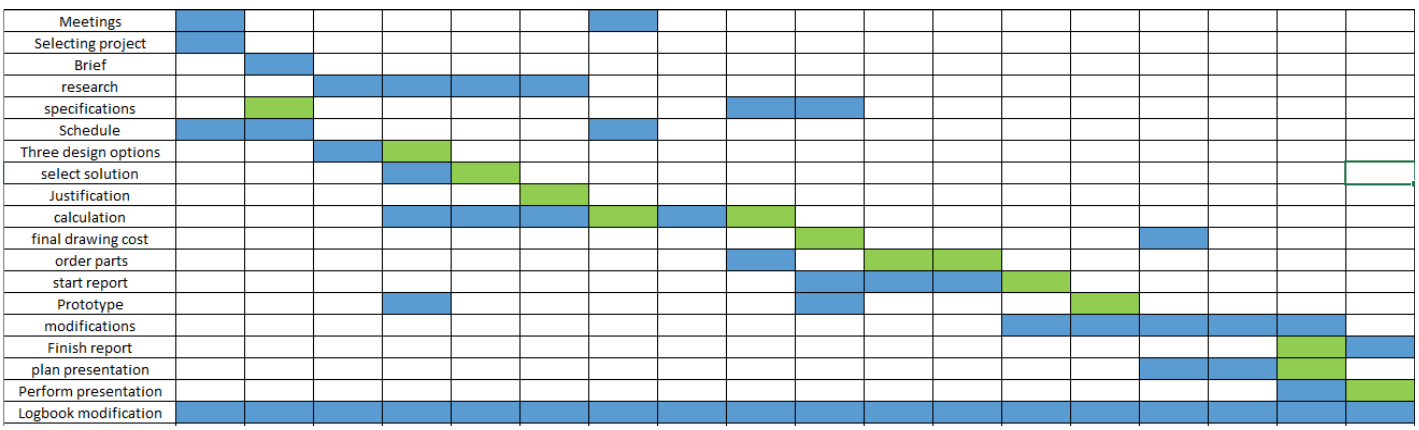
The overall aim of this project is to fabricate a hydraulic car lift. Below are the stages that will be followed in order for the successful completion of the project and to enable the mechanic to stay on track.

- Coming up with 3 different designs for the car lift and select the best
- Design should lift capacity of 3 tonnes
- Determine the costs of the lift and make sure that they are within the designated budget
- Test the capabilities of the lift
- Conduct a safety tests following the safety legislation
- Complete within the time frame & budget
- Produce a copy of a written report
- Present in a presentation

Schedule

The schedule was designed in the form of a gantt chart which, over the course of 18 weeks, will be updated every 5 weeks to ensure that the mechanics stay on track and ensure the smooth flow of production. The initial and final schedule are shown below.



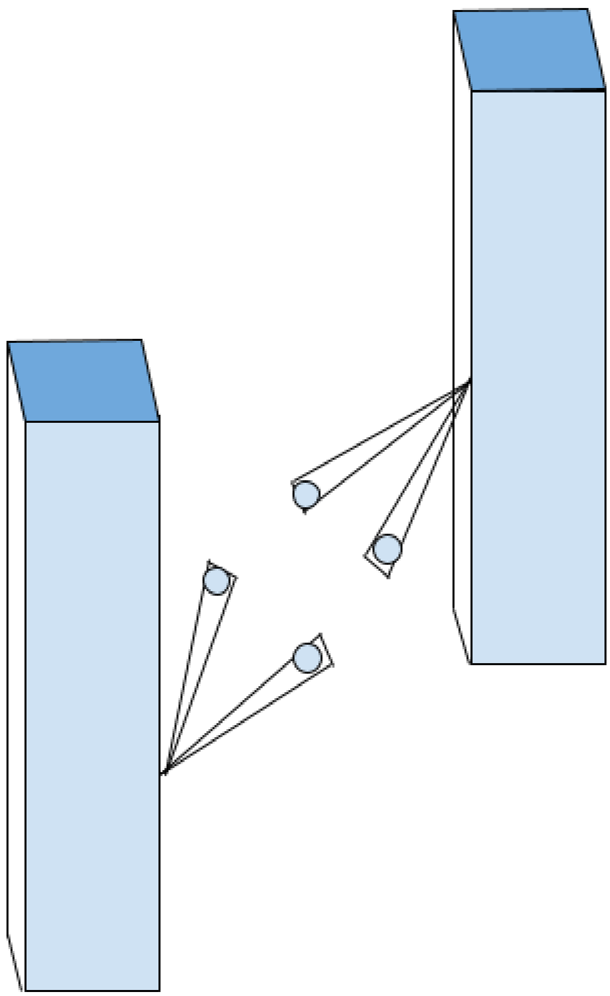


(See appendix i-v for all 5 schedules)

Selection And Justification

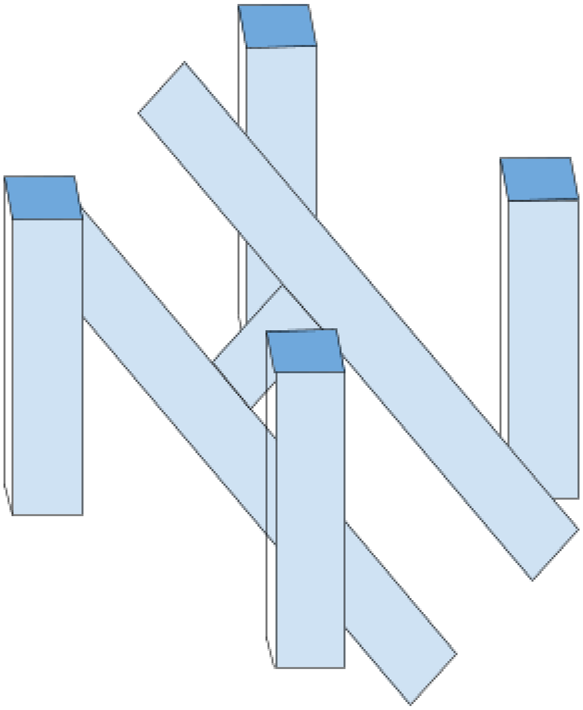
When designing the car lift for this project, three designs were constructed and the best one to serve the needs of the client was chosen.

Design 1 - 2 post



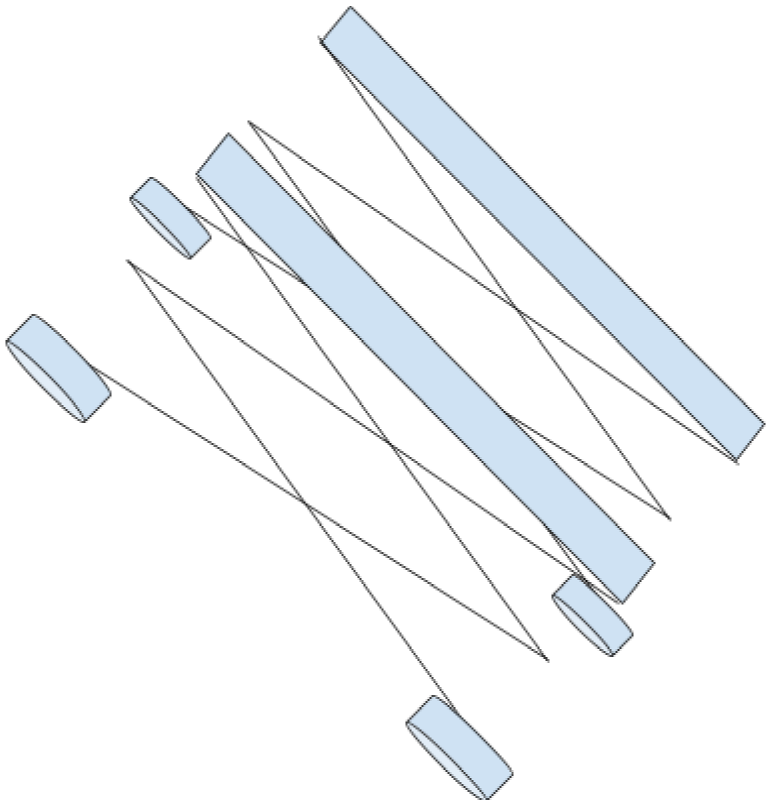
For this design, 2 posts will be fabricated as well as 4 mounting arms that will mount to the structural strong points of a vehicle such as its subframe. This design allows for greater accessibility to the vehicle and allows for the wheels of the vehicle to be removed for easier access to the brakes and wheel well. The 2 posts will be mounted to the ground using anchor bolts to keep the lift structurally sound.

Design 2 - 4 post



This design details a 4 post lift with a drive on ramp. It is similar to the 2 post design, and has posts with hydraulic cylinders anchored to the ground with anchor bolts which will lift the vehicle up to the required height of 2 metres. The issue with this design, however, is that the wheels must be attached to the vehicle in order for it to be lifted. This also makes it more expensive with twice the amount of materials required. Despite these issues, however, this design is far more stable than the 2 post design. Accessibility will also be hindered as the supporting beam could interfere with certain parts such as the transmission.

Design 3 - scissor



The third and final design is a scissor lift that will also mount to the frame of the vehicle. This design was favoured as it is portable allowing the client to store it away and have the working space used for storage of vehicles or workstations. This design would also be far cheaper than the previously stated designs. The issues with this design however is that it cannot be anchored, making it potentially unsafe and prone to capsizing. This design also struggles to reach the 2m height(reaching heights of around 1.5-1.8m).

Since the main requirements were safety and accessibility of the vehicle, each of these designs were compared to reach a decision. The final decision was based on a design matrix where a rating of importance was assigned on a scale of 1-5. These parameters were cost, stability, safety, accessibility, reliability and maintenance. The designs were sketched using a drawing program before the final design was fully rendered in autoCAD inventor.(seen in appendix x and appendix xi)

	Cost	Stability	Safety	Accessibility	Reliability	Maintenance	Total
Importance	2	4	5	5	3	4	
Design 1	3	4	5	5	4	4	100
Design 2	2	5	5	3	4	4	92
Design 3	4	3	2	2	2	3	58

Total Value = $\sum$(importance * design)

As seen from the justification table, design was most favourable to the clients requested specifications.

Technical Description

The working environment for the hydraulic car lift will be a storage unit used as a garage. It will be required to lift vehicles off the ground to enable the mechanic to inspect the underside or to allow easier access to certain places such as wheel wells. Hence, the reason why a lifting capacity of 2 tonnes and lifting height of 2m is ideal.

Calculations must be performed to determine what kind of forces the lift will be experiencing. To understand the forces acting upon the lift, the mass of the vehicle must be converted to its weight. This is done by simply multiplying its mass by the force of gravity. Since the capacity of the lift is 3000kg, this value will be used throughout the calculations. The posts can be treated like cantilevers to understand the bending moments and the shear forces acting upon them (see appendix xii and xiii for further details). Once this has been calculated the deflection of the arms must be calculated using standard loading equations. The reason for this is to ensure that the arms will not bend too far as this would cause the vehicle to fall off of the arms themselves. The young's modulus of a material will come from the chosen material. The second moment of area will be required and that will simply be calculated based on the dimensions of the inner tube of the extendable arm whilst fully extended, as that will be the most likely point of failure and largest deflection.(see appendix xii and appendix xvii)

Material selection and Grades

The material used for the posts and arms of the lift is going to be mild steel. The reason this material was chosen is that it has to withstand the compressive and shear strength of the mass of the vehicle whilst also being relatively cheap to keep costs down. It also has to be weldable to be able to attach the base plates and, since mild steel is generally used in framework design, it makes sense to use it for the framework of the car lift.

Advantages

- Cost effective
- Recyclable
- Weldable
- Ductile

Disadvantages

- Heavy
- Can Corrode

There are numerous grades of steel to pick from however based on the requirements the grade that has been chosen for the framework is Grade S275JR

Chemical Composition (% by weight)					
C	Mn	P	S	Cu	Ni
0.22	1.5	0.0035	0.035	0.55	0.012

The individual tensile and yield stress of S275JR will be displayed as followed in a table that has been sourced.

	Minimum yield strength Reh MPa						Tensile strength Rm MPa		Minimum elongation - A Lo = 5,65 * √So (%)				Notch impact test	
Steel grade	Nominal thickness mm						Nominal thickness mm		Nominal thickness mm				Temperature	Min. absorbed energy
	≤16	>16 ≤40	>40 ≤63	>63 ≤80	>80 ≤100	>100 ≤125	>3 ≤100	>100 ≤125	>3 ≤40	>40 ≤63	>63 ≤100	>100 ≤125	°C	J
S275JR	275	265	255	245	235	225	410-560	400-540	23	22	21	19	+20	27

(S275JR Steel Grade, Mechanical Properties, Chemical Composition, Grade Equivalent, 2022)

The yield stress is a measure of the maximum stress that can occur in a material with casing plastic deformation, that is to the point where it is permanent deformation. This is important as the framework of the hydraulic car lift must retain its shape in order to function properly. Tensile strength is the maximum load that a material can support without any structural damages, such as fractures or cracking when undergoing a load over a certain area. The choice of material allows for large amounts of loads to be applied to the car lift without any structural damage occurring to the framework itself.

To balance between strength and costs of material, the decision is made of a thickness of between 16 to 40mm, giving a minimum yield stress of 265 MNm^2 and a tensile strength of 410-560MNm^{-2}.

Posts

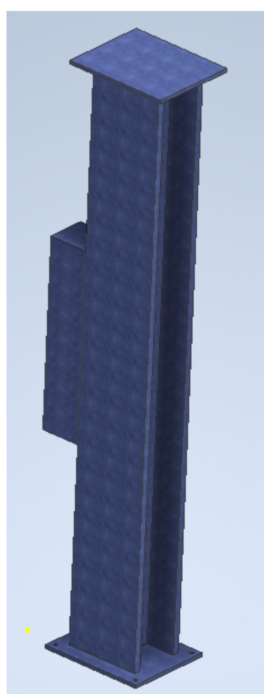
The final design for the hydraulic car lift consists of 2 posts that houses the 2 direct drive piston cylinders, mounting bracket with stabilising steel cables and safety latches in an event of a hydraulic failure.

This will be fabricated from a large steel beam that will have a channel machined out of it, leaving the sides intact to allow for the mounting of the pump unit as well as for structural support.

Machining a gap in the middle was also considered to allow for the hydraulic cylinders to be situated. As well as the mounting bracket, steel wire was chosen to stabilise the arms during the lifting process. When calculating the stress affecting the car lift, the post was treated as though it was a beam cantilever. This was to produce the bending moment and shear force diagrams to visually show the forces affecting the post whilst a car is on it.

The posts themselves, along with all of the other fabricated pieces, will be made of S275JR as it will all be subjected under the same load, making it the obvious choice as the material can handle it. Although the posts may not break under the load, the posts must be anchored to the ground to ensure that they do not capsize.

Holes will be drilled into the concrete floor of the garage and will be secured with Zinc Yellow-Chromate Plated Steel Grade 5 anchor bolts. With each individual bolt rated with a pull-out weight of 1358kg, 4 bolts is sufficient enough to hold down the posts firmly into the ground.(McMaster-Carr, 2022)

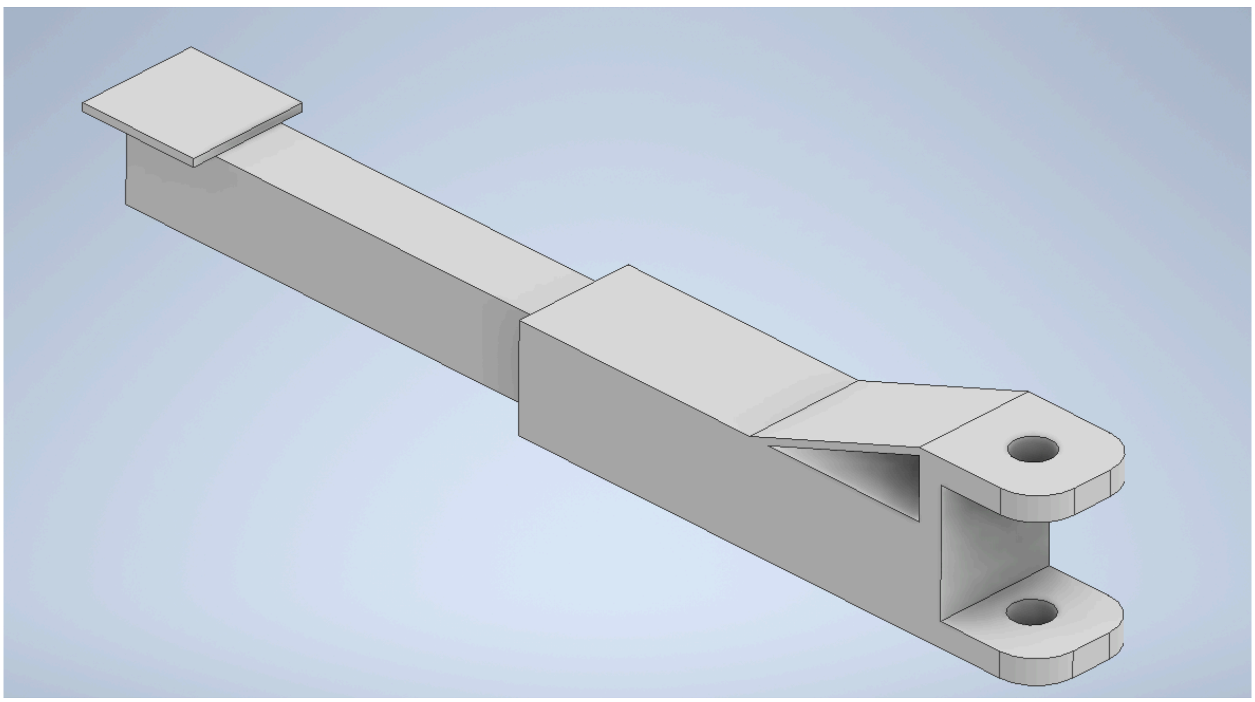


(see CAD drawing in appendix Vi)

Arms

The arms of the Hydraulic car lift are going to be fabricated with hollow S275JR steel tubes with a wall thickness of 25mm slid into a second steel tube with a wall thickness of 25mm. When calculating the deflection, the length should be considered at its maximum as that is when it will be the most likely point of failure. It can be extended to a length of 1.25m all the way down to 0.560m giving it a large range of motion and allowing it to adapt to any vehicle that may be going onto the ramp.

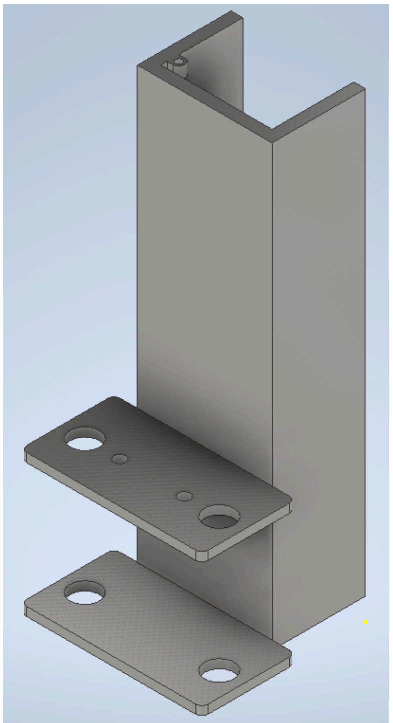
In order to lock the arms into place so that they do not swing and cause any health and safety hazards, a spring loaded pin will be slotted into the mounting bracket. At the end is a gear mesh which will interlock with another gear mesh on the connecting end of the arms, locking them together as the ramp is being lifted. On the footpad side, there will be a rubber grommet going over the pad. This is to provide a cushioned surface on which the sub-frame/frame work of the vehicle can sit on so that there is minimal damage done to it.



(see CAD drawing in appendix vii)

Mounting Plates

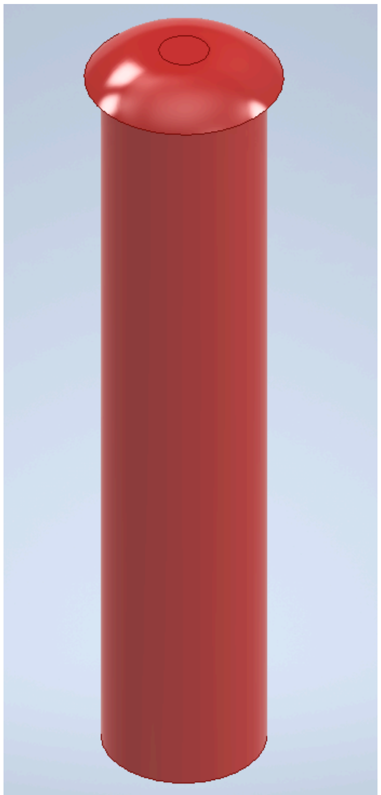
The mounting plates will allow for the arms to be connected to the posts. The plate is slotted in between the channel that was machined out of the post and will slide freely along the z-axis. At the top of the plate is a hole which allows for a steel cable to be bolted into, The purpose for the steel cable is to ensure that the legs are being lifted at the same time to ensure they are level.As the steel cable will not be bearing a large load calculations are not considered for them Moving down from the plate are the holes where the connecting pins and locking pins will be situated. The legs will slide between the plates where the holes will line up and the pins slotted into place.



(see CAD drawing in appendix viii)

Pin

The pin is the connecting piece for the mounting plate and the legs, as the legs are fabricated to unique dimensions, the pins couldn’t be sourced as they wouldn't be the correct size of the arm’s hole diameter.



(see CAD drawing in appendix ix)

Miscellaneous

(FORAVER Hydraulic Car Lift Power Unit 2.64 Gallons 3 HP Hydraulic Pump Power Unit Auto Car Lift 3T/6600LBS Capacity Steel Tank Vehicle Hoist Heavy Duty, 2022)

The pump unit that will pump the hydraulic fluid to the hydraulic cylinders will be sourced from an approved manufacturer. The pump is capable of lifting 3 tonnes of mass off the ground using a 220V with a power draw of 2.2kW. The power of the pump is 3hp which is sufficient power for operation. The pump unit will be mounted on the side of the post, where the block is located on the 3d model(see appendix xi)

(www.advansys.com, 2022)

The other component of the hydraulic car lift that will be sourced is the direct drive hydraulic cylinders. As this will be situated in a storage unit, there is plenty of ceiling space which allows for the direct drive system over a chain system. Direct drive is preferable as the lifting height to lifting power is 1:1. These will be installed inside of the posts themselves and the piston will rest beneath the mounting plate, pushing it as it rises. Another benefit to this is there are less moving parts compared to a chain over system, meaning less wear and tear and overall less maintenance and replacements. This specific cylinder can reach heights of 3m making it more than sufficient.

To ensure that the lift meets the requirements from the customer's requests, tests must be performed. The things that will be tested will be the anchor bolts to ensure they are producing the same results as the manufacturer states. The second thing to be tested was whether or not the safety latches could withstand the weight in the event of a hydraulic failure.

Anchor bolts test

The anchor bolts were placed into a sample piece of concrete, with similar properties as the floor of the garage, and using a hydraulic manifold they were pulled from the ground. The results were similar to that stated by the manufacturer making them suitable as anchorages.

Safety latches test

The mount plate was brought up to height and once the safety latch had been engaged, specified weights were loaded onto the arms in increments of 100kg, with the help of lifting equipment. Results were the safety latches held up to 3 tonnes capacity.
Once The tests were completed the budget was calculated to determine if the project was financially viable for the client’s needs.

Implementation

During the manufacturing stage of the hydraulic car lift, meetings with the client were made as often as possible to ensure that everything was as requested. Meetings were set up with the project supervisor, engineering team and the client to allow for the client to discuss, analyse and evaluate any designs from the project engineer. The customer specified that the lift has to reach a height of 2 metres to allow for them to work under the vehicle without strain, and that it is capable of 3 tonnes to allow for work vehicles such as vans to be serviced. Most importantly is that it has to be safe as the client wishes to have as few safety faults as plausible.

A second meeting was then arranged for them to review the selected design choices and to choose one they saw would be most suitable for them based on the justifications set out. Once reviewing the designs the final decision was made to choose design one, the two post design as it was well rounded with a good cost and safety involved.

Over a period of time, CAD drawings were designed and 3D models constructed giving an excellent visual aid for both the engineers and the client, who was happy with the overall design.

During the welding of the base plates, ensure the welds hold up by performing Non-Destructive testing (NDT). NDT is a testing and analysis technique used to evaluate the structure or system for characteristic differences or welding defects without causing damage to the original part. Due to the location of the welds, The best choice for the test would be using lasers, specifically laser profilometry. A high speed rotating laser light source is passed over the surface of the welds to detect corrosion, pitting erosion and cracks by detecting changes in the surface and displaying it via a 3D image.

Verification strategy

When revisiting the brief, The client requested a hydraulic car lift that he wishes to use to inspect and service vehicles and must be able to lift 3 tonnes off the 2 metres off the ground safely, all with a budget of £10,000 and must work safely.

Regular meetings allowed for the client to review the work and discuss the specifications and any changes that were needed, to ensure that they do meet their required specifications some actions that will be taken to verify if the hydraulic lift is capable of performing the taste required by the client will be:

sub-unit	What is required	Activity	Signature
Post	To hold everything together and be firmly mounted to the ground	Ensure that the material is strong enough and that mounting bolts are secured	
Arm	To hold the car in the mounting points.	Test the amount of weight until failure	
Mounting plate	Allows the arms to be mounted to the post	If all the fitments are correct and if it can move freely in the post	
Pin	Holds the arm onto the mounting plate	Test if the pin will break under the weight and that it is able to hold.	
Pump unit	Pumps hydraulic fluid to the cylinders	Ensure that the pressure is adequate and it operates properly	
Hydraulic cylinder	To provide the lifting power to the lift	It reaches the height of 2m and can lift 3 tonnes	

The product produced is capable of lifting a 3 tonne vehicle off of the ground by 2m which has been proven by the informal and formal tests completed to the lift. All of this has been completed within the 18 weeks and under the budget of £10,000

- strength
- Material Testing
- General inspections
- Costs
- Safety
- Ease of use

These processes will be compared with each design to check if the 3 chosen designs meet with the brief and specifications. This will be scored on a ten point scale with higher scores being better.

Hydraulic lift

	Design 1	Design 2	Design 3
Strength	7	8	5
Material Testing	9	7	8
General inspections	10	8	6
Costs	6	4	10
Safety	8	10	4
Ease of us	9	9	8
Total	49	46	41

When looking at the table it is clear that the first design is best suited for the clients needs based on the specifications required.

Costings

Hardware			
	Price per unit measurement(£)	required amount	actual price
S275Jr Channels beam (6 meters)	£22.75	6	£136.50
Paint (4 quart)	£40.00	4	£160.00
S275JR plates (4 meters)	£78.50	4	£314.00
Sr275JR mounting bracket material (1.5 meters)	£22.75	1.5	£34.13
Tube for legs, outer (3 meters)	£49.46	3	£148.38
Tube for legs, inner (3 meters)	£38.34	3	£115.02
Pump Unit			£220.00
10 pack of anchor bolts			£36.81
Hydraulic cylinder	£144.00	2	£288.00
Steel cable			£154.00
Pulley underbed		1	£69.00
Top Pulley		2	£78.50
Rubber Pads	£17.50	4	£70.00
Lock nuts for cable (pack of 4)		2	£17.89
Hydraulic Hose	£27.12	2	£54.24
Contractors			
Project engineer	£40/hr for 120hours		£4,800.00
Installation team			£1,000.00
Electrical engineers (circuit breaker and wiring)	Day job		£250.00
Welders	Mobile welding job £250-350		£275.00
engineering team	£10/hr for 120		£1,200.00
total			£9,421.47

As seen in the table above all costs were considered from small fasteners to main component materials. All these prices were calculated by the required amount and multiplying it by the price per unit, for any individual pieces or a bulk of items the required amount was either left blank or the required amount with the price of the total bulk. The overall price of the car lift was £9,421.47. well within the £10,000 budget and with £578.53 left over, which can be used for any replacement parts or maintenance requirements, such as paint.

Health and safety

Health and safety was a critical thing to think about during the project. The health and safety regulations that have been followed were:

- Health And Safety At Work Act 1974
- Provision of Use of Work Equipment Regulations 1998
- Lifting Operations And Lifting Equipment Regulations 1992
- Personal Protective Equipment At Work Regulations 1992
- Control Of Substances Hazardous to Health 2002

In case of any failures that could occur, safety latches are placed to catch the vehicle, which can be disengaged with a lever near the pump unit. Other things to help health and safety is training for the car lift. This will involve how to locate the arms under the vehicle properly to the correct mounting points. Another thing is the operation itself, with how to operate the lift, where the safety latch release is, etc.

Discussion

The initial objectives and schedule guided the project excently with everything being done at the correct time,despite some changes in the schedule.The objectives allowed for the engineering team to gain an understanding on what has to be done for the project and how it should also be done. The schedule was mandatory for keeping the 18-week project objectives en route to completion with each passing milestone.

Some challenges throughout the project was material selection, the initial choice of material was to be Corten grade A Steel however due to issues with supplying the material, it was opted to be changed to S275JR, as it was far more available to be purchased. Other issues were the fasteners for the posts as it was intended to use M20 bolts to directly bolt it into the ground alongside a sleeve that would slide into a hole in the concrete. Whilst able to handle the shear stresses acting upon them, They would not have been able to handle the pulling forces and would have been ripped from the ground. Changes were made to selecting anchor bolts as they were tested internally and externally and results showed that they were capable of handling the pulling forces acting upon them.

When sourcing a direct drive cylinder, the initially sourced product was not meant for car lifts and was not going to give the desired height of 2m, this was fixed by finding a new cylinder capable of lifting 3 tonnes to a height of 2m, which proved beneficial in the end as it came out cheaper than the first product.

Overall creation of the CAD designs and 3D models had no issues, As the supplied pump unit provided no downloadable file for a CAD drawing or 3D model a cuboid shape with provided dimensions was placed in the mounting point location.

Conclusions

In conclusion the client was happy with the final design and completed the hydraulic car lift. There were some troubles along the way with certain calculations and designing of the lift. Overall this was a successful project.

A powerpoint presentation was performed on the 30th of may and detailed the progress made up to that point. The presentation was performed to the engineer supervisor alongside the client. It would showcase the specifications, designs and design choice, discuss the current costs, what improvements will be made and what is going to be done. Overall the presentation was a success with the weakest point being visual showcasing of the presentation itself.

Acknowledgements

Project supervisor - Willie Livie
CAD Assistance - Kevin Dodd

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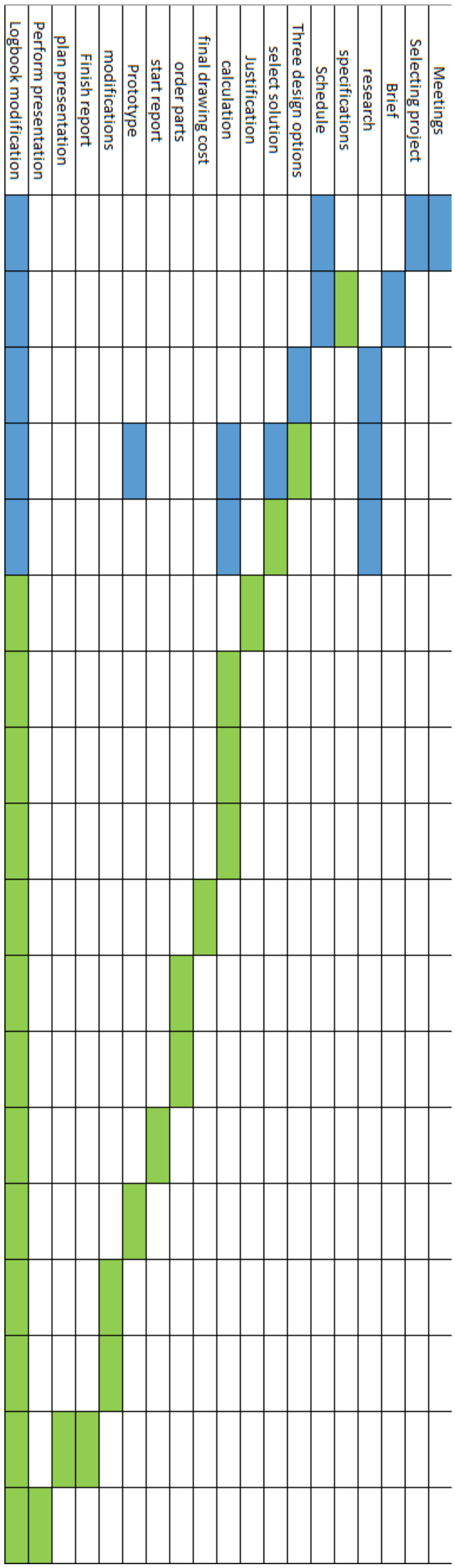
Appendix i

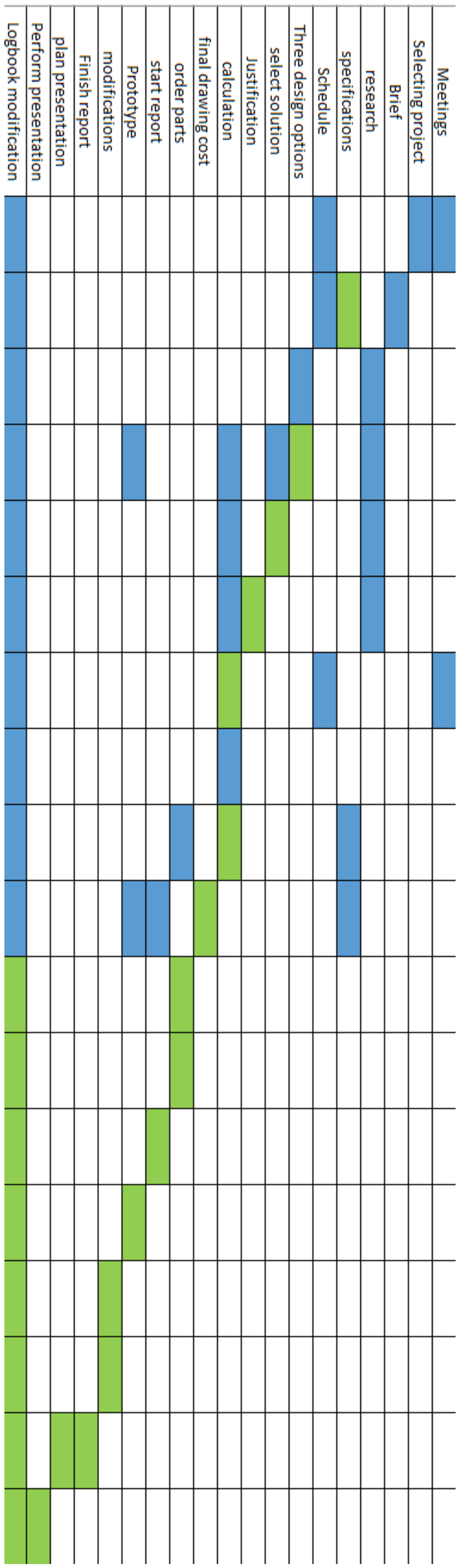
Week	1	2	3	4	5 (10/03)	6	7	8	9	10 (28/04)	11	12	13	14	15(02/06)	16	17	18
Meetings	■						■											
Selecting project	■																	
Brief		■																
research			■															
specifications		■																
Schedule	■	■																
Three design options				■														
select solution					■													
Justification						■												
calculation							■	■	■									
final drawing cost										■								
order parts											■	■						
start report													■					
Prototype														■				
modifications															■	■		
Finish report																	■	
plan presentation																	■	
Perform presentation																		■
Logbook modification	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Appendix ii

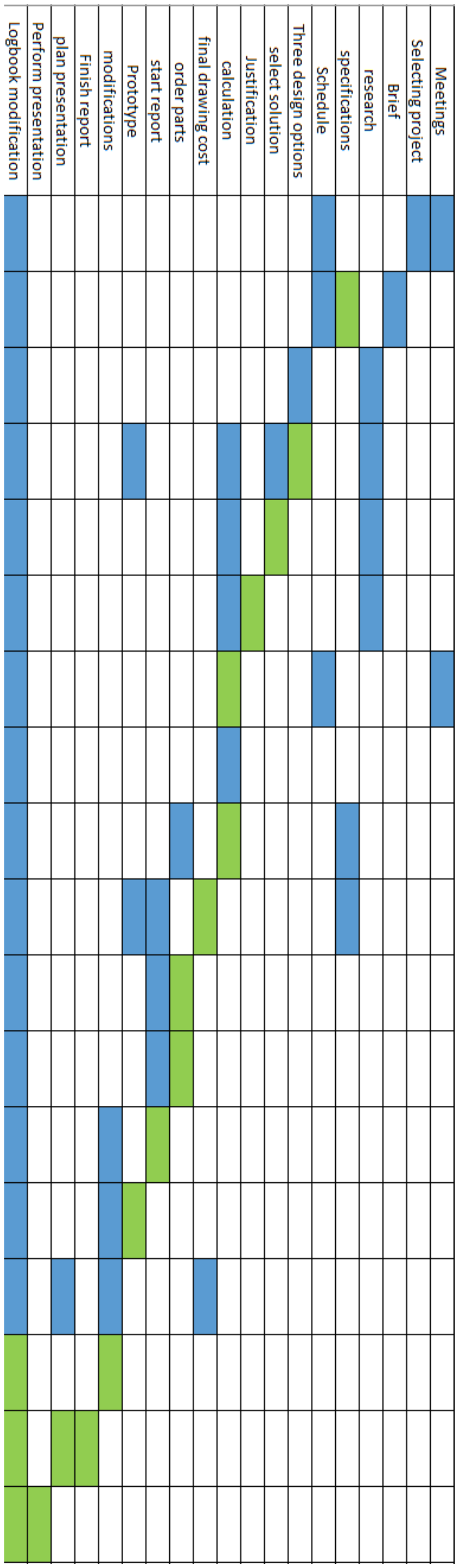


Meetings
Selecting project
Brief
research
specifications
Schedule
Three design options
select solution
Justification
calculation
final drawing cost
order parts
start report
Prototype
modifications
Finish report
plan presentation
Perform presentation
Logbook modification

Appendix iii

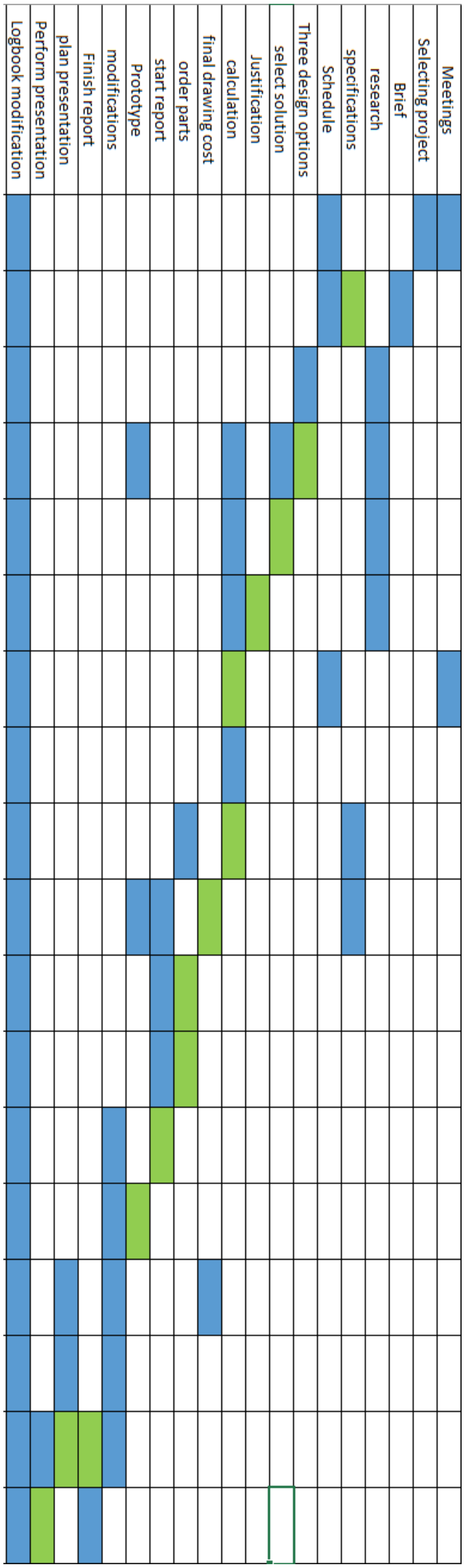


Appendix iv

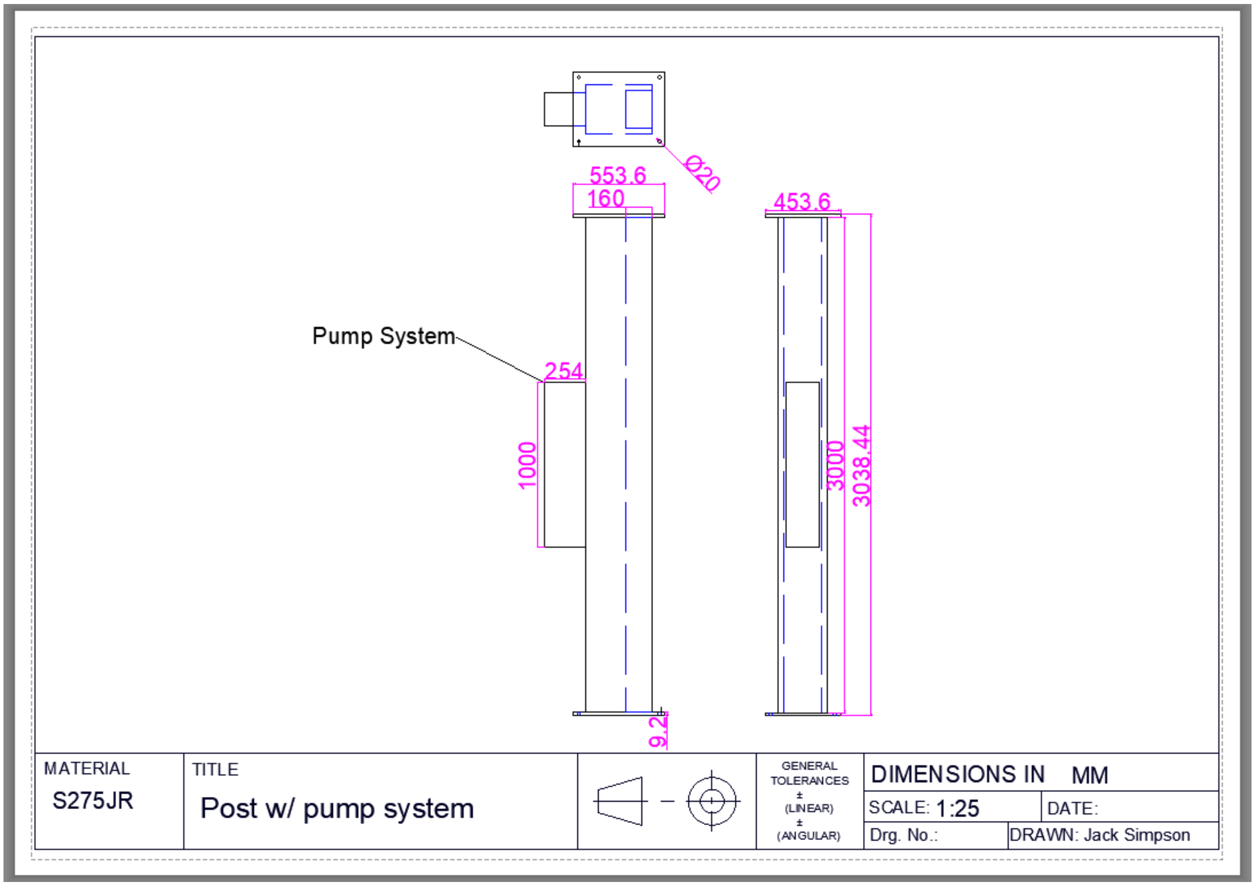


Meetings
Selecting project
Brief
research
specifications
Schedule
Three design options
select solution
Justification
calculation
final drawing cost
order parts
start report
Prototype
modifications
Finish report
plan presentation
Perform presentation
Logbook modification

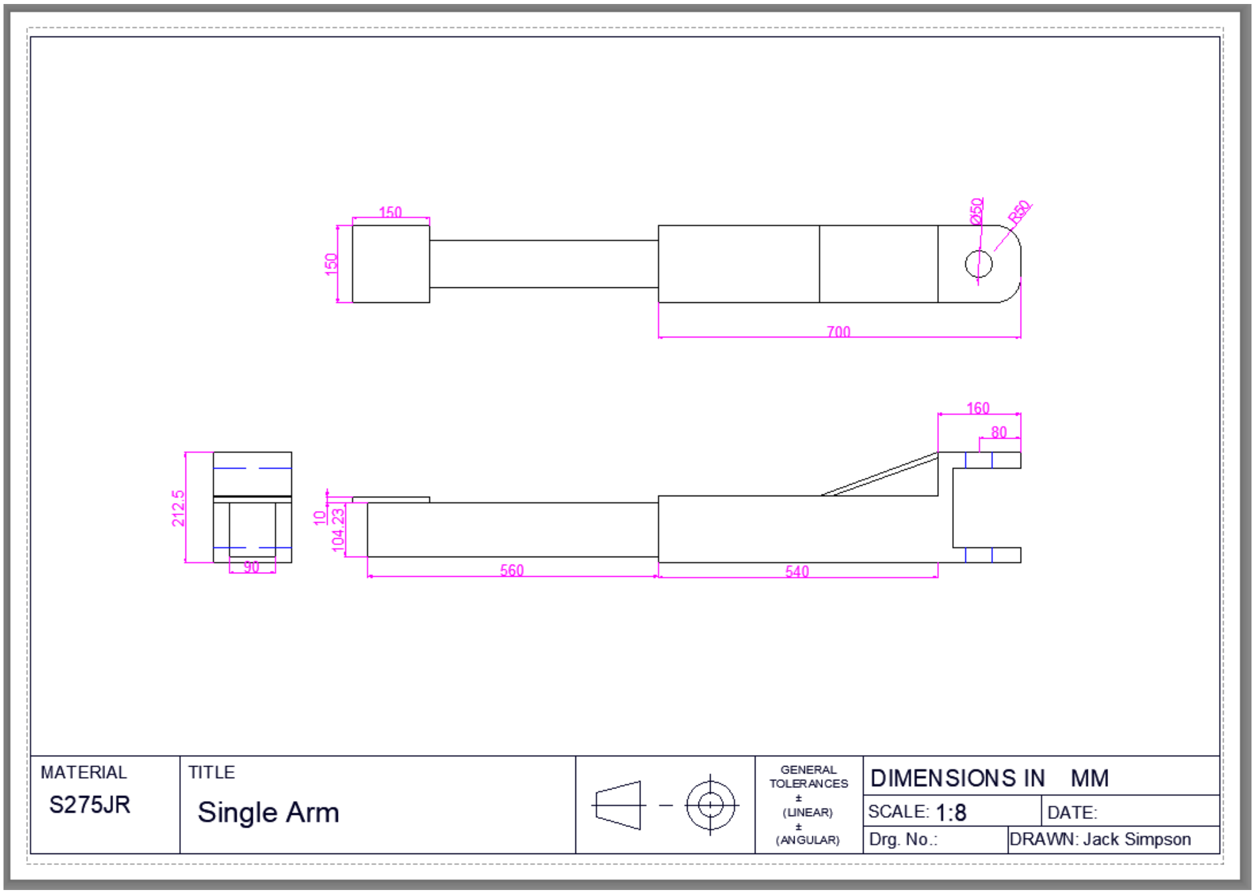
Appendix v


Meetings
Selecting project
Brief
research
specifications
Schedule
Three design options
select solution
Justification
calculation
final drawing cost
order parts
start report
Prototype
modifications
Finish report
plan presentation
Perform presentation
Logbook modification

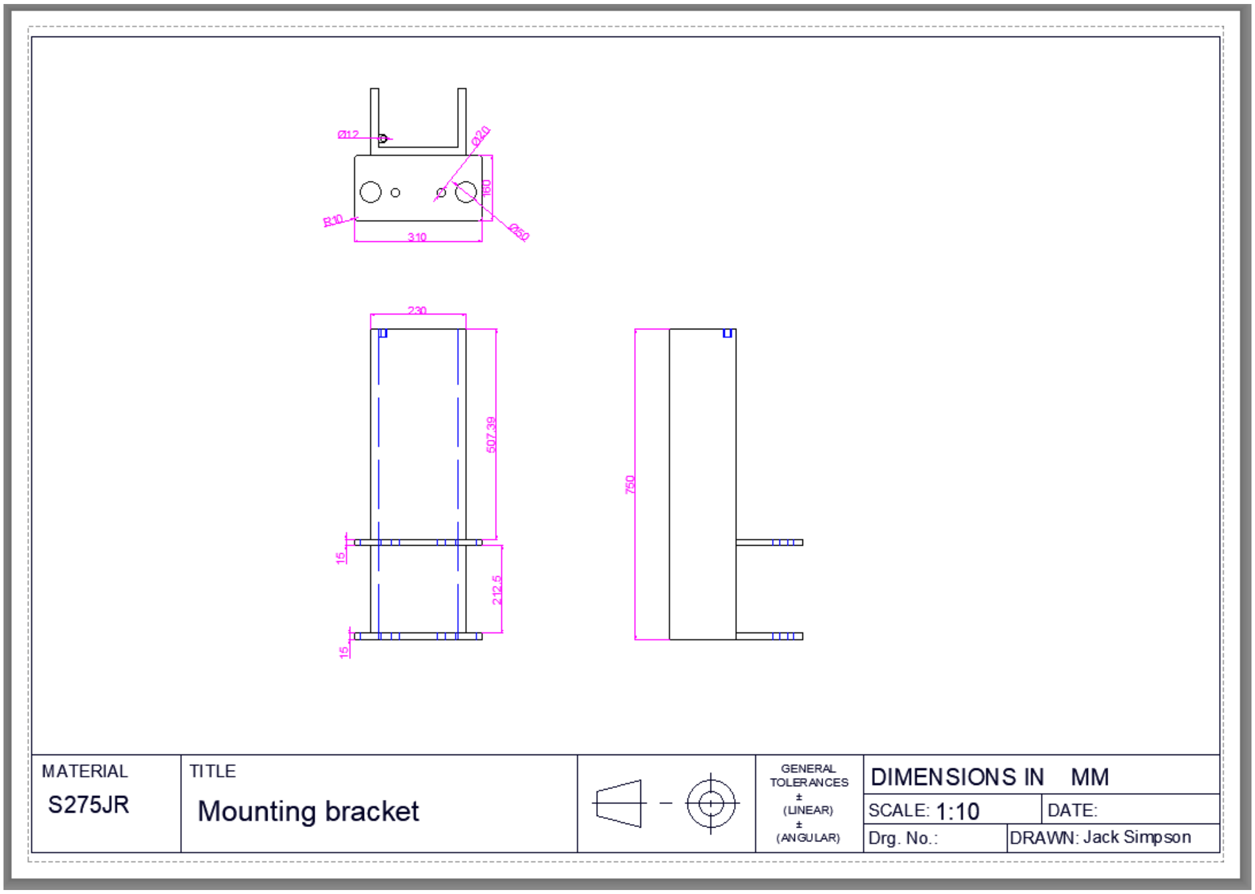
Appendix vi


Ø20
553.6
160
453.6
Pump System
254
1000
3000
3038.44
9.2
MATERIAL
S275JR
TITLE
Post w/ pump system
GENERAL TOLERANCES
± (LINEAR)
± (ANGULAR)
DIMENSIONS IN MM
SCALE: 1:25
DATE:
Drg. No.:
DRAWN: Jack Simpson

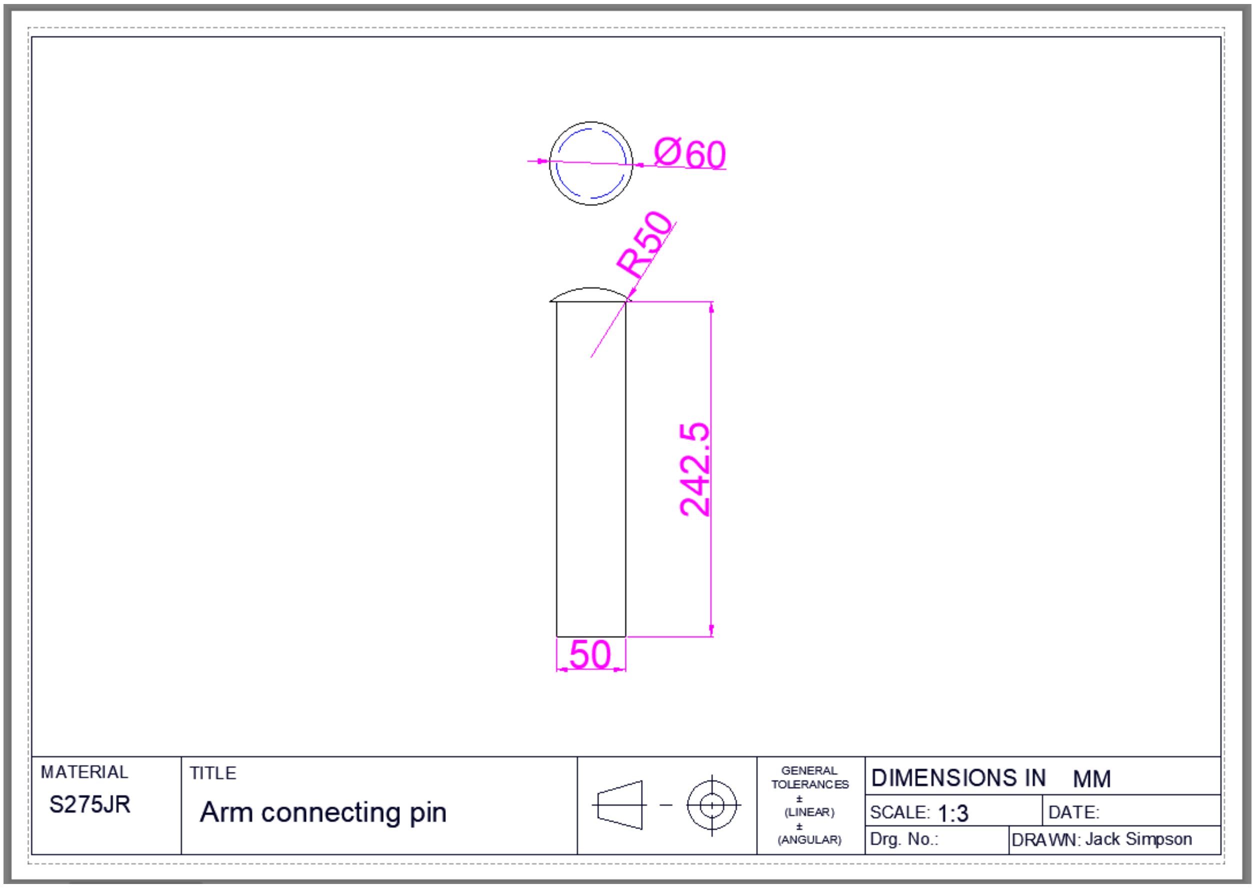
Appendix vii



Appendix viii

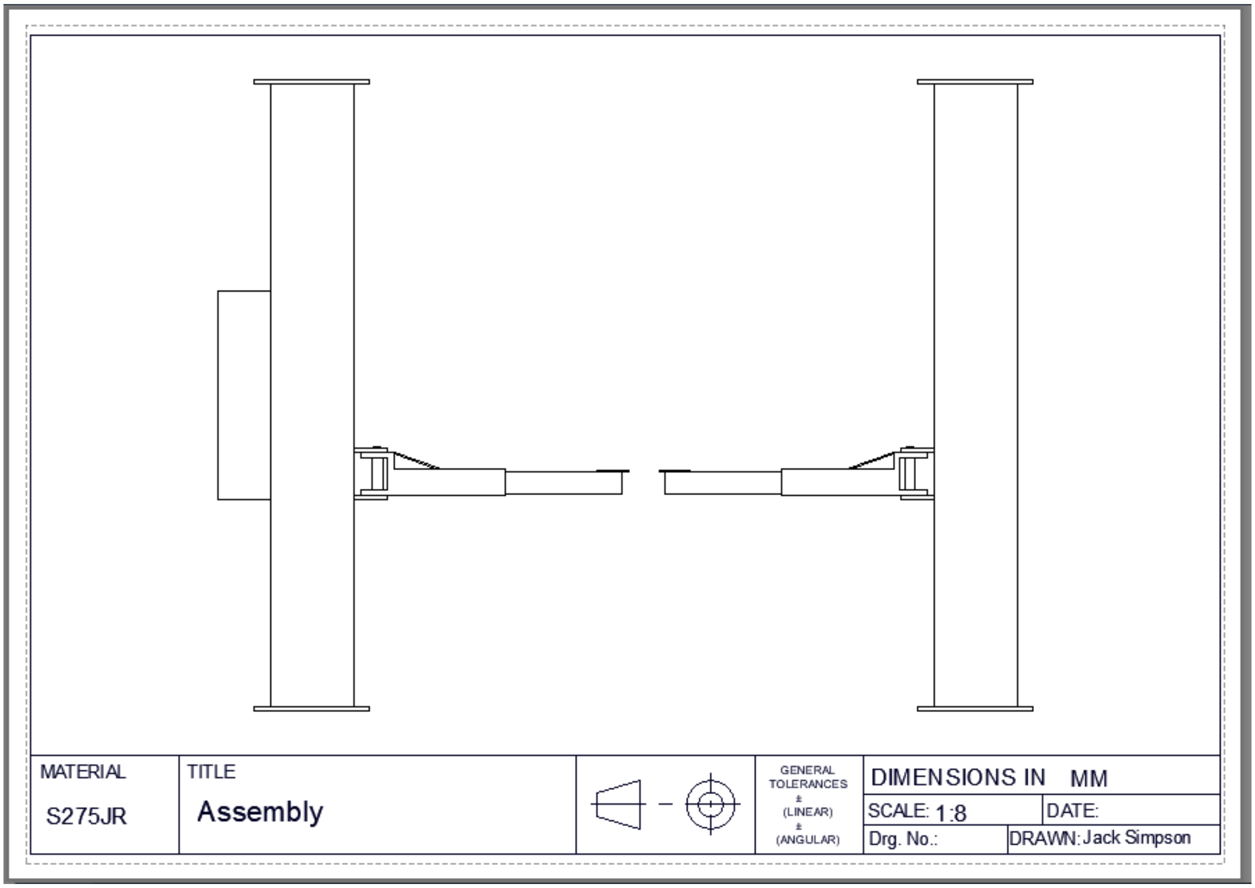


Appendix ix

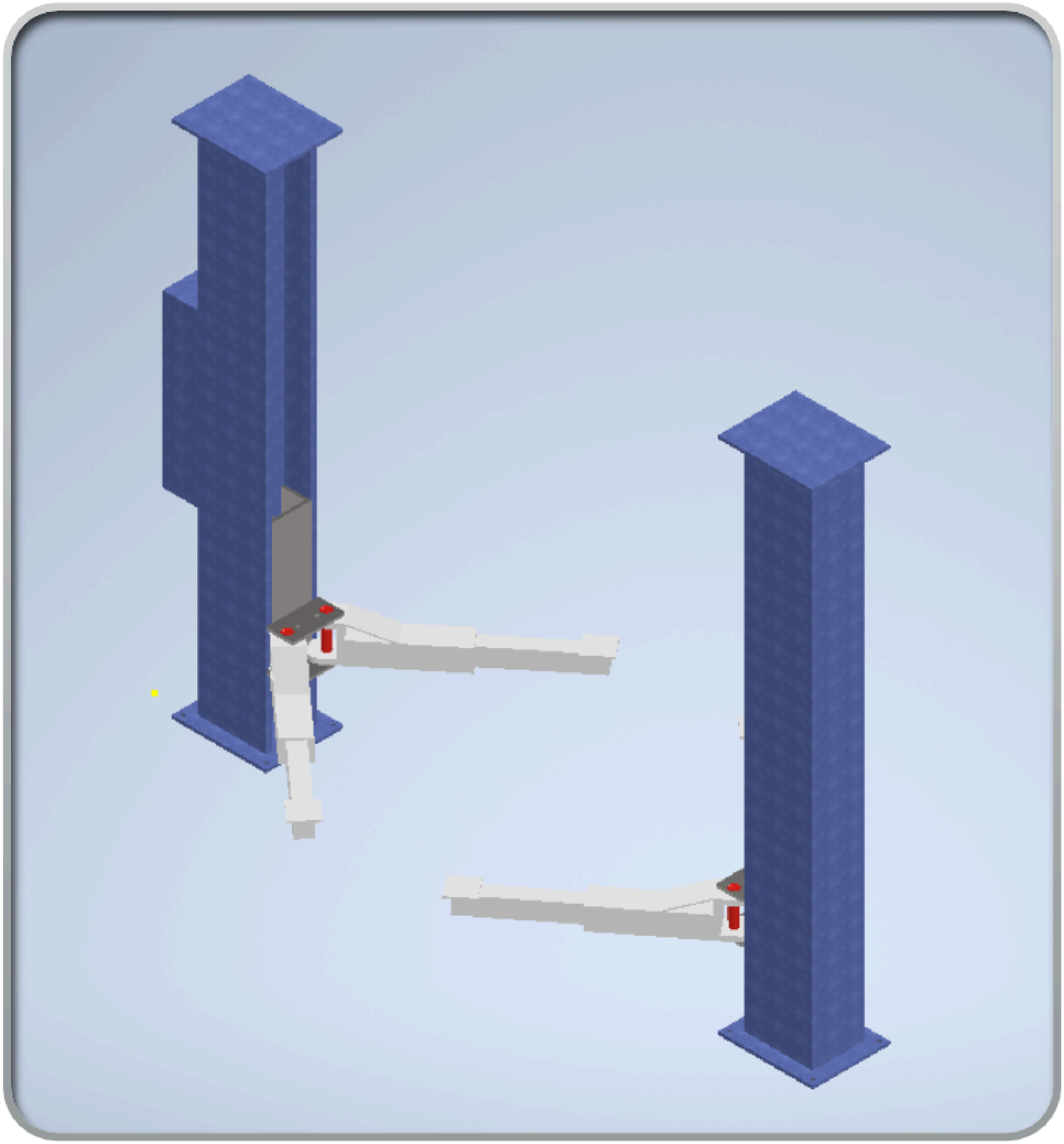


Ø60
R50
242.5
50
MATERIAL
S275JR
TITLE
Arm connecting pin
GENERAL TOLERANCES
± (LINEAR)
± (ANGULAR)
DIMENSIONS IN MM
SCALE: 1:3
DATE:
Drg. No.:
DRAWN: Jack Simpson

Appendix x


MATERIAL
S275JR
TITLE
Assembly
GENERAL TOLERANCES
± (LINEAR)
± (ANGULAR)
DIMENSIONS IN MM
SCALE: 1:8
DATE:
Drg. No.:
DRAWN: Jack Simpson

Appendix xi



Appendix xii

$$F = ma$$

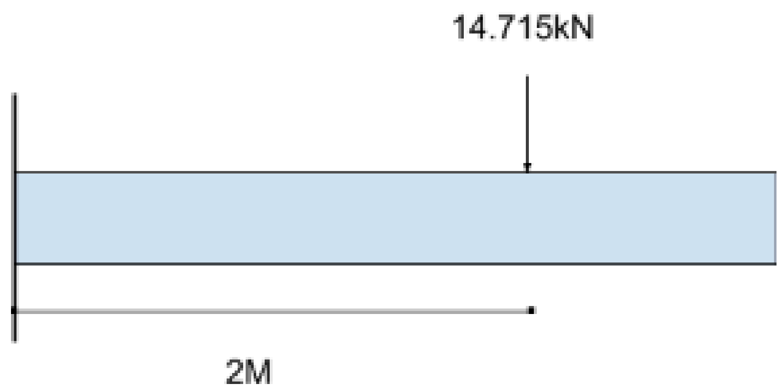
$$F = 3000 * 9.81$$

F = 29430N

2 posts = 29430N
1 post = 14715N

4 Arms = 29430N
1 arm = 7357.5N

Think of the Post as a Cantilever



Most likely point of failure will be at max height, 2m

$$\Sigma M = \Sigma F$$

$\Sigma M = 0$ about support

$$M_A + (R_A * 0) + (14.715 * 2) = 0$$

$$M_A = -29.43kN$$

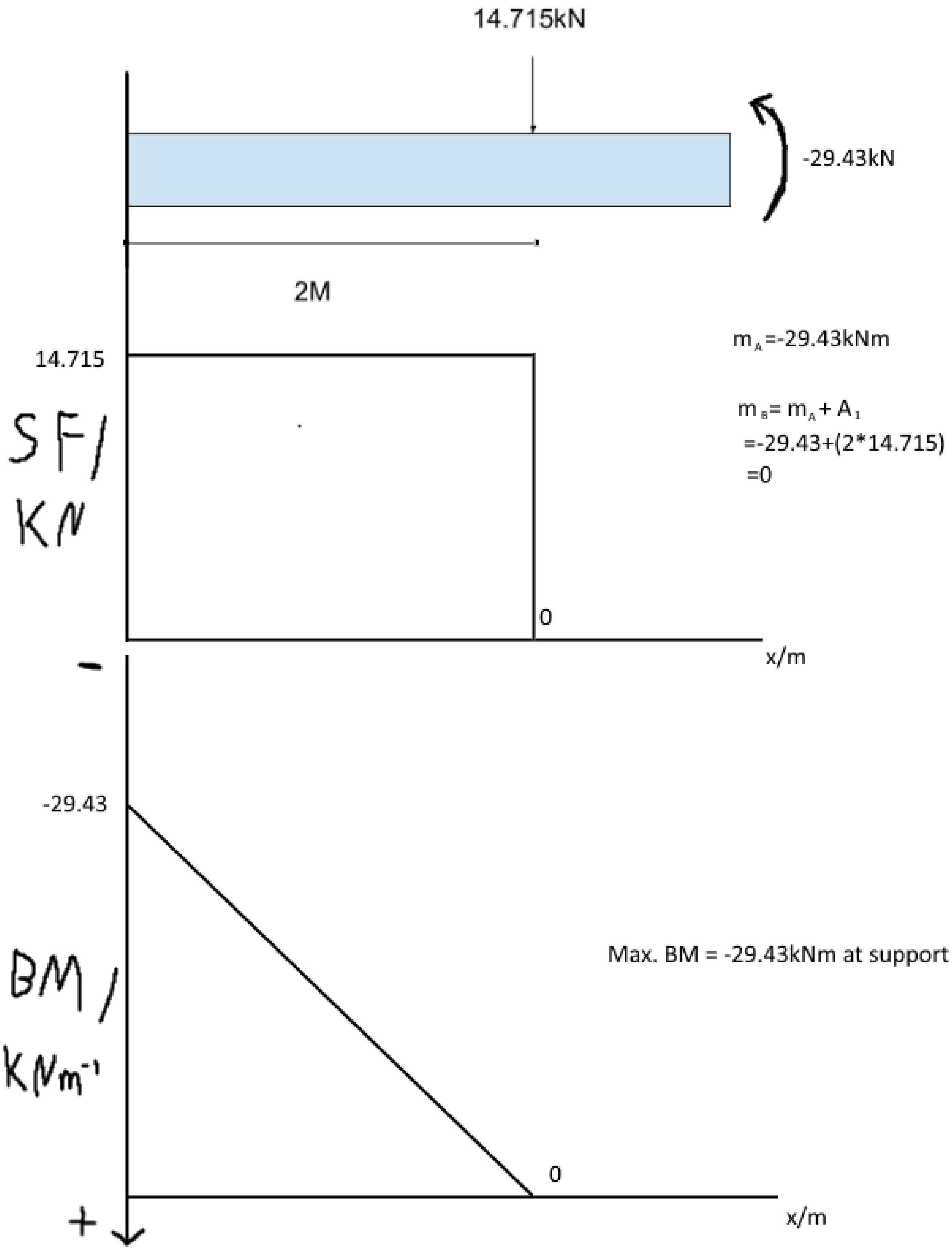
MAX BM at Fixing moment provided by support

$$R_A = \Sigma F = 0$$

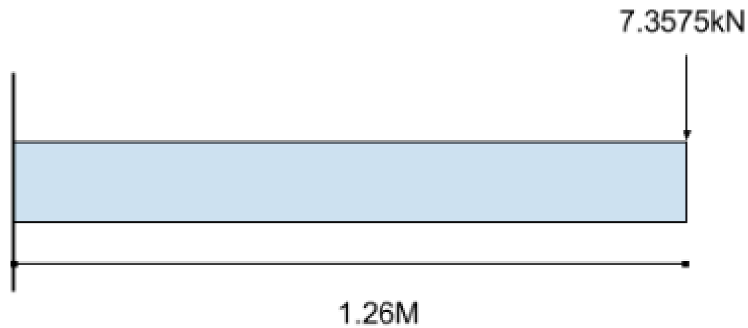
$$R_A - 14.715 = 0$$

$R_A = 14.715$kN

Appendix xiii



Appendix xiv



$$\Sigma M = \Sigma F$$

$$\Sigma M = 0 \text{ about support}$$

$$M_A + (R_A * 0) + (7.3575 * 1.26) = 0$$

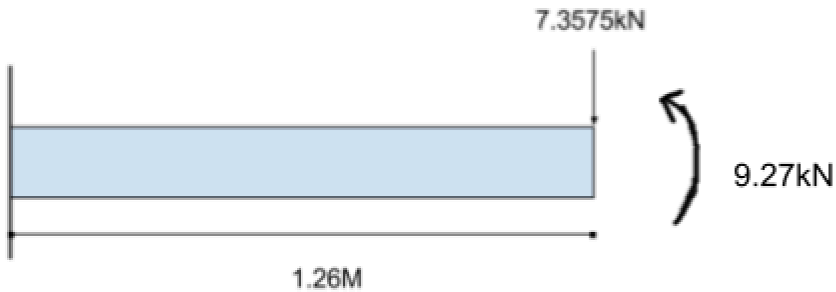
$$M_A = -9.27kN\text{m}$$

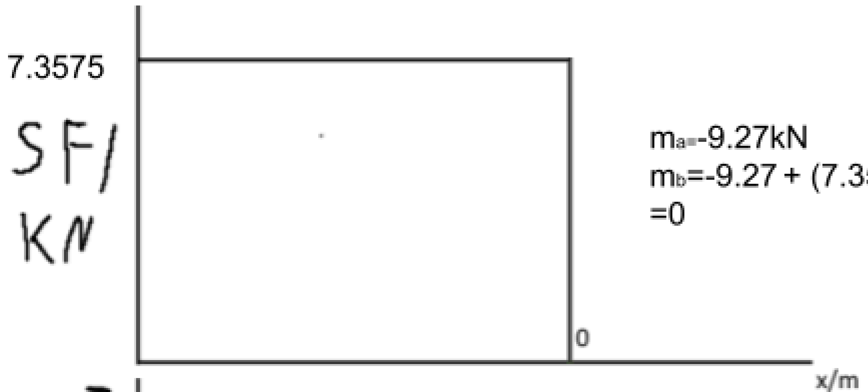
MAX BM at Fixing moment provided by support

$$R_A = \Sigma F = 0$$

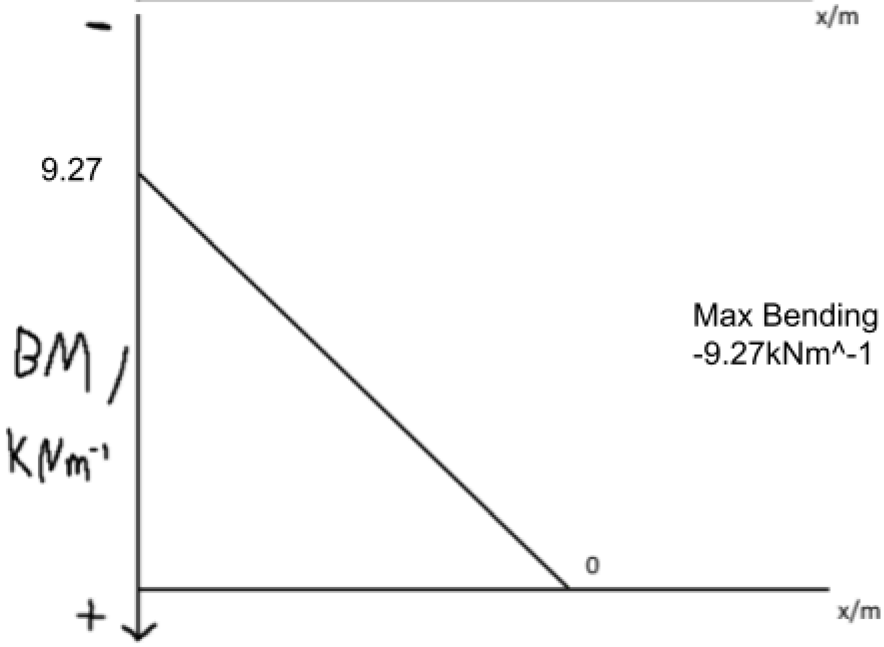
$$R_A - 9.27 = 0$$

$$R_A = 9.27\text{kN}$$





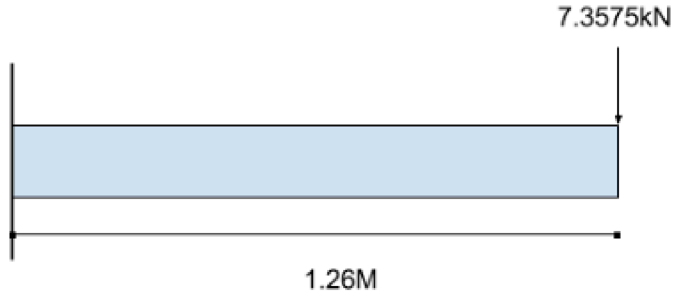
m_a=-9.27kN
m_b=-9.27 + (7.3575*1.26)
=0



Max Bending moment =
-9.27kNm^-1

Appendix xv

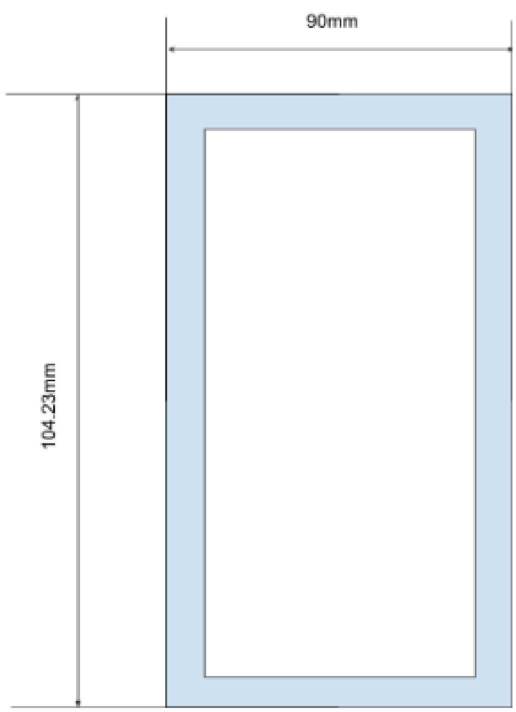
For a single leg 29.43/4=7.3575kN



$$M = -WL$$

$$\frac{dy}{dx} = -\frac{WL^2}{2EI}$$

$$y = -\frac{wL^3}{3EI}$$



Second Moment area

$$I = \frac{BD^3 - bd^3}{12}$$

$$I = \frac{90*(104.23)^3 - 65*(79.23)^3}{12}$$

$$I = 5,798,555.047mm^4$$

$$I = 5.798555047 * 10^6 mm^4$$

$$I = 5.799 * 10^6 mm^4$$

$$I = 5.799 * 10^{-6} m^4$$

Appendix xvi

$$M = -WL$$

$$M = -7.3575 * 1.26$$

$$M = -9.27045$$

$$M = -9.270\text{kNm}$$

$$\frac{dy}{dx} = -\frac{WL^2}{2EI}$$

$$\frac{dy}{dx} = -\frac{7.3575*10^{-3} * 1.26^2}{2*210*10^9*5.799*10^{-6}}$$

$$\frac{dy}{dx} = -4.79588722 * 10^{-3}$$

$$\frac{dy}{dx} = -4.796 * 10^{-3}\text{Number is a ratio}$$

$$y = -\frac{wL^3}{3EI}$$

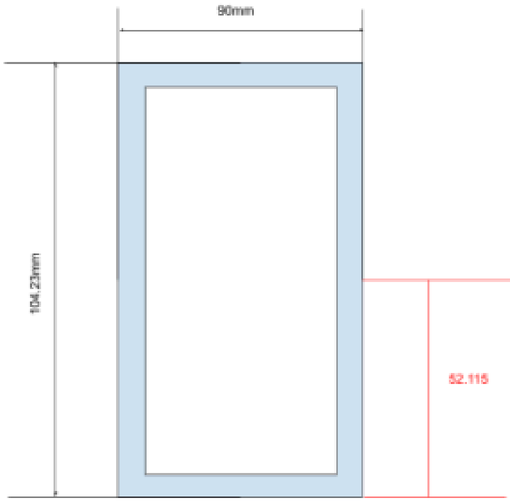
$$y = -\frac{7.3575*10^{-3} * 1.26^3}{3*210*10^9*5.799*10^{-6}}$$

$$y = -4.028545266 * 10^{-3}$$

$$y = -4.029 * 10^{-3}\text{m}$$

$$y = -4.029\text{mm @ free end}$$

Appendix xvii



$$A_t = A_1 - A_2$$

$$A_t = (104.23 * 90) - (65 * 79.23)$$

$$A_t = 4230.75mm^2$$

y=52.115mm from reference axis

$$I_{na} = I + Ah^2$$

$$I_{na} = 5.799 * 10^6 + (4230.75 * 52.115^2)$$

$$I_{na} = 17,289,603.72mm^4$$

$$I_{na} = 17.28960372 * 10^6 mm^4$$

$$I_{na} = 17.28960372 * 10^{-6} m^4$$

$$\sigma = \frac{9.27*10^3*52.115*10^{-3}}{17.28960372*10^6}$$

$$\sigma = 27941996.69Nm^{-2}$$

$$\sigma = 27.94MNm^{-2}$$

Factor of safety of 5

$$ultimate\ load = FoS * allowable$$

$$ultimate\ load = 5 * 28.42$$

$$ultimate\ load = 142.1MNm^{-2}$$