

UWTSD

WISA



Engineering Problem.

Engineering Design ACHA4001

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1 Introduction

1.1 Interpretation of client brief

The client runs a production line where aluminium components are anodised by being hoisted into large stainless-steel tanks containing 30% sulphuric acid at 25 degrees Celsius to protect them from degradation and improve their aesthetic. When these tanks are not in use, they have a removable lid that must be applied due to health and safety reasons.

However, this cover requires two people either side of it to manoeuvre because it is made from 5mm thick stainless-steel. As a result of this, many of the client's staff have stated that this is a difficult process, and their health and safety officer has deemed this task a major risk to employees.

Therefore, the aim of this project is to redesign or improve upon the current design of the lid to make it suitable to be operated safely by a single person. Considering the current material of the lid and its dimensions, there are a multitude of opportunities for improvement, ranging from designing a cover out of a lighter material, to designing a lifting aid, or an automated design. On the other hand, it must be taken into consideration what conditions and elements the new design will be subject to and must withstand, along with the client's stated requirements, which include no alterations to the tank, and needed overhead clearance whilst in operation.

2 Key Legislations

2.1 Health And Safety Regulations

1. Health and Safety at Work Act 1974 (HSWA).

The HSE (2020), states that the HSWA is the primary legislation that covers and enforces health and safety within businesses across the UK. This legislation outlines the duties that employers, employees, customers and the duties certain self-employed persons have towards themselves and others.

2. Manual Handling Operations Regulations 1992 (MHOR).

Health and safety executive (2019a), explains how the MHOR refers to an employer's responsibility to protect their employees from the risk of injury during hazardous manual handling in the workplace.

3. Provision and Use of Work Equipment Regulations 1998 (PUWER).

The HSE (2024) informs that PUWER requires that equipment and machinery used or owned by employers is suitable for the intended use and maintained with regular inspection and is correctly installed with suitable health and safety measures implemented.

4. Control of Substances Hazardous to Health Regulations (COSHH) 2002.

Health and Safety Executive (2019b) states that this law demands that employers must adequately control their employee's exposure to Hazardous substances and materials within the workplace.

2.2 Material And Structural Regulations

1. BS EN 1993 (Eurocode 3: Design of Steel Structures).

Eurocode 3, as explained by European Commission (n.d), applies to the design and engineering works with steel, is complies with the safety, serviceability, fire resistance and durability requirements of steel structures.

2. BS EN 1090-1 (Execution of Steel and Aluminium Structures).

Explained by Charles Day Steels (2024), this European standard ensures that structural components made with steel or aluminium must meet performance, quality and safety requirements before they may enter the market.

2.3 Environmental Regulations

1. Environmental Protection Act 1990.

As explained by Newman, O (2025), this act was implemented for management and control of environmental pollution, it requires businesses and companies to ensure their waste is handled, stored and disposed of correctly and responsibly.

2.4 Industry-Specific Standard

1. ISO 9001 (Quality Management Systems).

ISO (2015) states that this standard is recognised for quality management, it aids organisations in achieving improved performance, meeting customer expectations and demonstrating their commitment to establishing, implementing and maintaining quality, along with continuing to improve their quality management system (QMS).

3 Specification

Time	15 Days.
Target Market	. The singular company and their multiple sites.
Function	. Product will be used on the anodising tanks. . Needs to be operatable by one person. . Needs to be safe. . Needs to allow lid to seal against the tanks.
Design Constraints	. Must be able to withstand the temperature and acidity that it will be subject to. . Tank dimensions and material must not be altered. . Must be cost efficient. . Overhead clearance is needed.
Size	. Product must be lightweight. . Must fit on a Tank that is 1000mm tall, 1020mm wide and 1770mm long.
Aesthetics	. Aesthetics is not the top priority of this design.
Durability	. The product will be required to last with low maintenance. . The gas struts will need to be replaced or re-gassed every 3-10years (Sgs-engineering (2025)), this may change depending on the frequency of use.

Materials	. Materials need to be heat resistant and chemically resistant to 30% Sulphuric acid. . Materials need to be strong and durable. . Materials need to require minimal maintenance.
Safety	. Materials required are heavy, must be careful when transporting. . Design needs to cause minimal disruption to the busy work area around, therefore needs to be compact.
Cost	. Must be low cost as a couple hundred need to be produced.
Environmental Issues	. Can use recycled steel. . Source from eco-certified suppliers. . Consider using renewable energy sources in the fabrication process. . Ensure use of scrap recycling programs. . Ensure number of defective parts is reduced as much as possible. . Use low volatile organic compound coatings or water-based alternatives to coat the steel. . Use fume extraction systems. . Source materials locally.
Manufacture	. Couple hundred designs require manufacturing.
Testing	. Dimensions and alignment must be inspected. . Weld integrity must be assessed. . Load testing must be carried out to ensure design meets the safety standards.

4 Time Plan

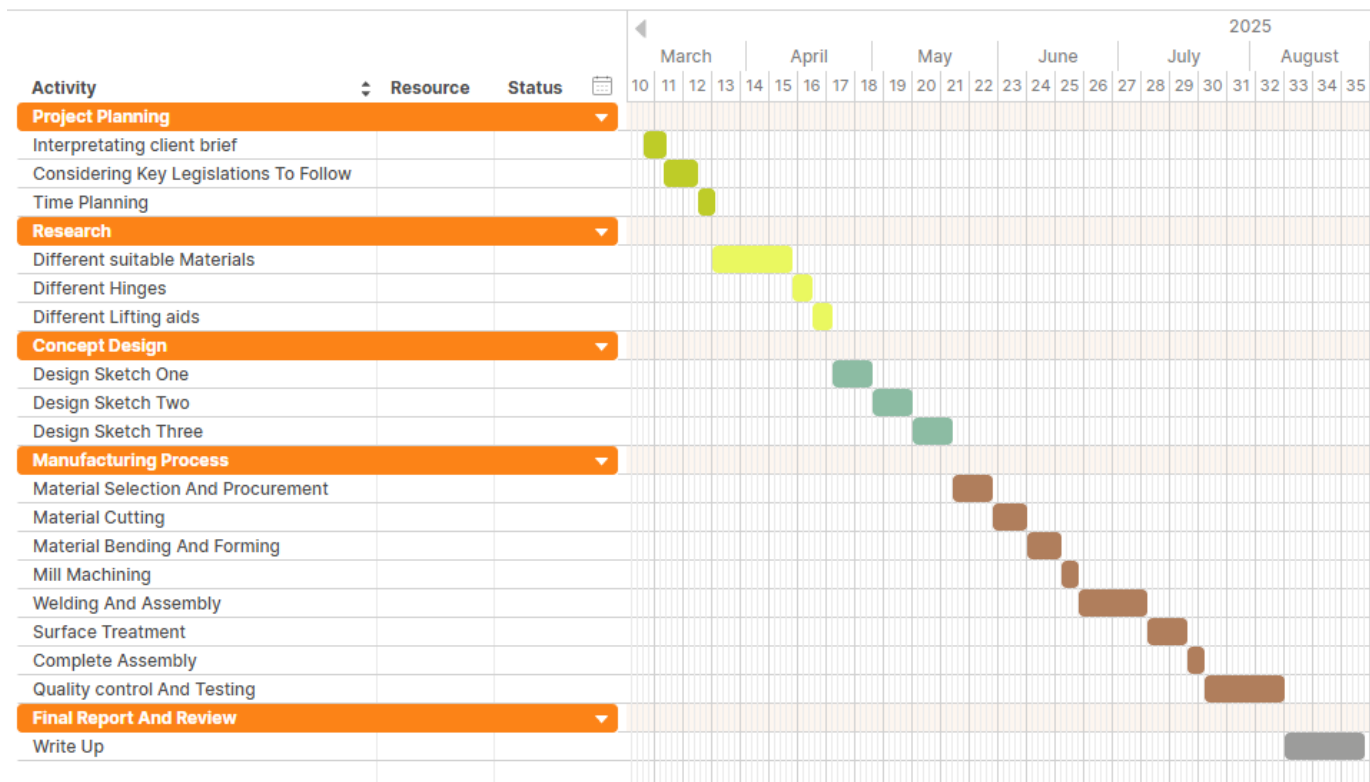


Figure 1: Gant Chart.

5 Research

5.1 Material Research

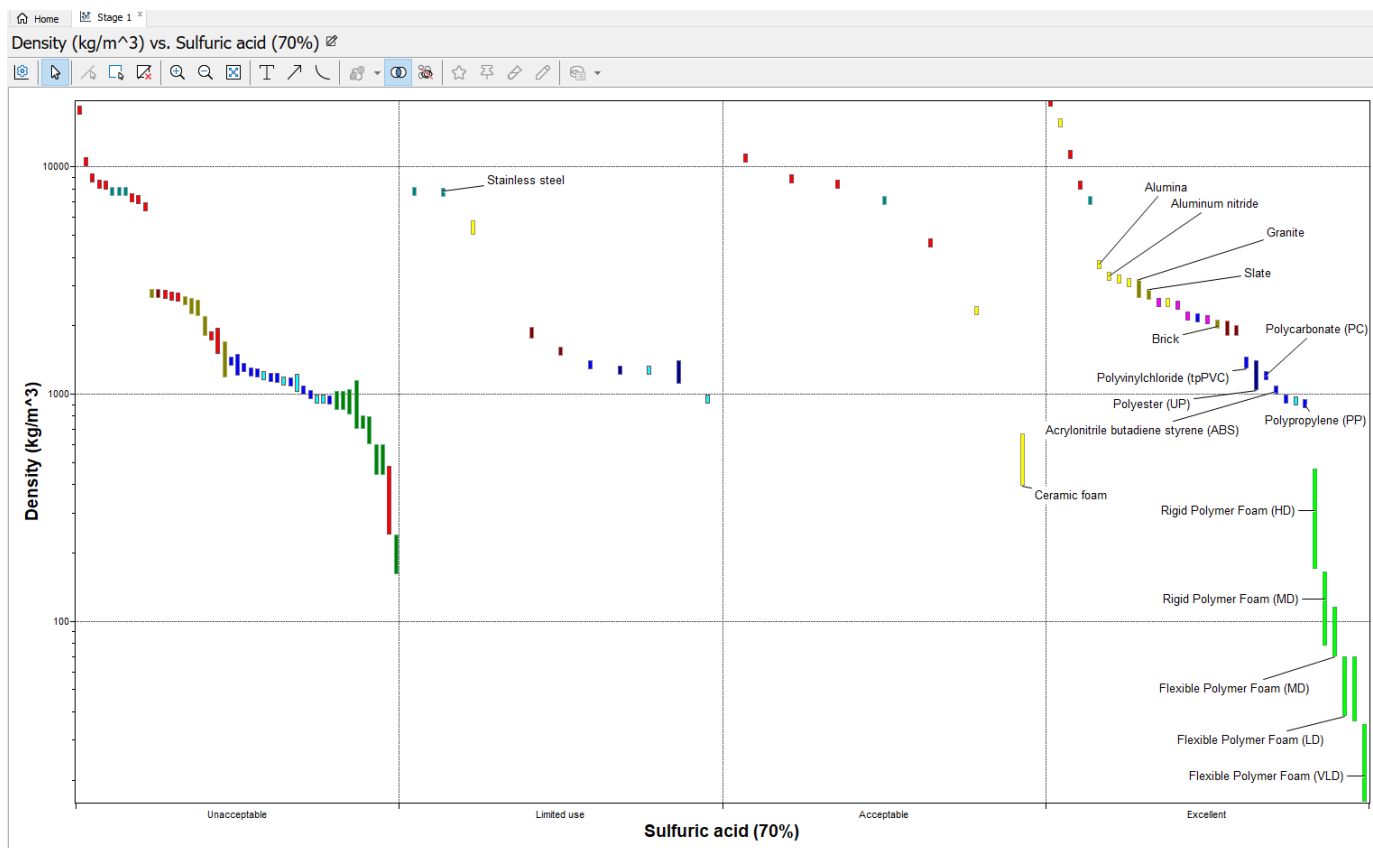


Figure 2: Chart showing the Density of materials against 70% Sulphuric Acid.

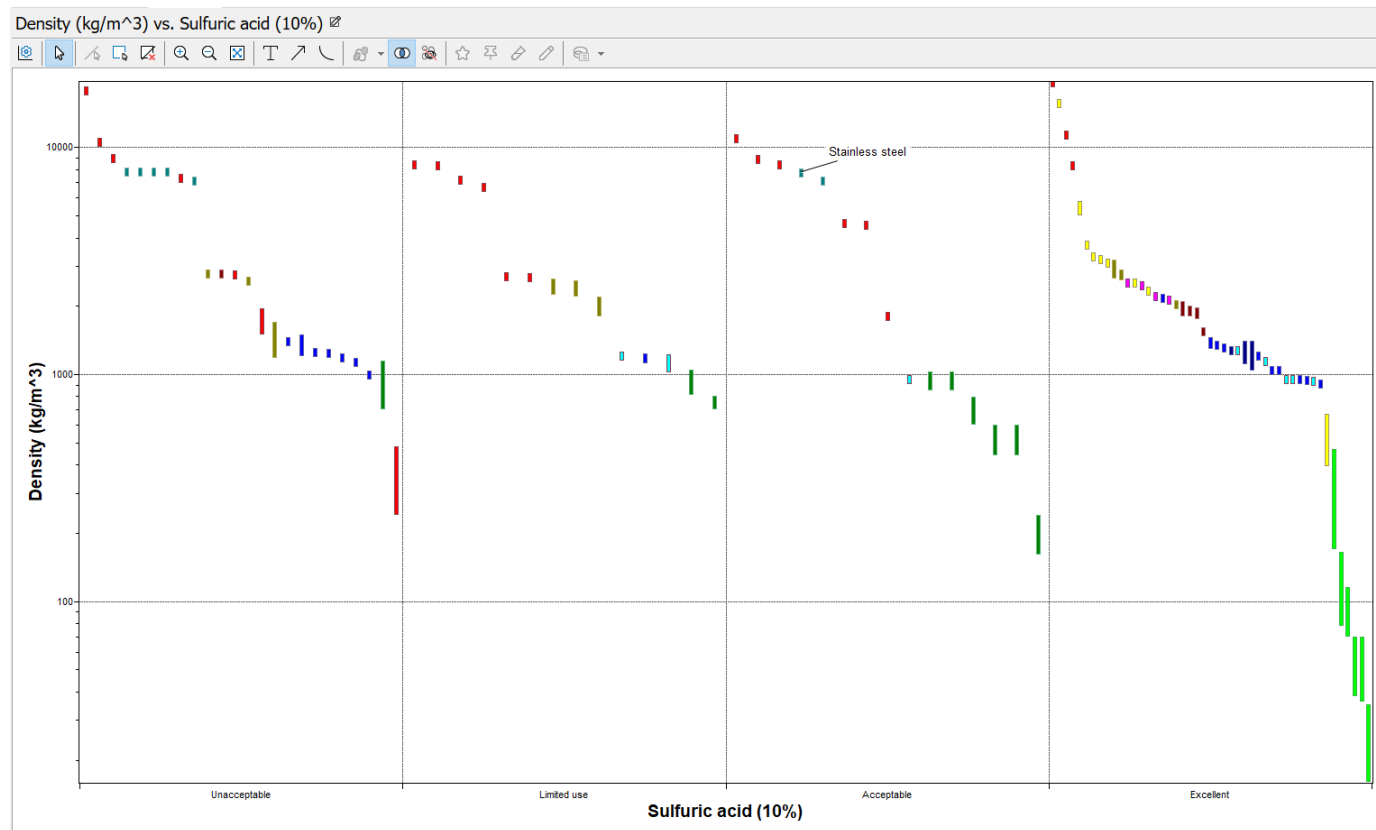


Figure 3: Chart showing the Density of materials against 10% Sulphuric Acid.

Figures 2 and 3 display how Stainless Steel, may not be the optimal material to use for this process, not only is it heavy to use as a lid that requires manual handling, but it is also not the most suitable to use in unison with Sulphuric acid, this is because at 10% Sulphuric Acid it is within the acceptable category, and in the limited use section for 70% Sulphuric Acid. This suggests that, for use with 30% Sulphuric Acid, it will range between the limited use and acceptable category, this indicates that the current setup requires regular maintenance, which may result in increased cost and possible safety risks if this maintenance and inspection is not carried out. This suggests that a more durable material could be utilised in the lid design.

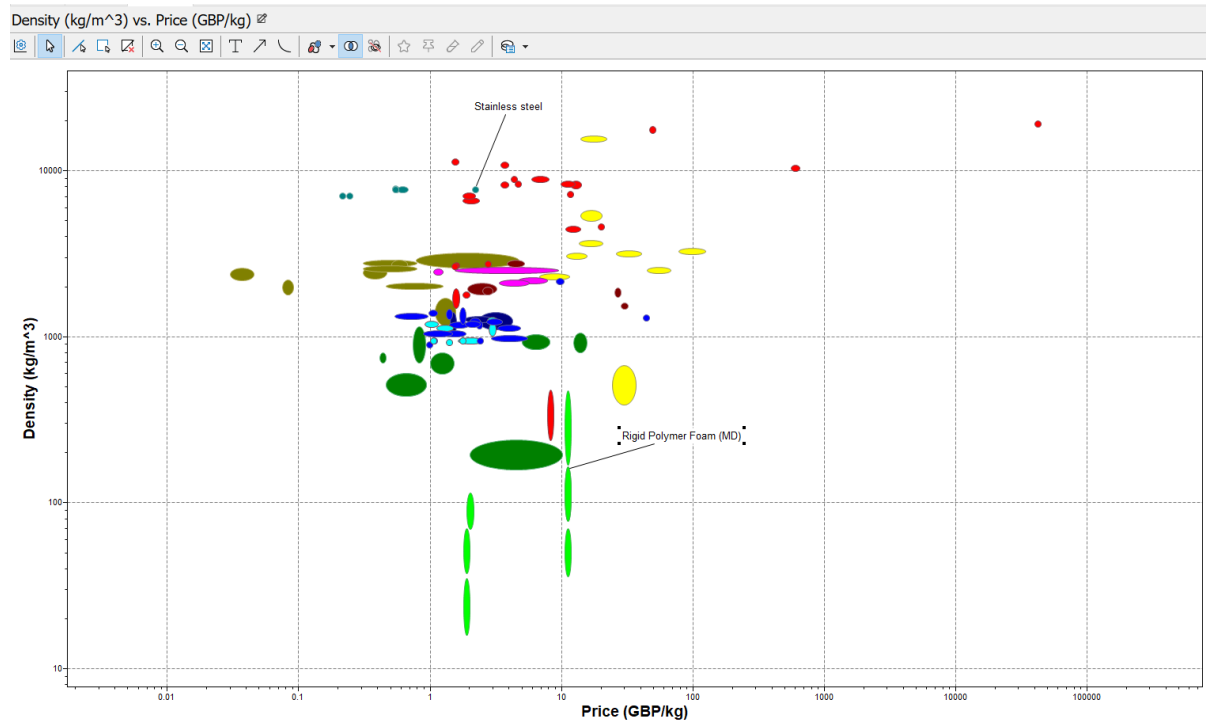


Figure 4: Graph of Material Density against Material Price.

With the chart in figure 4 it is visible that although amongst the densest materials, steel is relatively affordable. However, the data indicates that there are some materials that are more durable against Sulphuric Acid, and more lightweight, that aren't much more expensive than stainless steel, for example Rigid Polymer Foam (MD). This suggests that if a material change was to be utilised it may increase the investment into the upgrade.

On the other hand, figure 5 below displays the maximum temperatures materials can withstand against their densities. This chart shows that, although some materials are more chemically resistant to 30% Sulphuric Acid than Stainless Steel, they have a lower maximum temperature that they can withstand in comparison to Stainless Steel which has a maximum service temperature of around 750°C.

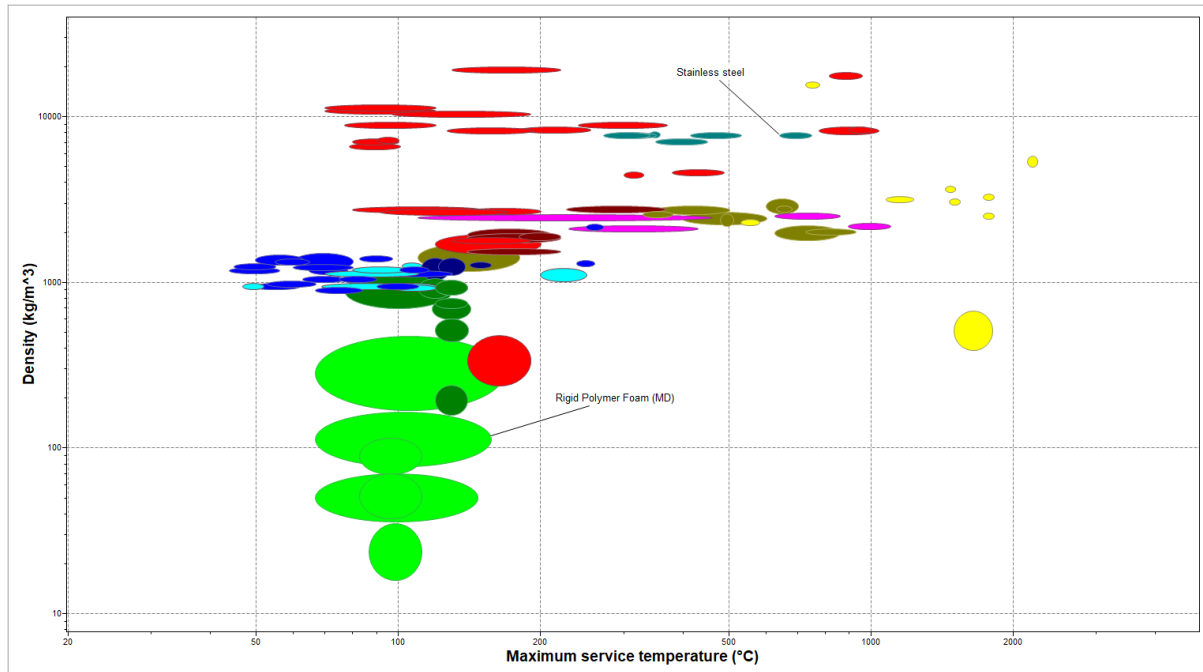


Figure 5: Chart of Material Density against Maximum Service Temperature.

These charts help highlight the desired material properties that must be considered if the altered lid design includes replacing the steel lid with another, lighter material to make lifting easier.

5.2 Support/Lifting/Bracket Mechanisms

There is an endless selection of brackets and lifting aids that can be considered to improve this design, making this route highly desired when tackling the task at hand.

For example, there are lifting hinges and piano hinges. Lifting hinges allow the cover to pivot open instead of having to be fully removed, reducing the amount of heavy lifting required. Piano hinges are long, continuous support hinges, this allows weight to be distributed more evenly, again reducing the heavy lifting required. In addition, there are sliding track brackets that enable the lid to simply slide horizontally out of the way instead of being lifted.

On the other hand, lifting aids can be used in unison with these different brackets to further improve the design and reduce the intensity of manual lifting required, making it more than possible for a single person to remove and replace the cover safely.

Firstly, gas struts are an excellent, cost-efficient, extremely effective and easy aid to use, they provide counterbalance assistance to make lifting drastically easier, they don't require any external power to function and are simple to install. However, it is important to note that the price may vary and can become quite expensive depending on the quality, strength and size of the strut, they may also need replacing after extended usage as they may eventually fail. Moreover, spring-assisted hinges are also a cost-friendly option that are reliable and require minimal maintenance as they involve using heavy-duty springs to reduce the force needed to lift the cover.

Finally, cantilevers are a lifting aid that extends horizontally and is supported at one end, this is the end that the structure relies on for strength and rigidity to support the weight of the load on the free, horizontal end. A cantilever would allow the cover to swing open instead of lifted completely off, this would reduce the manual handling requirement whilst also keeping the cover safely attached to the tank. Furthermore, cantilevers can be cost-effective as they can be built using simple materials such as steel tubing or reinforced aluminium, they are space efficient by keeping the lid attached and close to the tank, eliminating the need for storage space for the removed lid, they are also easy to operate with simple push and pull motions.

6 Design Concepts

6.1 Design One

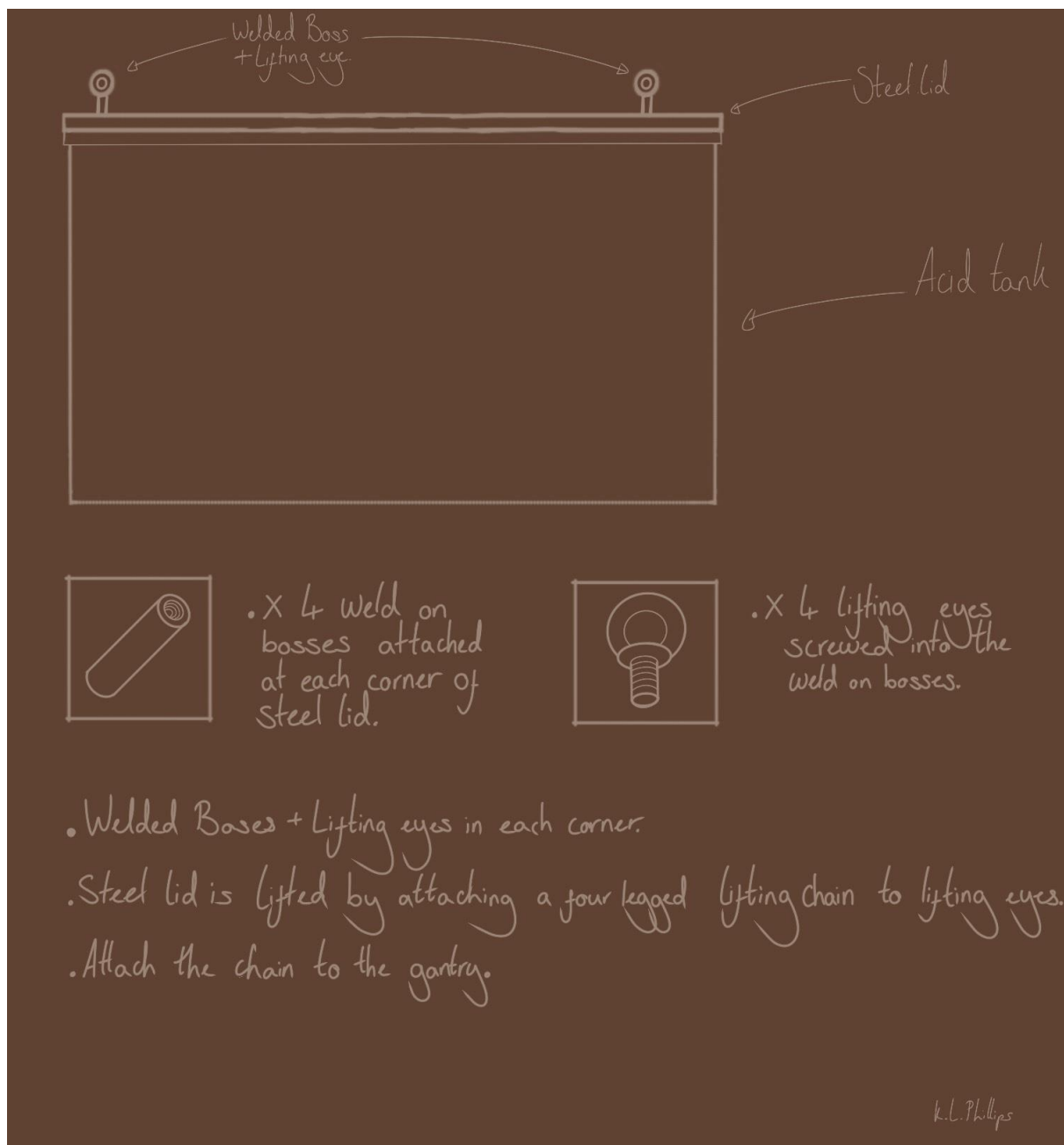


Figure 6: Sketch Of Design One.

6.2 Design Two

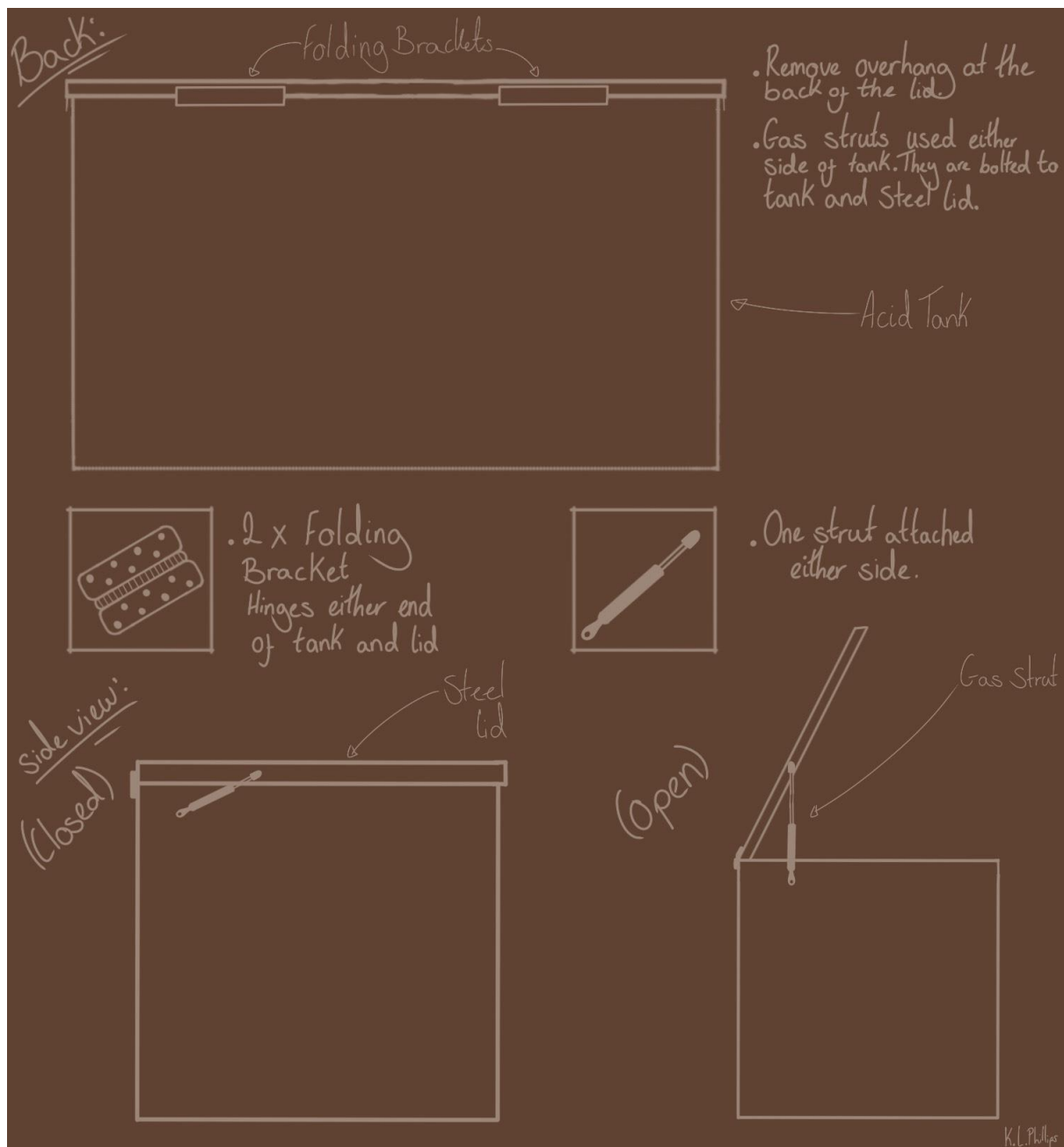


Figure 7: Sketch Of Second Design.

6.3 Chosen Design

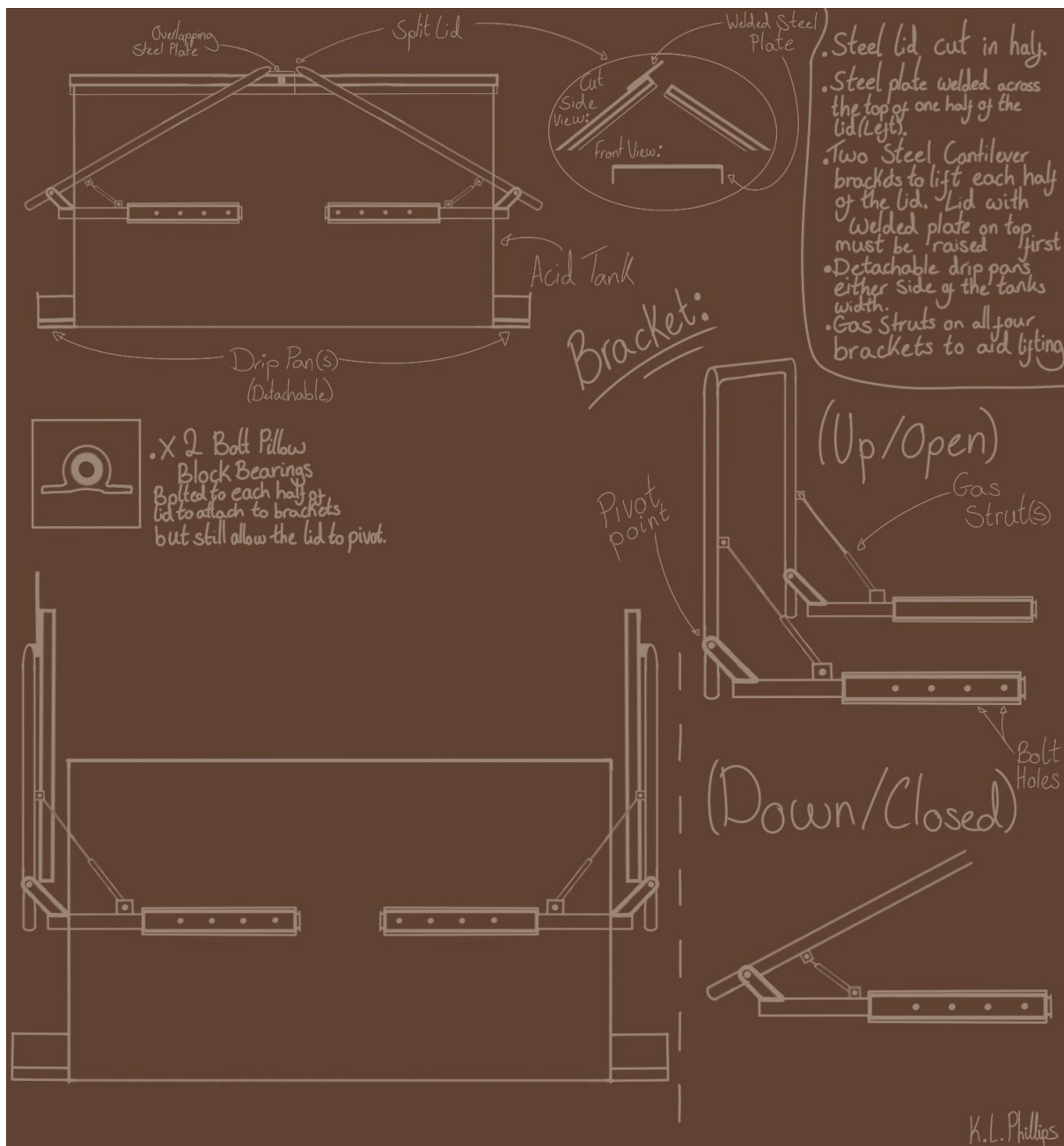


Figure 8: Sketch Of Chosen Design.

7 Manufacturing Process

Firstly, to manufacture the cantilever brackets it is vital to choose a suitable steel through the use of research, for example mild steel or stainless steel, based on load requirements and environmental conditions that it will be subject to. Once this is decided steel needs to be ordered in its required form, such as tubes, angles and plates. From here, the ordered steel needs to be cut, Kadezabek, S.

(2024), explains how steel can be cut using laser cutting systems, which is effective for cutting medium-thick plates. Water jet cutting provides precise results when cutting very thick plates of steel and doesn't cause any heat distortion, and plasma cutting is a good all-round cutting method that can handle a wide range of different thicknesses. When cutting any steel tubing or structural members bandsaws or shearing machines are excellent and efficient ways of doing this. Following this, the steel needs to be bent using press brakes, and tube bending machines are required to achieve the curved sections of this design. The next step required is machining, where milling machines can be used to drill holes for fasteners and attachment brackets. The following step involves starting the assembly of components using either MIG or TIG welding, in this step it is important to use welding fixtures because, as explained by Thefabricator (2023), they are an excellent way of eliminating variations caused by manual setup as they allow greater control over the welding process. As a result, increasing the repeatability and quality of components. After welding, edges of the steel can be deburred and smoothed out, followed by powder coating or galvanizing it to make the component more resistant to corrosion. The final steps include fitting the gas struts to the assembly, then carrying out quality control and testing, which would involve analysing weld integrity, dimensions and alignment, followed by a series of load tests to ensure the design meets the safety standards.

The alterations to the lid can be made using an angle grinder to cut the lid in half and remove the overhanging edges on the width at the back of each half, then an overlapping piece of 5mm thick steel that is 1020mm long and 100mm in width can be welded on top of the inner width of the left lid, holes will need to be created to attach the two pillow block bearings to each half of the lid(s).

8 Justification

Design one was not chosen because, not only is it time consuming to attach the four-legged chain to the lid, then to the gantry and to then move the lid away from the tank, there is still the issue of manual handling as the lid must be detached from the gantry and moved, this would also require extra space for the lid once it is removed. Furthermore, there are multiple health and safety risks involved, such as suspending a heavy load, manoeuvring in a potentially tight space and Sulphuric Acid dripping on the floor, people and equipment. Additionally, design two was not chosen because it does not account for overhead clearance, and the lid is still made of steel, therefore a good amount of force would be required to start lifting the lid before the struts could assist.

The final design was chosen because the cantilever design efficiently supports loads without requiring additional ground support and therefore saves space as it is a compact design, it is durable and strong with a long lifespan. Furthermore, due to the common manufacturing practices used it is cost-effective to produce and easily replicated, making it ideal for mass production. It is easily welded onto the tank and contains bolt-on connections, making it easy to install, combined with the gas struts it is an extra efficient and hassle-free way of removing and replacing the lid. Lastly, this can be an environmentally friendly design.

9 Conclusion

To conclude, the chosen design adequately addresses the lifting issue, implementing a safe mechanism that can be operated by a singular person, this solution also follows the requirements set by the customer, including no alterations were made to the tank and overhead clearance is accounted for. This design is also more time-efficient and is more durable due to the materials used to manufacture it and the robust mechanism, as a result it also requires minimum maintenance.

10 Further work

To potentially improve this design different materials could be analysed to replace the use of steel in the cantilever but must still be suitable and balance strength, weight and cost. In addition, the material of the cover could also have been changed and made lighter, this would have a chain effect on the cantilever design, as it would not require as robust materials to manufacture it. Advanced software could have been used to simulate and perform a stress analysis to ensure the cantilever and mounting points could safely handle the load and could also be used to simulate use over time to investigate the true durability of the design. Furthermore, a slow-return mechanism could have been utilised to reduce the strain on the person operating the design, allowing them to close the lid easier and safer. Lastly, deploying early versions of the design to users, after extensive stress and safety testing, and requesting their feedback, would provide great insight into how the reliability, usability, efficiency and durability of the design could be improved, if applicable.

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