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Engineering Design -
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2 Introduction and Interpretation of the Client Brief

2.1 Context and Problem Overview

Stainless steel tanks are essential components of industrial production processes, serving as storage and processing units. However, the current design of stainless steel tank lids causes significant operational challenges. These lids are difficult and heavy to handle, necessitating numerous personnel to properly operate the tank. This issue creates substantial health and safety issues while also impeding operational efficiency, which has a direct impact on profitability. As a result, a more refined design solution is necessary to address these health and safety concerns while yet allowing for single-person operations. Failure to address these concerns can result in production delays, higher labour costs, and a higher risk of workplace harm.

2.2 Objectives of the Design Solution

The objective of this project is to redesign the stainless steel tank lid to a number of technical criteria. The lid must ensure safe and ergonomic operation to mitigate health and safety risks, as well as facilitate single-person operation which decreases labour costs. The redesign of the tank must maintain compatibility and material specification of the existing lid.

2.3 Scope of the Project

This project is focused on the redesign of the tank lid and its operating mechanisms. The scope is limited to developing a solution that meets the defined safety and operational requirements. Modifications to the tank body, including changes to its dimensions or material composition, are outside the scope of this project. The redesigned lid will be compatible with existing equipment and processes, ensuring seamless integration into current operations.

3 Key Legislation Considerations

3.1 Health and Safety Regulations

3.1.1 Manual Handling Regulations (1992)

The design of the redesigned tank lid must comply with established health and safety regulations to ensure ergonomic and safe handling. Key guidelines include:

- Avoid the need for hazardous manual handling, ‘so far as is reasonably practicable
- Assess the risk of injury from any hazardous manual handling that can’t be avoided.
- Reduce the risk of injury from hazardous manual handling, ‘so far as is reasonably practicable. (HSE, 2016).

3.1.2 HSE Guidelines

The UK Health and Safety Executive (HSE) provides guidelines on safe lifting practices, which must be factored into the lid’s design. Specific considerations include:

- Keeping the load close to the body to minimize strain.
- Reducing awkward postures during lifting or lowering tasks.
- Implementing mechanisms to assist with the lifting process, such as hinges or counterbalance systems. (Health and Safety Executive, 2023)

3.1.3 The Machinery Directive (2006/42/EC)

This applies to designs that include mechanical aids. This includes ensuring that any extra systems are safe, reliable, and do not pose new hazards. (osha.europa.eu, 2006)

3.2 Material Safety

Given the use of stainless steel tanks in environments where sulphuric acid is present, material safety is a critical consideration for the redesigned lid. Legal and safety implications include:

3.2.1 Material Compatibility

The lid material must resist corrosion when exposed to sulphuric acid to maintain structural integrity and prevent hazardous leaks. Stainless steels such as grade 304 are suitable due to their high resistance to corrosion from sulphuric acid, particularly at concentrations used in industrial processes.

3.2.2 Regulatory Compliance

All materials used must comply with REACH (Registration, Evaluation, Authorisation, and Restriction of Chemicals) regulations to ensure safe handling and environmental impact. (European Commission, 2023).

3.2.3 Testing and Validation

Materials must undergo rigorous testing to confirm their resistance to chemical degradation, particularly under high temperatures or prolonged exposure to sulphuric acid.

4 Specification

4.1 Functional Requirements

The lid must be operable by a single person without any need for additional assistance, the lid must also cover the entire opening of the tank to prevent the spillage of corrosive chemicals that may cause serious injury. The brief also states there must be adequate clearance from above to lower metals into the tank.

4.2 Design Constraints

The tanks dimensions and composition must remain unchanged to ensure full compatibility with existing anodization processes, only the lid can be modified as per the client brief. Spatial clearance must be considered, especially overhead as that is where chemicals and metals will be inserted from.

4.3 Material Requirements

The lid must resist sulfuric acid to a high level to prevent corrosion and ensure the part stays durable for a long time. As previously mentioned, all materials must comply with REACH and other relevant safety regulations to remain compliant with the law. Due to heat being a factor during anodization, thermal resistance is another key factor which must be considered during the design process.

4.4 Ergonomic Considerations

The lid must facilitate single person operation, meaning it must include extra lifting mechanisms and/or handles. The lifting aids e.g., handles must be designed with ergonomics in mind to ensure ease of use and safety to personnel, there must also be even weight distribution to prevent tipping or excessive effort during operation.

5 Time Plan for Producing the Product

5.1 Gantt Chart

Depicted in Figure 1 is a Gantt chart describing the design and manufacture of the solution to the client brief.

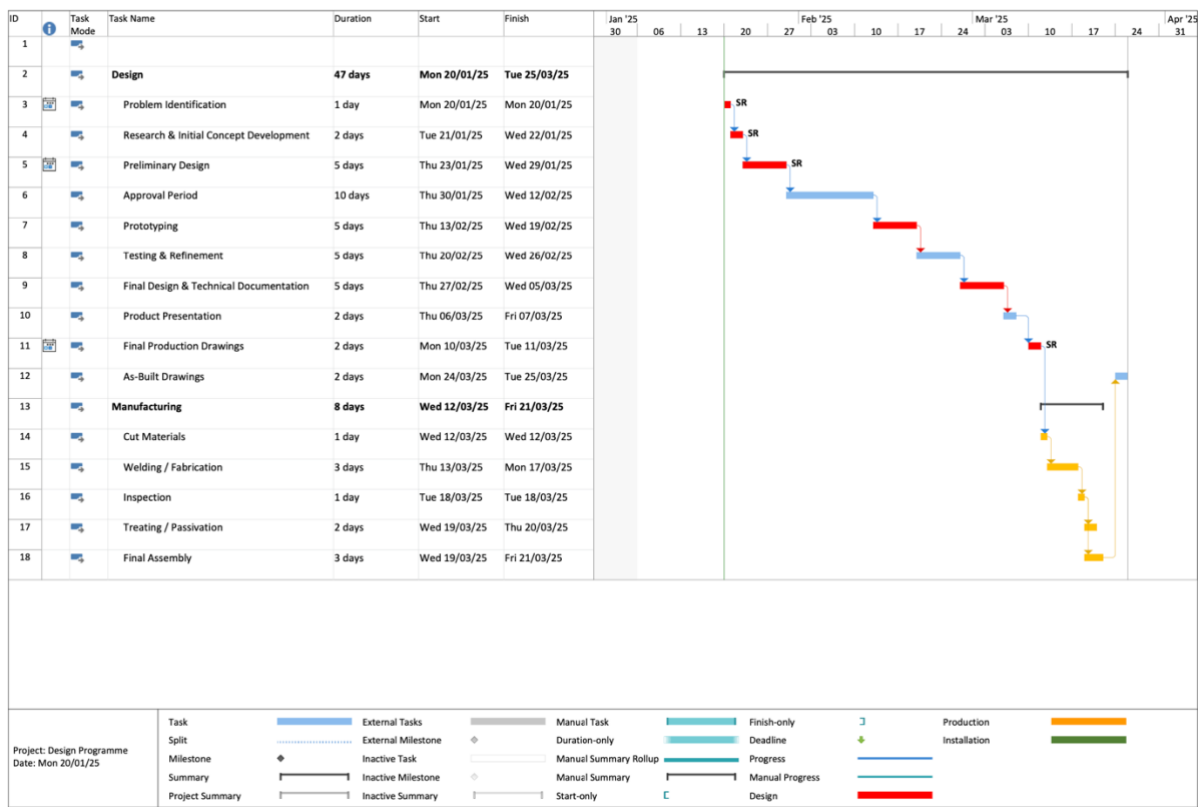


Figure 1: Gantt Chart

6 Relevant Research

6.1 Analysis of Current Lid Design

Analysis of the current lid design brings several ergonomic and health & safety implications to light. The existing design is difficult to operate by one person as the lifting handles are the opposite sides of the tank, approximately 1770mm apart. There is also a risk of the lid falling into the tank of sulphuric acid creating inherent risk to the operator, the products and the composition of the lid. In addition to the ergonomic challenges, it has been noted the tank's mass is in excess of 50kg thus doubling the safe lifting guidelines for one adult (male 25kg, female 16kg). (Health and Safety Executive, 2020).

6.2 Material Properties

6.2.1 Polypropylene (PP) Analysis

Polypropylene (PP) demonstrated excellent corrosion resistance and dimensional stability, with low decreases in tensile strength and hardness, making it an appropriate choice for non-structural components exposed to sulphuric acid.

6.2.2 PVC Analysis

PVC performed poorly in all areas, demonstrating severe degradation in corrosion resistance, mechanical characteristics, and dimensional stability, making it inappropriate for this application.

6.2.3 Stainless Steel Gr304 Analysis

Stainless steel (SS304) has demonstrated superior performance in all parameters, including exceptional corrosion resistance, dimensional stability, and low decreases in tensile strength and hardness, making it a great candidate for the lid material.

6.2.4 Aluminium Analysis

Aluminium (Al 6061) performed well in terms of corrosion resistance and dimensional stability, with small decreases in mechanical qualities, making it a viable but less ideal alternative to stainless steel.

7 Annotated Sketches of Multiple Design Concepts

7.1 Design 1 – Piano Hinge

Depicted in the drawings below is a design solution including a flanged 2 piece lid, piano hinge and ergonomic pull handles on a spindle all made from grade 304 Stainless Steel. This design provides an ergonomic solution to the issue with a handle that rotates 360° thus minimizing the risk of musculoskeletal injuries. The introduction of a flange on the lid creates a surface to which the handle can fix to thus saving space and making the operation more user friendly. The use of 3mm Stainless Steel Gr304 is used as it is deemed the most fit for purpose material as per section 6.2.3.

Piano hinges are used due to their ability to rotate 270° creating a compact solution when opened, leaving plenty of room around the tank. A slam plate is puddle welded to the active leaf to ensure there are no gaps between each leaf for substance to exit. The lid thickness has been reduced to 3mm and split in to two to minimise weight increasing operational efficiency and workplace safety.

This design is applicable for single person use and does not compromise space around it, it is also ergonomically favourable for personnel operating the system. However, the cost of manufacture and raw materials may be high due to stainless steel being the most expensive material of those tested.

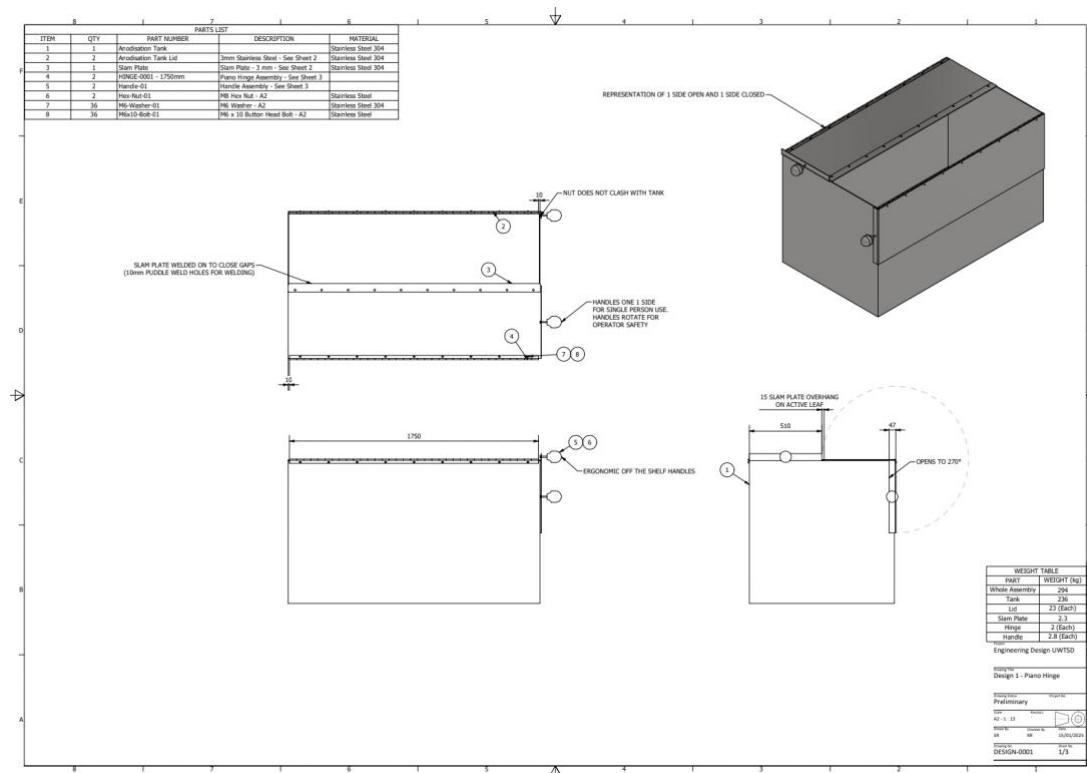


Figure 2: Design 1 – Sheet 1

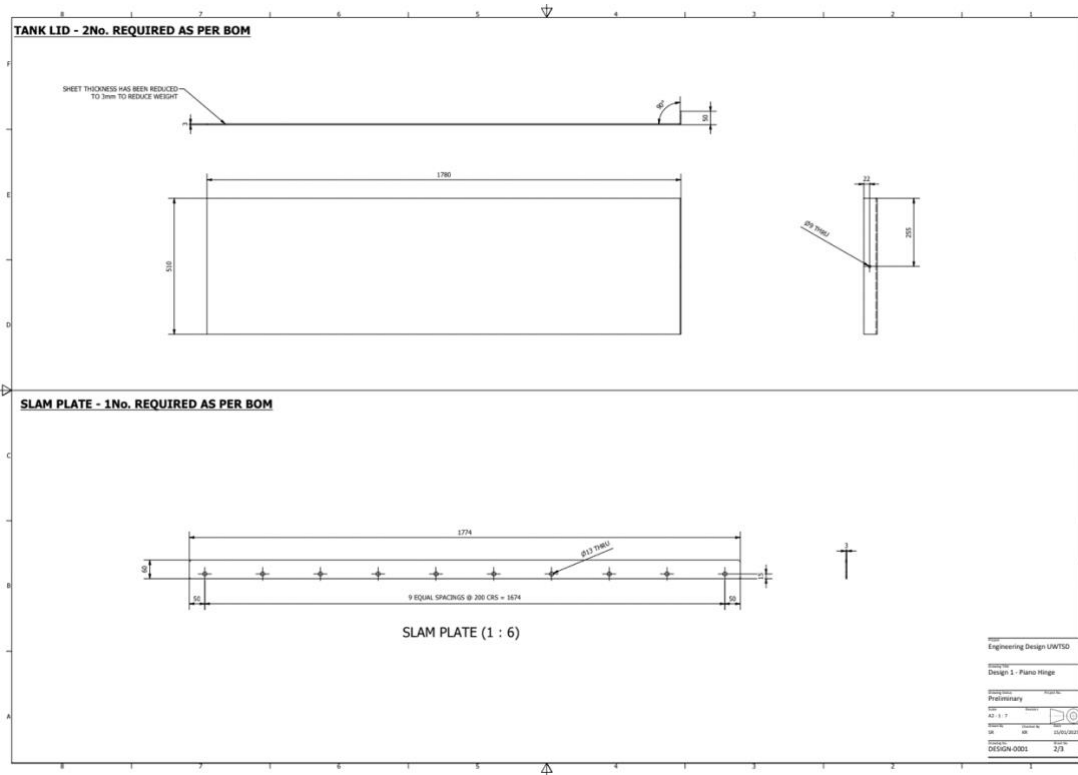


Figure 3: : Design 1 – Sheet 2

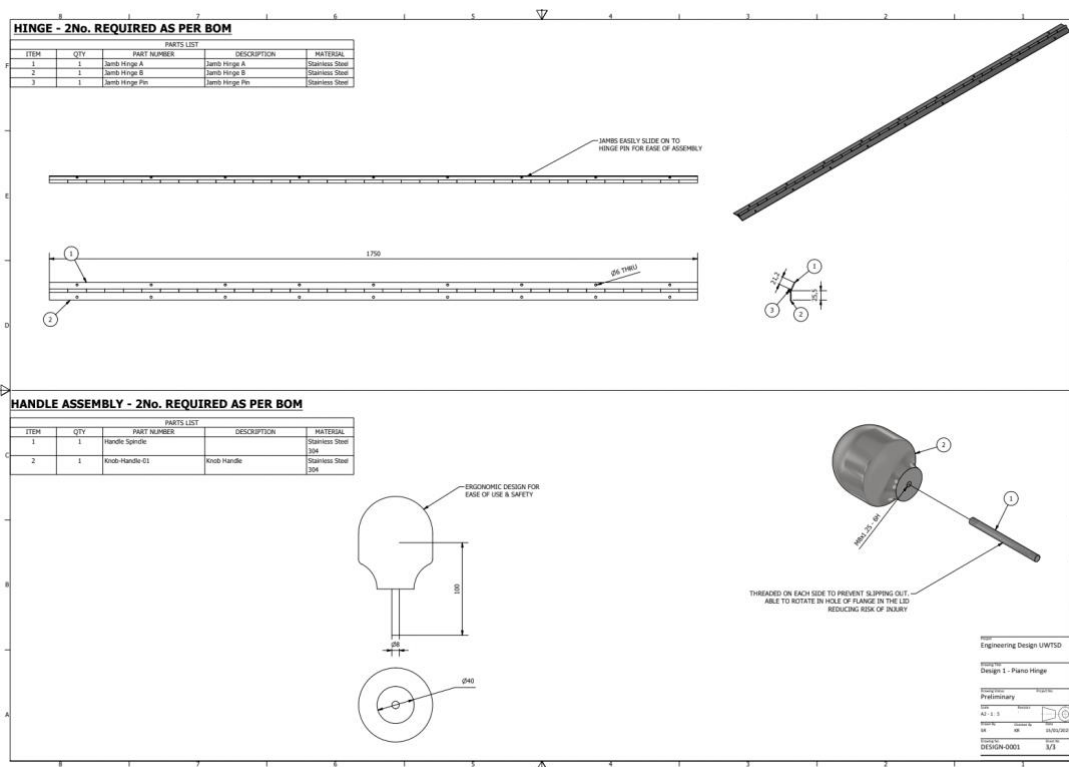


Figure 4: : Design 1 – Sheet 3

7.2 Design 2 – Flanged Lid

Design 2 provides detail of a simple design including using a singular lid with three flanged edges and two Polypropylene handles fixed with M5 socket heads. The flanged sides allow for the lid to slide off and lifted with assistance from two polypropylene pull handles. The design is a cost-effective solution to the issue despite using the most expensive material tested. The reduction to 3mm thickness saves weight and cost, the flanges added to three corners is also easily manufacturable as only bending is required.

Polypropylene handles provide ergonomic lifting aids which satisfy the client brief in several ways. Polypropylene proved it can maintain its structural integrity whilst in a heated environment involving sulphuric acid as shown in section 6.2.1. Polypropylene is also chosen for its ease of manufacture, low material cost and low weight.

Despite being easy to manufacture, the design does pose health and safety risks. The weight of the lid is 48kg making it significantly higher than the HSE safe lifting guidelines of max 25kg for men and 16kg for women, this poses an increased risk of injury in the workplace. The action of sliding a large, heavy sheet of metal is awkward and further increases risk of injury and part damage.

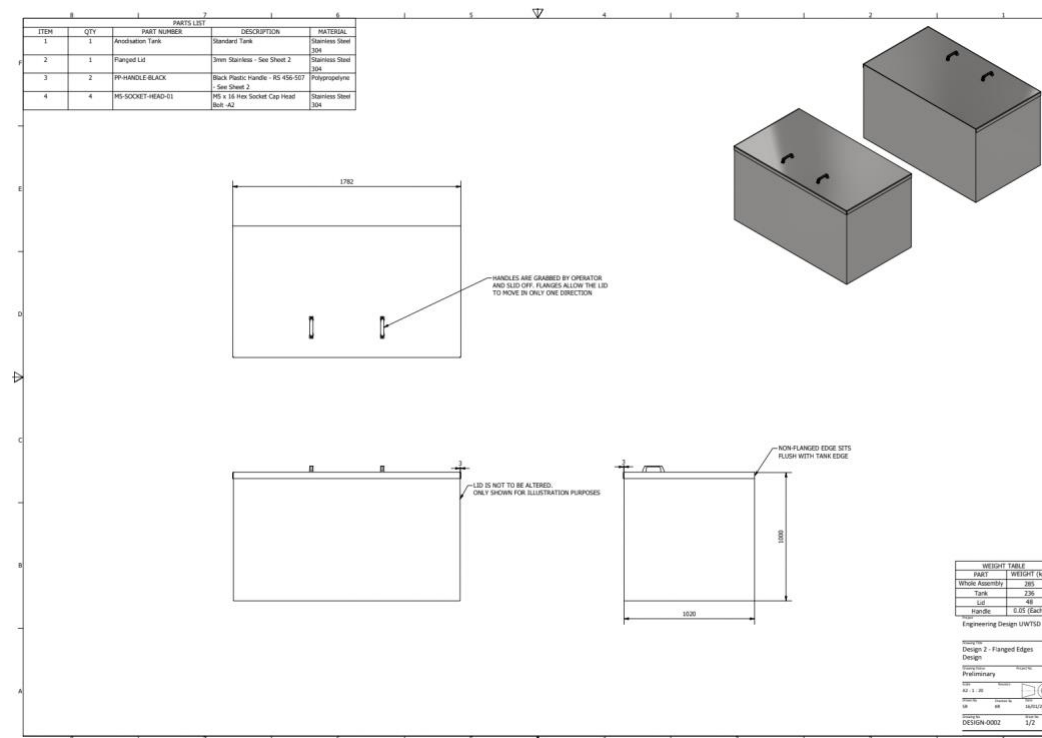


Figure 5: : Design 2 – Sheet 1

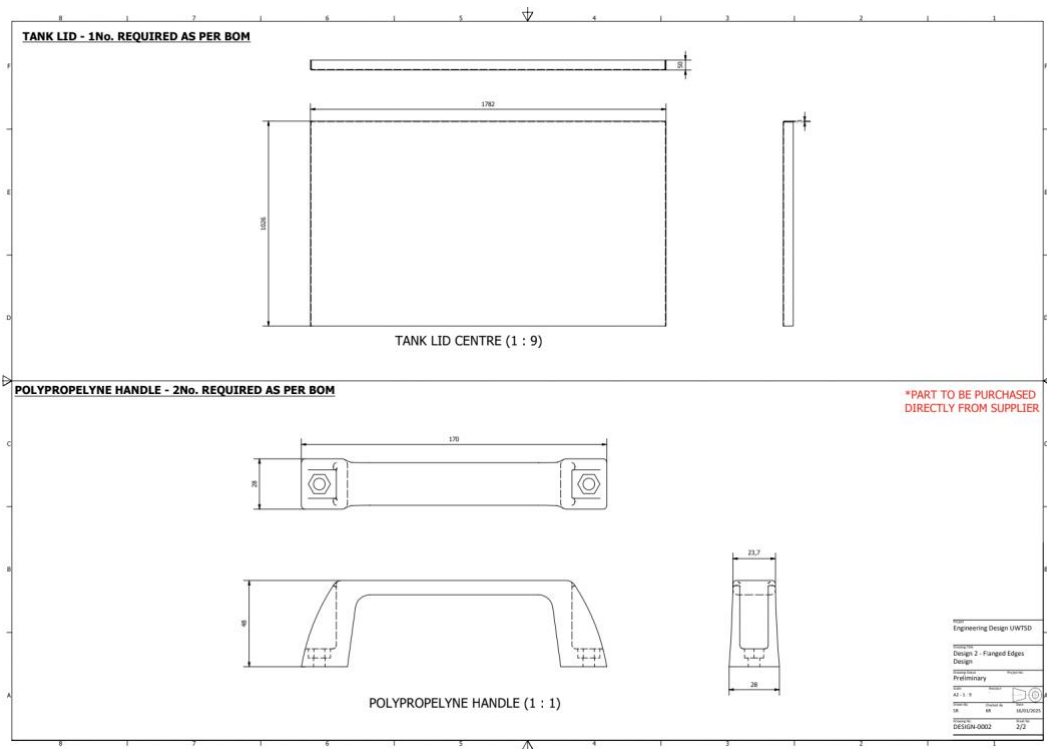


Figure 6: : Design 2 – Sheet 2

7.3 Design 3 – Three Piece Lid

The three piece lid design annotated below offers a similar solution to Design 2, however it takes the ergonomic and safety flaws of it into consideration. Three separate lids are placed on to the tank, each with flanges to allow it to be slid off. Polypropylene handles fixed with M5 socket heads provide cheap, lightweight lifting aids making removal and re-application of the lid easy.

Splitting the lid in to three rectifies Design 2's problem of an overweight lid, the lids now do not exceed 16kg making them ideal for lifting for all workers. Like design 1, slam plates are used to cover gaps between each lid minimising the risk of substance escaping the tank thus decreasing risk of workplace injury.

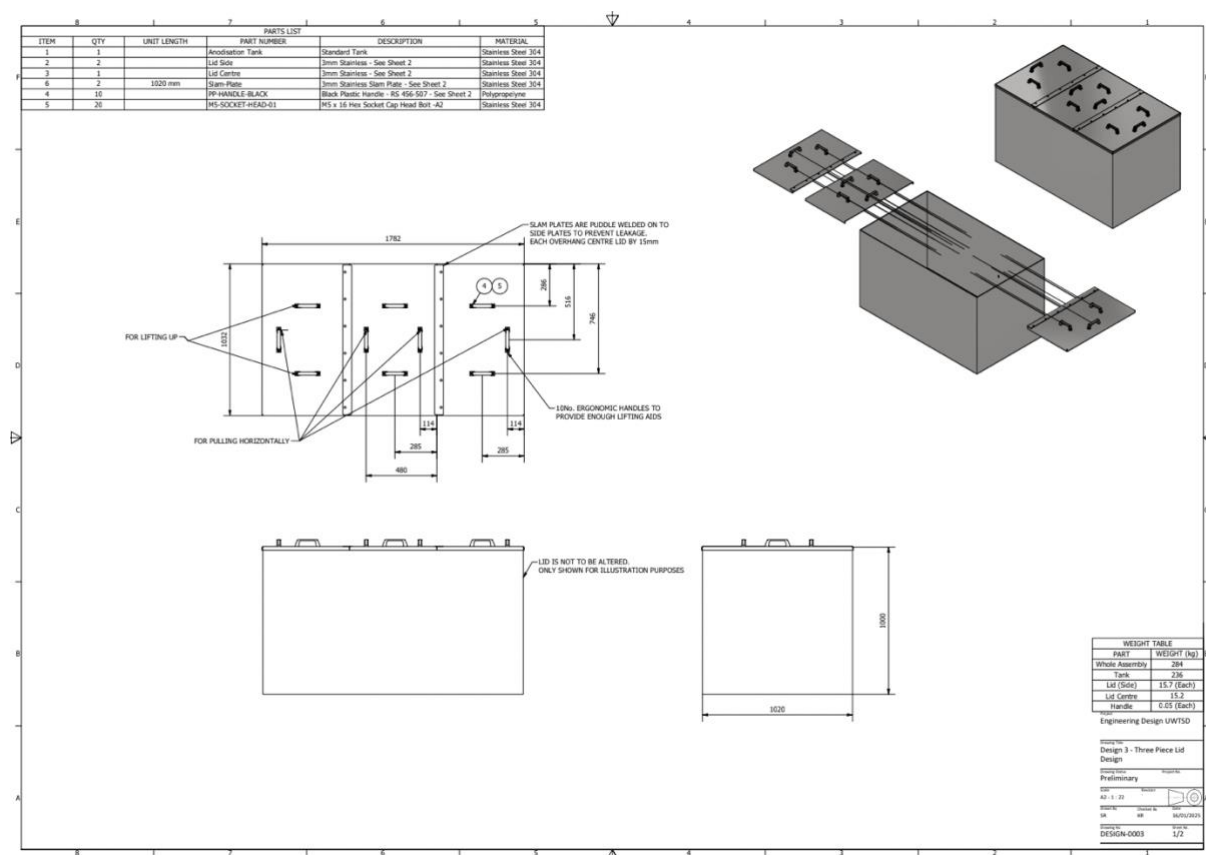


Figure 7: Design 3 – Sheet 1

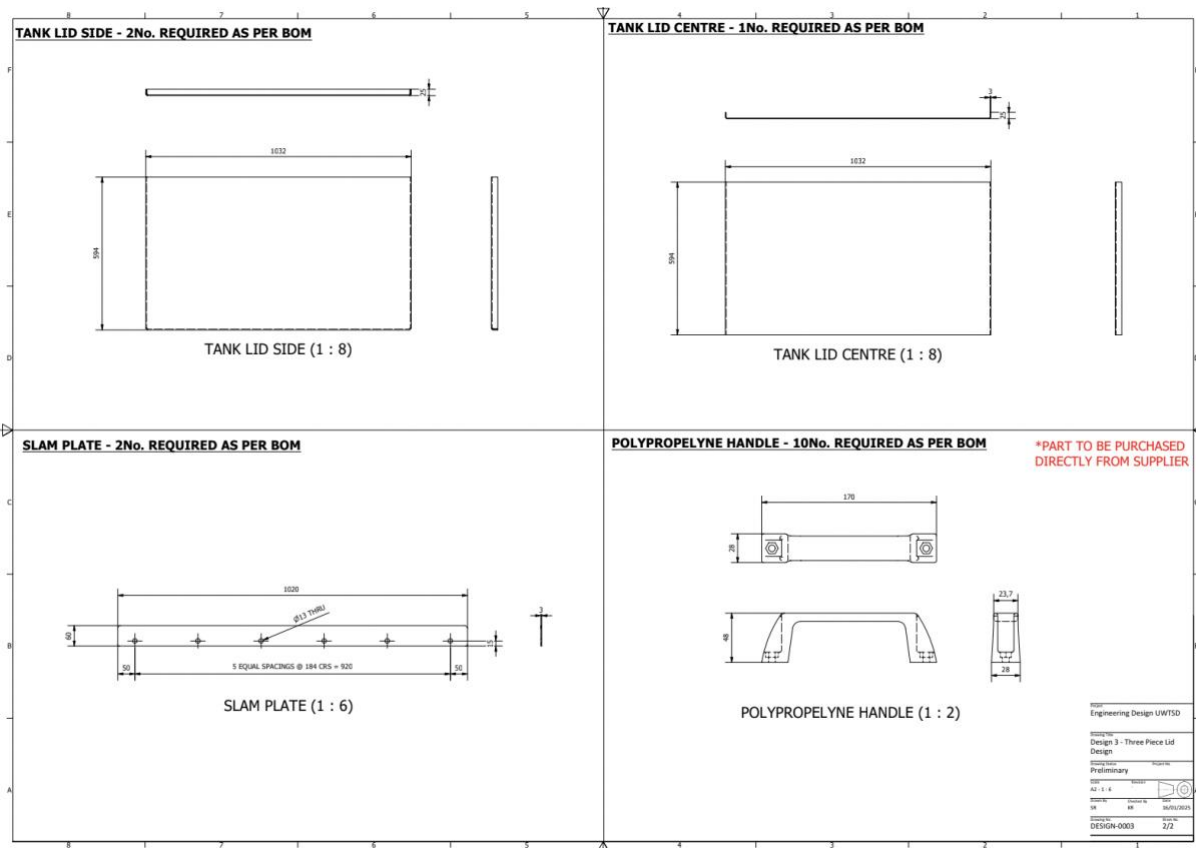


Figure 8: Design 3 – Sheet 2

8 Final Design and Manufacturing

8.1 Final Design and Drawings

Design 1's combination of ergonomic features, material durability, and adherence to regulatory standards has made it the optimal solution for the client brief.

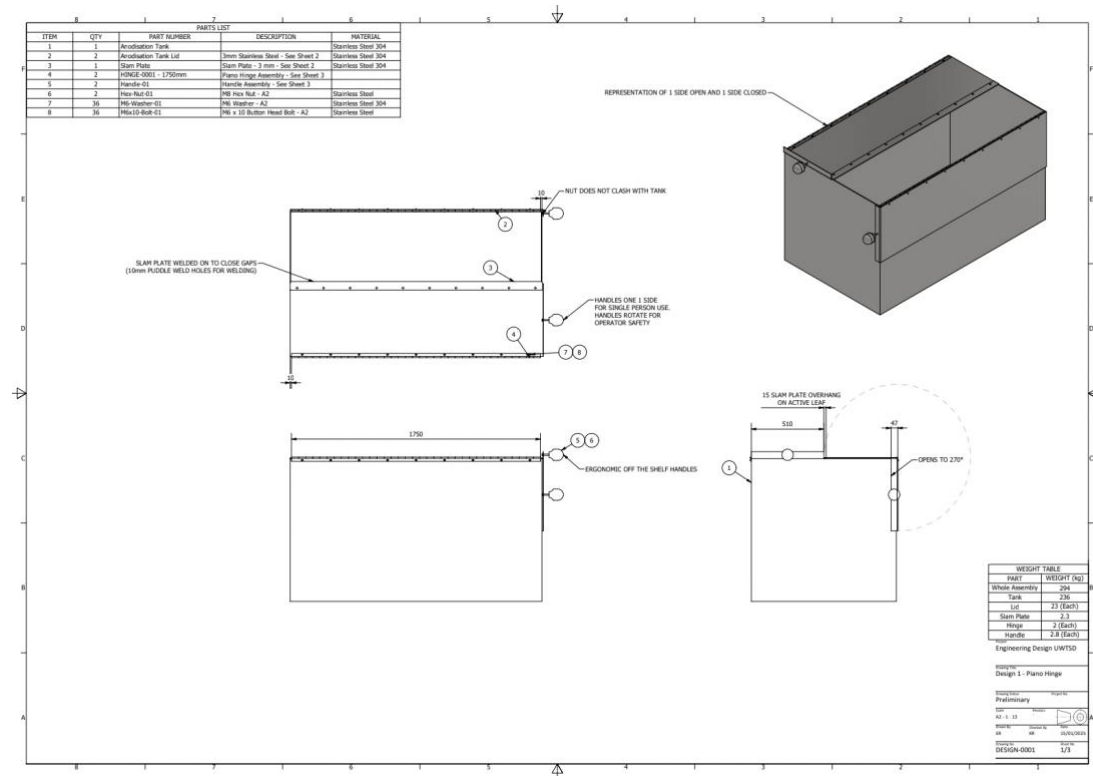


Figure 9: Final Design - Sheet 1

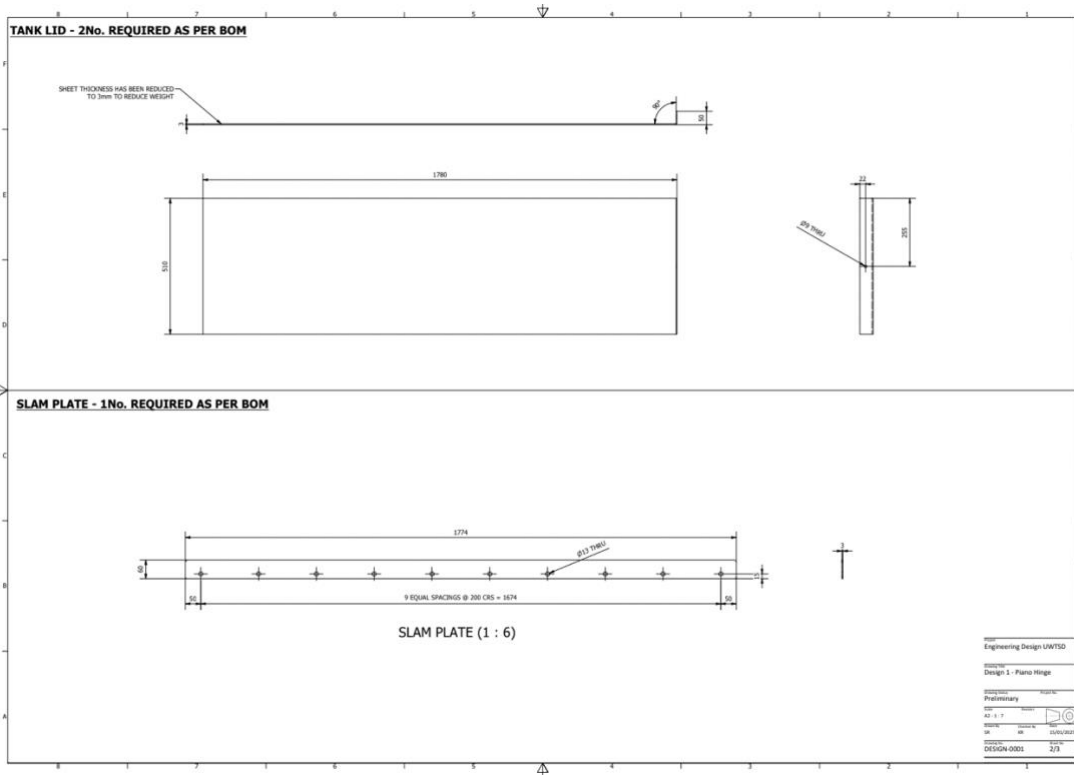


Figure 10: Final Design - Sheet 2

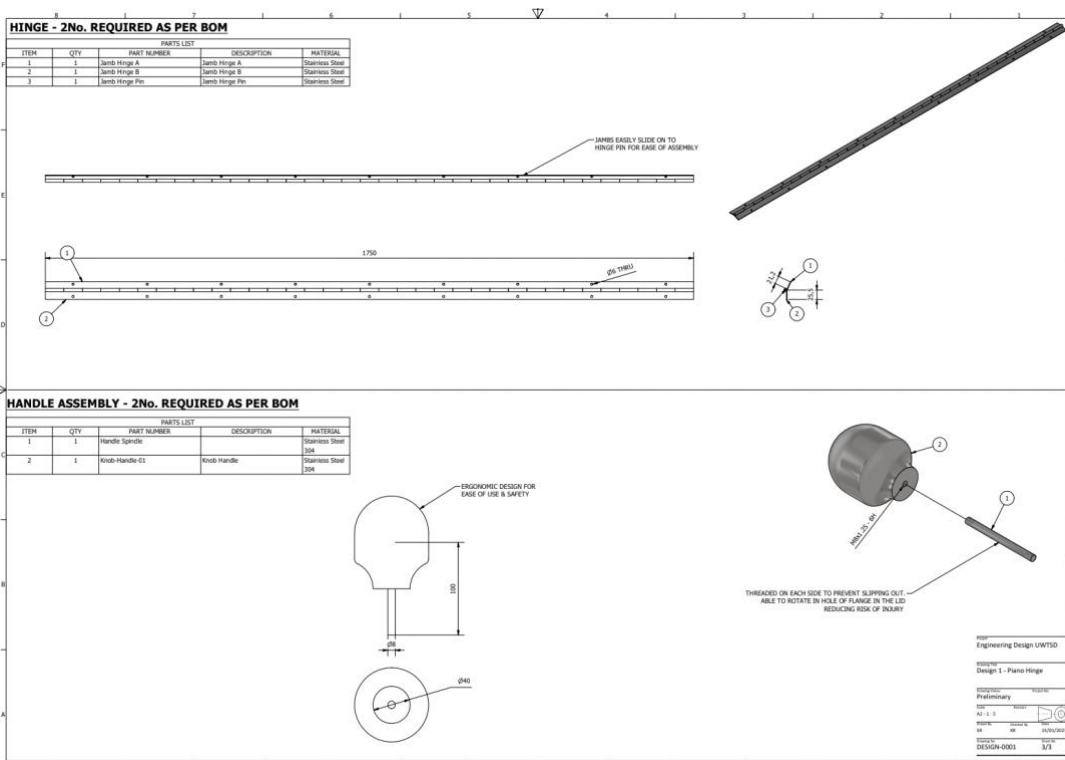


Figure 11: Final Design - Sheet 3

8.2 Material and Tolerances

All components are fabricated using Grade 304 Stainless Steel due to its superior corrosion resistance and compatibility when in sulphuric acid environment. Despite being heavy and expensive, the stainless steel is split into numerous components, so it remains easily operable.

The lid components will adhere to a ± 0.5 mm tolerance to ensure precise fitting and alignment to the existing tanks, the hinges will adhere to a lower tolerance of ± 0.1 mm to ensure seamless fitting and operation and avoid misalignments and gaps.

8.3 Manufacturing Plan

8.3.1 Fabrication

The lid is cut to size using a 3mm sheet of Grade 304 Stainless Steel using a CNC laser cutter to ensure high precision and low wastage, the same process is used for the slam plates. The flanges of the sheets will be produced by using a hydraulic press to accurately bend the sheets to 90° . Piano hinge parts will be machined with low tolerances to ensure a smooth finish and accurate alignment. Finally, the pull handle spindle will be machined and threaded through CNC and the handle knob will be die casted which is a cheap and efficient process.

8.3.2 Assembly and Finishing

The hinges are assembled using a full-length spindle for connection and are fixed to the tank and lid using A2 M6x10 button head bolts and A2 M6 washers, being made of stainless steel they reduce corrosion and ensure strength. Attached to one of the lid leaves is a 3mm thick slam plate which is puddle welded on to the face of the leaf through the 13mm diameter holes. The handle is assembled with an 8mm diameter spindle with an M8 thread either side, this thread enters M8 holes on both the M8 nut and handle. The 9mm diameter hole of the lid flanges ensures adequate clearance for the spindle to rotate 360° .

All components will be finished using a deburring process to remove all sharp edges for enhanced operator safety, all parts will be chemically treated to enhance corrosion resistance against sulphuric acid.

8.4 Design Rationale

The piano hinge allows rotation to 270° ensuring adequate clearance for lowering and aluminium parts into the tank. The introduction of flanges works well with the hinges to create a compact solution and minimise space requirements. 3mm Stainless Steel minimises weight and maintains structural integrity.

8.5 Ergonomics and Safety

The handles are designed to rotate 360° reducing awkward lifting motions, the placement of them ensure even weight distribution to reduce injury risk. The lids reduced weight and division in to two sections ensures compliance with HSE safe lifting guidelines for single person use.

9 Conclusion and Further Work

9.1 Summary of Design Solution

The final design uses a piano hinge system on two evenly sized leaves with flanges, ergonomic pull handles, and a slam plate made from grade 304 Stainless Steel. The objective of ensuring safely single-person operation whilst maintain compatibility of the existing tank been satisfied with this design. The design prioritises operator ergonomic whilst adhering to regulations.

9.2 Potential Improvements

Potential revisions of this design may opt for an automated or semi-automated design with the introduction of gas struts and/or pulley system. Other iterations can optimise material usage by minimizing waste product through changing designs or manufacturing processes. Additionally, other materials can be tested to minimise cost, weight, time and manufacturability.

9.3 Future Considerations

During implementation precise tolerances and manufacturing processes must be strictly adhered to, this will be achieved with in-depth quality control measures and regular maintenance. Structural integrity and corrosion resistance should be regularly checked in accordance with laws and regulatory standards to ensure compliance, safety, and effectiveness.

10 References

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