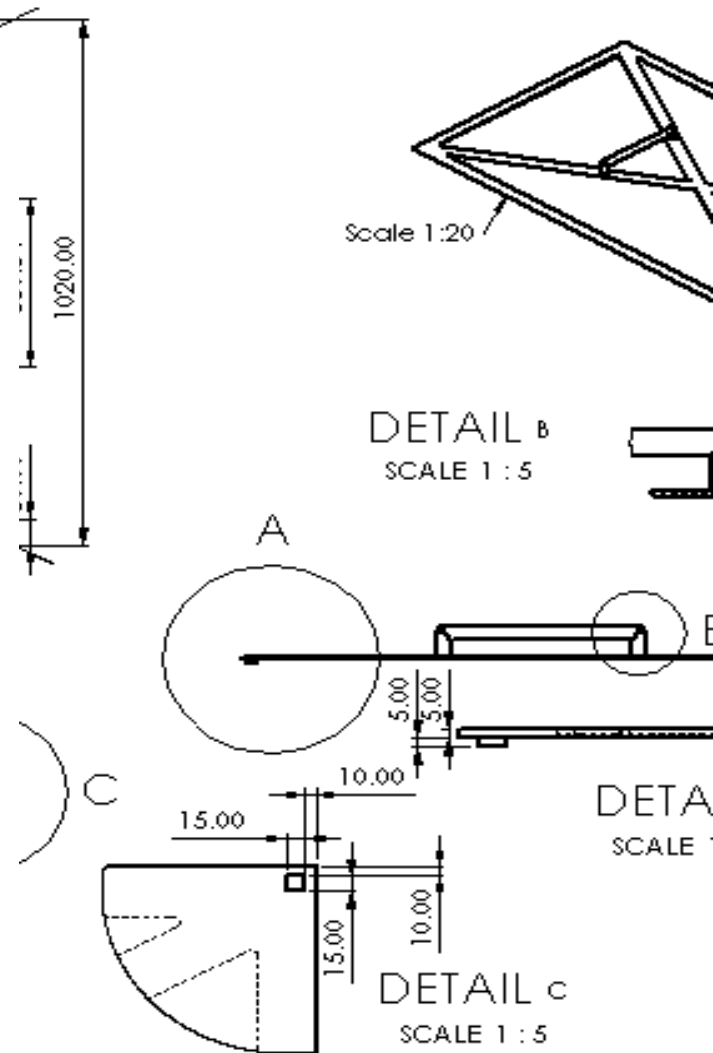


Engineering Problem



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APRIL 6

Engineering Design ACHA4001
Ethan Davies (2405602)
1879/2000



Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

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Introduction and interpretation of the client brief

This report aims to develop and design a solution to a problem caused by a tank that anodises aluminium for several manufactured parts. When the tank is inoperable, a Stainless-steel cover is placed over the tank for health and safety. The current cover requires two employees on either side of the tank to lift the cover off so that it can be used. Multiple members of staff have complained that the cover is difficult to place properly on the tank. Furthermore, a health and safety officer noted that the operation of lifting the cover is a major risk to staff. As there are a large number of these tanks at the facility, this is not including possible tanks at other facilities, there has been a call to design a solution that will solve the current health and safety concerns.

This report will go through important topics regarding a solution to the current tank cover,

Key legislation considerations

Health and safety for Manual handling at work

To comply with the Manual Handling Operations 1992, amended 2002, employers must adhere to specific guidelines set by the regulations made by the Health and Safety Executive (HSE). This is to reduce the risk of injury to employees who are handling tasks such as lifting, carrying, pushing, or pulling heavy loads.

The HSE suggests lifting a maximum of 25kg without assistance or a further risk assessment. When lifting loads heavier than 25kg or particularly challenging loads, a risk assessment should be carried out including factors like:

- Shape
- Weight
- Size
- How often the load is handled
 - As the acid tank is used for anodization, which typically takes 30 minutes to 2 hours, there will be a significant period between when the tank must be opened when lifting the cover off.
- The environment where the handling takes place
 - The environment where a load is handled should not be cluttered or confined; it should be well-lit and spacious. Additionally, the weather conditions or working conditions in the area are also a factor, as Extreme temperatures can further complicate the handling of a load.

Health and Safety for Working with Sulphuric Acid

High percentages of sulphuric acid are extremely corrosive and can cause burns to employees' skin when in direct contact. Diluted percentages of sulphuric acid can cause irritation and less extreme burns. Furthermore, as the sulphuric acid is heated, it is important to expect acidic vapours. This will require respirator masks as breathing air that contains high levels of sulphuric acid can irritate the eyes, nose, and throat, which in severe cases can cause damage to the lungs and overall health.

Specification

To design a solution addressing the safety concerns associated with lifting or removing the cover from an industrial tank. The current tank cover is heavy and requires two members of personnel to lift. Both of these factors cause a challenge to personnel to properly place the cover on the tank. Therefore, when designing a solution, the outcome should be:

- Safe to operate
- Can be operated by a single person
- Same dimensions: however, modifications can be made
- Clearance above the tank is required

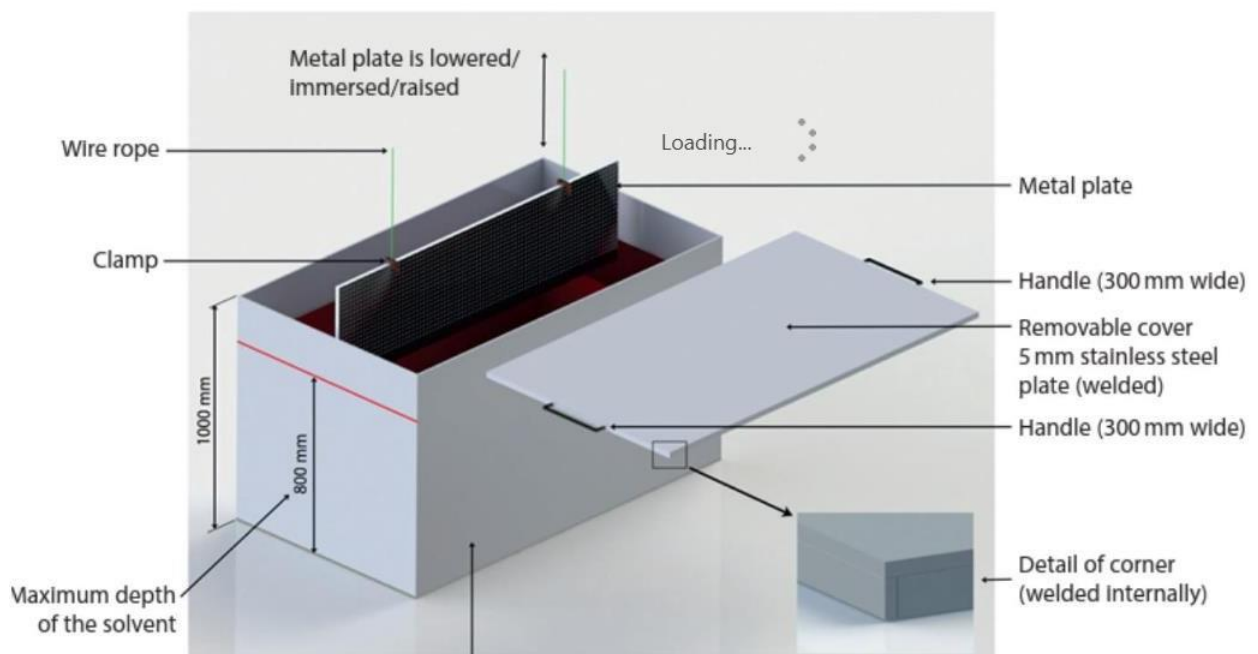


Figure 1: Image of Tank Which Cover Needs Redesign or Modification

Proposed Solutions According to the Specification

i. Pneumatic or electric lifting Mechanism

- a. A lifting mechanism can be mounted to the tank itself, or it can be designed to fit within the clearance space above the tank.
- b. This system can either be manually or electronically assisted to require minimal physical strain, reducing the risk of injury.

ii. Lightweight cover

-
- a. A replacement of the stainless-steel cover with a lightweight material or composite would allow easier operation, also allowing only one member of personnel to lift the lid.
 - b. As only one person would be required, it would make aligning the lid on the tank far easier, ensuring proper positioning.
 - c. When replacing the material, it is essential to select a material that is as corrosion resistant as stainless steel. It must also be as heat resistant as the tank gets heated to 25 degrees Celsius

iii. Rotation mechanism with handles

- a. A rotating mechanism could mean that there would only be a few modifications to each tank, which will allow staff to safely operate the cover

iv. Rolling Top

- a. A rolling top design would not only make moving the lid fairly simple, but it would also support the lid, allowing it to be adequately placed back onto the tank.

Furthermore, every design can benefit from assisted positioning and alignment methods. Such as guide pins or grooves around the edges of the tank and along the lid to ensure the tank is correctly covered when the lid is lowered.

Further Considerations

Any design implemented would require operator training as, even with an automated assisted system, staff would need to be properly trained to use the new system following health and safety regulations. Additionally, most designs will require maintenance overtime. Therefore, any designs or modifications made must be durable and only require minimal maintenance. This maintenance must also be cost-efficient as this solution will be used over multiple tanks within the facility, possibly even at other sites.

Time plan for producing the product

	A	B	C	D	E	F	G	H	I	J	K	L
1	Task Name		Weeks in 2025 Starting form March									
2			Week 1		Week 2		Week 3		Week 4		Week 5	
3			3rd- 9th		10th-16		17th-23		24th-30th		31st-6th	
4	Planning											
5	Research											
6	Design											
7	CAD Work											
8	Write up											

Figure 2: Gantt Chart timeline For This Assignment

Relevant research

Assuming that the stainless steel is a stainless 300 series and that the cover's size is accurate, the approximate Weight when calculated is 71.46 kg (157.55 LBS)

The tank contains 30% sulphuric acid, which is a clear, colourless and odourless liquid with a pH less than one, meaning it is highly acidic and incompatible with some materials and liquids. Sulfuric acid is also an irritant, meaning it should not come into contact with exposed skin, eyes, or even the respiratory system.

Examples of Proposed Solutions

Pneumatic or Electric Lifting Mechanisms



Figure 3: Boot strut for a seat leon from Dark Ice Designs



Figure 4: Boot Struts Sold by RS

Lightweight Cover

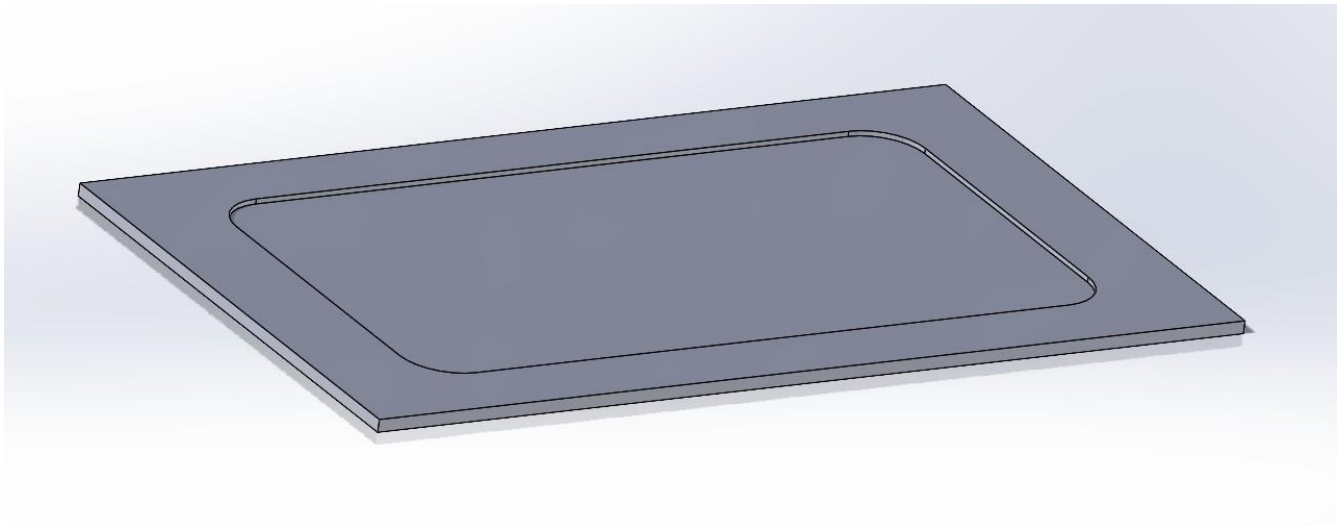


Figure 5: A lightweight cover designed by Charlie Morrish (See references)

Rotation Mechanism



Figure 6: Swivel Hinge Sold by Sash + Door Hardware

Rolling Top



Figure 7: Writing bureau that has a rolling top cover, Closed (by The New Dach Tree see references)



Figure 8: Writing bureau that has a rolling top cover, Open (by The New Dach Tree see references)

Materials

As the stainless-steel tank cover's weight is a challenge for personnel, an alternative material for the cover can be considered. It would be expensive to replace every cover with a new one. On the other hand, a change of material can make manoeuvring the cover easier as it would be lighter, lessening the risk of injury. Listed below are possible replacement materials for stainless steel:

- Aluminium alloy
- Titanium
- Fiberglass-reinforced Plastic

-
- High-density polyethylene plate

As Sulphuric acid is highly acidic, it means that there are a few incompatible materials, meaning they cannot be used. For example, metals such as Zinc, tin, and aluminium. Furthermore, organic materials also are incompatible, meaning substitute composite materials like hemp fibre composites are not usable. Olefins & Polymers USA find that sulphuric acid between 0-50% heated to 60 degrees Celsius, 35 degrees hotter than the tanks operating conditions, has a satisfactory resistance.

Annotated sketches of multiple design concepts

Pneumatic lifting mechanism

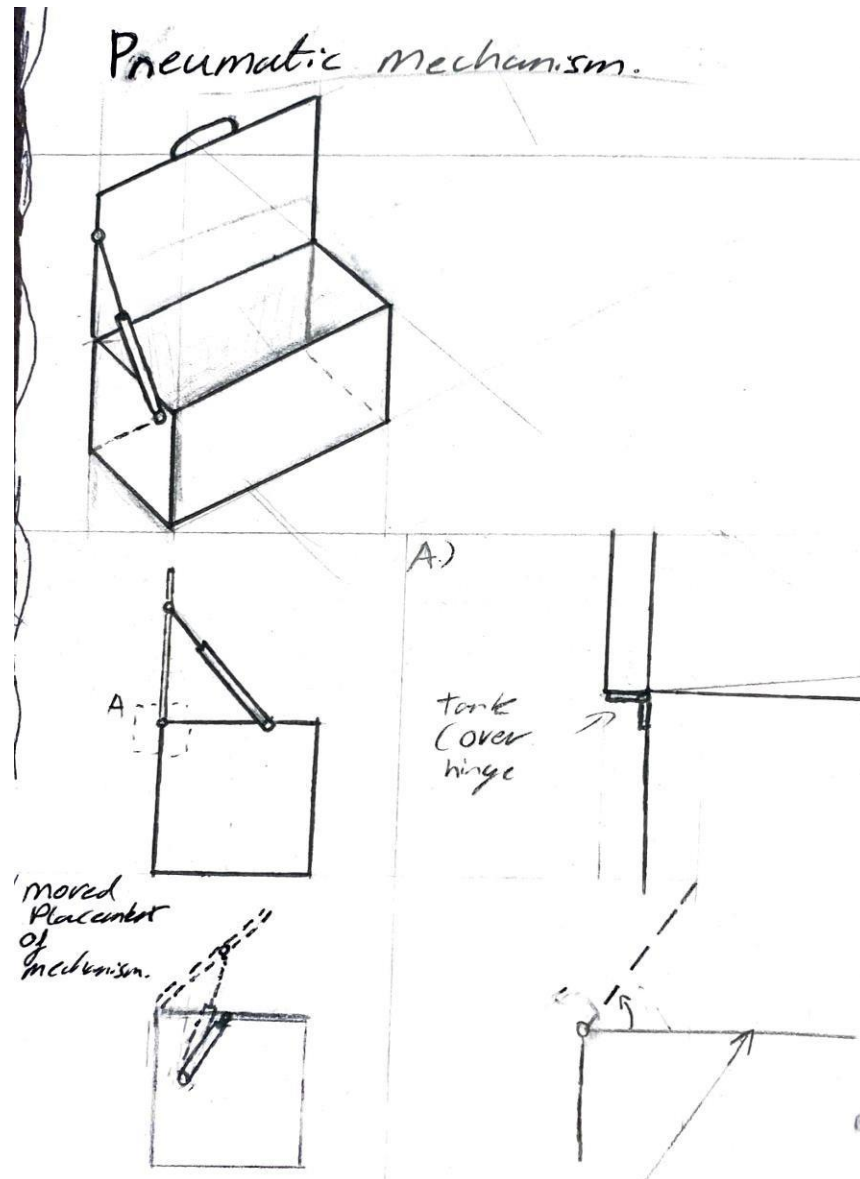


Figure 9: Concept Drawing of a Pneumatic lifting system

Lightweight Cover

Light weight design.

using a lighter material such as titanium.

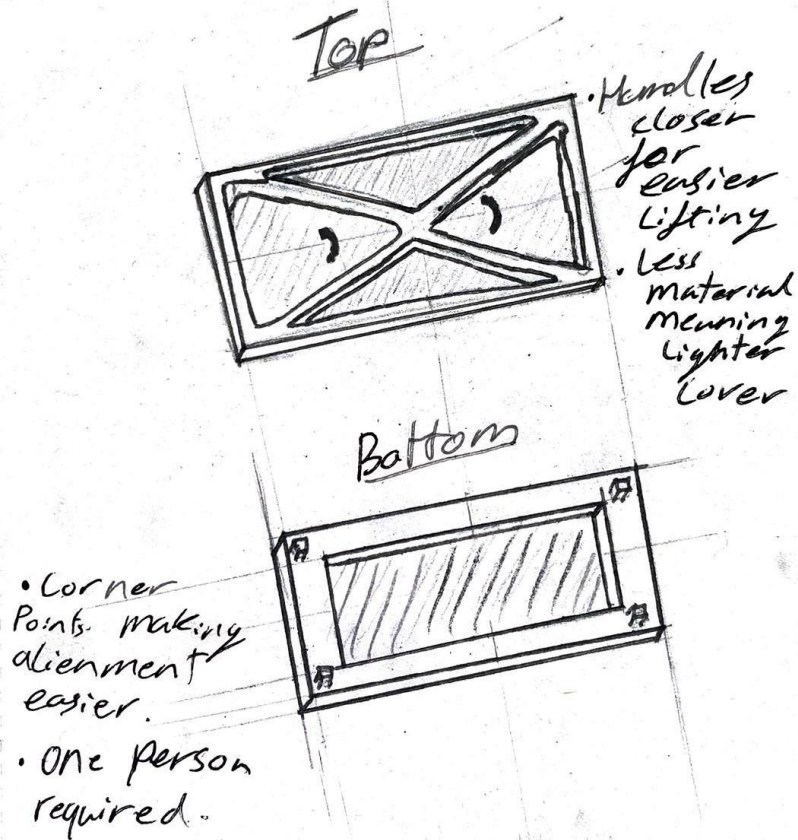


Figure 10: Concept Design for a Lightweight Cover

Rotation Mechanism

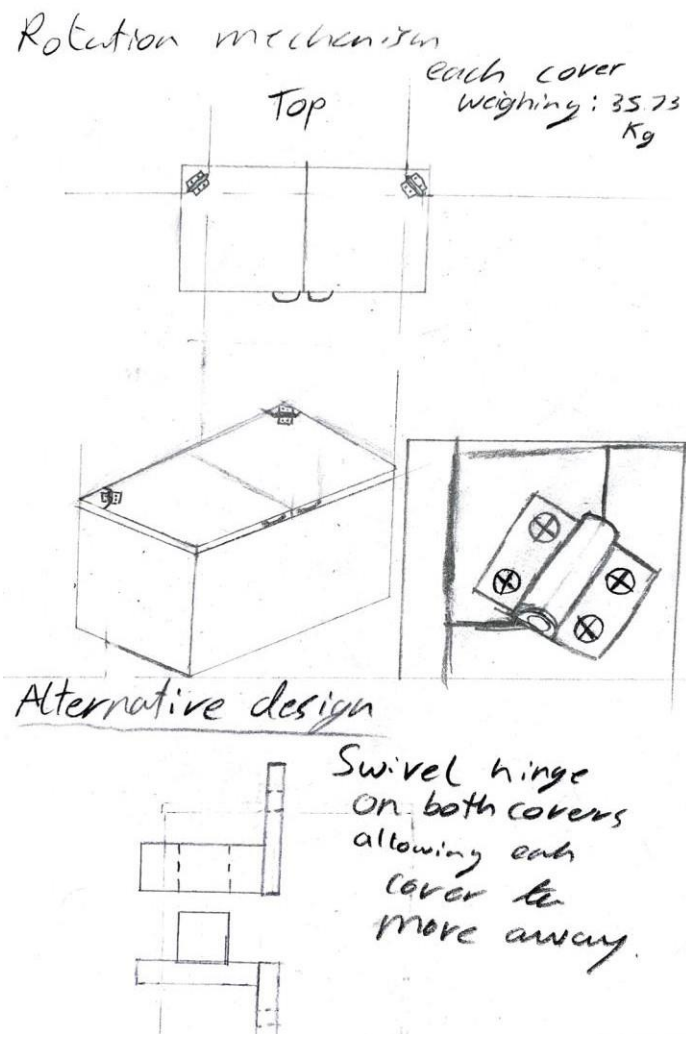


Figure 11: Concept Drawing of a Rotation Mechanism

CAD model of the final design

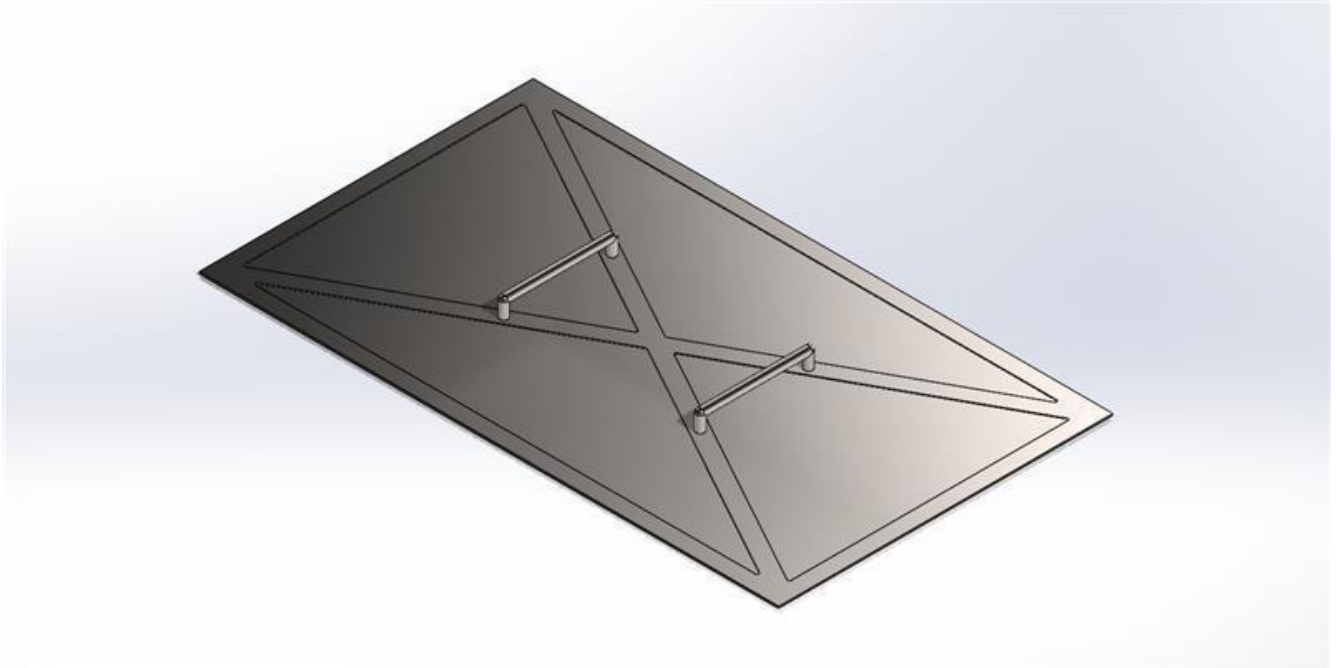


Figure 12: CAD model of a Lightweight Cover (View 1)

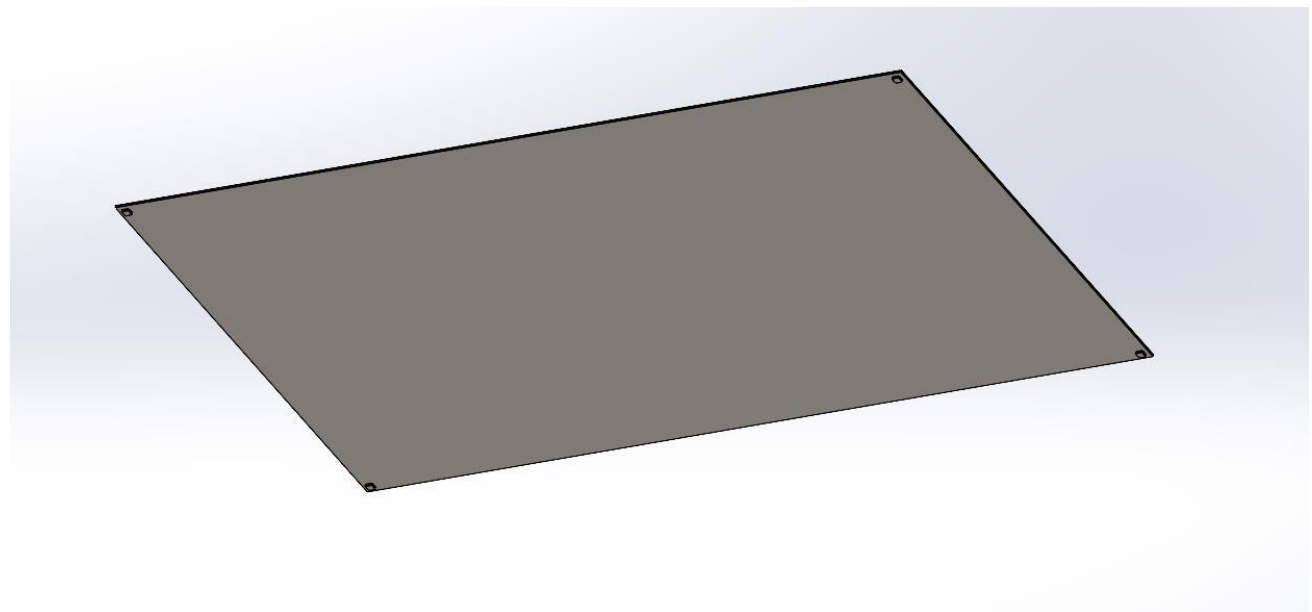


Figure 13: CAD model of a Lightweight Cover (View 2)



Figure 14: CAD model of a Lightweight Cover (View 3)

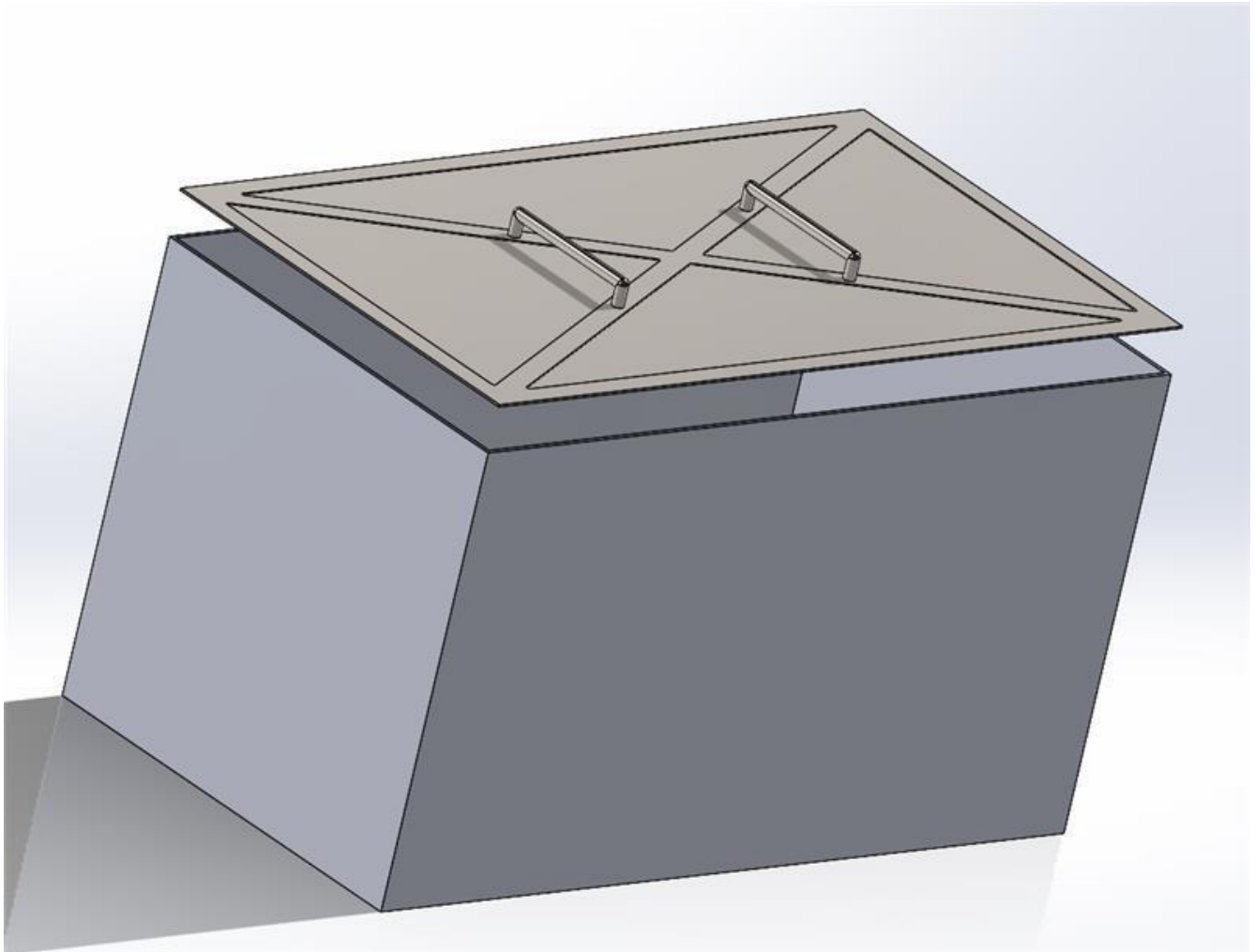


Figure 15: CAD model of a Lightweight Cover (View 4)

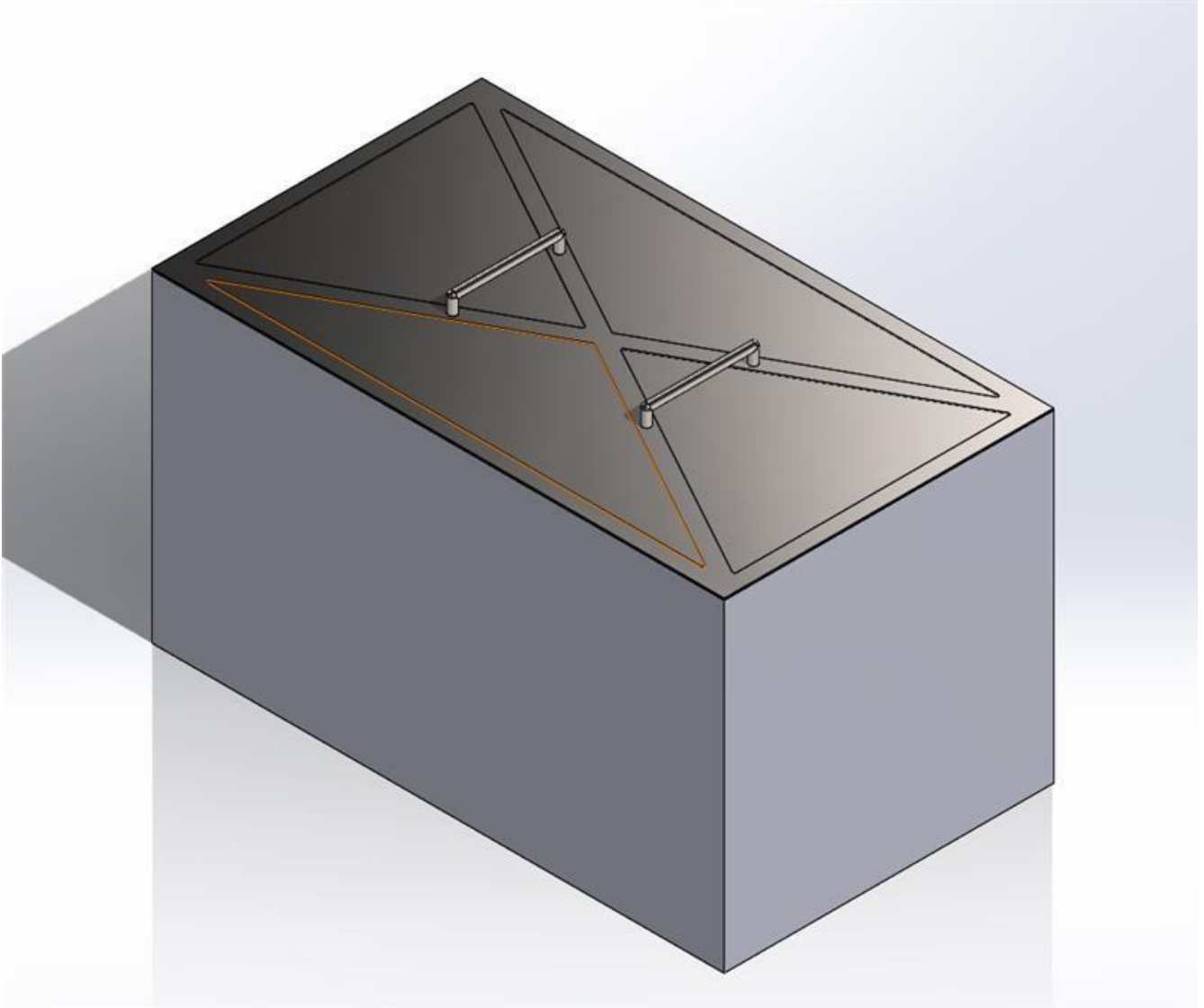


Figure 16: CAD model of a Lightweight Cover (View 5)

Fully dimensioned technical drawings (BS8888), with material choices and tolerances

Technical Drawing

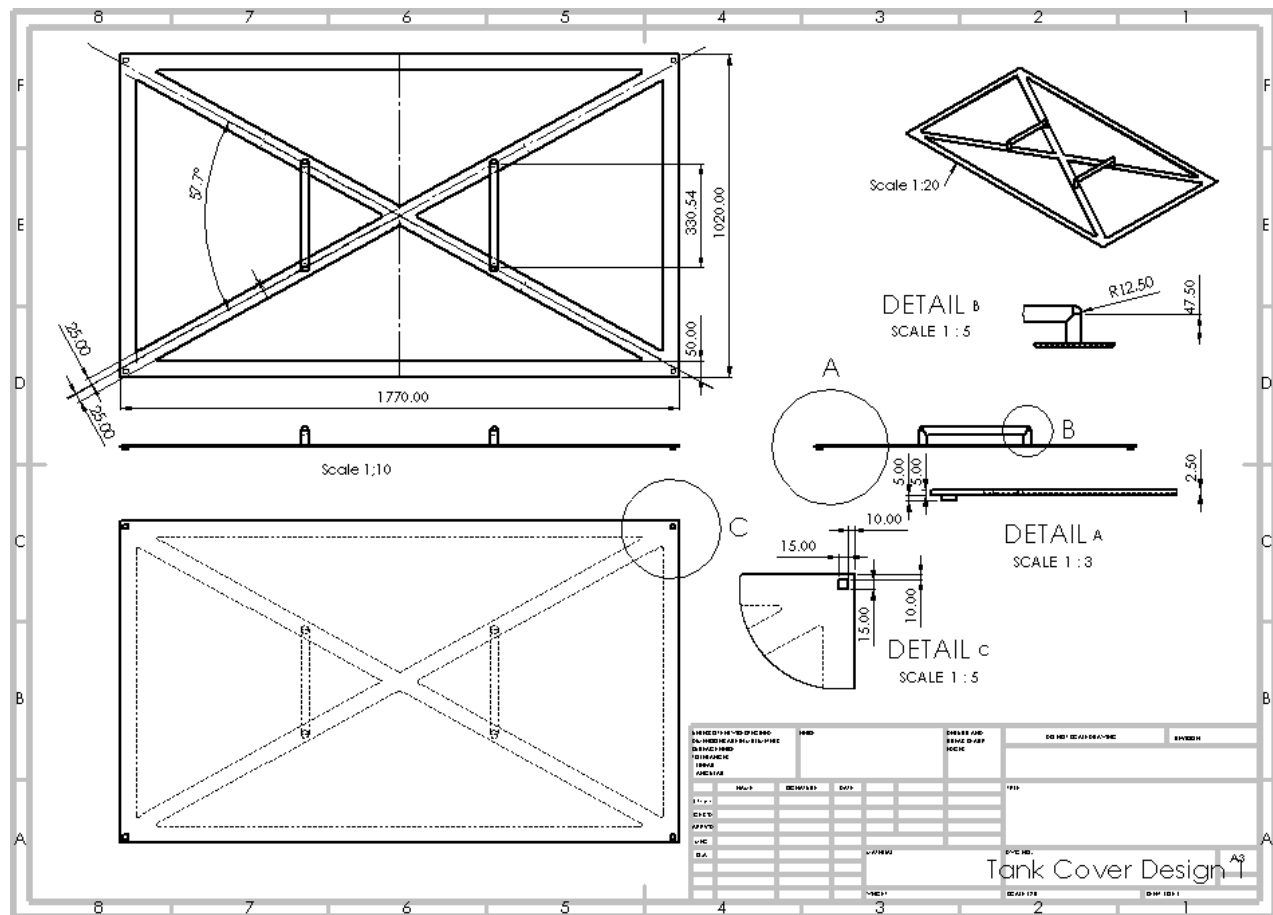


Figure 17: Technical Drawing of a Lightweight cover

Data For Redesigned Stainless-Steel Cover

Mass properties of Tank Cover Design I

Density = 0.01 grams per cubic millimeter Mass = 47336.20

grams

Volume = 6068743.20 cubic millimeters Surface area = 3733911.02

square millimeters

Center of mass: (millimeters) $X = 0.01$

$$Y = 4.87$$

$$Z = 0.00$$

Principal axes of inertia and principal moments of inertia: (grams * square millimeters) Taken at the center of mass.

$$I_x = (1.00, 0.00, 0.00)$$

$$P_x = 4301372174.02$$

$$I_y = (0.00, 0.00, -1.00)$$

$$P_y = 12574026179.25$$

$$I_z = (0.00, 1.00, 0.00)$$

$$P_z = 16861561011.08$$

Moments of inertia: (grams * square millimeters)

Taken at the center of mass and aligned with the output coordinate system. (Using positive tensor notation.) $L_{xx} = 4301372174.14$

$L_{xy} =$

$$10329.58$$

$$L_{xz} = -30217.15$$

$$L_{yx} = 10329.58$$

$$L_{yy} = 16861561011.07$$

$$L_{yz} = 5215.85$$

$$L_{zx} = -30217.15$$

$$L_{zy} = 5215.85$$

$$L_{zz} = 12574026179.14$$

Moments of inertia: (grams * square millimeters)

Taken at the output coordinate system. (Using positive tensor notation.) $I_{xx} = 4302496765.59$

$$I_{xy} = 11527.35$$

$$I_{xz} = -30216.65$$

$$I_{yx} = 11527.35$$

$$I_{yy} = 16861561012.54$$

$$I_{yz} = 5688.43$$

$$I_{zx} = -30216.65$$

$$I_{zy} = 5688.43$$

$$I_{zz} = 12575150771.68$$

Data For Redesigned Titanium Cover

Density = 0.00 grams per cubic millimeter Mass = 27916.22

grams

Volume = 6068743.20 cubic millimeters Surface area = 3733911.02

square millimeters Center of mass: (millimeters)

$$X = 0.01$$

$$Y = 4.87$$

$$Z = 0.00$$

Principal axes of inertia and principal moments of inertia: (grams * square millimeters) Taken at the center of mass.

$$\begin{aligned} I_x &= (1.00, 0.00, 0.00) & P_x &= 2536706666.73 \\ I_y &= (0.00, 0.00, -1.00) & P_y &= 7415451336.48 \\ I_z &= (0.00, 1.00, 0.00) & P_z &= 9943997519.36 \end{aligned}$$

Moments of inertia: (grams * square millimeters)

Taken at the center of mass and aligned with the output coordinate system. (Using positive tensor notation.) $L_{xx} = 2536706666.80$ $L_{xy} = 6091.81$
 $L_{xz} = -17820.37$

$$\begin{aligned} L_{yx} &= 6091.81 & L_{yy} &= 9943997519.35 & L_{yz} &= 3076.01 \\ L_{zx} &= -17820.37 & L_{zy} &= 3076.01 & L_{zz} &= 7415451336.42 \end{aligned}$$

Moments of inertia: (grams * square millimeters)

Taken at the output coordinate system. (Using positive tensor notation.) $I_{xx} = 2537369887.40$
 $I_{xy} = 6798.18$ $I_{xz} = -17820.07$

$$\begin{aligned} I_{yx} &= 6798.18 & I_{yy} &= 9943997520.22 & I_{yz} &= 3354.71 \\ I_{zx} &= -17820.07 & I_{zy} &= 3354.71 & I_{zz} &= 7416114557.66 \end{aligned}$$

Manufacturing processes for each component

The selected design requires the purchase of a Fair amount of Titanium. Which will be machined down to the required shape through the CNC process. The cover handles will be fabricated separately by bending and welding metal piping. Since this component serves solely as a tank cover, extremely tight tolerances are not a necessity, as there is sufficient allowance for variation without compromising the functionality of the cover.

Justification for design choices

The Final Design was chosen because it would Significantly Reduce the danger of lifting the tank's cover. Weight was the main concern when redesigning the cover; therefore, switching the stainless-steel cover to a titanium cover with cut-out material would greatly reduce the amount of weight the cover has. Additionally, as the cover would now be lighter, the design has changed the placement of the handles. This, theoretically, should allow a single member of staff to lift the cover away.

Another complaint that staff had made was the challenge to properly place the cover on the tank. The addition of squares protruding from the base of the cover that align with the corners of the tank would allow a simple way to properly place the cover on the tank.

Conclusion and further work

After further discussion of the design, there are a few points that can be amended to further improve the design. The design, even though significantly lighter than the previous cover, is still slightly heavier than the recommended lifting weight for employees, as seen in the data calculated through SolidWorks. There is further weight to be lost through the handles of the cover. The design in SolidWorks has solid titanium handles, where realistically, the actual design can benefit from handles that are not only hollow but also made from another lighter material. There would be a minimal risk to the handles encountering the sulphuric Acid.

To further lessen the risk of injury to staff, the design could also integrate another previous design concept. The addition of pneumatic assistance would exponentially increase the safety of opening the tank.

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Legend: S = Satisfactory O = Some attack U = Unsatisfactory HDPE Chemical Resistance Guide. (n.d.). Available at: <https://www.ineos.com/globalassets/ineos-group/businesses/ineos-olefins-and-polymers-usa/products/technical-information--patents/ineos-hdpe-chemical-resistance-guide.pdf>. [Accessed 05/04/25]

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