

University of Wales Trinity Saint David

School of Engineering



Engineering Problem

Engineering Design

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# 1 Introduction

The anodization process is essential in automotive original equipment manufacturing (OEM), enhancing aluminium's corrosion resistance and aesthetic properties. Although aluminium is naturally resistant to corrosion, environmental and operational factors can compromise its durability, making anodization critical to maintaining high-quality standards. "Despite being a corrosion resistant metal, aluminium may still corrode, tarnish, and oxidise. The process of anodising aluminium enhances its natural resistance to corrosion" (2024, thyssenkrupp).

A key issue has been identified with the stainless-steel tank used in the anodization process, specifically its removable 5 mm thick lid. The lid, required for health and safety compliance when the tank is not in use, poses operational challenges. It currently requires two operators for removal and refitting due to its weight and complexity, with frequent alignment issues reported by staff. These challenges increase operational inefficiencies and present safety risks, including potential injuries and mishandling.

This report aims to develop a safer, single-operator solution for the tank lid that addresses these challenges while ensuring compliance with health and safety standards. The redesign seeks to improve workplace ergonomics, reduce downtime, and optimize operational efficiency.

Using the product design cycle, this document explores the problem, outlines design criteria, and presents feasible solutions. CAD models, technical drawings, and material justifications will support the proposal, ensuring a practical and sustainable solution for the anodization process.

## 2 Key Legislation Considerations

The design must adhere to health and safety regulations and industry standards, including

1. Manual Handling Operations Regulations (1992): The lids design should minimize the risk of injury by reducing physical effort and awkward postures.
  - “In general, if any dimension of the load exceeds about 75 cm, handling it is likely to pose an increased risk of injury, especially if this size is exceeded in more than one dimension.” (2016, HSE).
  - “Being able to adopt a comfortable, stable posture is important, as is avoiding twisted or bent postures.” (2016, HSE).
2. COSHH Regulations (2022): As the tank contains 30% sulphuric acid which is corrosive, the design must prevent spills or exposure during handling and storing.
  - “Corrosive causes severe skin burns and eye damage. Avoid spilling. Avoid contact with skin and eyes.” (2012, UNIVAR)
  - “The design and use of appropriate work processes, systems and engineering controls and the provision and use of suitable work equipment and materials and the control of exposure at source.” (2024, Legislation)
3. BS8888 Technical Product Documentation, technical drawing must comply with the standard for clarity.
4. ISO 12100 (2010) Safety of machinery – General principles for design – Risk assessment and risk reduction.

### 3 Specification

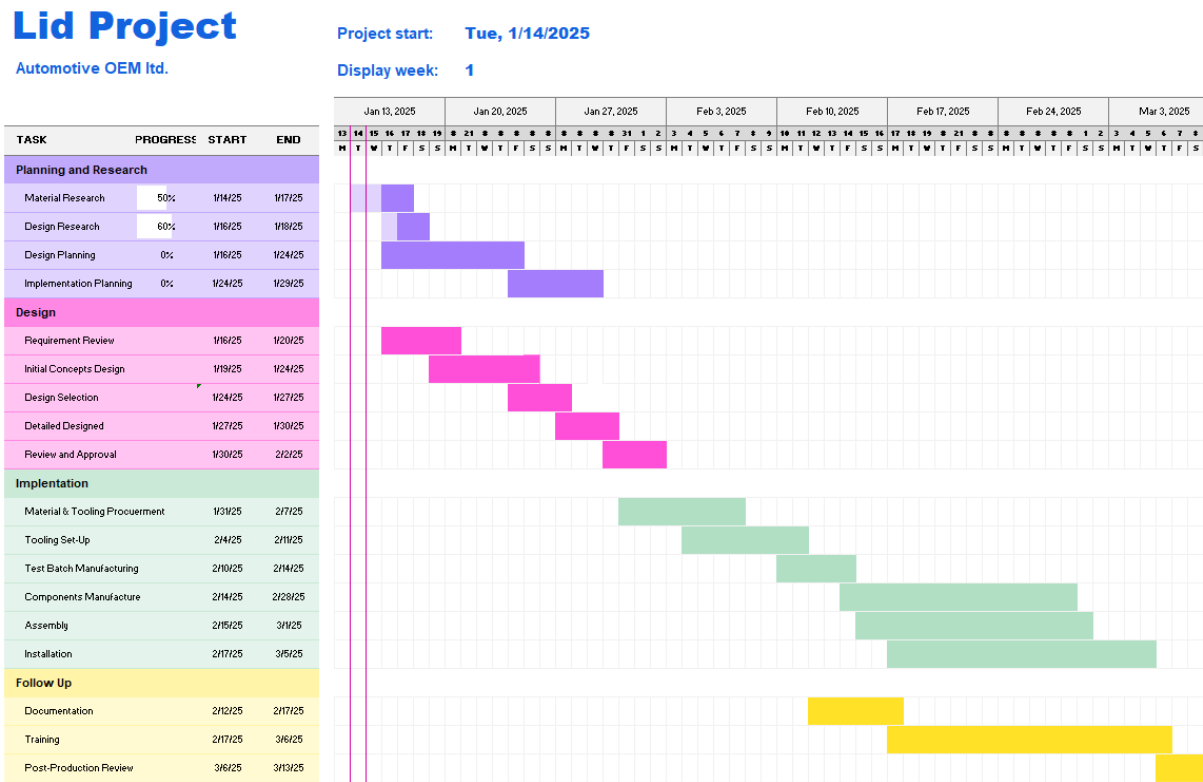
*Table 1 – Specification Table*

|                          |                                                                                                                                                                                                |
|--------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Performance              | <ul style="list-style-type: none"><li>• Cover the top of the tank</li><li>• Be able to be removed by one person</li><li>• Allow unobstructed access for hoisting parts into the tank</li></ul> |
| Environment              | <ul style="list-style-type: none"><li>• OEM facility, indoors</li><li>• Anodization environment, 30% Sulphuric acid</li><li>• Heated unit to 25°C</li></ul>                                    |
| Maintenance              | <ul style="list-style-type: none"><li>• Annual inspection</li><li>• Non specialist parts required</li><li>• To be carried out by facilities maintenance team</li></ul>                         |
| Target Product Cost      | <ul style="list-style-type: none"><li>• £700</li></ul>                                                                                                                                         |
| Quantity                 | <ul style="list-style-type: none"><li>• low hundreds of units</li></ul>                                                                                                                        |
| Size and Weight          | <ul style="list-style-type: none"><li>• 1020mm x 1770mm</li><li>• Each removable item must be below 16kg</li></ul>                                                                             |
| Manufacturing Facilities | <ul style="list-style-type: none"><li>• Design for ease of production at scale of low hundreds.</li><li>• Design with the possibility of use of the company current equipment</li></ul>        |
| Materials                | <ul style="list-style-type: none"><li>• Lightweight</li><li>• Corrosion resistance</li><li>• Resistance to sulphuric acid (30%) and temperature of 25°C</li></ul>                              |
| Aesthetics/Finish        | <ul style="list-style-type: none"><li>• Easy to clean</li><li>• No sharp edges</li></ul>                                                                                                       |
| Product Life Span        | <ul style="list-style-type: none"><li>• 5yrs (The duration of the tank)</li></ul>                                                                                                              |
| Installation             | <ul style="list-style-type: none"><li>• To be able to be installed by the facility maintenance team</li></ul>                                                                                  |
| Operation                | <ul style="list-style-type: none"><li>• It should enable a single person to handle and operate the lid efficiently</li></ul>                                                                   |
| Health & Safety          | <ul style="list-style-type: none"><li>• HSE maximum safe lifting weight 16kg for woman</li><li>• Ensure that the operator is away from the sulphuric acid</li></ul>                            |

4 Time plan for producing the product

Table 2 is a Gantt chart with the time plan from the research and planning through the design and manufacturing to the after-production review. The complete cycle is 8 weeks

Table 2 - Time Plan



## 5 Research

### 5.1 Material Resistance to Sulphuric Acid.

Table 3 shows the result of the material testing carried out when the selection for which material to use for the tank. This shows that there were no extreme changes to the materials, polypropylene, stainless steel and aluminium, where there was a server performance failure with PVC. All materials have also been tested with a weaker ratio of sulphur than what is being used in the process.

Table 3 - Material Performance (2024, UWTSD)

| Material                | Polypropylene (PP)                                                                     | PVC (Polyvinyl Chloride)                                                                | Stainless Steel (SS304)                                                                | Aluminum (Al 6061)                                                                     |
|-------------------------|----------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|
| Acid Concentration (%)  | 20                                                                                     | 10                                                                                      | 15                                                                                     | 10                                                                                     |
| Temperature (°C)        | 25                                                                                     | 20                                                                                      | 25                                                                                     | 20                                                                                     |
| Visual Inspection       | No visible signs of degradation or discoloration observed after 24 hours of immersion. | Significant surface degradation and discoloration observed after 24 hours of immersion. | No visible signs of degradation or discoloration observed after 24 hours of immersion. | No visible signs of degradation or discoloration observed after 24 hours of immersion. |
| Weight Change (grams)   | Initial: 50.0<br>Final: 49.9                                                           | Initial: 60.0<br>Final: 55.0                                                            | Initial: 70.0<br>Final: 70.1                                                           | Initial: 45.0<br>Final: 45.0                                                           |
| Dimensional Change (cm) | Initial: 10 x 10 x 1<br>Final: 10 x 10 x 1                                             | Initial: 15 x 15 x 1<br>Final: 14.5 x 14.5 x 1                                          | Initial: 10 x 10 x 1<br>Final: 10 x 10 x 1                                             | Initial: 20 x 20 x 1<br>Final: 20 x 20 x 1                                             |
| Tensile Strength (MPa)  | Initial: 30<br>Final: 29                                                               | Initial: 25<br>Final: 10                                                                | Initial: 200<br>Final: 198                                                             | Initial: 150<br>Final: 146                                                             |
| Hardness (HRB)          | Initial: 80<br>Final: 79                                                               | Initial: 70<br>Final: 50                                                                | Initial: 200<br>Final: 198                                                             | Initial: 120<br>Final: 118                                                             |

Table 4 shows the recommendation of material to be used as storage material compared to the percentage of sulphur strength that will be contained. This shows a poor resistive performance from the metals and a strong resistance performance from the polymer material, this may be slightly biased as the data is from a tank supplier and who have more interest in pushing the plastic products.

Table 4 - Sulphuric Acid Material Resistance Chart (2024,Protank)

| Sulfuric Acid Material Resistance Chart |                                      |                                       |                                        |
|-----------------------------------------|--------------------------------------|---------------------------------------|----------------------------------------|
| Material                                | 0-10% H <sub>2</sub> SO <sub>4</sub> | 10-75% H <sub>2</sub> SO <sub>4</sub> | 75-100% H <sub>2</sub> SO <sub>4</sub> |
| 304 SS                                  | Not Recommended                      | Not Recommended                       | Fair / Moderate                        |
| 316 SS                                  | Good / Minor                         | Not Recommended                       | Not Recommended                        |
| CPVC                                    | Excellent                            | Excellent                             | Fair / Moderate                        |
| PVC                                     | Excellent                            | Excellent                             | Fair / Moderate                        |
| XLPE                                    | Excellent                            | Excellent                             | Good / Minor                           |
| HDPE                                    | Excellent                            | Excellent                             | Excellent                              |
| LDPE                                    | Excellent                            | Excellent                             | Good / Minor                           |
| Polypropylene                           | Excellent                            | Excellent                             | Fair / Moderate                        |
| FRP                                     | Excellent                            | Good / Minor                          | Not Recommended                        |
| Nylon                                   | Fair / Moderate                      | Not Recommended                       | Not Recommended                        |
| Neoprene                                | Good / Minor                         | Good / Minor                          | Not Recommended                        |
| PTFE                                    | Excellent                            | Excellent                             | Excellent                              |
| PVDF / Kynar                            | Excellent                            | Excellent                             | Excellent                              |
| VITON                                   | Excellent                            | Excellent                             | Excellent                              |
| Hastelloy-C                             | Good / Minor                         | Good / Minor                          | Good / Minor                           |
| Teflon                                  | Excellent                            | Excellent                             | Excellent                              |
| EPDM                                    | Excellent                            | Good/ Minor                           | Good / Minor                           |
| Aluminum                                | Fair / Moderate                      | Not Recommended                       | Not Recommended                        |
| Brass                                   | Not Recommended                      | Not Recommended                       | Not Recommended                        |
| Titanium                                | Not Recommended                      | Not Recommended                       | Not Recommended                        |

5.2 Design Inspirations, Available of the Shelf Parts and Product Info

Figure 1 shows there are already plenty of off the shelf heavy duty polymer lids but unfortunately the treatment tank isn't to a standard size.

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  <p><b>Plastic Lid For A Pallet Box - 1175x810x40mm</b></p> <p>Art#: 61130</p> <ul style="list-style-type: none"><li>• Sustainable</li><li>• Easy To Clean</li><li>• Made From HDPE Plastic</li><li>• Suitable For The Food Industry</li></ul> <p>1175x810x40 (LxWxH)</p> <p>From <b>£55.96</b><br/>£67.71 Incl. VAT</p> <p><a href="#">Read more</a></p> <p> In Stock<br/> Estimated Lead Time &gt; 3-4 Weeks</p> |  <p><b>Plastic Clip for Euro Stacking Boxes</b></p> <p>Art#: 69996</p> <ul style="list-style-type: none"><li>• Attachment Clips</li><li>• Easy to use</li><li>• Safely Transport Products</li><li>• Strong and Stable</li></ul> <p>0x0x0 (LxWxH)</p> <p><b>£0.95</b><br/>£1.14 Incl. VAT</p> <p><a href="#">Read more</a></p> <p> In Stock<br/> Express Delivery Available</p> |  <p><b>Plastic Lid For A Pallet Box - 1210x1010x40mm</b></p> <p>Art#: 61110</p> <ul style="list-style-type: none"><li>• Sustainable</li><li>• Easy To Clean</li><li>• Made From HDPE Plastic</li><li>• Suitable For The Food Industry</li></ul> <p>1210x1010x40 (LxWxH)</p> <p>From <b>£60.76</b><br/>£73.52 Incl. VAT</p> <p><a href="#">Read more</a></p> <p> In Stock<br/> Express Delivery Available</p> |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

Figure 1 - HDPE lids (2024, Rotomshop)

Figure 2 provides several different hinges ideas.

|                                                                                                          |                                                                                                              |                                                                                                            |                                                                                                                |
|----------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|
|  <p>Door Hinges</p>   |  <p>Tee Hinges</p>        |  <p>Cabinet Hinges</p> |  <p>Specialist Hinges</p> |
|  <p>Window Hinges</p> |  <p>Finger Protectors</p> |  <p>Gate Hinges</p>    |  <p>Hinge Pads</p>        |

Figure 2 - Different hinges available (2024, Screwfix)

Figure 3 shows options for off the shelf handles

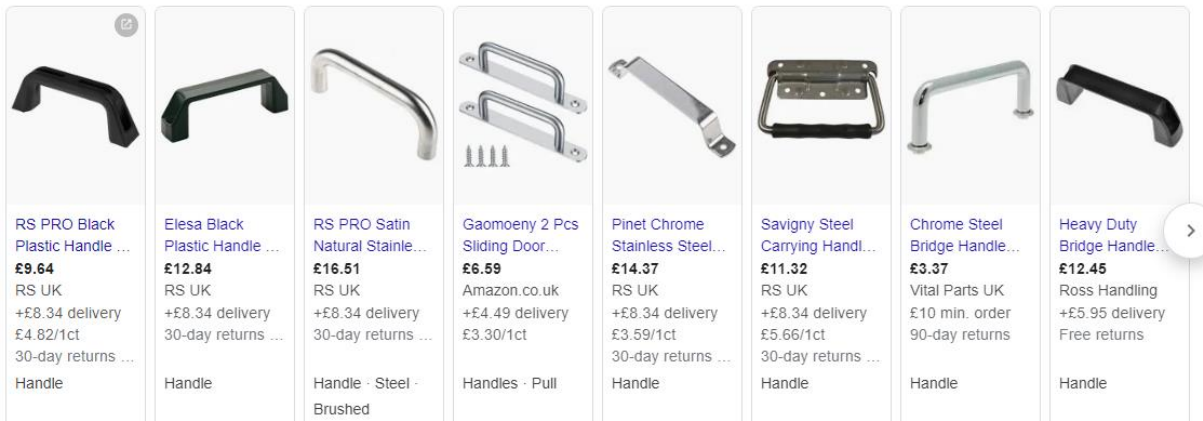


Figure 3 - Different handle styles (2024, smec)

Figure 4 and Figure 5 show that aluminium is 12.5kg per meter lighter than steel.

| More Information     |                  | FAQ |  |
|----------------------|------------------|-----|--|
| Material             | Stainless Steel  |     |  |
| Weldability          | Excellent        |     |  |
| Shape                | Sheet            |     |  |
| Corrosion Resistance | Good             |     |  |
| Finish               | Brushed Polished |     |  |
| Grade                | 304              |     |  |
| Thickness            | 5mm              |     |  |
| Weight/Metre (Kg)    | 39.6             |     |  |

Figure 4 - Stainless Steel product information (2024, metals4u)

|                                                                                     |                                               |          |         |         |
|-------------------------------------------------------------------------------------|-----------------------------------------------|----------|---------|---------|
|  | 2000mm x 1000mm x 5mm thick - aluminium sheet | 27.1 kg  | £260.00 |         |
|  | 2000mm x 1000mm x 3mm thick - aluminium sheet | 16.26 kg | £140.00 |         |
|  | 2000mm x 1000mm x 4mm thick - aluminium sheet | 21.66 kg | £210.00 | £252.00 |

Figure 5 - Aluminium products weights and price (2024, The Metal Store)

### 5.3 Processing Technique

Research that laser cutting is the most common form of metal sheet cutting and cold bending will increase the strength creating a stronger final shape.

- “Laser cutting is single of the furthermost types for cutting of materials, like titanium, stainless steel, aluminium” (2022, Materialstoday:Proceedings)

- 

#### **Advantages of Cold Working**

Some of the major advantages of the Cold Working process are:

- Precise dimensional accuracy can be upheld.
- Metals remain unheated throughout the process.
- Superior surface finish is attainable as there is no oxidation during cold metalworking.
- Enhanced strength and hardness of the metal are achieved.
- Cold working imparts increased strength and hardness to the metal.
- Improved material strength and wear properties can be realised.

(2023, Testbook)

- “TIG welding aluminium is one of the most popular welding processes chosen for this material.” (2020, UTI)

## 6 Annotated Sketches of Multiple Design Concepts

### 6.1 Design 1

This design *figure 6* contains the lid material. The lid has been cut length ways into four sections, with the handles removed from the outer edges and placed near the centre 2 panels are then joined with hinges creating a double door in the centre of the lid. On the underside blocks are added to secure the movement of the lid and guide the lid to its seating position.

The centre part of the lids can be open by pulling the handles towards the edge, like a wardrobe door function. This will allow access for the sheets to entre the treatment tank.

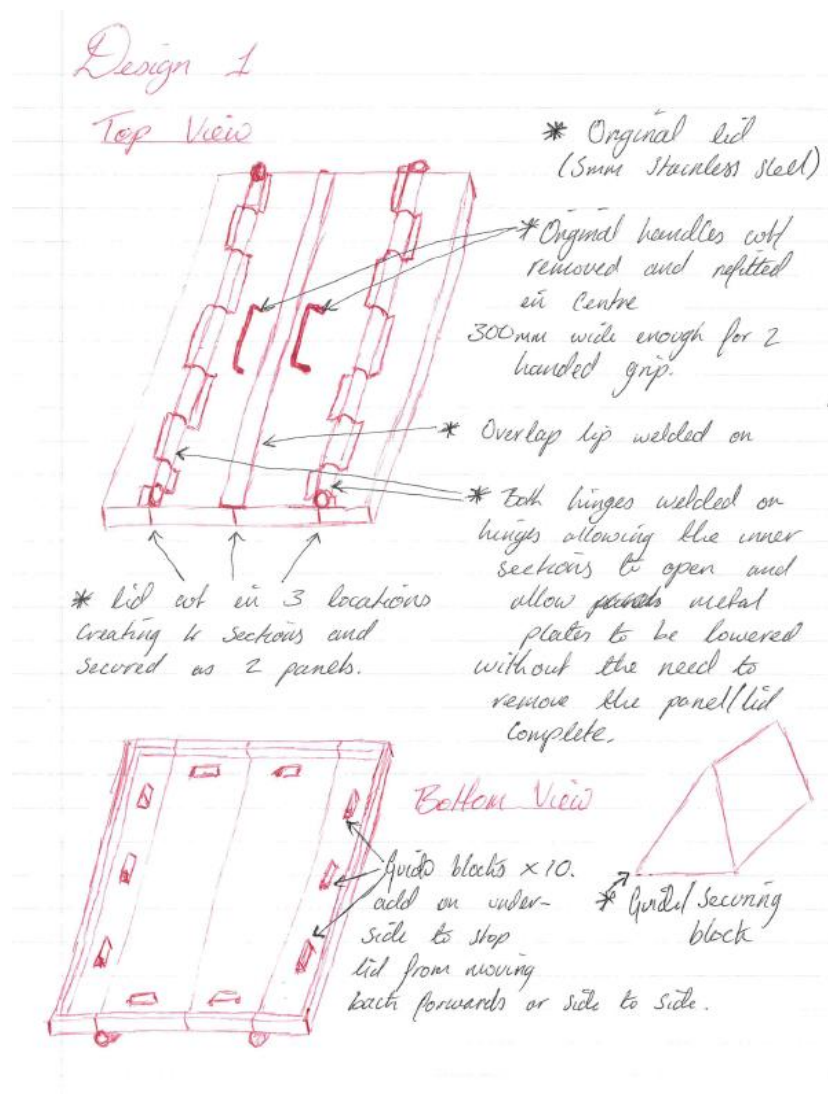


Figure 6 - Design 1

## 6.2 Design 2

This design *figure 7* has a lid moulded from HDPE polymer, containing euro stacking plastic clips. Two handles are in the mould for ease of handling and imprint patterns for additional stiffness. Modifications are required to the tank with stainless steel catches required to be welded on for when securing the lid on is required.

By the lid is secured by quick release slide clips, these secure the lid to the tank and can be release with ease and efficiency, the polymer material is light weight meaning the lid can be removed and refitted with ease.

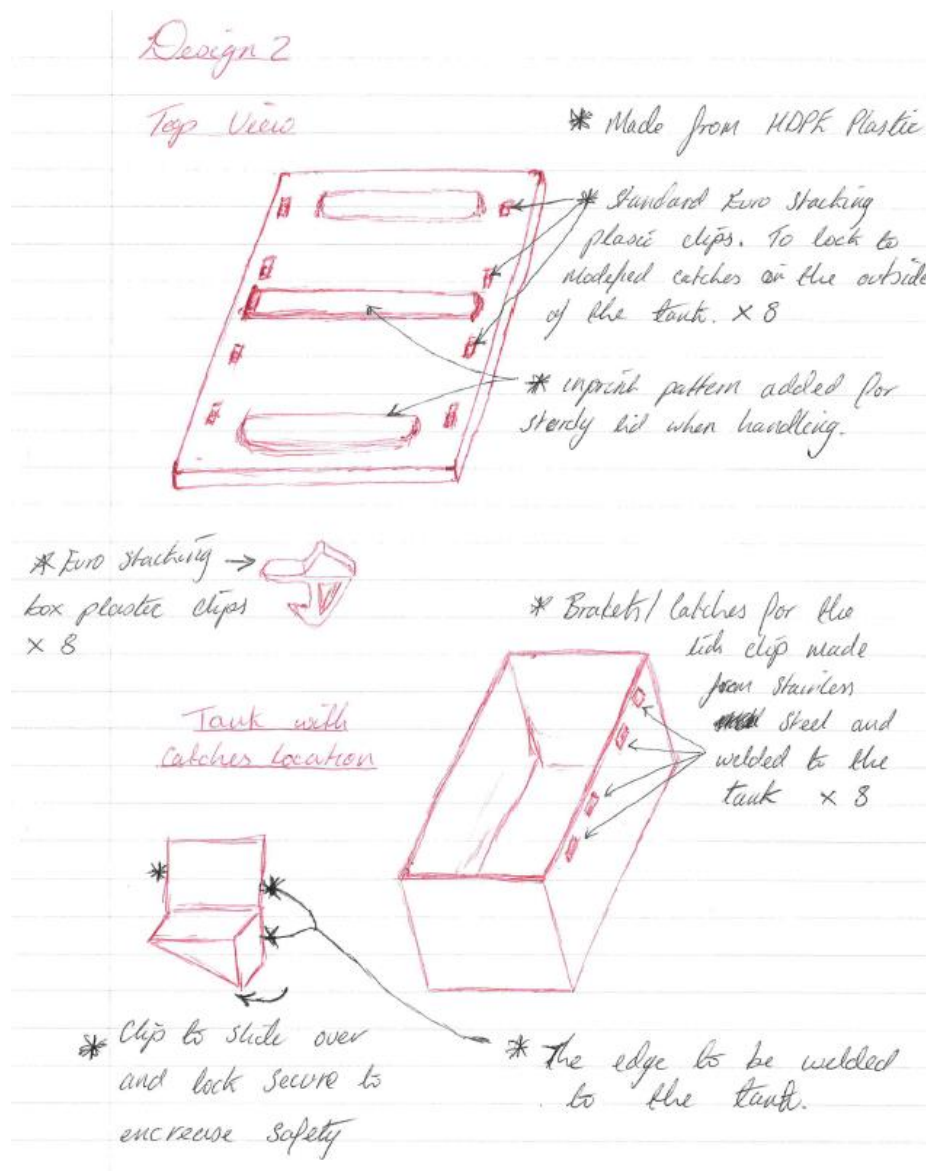


Figure 7- Design 2

### 6.3 Design 3

In figure 8 has the lid as a two-part piece. The lid is made from aluminium and the lips/side are metal bended into position, off the shelf handles have been placed in positions where the operator can carry and manoeuvre the lid with ease and control. A pin then can be dropped in the centre when both panels are fitted correctly to secure the lids.

This lid is split in two with a securing pin in the centre, by removing the securing pin both lids can slide back and then with the handles the lids can be handle with ease and comfort by one operator.

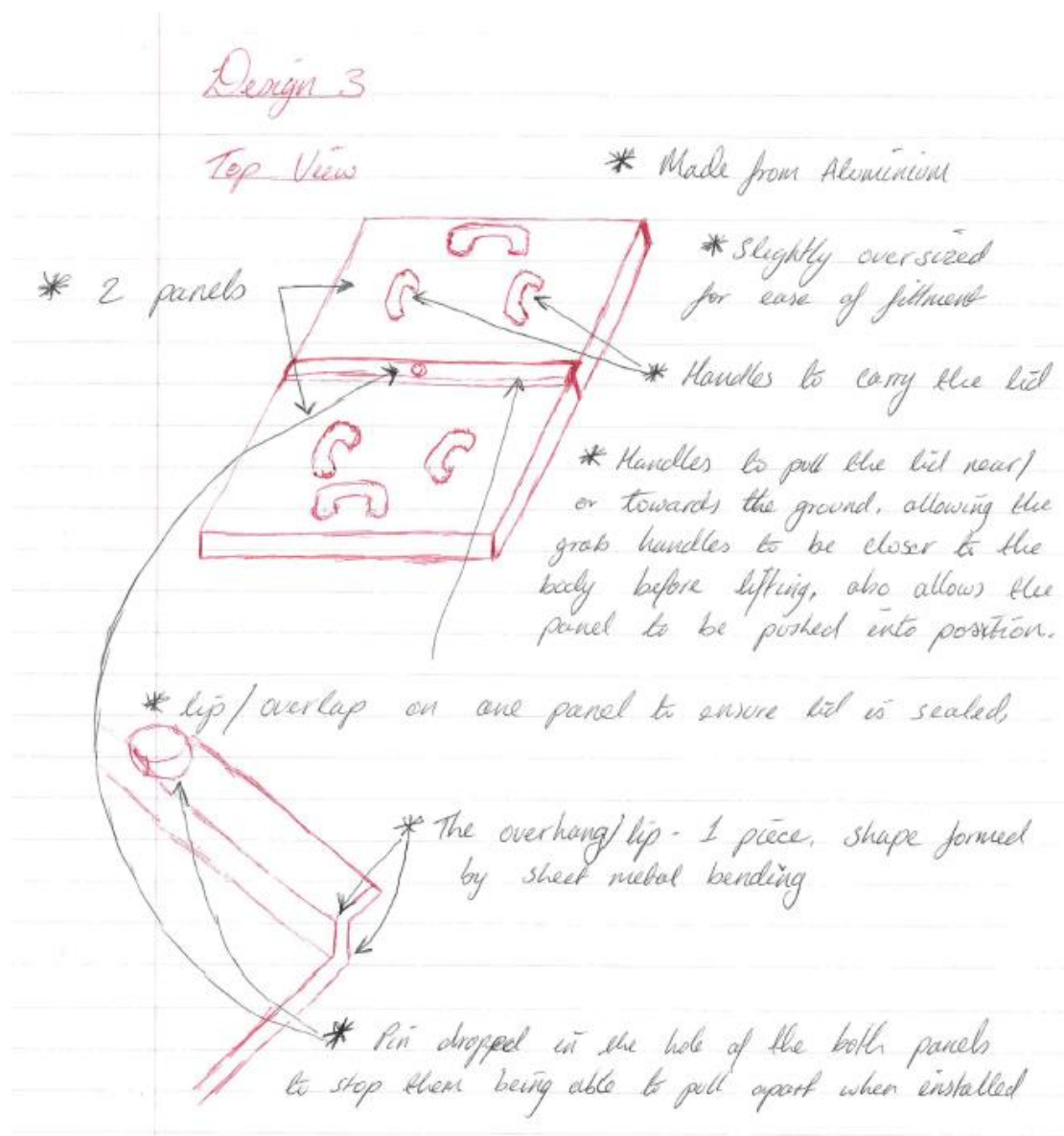


Figure 8 - Design 3

## 7 CAD Model of the Final Design

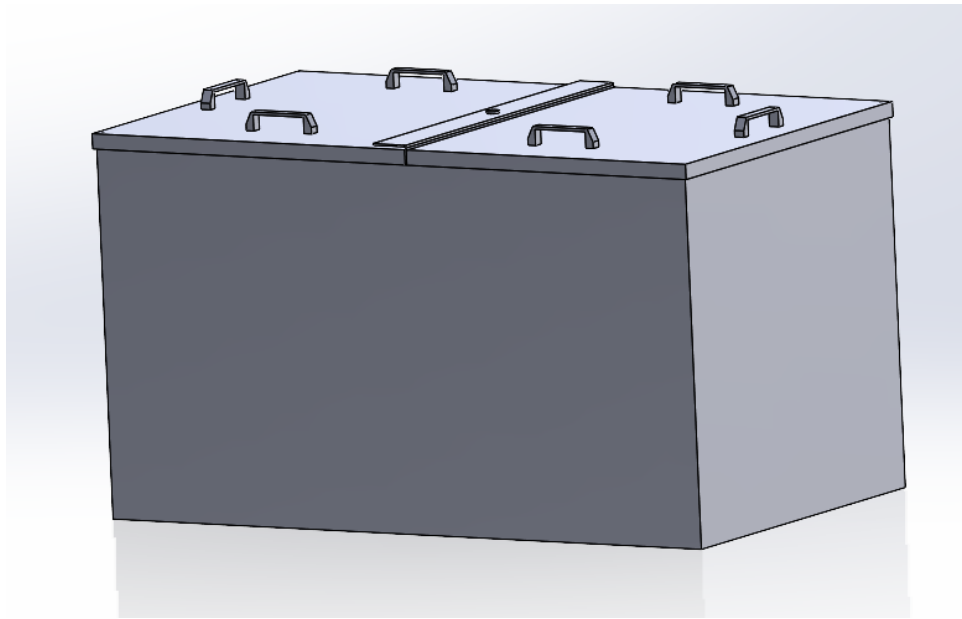


*Figure 9 – Tank Fully Assembled with New Design Covers*

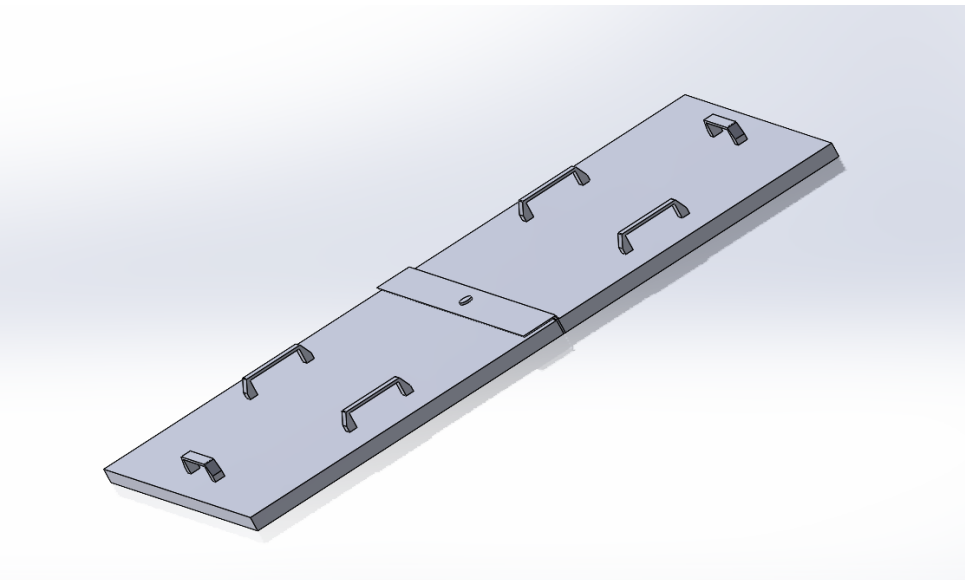


*Figure 10 - New Design Tank Cover*

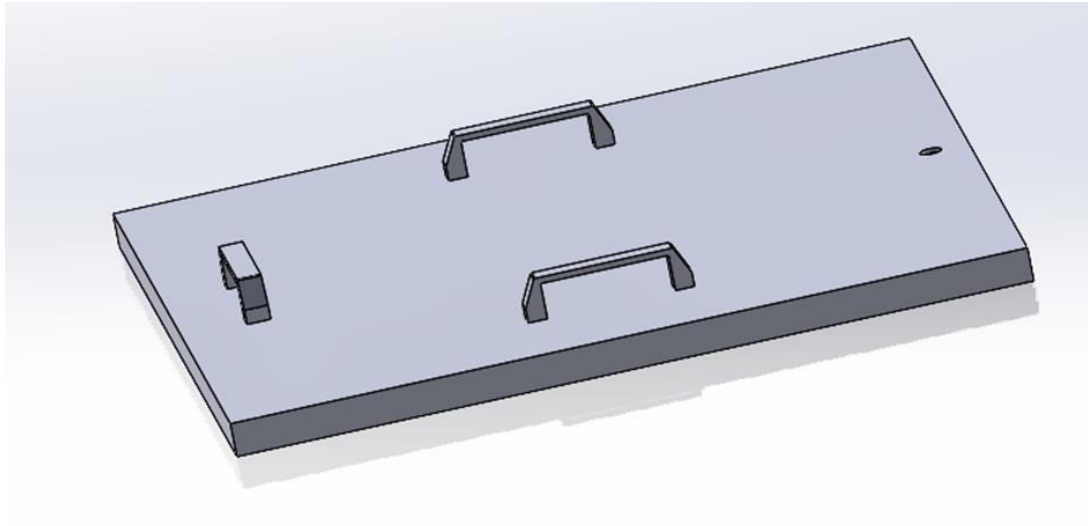


*Figure 11 - Left Hand Lid*

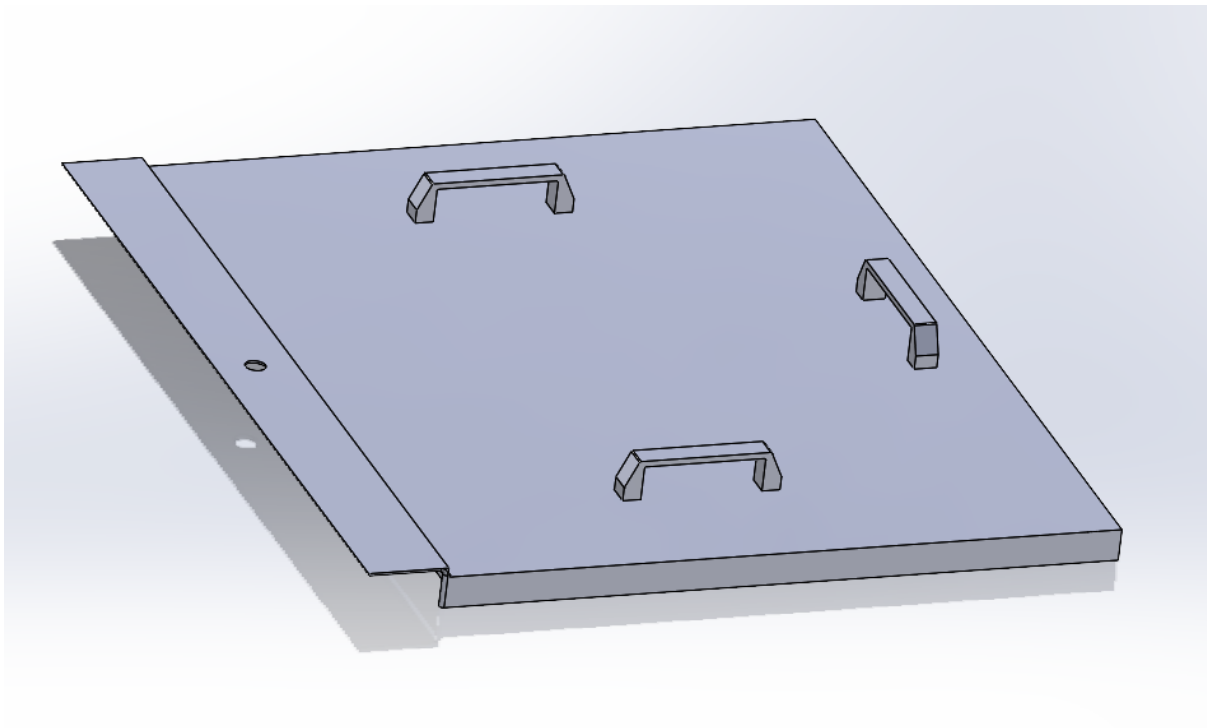


*Figure 12 - Right Hand Lid*



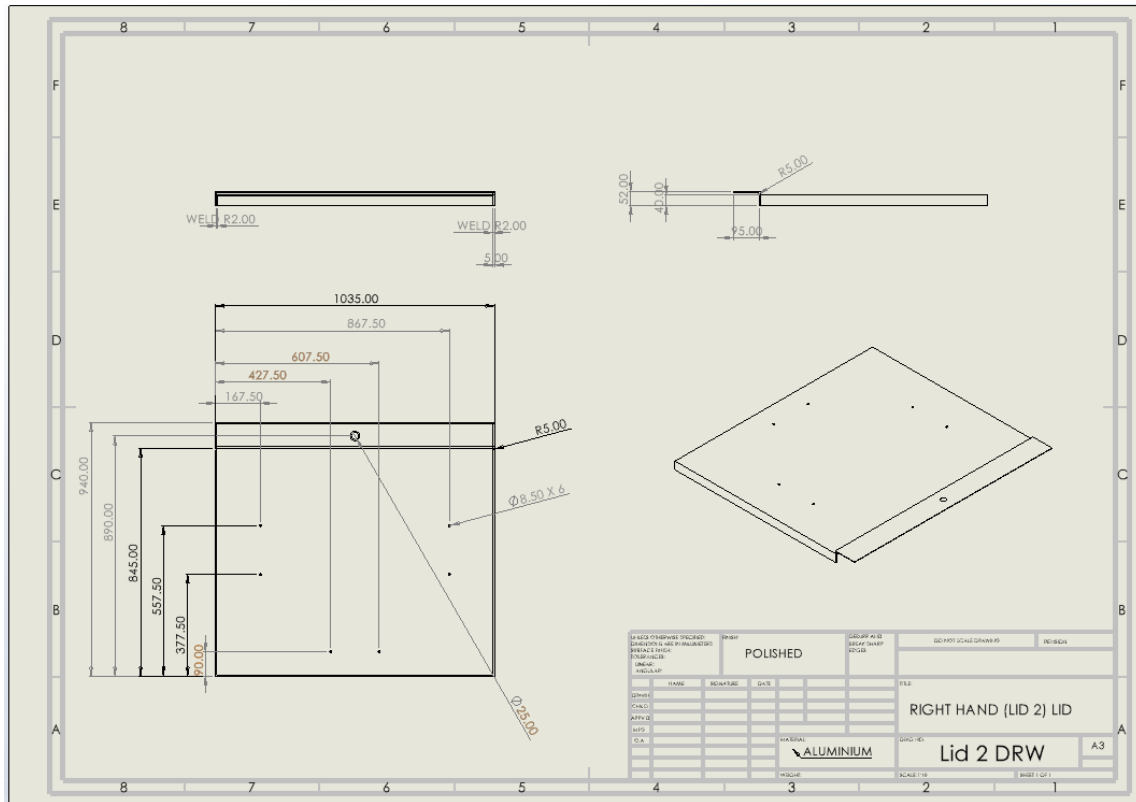


Figure 14 - Right Hand Bin Lid

## 9 Manufacturing Process of the Aluminium Lid

### 9.1 Sheet Metal Working

Aluminium sheets are cut with precision into the required panel shapes using cutting equipment either laser cutter or water jet cutting machines. This equipment will do the outer profile and the cut-out for the handle fixings and the securing pin holes.

The panels are deburred to remove sharp edges

The overhanging edges on each panel is formed using sheet metal bending process, this process is also used for the overlapping tongue

Both corners of the lip are then manually welded to ensure the lid stiffness and shape is maintained during its lifetime

### 9.2 Assembly

With the securing pin, handles and fasteners being off the shelf items, these items can be assembled by the maintenance team at the factory manufacturing cost

## 10 Design Choice Justification

Using a decision-making matrix tool *Table 4*, five criteria was selected feasibility, cost, efficacy, sustainability and safety and risk. These are scored from 1-5 low to high importance each design was scored against the criteria's as well as multiplied against the criteria weights to retrieve the scores. Using the scores we can then see which design had the highest score.

*Table 1 - Decision Making Matrix*

| Criteria        | Weight | Design 1 |       | Design 2 |       | Design 3 |       |
|-----------------|--------|----------|-------|----------|-------|----------|-------|
|                 |        | Score    | Total | Score    | Total | Score    | Total |
| Feasibility     | 5      | 4        | 25    | 3        | 15    | 4        | 20    |
| Cost            | 4      | 5        | 20    | 3        | 12    | 4        | 16    |
| Efficiency      | 5      | 3        | 15    | 5        | 25    | 4        | 20    |
| Sustainability  | 3      | 4        | 12    | 3        | 9     | 4        | 12    |
| Safety and Risk | 5      | 3        | 15    | 4        | 20    | 4        | 20    |
|                 | Total  |          | 82    |          | 81    |          | 86    |

### 10.1 Feasibility

Design 1 and 3 have been scored the highest with a score of four. Design one is highly feasible as the original lid is retained saving on shaping. The downfall is that most tasks in doing the modifications are labour intensive for example, the cutting and relocating the handles, welding the guide blocks, hinges and the overlap plate.

Design 3 uses a straightforward manufacturing process, laser cutting and sheet metal bending. The modular design, assembly process and off the shelf parts ensures the ease of production and making it feasible for the production unit numbers.

Design 2 has a lower score as the process of manufacturing is injection moulding. This is less feasible due to the low production numbers would increase the cost of product due to the set-up time and custom moulds required for producing the product.

## 10.2 Cost

Design 1 is the most cost effective with a score of five as the original lid material is contained and the handle, the only additional cost are the off the shelf hinges, guide blocks and the additional labour hours.

Design 2 has been scored the lowest with a score of three, HDPE is a cheaper material compared to aluminium but the set-up cost on this low production scale and the extra labour hours and modifications to the tanks would increase the cost per unit higher than the other two options.

Design 3 uses aluminium which is a cost-effective material as it balances lightweight, durability and affordability. The off the shelf handles and fasteners also keep the cost lower with the uncomplex pattern and manufacturing process of the design. The main labour cost will be deburring and welding the corners.

## 10.3 Efficiency

Design 1 has been scored the lowest due fact that the size of the item that can be fitted to the tank is limited by the width of the doors and to be able to use the complete size of the tank the operation of removing the lid would require more than the one operative. The hinges will increase maintenance task and inspection and increases the risk of production down time.

Design 2 is the most efficient design with its quick release clips and lightweight material, this allows the lid to be secured and unsecured quickly and effortlessly and the removal of the lid can be removed by one person in one movement easily.

Design 3 has a score of four as the lid must be removed in two sections this increases the time of removal and fitment of the lid but the handle locations, lightweight materials, oversized lid and the securing pin ensures that the task is as fast and effective as possible with the design as a two-section item

## 10.4 Sustainability

Design 1 and Design 3 have a score of four as both materials used are metal and can be recycled, Design 1 used the original material, but the lifetime of the lid is expected to last as long as the tank whereas the aluminium in Design 3 is expected to out last the tank and be reused again meaning on balance the sustainability on balance is the same

Design 2 is HDPE, the reliance on plastic isn't socially, environmentally accepted but the material is recyclable. Even with the material being recyclable the adaptation or ability to modify the lid is limited.

### 10.5 Safety and Risk

Design 1 has had the lowest score even though that opening the doors is the safest and easiest task of the three designs, the consideration of the requirement of needing to remove the complete lid has been factored in this scoring

Design 2 hasn't had the full score of five even though its made of the lightest material due to the size of the panel is larger than the recommendation of the Health and Safety regulations

Design 3 by splitting the panel and using light weight materials ensures that the design is within the guidelines of Health and Safety but have to take in the consideration that the securing pin location is on top of the tank which does have the risk of working over the tank and the sulphuric acid.

## 11 Conclusion

The design process for the tank lid addresses critical safety and operational concerns while taking in the consideration of cost, sustainability and feasibility. With the aid of the decision matrix tool the final choice Design 2 is the best option as its modular design, simple manufacturing process and aluminium as the main material with off the shelf components provides the best balance while ensuring that health and safety regulation is met. The lid increases the ease of functionality for a single person operation and aligns with the project specification.

### 11.1 Further Works

- Prototype – Prototype would allow for a more accurate scores of functionalities, manufacturing time and maintenance
- Market research – Evaluation for higher production numbers.

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