Conceptual frame for a large-scale electrolyser vessel

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Deadline: Monday 15th December, 2025 [23:59], Last Updated: Tuesday 21st October, 2025 [22:40],
Days left until deadline: 54 days and 1 hour and 20 minutes.

Abstract

This report presents the *development* of an assembly and maintenance frame for Supercritical Solutions' large-scale electrolyser vessel. The project uses the DMAIC framework to guide systematic problem definition, measurement, analysis, improvement, and control. Design concepts are generated, evaluated, and optimized to satisfy technical, operational, and sustainability requirements, while integrating stakeholder and customer needs through tools such as the Voice of the Customer (VoC) and Objective Tree Diagram (OTD). Risk management, including DFMEA, and quality control measures are applied to ensure a robust, safe, and practical solution. The report documents methodology, key design decisions, and professional competencies developed.

1. Introduction

Electrolysers play a critical role in industrial hydrogen production, requiring robust support structures for safe and efficient operation. Designing assembly and maintenance frames for large-scale vessels presents challenges including structural integrity, accessibility, maintenance, and long-term reliability.

This project focuses on developing an assembly and maintenance frame for Supercritical Solutions' electrolyser vessel, applying systems thinking and the DMAIC methodology. Stakeholder and customer requirements are captured using VoC and OTD, while design evaluation uses tools such as QFD and concept trade-off analysis. Risk assessment via DFMEA and quality planning ensure compliance with technical, operational, and sustainability standards.

The report outlines project methodology, key engineering decisions, and rationale behind the chosen solution, highlighting professional skills developed including project management, teamwork, critical thinking, and problem-solving.

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- **Customer and Stakeholder Requirements**: List functional requirements (load support, accessibility, safety, ergonomics) using **VoC**.
- **Project Objectives**: Include **OTD** showing link from high-level goals to design targets.
- **Constraints and Specifications**: Material, dimensional, regulatory, cost, and sustainability requirements.

2. Define (D)

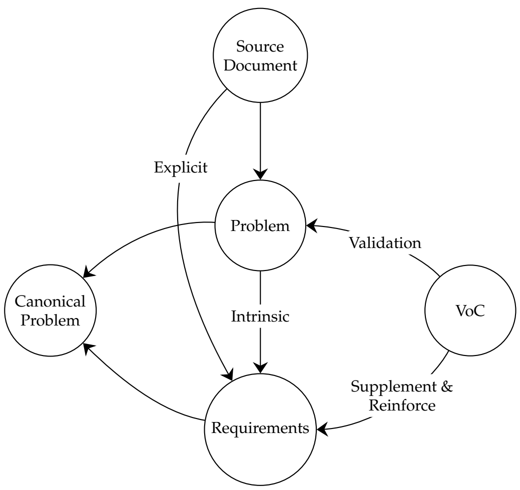

Figure 1: Define Phase Workflow: From Source to Canonical Problem

2.1 Approach Overview

This Define phase establishes a clear and validated understanding of the problem by consolidating information from the Initial Industry Brief, Voice of the Customer (VoC), and stakeholder inputs. Our approach follows a structured path:

- Extract key information from the Industry Live Brief to identify preliminary problems.
- Validate and refine these problems and requirements through VoC feedback.
- Translate validated insights into measurable requirements and objectives.
- Define material, dimensional, and regulatory constraints to ground the design in feasibility.

By combining insights from source documents, VoC feedback, and iterative refinement, we ensure that the problem definition is both grounded in reality and rigorously specified.

This integration of intrinsic context, explicit formulation, validation, and reinforcement leads to a canonical problem that clearly defines requirements, objectives, and constraints, providing a solid foundation for the next phases of concept development and evaluation.

2.2 Industry Live Brief Breakdown

Our initial source document is the live brief provided by **Supercritical Solutions Ltd**, which defines the project as:

> “ Designing an assembly and maintenance frame for Supercritical’s large-scale electrolyser vessel. ”
>
> *Zaarour, 2025, p. 1*

This statement establishes the project’s core intent — to create a support and handling system for a critical industrial component. Implicit within this is the need for mechanical stability, safety in operation, and consideration of human and environmental factors.

> “ This project focuses on developing a conceptual assembly and maintenance frame for a large-scale electrolyser module. The outer vessel houses several internal sub-units (“black boxes”), designed for efficient replacement, inspection, and servicing. ”
>
> *Zaarour, 2025, p. 1*

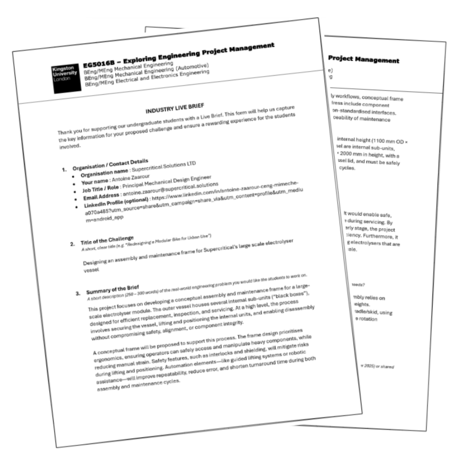

Figure 2: Zaarour, 2025, p.1,2

This section of the brief introduces the system's architecture, a primary vessel containing replaceable "black box" modules. From this, it becomes clear that modularity and maintainability are central design requirements. The frame must therefore facilitate the lifting, positioning, and removal of these sub-units without damaging components or disrupting alignment.

> " At a high level, the process involves securing the vessel, lifting and positioning the internal units, and enabling disassembly without compromising safety, alignment, or component integrity. A conceptual frame will be proposed to support this process. "
>
> *Zaarour, 2025, p. 1*

Here, the operational workflow is defined. The frame must perform under heavy loads, maintain precise alignment, and allow repeatable assembly and disassembly. This introduces key engineering considerations such as load path design, lifting safety, and tolerance management. It also frames the system as one that supports **both assembly and maintenance**, implying a dual-purpose design philosophy.

> " The frame design prioritises *ergonomics*, ensuring operators can safely access and manipulate heavy components while reducing manual strain. Safety features, such as interlocks and shielding, will mitigate risks during lifting and positioning. Automation elements—like guided lifting systems or robotic assistance—will improve repeatability, reduce error, and shorten turnaround time during both assembly and maintenance cycles. "
>
> *Zaarour, 2025, p. 1*

This passage adds a human and process-oriented layer. The focus shifts from mechanical function to **operator safety, efficiency, and automation**. Ergonomics becomes a measurable design driver, suggesting the integration of human factors engineering. Automation hints at the use of advanced control systems or assistive mechanisms, raising new requirements for precision, reliability, and system integration.

> " The project plan will include mapping of assembly/disassembly workflows, conceptual frame design, and an evaluation of tooling requirements. Risks to address include component misalignment, equipment handling hazards, and delays from non-standardised interfaces. Quality considerations will centre on ensuring precision fits, traceability of maintenance activities, and robustness of the rig to repeated use. "
>
> *Zaarour, 2025, p. 2*

This section formalises the project management expectations. It highlights risk-based thinking and introduces the need for workflow mapping — key aspects of the DMAIC and systems engineering approaches. The emphasis on quality, traceability, and standardisation implies that the solution must not only perform mechanically but also fit within broader operational and maintenance systems.

> " The outer vessel measures 870 mm internal diameter × 3000 mm internal height (1100 mm OD × 3500 mm total height) and weighs 13 tons. Housed within the vessel are internal sub-units, collectively forming a "black box" assembly measuring 550 × 550 × 2000 mm in height, with a combined weight of 3 tons. These sub-units are attached to the vessel lid, and must be safely lifted, positioned, and removed during assembly and maintenance cycles. "
>
> *Zaarour, 2025, p. 2*

Finally, this portion of the brief defines the scale of the engineering problem. The component weights and dimensions directly inform material selection, structural design, and lifting mechanism specifications. It establishes performance baselines that shape load calculations, safety factors, and ergonomics constraints.

2.3 Summary

The live brief progressively defines both the technical and managerial scope of the project. It begins with the conceptual aim, introduces the modular system context, and culminates in quantifiable design constraints. From this breakdown, several key themes emerge:

- **Structural integrity and precision** are critical due to the vessel's mass and geometry.
- **Ergonomics and safety** drive accessibility and risk mitigation.
- **Automation and repeatability** offer opportunities for process efficiency.
- **Quality and traceability** link design to long-term maintainability.

Together, these insights establish a foundation for the project's structured DMAIC approach, ensuring that design, risk, and quality objectives align with the industrial requirements outlined by Supercritical Solutions.

3. Measure (M)

- **Existing System Analysis**: Identify limitations in current supports/frames.
- **Structural and Operational Data**: Vessel dimensions, weight, centre of mass, lifting points.
- **SWOT Analysis**: Strengths, weaknesses, opportunities, and threats of current design.

4. Analyse (A)

- **Concept Generation**: Brainstorm frame geometries, assembly approaches, and maintenance access strategies.
- **Concept Selection**: Use **Pugh Matrix** and evaluate trade-offs (cost vs. performance vs. safety).
- **Risk Assessment**: DFMEA of potential failure modes in assembly, lifting, and operation.
- **Design Calculations**: Structural analysis (stress, deflection, factor of safety), material selection.

5. Improve (I)

- **Final Design Concept**: Detailed drawings, CAD models, and key dimensions.
- **Optimization**: Geometry adjustments for weight reduction, improved access, cost efficiency.
- **Quality Control Measures**: Checkpoints for fabrication and assembly; integration of PDCA cycle.

6. Control (C)

- **Implementation Plan**: Stepwise assembly and maintenance protocols.
- **Final Risk Mitigation**: Address critical DFMEA items.
- **Sustainability and Lifecycle**: Material recyclability, maintenance requirements, durability.
- **Verification**: Ensure design meets technical, operational, and stakeholder requirements.

7. Conclusion

Summarize how the frame meets functional, safety, and sustainability goals. Highlight trade-offs, engineering analysis applied, and design optimization. Reflect on professional skills developed: problem-solving, teamwork, and project management.

8. Appendices

- Supporting calculations, sketches, CAD screenshots.
- DFMEA table.
- OTD and QFD diagrams.
- Meeting minutes and stakeholder feedback.

Reference

Zaarour, A. (2025). *Industry Live Brief: Designing an assembly and maintenance frame for Supercritical's large-scale electrolyser vessel* [PDF]. EG5016B – Exploring Engineering Project Management. Kingston University London.

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