

“Design & Engineering of Plant Air Receiver”

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Abstract:

The design and engineering of a plant air receiver is a critical aspect of compressed air systems used across various industrial applications. An air receiver acts as a reservoir of compressed air, helps in dampening pulsations from the compressor, and provides storage during peak demands. The objective of this project is to carry out a comprehensive study on the mechanical design of a vertical cylindrical air receiver based on ASME Boiler and Pressure Vessel Code (BPVC) Section VIII Division 1, considering internal pressure conditions, material selection, corrosion allowances, and operational temperatures. The flow of the project includes a literature survey to understand existing design practices, a methodology outlining the engineering steps, and an analytical section providing detailed calculations for shell thickness, head design, and other parameters. Additionally, the study explores suitable materials, their mechanical properties, and manufacturing considerations. The goal is to ensure safety,

structural integrity, and compliance with applicable codes.

This project also serves as a foundational guide for future design improvements and customized applications of air receivers in industrial settings

Key words: Compressed air system, air receiver, pressure vessel, ASME Section VIII, material selection, stress analysis, design parameters.

Introduction:

An air receiver serves as a storage vessel for compressed air, ensuring stable pressure and reducing compressor load. In industrial settings, efficient air receivers enhance system reliability and reduce energy consumption. Designing a safe, efficient air receiver requires calculating wall thickness, material properties, and adhering to safety codes. The design also involves selecting suitable materials that withstand the operating environment, considering corrosion, temperature, and pressure. The ASME BPVC Section VIII

Division 1 provides guidelines for designing pressure vessels, ensuring they can withstand internal pressures safely while maintaining operational integrity. This project emphasizes applying these principles to design a plant air receiver that meets the required standards and ensures operational safety.

This section sets the stage for the analytical and engineering approach that follows. It highlights the importance of code compliance, material strength, and safety margins while underlining the practical significance of designing a robust air receiver for industrial usage. Through this project, the goal is to understand and apply theoretical concepts in real-world design, enabling effective pressure vessel development with optimal safety, efficiency, and performance.

Literature survey:

A comprehensive review of existing literature highlights essential considerations in pressure vessel design, including material properties, stress analysis, and safety factors. Studies show that ASME codes provide a reliable framework for ensuring structural integrity under pressure. Previous research emphasizes the importance of material selection, focusing on corrosion resistance and weldability for long-term durability. Literature also discusses the role of corrosion allowances and their impact on vessel longevity. A study by Moss (2004) provided valuable insights into the mechanical properties of materials used in pressure vessel construction. Moreover, industry guidelines stress the importance of joint efficiency and manufacturing techniques for achieving safe and cost-effective designs. These insights form the foundation for this project's design approach.

Problem Statement:

The following design specifications for the Plant Air Receiver for design, Engineering. Plant Air Receiver having design capacity

Material: **SA 516 Gr. 70**

P=internal design pressure(1200kpa):1.2MPA,

D=internal diameter=2000mm,

T=temperature 85°C,

S=allowable, stress max. =138mpa (Sec-II Part-D Subpart 1, Table-1A),

CA=Corrosion allowance=3mm,

E=Joint efficiency=1,

P: External Press. =0.1mpa (atm press.),

T/L= tan to tan Length 5000mmm (L=4900)

Calculate the thickness from given data

Objective:

The primary objective of this project is to develop a comprehensive design for a plant air receiver that meets industrial requirements and safety regulations. The design must ensure structural integrity under specified working conditions, including operating pressure and temperature. Additional objectives include selecting appropriate materials that provide strength, durability, and resistance to corrosion. The design should also accommodate ease of maintenance and minimize energy loss during operation. Analytical methods will be used to verify the mechanical stability and performance of the air receiver. The final design must comply with relevant engineering standards such as ASME Section VIII and should be suitable for practical implementation in a plant environment.

1. Determine the minimum wall thickness using ASME Section VIII Div. 1.
2. Ensure compliance with industry safety standards and regulatory codes.
3. Evaluate material suitability considering corrosion and temperature effects.
4. Provide a structural analysis for both cylindrical and head components.
5. Integrate fabrication considerations including joint efficiency and welding quality.
6. Support long-term operational reliability with a defined corrosion allowance.
7. Optimize design for cost-effectiveness without compromising safety.

Scope:

The scope of this project encompasses the complete mechanical design and engineering of a vertical cylindrical air receiver used in industrial compressed air systems. This includes all aspects from understanding functional requirements, applying relevant design codes, performing analytical calculations, selecting appropriate materials, and

validating the structural integrity of the vessel under defined operating conditions. While the primary focus is on stationary receivers used in manufacturing plants, the principles discussed can be extended to other industries. The report also addresses corrosion allowance, safety valves, inspection ports, and drainage systems as part of the overall design. However, the scope does not include dynamic simulations or cost estimation for large-scale production.

Methodology:

The methodology for designing a plant air receiver involves a systematic approach combining engineering principles, code compliance, analytical calculations, and practical considerations. This structured process ensures that the final design meets the functional, structural, and safety requirements outlined by international pressure vessel standards—specifically, the ASME Boiler and Pressure Vessel Code (BPVC), Section VIII, Division 1.

The following steps form the core methodology:

Step 1: Define Design Parameters

Collect all relevant input data, including:

- Internal design pressure (1.2 MPa)
- Internal diameter (2000 mm)
- Design temperature (85°C)
- Allowable material stress (138 MPa)
- Corrosion allowance (3 mm)
- Joint efficiency ($E = 1$)
- Vessel length (5000 mm)

Step 2: Select Design Code

Use ASME BPVC Section VIII, Division 1 as the governing standard for all design calculations, including thickness determination, stress checks, and inspection recommendations.

Step 3: Calculate Required Thickness

Perform analytical calculations for:

- **Shell thickness** using the cylindrical vessel formula under internal pressure.

- **Head thickness** (using either ellipsoidal or hemispherical head formula depending on selection).
- **Additional allowances** for corrosion and fabrication tolerances.

Step 4: Material Selection

Identify suitable materials based on design conditions, availability, and mechanical properties. Ensure that selected materials comply with ASME Section II Part D and can withstand the specified stress and temperature conditions.

Step 5: Validate Against Code Requirements

Ensure the calculated thickness, stress values, and safety margins comply with code limits. Apply correction factors for corrosion and joint efficiency.

Step 6: Design Drawing Preparation

Create detailed engineering drawings with all critical dimensions, nozzle placements, support structure, and welding joints.

Step 7: Documentation

Compile all calculations, material data, code references, and drawings into a structured project report.

Analytical Study

1. Design Calculation: -

Given Design Parameters:

- Internal Pressure, $P = 1.2 \text{ MPa} = 1200 \text{ kPa}$
- Internal Diameter, $D = 2000 \text{ mm}$
- Design Temperature, $T = 85^\circ\text{C}$
- Allowable Stress, $S = 138 \text{ MPa}$
- Corrosion Allowance, $CA = 3 \text{ mm}$
- Joint Efficiency, $E = 1.0$
- External Pressure = 0.1 MPa

(Atmospheric, negligible in design)

- Tangent to Tangent Length = 5000 mm

1. Shell Thickness Calculation (Cylindrical Shell Under Internal Pressure)

Formula from ASME Section VIII Div. 1 (UG-27):

hence, corroded allowance = 3mm

$$R = 1000 + 3\text{mm} = 1003\text{mm}$$

$$t = PR / (SE - 0.6P)$$

$$= 1.2 \times 1003 / (138 \times 1 - 0.6 \times 1.2)$$

$$t = 8.76 \text{ mm}$$

$$Tr = 8.76 \text{ mm} \rightarrow \text{required thickness.}$$

Now design thickness

$$Td = tr + CA$$

$$= 8.76 + 3$$

$$= 11.76 \text{ mm}$$

Nominal thickness

$$Tn = 12 \text{ mm}$$

By UG-28

Step 1: Assume thickness

$$t = 9 \text{ mm} (12 - 3 = 9)$$

step 2:

Do (outside dia) = Inside Dia + 2x thickness.

$$= 2000 + 2 \times 12$$

$$= 2024 \text{ mm}$$

step 3:

$$L = T/L \text{ to } T/1 + 2x \text{ depth of dishend} / 3$$

$$= 5000 + 2 \times (0.25 \times 2000) / 5$$

$$L = 5333.33 \text{ mm.}$$

$$L/Do = 5333.33 / 2024$$

$$= 2.63$$

step 4: factor A = 0.00011

step 5: refer CS2

step 6:

$$Pa = \{2AF / [3 \times (Do/t)]\}$$

$$= (2 \times 0.00011 \times 2 \times 10^5) / (3 \times 224.88)$$

$$Pa = 0.06.52 \text{ MPA} < 0.1 \text{ MPA}$$

design pressure vessel is not Safe

Design is not safe

take Tn = 14

assume,

$$t = \text{nominal thickness} - CA$$

$$= 14 - 3$$

$$= 11 \text{ mm}$$

$$Do = ID + (2X + Tn)$$

$$= 2000 + (2 \times 14)$$

$$= 2028$$

$$(DO)/t = 2023/11 = 184.36$$

$$L = \{T/L \text{ to } T/L + [2 \times \text{depth of Dishend}/3]\}$$

$$= 5000 + (2 \times 0.25 \times 2000/3)$$

$$L = 5333.33$$

$$L/Do = (5333.33/2028)$$

$$= 2.629$$

To Find factor B (Sec-II Part-D, subpart 3 fig. CS

As the value of A falling to the left of the

applicable material temperature line

$$A = 0.0002$$

$$B = 20$$

$$Pa = \{4B / [3(Do/t)]\}$$

$$= \{4 \times 20 / [3 \times 184.56]\}$$

$$pa = (4 \times B) / [3(Do/t)]$$

$$= (4 \times 20) / (3 \times 184.36)$$

$$Pa = 0.144$$

Pa > 0.1mpa (Design is safe)

Material Selection

Material selection plays a crucial role in the design of pressure vessels like air receivers. The selected material must not only satisfy strength and temperature requirements but also offer adequate resistance to corrosion, be weldable, cost-effective, and easily available. In this project, the material study has been conducted in line with ASME Boiler and Pressure Vessel Code (BPVC), Section II, Part D, Subpart 1, which provides allowable stress values for different materials at various temperatures.

Material Selection Criteria:

The choice of material for the air receiver is based on the following key criteria:

1. **Allowable Stress:** The maximum stress a material can safely withstand without failure at the

given temperature. For this project, an allowable stress of **138 MPa at 85°C** is used.

2. **Temperature Resistance:** The material must retain its mechanical properties at the operating temperature of 85°C.

3. **Corrosion Resistance:** Since the vessel may be exposed to moisture, rust, and contaminants from compressed air, corrosion resistance is vital. Hence, a **corrosion allowance (CA) of 3 mm** is incorporated into the design.

4. **Weldability:** Since the vessel includes welded joints, good weldability is essential for both fabrication and structural integrity.

5. **Compliance:** The material must be listed and approved under ASME standards for pressure vessel use.

6. **Economic Viability:** The cost and availability of the material must suit industrial manufacturing conditions.

Recommended Material:

One of the most used materials that fulfills the above criteria is **SA-516 Grade 70 carbon steel**, which is a normalized fine-grain steel known for its excellent notch toughness and weldability.

Properties of SA-516 Gr. 70:

- **Yield Strength:** 260 MPa (typical)
- **Ultimate Tensile Strength:** 485–620 MPa
- **Allowable Stress (at 85°C):** 138 MPa (as per ASME Section II, Table 1A)
- **Good weldability:** Suitable for manual, MIG, and TIG welding
- **Availability:** Widely available in plate form
- **Cost:** Economical for large-scale manufacturing

This material is ideal for moderate-temperature applications such as air receivers, boilers, and storage tanks. It also maintains good ductility and impact resistance even in thicker sections.

Corrosion Allowance:

Even though SA-516 Gr. 70 has acceptable corrosion resistance, especially when painted or coated, an additional **corrosion allowance of 3 mm** is included in the thickness calculation. This ensures that the pressure boundary remains safe even after years of

service where material loss may occur due to oxidation or internal moisture.

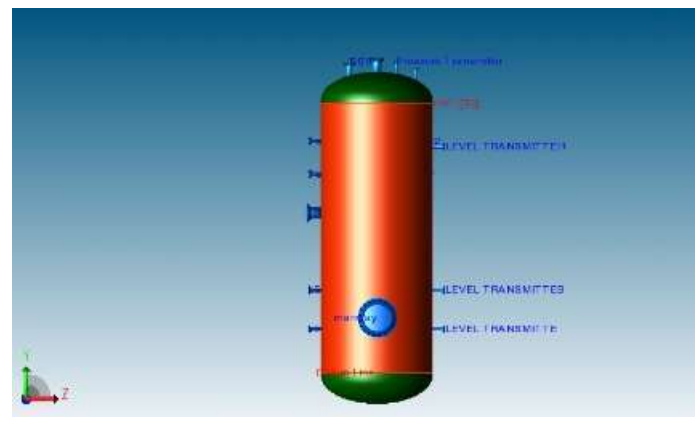
Welding and Fabrication Compatibility:

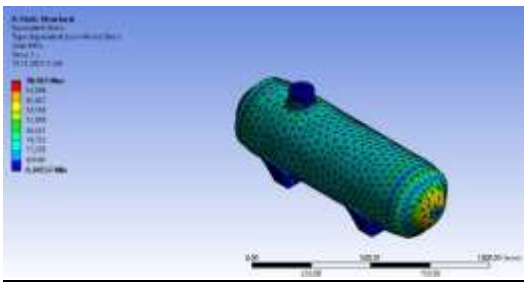
SA-516 Gr. 70 offers excellent compatibility with common welding practices and can be used with radiographic testing for weld inspection. The high joint efficiency ($E = 1$) used in this design assumes full penetration welds that are radiographically tested as per ASME standards.

Summary of Material Study:

- **Selected Material:** SA-516 Gr. 70
- **Allowable Stress Used:** 138 MPa
- **Corrosion Allowance:** 3 mm
- **Weld Efficiency:** 100% ($E = 1$)
- **Advantages:** Strong, weldable, economical, ASME code-compliant

Design Model Parts :





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