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Design and Engineering of Nitrogen Receiver

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Abstract*: Within numerous industrial applications, pressurized nitrogen gas plays a critical role. Nitrogen receiver pressure vessels function as the secure storage tanks for this gas, guaranteeing its safe and on-demand availability. These vessels are constructed from high-strength steel in accordance with ASME Boiler and Pressure Vessel Code (BPVC) standards. This ensures they can withstand the internal pressure of the contained nitrogen. ASME BPVC, a comprehensive set of rules, dictates the design, fabrication, inspection, and testing of pressure vessels. By adhering to these stringent standards, manufacturers guarantee the safety and reliability of these vessels. In conclusion, nitrogen receiver pressure vessels, designed and built following ASME standards, are an integral part of industrial gas storage and distribution. Their ability to safely store pressurized nitrogen in compliance with strict safety regulations makes them essential for various processes across numerous industries.*

Keywords: Pressure Vessel Design, Cryogenic Systems, ASME safety standard, Pressure vessel code

I. INTRODUCTION

A pressure vessel is a container designed to hold gases or liquids at a pressure substantially different from the ambient pressure. Pressure vessel is an enclosed unit in which the pressure acts from inside or outside the enclosed volume. They are most commonly used in industries as heat exchangers, reactors, storage vessels, etc. Design involves parameters such as maximum safe operating pressure and temperature, safety factor, corrosion allowance and minimum design temperature. Nitrogen receivers are storage tanks for compressed and dried nitrogen storing, filling and delivery for further use. Areas of application are chemical, oil and gas, metallurgical industries. They are also used in the field of nitrogen extinguishing, in heating systems, as part of process equipment (for example, nitrogen stations and generators, compressors). They perform the following functions: storage, cooling, surge control, maintaining pressure as a result of gas consumption (including uneven flow), condensate collection.

The majority of pressure vessels are made of tubes and sheets that have been rolled into cylinders because they are only needed to carry low pressures. Those storage spaces or compartments with a weight difference between the interior and the exterior were given the name pressure vessel. Pressure vessels are containers made for industrial use that are intended to hold liquids and gases. The design, production, and use of pressure vessels are governed by national and international codes. Pressure vessels can be dangerous, and fatal accidents have occurred in the history of their development and operation. Consequently, pressure vessel design, manufacture, and operation are regulated by engineering authorities backed by legislation. For these reasons, the definition of a pressure vessel varies from country to country.

II. LITERATURE SURVEY

In the pursuit of designing and engineering of nitrogen receiver, several research papers and studies have provided valuable insights and guidance. This section highlights some of the key contributions in this field.

1. Niranjana S. J., Smit Vishal Patel, Ankur Kumar Dubey, “Design and Analysis of Vertical Pressure Vessel using ASME code and FEA technique” 2018
2. Rohitkumar S. Biradar “Finite Element Modelling and Analysis of Pressure vessel” 2022.
3. Mangesh Nadkarni, Rohan Mehta, Ritesh Sarode, Suraj Ghadge, Prof. Ganesh Karpe “Design of Pressure vessel for Nitrogen gas storage” 2018.

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4. Shyam R Gupta1 , Ashish Desai2 , “Optimize Nozzle Location for Minimization of Stress In Pressure Vessel,” Innovative Research in Science & Technology| Vol. 1, Issue 1, June 2014| ISSN(online): 2349-6010.

III. PROPOSED METHODOLOGY

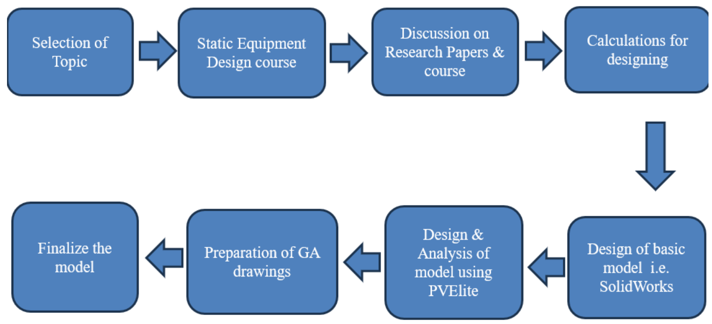

Figure 1: Methodology

3.1 Design Objectives

- **Capacity and Efficiency**: Design the nitrogen receiver to efficiently store and deliver the required amount of nitrogen based on the application's needs.
- **Safety Compliance**: Ensure that the design meets all **safety** regulations and standards to prevent accidents, leaks, or any other potential hazards associated with handling nitrogen.
- **Reliability and Durability**: Develop a robust design that can withstand the operational conditions, pressures, and temperatures over its intended lifespan with minimal maintenance requirements.
- **Cost-effectiveness**: Optimize the design to achieve the desired functionality within the allocated budget, considering factors such as material costs, manufacturing processes, and operational expenses.
- **Environmental Considerations**: Minimize the environmental impact of the nitrogen receiver's operation by incorporating eco-friendly materials, efficient energy usage, and proper waste management strategies.
- **Integration Compatibility**: Ensure compatibility and seamless integration with existing systems or processes where the nitrogen receiver will be utilized.
- **Performance Optimization**: Maximize the performance of the nitrogen receiver in terms of nitrogen purity, pressure control, and flow rate to meet the specific requirements of the application.
- **Operational Flexibility**: Design the receiver to accommodate variations in nitrogen demand and operational conditions while maintaining optimal performance and efficiency

3.2 Working Principle

Principle step-by-step:

1. Filling Process:

- Source: Nitrogen gas is supplied from an external source like a nitrogen generator or a larger storage tank.
- Inlet Nozzle: The nitrogen gas enters the vessel through the inlet nozzle.
- Pressure Regulation: A pressure regulator(not shown within the vessel itself) controls the incoming gas pressure, ensuring it doesn't exceed the safe working pressure of the vessel. This regulator is typically located upstream of the inlet nozzle
- Pressure Gauge: A pressure gauge mounted on the vessel displays the internal pressure in real-time.
- Filling Termination: The filling process stops when the pressure inside the vessel reaches the desired level, set by the pressure regulator or manually controlled.

2. Storage:

- Once filled, the compressed nitrogen gas is stored within the vessel.

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- Safety Relief Valve: A safety relief valve is typically included as a safety feature. If the pressure inside the vessel builds upexcessively due to unforeseen circumstances, this valve opens automatically, releasing pressure and preventing potential vessel rupture.
- Temperature Sensor: A temperature sensor may be installed to monitor the gas temperature within the vessel. While not critical for basic operation, it can be helpful for certain applications or troubleshooting.

3. Discharge Process:

- Outlet Nozzle: Nitrogen gas is released from the vessel through the outlet nozzle.
- Pressure Regulation (Optional): Depending on the application, a pressure regulator may be installed at the outlet nozzle to further control the pressure of the discharged gas.
- Flow Control Valve: A flow control valve, typically located near the outlet nozzle. allows for regulating the flow rate of the discharged nitrogen gas.

4. Drainage:

- Drain Nozzle: A drain nozzle is often present at the bottom of the vessel to allow for draining any condensate or liquid impurities that may accumulate aver time. This helps maintain the quality of the stored nitrogen

5. Monitoring and Control:

- Pressure Gauge: The pressure gauge continuously monitors the internal pressure of the vessel, ensuring safe operation within the designated pressure limits.
- Level Sensor (Optional): In some cases, a level sensor may be used to monitor the remaining nitrogen quantity within the vessel. This can be helpful for maintenance purposes and timely refilling.
- Alarm System (Optional): An alarm system can be integrated to trigger alerts for situations like low pressure, high temperature, or other potential issues.

Overall, this small nitrogen receiver pressure vessel operates by safely storing compressed nitrogen gas and enabling controlled discharge when needed. The various sensors and safety features ensure the system's safe and efficient operation

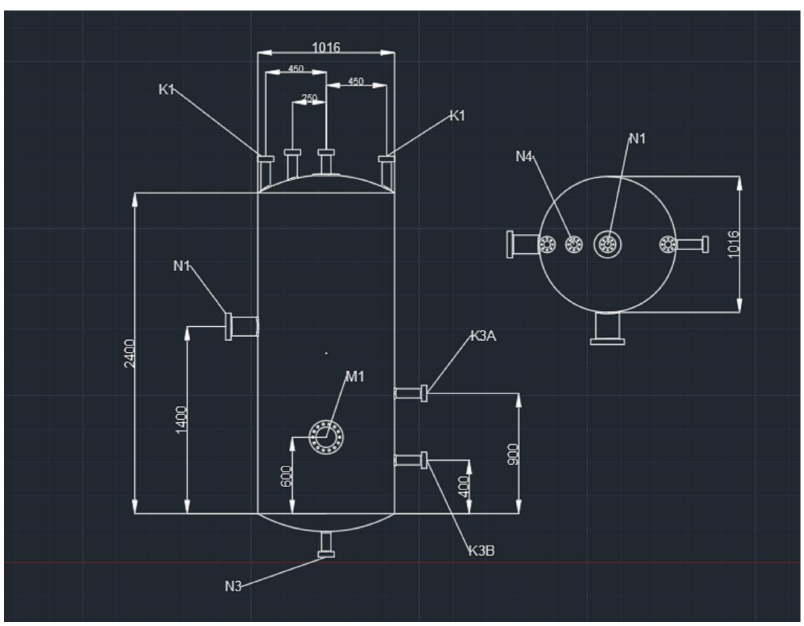

Fig.1 AutoCAD Design

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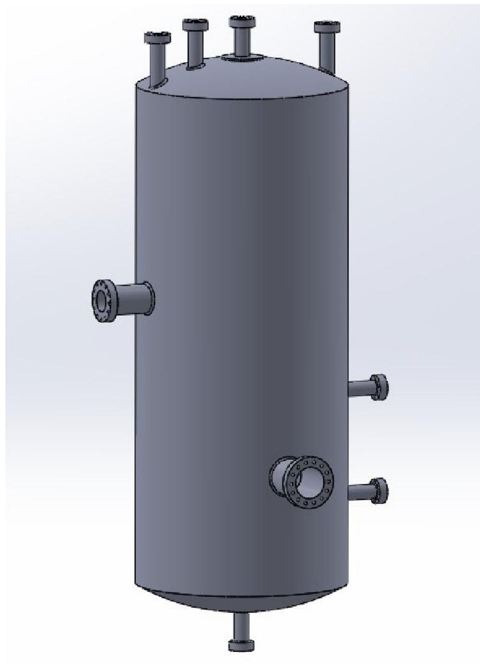

Fig.2 SolidWorks Model

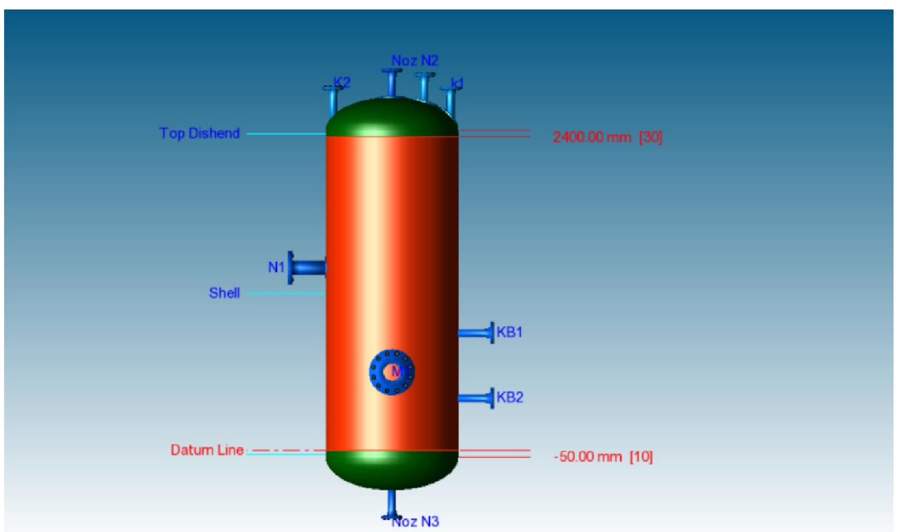

Fig.3 PV-Elite Model

IV. RESULTS

In conclusion, the design and engineering of a Nitrogen Receiver is a complex and challenging project that requires a thorough understanding of pressure vessel design and the ASME code. As a final year Mechanical engineering student, this project has provided me with valuable hands-on experience in applying theoretical knowledge to real-world engineering problems. The process of calculating the thickness of the shell for both internal and external pressure has allowed me to gain a deeper understanding of the factors that must be considered in pressure vessel design, such as material properties, operating conditions, and safety margins. Furthermore, this project has highlighted the importance of adhering to industry standards and codes, such as the ASME code, in order to ensure the safety and reliability of pressure vessel designs. The ASME code provides guidelines and regulations for the design, construction, and inspection of pressure vessels, and it is crucial for engineers to follow these standards to minimize the risk of failure and ensure compliance with legal and regulatory requirements.

V. FUTURE SCOPE

The extremely low temperature of liquid nitrogen would cause it to absorb heat from the surrounding environment, leading to rapid vaporization and pressure buildup. This could cause the vessel to fail catastrophically. Insulation acts as a critical barrier. It minimizes heat transfer, keeping the liquid nitrogen in its desired state and preventing dangerous pressure increases. This not only enhances safety but also improves efficiency by reducing nitrogen loss and the need for constant cooling. In short, proper insulation is essential for the safe, reliable, and cost-effective operation of a nitrogen receiver pressure vessel. In future scope the vessel can be used for liquid state of nitrogen also after making necessary research and calculation for insulation.

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