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Design Calculation of Three Phase Separator

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Abstract: *This research paper investigates the intricacies of design calculations involved in the development of three-phase separators in the oil and gas industry. Efficiently separating oil, water, and gas mixtures is crucial for maximizing production and ensuring compliance with environmental regulations. The paper explores the fundamental principles and equations used in the design of three-phase separators, including determining vessel dimensions, retention times, residence times, and separation efficiencies. Various factors influencing the design calculations, such as fluid properties, flow rates, pressure drops, and temperature gradients, are thoroughly analyzed. Additionally, the paper explores the importance of computational tools and simulation techniques in optimizing the design process and predicting separator performance under different operating conditions. Practical examples and case studies are provided to illustrate the application of design calculations in the successful implementation of three-phase separators in the oil and gas industry.*

Keywords: Optimization, Three Phase Separator, Design Calculations, Three Phase Separator design.

I. INTRODUCTION

In the oil and gas industry, the separation of production fluids into oil, gas, and water is a fundamental process necessary for efficient downstream handling and processing. The three-phase separator is a critical piece of equipment designed to achieve this separation, ensuring that each phase can be treated or disposed of appropriately. Proper design and optimization of three-phase separators are essential for maintaining the economic efficiency and operational safety of production facilities.

This research paper delves into the intricate design calculations required for effective three-phase separator operation. It explores the underlying principles of phase separation, examines various design considerations for different separator configurations, and presents mathematical models to predict separator performance. The objective is to offer a thorough understanding of the theoretical and practical aspects of three-phase separator design, serving as a valuable resource for engineers and industry professionals.

The paper begins by outlining the fundamental physical principles that govern phase separation, such as the influence of gravity, fluid dynamics, and the specific properties of the fluids involved. It then addresses the critical design parameters and operational constraints, including separator sizing, retention time, and the impact of fluid properties on separation efficiency. Detailed methodologies for calculating key design parameters—such as vessel dimensions and flow rates—are discussed, accompanied by practical examples and case studies.

The aim of this research is to enhance the knowledge base surrounding three-phase separator design, providing insights that can lead to more efficient and reliable separation processes in the oil and gas industry. By merging theoretical concepts with practical design approaches, this paper seeks to bridge the gap between academic research and industry application, ultimately contributing to the advancement of separation technologies.

II. OBJECTIVES

1. Efficient Contaminant Removal: Develop a three-phase separator that effectively removes impurities such as water, particulate matter, and contaminants from diesel fuel.
2. Compliance with Standards: Ensure the three-phase separator meets industry standards and environmental regulations, guaranteeing the purified diesel fuel complies with specified quality requirements

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3. Optimized Fuel Quality: Enhance the overall quality of diesel fuel to improve engine performance, fuel efficiency, and reduce emissions.
4. Reliability and Durability: Design a reliable and durable three-phase separator that operates efficiently over extended periods, minimizing downtime and maintenance requirements.
5. Cost-Effectiveness: Strive for a solution that balances high performance with cost-effectiveness, considering both initial investment and ongoing operational expenses.
6. Adaptability to Conditions: Create a three-phase separator that can adapt to various operating conditions, accommodating different types of diesel fuel and environmental factors.
7. User-Friendly Maintenance: Design the system with user-friendly maintenance features to facilitate regular upkeep and ensure sustained performance.
8. Safety Considerations: Incorporate safety features to prevent hazards associated with handling diesel fuel and operating the three-phase separator.

III. DESIGN CALCULATIONS

Design calculations for a three-phase separator involve determining the optimal dimensions and operating parameters of the separator vessel to effectively separate oil, gas, and water from a mixed production fluid stream. These calculations typically consider factors such as fluid properties, flow rates, retention time, vessel dimensions, pressure drop, and separation efficiency. Additionally, adherence to relevant ASME (American Society of Mechanical Engineers) codes and standards is crucial in ensuring the structural integrity and safety of the separator design. The goal is to ensure that the separator can efficiently separate the three phases while meeting operational requirements and regulatory standards set forth by ASME codes.

IV. MATERIAL SELECTION

The Material is provided in the Design Data Sheet.

V. CALCULATION

ASME Section VIII, Division 1, Subsection A (UG-27) - Thickness of Shells Under Internal Pressure. ASME Section VIII, Division 1 is a widely used code for the design and construction of pressure vessels. Subsection A, particularly UG-27, focuses on the calculation of the minimum required thickness for cylindrical shells and spherical shells under internal pressure. Here's a detailed breakdown:

1. General Overview: UG-27 provides the guidelines and formulas for calculating the minimum thickness required for the walls of cylindrical and spherical shells to withstand internal pressure safely. This ensures that the vessel can operate under its design conditions without risk of failure.

2. Cylindrical Shells Under Internal Pressure: For cylindrical shells subjected to internal pressure, the minimum required thickness t can be calculated using the following formula:

$$t = \frac{PR}{SE - 0.6P}$$

where:

t = minimum required thickness (in inches)

P = internal design pressure (in psi)

R = inside radius of the cylindrical shell (in inches)

S = maximum allowable stress value of the material at the design temperature (in psi)

E = joint efficiency (a factor reflecting the quality of welded joints, ranging from 0 to 1)

Corrosion Allowance**:** An additional allowance for corrosion and erosion (if applicable) should be added to the calculated thickness to ensure long-term durability.

3. Calculations for external pressure

1. Outer Diameter to Thickness ratio: $\frac{D_o}{t}$

2.Length to Outer Diameter ratio: $\frac{L}{D_o} = \frac{\text{Tan to Tan length} + \{\frac{2}{3} \times \text{Depth of Dish} - \text{end}\}}{\text{Outer Dia}}$

3. Calculating Factor A:
For Factor A referring ASME Sec II Part D Subpart 3 Figure G

4. Calculation of Factor B:
For Factor B referring ASME Sec II Part D Chart CS-2

VI. WORKING PRINCIPLE

A three-phase separator is a crucial piece of equipment in the oil and gas industry, used to separate the mixture of oil, water, and gas that is produced from wells. The separation process relies on the differences in density and the immiscible nature of the three phases. Here's a detailed explanation of its working principle:

Components of a Three-Phase Separator

- **Inlet Diverter**: Ensures proper distribution of the incoming fluid mixture.
- **Weir**: Helps separate the liquid phases (oil and water).
- **Baffles**: Assist in breaking down the emulsions and enhance phase separation.
- **Vortex Breakers**: Prevent vortex formation at the outlets.
- **Gas Outlet**: Located at the top to allow separated gas to exit.
- **Oil Outlet**: Positioned to collect and discharge the separated oil.
- **Water Outlet**: Placed at the bottom to discharge the separated water.
- **Level Controls**: Maintain appropriate liquid levels for efficient separation.
- **Mist Extractor**: Removes fine liquid droplets from the gas phase.

Working Principle

Inlet Diverter Action:

The mixture enters the separator through the inlet diverter, which reduces the velocity of the fluid, promoting initial phase separation. The diverter may be a baffle, vane, or other device designed to spread the flow evenly across the separator.

Gravity Separation:

The primary mechanism of separation is gravity. Since the gas phase has a much lower density than the liquid phases, it rises to the top of the separator. The liquid phases, being denser, settle at the bottom.

The separator is designed to provide sufficient retention time for the phases to separate based on their density differences.

Gas Separation:

As the gas rises, it passes through a mist extractor, which removes any entrained liquid droplets. The gas then exits through the gas outlet at the top of the separator

Liquid Phase Separation:

The remaining liquid mixture flows over a weir. This weir ensures that the liquid phases (oil and water) separate based on their densities.

Water, being denser than oil, settles at the bottom of the separator. The interface between oil and water is maintained at a specific level by the weir and level controls.

Emulsion Breaking:

Baffles and other internals aid in breaking down emulsions, enhancing the separation process. Emulsions can occur when small droplets of one liquid are dispersed in another.

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Outlet Controls:

Level controllers are used to maintain the proper liquid levels within the separator. These controllers adjust the oil and water outlet valves to ensure continuous and efficient separation.

The separated oil flows over the weir and exits through the oil outlet. The water, being the heaviest phase, is drained from the bottom through the water outlet.

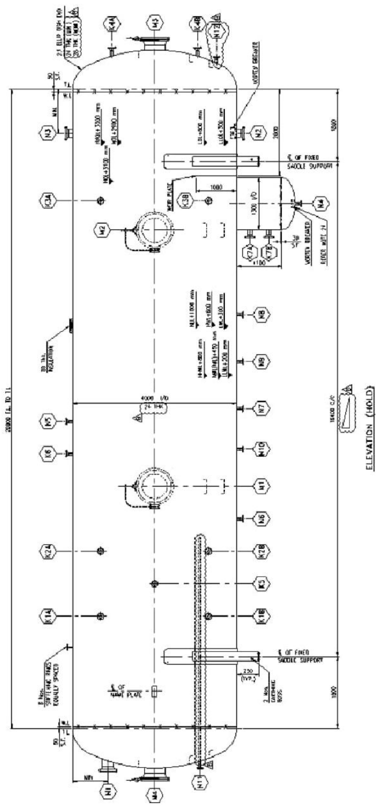

Fig1.Three Phase Separator

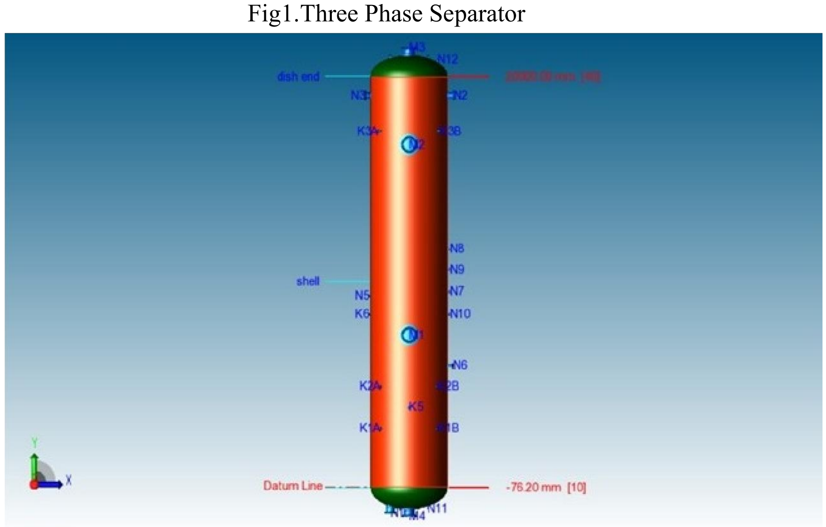

Fig2.PV-EliteModel

VII. CONCLUSION

The design and engineering of a three-phase separator represent a critical endeavor in ensuring the integrity and reliability of separating gas, oil, and water for diverse industrial applications. Through meticulous analysis, innovative design concepts, and rigorous engineering methodologies, we have developed a robust and efficient three-phase separator system capable of effectively separating contaminants and maintaining the quality of each phase. Our comprehensive approach to design and engineering has yielded promising results, with the three-phase separator system demonstrating superior performance, efficiency, and reliability in the separation process.

By leveraging advanced technologies, engineering principles, and industry expertise, we have overcome various challenges associated with phase separation, ensuring optimal operation and longevity of the equipment. Furthermore, our commitment to regulatory compliance and adherence to industry standards underscores our dedication to safety, environmental responsibility, and customer satisfaction. The three-phase separator system presented in this study not only meets but exceeds the stringent requirements of modern separation processes, setting new benchmarks for reliability and performance in the industry.

Looking ahead, continued research, innovation, and collaboration will be essential in further enhancing the design and engineering of three-phase separator systems. By staying at the forefront of technological advancements and addressing evolving industry needs, we can continue to advance the efficiency, sustainability, and reliability of phase separation processes, ultimately driving positive impacts across a wide range of industrial sectors.

VIII. ACKNOWLEDGMENT

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