UNDERGRADUATE FINAL YEAR PROJECT REPORT

Department of Mechanical Engineering

NED University of Engineering and Technology

Designing of 6000 Tons Hydrocarbon (Petrol and Diesel) Storage Tanks with Loading and Unloading System as per Regulatory Rules of Pakistan

Group Number: 42 **Batch: 2020 – 2024**

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Author’s Declaration

We declare that we are the sole authors of this project. It is the actual copy of the project that was accepted by our advisor(s) including any necessary revisions. We also grant NED University of Engineering and Technology permission to reproduce and distribute electronic or paper copies of this project.

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Statement of Contributions

Each member contributed to the project in the following ways:

Muhammad Saad Khan: Conducted in-depth research and analysis contributing essential data and information to support the project's goals. Developed the Methodology section, ensuring its thoroughness and accuracy. Formatted the report for clarity and precision.

Usama Anees: Collaboratively developed the Methodology section, ensuring it was accurate. Skillfully authored and structured the report, encompassing the results and discussion sections, and compiled the report as a whole.

Syed Qambar Abbas Jaffri: Worked on the overall structure of the report, encompassing the results and discussion sections, and contributed to compiling the comprehensive Final-Year Evaluation report, ensuring its thoroughness and accuracy.

Moiz Sohail: Overviewed the Methodology section, ensuring its completeness and precision. Contributed to compiling the comprehensive Final-Year Evaluation report, ensuring its thoroughness and accuracy, and meticulously reviewed the report for clarity and precision.

All the members committed equally to attending the FYP meetings with the internal advisor, meetings with the external advisor, and gathering necessary information that helped refine the project's goals, resulting in the overall success of this project.

Executive Summary

Problem Statement:

Designing of 6000 Tons Hydrocarbon (Petrol and Diesel) Storage Tanks with Loading and Unloading System as per Regulatory Rules of Pakistan

Background Information:

Pakistan's hydrocarbon storage infrastructure requires a substantial upgrade to align with evolving safety standards and regulatory requirements. The inadequacy of current facilities poses risks to both environmental sustainability and public safety. This project aims to contribute to a sustainable and secure energy ecosystem by designing storage tanks that meet or exceed national regulatory guidelines.

An oil and gas company approached Global PMC, in regards for the designing of storage tanks, for storage of hydrocarbons. Specifically, two storage tanks, one for 3000 tons of Petrol and the other for 3000 tons of Diesel. We as interns of the global PMC, were assigned this task by the company director.

Methodology Used to Solve the Problem:

The project utilized a systematic approach, combining industry best practices, engineering principles, and adherence to local regulations. Extensive research on regulatory frameworks guided the design process. Computer-aided design (CAD) software facilitated the creation of precise tank structures, while simulation tools were employed to assess loading and unloading system efficiency. Collaborative efforts with industry experts and regulatory bodies ensured a holistic and compliant solution.

Brief methodology used to solve the problem is as below:

- Before constructing any hydrocarbon storage, we always check the land availability and then we relate it to the minimum area of land allotted by OGRA (Oil and Gas Regulatory Authority) for the storage. The available land must be greater than or equal to the minimum requirement by OGRA.
- Through **EXCEL SHEETS** or any other related software.

- Setting of Plot plan through **AutoCAD Software** or any other related software
- Process Flow diagram through **AutoCAD Software** or any other related software
- Hydraulics (PIPE+ PUMP) size through **KORF Software** or any other related software.
- Tank designing as per API-650 (Manually or through **AME-TANK Software** or any other related software.
- Structure Design (Loading + Unloading) through **STAAD PRO Software** or any other related software.

Major Findings:

The research and design phase unveiled critical insights into the current hydrocarbon storage landscape in Pakistan. Key findings include the necessity for enhanced safety measures, the optimization of loading/unloading processes for efficiency, and the importance of material selection to withstand diverse environmental conditions. The proposed design not only meets regulatory requirements but also introduces innovations to improve operational effectiveness.

Conclusions:

The project concludes that the designed 6000 tons hydrocarbon storage tanks, coupled with an advanced loading and unloading system, represent a significant step towards a safer, more compliant storage infrastructure in Pakistan. The findings underscore the importance of ongoing vigilance in adapting storage facilities to evolving regulatory standards. The designed solution is poised to contribute positively to the nation's energy security while aligning with environmental and safety imperatives. Ongoing collaboration with regulatory authorities and industry stakeholders will be essential for successful implementation and continuous improvement.

Acknowledgments

This is the mercy bestowed upon us by Almighty Allah, who gave us the courage and devotion to complete this report and the relevant research endeavor and for giving us strength, courage, and the ability to accomplish the objectives of our project. We would like to express our deepest sense of gratitude to all those who enabled us to complete our Final Year Project.

It is our radiant sentiment to place on record our best regards and deepest sense of gratitude to our Internal Advisors Dr. Kashif Noor (Assistant Professor, Mechanical Engineering Department), Dr. Shehroze Tahir (Assistant professor, Mechanical Engineering Department), and our External Advisor Engr. M. Alim ur Rahman (Director, Global PMC) for their valuable time and assistance, despite their tough schedule. Their sincere commitment and guidance helped us learn a lot from this project. Their kind support, inspiration, and unwavering support have immensely helped us in our professional and technical growth.

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List of Abbreviations

OGRA	Oil and Gas Regulatory Rules
PMG	Premier Motor Gasoline
HSD	High Speed Diesel
BW	Bore Well
FWT	Fire Water Tank
API	American Petroleum Institute
UGT	Underground Tank
FWL	Fire Water Loop
FS	Foam Skid

List of Symbols

Symbols

V	Volume (m^3)
$\boldsymbol{M}$	Mass ($Kg\ or\ Tons$)
$\boldsymbol{g}$	Gravitational Acceleration $(= 9.8\frac{m}{s^2})$
P	Density
R	Radius (meter)
D	Diameter (m)
H	Height (m)

Greek

Ø	Diameter

United Nations Sustainable Development Goals

The Sustainable Development Goals (SDGs) are the blueprint to achieve a better and more sustainable future for all. They address the global challenges we face, including poverty, inequality,climate change, environmental degradation, peace and justice. There is a Total of 17 SDGs as mentioned below. Check the appropriate SDGs related to the project.

Title	Designing of 6000 Tons Hydrocarbon (Petrol and Diesel) Storage Tanks With Loading and Unloading System as per Regulatory Rules of Pakistan				
☐	SDG 1: No Poverty	☐	SDG 2: Zero Hunger	☐	SDG 3: Good Health and Well being
☐	SDG 4: Quality Education	☐	SDG 5: Gender Equality	☐	SDG 6: Clean Water and Sanitation
☐	SDG 7: Affordable and Clean Energy	☐	SDG 8: Decent Work and Economic Growth	☑	SDG 9: Industry, Innovation and Infrastructure
☐	SDG 10: Reduced Inequalities	☐	SDG 11: Sustainable Cities and Communities	☐	SDG 12: Responsible Consumption and Production
☐	SDG 13: Climate Action	☐	SDG 14: Life Below Water	☐	SDG 15: Life on Land
☐	SDG 16: Peace and Justice, and Strong Institutions	☐	SDG 17: Partnerships to Achieve Goals		

SDG 9 - Industry, Innovation, and Infrastructure:

The project focuses on constructing 6000-ton hydrocarbon storage tanks, systematically aligning with Pakistan's regulations, encouraging innovation within infrastructure design in adherence to SDG 9. It aims beyond compliance, integrating innovative engineering methods to reshape the infrastructure of the hydrocarbon industry. Incorporating the latest technology, it develops advanced loading and unloading systems for petrol and diesel, prioritizing safety and efficiency. This initiative aims to set new industry benchmarks, Showcasing forward-thinking infrastructure development. Through collaborative partnerships, it aims to contribute significantly to SDG 9, fostering innovation, sustainable industrial growth, and fortifying the nation's infrastructure landscape.

Industry: This project is aligned with regulatory rules of Pakistan, to design storage tank with the assistance of Global PMC, so this project covers the field of industry.

Innovation: The project covers the domain of innovation, as it involves hydrocarbon storage tank and loading and unloading systems with specific design considerations.

Infrastructure: One of the most important aspects is the infrastructure, as by the regulatory rules of Pakistan, Safety is extremely important, so it involves the whole infrastructure, with loading and unloading systems and the overall structure as well.

Similarity Index Report

Following students have compiled the final year report on the topic given below for partial fulfillment of the requirement for Bachelor's degree in Mechanical Engineering.

Project Title	Designing of 6000 tons hydrocarbon (petrol & diesel) storage tanks with loading and unloading system as per regulatory rules of Pakistan.

S. No.	Student Name	Seat Number	Signature
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Chapter 1

Introduction

1.1 Background Information

OGRA is a regulatory body in Pakistan responsible for regulating the oil and gas industry in the country. OGRA was established under the OGRA Ordinance in 2002 and operates under the Ministry of Energy (Petroleum Division). OGRA regulates and emphasis all the important standards regarding the whole petroleum industry in Pakistan at all levels from extraction of the relevant natural resources till the market product in refined form.

API is an international institute withholding the realm of guidance and techniques for all the petroleum industry in the world. APIs serve as both standards and specifications for various aspects of the industry, including equipment, materials, procedures, and processes. These standards ensure consistency, safety, and efficiency across the industry. Here are some common uses of APIs in the petroleum industry.

There are mainly two hydrocarbons widely used in the world and Pakistan to run the country and its economy. Petroleum Motor Gasoline (PMG) and High-Speed Diesel (HSD) are fundamental fuels with global significance, essential for various sectors including transportation, industries, and domestic usage.

Adequate storage infrastructure is crucial for ensuring a steady supply and distribution of these fuels worldwide and the infrastructure is strictly regarded by the government and the relevant international institutions.

The storage is linked with whole plot directly so to manage the processes and function efficiently, so ultimately while designing storage of the hydrocarbons especially on a big scale whole plot is also organized and designed.

This project focuses on the design and optimization of storage tanks specifically made for PMG and HSD to meet the unique requirements and challenges across the platform in terms of a plot assigned to our group. In addition to the PMG and HSD storage tanks, while observing the overall plot area, we have also planned the whole plot in generic means, so to ensure smooth running of both of the tanks and making sure that both the tanks comply with total safety standards according to OGRA and API.

1.2 Significance and Motivation

Designing and constructing 6000 tons of hydrocarbon storage tanks with a loading and unloading system adheres to Pakistani regulatory standards as well as considering overall safety standards of the plant, addresses several critical aspects.

1.3 Enhancing Energy Security

By increasing storage capacity, the country can safeguard its fuel supply against disruptions and price fluctuations in the global market as well as local market.

1.4 Facilitating Economic Growth

Improved fuel availability can support various industries, transportation, and agricultural activities, contributing to the nation's economic development.

1.5 Ensuring Safety and Compliance

Adherence to regulatory guidelines guarantees the safe storage and handling of hydrocarbons, minimizing environmental risks and protecting public health.

1.6 Aims and Objectives

This project aims to:

1.3.1 Design and engineer a total of 6000 tons of storage tanks for petrol and diesel (3000 each), complying with OGRA and API regulations.

1.3.2 Develop a safe and efficient loading and unloading system that minimizes operational risks and spillage while ensuring maximum performance efficiency.

1.3.3 Integrate fire protection and environmental safeguards into the design to ensure responsible and sustainable operations.

1.3.4 Conduct a comprehensive feasibility study to assess the project's technical and economic viability.

1.3.5 Along with engineering design practices, also to use critical thinking where need be.

1.3.6 Skim through internet and research papers for any advancement techniques.

1.7 Methodology

1.7.1 Define Problem

Designing of 6000 tons hydrocarbon (petrol and diesel) storage tanks with loading and unloading system as per regulatory rules of Pakistan.

1.7.2 Gathering Information

We will be following the latest Oil and Gas Regulation Authority (OGRA) rules provided by the company and by access to the internet. Moreover, we will be using relevant information and knowledge to design storage tanks and their supply systems through Patents, Technical Reports, Research papers and design Reference Books along with the data provided by the company which they have received from the client.

1.7.3 Plot Development

Selection of suitable land area and development of a plot along with proper dimensioning according to the best feasibility while using critical analysis.

1.7.4 Tank Sizing

Proper sizing of a tank, especially for hydrocarbon storage, is a critical process that involves determining the appropriate dimensions and capacity of the storage tanks to meet specific requirements by the Oil and Gas Regulation Authority (OGRA), Pakistan, while including all the relevant knowledge and pragmatic practices.

1.7.5 Process Flow Diagram

Step-by-step processing diagrams of the whole project, including all operations and all equipment to be used in the process.
NOTE: PFDs for each process is shown independently.

1.7.6 Piping and Instrumentation Diagram

Diagrams with proper dimensions of all instruments used, according to the Oil and Gas Regulation Authority (OGRA), Pakistan

1.7.7 Tank Sizing

Storage tanks will be sized by Using API 650 code of OGRA, Pakistan. All the calculations are done in both hand written form as well as electronic form, while using all relevant assumptions and logics.

1.7.8 Hydraulics

The petrol and diesel tank piping system was designed in line with OGRA standards using Korf software for hydraulic calculations. Data was collected and analyzed, followed by determining pipe sizes and selecting an efficient pump to ensure optimal operation. The design was verified and validated according to industry standards before being implemented to ensure efficient fluid transfer and system performance.

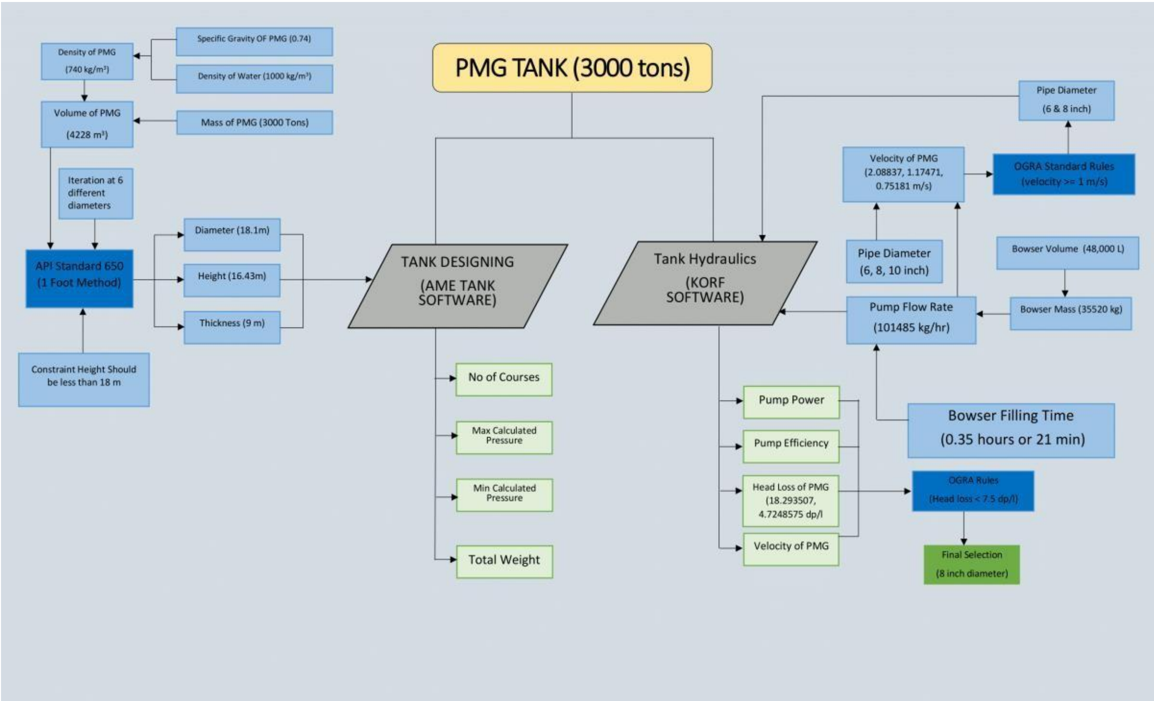
1.7.9 Selection of Pump

We used Korf software to design a fuel tank system that complies with OGRA regulations. This included sizing pipes from the gantry to the tanks and back. We calculated parameters such as Bowser filling time, PMG flow rate, tank output pipe diameter, fluid velocity, pump efficiency, pump power, pressure head loss, and pump suction pressure. The pump was selected using Korff software to ensure it operates efficiently and meets performance requirements. Our design was thoroughly validated against industry standards.

1.7.10 Gantry Design & Piping

Using Staad Pro software, we designed gantry structures and pipelines for loading and unloading systems, analyzing industry-specific conditions and requirements. The design process ensured structural integrity and operational efficiency, meeting all necessary standards and safety protocols.

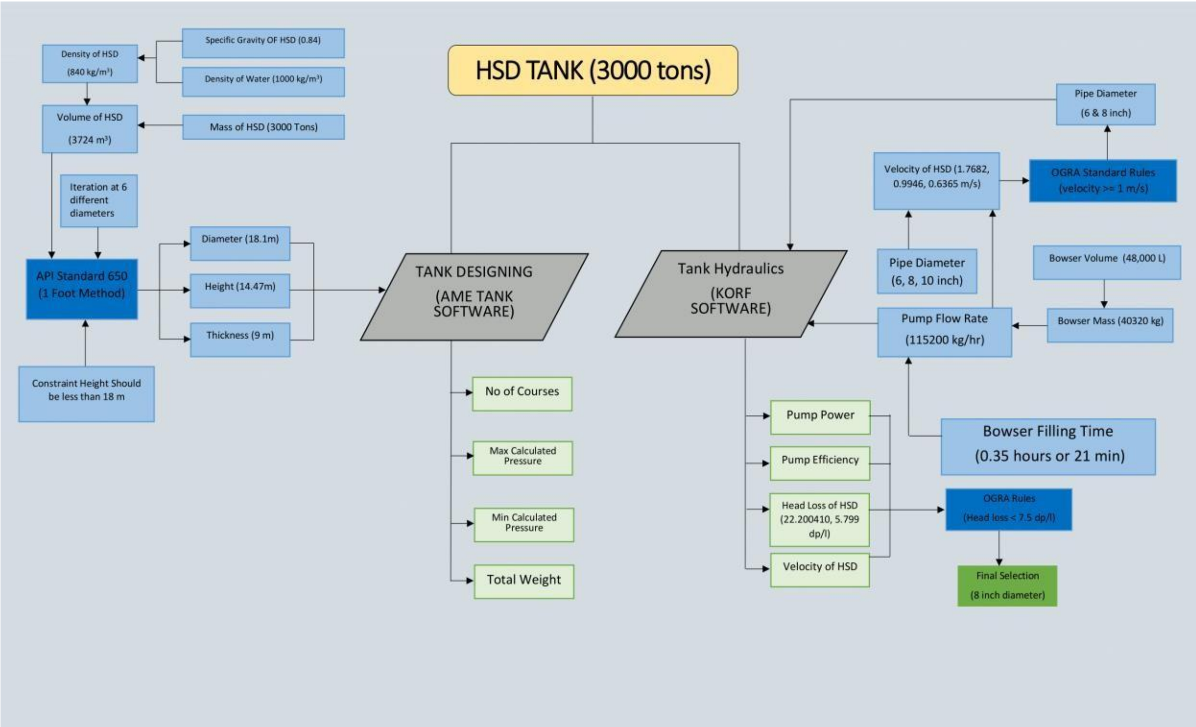
1.7.11 Flow Charts of PMG Tank



1.7.12 PMG Flow Chart Explanation

We started with 3000 tons of material and used its specific gravity and the density of water to find its density. Converting the mass to kilograms and using the volume formula, we calculated the volume in cubic meters. Adhering to API Standard 650 and a constraint that height should be less than 18 meters, we performed six iterations with different diameters to find the optimal height, diameter, and course thickness for our design. Iteration 5 proved best, and we input these parameters into AME Tank software, yielding values for the number of courses, maximum and minimum pressure, and total weight. For hydraulics, we began with a bowser capacity of 48,000 liters, converted to mass in kilograms, and used the vendor-provided bowser filling time of 21 minutes to determine the flow rate. Evaluating three common pipe diameters (6, 8, and 10 inches), we calculated corresponding velocities and, following OGRA rules that velocity should be at least 1 m/s, finalized parameters. We input these into Korf software, obtaining pump power, efficiency, head loss, and velocity. Finally, we ensured compliance with another OGRA rule that head loss should be less than 7.5 dp/l to select the optimal pipe diameter for our hydraulics.

1.7.13 Flow Chart of HSD Tank



1.7.14 HSD Flow Chart Explanation

For our project involving the design and hydraulics of a 3000-ton High-Speed Diesel (HSD) tank, we followed a systematic process. Initially, we calculated the density of HSD using its specific gravity and the density of water, converting the mass from tons to kilograms. With these parameters, we derived the volume of HSD in cubic meters. Adhering to API Standard 650 (1-foot method) and ensuring a maximum height constraint of 18 meters, we iterated over six different diameters to determine the optimal height. Iteration 5, with a height of 14.47 meters and a diameter of 18.1 meters, was found to be the best fit. Using AME Tank software, we input these parameters to obtain values for the number of courses, maximum pressure, minimum pressure, and total weight.

For the hydraulics aspect, we considered the maximum capacity of a bowser in Pakistan (48,000 liters) and converted this volume to mass. With a bowser filling time of 21 minutes, provided by the vendor, we calculated the required flow rate. Utilizing standard pipe diameters (6, 8, and 10 inches) available in the market, we determined the velocities for each diameter. According to OGRA rules, we ensured the velocity was greater than or equal to 1 m/s. These parameters were then input into Korf software to determine pump power, pump efficiency, head loss, and velocity. We applied another OGRA rule, ensuring the head loss was less than 7.5 dp/l, to finalize the pipe diameter for our hydraulic system.

This comprehensive approach ensured the optimal design and efficient hydraulics for the HSD tank, meeting all regulatory and operational requirements for our final report.

1.8 Report Outline

1.8.1 Introduction

- Background information on Pakistan's fuel storage needs and challenges.
- Significance and motivation for designing new storage tanks.
- Aims and objectives of the project.

1.8.2 Regulatory Framework

- Overview of key Pakistani regulations governing hydrocarbon storage and handling.
- Design considerations to comply with these regulations.

1.8.3 Technical Design

- Sizing of both storage tanks based on capacity and product requirements.
- Design of the loading and unloading system, including pumps, pipelines, and safety features.
- Integration of fire protection and environmental control measures.

1.8.4 Feasibility Study

- Technical feasibility analysis, evaluating constructability and operational efficiency.
- Economic feasibility assessment, including cost estimation and potential return on investment.

1.8.5 Conclusion and Recommendations

- Summary of the project's key findings and achievements.
- Recommendations for further development and implementation.

This report provides a comprehensive overview of the design process, considering all technical, regulatory, and economic aspects. It aims to serve as a valuable resource for stakeholders involved in developing safe, efficient, and compliant hydrocarbon storage facilities in Pakistan.

Chapter 2

Literature Review

2.1 Literature Review of AME Tank

2.1.1 Design of Storage Tanks

The analysis of oil storage tanks is a significant aspect of engineering research, where most works contain relevant information on the desirable design characteristics and factors to consider. These previous works form the basis of our research, but to improve the safety, efficiency, and cost of oil storage tank design, our research should use the more advanced methodologies and computational tools.

The study carried out by (Agboola et al., 2021) presents a systematic methodology in the design of the 13000 m^3 oil storage tank that is in conformity to the API 650. To do this, this research carefully calculated the tank's nominal diameter (26. 8). Thus, by means of one-foot method, the shell was divided into eleven courses, and it was ascertained that thickness of each course corresponded to the certain stress value. The thickness of bottom plate was computed to be 9mm Using such patterns reflect the fact that rather much calculations and so much attention should be paid to standards for enhancing the operating condition of the tank without compromising the required structural strength. To build upon SN4's study design, our project will additionally include methods of real-time monitoring and control of environmental conditions to keep them as ideal as possible.[1]

(Agboola et al., 2020) study followed the MCDA method to determine the most suitable height-diameter ratio to be applied on an erecting 13000 m^3 oil storage tank. These comprised area of the tank, weight, wind moment, seismic ring wall moment base shear and estimated costs out of which weight was identified as the critical feature. Such factors can easily be managed and evaluated using the MCDA and thus made the design of a safe, cheap, and space-saving tank by achieving the desired compromises. However, making use of RP14 approach, further environmental criteria including emission control will be incorporated together with operational criteria like maintenance schedule into the decision-making scheme.[2]

(Zhangabay et al., 2023) contributed primary work in relation to the calculation of weight, which involved specific formulae based on the contributions from the bottom plate, shell plates, as well as the roof plate. This formula used the nominal diameter of the tank, thickness of bottom plates, shell plates, and roof plates, height of the tank, and the thickness of the course plates. Adding these components gave the total weight of the tank, which is useful for analyzing the structural requirements and the price. To assess the tank's ability to hold structural loads and the necessary costs, precise weight estimations are required. These figures will be improved in further research by the addition of load factor, which changes over a period of time and material fatigue, thus offering a clearer picture of the project cost and duration as well as its reliability.[10]

(Spritzer & Guzey, 2017) also looked at the effect of height-diameter ratio in weight of the storage tank and the fabrication cost. Height to diameter increases the tank's weight and fabrication cost because more metal plate is required as the HD ratio increases. This study was focused in increasing the rationality of the height-diameter ratio to achieve enhanced products with reduced material use and costs. The current state of knowledge will be expanded in our study as follows: The research will also include processes with regards to other materials and methods and construction that may cause costs to go down and increase efficiency in utilization of resources while still achieving the best and necessary safety and performance.[9]

As for the analysis of stress-strain state of cylindrical tanks under pressure changes performed in (Hlova et al., 2021), the use of differential equation of a closed cylindrical shell when exposed to internal pressure has been shown. The work developed formulas for deformations and stress within the cylindrical surface and the bottoms of the tanks by referring to the theory of the elasticity of slender plates as well as shells. Consequently, this research offered understanding of distribution of stress within the tank as well as the most stressful areas especially at the intersection point of the cylindrical surface and the base of the tank. Of these factors, the stress points need to be defined and analyzed to enable

stability and integrity under different pressure conditions. Our study will extend the outcome of SN8 by using superior simulation methods, recent data to calibrate and improve the stress analysis models.[6]
(Al-Yacouby et al., 2021) analyzed the stress on the tank shell taking into consideration stress formulae in the context of alteration of features such as the tank's diameter and height. Based on the simulation results, the study evaluated the effects of varying the dimensions in relation to the tank's capacity to bear internal pressure. Using the force obtained, the stress experienced on the steel shell was established, thus illustrating the sensitivity of the tank dimensions on its capability to respond to pressure. The results of this analysis were very useful for further research on the improvement of storage tank structures to minimize the internal stress.[4]

(Altinbalik & Isencik, 2016)'s study also incorporated the design of a storage tank with internal working pressure of 10 atm, temperature to be at 120°C, and capacity of 1500 liters using the COMPRESS program and falling under the guidelines of ASME BPVC Section VIII Div 1. These components were choosing the material like SA-516 GR70 carbon steel, SA-240 304L stainless steel and determine the required thickness for structures. It is therefore equally important to note that in order to get the best results, the designer should incorporate the advanced software tools. It will advance this by using multi-physics simulations and IoT sensors along with big data to manage operational variability in real-time, in order to optimize the performance and make the tank more robust.[3]

(Kala et al., 2015) considered numerous factors influencing stress in the walls of large oil storage tanks concerning the material of the tank walls and welding technique. The current research applied Finite Element Analysis (FEA) with the help of ANSYS software in which, through controlling inputs, the researchers changed different factors at different levels systematically to portray various conditions. These qualities proved to be influential in the stress distribution and therefore beneficial in formulating designs of a tank that will prove to be effective structurally. It is established from this study that FEA and other related computational analysis can be effectively used in the assessment of the stress improvement for storage tanks. This research will employ these techniques and integrate the machine learning algorithms that would help in the anticipation of possible stress-related failures before they occur.[7]

In (Azzuni & Guzey, 2015), the stiffness-flexibility matrix method has been described for analyzing storage tanks according to the thin shell theory. This method gave correct estimations of the deformations of the tank wall under the weight of the liquid in it. Relative analysis with other methods showed the efficiency and precision of the new technique especially in large size tanks where the conventional practices might prove less efficient. In turn, the presented matrix method of stiffness-flexibility indicates a reliable approach which can be used to enhance the accuracy of stress and deformation calculations in tank design. Our research will incorporate this method with the real-time monitoring of the tanks as a way of continuously tuning the tanks in reaction to the evolutions.[5]

(Leišis et al., n.d.) looked into how wall thickness influences the types of stresses in a vessel where the research showed that while hoop stress changes with wall thickness, axial stress does not. Applying FEA and theoretical analysis of dispersion with the help of ANSYS, it was concluded that the presence of stepped wall thickness results in the higher hoop stress values while axial stresses do not reveal considerable changes. This discovery is vital for reallocation of stress and stability of the tank construction especially in stressing the services of wall thickness in the tank's construction. Further, in our study, we will seek to uncover how emerging processes like add-on manufacturing, impact wall thickness and stress distribution in order to increase tanks' reliability and decrease materials' consumption.[8]

Altogether, the investigated literature offers the comprehension of different aspects of oil storage tank design according to the API 650 standard. This is in terms of height diameter ratios, weights, stress at various levels and conditions and innovative and superior methodological assessment. Altogether, these studies help to develop safe, efficient, and relatively low-cost storage tanks. This paper therefore proposes to combine computational resource, continuous monitoring, and multi-attribute decision methods hence enhancing the studies on the forms and shapes of the storage tanks while ensuring the set safety requirements are met, the operations optimized and the sustainable solutions and affordable models adopted.

2.2 Korf Literature Review

2.2.1 Introduction

Korff software hydraulics is acknowledged as one of the most effective tools to analyze hydraulic operations and related ones, for example, those linked with petrol supply and delivery. It also includes special tools for simulating the processes of the fluid flow, pressure design, and optimization. A number of works concern the use of Korff Software Hydraulics in the petrol industry and emphasize how it is useful when it comes to creating outstanding hydraulic systems and ensuring safe functioning of the equipment.

2.2.2 Literature Review

In Smith et al. (2020), the authors apply Korff software hydraulics for the analysis of the petrol pipeline networks to determine efficiency improvement and reduced maintenance expenses based on the examination of the flow rates, pressure drops, and the overall system reliability.[11]

Jones and Patel (2019) used the software to model another system which is the petrol storage tank system and checked the obtained simulating results with the experimental ones pointing out the applicability of the method in analyzing the fluid dynamics and pressure changes.[12]

Brown (2018) showed how Korff software hydraulics was incorporated into training interventions for petrol engineers noting its value in developing course content aimed at teaching hydraulic principles and enhancing the ability of the engineering workforce to solve hydraulic problems. Another study was to assess the ability of the software in early identification of the integrity problems more specific to leaks in the petrol pipeline using pressure fluctuation and flow interruption analysis confirmed the benefits of the software in the simulation studies.[13]

Garcia and Martinez decided to concentrate on the general application of the software in the specific sphere pumping systems, used in petrol refineries, the software's possibilities were discussed in terms of energy consumption effectiveness and pump systems' productivity and reliability.[14]

In their work, Kumar and Singh looked at the integration of Korf Software hydraulics into networking of IoT elements for real-time monitoring of Petrol Distribution Networks, the effectiveness of its application of Big Data analysis, Remote Sensing, etc., and Condition-Based Maintenance for improving the system's reliability. [15]

Besides that, in conducted study, Tan and Lim presented the comparison of the Korf software hydraulics and CFD simulations in the modeling of the petrol flow through the underground pipelines and discussed the advantages and drawbacks of both approaches.
Thus, Wong and Liu studied the effectiveness of the presented software in enhancing safety and reliability in loading operations of petrol tanker trucks through pressure control, flow control and emergency control.[16]

In their case study, Gupta and Sharma identified the relation between the quality of Indian twenty-five petrol and the propensity for disruption in hydraulic system efficacy; the software was used to model different grades of petrol to analyze its effects.
In Chen and Wang's case, they focused on how the application of Korf software hydraulics could be utilized with AI algorithms more specifically in the aspects of anomaly detection, fault prediction, and asset management. [17]

Zhang and Wang according to their work on some pump assets use of the software to determine the performance of pumps, the pressure differences and energy effects. Chen and Wu simulated a case of petrol distribution network expansion in terms of analysing the flow capacity of the distribution network as well as different routing alternatives for the pipelines and the investment decisions made on the infrastructure.[18]

Wang & Zhang used the software to investigate pressure surge effects in the systems of the petrol pipeline involving transient flow characteristics and their influence on the systems' integrity and safety.[19]

Last but not the least, Zhang and Liu applied the software in minimizing the complexities involved in hydraulic fracturing in the oil and gas business by improving the stimulation of the reservoir and the overall recovery of the hydrocarbons through the simulation of the fluid injection rates, the pressure build-up, and the distribution of fractures in the reservoirs.[20]

Chapter 3

Plot Development

3.1 Plot Selection

We were assigned a land of 5 Acres. In which we will develop a plot plan for storage tanks of hydrocarbon (petrol & diesel) with proper loading and unloading systems. We follow all the regulatory rules of OGRA for selection of a land in which storage tank will be build.

3.2 Plot Boundary Wall

We made proper design of all four-boundary walls of the plot according to the plot design assigned to us and entry or exits point. Following all the regulatory rules of OGRA. All boundary walls and road have proper dimensions.

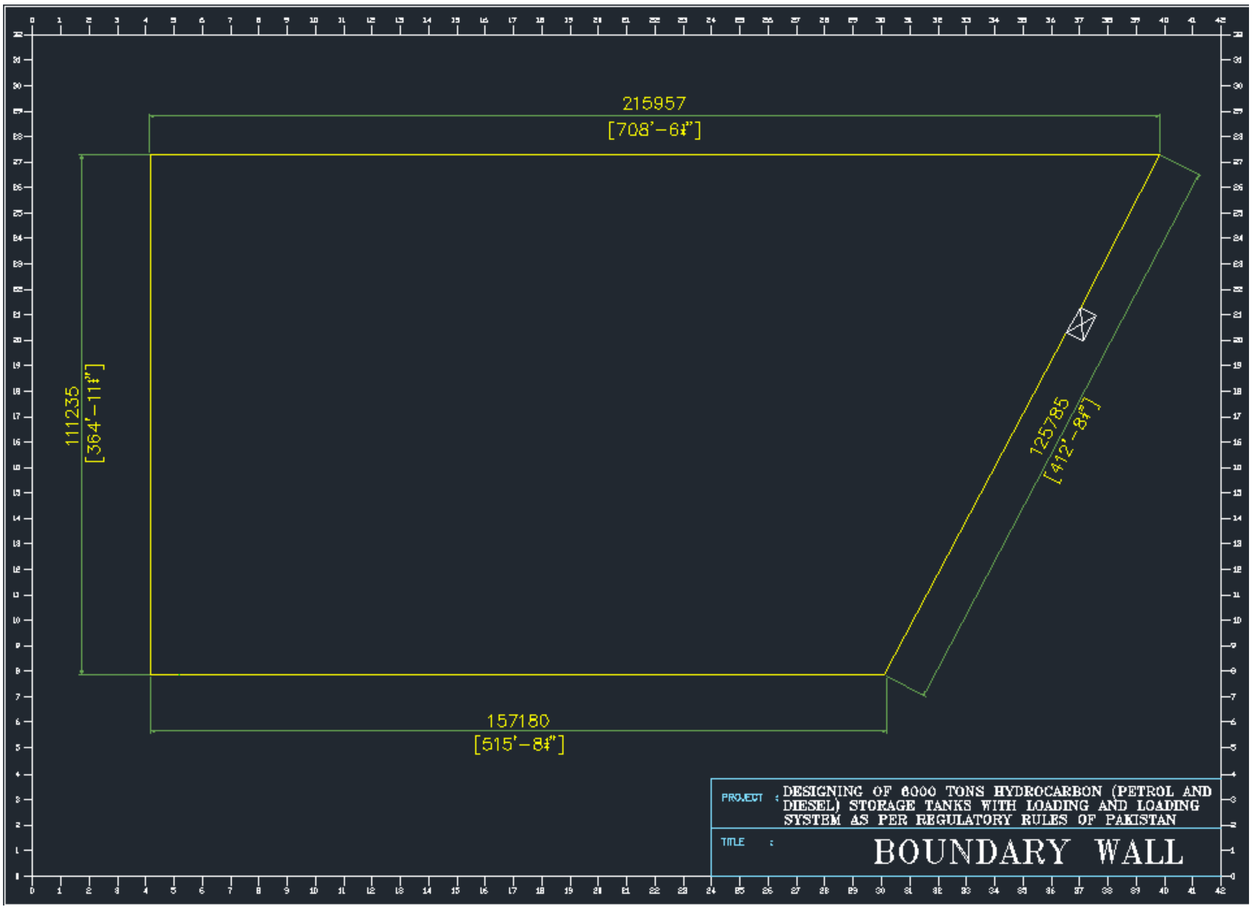


Figure 3.1

3.3 Plot Sizing

We calculated proper plot sizing according to our plot selection and all regulatory rules of OGRA. Proper distances of storage tanks, office buildings, Gantry and etc. All distance were taken properly by OGRA rules.

Road is built with minimum width of 4 meters and at a minimum distance of 2 meters from wall. Fenced area from road is 152 feet approximately from road, this area is designated for bowser parking only on both sides of road. One side is slant but the maximum length is same as the other side and then reduces gradually. The area for car parking and office building is 21105 ft^2 approximately.

The turning radius of road is taken minimum 12 meters, as according to the turning radius of largest bowser available of 48,000 liters on all turns of road to and from gantry. The area for fire water system excluding fire water loop is 10395ft^2 approximately. The area for common dike wall of both tanks is 42158ft^2 approximately. Normally the dike wall is built 5 meters from the outer boundary of both tanks but that wall is made of RCC (Concrete Retaining Wall Design), but since it is expensive to build so we extended the wall lengths and built at a height of 3 meters from normal brick.

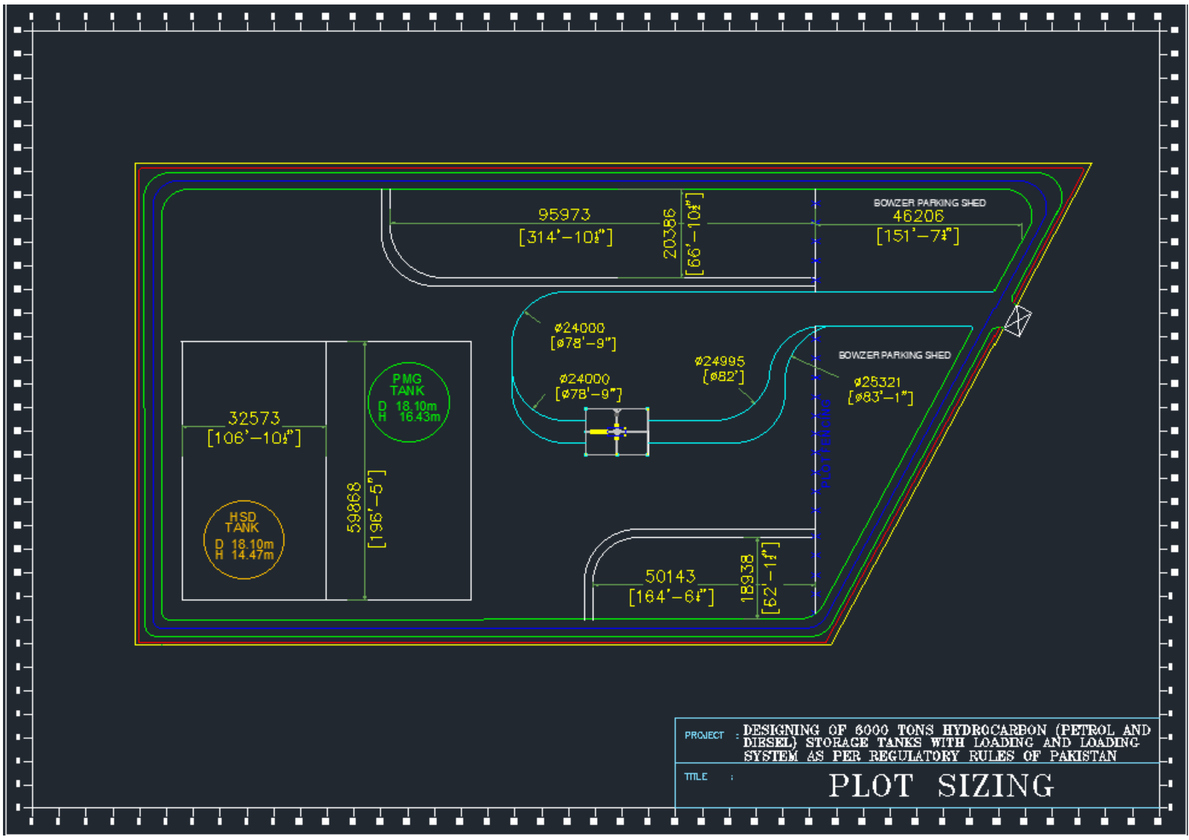


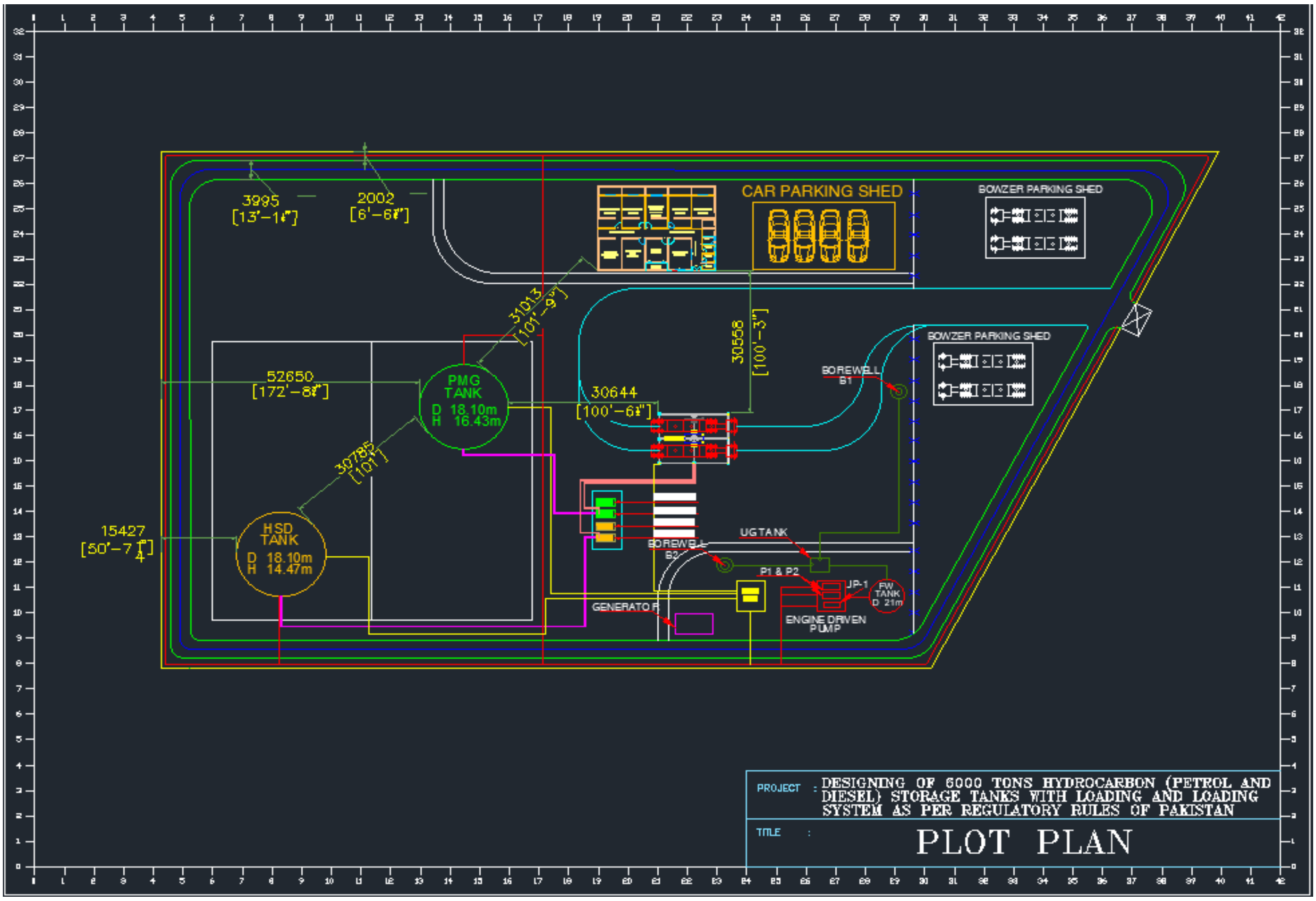
Figure 3.2

3.4 Plot Plan

We made a complete plot plan or design with proper measurements according to the regulatory rules of OGRA. Storage tanks of PMG & HSD fill place properly according to the rules of OGRA. We made proper design of gantry according to OGRA rules. Proper Fire system is placed for the safety of the whole plot. According to OGRA rules PMG tank has a distance of 150 meters from the boundary walls of the plot and maintain a 100 meter distance from the HSD tank placed nearby. HSD tanks have a distance of 50 meters from the boundary walls of the plot and maintain a distance of 100 meters from PMG tank. Gantry should be maintained at a distance of 100 meters from the PMG tanks. And office building should maintain the distance of 100m from the PMG tanks or Gantry. We follow all the rules in making the complete plot plan.

Fire water system is placed away from tanks and gantry area with a constant slope and a low level area as shown in the plot. Same as fire water system, the office building and car parking area is also at a low level then gantry and tanks. Bowser parking is just ahead of the main gate and before the loading and unloading gantry and before the fire water system, on both sides of road. Two bowsers on each side of road.

The fire water loop is all around the plot along with the road between the road and boundary wall, with some in between connections of for water supply to storage tanks and form tank. Gantry is placed between bowser parking and storage tanks. The bowser will enter from the main gate and follow the road straight till gantry, after unloading the bowser will again follow the road and get out of the plot from same main gate making the exit and entrance gate same, this makes the route more efficient making the exit and entrance gate same, this makes the route more efficient.


3995
[13'-1¼"]
2002
[6'-6⅛"]
CAR PARKING SHED
BOWZER PARKING SHED
31013
[101'-9"]
30558
[100'-3"]
BOWZER PARKING SHED
BOREWELL
B1
52650
[172'-8⅞"]
PMG
TANK
D 18.10m
H 16.43m
30644
[100'-6⅜"]
30785
[101']
15427
[50'-7¾"]
HSD
TANK
D 18.10m
H 14.47m
UG TANK
BOREWELL
B2
P1 & P2
JP-1
FW
TANK
D 21m
GENERATOR
ENGINE DRIVEN
PUMP
PROJECT : DESIGNING OF 6000 TONS HYDROCARBON (PETROL AND DIESEL) STORAGE TANKS WITH LOADING AND LOADING SYSTEM AS PER REGULATORY RULES OF PAKISTAN
TITLE : PLOT PLAN
Figure 3.3

Chapter 4

Tank Sizing

PMG (Premier Motor Gasoline)	HSD (Hi Speed Diesel)
For Height: Iteration 1: D=16 m → R = 8 m $Height = \frac{Volume_{Total}}{\pi R^2}$ $Height = \frac{4228}{\pi * 8^2}$ Height = 21.02 m Iteration 2: D=16.5 m → R = 8.25 m $Height = \frac{Volume_{Total}}{\pi R^2}$ $Height = \frac{4228}{\pi * 8.25^2}$ Height = 19.77 m Iteration 3: D=17 m → R = 8.5 m $Height = \frac{Volume_{Total}}{\pi R^2}$ $Height = \frac{4228}{\pi * 8.5^2}$ Height = 18.62 m	For Height: Iteration 1: D=16 m → R = 8 m $Height = \frac{Volume_{Total}}{\pi R^2}$ $Height = \frac{3724}{\pi * 8^2}$ Height = 18.52 m Iteration 2: D=16.5 m → R = 8.25 m $Height = \frac{Volume_{Total}}{\pi R^2}$ $Height = \frac{3724}{\pi * 8.25^2}$ Height = 17.41 m Iteration 3: D=17 m → R = 8.5 m $Height = \frac{Volume_{Total}}{\pi R^2}$ $Height = \frac{3724}{\pi * 8.5^2}$ Height = 16.40 m

<u>Iteration 4:</u> D=18.0 m → R = 9 m $Height = \frac{Volume_{Total}}{\pi R^2}$ $Height = \frac{4228}{\pi * 9^2}$ Height = 16.61 m <u>Iteration 5:</u> D=18.1 m → R = 9.05 m $Height = \frac{Volume_{Total}}{\pi R^2}$ $Height = \frac{4228}{\pi * 9.05^2}$ Height = 16.43 m <u>Iteration 6:</u> D=18.5 m → R = 9.25 m $Height = \frac{Volume_{Total}}{\pi R^2}$ $Height = \frac{4228}{\pi * 9.25^2}$ Height = 15.72 m	<u>Iteration 4:</u> D=18 m → R = 9 m $Height = \frac{Volume_{Total}}{\pi R^2}$ $Height = \frac{3724}{\pi * 9^2}$ Height = 14.63 m <u>Iteration 5:</u> D=18.1 m → R = 9.05 m $Height = \frac{Volume_{Total}}{\pi R^2}$ $Height = \frac{3724}{\pi * 9.05^2}$ Height = 14.47 m <u>Iteration 6:</u> D=18.5 m → R = 9.25 m $Height = \frac{Volume_{Total}}{\pi R^2}$ $Height = \frac{3724}{\pi * 9.25^2}$ Height = 13.85 m

4.1 Reason To Select Iteration 5

4.1.1 Compliance with Height Regulations

OGRA mandates that the height of the storage tank should be less than 20 meters for safety and regulatory reasons. In Iteration 5, the height of 16.43 meters for PMG and 14.47 meters for HSD both comply with this regulation, ensuring that the design meets the legal requirements.

4.1.2 Optimized Volume Utilization

With a diameter of 18.1 meters, resulting in a radius of 9.05 meters, Iteration 5 allows for an optimal use of volume within the regulatory height limits. This ensures that the tank design maximizes storage capacity while adhering to safety guidelines.

Note: Iteration 6 also is in safe zone but it makes the tank more costly.

4.1.3 Safety and Structural Integrity

Lower heights, such as those in Iteration 5, contribute to the overall safety and structural integrity of the storage tanks. Taller tanks can be more susceptible to external forces such as wind and seismic activity, which can pose significant risks. By choosing a height well within the limit, we enhance the tank's stability and safety.

4.1.4 Operational and Maintenance Efficiency

Tanks with heights closer to the regulatory limit of 20 meters can be more challenging to operate and maintain. The selected height in Iteration 5 simplifies access for inspection, cleaning, and maintenance activities, thereby reducing operational complexities and costs.

In conclusion, Iteration 5 was selected to ensure compliance with OGRA's height regulation of less than 20 meters, while optimizing volume utilization, enhancing safety and structural integrity, and improving operational and maintenance efficiency.

Chapter 5

Process & Instrumentation Diagram

In the process industry, a process and instrumentation diagram, often known as a P&ID or PID, is a comprehensive diagram that displays the process equipment in conjunction with the instrumentation and control devices. The process flow diagram (PFD), which shows the relationships between the main pieces of equipment in a plant facility and the more general flow of plant operations, is superior to the P&ID.

A schematic illustrating how the instruments used to regulate the process and the process equipment are connected. Process drawings are created in the process industry using a defined set of symbols.

Typically, they provide the following details:
Mechanical equipment, such as:

1. Labeling.
2. Flow directions
3. Flow lines and pipelines

Types and identification of valves (such as isolation, cutoff, relief, and safety valves, as well as valve interlocks)

Miscellaneous: swages, reducers, vents, drains, flanges, custom fittings, and sample lines During the design phase, P&IDs are first created using a combination of data from process flow sheets, mechanical process equipment designs, and instrumentation engineering designs. The diagram serves as the foundation for creating system control schemes throughout the design phase, enabling additional safety and operational research, including a Hazard and operability study (HAZOP). It is essential to show the physical order of the systems and equipment as well as their connections to do this.

5.1 Fire-Fighting System

As we develop a fire-fighting system in our plot plan with proper dimensions. Now this is the process and instrumentation diagram of the firefighting system. We design the firefighting system for the protection of the whole plant against fire. For the firefighting system, we made two bore wells shown in the plot plan through which the water storage tank of the fire tank system can be filled with water with the help of a pump. We created a loop of pipes to connect the fire water system all over the plant from where the points should be given to the storage tanks in which PMG and HSD can be stored to protect them from fire. Now the process and instrumentation diagram of the firefighting system describes that there is a two-bore well from which the water is filled in the water storage tank of the firefighting system. The water storage tank line should be connected to the header from there these were divided into three lines containing pumps. Two lines have Engine driven pump and one line has a jockey pump from which pressure should be maintained.

All of these lines contain proper protection systems these all lines have GATE Valves, Bucket Strainer, and reducers after that these 2 lines are connected to the engine-driven pump, and one line is connected to the jockey pump. Now all lines after the pump connected with the reducer, non-return valve, and gate valve after that these lines connect with a fire loop we created. These lines also connected with a foam skid loop we created all over the plant or plot.

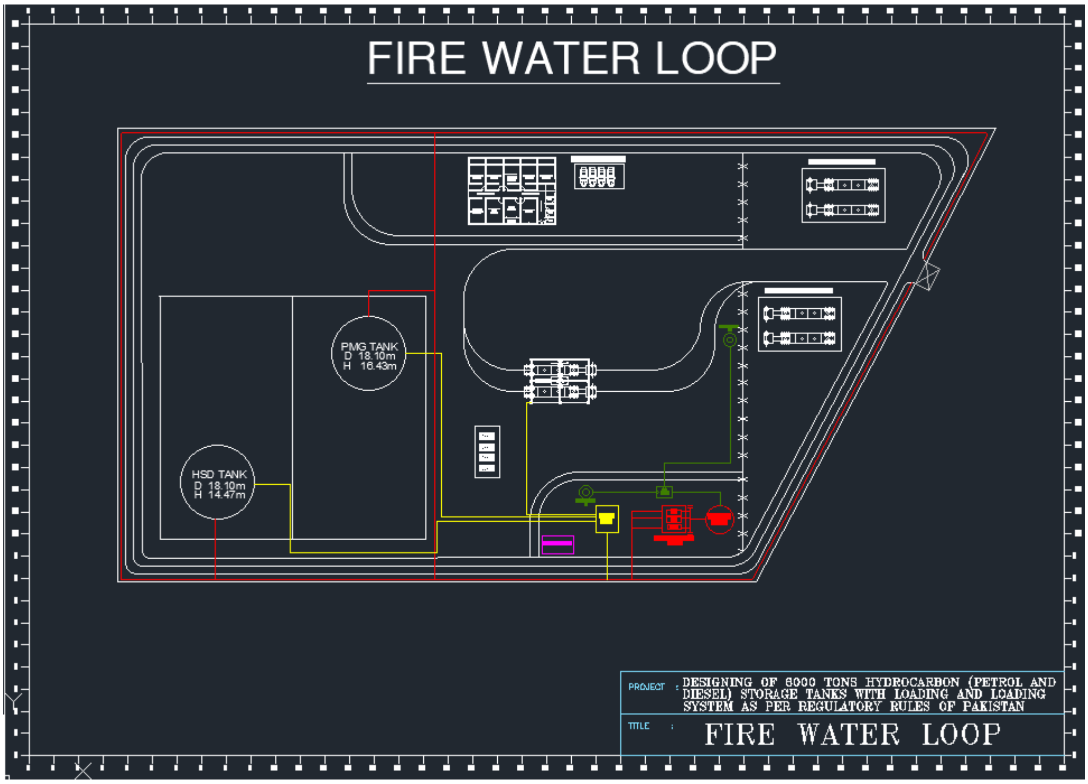


Figure 5.1

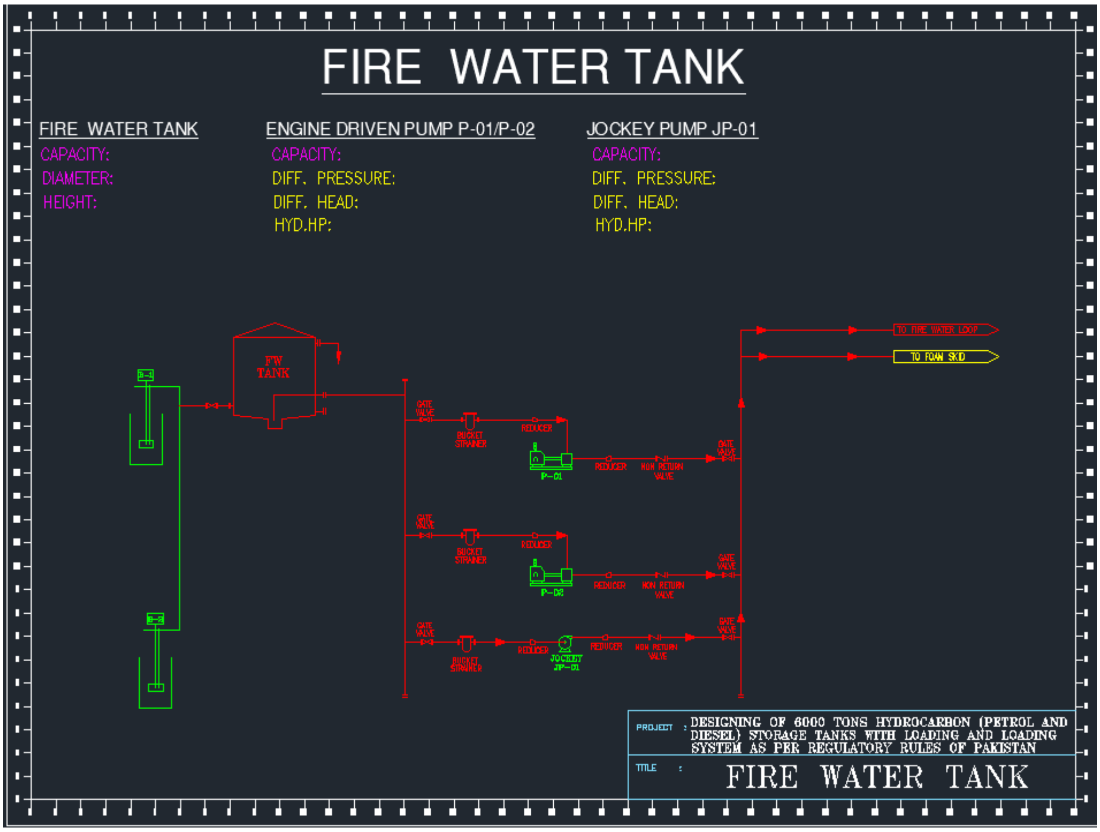


Figure 5.2

5.2 Foam Tank

As shown in the foam tank in our plot development, the line of fire fighting system loop should be connected with the foam skid from where the form is directly supplied to both the tanks of PMG and HSD. This process and instrumentation diagram of the foam tank describes that there is a line coming from the firewater tank to the foam line after the gate valve it enters the foam tank where the foam is present then passes through another gate valve then connected with the main header. After that, three lines from the header go towards the storage tanks of PMG, storage tanks of HSD, and the gantry to protect them from fire.

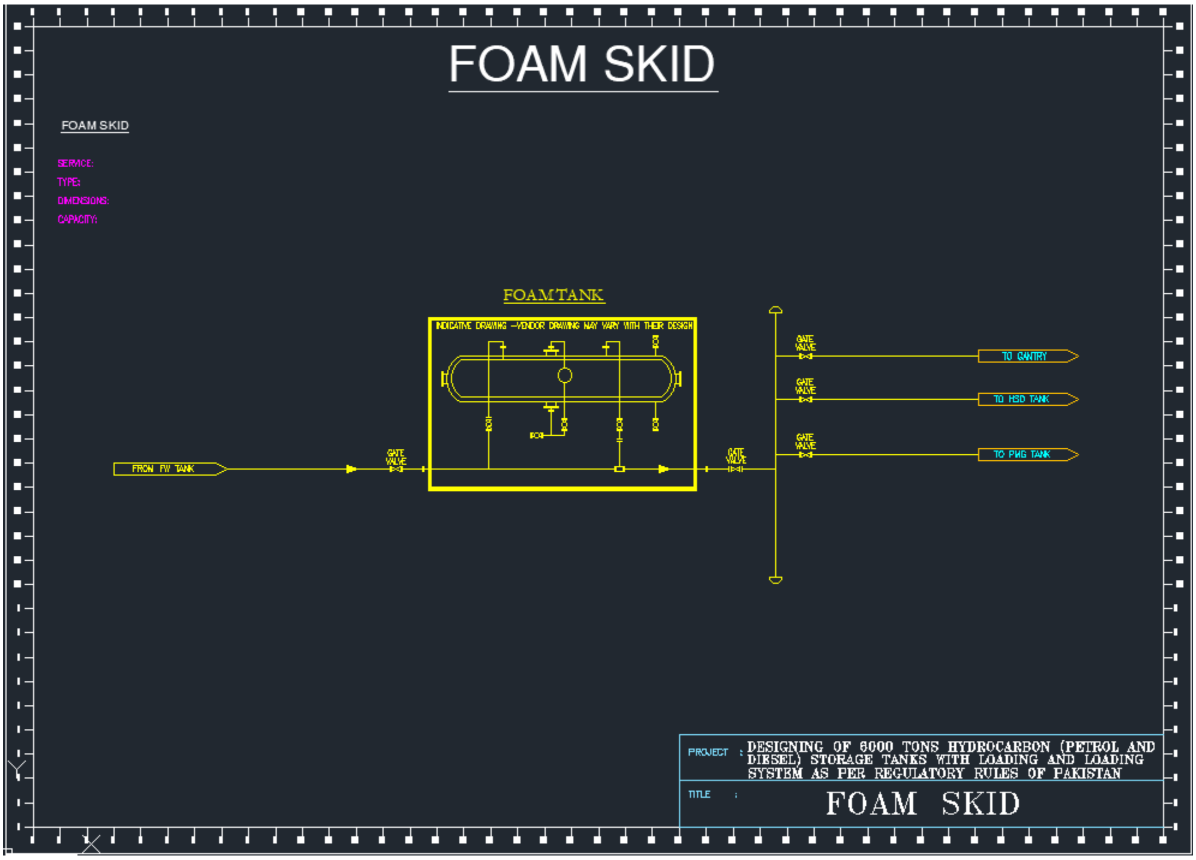


Figure 5.3

5.3 PMG Storage Tank

We design a PMG Storage tank of capacity 3000 tons with proper dimensions. The process and instrumentation diagram of the PMG Tank describes how the PMG storage tank can be loaded or unloaded. This P&ID tells us that the line is coming from the gantry through the pump, which is connecting with a line having a gate valve and a non-returning valve. This line fills the PMG tank through a bowser, which is unloaded on the gantry.

On the other hand, this PMG tank can be unloaded through a line having a gate valve and then connected with a pump, directly connected to the gantry this is the complete process of how the PMG tank can be loaded and unloaded through the gantry.

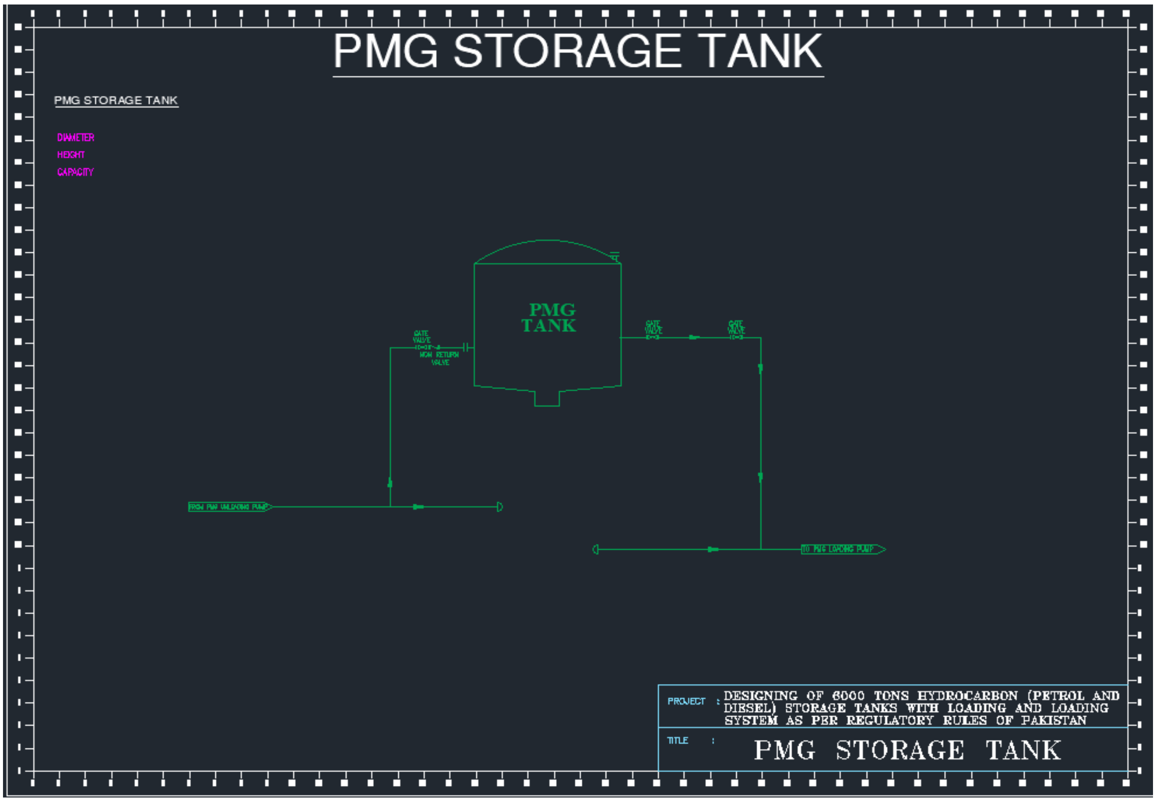
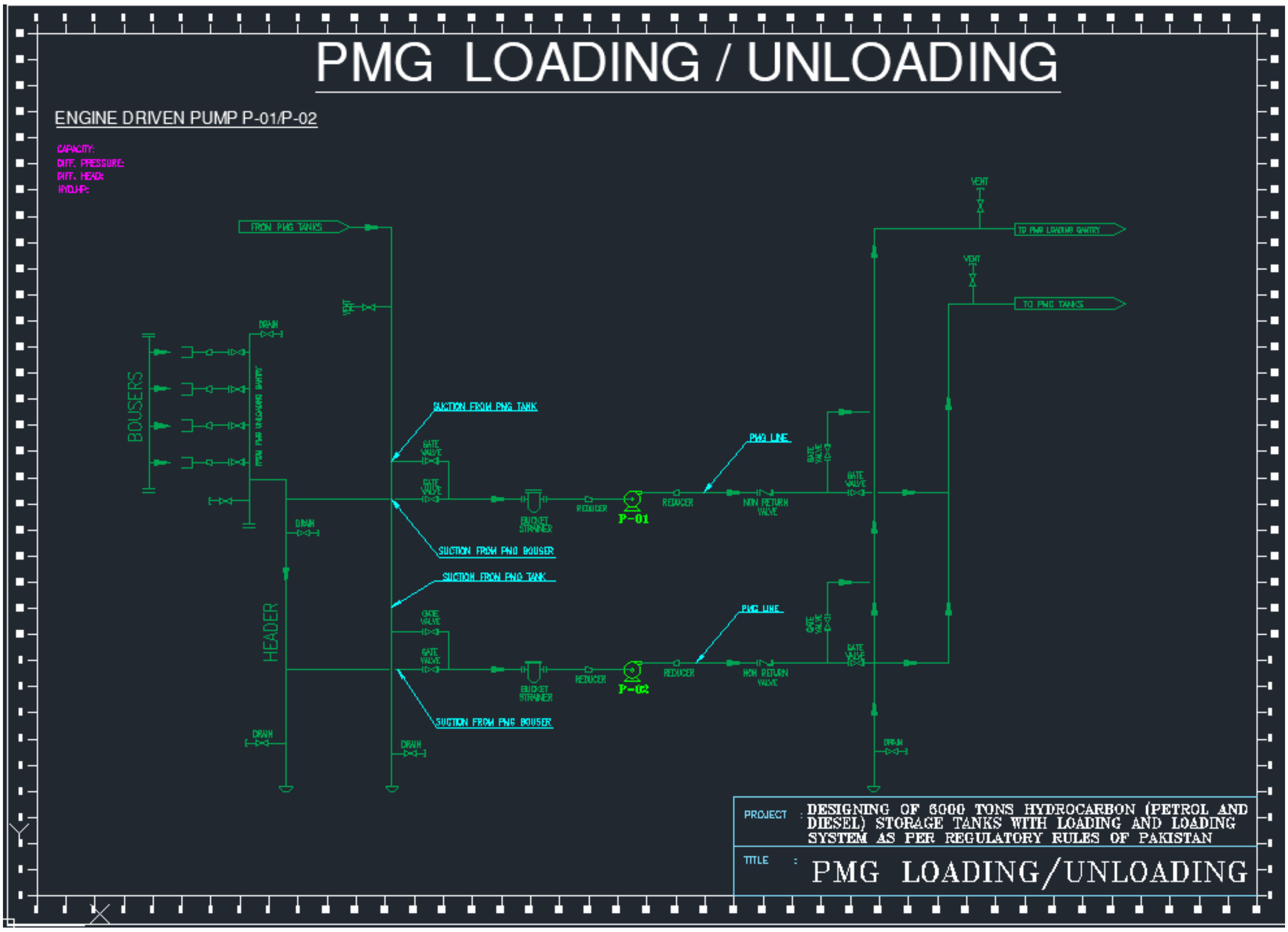


Figure 5.4

5.4 PMG Loading and Unloading

The PMG is first loaded in the PMG storage tank through pipes that connect the PMG storage tank to the un-loading gantry which is further connected by a loaded bowser, which is then unloaded via flexible pipes from the side bottom of the tank, and the PMG is transferred to the PMG tank. Along the connecting line, there is a gate valve to connect the flow, then there is a bucket strainer placed in between the pipes to strain out all the extravagant particles from the PMG. The reducer is connected to maintain the required flow and designated pressure. An engine-driven centrifugal pump is connected in between the flow network to make the flow happen. After that another reducer is placed after the pump flow it is again maintained accordingly. After that, a non-return valve is placed because now the flow will elevate and in any case, the flow of PMG must not flow back, and on the climax is placed another gate valve to control the flow externally. Finally, the last patch of pipe is connected to the PMG tank from the upper end of the tank with a vent opening to maintain suitable pressure at all times.

Now from the PMG storage tank, we fill the incoming bowser through the loading gantry via connecting lines (pipes). Along the connecting line, there is an air vent to maintain the pressure and a gate valve to connect the flow, then there is a bucket strainer placed in between the pipes to strain out all the extravagant particles from the PMG. The reducer is connected to maintain the required flow and designated pressure. An engine-driven centrifugal pump is connected in between the flow network to make the flow happen. After that another reducer is placed after the pump flow it is again maintained accordingly. After that, a non-return valve is placed because now the flow will elevate and, in any case, the flow of PMG must not flow back, and on the climax is placed another gate valve to control the flow externally. Finally, the last patch of pipe is connected to the loading gantry which will then fill the bowser via flexible pipes from above the bowser. This whole process is duplicated for a standby loading and unloading system.



PMG LOADING / UNLOADING
ENGINE DRIVEN PUMP P-01/P-02
CAPACITY:
DIFF. PRESSURE:
DIFF. HEAD:
HYD.HP:
FROM PMG TANKS
BOUSERS
DRAIN
HEADER
SUCTION FROM PMG TANK
GATE VALVE
BUCKET STRAINER
REDUCER
P-01
P-02
SUCTION FROM PMG BOUSER
PMG LINE
NON RETURN VALVE
VENT
TO PMG TANKS
PROJECT : DESIGNING OF 6000 TONS HYDROCARBON (PETROL AND DIESEL) STORAGE TANKS WITH LOADING AND LOADING SYSTEM AS PER REGULATORY RULES OF PAKISTAN
TITLE : PMG LOADING/UNLOADING

Figure 5.5

5.5 HSD Storage Tank

We design an HSD Storage tank with a capacity of 3000 tons with proper dimensions. The process and instrumentation diagram of the PMG Tank describes how the HSD storage tank can be loaded or unloaded. This P&ID tells us that the line is coming from the gantry through the pump, which is connecting with a line having a gate valve and a non-returning valve. This line fills the HSD tank through a bowser, which is unloaded on the gantry.

On the other hand, this HSD tank can be unloaded through a line having a gate valve and then connected with a pump, directly connected to the gantry this is the complete process of how the HSD tank can be loaded and unloaded through the gantry.

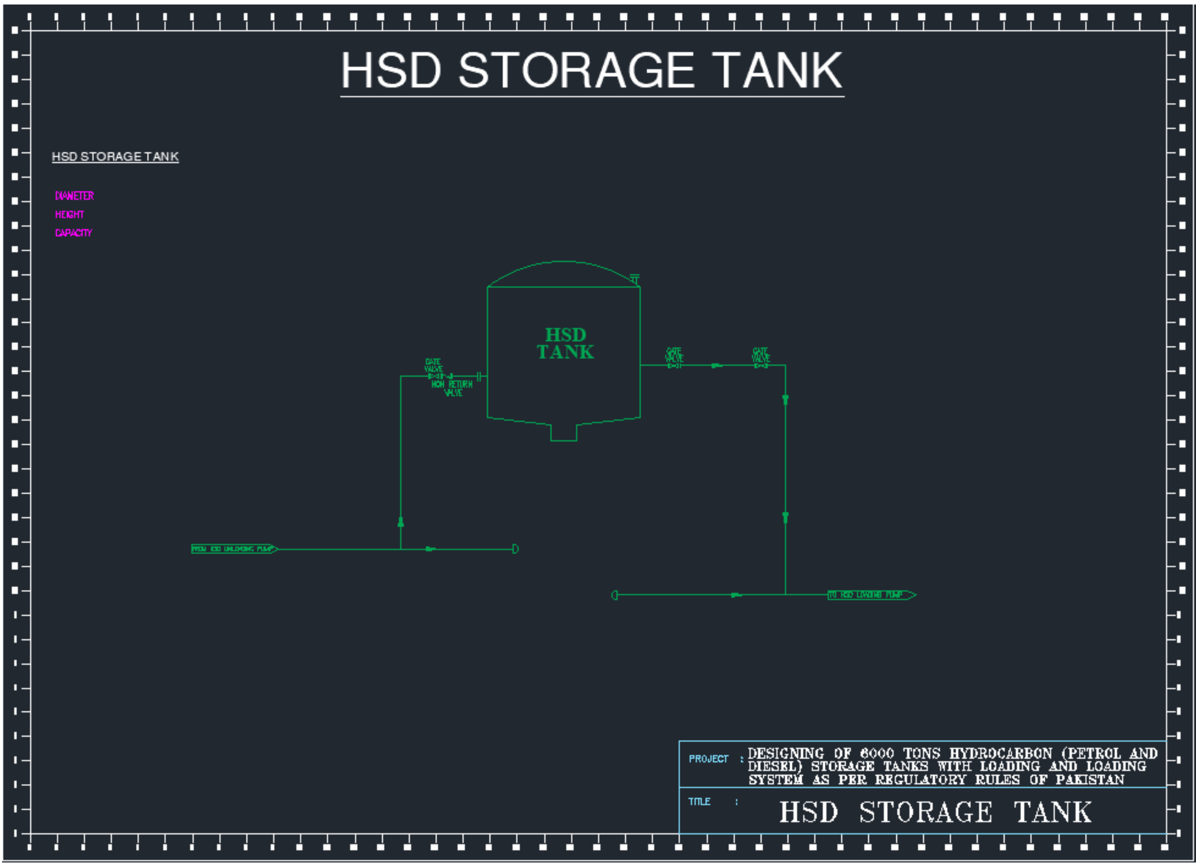
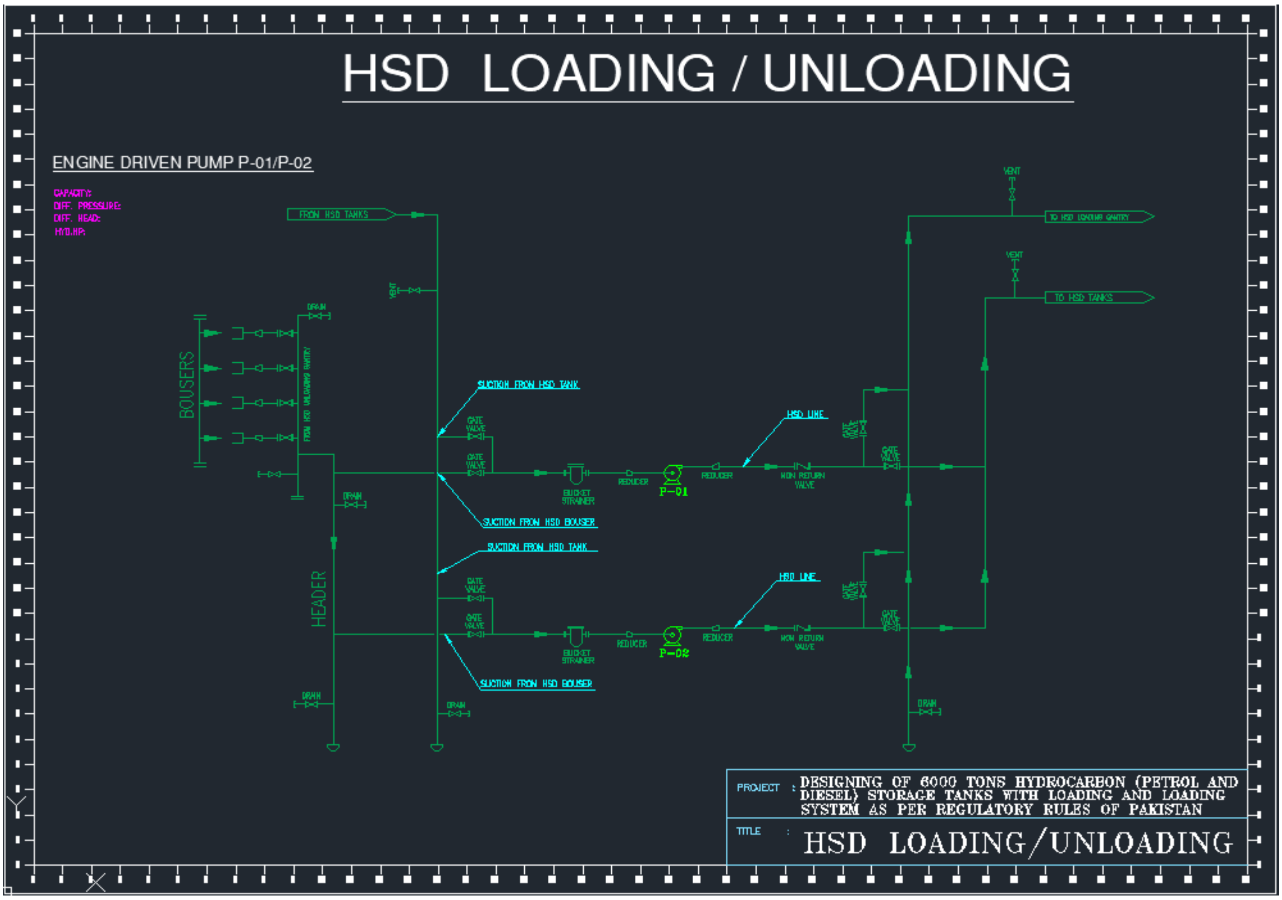


Figure 5.6

5.6 HSD Loading and Unloading

HSD is loaded into the storage tank through pipes connected to the unloading gantry, using a bowser and flexible pipes located at the tank's lower side. The process begins with a gate valve to precisely control the flow. A bucket strainer along the pipeline removes particles from the HSD to ensure its purity during transfer. Reducers are strategically placed to maintain optimal flow and pressure. An engine-driven centrifugal pump facilitates efficient transfer, followed by another reducer downstream to further refine the flow as needed. A non-return valve prevents backflow, and a final gate valve regulates external flow, allowing for precise adjustments during loading. At the tank's upper end, a vent maintains safe pressure levels.

Conversely, loading the bowser from the PMG storage tank via the gantry follows a similar methodical process. Starting with an air vent for pressure control, a gate valve regulates HSD flow into connecting pipes. A bucket strainer filters impurities, ensuring clean HSD transfer. Reducers and an engine-driven centrifugal pump manage flow and maintain pressure. Additional reducers post-pump further adjust flow dynamics. A non-return valve prevents reverse flow, and a gate valve controls external flow via flexible pipes above the bowser. This dual-system approach ensures reliability and meets safety standards for HSD handling.



HSD LOADING / UNLOADING
ENGINE DRIVEN PUMP P-01/P-02
CAPACITY:
DIFF. PRESSURE:
DIFF. HEAD:
HYD.HP:
FROM HSD TANKS
TO HSD TANKS
BOUSERS
HEADER
SUCTION FROM HSD TANK
SUCTION FROM HSD BOUSER
HSD LINE
GATE VALVE
BUCKET STRAINER
REDUCER
NON RETURN VALVE
P-01
P-02
VENT
DRAIN
PROJECT : DESIGNING OF 6000 TONS HYDROCARBON (PETROL AND DIESEL) STORAGE TANKS WITH LOADING AND LOADING SYSTEM AS PER REGULATORY RULES OF PAKISTAN
TITLE : HSD LOADING/UNLOADING

Figure 5.7

Chapter 6

Tank Designing

6.1 Introduction

Tank designing refers to the process of creating a detailed plan and specifications for building a tank, which is a container designed to hold liquids, gases, or solids. Tank design involves various engineering disciplines, including mechanical, civil, and chemical engineering, and takes into account factors such as:

- Capacity and volume
- Material selection (e.g., steel, concrete, fiberglass)
- Shape and geometry
- Wall thickness and strength
- Insulation and coatings
- Accessories (e.g., valves, pumps, gauges)

The goal of tank design is to create a safe, efficient, and cost-effective container that meets specific requirements and regulations.

AME-Tank software is a comprehensive tool used for the design, analysis, and simulation of tanks and vessels. Here's an explanation of its features and capabilities:

6.1.1 Design Module

- Creates tank designs based on user input (e.g., capacity, material, dimensions)
- Offers pre-defined tank shapes (e.g., cylindrical, rectangular, spherical)
- Allows for customization of tank geometry and accessories (e.g., valves, pipes, ladders)

6.1.2 Analysis Module

- Performs structural analysis (e.g., stress, strain, deflection) using finite element methods

- Calculates tank stability and settlement under various loads (e.g., wind, seismic, hydrostatic)
- Evaluates tank wall thickness and material selection

6.1.3 Simulation Module

- Simulates tank behavior under various operating conditions (e.g., filling, draining, thermal expansion)
- Predicts fluid dynamics, heat transfer, and mass transport phenomena
- Allows for modeling of complex systems (e.g., piping, pumps, valves)

6.1.4 Safety and Regulatory Compliance

- Checks design against relevant codes and standards (e.g., API, ASME, OSHA)
- Ensures compliance with safety regulations and industry best practices

6.1.5 Documentation and Reporting

- Generates detailed design reports, drawings, and specifications
- Creates operating and maintenance manuals

6.1.6 Benefits

- Streamlines tank design and analysis processes
- Reduces engineering time and costs
- Improves tank safety and reliability
- Enhances collaboration and communication among stakeholders

6.2 Methodology

Based on the guidelines provided by OGRA for designing petrol and diesel tanks, we utilized the AME TANK software to facilitate the design process. Here's the methodology we followed:

6.2.1 Software Selection

We opted for AME TANK software due to its capability to handle complex tank design parameters such as material selection, diameter, and height based on regulatory requirements and operational considerations.

6.2.2 Parameter Selection

Using the software, we input specific parameters required for tank design, including the type of material suitable for storing petroleum products, diameter, and height. For instance, for PMG storage, a diameter of 18.1 meters was selected, with a corresponding height of 16.43 meters. Similarly, for HSD storage, a diameter of 18.1 meters was chosen, with a height of 17.47 meters.

6.2.3 Design Considerations

The software allowed us to visualize and analyze different design scenarios based on these parameters. It provided tools to optimize tank dimensions to meet storage capacity requirements while adhering to safety standards and environmental regulations.

6.2.4 Rules Compliance

Throughout the design process, we ensured compliance with OGRA regulations regarding tank capacity, structural integrity, and safety measures. The software's simulation capabilities allowed us to validate the design against industry standards and local regulatory requirements.

6.2.5 Documentation and Reporting

AME TANK software enabled us to generate detailed reports and documentation, summarizing the design parameters, calculations, and compliance checks. This documentation serves as a comprehensive record of the design process and ensures transparency in project deliverables.

In conclusion, AME-Tank software is a powerful tool for tank designers, engineers, and operators, enabling them to create efficient, safe, and compliant tank designs while minimizing errors and reducing project timelines.

6.3 Explanation

We carefully followed the API 650 1 FOOT METHOD, using all the necessary factors to create two tanks. One tank, meant for storing HSD, has a diameter of 18.10 meters and a height of 14.47 meters. The other, for PMG, shares the same diameter but stands taller at 16.43 meters.

To make sure we understood everything clearly, we did manual calculations first. We figured out how many layers the tank needed and calculated the right thickness for the design and for when the tank is full of liquid. Then, we used the AME TANK software, which is really good for designing tanks, to finish off the design.

$$Courses = \frac{Tank\ Height}{Plate\ Width}$$

we selected suitable material, A36 steel with suitable sizes being plates 1.5 meters wide and 6 meters long, which are normally available in market. We also added a 3-meter allowance for corrosion. These measurements are standard in the industry, but flexible, and API 650 doesnot set strict rules about plate sizes or corrosion allowances.

We didn't just stop there; we considered lots of different things to make sure the tank was solidly designed. The final report covers everything we need to know about how the tank was designed, meeting all the requirements.

Besides the design details, we also looked at the cost to see how much it would be to build the tank. This gives us a good idea of what the project will involve financially.

- A36 Steel Material Cost = 270 PKR per Kg
- A36 Steel Material polishing and others charges = 230 PKR per Kg
- Total A36 Material Cost = 500 PKR per Kg

In the end, our meticulous approach ensured that the tanks were not only well-designed but also cost-effective, meeting both engineering standards and budgetary considerations.

6.4 Manual Calculations For HSD

HSD	
No of Courses	**Height (mm)**
1	14.47
2	12.97
3	11.47
4	9.97
5	8.47
6	6.97
7	5.47
8	3.97
9	2.47
10	0.97

- We have taken each reading with a difference of 1.5 k as per API 650.

Design Thickness Formula:

$$t_d = \frac{4.9D(H-0.3)SG}{Sd} + CA$$

Hydrostatic Thickness Formula:

$$t_t = \frac{4.9D(H-0.3)SG}{St}$$

Where,

t_d = Design shell thickness, in mm

t_t = Hydrostatic test shell thickness, in mm

D = Nominal tank diameter, in m

H = Design liquid level, in m

SG = Design Specific Gravity of a liquid

S_d = Allowable Stress for the design condition, in MPA

S_t = Allowable Stress for the hydrostatic condition, in MPA

C = Corrosion Allowance, in mm

S#	Design Thickness td (mm)	Hydrostatic Thickness t_t (mm)
1	9.598	6.173
2	8.411	5.062
3	7.339	4.060
4	6.383	3.166
5	5.543	2.380
6	4.819	1.702
7	4.210	1.132
8	3.718	0.671
9	3.341	0.319

6.5 Manual Calculations For PMG

PMG	
No of Courses	**Height (mm)**
1	16.43
2	14.93
3	13.43
4	11.93
5	10.43
6	8.93
7	7.43
8	5.93
9	4.43
10	2.93
11	1.43

- We have taken each reading with a difference of 1.5 k as per API 650.

Design Thickness Formula:

$$t_d = \frac{4.9D(H - 0.3)SG}{Sd} + CA$$

Hydrostatic Thickness Formula:

$$t_t = \frac{4.9D(H - 0.3)SG}{St}$$

Where,

t_d = Design shell thickness, in mm

t_t = Hydrostatic test shell thickness, in mm

D = Nominal tank diameter, in m

H = Design liquid level, in m

SG = Design Specific Gravity of a liquid

S_d = Allowable Stress for the design condition, in MPA

S_t = Allowable Stress for the hydrostatic condition, in MPA

S#	Design Thickness td (mm)	Hydrostatic Thickness tt (mm)
1	9.616	6.191
2	8.504	5.150
3	7.493	4.204
4	6.584	3.354
5	5.778	2.599
6	5.073	1.940
7	4.470	1.376
8	3.970	0.907
9	3.571	0.534
10	3.274	0.257
11	3.079	0.074

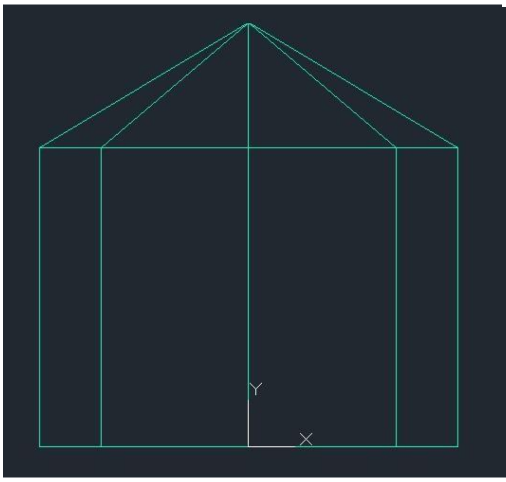


Figure 6.1

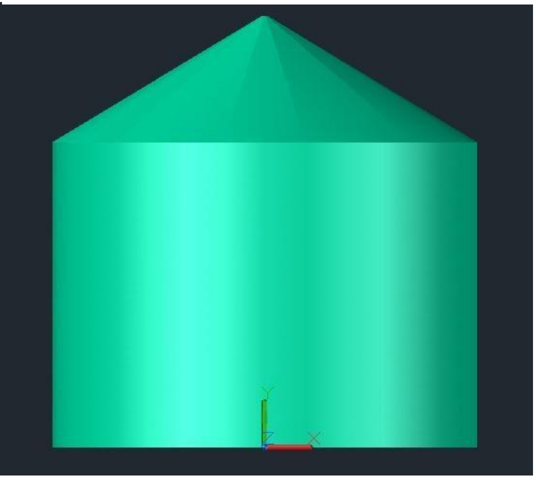


Figure 6.2

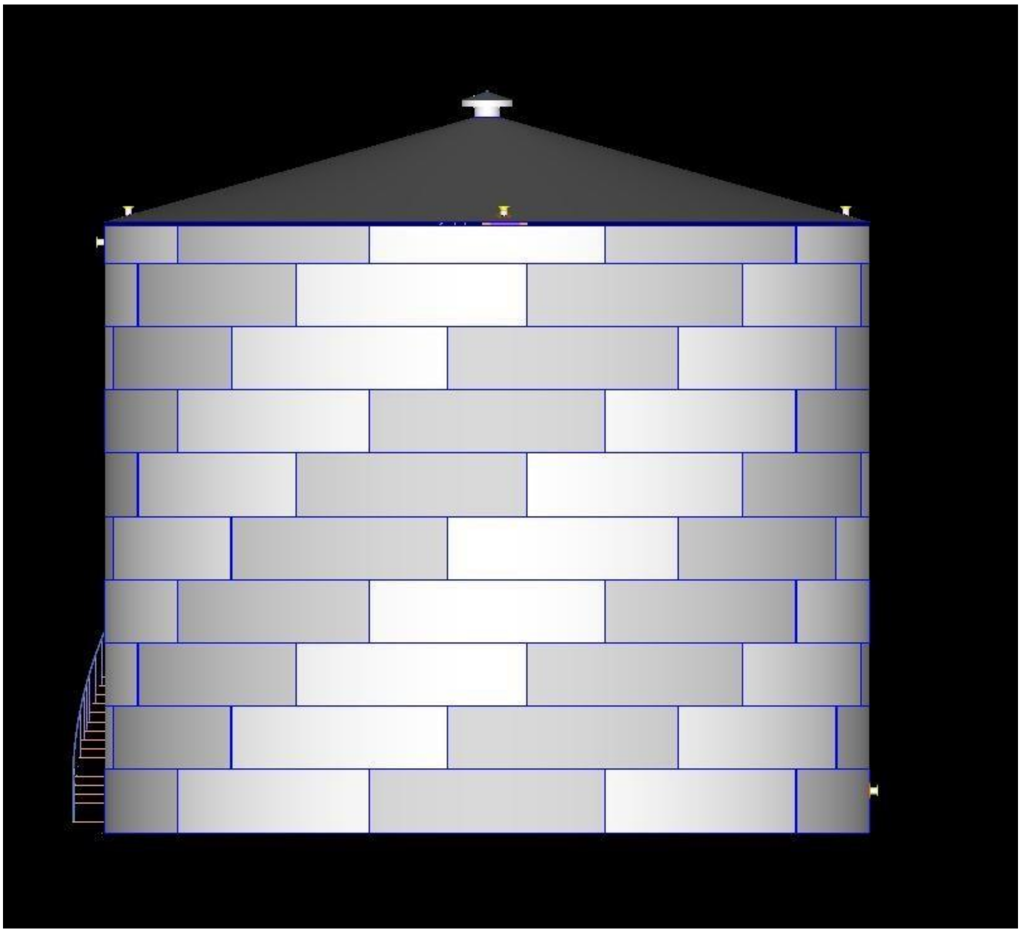


Figure 6.3

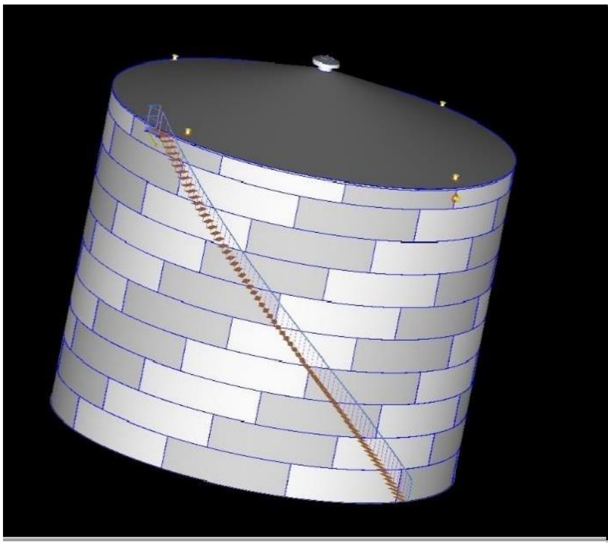


Figure 6.4

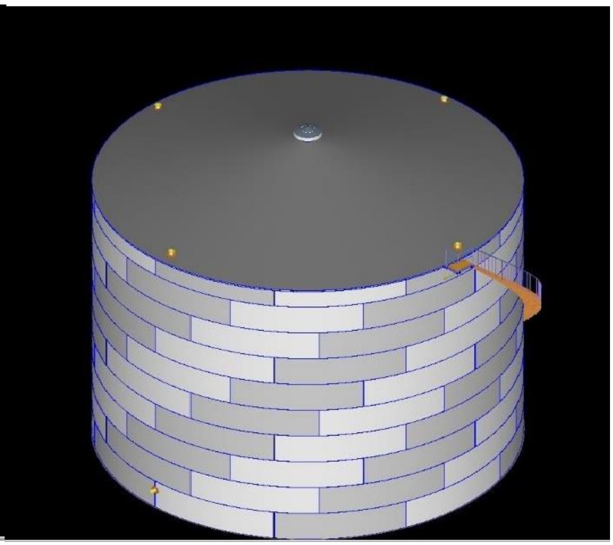


Figure 6.5

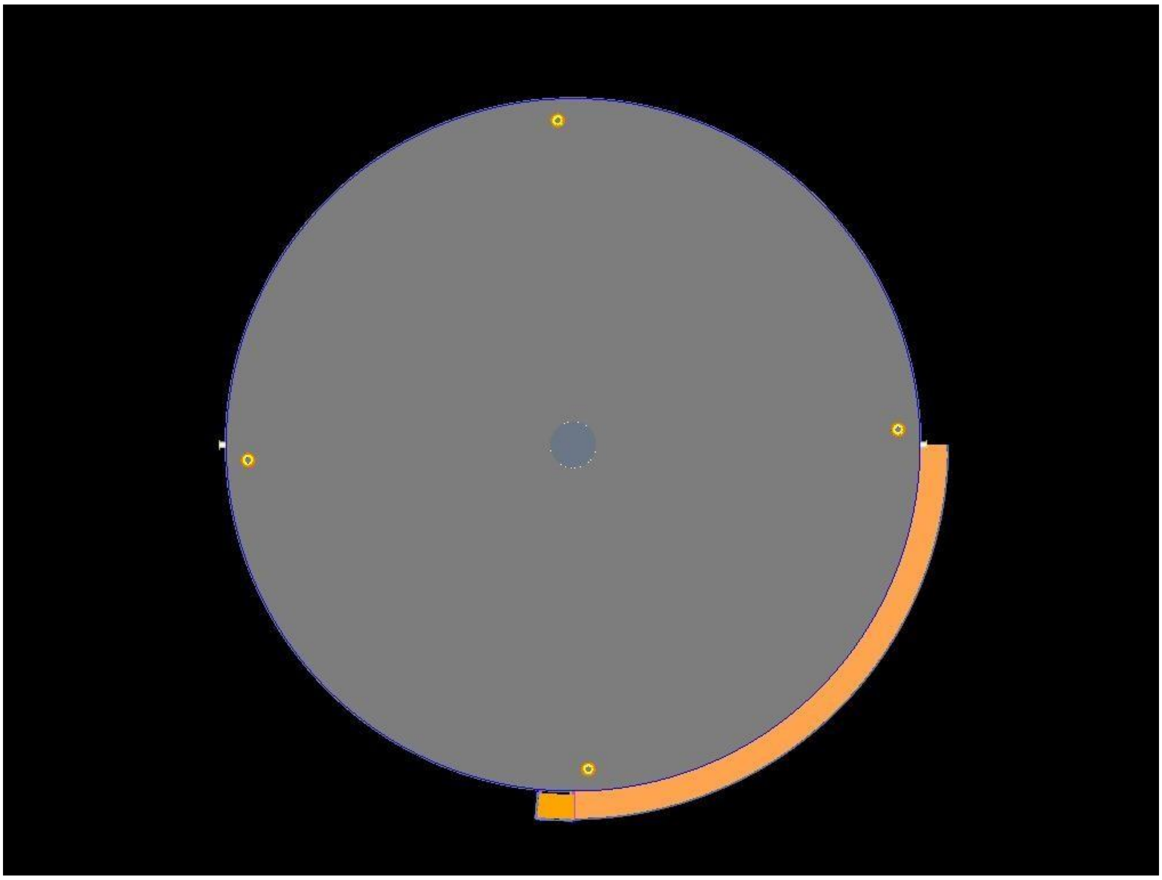


Figure 6.6

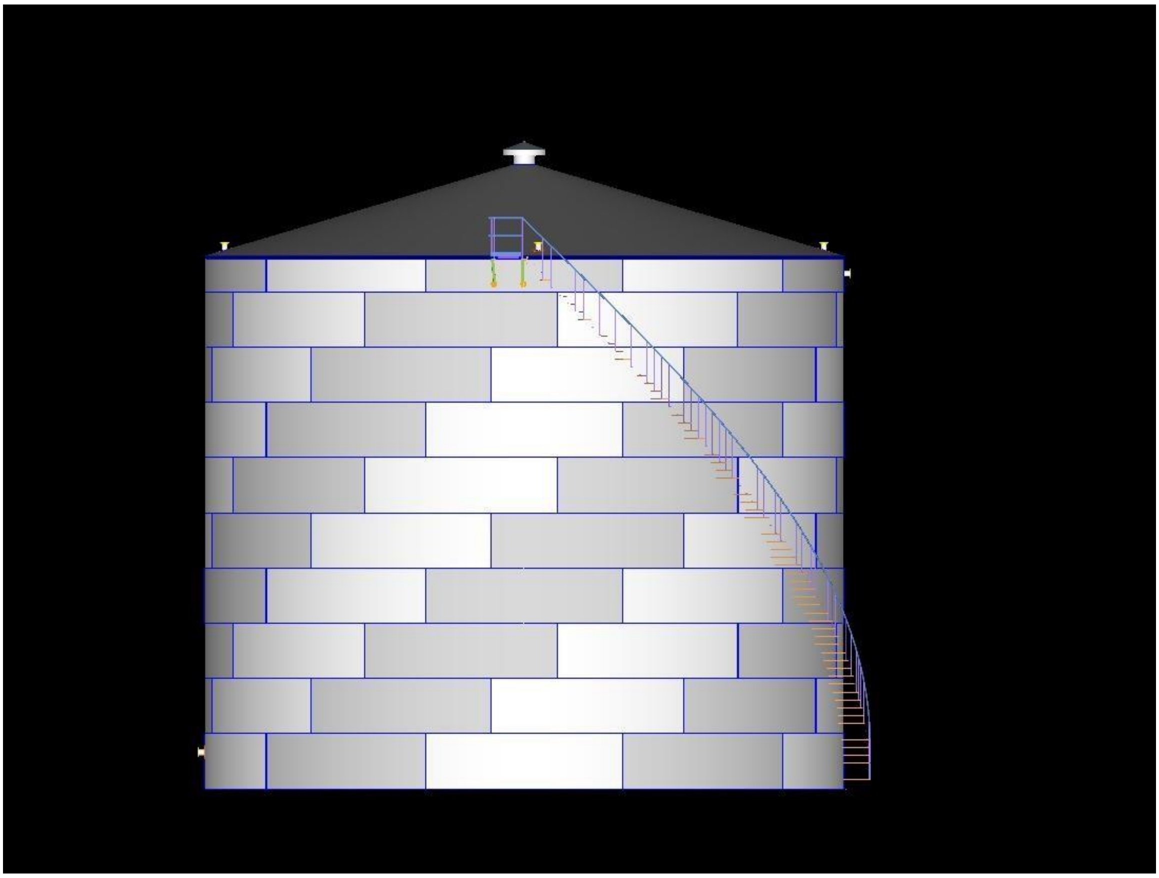


Figure 6.7

Chapter 7

Hydraulics

7.1 Introduction

Hydraulics is a technology that utilizes fluid pressure to transmit force or energy, often used in mechanical systems and machines. It's based on Pascal's principle, which states that when pressure is applied to a confined fluid, it transmits the pressure equally in all directions.

In hydraulic systems, a liquid (usually oil or water) is used to transmit power, motion, or pressure from one point to another. This is achieved through various components, such as:

- Pumps: Create fluid pressure
- Cylinders: Convert pressure into linear motion
- Motors: Convert pressure into rotary motion
- Valves: Control fluid flow and pressure

The basic principle of hydraulics is Pascal's Law, which states:
"A change in pressure at any point in a confined fluid (liquid) is transmitted equally and undiminished throughout the fluid, in all directions, and to all parts of the container."

This principle has three key aspects:

- Pressure Transmission: Pressure applied to the fluid is transmitted throughout the system.
- Equal Pressure: The pressure is equal in all directions and at all points in the fluid.
- Undiminished Pressure: The pressure is not reduced or lost as it is transmitted through the fluid.

This principle allows hydraulics to:

- Amplify force (by increasing pressure)
- Change the direction of force (using valves and cylinders)
- Transmit force over long distances (through hoses and pipes)

Korff Software is a suite of tools used for designing, analyzing, and simulating hydraulic systems and fluid power components. It is widely used in various industries, including construction, aerospace, and manufacturing.

The software provides a comprehensive platform for engineers and technicians to:

- Design: Create and model hydraulic systems, including piping, cylinders, pumps, and valves.
- Analyze: Simulate system behavior, predict performance, and optimize component sizing.
- Simulate: Test and validate system designs, identifying potential issues and improvements.

Key features of Korf Software include:

- Hydraulic Circuit Design: Create and edit hydraulic circuits, including component selection and sizing.
- Fluid Flow Simulation: Analyze fluid flow, pressure, and velocity in the system.
- Component Library: Access a comprehensive library of hydraulic components, including pumps, motors, cylinders, and valves.
- System Optimization: Optimize system performance, efficiency, and cost.
- Reporting and Visualization: Generate detailed reports and visualize system behavior using graphs and charts.

7.2 Methodology

To design a robust system for petrol and diesel tanks that meets OGRA regulations, the process starts with a thorough understanding of regulatory guidelines governing safety and operations. This involves studying OGRA standards and documents like the S.R.O 624(I)/2009 from the Pakistani government, which detail essential safety protocols and operational criteria. Following this regulatory review, the next step is defining specific system requirements and technical details. This includes calculating required flow rates for petrol (PMG) and diesel, determining optimal tank capacities based on storage needs and site conditions, and considering safety and environmental factors as mandated by OGRA.

Hydraulic analysis plays a crucial role and is facilitated using advanced software such as Korf. This software allows for precise calculations and simulations necessary to design the piping network connecting the gantry to the tanks and back. Key aspects addressed during hydraulic analysis include:

7.2.1 Calculating Flow Rates

Precisely determining the flow rates needed for efficient transfer of PMG and diesel between the gantry and tanks, ensuring compliance with operational needs and safety standards.

7.2.1 Sizing Tank Output Pipes: Determining the right diameters for tank output pipes to minimize friction losses and maintain optimal flow rates throughout the system.

7.2.2 Optimizing Fluid Velocity

Analyzing and optimizing fluid velocities within the pipes to improve operational efficiency, reduce energy use, and adhere to OGRA guidelines.

7.2.3 Selecting and Evaluating Pumps

Choosing pumps based on their efficiency, power ratings, and ability to handle suction and discharge operations effectively. This ensures reliable performance and meets safety requirements during fluid transfers.

After hydraulic analysis, the design is validated through simulations using Korf software. This process ensures that chosen pipe sizes, pump capacities, and system configurations meet hydraulic performance standards and comply with OGRA regulations. It allows for adjustments to enhance system efficiency and reliability, considering factors like pressure losses due to pipe friction and elevation changes.

Comprehensive engineering documentation, including detailed Process and Instrumentation Diagrams (P&IDs), pipe plans, and equipment specifications, is prepared based on finalized design parameters. These documents guide construction, installation, and operational aspects such as safety protocols and emergency procedures. Throughout the design process, meticulous attention is given to compliance with OGRA regulations and industry standards, with all calculations, simulations, and specifications documented to facilitate regulatory approval and ensure operational readiness.

This detailed methodology aims to achieve efficient, safe, and compliant design of petrol and diesel tank systems, ensuring reliable performance and longevity in handling and storing hydrocarbon fuels.

In our tank design project, we made sure our tanks could fill up smoothly from both the gantry and the tanks themselves. To handle the hydraulics of this process, we used Korf software. But to make Korf work well, we had to give it some specific information.

7.3 Explanation

At first, we did some manual calculations to figure out things like the size of the pipes, how fast the liquid should flow, and how long it would take to fill. Then, we plugged these numbers into KORF. It helped us determine important stuff like Pump Power, Pump Efficiency, Head, and velocity.

We repeated this entire procedure twice, once for the PMG tank and once for the HSD tank because we have two tanks in our setup. This approach ensured that both tanks were properly accounted for in terms of their hydraulic functioning. By doing this, we set up hydraulic systems for both tanks that work efficiently and ensure the smooth transfer of liquids in our tank setup.

7.4 Manual Calculations

1) <u>PMG to GANTRY:</u>

A. Time: 21 min = 0.35 hr — 1 min = 0.0166667 hr
- Provided by company

B. Bowser = 48000 litre = 35520 kg (PMG) — 1 litre = 0.74 kg
- $flow\ rate = \frac{35520}{0.35}$
- $flow\ rate = 101485.7\,\frac{kg}{hr}$
- $flow\ rate = 0.038095\ m^3/s$ — 1 kg/hr = 0.00000028 m^3/s

C. $Velocity = \frac{flow\ rate}{Area}$

a) Iteration 1 — Pipe diameter = 6 in = 0.1524 m
- $Velocity = \frac{0.038095}{\pi(0.0762)^2}$ — Area = πr^2
- $Velocity = 2.08837\ m/s$

b) Iteration 2 — Pipe diameter = 8 in = 0.2032 m
- $Velocity = \frac{0.038095}{\pi(0.1016)^2}$ — 1 in = 0.0254
- $Velocity = 1.17471\ m/s$

c) Iteration 3 Pipe diameter = 10 in = 0.254 m

- $Velocity = \frac{0.038095}{\pi(0.127)^2}$
- $Velocity = 0.75181\ m/s$

We initially selected an 8-inch pipe, with a 6-inch pipe for the smaller diameter and a 10-inch pipe for the larger diameter. The head loss in the 6-inch pipe was 18.29 dP/L, which significantly exceeds the acceptable limit of 7.5 dP/L. On the other hand, the head loss in the 10-inch pipe was 1.554 dP/L, which is within the limit. However, the velocity was very low and the cost was prohibitively expensive. Consequently, we opted for the 8-inch pipe, which exhibited a velocity of 1.1m/s and a head loss of 4.725dP/L, both within acceptable limits. Therefore, in iteration 2, we selected the 8-inch diameter pipe. This decision was based on our software's analysis for our final year project.

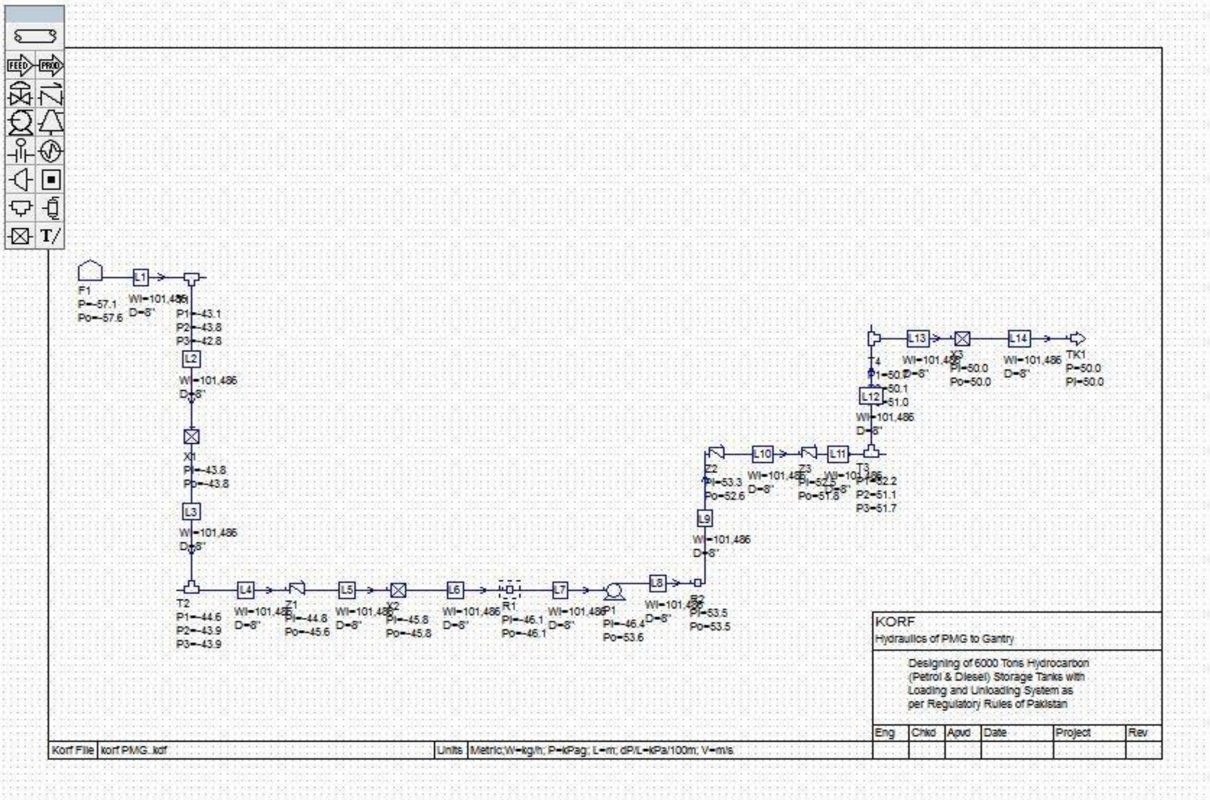


Figure 7.1

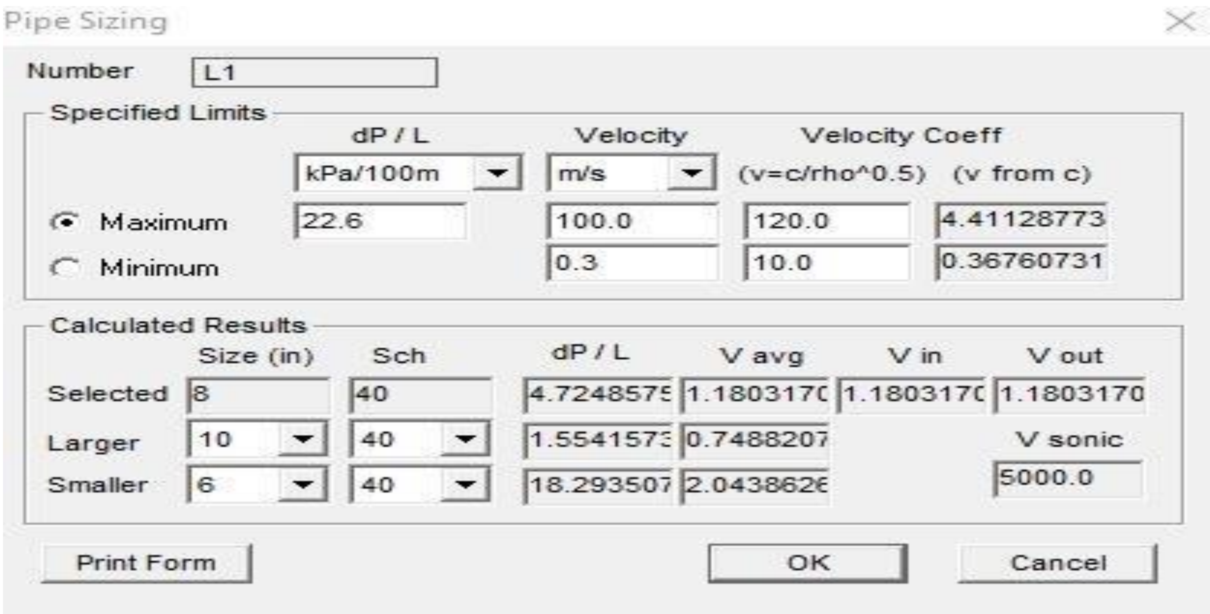


Figure 7.2

2) <u>Gantry to PMG:</u>

- We'll repeat the same process again of PMG-to-Gantry specifically for the gantry-to-PMG tank.

3) <u>HSD to GANTRY:</u>

D. Time: 21 min = 0.35 hr — 1 min = 0.0166667 hr

- Provided by company

E. Bowser = 48000 litre = 40320 kg (HSD) — 1 litre = 0.84 kg

- $flow\ rate = \frac{40320}{0.35}$
- $flow\ rate = 115200\frac{kg}{hr}$
- $flow\ rate = 0.032256\ m^3/s$ — 1 kg/hr = 0.00000028 m^3/s

F. $Velocity = \frac{flow\ rate}{Area}$

d) Iteration 1 — Pipe diameter = 6 in = 0.1524 m

- $Velocity = \frac{0.032256}{\pi(0.0762)^2}$ — 1 in = 0.0254 m
- $Velocity = 1.7682\ m/s$ — Area = πr^2

e) Iteration 2 Pipe diameter = 8 in = 0.2032 m

- $Velocity = \frac{0.032256}{\pi(0.1016)^2}$
- $Velocity = 0.9946\ m/s$

f) Iteration 3 Pipe diameter = 10 in = 0.254 m

- $Velocity = \frac{0.032256}{\pi(0.127)^2}$
- $Velocity = 0.6365\ m/s$

We initially selected an 8-inch pipe, with a 6-inch pipe for the smaller diameter and a 10-inch pipe for the larger diameter. The head loss in the 6-inch pipe was 22.20 dP/L, which significantly exceeds the acceptable limit of 7.5 dP/L. On the other hand, the head loss in the 10-inch pipe was 1.9227 dP/L, which is within the limit. However, the velocity was excessively high and the cost was prohibitively expensive. Consequently, we opted for the 8-inch pipe, which exhibited a velocity of 1.18/s and a head loss of 5.799 dP/L, both within acceptable limits. Therefore, in iteration 2, we selected the 8-inch diameter pipe. This decision was based on our software's analysis for our final year project.

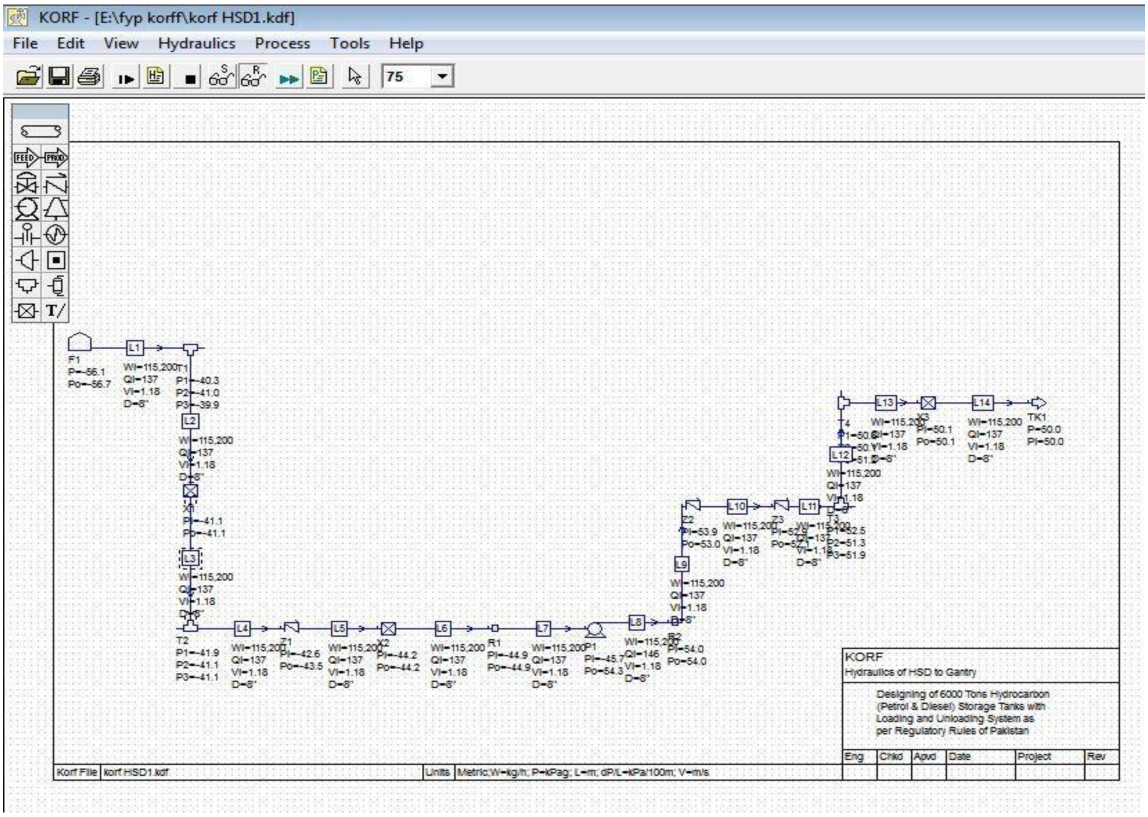


Figure 7.3

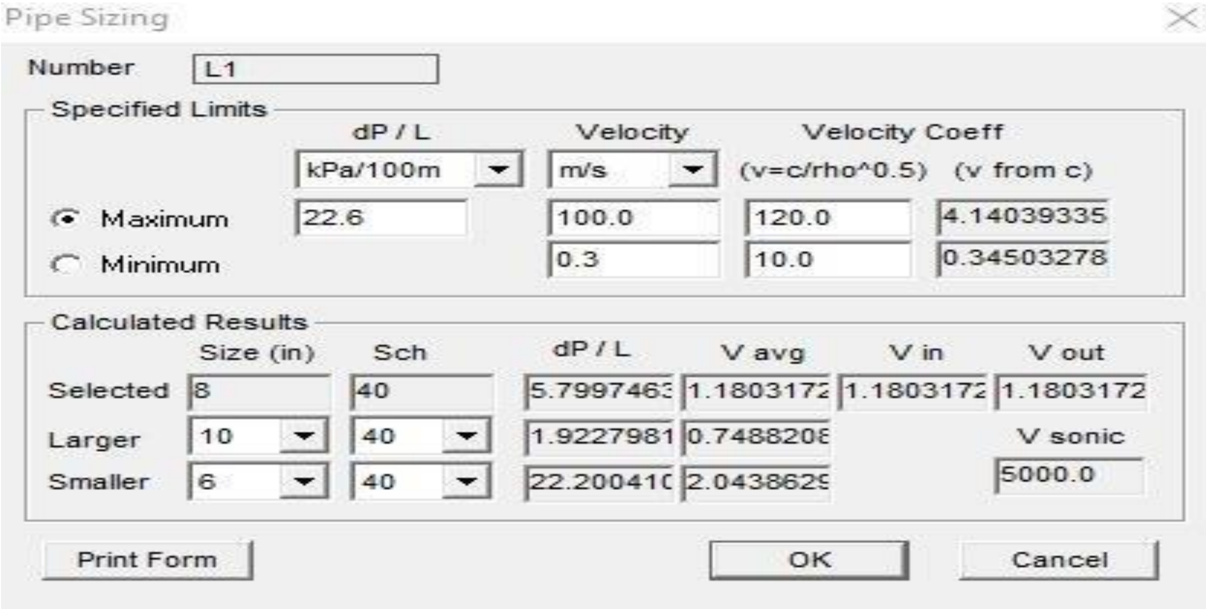


Figure 7.4

4) <u>Gantry to HSD:</u>

- We'll repeat the same process again of HSD-to-Gantry specifically for the gantry-to-PMG tank.

Chapter 8

Pump

8.1 Selection of pump

Figure 8.1

Figure 8.2

Pump selection involves considering various factors to ensure the chosen pump meets the specific requirements of the application. Here are some key factors to consider when selecting a pump:

8.1.1 Type of Pump

- **Centrifugal Pumps**: Ideal for liquids with low viscosity.
- **Positive Displacement Pumps**: Suitable for high-viscosity fluids and precise flow control.

8.1.2 Flow Rate and Head

- **Flow Rate (Q)**: The volume of fluid the pump must move per unit time (e.g., liters per minute).
- **Head (H)**: The height to which the pump can raise the fluid, considering both static and dynamic head.

8.1.3 Fluid Characteristics

- **Viscosity**: Thicker fluids require pumps with higher torque.
- **Density**: Denser fluids need more power to pump.
- **Corrosiveness**: Corrosive fluids require materials that resist degradation.
- **Temperature**: High-temperature fluids may need specialized pump

materials.

8.1.4 Power Requirements

- Ensure the pump's power requirements match the available power supply.
- Consider the efficiency of the pump to minimize energy consumption.

8.1.5 Pump Materials

- Select materials compatible with the fluid to prevent corrosion and wear.
- Common materials include stainless steel, cast iron, and various polymers.

8.1.6 Pump Efficiency

- Higher efficiency pumps reduce energy costs and environmental impact.
- Look for pumps with efficiency curves that match the operating conditions.

8.1.7 Operating Conditions

- Ensure the pump can handle the operating pressure and temperature ranges.
- Consider the duty cycle and ensure the pump can operate continuously if needed.

8.1.8 Compliance and Standards

- Ensure the pump meets industry standards and regulations for safety and performance.
- By considering these factors, you can select a pump that is well-suited for your specific application, ensuring efficient and reliable operation.

8.2 Type of Pump

8.2.1 Centrifugal Pump

I) Advantages:

- High flow rates.
- Simpler design with fewer moving parts.

- Lower maintenance costs.

II) Applications:

- Ideal for large volume transfers in short periods.
- Used where the viscosity of the fuel is low.

III) Types:

- **Single-Stage Centrifugal Pumps**: Used for straightforward, high-flow, low-pressure applications.
- **Multistage Centrifugal Pumps**: Employed when higher pressures are needed.

8.2.2 Positive Displacement Pumps

I) Advantages:

- Precise flow control.
- Can handle high-viscosity fluids.
- Effective in metering applications.

II) Applications:

- Suitable for situations requiring consistent flow regardless of pressure variations.
- Ideal for unloading operations where precise control over flow is necessary.

III) Types:

- **Gear Pumps**: Common in fuel transfer because they handle viscous fluids well and provide a consistent flow rate.
- **Diaphragm Pumps**: Used for applications requiring chemical resistance and leak-free operation.
- **Piston Pumps**: Suitable for high-pressure applications.

8.3 Specific Considerations for HSD and PMG

8.3.1 Safety and Compliance

- Pumps must be explosion-proof and certified for use with flammable liquids.

- Ensure compliance with relevant safety standards and regulations (e.g., ATEX, API).

8.3.2 Material Compatibility

- Pumps must be constructed from materials compatible with diesel and petrol to prevent corrosion and degradation.

8.3.3 Efficiency

- Look for pumps with high efficiency to minimize energy consumption and operational costs.

8.4 Commonly Used Pumps

8.4.1 Centrifugal Pumps

- **ANSI Process Pumps**: Standardized pumps for handling hydrocarbons.
- **API 610 Pumps**: Specifically designed for the petroleum industry.

8.4.2 Positive Displacement Pumps

- **Internal Gear Pumps**: Reliable for handling various fuels including HSD and PMG.
- **Rotary Vane Pumps**: Provide smooth, low-pulsation flow, ideal for fuel transfer applications.

8.5 Summary

- **Centrifugal Pumps** are typically used for their high flow rates and efficiency in bulk transfer operations.
- **Positive Displacement Pumps** are chosen for their precision and ability to handle high viscosities, making them suitable for unloading and metering applications.

The choice of pump depends on the specific requirements of the loading and unloading system, including flow rate, pressure, and the physical properties of the fuels being handled.

Centrifugal pumps are commonly motor-driven. In fact, the most typical configuration for a centrifugal pump involves an electric motor as the prime mover. Here's an overview:

8.6 Motor-Driven Centrifugal Pumps

8.6.1 Electric Motors

- **AC Motors**: The most common type used in industrial applications. They can be single-phase or three-phase.
- **DC Motors**: Used in applications where variable speed control is required, though less common than AC motors.

8.6.2 Advantages of Electric Motor-Driven Centrifugal Pumps

- **Efficiency**: Electric motors are highly efficient and can be easily controlled.
- **Reliability**: Electric motors require less maintenance compared to internal combustion engines.
- **Ease of Integration**: Easily integrated into automated systems with control panels and sensors.
- **Environmentally Friendly**: No emissions, making them suitable for use in a wide range of environments.

For handling hydrocarbons such as High-Speed Diesel (HSD) and Petrol (Motor Gasoline, PMG), you need a pump that is both reliable and safe to use with flammable liquids. Here are a few recommended options:

8.7 Recommended Pumps for Hydrocarbons

8.7.1 API 610 Centrifugal Pumps

- **Model**: Goulds 3700
- **Description**: This pump is designed specifically for the petroleum industry, adhering to API 610 standards. It's ideal for handling various hydrocarbons, including diesel and gasoline.
- **Features**:
    - High reliability and efficiency.
    - Robust construction with materials resistant to corrosion.
    - Designed to handle high temperatures and pressures.
- **Application**: Suitable for both loading and unloading operations, and general fuel transfer.

8.7.2 ANSI Process Pumps

- **Model**: Flowserve Durco Mark 3
- **Description**: These pumps are standardized and designed to handle a variety of hydrocarbons.
- **Features**:
  - High efficiency and reliability.
  - Available in a wide range of materials to suit different fluids.
  - Designed for easy maintenance and long service life.
- **Application**: Suitable for a variety of hydrocarbon transfer applications, including both diesel and gasoline.

8.8 Suitability for HSD and PMG: ANSI Process Pumps vs. API 610 Pumps

8.8.1 ANSI Process Pumps

- **Pros**: Cost-effective, easy maintenance, versatile for various chemicals.
- **Cons**: Limited to moderate pressure and temperature, less robust for hydrocarbons.

8.8.2 API 610 Pumps

- **Pros**: High safety standards, handles high pressures and temperatures, robust and reliable for hydrocarbons.
- **Cons**: More expensive, complex design.

Conclusion: **API 610 pumps** are more suitable for HSD and PMG due to their superior safety, reliability, and ability to handle the demanding conditions of hydrocarbon processing.

8.9 Key Considerations

8.9.1 Safety

Ensure the pump is explosion-proof and meets relevant safety standards (e.g., ATEX, API).

8.9.2 Material Compatibility

Select pumps made from materials that can withstand the chemical properties of diesel and gasoline.

8.9.3 Flow Rate and Pressure Requirements

Ensure the pump meets the specific flow rate and pressure requirements of your operation.

8.9.4 Maintenance and Reliability

Choose pumps known for their reliability and ease of maintenance to minimize downtime.

By selecting a pump from these recommended options, you can ensure safe and efficient handling of HSD and PMG in your loading and unloading systems.

8.10 Selection of Centrifugal Pump for Suction and Discharge Processes (API 610)

We have selected a centrifugal pump that meets API 610 standards for handling High-Speed Diesel (HSD) and Petrol (Motor Gasoline, PMG) in both suction and discharge processes. The API 610 standard ensures high safety and reliability, making the pump suitable for handling flammable and hazardous hydrocarbons. These pumps are designed to withstand the high pressures and temperatures typical in hydrocarbon processing, with materials that resist corrosion and erosion, ensuring long-term durability and reduced maintenance.

A typical API 610 centrifugal pump, like the Goulds 3700, offers high flow rates and pressures, making it effective for both loading (suction) and unloading (discharge) operations. The standardized parts and global support for API 610 pumps make maintenance straightforward and reduce downtime. By selecting an API 610 centrifugal pump, such as the Goulds 3700, for HSD and PMG handling, you ensure compliance with industry safety standards, reliable performance, and efficient, safe hydrocarbon processing.

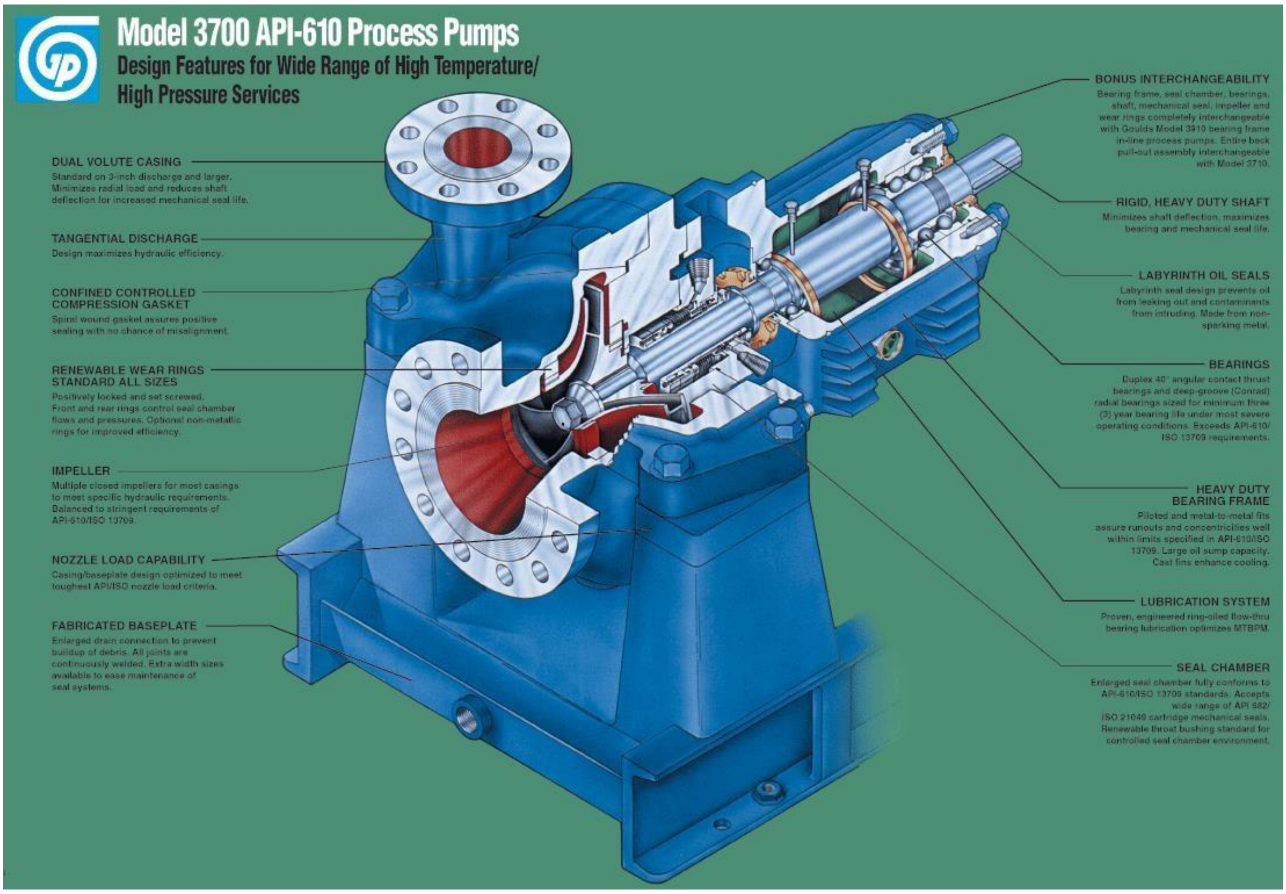

Model 3700 API-610 Process Pumps
Design Features for Wide Range of High Temperature/ High Pressure Services
DUAL VOLUTE CASING
Standard on 3-inch discharge and larger. Minimizes radial load and reduces shaft deflection for increased mechanical seal life.
TANGENTIAL DISCHARGE
Design maximizes hydraulic efficiency.
CONFINED CONTROLLED COMPRESSION GASKET
Spiral wound gasket assures positive sealing with no chance of misalignment.
RENEWABLE WEAR RINGS STANDARD ALL SIZES
Positively locked and set screwed. Front and rear rings control seal chamber flows and pressures. Optional non-metallic rings for improved efficiency.
IMPELLER
Multiple closed impellers for most casings to meet specific hydraulic requirements. Balanced to stringent requirements of API-610/ISO 13709.
NOZZLE LOAD CAPABILITY
Casing/baseplate design optimized to meet toughest API/ISO nozzle load criteria.
FABRICATED BASEPLATE
Enlarged drain connection to prevent buildup of debris. All joints are continuously welded. Extra width sizes available to ease maintenance of seal systems.
BONUS INTERCHANGEABILITY
Bearing frame, seal chamber, bearings, shaft, mechanical seal, impeller and wear rings completely interchangeable with Goulds Model 3910 bearing frame in-line process pumps. Entire back pull-out assembly interchangeable with Model 3710.
RIGID, HEAVY DUTY SHAFT
Minimizes shaft deflection, maximizes bearing and mechanical seal life.
LABYRINTH OIL SEALS
Labyrinth seal design prevents oil from leaking out and contaminants from intruding. Made from non-sparking metal.
BEARINGS
Duplex 40° angular contact thrust bearings and deep-groove (Conrad) radial bearings sized for minimum three (3) year bearing life under most severe operating conditions. Exceeds API-610/ ISO 13709 requirements.
HEAVY DUTY BEARING FRAME
Piloted and metal-to-metal fits assure runouts and concentricities well within limits specified in API-610/ISO 13709. Large oil sump capacity. Cast fins enhance cooling.
LUBRICATION SYSTEM
Proven, engineered ring-oiled flow-thru bearing lubrication optimizes MTBPM.
SEAL CHAMBER
Enlarged seal chamber fully conforms to API-610/ISO 13709 standards. Accepts wide range of API 682/ ISO 21049 cartridge mechanical seals. Renewable throat bushing standard for controlled seal chamber environment.

Figure 8.3

8.11 Centrifugal Goulds pump (Model 3700 || API 610)

In designing the Goulds centrifugal pump (Model 3700, API 610) with a 6-inch diameter, our primary objective is to efficiently transport High-Speed Diesel (HSD) and Petrol (Motor Gasoline, PMG) from the gantry to the tanks and vice versa, achieving a flow rate of 600 gallons per minute (GPM). This capability ensures that the bowser can fill and empty within the specified 21-minute timeframe, meeting operational requirements seamlessly.

The pump design encompasses a total of 4 units, all identical in specifications: 2 pumps designated for active operation (working pumps) and 2 as standby units. Each pump is engineered to handle both suction and discharge operations effectively, with a focus on critical parameters such as efficiency, power requirements, flow rate, density considerations, volume flow, head pressure, differential pressure (Pout-Pin), and inlet and outlet pressures (PresIn, PresOut).

- **Efficiency**: Ensuring optimal energy utilization and minimizing operational costs.
- **Power Requirements**: Determining the necessary mechanical or electrical power input for reliable pump performance.
- **Flow Rate**: Designed to achieve a flow rate of 600 gallons per minute (GPM), crucial for meeting filling and emptying timelines.
- **Density Considerations**: Addressing the varying densities of HSD and PMG to maintain consistent and efficient fluid handling.
- **Volume Flow**: Calculating the volumetric flow rate to determine the pump's capacity and throughput capability.
- **Head Pressure**: Engineered to generate sufficient pressure to overcome system resistance and maintain steady flow rates.
- **Differential Pressure (Pout-Pin)**: Ensuring effective fluid movement through the pump by understanding the differential pressure across its operation.
- **Inlet and Outlet Pressures (PresIn, PresOut)**: Specifying inlet and outlet pressures to optimize suction efficiency and fluid delivery reliability.

This meticulous approach ensures that each pump operates reliably under varying conditions, supporting continuous and efficient handling of HSD and PMG. By integrating these parameters into our design strategy, we aim to optimize operational performance, minimize energy consumption, and enhance safety in industrial fuel transfer processes.

8.12 Manual Calculations:

1) PMG (Petrol Motor Gasoline) to GANTRY:

G. Time: 21 min = 0.35 hr   1 min = 0.0166667 hr
- Provided by company

H. Bowser = 48000 litre = 35520 kg (PMG)   1 litre = 0.74 kg
- $flow\ rate = \frac{35520}{0.35}$
- $flow\ rate = 101{,}485.7\,\frac{kg}{hr}$
- $flow\ rate = 0.038095\ m^3/s$ 1 kg/hr = 0.00000028 m^3/s

g) Iteration 1
- $time = 20\ mins = 0.33hr$
- $flowrate = \frac{35520}{0.33}$
- $flowrate = 107{,}636.36\ kg/hr$

h) Iteration 2
- $time = 19\ mins = 0.317hr$
- $flowrate = \frac{35520}{0.317}$
- $flowrate = 112{,}050.473\ kg/hr$

2) HSD (High-Speed Diesel) to GANTRY:

I. Time: 21 min = 0.35 hr   1 min = 0.0166667 hr
- Provided by company

J. Bowser = 48000 litre = 40320 kg (HSD)   1 litre = 0.84 kg
- $flow\ rate = \frac{40320}{0.35}$
- $flow\ rate = 115200\,\frac{kg}{hr}$
- $flow\ rate = 0.032256\ m^3/s$ 1 kg/hr = 0.00000028 m^3/s

i) Iteration 1
- $time = 20\ mins = 0.33hr$

- $flowrate = \frac{40320}{0.33}$
- $flowrate = 122{,}181.81\ kg/hr$

j) Iteration 2

- $time = 19\ mins = 0.317hr$
- $flowrate = \frac{40320}{0.317}$
- $flowrate = 127{,}192.42\ kg/hr$

We began by manually designing the pumps, meticulously considering all project requirements such as efficiency, power, and a flow rate of 600 GPM for handling High-Speed Diesel (HSD) and Petrol (Motor Gasoline, PMG). Subsequently, we utilized specialized software to refine and optimize our designs, ensuring accuracy and performance. This dual approach of manual and software-based design ensured that our pumps were meticulously crafted to meet and exceed project specifications, guaranteeing reliability, efficiency, and safety in industrial fuel handling processes.

Chapter 9

Gantry

Gantry is a structure frame, which basically is a support system for bowser loading and unloading, so according to the requirements it is equipped with the relevant pipes and other accessories. And the dimensioning is done according to the biggest bowser that maybe available, it acts as the heart of the whole plant as it pumps the original material in and out as per required. As we will be using two hydrocarbons mainly, PMG and HSD and for both we will design a single gantry as it will perform the task for both simultaneously and will subsidize the cost.

We designed our gantry in Staad's pro software, where at first, we choose the type of structure to be "Space-frame", but instead of direct input of this command we choose to build the frame by our own node placement to make it more economical in every way, first in two dimension and then converting it into three dimensions. After the suitable node placement of the lower portion, we then will follow the same procedure for the roof. As instructed by our client the structure will have the minimum load a normal gantry can bear so according to the requirement, we choose the relevant design with no extra supports to reduce the cost of the project. Then we apply fixed support to all the base nodes to make sure the structure is static. The total number of nodes used were 32, which is an economical design for two bowser gantries. And the number of elements used were 48 means the elements between the nodes. The area of the beam is taken as 484 cm-sq where area of column is taken as 196 cm-sq, to support the required structure and the material as a result comes in 4 different forms, starting from steel which has highest Young's modulus of 205.00 KN/mm-sq, then comes stainless-steel with a Young's modulus of 197.930 KN/mm-sq, then aluminum with Young's modulus of 66.948 KN/mm-sq, at last we have concrete with Young's modulus of 21.718 KN/mm-sq making it the lowest. Moreover, the poison ratio in an interesting fact comes out to be the same for steel, stainless-steel and aluminum which is 0.300 which points out right because all three materials are metals and come in same category, while for concrete it significantly reduces to 0.170 because of the material used, so the most viable option among in them is steel which will be economical and most safe to be used that is why we choose our structure material to be steel. When it comes to applying load as per the requirement of our client, we made it quite simple and we only added dead load of the gantry while designing and no live load or seismic load or snow load, or any other. And the dead load will comply of just the material and structure weight, which will be sufficient and will be economical to the final project cost.

The final structure comes out in a refined form and below are the pictures of the final gantry structure designed by our group which will bear the loads applied as above and will have a reduced cost.

Note: the structure was finalized after multiple designs failed and then after multiple designs passed and from those designs three most economical designs were chosen by our group and final design was chosen by the industrial specialist and approved for our project.

9.1 Summary of Work

The report from STAAD.Pro presents a comprehensive design of a gantry, developed with detailed specifications and structured methodology. This gantry project, is characterized as a space frame, which inherently suggests a three-dimensional framework of interconnected elements. The space frame in this design is composed of 32 nodes and 48 beam elements, strategically positioned to support the overall structure.

The coordinates of these nodes are clearly determined; these are points indicating a place in the three-dimensional space. For example, Node 1 is at point (575. 60577, 89. 72561, 0), Node 2 is at (9365. 73859, 89. 72561, 0), and Node 3 is at (575. 60577, 89. 72561, 7141. The coordinates of each node not only possess a constructable meaning but also concern the stability and configuration of the
structure where the beams, connecting these nodes, must be located without shake.

Beam elements are the members that join nodes together in a particular pattern to create the over-all structure of the gantry. A beam is defined by the nodal coordinates at the start and end nodes of the beam as well as by the length and other characteristics. For instance,

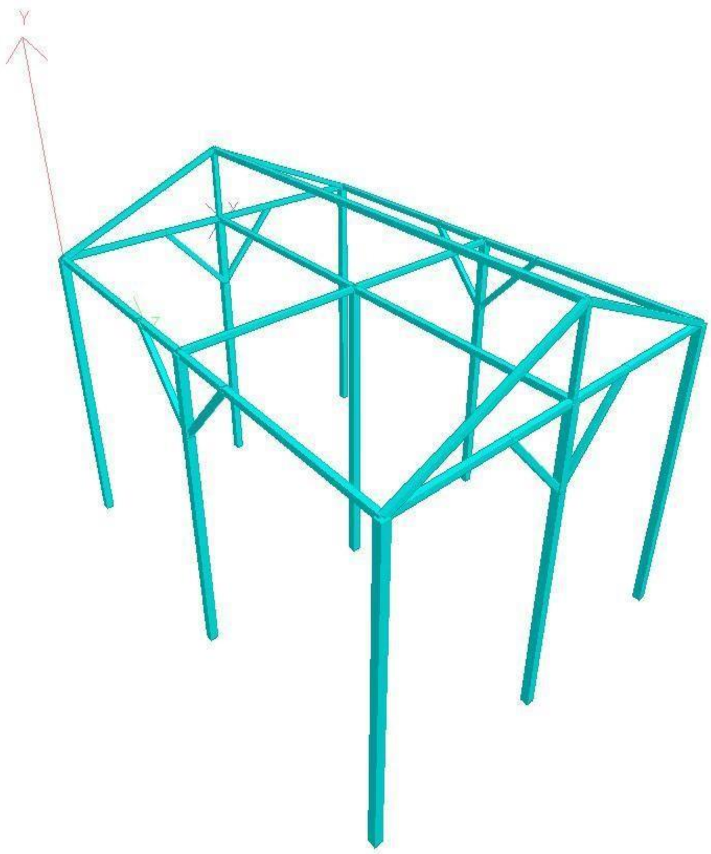
it is indicated that Beam 1 links Node 1 to Node 26 with a length of 3280 units. 0 mm, which leaves the property β at the level of 0 degrees. Again, beam 2 joins Node 3 to Node 4 and has a length of 5280. 0mm in length, also has property β of 0 degrees. These beams are very important due to the fact that they take loads and
contribute to the creation of a rigid structure.
The sections of the beams are characterized by the geometrical characteristics and type of the material. There are rectangular sections included in the design with dimensions for instance 0. 22x0. 22 meters and 0. 14x0. 14 meters. These sections have particular area and moments of inertia which is so important so as to determine how the beams will act under some load. For instance, a section measuring 0. 22x0. The rectangle with a length of 22 meters has an area of 484. 0 cm^2 and moments of inertia (Iyy, Izz) of 19. 5 x 10^3 cm^4. These properties keep the beams from deforming when the forces exerted on them are applied Those properties maintain acceptable value of deformation for the
beams when the force is applied on them.

By mechanical properties, the materials used in the design of the product are described. The gantry mainly uses steel and concrete wherein the former possesses a certain characteristic different from the latter. Take steel by example, it has Young's Modulus (E) of 205. 0 kN/mm^2 and Poisson's Ratio (ν) of 0. 300 people, 7 people per square kilometer. 83g/cm^3 and coefficient of thermal expansion (α)=12 x 10^{-6} /°C. Young's Modulus of Concrete is 21 as compared to steel. Poisson's Ratio (ν) of 0. The ultimate tensile strength or UTS is around 600 MPa and the yield strength or 0.2% offset is around 450 MPa. 170, a density of.-company, indicating a strength nearly twice that of the next closest element; #160, a density of 1. <|reserved_special_token_281|>, a density of 4 g/cm^3, and a coefficient of thermal expansion (α) of 10 x 10^{-6} /°C. These material properties are rather important in determining the structure's behavior under varying environmental conditions or loads.

Another important component is supporting conditions, which have also to be specified. Here, all supports are immobilized in all six directions; the translational (X, Y, Z) and rotational (rX, rY, rZ) freedoms. This condition of fixed support also makes it difficult for the structure to vibrate or rotate in some undesirable manner.

Included in the load cases intended during the design procedure are dead load as the primary load case. Out of this dead load, is the exercising of the permanent static load of the structure in form of weight of beams, nodes, or any other permanent fittings of the structures. This load has to be accounted for to the last gram to be certain that the gantry is capable of handling its weight as well as any other loads that it might come across while being used.

9.2 Gantry Design in (3-D form)



In summary, the STAAD.Pro report offers a comprehensive layouts and analyses of a gantry structure for nodes, beam, components, materials, supports, and loads with marked sections. Altogether, it provides an all-embracing outlook and guarantee that the gantry structure will have the aptitude to endure forces and conditions as are likely to be encountered hence its stability and safety.

9.3 STAAD.Pro Report

Software licensed to	Job No	Sheet No 1	Rev
	Part		
Job Title	Ref		
	By	Date 21-Feb-24	Chd
Client	File Gantry by Saad.std	Date/Time 21-Feb-2024 17:54	

Job Information

	Engineer	Checked	Approved
Name:			
Date:	21-Feb-24		

Structure Type	SPACE FRAME

Number of Nodes	32	Highest Node	32
Number of Elements	48	Highest Beam	48

Number of Basic Load Cases	1
Number of Combination Load Cases	0

Included in this printout are data for:

All	The Whole Structure

Included in this printout are results for load cases:

Type	L/C	Name
Primary	3	Dead Load

Nodes

Node	X (mm)	Y (mm)	Z (mm)
1	0.000	0.000	0.000
2	5.28E+3	0.000	0.000
3	0.000	0.000	7E+3
4	5.28E+3	0.000	7E+3
5	0.000	0.000	14E+3
6	5.28E+3	0.000	14E+3
7	10.6E+3	0.000	7E+3
8	10.6E+3	0.000	0.000
9	10.6E+3	0.000	14E+3
10	0.000	-8E+3	0.000
11	5.28E+3	-8E+3	0.000
12	0.000	-8E+3	7E+3
13	5.28E+3	-8E+3	7E+3
14	0.000	-8E+3	14E+3
15	5.28E+3	-8E+3	14E+3
16	10.6E+3	-8E+3	7E+3
17	10.6E+3	-8E+3	0.000
18	10.6E+3	-8E+3	14E+3
19	5.28E+3	2E+3	0.000
20	5.28E+3	2E+3	14E+3
21	5.28E+3	-2E+3	14E+3
22	7.28E+3	0.000	14E+3

Print Time/Date: 21/02/2024 21:55 STAAD.Pro V8i (SELECTseries 5) 20.07.10.64 Print Run 1 of 5

Nodes Cont...

Node	X (mm)	Y (mm)	Z (mm)
23	3.28E+3	0.000	14E+3
24	5.28E+3	-2E+3	0.000
25	7.28E+3	0.000	0.000
26	3.28E+3	0.000	0.000
27	0.000	0.000	9E+3
28	0.000	0.000	5E+3
29	0.000	-2E+3	7E+3
30	10.6E+3	0.000	9E+3
31	10.6E+3	0.000	5E+3
32	10.6E+3	-2E+3	7E+3

Beams

Beam	Node A	Node B	Length (mm)	Property	β (degrees)
1	1	26	3.28E+3	2	0
2	3	4	5.28E+3	2	0
3	5	23	3.28E+3	2	0
4	1	28	5E+3	2	0
5	3	27	2E+3	2	0
6	6	4	7E+3	2	0
7	4	2	7E+3	2	0
8	7	31	2E+3	2	0
9	9	30	5E+3	2	0
10	6	22	2E+3	2	0
11	4	7	5.28E+3	2	0
12	2	25	2E+3	2	0
13	1	10	8E+3	1	0
14	2	24	2E+3	1	0
15	3	29	2E+3	1	0
16	4	13	8E+3	1	0
17	5	14	8E+3	1	0
18	6	21	2E+3	1	0
19	7	32	2E+3	1	0
20	8	17	8E+3	1	0
21	9	18	8E+3	1	0
22	2	19	2E+3	2	0
23	1	19	5.64E+3	2	0
24	8	19	5.64E+3	2	0
25	5	20	5.64E+3	2	0
26	20	9	5.64E+3	2	0
27	20	6	2E+3	2	0
28	19	20	14E+3	2	0
29	21	15	6E+3	1	0

Beams Cont...

Beam	Node A	Node B	Length (mm)	Property	β (degrees)
30	22	9	3.28E+3	2	0
31	23	6	2E+3	2	0
32	21	22	2.83E+3	2	0
33	21	23	2.83E+3	2	0
34	24	11	6E+3	1	0
35	25	8	3.28E+3	2	0
36	26	2	2E+3	2	0
37	24	25	2.83E+3	2	0
38	24	26	2.83E+3	2	0
39	27	5	5E+3	2	0
40	28	3	2E+3	2	0
41	29	12	6E+3	1	0
42	30	7	2E+3	2	0
43	31	8	5E+3	2	0
44	32	16	6E+3	1	0
45	29	28	2.83E+3	2	0
46	29	27	2.83E+3	2	0
47	32	30	2.83E+3	2	0
48	32	31	2.83E+3	2	0

Section Properties

Prop	Section	Area (cm^2)	I_{yy} (cm^4)	I_{zz} (cm^4)	J (cm^4)	Material
1	Rect 0.22x0.22	484.000	19.5E+3	19.5E+3	32.9E+3	CONCRETE
2	Rect 0.14x0.14	196.000	3.2E+3	3.2E+3	5.4E+3	CONCRETE

Materials

Mat	Name	E (kN/mm^2)	ν	Density (kg/m^3)	α (/°C)
1	STEEL	205.000	0.300	7.83E+3	12E -6
2	STAINLESSSTEEL	197.930	0.300	7.83E+3	18E -6
3	ALUMINUM	68.948	0.330	2.71E+3	23E -6
4	CONCRETE	21.718	0.170	2.4E+3	10E -6

Supports

Node	X (kN/mm)	Y (kN/mm)	Z (kN/mm)	rX (kN˙m/deg)	rY (kN˙m/deg)	rZ (kN˙m/deg)
1	Fixed	Fixed	Fixed	-	-	-
2	Fixed	Fixed	Fixed	-	-	-
3	Fixed	Fixed	Fixed	-	-	-
4	Fixed	Fixed	Fixed	-	-	-
5	Fixed	Fixed	Fixed	-	-	-
6	Fixed	Fixed	Fixed	-	-	-
7	Fixed	Fixed	Fixed	-	-	-
8	Fixed	Fixed	Fixed	-	-	-
9	Fixed	Fixed	Fixed	-	-	-
10	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
11	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
12	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
13	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
14	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
15	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
16	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
17	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
18	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
19	Fixed	Fixed	Fixed	-	-	-
20	Fixed	Fixed	Fixed	-	-	-
21	Fixed	Fixed	Fixed	-	-	-
24	Fixed	Fixed	Fixed	-	-	-
29	Fixed	Fixed	Fixed	-	-	-
32	Fixed	Fixed	Fixed	-	-	-

Releases

There is no data of this type.

Primary Load Cases

Number	Name	Type
3	Dead Load	Dead

Combination Load Cases

There is no data of this type.

Load Generators

There is no data of this type.

3 Dead Load : Selfweight

Direction	Factor	Assigned Geometry
Y	-1.000	1 - 48

Conclusions

The project concludes that the designed 6000 tons hydrocarbon storage tanks, coupled with an advanced loading and unloading system, represent a significant step towards a safer, more compliant storage infrastructure in Pakistan. The findings underscore the importance of ongoing vigilance in adapting storage facilities to evolving regulatory standards. The designed solution is poised to contribute positively to the nation's energy security while aligning with environmental and safety imperatives. Ongoing collaboration with regulatory authorities and industry stakeholders will be essential for successful implementation and continuous improvement.

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Appendix A

AME TANK REPORT

AME Report of PMG

TABLE OF CONTENTS

ANCHOR BOLT SUMMARY OF RESULTS

CAPACITIES AND WEIGHTS

MAWP & MAWV SUMMARY

SUMMARY OF DESIGN DATA AND REMARKS Back

Job : 2024-2-20-13-27

Date of Calcs. : 20-Feb-2024

Mfg. or Insp. Date :

Designer : Hp

Project :

Tag Number :

Plant : PURCHASER DESCRIPTION CITY AND STATE

Plant Location :

Site :

Design Basis : API-650 12th Edition, March 2013

TANK NAMEPLATE INFORMATION

Pressure Combination Factor	0.4
Design Standard	API-650 12th Edition, March 2013
Appendices Used	E
Roof	A36M : 8 mm
Shell (1)	A36M : 12 mm
Shell (2)	A36M : 12 mm
Shell (3)	A36M : 10 mm
Shell (4)	A36M : 10 mm
Shell (5)	A36M : 8 mm
Shell (6)	A36M : 8 mm
Shell (7)	A36M : 8 mm
Shell (8)	A36M : 6 mm

Shell (9)	A36M : 6 mm
Shell (10)	A36M : 6 mm
Shell (11)	A36M : 6 mm
Bottom	A36M : 9 mm

Design Internal Pressure = 0 KPa or 0 mmh2o

Design External Pressure = -0 KPa or -0 mmh2o

MAWP = 3.0039 KPa or 306.3477 mmh2o

MAWV = -1.2306 KPa or -125.493 mmh2o

D of Tank = 18.1 m

OD of Tank = 18.124 m

ID of Tank = 18.1 m

CL of Tank = 18.112 m

Shell Height = 16.43 m

S.G of Contents = 1

Max Liq. Level = 14.787 m

Min Liq. Level = 0 m

Design Temperature = 50 ºC

Tank Joint Efficiency = 1

Ground Snow Load = 0 KPa

Roof Live Load = 1 KPa

Additional Roof Dead Load = 0 KPa

Basic Wind Velocity = 201 kph

Wind Importance Factor = 1

Using Seismic Method: API-650 - ASCE7 Mapped(Ss & S1)

SUMMARY OF SHELL RESULTS

Shell #	Width (mm)	Material	CA (mm)	JE	Min Yield Strength (MPa)	Tensile Strength (MPa)	Sd (MPa)	St (MPa)	Weight (N)	Weight CA (N)	t-min Erection (mm)	t-Des (mm)	t-Test (mm)	t-min Seismic (mm)	t-min Ext Pe (mm)	t-min (mm)	t-Actual (mm)	Status
1	1500	A36M	3	1	250	400	160	171	78,658	59,003	6	11.0303	7.5138	7.5979	NA	11.0303	12	OK
2	1500	A36M	3	1	250	400	160	171	78,658	59,003	6	10.1989	6.7358	7.1261	NA	10.1989	12	OK
3	1500	A36M	3	1	250	400	160	171	65,555	45,896	6	9.3674	5.9578	6.4099	NA	9.3674	10	OK
4	1500	A36M	3	1	250	400	160	171	65,555	45,896	6	8.5359	5.1798	5.968	NA	8.5359	10	OK
5	1500	A36M	3	1	250	400	160	171	52,450	32,787	6	7.7045	4.4018	5.2545	NA	7.7045	8	OK
6	1500	A36M	3	1	250	400	160	171	52,450	32,787	6	6.873	3.6238	4.8581	NA	6.873	8	OK
7	1500	A36M	3	1	250	400	160	171	52,450	32,787	6	6.0415	2.8459	4.4609	NA	6.0415	8	OK
8	1500	A36M	3	1	250	400	160	171	39,342	19,674	6	5.21	2.0679	3.8502	NA	6	6	OK
9	1500	A36M	3	1	250	400	160	171	39,342	19,674	6	4.3786	1.2899	3.5311	NA	6	6	OK
10	1500	A36M	3	1	250	400	160	171	39,342	19,674	6	3.5471	0.5119	3.2126	NA	6	6	OK
11	1350	A36M	3	1	250	400	160	171	35,408	17,706	6	2.7156	-0.2661	2.901	NA	6	6	OK

Total Weight of Shell = 599,215.464 N

CONE ROOF

Plates Material = A36M

Structural Material = A36M

t.required = 8 mm

t.actual = 8 mm

Roof corrosion allowance = 3 mm

Roof Joint Efficiency = 1

Plates Overlap Weight = 5,929.895 N

Plates Weight = 165,346.1429 N

RAFTERS:

Qty	At Radius (m)	Size	Length (m)	W (N/m)	Ind. Weight (N)	Total Weight (N)
28	9.05	W10X12	8.7749	175.1268	1,536.7375	43,028.6521

Rafters Total Weight = 43,028.6521 N

COLUMNS:

Qty	At Radius (m)	Size	Length (m)	W (N/m)	Ind. Weight (N)	Total Weight (N)
1	0	10" SCH STD	18.5579	591.3562	10,974.3753	10,974.3753

Columns Total Weight = 10,974.3753 N

Bottom Type : Flat Bottom Non Annular

Bottom Material = A36M

t.required = 9 mm

t.actual = 9 mm

Bottom corrosion allowance = 3 mm

Bottom Joint Efficiency = 1

Total Weight of Bottom = 180,531.2287 N

TOP END STIFFENER : Detail D

Size = l80x80x10

Material = A36M

Weight = 6,630.4943 N

STRUCTURALLY SUPPORTED CONICAL ROOF Back

A = Actual Part. Area of Roof-to-shell Juncture per API-650 (cm^2)

A-min = Minimum participating area (cm^2) per API-650 5.10.5.2

a-min-A = Minimum participating area due to full design pressure per API-650 F.5.1 (cm^2)

a-min-Roof = Minimum participating area per API-650 App. F.5.2 (cm^2)

Add-DL = Added Dead load (kPa)

Alpha = 1/2 the included apex angle of cone (degrees)

Aroof = Contributing Area due to roof plates (cm^2)

Ashell = Contributing Area due to shell plates (cm^2)

CA = Roof corrosion allowance (mm)

D = Tank Nominal Diameter per API-650 5.6.1.1 Note 1 (m)

density = Density of roof (kg/mm3)

DL = Dead load (kPa)

e.1b = Gravity Roof Load (1) - Balanced (kPa)

e.1u = Gravity Roof Load (1) - Unbalanced (kPa)

e.2b = Gravity Roof Load (2) - Balanced (kPa)

e.2u = Gravity Roof Load (2) - Unbalanced (kPa)

Fp = Pressure Combination Factor

Fy = smallest of the yield strength (MPa)

Fy-roof = Minimum yield strength for shell material (Table 5-2a) (MPa)

Fy-shell = Minimum yield strength for shell material (Table 5-2a) (MPa)

Fy-stiff = Minimum yield strength for stiffener material (Table 5-2a) (MPa)

hr = Roof height (m)

ID = Tank Inner Diameter (m)

Insulation = Roof Insulation (m)

JEr = Roof joint efficiency

Lr = Entered Roof Live Load (kPa)

Lr-1 = Computed Roof Live Load, including External Pressure

Max-p = Max Roof Load due to participating Area (kPa)

Net-Uplift = Uplift due to internal pressure minus nominal weight of shell, roof and attached framing (N), per API-650 F.1.2

P = Minimum participating area (kPa)

P-ext-2 = Max external pressure due to roof shell joint area (kPa)

P-F51 = Max design pressure reversing a-min-A calculation (kPa)

P-max-ext-T = Total max external pressure due to roof actual thickness and roof participating area (kPa)

P-max-internal = Maximum design pressure and test procedure per API-650 F.4, F.5. (kPa)

P-Std = Max pressure pressure allowed per API-650 App. F.1 & F.7 (kPa)

P-Uplift = Uplift case per API-650 1.1.1 (N)

P-weight = Dead load of roof plate (kPa)

Pe = External Pressure (kPa)

pt = Roof cone pitch (mm) rise per 12 (mm)

Pv = Internal Pressure (kPa)

R = Roof horizontal radius (m)

Ra = Roof surface area (cm^2)

Roof-wc = Weight corroded of roof plates (N)

S = Ground Snow Load per ASCE 7-05 Fig 7-1 (kPa)

Sb = Balanced Design Snow Load per API-650 Section 5.2.1.h.1 (kPa)

Shell-wc = Weight corroded of shell (N)

Su = Unbalanced Design Snow Load per API-650 Section 5.2.1.h.2 (kPa)

T = Balanced Roof Design Load per API-650 Appendix R (kPa)

t-calc = Minimum nominal roof plates thickness per API-650 Section 5.10.5.1 (mm)

t-Ins = thickness of Roof Insulation (m)

Theta = Angle of cone to the horizontal (degrees)

U = Unbalanced Roof Design Load per API-650 Appendix R (kPa)

Wc = Maximum width of participating shell per API-650 Fig. F-2 (mm)

Wh = Maximum width of participating roof per API-650 Fig. F-2 (mm)

Roof Design Per API-650

Note: Tank Pressure Combination Factor Fp = 0.4

D = 18.1 m

ID = 18.1 m

CA = 3 mm

R = 9.0725 m

Fp = 0.4

JEr = 1

JEs = 1

JEst = 1

Insulation = 0 m

Add-DL = 0 kPa

Lr = 1 kPa

S = 0 kPa

Sb = 0 kPa

Su = 0 kPa

density = 0.000007841 kg/mm3

P-weight = 0.6426 KPa

Pe = 0 kPa

pt = 3.4 mm rise per 12 mm

t-actual = 8 mm

Fy-roof = 250 MPa

Fy-shell = 250 MPa

Fy-stiff = 250 MPa

Shell-wc = 384,892.1321 N

Roof-wc = 103,341.3393 N

P-Std = 18 kPa, Per API-650 F.1.3

t-1 = 6 mm

CA-1 = 3 mm

Sd = 160 MPa

Theta = TAN^-1 (pt/12)

Theta = TAN^-1 (3.4/12)

Theta = 15.8192 degrees

Alpha = 90 - Theta

Alpha = 90 - 15.8192

Alpha = 74.1808 degrees

Ap-Vert = D^2 * TAN(Theta)/4

Ap-Vert = 18.1^2 * TAN(15.8192)/4

Ap-Vert = 23.2057 m^2

Horizontal Projected Area of Roof per API-650 5.2.1.f

Xw = D * 0.5

Xw = 18.1 * 0.5

Xw = 9.05 m

Ap = PI * (D/2)^2

Ap = PI * (18.1/2)^2

Ap = 257.3042 m^2

DL = Insulation + P-weight + Add-DL

DL = 0 + 0.6426 + 0

DL = 0.6426 kPa

Roof Loads per API-650 5.2.2

e.1b = DL + MAX(Sb , Lr) + (0.4 * Pe)

e.1b = 0.6426 + MAX(0 , 1) + (0.4 * 0)

e.1b = 1.6426 kPa

e.2b = DL + Pe + (0.4 * MAX(Sb , Lr))

e.2b = 0.6426 + 0 + (0.4 * MAX(0 , 1))

e.2b = 1.0426 kPa

T = MAX(e.1b , e.2b)

T = MAX(1.6426 , 1.0426)

T = 1.6426 kPa

e.1u = DL + MAX(Su , Lr) + (0.4 * Pe)

e.1u = 0.6426 + MAX(0 , 1) + (0.4 * 0)

e.1u = 1.6426 kPa

e.2u = DL + Pe + (0.4 * MAX(Su , Lr))

e.2u = 0.6426 + 0 + (0.4 * MAX(0 , 1))

e.2u = 1.0426 kPa

U = MAX(e.1u , e.2u)

U = MAX(1.6426 , 1.0426)

U = 1.6426 kPa

Lr-1 = MAX(T , U)

Lr-1 = MAX(1.6426 , 1.6426)

Lr-1 = 1.6426 kPa

Ra = PI * R * SQRT(R^2 + hr^2)

Ra = PI * 9.0725 * SQRT(9.0725^2 + 2.5705^2)

Ra = 2,687,642.7946 cm^2 or 268.7643 m^2

Roof Plates Weight = density * Ra * t-actual

Roof Plates Weight = 0.000007841 * 2,687,642.7946 * 8

Roof plates Weight = 165,346.1429 N

BAY 1 DETAILS

MINIMUM # OF RAFTERS

l = Maximum rafter spacing per API-650 5.10.4.4 (mm)

l-actual-1 = Actual rafter spacing (mm)

Max-T1-1 = Due to roof thickness (kPa)

N-actual-1 = Actual number of rafter

N-min-1 = Minimum number of rafter

P = Uniform pressure as determined from load combinations described in Appendix R (kPa)

P-ext-1-1 = Due to roof thickness vacuum limited by actual rafter spacing (kPa)

R-1 = Outer radius (mm)

RLoad-Max-1 = Maximun roof load based on actual rafter spacing (kPa)

t-calc-1 = Minimum roof thickness based on actual rafter spacing (mm)

FOR OUTER SHELL RING

P = Lr-1

P = 1.6426 kPa

R-1 = 9050 mm

l = MIN(((t-Roof - CA-Roof) * SQRT((1.5 * Fy-Roof)/P)) , 2100.0)

l = MIN(((8 - 3) * SQRT((1.5 * 250) / 1.6426)) , 2100)

l = MIN(2389.0129 , 2100)

l = 2100 mm

N-min-1 = (2 * PI * R-1)/l

N-min-1 = (2 * PI * 9050)/2100

N-min-1 = 28

N-min-1 must be a multiple of 1, therefore N-min-1 = 28.

N-actual-1 = 28

l-actual-1 = (2 * PI * R-1)/N-actual-1

l-actual-1 = (2 * PI * 9050)/28

l-actual-1 = 2030.8153 mm

Minimum roof thickness based on actual rafter spacing

t-calc-1 = l-actual-1/SQRT((1.5 * Fy-Roof)/P) + CA-Roof

t-calc-1 = 2030.8153/SQRT((1.5 * 250)/1.6426) + 3

t-calc-1 = 7.2503 mm

NOTE: Governs for roof plate thickness.

RLoad-Max-1 = (1.5 * Fy-Roof)/(l-actual-1/(t-Roof - CA-Roof))^2

RLoad-Max-1 = (1.5 * 250)/(2030.8153/(8 - 3))^2

RLoad-Max-1 = 2.2732 kPa

Max-T1-1 = RLoad-Max-1

Max-T1-1 = 2.2732 kPa

P-ext-1-1 = Max-T1-1 - DL - (0.4 * MAX(Sb , Lr))

P-ext-1-1 = 2.2732 - 0.6426 - (0.4 * MAX(0 , 1))

P-ext-1-1 = -1.2306 kPa

Pa-rafter-3-1 = P-ext-1-1

Pa-rafter-3-1 = -1.2306 kPa

t-required-1 = MAX(7.2503 , (5 + 3))
t-required-1 = 8 mm

RAFTER DESIGN

Average-p-width-1 = Average plate width (m)
Average-r-s-inner-1 = Average rafter spacing on inner girder (m)
Average-r-s-shell-1 = Average rafter spacing on shell (m)
Max-P-1 = Load allowed for each rafter in ring (MPa)
Max-r-span-1 = Maximum rafter span (m)
Max-T1-rafter-1 = Due to roof thickness (kPa)
Mmax-rafter-1 = Maximum moment bending (mm-kg)
P = Uniform pressure as determined from load combinations described in Appendix R (kPa)
P-ext-2-1 = Vacuum limited by rafter type (kPa)
R-1 = Outer radius (mm)
R-Inner-1 = Inner radius (m)
Rafter-Weight-1 = (Kg/m)
Sx-rafter-actual-1 = Actual elastic section modulus about the x axis (cm^3)
Sx-rafter-Req'd-1 = Required elastic section modulus about the x axis (cm^3)
Theta = Angle of cone to the horizontal (degrees)
W-Max-rafter-1 = Maximum stress allowed for each rafter in ring (N/mm)
W-rafter-1 = (kg/m)

SPAN TO SHELL

P = 1.6426 kPa
Rafter-Weight-1 = 17.858 Kg/m
Theta = 15.8192 degrees
R-1 = 9127 mm
R-Inner1 = 564.5 mm

Max-r-span-1 = (R-1 - R-Inner-1)/COS(Theta)
Max-r-span-1 = (9127 - 564.5)/COS(15.8192)
Max-r-span-1 = 8.775 m

Average-r-s-inner-1 = (2 * PI * R-Inner-1)/N-actual-1
Average-r-s-inner-1 = (2 * PI * 564.5)/28

Average-r-s-inner-1 = 0.1267 m

Average-r-s-shell-1 = (2 * PI * R-1)/N-actual-1
Average-r-s-shell-1 = (2 * PI * 9127)/28
Average-r-s-shell-1 = 2.0481 m

Average-p-width-1 = (Average-r-s-inner-1 + Average-r-s-shell-1)/2
Average-p-width-1 = (0.1267 + 2.0481)/2
Average-p-width-1 = 1.0874 m

W-rafter-1 = (P * Average-p-width-1) + Rafter-Weight-1
W-rafter-1 = (167.5461 * 1.0874) + 17.858
W-rafter-1 = 199.9942 Kgf/m

Mmax-rafter-1 = (W-rafter-1 * Max-r-span-1^2)/8
Mmax-rafter-1 = (199.9942 * 8.775^2)/8
Mmax-rafter-1 = 1,924,959 mm-kgf

Sx-rafter-Req'd-1 = Mmax-rafter-1/Sd
Sx-rafter-Req'd-1 = 1,924,959/160
Sx-rafter-Req'd-1 = 117.9837 cm^3

Sx-actual-1 = 178.619 cm^3

W-Max-rafter-1 = (Sx-rafter-actual-1 * Sd * 8)/Max-r-span-1^2)
W-Max-rafter-1 = (178.619 * 160 * 8)/8.775^2)
W-Max-rafter-1 = 2.9692 N/mm

Max-P-1 = (W-Max-rafter-1 - Rafter-Weight-1)/Average-p-width-1
Max-P-1 = 0.0027 MPa

Max-T1-rafter-1 = Max-P-1
Max-T1-rafter-1 = 2.7 kPa

P-ext-2-1 = Max-T1-rafter-1 - DL - (Fp * MAX(S , Lr))
P-ext-2-1 = 2.7 - 0.6426 - (0.4 * MAX(0 , 1))
P-ext-2-1 = -1.6716 kPa

P2-rafter-3-1 = P-ext-2-1

P2-rafter-3-1 = -1.6716 kPa

Limited by rafter type

CENTER COLUMN

A-actual-1 = Actual area of column (mm^2)

A-req-1 = Required area of column (mm^2)

C-length-1 = Column length (mm)

E-c = Modulus of elasticity of the column material (MPa)

Fa-1 = Allowable compressive stress per API-650 5.10.3.4 (MPa)

Fy-c = Allowable design stress (MPa)

Max-P-column-1 = Maximum Load allowed for each column in ring (MPa)

Max-T1-column-1 = Due to roof thickness (kPa)

P-c-1 = Total roof load supported by each column (N)

P-ext-3-1 = Vacuum limited by column type (kPa)

Pa-column-3-1 = Vacuum limited by column type (kPa)

Pa-column-3-1 = Vacuum limited by column type (kPa)

R-c-1 = Per API-650 5.10.3.3

Radius-Gyr-1 = Radius of gyration

Radius-Gyr-req-1 = Radius of gyration required

W-column-1 = Total weight of column (N)

W-Max-column-1 = Maximum weight allowed for each column in ring (N)

W-column-1 = 10,974.3753 N

Fy-c = 241.3165 MPa

E-c = 197,190.0782 MPa

A-actual-1 = 76.8275 cm^2

C-length-1 = 18.5579 m

Radius-Gyr-1 = 93.26 mm

If C-length-1/Radius-Gyr-1 must be less than 180, then

Radius-Gyr-req-1 = C-length-1/180

Radius-Gyr-req-1 = 18.5579/180

Radius-Gyr-req-1 = 103.0999 mm

Per API-650 5.10.3.3

R-c-1 = C-length-1/Radius-Gyr-1
R-c-1 = 18.5579/93.26
R-c-1 = 198.9919

Rafter-L-1 = (- R-1 - R-Inner1)/COS(Theta)
Rafter-L-1 = (- 9050 - 0)/COS(15.8192)
Rafter-L-1 = 8774.9969 mm

P-c-1 = W-column-1 + (Rafter-L-1 * W-rafter-1 * N-actual-1)/2
P-c-1 = 10,974.3753 + (8774.9969 * 199.9942 * 28)/2
P-c-1 = 251,916.7497 N

Since R-c-1 > 120, using API-650 Formulas in 5.10.3.4

Fa-1 = (/ (* 12 (EXPT PI 2) E-c) (* 23 (EXPT R-c-1 2)))
Fa-1 = (/ (* 12 (EXPT PI 2) 197,190.0782) (* 23 (EXPT 198.9919 2)))

Per API-650 M.3.5
Fa is not modified Since Design Temp. <= 93.3333 ºC.
(API-650 M.3.5 N.A.)

Fa-1 = 42.3821 MPa

A-req-1 = P-c-1/Fa-1
A-req-1 = 251,916.7497/42.3821
A-req-1 = 5943.9352 mm^2

W-Max-column-1 = (Fa-1 * A-actual-1) - W-column-1
W-Max-column-1 = (42.3821 * 76.8275) - 10,974.3753
W-Max-column-1 = 324,492.3632 N

Max-P-column-1 = ((W-Max-column-1/((Rafter-L-1 * N-actual-1)/2)) - Rafter-Weight-1)/(AVERAGE

Average-r-s-inner-1 , Average-r-s-shell-1)

Max-P-column-1 = ((324,492.3632/((8774.9969 * 28)/2)) - 17.858)/(AVERAGE 0 , 2.0308)

Max-P-column-1 = 0.0024 MPa

Max-T1-column-1 = Max-P-column-1

Max-T1-column-1 = 2.4 kPa

P-ext-3-1 = Max-T1-column-1 - DL - (Fp * MAX(S , Lr))

P-ext-3-1 = 2.4 - 0.6426 - (0.4 * MAX(0 , 1))

P-ext-3-1 = -1.3701 kPa

Pa-column-3-1 = P-ext-3-1

Pa-column-3-1 = -1.3701 kPa

Limited by column type

P-max-ext-T = MAX(P-ext-1-1 , P-ext-2-1 , P-ext-3-1)

P-max-ext-T = MAX(-1.2306 , -1.6716 , -1.3701)

P-max-ext-T = -1.2306 kPa

TOP MEMBER DESIGN

CA_roof (Thickness of roof plate) = 3 mm

CA_shell (Thickness of shell plate) = 3 mm

D (Shell nominal diameter) = 18.112 m

ID (Shell inside diameter) = 18.1 m

Theta angle (Angle between the roof and a horizontal plane at the roof-to-shell junction) = 15.8192 deg

tc (Thickness of shell plate) = 6 mm

th (Thickness of roof plate) = 8 mm

Shell inside radius

Rc = ID / 2 = 18100.0 / 2 = 9050.0 mm

Shell nominal diameter (D) = 18.112 m

Length of normal to roof

R2 = Rc / SIN(Theta angle) = 9050.0 / SIN(15.8192) = 33198.5128 mm

Thickness of corroded roof plate

th_corroded = th - CA_roof = 8 - 3 = 5 mm

Thickness of corroded shell plate

tc_corroded = tc - CA_shell = 6 - 3 = 3 mm

CA_stiff > 0

Note: The calculation does not take into account the stiffener corrosion allowance, make sure to pick a stiffener size that make up the difference in the thicknesses (corroded vs nominal).

Maximum width of participating roof *API-650 Figure F-2*

Wh = MIN((0.3 * SQRT((R2 * th_corroded))) , 300)

= MIN((0.3 * SQRT((33198.5128 * 5))) , 300)

= 122.2266 mm

Maximum width of participating shell *API-650 Figure F-2*

Wc = 0.6 * SQRT((Rc * tc_corroded)) = 0.6 * SQRT((9050.0 * 3)) = 98.8635 mm

Nominal weight of shell plates and framing

DLS = Ws + W_framing = 599215.464 + 27996.0983 = 627211.5623 N

Nominal weight of roof plates and attached structural

DLR = Wr + W_structural = 165346.1429 + 2254.7422 = 167600.8851 N

Compression Ring Detail d Properties

ID (Shell inside diameter) = 18.1 m

Size (Compression ring size) = l80x80x10

Wc (Length of contributing shell) = 98.8635 mm

Wh (Length of contributing roof) = 122.2266 mm

tc (Thickness of shell plate) = 3 mm

th (Thickness of roof plate) = 5 mm

Angle vertical leg size (l_vert) = 80 mm

Angle horizontal leg size (l_horz) = 80 mm

Angle thickness (t_angle) = 10.0 mm

Angle area (A_angle) = 1510.0 mm^2

Angle centroid (c_angle) = 23.4 mm

Angle moment of inertia (I_angle) = 875000.0 mm^4

Length of contributing shell reduced

wc_reduced = Wc - l_vert = 98.8635 - 80 = 18.8635 mm

Contributing shell moment of inertia

I_shell = (wc_reduced * (tc_corroded^3)) / 12

= (18.8635 * (3^3)) / 12

= 42.443 mm^4

Contributing shell area

A_shell = wc_reduced * tc_corroded = 18.8635 * 3 = 56.5906 mm^2

Contributing roof area

A_roof = Wh * th_corroded = 122.2266 * 5 = 611.1328 mm^2

Detail total area

A_detail = A_shell + A_roof + A_angle

= 56.5906 + 611.1328 + 1510.0

= 2177.7234 mm^2

Find combined moment of inertia about shell inside axis with negative value toward center

Description	Variable	Equation	Value	Unit
Shell centroid	d_shell	tc_corroded / 2	1.5000	mm
Stiffener centroid	d_stiff	(the-reference (current-object) '(superior angle-centroid) t t t nil 'default-the-error nil)	23.4000	mm
moment of inertia of first body	I_1	I_angle + (A_angle * (d_stiff^2))	1701815.6000	mm^4

moment of inertia of second body	I_2	I_shell + (A_shell * (d_shell^2))	169.7719	mm^4
Total area	A_sum	A_angle + A_shell	1566.5906	mm^2
Sum of moments of inertia's	I_sum	I_1 + I_2	1701985.3719	mm^4
Combined centroid	c_combined	((d_stiff * A_angle) + (d_shell * A_shell)) / (A_angle + A_shell)	22.6089	mm
Combined moment of inertia	I_combined	I_sum - (A_sum * (c_combined^2))	901203.4320	mm^4
Distance from neutral axis to edge 1 (inside)	e1	l_horz - c_combined	57.3911	mm
Distance from neutral axis to edge 2 (outside)	e2	l_horz - e1	22.6089	mm
Combined stiffener shell section modulus	S	I_combined / MAX(e1 , e2)	15702.8421	mm^3

Roof Design Requirements

Appendix F Requirements

A_actual (Area resisting compressive force) = 2177.7234 mm^2
D (Tank nominal diameter) = 18.112 m
DLR (Nominal weight of roof plates and attached structural) = 167600.8851 N
DLS (Nominal weight of shell plates and framing) = 627211.5623 N
Fy (Minimum specified yield-strength of the materials in the roof-to-shell junction) = 250 MPa
ID (Tank inside diameter) = 18.1 m
Mw (Wind moment) = 6.1039875405E6 N.m
P (Design pressure) = 0.0 kPa

Theta angle (Angle between the roof and a horizontal plane at the roof-to-shell junction) = 15.8192 deg

W_framing (Weight of framing supported by the shell and roof) = 27996.0983 N

W_structural (Weight of roof attached structural) = 2254.7422 N

Wr (Roof plates weight) = 165346.1429 N

Ws (Shell plates weight) = 599215.464 N

Uplift due to internal pressure *API-650 F.1.2*

P_uplift = P * pi * ((ID^2) / 4) = 0.0 * pi * ((18.1^2) / 4) = 0.0 N

Tank design does not have to meet App. F requirements.

Maximum allowable internal pressure for the actual resisting area *API 650 F.5.1*

P_F51 = ((Fy * TAN(Theta angle) * A_actual) / (200 * (D^2))) + ((0.00127 * DLR) / (D^2))

= ((250 * TAN(15.8192) * 2177.7234) / (200 * (18.112^2))) + ((0.00127 * 167600.8851) / (18.112^2))

= 3.0 kPa

Maximum allowable internal pressure

P_max_internal = MIN(P_std , P_F51) = MIN(18 , 3.0) = 3.0 kPa

SUMMARY OF ROOF RESULTS Back

Material = A36M

Structural Material = A36M

t-actual = 8 mm

t-required = 8 mm

t-calc = 7.2503 mm

P-Max-Internal = 3 kPa

P-Max-External = -1.2306 kPa

Roof Plates Weight = 165,346.1429 N

Weight of Rafters = 43,028.6521 N

Weight of Girders = 0 N

Weight of Columns = 10,974.3753 N

SHELL COURSE DESIGN (Bottom course is #1) Back

API-650 ONE FOOT METHOD

D = Tank Nominal diameter (m) per API-650 5.6.1.1 Note 1

H = Max liquid level (m)

I-p = Design internal pressure (kPa)

L = Factor

I-p = 0 kPa

D = 18.1 m

H = 14.787 m

L = (500 * D (t-1 - Ca-1))^0.5

L = (500 * 18.1 (12 - 3))^0.5 = 285.3945

Course # 1

Ca-1 = Corrosion allowance per API-650 5.3.2 (mm)

G = Design specific gravity of the liquid to be stored

H' = Effective liquid head at design pressure (m)

hmax-1 = Max liquid level based on shell thickness (m)

JE = Joint efficiency

pmax-1 = Max pressure at design (kPa)

pmax-int-shell-1 = Max internal pressure at design (kPa)

Sd = Allowable design stress for the design condition per API-650 Table 5-2b (MPa)

St = Allowable stress for the hydrostatic test condition per API-650 5.6.2.2 (MPa)

t-1 = Shell actual thickness (mm)

t-calc-1 = Shell thickness design condition td (mm)

t-seismic-1 = See E.6.2.4 table in SEISMIC calculations.

t-test-1 = Shell thickness hydrostatic test condition (mm)

Material = A36M

Width = 1.5 m

Ca-1 = 3 mm

JE = 1

t-1 = 12 mm

Sd = 160 MPa

St = 171 MPa

Design Condition G = 1 (per API-650)

H' = H
H' = 14.787
H' = 14.787 m

t-calc-1 = (4.9 * D * (H' - 0.3) * G)/Sd + Ca-1 (per API-650 5.6.3.2)
t-calc-1 = (4.9 * 18.1 * (14.787 - 0.3) * 1)/160 + 3
t-calc-1 = 11.0303 mm

hmax-1 = Sd * (t-1 - CA-1)/(2.6 * D * G) + 1
hmax-1 = 160 * (12 - 3)/(2.6 * 18.1 * 1) + 1
hmax-1 = 16.5374 m

pmax-1 = (hmax-1 - H) * 9.8 * G
pmax-1 = (16.5374 - 14.787) * 9.8 * 1
pmax-1 = 17.1538 kPa

pmax-int-shell-1 = pmax-1
pmax-int-shell-1 = 17.1538 kPa

Hydrostatic Test Condition G = 1

H' = H
H' = 14.787
H' = 14.787 m

t-test-1 = (* 4.9 D (H' - 0.3))/St
t-test-1 = (* 4.9 18.1 (14.787 - 0.3))/171
t-test-1 = 7.5138 mm

Course # 2

Ca-2 = Corrosion allowance per API-650 5.3.2 (mm)
G = Design specific gravity of the liquid to be stored

H' = Effective liquid head at design pressure (m)

hmax-2 = Max liquid level based on shell thickness (m)

JE = Joint efficiency

pmax-2 = Max pressure at design (kPa)

pmax-int-shell-2 = Max internal pressure at design (kPa)

Sd = Allowable design stress for the design condition per API-650 Table 5-2b (MPa)

St = Allowable stress for the hydrostatic test condition per API-650 5.6.2.2 (MPa)

t-2 = Shell actual thickness (mm)

t-calc-2 = Shell thickness design condition td (mm)

t-seismic-2 = See E.6.2.4 table in SEISMIC calculations.

t-test-2 = Shell thickness hydrostatic test condition (mm)

Material = A36M

Width = 1.5 m

Ca-2 = 3 mm

JE = 1

t-2 = 12 mm

Sd = 160 MPa

St = 171 MPa

Design Condition G = 1 (per API-650)

H' = H

H' = 13.287

H' = 13.287 m

t-calc-2 = (4.9 * D * (H' - 0.3) * G)/Sd + Ca-2 (per API-650 5.6.3.2)

t-calc-2 = (4.9 * 18.1 * (13.287 - 0.3) * 1)/160 + 3

t-calc-2 = 10.1989 mm

hmax-2 = Sd * (t-2 - CA-2)/(2.6 * D * G) + 1

hmax-2 = 160 * (12 - 3)/(2.6 * 18.1 * 1) + 1

hmax-2 = 16.5374 m

pmax-2 = (hmax-2 - H) * 9.8 * G

pmax-2 = (16.5374 - 13.287) * 9.8 * 1

pmax-2 = 31.8538 kPa

pmax-int-shell-2 = MIN(pmax-int-shell-1 pmax-2)

pmax-int-shell-2 = MIN(17.1538 31.8538)

pmax-int-shell-2 = 17.1538 kPa

Hydrostatic Test Condition G = 1

H' = H

H' = 13.287

H' = 13.287 m

t-test-2 = (* 4.9 D (H' - 0.3))/St

t-test-2 = (* 4.9 18.1 (13.287 - 0.3))/171

t-test-2 = 6.7358 mm

Course # 3

Ca-3 = Corrosion allowance per API-650 5.3.2 (mm)

G = Design specific gravity of the liquid to be stored

H' = Effective liquid head at design pressure (m)

hmax-3 = Max liquid level based on shell thickness (m)

JE = Joint efficiency

pmax-3 = Max pressure at design (kPa)

pmax-int-shell-3 = Max internal pressure at design (kPa)

Sd = Allowable design stress for the design condition per API-650 Table 5-2b (MPa)

St = Allowable stress for the hydrostatic test condition per API-650 5.6.2.2 (MPa)

t-3 = Shell actual thickness (mm)

t-calc-3 = Shell thickness design condition td (mm)

t-seismic-3 = See E.6.2.4 table in SEISMIC calculations.

t-test-3 = Shell thickness hydrostatic test condition (mm)

Material = A36M

Width = 1.5 m

Ca-3 = 3 mm

JE = 1

t-3 = 10 mm

Sd = 160 MPa

St = 171 MPa

Design Condition G = 1 (per API-650)

H' = H

H' = 11.787

H' = 11.787 m

t-calc-3 = (4.9 * D * (H' - 0.3) * G)/Sd + Ca-3 (per API-650 5.6.3.2)

t-calc-3 = (4.9 * 18.1 * (11.787 - 0.3) * 1)/160 + 3

t-calc-3 = 9.3674 mm

hmax-3 = Sd * (t-3 - CA-3)/(2.6 * D * G) + 1

hmax-3 = 160 * (10 - 3)/(2.6 * 18.1 * 1) + 1

hmax-3 = 12.9301 m

pmax-3 = (hmax-3 - H) * 9.8 * G

pmax-3 = (12.9301 - 11.787) * 9.8 * 1

pmax-3 = 11.2028 kPa

pmax-int-shell-3 = MIN(pmax-int-shell-2 pmax-3)

pmax-int-shell-3 = MIN(17.1538 11.2028)

pmax-int-shell-3 = 11.2028 kPa

Hydrostatic Test Condition G = 1

H' = H

H' = 11.787

H' = 11.787 m

t-test-3 = (* 4.9 D (H' - 0.3))/St

t-test-3 = (* 4.9 18.1 (11.787 - 0.3))/171

t-test-3 = 5.9578 mm

Course # 4

Ca-4 = Corrosion allowance per API-650 5.3.2 (mm)

G = Design specific gravity of the liquid to be stored
H' = Effective liquid head at design pressure (m)
hmax-4 = Max liquid level based on shell thickness (m)
JE = Joint efficiency
pmax-4 = Max pressure at design (kPa)
pmax-int-shell-4 = Max internal pressure at design (kPa)
Sd = Allowable design stress for the design condition per API-650 Table 5-2b (MPa)
St = Allowable stress for the hydrostatic test condition per API-650 5.6.2.2 (MPa)
t-4 = Shell actual thickness (mm)
t-calc-4 = Shell thickness design condition td (mm)
t-seismic-4 = See E.6.2.4 table in SEISMIC calculations.
t-test-4 = Shell thickness hydrostatic test condition (mm)

Material = A36M
Width = 1.5 m
Ca-4 = 3 mm
JE = 1
t-4 = 10 mm
Sd = 160 MPa
St = 171 MPa

Design Condition G = 1 (per API-650)

H' = H
H' = 10.287
H' = 10.287 m

t-calc-4 = (4.9 * D * (H' - 0.3) * G)/Sd + Ca-4 (per API-650 5.6.3.2)
t-calc-4 = (4.9 * 18.1 * (10.287 - 0.3) * 1)/160 + 3
t-calc-4 = 8.5359 mm

hmax-4 = Sd * (t-4 - CA-4)/(2.6 * D * G) + 1
hmax-4 = 160 * (10 - 3)/(2.6 * 18.1 * 1) + 1
hmax-4 = 12.9301 m

pmax-4 = (hmax-4 - H) * 9.8 * G
pmax-4 = (12.9301 - 10.287) * 9.8 * 1

pmax-4 = 25.9028 kPa

pmax-int-shell-4 = MIN(pmax-int-shell-3 pmax-4)
pmax-int-shell-4 = MIN(11.2028 25.9028)
pmax-int-shell-4 = 11.2028 kPa

Hydrostatic Test Condition G = 1

H' = H
H' = 10.287
H' = 10.287 m

t-test-4 = (* 4.9 D (H' - 0.3))/St
t-test-4 = (* 4.9 18.1 (10.287 - 0.3))/171
t-test-4 = 5.1798 mm

Course # 5

Ca-5 = Corrosion allowance per API-650 5.3.2 (mm)
G = Design specific gravity of the liquid to be stored
H' = Effective liquid head at design pressure (m)
hmax-5 = Max liquid level based on shell thickness (m)
JE = Joint efficiency
pmax-5 = Max pressure at design (kPa)
pmax-int-shell-5 = Max internal pressure at design (kPa)
Sd = Allowable design stress for the design condition per API-650 Table 5-2b (MPa)
St = Allowable stress for the hydrostatic test condition per API-650 5.6.2.2 (MPa)
t-5 = Shell actual thickness (mm)
t-calc-5 = Shell thickness design condition td (mm)
t-seismic-5 = See E.6.2.4 table in SEISMIC calculations.
t-test-5 = Shell thickness hydrostatic test condition (mm)

Material = A36M
Width = 1.5 m
Ca-5 = 3 mm
JE = 1
t-5 = 8 mm

Sd = 160 MPa

St = 171 MPa

Design Condition G = 1 (per API-650)

H' = H

H' = 8.787

H' = 8.787 m

t-calc-5 = (4.9 * D * (H' - 0.3) * G)/Sd + Ca-5 (per API-650 5.6.3.2)

t-calc-5 = (4.9 * 18.1 * (8.787 - 0.3) * 1)/160 + 3

t-calc-5 = 7.7045 mm

hmax-5 = Sd * (t-5 - CA-5)/(2.6 * D * G) + 1

hmax-5 = 160 * (8 - 3)/(2.6 * 18.1 * 1) + 1

hmax-5 = 9.3229 m

pmax-5 = (hmax-5 - H) * 9.8 * G

pmax-5 = (9.3229 - 8.787) * 9.8 * 1

pmax-5 = 5.2519 kPa

pmax-int-shell-5 = MIN(pmax-int-shell-4 pmax-5)

pmax-int-shell-5 = MIN(11.2028 5.2519)

pmax-int-shell-5 = 5.2519 kPa

Hydrostatic Test Condition G = 1

H' = H

H' = 8.787

H' = 8.787 m

t-test-5 = (* 4.9 D (H' - 0.3))/St

t-test-5 = (* 4.9 18.1 (8.787 - 0.3))/171

t-test-5 = 4.4018 mm

Course # 6

Ca-6 = Corrosion allowance per API-650 5.3.2 (mm)

G = Design specific gravity of the liquid to be stored

H' = Effective liquid head at design pressure (m)

hmax-6 = Max liquid level based on shell thickness (m)

JE = Joint efficiency

pmax-6 = Max pressure at design (kPa)

pmax-int-shell-6 = Max internal pressure at design (kPa)

Sd = Allowable design stress for the design condition per API-650 Table 5-2b (MPa)

St = Allowable stress for the hydrostatic test condition per API-650 5.6.2.2 (MPa)

t-6 = Shell actual thickness (mm)

t-calc-6 = Shell thickness design condition td (mm)

t-seismic-6 = See E.6.2.4 table in SEISMIC calculations.

t-test-6 = Shell thickness hydrostatic test condition (mm)

Material = A36M

Width = 1.5 m

Ca-6 = 3 mm

JE = 1

t-6 = 8 mm

Sd = 160 MPa

St = 171 MPa

Design Condition G = 1 (per API-650)

H' = H

H' = 7.287

H' = 7.287 m

t-calc-6 = (4.9 * D * (H' - 0.3) * G)/Sd + Ca-6 (per API-650 5.6.3.2)

t-calc-6 = (4.9 * 18.1 * (7.287 - 0.3) * 1)/160 + 3

t-calc-6 = 6.873 mm

hmax-6 = Sd * (t-6 - CA-6)/(2.6 * D * G) + 1

hmax-6 = 160 * (8 - 3)/(2.6 * 18.1 * 1) + 1

hmax-6 = 9.3229 m

pmax-6 = (hmax-6 - H) * 9.8 * G

pmax-6 = (9.3229 - 7.287) * 9.8 * 1

pmax-6 = 19.9519 kPa

pmax-int-shell-6 = MIN(pmax-int-shell-5 pmax-6)

pmax-int-shell-6 = MIN(5.2519 19.9519)

pmax-int-shell-6 = 5.2519 kPa

Hydrostatic Test Condition G = 1

H' = H

H' = 7.287

H' = 7.287 m

t-test-6 = (* 4.9 D (H' - 0.3))/St

t-test-6 = (* 4.9 18.1 (7.287 - 0.3))/171

t-test-6 = 3.6238 mm

Course # 7

Ca-7 = Corrosion allowance per API-650 5.3.2 (mm)

G = Design specific gravity of the liquid to be stored

H' = Effective liquid head at design pressure (m)

hmax-7 = Max liquid level based on shell thickness (m)

JE = Joint efficiency

pmax-7 = Max pressure at design (kPa)

pmax-int-shell-7 = Max internal pressure at design (kPa)

Sd = Allowable design stress for the design condition per API-650 Table 5-2b (MPa)

St = Allowable stress for the hydrostatic test condition per API-650 5.6.2.2 (MPa)

t-7 = Shell actual thickness (mm)

t-calc-7 = Shell thickness design condition td (mm)

t-seismic-7 = See E.6.2.4 table in SEISMIC calculations.

t-test-7 = Shell thickness hydrostatic test condition (mm)

Material = A36M

Width = 1.5 m

Ca-7 = 3 mm

JE = 1

t-7 = 8 mm

Sd = 160 MPa

St = 171 MPa

Design Condition G = 1 (per API-650)

H' = H

H' = 5.787

H' = 5.787 m

t-calc-7 = (4.9 * D * (H' - 0.3) * G)/Sd + Ca-7 (per API-650 5.6.3.2)

t-calc-7 = (4.9 * 18.1 * (5.787 - 0.3) * 1)/160 + 3

t-calc-7 = 6.0415 mm

hmax-7 = Sd * (t-7 - CA-7)/(2.6 * D * G) + 1

hmax-7 = 160 * (8 - 3)/(2.6 * 18.1 * 1) + 1

hmax-7 = 9.3229 m

pmax-7 = (hmax-7 - H) * 9.8 * G

pmax-7 = (9.3229 - 5.787) * 9.8 * 1

pmax-7 = 34.6519 kPa

pmax-int-shell-7 = MIN(pmax-int-shell-6 pmax-7)

pmax-int-shell-7 = MIN(5.2519 34.6519)

pmax-int-shell-7 = 5.2519 kPa

Hydrostatic Test Condition G = 1

H' = H

H' = 5.787

H' = 5.787 m

t-test-7 = (* 4.9 D (H' - 0.3))/St

t-test-7 = (* 4.9 18.1 (5.787 - 0.3))/171

t-test-7 = 2.8459 mm

Course # 8

Ca-8 = Corrosion allowance per API-650 5.3.2 (mm)

G = Design specific gravity of the liquid to be stored

H' = Effective liquid head at design pressure (m)

hmax-8 = Max liquid level based on shell thickness (m)

JE = Joint efficiency

pmax-8 = Max pressure at design (kPa)

pmax-int-shell-8 = Max internal pressure at design (kPa)

Sd = Allowable design stress for the design condition per API-650 Table 5-2b (MPa)

St = Allowable stress for the hydrostatic test condition per API-650 5.6.2.2 (MPa)

t-8 = Shell actual thickness (mm)

t-calc-8 = Shell thickness design condition td (mm)

t-seismic-8 = See E.6.2.4 table in SEISMIC calculations.

t-test-8 = Shell thickness hydrostatic test condition (mm)

Material = A36M

Width = 1.5 m

Ca-8 = 3 mm

JE = 1

t-8 = 6 mm

Sd = 160 MPa

St = 171 MPa

Design Condition G = 1 (per API-650)

H' = H

H' = 4.287

H' = 4.287 m

t-calc-8 = (4.9 * D * (H' - 0.3) * G)/Sd + Ca-8 (per API-650 5.6.3.2)

t-calc-8 = (4.9 * 18.1 * (4.287 - 0.3) * 1)/160 + 3

t-calc-8 = 5.21 mm

hmax-8 = Sd * (t-8 - CA-8)/(2.6 * D * G) + 1

hmax-8 = 160 * (6 - 3)/(2.6 * 18.1 * 1) + 1

hmax-8 = 5.7157 m

pmax-8 = (hmax-8 - H) * 9.8 * G

pmax-8 = (5.7157 - 4.287) * 9.8 * 1

pmax-8 = 14.0009 kPa

pmax-int-shell-8 = MIN(pmax-int-shell-7 pmax-8)

pmax-int-shell-8 = MIN(5.2519 14.0009)

pmax-int-shell-8 = 5.2519 kPa

Hydrostatic Test Condition G = 1

H' = H

H' = 4.287

H' = 4.287 m

t-test-8 = (* 4.9 D (H' - 0.3))/St

t-test-8 = (* 4.9 18.1 (4.287 - 0.3))/171

t-test-8 = 2.0679 mm

Course # 9

Ca-9 = Corrosion allowance per API-650 5.3.2 (mm)

G = Design specific gravity of the liquid to be stored

H' = Effective liquid head at design pressure (m)

hmax-9 = Max liquid level based on shell thickness (m)

JE = Joint efficiency

pmax-9 = Max pressure at design (kPa)

pmax-int-shell-9 = Max internal pressure at design (kPa)

Sd = Allowable design stress for the design condition per API-650 Table 5-2b (MPa)

St = Allowable stress for the hydrostatic test condition per API-650 5.6.2.2 (MPa)

t-9 = Shell actual thickness (mm)

t-calc-9 = Shell thickness design condition td (mm)

t-seismic-9 = See E.6.2.4 table in SEISMIC calculations.

t-test-9 = Shell thickness hydrostatic test condition (mm)

Material = A36M

Width = 1.5 m

Ca-9 = 3 mm

JE = 1

t-9 = 6 mm

Sd = 160 MPa

St = 171 MPa

Design Condition G = 1 (per API-650)

H' = H

H' = 2.787

H' = 2.787 m

t-calc-9 = (4.9 * D * (H' - 0.3) * G)/Sd + Ca-9 (per API-650 5.6.3.2)

t-calc-9 = (4.9 * 18.1 * (2.787 - 0.3) * 1)/160 + 3

t-calc-9 = 4.3786 mm

hmax-9 = Sd * (t-9 - CA-9)/(2.6 * D * G) + 1

hmax-9 = 160 * (6 - 3)/(2.6 * 18.1 * 1) + 1

hmax-9 = 5.7157 m

pmax-9 = (hmax-9 - H) * 9.8 * G

pmax-9 = (5.7157 - 2.787) * 9.8 * 1

pmax-9 = 28.7009 kPa

pmax-int-shell-9 = MIN(pmax-int-shell-8 pmax-9)

pmax-int-shell-9 = MIN(5.2519 28.7009)

pmax-int-shell-9 = 5.2519 kPa

Hydrostatic Test Condition G = 1

H' = H

H' = 2.787

H' = 2.787 m

t-test-9 = (* 4.9 D (H' - 0.3))/St

t-test-9 = (* 4.9 18.1 (2.787 - 0.3))/171

t-test-9 = 1.2899 mm

Course # 10

Ca-10 = Corrosion allowance per API-650 5.3.2 (mm)

G = Design specific gravity of the liquid to be stored

H' = Effective liquid head at design pressure (m)

hmax-10 = Max liquid level based on shell thickness (m)

JE = Joint efficiency

pmax-10 = Max pressure at design (kPa)

pmax-int-shell-10 = Max internal pressure at design (kPa)

Sd = Allowable design stress for the design condition per API-650 Table 5-2b (MPa)

St = Allowable stress for the hydrostatic test condition per API-650 5.6.2.2 (MPa)

t-10 = Shell actual thickness (mm)

t-calc-10 = Shell thickness design condition td (mm)

t-seismic-10 = See E.6.2.4 table in SEISMIC calculations.

t-test-10 = Shell thickness hydrostatic test condition (mm)

Material = A36M

Width = 1.5 m

Ca-10 = 3 mm

JE = 1

t-10 = 6 mm

Sd = 160 MPa

St = 171 MPa

Design Condition G = 1 (per API-650)

H' = H

H' = 1.287

H' = 1.287 m

t-calc-10 = (4.9 * D * (H' - 0.3) * G)/Sd + Ca-10 (per API-650 5.6.3.2)

t-calc-10 = (4.9 * 18.1 * (1.287 - 0.3) * 1)/160 + 3

t-calc-10 = 3.5471 mm

hmax-10 = Sd * (t-10 - CA-10)/(2.6 * D * G) + 1

hmax-10 = 160 * (6 - 3)/(2.6 * 18.1 * 1) + 1

hmax-10 = 5.7157 m

pmax-10 = (hmax-10 - H) * 9.8 * G

pmax-10 = (5.7157 - 1.287) * 9.8 * 1

pmax-10 = 43.4009 kPa

pmax-int-shell-10 = MIN(pmax-int-shell-9 pmax-10)

pmax-int-shell-10 = MIN(5.2519 43.4009)

pmax-int-shell-10 = 5.2519 kPa

Hydrostatic Test Condition G = 1

H' = H

H' = 1.287

H' = 1.287 m

t-test-10 = (* 4.9 D (H' - 0.3))/St

t-test-10 = (* 4.9 18.1 (1.287 - 0.3))/171

t-test-10 = 0.5119 mm

Course # 11

Ca-11 = Corrosion allowance per API-650 5.3.2 (mm)

G = Design specific gravity of the liquid to be stored

H' = Effective liquid head at design pressure (m)

hmax-11 = Max liquid level based on shell thickness (m)

JE = Joint efficiency

pmax-11 = Max pressure at design (kPa)

pmax-int-shell-11 = Max internal pressure at design (kPa)

Sd = Allowable design stress for the design condition per API-650 Table 5-2b (MPa)

St = Allowable stress for the hydrostatic test condition per API-650 5.6.2.2 (MPa)

t-11 = Shell actual thickness (mm)

t-calc-11 = Shell thickness design condition td (mm)

t-seismic-11 = See E.6.2.4 table in SEISMIC calculations.

t-test-11 = Shell thickness hydrostatic test condition (mm)

Material = A36M

Width = 1.35 m

Ca-11 = 3 mm

JE = 1

t-11 = 6 mm

Sd = 160 MPa

St = 171 MPa

Design Condition G = 1 (per API-650)

H' = H

H' = -0.213

H' = -0.213 m

t-calc-11 = (4.9 * D * (H' - 0.3) * G)/Sd + Ca-11 (per API-650 5.6.3.2)

t-calc-11 = (4.9 * 18.1 * (-0.213 - 0.3) * 1)/160 + 3

t-calc-11 = 2.7156 mm

hmax-11 = Sd * (t-11 - CA-11)/(2.6 * D * G) + 1

hmax-11 = 160 * (6 - 3)/(2.6 * 18.1 * 1) + 1

hmax-11 = 5.7157 m

pmax-11 = (hmax-11 - H) * 9.8 * G

pmax-11 = (5.7157 - -0.213) * 9.8 * 1

pmax-11 = 58.1009 kPa

pmax-int-shell-11 = MIN(pmax-int-shell-10 pmax-11)

pmax-int-shell-11 = MIN(5.2519 58.1009)

pmax-int-shell-11 = 5.2519 kPa

Hydrostatic Test Condition G = 1

H' = H

H' = -0.213

H' = -0.213 m

t-test-11 = (* 4.9 D (H' - 0.3))/St

t-test-11 = (* 4.9 18.1 (-0.213 - 0.3))/171

t-test-11 = -0.2661 mm

SUMMARY OF SHELL RESULTS Back

t-min-Seismic = See API-650 E.6.1.4, table in SEISMIC calculations.

Shell API-650 Summary (Bottom is 1)

Shel l #	Widt h (mm)	Materi al	CA (mm)	J E	Min Yield Strengt h (MPa)	Tensile Strengt h (MPa)	Sd (MPa)	St (MPa)	Weig ht (N)	Weig ht CA (N)	t-min Erectio n (mm)	t-Des (mm)	t- Test (mm)	t-min Seism (mm	t min Ext P (mm)	t-min (mm)	t- Actu al (mm)	Statu s
1	1500	A36M	3	1	250	400	160	171	78,658	59,003	6	11.030 3	7.513 8	7.5979	NA	11.030 3	12	OK
2	1500	A36M	3	1	250	400	160	171	78,658	59,003	6	10.198 9	6.735 8	7.1261	NA	10.198 9	12	OK
3	1500	A36M	3	1	250	400	160	171	65,555	45,896	6	9.3674	5.957 8	6.4099	NA	9.3674	10	OK
4	1500	A36M	3	1	250	400	160	171	65,555	45,896	6	8.5359	5.179 8	5.968	NA	8.5359	10	OK
5	1500	A36M	3	1	250	400	160	171	52,450	32,787	6	7.7045	4.401 8	5.2545	NA	7.7045	8	OK
6	1500	A36M	3	1	250	400	160	171	52,450	32,787	6	6.873	3.623 8	4.8581	NA	6.873	8	OK
7	1500	A36M	3	1	250	400	160	171	52,450	32,787	6	6.0415	2.845 9	4.4609	NA	6.0415	8	OK
8	1500	A36M	3	1	250	400	160	171	39,342	19,674	6	5.21	2.067 9	3.8502	NA	6	6	OK
9	1500	A36M	3	1	250	400	160	171	39,342	19,674	6	4.3786	1.289 9	3.5311	NA	6	6	OK
10	1500	A36M	3	1	250	400	160	171	39,342	19,674	6	3.5471	0.511 9	3.2126	NA	6	6	OK
11	1350	A36M	3	1	250	400	160	171	35,408	17,706	6	2.7156	- 0.266 1	2.901	NA	6	6	OK

Total Weight = 599,215.464 N

INTERMEDIATE STIFFENER CALCULATIONS PER API-650 Section 5.9.7

D = Nominal diameter of the tank shell (m)

Hu = Vertical Distance Between the Intermediate Stiffener (Per API-650 5.9.7) (m)

L_act = Actual Transform Height Spacing between Stiffeners (m)

L_0 = Uniform Maximum Transform Height Spacing between Stiffineres (m)

V = Design wind speed (km/h)

Wtr = Transposed width of each shell course (m)

Zi = Required Intermediate Stiffener Section Modulus (per API-650 5.9.6.1) (cm^3)

Zi-actual = Actual Top Comp Ring Section Modulus (cm^3)

D = 18.1 m

V = 201 km/h

ME = 1

Hu = ME * 9.47 * tsmin * (SQRT (tsmin / D)^3) * (190 / V)^2

Hu = 1 * 9.47 * 6 * (SQRT (6 / 18.1)^3) * (190 / 201)^2

Hu = 9.69 m (Maximum Height of Unstiffened Shell)

Transforming courses (1) to (11)

Wtr = Course-width * (SQRT (t-uniform / t-course)^5)

Wtr-1 = 1.5 * (SQRT (6 / 12)^5) = 0.2652 m

Wtr-2 = 1.5 * (SQRT (6 / 12)^5) = 0.2652 m

Wtr-3 = 1.5 * (SQRT (6 / 10)^5) = 0.4183 m

Wtr-4 = 1.5 * (SQRT (6 / 10)^5) = 0.4183 m

Wtr-5 = 1.5 * (SQRT (6 / 8)^5) = 0.7307 m

Wtr-6 = 1.5 * (SQRT (6 / 8)^5) = 0.7307 m

Wtr-7 = 1.5 * (SQRT (6 / 8)^5) = 0.7307 m

Wtr-8 = 1.5 * (SQRT (6 / 6)^5) = 1.5 m

Wtr-9 = 1.5 * (SQRT (6 / 6)^5) = 1.5 m

Wtr-10 = 1.5 * (SQRT (6 / 6)^5) = 1.5 m

Wtr-11 = 1.43 * (SQRT (6 / 6)^5) = 1.43 m

Wtr = SUM(Wtr-n)

Wtr = 9.489 m

For uniformly spaced stiffeners

L_0 = Hts/# of Stiffeners + 1

L_0 = 9.489/(0 + 1)

L_0 = 9.489 m

L_act = Wrt

L_act = 9.489 m

Number of Intermediate Stiffeners Sufficient Since Hu >= L_act

SUMMARY OF SHELL STIFFENING RESULTS

Number of Intermediate stiffeners req'd (NS) = 0

FLAT BOTTOM: NON ANNULAR PLATE DESIGN Back

Ba = Area of bottom (cm^2)

Bottom-OD = Bottom diameter (m)

c = Factor

ca-1 = Bottom (1st) shell course corrosion allowance (mm)

Ca-bottom = Bottom corrosion allowance (mm)

D-bottom = Density of bottom (kg/mm3)

G = Design specific gravity of the liquid to be stored

H = Max liquid level (m)

H' = Effective liquid head at design pressure (m)

JE = Bottom joint efficiency

S = Maximum Stress in first shell course per API 650 Table 5.1.a

S1 = Product stress in the first shell course per API 650 Table 5.1.a

S2 = Hydrostatic test stress in the first shell course per API 650 Table 5.1.a

t-1 = Bottom (1st) shell course thickness (mm)

t-actual = Actual bottom thickness (mm)

t-calc = Minimum nominal bottom plates thickness per API-650 5.4.1 (mm)

t-min = Minimum nominal bottom plates thickness per API-650 5.4.1 (mm)

t-test-1 = Bottom (1st) shell course test thickness (mm)

t-vac = Vacuum calculations per ASME section VIII Div. 1 (mm)

td-1 = Bottom (1st) shell course design thickness (mm)

Material = A36M

t-actual = 9 mm

t-min = 6.0 + Ca-bottom

t-min = 6.0 + 3

t-min = 9 mm

t-calc = t-min

t-calc = 9 mm

Calculation of Hydrostatic Test Stress & Product Stress (per API-650 Section 5.5.1)

Bottom-OD = 18.224 m

JE = 1

D-bottom = 0.00000784 kg/mm3

t-1 = 12 mm

ca-1 = 3 mm

G = 1

H = 14.787 m

H' = 14.787 m

St = 171 MPa

Sd = 160 MPa

Ca-bottom = 3 mm

Product stress in first shell course

S1 = ((td-1 - ca-1) / (t-1 - ca-1)) * Sd

S1 = ((11.0303 - 3) / (12 - 3)) * 160

S1 = 142.7613 MPa

Hydrostatic test stress in first shell course

S2 = (t-test-1 / t-1) * St

S2 = (7.5138 / 12) * 171

S2 = 107.071 MPa

S = Max (S1, S2)

S = Max (142.7613 , 107.071)

S = 142.7613 MPa

ABS(E-p) < P-btm Then there is no uplift

SUMMARY OF BOTTOM RESULTS Back

Material = A36M

t-actual = 9 mm

t-req = 9 mm

NET UPLIFT DUE TO INTERNAL PRESSURE

Net-Uplift = 0 N, (See roof report for calculations)

WIND MOMENT (Per API-650 SECTION 5.11) Back

A = Area resisting the compressive force, as illustrated in Figure F.1

P-F41 = Design pressure determined in F.4.1

P-v = Internal pressure

Wind Velocity per API-650 ASCE 7-05

V_entered = 201 kph

I = 1

Vs (Wind Velocity) = SQRT(I) * V_entered = 201 kph

Vf = (Vs / 190)^2

Vf = (201 / 190)^2

Vf (Velocity Factor) = 1.1191

PWS = 0.86 * Vf

PWS = 0.9624 kPa

PWR = 1.44 * Vf

PWR = 1.6115 kPa

API-650 5.2.1.k Uplift Check

P-F41 = (A * Fy * TAN(Theta))/(200 * D^2) + (0.00127 * DLR)/D^2

P-F41 = (2177.72 * 250 * TAN(15.8191))/(200 * 18.1^2) + ((0.00127 * 167601) / 18.1^2)

P-F41 = 3.004 kPa

Wind-Uplift = MIN(PWR , (1.6 * P-F41 - Pv))

Wind-Uplift = MIN(1.6115 , 4.8063)

Wind-Uplift = 1.6116 kPa

Ap-Vert (Vertical Projected Area of Roof) = 23.2057 m^2

Horizontal Projected Area of Roof (Per API-650 5.2.1.f)

Xw (Moment Arm of UPLIFT wind force on roof) = 9.05 m

Ap (Projected Area of roof for wind moment) = 257.3043 m^2

M-roof (Moment Due to Wind Force on Roof) = Wind-Uplift * Ap * Xw

M-roof = (1,611.5634 * 257.3043 * 9.05)

M-roof = 3,752,693 N-m

Xs (Height from bottom to the Shell's center of gravity) = Shell Height/2

Xs = (16.43/2)

Xs = 8.215 m

As (Projected Area of Shell) = Shell Height * (D + 2 * t-ins)

As = 16.43 * (18.1 + 2 * 0)

As = 297.383 m^2

M-Shell (Moment Due to Wind Force on Shell) = (PWS * As * (Shell Height / 2))

M-Shell = (0.9624 * 297.383 * (16.43 / 2))

M-Shell = 2,351,295 N-m

Mw (Wind moment) = M-roof + M-shell

Mw = 3,752,693 + 2,351,295

Mw = 6,103,987.5404 N-m

RESISTANCE TO OVERTURNING (per API-650 5.11.2)

DLR = Nominal weight of roof plate plus weight of roof plates overlap plus any attached structural.
DLS = Nominal weight of the shell and any framing (but not roof plates) support by the shell and roof.
F-friction = Maximum of 40% of weight of tank
MDL = Moment about the shell-to-bottom joint from the nominal weight of the shell
MDLR = Moment about the shell-to-bottom joint from the nominal weight of the roof plate plus any attached structural.
MF = Stabilizing moment due to bottom plate and liquid weight
MPi = Destabilizing moment about the shell-to-bottom joint from design pressure
Mw = Destabilizing wind moment
tb = Bottom plate thickness less C.A.
wl = Circumferential loading of contents along shell-to-bottom joint

An unanchored tank must meet with this criteria:

Mw = 6,103,988 m-N
DLS = 627,211.5623 N
DLR = 167,600.885 N

MPi = P * (Pi * D^2 / 4) * (D / 2)
MPi = 0 * (3.1416 * 18.1^2 / 4) * (18.1 / 2)
MPi = 0 m-N

MDL = DLS * (D/2)
MDL = 627,211.5623 * 18.1/2
MDL = 5,676,265 N-m

MDLR = DLR * (D/2)
MDLR = 167,600.885 * 18.1/2
MDLR = 1,516,788 N-m

tb = 6 mm

wl = (min [59 * tb * SQRT(fy-btm * H-liq)] [140.8 * H-liq * D])

wl = (min [59 * 6 * SQRT(250 * 14.787)] [140.8 * 14.787 * 18.1])
wl = 21,523.5202 N/m

MF = (D/2) * wl * Pi * D
MF = 9.05 * 21,523.5202 * 3.1416 * 18.1
MF = 11,076,188 m-N

Criteria 3

M-shell + Fp * Mpi < MDL /1.5 + MDLR
2,351,294.7288 + 0.4 * 0 < 5,676,265 / 1.5 + 1,516,788
Since 2,351,295 < 5,300,965, Tank is stable

RESISTANCE TO SLIDING (per API-650 5.11.4)

F-wind = Vf * 18 * As
F-wind = 1.1191 * 18 * 297.383
F-wind = 277,633 N

F-friction = 0.4 * [(W-roof-corroded * g) + (W-shell-corroded * g) + (W-btm-corroded * g) + (W-roof-struct * g)]
F-friction = 0.4 * [(10,538 * 9.8) + (39,248 * 9.8) + (12,273 * 9.8) + (26,410 * 9.8)]
F-friction = 347,031 N

No anchorage needed to resist sliding since
F-friction > F-wind

Anchorage Requirement

Tank does not require anchorage

SITE GROUND MOTION CALCULATIONS

Anchorage_System (Anchorage System) = self anchored
D (Nominal Tank Diameter) = 18.1 m
Fa (Site Acceleration Coefficient) = 1.0

Fv (Site Velocity Coefficient) = 1.0

H (Maximum Design Product Level) = 14.787 m

I (Importance Factor) = 1.0

K (Spectral Acceleration Adjustment Coefficient) = 1.5

Q (MCE to Design Level Scale Factor) = 0.6667

Rwc (Convective Force Reduction Factor) = 2

Rwi (Impulsive Force Reduction Factor) = 3.5

S1 (Spectral Response Acceleration at a Period of One Second) = 0.05

Seismic_Site_Class (Seismic Site Class) = seismic site class b

Seismic_Use_Group (Seismic Use Group) = seismic use group i

Ss (Spectral Response Acceleration Short Period) = 0.1

TL (Regional Dependent Transistion Period for Longer Period Ground Motion) = 4 sec

Design Spectral Response Acceleration at Short Period *API 650 Sections E.4.6.1 and E.2.2*

SDS = Q * Fa * Ss = 0.6667 * 1.0 * 0.1 = 0.0667

Design Spectral Response Acceleration at a Period of One Second *API 650 Sections E.4.6.1 and E.2.2*

SD1 = Q * Fv * S1 = 0.6667 * 1.0 * 0.05 = 0.0333

Sloshing Coefficient *API 650 Section E.4.5.2*

Ks = 0.578 / SQRT(TANH(((3.68 * Liq_max) / D)))

= 0.578 / SQRT(TANH(((3.68 * 14.787) / 18.1)))

= 0.5794

Convective Natural Period *API 650 Section E.4.5.2*

Tc = 1.8 * Ks * SQRT(D) = 1.8 * 0.5794 * SQRT(18.1) = 4.4371 sec

Impulsive Design Response Spectrum Acceleration Coefficient *API 650 Sections E.4.6.1*

Ai = SDS * (I / Rwi) = 0.0667 * (1.0 / 3.5) = 0.0191

API 650 Sections E.4.6.1

Ai = MAX(Ai , 0.007) = MAX(0.0191 , 0.007) = 0.0191

Tc > TL

Convective Design Response Spectrum Acceleration Coefficient *API 650 Sections E.4.6.1*

Ac = K * SD1 * (TL / (Tc^2)) * (I / Rwc)

= 1.5 * 0.0333 * (4 / (4.4371^2)) * (1.0 / 2)

= 0.0051

Ac = MIN(Ac , Ai) = MIN(0.0051 , 0.0191) = 0.0051

Vertical Ground Acceleration Coefficient *API 650 Section E.6.1.3 and E.2.2*

Av = (2 / 3) * 0.7 * SDS = (2 / 3) * 0.7 * 0.0667 = 0.0311

Vertical Ground Acceleration Coefficient Specified by user (Av) = 0.0311

SEISMIC CALCULATIONS Back

< Mapped ASCE7 Method >

Ac = Convective spectral acceleration parameter

Ai = Impulsive spectral acceleration parameter

Av = Vertical Earthquake Acceleration Coefficient

Ci = Coefficient for impulsive period of tank system (Fig. E-1)

D/H = Ratio of Tank Diameter to Design Liquid Level

Density = Density of tank product (SG * 62.42786)

Fc = Allowable longitudinal shell-membrane compressive stress

Fty = Minimum specified yield strength of shell course

Fy = Minimum yield strength of bottom annulus

Ge = Effective specific gravity including vertical seismic effects

I = Importance factor defined by Seismic Use Group

k = Coefficient to adjust spectral acceleration from 5% - 0.5% damping

L = Required Annular Ring Width

Ls = Actual Annular Plate Width

Mrw = Ringwall moment-portion of the total overturning moment that acts at the base of the tank shell perimeter

Ms = Slab moment (used for slab and pile cap design)

Pa = Anchorage chair design load

Pab = Anchor seismic design load

Q = Scaling factor from the MCE to design level spectral accelerations

RCG = Height from Top of Shell to Roof Center of Gravity

Rwc = Force reduction factor for the convective mode using allowable stress design methods (Table E-4)

Rwi = Force reduction factor for the impulsive mode using allowable stress design methods (Table E-4)

S0 = Design Spectral Response Param. (5% damped) for 0-second Periods (T = 0.0 sec)

Sd1 = The design spectral response acceleration param. (5% damped) at 1 second based on ASCE7 methods per API 650 E.2.2

Sds = The design spectral response acceleration param. (5% damped) at short periods (T = 0.2 sec) based on ASCE7 methods per API 650 E.2.2

SigC = Maximum longitudinal shell compression stress

SigC-anchored = Maximum longitudinal shell compression stress

SUG = Seismic Use Group (Importance factors depends on SUG)

T-L = Regional Dependent Transition Period for Long Period Ground Motion (Per ASCE 7-05, fig. 22-15)

ta = Actual Annular Plate Thickness less C.A.

ts1 = Thickness of bottom Shell course minus C.A.

tu = Equivalent uniform thickness of tank shell

V = Total design base shear

Vc = Design base shear due to convective component from effective sloshing weight

Vi = Design base shear due to impulsive component from effective weight of tank and contents

wa = Force resisting uplift in annular region

Wab = Design uplift load on anchor per unit circumferential length

Wc = Effective Convective (Sloshing) Portion of the Liquid Weight

Weff = Effective Weight Contributing to Seismic Response

Wf = Weight of Floor (Incl. Annular Ring)

Wi = Effective Impulsive Portion of the Liquid Weight

wint = Uplift load due to design pressure acting at base of shell

Wp = Total weight of Tank Contents based on S.G.

Wr = Weight Fixed Roof, framing and 10 % of Design Snow Load & Insul.

Wrs = Roof Load Acting on Shell, Including 10% of Snow Load

Ws = Weight of Shell (Incl. Shell Stiffeners & Insul.)

wt = Shell and roof weight acting at base of shell

Xc = Height to center of action of the lateral seismic force related to the convective liquid force for ringwall moment

Xcs = Height to center of action of the lateral seismic force related to the convective liquid force for the slab moment

Xi = Height to center of action of the lateral seismic force related to the impulsive liquid force for ringwall moment

Xis = Height to center of action of the lateral seismic force related to the impulsive liquid force for the slab moment

Xr = Height from Bottom of Shell to Roof Center of Gravity

Xs = Height from Bottom to the Shell's Center of Gravity

g = 9.8 m/s^2

WEIGHTS

Ws = 61,764 kgf or 605,697.2362 N

Wf = 18,409 kgf or 180,531.2287 N

Wr = 16,861 kgf or 165,346.1429 N

EFFECTIVE WEIGHT OF PRODUCT

D/H = 1.224

Wp = 3,804,759 kgf

Wi = (1 - (0.218 * D/H)) * Wp

Wi = (1 - (0.218 * 1.224)) * 3,804,759

Wi = 2,789,488 kgf

Wc = 0.23 * D/H * TANH (3.67 * H/D) * Wp

Wc = 0.23 * 1.224 * TANH (3.67 * 0.817) * 3,804,759

Wc = 1,065,842 kgf

Weff = Wi + Wc

Weff = 2,789,488 + 1,065,842

Weff = 3,855,329.812 kgf

Wrs = 12,583 kgf

DESIGN LOADS

Vi = Ai * (Ws + Wr + Wf + Wi)

Vi = 0.0191 * (61,764 + 16,861 + 18,409 + 2,789,488)

Vi = 55,133 kgf

Vc = Ac * Wc

Vc = 0.0051 * 1,065,842

Vc = 5,435.7952 kgf

V = SQRT (Vi^2 + Vc^2)

V = SQRT (55,133^2 + 5,435.7952^2)

V = 55,399.8782 kgf

CENTER OF ACTION FOR EFFECTIVE LATERAL FORCES

Xs = 7.3935 m

RCG = 1/3 * R * (TAND (Theta))

RCG = 1/3 * 9072.5 * (TAND (15.8192))

RCG = 856.8472 mm or 0.8568 m

Xr = Shell Height + RCG

Xr = 16.43 + 0.8568

Xr = 17.2868 m

CENTER OF ACTION FOR RINGWALL OVERTURNING MOMENT

Xi = (0.5 - (0.094 * D/H)) * H

Xi = (0.5 - (0.094 * 1.224)) * 14.787

Xi = 5.6921 m

Xc = (1 - (COSH (3.67 * H/D) - 1) / ((3.67 * H/D) * SINH (3.67 * H/D))) * H

Xc = (1 - (COSH (3.67 * 0.817) - 1) / ((3.67 * 0.817) * SINH (3.67 * 0.817))) * 14.787

Xc = 10.3237 m

CENTER OF ACTION FOR SLAB OVERTURNING MOMENT

Xis = (0.5 + (0.06 * D/H)) * H)

Xis = (0.5 + (0.06 * 1.224)) * 14.787)

Xis = 8.4795 m

Xcs = (1 - (COSH (3.67 * H/D) - 1.937) / ((3.67 * H/D) * SINH(3.67 * H/D))) * H

Xcs = (1 - (COSH (3.67 * 0.817) - 1.937) / ((3.67 * 0.817) * SINH(3.67 * 0.817))) * 14.787

Xcs = 10.7858 m

Dynamic Liquid Hoop Forces

SHELL	Width (m)	Y (m)	Ni (N/mm)	Nc (N/mm)	Nh (N/mm)	SigT+ (MPa)	SigT- (MPa)
SUMMARY			= 2.6 * Ai * G * D^2	= 1.85 * Ac * G * D^2 * (COSH (3.68 * (H - Y)) / D) / (COSH (3.68 * H / D))	= 4.9011293 * Y * D * G	= (+ Nh (SQRT (Ni^2 + Nc^2 + (Av * Nh / 2.5)^2))) / t-n	= (- Nh (SQRT (Ni^2 + Nc^2 + (Av * Nh / 2.5)^2))) / t-n
Shell 1	1.5	14.4822	16.2691	0.3056	1,284.7223	108.9608	105.1595

Shell 2	1.5	12.9822	16.3005	0.3258	1,151.6566	97.78	94.1627
Shell 3	1.5	11.4822	15.9435	0.3765	1,018.591	103.896	99.8221
Shell 4	1.5	9.9822	15.1877	0.4625	885.5253	90.4293	86.6757
Shell 5	1.5	8.4822	14.033	0.5919	752.4596	96.1673	91.9475
Shell 6	1.5	6.9822	12.4796	0.7768	619.394	79.2601	75.5883
Shell 7	1.5	5.4822	10.5273	1.0345	486.3283	62.3142	59.2678
Shell 8	1.5	3.9822	8.1763	1.3891	353.2627	60.4414	57.3128
Shell 9	1.5	2.4822	5.4264	1.8739	220.197	37.7596	35.6393
Shell 10	1.5	0.9822	2.2778	2.5345	87.1313	15.1178	13.9259
Shell 11	1.35	-0.5177999999999994	-1.2696617073081582	3.4325	-45.93426600287395	-7.038345109127055	-8.273076891830927

Overturning Moment

Mrw = ((Ai * [(Wi * g) * Xi + (Ws * g) * Xs + (Wr * g) * Xr])^2 + [Ac * (Wc * g) * Xc]^2)^0.5

Mrw = ((0.0191 * [(2,789,488 * 9.8) * 5.6921 + (61,764 * 9.8) * 7.3935 + (16,861 * 9.8) * 17.2868])^2 + [0.0051 * (1,065,842 * 9.8) * 10.3237]^2)^0.5

Mrw = 3,162,448.046 N-m

Ms = ((Ai * [(Wi * g) * Xis + (Ws * g) * Xs + (Wr * g) * Xr])^2 + [Ac * (Wc * g) * Xcs]^2)^0.5

Ms = ((0.0191 * [(2,789,488 * 9.8) * 8.4795 + (61,764 * 9.8) * 7.3935 + (16,861 * 9.8) * 17.2868])^2 + [0.0051 * (1,065,842 * 9.8) * 10.7858]^2)^0.5

Ms = 4,606,608.4266 N-m

RESISTANCE TO DESIGN LOADS

Fy = 250 MPa

Ge = S.G. * (1- 0.4 * Av)

Ge = 1 * (1- 0.4 * 0.0311)

Ge = 0.9876

wa = MIN (99 * ta * (Fy * H * Ge)^0.5 , 201.1 * H * D * Ge)

wa = MIN (99 * 6 * (250 * 14.787 * 0.9876)^0.5) , 201.1 * 14.787 * 18.1 * 0.9876)

wa = MIN (35,890.3944 , 53,153.7867)

wa = 35,890.3944 N/m

wt = (Wrs + Ws) / (Pi * D)

wt = (12,583 + 61,764) / (3.1416 * 18.1)

wt = 12,821.9533 N/m

wint = P * (Pi * D^2 / 4) / (Pi * D)

wint = 0 * (3.1416 * 18.1^2 / 4) / (3.1416 * 18.1)

wint = 0 N/m

Anchorage Ratio

J = Mrw / (D^2 * [wt * (1 - 0.4 * Av)] + wa - 0.4 * wint

J = 3,162,448.046 / (18.1^2 * [12,821.9533 * (1 - 0.4 * 0.0311)] + 35,890.3944 - 0.4 * 0

J = 0.1988

Since J <= 0.785, The tank is self-anchored, per API 650 Table E-6

Maximum Longitudinal Shell-Membrane Compressive Stress

ts1 = 9 mm

SigC = [wt * (1 + (0.4 * Av)) + (1.273 * Mrw) / D^2] * (1 / (1,000 * ts))

SigC = [12,821.9533 * (1 + (0.4 * 0.0311)) + (1.273 * 3,162,448.046) / 18.1^2] * (1 / (1,000 * 9))

SigC = 2.8077 MPa

Allowable Longitudinal Shell-Membrane Compression Stress

Fty = 250 MPa

Criteria for Fc

Since [G * H * D^2 / ts1^2] >= 44

Since [1 * 14.787 * 18.1^2 / 9^2] >= 44

Since 59.807 >= 44 Then Fc = 83 * ts1 / D

Fc = 83 * ts1 / D

Fc = 83 * 9 / 18.1

Fc = 41.2707 MPa

SigC <= Fc Then the design is acceptable.

Hoop Stresses

SHELL SUMMARY	SigT+	Sd * 1.333	Fy * 0.9 * E	Allowable Membrane	t-Min	Shell Ok
Shell 1	108.9608	213.28	225	213.28	7.5979	OK
Shell 2	97.78	213.28	225	213.28	7.1261	OK
Shell 3	103.896	213.28	225	213.28	6.4099	OK
Shell 4	90.4293	213.28	225	213.28	5.9679	OK
Shell 5	96.1673	213.28	225	213.28	5.2544	OK
Shell 6	79.2601	213.28	225	213.28	4.8581	OK
Shell 7	62.3142	213.28	225	213.28	4.4608	OK
Shell 8	60.4414	213.28	225	213.28	3.8501	OK
Shell 9	37.7596	213.28	225	213.28	3.5311	OK
Shell 10	15.1178	213.28	225	213.28	3.2126	OK
Shell 11	-7.038345109127055	213.28	225	213.28	2.9009	OK

Mechanically Anchored

Number of anchor = 0

Wab = (1.273 * Mrw) / D^2 - wt * (1 - 0.4 * Av) + wint

Wab = (1.273 * 3,162,448.046) / 18.1^2 - 12,821.9533 * (1 - 0.4 * 0.0311) + 0

Wab = -374.0676 N/m

Pab = Wab * Pi * D / Na

Pab = -374.0676 * 3.1416 * 18.1 / 0

Pab = 0 N

Pa = 3 * Pab
Pa = 3 * 0
Pa = 0 N

Shell Compression in Mechanically-Anchored Tanks

SigC-anchored = [Wt * (1 + (0.4 * Av)) + (1.273 * Mrw) / D^2] * (1 / (1,000 * ts))
SigC-anchored = [12,821.9533 * (1 + (0.4 * 0.0311)) + (1.273 * 3,162,448.046) / 18.1^2] * (1 / (1,000 * 9))
SigC-anchored = 2.8077 MPa

Fc = 41.2707 MPa

Detailing Requirements (Anchorage)

SUG = I
Sds = 0.0667 g or 6.67 %g

Freeboard - Sloshing

TL-sloshing = 4 sec
I-sloshing = 1.0
Tc = 4.4371
k = 1.5
Sd1 = 0.0333 g or 3.33 %g
Af = 0.0101 g per API 650 E.7.2

Delta-s = 0.42 * D * Af
Delta-s = 0.42 * 18.1 * 0.0101
Delta-s = 0.0768 m

0.7 * Delta-s = 0.0537 m

Since Sds < 0.33g and SUG = I per API 650 Table E-7.
a. A freeboard of O.7*Delta-s is recommended for economic considerations but not required.

Sliding Resistance

mu = 0.4 (friction coefficient)
V = 55,399.8782 kgf

Vs = mu * (Ws + Wr + Wf + Wp) * (1 - 0.4 * Av)
Vs = 0.4 * (61,764 + 16,861 + 18,409 + 3,804,759) * (1 - 0.4 * 0.0311)
Vs = 1,541,301.7222 kgf

Since V <= Vs Then the tank will not experience major sliding and does not require additional lateral anchorage, per API 650 E.7.6.

Local Shear Transfer

Vmax = 2 * V / (Pi * D)
Vmax = 2 * 55,399.8782 / (3.1416 * 18.1)
Vmax = 1,948.5446 kgf/m

ANCHOR BOLT DESIGN

Bolt Material : A36M
Sy = 250 MPa

UPLIFT LOAD CASES, PER API-650 TABLE 5-21b

A-s-r = Bolt Root Area Req'd
bt = Uplift load per bolt
D = Tank D (m)
Fp = Pressure Combination Factor
Mrw = Seismic Ringwall Moment (Nm)
N = Anchor bolt quantity
P = Design pressure (pa)
Pf = Failure pressure per F.6 (KPa)
Pt = Test pressure per F.7.6 = 1.25 * P = 0 (pa)
sd = Allowable Anchor Bolt Stress (MPa)
Shell-sd-at-anchor = Allowable Shell Stress at Anchor Attachment (MPa)

t-actual = Actual Roof plate thickness (mm)

t-h = Roof plate thickness less CA (mm)

Vf = Velocity factor (kph)

W1 = Dead Load of Shell minus C.A. and Any Dead Load minus C.A. other than Roof Plate Acting on Shell

W2 = Dead Load of Shell minus C.A. and Any Dead Load minus C.A. including Roof Plate minus C.A. Acting on Shell

W3 = Dead Load of New Shell and Any Dead Load other than Roof Plate Acting on Shell

For Tank with Structural Supported Roof

W1 = W-shell-corroded + Shell Insulation

W1 = 384,892.1321 + 0

W1 = 384,892.1321 N

W2 = W-shell-corroded + Shell Insulation + Corroded Roof Plates Supported by Shell + Roof Dead Load Supported by Shell

W2 = 384,892.1321 + 0 + 103,341.3393 + 0

W2 = 488,233.4714 N

W3 = New Shell + Shell Insulation

W3 = 599,215.464 + 0

W3 = 599,215.464 N

Uplift Case 1: Design Pressure Only

U = [(P - 0.08 * t-h) * D^2 * 785] - W1

U = [(0 - 0.08 * 5) * 18.1^2 * 785] - 384,892.1321

U = -487,761.67217060196 N

bt = U/N

bt = 0 N

sd = 104.1666 MPa

Shell-sd-at-anchor = 166.6666 MPa

A-s-r = N.A., since Load per Bolt is zero

Uplift Case 2: Test Pressure Only

U = [(Pt - 0.08 * t-h) * D^2 * 785] - W1

U = [(0 - 0.08 * 5) * 18.1^2 * 785] - 384,892.1321

U = -487,761.67217060196 N

bt = U/N

bt = 0 N

sd = 138.8888 MPa

Shell-sd-at-anchor = 208.3333 MPa

A-s-r = N.A., since Load per Bolt is zero

Uplift Case 3: Failure Pressure Only

Not applicable since if there is a knuckle on tank roof, or tank roof is not frangible.

Pf (failure pressure per F.6) = N.A.

Uplift Case 4: Wind Load Only

PWR = Wind-Uplift per API 650 Table 5-21a, 5-21b

PWS = Wind-Pressure per API 650 Table 5-21a, 5-21b

PWR = 1.6116 KPa

PWS = 962.4614 N/m^2

MWH = PWS * D * (H^2 / 2) per API 650 Table 5-21a, 5-21b

MWH = 962.4614 * 18.1 * (16.43^2 / 2)

MWH = 2,351,294.7288 Nm

U = PWR * D^2 * 785 + (4 * MWH / D) - W2

U = 1.6116 * 18.1^2 * 785 + (4 * 2,351,294.7288 / 18.1) - 488,233.4714

U = 445,841.646 N

bt = U/N

bt = 0 N

sd = 200 MPa
Shell-sd-at-anchor = 208.3333 MPa

A-s-r = N.A., since Load per Bolt is zero

Uplift Case 5: Seismic Load Only

U = [4 * Mrw / D] - W2 * (1 - 0.4 * Av)
U = [4 * 3,162,448 / 18.1] - 488,233.4714 * (1 - 0.4 * 0.0311)
U = 216,723.6989 N

bt = U/N
bt = 0 N

sd = 200 MPa
Shell-sd-at-anchor = 208.3333 MPa

A-s-r = N.A., since Load per Bolt is zero

Uplift Case 6: Design Pressure + Wind Load

U = [(Fp * P + PWR - 0.08 * t-h) * D^2 * 785] + [4 * MWH / D] - W1
U = [(0.4 * 0 + 1.6116 - 0.08 * 5) * 18.1^2 * 785] + [4 * 2,351,294.7288 / 18.1] - 384,892.1321
U = 446,313.4454 N

bt = U/N
bt = 0 N

sd = 138.8888 MPa
Shell-sd-at-anchor = 208.3333 MPa

A-s-r = N.A., since Load per Bolt is zero

Uplift Case 7: Design Pressure + Seismic Load

U = [(Fp * P - 0.08 * t-h) * D^2 * 785] + [4 * Mrw / D] - W1 * (1 - 0.4 * Av)

U = [(0.4 * 0 - 0.08 * 5) * 18.1^2 * 785] + [4 * 3,162,448 / 18.1] - 384,892.1321 * (1 - 0.4 * 0.0311)
U = 215,909.932 N

bt = U/N
bt = 0 N

sd = 200 MPa
Shell-sd-at-anchor = 208.3333 MPa

A-s-r = N.A., since Load per Bolt is zero

Uplift Case 8: Frangibility Pressure

Not applicable since if there is a knuckle on tank roof, or tank roof is not frangible.
Pf (failure pressure per F.6) = N.A.

ANCHOR BOLT SUMMARY

Bolt Root Area Req'd = 0 mm^2
Bolt Diameter (d) = 56 mm (M56)
Threads per centimeters (n) = 0.1818

A-s = Actual Bolt Root Area
A-s = (pi / 4) * (d - 33.02 / n)^2
A-s = 0.7854 * (56 - 33.02 / 0.1818)^2
A-s = 1874.2177 mm^2

Exclusive of Corrosion
Bolt Diameter Req'd = 6.7477 mm (per ANSI B1.1)
Actual Bolt Diameter = 56 mm (M56)
Bolt Diameter Meets Requirements

ANCHOR CHAIR DESIGN

(from AISI 'Steel Plate Engr Data' Dec. 92, Vol. 2, Part VII)

Entered Parameters

Chair Material : A36M

Top Plate Type : DISCRETE

Chair Style : VERT. TAPERED

Top Plate Width (a) : 254 mm

Top Plate Length (b) : 204 mm

Vertical Plate Width (k) : 127 mm

Top Plate Thickness (c) : 26 mm

Bolt Eccentricity (e) : 102 mm

Outside of Top Plate to Hole Edge (f) : 67 mm

Distance Between Vertical Plates (g) : 108 mm

Chair Height (h) : 712 mm

Vertical Plates Thickness (j) : 26 mm

Bottom Plate thickness (m) : 9 mm

Shell Course + Repad Thickness (t) : 12 mm

Nominal Radius to Tank Centerline (r) : 9056 mm

Design Load per Bolt (P) : 0 N

Bolt Diameter (d) = 56 mm (M56)

Threads per unit length (n) = 0.1818

Bolt Yield Load = A-s * Sy

Bolt Yield Load = 1874.2177 * 250

Bolt Yield Load = 468,554.423 N

Seismic Design Bolt Load (Pa) = 0 N

Anchor Chairs will be designed to withstand

Design Load per Bolt

Anchor Chair Design Load, (P) : 0 N

NORMAL AND EMERGENCY VENTING (API-2000 6th EDITION) Back

NORMAL VENTING

T > 48.9

EMERGENCY VENTING

D (Tank diameter) = 18.1 m

H (Tank height) = 16.43 m

Pg (Design pressure) = 0.0 kPa

inslation_type (Insulation type) = no insulation

vapour_pressure_type (Vapour pressure type) = hexane or similar

As per API-2000 Table 9, Environmental factor for insulation (F_ins) = 1.0

As per API-2000 Table 9, Environmental factor for drainage (F_drain) = 0.5

Environmental factor *API-2000 4.3.3.3.4*

F = MIN(F_ins , F_drain) = MIN(1.0 , 0.5) = 0.5

Wetted surface area

ATWS = pi * D * MIN(H , 9.14) = pi * 18.1 * MIN(16.43 , 9.14) = 519.7262 m^2

Required emergency venting capacity *API-2000 Table 5 and 4.3.3.3.4*

q = 19910 * F = 19910 * 0.5 = 9955.0 m^3/hr

PLAN VIEW APPURTENANCE

MARK	CUST. MARK	DESCRIPTION	OUTSIDE PROJ (mm)	INSIDE PROJ (mm)	ORIENT	RADIUS (mm)	REMARKS	REF DWG
RN01		6" ROOF NOZZLE	203mm	0mm	270	8500mm		RN01
RN02		6" ROOF NOZZLE	203mm	0mm	90	8500mm		RN02
RN02		6" ROOF NOZZLE	203mm	0mm	180	8500mm		RN02
RN02		6" ROOF NOZZLE	203mm	0mm	0'	8500mm		RN02
RV01		24" FREEVENT	248mm	0mm	0'	0mm		RN97

ELEVATION VIEW APPURTENANCE

MARK	CUST. MARK	DESCRIPTION	OUTSIDE PROJ (mm)	INSIDE PROJ (mm)	ORIENT	ELEVATION (mm)	REMARKS	REF DWG
NP01A		STD API	--	--	0'	1016mm		NP01
SN01		6" SHELL NOZZLE	200mm	0mm	0'	16000mm		SN01
SN02		6" SHELL NOZZLE	200mm	0mm	180'	1000mm		SN02

Nozzle Nozzle-0001 Reinforcement Requirements

(Per API-650 and other references below)

NOZZLE Description : 6 in SCH 80 TYPE RFWN

t_rpr = (Re Pad Required Thickness)

t_n = (Thickness of Neck)
Sd_n = (Stress of Neck Material)
Sd_s = (Stress of Roof Material)
CA = (Corrosion Allowance of Neck)

MOUNTED ON ROOF: Elevation = 16.5976 ft

ROOF PARAMETERS:
t-calc = 8 mm
t_cr = 5 mm (Roof t-calc less C.A)
t_c = 8 mm
t_Basis = 5 mm

(FOR ROOF NOZZLE,REF. API-650 FIG 5-19, TABLE 5-14 AND FOOTNOTE A OF TABLE 5-14, or API-650 FIG 5-20, TABLE 5-15 AND FOOTNOTE A OF TABLE 5-15)

Required Area = t_Basis * D
Required Area = 5 * 168.275
Required Area = 841.375 mm^2

Available Roof Area = (t_c - t_Basis) * D
Available Roof Area = (8 - 5) * 168.275
Available Roof Area = 504.825 mm^2

Available Nozzle Neck Area = [4 * (t_n - CA) + t_c] * (t_n - ca) * MIN((Sd_n/Sd_s) 1)
Available Nozzle Neck Area = [4 * (10.9728 - 3) + 8] * (10.9728 - 3) * MIN((103.4213/160) 1)
Available Nozzle Neck Area = 329.2625 mm^2

A-rpr = (Required Area - Available Roof Area - Available Nozzle Neck Area)
A-rpr = 841.375 - 504.825 - 329.2625
A-rpr = 7.2875 mm^2

t_rpr = (A_rpr / D) + repad_CA
t_rpr = (7.2875 / 168.275) + 3
t_rpr = 3.0433 mm

Reinforcement Pad is required.

Based on Roof Nozzle Size of 6 in
Repad Size (OD) Must be 375 mm

Nozzle Nozzle-0002 Reinforcement Requirements

(Per API-650 and other references below)

NOZZLE Description : 6 in SCH 80 TYPE RFSO

t_rpr = (Re Pad Required Thickness)
t_n = (Thickness of Neck)
Sd_n = (Stress of Neck Material)
Sd_s = (Stress of Roof Material)
CA = (Corrosion Allowance of Neck)

MOUNTED ON ROOF: Elevation = 16.5976 ft

ROOF PARAMETERS:
t-calc = 8 mm
t_cr = 5 mm (Roof t-calc less C.A)
t_c = 8 mm
t_Basis = 5 mm

(FOR ROOF NOZZLE,REF. API-650 FIG 5-19, TABLE 5-14 AND FOOTNOTE A OF TABLE 5-14, or API-650 FIG 5-20, TABLE 5-15 AND FOOTNOTE A OF TABLE 5-15)

Required Area = t_Basis * D
Required Area = 5 * 168.275
Required Area = 841.375 mm^2

Available Roof Area = (t_c - t_Basis) * D
Available Roof Area = (8 - 5) * 168.275
Available Roof Area = 504.825 mm^2

Available Nozzle Neck Area = [4 * (t_n - CA) + t_c] * (t_n - ca) * MIN((Sd_n/Sd_s) 1)
Available Nozzle Neck Area = [4 * (10.9728 - 3) + 8] * (10.9728 - 3) * MIN((103.4213/160) 1)
Available Nozzle Neck Area = 329.2625 mm^2

A-rpr = (Required Area - Available Roof Area - Available Nozzle Neck Area)
A-rpr = 841.375 - 504.825 - 329.2625
A-rpr = 7.2875 mm^2

t_rpr = (A_rpr / D) + repad_CA
t_rpr = (7.2875 / 168.275) + 3
t_rpr = 3.0433 mm

Reinforcement Pad is required.
Based on Roof Nozzle Size of 6 in
Repad Size (OD) Must be 375 mm

Nozzle Nozzle-0003 Reinforcement Requirements

(Per API-650 and other references below)

NOZZLE Description : 6 in SCH 80 TYPE RFSO

t_rpr = (Re Pad Required Thickness)
t_n = (Thickness of Neck)
Sd_n = (Stress of Neck Material)
Sd_s = (Stress of Roof Material)
CA = (Corrosion Allowance of Neck)

MOUNTED ON ROOF: Elevation = 16.5976 ft

ROOF PARAMETERS:
t-calc = 8 mm
t_cr = 5 mm (Roof t-calc less C.A)
t_c = 8 mm
t_Basis = 5 mm

(FOR ROOF NOZZLE,REF. API-650 FIG 5-19, TABLE 5-14 AND FOOTNOTE A OF TABLE 5-14, or API-650 FIG 5-20, TABLE 5-15 AND FOOTNOTE A OF TABLE 5-15)

Required Area = t_Basis * D

Required Area = 5 * 168.275

Required Area = 841.375 mm^2

Available Roof Area = (t_c - t_Basis) * D

Available Roof Area = (8 - 5) * 168.275

Available Roof Area = 504.825 mm^2

Available Nozzle Neck Area = [4 * (t_n - CA) + t_c] * (t_n - ca) * MIN((Sd_n/Sd_s) 1)

Available Nozzle Neck Area = [4 * (10.9728 - 3) + 8] * (10.9728 - 3) * MIN((103.4213/160) 1)

Available Nozzle Neck Area = 329.2625 mm^2

A-rpr = (Required Area - Available Roof Area - Available Nozzle Neck Area)

A-rpr = 841.375 - 504.825 - 329.2625

A-rpr = 7.2875 mm^2

t_rpr = (A_rpr / D) + repad_CA

t_rpr = (7.2875 / 168.275) + 3

t_rpr = 3.0433 mm

Reinforcement Pad is required.

Based on Roof Nozzle Size of 6 in

Repad Size (OD) Must be 375 mm

Nozzle Nozzle-0004 Reinforcement Requirements

(Per API-650 and other references below)

NOZZLE Description : 6 in SCH 80 TYPE RFSO

t_rpr = (Re Pad Required Thickness)

t_n = (Thickness of Neck)

Sd_n = (Stress of Neck Material)

Sd_s = (Stress of Roof Material)

CA = (Corrosion Allowance of Neck)

MOUNTED ON ROOF: Elevation = 16.5976 ft

ROOF PARAMETERS:

t-calc = 8 mm

t_cr = 5 mm (Roof t-calc less C.A)

t_c = 8 mm

t_Basis = 5 mm

(FOR ROOF NOZZLE,REF. API-650 FIG 5-19, TABLE 5-14 AND FOOTNOTE A OF TABLE 5-14, or API-650 FIG 5-20, TABLE 5-15 AND FOOTNOTE A OF TABLE 5-15)

Required Area = t_Basis * D

Required Area = 5 * 168.275

Required Area = 841.375 mm^2

Available Roof Area = (t_c - t_Basis) * D

Available Roof Area = (8 - 5) * 168.275

Available Roof Area = 504.825 mm^2

Available Nozzle Neck Area = [4 * (t_n - CA) + t_c] * (t_n - ca) * MIN((Sd_n/Sd_s) 1)

Available Nozzle Neck Area = [4 * (10.9728 - 3) + 8] * (10.9728 - 3) * MIN((103.4213/160) 1)

Available Nozzle Neck Area = 329.2625 mm^2

A-rpr = (Required Area - Available Roof Area - Available Nozzle Neck Area)

A-rpr = 841.375 - 504.825 - 329.2625

A-rpr = 7.2875 mm^2

t_rpr = (A_rpr / D) + repad_CA

t_rpr = (7.2875 / 168.275) + 3

t_rpr = 3.0433 mm

Reinforcement Pad is required.

Based on Roof Nozzle Size of 6 in

Repad Size (OD) Must be 375 mm

Nozzle Nozzle-0005 Reinforcement Requirements

NOZZLE Description : 6 in SCH STD TYPE RFSO

t_rpr = (Re Pad Required Thickness)

t_n = (Thickness of Neck)

Sd_n = (Stress of Neck Material)

Sd_s = (Stress of Shell Course Material)

CA = (Corrosion Allowance of Neck)

MOUNTED ON SHELL 11 : Elevation = 16.0 ft

COURSE PARAMETERS:

t-calc = 6 mm

t_cr = 3 mm (Course t-calc less C.A)

t_c = 3 mm (Course t less C.A.)

t_Basis = 3 mm

(SHELL NOZZLE REF. API-650 TABLE 5-6, TABLE 3-6 AND FOOTNOTE A OF TABLE 5-7)

Required Area = t_Basis * D

Required Area = 3 * 168.275

Required Area = 504.825 mm^2

Available Shell Area = (t_c - t_Basis) * D

Available Shell Area = (3 - 3) * 168.275

Available Shell Area = 0 mm^2

Available Nozzle Neck Area = [4 * (t_n - CA) + t_c] * (t_n - CA) * MIN((Sd_n/Sd_s) 1)

Available Nozzle Neck Area = [4 * (10.97 - 3) + 3] * (10.97 - 3) * MIN((103.4213/160) 1)

Available Nozzle Neck Area = 226.0556 mm^2

A-rpr = (Required Area - Available Shell Area - Available Nozzle Neck Area)

A-rpr = 504.825 - 0 - 226.0556

A-rpr = 278.7694 mm^2

t_rpr = (A_rpr / D) + repad_CA

t_rpr = (278.7694 / 168.275) + 3

t_rpr = 4.6566 mm

Reinforcement Pad is required.

Based on Shell Nozzle Size of 6 in

Repad Size (L x W) Must be 400 x 495 mm

Nozzle Nozzle-0006 Reinforcement Requirements

NOZZLE Description : 6 in SCH STD TYPE RFSO

t_rpr = (Re Pad Required Thickness)

t_n = (Thickness of Neck)

Sd_n = (Stress of Neck Material)

Sd_s = (Stress of Shell Course Material)

CA = (Corrosion Allowance of Neck)

MOUNTED ON SHELL 1 : Elevation = 1.0 ft

COURSE PARAMETERS:

t-calc = 11.0303 mm

t_cr = 8.0303 mm (Course t-calc less C.A)

t_c = 9 mm (Course t less C.A.)

t_Basis = 8.0303 mm

(SHELL NOZZLE REF. API-650 TABLE 5-6, TABLE 3-6 AND FOOTNOTE A OF TABLE 5-7)

Required Area = t_Basis * D

Required Area = 8.0303 * 168.275

Required Area = 1351.303 mm^2

Available Shell Area = (t_c - t_Basis) * D

Available Shell Area = (9 - 8.0303) * 168.275

Available Shell Area = 163.172 mm^2

Available Nozzle Neck Area = [4 * (t_n - CA) + t_c] * (t_n - CA) * MIN((Sd_n/Sd_s) 1)

Available Nozzle Neck Area = [4 * (10.97 - 3) + 9] * (10.97 - 3) * MIN((103.4213/160) 1)

Available Nozzle Neck Area = 349.6958 mm^2

A-rpr = (Required Area - Available Shell Area - Available Nozzle Neck Area)

A-rpr = 1351.303 - 163.172 - 349.6958

A-rpr = 838.4351 mm^2

t_rpr = (A_rpr / D) + repad_CA

t_rpr = (838.4351 / 168.275) + 3

t_rpr = 7.9825 mm

Reinforcement Pad is required.

Based on Shell Nozzle Size of 6 in

Repad Size (L x W) Must be 400 x 495 mm

CAPACITIES and WEIGHTS Back

Maximum Capacity (to Max Liq Level) : 3,804 M^3

Capacity to Top of Shell (to Tank Height) : 4,227 M^3

Working Capacity (to Normal Working Level) : 3,804 M^3

Net working Capacity (Working Capacity - Min Capacity) : 3,804 M^3

Minimum Capacity (to Min Liq Level) : 0 M^3

Component	New Condition (N)	New Condition (Kg)	Corroded (N)	Corroded (Kg)
SHELL	599,216	61,103	384,893	39,249
ROOF	165,347	16,861	103,342	10,538
RAFTERS	43,029	4,388	43,029	4,388
GIRDERS	0	0	0	0
FRAMING	0	0	0	0
COLUMNS	10,975	1,120	10,975	1,120
BOTTOM	180,532	18,410	120,355	12,273
STAIRWAYS	11,641	1,187	11,641	1,187
STIFFENERS	6,631	677	6,631	677
WIND GIRDERS	0	0	0	0
ANCHOR CHAIRS	0	0	0	0
INSULATION	0	0	0	0

TOTAL	1,017,371	103,746	680,866	69,432

Weight of Tank, Empty : 1,017,371 N

Weight of Tank, Full of Product (SG = 1) : 38,329,310.8473 N

Weight of Tank, Full of Water : 38,329,306.6343 N

Net Working Weight, Full of Product : 38,329,306.6343 N

Net Working Weight Full of Water : 38,329,306.6343 N

Foundation Area Req'd : 260.8418 m^2

Foundation Loading, Empty : 3,900.3363 N/m^2

Foundation Loading, Full of Product : 143,044.2924 N/m^2

Foundation Loading, Full of Water : 143,044.2762 N/m^2

SURFACE AREAS

Roof : 268.7642 m^2

Shell : 934.2562 m^2

Bottom : 260.8418 m^2

Wind Moment : 6,103,987.5404 N-m

Seismic Moment : 4,606,608.4266 N-m

MISCELLANEOUS ATTACHED ROOF ITEMS

MISCELLANEOUS ATTACHED SHELL ITEMS

MAWP & MAWV SUMMARY

MAXIMUM CALCULATED INTERNAL PRESSURE

MAWP = 18 kPa or 1,835.658 mmh2o (per API-650 App. F.1.3 & F.7)

MAWP = 17.1538 kPa or 1,749.3617 mmh2o (due to shell)

MAWP = 3.004 kPa or 306.3509 mmh2o (due to roof)

TANK MAWP = 3.004 kPa or 306.3477 mmh2o

MAXIMUM CALCULATED EXTERNAL PRESSURE

MAWV = -6.9 kPa or -703.6689 mmh2o (per API-650 V.1)

MAWV = N/A (due to shell) (API-650 App.V not applicable)

MAWV = -1.2306 kPa or -125.4978 mmh2o (due to roof)

TANK MAWV = -1.2306 kPa or -125.493

AME Report of HSD

TABLE OF CONTENTS

SUMMARY OF DESIGN DATA AND REMARKS Back

Job : 2024-2-20-13-27

Date of Calcs. : 20-Feb-2024

Mfg. or Insp. Date :

Designer : Hp

Project :

Tag Number :

Plant : PURCHASER DESCRIPTION CITY AND STATE

Plant Location :

Site :

Design Basis : API-650 12th Edition, March 2013

TANK NAMEPLATE INFORMATION

Pressure Combination Factor	0.4
Design Standard	API-650 12th Edition, March 2013
Appendices Used	E
Roof	A36M : 8 mm
Shell (1)	A36M : 12 mm
Shell (2)	A36M : 12 mm
Shell (3)	A36M : 10 mm
Shell (4)	A36M : 10 mm
Shell (5)	A36M : 8 mm
Shell (6)	A36M : 8 mm
Shell (7)	A36M : 6 mm
Shell (8)	A36M : 6 mm
Shell (9)	A36M : 6 mm
Shell (10)	A36M : 6 mm
Bottom	A36M : 9 mm

Design Internal Pressure = 0 KPa or 0 mmh2o
Design External Pressure = -0 KPa or -0 mmh2o

MAWP = 3.0039 KPa or 306.3477 mmh2o
MAWV = -1.2306 KPa or -125.493 mmh2o

D of Tank = 18.1 m
OD of Tank = 18.124 m
ID of Tank = 18.1 m
CL of Tank = 18.112 m
Shell Height = 14.47 m
S.G of Contents = 1
Max Liq. Level = 14.47 m
Min Liq. Level = 0 m
Design Temperature = 50 ºC
Tank Joint Efficiency = 1
Ground Snow Load = 0 KPa
Roof Live Load = 1 KPa
Additional Roof Dead Load = 0 KPa
Basic Wind Velocity = 201 kph
Wind Importance Factor = 1

Using Seismic Method: API-650 - ASCE7 Mapped(Ss & S1)

DESIGNER REMARKS

Remarks or Comments

SUMMARY OF SHELL RESULTS

Shell #	Width (mm)	Material	CA (mm)	JE	Min Yield Strength (MPa)	Tensile Strength (MPa)	Sd (MPa)	St (MPa)	Weight (N)	Weight CA (N)	t-min Erection (mm)	t-Des (mm)	t-Test (mm)	t-min Seism (mm	t min Ext P (mm)	t-min (mm)	t-Actual (mm)	Status
1	1500	A36M	3	1	250	400	160	171	78,658	59,003	6	10.8546	7.3493	7.4982	NA	10.8546	12	OK
2	1500	A36M	3	1	250	400	160	171	78,658	59,003	6	10.0231	6.5714	7.0263	NA	10.0231	12	OK
3	1500	A36M	3	1	250	400	160	171	65,555	45,896	6	9.1917	5.7934	6.3166	NA	9.1917	10	OK
4	1500	A36M	3	1	250	400	160	171	65,555	45,896	6	8.3602	5.0154	5.8744	NA	8.3602	10	OK
5	1500	A36M	3	1	250	400	160	171	52,450	32,787	6	7.5287	4.2374	5.1708	NA	7.5287	8	OK
6	1500	A36M	3	1	250	400	160	171	52,450	32,787	6	6.6973	3.4594	4.7742	NA	6.6973	8	OK
7	1500	A36M	3	1	250	400	160	171	39,342	19,674	6	5.8658	2.6814	4.1014	NA	6	6	OK
8	1500	A36M	3	1	250	400	160	171	39,342	19,674	6	5.0343	1.9035	3.7828	NA	6	6	OK
9	1500	A36M	3	1	250	400	160	171	39,342	19,674	6	4.2029	1.1255	3.4637	NA	6	6	OK
10	890	A36M	3	1	250	400	160	171	23,343	11,673	6	3.3714	0.3475	3.1459	NA	6	6	OK

Total Weight of Shell = 534,699.9264 N

CONE ROOF

Plates Material = A36M

Structural Material = A36M

t.required = 8 mm

t.actual = 8 mm

Roof corrosion allowance = 3 mm

Roof Joint Efficiency = 1

Plates Overlap Weight = 5,929.895 N

Plates Weight = 165,346.1429 N

RAFTERS:

Qty	At Radius (m)	Size	Length (m)	W (N/m)	Ind. Weight (N)	Total Weight (N)
28	9.05	W10X12	8.7749	175.1268	1,536.7375	43,028.6521

Rafters Total Weight = 43,028.6521 N

COLUMNS:

Qty	At Radius (m)	Size	Length (m)	W (N/m)	Ind. Weight (N)	Total Weight (N)
1	0	10" SCH STD	16.5979	591.3562	9,815.317	9,815.317

Columns Total Weight = 9,815.317 N

Bottom Type : Flat Bottom Non Annular

Bottom Material = A36M
t.required = 9 mm
t.actual = 9 mm
Bottom corrosion allowance = 3 mm
Bottom Joint Efficiency = 1
Total Weight of Bottom = 180,531.2287 N

TOP END STIFFENER : Detail D

Size = l80x80x10
Material = A36M
Weight = 6,630.4943 N

STRUCTURALLY SUPPORTED CONICAL ROOF Back

A = Actual Part. Area of Roof-to-shell Juncture per API-650 (cm^2)

A-min = Minimum participating area (cm^2) per API-650 5.10.5.2

a-min-A = Minimum participating area due to full design pressure per API-650 F.5.1 (cm^2)

a-min-Roof = Minimum participating area per API-650 App. F.5.2 (cm^2)

Add-DL = Added Dead load (kPa)

Alpha = 1/2 the included apex angle of cone (degrees)

Aroof = Contributing Area due to roof plates (cm^2)

Ashell = Contributing Area due to shell plates (cm^2)

CA = Roof corrosion allowance (mm)

D = Tank Nominal Diameter per API-650 5.6.1.1 Note 1 (m)

density = Density of roof (kg/mm3)

DL = Dead load (kPa)

e.1b = Gravity Roof Load (1) - Balanced (kPa)

e.1u = Gravity Roof Load (1) - Unbalanced (kPa)

e.2b = Gravity Roof Load (2) - Balanced (kPa)

e.2u = Gravity Roof Load (2) - Unbalanced (kPa)

Fp = Pressure Combination Factor

Fy = smallest of the yield strength (MPa)

Fy-roof = Minimum yield strength for shell material (Table 5-2a) (MPa)

Fy-shell = Minimum yield strength for shell material (Table 5-2a) (MPa)

Fy-stiff = Minimum yield strength for stiffener material (Table 5-2a) (MPa)

hr = Roof height (m)

ID = Tank Inner Diameter (m)

Insulation = Roof Insulation (m)

JEr = Roof joint efficiency

Lr = Entered Roof Live Load (kPa)

Lr-1 = Computed Roof Live Load, including External Pressure

Max-p = Max Roof Load due to participating Area (kPa)

Net-Uplift = Uplift due to internal pressure minus nominal weight of shell, roof and attached framing (N), per API-650 F.1.2

P = Minimum participating area (kPa)

P-ext-2 = Max external pressure due to roof shell joint area (kPa)

P-F51 = Max design pressure reversing a-min-A calculation (kPa)

P-max-ext-T = Total max external pressure due to roof actual thickness and roof participating area (kPa)

P-max-internal = Maximum design pressure and test procedure per API-650 F.4, F.5. (kPa)

P-Std = Max pressure pressure allowed per API-650 App. F.1 & F.7 (kPa)

P-Uplift = Uplift case per API-650 1.1.1 (N)

P-weight = Dead load of roof plate (kPa)

Pe = External Pressure (kPa)

pt = Roof cone pitch (mm) rise per 12 (mm)

Pv = Internal Pressure (kPa)

R = Roof horizontal radius (m)

Ra = Roof surface area (cm^2)

Roof-wc = Weight corroded of roof plates (N)

S = Ground Snow Load per ASCE 7-05 Fig 7-1 (kPa)

Sb = Balanced Design Snow Load per API-650 Section 5.2.1.h.1 (kPa)

Shell-wc = Weight corroded of shell (N)

Su = Unbalanced Design Snow Load per API-650 Section 5.2.1.h.2 (kPa)

T = Balanced Roof Design Load per API-650 Appendix R (kPa)

t-calc = Minimum nominal roof plates thickness per API-650 Section 5.10.5.1 (mm)

t-Ins = thickness of Roof Insulation (m)

Theta = Angle of cone to the horizontal (degrees)

U = Unbalanced Roof Design Load per API-650 Appendix R (kPa)

Wc = Maximum width of participating shell per API-650 Fig. F-2 (mm)

Wh = Maximum width of participating roof per API-650 Fig. F-2 (mm)

Roof Design Per API-650

Note: Tank Pressure Combination Factor Fp = 0.4

D = 18.1 m

ID = 18.1 m

CA = 3 mm

R = 9.0725 m

Fp = 0.4

JEr = 1

JEs = 1

JEst = 1

Insulation = 0 m

Add-DL = 0 kPa

Lr = 1 kPa

S = 0 kPa

Sb = 0 kPa

Su = 0 kPa

density = 0.000007841 kg/mm3

P-weight = 0.6426 KPa

Pe = 0 kPa

pt = 3.4 mm rise per 12 mm

t-actual = 8 mm

Fy-roof = 250 MPa

Fy-shell = 250 MPa

Fy-stiff = 250 MPa

Shell-wc = 346,071.6058 N

Roof-wc = 103,341.3393 N

P-Std = 18 kPa, Per API-650 F.1.3

t-1 = 6 mm

CA-1 = 3 mm

Sd = 160 MPa

Theta = TAN^-1 (pt/12)

Theta = TAN^-1 (3.4/12)

Theta = 15.8192 degrees

Alpha = 90 - Theta

Alpha = 90 - 15.8192

Alpha = 74.1808 degrees

Ap-Vert = D^2 * TAN(Theta)/4

Ap-Vert = 18.1^2 * TAN(15.8192)/4

Ap-Vert = 23.2057 m^2

Horizontal Projected Area of Roof per API-650 5.2.1.f

Xw = D * 0.5

Xw = 18.1 * 0.5

Xw = 9.05 m

Ap = PI * (D/2)^2

Ap = PI * (18.1/2)^2

Ap = 257.3042 m^2

DL = Insulation + P-weight + Add-DL

DL = 0 + 0.6426 + 0

DL = 0.6426 kPa

Roof Loads per API-650 5.2.2

e.1b = DL + MAX(Sb , Lr) + (0.4 * Pe)

e.1b = 0.6426 + MAX(0 , 1) + (0.4 * 0)

e.1b = 1.6426 kPa

e.2b = DL + Pe + (0.4 * MAX(Sb , Lr))

e.2b = 0.6426 + 0 + (0.4 * MAX(0 , 1))

e.2b = 1.0426 kPa

T = MAX(e.1b , e.2b)

T = MAX(1.6426 , 1.0426)

T = 1.6426 kPa

e.1u = DL + MAX(Su , Lr) + (0.4 * Pe)

e.1u = 0.6426 + MAX(0 , 1) + (0.4 * 0)

e.1u = 1.6426 kPa

e.2u = DL + Pe + (0.4 * MAX(Su , Lr))

e.2u = 0.6426 + 0 + (0.4 * MAX(0 , 1))

e.2u = 1.0426 kPa

U = MAX(e.1u , e.2u)

U = MAX(1.6426 , 1.0426)

U = 1.6426 kPa

Lr-1 = MAX(T , U)

Lr-1 = MAX(1.6426 , 1.6426)

Lr-1 = 1.6426 kPa

Ra = PI * R * SQRT(R^2 + hr^2)

Ra = PI * 9.0725 * SQRT(9.0725^2 + 2.5705^2)

Ra = 2,687,642.7946 cm^2 or 268.7643 m^2

Roof Plates Weight = density * Ra * t-actual

Roof Plates Weight = 0.000007841 * 2,687,642.7946 * 8

Roof plates Weight = 165,346.1429 N

BAY 1 DETAILS

MINIMUM # OF RAFTERS

l = Maximum rafter spacing per API-650 5.10.4.4 (mm)

l-actual-1 = Actual rafter spacing (mm)

Max-T1-1 = Due to roof thickness (kPa)

N-actual-1 = Actual number of rafter

N-min-1 = Minimum number of rafter

P = Uniform pressure as determined from load combinations described in Appendix R (kPa)

P-ext-1-1 = Due to roof thickness vacuum limited by actual rafter spacing (kPa)

R-1 = Outer radius (mm)

RLoad-Max-1 = Maximun roof load based on actual rafter spacing (kPa)

t-calc-1 = Minimum roof thickness based on actual rafter spacing (mm)

FOR OUTER SHELL RING

P = Lr-1

P = 1.6426 kPa

R-1 = 9050 mm

l = MIN(((t-Roof - CA-Roof) * SQRT((1.5 * Fy-Roof)/P)) , 2100.0)

l = MIN(((8 - 3) * SQRT((1.5 * 250) / 1.6426)) , 2100)

l = MIN(2389.0129 , 2100)

l = 2100 mm

N-min-1 = (2 * PI * R-1)/l

N-min-1 = (2 * PI * 9050)/2100

N-min-1 = 28

N-min-1 must be a multiple of 1, therefore N-min-1 = 28.

N-actual-1 = 28

l-actual-1 = (2 * PI * R-1)/N-actual-1

l-actual-1 = (2 * PI * 9050)/28

l-actual-1 = 2030.8153 mm

Minimum roof thickness based on actual rafter spacing

t-calc-1 = l-actual-1/SQRT((1.5 * Fy-Roof)/P) + CA-Roof

t-calc-1 = 2030.8153/SQRT((1.5 * 250)/1.6426) + 3

t-calc-1 = 7.2503 mm

NOTE: Governs for roof plate thickness.

RLoad-Max-1 = (1.5 * Fy-Roof)/(l-actual-1/(t-Roof - CA-Roof))^2

RLoad-Max-1 = (1.5 * 250)/(2030.8153/(8 - 3))^2

RLoad-Max-1 = 2.2732 kPa

Max-T1-1 = RLoad-Max-1

Max-T1-1 = 2.2732 kPa

P-ext-1-1 = Max-T1-1 - DL - (0.4 * MAX(Sb , Lr))

P-ext-1-1 = 2.2732 - 0.6426 - (0.4 * MAX(0 , 1))

P-ext-1-1 = -1.2306 kPa

Pa-rafter-3-1 = P-ext-1-1

Pa-rafter-3-1 = -1.2306 kPa

t-required-1 = MAX(7.2503 , (5 + 3))

t-required-1 = 8 mm

RAFTER DESIGN

Average-p-width-1 = Average plate width (m)

Average-r-s-inner-1 = Average rafter spacing on inner girder (m)

Average-r-s-shell-1 = Average rafter spacing on shell (m)

Max-P-1 = Load allowed for each rafter in ring (MPa)

Max-r-span-1 = Maximum rafter span (m)

Max-T1-rafter-1 = Due to roof thickness (kPa)

Mmax-rafter-1 = Maximum moment bending (mm-kg)

P = Uniform pressure as determined from load combinations described in Appendix R (kPa)

P-ext-2-1 = Vacuum limited by rafter type (kPa)

R-1 = Outer radius (mm)

R-Inner-1 = Inner radius (m)

Rafter-Weight-1 = (Kg/m)

Sx-rafter-actual-1 = Actual elastic section modulus about the x axis (cm^3)

Sx-rafter-Req'd-1 = Required elastic section modulus about the x axis (cm^3)

Theta = Angle of cone to the horizontal (degrees)

W-Max-rafter-1 = Maximum stress allowed for each rafter in ring (N/mm)

W-rafter-1 = (kg/m)

SPAN TO SHELL

P = 1.6426 kPa

Rafter-Weight-1 = 17.858 Kg/m

Theta = 15.8192 degrees

R-1 = 9127 mm

R-Inner1 = 564.5 mm

Max-r-span-1 = (R-1 - R-Inner-1)/COS(Theta)

Max-r-span-1 = (9127 - 564.5)/COS(15.8192)

Max-r-span-1 = 8.775 m

Average-r-s-inner-1 = (2 * PI * R-Inner-1)/N-actual-1

Average-r-s-inner-1 = (2 * PI * 564.5)/28

Average-r-s-inner-1 = 0.1267 m

Average-r-s-shell-1 = (2 * PI * R-1)/N-actual-1

Average-r-s-shell-1 = (2 * PI * 9127)/28

Average-r-s-shell-1 = 2.0481 m

Average-p-width-1 = (Average-r-s-inner-1 + Average-r-s-shell-1)/2

Average-p-width-1 = (0.1267 + 2.0481)/2

Average-p-width-1 = 1.0874 m

W-rafter-1 = (P * Average-p-width-1) + Rafter-Weight-1

W-rafter-1 = (167.5461 * 1.0874) + 17.858

W-rafter-1 = 199.9942 Kgf/m

Mmax-rafter-1 = (W-rafter-1 * Max-r-span-1^2)/8

Mmax-rafter-1 = (199.9942 * 8.775^2)/8

Mmax-rafter-1 = 1,924,959 mm-kgf

Sx-rafter-Req'd-1 = Mmax-rafter-1/Sd

Sx-rafter-Req'd-1 = 1,924,959/160

Sx-rafter-Req'd-1 = 117.9837 cm^3

Sx-actual-1 = 178.619 cm^3

W-Max-rafter-1 = (Sx-rafter-actual-1 * Sd * 8)/Max-r-span-1^2)

W-Max-rafter-1 = (178.619 * 160 * 8)/8.775^2)

W-Max-rafter-1 = 2.9692 N/mm

Max-P-1 = (W-Max-rafter-1 - Rafter-Weight-1)/Average-p-width-1

Max-P-1 = 0.0027 MPa

Max-T1-rafter-1 = Max-P-1

Max-T1-rafter-1 = 2.7 kPa

P-ext-2-1 = Max-T1-rafter-1 - DL - (Fp * MAX(S , Lr))

P-ext-2-1 = 2.7 - 0.6426 - (0.4 * MAX(0 , 1))

P-ext-2-1 = -1.6716 kPa

P2-rafter-3-1 = P-ext-2-1

P2-rafter-3-1 = -1.6716 kPa

Limited by rafter type

CENTER COLUMN

A-actual-1 = Actual area of column (mm^2)

A-req-1 = Required area of column (mm^2)

C-length-1 = Column length (mm)

E-c = Modulus of elasticity of the column material (MPa)

Fa-1 = Allowable compressive stress per API-650 5.10.3.4 (MPa)

Fy-c = Allowable design stress (MPa)

Max-P-column-1 = Maximum Load allowed for each column in ring (MPa)

Max-T1-column-1 = Due to roof thickness (kPa)

P-c-1 = Total roof load supported by each column (N)

P-ext-3-1 = Vacuum limited by column type (kPa)

Pa-column-3-1 = Vacuum limited by column type (kPa)

Pa-column-3-1 = Vacuum limited by column type (kPa)

R-c-1 = Per API-650 5.10.3.3

Radius-Gyr-1 = Radius of gyration

Radius-Gyr-req-1 = Radius of gyration required

W-column-1 = Total weight of column (N)

W-Max-column-1 = Maximum weight allowed for each column in ring (N)

W-column-1 = 9,815.317 N

Fy-c = 241.3165 MPa

E-c = 197,190.0782 MPa

A-actual-1 = 76.8275 cm^2

C-length-1 = 16.5979 m

Radius-Gyr-1 = 93.26 mm

If C-length-1/Radius-Gyr-1 must be less than 180, then

Radius-Gyr-req-1 = C-length-1/180

Radius-Gyr-req-1 = 16.5979/180

Radius-Gyr-req-1 = 92.211 mm

Per API-650 5.10.3.3

R-c-1 = C-length-1/Radius-Gyr-1

R-c-1 = 16.5979/93.26

R-c-1 = 177.9754

Rafter-L-1 = (- R-1 - R-Inner1)/COS(Theta)

Rafter-L-1 = (- 9050 - 0)/COS(15.8192)

Rafter-L-1 = 8774.9969 mm

P-c-1 = W-column-1 + (Rafter-L-1 * W-rafter-1 * N-actual-1)/2

P-c-1 = 9,815.317 + (8774.9969 * 199.9942 * 28)/2

P-c-1 = 250,757.6914 N

Since R-c-1 > 120, using API-650 Formulas in 5.10.3.4

Fa-1 = (/ (* 12 (EXPT PI 2) E-c) (* 23 (EXPT R-c-1 2)))

Fa-1 = (/ (* 12 (EXPT PI 2) 197,190.0782) (* 23 (EXPT 177.9754 2)))

Per API-650 M.3.5

Fa is not modified Since Design Temp. <= 93.3333 ºC.

(API-650 M.3.5 N.A.)

Fa-1 = 45.1424 MPa

A-req-1 = P-c-1/Fa-1

A-req-1 = 250,757.6914/45.1424

A-req-1 = 5554.814 mm^2

W-Max-column-1 = (Fa-1 * A-actual-1) - W-column-1

W-Max-column-1 = (45.1424 * 76.8275) - 9,815.317

W-Max-column-1 = 345,816.9452 N

Max-P-column-1 = ((W-Max-column-1/((Rafter-L-1 * N-actual-1)/2)) - Rafter-Weight-1)/(AVERAGE Average-r-s-inner-1 , Average-r-s-shell-1)

Max-P-column-1 = ((345,816.9452/((8774.9969 * 28)/2)) - 17.858)/(AVERAGE 0 , 2.0308)

Max-P-column-1 = 0.0026 MPa

Max-T1-column-1 = Max-P-column-1

Max-T1-column-1 = 2.6 kPa

P-ext-3-1 = Max-T1-column-1 - DL - (Fp * MAX(S , Lr))

P-ext-3-1 = 2.6 - 0.6426 - (0.4 * MAX(0 , 1))

P-ext-3-1 = -1.5297 kPa

Pa-column-3-1 = P-ext-3-1

Pa-column-3-1 = -1.5297 kPa

Limited by column type

P-max-ext-T = MAX(P-ext-1-1 , P-ext-2-1 , P-ext-3-1)

P-max-ext-T = MAX(-1.2306 , -1.6716 , -1.5297)

P-max-ext-T = -1.2306 kPa

TOP MEMBER DESIGN

CA_roof (Thickness of roof plate) = 3 mm

CA_shell (Thickness of shell plate) = 3 mm

D (Shell nominal diameter) = 18.112 m

ID (Shell inside diameter) = 18.1 m

Theta angle (Angle between the roof and a horizontal plane at the roof-to-shell junction) = 15.8192 deg

tc (Thickness of shell plate) = 6 mm

th (Thickness of roof plate) = 8 mm

Shell inside radius

Rc = ID / 2 = 18100.0 / 2 = 9050.0 mm

Shell nominal diameter (D) = 18.112 m

Length of normal to roof

R2 = Rc / SIN(Theta angle) = 9050.0 / SIN(15.8192) = 33198.5128 mm

Thickness of corroded roof plate

th_corroded = th - CA_roof = 8 - 3 = 5 mm

Thickness of corroded shell plate

tc_corroded = tc - CA_shell = 6 - 3 = 3 mm

CA_stiff > 0

Note: The calculation does not take into account the stiffener corrosion allowance, make sure to pick a stiffener size that make up the difference in the thicknesses (corroded vs nominal).

Maximum width of participating roof *API-650 Figure F-2*

Wh = MIN((0.3 * SQRT((R2 * th_corroded))) , 300)
   = MIN((0.3 * SQRT((33198.5128 * 5))) , 300)
   = 122.2266 mm

Maximum width of participating shell *API-650 Figure F-2*
Wc = 0.6 * SQRT((Rc * tc_corroded)) = 0.6 * SQRT((9050.0 * 3)) = 98.8635 mm

Nominal weight of shell plates and framing
DLS = Ws + W_framing = 534699.9265 + 27996.0983 = 562696.0248 N

Nominal weight of roof plates and attached structural
DLR = Wr + W_structural = 165346.1429 + 2254.7422 = 167600.8851 N

Compression Ring Detail d Properties

ID (Shell inside diameter) = 18.1 m
Size (Compression ring size) = l80x80x10
Wc (Length of contributing shell) = 98.8635 mm
Wh (Length of contributing roof) = 122.2266 mm
tc (Thickness of shell plate) = 3 mm
th (Thickness of roof plate) = 5 mm

Angle vertical leg size (l_vert) = 80 mm
Angle horizontal leg size (l_horz) = 80 mm
Angle thickness (t_angle) = 10.0 mm
Angle area (A_angle) = 1510.0 mm^2
Angle centroid (c_angle) = 23.4 mm
Angle moment of inertia (I_angle) = 875000.0 mm^4

Length of contributing shell reduced
wc_reduced = Wc - l_vert = 98.8635 - 80 = 18.8635 mm

Contributing shell moment of inertia
I_shell = (wc_reduced * (tc_corroded^3)) / 12
        = (18.8635 * (3^3)) / 12
        = 42.443 mm^4

Contributing shell area

A_shell = wc_reduced * tc_corroded = 18.8635 * 3 = 56.5906 mm^2

Contributing roof area

A_roof = Wh * th_corroded = 122.2266 * 5 = 611.1328 mm^2

Detail total area

A_detail = A_shell + A_roof + A_angle

= 56.5906 + 611.1328 + 1510.0

= 2177.7234 mm^2

Find combined moment of inertia about shell inside axis with negative value toward center

Description	Variable	Equation	Value	Unit
Shell centroid	d_shell	tc_corroded / 2	1.5000	mm
Stiffener centroid	d_stiff	(the-reference (current-object) '(superior angle-centroid) t t t nil 'default-the-error nil)	23.4000	mm
moment of inertia of first body	I_1	I_angle + (A_angle * (d_stiff^2))	1701815.6000	mm^4
moment of inertia of second body	I_2	I_shell + (A_shell * (d_shell^2))	169.7719	mm^4
Total area	A_sum	A_angle + A_shell	1566.5906	mm^2
Sum of moments of inertia's	I_sum	I_1 + I_2	1701985.3719	mm^4
Combined centroid	c_combined	((d_stiff * A_angle) + (d_shell * A_shell)) / (A_angle + A_shell)	22.6089	mm
Combined moment of inertia	I_combined	I_sum - (A_sum * (c_combined^2))	901203.4320	mm^4
Distance from neutral axis to edge 1 (inside)	e1	l_horz - c_combined	57.3911	mm

Distance from neutral axis to edge 2 (outside)	e2	l_horz - e1	22.6089	mm
Combined stiffener shell section modulus	S	I_combined / MAX(e1 , e2)	15702.8421	mm^3

Roof Design Requirements

Appendix F Requirements

A_actual (Area resisting compressive force) = 2177.7234 mm^2

D (Tank nominal diameter) = 18.112 m

DLR (Nominal weight of roof plates and attached structural) = 167600.8851 N

DLS (Nominal weight of shell plates and framing) = 562696.0248 N

Fy (Minimum specified yield-strength of the materials in the roof-to-shell junction) = 250 MPa

ID (Tank inside diameter) = 18.1 m

Mw (Wind moment) = 5.5764583523E6 N.m

P (Design pressure) = 0.0 kPa

Theta angle (Angle between the roof and a horizontal plane at the roof-to-shell junction) = 15.8192 deg

W_framing (Weight of framing supported by the shell and roof) = 27996.0983 N

W_structural (Weight of roof attached structural) = 2254.7422 N

Wr (Roof plates weight) = 165346.1429 N

Ws (Shell plates weight) = 534699.9265 N

Uplift due to internal pressure *API-650 F.1.2*

P_uplift = P * pi * ((ID^2) / 4) = 0.0 * pi * ((18.1^2) / 4) = 0.0 N

Tank design does not have to meet App. F requirements.

Maximum allowable internal pressure for the actual resisting area *API 650 F.5.1*

P_F51 = ((Fy * TAN(Theta angle) * A_actual) / (200 * (D^2))) + ((0.00127 * DLR) / (D^2))

= ((250 * TAN(15.8192) * 2177.7234) / (200 * (18.112^2))) + ((0.00127 * 167600.8851) / (18.112^2))

= 3.0 kPa

Maximum allowable internal pressure

P_max_internal = MIN(P_std , P_F51) = MIN(18 , 3.0) = 3.0 kPa

SUMMARY OF ROOF RESULTS Back

Material = A36M

Structural Material = A36M

t-actual = 8 mm

t-required = 8 mm

t-calc = 7.2503 mm

P-Max-Internal = 3 kPa

P-Max-External = -1.2306 kPa

Roof Plates Weight = 165,346.1429 N

Weight of Rafters = 43,028.6521 N

Weight of Girders = 0 N

Weight of Columns = 9,815.317 N

SHELL COURSE DESIGN (Bottom course is #1) Back

API-650 ONE FOOT METHOD

D = Tank Nominal diameter (m) per API-650 5.6.1.1 Note 1

H = Max liquid level (m)

I-p = Design internal pressure (kPa)

L = Factor

I-p = 0 kPa

D = 18.1 m

H = 14.47 m

L = (500 * D (t-1 - Ca-1))^0.5

L = (500 * 18.1 (12 - 3))^0.5 = 285.3945

Course # 1

Ca-1 = Corrosion allowance per API-650 5.3.2 (mm)

G = Design specific gravity of the liquid to be stored

H' = Effective liquid head at design pressure (m)

hmax-1 = Max liquid level based on shell thickness (m)

JE = Joint efficiency

pmax-1 = Max pressure at design (kPa)

pmax-int-shell-1 = Max internal pressure at design (kPa)

Sd = Allowable design stress for the design condition per API-650 Table 5-2b (MPa)

St = Allowable stress for the hydrostatic test condition per API-650 5.6.2.2 (MPa)

t-1 = Shell actual thickness (mm)

t-calc-1 = Shell thickness design condition td (mm)

t-seismic-1 = See E.6.2.4 table in SEISMIC calculations.

t-test-1 = Shell thickness hydrostatic test condition (mm)

Material = A36M

Width = 1.5 m

Ca-1 = 3 mm

JE = 1

t-1 = 12 mm

Sd = 160 MPa

St = 171 MPa

Design Condition G = 1 (per API-650)

H' = H

H' = 14.47

H' = 14.47 m

t-calc-1 = (4.9 * D * (H' - 0.3) * G)/Sd + Ca-1 (per API-650 5.6.3.2)

t-calc-1 = (4.9 * 18.1 * (14.47 - 0.3) * 1)/160 + 3

t-calc-1 = 10.8546 mm

hmax-1 = Sd * (t-1 - CA-1)/(2.6 * D * G) + 1

hmax-1 = 160 * (12 - 3)/(2.6 * 18.1 * 1) + 1

hmax-1 = 16.5374 m

pmax-1 = (hmax-1 - H) * 9.8 * G

pmax-1 = (16.5374 - 14.47) * 9.8 * 1

pmax-1 = 20.2604 kPa

pmax-int-shell-1 = pmax-1

pmax-int-shell-1 = 20.2604 kPa

Hydrostatic Test Condition G = 1

H' = H

H' = 14.47

H' = 14.47 m

t-test-1 = (* 4.9 D (H' - 0.3))/St

t-test-1 = (* 4.9 18.1 (14.47 - 0.3))/171

t-test-1 = 7.3493 mm

Course # 2

Ca-2 = Corrosion allowance per API-650 5.3.2 (mm)

G = Design specific gravity of the liquid to be stored

H' = Effective liquid head at design pressure (m)

hmax-2 = Max liquid level based on shell thickness (m)

JE = Joint efficiency

pmax-2 = Max pressure at design (kPa)

pmax-int-shell-2 = Max internal pressure at design (kPa)

Sd = Allowable design stress for the design condition per API-650 Table 5-2b (MPa)

St = Allowable stress for the hydrostatic test condition per API-650 5.6.2.2 (MPa)

t-2 = Shell actual thickness (mm)

t-calc-2 = Shell thickness design condition td (mm)

t-seismic-2 = See E.6.2.4 table in SEISMIC calculations.

t-test-2 = Shell thickness hydrostatic test condition (mm)

Material = A36M

Width = 1.5 m

Ca-2 = 3 mm

JE = 1

t-2 = 12 mm

Sd = 160 MPa

St = 171 MPa

Design Condition G = 1 (per API-650)

H' = H

H' = 12.97

H' = 12.97 m

t-calc-2 = (4.9 * D * (H' - 0.3) * G)/Sd + Ca-2 (per API-650 5.6.3.2)

t-calc-2 = (4.9 * 18.1 * (12.97 - 0.3) * 1)/160 + 3

t-calc-2 = 10.0231 mm

hmax-2 = Sd * (t-2 - CA-2)/(2.6 * D * G) + 1

hmax-2 = 160 * (12 - 3)/(2.6 * 18.1 * 1) + 1

hmax-2 = 16.5374 m

pmax-2 = (hmax-2 - H) * 9.8 * G

pmax-2 = (16.5374 - 12.97) * 9.8 * 1

pmax-2 = 34.9604 kPa

pmax-int-shell-2 = MIN(pmax-int-shell-1 pmax-2)

pmax-int-shell-2 = MIN(20.2604 34.9604)

pmax-int-shell-2 = 20.2604 kPa

Hydrostatic Test Condition G = 1

H' = H

H' = 12.97

H' = 12.97 m

t-test-2 = (* 4.9 D (H' - 0.3))/St

t-test-2 = (* 4.9 18.1 (12.97 - 0.3))/171

t-test-2 = 6.5714 mm

Course # 3

Ca-3 = Corrosion allowance per API-650 5.3.2 (mm)
G = Design specific gravity of the liquid to be stored
H' = Effective liquid head at design pressure (m)
hmax-3 = Max liquid level based on shell thickness (m)
JE = Joint efficiency
pmax-3 = Max pressure at design (kPa)
pmax-int-shell-3 = Max internal pressure at design (kPa)
Sd = Allowable design stress for the design condition per API-650 Table 5-2b (MPa)
St = Allowable stress for the hydrostatic test condition per API-650 5.6.2.2 (MPa)
t-3 = Shell actual thickness (mm)
t-calc-3 = Shell thickness design condition td (mm)
t-seismic-3 = See E.6.2.4 table in SEISMIC calculations.
t-test-3 = Shell thickness hydrostatic test condition (mm)

Material = A36M
Width = 1.5 m
Ca-3 = 3 mm
JE = 1
t-3 = 10 mm
Sd = 160 MPa
St = 171 MPa

Design Condition G = 1 (per API-650)

H' = H
H' = 11.47
H' = 11.47 m

t-calc-3 = (4.9 * D * (H' - 0.3) * G)/Sd + Ca-3 (per API-650 5.6.3.2)
t-calc-3 = (4.9 * 18.1 * (11.47 - 0.3) * 1)/160 + 3
t-calc-3 = 9.1917 mm

hmax-3 = Sd * (t-3 - CA-3)/(2.6 * D * G) + 1
hmax-3 = 160 * (10 - 3)/(2.6 * 18.1 * 1) + 1
hmax-3 = 12.9301 m

pmax-3 = (hmax-3 - H) * 9.8 * G

pmax-3 = (12.9301 - 11.47) * 9.8 * 1
pmax-3 = 14.3094 kPa

pmax-int-shell-3 = MIN(pmax-int-shell-2 pmax-3)
pmax-int-shell-3 = MIN(20.2604 14.3094)
pmax-int-shell-3 = 14.3094 kPa

Hydrostatic Test Condition G = 1

H' = H
H' = 11.47
H' = 11.47 m

t-test-3 = (* 4.9 D (H' - 0.3))/St
t-test-3 = (* 4.9 18.1 (11.47 - 0.3))/171
t-test-3 = 5.7934 mm

Course # 4

Ca-4 = Corrosion allowance per API-650 5.3.2 (mm)
G = Design specific gravity of the liquid to be stored
H' = Effective liquid head at design pressure (m)
hmax-4 = Max liquid level based on shell thickness (m)
JE = Joint efficiency
pmax-4 = Max pressure at design (kPa)
pmax-int-shell-4 = Max internal pressure at design (kPa)
Sd = Allowable design stress for the design condition per API-650 Table 5-2b (MPa)
St = Allowable stress for the hydrostatic test condition per API-650 5.6.2.2 (MPa)
t-4 = Shell actual thickness (mm)
t-calc-4 = Shell thickness design condition td (mm)
t-seismic-4 = See E.6.2.4 table in SEISMIC calculations.
t-test-4 = Shell thickness hydrostatic test condition (mm)

Material = A36M
Width = 1.5 m
Ca-4 = 3 mm
JE = 1

t-4 = 10 mm

Sd = 160 MPa

St = 171 MPa

Design Condition G = 1 (per API-650)

H' = H

H' = 9.97

H' = 9.97 m

t-calc-4 = (4.9 * D * (H' - 0.3) * G)/Sd + Ca-4 (per API-650 5.6.3.2)

t-calc-4 = (4.9 * 18.1 * (9.97 - 0.3) * 1)/160 + 3

t-calc-4 = 8.3602 mm

hmax-4 = Sd * (t-4 - CA-4)/(2.6 * D * G) + 1

hmax-4 = 160 * (10 - 3)/(2.6 * 18.1 * 1) + 1

hmax-4 = 12.9301 m

pmax-4 = (hmax-4 - H) * 9.8 * G

pmax-4 = (12.9301 - 9.97) * 9.8 * 1

pmax-4 = 29.0094 kPa

pmax-int-shell-4 = MIN(pmax-int-shell-3 pmax-4)

pmax-int-shell-4 = MIN(14.3094 29.0094)

pmax-int-shell-4 = 14.3094 kPa

Hydrostatic Test Condition G = 1

H' = H

H' = 9.97

H' = 9.97 m

t-test-4 = (* 4.9 D (H' - 0.3))/St

t-test-4 = (* 4.9 18.1 (9.97 - 0.3))/171

t-test-4 = 5.0154 mm

Course # 5

Ca-5 = Corrosion allowance per API-650 5.3.2 (mm)

G = Design specific gravity of the liquid to be stored

H' = Effective liquid head at design pressure (m)

hmax-5 = Max liquid level based on shell thickness (m)

JE = Joint efficiency

pmax-5 = Max pressure at design (kPa)

pmax-int-shell-5 = Max internal pressure at design (kPa)

Sd = Allowable design stress for the design condition per API-650 Table 5-2b (MPa)

St = Allowable stress for the hydrostatic test condition per API-650 5.6.2.2 (MPa)

t-5 = Shell actual thickness (mm)

t-calc-5 = Shell thickness design condition td (mm)

t-seismic-5 = See E.6.2.4 table in SEISMIC calculations.

t-test-5 = Shell thickness hydrostatic test condition (mm)

Material = A36M

Width = 1.5 m

Ca-5 = 3 mm

JE = 1

t-5 = 8 mm

Sd = 160 MPa

St = 171 MPa

Design Condition G = 1 (per API-650)

H' = H

H' = 8.47

H' = 8.47 m

t-calc-5 = (4.9 * D * (H' - 0.3) * G)/Sd + Ca-5 (per API-650 5.6.3.2)

t-calc-5 = (4.9 * 18.1 * (8.47 - 0.3) * 1)/160 + 3

t-calc-5 = 7.5287 mm

hmax-5 = Sd * (t-5 - CA-5)/(2.6 * D * G) + 1

hmax-5 = 160 * (8 - 3)/(2.6 * 18.1 * 1) + 1

hmax-5 = 9.3229 m

pmax-5 = (hmax-5 - H) * 9.8 * G

pmax-5 = (9.3229 - 8.47) * 9.8 * 1

pmax-5 = 8.3585 kPa

pmax-int-shell-5 = MIN(pmax-int-shell-4 pmax-5)

pmax-int-shell-5 = MIN(14.3094 8.3585)

pmax-int-shell-5 = 8.3585 kPa

Hydrostatic Test Condition G = 1

H' = H

H' = 8.47

H' = 8.47 m

t-test-5 = (* 4.9 D (H' - 0.3))/St

t-test-5 = (* 4.9 18.1 (8.47 - 0.3))/171

t-test-5 = 4.2374 mm

Course # 6

Ca-6 = Corrosion allowance per API-650 5.3.2 (mm)

G = Design specific gravity of the liquid to be stored

H' = Effective liquid head at design pressure (m)

hmax-6 = Max liquid level based on shell thickness (m)

JE = Joint efficiency

pmax-6 = Max pressure at design (kPa)

pmax-int-shell-6 = Max internal pressure at design (kPa)

Sd = Allowable design stress for the design condition per API-650 Table 5-2b (MPa)

St = Allowable stress for the hydrostatic test condition per API-650 5.6.2.2 (MPa)

t-6 = Shell actual thickness (mm)

t-calc-6 = Shell thickness design condition td (mm)

t-seismic-6 = See E.6.2.4 table in SEISMIC calculations.

t-test-6 = Shell thickness hydrostatic test condition (mm)

Material = A36M

Width = 1.5 m

Ca-6 = 3 mm

JE = 1

t-6 = 8 mm

Sd = 160 MPa

St = 171 MPa

Design Condition G = 1 (per API-650)

H' = H

H' = 6.97

H' = 6.97 m

t-calc-6 = (4.9 * D * (H' - 0.3) * G)/Sd + Ca-6 (per API-650 5.6.3.2)

t-calc-6 = (4.9 * 18.1 * (6.97 - 0.3) * 1)/160 + 3

t-calc-6 = 6.6973 mm

hmax-6 = Sd * (t-6 - CA-6)/(2.6 * D * G) + 1

hmax-6 = 160 * (8 - 3)/(2.6 * 18.1 * 1) + 1

hmax-6 = 9.3229 m

pmax-6 = (hmax-6 - H) * 9.8 * G

pmax-6 = (9.3229 - 6.97) * 9.8 * 1

pmax-6 = 23.0585 kPa

pmax-int-shell-6 = MIN(pmax-int-shell-5 pmax-6)

pmax-int-shell-6 = MIN(8.3585 23.0585)

pmax-int-shell-6 = 8.3585 kPa

Hydrostatic Test Condition G = 1

H' = H

H' = 6.97

H' = 6.97 m

t-test-6 = (* 4.9 D (H' - 0.3))/St

t-test-6 = (* 4.9 18.1 (6.97 - 0.3))/171

t-test-6 = 3.4594 mm

Course # 7

Ca-7 = Corrosion allowance per API-650 5.3.2 (mm)

G = Design specific gravity of the liquid to be stored

H' = Effective liquid head at design pressure (m)

hmax-7 = Max liquid level based on shell thickness (m)

JE = Joint efficiency

pmax-7 = Max pressure at design (kPa)

pmax-int-shell-7 = Max internal pressure at design (kPa)

Sd = Allowable design stress for the design condition per API-650 Table 5-2b (MPa)

St = Allowable stress for the hydrostatic test condition per API-650 5.6.2.2 (MPa)

t-7 = Shell actual thickness (mm)

t-calc-7 = Shell thickness design condition td (mm)

t-seismic-7 = See E.6.2.4 table in SEISMIC calculations.

t-test-7 = Shell thickness hydrostatic test condition (mm)

Material = A36M

Width = 1.5 m

Ca-7 = 3 mm

JE = 1

t-7 = 6 mm

Sd = 160 MPa

St = 171 MPa

Design Condition G = 1 (per API-650)

H' = H

H' = 5.47

H' = 5.47 m

t-calc-7 = (4.9 * D * (H' - 0.3) * G)/Sd + Ca-7 (per API-650 5.6.3.2)

t-calc-7 = (4.9 * 18.1 * (5.47 - 0.3) * 1)/160 + 3

t-calc-7 = 5.8658 mm

hmax-7 = Sd * (t-7 - CA-7)/(2.6 * D * G) + 1

hmax-7 = 160 * (6 - 3)/(2.6 * 18.1 * 1) + 1

hmax-7 = 5.7157 m

pmax-7 = (hmax-7 - H) * 9.8 * G

pmax-7 = (5.7157 - 5.47) * 9.8 * 1

pmax-7 = 2.4075 kPa

pmax-int-shell-7 = MIN(pmax-int-shell-6 pmax-7)

pmax-int-shell-7 = MIN(8.3585 2.4075)

pmax-int-shell-7 = 2.4075 kPa

Hydrostatic Test Condition G = 1

H' = H

H' = 5.47

H' = 5.47 m

t-test-7 = (* 4.9 D (H' - 0.3))/St

t-test-7 = (* 4.9 18.1 (5.47 - 0.3))/171

t-test-7 = 2.6814 mm

Course # 8

Ca-8 = Corrosion allowance per API-650 5.3.2 (mm)

G = Design specific gravity of the liquid to be stored

H' = Effective liquid head at design pressure (m)

hmax-8 = Max liquid level based on shell thickness (m)

JE = Joint efficiency

pmax-8 = Max pressure at design (kPa)

pmax-int-shell-8 = Max internal pressure at design (kPa)

Sd = Allowable design stress for the design condition per API-650 Table 5-2b (MPa)

St = Allowable stress for the hydrostatic test condition per API-650 5.6.2.2 (MPa)

t-8 = Shell actual thickness (mm)

t-calc-8 = Shell thickness design condition td (mm)

t-seismic-8 = See E.6.2.4 table in SEISMIC calculations.

t-test-8 = Shell thickness hydrostatic test condition (mm)

Material = A36M

Width = 1.5 m

Ca-8 = 3 mm

JE = 1

t-8 = 6 mm

Sd = 160 MPa

St = 171 MPa

Design Condition G = 1 (per API-650)

H' = H

H' = 3.97

H' = 3.97 m

t-calc-8 = (4.9 * D * (H' - 0.3) * G)/Sd + Ca-8 (per API-650 5.6.3.2)

t-calc-8 = (4.9 * 18.1 * (3.97 - 0.3) * 1)/160 + 3

t-calc-8 = 5.0343 mm

hmax-8 = Sd * (t-8 - CA-8)/(2.6 * D * G) + 1

hmax-8 = 160 * (6 - 3)/(2.6 * 18.1 * 1) + 1

hmax-8 = 5.7157 m

pmax-8 = (hmax-8 - H) * 9.8 * G

pmax-8 = (5.7157 - 3.97) * 9.8 * 1

pmax-8 = 17.1075 kPa

pmax-int-shell-8 = MIN(pmax-int-shell-7 pmax-8)

pmax-int-shell-8 = MIN(2.4075 17.1075)

pmax-int-shell-8 = 2.4075 kPa

Hydrostatic Test Condition G = 1

H' = H

H' = 3.97

H' = 3.97 m

t-test-8 = (* 4.9 D (H' - 0.3))/St

t-test-8 = (* 4.9 18.1 (3.97 - 0.3))/171

t-test-8 = 1.9035 mm

Course # 9

Ca-9 = Corrosion allowance per API-650 5.3.2 (mm)

G = Design specific gravity of the liquid to be stored

H' = Effective liquid head at design pressure (m)

hmax-9 = Max liquid level based on shell thickness (m)

JE = Joint efficiency

pmax-9 = Max pressure at design (kPa)

pmax-int-shell-9 = Max internal pressure at design (kPa)

Sd = Allowable design stress for the design condition per API-650 Table 5-2b (MPa)

St = Allowable stress for the hydrostatic test condition per API-650 5.6.2.2 (MPa)

t-9 = Shell actual thickness (mm)

t-calc-9 = Shell thickness design condition td (mm)

t-seismic-9 = See E.6.2.4 table in SEISMIC calculations.

t-test-9 = Shell thickness hydrostatic test condition (mm)

Material = A36M

Width = 1.5 m

Ca-9 = 3 mm

JE = 1

t-9 = 6 mm

Sd = 160 MPa

St = 171 MPa

Design Condition G = 1 (per API-650)

H' = H

H' = 2.47

H' = 2.47 m

t-calc-9 = (4.9 * D * (H' - 0.3) * G)/Sd + Ca-9 (per API-650 5.6.3.2)

t-calc-9 = (4.9 * 18.1 * (2.47 - 0.3) * 1)/160 + 3

t-calc-9 = 4.2029 mm

hmax-9 = Sd * (t-9 - CA-9)/(2.6 * D * G) + 1

hmax-9 = 160 * (6 - 3)/(2.6 * 18.1 * 1) + 1

hmax-9 = 5.7157 m

pmax-9 = (hmax-9 - H) * 9.8 * G
pmax-9 = (5.7157 - 2.47) * 9.8 * 1
pmax-9 = 31.8075 kPa

pmax-int-shell-9 = MIN(pmax-int-shell-8 pmax-9)
pmax-int-shell-9 = MIN(2.4075 31.8075)
pmax-int-shell-9 = 2.4075 kPa

Hydrostatic Test Condition G = 1

H' = H
H' = 2.47
H' = 2.47 m

t-test-9 = (* 4.9 D (H' - 0.3))/St
t-test-9 = (* 4.9 18.1 (2.47 - 0.3))/171
t-test-9 = 1.1255 mm

Course # 10

Ca-10 = Corrosion allowance per API-650 5.3.2 (mm)
G = Design specific gravity of the liquid to be stored
H' = Effective liquid head at design pressure (m)
hmax-10 = Max liquid level based on shell thickness (m)
JE = Joint efficiency
pmax-10 = Max pressure at design (kPa)
pmax-int-shell-10 = Max internal pressure at design (kPa)
Sd = Allowable design stress for the design condition per API-650 Table 5-2b (MPa)
St = Allowable stress for the hydrostatic test condition per API-650 5.6.2.2 (MPa)
t-10 = Shell actual thickness (mm)
t-calc-10 = Shell thickness design condition td (mm)
t-seismic-10 = See E.6.2.4 table in SEISMIC calculations.
t-test-10 = Shell thickness hydrostatic test condition (mm)

Material = A36M

Width = 0.89 m

Ca-10 = 3 mm

JE = 1

t-10 = 6 mm

Sd = 160 MPa

St = 171 MPa

Design Condition G = 1 (per API-650)

H' = H

H' = 0.97

H' = 0.97 m

t-calc-10 = (4.9 * D * (H' - 0.3) * G)/Sd + Ca-10 (per API-650 5.6.3.2)

t-calc-10 = (4.9 * 18.1 * (0.97 - 0.3) * 1)/160 + 3

t-calc-10 = 3.3714 mm

hmax-10 = Sd * (t-10 - CA-10)/(2.6 * D * G) + 1

hmax-10 = 160 * (6 - 3)/(2.6 * 18.1 * 1) + 1

hmax-10 = 5.7157 m

pmax-10 = (hmax-10 - H) * 9.8 * G

pmax-10 = (5.7157 - 0.97) * 9.8 * 1

pmax-10 = 46.5075 kPa

pmax-int-shell-10 = MIN(pmax-int-shell-9 pmax-10)

pmax-int-shell-10 = MIN(2.4075 46.5075)

pmax-int-shell-10 = 2.4075 kPa

Hydrostatic Test Condition G = 1

H' = H

H' = 0.97

H' = 0.97 m

t-test-10 = (* 4.9 D (H' - 0.3))/St

t-test-10 = (* 4.9 18.1 (0.97 - 0.3))/171

t-test-10 = 0.3475 mm

SUMMARY OF SHELL RESULTS Back

t-min-Seismic = See API-650 E.6.1.4, table in SEISMIC calculations.

Shell API-650 Summary (Bottom is 1)

Shel l #	Widt h (mm)	Materi al	CA (mm)	J E	Min Yield Strengt h (MPa)	Tensile Strengt h (MPa)	Sd (MPa)	St (MPa)	Weig ht (N)	Weig ht CA (N)	t-min Erectio n (mm)	t-Des (mm)	t- Test (mm)	t-min Seism (mm	t min Ext Pe (mm)	t-min (mm)	t- Actu al (mm)	Statu s
1	1500	A36M	3	1	250	400	160	171	78,658	59,003	6	10.854 6	7.349 3	7.4982	NA	10.854 6	12	OK
2	1500	A36M	3	1	250	400	160	171	78,658	59,003	6	10.023 1	6.571 4	7.0263	NA	10.023 1	12	OK
3	1500	A36M	3	1	250	400	160	171	65,555	45,896	6	9.1917	5.793 4	6.3166	NA	9.1917	10	OK
4	1500	A36M	3	1	250	400	160	171	65,555	45,896	6	8.3602	5.015 4	5.8744	NA	8.3602	10	OK
5	1500	A36M	3	1	250	400	160	171	52,450	32,787	6	7.5287	4.237 4	5.1708	NA	7.5287	8	OK
6	1500	A36M	3	1	250	400	160	171	52,450	32,787	6	6.6973	3.459 4	4.7742	NA	6.6973	8	OK
7	1500	A36M	3	1	250	400	160	171	39,342	19,674	6	5.8658	2.681 4	4.1014	NA	6	6	OK
8	1500	A36M	3	1	250	400	160	171	39,342	19,674	6	5.0343	1.903 5	3.7828	NA	6	6	OK
9	1500	A36M	3	1	250	400	160	171	39,342	19,674	6	4.2029	1.125 5	3.4637	NA	6	6	OK
10	890	A36M	3	1	250	400	160	171	23,343	11,673	6	3.3714	0.347 5	3.1459	NA	6	6	OK

Total Weight = 534,699.9264 N

INTERMEDIATE STIFFENER CALCULATIONS PER API-650 Section 5.9.7

D = Nominal diameter of the tank shell (m)

Hu = Vertical Distance Between the Intermediate Stiffener (Per API-650 5.9.7) (m)

L_act = Actual Transform Height Spacing between Stiffeners (m)

L_0 = Uniform Maximum Transform Height Spacing between Stiffineres (m)

V = Design wind speed (km/h)

Wtr = Transposed width of each shell course (m)

Zi = Required Intermediate Stiffener Section Modulus (per API-650 5.9.6.1) (cm^3)

Zi-actual = Actual Top Comp Ring Section Modulus (cm^3)

D = 18.1 m

V = 201 km/h

ME = 1

Hu = ME * 9.47 * tsmin * (SQRT (tsmin / D)^3) * (190 / V)^2

Hu = 1 * 9.47 * 6 * (SQRT (6 / 18.1)^3) * (190 / 201)^2

Hu = 9.69 m (Maximum Height of Unstiffened Shell)

Transforming courses (1) to (10)

Wtr = Course-width * (SQRT (t-uniform / t-course)^5)

Wtr-1 = 1.5 * (SQRT (6 / 12)^5) = 0.2652 m

Wtr-2 = 1.5 * (SQRT (6 / 12)^5) = 0.2652 m

Wtr-3 = 1.5 * (SQRT (6 / 10)^5) = 0.4183 m

Wtr-4 = 1.5 * (SQRT (6 / 10)^5) = 0.4183 m

Wtr-5 = 1.5 * (SQRT (6 / 8)^5) = 0.7307 m

Wtr-6 = 1.5 * (SQRT (6 / 8)^5) = 0.7307 m

Wtr-7 = 1.5 * (SQRT (6 / 6)^5) = 1.5 m

Wtr-8 = 1.5 * (SQRT (6 / 6)^5) = 1.5 m

Wtr-9 = 1.5 * (SQRT (6 / 6)^5) = 1.5 m

Wtr-10 = 0.97 * (SQRT (6 / 6)^5) = 0.97 m

Wtr = SUM(Wtr-n)

Wtr = 8.2983 m

For uniformly spaced stiffeners

L_0 = Hts/# of Stiffeners + 1

L_0 = 8.2983/(0 + 1)

L_0 = 8.2983 m

L_act = Wrt

L_act = 8.2983 m

Number of Intermediate Stiffeners Sufficient Since Hu >= L_act

SUMMARY OF SHELL STIFFENING RESULTS

Number of Intermediate stiffeners req'd (NS) = 0

FLAT BOTTOM: NON ANNULAR PLATE DESIGN Back

Ba = Area of bottom (cm^2)

Bottom-OD = Bottom diameter (m)

c = Factor

ca-1 = Bottom (1st) shell course corrosion allowance (mm)

Ca-bottom = Bottom corrosion allowance (mm)

D-bottom = Density of bottom (kg/mm3)

G = Design specific gravity of the liquid to be stored

H = Max liquid level (m)

H' = Effective liquid head at design pressure (m)

JE = Bottom joint efficiency

S = Maximum Stress in first shell course per API 650 Table 5.1.a

S1 = Product stress in the first shell course per API 650 Table 5.1.a

S2 = Hydrostatic test stress in the first shell course per API 650 Table 5.1.a

t-1 = Bottom (1st) shell course thickness (mm)

t-actual = Actual bottom thickness (mm)

t-calc = Minimum nominal bottom plates thickness per API-650 5.4.1 (mm)

t-min = Minimum nominal bottom plates thickness per API-650 5.4.1 (mm)

t-test-1 = Bottom (1st) shell course test thickness (mm)

t-vac = Vacuum calculations per ASME section VIII Div. 1 (mm)

td-1 = Bottom (1st) shell course design thickness (mm)

Material = A36M

t-actual = 9 mm

t-min = 6.0 + Ca-bottom

t-min = 6.0 + 3

t-min = 9 mm

t-calc = t-min

t-calc = 9 mm

Calculation of Hydrostatic Test Stress & Product Stress (per API-650 Section 5.5.1)

Bottom-OD = 18.224 m

JE = 1

D-bottom = 0.00000784 kg/mm3

t-1 = 12 mm

ca-1 = 3 mm

G = 1

H = 14.47 m

H' = 14.47 m

St = 171 MPa

Sd = 160 MPa

Ca-bottom = 3 mm

Product stress in first shell course

S1 = ((td-1 - ca-1) / (t-1 - ca-1)) * Sd

S1 = ((10.8546 - 3) / (12 - 3)) * 160

S1 = 139.6374 MPa

Hydrostatic test stress in first shell course

S2 = (t-test-1 / t-1) * St

S2 = (7.3493 / 12) * 171

S2 = 104.7281 MPa

S = Max (S1, S2)

S = Max (139.6374 , 104.7281)

S = 139.6374 MPa

ABS(E-p) < P-btm Then there is no uplift

SUMMARY OF BOTTOM RESULTS Back

Material = A36M

t-actual = 9 mm

t-req = 9 mm

NET UPLIFT DUE TO INTERNAL PRESSURE

Net-Uplift = 0 N, (See roof report for calculations)

WIND MOMENT (Per API-650 SECTION 5.11) Back

A = Area resisting the compressive force, as illustrated in Figure F.1

P-F41 = Design pressure determined in F.4.1

P-v = Internal pressure

Wind Velocity per API-650 ASCE 7-05

V_entered = 201 kph

I = 1

Vs (Wind Velocity) = SQRT(I) * V_entered = 201 kph

Vf = (Vs / 190)^2

Vf = (201 / 190)^2

Vf (Velocity Factor) = 1.1191

PWS = 0.86 * Vf

PWS = 0.9624 kPa

PWR = 1.44 * Vf

PWR = 1.6115 kPa

API-650 5.2.1.k Uplift Check

P-F41 = (A * Fy * TAN(Theta))/(200 * D^2) + (0.00127 * DLR)/D^2

P-F41 = (2177.72 * 250 * TAN(15.8191))/(200 * 18.1^2) + ((0.00127 * 167601) / 18.1^2)

P-F41 = 3.004 kPa

Wind-Uplift = MIN(PWR , (1.6 * P-F41 - Pv))

Wind-Uplift = MIN(1.6115 , 4.8063)

Wind-Uplift = 1.6116 kPa

Ap-Vert (Vertical Projected Area of Roof) = 23.2057 m^2

Horizontal Projected Area of Roof (Per API-650 5.2.1.f)

Xw (Moment Arm of UPLIFT wind force on roof) = 9.05 m

Ap (Projected Area of roof for wind moment) = 257.3043 m^2

M-roof (Moment Due to Wind Force on Roof) = Wind-Uplift * Ap * Xw

M-roof = (1,611.5634 * 257.3043 * 9.05)

M-roof = 3,752,693 N-m

Xs (Height from bottom to the Shell's center of gravity) = Shell Height/2

Xs = (14.47/2)

Xs = 7.235 m

As (Projected Area of Shell) = Shell Height * (D + 2 * t-ins)

As = 14.47 * (18.1 + 2 * 0)

As = 261.907 m^2

M-Shell (Moment Due to Wind Force on Shell) = (PWS * As * (Shell Height / 2))

M-Shell = (0.9624 * 261.907 * (14.47 / 2))

M-Shell = 1,823,766 N-m

Mw (Wind moment) = M-roof + M-shell

Mw = 3,752,693 + 1,823,766

Mw = 5,576,458.3522 N-m

RESISTANCE TO OVERTURNING (per API-650 5.11.2)

DLR = Nominal weight of roof plate plus weight of roof plates overlap plus any attached structural.

DLS = Nominal weight of the shell and any framing (but not roof plates) support by the shell and roof.

F-friction = Maximum of 40% of weight of tank

MDL = Moment about the shell-to-bottom joint from the nominal weight of the shell

MDLR = Moment about the shell-to-bottom joint from the nominal weight of the roof plate plus any attached structural.

MF = Stabilizing moment due to bottom plate and liquid weight

MPi = Destabilizing moment about the shell-to-bottom joint from design pressure

Mw = Destabilizing wind moment

tb = Bottom plate thickness less C.A.

wl = Circumferential loading of contents along shell-to-bottom joint

An unanchored tank must meet with this criteria:

Mw = 5,576,458 m-N

DLS = 562,696.0247 N

DLR = 167,600.885 N

MPi = P * (Pi * D^2 / 4) * (D / 2)

MPi = 0 * (3.1416 * 18.1^2 / 4) * (18.1 / 2)

MPi = 0 m-N

MDL = DLS * (D/2)

MDL = 562,696.0247 * 18.1/2

MDL = 5,092,399 N-m

MDLR = DLR * (D/2)

MDLR = 167,600.885 * 18.1/2

MDLR = 1,516,788 N-m

tb = 6 mm

wl = (min [59 * tb * SQRT(fy-btm * H-liq)] [140.8 * H-liq * D])

wl = (min [59 * 6 * SQRT(250 * 14.47)] [140.8 * 14.47 * 18.1])

wl = 21,291.5624 N/m

MF = (D/2) * wl * Pi * D

MF = 9.05 * 21,291.5624 * 3.1416 * 18.1

MF = 10,956,821 m-N

Criteria 3

M-shell + Fp * Mpi < MDL /1.5 + MDLR

1,823,765.5406 + 0.4 * 0 < 5,092,399 / 1.5 + 1,516,788

Since 1,823,766 < 4,911,721, Tank is stable

RESISTANCE TO SLIDING (per API-650 5.11.4)

F-wind = Vf * 18 * As

F-wind = 1.1191 * 18 * 261.907

F-wind = 244,513 N

F-friction = 0.4 * [(W-roof-corroded * g) + (W-shell-corroded * g) + (W-btm-corroded * g) + (W-roof-struct * g)]

F-friction = 0.4 * [(10,538 * 9.8) + (35,289 * 9.8) + (12,273 * 9.8) + (26,291 * 9.8)]

F-friction = 331,039 N

No anchorage needed to resist sliding since

F-friction > F-wind

Anchorage Requirement

Tank does not require anchorage

SITE GROUND MOTION CALCULATIONS

Anchorage_System (Anchorage System) = self anchored

D (Nominal Tank Diameter) = 18.1 m

Fa (Site Acceleration Coefficient) = 1.0

Fv (Site Velocity Coefficient) = 1.0

H (Maximum Design Product Level) = 14.47 m

I (Importance Factor) = 1.0

K (Spectral Acceleration Adjustment Coefficient) = 1.5

Q (MCE to Design Level Scale Factor) = 0.6667

Rwc (Convective Force Reduction Factor) = 2

Rwi (Impulsive Force Reduction Factor) = 3.5

S1 (Spectral Response Acceleration at a Period of One Second) = 0.05

Seismic_Site_Class (Seismic Site Class) = seismic site class b

Seismic_Use_Group (Seismic Use Group) = seismic use group i

Ss (Spectral Response Acceleration Short Period) = 0.1

TL (Regional Dependent Transistion Period for Longer Period Ground Motion) = 4 sec

Design Spectral Response Acceleration at Short Period *API 650 Sections E.4.6.1 and E.2.2*

SDS = Q * Fa * Ss = 0.6667 * 1.0 * 0.1 = 0.0667

Design Spectral Response Acceleration at a Period of One Second *API 650 Sections E.4.6.1 and E.2.2*

SD1 = Q * Fv * S1 = 0.6667 * 1.0 * 0.05 = 0.0333

Sloshing Coefficient *API 650 Section E.4.5.2*

Ks = 0.578 / SQRT(TANH(((3.68 * Liq_max) / D)))

= 0.578 / SQRT(TANH(((3.68 * 14.47) / 18.1)))

= 0.5796

Convective Natural Period *API 650 Section E.4.5.2*

Tc = 1.8 * Ks * SQRT(D) = 1.8 * 0.5796 * SQRT(18.1) = 4.4386 sec

Impulsive Design Response Spectrum Acceleration Coefficient *API 650 Sections E.4.6.1*

Ai = SDS * (I / Rwi) = 0.0667 * (1.0 / 3.5) = 0.0191

API 650 Sections E.4.6.1

Ai = MAX(Ai , 0.007) = MAX(0.0191 , 0.007) = 0.0191

Tc > TL

Convective Design Response Spectrum Acceleration Coefficient *API 650 Sections E.4.6.1*

Ac = K * SD1 * (TL / (Tc^2)) * (I / Rwc)

= 1.5 * 0.0333 * (4 / (4.4386^2)) * (1.0 / 2)

= 0.0051

Ac = MIN(Ac , Ai) = MIN(0.0051 , 0.0191) = 0.0051

Vertical Ground Acceleration Coefficient *API 650 Section E.6.1.3 and E.2.2*

Av = (2 / 3) * 0.7 * SDS = (2 / 3) * 0.7 * 0.0667 = 0.0311

Vertical Ground Acceleration Coefficient Specified by user (Av) = 0.0311

SEISMIC CALCULATIONS

< Mapped ASCE7 Method >

Ac = Convective spectral acceleration parameter

Ai = Impulsive spectral acceleration parameter

Av = Vertical Earthquake Acceleration Coefficient

Ci = Coefficient for impulsive period of tank system (Fig. E-1)

D/H = Ratio of Tank Diameter to Design Liquid Level

Density = Density of tank product (SG * 62.42786)

Fc = Allowable longitudinal shell-membrane compressive stress

Fty = Minimum specified yield strength of shell course

Fy = Minimum yield strength of bottom annulus

Ge = Effective specific gravity including vertical seismic effects

I = Importance factor defined by Seismic Use Group

k = Coefficient to adjust spectral acceleration from 5% - 0.5% damping

L = Required Annular Ring Width

Ls = Actual Annular Plate Width

Mrw = Ringwall moment-portion of the total overturning moment that acts at the base of the tank shell perimeter

Ms = Slab moment (used for slab and pile cap design)

Pa = Anchorage chair design load

Pab = Anchor seismic design load

Q = Scaling factor from the MCE to design level spectral accelerations

RCG = Height from Top of Shell to Roof Center of Gravity

Rwc = Force reduction factor for the convective mode using allowable stress design methods (Table E-4)

Rwi = Force reduction factor for the impulsive mode using allowable stress design methods (Table E-4)

S0 = Design Spectral Response Param. (5% damped) for 0-second Periods (T = 0.0 sec)

Sd1 = The design spectral response acceleration param. (5% damped) at 1 second based on ASCE7 methods per API 650 E.2.2

Sds = The design spectral response acceleration param. (5% damped) at short periods (T = 0.2 sec) based on ASCE7 methods per API 650 E.2.2

SigC = Maximum longitudinal shell compression stress

SigC-anchored = Maximum longitudinal shell compression stress

SUG = Seismic Use Group (Importance factors depends on SUG)

T-L = Regional Dependent Transition Period for Long Period Ground Motion (Per ASCE 7-05, fig. 22-15)

ta = Actual Annular Plate Thickness less C.A.

ts1 = Thickness of bottom Shell course minus C.A.

tu = Equivalent uniform thickness of tank shell

V = Total design base shear

Vc = Design base shear due to convective component from effective sloshing weight

Vi = Design base shear due to impulsive component from effective weight of tank and contents

wa = Force resisting uplift in annular region

Wab = Design uplift load on anchor per unit circumferential length

Wc = Effective Convective (Sloshing) Portion of the Liquid Weight

Weff = Effective Weight Contributing to Seismic Response

Wf = Weight of Floor (Incl. Annular Ring)

Wi = Effective Impulsive Portion of the Liquid Weight

wint = Uplift load due to design pressure acting at base of shell

Wp = Total weight of Tank Contents based on S.G.

Wr = Weight Fixed Roof, framing and 10 % of Design Snow Load & Insul.

Wrs = Roof Load Acting on Shell, Including 10% of Snow Load

Ws = Weight of Shell (Incl. Shell Stiffeners & Insul.)

wt = Shell and roof weight acting at base of shell

Xc = Height to center of action of the lateral seismic force related to the convective liquid force for ringwall moment

Xcs = Height to center of action of the lateral seismic force related to the convective liquid force for the slab moment

Xi = Height to center of action of the lateral seismic force related to the impulsive liquid force for ringwall moment

Xis = Height to center of action of the lateral seismic force related to the impulsive liquid force for the slab moment

Xr = Height from Bottom of Shell to Roof Center of Gravity

Xs = Height from Bottom to the Shell's Center of Gravity

g = 9.8 m/s^2

WEIGHTS

Ws = 55,185 kgf or 541,181.6986 N

Wf = 18,409 kgf or 180,531.2287 N

Wr = 16,861 kgf or 165,346.1429 N

EFFECTIVE WEIGHT OF PRODUCT

D/H = 1.2509

Wp = 3,723,193 kgf

Wi = (1 - (0.218 * D/H)) * Wp

Wi = (1 - (0.218 * 1.2509)) * 3,723,193

Wi = 2,707,922 kgf

Wc = 0.23 * D/H * TANH (3.67 * H/D) * Wp

Wc = 0.23 * 1.2509 * TANH (3.67 * 0.7994) * 3,723,193

Wc = 1,065,115 kgf

Weff = Wi + Wc

Weff = 2,707,922 + 1,065,115

Weff = 3,773,036.6567 kgf

Wrs = 12,583 kgf

DESIGN LOADS

Vi = Ai * (Ws + Wr + Wf + Wi)

Vi = 0.0191 * (55,185 + 16,861 + 18,409 + 2,707,922)

Vi = 53,449 kgf

Vc = Ac * Wc

Vc = 0.0051 * 1,065,115

Vc = 5,432.086 kgf

V = SQRT (Vi^2 + Vc^2)

V = SQRT (53,449^2 + 5,432.086^2)

V = 53,724.3187 kgf

CENTER OF ACTION FOR EFFECTIVE LATERAL FORCES

Xs = 7.235 m

RCG = 1/3 * R * (TAND (Theta))

RCG = 1/3 * 9072.5 * (TAND (15.8192))

RCG = 856.8472 mm or 0.8568 m

Xr = Shell Height + RCG

Xr = 14.47 + 0.8568

Xr = 15.3268 m

CENTER OF ACTION FOR RINGWALL OVERTURNING MOMENT

Xi = (0.5 - (0.094 * D/H)) * H

Xi = (0.5 - (0.094 * 1.2509)) * 14.47

Xi = 5.5336 m

Xc = (1 - (COSH (3.67 * H/D) - 1) / ((3.67 * H/D) * SINH (3.67 * H/D))) * H

Xc = (1 - (COSH (3.67 * 0.7994) - 1) / ((3.67 * 0.7994) * SINH (3.67 * 0.7994))) * 14.47

Xc = 10.0362 m

CENTER OF ACTION FOR SLAB OVERTURNING MOMENT

Xis = (0.5 + (0.06 * D/H)) * H)

Xis = (0.5 + (0.06 * 1.2509)) * 14.47)

Xis = 8.321 m

Xcs = (1 - (COSH (3.67 * H/D) - 1.937) / ((3.67 * H/D) * SINH(3.67 * H/D))) * H

Xcs = (1 - (COSH (3.67 * 0.7994) - 1.937) / ((3.67 * 0.7994) * SINH(3.67 * 0.7994))) * 14.47

Xcs = 10.5292 m

Dynamic Liquid Hoop Forces

SHELL	Width (m)	Y (m)	Ni (N/mm)	Nc (N/mm)	Nh (N/mm)	SigT+ (MPa)	SigT- (MPa)
SUMMARY			= 2.6 * Ai * G * D^2	= 1.85 * Ac * G * D^2 * (COSH (3.68 * (H - Y)) / D) / (COSH (3.68 * H / D))	= 4.9011293 * Y * D * G	= (+ Nh (SQRT (Ni^2 + Nc^2 + (Av * Nh / 2.5)^2))) / t-n	= (- Nh (SQRT (Ni^2 + Nc^2 + (Av * Nh / 2.5)^2))) / t-n
Shell 1	1.5	14.1652	16.2691	0.3258	1,256.6011	106.5971	102.8363

Shell 2	1.5	12.6652	16.2583	0.3474	1,123.5354	95.4148	91.841
Shell 3	1.5	11.1652	15.817	0.4014	990.4698	101.0523	97.0415
Shell 4	1.5	9.6652	14.9769	0.4932	857.4041	87.5797	83.901
Shell 5	1.5	8.1652	13.738	0.6311	724.3384	92.5975	88.4871
Shell 6	1.5	6.6652	12.1003	0.8282	591.2728	75.6821	72.136
Shell 7	1.5	5.1652	10.0637	1.103	458.2071	78.3042	74.4314
Shell 8	1.5	3.6652	7.6284	1.4811	325.1415	55.6503	52.7301
Shell 9	1.5	2.1652	4.7943	1.998	192.0758	32.9655	31.0597
Shell 10	0.89	0.6652	1.5613	2.7023	59.0101	10.3693	9.3006

Overturning Moment

Mrw = ((Ai * [(Wi * g) * Xi + (Ws * g) * Xs + (Wr * g) * Xr])^2 + [Ac * (Wc * g) * Xc]^2)^0.5
Mrw = ((0.0191 * [(2,707,922 * 9.8) * 5.5336 + (55,185 * 9.8) * 7.235 + (16,861 * 9.8) * 15.3268])^2 + [0.0051 * (1,065,115 * 9.8) * 10.0362]^2)^0.5
Mrw = 2,978,281.0086 N-m

Ms = ((Ai * [(Wi * g) * Xis + (Ws * g) * Xs + (Wr * g) * Xr])^2 + [Ac * (Wc * g) * Xcs]^2)^0.5
Ms = ((0.0191 * [(2,707,922 * 9.8) * 8.321 + (55,185 * 9.8) * 7.235 + (16,861 * 9.8) * 15.3268])^2 + [0.0051 * (1,065,115 * 9.8) * 10.5292]^2)^0.5
Ms = 4,379,770.2555 N-m

RESISTANCE TO DESIGN LOADS

Fy = 250 MPa

Ge = S.G. * (1- 0.4 * Av)
Ge = 1 * (1- 0.4 * 0.0311)
Ge = 0.9876

wa = MIN (99 * ta * (Fy * H * Ge)^0.5 , 201.1 * H * D * Ge)
wa = MIN (99 * 6 * (250 * 14.47 * 0.9876)^0.5) , 201.1 * 14.47 * 18.1 * 0.9876)
wa = MIN (35,503.6055 , 52,014.2891)
wa = 35,503.6055 N/m

wt = (Wrs + Ws) / (Pi * D)

wt = (12,583 + 55,185) / (3.1416 * 18.1)
wt = 11,687.3713 N/m

wint = P * (Pi * D^2 / 4) / (Pi * D)
wint = 0 * (3.1416 * 18.1^2 / 4) / (3.1416 * 18.1)
wint = 0 N/m

Anchorage Ratio

J = Mrw / (D^2 * [wt * (1 - 0.4 * Av)] + wa - 0.4 * wint
J = 2,978,281.0086 / (18.1^2 * [11,687.3713 * (1 - 0.4 * 0.0311)] + 35,503.6055 - 0.4 * 0
J = 0.1932

Since J <= 0.785, The tank is self-anchored, per API 650 Table E-6

Maximum Longitudinal Shell-Membrane Compressive Stress

ts1 = 9 mm
SigC = [wt * (1 + (0.4 * Av)) + (1.273 * Mrw) / D^2] * (1 / (1,000 * ts))
SigC = [11,687.3713 * (1 + (0.4 * 0.0311)) + (1.273 * 2,978,281.0086) / 18.1^2] * (1 / (1,000 * 9))
SigC = 2.6006 MPa

Allowable Longitudinal Shell-Membrane Compression Stress

Fty = 250 MPa

Criteria for Fc

Since [G * H * D^2 / ts1^2] >= 44
Since [1 * 14.47 * 18.1^2 / 9^2] >= 44
Since 58.5249 >= 44 Then Fc = 83 * ts1 / D

Fc = 83 * ts1 / D
Fc = 83 * 9 / 18.1
Fc = 41.2707 MPa

SigC <= Fc Then the design is acceptable.

Hoop Stresses

SHELL SUMMARY	SigT+	Sd * 1.333	Fy * 0.9 * E	Allowable Membrane	t-Min	Shell Ok
Shell 1	106.5971	213.28	225	213.28	7.4981	OK
Shell 2	95.4148	213.28	225	213.28	7.0263	OK
Shell 3	101.0523	213.28	225	213.28	6.3166	OK
Shell 4	87.5797	213.28	225	213.28	5.8744	OK
Shell 5	92.5975	213.28	225	213.28	5.1707	OK
Shell 6	75.6821	213.28	225	213.28	4.7742	OK
Shell 7	78.3042	213.28	225	213.28	4.1014	OK
Shell 8	55.6503	213.28	225	213.28	3.7827	OK
Shell 9	32.9655	213.28	225	213.28	3.4636	OK
Shell 10	10.3693	213.28	225	213.28	3.1458	OK

Mechanically Anchored

Number of anchor = 0

Wab = (1.273 * Mrw) / D^2 - wt * (1 - 0.4 * Av) + wint

Wab = (1.273 * 2,978,281.0086) / 18.1^2 - 11,687.3713 * (1 - 0.4 * 0.0311) + 0

Wab = 30.779 N/m

Pab = Wab * Pi * D / Na

Pab = 30.779 * 3.1416 * 18.1 / 0

Pab = 0 N

Pa = 3 * Pab

Pa = 3 * 0

Pa = 0 N

Shell Compression in Mechanically-Anchored Tanks

SigC-anchored = [Wt * (1 + (0.4 * Av)) + (1.273 * Mrw) / D^2] * (1 / (1,000 * ts))
SigC-anchored = [11,687.3713 * (1 + (0.4 * 0.0311)) + (1.273 * 2,978,281.0086) / 18.1^2] * (1 / (1,000 * 9))
SigC-anchored = 2.6006 MPa

Fc = 41.2707 MPa

Detailing Requirements (Anchorage)

SUG = I
Sds = 0.0667 g or 6.67 %g

Freeboard - Sloshing

TL-sloshing = 4 sec
I-sloshing = 1.0
Tc = 4.4386
k = 1.5
Sd1 = 0.0333 g or 3.33 %g
Af = 0.0101 g per API 650 E.7.2

Delta-s = 0.42 * D * Af
Delta-s = 0.42 * 18.1 * 0.0101
Delta-s = 0.0768 m

0.7 * Delta-s = 0.0537 m

Since Sds < 0.33g and SUG = I per API 650 Table E-7.
a. A freeboard of O.7*Delta-s is recommended for economic considerations but not required.

Sliding Resistance

mu = 0.4 (friction coefficient)
V = 53,724.3187 kgf

Vs = mu * (Ws + Wr + Wf + Wp) * (1 - 0.4 * Av)
Vs = 0.4 * (55,185 + 16,861 + 18,409 + 3,723,193) * (1 - 0.4 * 0.0311)
Vs = 1,506,482.4289 kgf

Since V <= Vs Then the tank will not experience major sliding and does not require additional lateral anchorage, per API 650 E.7.6.

Local Shear Transfer

Vmax = 2 * V / (Pi * D)
Vmax = 2 * 53,724.3187 / (3.1416 * 18.1)
Vmax = 1,889.6112 kgf/m

ANCHOR BOLT DESIGN

Bolt Material : A36M
Sy = 250 MPa

UPLIFT LOAD CASES, PER API-650 TABLE 5-21b

A-s-r = Bolt Root Area Req'd
bt = Uplift load per bolt
D = Tank D (m)
Fp = Pressure Combination Factor
Mrw = Seismic Ringwall Moment (Nm)
N = Anchor bolt quantity
P = Design pressure (pa)
Pf = Failure pressure per F.6 (KPa)
Pt = Test pressure per F.7.6 = 1.25 * P = 0 (pa)
sd = Allowable Anchor Bolt Stress (MPa)
Shell-sd-at-anchor = Allowable Shell Stress at Anchor Attachment (MPa)
t-actual = Actual Roof plate thickness (mm)
t-h = Roof plate thickness less CA (mm)
Vf = Velocity factor (kph)

W1 = Dead Load of Shell minus C.A. and Any Dead Load minus C.A. other than Roof Plate Acting on Shell

W2 = Dead Load of Shell minus C.A. and Any Dead Load minus C.A. including Roof Plate minus C.A. Acting on Shell

W3 = Dead Load of New Shell and Any Dead Load other than Roof Plate Acting on Shell

For Tank with Structural Supported Roof

W1 = W-shell-corroded + Shell Insulation

W1 = 346,071.6058 + 0

W1 = 346,071.6058 N

W2 = W-shell-corroded + Shell Insulation + Corroded Roof Plates Supported by Shell + Roof Dead Load Supported by Shell

W2 = 346,071.6058 + 0 + 103,341.3393 + 0

W2 = 449,412.9451 N

W3 = New Shell + Shell Insulation

W3 = 534,699.9264 + 0

W3 = 534,699.9264 N

Uplift Case 1: Design Pressure Only

U = [(P - 0.08 * t-h) * D^2 * 785] - W1

U = [(0 - 0.08 * 5) * 18.1^2 * 785] - 346,071.6058

U = -448,941.14583333815 N

bt = U/N

bt = 0 N

sd = 104.1666 MPa

Shell-sd-at-anchor = 166.6666 MPa

A-s-r = N.A., since Load per Bolt is zero

Uplift Case 2: Test Pressure Only

U = [(Pt - 0.08 * t-h) * D^2 * 785] - W1

U = [(0 - 0.08 * 5) * 18.1^2 * 785] - 346,071.6058

U = -448,941.14583333815 N

bt = U/N

bt = 0 N

sd = 138.8888 MPa

Shell-sd-at-anchor = 208.3333 MPa

A-s-r = N.A., since Load per Bolt is zero

Uplift Case 3: Failure Pressure Only

Not applicable since if there is a knuckle on tank roof, or tank roof is not frangible.

Pf (failure pressure per F.6) = N.A.

Uplift Case 4: Wind Load Only

PWR = Wind-Uplift per API 650 Table 5-21a, 5-21b

PWS = Wind-Pressure per API 650 Table 5-21a, 5-21b

PWR = 1.6116 KPa

PWS = 962.4614 N/m^2

MWH = PWS * D * (H^2 / 2) per API 650 Table 5-21a, 5-21b

MWH = 962.4614 * 18.1 * (14.47^2 / 2)

MWH = 1,823,765.5406 Nm

U = PWR * D^2 * 785 + (4 * MWH / D) - W2

U = 1.6116 * 18.1^2 * 785 + (4 * 1,823,765.5406 / 18.1) - 449,412.9451

U = 368,081.1363 N

bt = U/N

bt = 0 N

sd = 200 MPa

Shell-sd-at-anchor = 208.3333 MPa

A-s-r = N.A., since Load per Bolt is zero

Uplift Case 5: Seismic Load Only

U = [4 * Mrw / D] - W2 * (1 - 0.4 * Av)

U = [4 * 2,978,281 / 18.1] - 449,412.9451 * (1 - 0.4 * 0.0311)

U = 214,361.4002 N

bt = U/N

bt = 0 N

sd = 200 MPa

Shell-sd-at-anchor = 208.3333 MPa

A-s-r = N.A., since Load per Bolt is zero

Uplift Case 6: Design Pressure + Wind Load

U = [(Fp * P + PWR - 0.08 * t-h) * D^2 * 785] + [4 * MWH / D] - W1

U = [(0.4 * 0 + 1.6116 - 0.08 * 5) * 18.1^2 * 785] + [4 * 1,823,765.5406 / 18.1] - 346,071.6058

U = 368,552.9356 N

bt = U/N

bt = 0 N

sd = 138.8888 MPa

Shell-sd-at-anchor = 208.3333 MPa

A-s-r = N.A., since Load per Bolt is zero

Uplift Case 7: Design Pressure + Seismic Load

U = [(Fp * P - 0.08 * t-h) * D^2 * 785] + [4 * Mrw / D] - W1 * (1 - 0.4 * Av)

U = [(0.4 * 0 - 0.08 * 5) * 18.1^2 * 785] + [4 * 2,978,281 / 18.1] - 346,071.6058 * (1 - 0.4 * 0.0311)

U = 213,547.6332 N

bt = U/N
bt = 0 N

sd = 200 MPa
Shell-sd-at-anchor = 208.3333 MPa

A-s-r = N.A., since Load per Bolt is zero

Uplift Case 8: Frangibility Pressure

Not applicable since if there is a knuckle on tank roof, or tank roof is not frangible.
Pf (failure pressure per F.6) = N.A.

ANCHOR BOLT SUMMARY

Bolt Root Area Req'd = 0 mm^2
Bolt Diameter (d) = 56 mm (M56)
Threads per centimeters (n) = 0.1818

A-s = Actual Bolt Root Area
A-s = (pi / 4) * (d - 33.02 / n)^2
A-s = 0.7854 * (56 - 33.02 / 0.1818)^2
A-s = 1874.2177 mm^2

Exclusive of Corrosion
Bolt Diameter Req'd = 6.7477 mm (per ANSI B1.1)
Actual Bolt Diameter = 56 mm (M56)
Bolt Diameter Meets Requirements

ANCHOR CHAIR DESIGN

(from AISI 'Steel Plate Engr Data' Dec. 92, Vol. 2, Part VII)

Entered Parameters

Chair Material : A36M

Top Plate Type : DISCRETE

Chair Style : VERT. TAPERED

Top Plate Width (a) : 254 mm

Top Plate Length (b) : 204 mm

Vertical Plate Width (k) : 127 mm

Top Plate Thickness (c) : 26 mm

Bolt Eccentricity (e) : 102 mm

Outside of Top Plate to Hole Edge (f) : 67 mm

Distance Between Vertical Plates (g) : 108 mm

Chair Height (h) : 712 mm

Vertical Plates Thickness (j) : 26 mm

Bottom Plate thickness (m) : 9 mm

Shell Course + Repad Thickness (t) : 12 mm

Nominal Radius to Tank Centerline (r) : 9056 mm

Design Load per Bolt (P) : 0 N

Bolt Diameter (d) = 56 mm (M56)

Threads per unit length (n) = 0.1818

Bolt Yield Load = A-s * Sy

Bolt Yield Load = 1874.2177 * 250

Bolt Yield Load = 468,554.423 N

Seismic Design Bolt Load (Pa) = 0 N

Anchor Chairs will be designed to withstand

Design Load per Bolt

Anchor Chair Design Load, (P) : 0 N

NORMAL AND EMERGENCY VENTING (API-2000 6th EDITION) Back

NORMAL VENTING

T > 48.9

EMERGENCY VENTING

D (Tank diameter) = 18.1 m

H (Tank height) = 14.47 m

Pg (Design pressure) = 0.0 kPa

inslation_type (Insulation type) = no insulation

vapour_pressure_type (Vapour pressure type) = hexane or similar

As per API-2000 Table 9, Environmental factor for insulation (F_ins) = 1.0

As per API-2000 Table 9, Environmental factor for drainage (F_drain) = 0.5

Environmental factor *API-2000 4.3.3.3.4*

F = MIN(F_ins , F_drain) = MIN(1.0 , 0.5) = 0.5

Wetted surface area

ATWS = pi * D * MIN(H , 9.14) = pi * 18.1 * MIN(14.47 , 9.14) = 519.7262 m^2

Required emergency venting capacity *API-2000 Table 5 and 4.3.3.3.4*

q = 19910 * F = 19910 * 0.5 = 9955.0 m^3/hr

PLAN VIEW APPURTENANCE

MARK	CUST. MARK	DESCRIPTION	OUTSIDE PROJ (mm)	INSIDE PROJ (mm)	ORIENT	RADIUS (mm)	REMARKS	REF DWG
RN01		6" ROOF NOZZLE	203mm	0mm	270	8500mm		RN01
RN02		6" ROOF NOZZLE	203mm	0mm	90	8500mm		RN02
RN02		6" ROOF NOZZLE	203mm	0mm	180	8500mm		RN02
RN02		6" ROOF NOZZLE	203mm	0mm	0'	8500mm		RN02
RV01		24" FREEVENT	248mm	0mm	0'	0mm		RN97

ELEVATION VIEW APPURTENANCE

MARK	CUST. MARK	DESCRIPTION	OUTSIDE PROJ (mm)	INSIDE PROJ (mm)	ORIENT	ELEVATION (mm)	REMARKS	REF DWG
NP01A		STD API	--	--	0'	1016mm		NP01
SN01		6" SHELL NOZZLE	200mm	0mm	0'	14000mm		SN01
SN02		6" SHELL NOZZLE	200mm	0mm	180'	1000mm		SN02

Nozzle Nozzle-0001 Reinforcement Requirements

(Per API-650 and other references below)

NOZZLE Description : 6 in SCH 80 TYPE RFWN

t_rpr = (Re Pad Required Thickness)

t_n = (Thickness of Neck)
Sd_n = (Stress of Neck Material)
Sd_s = (Stress of Roof Material)
CA = (Corrosion Allowance of Neck)

MOUNTED ON ROOF: Elevation = 14.6376 ft

ROOF PARAMETERS:
t-calc = 8 mm
t_cr = 5 mm (Roof t-calc less C.A)
t_c = 8 mm
t_Basis = 5 mm

(FOR ROOF NOZZLE,REF. API-650 FIG 5-19, TABLE 5-14 AND FOOTNOTE A OF TABLE 5-14, or API-650 FIG 5-20, TABLE 5-15 AND FOOTNOTE A OF TABLE 5-15)

Required Area = t_Basis * D
Required Area = 5 * 168.275
Required Area = 841.375 mm^2

Available Roof Area = (t_c - t_Basis) * D
Available Roof Area = (8 - 5) * 168.275
Available Roof Area = 504.825 mm^2

Available Nozzle Neck Area = [4 * (t_n - CA) + t_c] * (t_n - ca) * MIN((Sd_n/Sd_s) 1)
Available Nozzle Neck Area = [4 * (10.9728 - 3) + 8] * (10.9728 - 3) * MIN((103.4213/160) 1)
Available Nozzle Neck Area = 329.2625 mm^2

A-rpr = (Required Area - Available Roof Area - Available Nozzle Neck Area)
A-rpr = 841.375 - 504.825 - 329.2625
A-rpr = 7.2875 mm^2

t_rpr = (A_rpr / D) + repad_CA
t_rpr = (7.2875 / 168.275) + 3
t_rpr = 3.0433 mm

Reinforcement Pad is required.

Based on Roof Nozzle Size of 6 in
Repad Size (OD) Must be 375 mm

Nozzle Nozzle-0002 Reinforcement Requirements

(Per API-650 and other references below)

NOZZLE Description : 6 in SCH 80 TYPE RFSO

t_rpr = (Re Pad Required Thickness)
t_n = (Thickness of Neck)
Sd_n = (Stress of Neck Material)
Sd_s = (Stress of Roof Material)
CA = (Corrosion Allowance of Neck)

MOUNTED ON ROOF: Elevation = 14.6376 ft

ROOF PARAMETERS:
t-calc = 8 mm
t_cr = 5 mm (Roof t-calc less C.A)
t_c = 8 mm
t_Basis = 5 mm

(FOR ROOF NOZZLE,REF. API-650 FIG 5-19, TABLE 5-14 AND FOOTNOTE A OF TABLE 5-14, or API-650 FIG 5-20, TABLE 5-15 AND FOOTNOTE A OF TABLE 5-15)

Required Area = t_Basis * D
Required Area = 5 * 168.275
Required Area = 841.375 mm^2

Available Roof Area = (t_c - t_Basis) * D
Available Roof Area = (8 - 5) * 168.275
Available Roof Area = 504.825 mm^2

Available Nozzle Neck Area = [4 * (t_n - CA) + t_c] * (t_n - ca) * MIN((Sd_n/Sd_s) 1)
Available Nozzle Neck Area = [4 * (10.9728 - 3) + 8] * (10.9728 - 3) * MIN((103.4213/160) 1)
Available Nozzle Neck Area = 329.2625 mm^2

A-rpr = (Required Area - Available Roof Area - Available Nozzle Neck Area)
A-rpr = 841.375 - 504.825 - 329.2625
A-rpr = 7.2875 mm^2

t_rpr = (A_rpr / D) + repad_CA
t_rpr = (7.2875 / 168.275) + 3
t_rpr = 3.0433 mm

Reinforcement Pad is required.
Based on Roof Nozzle Size of 6 in
Repad Size (OD) Must be 375 mm

Nozzle Nozzle-0003 Reinforcement Requirements

(Per API-650 and other references below)

NOZZLE Description : 6 in SCH 80 TYPE RFSO

t_rpr = (Re Pad Required Thickness)
t_n = (Thickness of Neck)
Sd_n = (Stress of Neck Material)
Sd_s = (Stress of Roof Material)
CA = (Corrosion Allowance of Neck)

MOUNTED ON ROOF: Elevation = 14.6376 ft

ROOF PARAMETERS:
t-calc = 8 mm
t_cr = 5 mm (Roof t-calc less C.A)
t_c = 8 mm
t_Basis = 5 mm

(FOR ROOF NOZZLE,REF. API-650 FIG 5-19, TABLE 5-14 AND FOOTNOTE A OF TABLE 5-14, or API-650 FIG 5-20, TABLE 5-15 AND FOOTNOTE A OF TABLE 5-15)

Required Area = t_Basis * D

Required Area = 5 * 168.275
Required Area = 841.375 mm^2

Available Roof Area = (t_c - t_Basis) * D
Available Roof Area = (8 - 5) * 168.275
Available Roof Area = 504.825 mm^2

Available Nozzle Neck Area = [4 * (t_n - CA) + t_c] * (t_n - ca) * MIN((Sd_n/Sd_s) 1)
Available Nozzle Neck Area = [4 * (10.9728 - 3) + 8] * (10.9728 - 3) * MIN((103.4213/160) 1)
Available Nozzle Neck Area = 329.2625 mm^2

A-rpr = (Required Area - Available Roof Area - Available Nozzle Neck Area)
A-rpr = 841.375 - 504.825 - 329.2625
A-rpr = 7.2875 mm^2

t_rpr = (A_rpr / D) + repad_CA
t_rpr = (7.2875 / 168.275) + 3
t_rpr = 3.0433 mm

Reinforcement Pad is required.
Based on Roof Nozzle Size of 6 in
Repad Size (OD) Must be 375 mm

Nozzle Nozzle-0004 Reinforcement Requirements

(Per API-650 and other references below)

NOZZLE Description : 6 in SCH 80 TYPE RFSO

t_rpr = (Re Pad Required Thickness)
t_n = (Thickness of Neck)
Sd_n = (Stress of Neck Material)
Sd_s = (Stress of Roof Material)
CA = (Corrosion Allowance of Neck)

MOUNTED ON ROOF: Elevation = 14.6376 ft

ROOF PARAMETERS:
t-calc = 8 mm
t_cr = 5 mm (Roof t-calc less C.A)
t_c = 8 mm
t_Basis = 5 mm

(FOR ROOF NOZZLE,REF. API-650 FIG 5-19, TABLE 5-14 AND FOOTNOTE A OF TABLE 5-14, or API-650 FIG 5-20, TABLE 5-15 AND FOOTNOTE A OF TABLE 5-15)

Required Area = t_Basis * D
Required Area = 5 * 168.275
Required Area = 841.375 mm^2

Available Roof Area = (t_c - t_Basis) * D
Available Roof Area = (8 - 5) * 168.275
Available Roof Area = 504.825 mm^2

Available Nozzle Neck Area = [4 * (t_n - CA) + t_c] * (t_n - ca) * MIN((Sd_n/Sd_s) 1)
Available Nozzle Neck Area = [4 * (10.9728 - 3) + 8] * (10.9728 - 3) * MIN((103.4213/160) 1)
Available Nozzle Neck Area = 329.2625 mm^2

A-rpr = (Required Area - Available Roof Area - Available Nozzle Neck Area)
A-rpr = 841.375 - 504.825 - 329.2625
A-rpr = 7.2875 mm^2

t_rpr = (A_rpr / D) + repad_CA
t_rpr = (7.2875 / 168.275) + 3
t_rpr = 3.0433 mm

Reinforcement Pad is required.
Based on Roof Nozzle Size of 6 in
Repad Size (OD) Must be 375 mm

Nozzle Nozzle-0005 Reinforcement Requirements

NOZZLE Description : 6 in SCH STD TYPE RFSO

t_rpr = (Re Pad Required Thickness)
t_n = (Thickness of Neck)
Sd_n = (Stress of Neck Material)
Sd_s = (Stress of Shell Course Material)
CA = (Corrosion Allowance of Neck)

MOUNTED ON SHELL 10 : Elevation = 14.0 ft

COURSE PARAMETERS:
t-calc = 6 mm
t_cr = 3 mm (Course t-calc less C.A)
t_c = 3 mm (Course t less C.A.)
t_Basis = 3 mm

(SHELL NOZZLE REF. API-650 TABLE 5-6, TABLE 3-6 AND FOOTNOTE A OF TABLE 5-7)

Required Area = t_Basis * D
Required Area = 3 * 168.275
Required Area = 504.825 mm^2

Available Shell Area = (t_c - t_Basis) * D
Available Shell Area = (3 - 3) * 168.275
Available Shell Area = 0 mm^2

Available Nozzle Neck Area = [4 * (t_n - CA) + t_c] * (t_n - CA) * MIN((Sd_n/Sd_s) 1)
Available Nozzle Neck Area = [4 * (10.97 - 3) + 3] * (10.97 - 3) * MIN((103.4213/160) 1)
Available Nozzle Neck Area = 226.0556 mm^2

A-rpr = (Required Area - Available Shell Area - Available Nozzle Neck Area)
A-rpr = 504.825 - 0 - 226.0556
A-rpr = 278.7694 mm^2

t_rpr = (A_rpr / D) + repad_CA
t_rpr = (278.7694 / 168.275) + 3
t_rpr = 4.6566 mm

Reinforcement Pad is required.
Based on Shell Nozzle Size of 6 in
Repad Size (L x W) Must be 400 x 495 mm

Nozzle Nozzle-0006 Reinforcement Requirements

NOZZLE Description : 6 in SCH STD TYPE RFSO

t_rpr = (Re Pad Required Thickness)
t_n = (Thickness of Neck)
Sd_n = (Stress of Neck Material)
Sd_s = (Stress of Shell Course Material)
CA = (Corrosion Allowance of Neck)

MOUNTED ON SHELL 1 : Elevation = 1.0 ft

COURSE PARAMETERS:
t-calc = 10.8546 mm
t_cr = 7.8546 mm (Course t-calc less C.A)
t_c = 9 mm (Course t less C.A.)
t_Basis = 7.8546 mm

(SHELL NOZZLE REF. API-650 TABLE 5-6, TABLE 3-6 AND FOOTNOTE A OF TABLE 5-7)

Required Area = t_Basis * D
Required Area = 7.8546 * 168.275
Required Area = 1321.7342 mm^2

Available Shell Area = (t_c - t_Basis) * D
Available Shell Area = (9 - 7.8546) * 168.275
Available Shell Area = 192.7408 mm^2

Available Nozzle Neck Area = [4 * (t_n - CA) + t_c] * (t_n - CA) * MIN((Sd_n/Sd_s) 1)
Available Nozzle Neck Area = [4 * (10.97 - 3) + 9] * (10.97 - 3) * MIN((103.4213/160) 1)
Available Nozzle Neck Area = 349.6958 mm^2

A-rpr = (Required Area - Available Shell Area - Available Nozzle Neck Area)

A-rpr = 1321.7342 - 192.7408 - 349.6958

A-rpr = 779.2975 mm^2

t_rpr = (A_rpr / D) + repad_CA

t_rpr = (779.2975 / 168.275) + 3

t_rpr = 7.6311 mm

Reinforcement Pad is required.

Based on Shell Nozzle Size of 6 in

Repad Size (L x W) Must be 400 x 495 mm

CAPACITIES and WEIGHTS Back

Maximum Capacity (to Max Liq Level) : 3,723 M^3

Capacity to Top of Shell (to Tank Height) : 3,723 M^3

Working Capacity (to Normal Working Level) : 3,804 M^3

Net working Capacity (Working Capacity - Min Capacity) : 3,804 M^3

Minimum Capacity (to Min Liq Level) : 0 M^3

Component	New Condition (N)	New Condition (Kg)	Corroded (N)	Corroded (Kg)
SHELL	534,700	54,525	346,072	35,290
ROOF	165,347	16,861	103,342	10,538
RAFTERS	43,029	4,388	43,029	4,388
GIRDERS	0	0	0	0
FRAMING	0	0	0	0
COLUMNS	9,816	1,001	9,816	1,001
BOTTOM	180,532	18,410	120,355	12,273
STAIRWAYS	9,993	1,019	9,993	1,019
STIFFENERS	6,631	677	6,631	677
WIND GIRDERS	0	0	0	0
ANCHOR CHAIRS	0	0	0	0
INSULATION	0	0	0	0
TOTAL	950,048	96,881	639,238	65,186

Weight of Tank, Empty : 950,048 N

Weight of Tank, Full of Product (SG = 1) : 37,462,098.6334 N

Weight of Tank, Full of Water : 37,462,099.7095 N

Net Working Weight, Full of Product : 37,462,099.7095 N

Net Working Weight Full of Water : 37,462,099.7095 N

Foundation Area Req'd : 260.8418 m^2

Foundation Loading, Empty : 3,642.2374 N/m^2

Foundation Loading, Full of Product : 139,977.7247 N/m^2

Foundation Loading, Full of Water : 139,977.7289 N/m^2

SURFACE AREAS

Roof : 268.7642 m^2

Shell : 822.8051 m^2

Bottom : 260.8418 m^2

Wind Moment : 5,576,458.3522 N-m

Seismic Moment : 4,379,770.2555 N-m

MISCELLANEOUS ATTACHED ROOF ITEMS

MISCELLANEOUS ATTACHED SHELL ITEMS

MAWP & MAWV SUMMARY

MAXIMUM CALCULATED INTERNAL PRESSURE

MAWP = 18 kPa or 1,835.658 mmh2o (per API-650 App. F.1.3 & F.7)

MAWP = 20.2604 kPa or 2,066.1759 mmh2o (due to shell)

MAWP = 3.004 kPa or 306.3509 mmh2o (due to roof)

TANK MAWP = 3.004 kPa or 306.3477 mmh2o

MAXIMUM CALCULATED EXTERNAL PRESSURE

MAWV = -6.9 kPa or -703.6689 mmh2o (per API-650 V.1)

MAWV = N/A (due to shell) (API-650 App.V not applicable)

MAWV = -1.2306 kPa or -125.4978 mmh2o (due to roof)

TANK MAWV = -1.2306 kPa or -125.493

Appendix B

KORF REPORT

Four Reports of Korf

Gantry to PMG

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Designing of 6000 Tons Hydrocarbon (Petrol & Diesel) Storage Tanks with Loading and Unloading System as per Regulatory Rules of Pakistan	This information is confidential, and shall not be reproduced by any means without the written permission of KORF.	Page: 219 Proj: By : Chkd/Apvd: /
CASE 1 NORMAL	GENERAL	Date: 21 Feb 24, 13:29

===
==

FILE NAME : C:\Users\gpmc\Downloads\Start.kdf

DEFAULTS : Fitting method = Crane
fT based on steel = Yes
Compressible = Isothermal
Two phase flow = Homogeneous
Acceleration = Homogeneous
Elevation den = Flanigan
Dukler hold-up = Hughmark
Smooth pipe f = No
Sonic velocity = HEMOmega
Two phase orifice = Homogeneous
Two phase valve = Homogeneous
Atmospheric pres = 101.325 kPa abs

VIEW/PRINT SETTINGS:
Font = Courier, Size 7-8
Orientation = Landscape
Margins = 1-2 cm.

RUN MESSAGE: Case 1 Hydraulic solution reached after 2 iterations.

NOTES:
1) Close this report before running/viewing next results.
2) Report is not automatically saved or printed.
Save the report as rtf file from the Korf menu (Hydraulics | Results | Save Report) or editor menu (File | Save As for MS Word).
After the final run, print the saved report with an editor (MS Word, etc.) for quality assurance purposes.

Circuit Feed 1

Number	Description	Flow kg/h	Density kg/m3	Visc cP	Dia in	Sch	Length m	dP/L kPa/100m	Velocity m/s	Elev m	dPelev kPa	dPin-out kPa	Pin kPag	Pout kPag
F1	Feed									0	(	0	-43.58	-43.58
L1	Pipe	101,486	740	1.48	8	40	1.0	4.72	1.18		0	0.0472	-43.58	-43.62
X1	Misc Equipment						K = 0.0			0-0	0	0	-43.62	-43.62
L2	Pipe	101,486	740	1.48	8	40	1.0	4.72	1.18		0	0.0472	-43.62	-43.67
T1	Tee									0			-43.67	-44.29
L3	Pipe	101,486	740	1.48	8	40	8.0	4.72	1.18		0	0.378	-44.29	-44.67
T4	Tee									0			-44.67	-45.24
L4	Pipe	101,486	740	1.48	8	40	2.5	4.72	1.18		0	0.118	-45.24	-45.36
Z1	Check									0		0.725	-45.36	-46.08
L5	Pipe	101,486	740	1.48	8	40	2.5	4.72	1.18		0	0.118	-46.08	-46.2
Z2	Check									0		0.725	-46.2	-46.92
L6	Pipe	101,486	740	1.48	8	40	2.5	4.72	1.18		0	0.118	-46.92	-47.04
R1	Reducer						K = 0.0			0		0	-47.04	-47.04
L7	Pipe	101,486	740	1.48	8	40	2.5	4.72	1.18		0	0.118	-47.04	-47.16
P1	Pump									0		-100	-47.16	52.84
L8	Pipe	101,486	740	1.48	8	40	6.0	4.72	1.18		0	0.283	52.84	52.56
R2	Reducer						K = 0.0			0		0	52.56	52.56
L9	Pipe	101,486	740	1.48	8	40	6.0	4.72	1.18		0	0.283	52.56	52.27
X2	Misc Equipment						K = 0.0			0-0	0	0	52.27	52.27
L10	Pipe	101,486	740	1.48	8	40	6.0	4.72	1.18		0	0.283	52.27	51.99
Z3	Check									0		0.725	51.99	51.26
L11	Pipe	101,486	740	1.48	8	40	6.0	4.72	1.18		0	0.283	51.26	50.98
T2	Tee									0			50.98	50.56
L12	Pipe	101,486	1,000	1.0	8	40	1.25	3.3	0.873		0	0.0413	50.56	50.52
X3	Misc Equipment						K = 0.0			0-0	0	0	50.52	50.52
L13	Pipe	101,486	1,000	1.0	8	40	1.25	3.3	0.873		0	0.0413	50.52	50.48
T3	Tee									0			50.48	50.02
L14	Pipe	101,486	1,000	1.0	8	40	0.50	3.3	0.873		0	0.0165	50.02	50.0
TK1	Product									0	0	0	50.0	50.0

NOTES - (1) dPElev and dPin-out represent DRAWING Inlet - Outlet.
(2) dPin-out = dPElev + dPfrictional + dPaccel
(3) Vessel/Tank dPElev represent effect of fluid levels inside vessel.
(4) Elev represent equipment or nozzle (vessel/tank) elevation.

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-----------------------------------------------------------------------------------------
Line number          | L1                | L2                | L3                | L4
Line name            | Pipe              | Pipe              | Pipe              | Pipe
-----------------------------------------------------------------------------------------
PROCESS DATA            | AVG   IN    OUT    | AVG   IN    OUT    | AVG   IN    OUT    | AVG   IN    OUT
 Temperature    C       | 25.0   25.0   25.0   | 25.0   25.0   25.0   | 25.0   25.0   25.0   | 25.0   25.0   25.0
 Pressure     kPag      | -43.6  -43.58  -43.62  | -43.65  -43.62  -43.67  | -44.48  -44.29  -44.67  | -45.3  -45.24  -45.36
 Liq Fraction   wt      | 1.0   1.0   1.0   | 1.0   1.0   1.0   | 1.0   1.0   1.0   | 1.0   1.0   1.0
 Total-Flow    kg/h     | 101,486           | 101,486           | 101,486           | 101,486
    Dens-NS   kg/m3     | 740   740   740   | 740   740   740   | 740   740   740   | 740   740   740
       Elev  kg/m3      | 740               | 740               | 740               | 740
    Visc-NS    cP       | 1.48              | 1.48              | 1.48              | 1.48
 Vapor-Flow     kg/h    | 0                 | 0                 | 0                 | 0
    Density   kg/m3     | 0   0   0   | 0   0   0   | 0   0   0   | 0   0   0
    Visc      cP        | 0   0   0   | 0   0   0   | 0   0   0   | 0   0   0
    Mol wt              | 0   0   0   | 0   0   0   | 0   0   0   | 0   0   0
    Z                   | 0   0   0   | 0   0   0   | 0   0   0   | 0   0   0
    Cp/Cv               | 0   0   0   | 0   0   0   | 0   0   0   | 0   0   0
 Liquid-Flow (wt)  kg/h | 101,486           | 101,486           | 101,486           | 101,486
    Flow (vol) m3/h     | 137.1             | 137.1             | 137.1             | 137.1
    Density   kg/m3     | 740   740   740   | 740   740   740   | 740   740   740   | 740   740   740
    Visc      cP        | 1.48   1.48   1.48   | 1.48   1.48   1.48   | 1.48   1.48   1.48   | 1.48   1.48   1.48
PIPE DATA               |                   |                   |                   |
 Material               | Steel             | Steel             | Steel             | Steel
 Size         in        | 8                 | 8                 | 8                 | 8
 Length        m        | 1.0               | 1.0               | 8.0               | 2.5
 Schedule               | 40                | 40                | 40                | 40
 ID Flow/Hydr    mm     | 203     / 203     | 203     / 203     | 203     / 203     | 203     / 203
 Roughness (E-3)  mm    | 45.7              | 45.7              | 45.7              | 45.7
 Safety factor          | 1.0               | 1.0               | 1.0               | 1.0
 Sum of elev's   m      | 0                 | 0                 | 0                 | 0
VELOCITY                |                   |                   |                   |
 Velocity      m/s      | 1.18   1.18   1.18   | 1.18   1.18   1.18   | 1.18   1.18   1.18   | 1.18   1.18   1.18
 Sonic (Vap)    m/s     | 5,000             | 5,000             | 5,000             | 5,000
PRESSURE DROP (In-Out)  |                   |                   |                   |
 Overall       kPa      | 0.04725           | 0.04725           | 0.378             | 0.1181
 Friction      kPa      | 0.04725           | 0.04725           | 0.378             | 0.1181
 Accel'n       kPa      | 0                 | 0                 | 0                 | 0
 Static        kPa      | 0                 | 0                 | 0                 | 0
 dP/Length     kPa/100m | 4.72              | 4.72              | 4.72              | 4.72
LINE SIZING             | MAX/LARGER MIN/SMALLER | MAX/LARGER MIN/SMALLER | MAX/LARGER
MIN/SMALLER | MAX/LARGER  MIN/SMALLER
 dP/Length     kPa/100m | 22.6              | 22.6              | 22.6              | 22.6
 Velocity      m/s      | 100      0.30     | 100      0.30     | 100      0.30     | 100      0.30
 VelCoef       m/s      | 4.41     0.368    | 4.41     0.368    | 4.41     0.368    | 4.41     0.368
 Size-Larger/Small in   | 10       6        | 10       6        | 10       6        | 10       6
   dP/Length  kPa/100m  | 1.55     18.3     | 1.55     18.3     | 1.55     18.3     | 1.55     18.3
   Velocity    m/s      | 0.749    2.04     | 0.749    2.04     | 0.749    2.04     | 0.749    2.04
```

Line number	L1	L2	L3	L4
Line name	Pipe	Pipe	Pipe	Pipe
LIQUID HOLDUP				
Liquid Fraction (vol)	1.0	1.0	1.0	1.0
Liquid Holdup(dP) (vol)	1.0	1.0	1.0	1.0
2-PHASE METHOD	Homogeneous	Homogeneous	Homogeneous	Homogeneous
FLOW REGIME				
Horizontal (Mandane)	-	-	-	-
Horizontal (Dukler)	-	-	-	-
Vertical Up (Fair)	-	-	-	-
Vertical Up (Dukler)	-	-	-	-
Vertical Down (Golan)	-	-	-	-
HOMOGENEOUS/DUKLER/BEGGS				
Reynolds No	119,643	119,643	119,643	119,643
Friction factor	0.01858	0.01858	0.01858	0.01858
Friction factor (turb)	0.01406	0.01406	0.01406	0.01406
ftp/fns	0	0	0	0
Dentp/Denns	0	0	0	0
LOCKHART-M/CHENOWETH-M				
Liquid-Re	0	0	0	0
f	0	0	0	0
Psi/Psi^2	0	0	0	0
Vapor-Re	0	0	0	0
f	0	0	0	0
Psi^2	0	0	0	0
X factor	0	0	0	0
FITTINGS	TYPE No L/D K	TYPE No L/D K	TYPE No L/D K	TYPE No L/D K
	Entrance 0 0 0.50	Entrance 0 0 0.50	Entrance 0 0 0.50	Entrance 0 0 0.50
	Exit 0 0 1.0	Exit 0 0 1.0	Exit 0 0 1.0	Exit 0 0 1.0
	Gate valve 0 8.0 0	Gate valve 0 8.0 0	Gate valve 0 8.0 0	Gate valve 0 8.0 0
	Globe valv 0 340 0	Globe valv 0 340 0	Globe valv 0 340 0	Globe valv 0 340 0
	Check 0 50.0 0	Check 0 50.0 0	Check 0 50.0 0	Check 0 50.0 0
	Stop-check 0 400 0	Stop-check 0 400 0	Stop-check 0 400 0	Stop-check 0 400 0
	Elbow 0 20.0 0	Elbow 0 20.0 0	Elbow 0 20.0 0	Elbow 0 20.0 0
	180 Bend 0 50.0 0	180 Bend 0 50.0 0	180 Bend 0 50.0 0	180 Bend 0 50.0 0
	T-Straight 0 20.0 0	T-Straight 0 20.0 0	T-Straight 0 20.0 0	T-Straight 0 20.0 0
	T-Branch 0 60.0 0	T-Branch 0 60.0 0	T-Branch 0 60.0 0	T-Branch 0 60.0 0
	Other 1 0 0	Other 1 0 0	Other 1 0 0	Other 1 0 0
Fitting K	0	0	0	0
Fitting L/D	0	0	0	0
Total Eq Length m	1.00	1.00	8.00	2.50

Line number		L5			L6			L7			L8		
Line name		Pipe			Pipe			Pipe			Pipe		
PROCESS DATA		AVG	IN	OUT	AVG	IN	OUT	AVG	IN	OUT	AVG	IN	OUT
Temperature	C	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Pressure	kPag	-46.14	-46.08	-46.2	-46.98	-46.92	-47.04	-47.1	-47.04	-47.16	52.7	52.84	52.56
Liq Fraction	wt	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Total-Flow	kg/h	101,486			101,486			101,486			101,486		
Dens-NS	kg/m3	740	740	740	740	740	740	740	740	740	740	740	740
Elev	kg/m3	740			740			740			740		
Visc-NS	cP	1.48			1.48			1.48			1.48		
Vapor-Flow	kg/h	0			0			0			0		
Density	kg/m3	0	0	0	0	0	0	0	0	0	0	0	0
Visc	cP	0	0	0	0	0	0	0	0	0	0	0	0
Mol wt		0	0	0	0	0	0	0	0	0	0	0	0
Z		0	0	0	0	0	0	0	0	0	0	0	0
Cp/Cv		0	0	0	0	0	0	0	0	0	0	0	0
Liquid-Flow (wt)	kg/h	101,486			101,486			101,486			101,486		
Flow (vol)	m3/h	137.1			137.1			137.1			137.1		
Density	kg/m3	740	740	740	740	740	740	740	740	740	740	740	740
Visc	cP	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48
PIPE DATA													
Material		Steel			Steel			Steel			Steel		
Size	in	8			8			8			8		
Length	m	2.5			2.5			2.5			6.0		
Schedule		40			40			40			40		
ID Flow/Hydr	mm	203	/ 203		203	/ 203		203	/ 203		203	/ 203	
Roughness (E-3)	mm	45.7			45.7			45.7			45.7		
Safety factor		1.0			1.0			1.0			1.0		
Sum of elev's	m	0			0			0			0		
VELOCITY													
Velocity	m/s	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18
Sonic (Vap)	m/s	5,000			5,000			5,000			5,000		
PRESSURE DROP (In-Out)													
Overall	kPa	0.1181			0.1181			0.1181			0.2835		
Friction	kPa	0.1181			0.1181			0.1181			0.2835		
Accel'n	kPa	0			0			0			0		
Static	kPa	0			0			0			0		
dP/Length	kPa/100m	4.72			4.72			4.72			4.72		

LINE SIZING		MAX/LARGER	MIN/SMALLER	MAX/LARGER	MIN/SMALLER	MAX/LARGER	MIN/SMALLER	MAX/LARGER	MIN/SMALLER
dP/Length	kPa/100m	22.6		22.6		22.6		22.6	
Velocity	m/s	100	0.30	100	0.30	100	0.30	100	0.30
VelCoef	m/s	4.41	0.368	4.41	0.368	4.41	0.368	4.41	0.368
Size-Larger/Small	in	10	6	10	6	10	6	10	6
dP/Length	kPa/100m	1.55	18.3	1.55	18.3	1.55	18.3	1.55	18.3
Velocity	m/s	0.749	2.04	0.749	2.04	0.749	2.04	0.749	2.04

Line number	L5	L6	L7	L8
Line name	Pipe	Pipe	Pipe	Pipe
LIQUID HOLDUP				
Liquid Fraction (vol)	1.0	1.0	1.0	1.0
Liquid Holdup(dP) (vol)	1.0	1.0	1.0	1.0
2-PHASE METHOD	Homogeneous	Homogeneous	Homogeneous	Homogeneous
FLOW REGIME				
Horizontal (Mandane)	-	-	-	-
Horizontal (Dukler)	-	-	-	-
Vertical Up (Fair)	-	-	-	-
Vertical Up (Dukler)	-	-	-	-
Vertical Down (Golan)	-	-	-	-
HOMOGENEOUS/DUKLER/BEGGS				
Reynolds No	119,643	119,643	119,643	119,643
Friction factor	0.01858	0.01858	0.01858	0.01858
Friction factor (turb)	0.01406	0.01406	0.01406	0.01406
ftp/fns	0	0	0	0
Dentp/Denns	0	0	0	0
LOCKHART-M/CHENOWETH-M				
Liquid-Re	0	0	0	0
f	0	0	0	0
Psi/Psi^2	0	0	0	0
Vapor-Re	0	0	0	0
f	0	0	0	0
Psi^2	0	0	0	0
X factor	0	0	0	0
FITTINGS	TYPE No L/D K	TYPE No L/D K	TYPE No L/D K	TYPE No L/D K
	Entrance 0 0 0.50	Entrance 0 0 0.50	Entrance 0 0 0.50	Entrance 0 0 0.50
	Exit 0 0 1.0	Exit 0 0 1.0	Exit 0 0 1.0	Exit 0 0 1.0
	Gate valve 0 8.0 0	Gate valve 0 8.0 0	Gate valve 0 8.0 0	Gate valve 0 8.0 0
	Globe valv 0 340 0	Globe valv 0 340 0	Globe valv 0 340 0	Globe valv 0 340 0
	Check 0 50.0 0	Check 0 50.0 0	Check 0 50.0 0	Check 0 50.0 0
	Stop-check 0 400 0	Stop-check 0 400 0	Stop-check 0 400 0	Stop-check 0 400 0
	Elbow 0 20.0 0	Elbow 0 20.0 0	Elbow 0 20.0 0	Elbow 0 20.0 0
	180 Bend 0 50.0 0	180 Bend 0 50.0 0	180 Bend 0 50.0 0	180 Bend 0 50.0 0
	T-Straight 0 20.0 0	T-Straight 0 20.0 0	T-Straight 0 20.0 0	T-Straight 0 20.0 0
	T-Branch 0 60.0 0	T-Branch 0 60.0 0	T-Branch 0 60.0 0	T-Branch 0 60.0 0
	Other 1 0 0	Other 1 0 0	Other 1 0 0	Other 1 0 0
Fitting K	0	0	0	0
Fitting L/D	0	0	0	0
Total Eq Length m	2.50	2.50	2.50	6.00

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Designing of 6000 Tons Hydrocarbon (Petrol & Diesel) Storage Tanks with Loading and Unloading System as per Regulatory Rules of Pakistan

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CASE 1 NORMAL

PIPE LINE REPORT

Date: 21 Feb 24, 13:29

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Line number		L9			L10			L11			L12		
Line name		Pipe			Pipe			Pipe			Pipe		
PROCESS DATA		AVG	IN	OUT	AVG	IN	OUT	AVG	IN	OUT	AVG	IN	OUT
Temperature	C	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Pressure	kPag	52.41	52.56	52.27	52.13	52.27	51.99	51.12	51.26	50.98	50.54	50.56	50.52
Liq Fraction	wt	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Total-Flow	kg/h	101,486			101,486			101,486			101,486		
Dens-NS	kg/m3	740	740	740	740	740	740	740	740	740	1,000	1,000	1,000
Elev	kg/m3	740			740			740			1,000		
Visc-NS	cP	1.48			1.48			1.48			1.0		
Vapor-Flow	kg/h	0			0			0			0		
Density	kg/m3	0	0	0	0	0	0	0	0	0	0	0	0
Visc	cP	0	0	0	0	0	0	0	0	0	0	0	0
Mol wt		0	0	0	0	0	0	0	0	0	0	0	0
Z		0	0	0	0	0	0	0	0	0	0	0	0
Cp/Cv		0	0	0	0	0	0	0	0	0	0	0	0
Liquid-Flow (wt)	kg/h	101,486			101,486			101,486			101,486		
Flow (vol)	m3/h	137.1			137.1			137.1			101.5		
Density	kg/m3	740	740	740	740	740	740	740	740	740	1,000	1,000	1,000
Visc	cP	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.0	1.0	1.0
PIPE DATA													
Material		Steel			Steel			Steel			Steel		
Size	in	8			8			8			8		
Length	m	6.0			6.0			6.0			1.25		
Schedule		40			40			40			40		
ID Flow/Hydr	mm	203 / 203			203 / 203			203 / 203			203 / 203		
Roughness (E-3)	mm	45.7			45.7			45.7			45.7		
Safety factor		1.0			1.0			1.0			1.0		
Sum of elev's	m	0			0			0			0		
VELOCITY													
Velocity	m/s	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	0.873	0.873	0.873
Sonic (Vap)	m/s	5,000			5,000			5,000			5,000		
PRESSURE DROP (In-Out)													
Overall	kPa	0.2835			0.2835			0.2835			0.04126		
Friction	kPa	0.2835			0.2835			0.2835			0.04126		
Accel'n	kPa	0			0			0			0		
Static	kPa	0			0			0			0		
dP/Length	kPa/100m	4.72			4.72			4.72			3.3		
LINE SIZING		MAX/LARGER	MIN/SMALLER		MAX/LARGER	MIN/SMALLER		MAX/LARGER	MIN/SMALLER		MAX/LARGER	MIN/SMALLER	
dP/Length	kPa/100m	22.6			22.6			22.6			22.6		
Velocity	m/s	100	0.30		100	0.30		100	0.30		100	0.30	
VelCoef	m/s	4.41	0.368		4.41	0.368		4.41	0.368		3.79	0.316	
Size-Larger/Small	in	10	6		10	6		10	6		10	6	
dP/Length	kPa/100m	1.55	18.3		1.55	18.3		1.55	18.3		1.08	12.9	
Velocity	m/s	0.749	2.04		0.749	2.04		0.749	2.04		0.554	1.51	

Line number	L9	L10	L11	L12
Line name	Pipe	Pipe	Pipe	Pipe
LIQUID HOLDUP				
Liquid Fraction (vol)	1.0	1.0	1.0	1.0
Liquid Holdup(dP) (vol)	1.0	1.0	1.0	1.0
2-PHASE METHOD	Homogeneous	Homogeneous	Homogeneous	Homogeneous
FLOW REGIME				
Horizontal (Mandane)	-	-	-	-
Horizontal (Dukler)	-	-	-	-
Vertical Up (Fair)	-	-	-	-
Vertical Up (Dukler)	-	-	-	-
Vertical Down (Golan)	-	-	-	-
HOMOGENEOUS/DUKLER/BEGGS				
Reynolds No	119,643	119,643	119,643	177,072
Friction factor	0.01858	0.01858	0.01858	0.01754
Friction factor (turb)	0.01406	0.01406	0.01406	0.01406
ftp/fns	0	0	0	0
Dentp/Denns	0	0	0	0
LOCKHART-M/CHENOWETH-M				
Liquid-Re	0	0	0	0
f	0	0	0	0
Psi/Psi^2	0	0	0	0
Vapor-Re	0	0	0	0
f	0	0	0	0
Psi^2	0	0	0	0
X factor	0	0	0	0
FITTINGS	TYPE No L/D K	TYPE No L/D K	TYPE No L/D K	TYPE No L/D K
	Entrance 0 0 0.50	Entrance 0 0 0.50	Entrance 0 0 0.50	Entrance 0 0 0.50
	Exit 0 0 1.0	Exit 0 0 1.0	Exit 0 0 1.0	Exit 0 0 1.0
	Gate valve 0 8.0 0	Gate valve 0 8.0 0	Gate valve 0 8.0 0	Gate valve 0 8.0 0
	Globe valv 0 340 0	Globe valv 0 340 0	Globe valv 0 340 0	Globe valv 0 340 0
	Check 0 50.0 0	Check 0 50.0 0	Check 0 50.0 0	Check 0 50.0 0
	Stop-check 0 400 0	Stop-check 0 400 0	Stop-check 0 400 0	Stop-check 0 400 0
	Elbow 0 20.0 0	Elbow 0 20.0 0	Elbow 0 20.0 0	Elbow 0 20.0 0
	180 Bend 0 50.0 0	180 Bend 0 50.0 0	180 Bend 0 50.0 0	180 Bend 0 50.0 0
	T-Straight 0 20.0 0	T-Straight 0 20.0 0	T-Straight 0 20.0 0	T-Straight 0 20.0 0
	T-Branch 0 60.0 0	T-Branch 0 60.0 0	T-Branch 0 60.0 0	T-Branch 0 60.0 0
	Other 1 0 0	Other 1 0 0	Other 1 0 0	Other 1 0 0
Fitting K	0	0	0	0
Fitting L/D	0	0	0	0
Total Eq Length m	6.00	6.00	6.00	1.25

Line number		L13			L14		
Line name		Pipe			Pipe		
PROCESS DATA		AVG	IN	OUT	AVG	IN	OUT
Temperature	C	25.0	25.0	25.0	25.0	25.0	25.0
Pressure	kPag	50.5	50.52	50.48	50.01	50.02	50.0
Liq Fraction	wt	1.0	1.0	1.0	1.0	1.0	1.0
Total-Flow	kg/h	101,486			101,486		
Dens-NS	kg/m3	1,000	1,000	1,000	1,000	1,000	1,000
Elev	kg/m3	1,000			1,000		
Visc-NS	cP	1.0			1.0		
Vapor-Flow	kg/h	0			0		
Density	kg/m3	0	0	0	0	0	0
Visc	cP	0	0	0	0	0	0
Mol wt		0	0	0	0	0	0
Z		0	0	0	0	0	0
Cp/Cv		0	0	0	0	0	0
Liquid-Flow (wt)	kg/h	101,486			101,486		
Flow (vol)	m3/h	101.5			101.5		
Density	kg/m3	1,000	1,000	1,000	1,000	1,000	1,000
Visc	cP	1.0	1.0	1.0	1.0	1.0	1.0
PIPE DATA							
Material		Steel			Steel		
Size	in	8			8		
Length	m	1.25			0.50		
Schedule		40			40		
ID Flow/Hydr	mm	203	/ 203		203	/ 203	
Roughness (E-3)	mm	45.7			45.7		
Safety factor		1.0			1.0		
Sum of elev's	m	0			0		
VELOCITY							
Velocity	m/s	0.873	0.873	0.873	0.873	0.873	0.873
Sonic (Vap)	m/s	5,000			5,000		
PRESSURE DROP (In-Out)							
Overall	kPa	0.04126			0.01651		
Friction	kPa	0.04126			0.01651		
Accel'n	kPa	0			0		
Static	kPa	0			0		
dP/Length	kPa/100m	3.3			3.3		
LINE SIZING		MAX/LARGER	MIN/SMALLER		MAX/LARGER	MIN/SMALLER	
dP/Length	kPa/100m	22.6			22.6		
Velocity	m/s	100	0.30		100	0.30	
VelCoef	m/s	3.79	0.316		3.79	0.316	
Size-Larger/Small	in	10	6		10	6	
dP/Length	kPa/100m	1.08	12.9		1.08	12.9	
Velocity	m/s	0.554	1.51		0.554	1.51	

Line number	L13	L14
Line name	Pipe	Pipe
LIQUID HOLDUP		
Liquid Fraction (vol)	1.0	1.0
Liquid Holdup(dP) (vol)	1.0	1.0
2-PHASE METHOD	Homogeneous	Homogeneous
FLOW REGIME		
Horizontal (Mandane)	-	-
Horizontal (Dukler)	-	-
Vertical Up (Fair)	-	-
Vertical Up (Dukler)	-	-
Vertical Down (Golan)	-	-
HOMOGENEOUS/DUKLER/BEGGS		
Reynolds No	177,072	177,072
Friction factor	0.01754	0.01754
Friction factor (turb)	0.01406	0.01406
ftp/fns	0	0
Dentp/Denns	0	0
LOCKHART-M/CHENOWETH-M		
Liquid-Re	0	0
f	0	0
Psi/Psi^2	0	0
Vapor-Re	0	0
f	0	0
Psi^2	0	0
X factor	0	0
FITTINGS	TYPE No L/D K	TYPE No L/D K
	Entrance 0 0 0.50	Entrance 0 0 0.50
	Exit 0 0 1.0	Exit 0 0 1.0
	Gate valve 0 8.0 0	Gate valve 0 8.0 0
	Globe valv 0 340 0	Globe valv 0 340 0
	Check 0 50.0 0	Check 0 50.0 0
	Stop-check 0 400 0	Stop-check 0 400 0
	Elbow 0 20.0 0	Elbow 0 20.0 0
	180 Bend 0 50.0 0	180 Bend 0 50.0 0
	T-Straight 0 20.0 0	T-Straight 0 20.0 0
	T-Branch 0 60.0 0	T-Branch 0 60.0 0
	Other 1 0 0	Other 1 0 0
Fitting K	0	0
Fitting L/D	0	0
Total Eq Length m	1.25	0.500

NOTES - (1) dPoverall = dPfrictional + dPaccel + dPstatic
(2) NS = No slip or homogenous

Designing of 6000 Tons Hydrocarbon (Petrol & Diesel) Storage Tanks with Loading and Unloading System as per Regulatory Rules of Pakistan

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CASE 1 NORMAL

FEED SUMMARY

Date: 21 Feb 24, 13:29

Number	Description	Elevation m	Density kg/m3	Level m	Rel Elev m	dP loss kPa	dP level kPa	dP inlet kPa	dP total kPa	Pres kPag
F1	Feed	0	740	0	0	0	0	0	0	-43.6

NOTES - (1) dP Inlet for Feed, Products and Vessels represent pressure to velocity conversion only, not friction.

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CASE 1 NORMAL

PRODUCT SUMMARY

Date: 21 Feb 24, 13:29

Number	Description	Elevation m	Density kg/m3	Level m	Rel Elev m	dP loss kPa	dP level kPa	dP inlet kPa	dP total kPa	Pres kPag
TK1	Product	0	1,000	0	0	0	0	0	0	50.0

NOTES - (1) dP Inlet for Feed, Products and Vessels represent pressure to velocity conversion only, not friction.

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CASE 1 NORMAL

PUMP SUMMARY

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Number	Description	Eff	Power kW	Flow kg/h	Density kg/m3	Vol Flow m3/h	Head m	Pout-Pin kPa	PresIn kPag	PresOut kPag
P1	Pump	0.6982	5.46	101,486	740	137	13.8	100	-47.2	52.8

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Designing of 6000 Tons Hydrocarbon (Petrol & Diesel) Storage Tanks with Loading and Unloading System as per Regulatory Rules of Pakistan

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Proj:
By :
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CASE 1 NORMAL

T-PIECE SUMMARY

Date: 21 Feb 24, 13:29
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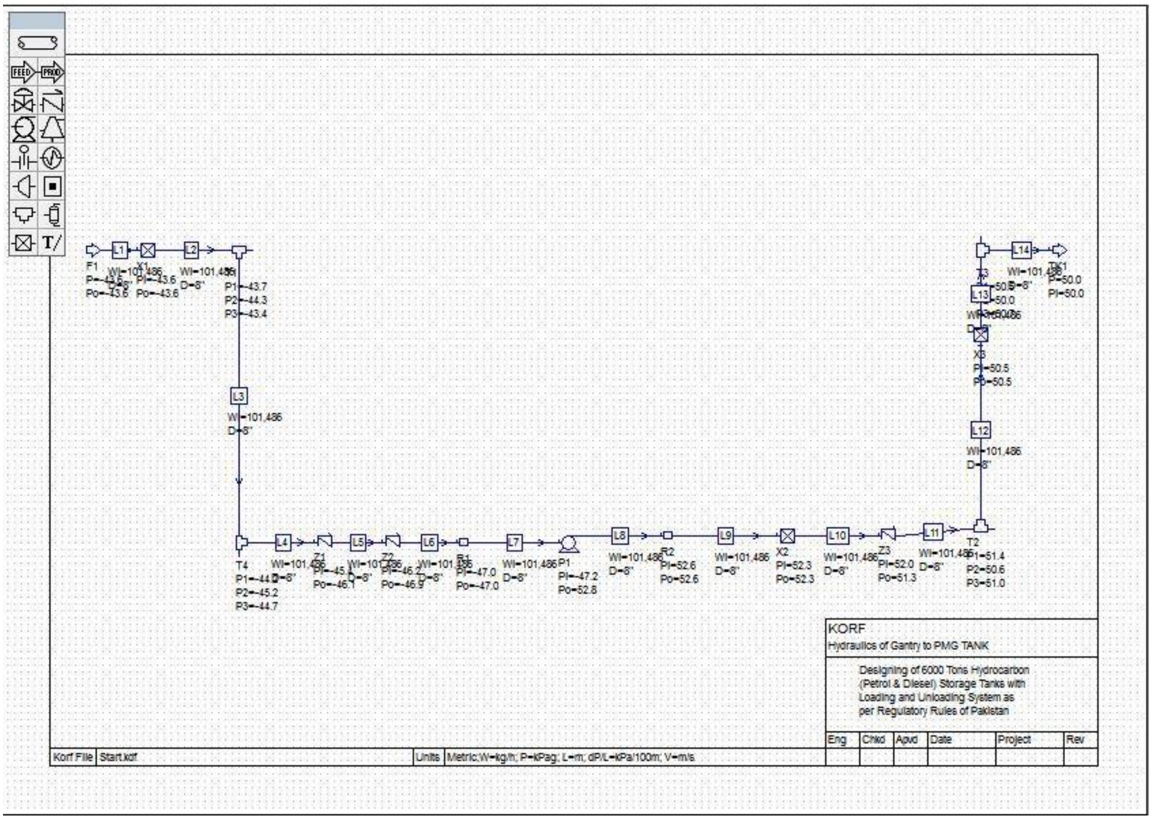
Number	Description	Service	Line	Spacing L/ID	Kc	Q/Qc	A/Ac	Pressure kPag
T1	Tee	Combined	L2			1.0	1.0	-43.7
		Branch	L3		1.21	1.0	1.0	-44.3
T2	Tee	Combined	L12			1.0	1.0	50.6
		Branch	L11		1.1	1.0	1.0	51.0
T3	Tee	Combined	L13			1.0	1.0	50.5
		Branch	L14		1.21	1.0	1.0	50.0
T4	Tee	Combined	L4			1.0	1.0	-45.2
		Branch	L3		1.1	1.0	1.0	-44.7


KORF
Hydraulics of Gantry to PMG TANK
Designing of 6000 Tons Hydrocarbon
(Petrol & Diesel) Storage Tanks with
Loading and Unloading System as
per Regulatory Rules of Pakistan
Eng
Chkd
Apvd
Date
Project
Rev
Korf File
Start.kdf
Units
Metric:W=kg/h; P=kPag; L=m; dP/L=kPa/100m; V=m/s

PMG to Gantry

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CASE 1 NORMAL GENERAL Date: 20 Feb 24, 11:50
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FILE NAME :

DEFAULTS : Fitting method = Crane
fT based on steel = Yes
Compressible = Isothermal
Two phase flow = Homogeneous
Acceleration = Homogeneous
Elevation den = Flanigan
Dukler hold-up = Hughmark
Smooth pipe f = No
Sonic velocity = HEMOmega
Two phase orifice = Homogeneous
Two phase valve = Homogeneous
Atmospheric pres = 101.325 kPa abs

VIEW/PRINT SETTINGS:
Font = Courier, Size 7-8
Orientation = Landscape
Margins = 1-2 cm.

RUN MESSAGE: Case 1 Hydraulic solution reached after 2 iterations.

NOTES:
1) Close this report before running/viewing next results.
2) Report is not automatically saved or printed.
Save the report as rtf file from the Korf menu (Hydraulics | Results | Save Report) or editor menu (File | Save As for MS Word).
After the final run, print the saved report with an editor (MS Word, etc.) for quality assurance purposes.

Circuit Feed 1

Number	Description	Flow kg/h	Density kg/m3	Visc cP	Dia in	Sch	Length m	dP/L kPa/100m	Velocity m/s	Elev m	dPelev kPa	dPin-out kPa	Pin kPag	Pout kPag
F1	Feed									0	0	0.515	-42.46	-42.98
L1	Pipe	101,486	740	1.48	8	40	2.14	4.72	1.18	0		0.101	-42.98	-43.08
T1	Tee									0			-43.08	-43.7
L2	Pipe	101,486	740	1.48	8	40	2.14	4.72	1.18	0		0.101	-43.7	-43.81
X1	Misc Equipment				K = 0.0					0-0	0	0	-43.81	-43.81
L3	Pipe	101,486	740	1.48	8	40	2.14	4.72	1.18	0		0.101	-43.81	-43.91
T2	Tee									0			-43.91	-44.58
L4	Pipe	101,486	740	1.48	8	40	2.14	4.72	1.18	0		0.101	-44.58	-44.68
Z1	Check									0		0.725	-44.68	-45.4
L5	Pipe	101,486	740	1.48	8	40	2.14	4.72	1.18	0		0.101	-45.4	-45.5
X2	Misc Equipment				K = 0.0					0-0	0	0	-45.5	-45.5
L6	Pipe	101,486	740	1.48	8	40	2.14	4.72	1.18	0		0.101	-45.5	-45.6
R1	Reducer				K = 0.0					0		0	-45.6	-45.6
L7	Pipe	101,486	740	1.48	8	40	2.14	4.72	1.18	0		0.101	-45.6	-45.71
P1	Pump									0		-100	-45.71	54.29
L8	Pipe	101,486	740	1.48	8	40	5.0	4.72	1.18	0		0.236	54.29	54.06
R2	Reducer				K = 0.0					0		0	54.06	54.06
L9	Pipe	101,486	740	1.48	8	40	5.0	4.72	1.18	0		0.236	54.06	53.82
Z2	Check									0		0.725	53.82	53.1
L10	Pipe	101,486	740	1.48	8	40	5.0	4.72	1.18	0		0.236	53.1	52.86
Z3	Check									0		0.725	52.86	52.14
L11	Pipe	101,486	740	1.48	8	40	5.0	4.72	1.18	0		0.236	52.14	51.9
T3	Tee									0			51.9	51.33
L12	Pipe	101,486	740	1.48	8	40	5.0	4.72	1.18	0		0.236	51.33	51.1
T4	Tee									0			51.1	50.47
L13	Pipe	101,486	740	1.48	8	40	5.0	4.72	1.18	0		0.236	50.47	50.24
X3	Misc Equipment				K = 0.0					0-0	0	0	50.24	50.24
L14	Pipe	101,486	740	1.48	8	40	5.0	4.72	1.18	0		0.236	50.24	50.0
TK1	Product									0	0	0	50.0	50.0

NOTES - (1) dPElev and dPin-out represent DRAWING Inlet - Outlet.
(2) dPin-out = dPElev + dPfrictional + dPaccel
(3) Vessel/Tank dPElev represent effect of fluid levels inside vessel.
(4) Elev represent equipment or nozzle (vessel/tank) elevation.

Line number		L1			L2			L3			L4		
Line name		Pipe			Pipe			Pipe			Pipe		
PROCESS DATA		AVG	IN	OUT	AVG	IN	OUT	AVG	IN	OUT	AVG	IN	OUT
Temperature	C	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Pressure	kPag	-43.03	-42.98	-43.08	-43.76	-43.7	-43.81	-43.86	-43.81	-43.91	-44.63	-44.58	-44.68
Liq Fraction	wt	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Total-Flow	kg/h	101,486			101,486			101,486			101,486		
Dens-NS	kg/m3	740	740	740	740	740	740	740	740	740	740	740	740
Elev	kg/m3	740			740			740			740		
Visc-NS	cP	1.48			1.48			1.48			1.48		
Vapor-Flow	kg/h	0			0			0			0		
Density	kg/m3	0	0	0	0	0	0	0	0	0	0	0	0
Visc	cP	0	0	0	0	0	0	0	0	0	0	0	0
Mol wt		0	0	0	0	0	0	0	0	0	0	0	0
Z		0	0	0	0	0	0	0	0	0	0	0	0
Cp/Cv		0	0	0	0	0	0	0	0	0	0	0	0
Liquid-Flow (wt)	kg/h	101,486			101,486			101,486			101,486		
Flow (vol)	m3/h	137.1			137.1			137.1			137.1		
Density	kg/m3	740	740	740	740	740	740	740	740	740	740	740	740
Visc	cP	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48
PIPE DATA													
Material		Steel			Steel			Steel			Steel		
Size	in	8			8			8			8		
Length	m	2.14			2.14			2.14			2.14		
Schedule		40			40			40			40		
ID Flow/Hydr	mm	203	/ 203		203	/ 203		203	/ 203		203	/ 203	
Roughness (E-3)	mm	45.7			45.7			45.7			45.7		
Safety factor		1.0			1.0			1.0			1.0		
Sum of elev's	m	0			0			0			0		
VELOCITY													
Velocity	m/s	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18
Sonic (Vap)	m/s	5,000			5,000			5,000			5,000		
PRESSURE DROP (In-Out)													
Overall	kPa	0.1011			0.1011			0.1011			0.1011		
Friction	kPa	0.1011			0.1011			0.1011			0.1011		
Accel'n	kPa	0			0			0			0		
Static	kPa	0			0			0			0		
dP/Length	kPa/100m	4.72			4.72			4.72			4.72		
LINE SIZING		MAX/LARGER	MIN/SMALLER		MAX/LARGER	MIN/SMALLER		MAX/LARGER	MIN/SMALLER		MAX/LARGER	MIN/SMALLER	
dP/Length	kPa/100m	22.6			22.6			22.6			22.6		
Velocity	m/s	100	0.30		100	0.30		100	0.30		100	0.30	
VelCoef	m/s	4.41	0.368		4.41	0.368		4.41	0.368		4.41	0.368	
Size-Larger/Small	in	10	6		10	6		10	6		10	6	
dP/Length	kPa/100m	1.55	18.3		1.55	18.3		1.55	18.3		1.55	18.3	
Velocity	m/s	0.749	2.04		0.749	2.04		0.749	2.04		0.749	2.04	

Line number	L1	L2	L3	L4
Line name	Pipe	Pipe	Pipe	Pipe
LIQUID HOLDUP				
Liquid Fraction (vol)	1.0	1.0	1.0	1.0
Liquid Holdup(dP) (vol)	1.0	1.0	1.0	1.0
2-PHASE METHOD	Homogeneous	Homogeneous	Homogeneous	Homogeneous
FLOW REGIME				
Horizontal (Mandane)	-	-	-	-
Horizontal (Dukler)	-	-	-	-
Vertical Up (Fair)	-	-	-	-
Vertical Up (Dukler)	-	-	-	-
Vertical Down (Golan)	-	-	-	-
HOMOGENEOUS/DUKLER/BEGGS				
Reynolds No	119,643	119,643	119,643	119,643
Friction factor	0.01858	0.01858	0.01858	0.01858
Friction factor (turb)	0.01406	0.01406	0.01406	0.01406
ftp/fns	0	0	0	0
Dentp/Denns	0	0	0	0
LOCKHART-M/CHENOWETH-M				
Liquid-Re	0	0	0	0
f	0	0	0	0
Psi/Psi^2	0	0	0	0
Vapor-Re	0	0	0	0
f	0	0	0	0
Psi^2	0	0	0	0
X factor	0	0	0	0
FITTINGS	TYPE No L/D K	TYPE No L/D K	TYPE No L/D K	TYPE No L/D K
	Entrance 0 0 0.50	Entrance 0 0 0.50	Entrance 0 0 0.50	Entrance 0 0 0.50
	Exit 0 0 1.0	Exit 0 0 1.0	Exit 0 0 1.0	Exit 0 0 1.0
	Gate valve 0 8.0 0	Gate valve 0 8.0 0	Gate valve 0 8.0 0	Gate valve 0 8.0 0
	Globe valv 0 340 0	Globe valv 0 340 0	Globe valv 0 340 0	Globe valv 0 340 0
	Check 0 50.0 0	Check 0 50.0 0	Check 0 50.0 0	Check 0 50.0 0
	Stop-check 0 400 0	Stop-check 0 400 0	Stop-check 0 400 0	Stop-check 0 400 0
	Elbow 0 20.0 0	Elbow 0 20.0 0	Elbow 0 20.0 0	Elbow 0 20.0 0
	180 Bend 0 50.0 0	180 Bend 0 50.0 0	180 Bend 0 50.0 0	180 Bend 0 50.0 0
	T-Straight 0 20.0 0	T-Straight 0 20.0 0	T-Straight 0 20.0 0	T-Straight 0 20.0 0
	T-Branch 0 60.0 0	T-Branch 0 60.0 0	T-Branch 0 60.0 0	T-Branch 0 60.0 0
	Other 1 0 0	Other 1 0 0	Other 1 0 0	Other 1 0 0
Fitting K	0	0	0	0
Fitting L/D	0	0	0	0
Total Eq Length m	2.14	2.14	2.14	2.14

Line number		L5			L6			L7			L8		
Line name		Pipe			Pipe			Pipe			Pipe		
PROCESS DATA		AVG	IN	OUT	AVG	IN	OUT	AVG	IN	OUT	AVG	IN	OUT
Temperature	C	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Pressure	kPag	-45.45	-45.4	-45.5	-45.55	-45.5	-45.6	-45.66	-45.6	-45.71	54.18	54.29	54.06
Liq Fraction	wt	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Total-Flow	kg/h	101,486			101,486			101,486			101,486		
Dens-NS	kg/m3	740	740	740	740	740	740	740	740	740	740	740	740
Elev	kg/m3	740			740			740			740		
Visc-NS	cP	1.48			1.48			1.48			1.48		
Vapor-Flow	kg/h	0			0			0			0		
Density	kg/m3	0	0	0	0	0	0	0	0	0	0	0	0
Visc	cP	0	0	0	0	0	0	0	0	0	0	0	0
Mol wt		0	0	0	0	0	0	0	0	0	0	0	0
Z		0	0	0	0	0	0	0	0	0	0	0	0
Cp/Cv		0	0	0	0	0	0	0	0	0	0	0	0
Liquid-Flow (wt)	kg/h	101,486			101,486			101,486			101,486		
Flow (vol)	m3/h	137.1			137.1			137.1			137.1		
Density	kg/m3	740	740	740	740	740	740	740	740	740	740	740	740
Visc	cP	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48
PIPE DATA													
Material		Steel			Steel			Steel			Steel		
Size	in	8			8			8			8		
Length	m	2.14			2.14			2.14			5.0		
Schedule		40			40			40			40		
ID Flow/Hydr	mm	203	/ 203		203	/ 203		203	/ 203		203	/ 203	
Roughness (E-3)	mm	45.7			45.7			45.7			45.7		
Safety factor		1.0			1.0			1.0			1.0		
Sum of elev's	m	0			0			0			0		
VELOCITY													
Velocity	m/s	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18
Sonic (Vap)	m/s	5,000			5,000			5,000			5,000		
PRESSURE DROP (In-Out)													
Overall	kPa	0.1011			0.1011			0.1011			0.2362		
Friction	kPa	0.1011			0.1011			0.1011			0.2362		
Accel'n	kPa	0			0			0			0		
Static	kPa	0			0			0			0		
dP/Length	kPa/100m	4.72			4.72			4.72			4.72		

LINE SIZING		MAX/LARGER	MIN/SMALLER	MAX/LARGER	MIN/SMALLER	MAX/LARGER	MIN/SMALLER	MAX/LARGER	MIN/SMALLER
dP/Length	kPa/100m	22.6		22.6		22.6		22.6	
Velocity	m/s	100	0.30	100	0.30	100	0.30	100	0.30
VelCoef	m/s	4.41	0.368	4.41	0.368	4.41	0.368	4.41	0.368
Size-Larger/Small	in	10	6	10	6	10	6	10	6
dP/Length	kPa/100m	1.55	18.3	1.55	18.3	1.55	18.3	1.55	18.3
Velocity	m/s	0.749	2.04	0.749	2.04	0.749	2.04	0.749	2.04

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CASE 1 NORMAL PIPE LINE REPORT Date: 20 Feb 24, 11:50

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Line number	L5	L6	L7	L8
Line name	Pipe	Pipe	Pipe	Pipe
LIQUID HOLDUP				
Liquid Fraction (vol)	1.0	1.0	1.0	1.0
Liquid Holdup(dP) (vol)	1.0	1.0	1.0	1.0
2-PHASE METHOD	Homogeneous	Homogeneous	Homogeneous	Homogeneous
FLOW REGIME				
Horizontal (Mandane)	-	-	-	-
Horizontal (Dukler)	-	-	-	-
Vertical Up (Fair)	-	-	-	-
Vertical Up (Dukler)	-	-	-	-
Vertical Down (Golan)	-	-	-	-
HOMOGENEOUS/DUKLER/BEGGS				
Reynolds No	119,643	119,643	119,643	119,643
Friction factor	0.01858	0.01858	0.01858	0.01858
Friction factor (turb)	0.01406	0.01406	0.01406	0.01406
ftp/fns	0	0	0	0
Dentp/Denns	0	0	0	0
LOCKHART-M/CHENOWETH-M				
Liquid-Re	0	0	0	0
f	0	0	0	0
Psi/Psi^2	0	0	0	0
Vapor-Re	0	0	0	0
f	0	0	0	0
Psi^2	0	0	0	0
X factor	0	0	0	0
FITTINGS	TYPE No L/D K	TYPE No L/D K	TYPE No L/D K	TYPE No L/D K
	Entrance 0 0 0.50	Entrance 0 0 0.50	Entrance 0 0 0.50	Entrance 0 0 0.50
	Exit 0 0 1.0	Exit 0 0 1.0	Exit 0 0 1.0	Exit 0 0 1.0
	Gate valve 0 8.0 0	Gate valve 0 8.0 0	Gate valve 0 8.0 0	Gate valve 0 8.0 0
	Globe valv 0 340 0	Globe valv 0 340 0	Globe valv 0 340 0	Globe valv 0 340 0
	Check 0 50.0 0	Check 0 50.0 0	Check 0 50.0 0	Check 0 50.0 0
	Stop-check 0 400 0	Stop-check 0 400 0	Stop-check 0 400 0	Stop-check 0 400 0
	Elbow 0 20.0 0	Elbow 0 20.0 0	Elbow 0 20.0 0	Elbow 0 20.0 0
	180 Bend 0 50.0 0	180 Bend 0 50.0 0	180 Bend 0 50.0 0	180 Bend 0 50.0 0
	T-Straight 0 20.0 0	T-Straight 0 20.0 0	T-Straight 0 20.0 0	T-Straight 0 20.0 0
	T-Branch 0 60.0 0	T-Branch 0 60.0 0	T-Branch 0 60.0 0	T-Branch 0 60.0 0
	Other 1 0 0	Other 1 0 0	Other 1 0 0	Other 1 0 0
Fitting K	0	0	0	0
Fitting L/D	0	0	0	0
Total Eq Length m	2.14	2.14	2.14	5.00

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CASE 1 NORMAL — PIPE LINE REPORT — Date: 20 Feb 24, 11:50

Line number		L9	L10	L11	L12
Line name		Pipe	Pipe	Pipe	Pipe
PROCESS DATA		AVG IN OUT	AVG IN OUT	AVG IN OUT	AVG IN OUT
Temperature	C	25.0 25.0 25.0	25.0 25.0 25.0	25.0 25.0 25.0	25.0 25.0 25.0
Pressure	kPag	53.94 54.06 53.82	52.98 53.1 52.86	52.02 52.14 51.9	51.21 51.33 51.1
Liq Fraction	wt	1.0 1.0 1.0	1.0 1.0 1.0	1.0 1.0 1.0	1.0 1.0 1.0
Total-Flow	kg/h	101,486	101,486	101,486	101,486
Dens-NS	kg/m3	740 740 740	740 740 740	740 740 740	740 740 740
Elev	kg/m3	740	740	740	740
Visc-NS	cP	1.48	1.48	1.48	1.48
Vapor-Flow	kg/h	0	0	0	0
Density	kg/m3	0 0 0	0 0 0	0 0 0	0 0 0
Visc	cP	0 0 0	0 0 0	0 0 0	0 0 0
Mol wt		0 0 0	0 0 0	0 0 0	0 0 0
Z		0 0 0	0 0 0	0 0 0	0 0 0
Cp/Cv		0 0 0	0 0 0	0 0 0	0 0 0
Liquid-Flow (wt)	kg/h	101,486	101,486	101,486	101,486
Flow (vol)	m3/h	137.1	137.1	137.1	137.1
Density	kg/m3	740 740 740	740 740 740	740 740 740	740 740 740
Visc	cP	1.48 1.48 1.48	1.48 1.48 1.48	1.48 1.48 1.48	1.48 1.48 1.48
PIPE DATA					
Material		Steel	Steel	Steel	Steel
Size	in	8	8	8	8
Length	m	5.0	5.0	5.0	5.0
Schedule		40	40	40	40
ID Flow/Hydr	mm	203 / 203	203 / 203	203 / 203	203 / 203
Roughness (E-3)	mm	45.7	45.7	45.7	45.7
Safety factor		1.0	1.0	1.0	1.0
Sum of elev's	m	0	0	0	0
VELOCITY					
Velocity	m/s	1.18 1.18 1.18	1.18 1.18 1.18	1.18 1.18 1.18	1.18 1.18 1.18
Sonic (Vap)	m/s	5,000	5,000	5,000	5,000
PRESSURE DROP (In-Out)					
Overall	kPa	0.2362	0.2362	0.2362	0.2362
Friction	kPa	0.2362	0.2362	0.2362	0.2362
Accel'n	kPa	0	0	0	0
Static	kPa	0	0	0	0
dP/Length	kPa/100m	4.72	4.72	4.72	4.72
LINE SIZING		MAX/LARGER MIN/SMALLER	MAX/LARGER MIN/SMALLER	MAX/LARGER MIN/SMALLER	MAX/LARGER MIN/SMALLER
dP/Length	kPa/100m	22.6	22.6	22.6	22.6
Velocity	m/s	100 0.30	100 0.30	100 0.30	100 0.30
VelCoef	m/s	4.41 0.368	4.41 0.368	4.41 0.368	4.41 0.368
Size-Larger/Small	in	10 6	10 6	10 6	10 6
dP/Length	kPa/100m	1.55 18.3	1.55 18.3	1.55 18.3	1.55 18.3
Velocity	m/s	0.749 2.04	0.749 2.04	0.749 2.04	0.749 2.04

Line number	L9	L10	L11	L12
Line name	Pipe	Pipe	Pipe	Pipe
LIQUID HOLDUP				
Liquid Fraction (vol)	1.0	1.0	1.0	1.0
Liquid Holdup(dP) (vol)	1.0	1.0	1.0	1.0
2-PHASE METHOD	Homogeneous	Homogeneous	Homogeneous	Homogeneous
FLOW REGIME				
Horizontal (Mandane)	-	-	-	-
Horizontal (Dukler)	-	-	-	-
Vertical Up (Fair)	-	-	-	-
Vertical Up (Dukler)	-	-	-	-
Vertical Down (Golan)	-	-	-	-
HOMOGENEOUS/DUKLER/BEGGS				
Reynolds No	119,643	119,643	119,643	119,643
Friction factor	0.01858	0.01858	0.01858	0.01858
Friction factor (turb)	0.01406	0.01406	0.01406	0.01406
ftp/fns	0	0	0	0
Dentp/Denns	0	0	0	0
LOCKHART-M/CHENOWETH-M				
Liquid-Re	0	0	0	0
f	0	0	0	0
Psi/Psi^2	0	0	0	0
Vapor-Re	0	0	0	0
f	0	0	0	0
Psi^2	0	0	0	0
X factor	0	0	0	0
FITTINGS	TYPE No L/D K	TYPE No L/D K	TYPE No L/D K	TYPE No L/D K
	Entrance 0 0 0.50	Entrance 0 0 0.50	Entrance 0 0 0.50	Entrance 0 0 0.50
	Exit 0 0 1.0	Exit 0 0 1.0	Exit 0 0 1.0	Exit 0 0 1.0
	Gate valve 0 8.0 0	Gate valve 0 8.0 0	Gate valve 0 8.0 0	Gate valve 0 8.0 0
	Globe valv 0 340 0	Globe valv 0 340 0	Globe valv 0 340 0	Globe valv 0 340 0
	Check 0 50.0 0	Check 0 50.0 0	Check 0 50.0 0	Check 0 50.0 0
	Stop-check 0 400 0	Stop-check 0 400 0	Stop-check 0 400 0	Stop-check 0 400 0
	Elbow 0 20.0 0	Elbow 0 20.0 0	Elbow 0 20.0 0	Elbow 0 20.0 0
	180 Bend 0 50.0 0	180 Bend 0 50.0 0	180 Bend 0 50.0 0	180 Bend 0 50.0 0
	T-Straight 0 20.0 0	T-Straight 0 20.0 0	T-Straight 0 20.0 0	T-Straight 0 20.0 0
	T-Branch 0 60.0 0	T-Branch 0 60.0 0	T-Branch 0 60.0 0	T-Branch 0 60.0 0
	Other 1 0 0	Other 1 0 0	Other 1 0 0	Other 1 0 0
Fitting K	0	0	0	0
Fitting L/D	0	0	0	0
Total Eq Length m	5.00	5.00	5.00	5.00

Line number	L13			L14		
Line name	Pipe			Pipe		
PROCESS DATA	AVG	IN	OUT	AVG	IN	OUT
Temperature C	25.0	25.0	25.0	25.0	25.0	25.0
Pressure kPag	50.35	50.47	50.24	50.12	50.24	50.0
Liq Fraction wt	1.0	1.0	1.0	1.0	1.0	1.0
Total-Flow kg/h	101,486			101,486		
Dens-NS kg/m3	740	740	740	740	740	740
Elev kg/m3	740			740		
Visc-NS cP	1.48			1.48		
Vapor-Flow kg/h	0			0		
Density kg/m3	0	0	0	0	0	0
Visc cP	0	0	0	0	0	0
Mol wt	0	0	0	0	0	0
Z	0	0	0	0	0	0
Cp/Cv	0	0	0	0	0	0
Liquid-Flow (wt) kg/h	101,486			101,486		
Flow (vol) m3/h	137.1			137.1		
Density kg/m3	740	740	740	740	740	740
Visc cP	1.48	1.48	1.48	1.48	1.48	1.48
PIPE DATA						
Material	Steel			Steel		
Size in	8			8		
Length m	5.0			5.0		
Schedule	40			40		
ID Flow/Hydr mm	203	/ 203		203	/ 203	
Roughness (E-3) mm	45.7			45.7		
Safety factor	1.0			1.0		
Sum of elev's m	0			0		
VELOCITY						
Velocity m/s	1.18	1.18	1.18	1.18	1.18	1.18
Sonic (Vap) m/s	5,000			5,000		
PRESSURE DROP (In-Out)						
Overall kPa	0.2362			0.2362		
Friction kPa	0.2362			0.2362		
Accel'n kPa	0			0		
Static kPa	0			0		
dP/Length kPa/100m	4.72			4.72		
LINE SIZING	MAX/LARGER	MIN/SMALLER		MAX/LARGER	MIN/SMALLER	
dP/Length kPa/100m	22.6			22.6		
Velocity m/s	100	0.30		100	0.30	
VelCoef m/s	4.41	0.368		4.41	0.368	
Size-Larger/Small in	10	6		10	6	
dP/Length kPa/100m	1.55	18.3		1.55	18.3	
Velocity m/s	0.749	2.04		0.749	2.04	

Line number	L13	L14
Line name	Pipe	Pipe
LIQUID HOLDUP		
Liquid Fraction (vol)	1.0	1.0
Liquid Holdup(dP) (vol)	1.0	1.0
2-PHASE METHOD	Homogeneous	Homogeneous
FLOW REGIME		
Horizontal (Mandane)	-	-
Horizontal (Dukler)	-	-
Vertical Up (Fair)	-	-
Vertical Up (Dukler)	-	-
Vertical Down (Golan)	-	-
HOMOGENEOUS/DUKLER/BEGGS		
Reynolds No	119,643	119,643
Friction factor	0.01858	0.01858
Friction factor (turb)	0.01406	0.01406
ftp/fns	0	0
Dentp/Denns	0	0
LOCKHART-M/CHENOWETH-M		
Liquid-Re	0	0
f	0	0
Psi/Psi^2	0	0
Vapor-Re	0	0
f	0	0
Psi^2	0	0
X factor	0	0
FITTINGS	TYPE No L/D K	TYPE No L/D K
	Entrance 0 0 0.50	Entrance 0 0 0.50
	Exit 0 0 1.0	Exit 0 0 1.0
	Gate valve 0 8.0 0	Gate valve 0 8.0 0
	Globe valv 0 340 0	Globe valv 0 340 0
	Check 0 50.0 0	Check 0 50.0 0
	Stop-check 0 400 0	Stop-check 0 400 0
	Elbow 0 20.0 0	Elbow 0 20.0 0
	180 Bend 0 50.0 0	180 Bend 0 50.0 0
	T-Straight 0 20.0 0	T-Straight 0 20.0 0
	T-Branch 0 60.0 0	T-Branch 0 60.0 0
	Other 1 0 0	Other 1 0 0
Fitting K	0	0
Fitting L/D	0	0
Total Eq Length m	5.00	5.00

NOTES - (1) dPoverall = dPfrictional + dPaccel + dPstatic
(2) NS = No slip or homogenous

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CASE 1 NORMAL FEED SUMMARY Date: 20 Feb 24, 11:50

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Number	Description	Elevation	Density	Level	Rel Elev	dP loss	dP level	dP inlet	dP total	Pres
		m	kg/m3	m	m	kPa	kPa	kPa	kPa	kPag
F1	Feed	0	740	0	0	0	0	0.515	0.515	-42.5

NOTES - (1) dP Inlet for Feed, Products and Vessels represent pressure to velocity conversion only, not friction.

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CASE 1 NORMAL PRODUCT SUMMARY Date: 20 Feb 24, 11:50

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Number	Description	Elevation	Density	Level	Rel Elev	dP loss	dP level	dP inlet	dP total	Pres
		m	kg/m3	m	m	kPa	kPa	kPa	kPa	kPag
TK1	Product	0	740	0	0	0	0	0	0	50.0

NOTES - (1) dP Inlet for Feed, Products and Vessels represent pressure to velocity conversion only, not friction.

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CASE 1 NORMAL	PUMP SUMMARY	Date: 20 Feb 24, 11:50

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Number	Description	Eff	Power kW	Flow kg/h	Density kg/m3	Vol Flow m3/h	Head m	Pout-Pin kPa	PresIn kPag	PresOut kPag
P1	Pump	0.6982	5.46	101,486	740	137	13.8	100	-45.7	54.3

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CASE 1 NORMAL	T-PIECE SUMMARY	Date: 20 Feb 24, 11:50

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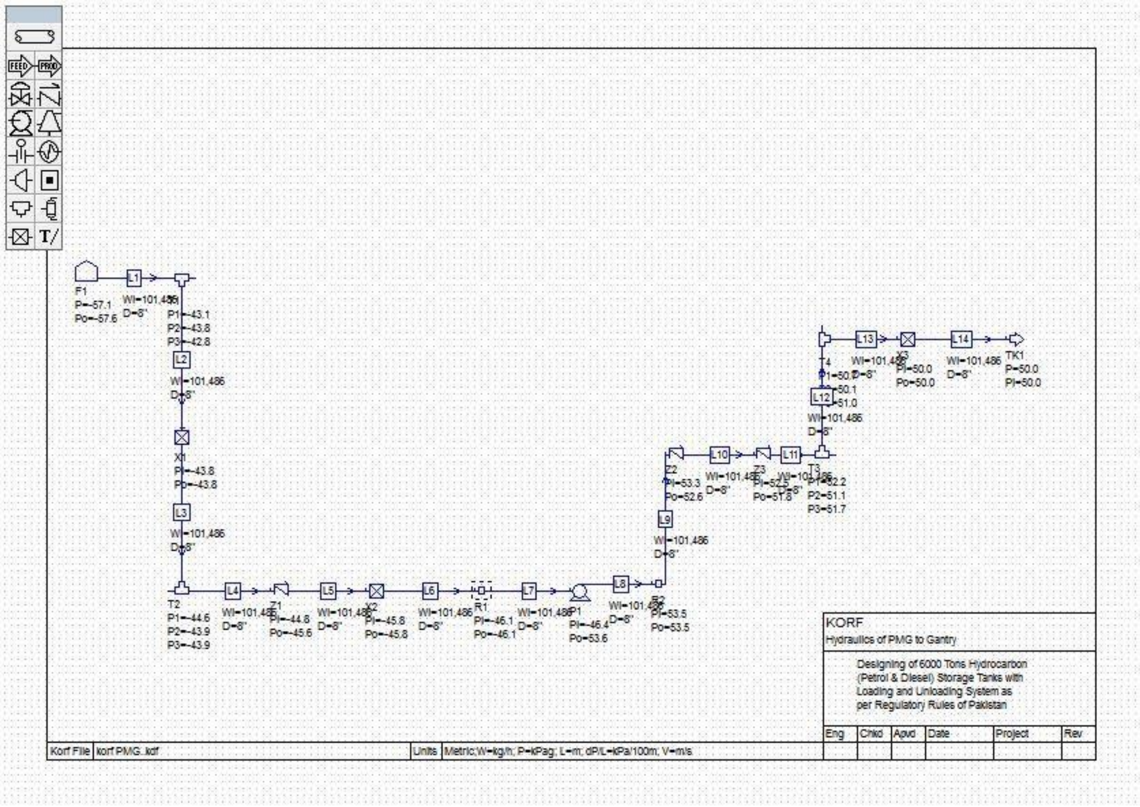
Number	Description	Service	Line	Spacing L/ID	Kc	Q/Qc	A/Ac	Pressure kPag
T1	Tee	Combined	L1			1.0	1.0	-43.1
		Branch	L2		1.21	1.0	1.0	-43.7
T2	Tee	Combined	L3			1.0	1.0	-43.9
		Manifold	L4	0	1.3	1.0	1.0	-44.6
T3	Tee	Combined	L12			1.0	1.0	51.3
		Branch	L11		1.1	1.0	1.0	51.9
T4	Tee	Combined	L12			1.0	1.0	51.1
		Branch	L13		1.21	1.0	1.0	50.5


KORF
Hydraulics of PMG to Gantry
Designing of 6000 Tons Hydrocarbon (Petrol & Diesel) Storage Tanks with Loading and Unloading System as per Regulatory Rules of Pakistan
Eng
Chkd
Apvd
Date
Project
Rev
Korf File
korf PMG..kdf
Units
Metric;W=kg/h; P=kPag; L=m; dP/L=kPa/100m; V=m/s

Gantry to HSD

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Designing of 6000 Tons Hydrocarbon (Petrol & Diesel) Storage Tanks with Loading and Unloading System as per Regulatory Rules of Pakistan

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CASE 1 NORMAL GENERAL Date: 21 Feb 24, 14:46
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FILE NAME : C:\Users\gpmc\Desktop\gantry to pmg tank.kdf

DEFAULTS : Fitting method = Crane
fT based on steel = Yes
Compressible = Isothermal
Two phase flow = Homogeneous
Acceleration = Homogeneous
Elevation den = Flanigan
Dukler hold-up = Hughmark
Smooth pipe f = No
Sonic velocity = HEMOmega
Two phase orifice = Homogeneous
Two phase valve = Homogeneous
Atmospheric pres = 101.325 kPa abs

VIEW/PRINT SETTINGS:
Font = Courier, Size 7-8
Orientation = Landscape
Margins = 1-2 cm.

RUN MESSAGE: Case 1 Hydraulic solution reached after 2 iterations.

NOTES:
1) Close this report before running/viewing next results.
2) Report is not automatically saved or printed.
Save the report as rtf file from the Korf menu (Hydraulics | Results | Save Report) or editor menu (File | Save As for MS Word).
After the final run, print the saved report with an editor (MS Word, etc.) for quality assurance purposes.

Circuit Feed 1

Number	Description	Flow kg/h	Density kg/m3	Visc cP	Dia in	Sch	Length m	dP/L kPa/100m	Velocity m/s	Elev m	dPelev kPa	dPin-out kPa	Pin kPag	Pout kPag
F1	Feed									0	0	0	-40.54	-40.54
L1	Pipe	115,200	840	2.68	8	40	1.0	5.8	1.18	0		0.058	-40.54	-40.59
X1	Misc Equipment						K = 0.0			0-0	0	0	-40.59	-40.59
L2	Pipe	115,200	840	2.68	8	40	1.0	5.8	1.18	0		0.058	-40.59	-40.65
T1	Tee									0			-40.65	-41.36
L3	Pipe	115,200	840	2.68	8	40	8.0	5.8	1.18	0		0.464	-41.36	-41.82
T4	Tee									0			-41.82	-42.47
L4	Pipe	115,200	840	2.68	8	40	2.5	5.8	1.18	0		0.145	-42.47	-42.61
Z1	Check									0		0.823	-42.61	-43.44
L5	Pipe	115,200	840	2.68	8	40	2.5	5.8	1.18	0		0.145	-43.44	-43.58
Z2	Check									0		0.823	-43.58	-44.4
L6	Pipe	115,200	840	2.68	8	40	2.5	5.8	1.18	0		0.145	-44.4	-44.55
R1	Reducer						K = 0.0			0		0	-44.55	-44.55
L7	Pipe	115,200	840	2.68	8	40	2.5	5.8	1.18	0		0.145	-44.55	-44.69
P1	Pump									0		-100	-44.69	55.31
L8	Pipe	115,200	840	2.68	8	40	12.8	5.8	1.18	0		0.739	55.31	54.57
R2	Reducer						K = 0.0			0		0	54.57	54.57
L9	Pipe	115,200	840	2.68	8	40	12.8	5.8	1.18	0		0.739	54.57	53.83
X2	Misc Equipment						K = 0.0			0-0	0	0	53.83	53.83
L10	Pipe	115,200	840	2.68	8	40	12.8	5.8	1.18	0		0.739	53.83	53.09
Z3	Check									0		0.823	53.09	52.27
L11	Pipe	115,200	840	2.68	8	40	12.8	5.8	1.18	0		0.739	52.27	51.53
T2	Tee									0			51.53	50.88
L12	Pipe	115,200	840	2.68	8	40	1.25	5.8	1.18	0		0.0725	50.88	50.81
X3	Misc Equipment						K = 0.0			0-0	0	0	50.81	50.81
L13	Pipe	115,200	840	2.68	8	40	1.25	5.8	1.18	0		0.0725	50.81	50.74
T3	Tee									0			50.74	50.03
L14	Pipe	115,200	840	2.68	8	40	0.50	5.8	1.18	0		0.029	50.03	50.0
TK1	Product									0	0	0	50.0	50.0

NOTES - (1) dPElev and dPin-out represent DRAWING Inlet - Outlet.
(2) dPin-out = dPElev + dPfrictional + dPaccel
(3) Vessel/Tank dPElev represent effect of fluid levels inside vessel.
(4) Elev represent equipment or nozzle (vessel/tank) elevation.

Designing of 6000 Tons Hydrocarbon (Petrol & Diesel) Storage Tanks with Loading and Unloading System as per Regulatory Rules of Pakistan

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CASE 1 NORMAL

PIPE LINE REPORT

Date: 21 Feb 24, 14:46

Line number		L1	L2	L3	L4
Line name		Pipe	Pipe	Pipe	Pipe
PROCESS DATA		AVG IN OUT	AVG IN OUT	AVG IN OUT	AVG IN OUT
Temperature	C	25.0 25.0 25.0	25.0 25.0 25.0	25.0 25.0 25.0	25.0 25.0 25.0
Pressure	kPag	-40.57 -40.54 -40.59	-40.62 -40.59 -40.65	-41.59 -41.36 -41.82	-42.54 -42.47 -42.61
Liq Fraction	wt	1.0 1.0 1.0	1.0 1.0 1.0	1.0 1.0 1.0	1.0 1.0 1.0
Total-Flow	kg/h	115,200	115,200	115,200	115,200
Dens-NS	kg/m3	840 840 840	840 840 840	840 840 840	840 840 840
Elev	kg/m3	840	840	840	840
Visc-NS	cP	2.68	2.68	2.68	2.68
Vapor-Flow	kg/h	0	0	0	0
Density	kg/m3	0 0 0	0 0 0	0 0 0	0 0 0
Visc	cP	0 0 0	0 0 0	0 0 0	0 0 0
Mol wt		0 0 0	0 0 0	0 0 0	0 0 0
Z		0 0 0	0 0 0	0 0 0	0 0 0
Cp/Cv		0 0 0	0 0 0	0 0 0	0 0 0
Liquid-Flow (wt)	kg/h	115,200	115,200	115,200	115,200
Flow (vol)	m3/h	137.1	137.1	137.1	137.1
Density	kg/m3	840 840 840	840 840 840	840 840 840	840 840 840
Visc	cP	2.68 2.68 2.68	2.68 2.68 2.68	2.68 2.68 2.68	2.68 2.68 2.68
PIPE DATA					
Material		Steel	Steel	Steel	Steel
Size	in	8	8	8	8
Length	m	1.0	1.0	8.0	2.5
Schedule		40	40	40	40
ID Flow/Hydr	mm	203 / 203	203 / 203	203 / 203	203 / 203
Roughness (E-3)	mm	45.7	45.7	45.7	45.7
Safety factor		1.0	1.0	1.0	1.0
Sum of elev's	m	0	0	0	0
VELOCITY					
Velocity	m/s	1.18 1.18 1.18	1.18 1.18 1.18	1.18 1.18 1.18	1.18 1.18 1.18
Sonic (Vap)	m/s	5,000	5,000	5,000	5,000
PRESSURE DROP (In-Out)					
Overall	kPa	0.0580	0.0580	0.464	0.145
Friction	kPa	0.0580	0.0580	0.464	0.145
Accel'n	kPa	0	0	0	0
Static	kPa	0	0	0	0
dP/Length	kPa/100m	5.8	5.8	5.8	5.8
LINE SIZING		MAX/LARGER MIN/SMALLER	MAX/LARGER MIN/SMALLER	MAX/LARGER MIN/SMALLER	MAX/LARGER MIN/SMALLER
dP/Length	kPa/100m	22.6	22.6	22.6	22.6
Velocity	m/s	100 0.30	100 0.30	100 0.30	100 0.30
VelCoef	m/s	4.14 0.345	4.14 0.345	4.14 0.345	4.14 0.345
Size-Larger/Small	in	10 6	10 6	10 6	10 6
dP/Length	kPa/100m	1.92 22.2	1.92 22.2	1.92 22.2	1.92 22.2
Velocity	m/s	0.749 2.04	0.749 2.04	0.749 2.04	0.749 2.04

Line number	L1	L2	L3	L4
Line name	Pipe	Pipe	Pipe	Pipe
LIQUID HOLDUP				
Liquid Fraction (vol)	1.0	1.0	1.0	1.0
Liquid Holdup(dP) (vol)	1.0	1.0	1.0	1.0
2-PHASE METHOD	Homogeneous	Homogeneous	Homogeneous	Homogeneous
FLOW REGIME				
Horizontal (Mandane)	-	-	-	-
Horizontal (Dukler)	-	-	-	-
Vertical Up (Fair)	-	-	-	-
Vertical Up (Dukler)	-	-	-	-
Vertical Down (Golan)	-	-	-	-
HOMOGENEOUS/DUKLER/BEGGS				
Reynolds No	75,000	75,000	75,000	75,000
Friction factor	0.02009	0.02009	0.02009	0.02009
Friction factor (turb)	0.01406	0.01406	0.01406	0.01406
ftp/fns	0	0	0	0
Dentp/Denns	0	0	0	0
LOCKHART-M/CHENOWETH-M				
Liquid-Re	0	0	0	0
f	0	0	0	0
Psi/Psi^2	0	0	0	0
Vapor-Re	0	0	0	0
f	0	0	0	0
Psi^2	0	0	0	0
X factor	0	0	0	0
FITTINGS	TYPE No L/D K	TYPE No L/D K	TYPE No L/D K	TYPE No L/D K
	Entrance 0 0 0.50	Entrance 0 0 0.50	Entrance 0 0 0.50	Entrance 0 0 0.50
	Exit 0 0 1.0	Exit 0 0 1.0	Exit 0 0 1.0	Exit 0 0 1.0
	Gate valve 0 8.0 0	Gate valve 0 8.0 0	Gate valve 0 8.0 0	Gate valve 0 8.0 0
	Globe valv 0 340 0	Globe valv 0 340 0	Globe valv 0 340 0	Globe valv 0 340 0
	Check 0 50.0 0	Check 0 50.0 0	Check 0 50.0 0	Check 0 50.0 0
	Stop-check 0 400 0	Stop-check 0 400 0	Stop-check 0 400 0	Stop-check 0 400 0
	Elbow 0 20.0 0	Elbow 0 20.0 0	Elbow 0 20.0 0	Elbow 0 20.0 0
	180 Bend 0 50.0 0	180 Bend 0 50.0 0	180 Bend 0 50.0 0	180 Bend 0 50.0 0
	T-Straight 0 20.0 0	T-Straight 0 20.0 0	T-Straight 0 20.0 0	T-Straight 0 20.0 0
	T-Branch 0 60.0 0	T-Branch 0 60.0 0	T-Branch 0 60.0 0	T-Branch 0 60.0 0
	Other 1 0 0	Other 1 0 0	Other 1 0 0	Other 1 0 0
Fitting K	0	0	0	0
Fitting L/D	0	0	0	0
Total Eq Length m	1.00	1.00	8.00	2.50

Designing of 6000 Tons Hydrocarbon (Petrol & Diesel) Storage Tanks with Loading and Unloading System as per Regulatory Rules of Pakistan

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CASE 1 NORMAL

PIPE LINE REPORT

Date: 21 Feb 24, 14:46

Line number		L5			L6			L7			L8		
Line name		Pipe			Pipe			Pipe			Pipe		
PROCESS DATA		AVG	IN	OUT	AVG	IN	OUT	AVG	IN	OUT	AVG	IN	OUT
Temperature	C	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Pressure	kPag	-43.51	-43.44	-43.58	-44.48	-44.4	-44.55	-44.62	-44.55	-44.69	54.94	55.31	54.57
Liq Fraction	wt	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Total-Flow	kg/h	115,200			115,200			115,200			115,200		
Dens-NS	kg/m3	840	840	840	840	840	840	840	840	840	840	840	840
Elev	kg/m3	840			840			840			840		
Visc-NS	cP	2.68			2.68			2.68			2.68		
Vapor-Flow	kg/h	0			0			0			0		
Density	kg/m3	0	0	0	0	0	0	0	0	0	0	0	0
Visc	cP	0	0	0	0	0	0	0	0	0	0	0	0
Mol wt		0	0	0	0	0	0	0	0	0	0	0	0
Z		0	0	0	0	0	0	0	0	0	0	0	0
Cp/Cv		0	0	0	0	0	0	0	0	0	0	0	0
Liquid-Flow (wt)	kg/h	115,200			115,200			115,200			115,200		
Flow (vol)	m3/h	137.1			137.1			137.1			137.1		
Density	kg/m3	840	840	840	840	840	840	840	840	840	840	840	840
Visc	cP	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68
PIPE DATA													
Material		Steel			Steel			Steel			Steel		
Size	in	8			8			8			8		
Length	m	2.5			2.5			2.5			12.8		
Schedule		40			40			40			40		
ID Flow/Hydr	mm	203	/ 203		203	/ 203		203	/ 203		203	/ 203	
Roughness (E-3)	mm	45.7			45.7			45.7			45.7		
Safety factor		1.0			1.0			1.0			1.0		
Sum of elev's	m	0			0			0			0		
VELOCITY													
Velocity	m/s	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18
Sonic (Vap)	m/s	5,000			5,000			5,000			5,000		
PRESSURE DROP (In-Out)													
Overall	kPa	0.145			0.145			0.145			0.7395		
Friction	kPa	0.145			0.145			0.145			0.7395		
Accel'n	kPa	0			0			0			0		
Static	kPa	0			0			0			0		
dP/Length	kPa/100m	5.8			5.8			5.8			5.8		
LINE SIZING		MAX/LARGER	MIN/SMALLER		MAX/LARGER	MIN/SMALLER		MAX/LARGER	MIN/SMALLER		MAX/LARGER	MIN/SMALLER	
dP/Length	kPa/100m	22.6			22.6			22.6			22.6		
Velocity	m/s	100	0.30		100	0.30		100	0.30		100	0.30	
VelCoef	m/s	4.14	0.345		4.14	0.345		4.14	0.345		4.14	0.345	
Size-Larger/Small	in	10	6		10	6		10	6		10	6	
dP/Length	kPa/100m	1.92	22.2		1.92	22.2		1.92	22.2		1.92	22.2	
Velocity	m/s	0.749	2.04		0.749	2.04		0.749	2.04		0.749	2.04	

Line number	L5	L6	L7	L8
Line name	Pipe	Pipe	Pipe	Pipe
LIQUID HOLDUP				
Liquid Fraction (vol)	1.0	1.0	1.0	1.0
Liquid Holdup(dP) (vol)	1.0	1.0	1.0	1.0
2-PHASE METHOD	Homogeneous	Homogeneous	Homogeneous	Homogeneous
FLOW REGIME				
Horizontal (Mandane)	-	-	-	-
Horizontal (Dukler)	-	-	-	-
Vertical Up (Fair)	-	-	-	-
Vertical Up (Dukler)	-	-	-	-
Vertical Down (Golan)	-	-	-	-
HOMOGENEOUS/DUKLER/BEGGS				
Reynolds No	75,000	75,000	75,000	75,000
Friction factor	0.02009	0.02009	0.02009	0.02009
Friction factor (turb)	0.01406	0.01406	0.01406	0.01406
ftp/fns	0	0	0	0
Dentp/Denns	0	0	0	0
LOCKHART-M/CHENOWETH-M				
Liquid-Re	0	0	0	0
f	0	0	0	0
Psi/Psi^2	0	0	0	0
Vapor-Re	0	0	0	0
f	0	0	0	0
Psi^2	0	0	0	0
X factor	0	0	0	0
FITTINGS	TYPE No L/D K	TYPE No L/D K	TYPE No L/D K	TYPE No L/D K
	Entrance 0 0 0.50	Entrance 0 0 0.50	Entrance 0 0 0.50	Entrance 0 0 0.50
	Exit 0 0 1.0	Exit 0 0 1.0	Exit 0 0 1.0	Exit 0 0 1.0
	Gate valve 0 8.0 0	Gate valve 0 8.0 0	Gate valve 0 8.0 0	Gate valve 0 8.0 0
	Globe valv 0 340 0	Globe valv 0 340 0	Globe valv 0 340 0	Globe valv 0 340 0
	Check 0 50.0 0	Check 0 50.0 0	Check 0 50.0 0	Check 0 50.0 0
	Stop-check 0 400 0	Stop-check 0 400 0	Stop-check 0 400 0	Stop-check 0 400 0
	Elbow 0 20.0 0	Elbow 0 20.0 0	Elbow 0 20.0 0	Elbow 0 20.0 0
	180 Bend 0 50.0 0	180 Bend 0 50.0 0	180 Bend 0 50.0 0	180 Bend 0 50.0 0
	T-Straight 0 20.0 0	T-Straight 0 20.0 0	T-Straight 0 20.0 0	T-Straight 0 20.0 0
	T-Branch 0 60.0 0	T-Branch 0 60.0 0	T-Branch 0 60.0 0	T-Branch 0 60.0 0
	Other 1 0 0	Other 1 0 0	Other 1 0 0	Other 1 0 0
Fitting K	0	0	0	0
Fitting L/D	0	0	0	0
Total Eq Length m	2.50	2.50	2.50	12.75

		L9			L10			L11			L12		
Line number		L9			L10			L11			L12		
Line name		Pipe			Pipe			Pipe			Pipe		
PROCESS DATA		AVG	IN	OUT	AVG	IN	OUT	AVG	IN	OUT	AVG	IN	OUT
Temperature	C	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Pressure	kPag	54.2	54.57	53.83	53.46	53.83	53.09	51.9	52.27	51.53	50.85	50.88	50.81
Liq Fraction	wt	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Total-Flow	kg/h	115,200			115,200			115,200			115,200		
Dens-NS	kg/m3	840	840	840	840	840	840	840	840	840	840	840	840
Elev	kg/m3	840			840			840			840		
Visc-NS	cP	2.68			2.68			2.68			2.68		
Vapor-Flow	kg/h	0			0			0			0		
Density	kg/m3	0	0	0	0	0	0	0	0	0	0	0	0
Visc	cP	0	0	0	0	0	0	0	0	0	0	0	0
Mol wt		0	0	0	0	0	0	0	0	0	0	0	0
Z		0	0	0	0	0	0	0	0	0	0	0	0
Cp/Cv		0	0	0	0	0	0	0	0	0	0	0	0
Liquid-Flow (wt)	kg/h	115,200			115,200			115,200			115,200		
Flow (vol)	m3/h	137.1			137.1			137.1			137.1		
Density	kg/m3	840	840	840	840	840	840	840	840	840	840	840	840
Visc	cP	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68
PIPE DATA													
Material		Steel			Steel			Steel			Steel		
Size	in	8			8			8			8		
Length	m	12.8			12.8			12.8			1.25		
Schedule		40			40			40			40		
ID Flow/Hydr	mm	203	/ 203		203	/ 203		203	/ 203		203	/ 203	
Roughness (E-3)	mm	45.7			45.7			45.7			45.7		
Safety factor		1.0			1.0			1.0			1.0		
Sum of elev's	m	0			0			0			0		
VELOCITY													
Velocity	m/s	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18
Sonic (Vap)	m/s	5,000			5,000			5,000			5,000		
PRESSURE DROP (In-Out)													
Overall	kPa	0.7395			0.7395			0.7395			0.0725		
Friction	kPa	0.7395			0.7395			0.7395			0.0725		
Accel'n	kPa	0			0			0			0		
Static	kPa	0			0			0			0		
dP/Length	kPa/100m	5.8			5.8			5.8			5.8		

LINE SIZING		MAX/LARGER	MIN/SMALLER	MAX/LARGER	MIN/SMALLER	MAX/LARGER	MIN/SMALLER	MAX/LARGER	MIN/SMALLER
dP/Length	kPa/100m	22.6		22.6		22.6		22.6	
Velocity	m/s	100	0.30	100	0.30	100	0.30	100	0.30
VelCoef	m/s	4.14	0.345	4.14	0.345	4.14	0.345	4.14	0.345
Size-Larger/Small	in	10	6	10	6	10	6	10	6
dP/Length	kPa/100m	1.92	22.2	1.92	22.2	1.92	22.2	1.92	22.2
Velocity	m/s	0.749	2.04	0.749	2.04	0.749	2.04	0.749	2.04

Line number	L9	L10	L11	L12
Line name	Pipe	Pipe	Pipe	Pipe
LIQUID HOLDUP				
Liquid Fraction (vol)	1.0	1.0	1.0	1.0
Liquid Holdup(dP) (vol)	1.0	1.0	1.0	1.0
2-PHASE METHOD	Homogeneous	Homogeneous	Homogeneous	Homogeneous
FLOW REGIME				
Horizontal (Mandane)	-	-	-	-
Horizontal (Dukler)	-	-	-	-
Vertical Up (Fair)	-	-	-	-
Vertical Up (Dukler)	-	-	-	-
Vertical Down (Golan)	-	-	-	-
HOMOGENEOUS/DUKLER/BEGGS				
Reynolds No	75,000	75,000	75,000	75,000
Friction factor	0.02009	0.02009	0.02009	0.02009
Friction factor (turb)	0.01406	0.01406	0.01406	0.01406
ftp/fns	0	0	0	0
Dentp/Denns	0	0	0	0
LOCKHART-M/CHENOWETH-M				
Liquid-Re	0	0	0	0
f	0	0	0	0
Psi/Psi^2	0	0	0	0
Vapor-Re	0	0	0	0
f	0	0	0	0
Psi^2	0	0	0	0
X factor	0	0	0	0
FITTINGS	TYPE No L/D K	TYPE No L/D K	TYPE No L/D K	TYPE No L/D K
	Entrance 0 0 0.50	Entrance 0 0 0.50	Entrance 0 0 0.50	Entrance 0 0 0.50
	Exit 0 0 1.0	Exit 0 0 1.0	Exit 0 0 1.0	Exit 0 0 1.0
	Gate valve 0 8.0 0	Gate valve 0 8.0 0	Gate valve 0 8.0 0	Gate valve 0 8.0 0
	Globe valv 0 340 0	Globe valv 0 340 0	Globe valv 0 340 0	Globe valv 0 340 0
	Check 0 50.0 0	Check 0 50.0 0	Check 0 50.0 0	Check 0 50.0 0
	Stop-check 0 400 0	Stop-check 0 400 0	Stop-check 0 400 0	Stop-check 0 400 0
	Elbow 0 20.0 0	Elbow 0 20.0 0	Elbow 0 20.0 0	Elbow 0 20.0 0
	180 Bend 0 50.0 0	180 Bend 0 50.0 0	180 Bend 0 50.0 0	180 Bend 0 50.0 0
	T-Straight 0 20.0 0	T-Straight 0 20.0 0	T-Straight 0 20.0 0	T-Straight 0 20.0 0
	T-Branch 0 60.0 0	T-Branch 0 60.0 0	T-Branch 0 60.0 0	T-Branch 0 60.0 0
	Other 1 0 0	Other 1 0 0	Other 1 0 0	Other 1 0 0
Fitting K	0	0	0	0
Fitting L/D	0	0	0	0
Total Eq Length m	12.75	12.75	12.75	1.25

Line number		L13			L14		
Line name		Pipe			Pipe		
PROCESS DATA		AVG	IN	OUT	AVG	IN	OUT
Temperature	C	25.0	25.0	25.0	25.0	25.0	25.0
Pressure	kPag	50.77	50.81	50.74	50.01	50.03	50.0
Liq Fraction	wt	1.0	1.0	1.0	1.0	1.0	1.0
Total-Flow	kg/h	115,200			115,200		
Dens-NS	kg/m3	840	840	840	840	840	840
Elev	kg/m3	840			840		
Visc-NS	cP	2.68			2.68		
Vapor-Flow	kg/h	0			0		
Density	kg/m3	0	0	0	0	0	0
Visc	cP	0	0	0	0	0	0
Mol wt		0	0	0	0	0	0
Z		0	0	0	0	0	0
Cp/Cv		0	0	0	0	0	0
Liquid-Flow (wt)	kg/h	115,200			115,200		
Flow (vol)	m3/h	137.1			137.1		
Density	kg/m3	840	840	840	840	840	840
Visc	cP	2.68	2.68	2.68	2.68	2.68	2.68
PIPE DATA							
Material		Steel			Steel		
Size	in	8			8		
Length	m	1.25			0.50		
Schedule		40			40		
ID Flow/Hydr	mm	203	/ 203		203	/ 203	
Roughness (E-3)	mm	45.7			45.7		
Safety factor		1.0			1.0		
Sum of elev's	m	0			0		
VELOCITY							
Velocity	m/s	1.18	1.18	1.18	1.18	1.18	1.18
Sonic (Vap)	m/s	5,000			5,000		
PRESSURE DROP (In-Out)							
Overall	kPa	0.0725			0.0290		
Friction	kPa	0.0725			0.0290		
Accel'n	kPa	0			0		
Static	kPa	0			0		
dP/Length	kPa/100m	5.8			5.8		
LINE SIZING		MAX/LARGER	MIN/SMALLER		MAX/LARGER	MIN/SMALLER	
dP/Length	kPa/100m	22.6			22.6		
Velocity	m/s	100	0.30		100	0.30	
VelCoef	m/s	4.14	0.345		4.14	0.345	
Size-Larger/Small	in	10	6		10	6	
dP/Length	kPa/100m	1.92	22.2		1.92	22.2	
Velocity	m/s	0.749	2.04		0.749	2.04	

Line number	L13	L14
Line name	Pipe	Pipe
LIQUID HOLDUP		
Liquid Fraction (vol)	1.0	1.0
Liquid Holdup(dP) (vol)	1.0	1.0
2-PHASE METHOD	Homogeneous	Homogeneous
FLOW REGIME		
Horizontal (Mandane)	-	-
Horizontal (Dukler)	-	-
Vertical Up (Fair)	-	-
Vertical Up (Dukler)	-	-
Vertical Down (Golan)	-	-
HOMOGENEOUS/DUKLER/BEGGS		
Reynolds No	75,000	75,000
Friction factor	0.02009	0.02009
Friction factor (turb)	0.01406	0.01406
ftp/fns	0	0
Dentp/Denns	0	0
LOCKHART-M/CHENOWETH-M		
Liquid-Re	0	0
f	0	0
Psi/Psi^2	0	0
Vapor-Re	0	0
f	0	0
Psi^2	0	0
X factor	0	0
FITTINGS	TYPE No L/D K	TYPE No L/D K
	Entrance 0 0 0.50	Entrance 0 0 0.50
	Exit 0 0 1.0	Exit 0 0 1.0
	Gate valve 0 8.0 0	Gate valve 0 8.0 0
	Globe valv 0 340 0	Globe valv 0 340 0
	Check 0 50.0 0	Check 0 50.0 0
	Stop-check 0 400 0	Stop-check 0 400 0
	Elbow 0 20.0 0	Elbow 0 20.0 0
	180 Bend 0 50.0 0	180 Bend 0 50.0 0
	T-Straight 0 20.0 0	T-Straight 0 20.0 0
	T-Branch 0 60.0 0	T-Branch 0 60.0 0
	Other 1 0 0	Other 1 0 0
Fitting K	0	0
Fitting L/D	0	0
Total Eq Length m	1.25	0.500

NOTES - (1) dPoverall = dPfrictional + dPaccel + dPstatic
(2) NS = No slip or homogenous

Designing of 6000 Tons Hydrocarbon (Petrol & Diesel) Storage Tanks with Loading and Unloading System as per Regulatory Rules of Pakistan

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CASE 1 NORMAL

FEED SUMMARY

Date: 21 Feb 24, 14:46

Number	Description	Elevation	Density	Level	Rel Elev	dP loss	dP level	dP inlet	dP total	Pres
		m	kg/m3	m	m	kPa	kPa	kPa	kPa	kPag
F1	Feed	0	840	0	0	0	0	0	0	-40.5

NOTES - (1) dP Inlet for Feed, Products and Vessels represent pressure to velocity conversion only, not friction.

Designing of 6000 Tons Hydrocarbon (Petrol & Diesel) Storage Tanks with Loading and Unloading System as per Regulatory Rules of Pakistan

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CASE 1 NORMAL

PRODUCT SUMMARY

Date: 21 Feb 24, 14:46

Number	Description	Elevation	Density	Level	Rel Elev	dP loss	dP level	dP inlet	dP total	Pres
		m	kg/m3	m	m	kPa	kPa	kPa	kPa	kPag
TK1	Product	0	840	0	0	0	0	0	0	50.0

NOTES - (1) dP Inlet for Feed, Products and Vessels represent pressure to velocity conversion only, not friction.

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Designing of 6000 Tons Hydrocarbon (Petrol & Diesel) Storage Tanks with Loading and Unloading System as per Regulatory Rules of Pakistan

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CASE 1 NORMAL

PUMP SUMMARY

Date: 21 Feb 24, 14:46

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Number	Description	Eff	Power kW	Flow kg/h	Density kg/m3	Vol Flow m3/h	Head m	Pout-Pin kPa	PresIn kPag	PresOut kPag
P1	Pump	0.6982	5.46	115,200	840	137	12.1	100	-44.7	55.3

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CASE 1 NORMAL

T-PIECE SUMMARY

Date: 21 Feb 24, 14:46

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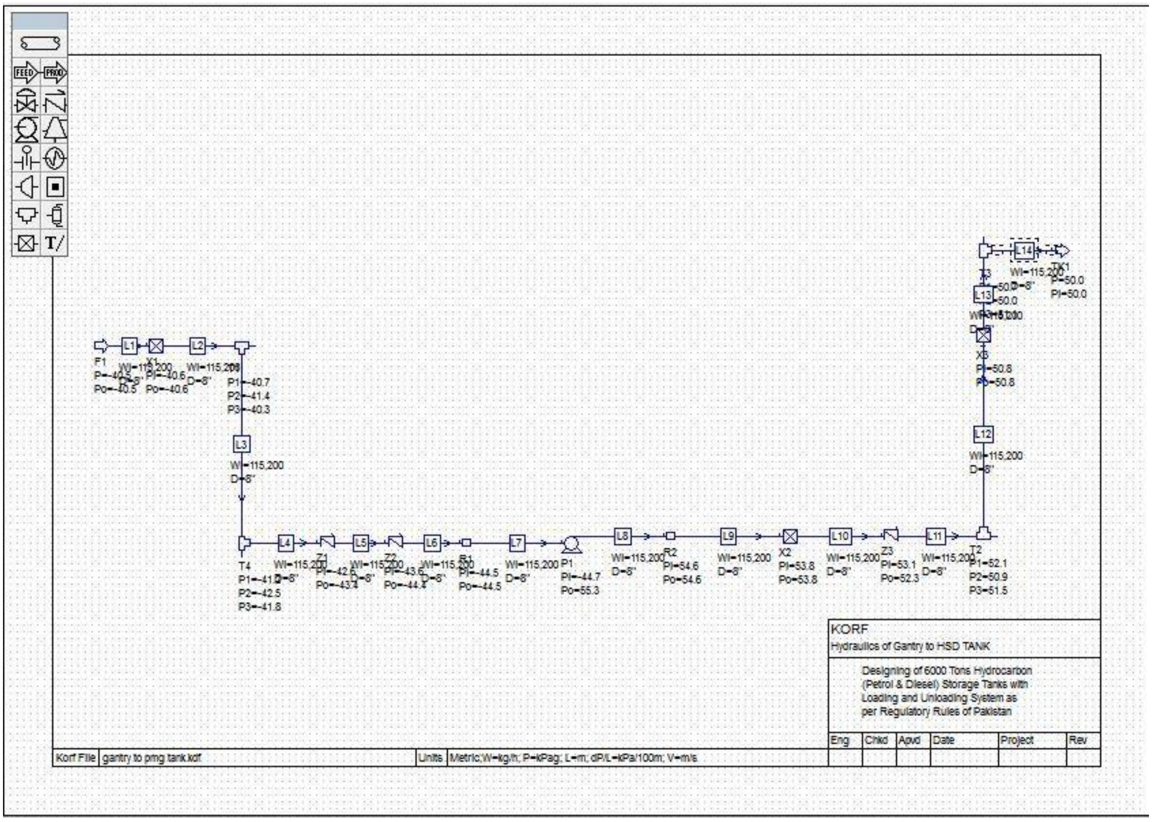
Number	Description	Service	Line	Spacing L/ID	Kc	Q/Qc	A/Ac	Pressure kPag
T1	Tee	Combined	L2			1.0	1.0	-40.7
		Branch	L3		1.21	1.0	1.0	-41.4
T2	Tee	Combined	L12			1.0	1.0	50.9
		Branch	L11		1.1	1.0	1.0	51.5
T3	Tee	Combined	L13			1.0	1.0	50.7
		Branch	L14		1.21	1.0	1.0	50.0
T4	Tee	Combined	L4			1.0	1.0	-42.5
		Branch	L3		1.1	1.0	1.0	-41.8



KORF
Hydraulics of Gantry to HSD TANK
Designing of 6000 Tons Hydrocarbon (Petrol & Diesel) Storage Tanks with Loading and Unloading System as per Regulatory Rules of Pakistan
Eng
Chkd
Apvd
Date
Project
Rev
Korf File
gantry to pmg tank.kdf
Units
Metric;W=kg/h; P=kPag; L=m; dP/L=kPa/100m; V=m/s

HSD to Gantry

FILE NAME : E:\fyp korff\korf HSD1.kdf

DEFAULTS : Fitting method = Crane
fT based on steel = Yes
Compressible = Isothermal
Two phase flow = Homogeneous
Acceleration = Homogeneous
Elevation den = Flanigan
Dukler hold-up = Hughmark
Smooth pipe f = No
Sonic velocity = HEMOmega
Two phase orifice = Homogeneous
Two phase valve = Homogeneous
Atmospheric pres = 101.325 kPa abs

VIEW/PRINT SETTINGS:
Font = Courier, Size 7-8
Orientation = Landscape
Margins = 1-2 cm.

RUN MESSAGE: Case 1 Hydraulic solution reached after 2 iterations.

NOTES:
1) Close this report before running/viewing next results.
2) Report is not automatically saved or printed.
Save the report as rtf file from the Korf menu (Hydraulics | Results | Save Report) or editor menu (File | Save As for MS Word).
After the final run, print the saved report with an editor (MS Word, etc.) for quality assurance purposes.

Circuit Feed 1

Number	Description	Flow kg/h	Density kg/m3	Visc cP	Dia in	Sch	Length m	dP/L kPa/100m	Velocity m/s	Elev m	dPelev kPa	dPin-out kPa	Pin kPag	Pout kPag
F1	Feed									2.0	0	0.585	-56.13	-56.71
L1	Pipe	115,200	840	2.68	8	40	0.50	5.8	1.18		-16.5	-16.4	-56.71	-40.29
T1	Tee									0			-40.29	-41.0
L2	Pipe	115,200	840	2.68	8	40	1.25	5.8	1.18		0	0.0725	-41.0	-41.07
X1	Misc Equipment						K = 0.0			0-0	0	0	-41.07	-41.07
L3	Pipe	115,200	840	2.68	8	40	1.25	5.8	1.18		0	0.0725	-41.07	-41.14
T2	Tee									0			-41.14	-41.9
L4	Pipe	115,200	840	2.68	8	40	12.8	5.8	1.18		0	0.739	-41.9	-42.64
Z1	Check									0		0.823	-42.64	-43.46
L5	Pipe	115,200	840	2.68	8	40	12.8	5.8	1.18		0	0.739	-43.46	-44.2
X2	Misc Equipment						K = 0.0			0-0	0	0	-44.2	-44.2
L6	Pipe	115,200	840	2.68	8	40	12.8	5.8	1.18		0	0.739	-44.2	-44.94
R1	Reducer						K = 0.0			0		0	-44.94	-44.94
L7	Pipe	115,200	840	2.68	8	40	12.8	5.8	1.18		0	0.739	-44.94	-45.68
P1	Pump									0		-100	-45.68	54.32
L8	Pipe	115,200	790	2.08	8	40	2.5	5.9	1.26		0	0.306	54.32	54.01
R2	Reducer						K = 0.0			0		0	54.01	54.01
L9	Pipe	115,200	840	2.68	8	40	2.5	5.8	1.18		0	0.145	54.01	53.87
Z2	Check									0		0.823	53.87	53.04
L10	Pipe	115,200	840	2.68	8	40	2.5	5.8	1.18		0	0.145	53.04	52.9
Z3	Check									0		0.823	52.9	52.08
L11	Pipe	115,200	840	2.68	8	40	2.5	5.8	1.18		0	0.145	52.08	51.93
T3	Tee									0			51.93	51.29
L12	Pipe	115,200	840	2.68	8	40	8.0	5.8	1.18		0	0.464	51.29	50.82
T4	Tee									0			50.82	50.12
L13	Pipe	115,200	840	2.68	8	40	1.0	5.8	1.18		0	0.058	50.12	50.06
X3	Misc Equipment						K = 0.0			0-0	0	0	50.06	50.06
L14	Pipe	115,200	840	2.68	8	40	1.0	5.8	1.18		0	0.058	50.06	50.0
TK1	Product									0	0	0	50.0	50.0

NOTES - (1) dPElev and dPin-out represent DRAWING Inlet - Outlet.
(2) dPin-out = dPElev + dPfrictional + dPaccel
(3) Vessel/Tank dPElev represent effect of fluid levels inside vessel.
(4) Elev represent equipment or nozzle (vessel/tank) elevation.

		L1			L2			L3			L4		
Line number		L1			L2			L3			L4		
Line name		Pipe			Pipe			Pipe			Pipe		
PROCESS DATA		AVG	IN	OUT	AVG	IN	OUT	AVG	IN	OUT	AVG	IN	OUT
Temperature	C	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Pressure	kPag	-48.5	-56.71	-40.29	-41.03	-41.0	-41.07	-41.1	-41.07	-41.14	-42.27	-41.9	-42.64
Liq Fraction	wt	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Total-Flow	kg/h	115,200			115,200			115,200			115,200		
Dens-NS	kg/m3	840	840	840	840	840	840	840	840	840	840	840	840
Elev	kg/m3	840			840			840			840		
Visc-NS	cP	2.68			2.68			2.68			2.68		
Vapor-Flow	kg/h	0			0			0			0		
Density	kg/m3	0	0	0	0	0	0	0	0	0	0	0	0
Visc	cP	0	0	0	0	0	0	0	0	0	0	0	0
Mol wt		0	0	0	0	0	0	0	0	0	0	0	0
Z		0	0	0	0	0	0	0	0	0	0	0	0
Cp/Cv		0	0	0	0	0	0	0	0	0	0	0	0
Liquid-Flow (wt)	kg/h	115,200			115,200			115,200			115,200		
Flow (vol)	m3/h	137.1			137.1			137.1			137.1		
Density	kg/m3	840	840	840	840	840	840	840	840	840	840	840	840
Visc	cP	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68
PIPE DATA													
Material		Steel			Steel			Steel			Steel		
Size	in	8			8			8			8		
Length	m	0.50			1.25			1.25			12.8		
Schedule		40			40			40			40		
ID Flow/Hydr	mm	203	/ 203		203	/ 203		203	/ 203		203	/ 203	
Roughness (E-3)	mm	45.7			45.7			45.7			45.7		
Safety factor		1.0			1.0			1.0			1.0		
Sum of elev's	m	0			0			0			0		
VELOCITY													
Velocity	m/s	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18
Sonic (Vap)	m/s	5,000			5,000			5,000			5,000		
PRESSURE DROP (In-Out)													
Overall	kPa	-16.43			0.0725			0.0725			0.7395		
Friction	kPa	0.0290			0.0725			0.0725			0.7395		
Accel'n	kPa	0			0			0			0		
Static	kPa	-16.46			0			0			0		
dP/Length	kPa/100m	5.8			5.8			5.8			5.8		
LINE SIZING		MAX/LARGER	MIN/SMALLER		MAX/LARGER	MIN/SMALLER		MAX/LARGER	MIN/SMALLER		MAX/LARGER	MIN/SMALLER	
dP/Length	kPa/100m	22.6			22.6			22.6			22.6		
Velocity	m/s	100	0.30		100	0.30		100	0.30		100	0.30	
VelCoef	m/s	4.14	0.345		4.14	0.345		4.14	0.345		4.14	0.345	
Size-Larger/Small	in	10	6		10	6		10	6		10	6	
dP/Length	kPa/100m	1.92	22.2		1.92	22.2		1.92	22.2		1.92	22.2	
Velocity	m/s	0.749	2.04		0.749	2.04		0.749	2.04		0.749	2.04	

Line number	L1	L2	L3	L4
Line name	Pipe	Pipe	Pipe	Pipe
LIQUID HOLDUP				
Liquid Fraction (vol)	1.0	1.0	1.0	1.0
Liquid Holdup(dP) (vol)	1.0	1.0	1.0	1.0
2-PHASE METHOD	Homogeneous	Homogeneous	Homogeneous	Homogeneous
FLOW REGIME				
Horizontal (Mandane)	-	-	-	-
Horizontal (Dukler)	-	-	-	-
Vertical Up (Fair)	-	-	-	-
Vertical Up (Dukler)	-	-	-	-
Vertical Down (Golan)	-	-	-	-
HOMOGENEOUS/DUKLER/BEGGS				
Reynolds No	75,000	75,000	75,000	75,000
Friction factor	0.02009	0.02009	0.02009	0.02009
Friction factor (turb)	0.01406	0.01406	0.01406	0.01406
ftp/fns	0	0	0	0
Dentp/Denns	0	0	0	0
LOCKHART-M/CHENOWETH-M				
Liquid-Re	0	0	0	0
f	0	0	0	0
Psi/Psi^2	0	0	0	0
Vapor-Re	0	0	0	0
f	0	0	0	0
Psi^2	0	0	0	0
X factor	0	0	0	0
FITTINGS	TYPE No L/D K	TYPE No L/D K	TYPE No L/D K	TYPE No L/D K
	Entrance 0 0 0.50	Entrance 0 0 0.50	Entrance 0 0 0.50	Entrance 0 0 0.50
	Exit 0 0 1.0	Exit 0 0 1.0	Exit 0 0 1.0	Exit 0 0 1.0
	Gate valve 0 8.0 0	Gate valve 0 8.0 0	Gate valve 0 8.0 0	Gate valve 0 8.0 0
	Globe valv 0 340 0	Globe valv 0 340 0	Globe valv 0 340 0	Globe valv 0 340 0
	Check 0 50.0 0	Check 0 50.0 0	Check 0 50.0 0	Check 0 50.0 0
	Stop-check 0 400 0	Stop-check 0 400 0	Stop-check 0 400 0	Stop-check 0 400 0
	Elbow 0 20.0 0	Elbow 0 20.0 0	Elbow 0 20.0 0	Elbow 0 20.0 0
	180 Bend 0 50.0 0	180 Bend 0 50.0 0	180 Bend 0 50.0 0	180 Bend 0 50.0 0
	T-Straight 0 20.0 0	T-Straight 0 20.0 0	T-Straight 0 20.0 0	T-Straight 0 20.0 0
	T-Branch 0 60.0 0	T-Branch 0 60.0 0	T-Branch 0 60.0 0	T-Branch 0 60.0 0
	Other 1 0 0	Other 1 0 0	Other 1 0 0	Other 1 0 0
Fitting K	0	0	0	0
Fitting L/D	0	0	0	0
Total Eq Length m	0.500	1.25	1.25	12.75

Line number		L5			L6			L7			L8		
Line name		Pipe			Pipe			Pipe			Pipe		
PROCESS DATA		AVG	IN	OUT	AVG	IN	OUT	AVG	IN	OUT	AVG	IN	OUT
Temperature	C	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Pressure	kPag	-43.83	-43.46	-44.2	-44.57	-44.2	-44.94	-45.31	-44.94	-45.68	54.16	54.32	54.01
Liq Fraction	wt	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Total-Flow	kg/h	115,200			115,200			115,200			115,200		
Dens-NS	kg/m3	840	840	840	840	840	840	840	840	840	790	840	740
Elev	kg/m3	840			840			840			790		
Visc-NS	cP	2.68			2.68			2.68			2.08		
Vapor-Flow	kg/h	0			0			0			0		
Density	kg/m3	0	0	0	0	0	0	0	0	0	0	0	0
Visc	cP	0	0	0	0	0	0	0	0	0	0	0	0
Mol wt		0	0	0	0	0	0	0	0	0	0	0	0
Z		0	0	0	0	0	0	0	0	0	0	0	0
Cp/Cv		0	0	0	0	0	0	0	0	0	0	0	0
Liquid-Flow (wt)	kg/h	115,200			115,200			115,200			115,200		
Flow (vol)	m3/h	137.1			137.1			137.1			145.8		
Density	kg/m3	840	840	840	840	840	840	840	840	840	790	840	740
Visc	cP	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.08	2.68	1.48
PIPE DATA													
Material		Steel			Steel			Steel			Steel		
Size	in	8			8			8			8		
Length	m	12.8			12.8			12.8			2.5		
Schedule		40			40			40			40		
ID Flow/Hydr	mm	203 / 203			203 / 203			203 / 203			203 / 203		
Roughness (E-3)	mm	45.7			45.7			45.7			45.7		
Safety factor		1.0			1.0			1.0			1.0		
Sum of elev's	m	0			0			0			0		
VELOCITY													
Velocity	m/s	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.26	1.18	1.34
Sonic (Vap)	m/s	5,000			5,000			5,000			1.86		
PRESSURE DROP (In-Out)													
Overall	kPa	0.7395			0.7395			0.7395			0.3057		
Friction	kPa	0.7395			0.7395			0.7395			0.1476		
Accel'n	kPa	0			0			0			0.1581		
Static	kPa	0			0			0			0		
dP/Length	kPa/100m	5.8			5.8			5.8			5.9		

LINE SIZING		MAX/LARGER	MIN/SMALLER	MAX/LARGER	MIN/SMALLER	MAX/LARGER	MIN/SMALLER	MAX/LARGER	MIN/SMALLER
dP/Length	kPa/100m	22.6		22.6		22.6		22.6	
Velocity	m/s	100	0.30	100	0.30	100	0.30	100	0.30
VelCoef	m/s	4.14	0.345	4.14	0.345	4.14	0.345	4.27	0.356
Size-Larger/Small	in	10	6	10	6	10	6	10	6
dP/Length	kPa/100m	1.92	22.2	1.92	22.2	1.92	22.2	1.95	22.7
Velocity	m/s	0.749	2.04	0.749	2.04	0.749	2.04	0.796	2.17

Line number	L5	L6	L7	L8
Line name	Pipe	Pipe	Pipe	Pipe
LIQUID HOLDUP				
Liquid Fraction (vol)	1.0	1.0	1.0	1.0
Liquid Holdup(dP) (vol)	1.0	1.0	1.0	1.0
2-PHASE METHOD	Homogeneous	Homogeneous	Homogeneous	Homogeneous
FLOW REGIME				
Horizontal (Mandane)	-	-	-	-
Horizontal (Dukler)	-	-	-	-
Vertical Up (Fair)	-	-	-	-
Vertical Up (Dukler)	-	-	-	-
Vertical Down (Golan)	-	-	-	-
HOMOGENEOUS/DUKLER/BEGGS				
Reynolds No	75,000	75,000	75,000	96,635
Friction factor	0.02009	0.02009	0.02009	0.01923
Friction factor (turb)	0.01406	0.01406	0.01406	0.01406
ftp/fns	0	0	0	0
Dentp/Denns	0	0	0	0
LOCKHART-M/CHENOWETH-M				
Liquid-Re	0	0	0	0
f	0	0	0	0
Psi/Psi^2	0	0	0	0
Vapor-Re	0	0	0	0
f	0	0	0	0
Psi^2	0	0	0	0
X factor	0	0	0	0
FITTINGS	TYPE No L/D K	TYPE No L/D K	TYPE No L/D K	TYPE No L/D K
	Entrance 0 0 0.50	Entrance 0 0 0.50	Entrance 0 0 0.50	Entrance 0 0 0.50
	Exit 0 0 1.0	Exit 0 0 1.0	Exit 0 0 1.0	Exit 0 0 1.0
	Gate valve 0 8.0 0	Gate valve 0 8.0 0	Gate valve 0 8.0 0	Gate valve 0 8.0 0
	Globe valv 0 340 0	Globe valv 0 340 0	Globe valv 0 340 0	Globe valv 0 340 0
	Check 0 50.0 0	Check 0 50.0 0	Check 0 50.0 0	Check 0 50.0 0
	Stop-check 0 400 0	Stop-check 0 400 0	Stop-check 0 400 0	Stop-check 0 400 0
	Elbow 0 20.0 0	Elbow 0 20.0 0	Elbow 0 20.0 0	Elbow 0 20.0 0
	180 Bend 0 50.0 0	180 Bend 0 50.0 0	180 Bend 0 50.0 0	180 Bend 0 50.0 0
	T-Straight 0 20.0 0	T-Straight 0 20.0 0	T-Straight 0 20.0 0	T-Straight 0 20.0 0
	T-Branch 0 60.0 0	T-Branch 0 60.0 0	T-Branch 0 60.0 0	T-Branch 0 60.0 0
	Other 1 0 0	Other 1 0 0	Other 1 0 0	Other 1 0 0
Fitting K	0	0	0	0
Fitting L/D	0	0	0	0
Total Eq Length m	12.75	12.75	12.75	2.50

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Designing of 6000 Tons Hydrocarbon (Petrol & Diesel) Storage Tanks with Loading and Unloading System as per Regulatory Rules of Pakistan

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CASE 1 NORMAL

PIPE LINE REPORT

Date: 21 Feb 24, 13:08

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Line number		L9	L10	L11	L12
Line name		Pipe	Pipe	Pipe	Pipe
PROCESS DATA		AVG IN OUT	AVG IN OUT	AVG IN OUT	AVG IN OUT
Temperature	C	25.0 25.0 25.0	25.0 25.0 25.0	25.0 25.0 25.0	25.0 25.0 25.0
Pressure	kPag	53.94 54.01 53.87	52.97 53.04 52.9	52.0 52.08 51.93	51.06 51.29 50.82
Liq Fraction	wt	1.0 1.0 1.0	1.0 1.0 1.0	1.0 1.0 1.0	1.0 1.0 1.0
Total-Flow	kg/h	115,200	115,200	115,200	115,200
Dens-NS	kg/m3	840 840 840	840 840 840	840 840 840	840 840 840
Elev	kg/m3	840	840	840	840
Visc-NS	cP	2.68	2.68	2.68	2.68
Vapor-Flow	kg/h	0	0	0	0
Density	kg/m3	0 0 0	0 0 0	0 0 0	0 0 0
Visc	cP	0 0 0	0 0 0	0 0 0	0 0 0
Mol wt		0 0 0	0 0 0	0 0 0	0 0 0
Z		0 0 0	0 0 0	0 0 0	0 0 0
Cp/Cv		0 0 0	0 0 0	0 0 0	0 0 0
Liquid-Flow (wt)	kg/h	115,200	115,200	115,200	115,200
Flow (vol)	m3/h	137.1	137.1	137.1	137.1
Density	kg/m3	840 840 840	840 840 840	840 840 840	840 840 840
Visc	cP	2.68 2.68 2.68	2.68 2.68 2.68	2.68 2.68 2.68	2.68 2.68 2.68
PIPE DATA					
Material		Steel	Steel	Steel	Steel
Size	in	8	8	8	8
Length	m	2.5	2.5	2.5	8.0
Schedule		40	40	40	40
ID Flow/Hydr	mm	203 / 203	203 / 203	203 / 203	203 / 203
Roughness (E-3)	mm	45.7	45.7	45.7	45.7
Safety factor		1.0	1.0	1.0	1.0
Sum of elev's	m	0	0	0	0
VELOCITY					
Velocity	m/s	1.18 1.18 1.18	1.18 1.18 1.18	1.18 1.18 1.18	1.18 1.18 1.18
Sonic (Vap)	m/s	5,000	5,000	5,000	5,000
PRESSURE DROP (In-Out)					
Overall	kPa	0.145	0.145	0.145	0.464
Friction	kPa	0.145	0.145	0.145	0.464
Accel'n	kPa	0	0	0	0
Static	kPa	0	0	0	0
dP/Length	kPa/100m	5.8	5.8	5.8	5.8
LINE SIZING		MAX/LARGER MIN/SMALLER	MAX/LARGER MIN/SMALLER	MAX/LARGER MIN/SMALLER	MAX/LARGER MIN/SMALLER
dP/Length	kPa/100m	22.6	22.6	22.6	22.6
Velocity	m/s	100 0.30	100 0.30	100 0.30	100 0.30
VelCoef	m/s	4.14 0.345	4.14 0.345	4.14 0.345	4.14 0.345
Size-Larger/Small	in	10 6	10 6	10 6	10 6
dP/Length	kPa/100m	1.92 22.2	1.92 22.2	1.92 22.2	1.92 22.2
Velocity	m/s	0.749 2.04	0.749 2.04	0.749 2.04	0.749 2.04

Line number	L9	L10	L11	L12
Line name	Pipe	Pipe	Pipe	Pipe
LIQUID HOLDUP				
Liquid Fraction (vol)	1.0	1.0	1.0	1.0
Liquid Holdup(dP) (vol)	1.0	1.0	1.0	1.0
2-PHASE METHOD	Homogeneous	Homogeneous	Homogeneous	Homogeneous
FLOW REGIME				
Horizontal (Mandane)	-	-	-	-
Horizontal (Dukler)	-	-	-	-
Vertical Up (Fair)	-	-	-	-
Vertical Up (Dukler)	-	-	-	-
Vertical Down (Golan)	-	-	-	-
HOMOGENEOUS/DUKLER/BEGGS				
Reynolds No	75,000	75,000	75,000	75,000
Friction factor	0.02009	0.02009	0.02009	0.02009
Friction factor (turb)	0.01406	0.01406	0.01406	0.01406
ftp/fns	0	0	0	0
Dentp/Denns	0	0	0	0
LOCKHART-M/CHENOWETH-M				
Liquid-Re	0	0	0	0
f	0	0	0	0
Psi/Psi^2	0	0	0	0
Vapor-Re	0	0	0	0
f	0	0	0	0
Psi^2	0	0	0	0
X factor	0	0	0	0
FITTINGS	TYPE No L/D K	TYPE No L/D K	TYPE No L/D K	TYPE No L/D K
	Entrance 0 0 0.50	Entrance 0 0 0.50	Entrance 0 0 0.50	Entrance 0 0 0.50
	Exit 0 0 1.0	Exit 0 0 1.0	Exit 0 0 1.0	Exit 0 0 1.0
	Gate valve 0 8.0 0	Gate valve 0 8.0 0	Gate valve 0 8.0 0	Gate valve 0 8.0 0
	Globe valv 0 340 0	Globe valv 0 340 0	Globe valv 0 340 0	Globe valv 0 340 0
	Check 0 50.0 0	Check 0 50.0 0	Check 0 50.0 0	Check 0 50.0 0
	Stop-check 0 400 0	Stop-check 0 400 0	Stop-check 0 400 0	Stop-check 0 400 0
	Elbow 0 20.0 0	Elbow 0 20.0 0	Elbow 0 20.0 0	Elbow 0 20.0 0
	180 Bend 0 50.0 0	180 Bend 0 50.0 0	180 Bend 0 50.0 0	180 Bend 0 50.0 0
	T-Straight 0 20.0 0	T-Straight 0 20.0 0	T-Straight 0 20.0 0	T-Straight 0 20.0 0
	T-Branch 0 60.0 0	T-Branch 0 60.0 0	T-Branch 0 60.0 0	T-Branch 0 60.0 0
	Other 1 0 0	Other 1 0 0	Other 1 0 0	Other 1 0 0
Fitting K	0	0	0	0
Fitting L/D	0	0	0	0
Total Eq Length m	2.50	2.50	2.50	8.00

Line number		L13			L14		
Line name		Pipe			Pipe		
PROCESS DATA		AVG	IN	OUT	AVG	IN	OUT
Temperature	C	25.0	25.0	25.0	25.0	25.0	25.0
Pressure	kPag	50.09	50.12	50.06	50.03	50.06	50.0
Liq Fraction	wt	1.0	1.0	1.0	1.0	1.0	1.0
Total-Flow	kg/h	115,200			115,200		
Dens-NS	kg/m3	840	840	840	840	840	840
Elev	kg/m3	840			840		
Visc-NS	cP	2.68			2.68		
Vapor-Flow	kg/h	0			0		
Density	kg/m3	0	0	0	0	0	0
Visc	cP	0	0	0	0	0	0
Mol wt		0	0	0	0	0	0
Z		0	0	0	0	0	0
Cp/Cv		0	0	0	0	0	0
Liquid-Flow (wt)	kg/h	115,200			115,200		
Flow (vol)	m3/h	137.1			137.1		
Density	kg/m3	840	840	840	840	840	840
Visc	cP	2.68	2.68	2.68	2.68	2.68	2.68
PIPE DATA							
Material		Steel			Steel		
Size	in	8			8		
Length	m	1.0			1.0		
Schedule		40			40		
ID Flow/Hydr	mm	203	/ 203		203	/ 203	
Roughness (E-3)	mm	45.7			45.7		
Safety factor		1.0			1.0		
Sum of elev's	m	0			0		
VELOCITY							
Velocity	m/s	1.18	1.18	1.18	1.18	1.18	1.18
Sonic (Vap)	m/s	5,000			5,000		
PRESSURE DROP (In-Out)							
Overall	kPa	0.0580			0.0580		
Friction	kPa	0.0580			0.0580		
Accel'n	kPa	0			0		
Static	kPa	0			0		
dP/Length	kPa/100m	5.8			5.8		
LINE SIZING		MAX/LARGER	MIN/SMALLER		MAX/LARGER	MIN/SMALLER	
dP/Length	kPa/100m	22.6			22.6		
Velocity	m/s	100	0.30		100	0.30	
VelCoef	m/s	4.14	0.345		4.14	0.345	
Size-Larger/Small	in	10	6		10	6	
dP/Length	kPa/100m	1.92	22.2		1.92	22.2	
Velocity	m/s	0.749	2.04		0.749	2.04	

Line number	L13	L14
Line name	Pipe	Pipe
LIQUID HOLDUP		
Liquid Fraction (vol)	1.0	1.0
Liquid Holdup(dP) (vol)	1.0	1.0
2-PHASE METHOD	Homogeneous	Homogeneous
FLOW REGIME		
Horizontal (Mandane)	-	-
Horizontal (Dukler)	-	-
Vertical Up (Fair)	-	-
Vertical Up (Dukler)	-	-
Vertical Down (Golan)	-	-
HOMOGENEOUS/DUKLER/BEGGS		
Reynolds No	75,000	75,000
Friction factor	0.02009	0.02009
Friction factor (turb)	0.01406	0.01406
ftp/fns	0	0
Dentp/Denns	0	0
LOCKHART-M/CHENOWETH-M		
Liquid-Re	0	0
f	0	0
Psi/Psi^2	0	0
Vapor-Re	0	0
f	0	0
Psi^2	0	0
X factor	0	0
FITTINGS	TYPE No L/D K	TYPE No L/D K
	Entrance 0 0 0.50	Entrance 0 0 0.50
	Exit 0 0 1.0	Exit 0 0 1.0
	Gate valve 0 8.0 0	Gate valve 0 8.0 0
	Globe valv 0 340 0	Globe valv 0 340 0
	Check 0 50.0 0	Check 0 50.0 0
	Stop-check 0 400 0	Stop-check 0 400 0
	Elbow 0 20.0 0	Elbow 0 20.0 0
	180 Bend 0 50.0 0	180 Bend 0 50.0 0
	T-Straight 0 20.0 0	T-Straight 0 20.0 0
	T-Branch 0 60.0 0	T-Branch 0 60.0 0
	Other 1 0 0	Other 1 0 0
Fitting K	0	0
Fitting L/D	0	0
Total Eq Length m	1.00	1.00

NOTES - (1) dPoverall = dPfrictional + dPaccel + dPstatic
(2) NS = No slip or homogenous

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Designing of 6000 Tons Hydrocarbon (Petrol & Diesel) Storage Tanks with Loading and Unloading System as per Regulatory Rules of Pakistan

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CASE 1 NORMAL FEED SUMMARY Date: 21 Feb 24, 13:08

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Number	Description	Elevation	Density	Level	Rel Elev	dP loss	dP level	dP inlet	dP total	Pres
		m	kg/m3	m	m	kPa	kPa	kPa	kPa	kPag
F1	Feed	2.0	840	0	0	0	0	0.585	0.585	-56.1

NOTES - (1) dP Inlet for Feed, Products and Vessels represent pressure to velocity conversion only, not friction.

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Designing of 6000 Tons Hydrocarbon (Petrol & Diesel) Storage Tanks with Loading and Unloading System as per Regulatory Rules of Pakistan

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CASE 1 NORMAL PRODUCT SUMMARY Date: 21 Feb 24, 13:08

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Number	Description	Elevation	Density	Level	Rel Elev	dP loss	dP level	dP inlet	dP total	Pres
		m	kg/m3	m	m	kPa	kPa	kPa	kPa	kPag
TK1	Product	0	840	0	0	0	0	0	0	50.0

NOTES - (1) dP Inlet for Feed, Products and Vessels represent pressure to velocity conversion only, not friction.

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Designing of 6000 Tons Hydrocarbon (Petrol & Diesel) Storage Tanks with Loading and Unloading System as per Regulatory Rules of Pakistan	This information is confidential, and shall not be reproduced by any means without the written permission of KORF.	Page: 270 Proj: By : Chkd/Apvd: /
CASE 1 NORMAL	PUMP SUMMARY	Date: 21 Feb 24, 13:08

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Number	Description	Eff	Power kW	Flow kg/h	Density kg/m3	Vol Flow m3/h	Head m	Pout-Pin kPa	PresIn kPag	PresOut kPag
P1	Pump	0.6982	5.46	115,200	840	137	12.1	100	-45.7	54.3

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Designing of 6000 Tons Hydrocarbon (Petrol & Diesel) Storage Tanks with Loading and Unloading System as per Regulatory Rules of Pakistan	This information is confidential, and shall not be reproduced by any means without the written permission of KORF.	Page: 270 Proj: By : Chkd/Apvd: /
CASE 1 NORMAL	T-PIECE SUMMARY	Date: 21 Feb 24, 13:08

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Number	Description	Service	Line	Spacing L/ID	Kc	Q/Qc	A/Ac	Pressure kPag
T1	Tee	Combined	L1			1.0	1.0	-40.3
		Branch	L2		1.21	1.0	1.0	-41.0
T2	Tee	Combined	L3			1.0	1.0	-41.1
		Manifold	L4	0	1.3	1.0	1.0	-41.9
T3	Tee	Combined	L12			1.0	1.0	51.3
		Branch	L11		1.1	1.0	1.0	51.9
T4	Tee	Combined	L12			1.0	1.0	50.8
		Branch	L13		1.21	1.0	1.0	50.1