Maintenance of Fiberglass Rainforced Plastic and Three Layer Polyethylene Pipes

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ABSTRACT

This paper examines the critical role of piping systems in the transportation of fluids, gases, and slurries across various industrial applications, with a focus on the transition from Fiberglass Reinforced Plastic (FRP) pipes to Carbon Steel pipes coated with 3 Layer Polyethylene (3LPE) for Liquefied Petroleum Gas (LPG) distribution at the Integrated Terminal PT Pertamina Perak in Surabaya. The study highlights the construction of a direction keet, which serves as a temporary operational hub for project materials, enhancing organizational efficiency and safety compliance in high-risk environments. The research emphasizes the importance of routine maintenance and inspections in ensuring the reliability and safety of gas distribution systems, identifying the vulnerabilities of FRP pipes, including susceptibility to vibrations and subsequent leaks. In contrast, Carbon Steel 3LPE pipes exhibit superior mechanical properties, including enhanced resistance to vibrations, impacts, and corrosion, which contribute to their longevity and reliability. Non-Destructive Testing (NDT) procedures confirmed the integrity of the welded joints, ensuring compliance with safety standards. The findings underscore the necessity of thorough material selection and adherence to health and safety regulations, providing a valuable reference for future projects aimed at improving safety and efficiency in energy distribution systems. Ultimately, this research offers evidence-based recommendations for optimizing material choice in pipeline construction and management, reinforcing the strategic importance of effective project management in the energy sector.

I. INTRODUCTION

A piping system is a critical infrastructure component used for the transportation of fluids, gases, and slurries in various industrial applications, including oil and gas, chemical processing, and water distribution (Abdurrahman, and Rahman., 2024). The construction of a direction keet is an essential activity in project management, particularly in the context of large-scale industrial operations (Chen, and Wang., 2023). The direction keet serves as a temporary field office where project equipment and materials, including welding electrodes and safety gear, are stored and managed (Zulkifli, and Al-Mansoori., 2022). This facility not only provides a centralized location for resources but also enhances operational efficiency by facilitating better organization and accessibility of tools necessary for the successful execution of project tasks. The establishment of a direction keet is particularly crucial in high-risk environments, such as those involving the handling of Liquefied Petroleum Gas (LPG), where safety and compliance with health regulations are paramount (Badran, and El-Shafee, 2024). By ensuring that all necessary materials are readily available and that safety protocols are adhered to, the direction keet plays a vital role in minimizing risks associated with project operations. Moreover, the construction of such facilities reflects a commitment to maintaining high standards of safety and efficiency in project management, which is essential for the successful completion of tasks in the energy sector (Yoon, and Kim., 2024).

The maintenance of gas pipelines is an essential aspect of ensuring the reliability and safety of gas distribution systems. Pipelines that exhibit damage or leaks pose serious risks, including potential explosions and environmental contamination. Therefore, routine inspections and preventive maintenance are highly recommended (Liu, and Wang, 2023). Maintenance processes typically include visual inspections to identify damage, cleaning to remove debris and corrosive substances, and repairs when leaks are detected. In the context of gas pipelines, the selection of appropriate materials is crucial in minimizing maintenance frequency and costs, as evidenced by the transition from FRP to carbon steel 3LPE at Petroleum industries in Indonesia, which aims to enhance durability and reduce repair complexities Zhang, F., & Wang, S. (2024).

Fiberglass Reinforced Plastic (FRP) is a composite material known for its favorable properties, making it suitable for a wide range of applications, particularly in piping systems. Composed primarily of fiberglass and thermosetting resin, FRP offers structural strength and excellent chemical resistance, enabling it to handle various fluids, including corrosive substances (Chen, and Liu, 2023). One of its most notable advantages is its outstanding corrosion resistance, as the absence of ferrous components eliminates the risk of rust, making it ideal for harsh environments. FRP is also significantly lighter than traditional materials like steel, which simplifies installation and transportation, especially for extended pipeline systems (Khosravi, and Moshrefzadeh, 2023). Its good abrasion resistance makes it suitable for conveying fluids containing solid particles, while its non-conductive nature enhances safety in electrically sensitive areas. However, FRP is not without limitations; it is prone to damage from strong impacts and vibrations, which can lead to fatigue and leaks at joints. Furthermore, repairs can be complicated and costly, and the material has a defined service life that may necessitate eventual replacement (Wang, and Zhang., 2024).

Carbon Steel pipes coated with 3 Layer Polyethylene (3LPE) are highly valued for their strength, durability, and suitability in high-pressure applications. These pipes are composed primarily of iron with added carbon, which enhances their mechanical strength and toughness. The 3LPE coating, consisting of an adhesive layer, a polyethylene layer, and a protective outer layer, provides superior corrosion resistance, extending the service life of the pipes in harsh environments (Liu, and Zhao, 2023). Carbon Steel 3LPE pipes are capable of withstanding high tensile stress and temperature, making them ideal for demanding fluid transport systems. They also offer better resistance to vibrations compared to materials like FRP, minimizing the risk of structural failure or leakage. Additionally, their fire resistance adds a level of safety in high-temperature or fire-prone settings. Although the initial cost of Carbon Steel 3LPE pipes may be higher than that of alternatives such as FRP, the reduced need for frequent maintenance and repairs often translates into long-term cost efficiency (Zhang, and Liu., 2024). However, the material is susceptible to corrosion if not adequately coated, and installation requires more time and careful handling to ensure connection integrity. Corrosion in LPG piping systems is a serious hazard that can compromise safety, cause environmental damage, and lead to costly failures (Zhang, and Li, H., 2023). One of the most dangerous forms is external corrosion, which occurs when pipelines are exposed to moisture, aggressive soils, or marine environments without adequate protective coatings (Rahman, and Alshahrani, 2024). This results in gradual thinning of the pipe wall and can lead to ruptures or leaks. Internal corrosion is equally hazardous and typically arises from the presence of water, carbon dioxide, or hydrogen sulfide within the gas stream, which can form corrosive acids inside the pipe. Galvanic corrosion may also occur when LPG pipes made of carbon steel are in contact with dissimilar metals in the presence of an electrolyte, accelerating metal loss at connection points (Yusron et all, 2020). In joints and fittings, crevice corrosion can develop due to trapped contaminants and moisture, while stress corrosion cracking (SCC) can cause sudden, brittle failures under combined tensile stress and corrosive conditions (Huang, and Zhang., 2024).. These corrosion mechanisms increase the risk of LPG leakage, which can lead to fires, explosions, and environmental harm. Preventative strategies include using corrosion-resistant coatings like 3LPE, cathodic protection, proper dehydration of LPG, and routine inspections to detect and mitigate early signs of degradation (Zhao, and Li., 2023).

II. METHODS

A. *Observation Object*

This research uses a qualitative approach with a case study method, which aims to analyze and compare the use of Fiberglass Reinforced Plastic (FRP) pipes and 3LPE carbon steel pipes in the LPG distribution system at PT Pertamina Perak LPG Depot, Surabaya. Data was collected through direct observation during the study, as well as analysis of related documents. The research was conducted at Pertamina Integrated Terminal Surabaya in August 2024, where the researcher was directly involved in various activities related to the pipe replacement project.

B. *Pipe Replacement Procedure*

The pipe replacement procedure commences with the following preparatory measures: Prior to the commencement of the activity, a preparatory phase is initiated. This phase encompasses an introduction to the work location, an exposition of occupational safety and health regulations, and a briefing on the work procedures to be executed. Concurrently, a safety inspection is conducted to ensure that all aspects of OHS are met prior to the commencement of work. This encompasses the inspection of safety equipment and the comprehension of the risks present at the work site. The subsequent stage in the process is the unloading of the pipes. Following the arrival of the 3LPE carbon steel pipes, the researcher provided assistance in the process of unloading the pipes from the transport vehicle to the designated storage location. Direction Keet Creation: The researcher participated in the construction of the direction keet, which serves as a storage area for project tools and materials. This was followed by the creation of the Water Curtain and Welding Habitat: In accordance with the stipulated OHS requirements, the researcher participated in the fabrication of water curtains and welding habitats, with the objective of mitigating the risk of fire during the welding process. The subsequent stage of the process was the welding stage. The researcher participated in the welding process of 3LPE carbon steel pipe using the Shielded Metal Arc Welding (SMAW) method. In the course of this process, the researcher familiarised themselves with the welding steps and assisted in the preparation of the equipment. The final step in this research is quality testing: After the welding process, Non Destructive Test (NDT) tests including visual test, X-Ray test, and hydro test were conducted to ensure the quality of the pipe joints.

C. *The objective of this study is to undertake a comprehensive data collection process.*

The data was collected through three primary methods: direct observation, interviews with project supervisors, and analysis of maintenance documents and inspection reports. Observations were made to understand the work process and problems encountered in the use of FRP pipes and 3LPE carbon steel pipes. In order to obtain further information regarding the pipe replacement decision and the challenges faced during the project, interviews were conducted.

D. The following essay will present a data analysis.

The data obtained from the observations and interviews were analysed descriptively in order to identify the advantages and disadvantages of each type of pipe. A comparative analysis was conducted, with the parameters of comparison encompassing technical specifications, performance in the field, and maintenance costs. The results of this analysis are expected to provide useful recommendations for the selection of the most appropriate pipe material in LPG distribution applications.

III. Results and Discussion

The project aimed at replacing Fiberglass Reinforced Plastic (FRP) pipes with Carbon Steel 3LPE pipes at the Integrated Terminal PT Pertamina Perak has yielded significant findings regarding the performance and reliability of piping systems used for Liquefied Petroleum Gas (LPG) distribution. The initial phase involved conducting a comprehensive safety inspection, which is crucial in high-risk environments such as LPG handling facilities. This inspection ensured that all safety protocols were adhered to before any physical work commenced, thereby minimizing the risk of accidents. Subsequently, the unloading of Carbon Steel pipes was executed efficiently, allowing for the timely progression of the project. A key aspect of the project was the construction of a direction keet, which served as a temporary storage and operational hub for project materials and equipment. This facility not only enhanced the organization of tools and safety equipment but also contributed to improved workflow efficiency.

TABLE I. Specification of 3LPE Pipe and RFP pipe

Specification	Carbon Steel 3LPE Pipe	FRP Pipe
Nominal Diameter (DN)	200 mm	200 mm
Standard	API 5L and relevant industry standards	API 15 LR
Material Composition	Carbon Steel (API 5L Grade B)	Fiberglass and thermosetting resin
Coating	3 Layer Polyethylene (3LPE)	Not applicable
Density	Approximately 7.85 g/cm³	Approximately 1.5 to 2.0 g/cm³
Yield Strength	Minimum 245 MPa	Minimum 200 MPa
Tensile Strength	Minimum 400 MPa	Minimum 100 MPa
Impact Resistance	High	Moderate; susceptible to impact damage
Outer Diameter	Approximately 219 mm	Approximately 219 mm
Wall Thickness	Typically 6 mm to 10 mm	Typically 6 mm to 10 mm
Length	Standard lengths of 6 meters	Standard lengths of 6 meters
Pressure Rating	Up to 16 bar (1600 kPa)	Up to 10 bar (1000 kPa)
Temperature Range	-20°C to +80°C	-40°C to +70°C
Corrosion Resistance	Coated with 3LPE for external protection	Excellent due to absence of ferrous components
Installation Method	Welding, mechanical coupling, or adhesive bonding	Adhesive bonding or mechanical coupling
Maintenance Requirements	Regular inspections for corrosion and damage	Routine inspections for leaks and structural integrity
Quality Assurance Testing	Hydrostatic testing, visual inspections, mechanical property testing	Visual inspections, mechanical property testing
Certification	Compliance with API 5L standards	Compliance with API 15 LR standards

Based on table 1 the comparative analysis of the specifications for Carbon Steel 3LPE and FRP pipes highlights the distinct advantages and limitations inherent to each material. Carbon Steel pipes, particularly when coated with 3LPE, offer superior mechanical strength and durability, making them suitable for high-pressure applications. In contrast, FRP pipes are advantageous in corrosive environments due to their lightweight and corrosion-resistant properties, although they exhibit limitations in impact resistance and require careful handling during installation. The choice between these materials should be guided by the specific operational requirements and environmental conditions of the application.

The transition from Fiberglass Reinforced Plastic (FRP) pipes to Carbon Steel pipes coated with 3 Layer Polyethylene (3LPE) for Liquefied Petroleum Gas (LPG) distribution at the Integrated Terminal Petroleum industries in Indonesia has yielded significant insights into the performance, reliability, and safety of piping systems in high-risk environments. The initial findings highlight the operational challenges associated with the use of FRP pipes, particularly their susceptibility to damage from mechanical stress and environmental factors. Maintenance reports indicated that the FRP pipes, installed in 2017, experienced considerable issues, including leaks at the joints within a mere two years of service. These leaks were primarily attributed to cracking induced by vibrations during LPG transport, which underscores the inherent limitations of FRP in dynamic applications. The frequent need for repairs not only escalated maintenance costs but also posed significant safety risks, necessitating a reevaluation of material suitability for such critical applications. Conversely, the implementation of Carbon Steel 3LPE pipes has demonstrated a marked improvement in performance metrics. The mechanical properties of Carbon Steel, combined with the protective 3LPE coating, provide enhanced resistance to vibrations and impacts, thereby minimizing the likelihood of structural failure. The 3LPE coating affords superior corrosion protection, effectively mitigating the risks associated with external environmental factors, such as moisture and soil contaminants, which are prevalent in LPG distribution scenarios (Wang., and Chen, 2023). The successful execution of Non-Destructive Testing (NDT) procedures post-installation further validated the integrity of the welded joints, confirming compliance with stringent safety standards. The establishment of safety protocols during the transition process, including comprehensive safety inspections and the implementation of water curtains and welding habitats, exemplifies the commitment to maintaining a safe working environment (Zhang, and Liu., 2024). These measures not only protect personnel but also mitigate potential environmental hazards associated with LPG leaks, reinforcing the importance of safety in project management. The findings from this transition underscore the critical role of material selection in the design and maintenance of piping systems. The shift from FRP to Carbon Steel 3LPE not only addresses immediate operational challenges but also aligns with long-term strategic goals of enhancing safety and reliability in LPG distribution. This case study serves as a valuable reference for future projects, emphasizing the necessity for thorough evaluation of material properties and operational requirements in pipeline construction and management (Zhang, and Wang., 2023). The establishment of water curtains and welding habitats was another critical safety measure implemented during the project. These measures were necessary to mitigate fire hazards associated with welding activities, particularly given the proximity to LPG storage tanks. After the welding of the Carbon Steel pipes, a series of Non-Destructive Testing (NDT) procedures including visual inspections, X-ray tests, and hydro tests were conducted to verify the integrity of the welds (Wang, and Zhang., 2023). These tests confirmed that the weld quality met the required safety standards, ensuring the reliability of the new piping system. The transition from FRP to Carbon Steel 3LPE pipes was prompted by the operational challenges associated with the FRP material. Reports indicated that the FRP pipes, installed in 2017, experienced significant issues, including leaks at joints, within just two years. The maintenance reports highlighted that these leaks were primarily due to cracking caused by vibrations during the LPG transport process Xu, T., & Li, Y. (2024). Such vulnerabilities necessitated frequent repairs, which were often unplanned and costly. In contrast, the Carbon Steel 3LPE pipes demonstrated superior mechanical properties, including enhanced resistance to vibrations and impacts. The protective coating of 3LPE significantly reduces the likelihood of corrosion, thereby extending the lifespan of the piping system. This transition not only addresses the immediate issues of leakage and maintenance but also aligns with long-term operational goals of safety and reliability (Li, & Zhou., 2023).

The results of this project underscore the importance of material selection in the design and maintenance of piping systems. The shift to Carbon Steel 3LPE not only minimizes repair needs but also enhances the overall safety of the LPG distribution system. The findings from this case study serve as a valuable reference for future projects, emphasizing the necessity of thorough evaluation of material properties and operational requirements in pipeline construction and management. Furthermore, the adherence to health and safety regulations throughout the project highlights the commitment to maintaining a safe working environment. The successful implementation of safety measures not only protects workers but also mitigates environmental risks associated with potential leaks or accidents.

IV. Conclusion

The replacement of FRP with 3LPE pipes for LPG distribution represents a strategic decision informed by empirical data and operational experience. This transition not only enhances the efficiency and safety of the LPG distribution system but also contributes to the overall sustainability of energy infrastructure. Future studies should continue to explore the long-term performance of 3LPE pipes in various operational contexts, as well as the potential for integrating advanced materials and technologies to further improve pipeline integrity and reliability. This research illustrates the critical role of effective material selection and robust safety protocols in ensuring the efficiency and safety of pipeline systems. The insights gained from the transition from FRP to Carbon Steel 3LPE provide a framework for future decision-making in pipeline design and maintenance, ultimately contributing to the sustainability and safety of energy distribution systems. The results of this project highlight the critical role of material selection in the design and maintenance of piping systems. The shift from FRP to Carbon Steel 3LPE at PT Pertamina reflects a strategic decision aimed at enhancing the safety, efficiency, and longevity of LPG distribution systems. This case study serves as a valuable reference for future projects, emphasizing the need for thorough evaluation of material properties and operational requirements in pipeline construction and management. This research highlights the comparison between the use of Fiberglass Reinforced Plastic (FRP) pipes and 3LPE carbon steel pipes in the context of LPG distribution at PT Pertamina Perak LPG Depot, Surabaya. The uniqueness of this research lies in the in-depth analysis of the weaknesses of FRP pipes that often suffer from vibration damage, as well as the challenges in their complex maintenance process. By mining data from maintenance and inspection reports, this research not only provides insight into the performance of both pipe types, but also presents evidence-based recommendations for more efficient and safe material replacement. The findings indicate that while FRP pipes offer advantages such as excellent corrosion resistance and lightweight characteristics, they are susceptible to damage from vibrations and impacts, leading to frequent maintenance and repair needs. The maintenance reports revealed significant issues with the FRP pipes, including leaks at joints shortly after installation, which underscored the necessity for a more robust solution. The decision to replace FRP with Carbon Steel 3LPE was driven by the latter's superior mechanical properties, including enhanced resistance to vibrations and impacts, as well as its ability to withstand higher pressures. The implementation of stringent safety measures, including safety inspections, the establishment of water curtains, and welding habitats, further ensured the safety of personnel and the surrounding environment during the installation process.

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