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REHABILITATION OF AN SUBSEA PIPELINE IN THAILAND

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ABSTRACT: This paper describes a rehabilitation project carried out by Danphix using the Primus Line® lining technology for the rehabilitation of a 1000 m (0.6 m) long subsea pipeline. The pipeline is part of a larger oil network in the South of Thailand, managed by Chevron and owned by a Joint Venture formed by the latter with Shell and ExxonMobil. The pipeline starts at the offshore platform in front of Songkhla beach and reaches out to the stocking tank area within the on-shore installation premises. Made of carbon steel in a 200 mm diameter, the pipeline with eight 45° bends was shut down after some inspections reported a lack of integrity and a thinning of the pipeline walls beyond safety levels in certain areas. For this project, Danphix used Primus Line Technology: a high-performance system characterized by rapid installation times and specifically designed for the no-dig rehabilitation of pressure lines, even underwater. For oil conveyance applications, the system utilizes a reinforced composite lining that has a Kevlar layer in the middle designed to reinforce the lining and bear high operating pressure in time. An additional TPU layer ensures high chemical resistance.
This very challenging job required extensive preparation work to accurately design all steps of the project including the management of on- and off-shore sites. This included the set-up of a scaffolding over the water, anchored on one side of the off-shore platform, providing a firm floor for the various operations. Part of the preparation work was an accurate mechanical engineering study of the rehab process and lining installation to which some extent of maritime engineering was added up to ensure total site safety.

1. INTRODUCTION

The number of new challenges and projects that the oil and gas industry is facing quickly rises with each day that passes. A considerable fraction of these challenges is result of the continuously increasing damage taken by pressure pipelines caused by ageing and corrosion (see Fessler (2008) for details). If not tackled on time, the damages evolve into leakages, causing significant operational and environmental problems and leading to extremely high capital expenditures and even reputation loss for the pipe network operators and owners.
The conventional way of solving these issues is a complete replacement of the damaged line or, at least, of its most problematic section. This does not only lead to high capital expenditures as well but proves to be a huge engineering challenge; production plants and cities evolve over decades, making the access to old pipelines much more difficult if not unfeasible. However, these situations have also created a path for innovative solutions to appear and increasingly compete in the market: trenchless pipeline rehabilitation technology. Kaushal and Najafi (2020) compared the environmental impact of pipeline replacement with that of trenchless renewal. From localized repairs through lining techniques to complete pipeline replacement, according to the United Kingdom Society for Trenchless Technology (UKSTT) (2023), trenchless rehabilitation technology is an almost chirurgical alternative compared to traditional renovation methods, minimally disturbing the environment, traffic, operation, or any activity around the affected pipeline. Among the available techniques, the Primus Line® System, an aramid-reinforced thermoplastic pipeline, has displayed features that clearly differentiate it from all the others during the past decade.
This work exhibits the unique advantages of trenchlessly rehabilitating a pressure pipeline using the Primus Line® System and aims to raise awareness of the technology by presenting the reasons why three global oil and gas players chose it to rehabilitate a crucial, shared fuel jetty pipeline in Southeast Asia.

Rehabilitating a submarine fuel oil pipeline is never an easy job, and there are always many critical points involved. These are first of all related to the extent of danger connected with oil products that produce a waste residue inside the pipe likely to develop a toxic and highly inflammable gas: hydrogen sulfide (H_2S) forming explosive mixes when it comes in contact with air. Furthermore, one should consider the instancy of the operating environment. Open-sea conditions can be challenging in terms of workers' safety but also for the organization of the site, logistics, and daily work..

2. THE ANTECEDENT PIPE CONDITIONS

Chevron Corporation is a large North American oil corporation with over 50,000 employees in more than 180 countries and a turnover that last year skimmed 195 billion dollars. In 2020, they decided to rehab one of the subsea lines at the Songkhla Terminal, in South Thailand. Chevron is responsible for the operating management of the deposit that belongs to a Chevron Joint Venture with two more large operators in the same sector Shell and ExxonMobil.

The pipeline was originally assigned to the conveyance of fuel oil and extends over a 1000-meter water stretch starting from an offshore platform where the ships deliver oil. Oil is then conveyed through the pipeline to the storage tanks inside a facility on shore.

Made of carbon steel, the pipeline is 8 inches (200 mm) wide and turns eight times around 45°. The pipeline had been long out of service since the last inspections detected that loss of integrity was such to impair the necessary safety conditions for oil conveyance. All oil pipelines and pipelines undergo periodic checks to assess their wall thickness by means of ILI pigs, an internal inspection system designed to perform a point detection of any pipe wall thickness and its consistency. In this case, the inspection revealed several areas where the pipeline wall thickness was no longer sufficient to safely withstand the operating conditions at full capacity.

Figure 1. Songkhla offshore platform

Figure 2. Subsea liner route

Different options were considered by the owner, including repair, replacement, and refurbishment. Repair was not the permanent solution they were looking for and involved significant HSE risks. Replacement was a capital heavy solution and required a much longer timeframe, including various local authority clearances. Installing a new line would also involve a lengthy process of engaging the nearby fishing community, who would have been impacted by the construction works.

Regarding the third option, the pipeline could be refurbished by installing a hose inside the original pipeline. This, in turn, opened different options. However, some would need significant modifications of short bend elbows under water, and others would reduce the product transfer rate, increasing the demurrage and waiting time of each ship. Primus Line offered to install its flexible liner into the aging pipeline, using one winch pull, without needing any bend modifications, and virtually maintaining the original product flowrate (see a comparison between the offered solutions in Table 1). These reasons amounted to the selection of Primus Line to rehabilitate the pipeline.

Criterion/Option	Repair	Replacement	Other liners	Primus Liner
Permanent	− −	+ +	+	+ +
HSE risks	−	− −	+	+ +
Costs	−	− −	+	+ +
Timeframe	+	− −	+ +	+ +
Modifications	−	− −	−	+ +
Flowrate	+ +	+ +	− −	+ +

Table 1. Comparison between offered solutions

3. PIPELINE RECOVERY AND CONVERSION

Based on this situation, the idea came to rehabilitate the overall infrastructure, restore full capacity and convert it to a new use. While it was clear that not even a fully rehabilitated pipeline may be assigned to oil conveyance, which by the way was no longer a business activity of the terminal, it would have been a perfect resource for other refined by-products like diesel and gasoline.
The choice of the optimal recovery system was made by Chevron's technical staff that choose the Primus Line Hose Lining system which is designed to install inside the host pipe a flexible, stand-alone hose that works as a new pipe. For the execution of the job, Chevron awarded Danphix which qualified as a highly-skilled contractor with consolidated know-how in the field of Oil&Gas recovery and rehabilitation.

Figure 3. Pipeline weak points identified with a CCTV inspection

Figure 4. Host pipe 45° bend

4. SITE MANAGEMENT

The preliminary preparation work mainly involved accurate and punctual planning of all activities, starting from the set-up of the two sites at each end of the pipeline. The on-shore site was set-up at the facility of the oil company and hosted the base camp, equipment containers, offices, and all other equipment needed for on-shore operations. The off-shore site was arranged on a dedicated 50-meter-long and 25-meter large barge anchored to the platform

and to be used as the start line of most relining operations. The machinery, tools, and instrumentations needed for the execution of the works were set up on the barge, including cold cutting tools, pigs, and nitrogen tanks for the drainage and cleaning up of the old pipeline, winches, and steel wires for pulling the liner, and a 30-ton crane to handle the equipment as needed.
Moreover, a scaffolding was suspended all around the perimeter of the platform to access the pipeline whose end peeks out of the water level rising vertically against the wall of the platform.

Figure 5. Offshore platform

Figure 6. Offshore equipment mobilization

5. DESIGN WORK

The set-up of the two sites and the entire preliminary organization required intensive upstream preparation. In addition to the normal mechanical and process engineering activities, skilful maritime engineering work was needed to ensure the utmost safety of all on-site operations. As the team was working off-shore, all stability calculations had to forcedly account for the countless variables connected with this specific situation, including strong winds, and waves that definitely affect numerous operations among which for example all lifting activities. Quite uniquely, the entire design phase of the project has been remotely executed at Danphix headquarters in Reggio Emilia due to the difficult traveling to Thailand in the period between October and November 2020. That was indeed the time when Thailand was experiencing a total covid lockdown and entering the country was only possible with a special permit released by the Thai Ministry of Employment. Because of the slowness of the bureaucracy and the scarcity of any available flight, direct on-site surveys were not possible and the entire design work was finalized based on the technical data supplied by Chevron.

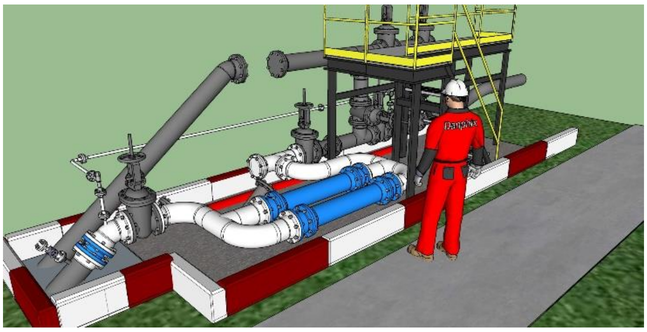

Figure 7. 3D render of the tie-in

Figure 8. Tie-in during construction

6. PIPELINE DRAINAGE AND CLEAN UP

Before relining, the pipeline was drained and cleaned up, which is a mandatory requirement for operating safety reasons. Drainage and clean-up are crucial step in which special pigs must eliminate any fuel oil residue from inside the pipe. Fuel oil residues may release hydrogen sulfide (H_2S), a very dangerous, highly inflammable, and toxic gas that may explode at certain concentrations in oxygen.

Drainage and clean-up have taken a considerable amount of time and were performed in different steps repeatedly using cleaning pigs of various types. These pigs are pushed inside the pipe by some fluid, nitrogen in this case. Nitrogen is an inert gas that does not react with other chemical compounds. Under this thrust force, the pig travels inside the pipeline and removes all leftovers of the previously conveyed materials leaving behind a perfectly inert pipe.

The cleaned-up pipeline was then cut off at both ends to allow access for liner insertion. The flanges were then welded on in order to fit the Primus Line connectors in place.

Figure 9. Cleaning pig at the pig receiver

Figure 10. Cleaning pig at the pig receiver

7. THE PRIMUS LINE TECHNOLOGY

Primus Line® is a flexible sliplining solution for the trenchless rehabilitation of pressure pipelines. The system consists of a flexible, aramid-reinforced liner and specially developed end fittings. The liner is self-supporting and not attached to the host pipe – an annular space remains – and is suitable for different media, such as gas, water, and oil, as well as various other applications. Gross (2019) has given a broad overview about water main rehabilitations. Besides the rehabilitation of damaged pipelines, this technology can also be used to increase the pressure within existing systems, transport media different from the original ones, protect the metal structure from corrosion, and build bypass systems or stand-alone solutions.

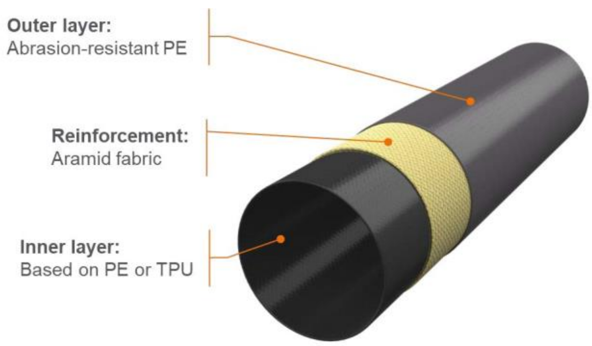

Figure 11. Layers of a Primus Liner

Figure 12. Primus Line Connector based on resin injection

Available in nominal diameters ranging from 6 to 20 inches (DN150-DN500), the liner is one of two parts of the Primus Line® System and consists of three different layers, as shown in Figure 1. The outer layer protects the internal, load-bearing core structure during the installation process. Regardless of the transported fluid, this layer is made of an abrasion-resistant polyethylene (PE). Depending on the required pressure rating, the core structure is made of either one or two layers of seamlessly woven aramid fabric; more than 4000 m can be manufactured without weak points in one single run. The aramid fabric absorbs the pulling force during the insertion of the Primus Liner as well as the operating pressure (up to 82 bar). Its inner layer varies with the transported medium: For water applications, it also is based on PE, while, for its use in the oil and gas industry, thermoplastic polyurethane (TPU) is the preferred solution because of the higher requirements concerning chemical resistance. Moreover, an exceptionally smooth inner surface is guaranteed, accounting for low head losses and negligible sedimentation and contamination levels.

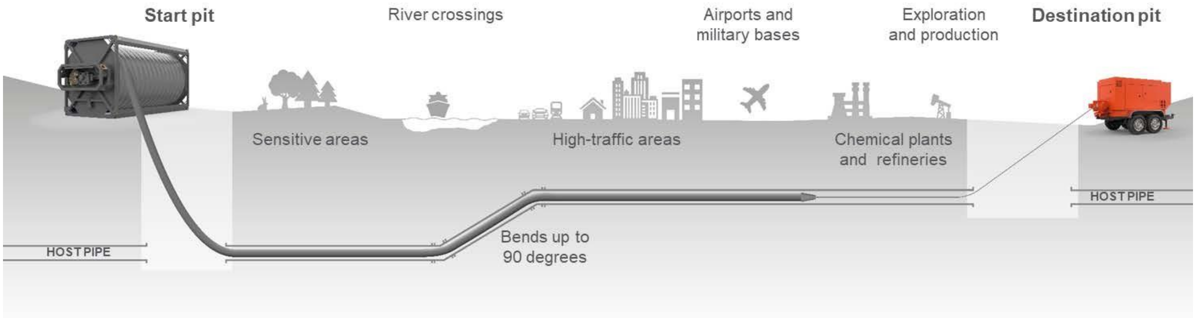

Figure 13. Sliplining the Primus Liner.

The TPU-covered liner is suitable for the renovation of oil pipelines due to its medium-specific inner layer and acts as a corrosion barrier between the fluid and host pipe. The conveyed fluid covers media such as crude oil, fuel oil, slag, diesel, and other refined products. Due to its layer composition and 6-mm wall thickness, the Primus Liner unites both flexibility and high material strength. In addition to its internal load-bearing capacity, its structure allows for the navigation in pipeline bends of up to 90° as well as the transportation of more than 5,700 m in one standard container.

The second part of the Primus Line® System are its specially developed and customizable termination fittings. To become a stand-alone system, the Primus Line Connectors must seal the annular space between liner and host pipe and integrate the rehabilitated section to the rest of the pipeline network through flanges or welded ends. Their clamping mechanisms divide them into two categories: steel connectors based on high-pressure resin injection and iron connectors based on hydraulic insertion. The former type is the standard choice in the oil and gas industry due to their robustness and versatility (see Figure 2).

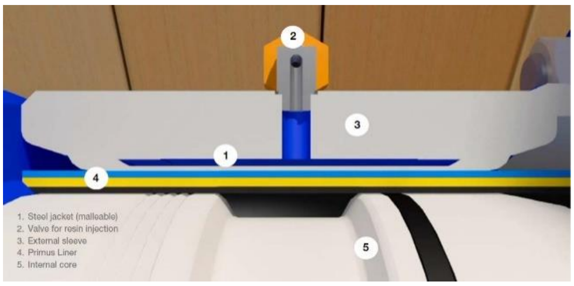

Figure 11. Resin injection process

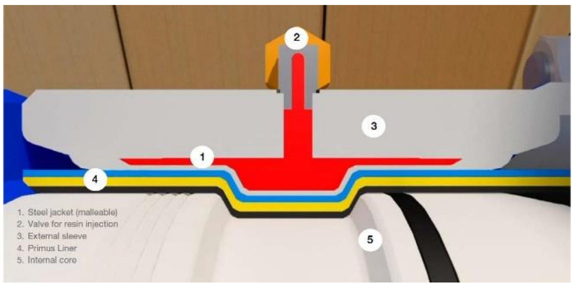

Figure 12. Resin injection process

The shown connector consists of a dimensionally stable, profiled connector core and an external sleeve with a deformable metal jacket, as shown in Figure 12. During the installation, a two-component resin injected through a valve on the external sleeve forces the metal jacket and, consequently, the liner into the contours of the connector core (without coming into direct contact with the liner or fluid). After the resin has cured, the connection is completely tight and permanent.

7. LINER INSTALLATION

The joint oil terminal in Songkhla, Thailand, was facing an integrity issue in early 2019: the aging of a subsea pipeline transferring refined products from the jetty to the onshore terminal. This kilometer-long line passing under the sea and a sand dune was critical for a smooth terminal operation. In reliability inspections, the facility noticed several weak sections on the pipeline's internal coating (Figure 3), limiting its life expectancy before reaching its minimum allowed wall thickness.

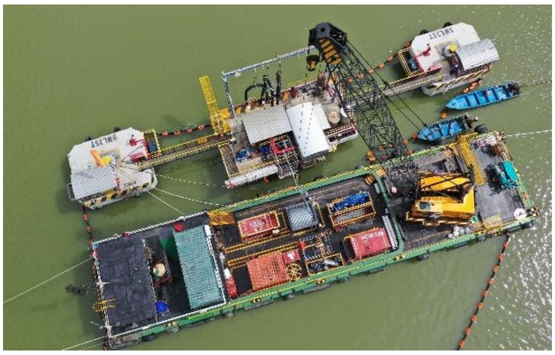

Figure 12. Liner installation phase

Figure 13. Liner installation phase

Being able to transport water-, gas-, and oil-based media, the chemical compatibility of the Primus Liner's inner coating with the product at hand must be guaranteed from an early project stage. Once approved, produced, and shipped, the first pipeline works were conducted to ensure a smooth system rehabilitation. To give a project overview, its key facts have been summarized in Table 2.

The first step in the rehabilitation was decommissioning the line, which was then separated at the beginning and end of the section to be rehabilitated as seen in Figure 5. This allowed to perform a full CCTV inspection of the section's internal condition and obtain images like those in Figure 6. The next step was cleaning the pipeline by sending a pig through it, according to an evaluation of the previous inspection. The pig's final run was used to establish the necessary cable connection between section ends to pull the liner through the pipeline. Since one of the section end was on water, a barge was used to properly position the transport reel (Figure 7). The folded Primus Liner was then winched into the host pipe, easily navigating all its bends.

After the liner reached the onshore end, it was reverted to its original circular shape using compressed air. The project-specific Primus Line Connectors were then installed, ensuring a tight and tensile connection, guaranteed through a hydrotest. The rehabilitated section was reconnected to the rest of the system, incorporating new pipework between the original structure and the Primus Line Connector (Figure 8). The line could then continue to operate free of corrosion or weak points for at least 20 years more. The new customized pipework included two lined spools called test pieces, which allow for invasive visual and even destructive inspections of the system without disrupting its operation. Depending on the analysis, it is possible to keep the line in function for an even longer period.

Figure 14. Liner pressure test before commissioning

Figure 15. Liner installation phase

8. CONLUSIONS

Among many advantages, Primus Line's trenchless technology distinguishes itself by being a stand-alone system that can still withstand high operation pressures. Its ultra-high flexibility allows for quick and long single-section installations (more than 2,000 m) and therefore environmental protection, 90°-bends navigation, and flowrate conservation with sizes up to 20".

Figure 16. Project team offshore.

The fuel jetty pipeline was successfully rehabilitated using the Primus Line® System (see Figure 9 for further project impressions). It was installed during the short turnkey timeframe of four weeks and managed completely remotely due to the ongoing pandemic. Without presenting any spills or safety incidences, the life of this subsea pipeline was extended by at least another 20 years (calculation based on American Petroleum Institute Specification 15S (2022)), increasing its operational reliability and saving millions in products and maintenance.