

Implementing a Deepwater-Pipeline-Management System

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Summary

As an operator, Total has experienced significant deepwater maintenance and repair activities, including cut-out and replacement of a damaged section of water-injection line, replacement of a flexible riser, replacement of an anchor line and its pile, and repair of an umbilical termination head (UTH).

There are few deepwater-pipeline operators with experience in pipeline repairs that need to be carried out with significant preparation time for intervention tools, including engineering and testing of the tools.

Deepwater operations [including inspection, maintenance, and repair (IMR)] require a completely different paradigm than conventional offshore operations, with need for specialized competencies, contractors, and tools. The pipeline-repair activities mastered in conventional offshore operations are becoming difficult tasks in deep water because they have to be performed remotely and the pipeline characteristics are quite different. Furthermore, there are many important challenges that still need to be overcome, such as repair of pipe-in-pipe systems, repair of production bundle, repair of flowline with hydrogen sulfide content, and repair of flowline connection, all of which challenge research and development to find proper tools and methodologies for deepwater intervention.

This paper describes the strategy developed and implemented on deepwater-pipeline intervention, based on a deepwater operational experience built over a decade. It also presents experiences of dealing with integrity issues and how to move forward in existing operations while preparing for future developments. Once the proper technologies are acquired, a pipeline-repair system should be established as part of an operational-management philosophy.

From the design stage, an operator involved in the development of deepwater operations should give serious consideration to how condition monitoring of the pipeline and its appurtenances will be performed and to how pipeline sections will be repaired or replaced should there be any failure during production. Being well prepared to face unexpected failures in the deepwater-pipeline network would allow the operator to maintain the level of integrity of the deepwater-pipeline network, minimize production loss and shortfall, minimize intervention costs, and maintain the operator's image with international media and the national oil company.

Introduction

Total has operated in deep water since 2000, and to this point, there have been six deepwater fields put into production, with several more under development. Each deepwater field has particularities related to reservoir formation, fluid properties, seabed conditions, available subsea technologies during development, and water depth.

During this relatively short period, there have been several important IMR activities performed on site, including cut-out and replacement of a damaged section of water-injection line. In this case, a 12-in. water-injection line had failed after 9 months in operation because of lateral buckling on the seabed several kilometers away from the injector wellhead. Investigations and analyses carried out concluded that the failure was caused by an overstress and an excess of bending during installation. The bend, combined with operating loads over 6 months, weakened the pipe and led to the rupture.

The preparation of the repair work took a long time because of the unavailability of prepared contractors for this type of repair and also because of the absence of dedicated equipment. The repair project was extremely demanding in terms of research and development (i.e., the design and fabrication of completely new subsea machining tools), and this was indeed the first time a repair operation such as this had been carried out at such a depth.

After several years of preparation, engineering, fabrication, and testing of tools, the repair work itself took a few weeks to complete, with a very minimum marine spread. The damaged section was cut remotely and replaced by an expansion spool equipped with two connectors, all in 1400 m of water (**Fig. 1**) (Total 2010).

The repair principle involved connecting a spool to the existing pipe with two connectors designed specially for that purpose (**Fig. 2**). Their special feature is that they leave a gap between the spool and the pipe in place, which means that the spool does not have to be manufactured with precision at the millimeter scale. The offshore installation was performed in less than 15 days, in two phases:

- The first phase was installation of the spool-deployment frame (SDF), end-connection skid (ECS), and the spool. The SDF was lowered and set down on the mud mats. Two ECSs were then added to the ends of the SDF. A spool was lowered and positioned precisely onto the SDF.
- The second phase was achievement and completion of the pipeline connections. A connector-installation tool (CIT) was used to lower one of the two connectors onto the first end of the spool. One end of the pipeline was lifted, aligned, and set in position on the CIT. The remainder of the pipeline was then put in the horizontal position and lined up correctly by means of two lifting tools: a pipeline-handling frame (PHF) and a pipeline-alignment clamp (PAC). The end of the pipeline underwent subsea machining and was then realigned with the spool, again using a PAC. The connector was translated between the spool and the pipe, again using the CIT. Once the connection had been activated hydraulically and tested for sealing, the whole operation was repeated on the other end of the spool.

This project entailed several challenges and implemented several technical qualifications and innovations:

- The repair was entirely subsea, with no surface recovery (1350-m water depth), and took less than 15 days of offshore work.

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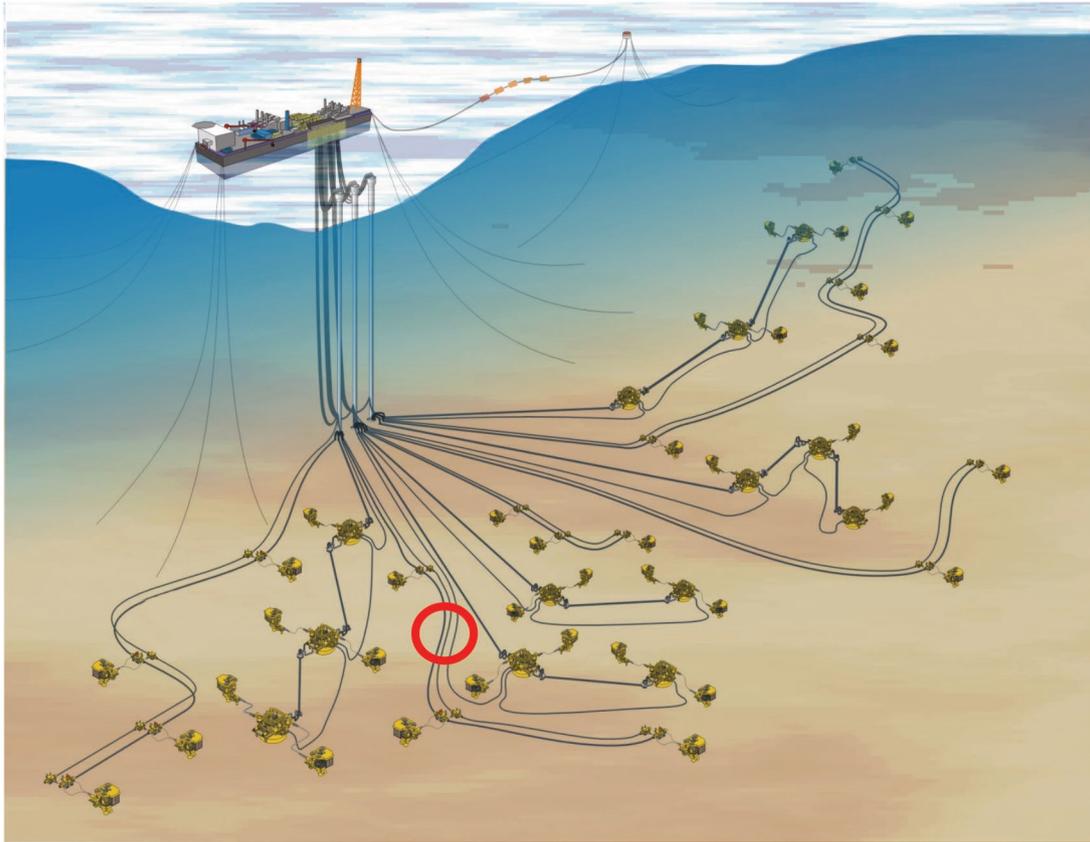


Fig. 1—Location of pipe failure.

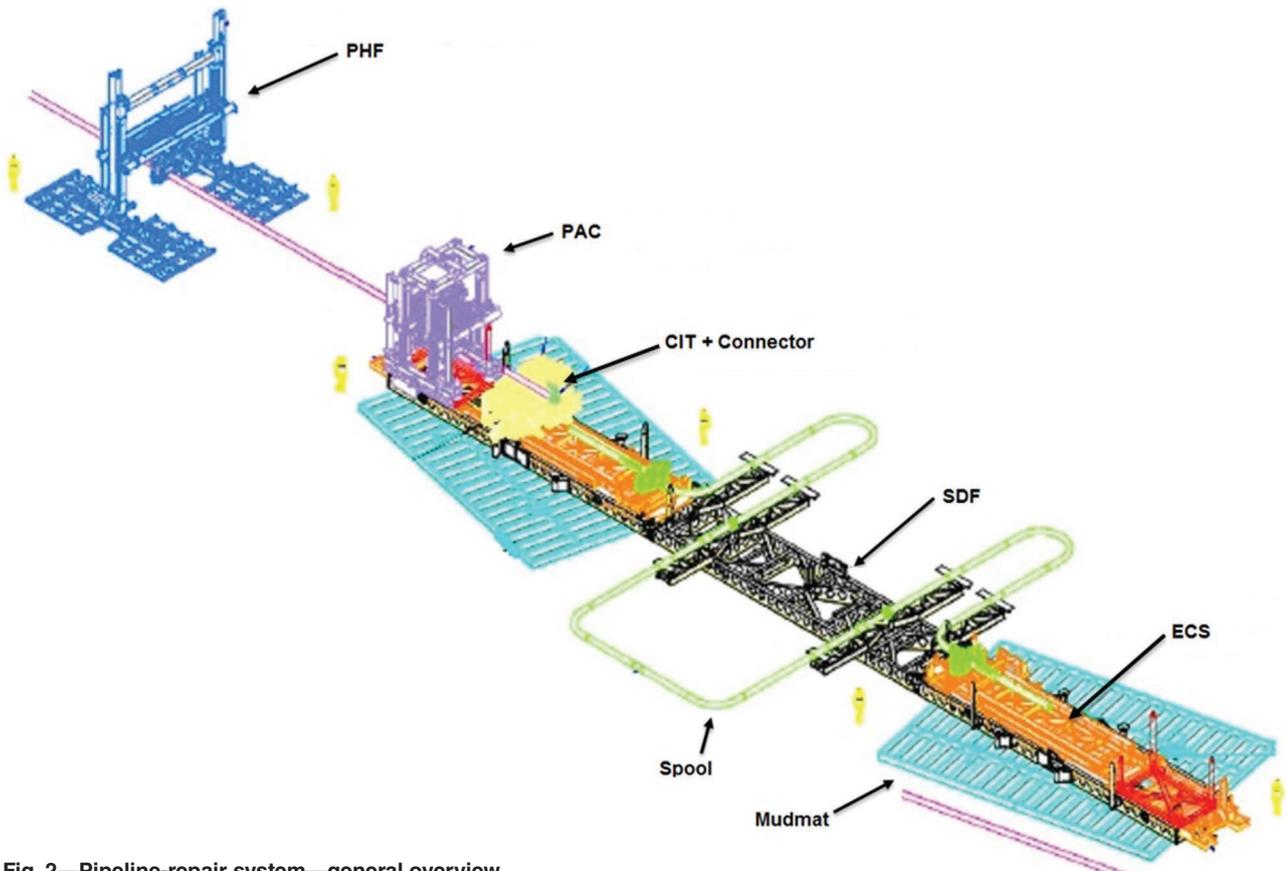


Fig. 2—Pipeline-repair system—general overview.



Fig. 3—Subsea pig-launcher-assembly layout.

- A coating-removal tool was used to remove the 3-mm polypropylene coating, thereby allowing steel-to-steel connection between the existing pipe and the connector.
- Reversible connectors were used, which could be activated and deactivated several times.
- A CIT was used, thereby allowing the connectors to be installed onto the spool and the existing pipe with zero buoyancy.
- A PAC was used to correct potential misalignment between the spool and the existing pipe without damaging the four seal barriers inside the connector.
- The installation required use of a field support vessel.

Replacement of a Flexible Riser

A flexible gas line between the top of the riser tower and the floating production, storage, and offloading (FPSO) vessel was damaged and needed to be replaced. It was a relatively simple operation, but it took a long time to complete because of the unavailability of a flexible handling vessel. The precommissioning of the newly installed flexible line was complicated because the gas-export pipeline at the bottom of the riser tower remained full of gas. A specific procedure was developed to allow the testing of the flexible line and its connections, while avoiding water ingress in the export pipeline.

Intelligent Pigging Runs

One of the well-known difficulties in deepwater pipelines is pigging. Deepwater-pipeline designs are difficult to pig because of the presence of manifolds, valves, tees, and flexible lines, and specially designed pigs are required to accommodate these constraints.

Total general specifications require that all pipelines be pig-gable. This may imply the installation of subsea-pigging facilities (temporary or permanent) or the use of loops. Total has success-



Fig. 4—Removal of intelligent pig from the pig receiver.

fully run intelligent pigs with both configurations. Intelligent pigging with a subsea pig launcher (Fig. 3) was performed in the North Sea in 2008 (Timmermans and Drennan 2009), while the intelligent-pigging run from the FPSO (Fig. 4) was performed in 2012.

Deepwater-Pipeline-Management System (PMS)

The feedback in the preceding paragraphs shows that deepwater operations require a completely different philosophy and preparedness than conventional offshore operations. One sure thing about deepwater intervention is that it is very costly and will take a very long time if it is not well anticipated. The repair methodology must be adapted to the working environment and is completely different from conventional offshore operation, in which several competent contractors are generally available with adapted equipment and marine spreads. The success stories of conventional offshore intervention simply are not applicable to deepwater operations—adjustments and additional tools are required to make the intervention work.

Total's PMS is based on conventional offshore- and onshore-pipeline operations, but the philosophy is still applicable to deepwater operations. The PMS covers design, construction, and operations, and consists of (Fig. 5)

- Pipeline database, including pipeline technical data sheets, pipeline history, pipeline anomalies, pipeline alignment sheets, and pipeline geographic-information systems (GIS)
- Pipeline-condition monitoring, including
 - Risk-based inspection system, taking into consideration assets information, risk assessments, anomalies, and history
 - Threat management, dealing with corrosion and structural/mechanical threats to assess the severity of any identified anomalies
 - Inspection methodologies, providing matrices on inspection techniques and anomalies detected

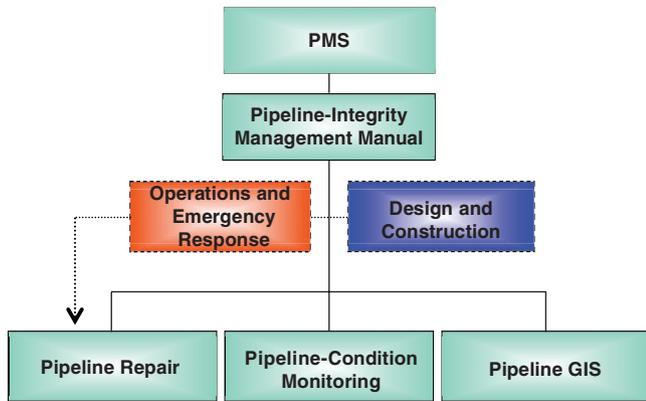


Fig. 5—PMS.

- Pipeline repair, providing as many repair procedures as possible following any possible failure mode on the pipelines. These procedures may be for temporary or permanent repairs. This also specifies the procedures for emergency pipeline repair, with a specific spares management.

The implementation of a PMS in a deepwater development should begin from the design stage. The design study should include

- The requirements for condition monitoring, the type of monitoring tools, and the locations and parameters to monitor; the information collected will be used and fed back to design a better subsea installation and, furthermore, to prepare and design the future repair, should it be necessary.
- The reparability of the subsea installation, to enable identification of the repair methodology and the spares required.
- Critical analysis of each asset to determine the level of readiness needed.
- The study of damage scenarios to propose mitigation methods.

Management of deepwater pipelines should ensure that all the pipelines are designed, installed, operated, and decommissioned in a safe and consistent manner.

Total adopts a risk-based approach to the management of pipeline risks and the scheduling of inspection intervals. Inspection techniques, inspection frequency, and effectiveness of inspection types have an impact on the ability to mitigate the identified risks and to ensure that pipeline risk levels are “as low as reasonably practicable.” Condition monitoring of deepwater pipelines should determine the methods to be used to monitor the internal and external integrity of deepwater pipelines.

There is limited information on failures in the reliability database for deepwater pipelines, and use of conventional offshore data (damage scenarios, types of defects and failures, and locations of defects and failures) can be misleading. To overcome this lack of data, there is a need to collect as much information as possible from the existing installation, such as pressure, temperature, stress/strain, vibration, and displacement, but the required tools are not always available, and, when they are available, they are difficult to install and to maintain (Fig. 6).

Several monitoring tools have been installed with no satisfactory performance, and data transfer to the surface facility is also difficult; if it has not been hard-wired, acoustic transmission is often not reliable and battery life is very limited. Several research-and-development projects were launched to try to overcome the problems with condition monitoring of deepwater installations. Manufacturers of the monitoring devices should be actively involved in making deepwater monitoring technologies more competitive. Additionally, the damage scenarios considered in the design studies often prove to be unreliable. For instance,

- The buckle location of a pipeline is difficult to predict, and the proximity of the subsea structure will interfere with the repair method.
- The soil conditions, which are used for the expansion models, are often not assessed sufficiently. The pipeline movements

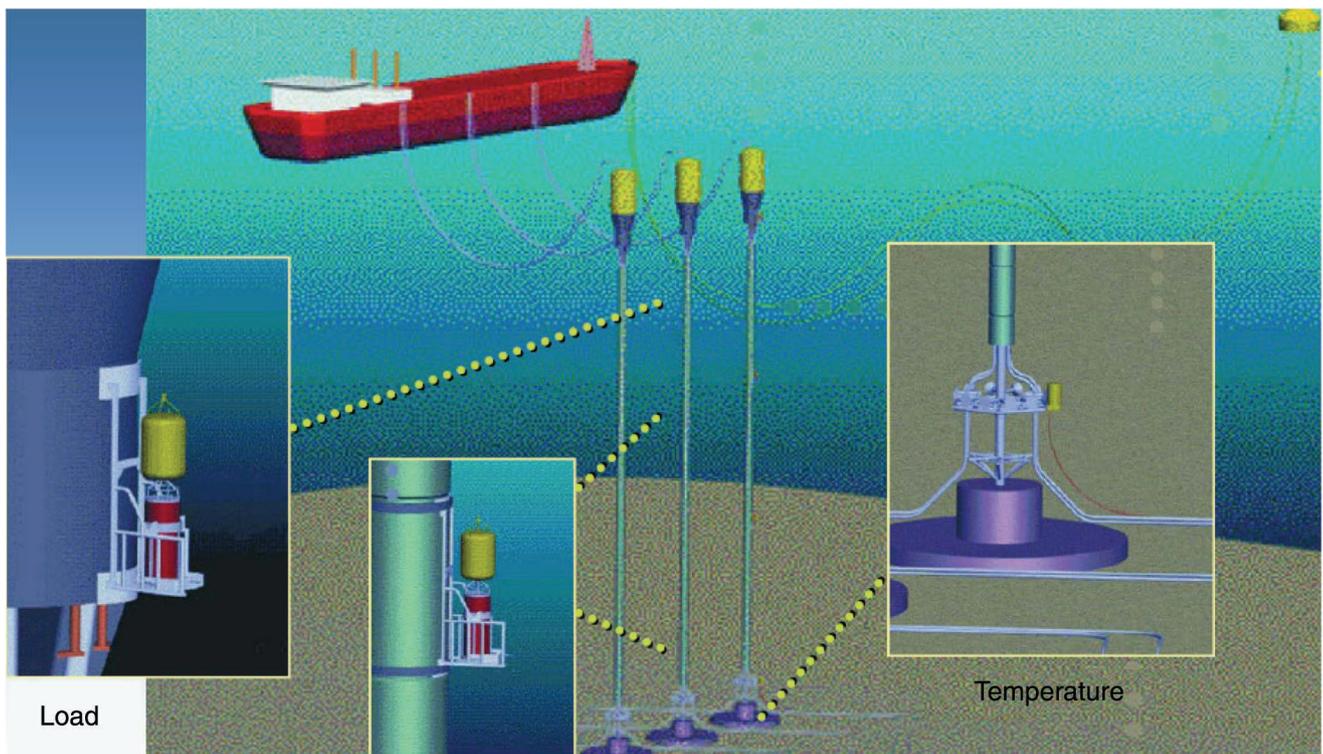


Fig. 6—Example of riser-tower monitoring devices.

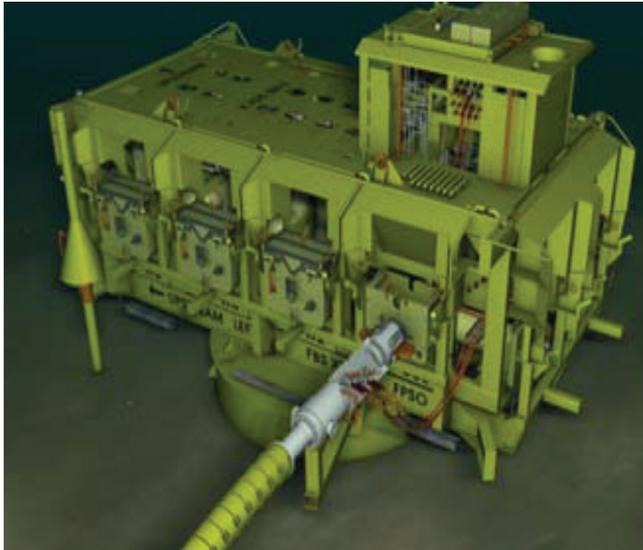


Fig. 7—UTH connecting the umbilical to the manifold.

can be underestimated, resulting in excessive stresses at the connecting spools.

- The interference with fishing activities, which were assessed as not applicable for deep water a decade ago, is now more and more frequent. As a result, some damage to equipment in deep water in excess of 1000 m has been found.

Way Forward

The integrity of deepwater installations does not concern merely the pipelines, but should also cover the appurtenances of the subsea installation, such as jumpers and umbilicals (control, chemical injection, power). Failure of these appurtenances may disturb deepwater-production operations significantly. Spares and special tools have to be prepared and be readily available onshore.

Total has experienced problems with the UTH of a methanol-injection umbilical. The failure of the methanol injection forced Total to launch a UTH repair, because the failure could have jeopardized production operations. The repair was performed by retrieving the umbilical onboard the working vessel (**Fig. 7**). The required spread was relatively simple, but the umbilical handling and the welding work on super-duplex-steel tubes required the expertise of a specialized contractor and the support of the headquarters metallurgy specialists. The repair procedures first had to be qualified to demonstrate the feasibility of the repair for each failure location in a

representative mock-up; to cover each potential failure; to capture constraints on the entire repair procedure (offshore, place, tooling, cleanliness); and to test equipment and personnel. The qualification was followed by trials onshore and offshore before the repair operation to test all equipment and consumables delivered, to capture constraints onboard the vessel, and to have personnel trained in actual conditions.

When the UTH was successfully lifted onboard the repair vessel and dismantled, the failure was found on the fillet weld at the junction between the tube and the coupling (**Fig. 8**). During offshore operations and despite trial tests, various problems were encountered that had to be solved on the job, such as

- Removal of the liquid remaining inside umbilical tubes
- Residual pumping effect, despite insulation plugs
- Limited number of trials possible (tube length)
- Difficulties in controlling the environment on the vessel deck
- Hydrogen diffusion in tubes, coming from the cathodic protection
- Tube misalignment
- Earthing of tubes

Conclusions

1. A PMS is still relevant and applicable in deepwater oil-and-gas operations, and may be part of the subsea-management system.
2. Condition monitoring and reparability requirements should be considered during the design stage of the development project.
3. There are not enough data regarding the behavior of deepwater installation or the monitoring tools to be developed for this purpose. Monitoring-device manufacturers and specialists should work closely with oil companies to generate a good synergy on applicable and effective monitoring devices in deepwater installations.
4. Deepwater-pipeline threats should be assessed periodically to identify new and previously overlooked threats.
5. Deepwater intervention is costly; any IMR intervention should be well anticipated and well prepared for by the field-operations team, with the objective to maintain the level of integrity of the deepwater-pipeline network; minimize production loss and shortfall; optimize intervention costs; and maintain the operator image with international media and the national oil company.

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Fig. 8—Crack on the interface weld after dismantling of the UTH.

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L. Theo M. Samosir works in the Total EP Technology Division in Pau, France, in pipeline integrity. He has worked with several Total EP affiliates in field-operations activities for more than 20 years, covering pipeline-condition monitoring, inspection, repair, and fitness for purpose. During this period, Samosir has dealt with onshore, swamp, and offshore pipelines. Currently, he is working on several emergency-pipeline-repair studies within the group for offshore conventional and deepwater pipelines.

Dominique Popineau is a pipeline specialist in the Total EP Technology Division. With 30 years of experience in pipelines, from design to construction and operation through to repairs, he has in-depth knowledge of the different stages in the life of a pipeline. Popineau was involved

with some of the first design, development, and installation of pipe-in-pipe system subsea. He was also involved in damage analysis and repair of deepwater pipelines, as well as preparation of deepwater emergency-pipeline-repair procedures.

Alain Lechon has 30 years of experience in subsea engineering in the offshore oil industry. He began his career working on the first subsea developments in Africa and Norway in the Advanced Research and Techniques department, where he devised subsea robots and tools before working for 10 years as a pipeline specialist. In 2002, Lechon took part in the Canyon Express gas-pipeline-laying operation, the deepest offshore project in the Gulf of Mexico at the time. In the last 5 years, he has designed a number of deepwater pipelines and monitored the technical aspects of the repair project on Girassol's I15 line. In 2009, Lechon joined the subsea team, where he works primarily on repair systems and on designing and constructing spools and jumpers.