WORLD FIRST PRESSIRISED SUBSEA PIPELINE REPAIR FACILITATED BY NON-PIGGABLE AND PIGGABLE ISOLATION TOOLS

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Project Description and Challenges

Offshore Oil Engineering Co. Ltd (COOEC) – a wholly owned subsidiary of China National Offshore Oil Corporation (CNOOC) were required to repair a damaged section of a 28" subsea gas export pipeline. The 778km pipeline, situated in the South China Sea, supplies gas to Hong Kong and had been damaged by an anchor drag approximately 500km from the offshore platform, 278km from Hong Kong. The damage occurred in a water depth of 90 meters. The anchor drag damaged one of two subsea Pipeline End Manifolds (PLEM) and had also dented the pipeline adjacent to the North PLEM.

Figure 1: Anchor damage location

Following discovery of the pipeline damage, a temporary repair was completed by installing a 400m long 14" bypass between the PLEMs, which enabled the pipeline to continue in operation, at its normal operating pressure of 70bar, while the permanent repair was being engineered.

The permanent repair required the removal of the existing PLEMs, removal of the 400m pipeline between the manifolds and removal of the severely dented section of the main pipeline. With subsequent installation of new pipeline sections onto both ends of the pipeline and the installation of two new PLEMs connected with a short tie-in spool. The new PLEMs were located 25m apart, instead of the original 400m.

After several, very detailed and thorough engineering studies and comprehensive risk assessments the client concluded that the permanent repair would be best achieved by recovering the subsea pipeline onto a pipelay barge. This would allow new sections of pipeline to be installed onto both ends of the existing pipeline. This was to be achieved in a conventional S-lay pipeline construction operation, while the pipeline remained pressurised with a shut-in pressure of 50bar.

As the pipeline is of crucial importance to the gas supply of Hong Kong, the shut-down period for the repair was required to be kept to a minimum, therefore the repair had to be done without depressurising and flooding the entire pipeline. In fact, the project specification was that only minimal water ingress was allowed into the pipeline during the entire repair workscope and any water entering the pipeline system had to be removed before the pipeline resumed operation.

To enable safe recovery of both ends of the subsea pipeline onto the pipe lay barge, without depressurising the entire pipeline or allowing water ingress into the pipeline, isolation tools

needed to be installed into the pipeline beyond the PLEMs isolating only the damaged section of the pipeline.

Following the project engineering evaluation and risk assessment, it was concluded that the primary isolation tools (Tecno Plugs™) needed to be located 700m away from the pipeline ends that were being recovered onto the pipelay barge. The reason for this was that the Tecno Plugs, providing the barriers from the hundreds of kilometres of the 50bar pipeline gas, had to be positioned beyond the catenary that would be lifted off the seabed while the pipeline was recovered onto the pipelay barge. The plugs were set in pipeline sections that would remain on the seabed, to ensure that these areas of the pipeline containing pressurised pipeline inventory would not be exposed to excessive stresses during the pipeline recovery, construction and laydown of the new pipeline sections.

The isolation tools had to provide; fully proven, fail-safe, Double Block and Bleed (DBB) isolation barriers from the pressurised pipeline. This level of isolation provided compliance with industry guidance for subsea isolations as all the subsea activities were performed by saturation divers with observation support provided from a Remotely Operated Vehicle (ROV).

Due to the damage caused by the anchor drag, it was not possible run any pigs through the pipeline, therefore the Remote Tecno Plugs had to be installed into the pipeline locally at the subsea damage location. As the North PLEM was severely damaged and the pipeline beyond the North PLEM was unpiggable due to the extent of the damage, the Remote Tecno Plug could not be deployed via the PLEM.

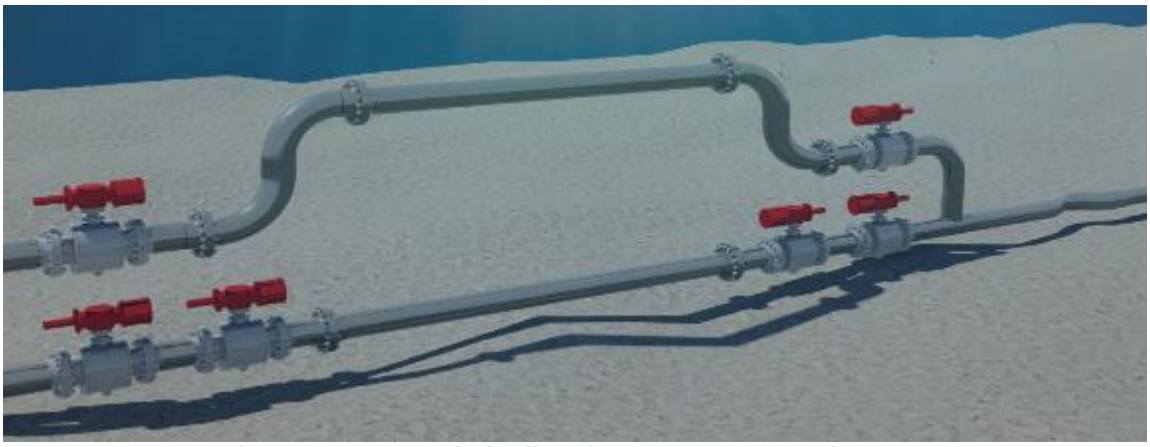

Figure 2: Damaged pipeline downstream of North PLEM

The South PLEM was not damaged by the anchor drag incident allowing the isolation valves within the South PLEM to provide the initial upstream DBB barrier. Therefore, a DBB barrier downstream of the damaged North PLEM needed to be installed to allow a section of the pipeline to be safely removed creating access for a piggable Remote Tecno Plug. This was done by installing a mechanical hot tap fitting onto the pipeline (50m beyond the damaged pipeline section) and hot tapping into the pressurised pipeline.

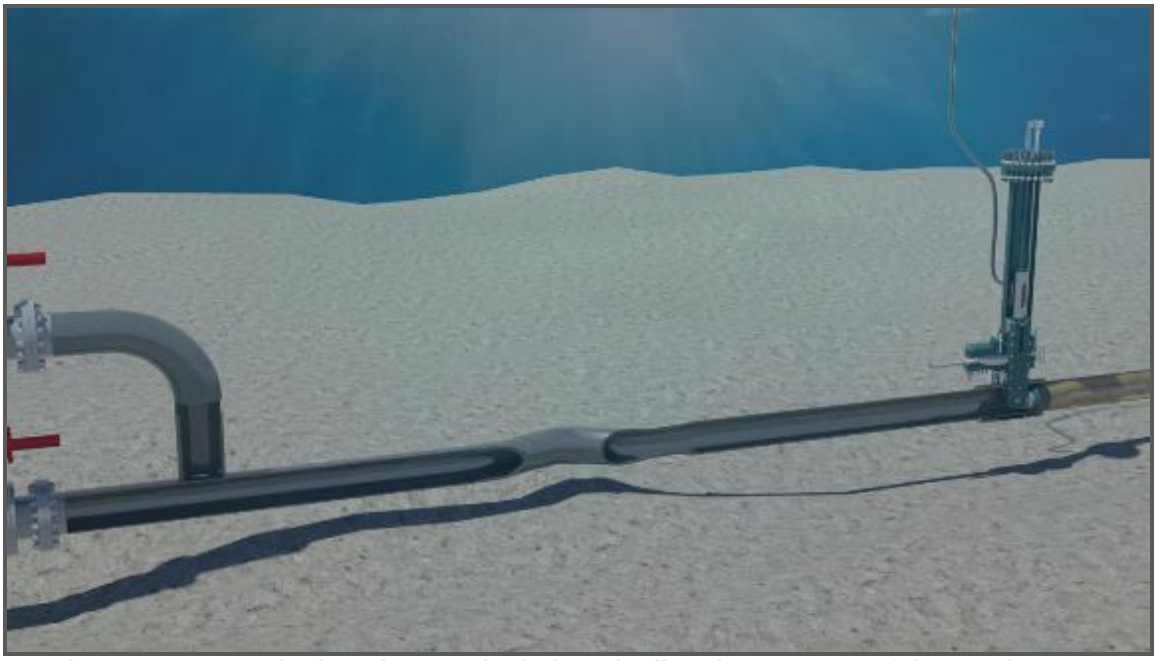

Figure 3: Hot tap deployed BISEP isolating pipeline downstream of the North PLEM

A BISEP™ was then deployed into the pipeline. The BISEP provided a fully proved Double Block and Bleed isolation barrier against the downstream pipeline gas pressure. No seawater ingress occurred throughout the hot tap and BISEP deployment operations.

Figure 4: Mechanical clamp and hot tap machine deployment

After the damaged pipeline section was isolated upstream by the PLEM valves and downstream by the BISEP, it was depressurised and flooded so a short section of the pipeline could be safely cut and removed by the divers. A subsea launcher, containing two Tecno Plugs, was then deployed from the vessel to the seabed and connected to the cut pipe end.

Figure 5: Flangeless Subsea Launcher deployment

After the subsea launcher was connected to the pipeline, nitrogen was injected into the launcher to purge all the seawater out of the pipeline section behind the BISEP. The integrity of the launcher installation, both sealing and locking capability was proven following the purging operation.

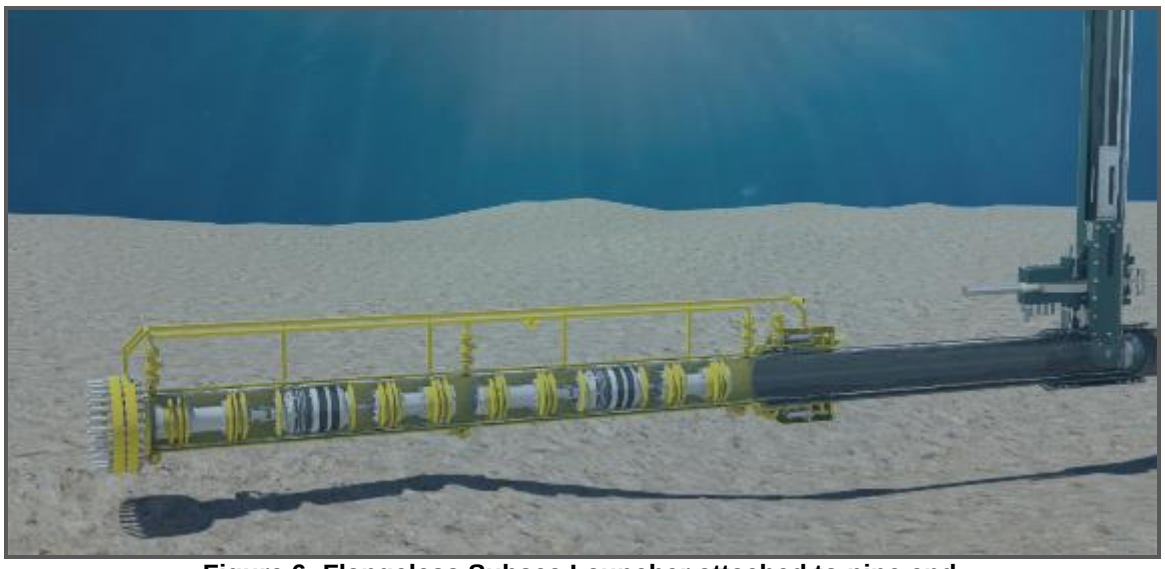

Figure 6: Flangeless Subsea Launcher attached to pipe end complete with both Remote Tecno Plugs

The BISEP was then unset and recovered from the pipeline. To prevent any potential damage to the Remote Tecno Plug pigging discs, a barred insertion plug was fitted into the hot tap fitting. Nitrogen was used to pig the first Tecno Plug 700m into the pipeline – against the 50bar shut-in pipeline pressure. Subsea pig detectors and STATS subsea Remote Tecno Plug tracking system confirmed the Tecno Plug had been pigged accurately to its required location.

The Tecno Plug was then remotely commanded to set inside the pipeline. This was done from the DSV based Remote Tecno Plug control console, via a subsea communication module placed next to the pipeline. This provided a two-way communication link between the Tecno Plug inside the pipeline and the topside control console on the vessel, using a combination of through-water acoustics and Extremely Low Frequency (ELF) through-pipe wall communication systems.

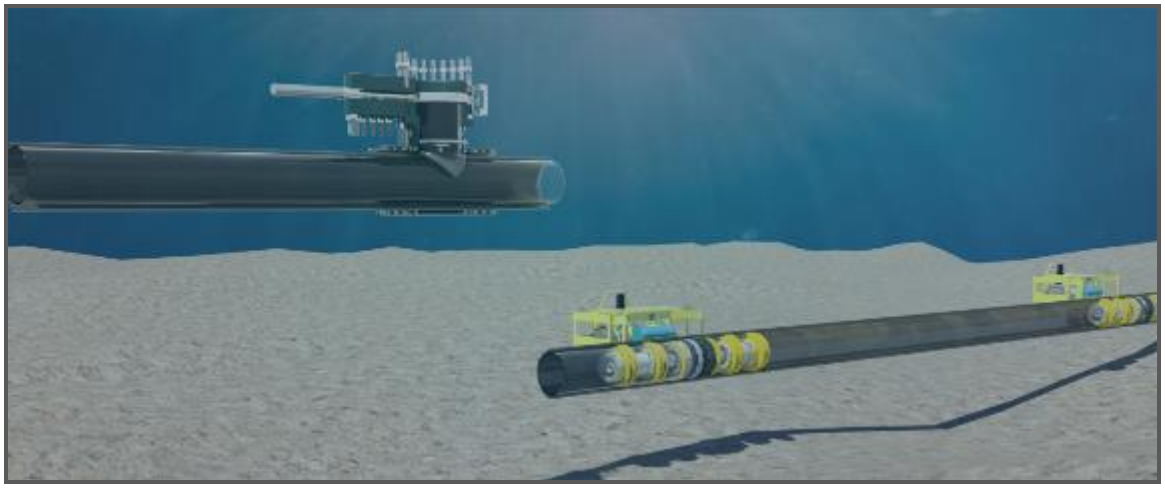

Figure 7: Remote Tecno Plugs pigged with Nitrogen to isolation location

Following confirmation that the Tecno Plug was fully activated, the nitrogen pressure behind the Tecno Plug was depressurised to 30bar creating a 20bar differential pressure. The secondary seal and primary seal were proved to be providing a high integrity double block barrier from the 50bar pipeline gas pressure.

Dual Redundancy in Activation: Fail-Safe Isolation

The Tecno Plug and BISEP have dual redundancy in activation, ensuring these isolation tools are fail-safe, while they are isolating. When the plug is set and providing a safety critical double block pipeline pressure barrier, two independent activation mechanisms are in place. These are the internal hydraulic system and the differential pressure acting across the plug.

The hydraulic pressure is locked in and maintained throughout the isolation period and the 20bar differential pressure acting across the Tecno Plug self-energises the plug, keeping the plug securely locked in position and maintaining both seals, independent of the internal hydraulic pressure.

Both separate activation mechanisms need to be removed to unset the plug. Therefore, if either the differential pressure or the locked in hydraulic pressure were to be inadvertently removed the isolation would still be securely maintained in a fail-safe condition.

The second Tecno Plug™ was then pigged 10m passed the mechanical hot tap fitting and activated. The pressure behind the plug was then vented to subsea ambient pressure and the double block isolation barrier was proved.

At this stage the subsea launcher and mechanical hot tap fitting were removed from the pipeline and recovered to the DSV. The hot tapped section was then cut off the end of the pipeline.

This left a bare pipe end into which a Pipeline Retrieval Tool (PRT) was installed for the pipeline recovery. To enable the pipeline to be recovered safely from the seabed (90m depth) onto the pipe lay barge, the catenary section was pressurised with 30bar nitrogen locked in between the first and second Tecno Plugs. The 50bar gas pressure in the 273km downstream pipeline section was securely isolated by the first Tecno Plug - located 700m away - in the pipeline section that remained on the seabed throughout the pipeline recovery.

Figure 8: Pipeline recovered to lay barge

The pipe lay barge then installed 400m of new pipe onto the recovered pipeline. The new pipeline end laid on the seabed was terminated with a new tie-in flange and a laydown head.

Moving on to the 500km long upstream section of the pipeline, the same method of isolation and pressure management in the catenary section - using two Tecno Plugs was repeated. The main difference being; a hot tap and BISEP isolation were not needed, as the South PLEM was undamaged and the pipeline isolation valves had been proved to be providing a satisfactory double block isolation.

A flanged subsea launcher was connected to the South PLEM tie-in flange and both Tecno Plugs were pigged, through the PLEM, to their respective set locations. The first plug was pigged 700m into the pipeline to provide the double block barrier, from the 50bar pipeline pressure. The Tecno Plug was now set at location in the pipeline section that would remain on the seabed throughout the pipeline recovery.

Again, to ensure safe recovery of the pipeline from the seabed onto the pipe lay barge, a second Tecno Plug was pigged 10m into the pipeline and activated, locking 30bar of nitrogen into the catenary section between the first and second Tecno Plugs.

Two new PLEMs were installed by the DSV while the pipelay barge welded new pipeline sections to the existing pipeline and laid them back onto the seabed. Throughout the entire pipeline isolation period all four Tecno Plugs in the pipeline were monitored, remotely from the DSV.

Figure 9: Pipeline End Manifold (PLEM) deployment

To prevent seawater flooding into the newly laid pipeline sections when connecting them to the new PLEMs. The pressure in the new sections, between the second Tecno Plug and the laydown heads, was increased to 30bar to equalise the pressure across the second Tecno Plug. The second plugs were then unset and by controlled venting at the laydown head, these plugs were pigged back toward the laydown heads using the 30bar nitrogen, locked in between the two plugs to drive the second plugs back toward the laydown heads. The plugs were then reset and their double block isolations were proved again so the laydown heads could safely be removed by the divers.

Once the pipelines were connected to the new PLEMs with tie-in spools, subsea receivers were fitted to the PLEMs. The receivers were used to recover both Tecno Plugs out of each pipeline section. After both plugs were confirmed to be in the subsea receivers the subsea pipeline isolation valves in the PLEMs were closed. The receivers, complete with Tecno Plugs inside, were then recovered to the DSV.

Figure 10: 25m tie-in spool deployment

The repair was completed by connecting the two PLEMs together with a final tie-in spool. Following leak testing and dewatering of the final tie-in spool the subsea pipeline isolation valves were opened and gas production was resumed.

Conclusion

The strategic use of the BISEP and Tecno Plug isolation tools ensured that the following primary project objectives were successfully achieved.

- The pipeline was repaired as safely and quickly as possible, without depressurising or flooding the entire pipeline.

- Minimal water ingress into the pipeline was allowed and the trace amounts of seawater that may have entered the system during the repair and tie-in were removed before the pipeline resumed operation.