Pressurised Subsea Pipeline Repair – Recent Case Studies

Despite good pipeline design and integrity management schemes, pipelines can and do get damaged and need to be repaired. Damage can be caused by any number of factors, such as dragged anchors, landslides, icebergs, fatigue, upheaval bucking or stress cracking. The resultant damage may cause the pipeline to become buckled or dented rendering the pipeline unpiggable, and in extreme cases rupturing the pipeline.

This paper explains how two damaged pipelines were repaired by sectional replacement, and in both cases, without depressurising the entire pipeline. These projects were performed using piggable and non-piggable, fully proved double block isolation tools.
CASE 1: 28” 780km Gas Export Pipeline Repair

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.

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 70 bar, 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. The subsequent pipeline replacement involved the 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 pipe lay vessel. 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 50 bar.

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 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 and without allowing water ingress into the pipeline, isolation tools needed to be installed into the pipeline beyond the PLEM to isolate 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 pipe lay barge. The reason for this was that the Tecno Plugs™, providing the barriers from the hundreds of kilometres of the 50 bar 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; i.e. 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 pipelines and they had to provide isolations that could be assessed to be in compliance with industry guidance for subsea isolations. Saturation divers performed all subsea activities with observation support from a Remotely Operated Vehicle (ROV).

Due to the damage caused by the anchor drag, it was not possible to 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.

The South PLEM was not damaged by the anchor drag incident, the isolation valves within the South PLEM could 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.
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.

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.
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.

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 50 bar 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 communication systems.

Following confirmation that the Tecno Plug™ was fully activated, the nitrogen pressure behind the Tecno Plug™ was depressurised to 30 bar creating a 20 bar differential pressure. The secondary seal and primary seals were proved to be providing a high integrity double block barrier from the 50 bar 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 being relied on as 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 isolation plug.

The hydraulic pressure is locked in and maintained throughout the isolation period and the 20 bar 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 are required 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 of the pipeline was then cut and recovered.

This left a bare pipe end into which a Pipeline Retrieval Tool (PRT) was installed for the pipeline recovery. This enabled the pipeline to be recovered safely from the seabed (90m depth) onto the pipe lay barge, the catenary section was pressurised with 30 bar nitrogen locked in between the first and second Tecno Plug™. The 50 bar 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.

The pipe lay barge then installed 400m of new pipe onto the recovered pipeline and laid it back onto the seabed with a newly installed tie-in flange and laydown head.

The project then moved onto 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. On this section of pipeline a hot tap and BISEP™ isolation was 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 50 bar pipeline pressure, this positioned the Tecno Plug™ 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 30 bar 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.

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 30 bar 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 30 bar nitrogen, locked in between the two plugs to drive the second plug back toward the laydown heads. The plugs were then reset and their double block isolations were proved again so the laydown heads could be safely removed by the divers.
Once the pipelines were connected to the new PLEM s with tie-in spools, subsea receivers were fitted to the PLEM s. The receivers were used to recover both Tecno Plugs™ out of each pipeline section. After both plugs were located within the subsea receivers the subsea pipeline isolation valves in the PLEM s were closed and the receivers, complete with Tecno Plugs™ inside were recovered to the DSV.

The repair was completed by connecting the two PLEM s 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.

Summary

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 entered the system during the repair and tie-in were removed before the pipeline resumed operation.
Case 2: 8” Condensate Subsea pipeline repair, without interruption of production, in the Gulf of Thailand

Project Description and Challenges

STATS Group were contracted by CUEL Ltd in June 2016 to assist with the repair of an 8” gas condensate liquid export pipeline, located in the Gulf of Thailand. The pipeline situated at a water depth of approximately 60 metres has an operating pressure ranging from 7 to 21 bar. The pipeline had been dragged approximately 8 metres out of position by a vessel anchor and required a permanent repair.

STATS utilised their range of subsea tooling to facilitate the repair which included BISEP’s™, Slab Valves, Hot Tap Fittings, Completion Plugs, End Connectors and Abandonment Plugs. This comprehensive suite of tools was engineered, manufactured, tested and deployed in field allowing the pipeline repair to be successfully completed in December 2016.

Following a detailed engineering and risk assessment by CUEL and the pipeline owner, a repair methodology and solution was developed whereby an 8” bypass was installed on the seabed as a permanent repair to re-route the pipeline medium away from the damaged pipeline section.
STATS and CUEL jointly began developing an isolation and repair solution which would allow the damaged section of pipeline to be isolated and safely removed from the system, with no impact to production, the environment or risk to diver safety.

STATS patented BISEP™ was selected to provide a fully proved, double-block, leak-tight isolation of the pressurised pipeline. The hot tap installed BISEP™ is deployed at the isolation location through a mechanical Hot Tap Fitting. The DNV GL type approved BISEP™ provides a fully proved, fail-safe, double block and bleed (DBB) isolation barrier from the pressurised pipeline, this level of isolation complies with industry guidance on isolation and intervention for diver access to subsea systems, ensuring diver and worksite safety.

The pipeline repair solution incorporated installing a permanent bypass pipeline, this allowed the operations to be completed without the need for shutting-in pipeline production or de-pressurising, therefore ensuring production was not interrupted.

Once the repair methodology was agreed and comprehensive risk assessment complete, STATS commenced key engineering and manufacturing to meet the project schedule.
Prior to deployment offshore, STATS shipped all the equipment to Thailand and performed a representative test scope that involved all the key stakeholders of the project including the vessel dive team. The test scope included actual pipe sections and involved a test scope that reflected the offshore operations with STATS technicians and client engineers.

The subsea operations commenced with the excavation and concrete removal of the pipeline at key sections to allow for the installation of six 8” by 8” #600 STATS diver installed subsea Hot Tap Fittings. At each of the three locations a Hot Tap Fitting was installed to provide a tie-in for the bypass pipeline and a second Hot Tap Fitting as the entry point for the BISEP™ isolation. During the offshore deployment, the subsea intervention stack-up was over boarded from the Diving Support Vessel (DSV) and fitted to the pipeline by saturation divers.

Once the Hot Tap Fittings were installed and bolts tightened, a pressure test of the annulus and body flange was completed to verify the pressure integrity of the clamp to the pipeline at 56 bar.

Key measurements were taken throughout and once the hot tap machine testing was completed, the Hot Tap Machine cutter was advanced to cut the hole in the pressurised pipe. Once hot tapping was complete the cutter was retracted, complete with the pipe coupon, back through the valve and into the Hot Tap Machine adaptor. The valve was shut and pressure integrity tests were
completed to allow the Hot Tap Machine to be unbolted and recovered to the surface. Once the Hot Tap Machine was recovered to the vessel deck, the coupon was removed, inspected and key dimensions verified.

By following a dedicated training programme onshore in Thailand, the vessel dive team were fully trained in the use of the Subsea Hot Tap Machine and successfully carried out the six hot taps on the pipeline.

On completion of the hot tapping work scope the next stage of the operation was to fit the permanent subsea bypass spool. The bypass spool was fabricated in lengths and deployed from the vessel to the seabed for careful positioning by divers. The final tie-in spools were then connected creating a bypass around the damaged pipe section. Once the flange joints were tested, the valves mounted to the STATS Hot Tap Fittings were opened to allow flow from the pipeline into the bypass section as well as the original pipeline.

The next phase of operations was to install the subsea BISEP’s™ at each of the three isolation locations. The BISEP’s™ were over boarded from the DSV and connected to the STATS supplied subsea Slab Valves that were bolted to the Hot Tap Fittings. Once the necessary verification tests were completed, the BISEP™ was activated via a hydraulic umbilical on the vessel deck to a hydraulic control consol. The BISEP™ head was deployed into the pipeline and the head compressed to activate the primary and secondary seals.
Once the BISEP™ head was deployed into the pipeline at each of the three isolation locations the pipeline content was re-routed through the new 8” bypass, ensured production was always maintained. Each BISEP™ then completed a series of seal tests to verify full integrity of the primary and secondary seals to achieve a fully proved, fail-safe, double block and bleed (DBB) isolation barrier of the pressurised pipeline. Upon completion of the BISEP™ seal testing, an Isolation Certificate was issued and renewed every 12 hours.

With the damaged section of pipeline isolated, flushing of the pipeline product was then carried out. A 2” hose was deployed from the vessel and connected by divers to the 2” connection point on the BISEP™ launcher, a second 2” hose was then connected to another BISEP™ launcher and the other end tied into the subsea flushing port on the permanent spool. Using a water pump on the vessel deck, the pipeline medium was flushed from the isolated damaged section back into the pipeline. Once flushing operations was completed, the damaged section was depressurised to subsea ambient pressure of 6 bar, divers could then be deployed to cut the pipeline.

At each of the three identified cut locations, the coating was removed from the pipeline and Diamond Wire Cutters were used to sever the pipeline. The damaged section of pipeline was then freed from the main pipeline and moved aside. In order to provide a barrier to the marine environment for long term wet storage of the damaged pipe section, STATS supplied three 8” #150 Subsea Abandonment Plugs which were installed by the divers into the open pipe ends. The mechanically activated abandonment plugs incorporate a set of taper lock grips and a single seal.

Once the damaged pipeline section was removed the bare end of the original pipeline were left exposed. To provide a pressure competent termination, STATS supplied subsea mechanical Connectors complete with a blind flange that were fitted to the three bare pipe ends. The 8” #300 Connectors were overboarded from the vessel and installed to the pipeline by the divers. Once
fitted over the end of the pipe the bolts were torqued to compress the internal lock and seal mechanism which securely grips the outside of the pipe.

Upon installation, an annulus test of the cavity between the two internal seals of the Connector was completed at 56 bar to confirm the Connector integrity. A further internal test of the Connector was completed via the body cavity by applying pressure through the BISEP™ launcher to pressurise the bore of the remaining pipe section to ensure the connectors were securely connected to the pipeline, before exposing them to the producing pipeline pressure and product.

Following successful installation and testing of the subsea Connectors, the BISEP™ was hydraulically unset. The BISEP™ head was retracted back into the BISEP™ launcher and the slab valve closed. Following a purge of the BISEP™ launcher to remove any residual pipeline medium the valve was tested to ensure pressure integrity. The BISEP™ launcher flange was then unbolted by the divers and the BISEP™ was removed and recovered to the surface.

On recovery of the BISEP™, the Hot Tap Machine was converted on the vessel deck to allow for the installation of STATS 8” #600 Subsea Completion Plug. The Hot Tap Machine was redeployed subsea with the Completion Plug and installed to the slab valve. Flange integrity tests were then completed before the
slab valve was opened. The Hot Tap Machine was then used to deploy the Completion Plug through the valve and into the flange of the Hot Tap Fitting and secured in place by lock segments which are actuated by the diver. The Completion Plug was then subjected to pressure testing and monitoring to ensure pressure integrity from the pipeline.

The Hot Tap Machine, complete with the slab valve, was then removed from the Hot Tap Fitting, leaving only the STATS Completion Plug installed.

A blind flange was installed, onto the hot tap fitting side branch flange, by the diver to provide an additional barrier from the pipeline contents. The same procedure was then repeated at the two other locations concluding a successful subsea isolation and repair operation.

Summary
This complex subsea pipeline repair project presented many operational and technical challenges. Its successful completion further demonstrates STATS ability to perform complex subsea pipeline intervention and isolation while maintaining high levels of safety at all times.