UNCONVENTIONAL APPLICATIONS OF ISOLATION PLUGS THROUGHOUT THE PIPELINE LIFE-CYCLE

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Abstract

Remote controlled, tethered isolation plugs and hot tap installed line-stop isolation tools are regularly used to provide fully proved double block isolations, enabling valve replacement or repairs without having to depressurise the entire pipeline. This type of isolation work scope could be described as conventional. Although, due to the safety criticality of any pipeline isolation, each application is engineered, tested and risk assessed against project specific parameters.

Isolation plugs are also used in unconventional, innovative ways throughout the pipeline life-cycle – from cradle to grave. This paper will describe case studies where isolation plugs have been used in non-standard ways to solve pipeline problems during the various phases of a pipeline's life.

During the construction phase, isolation plugs are used to facilitate pipeline recovery in the event of a wet buckle. To enable recovery of large diameter or deep-water pipelines, the catenary section of pipeline to be recovered off the seabed usually requires to be dewatered. To dewater the catenary section, isolation plugs are deployed subsea, either via a diverless subsea launcher or via a pipeline retrieval tool with a cassette sleeve that contains the isolation plug.

During the operational phase, midline sectional replacement and repair may be required. In the case of an unpiggable defect, isolation plugs have been developed that can be pigged from either end of a pipeline towards each other, allowing the isolated section to be vented, cut out and replaced. To facilitate leak-testing following the repair an additional leak-test module is utilised and high-integrity pressure equalisation is used to safely unset the plugs.

Finally, for pipeline abandonment and decommissioning, isolation plugs are used to permanently plug and abandon pipelines. These isolation plugs can also be used to install a subsea bypass allowing platforms to be removed.

Conventional Applications of Pipeline Isolation Plugs

Breaking containment on operating pipelines is a common requirement, which is typically to facilitate valve replacement, repair of damaged sections or so that modifications to the pipeline system can be implemented.

If the available methods of isolation (existing system valves, spades, etc.) are insufficient and it is not reasonably practicable to depressurise and purge the entire pipeline then an isolation tool will be required.

To ensure risk level is As Low As Reasonably Practicable (ALARP) and to comply with industry pipeline isolation standards and recommended practices for breaking containment activities on high pressure, hazardous service pipelines, the minimum level of isolation the isolation tools need to provide is a proved Double Block and Bleed (DBB) or a proved Double Block and Monitored (DBM) isolation.

Proved Double Block and Bleed /Monitored Isolation

Industry guidance on pressure isolation safety specifies that a proved double block and bleed/monitor isolation only exists when the sealing integrity of two separate isolation barriers is proved to be providing a secure barrier from the pressure threat before the isolation is relied upon.

Proving of the isolation barriers must be done in-situ (at the isolation location) where each isolation barrier is proved separately at the full isolated pressure with the isolated pressure differential being applied in the correct direction.

During the isolation period the void between the barrier seals should be monitored and should be maintained as a “zero energy zone” where the inter-seal volume and pressure is minimised.

This level of isolation ensures that no single isolation barrier failure will endanger the worksite during the breaking containment activities.

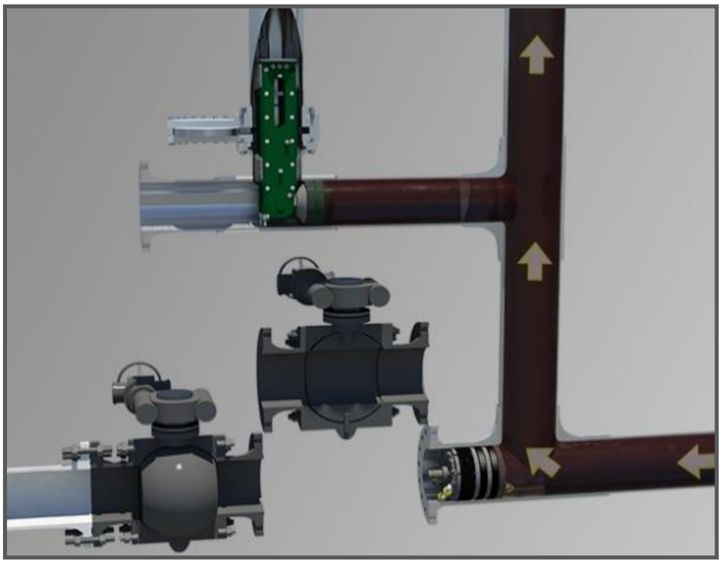
There are several types of isolation tools that provide DBB or DBM level of isolation. The type of isolation plug required is dependent on access options - into the pressurised pipeline.

If full bore access is available (e.g. pig launcher, receiver, removable blind or spool) then a piggable inline isolation tool such as the Type Approved Tecno Plug® can be used.

Remote Control Tecno Plug® In Pigging Configuration

The Tecno Plug is normally deployed with a remote-control system housed inside the control module that is installed into the pipeline and pigged to the isolation location. The plug is then commanded, via it's through-wall Extremely Low Frequency (ELF) communication system, to set itself in the pipeline before the double block seals are proved.

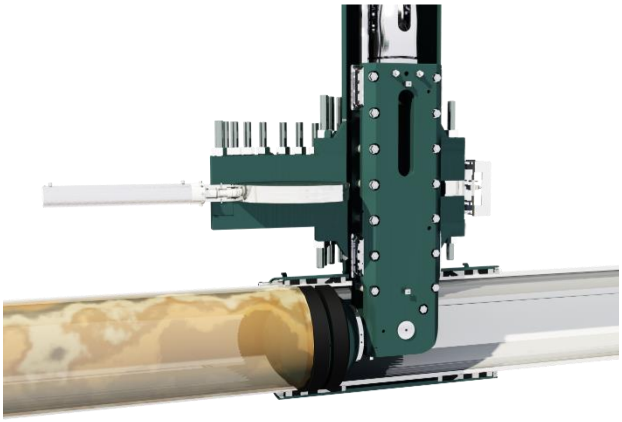
The level of isolation provided by the remote-controlled plug is defined as a proved Double-Block and Monitor (DBM) isolation - with a managed bleed facility. To comply with the designation of Double Block and Bleed (DBB) the isolation needs to have a facility to vent or bleed off any pressure build up in the annulus void between the seals - without affecting the worksite.



In some cases, the Tecno Plug is deployed with a control umbilical connected to the plug - without the remote-control module. This is normally required where there isn't enough space for the control module at the isolation location, such as in the "to scale" scenario illustrated (alongside).

For tethered isolations the control umbilical is managed through the pressure boundary via two stuffing boxes (strippers) installed to a modified blind or launcher/receiver door. If modifying the launcher/receiver door is not feasible in the project delivery timescale a double-block and bleed door plug is installed into the major barrel of the launcher. The level of isolation provided by the tethered plug is designated as a proved DBB isolation

When full bore access into the pipeline is not available, then a different type of isolation tool is needed. Such as the BISEP®, this type of plug is installed into the pipeline via a physical intervention through the pressurised pipe wall; i.e. a hot tap is performed - to create access into the pipeline. The level of isolation provided by the BISEP is designated as a proved DBB isolation.



Construction Phase - Wet Buckle Contingency

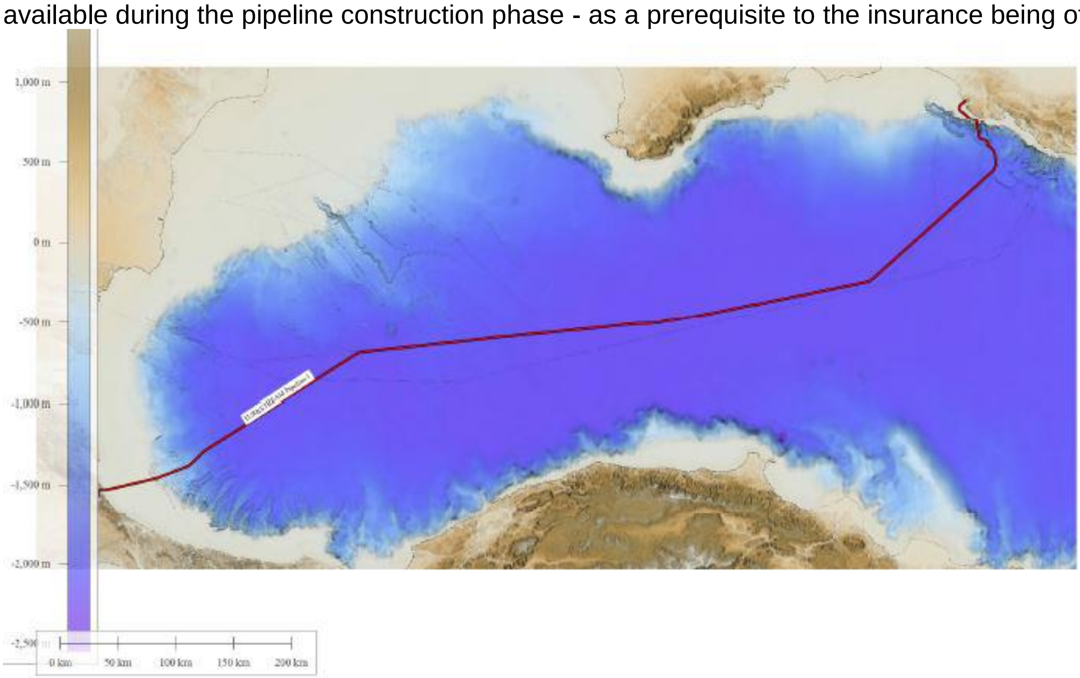
What is a wet buckle and why is a contingency system required?
A wet buckle is an undesired loss of integrity in a pipeline that allows raw seawater to flood into an air-filled pipeline that can occur while a subsea pipeline is being constructed. Wet buckles occur during installation, where the pipeline is most stressed, normally near the touch down point - at the sag bend location or at the overbend on the installation vessel.

If a wet buckle occurs, especially during deep water large diameter pipeline installations the pipeline will have to be released to the seabed as the increased weight of the flooded pipeline will overload the pipeline handing system.

Following a wet buckle and subsequent emergency abandonment of the pipeline, it will usually be necessary to dewater the pipeline and provide a method of recovering the pipeline back onto the pipe lay vessel.

A wet buckle contingency is method of mitigating against the effects of a wet buckle that remediates the situation and allows continuation of the pipeline installation and commissioning operations so the pipeline can be completed and handed over for pipeline operations to commence.

Dependent on the size of the project and potential consequences of a wet buckle, the insurers of pipeline installation projects will often specify that a wet buckle continency system is readily available during the pipeline construction phase - as a prerequisite to the insurance being offered.



32" Pipelines Route 930km up to 2200m depth

A wet buckle contingency system is currently mobilised for a significant pipeline installation project. This project will install up to 4 x 32", 930km pipelines in water depths down to 2200m. The system provides wet buckle contingency for two wet buckle scenarios, as described below.

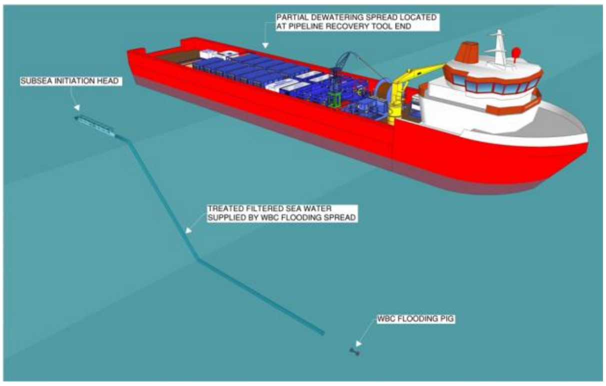
Deepwater Wet Buckle Recovery - scenario
The deep-water wet buckle recovery contingency system facilitates recovery of an abandoned flooded pipeline for continuation of pipeline installation. Additionally, it mitigates against any corrosion threat, by ensuring the raw seawater and debris that enters the pipeline via the wet buckle is removed and displaced with treated seawater.

Should a wet buckle occur in a deep water section, the released pipeline end will be prepared by cutting the line upstream of the wet buckle and removing the damaged section. Then a debris removal, raw seawater displacement pig train will be pigged through the pipeline with treated seawater. The pigs shall be pre-installed in the pipeline's subsea initiation head. The pigging water will be treated by filtering seawater and dosing it with corrosion inhibitor, oxygen scavenger and biocide. Once the first two pigs have been ejected from the prepared cut pipe end, pigging will cease, leaving one pig in the line preventing raw seawater contamination of the treated seawater. A Tecno plug will then be installed onto the cut end of the pipeline - using a diverless flangeless subsea launcher so the pipeline can be partially dewatered.

Subsea Diverless Flangeless Launcher

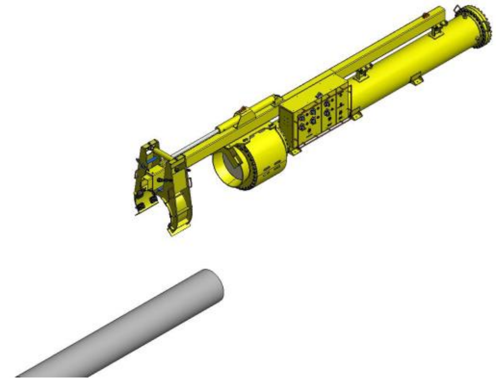
32" Remote Tecno Plug

The deep water wet buckle recovery sequence is shown in the following sequence of operations.

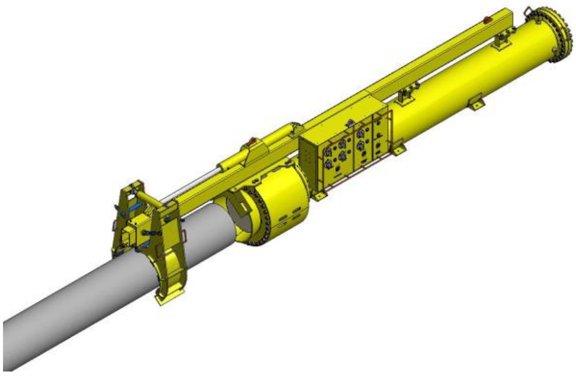


source: OPT 2015, Baker Hughes presentation, Deepwater Pipelines – the latest developments using coiled tubing down-lines for pre-commissioning and contingency dewatering (slide 15)

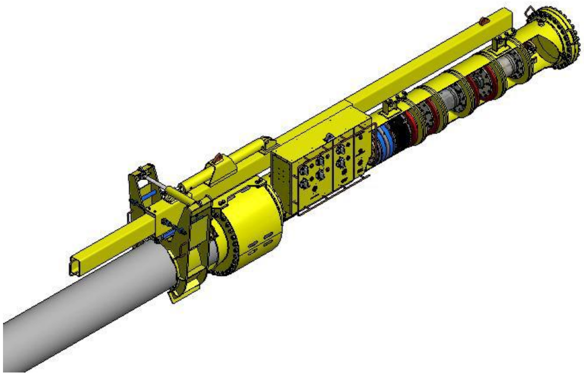
Raw seawater and debris displaced by pig train pigged from initiation head – using treated seawater.



Diverless launcher deployed from vessel down to the cut pipe end – potential depth 2200m



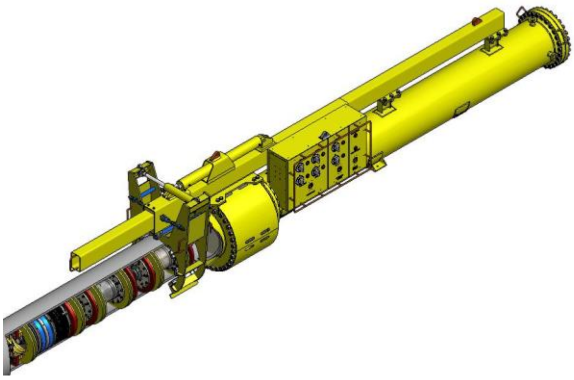
With the grabber clamp open
ROV positions the launcher onto end of pipe



Using hydraulic hot stab and control valves ROV activates grabber clamp to grip the pipeline and pull the launcher's flangeless connector module onto the end of the pipeline.

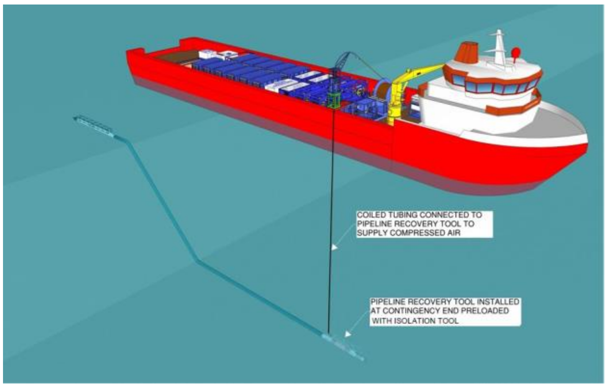
ROV then activates the connector module to set the locks and seals against the pipe.

Securely connecting the launcher to the pipeline.



ROV will the operate a subsea water pump to pig the Tecno Plug approx. 5m into the pipeline.

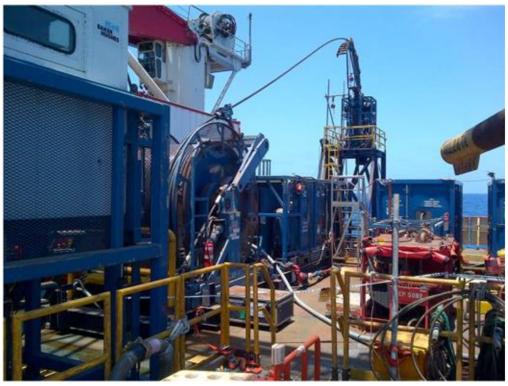
Subsea launcher then deactivated and disconnected from the pipeline.



source: OPT 2015 Baker Hughes presentation, Deepwater Pipelines – the latest developments using coiled tubing down-lines for pre-commissioning and contingency dewatering (slide 16)

Pipeline Retrieval Tool (PRT) installed into the end of the pipeline and activated by ROV

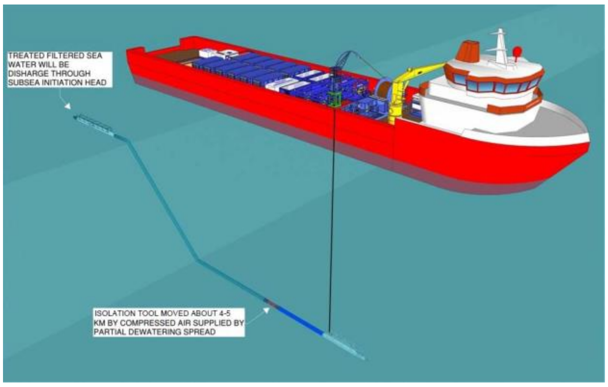
Coiled tubing deployed and connected to PRT via flexible flying lead that interfaces between subsea end of coiled tubing and PRT hot stab connection.



source: OPT 2015 Baker Hughes presentation, Deepwater Pipelines – the latest developments using coiled tubing down-lines for pre-commissioning and contingency dewatering (slide 10)

Coiled tubing spread capable of operating in water depths up to 3000m.

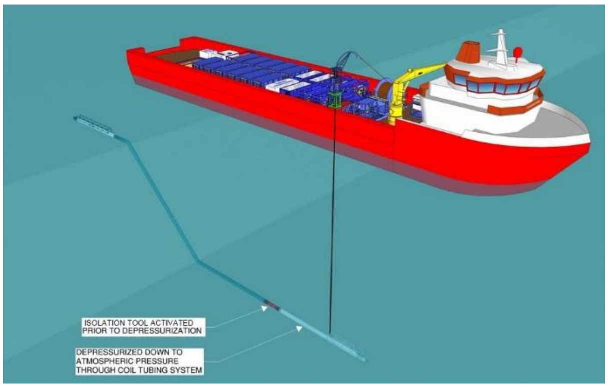
Used to inject compressed air up to 220bar to drive tecno plug 5km into pipeline - against 220bar hydrostatic head of treated seawater in the flooded pipeline.



source: OPT 2015 Baker Hughes presentation, Deepwater Pipelines – the latest developments using coiled tubing down-lines for pre-commissioning and contingency dewatering (slide 17)

Tecno Plug pigged 4-5km into the pipeline by compressed air supplied from partial dewatering spread on the vessel.

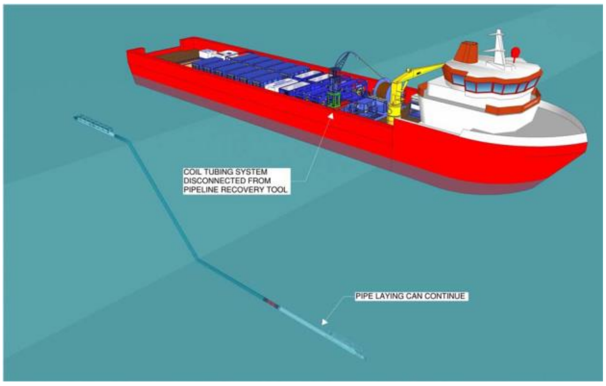
Treated/filtered seawater discharged from subsea initiation head during pigging.



source: OPT 2015 Baker Hughes presentation, Deepwater Pipelines – the latest developments using coiled tubing down-lines for pre-commissioning and contingency dewatering (slide 18)

Tecno Plug activated via through-wall subsea control system interfaced via ROV communication system.

The dewatered section of pipeline is then depressurised to atmospheric pressure through coiled tubing

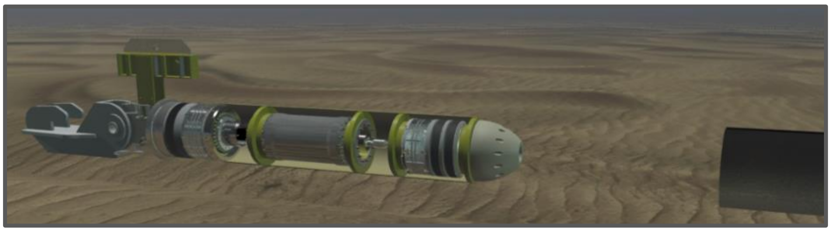


source: OPT 2015 Baker Hughes presentation, Deepwater Pipelines – the latest developments using coiled tubing down-lines for pre-commissioning and contingency dewatering (slide 19)

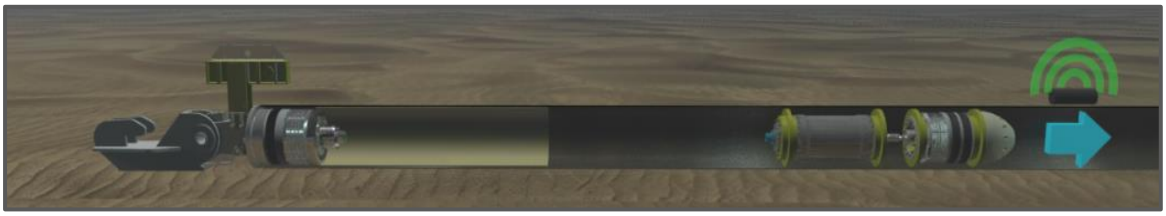
Coiled tubing disconnected from PRT

Pipelay vessel can now recover partially dewatered pipeline catenary section and resume pipeline installation.

In some scenarios, such as in shallow water, the above sequence can be simplified by using the PRT to load and deploy the Tecno Plug – this is done by fitting a cassette sleeve to the PRT - the Tecno Plug is then loaded into the cassette.



PRT with Cassette containing Tecno Plug



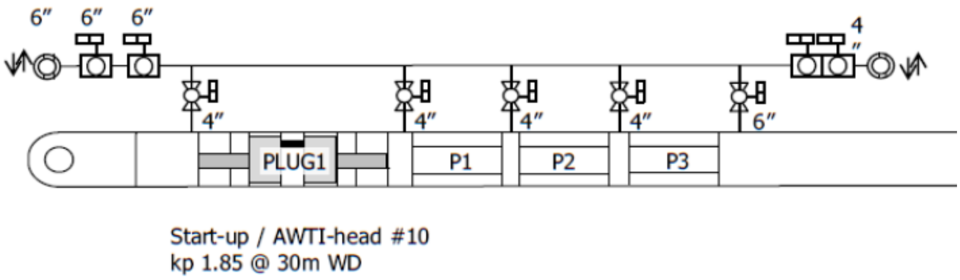
PRT set in pipe end and Tecno Plug pigged into pipeline for dewatering

Shallow Wet Buckle Flood Prevention - Scenario

The shore approach shallow water pipeline sections will be installed by a shallow water pipelay vessel, before the deep-water pipeline is installed by a much larger deep water pipelay vessel. The ends of both pipeline sections will be positioned adjacent to each other in approx. 30m seawater depth. The pipeline ends will be terminated with subsea laydown heads to enable recovery from the seabed. The pipelines will then be joined together by forming an above water welded connection. The joined pipeline will then be laid back on to the seabed.

The consequence of a wet buckle in the deep-water pipeline section, while it is being recovered and handled during the above water tie in, is that the deep-water section of the pipeline would be flooded with raw seawater. As this pipeline is due to be commissioned without performing a hydrotest and then dewatering it - as would conventionally be done - dewatering the flooded deep water section would require mobilisation of an significant dewatering spread.

The strategic use of isolation plugs will prevent seawater flooding into deep water section of the pipeline, if a wet buckle was to be experienced, while doing above water tie-ins.



Pipeline initiation laydown head showing pre-installed pigs and the isolation plug

Before the beginning and end points of the deep-water pipeline are laid on the seabed isolation plugs will be installed into the initiation and termination subsea laydown heads - at both ends of the deep-water pipeline.

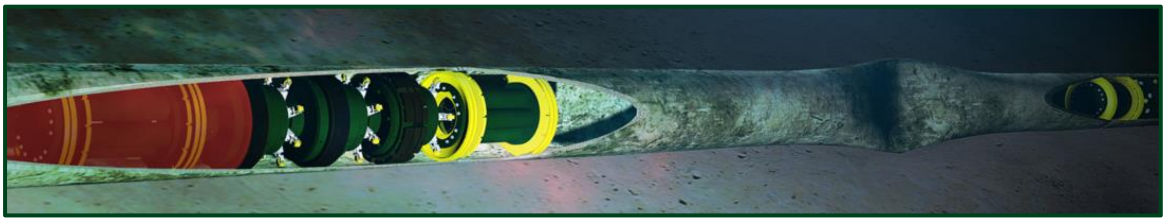
Before either end of the deep-water pipeline section is recovered from the seabed for the above water tie-in operations the tecno plug that was pre-installed in the laydown head will be pigged into the pipeline and will be set to function as flood prevention barriers – should a wet buckle occur. The plugs will be pigged to a distance that ensures the plugs are set in the pipeline beyond the touchdown point and the high stress region of the catenary sag bend.

Using Isolation Tools for a Pipeline repair

Isolation tools have been developed and supplied for Emergency Pipeline Repair Systems (EPRS).

The key developments for EPRS system isolation tools are:

- They can be supplied with the capability of being pigged through bore restrictions up to 10% of the pipeline diameter.
- They can be supplier with the ability to pig two plugs from opposite ends of a pipeline to be set at either side of an un-piggable defect (larger than 10% deformation) – counter opposed pigging capability.
- They can be supplied with the ability to equalise pressure across the isolation and apply test pressure without upsetting or disturbing the isolation.

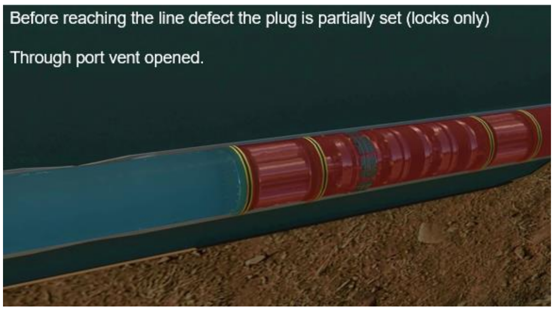


Isolation Plugs positioned at both sides of unpiggable pipeline defect

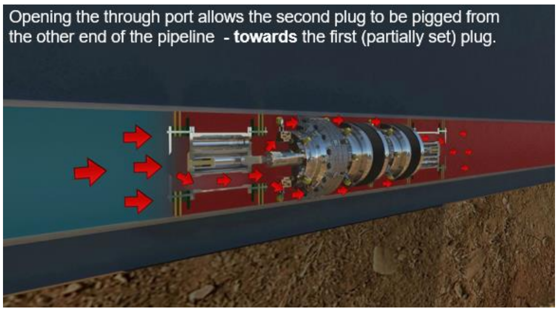
Counter Opposed Pigging

The following series of images explain how two isolation plugs are pigged from either side of an unpiggable pipeline defect so the defective section can be removed without depressurising or flooding the entire pipeline. It also explains how equalisation and testing is done.

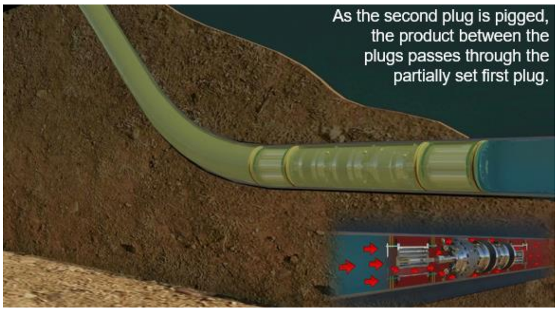
1. First plug deployed



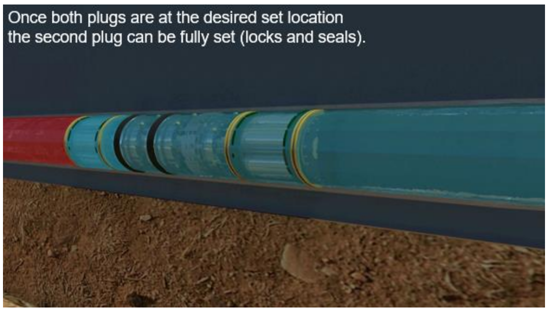
2. First plug at set location – locked in posiiotn and bypass opened



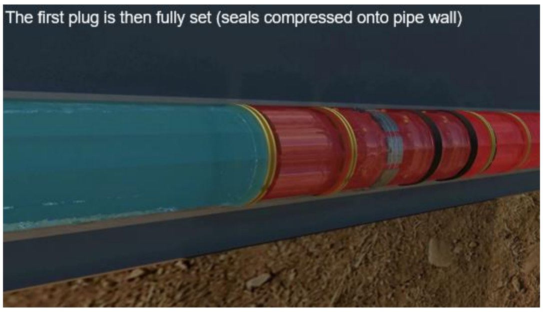
3. By-pass allowing counter opposed pigging



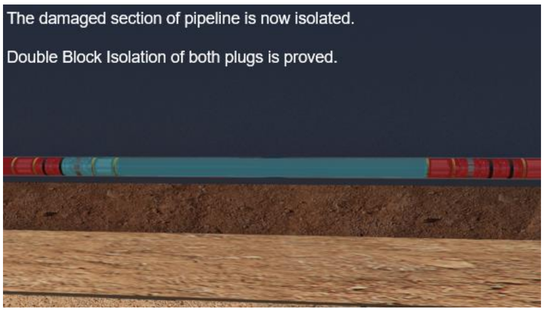
4. Second plug pigged into pipeline



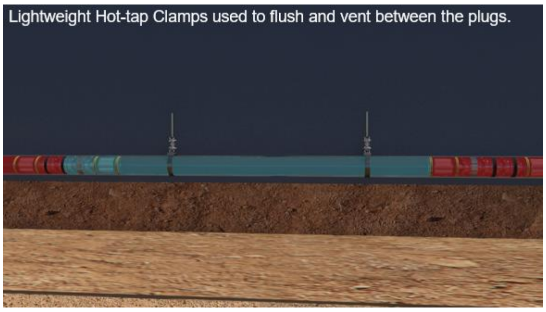
5. Second plug at set location and activated



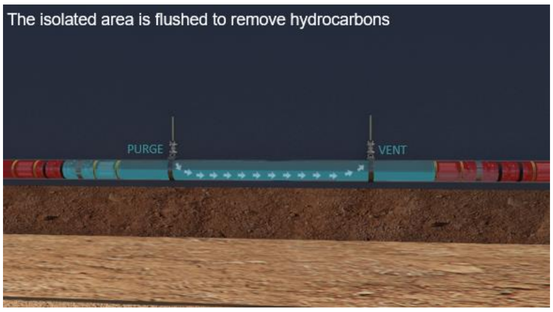
6. First plug fully set



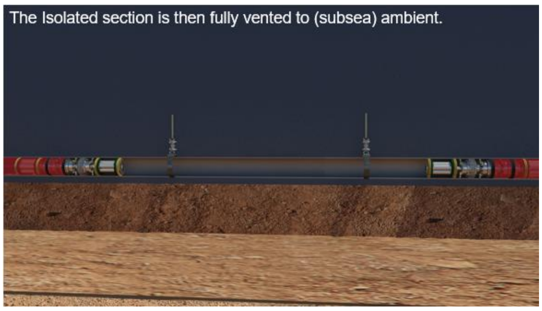
7. Both plugs fully set



8. Small hot taps for venting and flushing



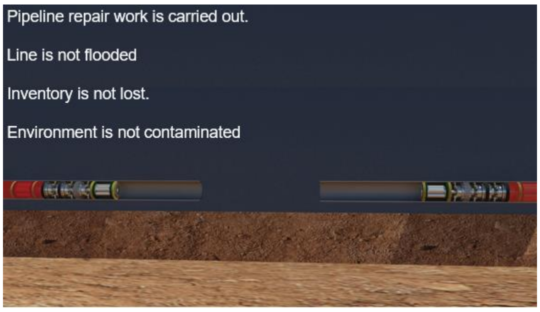
9. Isolated section flushed



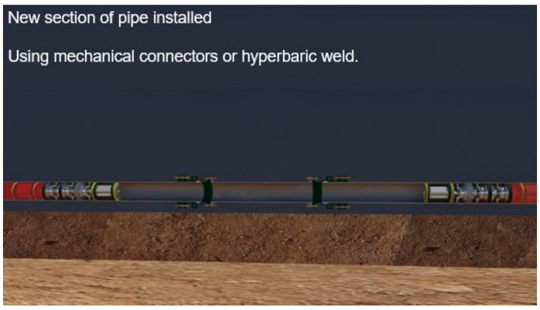
10. Isolated section depressurised

11. Secondary seal – Leak off test (both plugs)

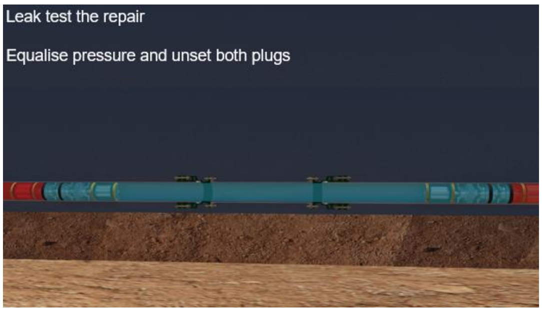
12. Primary seal – Pressure build up test (both plugs)



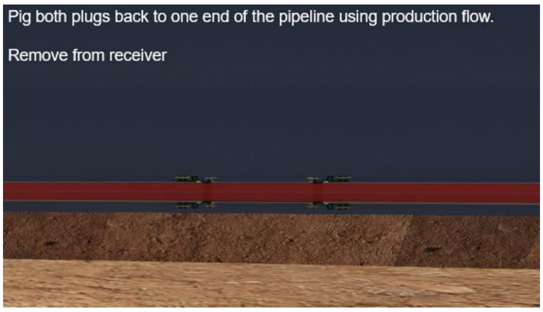
13. Defective section removed – no flooding.



14. New section Installed



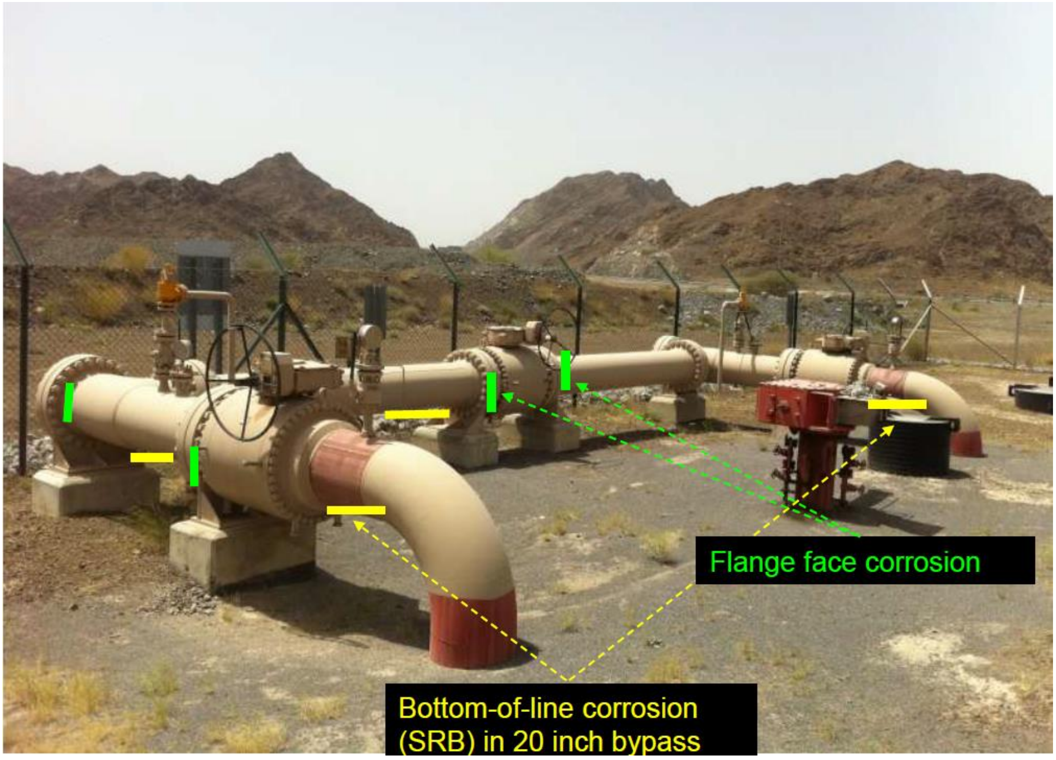
15. Equalisation and leak test facilitated by dual, high integrity equalisation valves and an additional leak test module.
NB: for isolation security purposes each equalisation valve is functioned by a separated control module



16. Plugs unset and pigged out of the pipeline.

Dead Leg Removal

Significant pipeline integrity threats in multiple bypass pipework dead legs (14 locations) had to be removed before loss of containment occurred.



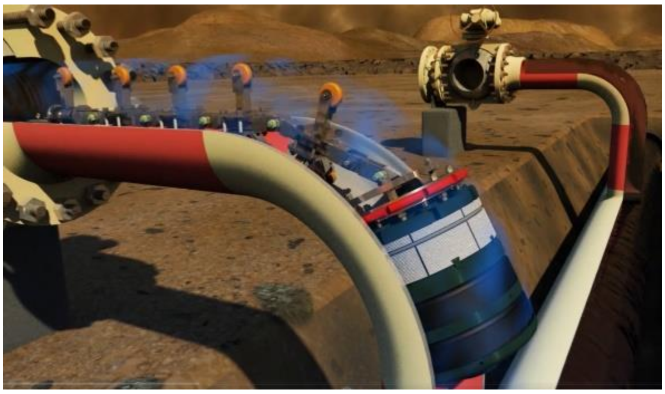
Integrity threats (14 separate dead legs)

STATS Group were approached by the client to engineer a solution whereby an isolation tool could be deployed to isolate the branch below the bend to allow safe removal of 20” bypass pipework on the main oil line - without affecting production in the main line.

As full-bore access to the bypass pipework was available, it was confirmed that a tethered Tecno Plug could be deployed from a temporary launcher attached to the bypass valve. One of the main engineering challenges was to design and manufacture a single module Tecno Plug capable of negotiating the 20” 1.5D long radius bend. As Tecno Plugs incorporate both seals in a single module, the plug has a compact body allowing it to be deployed around the corroded bend and positioned in the short pipe section, ensuring isolation of the bypass pipework without interrupting the flow of the main oil line.

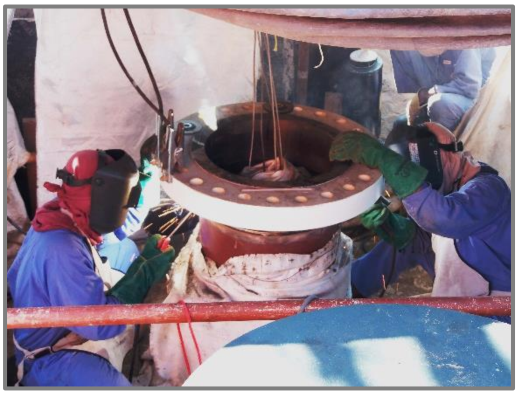
With the design of the short body Tecno Plug finalised, STATS engineered a hydraulic deployment system to deliver the plug to the exact isolation location, as positioning of the tool was critical due to the space restrictions. To deploy the plug hydraulic rams extended articulated stem bars that were packaged in the launcher, (as shown in accompanying image) driving the plug through the valve and around the bend to the set location.

Tecno Plug deployment system in temporary launcher



This novel concept ensured an efficient and controlled deployment on each of the 14 occasions. The isolation plugs were very accurately positioned below the section of pipework that was to be cut and removed.

With the proved double block and bleed (DBB) isolation confirmed, the dead legs were cut off and new flanges were welded on – approximately 200mm above the plug – whilst the main oil line continued flowing. This operation was successfully completed repeatedly to remove 14 separate dead legs



After the flanges were welded on and the welds hydrotested, new valves were installed. The temporary launcher was then fitted to the valve and the flange joints were leak tested. The Tecno plugs were unset and recovered into the temporary launcher. The valve was closed and the launcher and plug were removed. The valves were then all terminated with blind flanges.

Decommissioning/ Abandonment/ Dead leg Removal

The following case study explains an interesting and unconventional application of an isolation tool, where a permanent plugging solution was required for a 42” subsea dead leg that was connected to 96” pump header.

STATS Group were approached by a national oil company in the Middle East which had a requirement to isolate a 42” subsea pipeline dead leg housed within an oil storage tank. The storage tank has a capacity for 500,000 barrels of oil and was first installed in the Persian Gulf in the late 1960’s. The huge structure stores produced oil and has been in continuous use since it was commissioned. The operator had identified some irregular flow characteristics which made them suspect potential loss of integrity in the 42” dead leg. The operator was concerned that over time the problem would worsen, leading to unacceptable levels of water contamination of the oil export.

The 42” dead leg is connected to a 96” pump plenum (header) housed within the oil storage tank which supplies suction to three topside pumps and the main 36” NB feed transfer line. STATS Group were commissioned to engineer a solution to provide a secure isolation that would be deployed subsea via divers into the 42” dead leg through an open flange entry point. The isolation plug needed to negotiate two mitre joints and travel up a five-degree incline before reaching its final isolation position 38 metres away, directly ahead of the plenum tie in weld. A triple seal mechanical isolation plug was chosen and provided the option to remove the plug - if removal was required at a later date.

The project presented several challenges. Firstly, as the pipeline was constructed of thin wall pipe, consideration was given to ensure the weight of the isolation plug would not pose a risk of rupturing the pipeline during the deployment process. Additionally, the isolation plug was required to provide leak-tight isolation for at least 25 years so suitability of seal material for long term deployment was essential. STATS also had to ensure that the subsea deployment, setting and testing of the isolation plug could be conducted by divers within a strict 14-day window, allowing the storage tank to remain in a fully operational state throughout the work scope.

STATS proposed the use of a modified Tecno Plug. These non-intrusive inline isolation tools have an extensive track record of providing pressurised isolation of onshore and subsea pipelines in sizes from 3” to 48” and in a variety of applications. Due to the thin wall pipe of the dead leg a standard Tecno Plug would be too heavy to deploy safely on this occasion, therefore, the plug was re-engineered to reduce the overall weight.

As standard, STATS Tecno Plugs feature two elastomeric seals, the dual seal configuration providing an annulus void which is pressure tested to verify both seals are leak-tight. However, as a contingency measure a third seal was incorporated into the design, this additional seal provided a facility to fill the seal annulus with grout if additional sealing was required.

Once the Tecno Plug was deployed and set at location, each seal was leak tested at 110% of the maximum potential isolation pressure in turn and once the seal integrity was proved the annulus was then vented to ambient to create a zero-energy zone, providing a proved double block and bleed isolation. The large section elastomer seals are highly compatible with poor pipe surfaces, particularly corroded pipework, ensuring a leak-tight seal even in ageing assets. Due to the sealing capabilities of the Tecno Plug the additional contingency measure of grout filling the seal annulus was not required during the work scope.

As an additional fail-safe feature, a mechanical locking mechanism was incorporated into the plug design. Once the Tecno Plug was hydraulically set and following the successful seal integrity tests, the plug was mechanically locked in the set position with the aid of a ratchet mechanism, providing a mechanical lock that replaced the hydraulic activation keep the plug permanently set, once abandoned in the pipeline.

To allow the Tecno Plug to reach the desired isolation location, STATS engineered a hydraulically actuated deployment frame to allow stem bars to be installed in sections, pushing the Tecno Plug to location in a controlled manner. Flexible control lines attached to the rear of the Tecno Plug provide communication to set the plug, test and monitor the seals.

The Tecno Plug had to negotiate the mitre joints without snagging, so short stem bar sections were used which featured a wheeled centralising unit. The short stem bars also reduced the weight of each component, ensuring that one diver could safely and efficiently install and deploy the Tecno Plug to the desired set location without any issues.

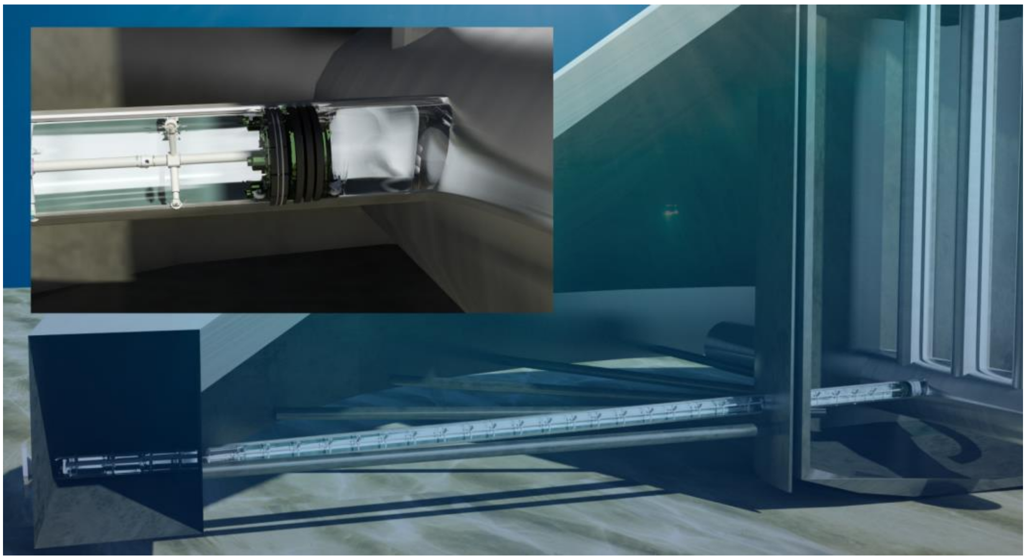
In addition to the 42" Tecno Plug, STATS also provided subsea hot tapping equipment for intervention on the 42" dead leg blind flange. This operation provided initial access to the pipeline to ensure no differential pressure or environmental concerns were present, ensuring safe conditions for the diver to remove the 42" blind flange. With the blind flange removed access was gained to install the inspection pig into the dead leg.

A third-party service company then supplied an intelligent pig which was propelled down the full length of the dead leg to gain real time data which could then be analysed to determine the condition of the pipeline and decide the best location to set the Tecno Plug. To achieve the best isolation results the Tecno Plug would need to be set in the thickest available section of pipe so that the maximum internal hydraulic pressures could be used to apply a gripping and sealing force from the Tecno Plug onto the pipe wall.

The success of the Tecno Plug deployment methodology relied heavily on a successful inspection run. Unfortunately, the timing of the dive operation meant the inspection data would not be available until after the plug was designed, manufactured, tested and mobilised to the dive vessel. Should the inspection pig fail to return any data, or if the results highlighted that the pipe wall was not at the required minimum thickness to allow the Tecno Plug to be hydraulically set without causing damage to the pipeline, a contingency plug would be deployed. Therefore, STATS engineered and delivered a 42" Expandable Rubber Plug which could be attached to the front of the deployment stem bars and deployed via the hydraulic frame to location, in place of the Tecno Plug. This alternative solution provided a contingency method that was suitable for a 12-month isolation duration.

Following the successful pipeline inspection and detailed analysis of the inspection data, the deployment of the Tecno Plug was successfully carried out within the tight deadline set by the client. Once the Tecno Plug was at location and successfully set and tested, the stem bar deployment system was attached to a specially adapted blind flange and bolted to the open flange, successfully completing the isolation and abandonment work scope.

Prior to the offshore deployment, STATS conducted a client witnessed Factory Acceptance Test at their operational base in Musaffah, Abu Dhabi, which also included two-days of diver familiarisation training on a full-scale replica pipe fixture. During this time, the expert divers learned the detailed operation of the Tecno Plug and stem bar to minimise the subsea duration. The stem bar system and procedure was modified to accommodate the diver suggestions which paid off, with the actual deployment time being less than half that originally predicted.



Tecno Plug located and providing permanent proved double block isolation, successfully eliminating the integrity threat.

The successful deployment of the 42” Tecno Plug and isolation of the dead leg was the result of a detailed analysis conducted during the Front-End Engineering process. This process includes generation of a project design premise, pipe stress analysis, FMECA, operational procedures and risk assessment.

Due to the thin wall pipe encountered in the dead leg, a Finite Element analysis of the pipe wall was conducted to ensure that the loads generated by the locks and seals would not over stress the pipe wall and cause damage to the pipeline. As the Tecno Plug is hydraulically set the force is transferred through the plug body and is applied to the pipe wall via the seals and locks. The compression end loads create a radial load at the seal and lock contact area - this analysis was then compared to allowable stress limits in compliance with Recommended Practice for Pipeline Subsea Repair, DNVGL-RP-F113.

Conclusion

This paper aims to highlight the many applications of fully proved double block isolation plugs and how they can be used in non-standard ways to solve pipeline problems, enabling valve replacement or repairs without having to depressurise the entire pipeline.