SPE 88566

Subsea Leaks Cured with Pressure-Activated Sealant

David W. Rusch / Seal-Tite International

This paper was prepared for presentation at the SPE Asia Pacific Oil and Gas Conference and Exhibition held in Perth, Australia, 18–20 October 2004.

Abstract

The paper describes the use of a pressure activated sealant technology to cure leaks in subsea wellbore equipment and control systems. The benefit of this technology is that use of an injectable pressure activated sealant to cure leaks provides a safe, cost-effective alternative to conventional well interventions. The paper outlines the capabilities of the pressure-activated sealants, the procedures used and the results of the sealant operations including case histories.

Introduction

As the industry moves into deeper waters, the capabilities of subsea wellbore equipment and control systems are severely tested. In spite of great advances in engineering, the complexity of the systems and the number of individual components in deepwater systems create numerous potential leak sites. Leaks can result in abnormal pressures in the wellbore equipment and control systems or releases of control fluids, oil, gas or other fluids. These leaks create issues of safety, environmental protection and cost.

The costs of well interventions rise dramatically with depth. Over the life of a deepwater well, the costs and risks of conventional well operations can be prohibitive. In analyzing the long-term costs of subsea operations, the industry must investigate new intervention technologies to repair leaking subsea wellbore equipment and control systems in-situ without the need of mobilizing expensive and risky intervention operations.

Common Subsea Failures

Over the life of a subsea system, it is possible for a leak to occur in most of the components of a subsea well system. Connection leaks are found in umbilical lines, hydraulic lines, control systems, flow hubs, tubing, casing and similar components. Dynamic seal leaks are experienced in SCSSVs, actuators, valves control systems and similar components. Static seal leaks are seen in wellheads, packers, hangers and similar components. Downhole leak sources include tubing, casing, packers, sleeves and other components. During installation, damage to components can create a variety of leak sources.

Sealant repairs have been performed on most of the above-listed components.

Subsea Leaks-The Problems

Analyzing and repairing leaking subsea systems is complicated by the remoteness of the equipment, the uniqueness of many of the subsea installations and the logistics of delivering a solution. Once installed, you can't put you hands on the hardware. The only means of analyzing leaks is through remote diagnostics - often limited to simply taking pressure readings. Further, many of the subsea systems have no service history, so there is no historical data to assist in diagnostics. Even if the problem is identified, the question is how do you deliver a solution? Do you use a rig, divers, ROV or some other method? What are the regulatory issues raised by the leak?

As an engineer evaluates solutions to the problems created by leaks, a first step is an analysis of the problem followed by a review of the options. Traditionally, the solution has been a mechanical workover of the well including replacement of well components. Considerations include availability of a rig, service company availability and coordination, replacement equipment, the cost of all of these factors and the impact of lost production.

Traditional Mechanical Repair Methods

When repairing a subsea leak, traditional mechanical repair methods become much more complicated and expensive. Whereas repairs to platform equipment (such as a loose fitting) can be accomplished with a simple turn of a wrench, mechanical repair of a leak at a depth of 1,000 meters requires considering some very different repair options – including some very risky, complex and expensive options. The direct costs of any subsea repair operation can be in the millions of dollars. Beyond the direct costs of the mechanical repair options, an operator must take into consideration the risk-adjusted costs of the operations. The problems with most traditional mechanical repair options are as follows:

- The operation requires considerable engineering and scheduling preparations.
- The operation requires an expensive, complex multi-service vessel or rig.

- Availability of a rig and the associated service company personnel and equipment must be considered.
- Recovery of the leaking component creates a risk of fluid releases and other environmental impacts.
- With any labor-intensive offshore operation, you risk injury to personnel.
- The disassembly and reassembly process creates a risk of damage to equipment during the operation - resulting in a repair operation much more complex than the original minor problem.
- In killing the well, you risk impairment or loss of the well.
- Even under the best of circumstances, you defer the production during the shut-in period.

Some of the mechanical repair options to cure leaks are as follows:

Rig Operation – The most conventional option of leak repair is to mobilize a rig to perform an intervention to recover and replace the leaking component. Selection of this option carries with it all of the costs and risks listed above.

ROV Operation – If the leaking component can be accessed by ROV, it is possible to use a specialized ROV with special manipulator arms in an attempt to reach into the location of the leaking component and repair or replace the component. The primary problem with this option is the question of whether the ROVs will be able to access the leaking component without damaging other components in the process. Although the cost of the ROV option is lower than the rig option, the risks of failing to repair the component or damaging other equipment significantly increased the risk-adjusted cost of this option.

Reroute Leaking Circuits – If the leaking component is on a control circuit, there may be a means of rerouting the system to take the leaking component out of service. Most control systems have redundant circuits. This option may require modifications to the system using an ROV.

With each of the mechanical repair options posing significant costs and risks, there is justification for investigating less intrusive intervention methods.

The Pressure Activated Sealant Concept

Traditional sealants are activated by temperature, time or simply by clogging a leak with particulates. Pressure activated sealants act through a totally different process.

Analogous to Blood

The sealant reaction is analogous to blood coagulating at a cut. Pressure activated sealants remain fluid in any hydraulic system or well until the sealant is released through a leak site. Only at the point of differential pressure, through the leak site, will the sealant reaction occur to bridge the leak.

Chemistry of the Sealant

The basic pressure-activated sealant formula consists of a super-saturated mixture of short-chain polymers, monomers and polymerizing chemicals in a carrier fluid. The sealant formula is adjusted with additional components based on temperature, pressure, system fluids and leak rate. These adjustments allow regulation of the pressure at which the sealant reachtio occurs. By regulating the injection pressure in the field, the service engineer is able to create the proper pressure differential at the leak site to seal the leak without clogging or plugging vital equipment.

At the leak site, differential pressure causes the sealing reaction to occur. The monomers and polymers in the formula are cross-linked by the polymerizing chemicals. As the reaction proceeds, the polymerized sealant plates out on the edges of the leak site and, simultaneously, links across the leak site to seal the leak. As the seal builds across the leak site, the leak is cured – just like blood coagulating across a cut.

Flexible Seal

The seal is a strong, flexible seal across the entire leak site. The seal is established through a chemical process–not by just clogging the leak with particulates as with many other sealants. The remainder of the sealant will remain fluid and will not clog the hydraulic system or well. The sealants can be left in the system or flushed out.

Contrasted to particulate sealants, a true pressure activated sealant does not contain any significant particulate materials. The problem with most sealants (other than a pressure activated sealant) is that they can plug vital components of the system. By using monomers, polymers and polymerizing chemicals rather than particulates, the particle size in the pressure-activated sealant are less than one (1) micron.

Sealant Limitations – Severe Leaks

Just as blood will not coagulate across a severe rupture of an artery, the pressure-activated sealant is unable to bridge across a large leak. The geometry of the leak is an important consideration as to the potential success of the sealant operation. To be effective, the leak must have a high ratio of adjacent surface area to the leak area and the sealant solution must be implemented while the leak is not too severe.

Critical Success Factors to the Sealant Solution

There are four components that are critical to the success of a pressure-activated sealant operation as follows:

- Accurate diagnostics
- A properly engineered procedure
- Full implementation of the procedure
- Maintenance of the proper post-operational procedures.

Diagnostics determine whether the sealant can be delivered in concentration to the leak site and whether a differential pressure can be established at the leak site to activate the sealing process. If a sealant operation is a viable option, using diagnostics, the operational procedure focuses on sealant delivery method, regulation of pressure and injection rate and verification of the sealing process.

Simple Sealant Delivery Methods

The methods of delivering the sealant are very flexible. The sealant will not harden during delivery regardless of the time, the temperature of the well (below 500°F) or the ambient pressures. Therefore, the delivery time or method is not critical.

The delivery method depends on the nature and location of the leak. If the sealant can be delivered to the leak site in concentration and the leak is within the capabilities of the sealant technolgy, then there is a high probability of curing the leak.

Platform Delivery Options

Some of the platform well delivery methods include:

- Pump sealant from the platform through an existing control line or access line to the leak site.
- Use of wireline dump bailer.
- Use of coiled tubing straddle packer.
- Atomize sealant into the gas lift gas system.
- Bullhead down an annulus

Subsea Delivery Options

For subsea applications, the selective sealing quality of the pressure-activated sealant allows for very flexible delivery methods. Potential delivery methods are as follows:

- Displace through subsea umbilical.
- Pump sealant through a temporary umbilical plugged into a hot stab using an ROV.
- Pump from an ROV "Belly Tank" into a hot stab near the leak site.

Subsea Component Testing

Compatibility and performance tests of the pressure-activated sealants with subsea components have been performed by independent laboratories, service companies and operating companies world-wide.

Laboratory Testing

Compatibility tests of the Seal-Tite sealant formula were conducted by CDA and Associates at the request of Petrobras. The testing proved that the sealants do not damage the materials found in the well. The tests also proved that the sealants have many superior attributes when compared with both glycol and petroleum based hydraulic fluids.

Subsea Control Valve Testing

A simulated leak was created in a subsea control valve by crimping the metal-to-metal seal. The severity of the leak was verified by pumping nitrogen through the damaged valve while the valve was suspended in a vat of water. Once the leak had been verified, the Seal-Tite pressure activated sealant was injected. A seal was quickly established by the sealant polymerization process. Thereafter, the seal was allowed to cure for a brief period and the pressure was raised to the full operational pressure of 5000 psi. To show the strength of the seal, the pressure on the valve was increased to 7000 psi. As a final test, the valve was cycled to verify that the full operation capabilities of the valve were maintained. The engineers were able to cycle the valve with no loss of hydraulic fluid; thus, proving that the leak was cured and the valve was fully operational.

Umbilical Testing

Petrobras of Brazil has conducted rigorous testing of the capabilities of the Seal-Tite sealant process in curing leaks in umbilical lines and the SCSSV mechanisms. Simulated leaks were created in the fittings, connections and hoses of umbilical systems. Seals in SCSSVs were damaged or removed to create severe leaks. Using the Seal-Tite sealant process, Seal-Tite was able to cure all leaks except where the line was actually cut deeply through the control line. The flexible seals established by Seal-Tite were able to hold at the rated equipment pressure of 5000 psi.

Subsea Distribution Units

Delivery of the sealant through Subsea Distribution Units and Logic Caps has also been extensively tested. In one test the targeted leak existed downstream of a hot stab assembly and an autoclave fitting with an internal diameter of only 1/16". The sealant was successfully delivered to the leak site and completed the seal.

Operational Statistics

A total of seventy-four (74) sealant operations have been performed on subea equipment. Of these seventy-four (74) operations, sixty-four (64) of the operations were successful, for a success rate of 86%. Additionally, ten (10) diagnostic operations were performed on leaking subsea equipment, but no sealant operation was performed due to the leak being beyond the capability of the sealant technology. Again, the leak geometry and severity are critical to the potential success of the sealant operation.

Subsea Job Histories

Out of the total of seventy-four (74) sealant operations, I will outline eleven (11) general job histories and two detailed job histories. The detailed job histories describe the repair of a fitting leak on a Shell subsea control pod and a tubing leak on a BP subsea well.

SubseaControl Systems

Subsea SCSSV Leak A subsea well capable of producing 7,000 BOPD and 15MMcf/day shut-in due to a leak in a 15,000 psi SCSSV. A Seal-Tite technician was called out to the platform. Within four hours of performing the Seal-Tite diagnostics, the SCSSV leak was sealed and the hydraulic system was holding 15,000 psi. Revenue in excess of $250,000 was brought back on line.

Subsea SCSSV and Stab Seal Leaks A North Sea operator was experiencing multiple leaks from (1) the SCSSV control line to the void cavity via the tree/tubing hanger stab seals and (2) from the cavity to the annulus via the 2" stab seals. The equipment was at a depth of 155 meters. The control line feeding the well was a "spur" off of a central manifold, so it was not prudent to inject sealant into the entire SCSSV system. In addition, there was no hot stab placement on the junction plate to facilitate placement of the sealant. A manifold assembly was constructed and put in place utilizing divers. Once the manifold was in place the work umbilical was installed. In order to seal both leaks, Seal-Tite injected one sealant down the control line and a different sealant blend into the cavity. Sealant placement operations were performed by manipulating the valves on the manifold. All leaks were successfully sealed.

Umbilicals

Subsea Umbilical Line Leaks Six separate umbilical lines were leaking at leak rates ranging from 1.1 liters per minute to 2.1 liters per minute. All Six leaks were cured and the umbilical lines returned to service at the normal operating pressures.

Subsea SCSSV System Leak A connection in the SCSSV system was experiencing a leak. Seal-Tite's sealant was delivered by ROV to a hot stab location. The sealant was pumped from the ROV and into the SCSSV system. The leak was cured, the SCSSV was cycled opened and closed and system pressure set at 4900 psi.

Subsea Wellheads and Trees

Subsea Completion Leaks Gas was observed bubbling from a subsea location in 1200 ft. of water. An ROV with camera was deployed. The video showed gas bubbles coming from the subsea completion assembly. A Seal-Tite technician was mobilized to the location. Diagnostics indicated a tubing hanger leak. Using a temporary umbilical to deliver Seal-Tite s pressure-activated sealant to the hanger void area, the sealant was injected through the leaking hanger seals. As the sealant polymerized within the leak site, the bubbling subsided and, then, stopped. The leak was sealed and pressure tested to 3000 psi.

Subsea Wellhead Leaks A large gas flow was escaping from a subsea wellhead in Petrobras' Pescada Field. A temporary umbilical was connected to the void area of the suspected source of the gas. Sealant was pumped and the leak cured to 3000 psi.

Subsea Actuator Valve Leaks The seals in the actuators for both the wing and master valve on a Brazil well were leaking large amounts of gas at a depth of 110 meters. For each actuator sealant operation, Seal-Tite sealant was pumped down a temporary umbilical to the grease fitting of the actuator. The leaks were sealed and the actuators cycled verifying that the dynamic seals of the actuators could hold pressure during cycling. Video of the pre-job leak rates and sealant operations are on the Seal-Tite CD-ROM.

Subsea Actuator Valve Leaks A well in Petrobras' Pirauna Field was experiencing multiple gas leaks to the sea from the tree cap and two actuators. The well was at a depth of 275 meters. All leaks were sealed using a temporary work umbilical deployed from a dive support vessel (DSV).

Subsea Equipment

Subsea Crossover Valve Leak Norsk Hydro was experiencing a leak in a crossover valve on a subsea well in 300 meters of water depth. The leak was causing communication from the production flow line back into the annulus vent line system. Using an ROV, a temporary umbilical was deployed to the subsea wellhead and hot-stabbed into the annulus vent valve. The cross over valve was opened, and the Seal-Tite sealant was displaced past the cross over valve and into the production flow line. After closing the cross over valve, the sealant was pushed through the leak site by pressurizing up on the production flow line. The seal was rapidly established, and later tested to 6500 psi.

VX Cavity Leaks A North Sea operator was experiencing multiple leaks from the production tubing to production annulus through the VX cavity stab seals and from the VX cavity to the sea through the Tree Gasket Release. The equipment was located at a depth of 400 meters. The leak was repaired by installing a temporary work umbilical (500 meters) into the hot stab for the VXT port. Sealant was injected into the cavity and the multiple leak sites were sealed simultaneously.

Subsea Flowline Hub Leaks A flow line hub for a Brazil well was experiencing a leak of 2.3 liters per minute. Seal-Tite sealant was delivered by umbilical to the flow line hub. The leak was cured and pressure cycled between 0 psi and 3000 psi.

Fitting Leak – Shell Popeye

At the Subsea Houston 2003 conference, Shell and Seal-Tite presented a paper on the use of the sealant technology to repair a control system leak on Shell's Popeye A-1 subsea completion. That paper is entitled "ROV Deployed Sealant Repair of Subsea Leak – Shell Popeye A-1 Case Study" [1] and is available from Quest International. A summary of the repair operation is as follows:

The Popeye Project

The Popeye Project is a gas field developed by four subsea wells in a single sand with multiple reservoirs. The field is located in ~2,100' water, has a six slot production manifold with two dual flowlines and a capacity of approximately 180 MMCF/day. The flowlines are tied back 24-miles to production facilities at ST 300A platform (Cougar). First production from Popeye began in January 1996 and peaked at 160 MMCFG/D and 9,000 BC/D from two wells. Current field production is 110 MMCFG/D and 3,900 BC/D from three active wells. Initial manifold pressure was 4,500 psi and has subsequently depleted to 3,200 psi. The field is expected to continue to produce past 2011 before becoming uneconomic.

A Simple Leak
A Difficult Location

On Shell's Popeye A-1 subsea completion, a leak developed in an autoclave fitting of a high-pressure hydraulic fluid supply line (10,500 psi). The cause of this leak was no more complex than the loosening of the threaded autoclave fitting. If the connection were on the surface, the repair could have been accomplished with a simple turn of a wrench. Instead, because the fitting was part of a subsea tree operating at a depth of 2,100 ft, a number of different repair options had to be considered – including some very risky, complex and expensive options.

Mechanical Repair Options

Recovery of the Tree – The most conventional option considered by Shell was to kill the well, recover the tree, tighten the fitting and reinstall the tree. There are numerous problems with this option as outlined under the heading, "Traditional Mechanical Repair Methods". The direct costs of such an operation are in excess of one million dollars, not including the risk adjusted costs of potential problems that might arise during the operation.

Tightening of the Fitting by ROV – Shell investigated the possibility of leasing two specialized ROVs with special manipulator arms to be used in an attempt to reach into the location of the leaking fitting and tighten the fitting in place. The primary problem with this option was the question of whether the ROVs would be able to access the fitting without damaging other components in the process. The fitting is located on the backside of the HFL bulkhead (*add photo or diagram of fitting location among other components*). Although the cost of the ROV option was lower than the tree recovery option, the risks of failing to tighten the fitting or damaging other equipment significantly increased the risk-adjusted cost of this option.

Reroute Leaking Circuit – The leaking fitting was on a circuit that is used to actuate the downhole SC-SSSV at ~10,000 psi. This circuit could be rerouted from the HFL to the control pod and from the control pod to the tree cap via ROV hot stabs and high-pressure hoses. This option would have required major modifications to the control pod and field modifications to the tree cap to accomplish. Removing the tree cap without damaging it with a winch downline would be a risky operation.

Each of the mechanical repair options posed significant costs and risks that argued against the use of a mechanical repair.

Sealant Repair Option

As an alternative to the mechanical repair options, Shell contacted explored the use of its pressure-activated sealant to cure the leak.

Popeye A-1 Leak Diagnostics

The location of the leaks was determined by pump cycling at the HPU on the host platform. The severity of the leak was calculated based on fluid loss as ~1 liter per minute. Using this data, Seal-Tite was able to determine that the leak was within the capabilities of its sealant technology.

Sealant Delivery Options

For the Popeye A-1 leak sealant operation, three delivery methods were considered:

1. Pump sealant from the platform through the existing control line to the leak site.
2. Pump sealant through a temporary umbilical plugged into a hot stab using an ROV.
3. Pump sealant from an ROV "Belly Tank" into a hot stab near the leak site.

The first option of pumping through the existing control umbilical was omitted due to the concern of plugging the solenoids in the control pod and/or the check valves on the vent lines.

The second option of pumping through an umbilical was eliminated due to the cost and difficulty of working with a 2,100 foot long umbilical off of a DSV. Additionally, since an ROV was necessary to plug the umbilical into the hot stab, there was no real benefit to selecting the umbilical option over the ROV delivery option.

Sealant Delivery Procedure

The procedure developed between Seal-Tite and Shell for delivery of the sealant by ROV was a fairly simple procedure as follows:

1. Open SC-SSSV by applying 10,000 psi control line pressure from host platform.
2. Secure remaining tree valves in the closed position in preparation of disconnecting the control pod.
3. Deploy control pod running tool on downline and engage control pod.
4. Release control pod from receiver plate. (This will trap several gallons of pressurized fluid in the high-pressure circuit to be utilized for future flushing operations).
5. Remove hydraulic flying lead ("HFL") with ROV from tree end and park.
6. Install flushing head (J-plate with hot stab) on tree bulkhead.
7. Install hot stab from ROV to flushing head and establish injection with sealant until leak ceases.
8. Cycle pressure as per Seal-Tite instructions to cure sealant.
9. Lower control pod on receiver plate.
10. Open valve on flushing head allowing several gallons of stored high-pressure control fluid to displace any residual sealant remaining in circuit.
11. Remove flushing head and install HFL.
12. Commission well.

Leak Sealant Operation

The actual sealant operation was performed with very few deviations from the procedure as planned. An expanded explanation of the sealant injection process is as follows:

1. On the dive boat, the ROV bladder was filled with Shell's standard hydraulic control fluid (Marston-Bentley HW-525).
2. On the first ROV run, the HW-525 was pumped to verify the leak rate. The pressure dropped from an initial pressure of 10,000 psi to 9000 psi in twenty (20) seconds and to 8000 psi in 4.5 minutes.
3. After performing leak rate diagnostics, the ROV was returned to the surface and the ROV bladder filled with a custom-blended sealant formula.
4. The sealant was pumped through the hot tap until an initial seal was established in the leaking fitting at a pressure of 10,400 psi.
5. After the initial seal was established, a slight pressure drop (100 psi) occurred over the next 40 minutes.
6. Once the pressure stabilized, the pressure was cycled three times between 0 psi and 10,400 psi. After the cycling, no further pressure drop was experienced.
7. Using the ROV, a manual internal ball valve was closed to isolate the pressure at 10,400 psi. The pressure was monitored for twelve hours to verify the seal.
8. Any residual sealant was flushed from the circuit using the pressurized fluid left in the high-pressure circuit as described in Step 4 of the Sealant Delivery Procedure.

9. Perform additional steps listed in the Sealant Delivery Procedure to return well to production.

Operational Summary

Using their pressure-activated sealant deployed by an ROV, Seal-Tite was able to seal the leak in the autoclave fitting to a pressure of 10,500 psi. The full operational capability of the control circuit was established within a couple of days from arriving on location and production was restored.

Subsea Tubing Leak – BP

At the Subsea Houston 2004 conference, BP presented a paper on the use of the sealant technology to repair a tubing leak on a BP subsea completion in the Gulf of Mexico. That paper is entitled "BP's Deepwater Intervention Techniques for Maintaining Integrity in Subsea Wells" [2] and is available from Quest International. A summary of the repair operation is as follows:

Pressure Communication

As stated in the BP paper, "In late 2002, BP identified a pressure anomaly in one of its subsea tieback wells. Pressure data acquired from the subsea well indicated slight pressure communication between the production tubing string and the production annulus." Diagnostics indicated that the leak was in the production tubing between the subsea tree and the subsurface safety valve (SCSSV). The distance between the tree and the SCSSV was approximately 760 meters.

Repair Options

Due to the high cost and risks associated with a subsea rig intervention, BP considered different repair options decided to evaluate a sealant solution. Prior to implementing the sealant solution, BP conducted a number of evaluations and tests of the sealant solution to determine the likelihood of success.

Sealant Delivery

Critical to the success of the sealant solution is the need to deliver concentrated sealant to the leak site and create a differential pressure through the leak site. Questions regarding sealant delivery and placement were asked and answered as follows:

1. Delivery of the sealant from the control platform through a 7900 ft umbilical to the wellhead would not affect the umbilical system.
2. Pumping the sealant through the isolation subsea gate valves in the wellhead would not damage or restrict the operation of the subsea gate valves.
3. A review of schematics of the wellbore verified that there were no restrictions in the proposed path of the sealant that would create a seal in the wrong location.

Sealant Placement

Once the sealant is in the annulus, the next issue was how to spot a sufficient volume of concentrated sealant at a leak site? As stated above, leak could have been located anywhere over the 760 meters of production tubing above the SCSSV. The cost of pumping in sufficient sealant to provide concentrated sealant coverage for the entire 760 meters of tubing was prohibitive. To minimize cost, it was necessary to develop a method of delivering a limited volume of concentrated sealant directly to the leak site.

Weighted Sealant

The annular fluid consisted of calcium chloride (10.5 PPG) topped with methanol (6.6 PPG) for pressure maintenance. Diagnoistics indicated that, over time, as the well cycled between production and shut-in, the calcium chloride above the leak site was displaced through the leak site and into the production stream. The displaced calcium chloride was replaced with the methanol being injected for pressure maintenance. Therefore, it was theorized that the methanol / calcium chloride interface was located at or near the leak site. The plan of action to deliver the sealant to the the methanol / calcium chloride interface at the leak site was as follows:

1. Inject a custom blend of sealant – weighted to 9.9 PPG – into the annulus.
2. Allow the weighted sealant to fall through the methanol to the the methanol / calcium chloride interface.
3. Increase pressure on the annulus to push the concentrated sealant from the annulus into and through the leak site.
4. By creating the differential pressure through the leak site, cause the sealant to polymerize within the leak site.

Operational Summary

Sealant was pumped through the methanol supply umbilical and into the annulus. Over the course of three days, sealant was delivered to the the methanol / calcium chloride interface at the leak site. Once the sealant reached the leak site, there was a gradual decrease in the leak rate. As a result of the operation, the repair of the tubing pressure communication was successful.

The integrity of the annulus was reestablish to the satisfaction of the MMS without the need of a costly rig intervention.

Conclusion

The pressure-activated sealant technology is significant in that it radically changes the long-term cost of maintaining a subsea completion. A leak can be quickly and effectively cured in-situ without the costs, risks and delays of a rig intervention. Added benefits include less exposure of personnel and the well to the risks associated with the workover process and a lower impact on the environment than a mechanical workover. The availability of this technology can result in a significant reduction in the long-term risks and costs of deepwater operations.

SPE Metric Conversions

psi x 6.894 757	E+00 = kPa
in x 2.54*	E-02 = m
ft x 3.048*	E-01 = m
mi x 1.609344	E+00 = km

All SI Metric Conversion Factors can be found at:
www.spe.org/spe/jsp/basic/0,,1104_1732,00.html

Acronyms and Abbreviations

in.	Inches
ft.	Feet
mi	Miles
mm	Millimeters
psi	Pounds Per Square Inch
”	Inches

References

1. Rusch, D., *Seal-Tite International,* “ROV Deployed Sealant Repair of Subsea Leak – Shell Popeye A-1 Case Study” presented at the Subsea Houston 2003 Conference, Houston, Sept. 18.
2. Gutierrez, D., *BP*, “BP’s Deepwater Intervention Techniques for Maintaining Integrity in Subsea Wells” presented at the Subsea Rio 2004 Conference, Rio de Janiero, Jan. 1- 3.