Phil Bosworth, Helix Well Ops, UK, looks at the history and current issues with developments in subsea well intervention, from the starting point of subsea intervention lubricators (SIL) for light intervention.

ADVANCING INTERVENTION

Figure 1. *Combo SIL/riser intervention vessel.*

The use of alternative techniques to drilling rig operations for subsea well intervention has grown greatly since their introduction in the late 1980s.

After an initial development period and slow acceptance of one alternative technique (only one SIL and vessel solution was available to the global industry for many years), the use of SIL-based light intervention ramped up quickly during the first decade of the new millennium. This drove the need for more SIL systems for light well intervention, plus the introduction of the heavy intervention vessels utilising high pressure risers back to surface.

Over the last five years some very costly industry developments have failed. However, as this decade continues various efforts to advance the SIL light well intervention technique still continue. These advances however have also been met with some market difficulties affecting capital investment, and hence have been matched by an upsurge in the heavier intervention systems and vessel solutions.

History and development of the subsea intervention lubricator (SIL)

Original SIL and its development

It is difficult to explain where this is all going without going back to the start. In 1987 a SIL was run from a monohull vessel for the first time. Figure 2 shows the SIL as it was then and Figure 3 shows the vessel *Seawell* that was purpose built to deploy these systems, as it still does today.

Figure 2. Original SIL in tower.

Figure 3. Original SIL intervention vessel.

Figure 4. Multi-purpose SIL.

Figure 5. Surface riser set-up.

This system is a 5 ⅛ in. bore with direct hydraulic controls for working on subsea trees (XT) down to water depths of 200 m. The system was redesigned in 2003 for improved efficiency and to improve the control system and emergency disconnect systems. An optional $7\,^{1}/_{16}$ in. subsea portion of the system was also introduced in 2005 to work with the same topsides equipment.

As expected, these pioneering solutions set many world firsts. Amongst many others, these include the first riser-less intervention operations:

- In the UK.
- In Norway.
- On horizontal XT systems.
- To deploy coiled tubing (CT) through tensioned riser.
- To flare off well returns.

The vessel is scheduled to enter dry dock in 2015 to have all systems upgraded, including its tower, which could extend its life for a further 10 years. This should result in the original 1987 well access solution continuing on to 2025, some 40 years on from inception.

First SIL specifically developed to enable riser attachment and CT operations

During the period 2000 - 2010, further vessels and SIL systems were added to the global provision.

In 2009 a unique solution was added that further extended the capabilities of SIL methodology.

This SIL system was 7 ⅜ in. bore, but along with other intervention systems introduced around that time, the advent of electronic multiplexed (MUX) control systems being incorporated was seen. This enabled the function reaction times and feedback necessary to perform these much more complex activities.

This both enabled SIL operations as before (as shown in Figure 4), and also used the same SIL system to attach a tensioned riser and surface lift frame to enable CT operations in-hole as shown in Figure 5. This could be done after light well intervention operations were complete in SIL mode, and essentially turned the unit into medium intervention mode whilst incorporating the additional time and cost savings of the light intervention mode before and after.

The vessel used for the combination light and medium operations is shown in Figure 1, the *Well Enhancer*.

SIL developed for 1500 m water depth operations.

In recent years a number of further systems were added to the global provision. These were primarily focused on extending the water depth capability for SIL operations and to match growing global subsea well stock.

These have varying limits between 1500 m and 2000 m, although there are ongoing developments to push limits further to 3000 m. It is anticipated that future market demand will grow in the 1500 - 3000 m range, but to date the only proven continuous service has been delivered in water depths of less than 1000 m, Figure 6 shows a 1500 m SIL system and Figure 7 shows the support vessel.

The 1500 m SIL was again 7 ⅜ in. bore and again used MUX controls for reaction times and feedback. They essentially used the same technology as the previous shallow water SIL systems and, importantly, this used the same dynamic grease seal on the wireline cable at the point of well entry at the seabed.

Handling the returned hydrocarbons during downhole tool change outs became more difficult in this environment and a number of differing methods between contractors were introduced to overcome this.

Approach for >1500 m water depth operations and expanded capability

Due to the drive to deliver SIL operations up to and beyond 1500 m water depth, and to service the growing subsea well intervention market needs beyond that point, the advent of the heavy intervention vessels were seen, starting in 2002 with the Q4000 vessel shown in Figure 8.

This vessel overcomes the deepwater difficulties with SIL operations by using proven top-tensioned riser techniques, but it was also inherently more capable than the SIL light intervention solutions.

CT operations could now be utilised as standard thus providing much more in-hole capability. In addition, substantially increased capabilities were provided to enable full well decommissioning without the use of an expensive drilling unit. This is of particular advantage in this burgeoning, cost-sensitive market, where SIL operations were limited to simply completing the first few steps and last step of a subsea well's abandonment.

There are now two main types of deepwater riser based intervention vessels, the semisubmersible unit as shown in Figure 8, and the large mono hull versions shown in Figure 9. In terms of easy reference these monohull vessels differ to the SIL monohull vessels by being approximately 25% longer and 40% wider, thus providing a sufficient platform for such operations. Figure 9 shows an existing vessel, a converted drill ship and a new design purpose built vessel for the Brazilian deepwater market.

The riser systems incorporated on these vessels are again 7 ⅜ in. bore similar to the latest SILs, and again used MUX controls for reaction times and feedback. However this time reaching a system rating for operations to 3000 m was achieved much more easily than having all the functions on the seabed, as when using a SIL system. Many of the tricky SIL operations at these depths, such as achieving the dynamic grease seal on the wireline, are returned to surface on the vessel.

Issues and current efforts with SIL development

Review of recent industry projects to deliver 3000 m SIL operations

In the race to transfer these SIL type operations to water depths of up to 3000 m, some of the major service companies introduced projects to try and pre-empt the future market.

These projects were focused on overcoming the challenges to reach this depth using innovative technology, but for a variety of reasons were cancelled or unable to achieve market acceptance. Two examples are discussed below.

Figure 10 shows a SIL system that was developed for 3000 m operations. The left hand view shows its relative size against a drilling blow out preventer stack and the right hand view its size against the existing 1500 m/2000 m SIL systems.

A prototype was developed and built primarily around removing the need for the dynamic wireline grease seal by enclosing it within the subsea equipment. It also incorporated a downhole tooling carousel and a wireline drum that is normally situated on the vessel deck. The issue of hydrocarbon returns still remained, although in a smaller quantity than standard SIL operations, but still required unproven alternative techniques to overcome. Incorporating all this innovative hardware into the stack increased its size, weight, complexity, the time to market and ultimately the cost.

This was a bold attempt to introduce novel technology to overcome the depth limitations of other SIL systems. It was also a very important lesson on the difficulties of matching technology development with commercial and business reality. A particularly hard task in a market such as the subsea well intervention market where there is always the alternative to do nothing, or use a rig.

Figure 11 shows a riser based SIL development. It had the capability to add a compliant riser for CT operations by attaching it to the top of the SIL after wireline operations were complete, similar to the *Well Enhancer* detailed earlier. This would permit CT operations through the riser, but without the need to incorporate a top tension deck compensation system.

This project was engineered over a two year period with a substantial team, and various prototype components were designed and actually built, along with system design work. This project was later abandoned.

This again is another important lesson in matching technology with the commercial and market picture of this niche and complex arena.

Current industry moves towards 2000 - 2500 m SIL operations.

Within the last year, the water depth record for SIL operations has been broken on more than one occasion, with the latest hitting the 2500 m mark. This is great news for the industry, but a few key questions still arise both from a market and technology perspective.

Very few of the wireline runs on these jobs have been achieved with electric line cable using a subsea dynamic grease seal. Operations have mainly been conducted using a new slickline wire, which enables some of the functions of electric line to be achieved but does not need the grease seal. However, the range of wireline operations possible is greatly reduced with this, further limiting on what the SIL service can deliver against a medium or heavy intervention solution.

Grease injection can be achieved at this depth but the reliability, efficiency and durability of this and hence overall suitability remains unknown at this stage.

The question still remains of whether there is sufficient market in the deepwater arena below 1500 m where the reward outweighs the risk of choosing the less capable SIL solution against the heavier and

Figure 6. *1500 m SIL in tower.*

Figure 7. *1500 m SIL intervention vessel.*

having 'more tools in the bag' for what may be found. It will be interesting to see how this progresses in the next couple of years.

Enabling technology partnership towards 3000 m SIL operations.

As has been seen, for a contractor to invest heavily in a new technology, anticipating market demand without a firm commitment for utilisation of that service is running the risk of an expensive failure.

One option is for contractors to combine and form an alliance. Linking a contractor with an established track record in SIL operations with a technology enabler could be the best way to achieve progress and yet remain commercially viable, delivering 3000 m SIL operations whilst ensuring the maximum capability provision of the wireline services

Figure 12 shows a new development in electric line technology, which essentially changes the outer surface of the cable from a braided to a slick surface. This cable has performed many thousands of tool runs in-hole on surface wells, but none subsea at this point.

This cable provides many advantages over standard cable, where all of these specifically lend themselves to a SIL environment:

1. Easier handling at surface – more efficient SIL ops with reduction in vessel time.
2. Well deployment speed greatly increased – efficiency and cost saving as above.
3. Stronger – eliminates the need for separate mandrel lift line subsea.
4. No grease injection required – greatly simplifying control system.
5. Removes the risk of cable damage and fishing – cannot fish like this during SIL ops.
6. Reduced in hole friction – same for surface and SIL environments.

The most substantial of these advantages for SIL ops being points 4 and 5, where you cannot fish a damaged amour cable as you can with normal pressure control at surface and not requiring a dynamic grease seal helps in so many ways.

The above would enable the full range of electric line services and contingency capabilities to be provided without the water depth limits discussed previously.

Tests have been completed on a XT in 350 m water depth so far. However this was just in a pressurised SIL to check running frictions from the head under pressure without the cable being run downhole.

The first commercial job on a live well in the UK using a SIL has been confirmed for late 2014. It will be interesting to see how this huge technology milestone turns out and then the lessons learnt being taken into deep water.

Conclusion

As can be seen, many technical advances have been made in this arena over the years; some have met with commercial success, but many have not.

As cost-effective subsea intervention needs grow faster and faster over the coming years and the global well count increases, it is fairly obvious that many twists and turns remain in trying to match technology advancement with commercial reality.

Figure 8. *Heavy intervention semi-sub.*

Figure 9. *Heavy intervention monohull.*

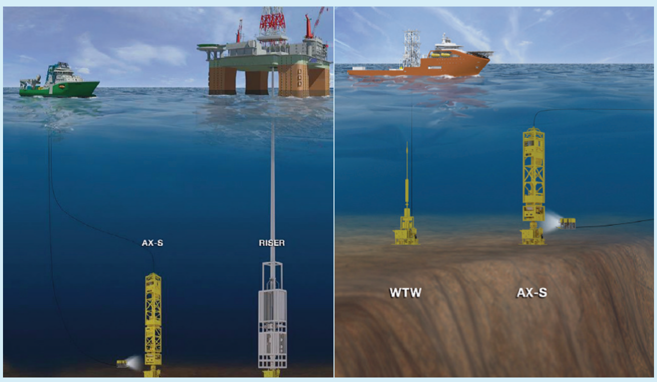

Figure 10. *Deepwater SIL development - AX-S System.*

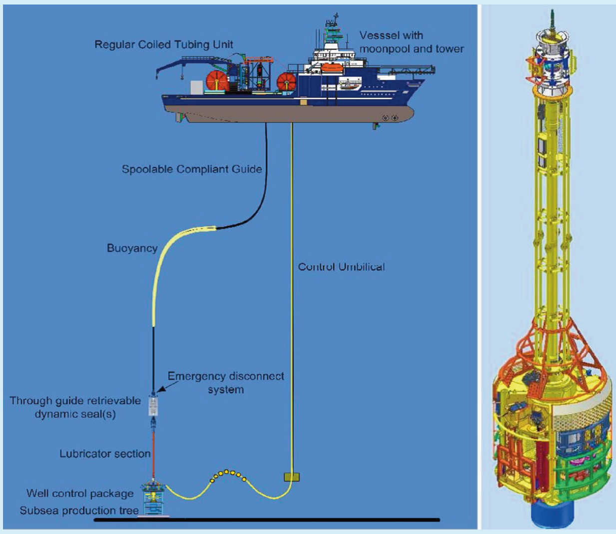

Figure 11. *Deepwater SIL and CT development - Schlumberger Compliant Riser.*

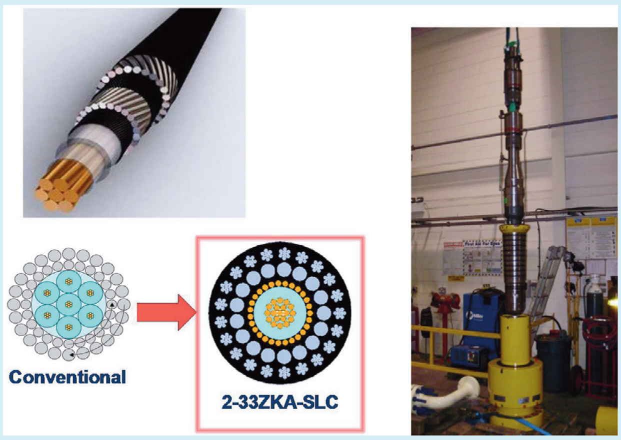

Figure 12. *Streamline cable and SIL head – Schlumberger.*