Making Balanced Connections To Reduce Rig Time

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As the terrestrial search for oil reservoirs winds down, bold exploration efforts beneath the sea are bearing fruit. These oil reserves are now being discovered below the surface at depths greater than 3,048 m (10,000 ft). Reservoirs at these depths, such as the Gulf of Mexico's Lower Tertiary, experience pressures as high as 25,000 psi and temperatures of 149 C (300 F).

Electric submersible pump (ESP) lift systems often are used to reach offshore depths and deliver pumping power capable of overcoming ambient pressure. Pumping the heavy bitumen in these deep and ultradeepwater reservoirs requires a delicate control scheme to protect the pump, including regularly stopping and restarting the system. Some oil production companies cite thousands of such stop-and-start cycles throughout the life of one downhole ESP system. Every time a pump is stopped and restarted, it represents a decompression cycle experienced by all the downhole equipment, a major source of material stress.

Adding to the challenges of these production environments, ESP cables must be spliced to reach the depths needed for deep and ultradeepwater plays. This splicing balances the electrical phases but introduces more components that can fail, potentially compromising the ESP string.

Offshore rig time for repairs and installation typically costs in the range of $200,000/d to $400,000/d. Costs for ultradeepwater rigs can exceed $1 million/d. This is in addition to opportunity costs for lost production time, which mount steadily as waiting periods for available equipment can reach weeks or even months.

Typically, rigging needs take shape under two different scenarios: planned installations and unplanned repairs. Both scenarios are more challenging in the ultradeep conditions of modern offshore wells. Technological innovations can help mitigate these challenges. Rig installations, for example, can be made more efficient by improving ease of assembly of equipment, while unplanned repairs can be avoided by using reliable components designed for modern offshore completions.

ESP electrical cable penetrating systems

Conventional ESP cable feed-through system technologies that ensure safe passage of electricity through well safety barriers were not designed for the sort of deepwater conditions in which production is becoming more prevalent.

Most ESP cable connections rely on elastomeric seals to hold out the pressure. These seals fatigue and plastically deform as the well pressure and temperature are cycled. When tightly constrained to withstand the pressures in deepwater conditions, the seals are more susceptible to failure by extrusion driven by thermal expansion.

Pressure-balanced connection system

A connector technology to address the challenges presented by deepwater conditions was developed by the BIW Connector Systems group within ITT Corp. The k-PaC Technology was designed to eliminate the weaknesses of conventional ESP cable connectors that are often exposed in offshore environments.

Connectors with this technology employ a pressure-balancing function that does not rely on elastomeric mateıwell pressure.
Rather, the pressure-balancing system works with the pressure to create a resilient sealing mechanism capable of functioning under higher pressures and temperatures than conventional technologies that employ elastomeric seals. The resilient seal accommodates stop-and-start cycles, and the improved temperature and pressure ratings extend the application of the connectors.

Figure 1 shows the key features of k-PaC Technology's pressure balancing concept. Movable barriers encapsulate a viscous dielectric medium (VDM) and accommodate well pressure without creating a large pressure differential across the connector.

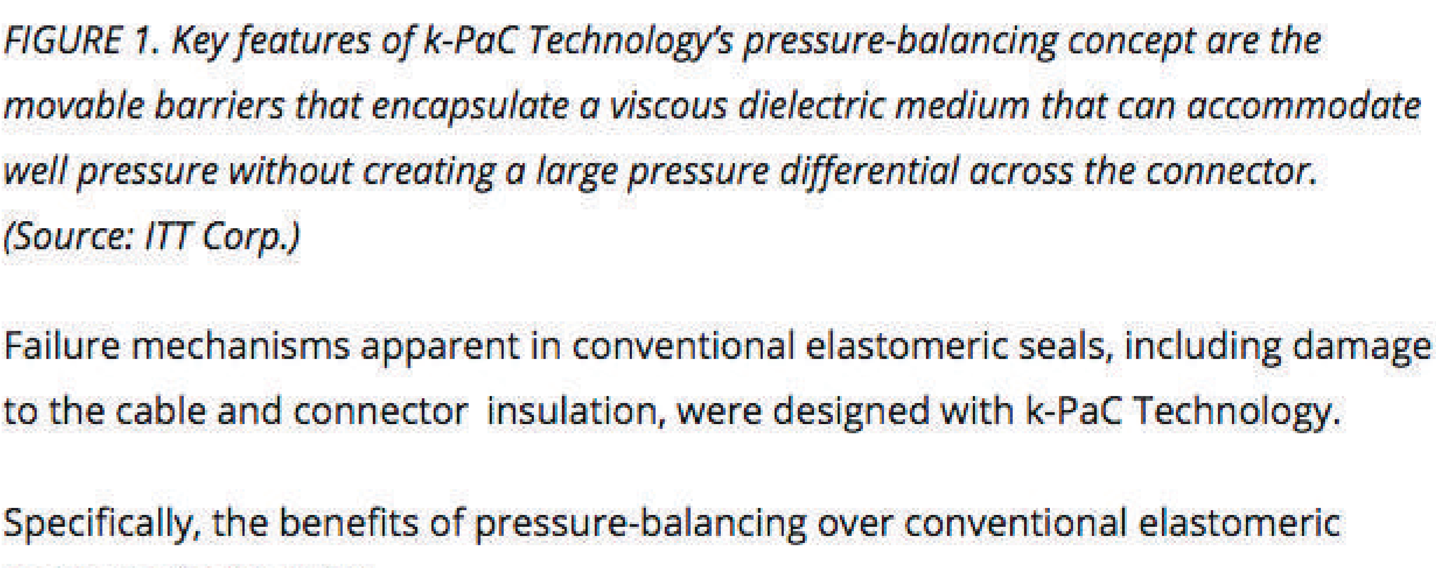

FIGURE 1. Key features of k-PaC Technology's pressure-balancing concept are the movable barriers that encapsulate a viscous dielectric medium that can accommodate well pressure without creating a large pressure differential across the connector. (Source: ITT Corp.)

Failure mechanisms apparent in conventional elastomeric seals, including damage to the cable and connector insulation, were designed with k-PaC Technology.

Specifically, the benefits of pressure-balancing over conventional elastomeric technologies include:
• Elimination of tensile stresses on both the conductor insulation and the connector's insulating components;
• Reduction, by the movable barriers, of the pressure difference across seals, preventing extrusion;
• Self-regulation by the barriers of the buildup of internal forces due to thermal expansion;
• The VDM acting as an extension of the leaded barrier by restricting gas absorption, which reduces decompression damage and preserves the conductor insulation; and
• Encapsulated VDM conforming to various cable geometries, allowing for quick assembly without error and the use of mix-matched cable splices.

Testing, field trials

After the technology concept was established, the physical development of the k-PaC Technology occurred in two main phases: prototyping and product qualification, and field trials.

During prototyping and qualification, the connectors were subjected to more than 1,500 hours of downhole environmental simulation in ITT BIW's HP/HT autoclaves. Significant lab upgrades were required to stress and monitor the new technology. Material qualification and system design required the use of a 1,200-C (2,192-F) oven and a 19,000-psi heated hydrostatic chamber, complete access to a multimillion-dollar material science laboratory, and, most prominently, development of an *in situ* electrical monitoring capability outfitted to an autoclave capable of 7,000 psi and 277 C (530 F).

Figure 2 shows the electrical feed-through on the environmental autoclave as well as an output plot demonstrating the electrical performance at temperature as the connecter underwent pressure cycling. Insights gained from the in situ electrical data were crucial to the successful development of the connectors.

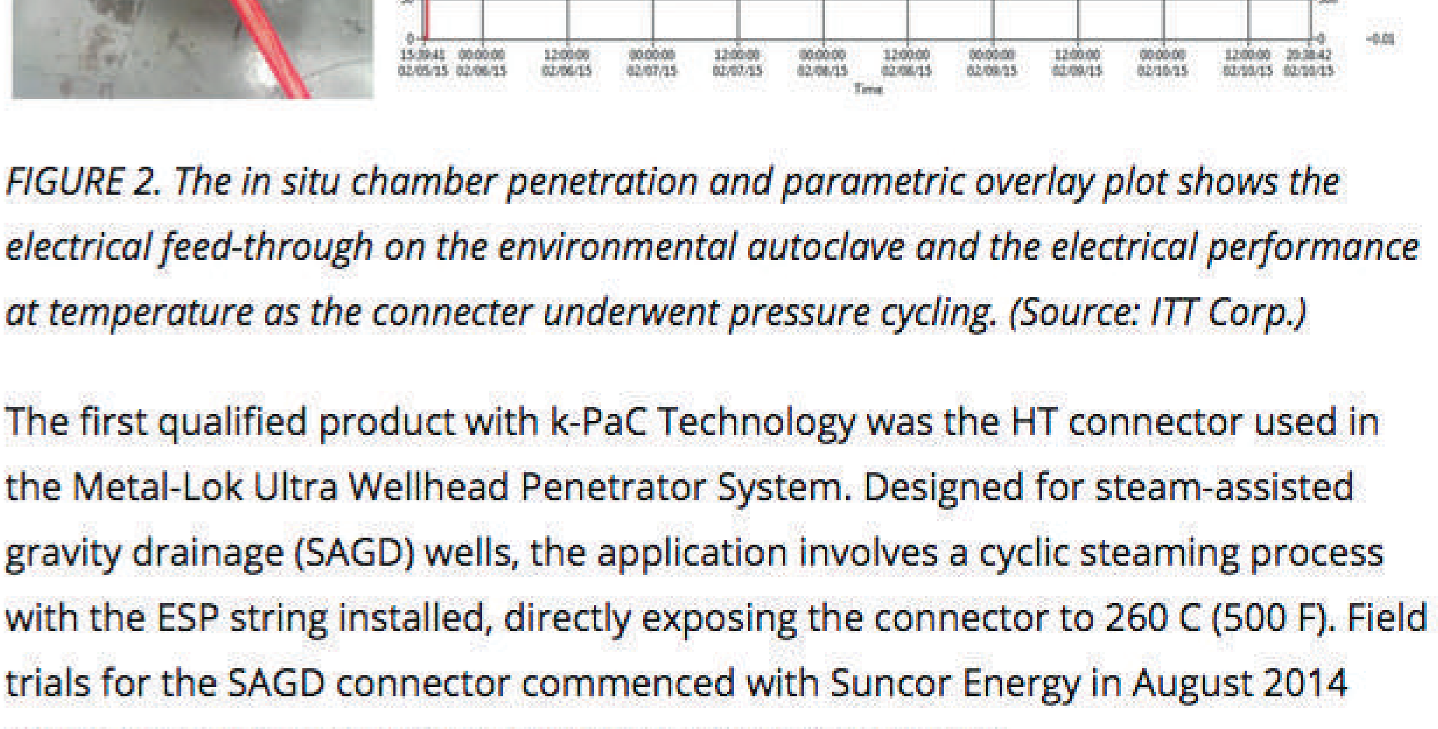

FIGURE 2. The in situ chamber penetration and parametric overlay plot shows the electrical feed-through on the environmental autoclave and the electrical performance at temperature as the connecter underwent pressure cycling. (Source: ITT Corp.)

The first qualified product with k-PaC Technology was the HT connector used in the Metal-Lok Ultra Wellhead Penetrator System. Designed for steam-assisted gravity drainage (SAGD) wells, the application involves a cyclic steaming process with the ESP string installed, directly exposing the connector to 260 C (500 F). Field trials for the SAGD connector commenced with Suncor Energy in August 2014 and have continued without any failure through May 2015.

The second qualified k-PaC Technology product is called the Presta Deep Water Mechanical Splice. This splice was designed specifically to meet the needs of offshore deepwater completions. The mechanical splice has undergone full qualification testing for broad applications up to 177 C (350 F) and greater than 15,000 psi and is currently being readied for trial in several deepwater applications.

Reduced rig time

Both products with k-PaC Technology were designed for simple, reliable and fast assembly. Functional tests were performed to measure the time needed for each product to be assembled. Assembly time for the three-phase SAGD connector was less than 30 minutes. The assembly time for three mechanical splices, including breakouts, was less than 90 minutes, representing a major improvement over legacy technologies.

To demonstrate the cost savings of rig time, compare the mechanical splice assembly time to an industry average of four to eight hours needed to complete a hand splice for deepwater offshore conditions. For a rig cost of $300,000/d ($12,500/hr), the mechanical splice saves an average of $31,333 per splice when compared to the fastest hand splice. The mechanical splice requires minimal training, enabling nonspecialized personnel to complete the splice and allowing multiple technicians to work together. No time is spent coordinating the arrival of a specialized handsplicing technician, and no hours are wasted while the rig fee clock is ticking.