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Increasing ESP Service Life

in the Harshest Well Conditions

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Electric submersible pump (ESP) technology has evolved as demands increase for longer service life in harsher applications. ESP strings are stressed by unconventional applications such as ultra-deep offshore wells with pressures in excess of 20,000 pounds per square inch (psi), steam-assisted gravity drainage (SAGD) wells that reach temperatures above 500 F (260 C) and sour wells with corrosive and invasive chemicals. Some wells also experience thousands of decompressions because of heavy bitumen or gassy oils. Such conditions require delicate operating procedures to preserve the pump and motor.

Even as market trends expose production operations to these extreme stressors, there is a growing expectation that the service life of ESP strings should be increased to five years or more. Conventional cable terminations and pressure blocking penetrator systems based on elastomeric sealing technology are unable to keep up with industry demands. To answer these demands, a new ESP electrical cable penetrator technology was needed to connect ESP cables through safety barriers.

A pressure-balancing connector technology has now been developed for high pressure, high temperature, corrosive gases, operator-power cycling and increased service life applications. This technology avoids the limitations of elastomeric seals by eliminating the components that fatigue in challenging well conditions. The technology has been incorporated into two product categories that have undergone extensive in-house testing. It has also undergone field trials in SAGD applications with unprecedented results. Deep offshore field trials and sour gas testing are scheduled to begin in the third quarter of 2015.

Evolving ESP Applications

ESP applications have broadened in recent years to apply to a variety of enhanced oil recovery (EOR) technologies. This is particularly true in ultra-deep offshore and SAGD environments. Both types of drilling push the historical norms for pressure and temperature extremes.

Heavy bitumen is being discovered in ultra-deep wells where pumping power must overcome fluid columns that produce pressures above 20,000 psi. The thick oil stresses pumps, requiring frequent cool down periods.[2] Some operators anticipate thousands of cool downs over the life of a well. These operational conditions are experienced as decompression cycles by the ESP string. The combination of high pressure and extensive decompression cycles stresses and fatigues conventional seals in penetrator systems.

Some SAGD operations steam the production well with an ESP string installed, preventing the escape of steam and allowing the operator to turn the pump on intermittently to determine whether production fluids are hot enough to flow.[1] While this new practice saves both money and time, it exposes the ESP cable and penetrator systems to temperatures as high as 500 F (260 C), well above the range of conventional sealing technologies. Some wells pose a threat to downhole equipment due to corrosive or invasive gases. Hydrogen sulfide is notorious for corroding conductors after permeating elastomeric barriers. Mobile gases such as carbon dioxide may exacerbate the damage of rapid gas decompression, a particularly acute problem for elastomeric bodies.

Operational conditions have also increased in complexity. For example, improved downhole instrumentation has enabled remote operation of ESPs, often leading to more frequent pressure changes.[3] These pressure cycles fatigue downhole equipment.

New Challenges Need New Technology

To meet the new challenges and expectations in the ESP market, one company set out to develop a new connector

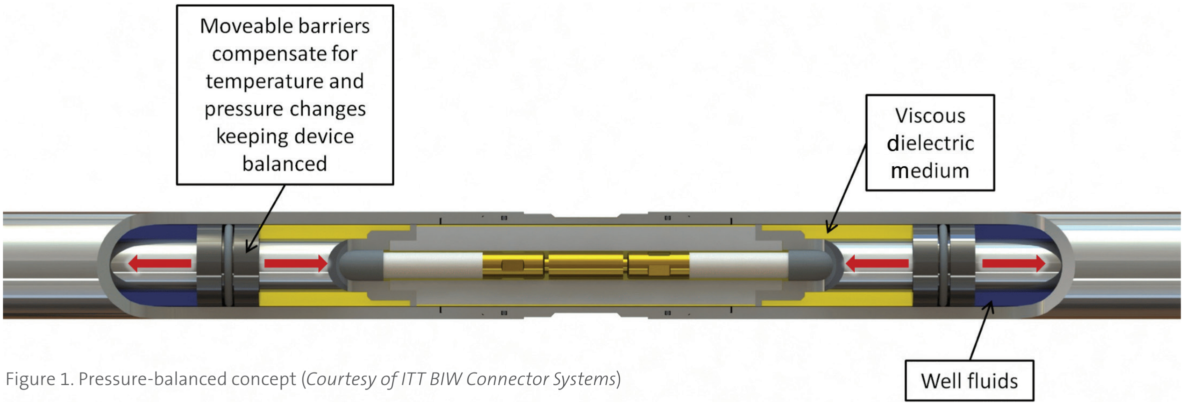

Figure 1. Pressure-balanced concept (*Courtesy of ITT BIW Connector Systems*)

technology. The design goals for this technology included increased reliability for all wells, qualification for the harshest well conditions, tolerant of frequent pump restarts and reduced field assembly time.

The resulting technology incorporates a pressure-balanced concept explained in Figure 1. This diagram shows a simple cable termination, common in ESP connectors, where two ends of an ESP power cable are joined in a splice where the cavity enclosing the conductor crimp bucket is protected from the conductive well fluids and the well environmentals.

This technology eliminates typical elastomeric failure modes by design. A viscous dielectric medium (VDM) is contained between movable barriers built into the connector, enabling pressure balancing to the well conditions. Key benefits include:

- Movable shuttles that accommodate the thermal expansion of the VDM without inducing tensile stresses along the connector's insulating components, enabling survival in HPHT environments
- A minimized pressure differential across the seals, preventing extrusion and allowing for extreme pressure applications
- Gas absorption restricted by the VDM, which acts as an extension of the leaded barrier. This reduces the effect of rapid gas decompression
- The encapsulated VDM that conforms to various cable geometries, allowing for faster assembly and mix-matched cable splices.

These benefits have been demonstrated through extensive testing. An in-situ monitoring capability was developed to observe electrical performance of products using the new technology during pressure cycling at rated temperatures.

Application-specific test regimes were incorporated to simulate deepwater offshore and SAGD wells. The tests were supplemented by external test houses and field trials to ensure the validity of the results.

Improved Reliability Across Applications

Two product lines incorporating the new technology have been developed for SAGD and deepwater offshore applications. A byproduct of this design is increased reliability for more typical or benign well conditions.

Reliability improvements in benign wells are the result of eliminating, by design, common failure modes of elastomeric sealing technologies. Thermal stresses and pressure differentials are better managed, resulting in lower fatigue effects and extended service life. Similarly, gas absorption is reduced by the VDM, enabling the connectors and pressure-blocking penetrators to survive more pump restarts and decompression cycles than previously possible.

One system using the new technology, a newly designed wellhead penetrator, was specifically developed for SAGD applications. Ongoing field trials are being conducted in Canada's Firebag field, where steam injection causes temperatures to approach 500 F (260 C). These wells use bullheading and the ESP string was exposed to direct steam prior to production. Two aspects of the new technology are crucial for SAGD fields: improved steam resistance and increased temperature rating.

A splice that uses the technology was designed for deepwater offshore applications, and is rated to 350 F (177 C) and 15,000 psi. The splice is more resistant to the effects of decompression cycles from pump restarts, enabling it to meet the needs of deepwater reservoirs containing bitumen or other fluids that are notoriously difficult to pump.

Assembly time was also a driver in the development of the splice because offshore rig time costs can reach as much as $1 million per day.[5] Three mechanical splices with breakouts can be assembled in the field in less than 90 minutes and do not require the support of a highly trained lead splice technician.[4] ■

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