Operators in the liquids-rich portion of the Eagle Ford shale continue to search for the best means to optimize the long-term production after the natural flow stage ends. The challenge is to manage changes in production rate, define and manage reservoir deliverability from the stimulated reservoir volume, and increase production efficiencies. Electrical submersible pump (ESP) systems are used in the transitional artificial lift phase to provide an integrated program that maximizes production over the complete life of the well.

The Eagle Ford shale play, extending 640 km (400 miles) across South Texas, includes unique reservoir characteristics and fluid behaviors that are especially challenging in downhole conditions that include high temperatures, high gas volume, slugging, unsteady flow, paraffin, and some scale deposits that complicate artificial lift solutions. Limited clearance from casing size and setting depths greater than 3,050 m (10,000 ft) pose additional obstacles to using ESPs.

Magnum Hunter Resources Corp. (MHR) and Schlumberger have teamed up to implement an unconventional ESP solution as part of a systematic approach to transitional artificial lift. The solution includes technologies and continual analysis to better understand the unique behavior of the reservoir, inflow, and flow characteristics to maximize long-term hydrocarbon recovery.

**MHR position**

MHR is exploiting 26,000 net Eagle Ford acres 100% prospective of oil, including 19,417 net acres in Gonzan-
les and Lavaca counties on the play’s northeastern flank. The operator’s Eagle Ford development strategy focuses on production and reservoir management. The production phase encompasses three main stages: initial production or natural flow, transitional artificial lift with the use of ESPs, and traditional beam pump or gas lift for the remainder of the well life.

The operator’s vertical depths average 3,050 m with laterals of 1,830 m (6,000 ft). Using the latest advances in completion techniques, the company has increased fracture stages from 15 to 25 stages through 5½-in. #23 casing, yielding an average 85% crude oil with high Btu gas. The Eagle Ford wells produce 40°API to 45°API gravity oil with less than 25% water cut in most wells. Bottomhole temperatures at pump setting depth range from 126.6°C to 135°C (260°F to 275°F).

The company’s Gonzo North 1H well, located in Gonzales County, began production March 14, 2011, but production declined rapidly, reflecting typical wells in the oil shale play. Oil output dropped from 913 b/d to 150 b/d in four months. The water rate declined from 836 b/d to 40 b/d in the same period.

Following conventional practices for the design and operation of a gassy well, an ESP system targeting an aggressive drawdown was placed in the vertical section close to the kickoff point in July 2011. Initial production was encouraging, but the uniqueness of the light fluid and unstable flow behavior in the unconventional liquids-rich reservoir quickly became evident. Production declined over 20 days from the first installation, dropping from 965 b/d to 339 b/d. The overheated ESP motor soon failed. Two additional ESP systems with similar configurations were installed and also failed in a short period of time.

Upon dismantlement and inspection, the systems showed unusual wear and severe overheating in the motors, power cable, and motor-lead extensions, even in an ESP that operated for less than a week. The failures prompted an investigation involving a collaboration of Schlumberger artificial lift, reservoir, and well services experts to find a solution.

**Transitional artificial lift solution**

After careful study, a systemic approach was devised that included a customized ESP design, fit-for-purpose hardware configuration of downhole and surface equipment, real-time surveillance and control, and performance analysis and optimization from experts dedicated to the project.
The unconventional ESP system, configured to provide maximum flexibility on flow rates and multiphase flow composition, included abrasion-resistant pumps with mixed flow stages, Advanced Gas Handler devices, and Poseidon gas-handling devices, all configured using a compression-type construction for extended operating ranges, variable rating motors, and a Sinewave variable speed drive to minimize potential harmonics and stress on the ESP electric system.

The LiftWatcher real-time surveillance and control service also was installed so personnel could monitor, configure, and set alarms on both the ESP operating parameters and the surface parameters that were connected to the motor controller as analog inputs. This included the tubing head pressure, casing pressure, and total gas rate from a flow computer. The LiftWatcher service enabled personnel to remotely adjust the ESP operating parameters, including the target pump intake pressure (PIP), to meet the controlled drawdown strategy. Additionally, special ESP field service and operating procedures were developed and implemented.

MHR and Schlumberger allocated resources to closely monitor and adjust the operations of the ESP system as the transitional artificial lift method to support the development strategy.

**Implementation**

The first unconventional ESP system was installed Sept. 23, 2011, in the Gonzo North 1H well. The ESP system motor controller was programmed to operate in a closed-loop control to maintain the target bottomhole flowing pressure or PIP. The motor controller turns the ESP off when the pressure drops below a low PIP trip point, and the ESP also trips when additional key parameters reach undesirable levels, including high motor temperature.

Traditional industry best practices on ESP operation call for minimizing the number of system starts. Ideally, ESP systems should run continuously, but the ESP system in Gonzo North 1H was shutting down several times a day to protect the system or when drawdown reached the lowest PIP. The excessive cycling of the ESP observed after the first two months of operation raised concerns over the impact on expected run life, system efficiency, and production.

Adjustment to the settings on the motor controller kept the ESP running for 21 consecutive days. No appreciable changes were noted on production, and motor temperature increased periodically. Cyclic operation resumed in late November 2011. Due to the additional adjustments on the duration of the ESP on/off cycles, a cyclic ESP operation with intermittent natural flow was established as PIP flattened shortly after buildup (+50 psi to +200 psi). The Gonzo North 1H well would flow during the ESP off cycle at approximately 25% of the ESP on rate, creating a more efficient lifting system that reduced lifting costs with no significant effect on the overall production decline trend. Via the LiftWatcher service, the operations teams received automated alerts by SMS or email when an operating parameter fell outside the defined operation threshold. The ESP system then could be remotely adjusted to optimize system performance.

The ESP was pulled from the well Sept. 22, 2012, after completing a one-year journey in which the system mostly operated cyclically. The ESP accumulated an unprecedented 1,478 starts, more than 10 times the starts of a typical ESP in its full life cycle. At the end of the transitional artificial lift stage, the total fluid production was only 75 b/d. The long-term expectation is that ultimate recovery will be higher because of the production and reservoir management approach of the operating company.

**Expanded rollout**

MHR is installing the unconventional Schlumberger ESP system as the transitional artificial lift method in all new wells following the natural flow stage. Currently, the operator has more than a dozen wells operating with the unconventional ESP system. The company also has installed the LiftWatcher surveillance service and Schlumberger downhole monitoring gauges in four additional wells, including two with gas lift and two with pumping units, to closely monitor flow pressure and optimize operations on the non-ESP wells.

Modifying the ESP system configuration and operation practices and controlling rapid bottomhole flowing pressure drawdown was instrumental to successfully execute the transitional artificial lift stage. As part of the continuous improvement process, Schlumberger and MHR have now substantially reduced the number of ESP system shutdowns associated with generator maintenance and/or operational causes.

Appropriate ESP hardware is only one piece of the puzzle to optimize transitional and third-stage artificial lift solutions. A systemic approach is required that includes appropriate and flexible ESP technology, operating procedures, real-time surveillance and control, and qualified people.