Optimization of Completions in Unconventional Reservoirs

Over the last decade, an industrywide shift to unconventional plays has been made possible by advances in technology, allowing the recovery of previously uneconomic reserves. The primary objective of completions in these unconventional reservoirs is to increase the effective surface area of the well to maximize reservoir contact. The full-length paper provides an introduction to unconventional reservoirs, describes the main methods of horizontal multistage completions, and discusses how the choice of method can affect good fracturing practices as well as long-term production.

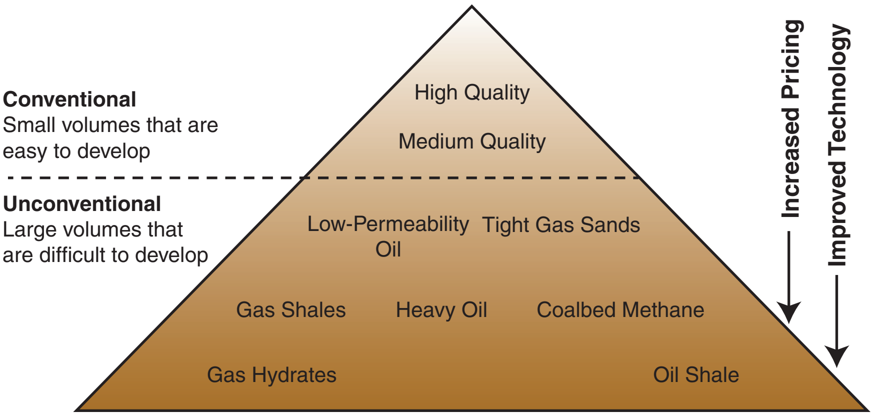

Fig. 1—Resource triangle.

Introduction

Unconventional Reservoirs. Over the last decade, an industrywide shift to unconventional plays has occurred as a result of the depletion of mature conventional reservoirs, increased demand, and advances in technology. Unconventional reservoirs have been defined as formations that cannot be produced at economic flow rates or that do not produce economic volumes of oil and gas without stimulation treatments or special recovery processes and technologies **(Fig. 1).** Types of unconventional reservoirs include those with poor fluid-flow characteristics because of small interpore connections and/or with stacked pay units.

*This article, written by Assistant Technology Editor Karen Bybee, contains highlights of paper SPE 143066, "Optimization of Completions in Unconventional Reservoirs for Ultimate Recovery—Case Studies," by **Daniel J. Snyder,** SPE, and **Rocky Seale,** SPE, Packers Plus Energy Services, originally prepared for the 2011 SPE EUROPEC/EAGE Annual Conference and Exhibition, Vienna, Austria, 23–26 May. The paper has not been peer reviewed.*

The primary objective of completions in these unconventional reservoirs is to increase the effective surface area of the well to maximize reservoir contact. Horizontal drilling and multistage fracturing are two technologies that accomplish this. The two main methods of horizontal multistage completions currently used in unconventional reservoirs are cemented liner "plug and perf" and openhole multistage-fracturing systems. Although both methods have the same goal of increasing access to the reservoir by the induction of fractures along the entire length of the horizontal wellbore, they differ significantly from an operational perspective.

Cemented-Liner Multistage-Fracturing Method. This type of completion involves cementing production casing in the horizontal wellbore and plug-and-perf stimulation. Mechanical isolation in the liner is accomplished by setting bridge plugs using pump-down wireline or coiled tubing (CT), followed by perforating and then fracturing the well to provide access to the reservoir. The cement provides the mechanical diversion in the annulus, while the bridge plug provides the mechanical diversion inside the liner. This process then is repeated for the number of stimulations desired for the horizontal wellbore. After all stages have been completed, CT is used to drill out the composite plugs, thus re-establishing access to the toe of the horizontal wellbore. Although an effective method of creating diversion along the horizontal section for discrete-stage stimulation, the inherent cost of multiple interventions with CT, perforating guns, and deployment of fracturing equipment needed for each stage is extremely high, not to mention being very inefficient and time consuming. Production using this method also can be limiting because cementing the wellbore closes many of the natural fractures and fissures that would otherwise contribute to overall production.

Openhole Multistage-System (OHMS) Fracturing Method. OHMSs were pioneered in 2001 with the goal of making multistage fracturing more efficient, in terms of both time and cost, as well as being repeatable and reliable. OHMSs use hydraulically set mechanical packers instead of cement to isolate sections of the wellbore. These packers have elastomer elements that extrude to seal against the wellbore and do not need to be removed or milled out to produce the well, and they provide isolation throughout the life of the well. The OHMS is run in the hole and the tools are spaced out on the production liner. When the system reaches total depth, the packers can be set and the drilling or workover rig can be moved to a different location. Instead of using wireline and perforating the casing to allow fracturing, these systems have fracturing ports to create openings between the packers. These tools can be opened hydraulically (at a specific pressure) or by dropping size-specific actuation balls into the system to shift the sleeve and expose the fracturing port. The balls create internal isolation from stage to stage, eliminating the need for bridge plugs. The major advantage of OHMS is that all the fracture treatments can be performed in a single, continuous pumping operation without the need for CT or wireline, saving time and costs and reducing high-risk health, safety, and environmental operations. Once the stimulation treatment is complete, the well can be flowed back immediately and production brought on line.

OHMS Trends in Carbonates

OHMS completion technology was designed originally for carbonate applications; as a result, the technology was proved in several now-prominent carbonate plays, such as the Devonian carbonate formation in west Texas and the James Lime formation in east Texas. As the technology evolved and allowed more stages to be treated effectively, the lateral lengths became longer. In 2004, the average lateral length for OHMS-completed wells in carbonate formations was 3,726 ft and the average stage spacing was 1,242 ft, providing an effective three-stage treatment. By 2006, the average lateral length had increased to 4,400 ft, and spacing between the stages had reduced to 699 ft, providing an average stage count of six.

In late 2006, there was a focus on optimizing production by treating each stage effectively, rather than by drilling longer laterals. This trend has continued to today. Lateral lengths decreased in the second half of 2006 through 2008, until the stage capability of the technology and the comfort factor of deploying more stages were accepted by various engineering disciplines, and operational procedures were developed. In 2008, the average stage count was 7.5 in a horizontal wellbore, averaging 5,219 ft in length for an average stage spacing of 532 ft. In the first half of 2009, the average stage count had increased to 9.8, while the average lateral length had remained relatively constant, thus decreasing the stage length. By late 2009, the stage count had increased to 13.6, and through 2010 it has continued to increase to 18 while the stage length has decreased steadily to the current length of 293 ft.

OHMS Trends in Tight Sandstone

In sandstone applications, the trends emulate those of carbonates as more efficiency was placed into the completion process as the technology evolved. In 2004, the average number of stages was only 3.8, with lateral lengths of 1,858 ft with 419-ft stage spacing. In 2006, the average stage count in sandstones was 4.8 per completion in an average lateral length of 2,024 ft. Through 2009, the number of stages increased from 7.7 to 9.6, the lateral lengths increased from 3,061 ft to 3,483 ft, and the stage spacing decreased by 45 ft to 321 ft. As procedures for drilling and completing these wells have evolved to the present, the average lateral length now is 4,260 ft, incorporating an average of 12.6 stages per completion. Stage spacing also has been reduced during that time, from an average of 378 ft in 2006 to 276 ft in 2010.

OHMS Trends in Shales

Over time, shales have gone through trends similar to those of sandstones and carbonates in that operators have been able to drill longer laterals in these challenging plays. In 2004, lateral lengths were only 1,863 ft, with an average stage count of 4.6 and 342-ft stages. By the middle of 2007, average lateral lengths were 2,791 ft and the average stage count was up to 7.7. In 2009, there was a slight increase in stage number from 8.6 to 10 while the lateral lengths stayed constant at 3,000 ft, with stage length going from 365 ft to 333 ft. Recently, lateral lengths have increased to 3,255 ft, the stage count has jumped to 12.3, and the stage length has decreased to 278 ft.

Re-Entry OHMS Applications

Another approach to optimizing unconventional or even conventional reservoirs is to re-enter existing vertical wells to drill and complete horizontal laterals and capture new pay. For example, in 2008 a re-entry project was undertaken by an operator with the objective of more efficiently completing the maturing parts of the Cleveland formation. The design targeted previously stimulated vertical wells and involved drilling a window in the casing to land a lateral in previously untapped zones between the vertical wells. After the lateral was drilled, a slimhole-design OHMS system for a 3¾-in. hole was installed using the same CT rig.

The operator was able to use a previously completed vertical wellbore to save on the cost of drilling and completing a new wellbore. The first 6 months of production was comparable to a newly drilled horizontal well. However, the well declined faster than a typical horizontal well, because the well already had produced for approximately 25 years.

Conclusions

As operators feel more comfortable with technology, jumps in trends occur. OHMS completions in shale, tight-sandstone, and tight-carbonate formations have inceased their number of stages while decreasing their stage lengths. With the release of OHMS systems capable of high-density completions (more stages in the same lateral length), operators immediately increased their stage counts. This trend still is increasing, which indicates that optimization of multistage completions has yet to be realized fully. As of September 2010, more than 5,200 OHMSs have been run worldwide in a variety of formations, both on- and offshore, proving the versatility of these systems. **JPT**