The ability to refracture source rock reservoirs has the potential to extend the life of the “shale revolution” beyond the normal 20-30 year productive life of a reservoir. It is considered the best option for combatting the more rapid decline rates of unconventional reservoirs.

By Dave Allison
and Mark Parker

HOUSTON—Source rock reservoirs (SRRs), which often are called shale reservoirs, have unique attributes that make refracturing a viable option when production rates drop below economic limits. The ability to successfully refrac SRRs provides the potential to extend the life of the “shale revolution” beyond the normal 20-30 year productive life of a reservoir.

Hydraulic fracturing of oil and gas reservoirs has been an accepted technique for enhancing production since its commercial introduction in 1949, and plays a major role in developing many oil and gas fields globally. The combination of fracturing technology and horizontal drilling has made exploiting SRRs a thriving endeavor in North America.
However, refracturing often is considered the best option for combatting production declines in unconventional reservoirs. Decline rates from SRR wells usually are more rapid than wells in conventional reservoirs because of their ultralow permeability, limited reservoir contact, and the original completion strategy.

The success or failure of refracturing can have implications for field development. The desire to reinvigorate wells by performing secondary or tertiary hydraulic fracture stimulation treatments has been present for many years. The need for improving production above the economic break-even point and tapping additional portions of the reservoir are lofty goals that have proven difficult, if not impossible, to achieve in conventional reservoirs.

Restimulations are appealing because treatments involve reusing the existing wellbore, which potentially provides a cost savings of $1 million-$4 million, compared with drilling a new well. Well costs outside of North America are 5-10 times greater, making refracturing a reservoir even more enticing.

Reusing a wellbore also can reduce environmental impact dramatically, compared with drilling and completing a new well in a different location. Additionally, permitting issues, pad construction, rig moves, pipelines, and several other operational issues can be eliminated when an existing wellbore can be reused.

Fracture Network

The low permeability of SRRs limits how far hydrocarbons will travel within the matrix of the reservoir. The reservoir must be fractured so the hydrocarbons need to travel only a few inches to enter a fracture. A fracture network with a large surface area is necessary to make SRR production economical (Figure 1).

The large distance between access points from the original completion, combined with a suboptimal fracture network, creates significant volumes of stranded hydrocarbons between access points. Refracs can help recover these isolated hydrocarbons.

Horizontal lengths vary, depending on several factors. However, it is not unusual for laterals to be 4,000 feet, and some wellbores extend up to 10,000 feet. This provides ready access to the SRR anywhere along the length of the wellbore. By contrast, most vertical wellbores in conventional reservoirs contact the reservoir in only one spot, which typically is 10 to a few hundred feet of exposed reservoir.

In the original completion, access to the reservoir typically is achieved by perforating the casing (85 percent of the North American market) or by inserting mechanical valves (frac sleeves are 15 percent of the North American market) into the casing string at predetermined points. Typically, there is significant distance between the access points, ranging from 150 to 400 feet, depending on the preferences, experience, and reservoir

Figure 2A is an artist rendering of a horizontal well fracture stimulation that created a complex fracture network at each access point. Figure 2B is an artist rendering of the same horizontal well after refracturing. An additional fracture network has developed to supplement the original complex network. Also, perforations were added between access points to access untapped hydrocarbons.
knowledge of the completion engineer.

Since a fracture stimulation will be placed at each of these access points, economics become a factor with respect to how close the access points are to one another. From a refrac perspective, there usually is sufficient room to add new perforations between existing access points to gain entry into potentially untapped portions of the reservoir.

The ultimate goal of the original stimulation was to create a fracture network that provided the greatest surface area exposure to the reservoir. A refrac treatment is employed with the same objective.

In certain SRRs, it is possible to use the existing access points for the refrac and still generate a new fracture network sufficient to increase production. In a formation such as the Barnett Shale, with its low in-situ stress anisotropy, enough pressure differential can be created within the fracture itself to cause the reservoir to fracture in new directions. Reusing the original access points helps control the cost of restimulation.

Steep production declines may be caused by stranded hydrocarbons that are not accessed by the first completion. Therefore, another approach for refracs is to add perforations between the original access points to create additional gateways to the stranded hydrocarbons (Figures 2A and 2B).

**Particulate Diverters**

Once a philosophy has been developed for how to create an additional fracture network, the practicalities of implementing the refrac must be addressed. The casing is now full of holes, and selective stimulation and isolation of these reservoir access points is paramount.

A variety of techniques have been developed through the years, and all have both advantages and disadvantages (Table 1). However, over the past several years, using environmentally acceptable self-removing diverting particles (EFSRDP) has gained favor in many SRRs.

These particulate diverters typically are used after a refrac fluid and proppant stage to temporarily isolate that portion of the reservoir, thus redirecting any subsequent stages to different parts of the wellbore and reservoir. A typical pumping schedule potentially would be:

- Establish injection to the reservoir;
- Pump the refrac fluid and prop-

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**TABLE 1**

**Compilation of the Most Common Methods Used to Create Temporary Isolation During Refracture Treatments**

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td><strong>Mechanical Methods</strong></td>
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| Rework wellbore                 | Use a rig to seal off all the original perforation, typically using cement. | 1. Best opportunity to create a wellbore that replicates the original completion conditions. | 1. Most costly.  
2. Most time consuming.  
3. Operationally complex.  
4. Typically, wellbore is only 75-90 percent of original specification. |
| Coiled tubing                   | Use a CT unit and downhole packers to place stimulation.                    | 1. Use wellbore in current state.  
2. Isolation of individual access points.  
3. Control of which access points are treated. | 1. High cost.  
2. Time-consuming.  
4. Equipment erosion and malfunction.  
5. Operationally complex.  
6. Risk of getting stuck. |
| **Particulate Methods**         |                                                                             |                                                 |                                                   |
| Rock salt                       | Use rock salt to isolate perforations between fracture stages.               | 1. Low cost.  
2. Permits continuous pumping.  
3. Bridges in unknown geometry of perforations/fracture. | 1. Lack control of the sequence in which access points are treated.  
2. Unknown removal profile.  
3. Requires saturated brine placement fluid.  
4. Often requires CT to remove nondissolved salt. |
| Perforation ball sealers        | Use perforation ball sealers to isolate perforations between fracture stages. | 1. Low cost  
2. Permits continuous pumping.  
3. Bridges on perforation.  
4. Removed by flowing the well. | 1. Lack control of the sequence in which access points are treated.  
2. Can erode when proppant passes.  
3. If perforation is noncircular, it will not seal.  
4. Can move off of perforation when pumping stops.  
5. Temperature limits. |
| Environmentally acceptable self-removing diverting particle | Use EFSRDP to isolate perforations between fracture stages. | 1. Low cost  
2. Permits continuous pumping.  
3. Bridges in unknown geometry of perforation/fracture.  
4. Predictable removal profile.  
5. Environmentally acceptable. | 1. Lack control of the sequence in which access points are treated.  
2. Temperature limits. |
**Pump the particulate diverters;**
- Repeat steps two and three as desired;
- Pump the refrac fluid and propellant;
- Displace with brine or base fluid; and
- Begin to flow the well.

When new perforations are added between access points, the pumping schedule described here is often modified. A particulate diverter stage is added before the first stimulation stage to temporarily block the path to some or all of the original access points. The pumping schedule then would be:
- Establish injection to the reservoir;
- Pump the particulate diverter;
- Pump the refrac fluid and propellant;
- Repeat steps three and four as desired;
- Pump the refrac fluid and propellant;
- Displace with brine or base fluid; and
- Begin to flow the well.

Using particulate diverters is somewhat problematic in that it is not possible to maintain total control of which reservoir access points are being treated. The fluids will always take the path of least resistance, and that path changes throughout the refrac treatment. However, because the wellbore has a limited number of reservoir access points, ultimately, most or all of the access points can be restimulated successfully, albeit in a random order.

Frac sleeves that can be opened and closed multiple times can bring more certainty and control over fluid and propellant placement during the restimulation. Frac sleeves provide full control of where the stimulation fluids and propellant are being placed, along with the order in which the reservoir is treated.

Frac sleeves of this type must be installed during the original drilling and completion phase. Frac sleeves with this capability may be controlled using coiled tubing equipment, or a rig and a downhole shifting tool to open and/or close a particular sleeve.

**Monitoring And Equipment**

Distributed temperature sensing with fiber optic cable can reveal where production is coming from in the wellbore and indicate areas that need restimulating. It also can reveal where frac fluids exit the wellbore during treatment/retreatment to indicate success.

Microseismic monitoring can be used to see the effectiveness of multistage fracture treatments in SRRs. Areas that are not well covered in the original fracture treatment can be identified and targeted for refracturing. The refrac can be evaluated as well to verify that the bypassed area along the wellbore is treated effectively.

Chemical tracers also can be effective for evaluating the primary fracture treatments. Planning for evaluating the original fracture treatment and subsequent refracs is necessary to select the chemical markers or isotopes to evaluate all stages.

The same surface equipment used to perform the storage, mixing/blending, and pumping for the original fracture operations can be used to perform the refrac. The number of pumping units and blending units used the first time normally would be used on the refrac. Storage for water, sand and chemicals can fluctuate, based on the volumes to be used and the methodology of the pumping schedule to be deployed.

**Case Histories**

Some attempts to refrac wells to maintain them as viable producers provide insight to the potential for keeping the shale revolution flourishing.

A horizontal Barnett Shale well in Tarrant County, Texas, was completed and brought on line in July 2004. A refrac was performed in October 2010 (Figure 3). The number of perforations along the...
2,000-foot lateral was increased by 80 percent. A treatment volume of approximately 80 percent of the original was used to re-establish economic production.

The initial production after the refrac was 55 percent of the original IP. The decline curve after the refrac revealed a different trajectory that suggested additional and more proportional surface area was created during the refrac than during the original completion.

In another instance, perforations in the heel portion of a 2,600-foot horizontal Barnett well in Tarrant County were added to supplement the original perforations. The refrac treatment was similar in size to the original fracture treatment and used environmentally acceptable self-removing diverting particles for isolation and diversion, whereas the original completion used plug-and-perf style operations (Figure 4).

Summary

Successfully applying a refracture treatment depends on technology that allows access to greater areas of ultralow permeability SRR. Monitoring the effectiveness of horizontal wellbores and the original completions will help guide technologies and methods to gain control of the wellbore and contact stranded reserves.

Refracturing treatments on horizontal wellbores completed in SRRs will have significant impact on the production and economics of field development. Consideration should be given from the beginning to determine the best way to accomplish a refrac campaign when primary production has declined to a predetermined point.

For wells completed using plug-and-perf techniques, gaining control of the wellbore is most important. This can be accomplished using EFSRDP. These particles can seal off old or new perforations to allow treatment to travel into another area of the wellbore for increased reservoir contact.

In wells completed using mechanical shifting sleeves, the wellbore is controlled by closing the sleeves and opening specific areas for retreating. Access to new reservoir can be gained by perforating between the mechanical sleeves. In this situation, EFSRDP can be used to divert flow into the new areas.

As refracturing techniques gain popularity in unconventional reservoirs, the ability to isolate reservoir access points and redirect the frac fluids and proppant to different parts of the reservoir is crucial to achieving a successful treatment. All known methods have advantages and disadvantages. However, EFSRDPs are selected often, based on their ease of use and excellent environmental profile.

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