HOW TO START/FIX/MANAGE A SMALL WATERFLOOD

BOTTOM LINE

Whether starting, fixing or managing a waterflood, three things are needed: (1) a multi-disciplinary team to thoroughly characterize the field, (2) all the data available, geological, geophysical, engineering, and (3) as many tests and analyses as can be reasonably performed to understand what has gone on and is going on in the reservoir.

PROBLEM ADDRESSED

The problems addressed are what to do with a field at its economic limit, whether on primary or secondary, how to recover unswept oil from an inefficient flood, and how to dramatically reduce well failure and the resulting high operating and maintenance costs.

KEY WORDS:

3-D Seismic
Corrosion
Mechanical Wear
Production Pattern
Reservoir characterization
Water injection/ production
Waterflood

TECHNOLOGY OVERVIEW

Targeting a Waterflood and Case Studies

To start, fix, or manage a waterflood takes a thorough characterization of the field and its history. This in turn requires the knowledge, skills and time of a cross discipline team, including the field foreman, production and reservoir engineers, geologist, geophysicist and owner. An example of a field that was first in the "fix" category and later moved to the "manage" category is the Foster field in Ector County, Texas. It was first discovered in 1939, started waterflooding in 1962; infill drilled to 20 acres in 1979 and, when purchased by Laguna Petroleum in 1992, was nearing its economic limit.

One of the first steps of the characterization was the construction of a detailed geological model. This was a challenge as the available logs were of widely varying age, quality and completeness. To fill in the blanks, a 3-D seismic survey was run to facilitate the porosity mapping. The inversion-modeled seismic matched the cross plot neutron density porosity well enough to use it to generate the maps. Among other things, the model indicated a permeability barrier not evident from the logs.

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SPEAKERS:

Targeting a Small Waterflood and Case Studies, Robert Trentham, University of Texas Permian Basin, Center for Energy & Economic Diversification, Odessa, TX

Reservoir Engineering, Scott Atkinson, ExL Petroleum, LP, Midland, TX

Operational Issues, Robert D. Kiker, PTTC Texas/SE New Mexico Region, Midland, TX

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In addition to the geological model, a well testing program was undertaken, including bottomhole pressure tests, water chemistry, production tests and rock properties. In some cases, due to the low permeability, some tests were conducted for 20 or 30 days. Given that the water injected over the years came from many different sources, the role of water analysis was important in understanding the reservoir. The information gained from the characterization was used to refrac and recomplete several wells, as well as switching production wells to injection. The results were increased production and reserves and the addition of 10 years or more to the economic life of the waterflood.

The importance of gathering all available data and performing a complete, multi-disciplinary characterization cannot be over emphasized. An example was given of a field where, due to erroneous and optimistic assumptions of porosity, oil-water and gas-water contacts and porosity cutoff, the original oil-in-place was revised downward by nearly 33%. Besides well files, data can be found in log and core libraries, state geological surveys, chemical companies and universities.

Reservoir Engineering

Reservoir engineering and the linkage with the geology are vital to a successful waterflood. The engineer and geologist can never look at enough detail in the reservoir description. The "top 10" reasons a waterflood can fail are:

10. Scale, bacteria or water quality issues reduce injectivity
9. Insufficient water supply
8. Underestimate of fill up volume
7. Out of zone injection
6. Early water breakthrough
5. Insufficient lift capacity
4. High oil viscosity
3. Incorrect perforations

2. Injection above formation frac pressure
1. Underestimating or misunderstanding reservoir heterogeneity

In practice, few waterfloods fail, but many fail to live up to expectations. Key considerations to prevent that are:

- Homework, homework, homework
- Determination of the baseline
- Complete and accurate production history of all fluids and gas
- Field pilot
- Analogous projects
- Saturation estimations: initial, current and post-flood
- Trapped gas versus bubble point pressure
- Consideration of fractional flow, relative permeabilities, fluid viscosities and mobility ratio

Oil and water viscosity are critical in a waterflood as they determine the mobility ratio and sweep efficiency. Oil viscosity can change over time with pressure and gas saturation, or with contact with chemicals or CO_2. Also important is the proper pattern spacing for the thickness and homogeneity. Generally, the number of producers and injectors is equal and arranged in a line drive, nine-spot or other pattern to minimize unswept areas. Pore volume must be considered for injection balancing. Analogies are very helpful, but should make sure the analogy is from the same reservoir (depositional environment, depth, etc.) and has similar rock and fluid properties. A complete production history, including a discernable secondary production period, should be available.

Fundamental questions to ask relate to original pore volume, remaining oil, integrity of the reservoir and penetrations, saturations, bubble point pressure and, of course, economics. Good advice includes using rules of thumb sparingly, look very hard at the risk of out-of-zone injection, understand the reservoir continuity and "correlatability," infill drilling to attack previously unswept zones, and pressure up the reservoir before attempting to produce a lot of oil.

Successful Practices that Operators Have Used to Reduce Lifting Costs

Waterfloods, by their nature, are expensive to operate. One of the biggest costs is the cost to lift, separate, and recycle the large volumes of water, in terms of both equipment and power costs. Another major expense is in the mechanical and corrosion wear and tear on downhole and surface equipment.

There are a number of things an operator can do to manage those costs. The electricity costs are a function of volume and price. Both should be examined. The operator should review and plot at least a year's electricity usage to look for anomalies and mistakes, then meet with a utility representative or consultant to understand the current utility rate structure and what other rates might be better for the operation. Generally, there are a number to choose from and, in states that have deregulated electricity, there are a lot of options. Interruptible rates can often save substantial costs at little operational inconvenience. Consider moving some activities to an off-peak time. If the lease has stranded gas, it may be possible to capture value with on-site power generation.

On the volume side of the equation, there are also a number of things to review. The operator should maintain low flowline pressure by keeping valves open, reducing restrictions and keeping flowlines clean. Inefficient and improperly sized motors should be replaced. Pumping costs can be minimized by producing with a full pump barrel, properly sized equipment, tight sheave belts and as long a stroke as possible.

As an alternative to conventional produced water pumping, separating and disposal, consider the relatively new technology of downhole oil water separation (DOWS). With DOWS systems the oil and water are separated downhole and the water injected below the production perforations. There are two types of DOWS. The hydrocyclone type is better for high volumes, but systems are more expensive and more prone to failure than gravity separation systems. Hydrocyclone systems can be paired with electric submerged pumps, rod pumps and progressive cavity pumps. The less expensive gravity separation systems are used only with rod pumps.

To state the obvious, reducing well failures reduces operating costs and keeps marginal wells on longer. Losses due to corrosion can be prevented with cathodic protection, on both the casing and the surface facilities, and chemical inhibitors. Types and volumes of inhibitors vary from field to field, but in general are applied, either in batch or continuous mode, at a rate of 1 - 4 gallons per 100 barrels of fluid produced. Downhole equipment should be selected to minimize corrosion. J 55 tubing should be used in a corrosive environment. Plastic coating and polyethylene liners are available. Norris Grade 90 sucker rods or even fiberglass should be used in that environment as well.

There are a number of steps the operator can take to minimize mechanical wear. Tubing anchors, if necessary, should be placed as close to the pump as possible. Rod guides should be used only where absolutely required since their use does damage inhibitor coating. If used, they should be molded onto the tubing, 3 - 4 per rod. Rod rotators should only be used when rod guides are used. The polyethylene liners mentioned above for corrosion are also good for mechanical wear. Finally, a pump-off controller is recommended for marginal wells as it saves money as well as wear and tear.

CONNECTIONS:

Scott Atkinson
ExL Petroleum, LP
6 Desta Drive, #2800
Midland, Texas 79705
Email: dscotta@apex2000.net

Robert D. Kiker
PTTC Texas/SE New Mexico Region
415 W. Wall Street, Suite 1720
Midland, Texas 79701
Email: pttcpermianbasin@marshill.com

Robert Trentham
University of Texas Permian Basin
Center for Energy & Economic Diversification
4901 E. University
Odessa, Texas 79762
Phone: 455-552-2432
Email: Trentham_r@utpb.edu

For information on PTTC's Texas and its activities contact:

Sigrid Clift
Bureau of Economic Geology
10100 Burnet Rd
Bldg 130
Austin, TX 78758
Phone 512.471.0320, Email sigrid.clift@beg.utexas.edu

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Petroleum Technology Transfer Council, P.O. Box 979, Tulsa, OK 74101-0979
toll-free 1-888-THE-PTTC; Email hq@pttc.org; web www.pttc.org