Successful Completion Optimization of the Eagle Ford Shale

Supplement to SPE Paper 170764
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Please see the Appendix slides included in this presentation for other important information.
Talk Outline

- Study Area and Eagle Ford Shale Intro
- Well Look-Back Study
- Eagle Ford Shale Completion Standard Design and Operations
- Completion Optimization Plan
- Case History Results
- Summary
Regional Overview of Texas
Permian & Eagle Ford Activity

Pioneer’s Eagle Ford Shale - Study Area

- Permian Midland Basin
- Spraberry/Wolfcamp Study Area
- Eagle Ford
Talk Outline

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Comprehensive Well Look-Back Study

Baseline Data Included in Analysis

- 142 wells on production (March 2012)
  - 60 had more than 120 days of production

- Data used in the analysis
  - Production rates
  - Well head pressure
  - Choke size
  - Perforated lateral length
  - Initial reservoir pressure
  - Reservoir temperature
  - Fluid pressure/volume/temperature

- Data pre-processing include:
  - Filtering
  - Normalization

- Calculated flow parameters:
  - Bottom-hole flowing pressure (Pwf)
  - Drawdown (initial reservoir pressure - Pwf)
  - Productivity Index
  - Normalized Rates (MCFPD/1000ft)
  - Gas-oil-ratio (GOR), gas-water-ratio (GWR), etc.

Ranking Plots (Illustration)

Best performing well
Identification of the “Key Performance Drivers”

- Deep Deposition
- Immature
- Fractures
- Total Organic Content (TOC)

Porosity

Clay Content

Dry Gas

5 mi

- Buda
- Live Oak
- Karnes
- Res
- De Witt

<15% 15-40% 40-90% >90%

GR FIII with ELAN VClay
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Pioneer’s Eagle Ford Shale - Historical Frac Design

- Typical Well:
  - 11,000’ - 14,500’ Total Vertical Depth (TVD)
  - 5 1/2” Production Casing Size
  - 2808,000 - 11,000 psi Reservoir Pressure
  - -350 °F Reservoir Temperature

- Typical Design:
  - Pump Down “Plug & Perf” Method
  - 9,000 - 12,000 psi Surface Treating Pressure
Zipper frac refers to a horizontal well completion method where hydraulic fracture operations and adjacent well preparation occur simultaneously for multiple wells on a single pad location. This method is designed to generate operational efficiencies and cost savings while also potentially improving the stimulated rock volume and resulting production of the wells.

1)
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Completion Optimization

Opportunity to increase EUR, reduce cost and add reserves

Cost Saving Initiatives

- Changed proppant type
  - e.g. ceramic proppant to white sand

Well Performance Improvement Initiatives

- Increased proppant - lb/ft (larger stimulated reservoir volume - SRV)
  - e.g. 800 lb/ft to 1,200 lb/ft
- Reduced cluster spacing (better near wellbore stimulation)
  - e.g. 70 ft to 50 ft
- Combo - Increased lb/ft & reduced cluster spacing
- Increased rate per cluster (better frac half-length - Xf, energy per cluster)
  - e.g. 11 bbls per minute per cluster to 16 bbls per minute per cluster
- Fluid type (improved proppant transport)
  - e.g. tailored fluid system viscosities
- Proppant size (improved fracture conductivity)
  - e.g. testing higher mesh size (20/40)
Completion Optimization - Test Matrix

Completion Optimization Matrix

Number of wells tested in each area  
*(illustrative purposes only)*

<table>
<thead>
<tr>
<th>Area</th>
<th>Increased Lb/Ft</th>
<th>Reduced Cluster Spacing</th>
<th>Combo</th>
<th>Increased Rate/Cluster</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>B</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1</td>
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</table>

**Key Considerations**

- **Variation in the following factors:**
  - Geological factors (sweet spots vs. marginal areas)
  - Hydrocarbon type (oil, gas, condensate)
  - Depths across the trend

- **Optimum drilling activity in the test period (2012 & 2013)**

- **Economic considerations**
Increased Lb/Ft and Combo Test

- Only one completion variable changed per test
- All other completion parameters held constant
- Benchmark completion analogue well chosen for comparison
- Microseismic & 3-D Seismic
- Radioactive Tracers
- Chemical Tracers
- Chemostratigraphy (XRF)
- Oil & Gas Isotope Geochemistry
- Frac Models
- Pressure Interference
- Production Data
- Reservoir Modeling
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# Performance Analysis Summary

## Reservoir Performance Analysis Workflow

1. **Diagnostic Plots and Decline Curve Analysis (DCA)**
   - Diagnostic plots compare the performance of optimized wells to that of conventional wells based on normalized production rates and cumulative volumes, flowing pressures, productivity indices and choke sizes.

2. **Decline Curve Analysis (DCA)**
   - Decline Curve Analysis (DCA) establishes a type curve for well performance based on early production data to forecast the well’s estimated ultimate recovery (EUR) of oil and gas.

3. **Rate Transient Analysis (RTA) and Reservoir Modeling**
   - Rate Transient Analysis (RTA) characterizes flow regimes from wellhead rate and pressure data to forecast EUR; this method is the first step in understanding the key parameters affecting fluid flow in the reservoir.

4. **Reservoir Modeling**
   - Reservoir modeling combines measured rate and pressure data with reservoir geometry and rock properties to forecast EUR.

### Comparison 

<table>
<thead>
<tr>
<th>Comparison</th>
<th>ΔCum (% Uplift)</th>
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</thead>
<tbody>
<tr>
<td>Lb/ft vs. Conventional</td>
<td>6 months: 7% 12 months: 11%</td>
</tr>
<tr>
<td>Combo vs. Conventional</td>
<td>4 months: 37%</td>
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</table>

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</tr>
</thead>
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<tr>
<td>Lb/ft vs. Conventional</td>
<td>21%</td>
</tr>
<tr>
<td>Combo vs. Conventional</td>
<td>42%</td>
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</table>

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</thead>
<tbody>
<tr>
<td>Lb/ft vs. Conventional</td>
<td>13%</td>
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<tr>
<td>Combo vs. Conventional</td>
<td>71%</td>
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<tr>
<td>Lb/ft vs. Conventional</td>
<td>11%</td>
</tr>
<tr>
<td>Combo vs. Conventional</td>
<td>49%</td>
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1) Diagnostic plots compare the performance of optimized wells to that of conventional wells based on normalized production rates and cumulative volumes, flowing pressures, productivity indices and choke sizes.
2) Decline Curve Analysis (DCA) establishes a type curve for well performance based on early production data to forecast the well’s estimated ultimate recovery (EUR) of oil and gas.
3) Rate Transient Analysis (RTA) characterizes flow regimes from wellhead rate and pressure data to forecast EUR; this method is the first step in understanding the key parameters affecting fluid flow in the reservoir.
4) Reservoir modeling combines measured rate and pressure data with reservoir geometry and rock properties to forecast EUR.
5) Increased proppant lb/ft and reduced cluster spacing.
Production Comparison

Normalized Cumulative Production (MBOE/1000')

Increased Lb/ft Design  Conventional Design

11% increase at 12 months
7% increase at 6 months

Normalized Days

Normalized Cumulative Production (MBOE/1000')

Combo Design*  Conventional Design

37% increase at 4 months

Normalized Days

* “Combo Design” includes increased proppant lb/ft and reduced cluster spacing
Completion Optimization - Results

- Over the past 2 years, Eagle Ford Shale completion design improved by:
  - Reducing cluster spacing
  - Increasing the pounds of proppant (white sand) pumped per foot
  - Increasing the barrels of frac fluid pumped per minute (BPM) in each cluster
  - Utilizing combinations of the above

- Results in 20% to 30% EUR increase with minimal increase in drilling and completion capital
  - Generating before tax returns of ~100% on incremental capital spent

- Completions designed by area due to varying geology
And Now...The Spraberry/Wolfcamp Shale Play

Permian
Midland Basin
Spraberry/Wolfcamp
"Stacked" Shale Play

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Permian Midland Basin Spraberry/Wolfcamp “Stacked” Shale Play
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Summary

- Maintaining the base completion design was critical to properly evaluate and understand reservoir changes across the trend in the Eagle Ford Shale play.

- Increased rate per cluster initiative became part of our standard completions; expect a 20% - 30% increase in EUR in the Eagle Ford Shale (Jaripatke et al. 2013).

- Increased lb/ft and combo designs resulted in EUR increases ranging from 10% - 40% depending on the area of the trend and are a part of the current Eagle Ford Shale completion design.

- One recipe does not fit all!

- This methodology is now being implemented in the Permian Midland Basin Spraberry/Wolfcamp “stacked” shale play.
To access SPE Paper 170764, please follow the link to OnePetro.org:

SPE 170764 on OnePetro.org
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