Optimization of Completions in Unconventional Reservoirs for Ultimate Recovery*

Rocky Seale1 and Daniel J. Snyder1

Search and Discovery Article #80142 (2011)
Posted March 18, 2011

*Adapted from oral presentation at AAPG Eastern Section Meeting, Kalamazoo, Michigan, September 25-29, 2010

1Packers Plus Energy Services Inc., Houston, TX 77069 (rocky.seale@packersplus.com)

Abstract

Over the last decade, an industry wide shift to unconventional plays has occurred due to advances in technology allowing for 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. Horizontal drilling and multi-stage fracturing are two technologies which have accomplished this. The two main methods of horizontal, multi-stage completions currently used in unconventional reservoirs are cemented liner “plug and perf” and open hole, multi-stage fracturing systems.

Operators working in a number of unconventional reservoirs, such as shales and other tight rock formations are experiencing faster than expected production decline rates, resulting in reduced long-term, ultimate recovery. This may be in part due to the abandonment of good fracturing practices, developed over the past 50 years, with the advent of horizontal, multi-stage fracturing. Issues such as near wellbore conductivity, flowback, and fracture tortuosity that can have a significant effect on the long-term production of wells need to be considered when choosing a completion method, particularly for unconventional reservoirs.

This presentation will introduce unconventional reservoirs, describe the main methods of horizontal, multi-stage completions, discuss how the choice of method can affect good fracturing practices and provide case study examples from a variety of unconventional reservoirs including tight sandstone, limestone and shale.
References


Optimization of Completions in Unconventional Reservoirs for Ultimate Recovery

Packers Plus Energy Services: Daniel J. Snyder, Rocky Seale
Outline

• Unconventional reservoirs
• Completions history
• Study areas
• Conclusions
• Summary
Resource Triangle

CONVENTIONAL
Small volumes that are easy to develop

UNCONVENTIONAL
Large volumes that are difficult to develop

- High Quality
- Medium Quality
- Low Perm Oil
- Tight Gas Sands
- Gas Shales
- Heavy Oil
- Coalbed Methane
- Gas Hydrates
- Oil Shale

Modified from Masters, 1979 and Miskimins, 2008
Unconventional Reservoirs

Map showing locations of three unconventional reservoirs:
- Bakken
- Cleveland Sand
- Barnett
Completions History

• Open Hole - “Hail Mary”
• Cemented Liner, Limited Entry
  – Ball Sealers
• Cemented Liner – “Plug and Perf”
• Open Hole Multi-Stage System (OHMS)
Cemented Liner “Plug and Perf”

Horizontal well
Top view
Open Hole System

Horizontal well
Top view
Carbonates

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Stages</td>
<td>3.0</td>
<td>17.2</td>
</tr>
<tr>
<td>Lateral length</td>
<td>3726</td>
<td>5864</td>
</tr>
<tr>
<td>Average Stage Length</td>
<td>1242</td>
<td>293</td>
</tr>
</tbody>
</table>

- Bakken Dolomite (oil)
  - 10,000 – 11,000 ft TVD
  - +250°F
  - 5% porosity
  - 0.04 mD
Bakken Dolomite

Oil Production Rate (BOPD)

- IP: 58%
- 30 Days: 48%
- 60 Days: 57%

Cemented Liner vs. OHMS
Tight Sandstones

- Cleveland Sand (oil & gas)
  - 7,500 ft TVD
  - +150°F
  - 4 to 14% porosity
  - 0.03 to 1.1 mD

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Stages</td>
<td>4.1</td>
<td>14.1</td>
</tr>
<tr>
<td>Lateral length</td>
<td>1650</td>
<td>3847</td>
</tr>
<tr>
<td>Average Stage Length</td>
<td>443</td>
<td>252</td>
</tr>
</tbody>
</table>
Cleveland Sand

Offsets

% Difference

OHMS Wells

Cumulative Production (BOE)

6 Months 1 Year 2 Years 3 Years

0 10,000 20,000 30,000 40,000 50,000 60,000 70,000 80,000 90,000 100,000

50% 30% 30% 30%
Shales

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Stages</td>
<td>4.6</td>
<td>12.3</td>
</tr>
<tr>
<td>Lateral length</td>
<td>1,863</td>
<td>3256</td>
</tr>
<tr>
<td>Average Stage Length</td>
<td>342</td>
<td>278</td>
</tr>
</tbody>
</table>

- Barnett Shale (gas)
  - 7,500 ft TVD
  - +180 °F
  - 3 to 5% porosity
  - 0.00007 to 0.0005 mD
Barnett Shale

**Well A**
7-stage open hole

**Well B**
8-stage cemented liner
Barnett Shale

• Well A
  – 1,276,503 lb proppant
  – 4,500 psi – 8,000 psi
  – 60 BPM – 140 BPM
  – 21 hours

• Well B
  – 1,273,745 lb proppant
  – 7,400 psi – 9,000 psi
  – 29 BPM – 93 BPM
  – 3+ days
Barnett Shale

<table>
<thead>
<tr>
<th></th>
<th>6 Months</th>
<th>12 Months</th>
<th>24 Months</th>
<th>36 Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well A</td>
<td>484,286</td>
<td>787,606</td>
<td>1,211,383</td>
<td>1,503,578</td>
</tr>
<tr>
<td>Well B</td>
<td>191,687</td>
<td>313,255</td>
<td>480,987</td>
<td>615,669</td>
</tr>
</tbody>
</table>

Production (MCF)

- Well A: 484,286 MCF (153% increase)
- Well B: 191,687 MCF (151% increase)

- Well A: 787,606 MCF (152% increase)
- Well B: 313,255 MCF (144% increase)

- Well A: 1,211,383 MCF
- Well B: 480,987 MCF

- Well A: 1,503,578 MCF
- Well B: 615,669 MCF
Barnett Shale

Production (MMCFG) vs. Time (Months)

- 6 Months: 50%
- 12 Months: 30%
- 24 Months: 30%
- 60 Months: 30%

2004-5 Offsets vs. OHMS Wells
Good Fracture Practices

- Don’t overdisplace proppant
- Ensure near wellbore conductivity
- Keep breakdown pressures low
- Minimize fracture tortuosity
- Promote immediate flowback
  - Minimize fluid loading
  - Optimize load recovery
Maximum Effective Reservoir Contact

Vertical wellbore
6 ⅛-in. x 100 ft

One vertical fracture
(100 ft x 150 ft x ⅛ in.)
23,562 ft²
Feeding into 2.1 ft²

Horizontal wellbore
6 ⅛-in.

One transverse fracture
(100 ft x 150 ft x ⅛ in.)
23,562 ft²
Feeding into 0.017 ft²
Drainage: Cemented Liner

Horizontal well
Top view
Drainage: Open Hole

Horizontal well
Top view
Conclusions

CEMENTED

- More complicated, takes longer, less productive

UNCEMENTED

- Simpler, quicker, higher production
Summary

• Good Frac Practices
  – Have not changed
• OHMS better results
  – More stages
Optimization of Completions in Unconventional Reservoirs for Ultimate Recovery

Packers Plus Energy Services: Daniel J. Snyder, Rocky Seale