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Artificial Lift Applications in Unconventional & Tight Reservoirs

Rajan N. Chokshi, Ph.D.
Presentation Outline

• How Lift applications differ for Unconventional & Tight wells
  • Well geometries
  • Flow behavior

• What works
  • Field Practices & Couple of Examples

• Importance of
  • Lift Life Cycle Planning
  • Lift Optimization, Monitoring & Surveillance

• Conclusions
Artificial Lift Applications are Well Understood...

Source: World Oil, Feb 2014, 2015:
“the percentage of U.S. oil wells produced by artificial lift is staying steady at about 95%.” for over ten years now.

2014: Wells on ALS: 564,961...

Total Oil wells: 579,420
Total oil wells: 600,679
Artificial Lift Applications are Well Understood...

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Plunger Lift</th>
<th>Foam Lift</th>
<th>Gas Lift</th>
<th>Reciprocating Rod Lift</th>
<th>Progressing Cavity Pump</th>
<th>Electrical Submersible Pump</th>
<th>Hydraulic Jet Pump</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prod Rates</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>Med</td>
<td>Med</td>
<td>Med</td>
<td>High</td>
</tr>
</tbody>
</table>

Courtesy: Weatherford
What’s Different Now? Two Trends

Unconventional & Tight Resources require improved technology & different approaches

Conventional Reservoirs
Small volumes that are easy to develop

Unconventional
Large volumes difficult to develop

What’s Different Now? Two Trends
Unconventional Wells – Long Laterals

Sources:
2. Sutton, Rob “Wellbore Geometry Effects on Well Production Performance”, Presentation in SPE Conference “Liquids Rich Shale... Do You Believe in Peak Oil?,” Rancho Palos Verdes, CA (May 2013) [13, 925 Surveys]
Different Flow Behaviors in Wellbore

Flow Patterns in Vertical:
- Bubble Flow
- Slug Flow
- Annular Flow
- Blown Flow

Flow Patterns in Horizontal:

FLOW DIRECTION
GAS VELOCITY
FLOW DIRECTION
Are Laterals Really Really Horizontal?

Complex Well Geometries

Closure Distance, ft

True Vertical Depth, ft


Austin Chalk
Bakken
Barnett
Eagle Ford
Niobrara
Woodford
Utica

Toe Up
Hybrid
Toe Down
Flow in Lateral - Trajectories

- 1° Toe Up: BUBBLE, SLUG, STRATIFIED, OIL, GAS, ANNULAR
- 1° Toe Down: BUBBLE, SLUG, STRATIFIED, OIL, GAS, ANNULAR

Superficial Liquid Velocity (fps)
Superficial Gas Velocity (fps)

Trapped Liquid
Trapped Gas

Courtesy: Tulsa Uni Horiz Well Art Lift Project Simulations
Permian Gas Horizontal Well: Flow Simulation Match

![Graphs and diagrams showing flow simulation results, including pressure, water holdup, gas holdup, distance from outlet, and simulation vs. measured data.](Image)

Courtesy: Pipe Fraction Flow LLC
Midland Wolfcamp Horiz. Oil Well – ESP Application

Courtesy: Pipe Fraction Flow LLC
Challenges of Turbulent Flow

- Pumping
- Gas-liquid separation
- Monitoring
- Back pressure
"... the average decline curves for Bakken and Eagle Ford wells have not shown significant changes since 2010. The major improvement can be observed in the increased 24-hr initial production, but this rate rapidly declines."

Variable Production Rates

- Must plan for a wide range of production rates

<table>
<thead>
<tr>
<th>Shale Play</th>
<th>1st Year Typ Decline Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barnett</td>
<td>65%</td>
</tr>
<tr>
<td>Eagle Ford</td>
<td>60%</td>
</tr>
<tr>
<td>Haynesville</td>
<td>81%</td>
</tr>
<tr>
<td>Marcellus</td>
<td>74%</td>
</tr>
<tr>
<td>Woodford</td>
<td>59%</td>
</tr>
<tr>
<td>Bakken</td>
<td>69%</td>
</tr>
</tbody>
</table>
Uncertain Inflow Phase Distribution

*What is the production from each zone?*
Production Challenges in Horizontal Wells

1. Deep, long, slender well geometries
   - The impact of well geometry on EUR

2. Sluggy and turbulent flow

3. Rapidly changing production rates

4. Uncertain inflow phase distribution
LESSONS LEARNED
Some Lessons – Draining the Lateral

• Involve production/operations with well geometry decisions during the well design.
  – Toe up orientation if possible.
  – ‘Rat hole’ for better gas separation???
  – Control tortuosity of horizontal section of well - Minimize undulations/traps
  – Intentionally plan/control vertical transition to horizontal section
  – Will casing geometries permit sufficiently sized ALS technology in future?
Some Lessons – Draining the Lateral

• *Early Operations*
  – Choke the production rate
    • Increases EUR
    • Increased FBHP delays gas breakout might reduce pooling in the lateral traps
  – Maintain adequate liquid levels
    » 200 ft above liner top
    » 75 to 100 ft above pump.
# Lift Toolbox for Unconventional & Tight Wells

<table>
<thead>
<tr>
<th></th>
<th>Gas Lift</th>
<th>Rod Lift</th>
<th>Plunger Lift</th>
<th>Capillary</th>
<th>Electrical Sub. Pump</th>
<th>Jet Pump</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gas shales</strong></td>
<td>Preferred</td>
<td>Low BHP</td>
<td>High GLR</td>
<td>Foam lift, inhibition</td>
<td>-</td>
<td>Frac fluid flow-back, Initial unloading</td>
</tr>
<tr>
<td><strong>Oil shales</strong></td>
<td>Limited</td>
<td>Preferred</td>
<td>-</td>
<td>Inhibition</td>
<td>High perm or choked</td>
<td></td>
</tr>
</tbody>
</table>

*Source: Internal research US shale plays, © Weatherford, 2010 - 2013*
Lessons – Deliquifying Laterals

• Mechanical pumps can pump from low spots but are not effective in “sweeping” liquids through laterals.

• Mechanical pumps can have gas interference issues.
  – Gas anchors are required in gassy wells.

• Where possible, land mechanical pumps:
  – In vertical section 50 to 100 ft above the liner top
  – In straight sections if within the deviated section

• Use continuous lift optimization (surveillance, analysis, prioritizing, adjustment)
Hybrid Lift in Gas Deliquification

Examples

Barnet Shale: Combination Lift Application
- Gas-Lift + Area Reduction + Foam Injection
- Foam injection in the lateral: Surfactant delivered at the toe

On Lift Life Cycle Planning

Jet Pump
Gas Lift
Rod Pump
Hydraulic Piston Pump
Plunger Lift
Foam

Completion Considerations
Change lift technologies without large workover rigs
∴ Less down-time

Well Prep
Early Production
Later Production

Production
Time

Courtesy: Weatherford
Hybrid Completion: JP → GL

- Tubing
- Casing
- Gas lift mandrel with double check GLV
- Hydraulic jet pump
- Standing valve shoe
- retrievable Packer

 Courtesy: Weatherford
Surveillance & Monitoring

- Accurate and timely monitoring is critical for production management and optimization.
  - Tracer chemicals for initial inflow
  - Production logging for snapshot of transients
    - Sporadic measurements are not adequate for managing dynamic production.

- Permanent downhole gage systems provide continuous real-time visibility of production conditions.
  - Artificial lift status
  - P, T, Q
  - Zonal contribution

- Data visualization and analysis software simplify production management and optimization.
Case: Permanent Electronic Gauges – Shale Rod Pumping

Continuous high granularity measurements revealed slugs

Case: Accurate Flow Measurements in Shale

Well A – Eagle Ford

Well C – Eagle Ford

Courtesy: Weatherford
Conclusions

• How are artificial lift applications different for unconventional & tight wells?
  – Well geometries pose production challenges
  – Understanding of flow behavior is very important and still developing.

Additional References
Conclusions

• What needs to be done?
  – Involve production & operations during well design
    – Toe Up.... Avoid Traps in Lateral
  – Select flexible lift systems
    – Stay current on what works where and why.
  – Think in terms of the lift life cycle
    – You will need to change to another lift – sooner or later...
  – Include Lift Monitoring & Surveillance from the beginning
    – Surface Flow and downhole P/T measurements add considerable value to
    the overall production optimization and recovery.

Additional References
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