Artificial Lift Performance Evaluation for Gas Well De-Watering (Pump versus Alternate Methods)

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Presentation

Introduction
  - Study Area
  - Challenges
  - Goal

Life of a Gas Well

Common Lift Methods for Gas Well

Analysis & Modeling
  - Reducing Wellhead Pressure
  - Inflow Performance Relation (IPR)

Pump versus Alternate Methods

Case Studies - Actual Field Data Sample

Selection Chart

Summary & Conclusion
INTRODUCTION (Study Area)

San Juan Basin
- Prolific gas basin – 17Tcf cum & Est. 26Tcf reserves

- Geology
- Simple structures
- Numerous fault with small fault offsets
- Fracture enhanced Permeability is important in all producing horizon
- 4-major reservoirs in ascending depth order
  - the Dakota – DK(6000’ -8600’),
  - Mesaverde-MV (4000’ – 6800’),
  - Pictured Cliffs-PC(1200’-4100’),
  - Fruitland Coal-FT(800’ -3800’)

San Juan Basin
Schematic Cross Section Hogback Monocline to Albuquerque
INTRODUCTION

Industry ➔ Optimum Artificial Lift Methods

Goal:

- Lower Failure Frequency
- Lower Intervention Cost
- Optimize Gas Production (with Lowest $p_{wf}$)

Challenges:

- Several Lift Types ➔ Numerous Choices
- Dynamic changes in the Life of the well (& Field)
- Application Limitation on every Lift Type
- Liquid loading in Gas well
Life of a Gas Well

Liquid Loading – Major Problem with Gas Well

Need for Liquid removal – Artificial Lift & Other Deliq. Methods
Common Lift Methods for Gas Well

Electric Submersible Pumping (ESP)
Plunger Lift
Reciprocating Rod Lift
Gas Lift
Hydraulic Lift
Progressing Cavity Pumping (PCP)
Foam Lift (Capillary)

Courtesy Weatherford Artificial Lift System
TWO Artificial Lift GROUPS

External Supplied Energy Systems

- Sucker Rod (Beam) Pump
- Progressing Cavity Pump (PCP)
- Electric Submersible Pump (ESP)
- Hydraulic Powered Pumps
- Jet Pump
- Downhole Eductor/Ejector
- Gas Lift.
- Other New Technology
Internal (Reservoir) Supplied Energy Systems

- Well Cycling On and Off (Timer/Stop clocking)
- Venting and Pit Blow-downs (environmentally unacceptable option)
- Surfactant (Foamer)
- Velocity String
- Well Swabbing
- Plunger
- Lower Surface Pressure with wellhead
- Straddle or central delivery point compressor
ANALYSIS & MODELING

Use several VLP Correlations to estimate $p_{wf}$ for various Artificial Lift System

Acquired Real life data and validate model results.

- $P_{wf} = CHP + \Delta P$
  - $P_{wf} =$ Flowing Bottomhole Pressure
  - $CHP =$ Casing Head Pressure
  - $\Delta P =$ Differential pressure between the surface pressure and bottom hole pressure
Reducing Wellhead Pressure

- \( Q = C \left( Pr \text{ (avg)}^2 - Pwf^2 \right)^n \) - (Back Pressure Equation)

(Wellhead Pressure \( \downarrow \) = \( Pwf \ \downarrow \) = Flow rates \( \uparrow \) and Fluid velocities \( \uparrow \))

Means:
- Central Delivery Point (CDP) Compressor.
- Straddle Compressor
- Individual Wellhead Compressor
- Resizing and re-routing flow lines (debottle-neck).

Results:
- Significant \( Q \uparrow \) for high Perm (No friction –adequate tubing size)
- Easier Economical Justification
- Need for greater Economical consideration for low perm
Tight Economy

- Close Absolute Open Flow (AOF)
- Steep slope of the IPR curve

(Difficult obtain accurate IPR for a tight fractured gas well – high DT to pseudo steady state Pr (avg).)
Pump versus Alternate Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>WHP=10 psi</th>
<th>WHP=50 psi</th>
<th>WHP=100 psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump(Beam, PCP, ESP)</td>
<td>13 psi</td>
<td>55 psi</td>
<td>107 psi</td>
</tr>
<tr>
<td>Conventional Plunger</td>
<td>45 psi</td>
<td>87 psi</td>
<td>139 psi</td>
</tr>
<tr>
<td>Continuous Flow Plunger</td>
<td>21 psi</td>
<td>61 psi</td>
<td>112 psi</td>
</tr>
<tr>
<td>Continuous Gas Lift</td>
<td>52 psi</td>
<td>90 psi</td>
<td>155 psi</td>
</tr>
</tbody>
</table>

Gas well with 120Mscfd and 10BLPD

<table>
<thead>
<tr>
<th>Method</th>
<th>WHP=10 psi</th>
<th>WHP=50 psi</th>
<th>WHP=100 psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam</td>
<td>14 psi</td>
<td>55 psi</td>
<td>108 psi</td>
</tr>
<tr>
<td>Gaslift</td>
<td>117 psi</td>
<td>167 psi</td>
<td>244 psi</td>
</tr>
<tr>
<td>ESP</td>
<td>14 psi</td>
<td>55 psi</td>
<td>108 psi</td>
</tr>
<tr>
<td>PCP</td>
<td>14 psi</td>
<td>55 psi</td>
<td>108 psi</td>
</tr>
</tbody>
</table>

Gas well with 250Mscfd and 100BLPD

- WHP = Surface pressures at the top of the flow path.
- This is CHP for beam and pumps, THP for Conv.gas lift, plunger
Sample of Actual Field Data

Plunger Lift Gauge Pilot Test (Week 1 thru 7)

<table>
<thead>
<tr>
<th>Index</th>
<th>Time</th>
<th>Text</th>
<th>BH Pres 1</th>
<th>BH Temp 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.001</td>
<td>Beginning of Test - gauges at Surfaces</td>
<td>486.23</td>
<td>70.89</td>
</tr>
<tr>
<td>2</td>
<td>0.415</td>
<td>End of Initial 72 hr Build up</td>
<td>737.05</td>
<td>251.66</td>
</tr>
<tr>
<td>3</td>
<td>0.415</td>
<td>4/22/2006 Produced well</td>
<td>732.45</td>
<td>251.59</td>
</tr>
<tr>
<td>4</td>
<td>1.991</td>
<td>5/3/2006 Soaped Well</td>
<td>683.33</td>
<td>251.32</td>
</tr>
<tr>
<td>5</td>
<td>3.848</td>
<td>5/16/2006 - installed single plunger</td>
<td>559.71</td>
<td>250.31</td>
</tr>
<tr>
<td>6</td>
<td>4.682</td>
<td>5/22/2006 end of Build up 2</td>
<td>740.47</td>
<td>251.40</td>
</tr>
<tr>
<td>7</td>
<td>4.991</td>
<td>5/28/2006 - installation of dual plunger</td>
<td>522.68</td>
<td>250.36</td>
</tr>
<tr>
<td>8</td>
<td>6.273</td>
<td>6/2/2006 Blew well down to fish tools</td>
<td>188.18</td>
<td>245.24</td>
</tr>
<tr>
<td>9</td>
<td>6.858</td>
<td>6/8/2006 final build-up before pulling gauges</td>
<td>696.92</td>
<td>251.17</td>
</tr>
</tbody>
</table>
Sample of Actual Field Data

Annular (PerfLift) Gas Lift Sample

Graph showing data over time with labels for Discharge Pressure, Intake Pressure, and Intake Temperature.
Sample of Actual Field Data

Beam Pump Case Study - Pwf

Petroleum Experts 2:
139.7 psig @ 2721'

PDHPG: 138 psig
WHP: 128 psig

Gradient traverse - plot (Leland Hill GU A1 07 Jul 08 09:26)
Sample of Actual Field Data

- ESPCP
- WHP – 125psig
- P (sensor) depth - 160psi
- Pi=140 psig
## Figure 6a: Lift Selection for De-Watering Gas Wells

**Little or NO Solids (LS)... See Flow Charts**

<table>
<thead>
<tr>
<th>Well Conditions</th>
<th>Vertical</th>
<th>Horizontal*</th>
<th>HST</th>
<th>S Shaped</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;20 bpd LS</td>
<td>(1) BP</td>
<td>(1) GL</td>
<td>(1)BP, (2)GL</td>
<td>(1)BP co-rod (2)GL</td>
</tr>
<tr>
<td></td>
<td>(2) RDPCP (hi end)</td>
<td>(2)ESP gas separation</td>
<td>(3) RDPCP SA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3) GL (lo end)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20–100 bpd LS</td>
<td>(1) BP</td>
<td>(1) GL</td>
<td>(1)BP, (2)GL</td>
<td>(1)BP co-rod (2)GL</td>
</tr>
<tr>
<td></td>
<td>(2) RDPCP (hi end)</td>
<td>(2)ESP gas separation</td>
<td>(3) RDPCP SA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3) GL (lo end)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100–Qmax bpd LS</td>
<td>(1) BP</td>
<td>(1) GL</td>
<td>(1)BP, (2)GL</td>
<td>(1)BP co-rod (2)GL</td>
</tr>
<tr>
<td></td>
<td>(2) RDPCP (hi end)</td>
<td>(2)ESP gas separation</td>
<td>(3) RDPCP SA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3) GL (lo end)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;Qmax LS</td>
<td>(1) BP</td>
<td>(1) GL</td>
<td>(1)BP, (2)GL</td>
<td>(1)BP co-rod (2)GL</td>
</tr>
<tr>
<td></td>
<td>(2) RDPCP (hi end)</td>
<td>(2)ESP gas separation</td>
<td>(3) RDPCP SA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3) GL (lo end)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>400 scf/bbl–1000*,&lt;20 bpd, Pcs&lt;1.5 p&lt;35psi LS</td>
<td>PLUNGER</td>
<td>PLUNGER</td>
<td>PLUNGER</td>
<td>PLUNGER</td>
</tr>
</tbody>
</table>

**Notes:**
- **BP** = Beam Pump with CoRod
- **RDPCP** = Rod Driven Progressive Cavity Pump
- **ESPCP** = elec sub PCP : TTC implied
- **GL** = Unconventional Gaslift (see chapter)
- **Qmax** ≈ 300–350 bpd
- **SS** = Severe Solids
- **LS** = Low Solids
- **SA** = Special Application
- *Horizontal poor for pmps
Solid and Critical Liquid Rate

2.375" Tubing w/0.875" Rods

2.375" Tubing No Rods

Critical Tubing Flow Rate vs Particle Size

For Reynolds Number 2 < N<sub>e</sub> < 500

Critical Sand Setting Rate (bbls/day)

US Standard Sieve Sizes

For Reynolds Number 2 < N<sub>e</sub> < 500

Critical Tubing Flow Rate vs Particle Size

Critical Sand Setting Rate (bbls/day)

US Standard Sieve Sizes

Courtesy Weatherford ALS
Compression achieves max rate but Economic Analysis Required

Figure 6b: Lift Selection for De-Watering Gas Wells
Severe or Heavy Solids (SS) -- See flow charts

<table>
<thead>
<tr>
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<th>Vertical</th>
<th>Horizontal*</th>
<th>HST</th>
<th>S Shaped</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;20 bpd SS (&lt;settling velocity)</td>
<td>(1)GL (2) RDPCP SA</td>
<td>(1)GL</td>
<td>(1)GL (2) BP SA (3) RDPCP SA</td>
<td>(1)GL (2) BP co-rad</td>
</tr>
<tr>
<td>20–100 bpd SS (&lt;settling velocity)</td>
<td>(1) GL (2) RDPCP SA</td>
<td>(1) GL</td>
<td>(1) GL (2) RDPCP SA (3) BP SA</td>
<td>(1)GL (2) BP co-rad</td>
</tr>
<tr>
<td>100–Qmax bpd SS</td>
<td>(1) GL (2) RDPCP depth dependent</td>
<td>(1) GL (2) ESPCP depth dependent</td>
<td>(1) RDPCP (2) GL</td>
<td>(1)GL (2) BP co-rad</td>
</tr>
<tr>
<td>&gt;Qmax SS</td>
<td>(1) GL (2) RDPCP depth dependent</td>
<td>(1) GL (2) ESPCP depth dependent</td>
<td>(1) RDPCP (2) GL</td>
<td>(1)GL (2) BP co-rad</td>
</tr>
<tr>
<td>400 scf/bbl–1000, &lt;30 bpd, Pcs&gt;1.5 LP&lt;35psi, LS</td>
<td>PLUNGER NOT APPLICABLE</td>
<td>PLUNGER NOT APPLICABLE</td>
<td>PLUNGER NOT APPLICABLE</td>
<td>PLUNGER NOT APPLICABLE</td>
</tr>
</tbody>
</table>

SS = Severe Solids
LS = Low Solids
BP = Beam Pump with CoRod for all cases
ESP = ESP Pump
GL = Unconventional Gaslift (see chapter)
Qmax = 300-350 bpd
SA = Special Application
RDP = Rod Driven Pump
Progressive Cavity Pump
Pcs = Bottomhole pressure
* Horizontal poor for pumps
Vertical Wells <20 BPD

Could use Plunger if Pressure and GLR Criteria met <20 bpd

Use Lo-Rate Beam Pump System

No or Little Solids

Vertical Well <20 BPD

Severe Solids Present

Rate > Critical

Yes

Use BP SA to lift Solids and Fluids (rate low for PCP)

For Liquid Rate < Critical Rate, Then use GL

No

OR 2nd-ly use BP SA RDPCP SA

Note: Critical Rate is rate required to lift solids above solids settling rate above pump

Consult Settling Rate Charts for rod/tubing combinations
Summary & Conclusion

- Wellhead pressure reduction in combination with liquid unloading is great for high perm well (field)
- The IPR curve is important (economical) evaluation.
- Pumping with liquid flowing up the tubing and gas flowing up the casing in a well with some rathole is much more effective than other unloading methods.
- Pumps problems may overshadow economical benefit of lowered Pwf
- Gas lift performs better at lower liquid rates.
- Unconventional (Quick drop, fast cycle, pacemaker) Plunger cycles have less effect on Pwf than conventional plunger
- If downtime can be minimized pumping systems with low runlife may still be more economical depending on Repair cost

Golden ??? (What is the economical avg runlife for your field???)
Annular Gas Lift and other unconventional Gas lift may be desirable as alternate to pumping

Currently existing liquid unloading technology methods pumping liquids off a gas well (with lowest WHP) = most capability Pwf

Pumping a gas well may not be the most economical and optimum artificial lift choice.

**Reasons**

-Solids (Severe) Production
- Gas Interference).
-Wellbore Geometry
-Low Runlife & High Failure frequency
SUMMARY

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Selection Chart

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For More Information – SPE Paper # 115950…..Peter Oyewole & James Lea
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