Activator Hydraulic Submersible Pump

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Agenda

- Technology Overview
- Technology Advantage
- Case Study and Results
- Operational Overview
- Pembina Assessment
Applications

• Low Pressure and Low Fluid Rate Gas Wells
  – Coalbed Methane
  – Conventional Gas
  – Barnett Shale

• Conventional Oil Wells
Animation Video on Operation
## Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow rate</td>
<td>0.5 to 190 bbl/day</td>
</tr>
<tr>
<td>Landing Depths</td>
<td>up to 5250 ft (to date)</td>
</tr>
<tr>
<td>OD</td>
<td>3.75” (fits in 4.5”, 5.5”, and 7” casing)</td>
</tr>
<tr>
<td>Power Source</td>
<td>Electricity, Propane, Field gas</td>
</tr>
<tr>
<td>Coil Tubing</td>
<td>3 separate strings</td>
</tr>
<tr>
<td></td>
<td>1 (1.25” production string)</td>
</tr>
<tr>
<td></td>
<td>2 (1.00” hydraulic string)</td>
</tr>
<tr>
<td>PlasCoil</td>
<td>2.5” x 2.0”</td>
</tr>
<tr>
<td></td>
<td>(1) 1” Plastic</td>
</tr>
<tr>
<td></td>
<td>(2) 5/8” Stainless Steel</td>
</tr>
</tbody>
</table>
Technological Advantages

- Ability to pump in horizontal (90 degrees) position and operational in the horizontal leg
- Easily operates between 0.5 to 190bbl/day [depth related]
- Handles frac and formation sand (utilizing sand screen)
Technological Advantages

• Cooling/lubrication system allows pump to operate in pumped-off state

• Can be easily relocated and redeployed

• Ease of operation; Operators like working with the surface controls

• Heat trace utilized from excess hydraulic oil in hoses keeps well head from freezing and will thaw out well head
Less Prone to Gas Locking

where

$$\left( \frac{P_2}{P_1} \right) = \left( \frac{V_1}{V_2} \right)^k = CR$$

CR = Compression Ratio

P2 = pressure of compressed gas at the end of the production stroke

P1 = pressure of gas when admitted into the chamber

V1 = volume in the piston chamber at the end of the intake stroke

V2 = volume occupied by the compressed gas at the end of the production stroke (i.e. “unswept volume”)

K = ratio of specific heats of the gas cp/cv (~1.29)

- The 1 gallon/stroke (3.8 L/stroke) Activator HSP has a V1 of 0.5 gallons (1.9 L) or 116 in3 (1,893 cm3) and a V2 of 2 in3 (32.8 cm3) so the volume term works out to 187 compression ratios. When P2 exceeds the hydrostatic pressure in the coiled tubing plus any static pressure on the tubing, the discharge valves will open.
Less Prone to Gas Locking

\[
\left( \frac{P_2}{P_1} \right) = \left( \frac{V_1}{V_2} \right)^k = CR
\]

where

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\( P_1 = \text{pressure of gas when admitted into the chamber} \)

\( V_1 = \text{volume in the piston chamber at the end of the intake stroke} \)

\( V_2 = \text{volume occupied by the compressed gas at the end of the production stroke (i.e “unswept volume”)} \)

\( K = \text{ratio of specific heats of the gas } cp/cv (\sim 1.29) \)

- Gas locking is possible, but with the pump able to develop 187 compression ratios, it would have to see a very low suction pressure or a very high discharge pressure. At 5,250 ft (1,600 m) and 100 psig (6.9 barg) flowing tubing pressure, flowing bottom hole pressure would have to be under 5 psig (0.3 barg) for a gas lock.
Technological Advantages

• Environment friendly
  – Low visual & noise impact
  – Reduced potential for spills/leaks
  – Pembina Institute declares HSP as a best practice
Devon Case Study: The Challenge

Conventional Gas well

- Initial Production 618Mcf/day -> no Liquid Loading
- Water inflow exceeded natural gas lifting capabilities [loaded up]
- Shut-in the well
Devon Case Study: Unfeasible Artificial Lift Solutions

Stop-Clocking
- Used but not viable long-term solution

Velocity String
- Only provided a short term solution

Pump Jack and PC pump considered
- Not feasible due to bridge plug (no cellar)
- Heat and gas-locking issues

Plunger lift
- Too much fluid and/or not enough bottom hole pressure
Devon Case Study: The Solution

Installed Activator- Hydraulic Submersible Pump

- Did not gas lock
- Doesn’t need to be sumped
- Within 12 hours the well was producing gas
Devon Case Study: The Results

• **First 2 months of Production**

• Initial flush (1 week): Producing 635Mcf/day with 31bbl/day water

• **After 2 months of Production**

• Averaging 175Mcf/day with 10bbl/day water

• Considerable gas in pump, but not gas locking

**Production Engineer’s Comments**

“Downhole pump seems to be working well. Very impressed with surface unit – good service. Runs very trouble free and extremely quiet.”
Case Study: Results

Devon: 16-30-39-18W4

- shut-in since May 1999 - liquid loading
- coil tubing corrosion failure (Dec, 2005)
- Initiated chemical batching after failure
- Chemical causing liquid foaming, unable to pump effectively as pump landed above perf's (no cellar)

Gas Rate (e3m³/day)

Shut-in since May 1999 - liquid loading
- coil tubing corrosion failure (Dec, 2005)
- Initiated chemical batching after failure
- Chemical causing liquid foaming, unable to pump effectively as pump landed above perf's (no cellar)
Devon Well Results from HSP

Devon: 6-31-36-15W4

Shut-in since November 1999 - liquid loading

Gas Rate (e3m³/day)

2.5 m³ wpd

0.5 m³ wpd
EnCana Well Results from HSP

- Landed ~4200ft
- Before pump install rate = 451 Mcf/day
- After pump install rate = 663 Mcf/day
- 48% increase in daily volumes
EnCana Well Results from HSP

Landed ~4395ft
Before pump install rate = 104 Mcf/day
After pump install rate = 340 Mcf/day
227% increase in daily volumes
Shallow/Low Pressure Gas Well Results

Shallow Gas (pump landed ~ 350 m)

- Raw Gas Rate (e3m3/d)
- Water Rate (m3/d)
- Static Pressure (psig)

Graph showing the raw gas rate, water rate, and static pressure over time from 2006-Oct to 2007-Mar.
Surface Unit on Location
Surface Unit on Location
Surface Unit Controls

HYDRAULIC CIRCUIT

1. SPOOL VALVE
2. HYDRAULIC OIL PUMP
3. FLOW DIVIDER
4. PRESSURE GAUGE
5. OIL FLOW AND TEMP GAUGE
Changing Flow Rate

Decrease Flow

Increase Flow
HSP Field Installation
HSP Field Installation
HSP Field Installation
New Coil Configuration

- All three strings in one string
- Faster and safer installation
- Installations begin in Q2 2008

PlasCoil 2.5” x 2.0”
(1) 1” Plastic
(2) 5/8” Stainless Steel
Operational Installs (small list)

- Over 45 HSP systems in operation as of March 2008
- Run life exceeding 2 years
- Deepest landed depth is ~4900 ft MD

Some Sample HSP Operational Installs

<table>
<thead>
<tr>
<th>Casing Size</th>
<th>Run Days (as of Feb 2008)</th>
<th>Max Prod. (bbl/day)</th>
<th>Average Prod. (bbl/day)</th>
<th>Landed Depth (ft)</th>
<th>BH Orientation (straight/deviated/horizontal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.00</td>
<td>755</td>
<td>101</td>
<td>50</td>
<td>3,300</td>
<td>86.5 degrees</td>
</tr>
<tr>
<td>4.50</td>
<td>665</td>
<td>63</td>
<td>19</td>
<td>2,900</td>
<td>Vertical</td>
</tr>
<tr>
<td>5.50</td>
<td>524</td>
<td>113</td>
<td>75</td>
<td>3,813</td>
<td>Vertical</td>
</tr>
<tr>
<td>4.50</td>
<td>466</td>
<td>19</td>
<td>6</td>
<td>3,410</td>
<td>Vertical</td>
</tr>
</tbody>
</table>
Operational Pump Installs

Devon Canada

- Gas well dewatering (landing depths between 820 to 3950ft)
- CBM horizontal applications (landing depths 4750ft MD); also installed HSPs with downhole sensors
- Testing Gas wells; Optimization Program

EnCana

- Conventional gas well dewatering (landing depths between 1640 to 4600ft MD)
- Tricentric configuration in gas well (deviated well with landing depth of 5100ft MD)
Operational Pump Installs

Apache Canada

- Commingled CBM wells; Horseshoe Canyon and Belly River zones
- Installation into “live” wells
- Testing various types of dewatering schedules
  - Portable HSP surface driver
  - Portable HSP system

Cordero

- Commingled CBM wells
- Low pressure and low fluid volume gas wells
- Tested other technologies
Operational Pump Installs (cont’d)

Ember Resources (pure CBM player)
- CBM application; landed horizontally (88 degrees) with landing depths 3450ft MD

Storm Cat Energy
- CBM (landing depths around 1970ft MD)
- HSP lasted PC pumps

ConocoPhillips (Canada)
- Conventional Gas dewatering
Operational Pump Installs (cont’d)

Baytex Energy Trust

- Conventional gas well dewatering

Harvest Energy Trust

- Conventional gas
- Harvest was surprised at the increase in gas volumes from HSP dewatering

Regent Resources

- Conventional Gas
Canadian Natural Resources (CNRL)

- Landed horizontally (89 degrees) into the open hole; 100ft into horizontal from heel
- TVD ~ 4500 ft ; MD 4950
- Daily production from zero to 420 mcf/day (peaked at 665mcf/day)
- Initial flush 50bbl/day ; now steady at 3bbl/day

Enerplus Energy Trust

- Conventional Gas
Operational Pump Installs (cont’d)

Compton Petroleum
  – Conventional Gas

Northpine Energy
  – Conventional Gas and Conventional Oil
Leveraging HSP technology

Portable HSP surface unit
- HSP downhole pump left in well, but surface unit is trailer mounted and portable

Portable HSP system
- Used for dewatering wells periodically
- HSP never left in wellbore; only used to dewater and then pulled out

Compression with HSP system
- Wellhead compressor combined with HSP system
- Compressor shares power from HSP surface driver

HSP for Barnett Shale
- Modified HSP system to handle higher fluid rates and greater depths
- Pilot project with major gas producer
Pembina Institute Assessment

- Pembina contracted by Global Energy
- Evaluate the triple-bottom-line of performance of competing pump technologies
  - Social
  - Economic
  - Environmental
Performance Criteria

• Noise
• Footprint and Visual Impact
• Efficiency
• Air Emissions
• Leaking
• Operational Performance
• Economic Performance
Pembina Assessment: Conclusions

The primary environmental and social benefits of the HSP are due to:

- The small size of the unit – reduced visual impact
- Reduced equipment requirements and set up time for installation and maintenance leading to reduced noise and environmental impact during set up
- Reduced chance of surface leaks due to less moving parts – Less chance of surface contamination.
- Reduced noise impacts when compared to standard packages offered with competing technologies (i.e. without sound attenuation options).
Pembina Assessment: Conclusions

“Overall the unit is packaged with environmental and social considerations in mind”

“Based on the available quantitative and qualitative data, including operator and landowner feedback, for the given application scenario, Pembina believes this pump can be considered a best practice for industry at this point in time.”
Why consider HSP?

- Ability to pump in horizontal (90 degrees) position
- Less prone to gas locking in low pressure wells
- Easily operates between 0.5 to 190bbl/day
- Handles frac and formation sand (utilizing sand screen)
- Cooling/lubrication system allows pump to operate in pumped-off state
- Installation into ‘live’ wells
- Portable enough to test marginal/suspended/liquid loaded gas wells
Contact Information

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