The Importance of Compression and Surface Pressure in Production Optimisation

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APLNG
Why emphasize the importance of Compression/Surface Pressure?

- Industry literature has very few papers on compression/surface pressure
- Almost all articles and papers on compression focus on the mechanical aspects
- I regularly hear things around the industry like – “compression doesn’t work on tight gas wells” or “my well is depleted so compression won’t be effective”
A brief survey...
Keys to prevent undervaluing compression and surface pressure

• Understand the effect of surface pressure on:
  – Critical Rate and Liquid Loading
  – Rate and Recovery
  – Artificial Lift (Part 2)
  – Compressor capacity and operating range (Part 2)

Note: All production data, examples and charts presented come from ConocoPhillips except where noted as coming from Origin CBM sites
Critical Rate and Liquid Loading

Why do all flowing gas wells make liquid and eventually load up and quit flowing?

- Produced natural gas saturated with water
- Surface temperature less than formation temperature
- Water will condense as gas flows up wellbore
- As reservoir press./velocity drops well loads with liquids
Example from typical tight gas well of Liquid Loading in Gas Well Life Cycle

Loading Up

Casing

Tubing

Loading with compression
Data on US Onshore Gas Wells gathered by Rob Sutton (Ref. #7)

- **Number of Gas Wells**
  - 448,641 (EIA 2006)
  - 334,938 (IHS Dec 2006)
- **Excludes PA**
- **Avg Rate**
  - 110 MCFD/Well
- **Tubing (IHS)**

<table>
<thead>
<tr>
<th>Size</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1/2 in</td>
<td>4%</td>
</tr>
<tr>
<td>2-3/8 in</td>
<td>79%</td>
</tr>
<tr>
<td>2-7/8 in</td>
<td>12%</td>
</tr>
<tr>
<td>Other</td>
<td>5%</td>
</tr>
</tbody>
</table>
Is the “average” gas well in USA below the critical rate?

Critical Unloading Rate Curve (Generated from Coleman Equation – Ref. #14)

2 3/8” @ 50 psig = +/−220 MCFD
Example CBM Well 1 (Origin Energy)

2 7/8” Critical Rate (Coleman)
350 MCFD @ 50 psig
Example CBM Well 2 (Origin Energy)

3.5”x7” Annulus flow, Coleman
@ 88 psig – 2080 MCFD
## Typical Australia CBM Well Critical Rate (Coleman), MMCFD

<table>
<thead>
<tr>
<th>Tubing</th>
<th>Casing</th>
<th>Flow Path</th>
<th>Surface Pressure, psig</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 7/8&quot;, 6.5#/ft.</td>
<td>7&quot;, 23#/ft.</td>
<td>Tubing</td>
<td>0.6 0.46 0.35 0.25 0.18</td>
</tr>
<tr>
<td>2 7/8&quot;, 6.5#/ft.</td>
<td>7&quot;, 23#/ft.</td>
<td>Annulus</td>
<td>3.4 2.5 1.9 1.4 0.95</td>
</tr>
<tr>
<td>3 1/2&quot;, 9.3 #/ft.</td>
<td>7&quot;, 23#/ft.</td>
<td>Tubing</td>
<td>1 0.7 0.52 0.38 0.26</td>
</tr>
<tr>
<td>3 1/2&quot;, 9.3 #/ft.</td>
<td>7&quot;, 23#/ft.</td>
<td>Annulus</td>
<td>3 2.2 1.6 1.2 0.83</td>
</tr>
</tbody>
</table>
Questions on Critical Rate

• Why do some wells continue to flow at rates below the critical rate?
  – High bottom hole pressure
  – Bubble Flow

• What happens to the liquids that are not produced at surface?
  – Injected into producing zones

• What about choking
What happens next?

Crit. Rate 400 MCFD @ 150 psig

Well Loaded probably due to pressure spikes

WHC Installed unloads well

WHC reconfig. to increase capacity lowers press. vs. using to unload

Crit. Rate 400 MCFD @ 150 psig

Ref. #5
Consistent pressure important to keep wells from loading

Production Separator Pressure

Ref. #10
Figure 2
Low Pressure Production Before & After

Before

After

MCFD

Total Volume  30 Day Moving Avg

Ref. #8
Critical Rate/Liquid Loading

- Is a pivotal concept in operating mature gas wells

- No analysis of gas wells can be done without including this concept

- Surface Pressure is a major factor in determining the critical rate and thus whether a gas well loads or whether we can keep it unloaded

- Consistent/low surface pressure is very helpful in optimisation
Pressure (Pwf) affects rate

Example Well - Fetkovich

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Rate</td>
<td>2600</td>
</tr>
<tr>
<td>Flowing Bottom Hole Pressure (Pwf)</td>
<td>190 PSIG</td>
</tr>
<tr>
<td>Reservoir Pressure (Pr)</td>
<td>280</td>
</tr>
<tr>
<td>Backpressure Exponent &quot;n&quot;</td>
<td>0.95</td>
</tr>
</tbody>
</table>

If Bottom Hole Pressure is reduced to 150 PSIG
Then:

Expected Rate: 3406 MSCFD
Pressure (Pwf) affects recovery - CSG

<table>
<thead>
<tr>
<th>Example</th>
<th>% Recovery Increase from 70 to 30 psia FBHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example A</td>
<td>20.7%</td>
</tr>
<tr>
<td>Example B</td>
<td>21.2%</td>
</tr>
<tr>
<td>Example C</td>
<td>4.9%</td>
</tr>
</tbody>
</table>
Understand how surface pressure affects rate/FBHP – Sys. Nodal Analysis

<table>
<thead>
<tr>
<th>Ref. #9</th>
<th>Well L</th>
<th>Well H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perm., md</td>
<td>0.2</td>
<td>2</td>
</tr>
<tr>
<td>Reservoir thickness, ft.</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Skin</td>
<td>-3</td>
<td>0</td>
</tr>
<tr>
<td>Depth, ft.</td>
<td>7000</td>
<td>7000</td>
</tr>
<tr>
<td>Tubing Diameter, in.</td>
<td>2.875</td>
<td>2.875</td>
</tr>
<tr>
<td>Surface Pressure, psig</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>PBHP, psia</td>
<td>670</td>
<td>670</td>
</tr>
<tr>
<td>Critical Rate, MCFD</td>
<td>900</td>
<td>900</td>
</tr>
<tr>
<td>Reservoir Pressure at Critical Rate, psia</td>
<td>1500</td>
<td>870</td>
</tr>
<tr>
<td>Increase from drop to 100 psig surface pressure, MCFD</td>
<td>200</td>
<td>1100</td>
</tr>
<tr>
<td>PBHP @ 100 psig Surf. Press., psia</td>
<td>192</td>
<td>254</td>
</tr>
</tbody>
</table>
Integrated Production Modeling – Reservoir Mat. Bal., Wellbore, Surface

IP = 8 mm cfd; GIP = 3 bcf

P = 950 psig
P = 200 psig
P = 50 psig
P = 0 psig

Ref. #6
Actual Prod. History that validates model results

Compression

Ref. #6
### Expected Recovery for Different Pressure Systems (in MMCF)

<table>
<thead>
<tr>
<th>Well type (OGIP)</th>
<th>HP (950 psig)</th>
<th>IP (200 psig)</th>
<th>LP (50 psig)</th>
<th>Ultralow (0 psig)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 bcf</td>
<td>426 (52%)</td>
<td>215 (26%)</td>
<td>168 (20%)</td>
<td>17 (2%)</td>
</tr>
<tr>
<td>3 bcf</td>
<td>1683 (65%)</td>
<td>557 (22%)</td>
<td>291 (11%)</td>
<td>53 (2%)</td>
</tr>
<tr>
<td>6 bcf</td>
<td>4385 (74%)</td>
<td>974 (18%)</td>
<td>385 (7%)</td>
<td>78 (1%)</td>
</tr>
</tbody>
</table>

Ref. #6

Well moved to lower pressure system when it reaches critical rate, no artificial lift
Typical Compression Economics

- Compressor installation capital
- Full maintenance Costs
- Company labor cost
- Fuel Gas
- Increased rate/recovery
## Wellhead Compression (WHC) Economics

<table>
<thead>
<tr>
<th>Well type (EUR)</th>
<th>Recovery</th>
<th>Project Economics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 bcf</td>
<td>17 mmcf (2%)</td>
<td>Negative</td>
</tr>
<tr>
<td>3 bcf</td>
<td>53 mmcf (2%)</td>
<td>Marginal</td>
</tr>
<tr>
<td>6 bcf</td>
<td>78 mmcf (1%)</td>
<td>Excellent</td>
</tr>
</tbody>
</table>
Wellhead Compression

- WHC only achieves desired performance when well is unloaded. Foamer, long shut-ins and/or swabbing needed.

Ref. #1

Shut in 24 hours and batch foamer
Ensure enough capacity to keep well unloaded.
Loop Line Evaluation Using Integrated Production Model (CBM Origin Energy)
Compression /Surface Pressure Strategy

- Integrated production modeling is an excellent tool to help identify the best strategy for Compression or “Debottlenecking”

- Must utilize a correlation that includes liquid hold up and loading

- WHC useful for best wells – optimize system pressures for “average” well
  - Highest cum. prod./highest productivity wells deplete to lowest reservoir pressure and are the best candidates
  - Highest rate increases are from wells near or below the critical rate
Keys to prevent undervaluing compression and surface pressure

- Understand the effect of surface pressure on:
  - Critical Rate and Liquid Loading
  - Rate and Recovery
  - Artificial Lift (Part 2)
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Note: All production data, examples and charts presented come from ConocoPhillips except where noted as coming from Origin CBM sites
Compression and Artificial Lift - Foamer

• There is synergy between using foamer and compression
  – Foamer lowers the critical rate – steadier flow
  – Foamer makes temp. higher surface press. easier to recover from
  – Foamer reduces holdup of liquid in tubing, reduces FBHP

• In Lobo Field Study 37 of 54 Wells with WHC now using continuous foamer
  – Annulus or Cap String

• Foamer could be the preferred option for better wells before compression
Foamer and WHC

- WHC effectiveness increased with foamer, having controls in place to keep the well from loading is important.
Foamer tried first on tight gas well

Install Continuous Backside Soap

Shut in and Batch Soap
Why try foamer first?

Horsepower Required at 1000 psig discharge – Must consider **fuel gas** as well as capital and operating costs

<table>
<thead>
<tr>
<th>Suction, psig</th>
<th>Horsepower/MMCFD</th>
<th>% Fuel Gas Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>309</td>
<td>5.9%</td>
</tr>
<tr>
<td>10</td>
<td>253</td>
<td>4.9%</td>
</tr>
<tr>
<td>25</td>
<td>216</td>
<td>4.2%</td>
</tr>
<tr>
<td>50</td>
<td>181</td>
<td>3.5%</td>
</tr>
<tr>
<td>125</td>
<td>130</td>
<td>2.5%</td>
</tr>
<tr>
<td>300</td>
<td>75</td>
<td>1.4%</td>
</tr>
</tbody>
</table>

Ref. #9
Compression and Plunger Lift

Figure 6-6: Performance Improvement Using Plunger Lift and Compression (Phillips and Listiak [3])
Lower surface pressure provides better pump fillage at same PBHP with potential for more production if you pump the well off.

Figure 6-7: Pressure Relations on a Pumping Well with a Gaseous Fluid Column (McCoy et al. 4)
Effect of Surface Pressure on Gas Lift System (Integrated Production Model)
Compression and Artificial Lift

• Lower surface pressure is helpful for essentially all forms of artificial lift

• Compression/lower surface pressure can be thought of as an alternate to artificial lift

• When reservoir pressure approaches surface pressure only lower pressure will help
Understand the operating range of compressors

• Well designed compressors can have a broad operating range which can be optimized to match the field/well’s performance

• Reciprocating compressors must be “configured” to achieve this optimum
Reciprocating Compressor

- Limits
  - Temp.
  - Force
  - Power
  - Pressure

- Configure
  - Clearance
  - Valves

- Performance
  - Rate
  - At Pressure
  - Match wells
Example Operating Range (CBM, Origin Energy) – Cat 3612 Engine/Ariel JGD Compressor
When is reconfiguration usually done?

- Initially upon installation
- Frequently it is not done again for many years...
- Needs to be done as often as necessary to optimise production by matching compressor performance to well/field performance
Why was “Stay in the Box” (SITB) method of config. developed?

- Consistent/Repeatable
- Objective
- Efficient
- Aligns interests of stakeholders

- **Optimises production** – *In South Texas, Full time position justified to do nothing but optimise compression*
The Completed "Box"

Increased rate from 8 MMCFD @ 235 psig to 10 MMCFD @ 170 psig

Over 1 MMCFD Uplift by matching compressor to field
Results of Implementing the SITB Method in South Texas

- Process accepted for use on both Company and Rental Units (90+)
- Reduced time doing/revisiting configurations
- Increased confidence/understanding/alignment/transparency
- Consistent improved production performance with reduced pressure/shutdowns and increased operating flexibility
Compression and surface pressure are important to optimising production

• We will not undervalue them when we understand the effect of surface pressure on:
  – Critical Rate and Liquid Loading
  – Rate and Recovery
  – Artificial Lift
  – Compressor capacity and operating range
How can we understand these things better?

- Training - field and engineering personnel
- Better communication/integration between disciplines and multi-discipline teams/approaches
- Focus on production/recovery optimisation


5. Harms, L. K., SPE 138488 - Wellhead Compression on Tight Gas Wells in the Long Run: A Follow-Up Case History on Seven Years of Success in Lobo


7. Sutton, R., 2009 ALRDC Gas Well Deliquification Workshop – US Gas Production Overview

8. Schulz, Harms, SPE 117433 An Unconventional but Definitive Analysis of a Field’s Production Improvement

9. Lea et al., Gas Well Deliquification (Book)


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