The Importance of Compression and Surface Pressure

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APLNG
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
  – Compressor capacity and operating range

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 CBM Well 1 (Origin Energy)

2 7/8” Critical Rate (Coleman)
350 MCFD @ 50 psig
## Typical Australia CBM Well Critical Rate (Coleman), MMCFD

<table>
<thead>
<tr>
<th>Tubing</th>
<th>Casing</th>
<th>Flow Path</th>
<th>200</th>
<th>100</th>
<th>50</th>
<th>20</th>
<th>2</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</td>
<td>0.46</td>
<td>0.35</td>
<td>0.25</td>
<td>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</td>
<td>2.5</td>
<td>1.9</td>
<td>1.4</td>
<td>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</td>
<td>0.7</td>
<td>0.52</td>
<td>0.38</td>
<td>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</td>
<td>2.2</td>
<td>1.6</td>
<td>1.2</td>
<td>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

WHC reconfig. to increase capacity lowers press. vs. using to unload
Consistent pressure important to keep wells from loading

Production Separator Pressure

Ref. #10
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
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></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

$IP = 8 \text{ mm cfd}; \text{GIP} = 3 \text{ bcf}$

- $P = 950 \text{ psig}$
- $P = 200 \text{ psig}$
- $P = 50 \text{ psig}$
- $P = 0 \text{ psig}$

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>

Well moved to lower pressure system when it reaches critical rate, no artificial lift.

Ref. #6
Typical Compression Economics

- Compressor installation capital
- Full maintenance Costs
- Company labor cost
- Fuel Gas
- Increased rate/recovery
<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

Wellhead Compressor Installed

Shut in 24 hours and batch foamer
Ensure enough capacity to keep well unloaded

Install WHC

Install Larger WHC

Ref. #5
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
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

Ref. #15
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
Example Operating Range (CBM, Origin Energy) – Cat 3612 Engine/Ariel JGD Compressor
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
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
References


References

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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)

References


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