Transitioning To Intermittent Gas Lift in Unconventionals

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Agenda

- Introduce Project Goals
  - Reduce GUF (Gas Utilization Factor) on low marginal producing wells (< 30 bpd)
  - Reduce total injection gas behind central facility to optimize operating costs
  - Reduce paraffin accumulation in tubing
  - Prepare well for end of life cycle (GAPL System)

- Intermittent Gas Lift (IGL) & Gas Assist Plunger Lift (GAPL) Overview & Results
  - Well selection criteria
  - Intermittent Gas Lift Overview
    - Results
  - Pilot Valve Overview
    - Results
    - Lift Efficiency
  - GAPL System Overview
    - Results

- Challenges
Artificial Lift Transition

The Premise

- Critical Lift requires a total gas rate of around 400-500 Mcf/day. Many of the wells in our Shale Unconventional wells are < 1 Mcf per bbl of oil.
- If our primary lift was going to be in continuous gas lift and each well was going to need 400 Mcf/day Injection long term then we would need ~ 260 Compressors in a field to support 4000 wells.
- We needed to adapt to a strategy that connected the amount of gas we used for lift to the amount of barrels we were lifting resulting in a lift cost in $/bbl that was somewhat consistent.
Lifting Cost Example

- **Lifting Costs:**
  - 1 3516 compressor can move ~6.1 MMCFD
  - Direct Cost: Compressor Rental
    - (3516) - $19k/month
  - Indirect Cost: Fuel Gas - $11k-18k/month
  - Total Yearly Cost - $350k - $450k
  - Cost per MCF - $.16 -$.20

<table>
<thead>
<tr>
<th>Artificial Lift Type</th>
<th>Oil Rate (bopd)</th>
<th>Gas Lift Needed (mcfd)</th>
<th>Lifting Cost ($/bbl)</th>
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</thead>
<tbody>
<tr>
<td>Continuous Injection</td>
<td>10</td>
<td>400</td>
<td>8.00</td>
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<tr>
<td>IGL</td>
<td>10</td>
<td>200-250</td>
<td>4.00-5.00</td>
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<td>Pilot Valve</td>
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<td>50-100</td>
<td>1.00-2.00</td>
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<tr>
<td>GAPL</td>
<td>10</td>
<td>50</td>
<td>1.00</td>
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In order to track and optimize we began to use GUF.

- Target GUF is based on Mcf/bbl/1000 feet.
- Typical goal GUF is near 500-1000 depending on Lift Type.
- For Example in a 10000 foot well the result would be 5 Mcf/bbl but no more than the critical rate.

Early Strategies Shown in image

<table>
<thead>
<tr>
<th>Artificial Lift Type</th>
<th>Liquid Rate (BPD)</th>
<th>Gas Lift Gas needed (Mcf/day)</th>
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<tbody>
<tr>
<td>Continuous Injection</td>
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<tr>
<td>IGL</td>
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<td>1000</td>
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<tr>
<td>Plunger Lift</td>
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<td></td>
<td>Lower Rate Well – IGL?</td>
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<tr>
<td>Continuous Injection</td>
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<td>IGL</td>
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<td>Plunger</td>
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<tr>
<td></td>
<td>Late Life – Plunger?</td>
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<tr>
<td>Continuous Injection</td>
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<td>50</td>
</tr>
</tbody>
</table>
Intermittent Gas Lift (Orifice)

- The first method in IGL is to inject a high amount of gas from surface for a short amount of time, with an extended gas lift injection shut in time
  - Objective to bring fluid to surface in slugs and extended downtime to allow well to build up a fluid level for the next cycle

- Equipment Needed:
  - Standing Valve in profile nipple below bottom gas lift mandrel
    - Objective is to catch any liquid fall back and to hold fluid level for next cycle
  - 16 or 20 port orifice valve in bottom mandrel
    - Normal unloading valves in EF are 12 ports. Having a bigger port in the orifice will allow higher gas injection to pass

- Challenges
  - Gas needed from central facility
    - Need to have enough gas in system to inject at high rates
    - Potentially an issue when multiple wells are on IGL behind the same central
  - More work needed around fluid level shots to determine lift efficiency
Intermittent Gas Lift Results

- Example Settings
  - On Cycle – Inject 1.0 MMCf/day for 40 Minutes
  - Off Cycle – Zero Injection for 135 Minutes
  - 1-2 bbls/day cycle, total injection 185 Mcf/day (GUF of 10)
  - Used with Cycling the tubing helped with Paraffin
  - Pretty Simple

- Risks/Challenges – Fluid Level shots to determine fluid inflow, Risk to GLV’s if Casing pressure rose too high we may multi-point during cycle.
Pilot Valves – Improved IGL

- Rather than intermit at the surface intermit downhole
  - Less ups and downs on the Gas Lift Gas utilization.
  - Replaces the Orifice (lowest injection point)
  - Simple – Possible intermediate step before plunger
  - If we have trouble plunger lifting.
Example well #1 was the first well to have the pilot valve and standing valve installed

- Realized reduction in gas lift injection from 300 MCF/D to 50 MCF/D (83% Reduction)
- Maintaining production similar to production rates during continuous gas lift operations
- 14 Months Continuous Operation 65 Mcf/day injection 13 bbls/day fluid.
Pilot Valve - Fluid Level Shots & Results

- Fluid level shots were taken before pilot valve cycled and after slug arrived at surface
  - Objective:
    - Determine liquid level in tubing before cycle
    - Determine efficiency (Liquid to surface/liquid level before cycle)
    - Determine well inflow after cycle

- Results:
  - 750’ of gas free fluid above standing valve (9,225’) before pilot valve cycles (~3.0 bbls)
  - 2.1 bbls of total fluid arrived at surface during cycle
  - Lift Efficiency calculated out to be ~70%
  - Slug arrived in 8 minutes with the standing valve located at 11,200’ (Slug Arrival Speed = 1400 ft/min.)

- In the past the well has plugged off the wellhead and flowline within a 4 week period.
  - With the help of the fluid level shots no paraffin has been detected since pilot valve installation (14 months running)
Gas Assist Plunger Lift (GAPL)

- New Gas Lift designs are completed with conventional mandrels in the upper section and one Side Pocket Mandrel on bottom.
- However we have many wells with SPM’s top to bottom.
GAPL Results

- Well used to be on continuously injection around EOT at 300 MCF/D
  - Injecting around EOT caused instability in the flow
  - Due to low rates and slow velocities, paraffin accumulation began to occur
- BS/SV Combo was installed in profile nipple and spiral 17” plunger was dropped
- The well remained on continuously gas lift but rates were reduced from 300 MCF/D to 50 MCF/D to provide some assistance to the plunger lift
GAPL with SPM

- Installed December 2017 in Phase 1
- System was operating only in Oman & Canada
- 8’ Long Plunger
  - 2 Conventional Plungers connected by a rod
- 10’ 10k psi Lubricator lowered by a winch system
- Operating similarly to a conventional plunger
  - Slower fall times → Lower rate wells
  - Cycling ~ 10 x day
- Reduced gas lift by > 60%
- Heavy paraffin well before → No paraffin build now
- Optimizing towards lower installation cost
Plunger Fall Tracking in GAPL well

- Plunger fall in GAPL wells is critical to optimization.
- Major Challenges
  - Paraffin
  - Length of plunger (SPM wells)
  - Fluid Level
Plunger Tracking is much like conventional gas wells however

- Larger initial tubing pressure drop when the plunger leaves the lubricator (due to weight)
- SPM’s are good indicators both acoustically and on Pressure Indication
  - The SPM’s show up really well below liquid level.
- When the plunger reaches the bumperspring it looks like a Mandrel but with Depth correlation and observing that the signature does not show it falling again you can be clear it’s on bottom
Eventually Plunger Fall time looks much like a conventional but Pressure and Fluid Level will have a major impact.

**Average Plunger Vel. (gas):** -223.91 ft/min  
**Average Plunger Vel. (Liq.):** -84.09 ft/min  
**Average Jts/min (gas):** 7.355  
**Average Jts/min (Liq.):** 2.715
Plunger Fall Challenges

- What does this look like?
SPM-GAPL Challenges

- Paraffin really slowed down plunger fall initially.
- Caused Major problems on getting to bottom.
Optimization – Minimum On Wells

Casing Pressure
Tubing Pressure

Oil Production
Water Production

Injection Rate
Production Rate

Jan 2018

Feb. 4 - 7, 2018
2018 Artificial Lift Strategies for Unconventional Wells Workshop
Oklahoma City, OK
Lessons

- Economics - wells will be very low producers
  - Plungers - $30-$40k
  - IGL - < $20k

- Operational challenges around re-entering wells
  - Mainly seeing scale (Iron Sulfide) restrictions deep
    - Pressure drops across bottom mandrel creating a cooling effect
    - Scale in profile nipple
    - Scale at EOT
    - Acid job potentially needed prior to job

- Challenges surrounding downhole setup
  - SPM Plungers can be run however they complicate things.
  - Packer set depth at 30 degree inclination
    - Is that deep enough for later in the life of the well
Pilot Valve – Fluid Level Shot Before Cycle
Pilot Valve Well - Fluid Level Shot After Cycle

Distance To Liquid: 10220 ft MD

RTTT (sec): 16.649

AV: 1225 ft

Fluid Above Tubing: 958 ft

Free Flow Above Tubing: 356 ft

Depth: 5457 ft

Flow Rate: 19.88 BPS

Pressure Buildup: 220 psi L/D @ 25 psig
Infrastructure
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