Pilot of Novel Switching Valve Self-Reciprocating Pump for Deliquification

- Michael Romer – ExxonMobil Upstream Research Company
- Matt Brown, Nick Ainsworth, and Oran Rundberg – XTO Energy
- David Bolt and Travis Bolt – Cormorant Engineering
- Randy Tolman – RC Tolman, LLC
Outline

Cormorant SVSRP Technology Overview
- Areas of Applicability
- Design Features
- Technology Progression

XTO Pilot
- Well Description
- System Diagram
- Deployment and Retrieval
- Performance
- Teardown Summaries

What’s Next?
Technology Overview

Switching Valve Self-Reciprocating Pump (SVSRP)
• Combines conventional rod pumping with novel downhole switching valve
• Fits deliquification niche

Primary Design Features
• Removal of 20-40 bfpd with 2-3/8” series pump at ~12,000ft TVD (pilot target)
• ~80 bfpd possible depending on application, pump size
• Requires single concentric string in production tubing
• Suitable for 4-1/2” and larger casing, 2-3/8” or 2-7/8” tubing
• Powered hydraulically—Single pumping skid can supply multiple pad wells
• Not limited by depth, deviation, or temperature
• Rig required only to install concentric string prior to running SVSRP
• Pumped in and out of well for servicing and re-installation
**Type I and II Artificial Lift**

**Type I AL:** Plunger Lift, Soaping

**Type II AL:** Pumps, Gas Lifting

Cormorant SVSRP Operational Area

**Production Rate (Mcfd)**

- **“Dry” Well**
- **8,000ft TVD Lift Depth**

- **“Wet” Well**

- **12,000ft TVD Lift Depth**

**Produced Liquids (bfpd)**

- **Natural Flow**
- **Unstable Flow**

- **Critical Rate**

**Typical 3 Bcf Gas Well**

400 Mcfd Critical Rate at 5 yr

**Years on Production**

0 5 10 15 20 25 30

**Production (Mcfd)**

0 500 1000 1500 2000 2500 3000

**Cumulative (MMcf)**

0 500 1000 1500 2000 2500 3000

**Type I AL:** Plunger Lift, Soaping

**Type II AL:** Pumps, Gas Lifting

Cormorant SVSRP Operational Area
## Type II Artificial Lift Comparison

<table>
<thead>
<tr>
<th>Lift Method</th>
<th>Maximum Drawdown</th>
<th>Deviated / Horiz. Wells</th>
<th>Lift Depth</th>
<th>≤ 5½” Casing</th>
<th>Accessible / Slickline</th>
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</thead>
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<tr>
<td>Gas Lift</td>
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</tbody>
</table>

Gas Well Unloading Selector courtesy of Weatherford

So what now?

Well completion may be uneconomical to produce
SVSRP Design Features

Designed to address 3 primary objectives:

1. Production Rate
   - Up to ~80 bpd depending on application, pump size

2. Initial Installation Cost
   - Uses single insert string
   - Surface pump could power SVSRPs in multiple wells

3. Replacement Costs
   - Rig not required for pump servicing
   - Pumps in and out of the well
Progression to SVSRP

Surface Switching Valve
- Prior Cormorant Systems: Single Action (T/C SA), Dual-Action (DA), 1.5 Action
- Maximum pumping output limited by transit time of hydraulic forces

Downhole Switching Valve
- First Cormorant system to incorporate an internal downhole engine valve
- Engine valve and signal rod determine the pump stroking direction with a single-conduit pressure input
## Pilot Well

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Detail</th>
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</thead>
<tbody>
<tr>
<td>Formation, Prod. Type</td>
<td>Mesaverde, Tight Gas</td>
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<tr>
<td>Well, Completion Type</td>
<td>S-shaped, Hyd. Fractured</td>
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<tr>
<td>Reservoir Press., Temp.</td>
<td>~3500–5000psi, 265°F</td>
</tr>
<tr>
<td>Water-to-Gas Ratio</td>
<td>20–500 bbl/MMscf</td>
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<tr>
<td>Gas Impurities</td>
<td>Up to 6.5% CO₂, No H₂S</td>
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<tr>
<td>Solids Production</td>
<td>Minimal</td>
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<tr>
<td>Gathering System Press.</td>
<td>~150 psi</td>
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<tr>
<td>Power Water Source</td>
<td>Field Produced Water</td>
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</table>

Map Courtesy of the U.S. Geological Survey

SVSRP Set Depth
~12,000ft TVD and ~4°/100ft DLS
Deployment and Retrieval

SVSRP 1
- Installed 2-3/8” series pump in-place. Landed inside of BHA on 2-1/16” concentric string
- Pumped out to ~2100ft with a pump truck (1.5hr); tagged with slickline to verify and pulled from there

SVSRP 2
- Deployed with pump truck at ~9gpm (3hr); verified landed with slickline
- Retrieved with slickline

SVSRP 3
- Deployed with power fluid pumping unit (~5gpm)
- Allowed to pump down overnight, SVSRP was operating in morning
• Three SVSRPs have been installed in the Pilot well (all 2-3/8” series)
  – SVSRP 1 net fluids removed were inconclusive
  – SVSRP 2 pumped with casing closed to verify action, steady when opened
  – SVSRP 3 performed consistently, more than 1.2 million engine valve cycles
• Run time has increased from 15 to 23 to 50+ days
  – Surface injection pressure range has decreased with each installation
Performance

- SVSRP 1 operated during daylight hours; SVSRP 2 and 3 were run 24hrs
- SVSRP 2 able to pump 15-25 bpd; SVSRP 3 reached 20-40 bpd
  - Casing fluid level ~1500-3000ft TVD; power fluid increased with skid mods.
  - SVSRP 3 uptime >97% in wintry conditions, <17°F average temp. during ops.
- Ratio of injected to net pumped fluid has improved with each installation
  - Theoretical η is ~5:1 with 2-3/8” series piston ODs (1.25” power, 0.75” water)
Teardown Summaries

SVSRP 1

- Inconclusive that pump was lifting fluids
- Determined that blockages in internal valving and/or flow paths limited ability to operate
- Pump served to “clean-up” well
- Mechanical components sound; SVSRP was operational following cleaning
- Improvements in circulating seal elastomers identified
- Engine valve and most other components run in SVSRP 3
SVSRP 2

- Pump stalled during operation
- Signal rod housing and engine valve (power fluid inlet side) plugged with debris
- Analysis determined debris was primarily quartz; source of influx undetermined
- Mechanical components sound; SVSRP was operational following cleaning
What’s Next?

• Further optimization of power fluid output from surface skid

• Evaluation of additional data-gathering tools

• Installation of larger pump (2-7/8” series) in this Pilot well

• Installation of 2-3/8” series pump in 1-3/4” coiled tubing concentric string in 2nd Pilot well

• Continue to retrieve, teardown, improve, and redeploy as applicable

2-3/8” vs. 2-7/8” series Engine Valves

Theoretical SVSRP Performance

2-3/8” series

2-7/8” series
Questions?
Backup
Testing began in May 2013 at the Cormorant test facility
- 15,000 ft of coil
- Oil / Water / Combination
- 8000 psi, 210°F
- Gas interference, Solids testing

Modeling
- Finite Element Model of the complete system developed to provide design and application tools for the pumps
- Model has been calibrated and validated with field and test data
Surface Unit

Uses the same SVSRP design for the surface pump
- Rod Pump technology known for reliability in pumping produced water
- Hydraulic valve, seal, and pump technologies reliable and serviceable
- Reliability and cost improvement over other high-pressure water pumps

Pumps produced water up to 4000 psi
- ~5 gpm to downhole pump
- Up to ~6 spm

Single-stage filtering system
- 200 gpm sock/bag filter
- 5-25 micron
- Duplex for ease of service

Electric or natural gas
- 10 – 30 hp
Threaded end cap with lifting eye. Contains collet for capturing pump fishing neck. Remove cap to remove captured pump. 3/8" rigid injection/return line side ports

Fishing neck sample for testing

End cap. injection/return line port on opposite side

SVSRP catch collet. Modular, with o-ring seals

Base for end cap. Welded to lubricator. Spanner wrench slots for backup tool support

Pump locator tool. Hand-thread in to determine if SVSRP in lubricator. Connected to sleeve above flange

Welded sleeve for pump locator tool

Threaded connection to remove lubricator

Flange for connection to crown valve. Ported with needle valve for pressure readings and bleed-off
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