Gas-Well De-Watering Method Field Study
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Outline

- Definition of Liquid Loading
- Description of GO System ®
- Goals of GO System ®
- Operational Highlights of GO System ®
- Case Study #1
- Case Study #2
- Differences Between Case Studies
- Additional Field Statistics
- Lessons Learned from Field Study
- Future Plans for GO System ®
Definition of Liquid Loading

• What is liquid loading?
  – Gradual build-up of well-bore fluid within the well over time

• What is the primary cause of liquid loading?
  – Decline in the formation GLR below the critical flow-rate for the applicable tubing size

• What effect does it have on the well?
  – Gradual covering up of well-bore perforations, creating back-pressure on formation and a decrease in production rates

• What types of wells does it typically affect?
  – Low-Producing Gas Wells
  – Low SBHP
  – Long Perforated Intervals
• Carrier sub(s) are spaced out along tail-pipe beneath a production packer
• GO Regulator exists inside of each sub which allows regulated gas passage
• During production, gas accumulates beneath the packer, between the tail-pipe and the casing
• As the gas builds beneath the packer, it pushes the formation liquid level down towards the carrier sub(s)
• This trapped gas is allowed to pass from the casing annulus into the tail-pipe through the regulator inside of the carrier sub
GO System ® Diagram

- Production Tubing
- Production Casing
- Production Packer
- Tail-pipe
- Fluid Level
- Formation Flow into Well-bore
- Gas-Lift System for Unloading
- Trapped Formation Gas
- Regulator
- EOT

Formation Flow into Fluid Level Regulator
Goals of the GO System ®

- Decrease the critical flow-rate beneath the packer

- Eliminate/Reduce fluid build-up across the well-bore perforations during production

- Maximize net gas production in well by maximizing the reservoir draw-down and by keeping perforations dry (near well-bore dehydration)
Operational Highlights of the GO System®

- No surface control / Driven by Reservoir (Low Maintenance)
- Allows the well to flow longer on its own without the additional expense and operational issues typically associated with gas-lift
- Regulators are slick-line retrievable
  - Interchangeable regulators give the system the flexibility to adapt to the needs of the well (Based on the production rates and flowing behavior of the well)
    - Note: Depends on casing size
Case Study #1

- Deep Gas Well in Rockies
- Perforations = 12,321’ to 13,740’ MD
- Casing = 7”, 32 #, N-80
- No Production Tubing (Flowing up casing)
- Well-Test Evaluation Date = September 24, 2004
- Production Rates
  - Water = 0 BPD
  - Oil = 0 BPD
  - Gas = 489 MCFPD
## Case Study #1 – Initial Press/Temp Profile

### Tubing Overview

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Pressure CHANGE (psia/ft)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 500</td>
<td>0.005</td>
<td>Static Profile</td>
</tr>
<tr>
<td>500 – 700</td>
<td>0.02</td>
<td>Static Profile</td>
</tr>
<tr>
<td>700 – 900</td>
<td>0.1</td>
<td>Flowing Profile</td>
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</table>

**Gas Contact @ 6240’ MD**

### Completion Overview

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Pressure CHANGE (psia/ft)</th>
<th>Description</th>
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</thead>
<tbody>
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<td>Static Profile</td>
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<tr>
<td>900 – 1000</td>
<td>0.27</td>
<td>Flowing Profile</td>
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</tbody>
</table>

**Gas / Oil Contact @ 12579’ MD**

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Feb. 1 - 5, 2010

2010 Gas-Lift Workshop
Case Study #1 – Optimization Plan

- Place well on conventional gas-lift w/ 3-1/2” tubing
- Install gas-lift system above the production packer set at +/- 12,200’ MD
- Install GO System ® beneath packer w/ 2-7/8” Tail-pipe, 2 GO ® Regulators, and EOT Depth at 12,900’ MD
  - Note: EOT depth was determined based upon a production log provided by the operator showing 100% H2O below a depth of 12,900’ MD / Cross-checked with well-test analysis (Temp Profile)
- Date of Installation – October 2004
Case Study #1 – Well-Bore Schematic

Sand Perfs
TCP perforated 120 deg phased
12321-33', 12344-371', 12400-404', 12511-528',
12538-560', 12600-580', 12610-640', 12,000-700',
12754-790', 12819-825', 12846-860', 13200-930',
12680-13000', 13033-1358', 13080-1401, 13152-2807',
13278-208', 13328-350', 13300-440', 13510-560',
14201'-505', 14.3'-740'

7'' Production Casing @ 13,800'
7'' 20# & 32# R-80 & L-80 LT&C & PLAS casing
Primary cement: 300 x 50/50 port & 400 x 33
Case Study #1 – Results w/ GO System ®

- Flowing Pressure/Temperature Log on 11/1/2004
- Gas gradient found from surface down to EOT
- Water level was found below EOT
- Gas influx (temperature cooling) was noted across each GO ® Regulator
- Production Rates – 11/1/2004
  - Water = 22 BPD
  - Oil = 10 BPD
  - Net Gas = 2 MMCFPD
  - Injection Gas = 1 MMCFPD
Case Study #1 – Final Press/Temp Profile w/ GO System ®

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Case Study #1 – Expanded Flowing Completion Profile with GO System®
Case Study #1 – Production History

Case Study #1 Production History Plot

- Net Gas
- Gas-Lift
- Water Rate
- Oil Rate

Date:
- 8/1/04
- 9/5/05
- 10/10/06
- 11/14/07
- 12/18/08
- 1/22/10

Gas Rate (MCFPD)
- 0
- 500
- 1000
- 1500
- 2000
- 2500

BBL/Day
- 0
- 100
- 200
- 300
- 400
- 500
Case Study #2

- Deep Gas Well in Rockies on Conventional Gas-Lift
- Perforations = 12,528’ to 13,487’ MD
- Casing = 7”, 32 #, N-80
- Tubing = 4-1/2” 12.6 # VAM
- No Initial Well-Test Evaluation Performed
- Production Rates = January 21, 2006
  - Water = 225 BPD
  - Oil = 0 BPD
  - Net Gas = 75 MCFPD
  - Injection Gas = 1200 MCFPD
Case Study #2 – Optimization Plan

- Place well on conventional gas-lift w/ 2-7/8” tubing
- Install gas-lift system above the packer set at +/- 12,490’ MD
- Install GO System ® beneath packer w/ 2-7/8” Tailpipe, 3 GO ® Regulators, and EOT Depth at 13,350’ MD
  - Note: EOT depth was not selected based upon a production log or well-test analysis. Depth was selected based upon a goal to keep the majority of the perforations uncovered with the ability to change the system at a later point in time.
- Date of Installation – April 2006
Case Study #2 – Well-Bore Schematic
Case Study #2 – Results w/ GO System®

- Flowing Pressure/Temperature Log on 5/3/2006
- Light mixed gas/fluid gradient found from surface down to orifice gas-lift mandrel at +/- 12,450’ MD
- Water level was found below orifice injection point down to bottom of perforations
- Minimal gas influx (temperature cooling) was noted across each GO Regulator (gas bubbling through)
  - Water = 156 BPD
  - Oil = 0 BPD
  - Net Gas = 0 MMCFPD
  - Injection Gas = 858 MCFPD
Case Study #2 – Next Course of Action

• Well was shut-in due to lack of net gas production
• Brought back on-line for Well-Test Evaluation performed on 1/16/2008
• GO System ® was evaluated again with similar results as those seen on 5/3/06 test
• Recommendation made to install annular gas-lift system
  – Inject gas down tubing / Flow up casing; Requires more injection gas to sweep annulus
  – EOT placed @ 13,500’ MD
  – Goal to artificially sweep annulus with injection gas and keep fluid off of perforations in order to maximize net gas production
Case Study #2 – Annular Flow Results

• Annular gas-lift system installed on 2/19/2009

• Only one point of gas injection possible at EOT (13,500’ MD)

• Production Rates 4/20/2009
  – Water = 625 BPD
  – Oil = 0 BPD
  – Net Gas = 0 MCFPD
  – Injection Gas = 2300 MCFPD
Differences Between Case Studies

• Primary Differences: Case Study #1 vs. Case Study #2
  – Initial well-test analysis was obtained prior to installation of #1
  – EOT for #1 was strategically set based upon temperature and production logs
  – Existence of hydrocarbon potential was identified on #1
    • Estimate of gas potential helped select tail-pipe size and size of GO® Regulators for gas passage and optimal performance
  – Case study #2 did not show any gas production with the GO system or annular lift / Minimal hydrocarbon potential existed which was not properly identified before installation
Additional Field Statistics

- Deep gas field in Texas
- Average well depth = +/- 10,000’ to 11,000’ MD
- Average perforated interval = +/- 150 feet
- Casing = 5-1/2” ; 15.5 # & 4-1/2” ; 11.6 #
- Tubing = 2-3/8” 4.7# L-80
- No initial well-test or reservoir data available prior to installation
- 29 total wells installed with GO System ®
  - Dates of installation – 2006 through 2009
- 20 wells still flowing naturally with GO System ®
  - Avg. daily production rates = 250 MCFPD ; 30 to 50 BWPD
- Need field/down-hole data to properly evaluate the system’s performance and its ability to be changed / improved
Lessons Learned from Field Study

• Primary Lessons Learned
  – Importance of data collection and/or an understanding of the well’s potential before installation of GO System ®
  – Importance of EOT depth selection in order to stay away from added water production where hydrocarbon potential may not exist (log evaluation if possible)
  – Well must have hydrocarbon potential / At least enough to critically unload the tail-pipe in order to allow the system to work properly
    • Choosing number and depth(s) of GO ® Regulator(s)
    • Choosing tail-pipe size (3-1/2”, 2-7/8”, 2-3/8”, etc.)
• Use of lessons learned will help in better selecting future candidates
Future Plans for GO System ®

• Currently developing a program in order to better identify and define design criteria for the GO System ®
  – Determine optimal number and depths GO ® Regulators
  – Estimate gas passage capabilities for sizing of regulators
• Currently developing a GO ® Regulator w/ closing capabilities
  – Will give the system the ability to work as deep as possible by allowing the upper regulators to close when the injection point reaches the regulator below it
    • Maximize reservoir draw-down
    • Maximize production rates
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