Plunger Lift Operations in the Marcellus Shale

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Overview

Plunger Lift Background

• Liquid Loading
• Vertical Wells
• Transition to Horizontal Wells
• Future of horizontal plunger lift installations
Liquid Loading in Marcellus
Conventional Plunger Lift

- 13 3/8" 1 jt. 44.50' Sanded In
- 9 5/8" 5 jts 182'
- 7" 45 jts 1809'

Tubing Design:
SN, 1 jt, 'X' nipple, 201 jts. To surface
EOT - 6390'

Marcellus Shale
6428' - 6440' - 2 SPF
6478' - 6490' - 2 SPF

DTD: 6706'
WLM TD: 6705'
Transition to Horizontal Wells

Challenges

• Tubing/Plunger Set Depth
  • Minimal Experience
• Safe Snubbing Operations
  • X and XN nipple profiles
• Plunger Type
Horizontal Installations

• Set tubing at 50°, 60°, 70°
• All solid stock plungers stick in X
  • X profile ID = 1.875”
• Shortened single pad plungers
  • 8” in length, conventional length = 12”
  • Collapsed Pad OD = 1.860”
  • Extended Pad OD = 2.000”
• Pass through X then expand
Horizontal Installations

- Tubing ID = 1.995"
- X Profile @ 10° ID = 1.875"
- Standing Valve
- XN Profile @ 69°
- EOT @ 70°
- 90° (MD 7,162, 6,514' TVD)
Echometer Testing Program

- Fall depths
  - Plungers pass X-profile
  - Plungers reach bottom
- Benefits of 2 plungers
- Plunger acceleration theory from 2010 Seminar
Echometer Testing Procedure

- Tubing/Casing Transducers
- Acoustic Trace on Lubricator
- “Listening” no gun used
Fall Profile
Two Plunger Fall Profile

- Acoustic trace behaves like a single plunger fall

- **1st Plunger  2nd Plunger**
Two Plunger Test- Liquid Production

One Plunger

Two Plungers

Single Slug

Two Slugs
Plunger Acceleration

- Plungers speed up at kickoff point, KOP (5750’)
- Velocity increase from 140 ft/min to 279 ft/min

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<th>Inc, °</th>
<th>Velocity, ft/min</th>
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Reasons for Plunger Acceleration

• Centripetal acceleration at KOP causes plunger to ride on the low side of tubing
• Flow is directed to high side of tubing reducing the resistance of the plunger’s fall
• Less flow resistance allows plunger to fall normally
• Collapsed pads reduces the surface friction between plunger and tubing ID
Preliminary Conclusions

- Plungers can pass through the X-profile and reach bottom
- Shortened Pad Plungers
- Two plungers are not needed to reach bottom
- Two plungers produce more fluid
- Plunger acceleration theory confirmed
- Encourages further testing
Testing for 90° Potential

• 53 Echometer tests for 7 different wells

• Data exported from Echometer into Spotfire to be analyzed

• Fall profiles plotted relative to KOP

• Extrapolated fall velocity trends from observed data
Single Well Analysis

- 9 tests analyzed
- Two distinct trends
- Evident in other tests
- Normalize depths and trend data

KOP = 5716 ft
Single Well Trends
Mitchell #2H-Trend after to KOP
Single Well Conclusions
Single Well Conclusions

• Polynomial trend extrapolated and compared to directional survey

• Velocity = 0 ft/min @ 77°
  – XN depth currently at 46°

• Additional 31° through curve and 400’ MD

• Plunger can fall to within 140’ of top perfs at 86°
Trend after KOP
Velocity and Inclination Trends
Conclusions

• Single well example with known inclination shows potential for extra 31° and 400’ MD
• Velocity for all 53 tests extrapolated to 0 ft/min at 74° theoretical inclination
• Average MD from 74° to 90° is 225’
• No tests actually show a velocity of 0 ft/min prior to plunger reaching EOT
• Testing will continue as tubing is installed to 90°
Additional Slides--Plunger Cycle

Liquid slug

1. Liquid Flow
2. Gas Flow
3. Valve Closes and Plunger Begins Fall

Unloading

After-Flow

Shut-in

Plunger Arrives

Casing Pressure

Tubing Pressure

Acoustic Trace

Plunger on Bottom

Plunger Hits Liquid

Liquid Flowing at Surface

(Rowlan, McCoy, Podio 2003)
Additional Slides-- Plunger Cycle

Shut in phase-Plunger is falling
Additional Slides-- 53 tests

\[ 204.5413014174 + (-0.1372636801 \times X) + (0.0011337525 \times X^2) + (-1.8976 \times 10^{-6} \times X^3) \]
Velocity Trend

$$204.5413014174 + (-0.1372636801 \times X) + (0.0011337525 \times X^2) + (-1.8976E-06 \times X^3)$$

Inclination Trend

$$-3.96 + (0.11 \times X)$$
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