Using Gas Lift to Unload
Horizontal Gas Wells

Rob Sutton – Marathon Oil Company
Conventional Gas Lift

• Application
  – Predominately liquid producers
  – Vertical/directional wells
  – Above packer
  – Reduce hydrostatic head
    • Reduce FBHP
    • Increase flow rate from reservoir
  – Avoid increased friction
    • Over injection of lift gas
    • Reduces flow rate
Well Performance Analysis

Field: Marathon
Well: Gas Lift Oil Well
Title: Vary GLR, 2.875 Tubing

Date: Feb 14, 2011
File: GLOW1X

INPUT DATA

HAGEDORN & BROWN REV. 4
PRODUCTIVITY INDEX
OPEN HOLE

- Oil grav: 45.80 Deg API
- Gas grav: 0.7670
- CO2: 4.00 %
- N2: 0.00 %
- H2S: 0.00 %
- Water grav: 1.0100
- Water cut: 75.0 %
- Form GLR: 1.500E+02 SCF/STB
- Mass depth: 7824. feet
- TVD: 5380. feet
- GL Inj Press: 1050. psia
- Tbg ID: 2.441 in
- Abs Rough: 0.00060 in
- Pwh: 100. psia
- Twh: 150. Deg F
- Tbh: 236. Deg F
- Res Press: 2250. psia
- Res Temp: 236. Deg F
- PI: 12.500 STBPD/psi

Producing GLR

- A A 150. SCF/STB
- B B 250. SCF/STB
- C C 500. SCF/STB
- D D 750. SCF/STB
- E E 1000. SCF/STB
Rate vs Total GLR Performance

Field: Marathon
Well: Gas Lift Oil Well
Title: Vary GLR, 2.875 Tubing

Optimum GLR

Date: Feb 14, 2011
File: GLOW1X

INPUT DATA
HAGEDORN & BROWN REV. 4
PRODUCTIVITY INDEX
OPEN HOLE
Oil grav 45.80 Deg API
Gas grav 0.7670
CO2 4.00%
N2 0.00%
H2S 0.00%
Water grav 1.0100
Water cut 75.0%

Form GLR 1.50E+02 SCF/STB
Max depth 7624. feet
TVD 6380. feet
GL Inj Press 1050. psi
Tbg ID 2.441 in
Abs Rough 0.00080 in
Pwh 100. psi
Twh 150. Deg F
Thb 238. Deg F
Res Press 2250. psi
Res Temp 238. Deg F
PI 12.600 STBPD/psi
Conventional Gas Lift Observations

• Factors affecting “optimum GLR”
  – Operating pressure
  – Pipe size
  – Reservoir pressure and deliverability

• Optimum GLR
  – Typical range
    • Formation GLR $<$ Optimum GLR $<$ 2,000 SCF/STB
Liquid Loading in Horizontal Gas Wells

• Clear liquid from horizontal section
  – Terrain induced slugging
  – Severe slugging
  – Stratified liquid flow

• Impact on reservoir & completion
  – Excessive drawdown may impair well
    • Evidence from Haynesville Shale presented by Petrohawk
  – Impaired productivity from liquid saturated hydraulic fractures

• Higher attrition rate compared to vertical wells
Horizontal Well Ideal Case
A Few Example Profiles

Video
Barnett Shale Horizontal & Vertical Wells

Barnett - Fraction of Annual Wells Drilled as Horizontal

Year
Fraction of Total

Barnett Shale Horizontal & Vertical Wells
HDPI & SPE 138447
Vertical vs Horizontal Well Attrition
Cleanup and Load Recovery in Vertical Fractures is Affected by Gravity, Viscous, and Capillary Forces

Flow downward, co-current at any rate, assisted by gravity. Lower Sw, better recovery and gas perm.

Possible water coning around well causing further damage?

Flow upward, co-current at high rates, counter-current at low rates, hindered by gravity.

Higher Sw, poor load recovery, and low gas perm.

From Barree & Associates
<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Water Produced (oz)</th>
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<tbody>
<tr>
<td>0</td>
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<tr>
<td>352</td>
<td>589.5</td>
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<tr>
<td>489.5</td>
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<td>591</td>
<td>620.3</td>
</tr>
<tr>
<td>634.7</td>
<td>635.3</td>
</tr>
</tbody>
</table>

Shut-in: 13 min

Mobile Water: ~1400 gm
Complex Horizontal Well Profiles

Example Horizontal Well Trajectories

Departure, ft
True Vertical Depth, ft
Well 1
Well 2

0 1,000 2,000 3,000 4,000 5,000 6,000
7,500 7,600 7,700 7,800 7,900 8,000

Well 1
Well 2
Turner Unloading Velocity

$$v_c = 1.5934 \left[ \frac{N_{we}}{30} \right]^{0.25} \left[ \frac{\sigma (\rho_L - \rho_g)}{\rho_g^2} \right]^{0.25} \left[ \frac{\sin(1.7(90 - \theta))}{0.740767} \right]^{0.38}$$

where

- $\rho_g =$ gas phase density, lbm/ft$^3$
- $\rho_L =$ liquid phase density, lbm/ft$^3$
- $\sigma =$ surface tension, dynes/cm
- $N_{we} =$ Weber Number (use 60 for original Turner)
- $\theta =$ hole angle (Deg from vertical)
- $v_c =$ critical velocity of liquid droplet, ft/sec
TNO-Shell Angle Modification for Hole Angle

- Turner Modification
  - 35% increase at 37°
Horizontal Well 1
(EOT Placement – 25°)
Horizontal Well 1
(EOT Placement – 25°)
Horizontal Well 1
(EOT Placement – 85°)
Horizontal Well 1
(EOT Placement – 85°)
Horizontal Well 1
(EOT Placement – 85°)

Casing Flow

Annular Flow

Velocity Profile

Velocity Profile

2.44-in Tubing

4.778-in Casing

2.441-in Tubing

Dead String

2.875 x 4.778-in Annulus
Observation

• “Right-size” completion – velocity management
  – Adjust setting depths and diameters to align flow velocity with velocity requirement to remove liquids

• Flowing well case – place EOT at 85-90°

• Extending tubing (dead string) into horizontal modifies the flow velocity profile but does not adequately address liquid accumulation problems
AVE Gas Lift

Annular Velocity Enhancer with Below Packer Gas Lift

Lift Gas

Production

Profile for Orifice

Crossover Assembly

Lift Gas

Production
Horizontal Well 1
(Gas Lift + Annular Flow with AVE – 2.875 x 4.778)

**Velocity Profile**

- **Gas Velocity**
- **Critical Velocity**

- **2.441-in Tubing**
- **AVE at 50°**
- **2.875 x 4.778-in Casing**

**Velocity Profile**

- **2.441-in Tubing**
- **Dead String**
- **2.875 x 4.778-in Annulus**
Horizontal Well 1
(Gas Lift + Annular Flow with AVE – 2.875 x 4.778)
Effect of Gas Lift to Achieve Critical Rate

Formation Gas Rate, MCFD

Bottomhole Pressure, psia

Horizontal Well 1
Outflow Performance - Flowing
Effect of Gas Lift to Achieve Critical Rate

Formation Gas Rate, MCFD
Bottomhole Pressure, psia

Flowing
Gas Lift

Gas lift to reach critical rate
Effect of Gas Lift to Achieve Critical Rate

- **Bottomhole Pressure, psia**
- **Formation Gas Rate, MCFD**

**Graph Legend:**
- Blue line: Flowing
- Pink line: Gas Lift
- Blue line: IPR

**Graph Highlights:**
- **Time Depletion**
- **Liquid Loading**
- **Effective Dewatering**

**Horizontal Well 1**
**Putting It All Together**
Horizontal Well 2
(EOT Placement – 89°)
Horizontal Well 2
(EOT Placement – 89°)
Horizontal Well 2
(Gas Lift + Annular Flow with AVE – 2.375 x 4.000)

Velocity Profile

Measured Depth, ft

Velocity, ft/sec

Gas Velocity
Critical Velocity

1.995-in Tubing
AVE at 50°

2.375 x 4.000-in Casing

Velocity Management
Conclusions

• Horizontal wells
  – Complex flow geometries
  – Higher attrition rate compared to verticals
    • Cause - liquid loading???

• Liquid Loading - General
  – Additional backpressure on reservoir
  – Reservoir/Completion
    • Reduced gas permeability
    • Water blocks
    • Impaired completion efficiency
Conclusions

- **Liquid Loading – Horizontal**
  - Directional effects
  - Complex geometries
    - Terrain induced slugging
    - Severe slugging

- **AVE Gas Lift**
  - Provides flow velocity management
  - Works in horizontal or vertical wells
  - Effectively keeps well unloaded
  - Avoids excessive drawdown in horizontal wells
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