Horizontal Production Solutions
Presented by Samuel Michaud
ICoTA 2011
Gas Lift

- Theory, Application, and Advantages
- Horizontal Production Challenges
- Solutions
- Coil Tubing Gas Lift
- Coil Tubing SAGD Gas Lift
Theory / Application - Gas Lift Objectives and Process

- To lift as deep as possible within constraints of production system
- Inject gas requirements through one single valve station
Applications

- Return dead or loaded wells back to production
- Increase production in flowing wells
- Wide range of production rates
- Remove or unload fluids from gas wells and/or keep gas well unloaded
- Good operation in high GOR wells
- Back flow salt water disposal or injection wells
- No moving parts
- Sand production not a major problem
Horizontal Production Challenges

• Challenges with traditional methods of artificial lift providing lift from the HZ section
• Logistics of getting equipment down around the 90 degree heel
• Life span and maintenance of equipment run past 90 degrees
• Commonly a lot of sand build-up in HZ section
Horizontal Production– Gas Lift

### Proposed Well Completion

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>114.3 mm casing set at 2179 m</td>
</tr>
<tr>
<td>1.</td>
<td>60.3 mm Bull Plug</td>
</tr>
<tr>
<td>2.</td>
<td>60.3 mm 6.99 kg/m EUE L-60 Pup Joint (5.6m)</td>
</tr>
<tr>
<td>3.</td>
<td>Weatherford SMOR-1A Side Pocket Gas Lift Mandrel 60.3 mm 6.99 kg/m EUE Box x Box 25.4 mm M&quot; Pocket with Ring Latch Profile, Special Clearance Round Cross Section, Orienting Feature and Internal Deflector Type Tool Guard Max OD 97.79 mm, Material 4130 Hilt. 25.4 mm No-1 Orifice Valve, Port Size TSD, Material Monel.</td>
</tr>
<tr>
<td>4.</td>
<td>60.3 mm 6.99 kg/m L-60 EUE Bsp x Pin Pup Joint (1.2 or 1.6 m)</td>
</tr>
<tr>
<td>5.</td>
<td>60.3 mm 6.99 kg/m EUE L-60 Tubing as Required</td>
</tr>
<tr>
<td>6.</td>
<td>60.3 mm 6.99 kg/m L-60 EUE Pin x Pin Pup Joint (2.6m)</td>
</tr>
<tr>
<td>7.</td>
<td>Weatherford SMOR-1A Side Pocket Gas Lift Mandrel 60.3 mm 6.99 kg/m EUE Box x Box 25.4 mm M&quot; Pocket with Ring Latch Profile, Special Clearance Round Cross Section, Orienting Feature and Internal Deflector Type Tool Guard Max OD 97.79 mm, Material 4130 Hilt. 25.4 mm No-1 Orifice Valve, Port Size TSD, Material Monel.</td>
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<td>9.</td>
<td>60.3 mm 6.99 kg/m EUE L-60 Tubing to surface as Required</td>
</tr>
<tr>
<td>10.</td>
<td>Tubing hanger</td>
</tr>
</tbody>
</table>

### Notes
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Horizontal Production—Gas Lift

Injecting gas down the annulus to the crossover packer

At the packer injection gas goes from annulus to tubing and injecting down tubing through horizontal section “sweeping” entire horizontal leg

Formation production is annular flow in the horizontal leg then returning to tubing production in the vertical section via the crossover packer
Coil Tubing Solutions – Gas Lift

- Coil tubing gas lift (bull plug / valve) can be run down into HZ section of tubing with ease
- Simple, reliable, minimal intervention to set up
- Unloading valves/mandrels can be spliced in to coil if required (low injection pressure)
- No moving parts - no rod wear - nothing to get jammed with sand
- No rig intervention required in most cases, can use existing tubing string
- Locked and packed into any profile nipple
- Low BHP wells, extended perforated intervals
- Below deviations where it is too risky to run packers
Coiled Tubing Gas Lift - Downhole Components

- Injection Gas
- Flow Line
- Coiled Tubing
- Gas Lift
- Mandrels and Valves
- Bull Plug

Formation
How A Gas Lift Valve Works

- 3 1/2-in. Casing
- 1 1/4-in. Coiled Tubing
- Gas Lift Mandrel
- Gas Lift Valve

[Diagram showing the components and the nitrogen charge]
Coil Tubing Gas Lift Valves

- Reduced running OD gas lift mandrels with internally mounted gas lift valves
- CT connectors are installed above and below each mandrel
- These special mandrels and valves are also used in pack-off and slim-hole, jointed pipe gas lift applications
- Provides gas lift applications without pulling well completion
Coiled Tubing Gas Lift Mandrels
Coiled Tubing Gas Lift Mandrels

Surgrip Coiled Tubing Connector Assembly
Coiled Tubing Gas Lift Surface Components

Injection Gas

CT Wellhead Connector

Flow Line

Formation
Coiled Tubing Gas Lift Installation
Gas Lift Theory / Application - SAGD

• Gas lift was one of the first artificial lift choices for SAGD operations. Gas Lift was chosen due to the low cost and its ability to accommodate the elevated temperature conditions and high fluid production rates.
• Gas lift deployed is a “poor boy” version which is simple completion consisting of production tubing landed in the producing interval – usually two strings one in heel and one near the toe. Coil tubing is run concentrically in the production tubing and gas is injected down the coil and production flows up the tubing (micro-annulus)
• Gas Lift currently accounts for ~ 45% of the market share in SAGD operations
• Inject gas into producing conduit to reduce fluid density , thus reducing the gradient
• Reduce the FBHP enough to allow fluids to flow to surface without mechanical interference
• Control injection volumes for optimal production
• Maintain a stable pressure drop across orifice valve to ensure stable inflow and consistent injection volumes which are commonly very low ~ 3-5 e3m3/day
Gas Lift Completion - SAGD

Dual tubing strings

Short string produces from the heel

Slotted liner

Long string produces from the toe

Gas injection through concentric coiled tubing & bull nose injectors

Instrumentation string
Gas Lift - SAGD - Equipment
Coil Tubing Gas Lift - Evaluation

Deviation Profile (Whd @ 3.40 meters)
Offset (meters)

True Vert Depth (meters)
Coil Tubing Gas Lift - Evaluation
Coil Tubing Gas Lift - Evaluation

FLOW RATE (m³/d)

FLOWING BTM PRES (kpag)

SIZING COIL

Inflow/Outflow Plot - NODAL ANALYSIS - GAS LIFT
Coil Tubing Gas Lift - Evaluation

Pressure Profile

Rate = 25.0 m³/d

Fluid Properties:
- Oil Gr = 801.7 Kg/m³
- Gas Gr = 0.65
- Water Gr = 1.06
- WLR = 30.0 %
- GOR = 100.0 m³/m³

Wellbore Data:
- WHP = 1000.0 kPag
- TVD = 1678.0 m
- Corr - Hage/Brown
  Anul/73.6/31.75/ 2399
  Csg/114./ 2799
Coil Tubing Gas Lift - Evaluation

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Hydraulic Jet Pump

- Theory – How They Work
- Applications – Where/Why They are Used
- Advantages
- Coil Tubing Jet Pumps
The use of high pressure fluids pumped from the surface to drive down-hole pumps.
Theory – How They Work

Power Fluid

Nozzle

Throat

Diffuser

Combination of Fluids

Formation Fluid
Theory – How They Work

Power
Fluid Pressure

Power
Fluid Velocity

Nozzle

Throat

Diffuser

\( P \)

\( \frac{P}{N} \)

\( P_s \)

\( P_a \)

\( P_d \)
Theory – How They Work

Nozzle

Secondary Flow

Mixed Flow

High Velocity Core

Throat

Diffuser

PN

QN

PS

QS

Pd

Qt
Applications – Where They Are Used

- Horizontal/Deviated Wells – Can be landed at 90°
- Sandy and Gassy Production – No Moving Parts Downhole
- FFR Frac Fluid Recovery – Highly Flexible
- Production Testing – Moveable Surface Assets
- Idle Well Revival – Can Land in Existing Tubing String
- Dewatering Gas/CBM Wells – Coil Jet Pump
- Backup for ESP & Gas Lift – Can Land in Sliding Sleeve
- Corrosive/Scaly/Waxy Wells – Power Fluid Additives
- Permanent Production – Low Maintenance
- Remote Locations – Pump Retrievable without Wireline/Service Rig
Hydraulic Jet Pump - Advantages

- No moving parts downhole
- High volume capability
- Run and retrieve via wireline or “free” circulation
- Deviated and horizontal wells
- No rods in tubing
- Tolerant of solids, corrosive fluids, gas
- Excellent for producing viscous crude
- Adaptable to existing BHA’s and sliding sleeves
- Repairable at well site
- Low pump maintenance, easy to repair
Coil Tubing Jet Pump

- Installs without pulling tubing
- Can be run in directional or horizontally completed wells
- Capable of “free pump” operation; circulates in and out hydraulically
- Jet pump design adaptable to a wide variety of well conditions and configurations

-Casing Used As Gas Vent for Liquid Wells or Gas Production for Gas Wells
Coil Tubing Jet Pump Completion
Each jet pump application will have unique surface requirements.

Essentially what is needed:

1. Reservoir Vessel / Separator – Stores produced fluid and power fluid, dumps to flowline or storage tank. Can act as a separator or be used in conjunction with another separation vessel, provides power fluid to Triplex.

2. Multiplex or HPS Pump – Provides power fluid to the jet pump. Can be fed either from a separation vessel or from water tanks.
Issues With Production:
- Highly deviated wells
- Unknown well capability

Coil Jet Pump Solution:
- Produced variable rates from 8 – 130m³/day
- Enabled client to develop PI/IRP’s for each well
- No operating expenses were incurred to change the nozzles and throats as they were installed “free style”
- Pumps have operated with no incidents or downtime
Jet Pump – Design & Evaluation

- P = IPR at Pump Depth
- C = Cavitation
- PP = 27 MPa PF
- V = IPR at Perforation Depth

Production Rate (M3/D) = 15 M3/D at 2 MPa Pump Intake Pressure

- Production Fluid Cavitation Region
- Power Fluid Cavitation Region

10/18/2017
113119:03
Jet Pump – Design & Evaluation

**Injection Pressure** = 20.0 MPa

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Production Rate</td>
<td>5.5 M3/D</td>
</tr>
<tr>
<td>Injection Rate</td>
<td>140.6 M3/D</td>
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<tr>
<td>Horsepower to Jet Pump</td>
<td>50.2 HP</td>
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<tr>
<td>Pump Intake Pressure</td>
<td>5.9 MPa</td>
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<tr>
<td>Discharge Pressure</td>
<td>24.4 MPa</td>
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<td>Cavitation Rate</td>
<td>51.0 M3/D</td>
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**Injection Pressure** = 23.3 MPa

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<th>Parameter</th>
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<tr>
<td>Production Rate</td>
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<tr>
<td>Injection Rate</td>
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<tr>
<td>Horsepower to Jet Pump</td>
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<tr>
<td>Pump Intake Pressure</td>
<td>4.1 MPa</td>
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<tr>
<td>Discharge Pressure</td>
<td>24.6 MPa</td>
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<tr>
<td>Cavitation Rate</td>
<td>41.8 M3/D</td>
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**Injection Pressure** = 26.7 MPa

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<tbody>
<tr>
<td>Production Rate</td>
<td>14.8 M3/D</td>
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<tr>
<td>Injection Rate</td>
<td>159.0 M3/D</td>
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<td>Horsepower to Jet Pump</td>
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<tr>
<td>Pump Intake Pressure</td>
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<tr>
<td>Discharge Pressure</td>
<td>24.8 MPa</td>
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<tr>
<td>Cavitation Rate</td>
<td>31.3 M3/D</td>
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**Injection Pressure** = 30.0 MPa

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<tbody>
<tr>
<td>Production Rate</td>
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<tr>
<td>Injection Rate</td>
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<td>Horsepower to Jet Pump</td>
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<tr>
<td>Pump Intake Pressure</td>
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<td>Discharge Pressure</td>
<td>25.0 MPa</td>
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<tr>
<td>Cavitation Rate</td>
<td>20.3 M3/D</td>
</tr>
</tbody>
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**WELL DATA SUMMARY**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Customer</td>
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<tr>
<td>Date</td>
<td>10/18/2011</td>
</tr>
<tr>
<td>Field &amp; Well</td>
<td></td>
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<tr>
<td>Location</td>
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</tr>
<tr>
<td>Run ID</td>
<td>113119-03</td>
</tr>
</tbody>
</table>

1. Perforation Depth (m) : 2108.0
2. Pump Vertical Depth (m) : 2190.0
5. Casing ID (mm) : 62.0
6. Tubing OD (mm) : 38.7
7. Tubing ID (mm) : 31.8
8. Return Tubing ID (mm) : N/A
9. Tubing Length (m) : 2265.0
10. Pipe Cond (1) new(2) avg(3) old : 2
11. Oil Gravity (API) : 35.000
12. Water Cut (%) : 75.00
13. Water Specific Gravity : 1.050

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Oilmaster 7X Jet Pump Performance Summary for User Target Specified Production Rate of 15.0 m3/D at 2.28 MPa Pump Intake Pressure

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Injection Pressure</td>
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<tr>
<td>Injection Rate</td>
<td>159.5 M3/D</td>
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<tr>
<td>Horsepower to Jet Pump</td>
<td>76.4 HP</td>
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<tr>
<td>Pump Intake Pressure</td>
<td>2.2 MPa</td>
</tr>
<tr>
<td>Discharge Pressure</td>
<td>24.0 MPa</td>
</tr>
<tr>
<td>Cavitation Rate</td>
<td>30.6 M3/D</td>
</tr>
</tbody>
</table>
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