Design, Surveillance and Optimization of Gas Lifted Wells with a Case Study

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Goals

- Establish feasibility
- Design the Gas Lift system
- Run unloading simulation
- Real Time Monitoring and Optimization
- Re-Design well for reservoir depletion
Establish Feasibility - Questions

What are the questions?

- Is the well flowing naturally?
- Does it meet the target production rate?
- Is injection gas available?
- Do I have compression capabilities?
Establish Feasibility – Model Requirements

- Fluid Properties (PVT Data)
- Reservoir Data
- Well Deviation and Completion Data
Gas Lift Design – Setup Model and Analyse

No Flow Possible

[Diagram showing the relationship between FBHP (psia) and Flow Rate (STB/d) with regions labeled as Outflow and Inflow]
Gas Lift Design – Setup Model and Analyse

Set injection inputs:

- Use Injection gas – 1500 MSCF/d
- Use Casing head pressure – 1200 psia

Determine outputs

- Production Rate
- Injection Depth
Gas Lift Design – Setup Model and Analyse

Injection Gas
1500 MSCF/d

Does this meet the target requirements?
Gas Lift Design – Sensitivity Analysis

• Set injection input sensitivity values:
  ➢ Use Injection gas – 200 – 5000 MSCF/d
  ➢ Use Casing head pressure – 1200 psia

• Determine outputs
  ➢ Production Rates
  ➢ Injection Depths
  ➢ Payback Ratios
Gas Lift Design – Analyse Results

<table>
<thead>
<tr>
<th>Operating Pressure (psia)</th>
<th>Liquid Rate (STB/d)</th>
<th>Oil Rate (STB/d)</th>
<th>Water Rate (STB/d)</th>
<th>Formation Gas Rate (MMSCF/d)</th>
<th>Injection Gas Rate (MMSCF/d)</th>
<th>Water Cut (Fraction)</th>
<th>Produced GOR (SCF/STB)</th>
<th>Injection MD (ft)</th>
<th>Payback Ratio (STB/MMSCF)</th>
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Gas Lift Design – Operating Range

![Graph showing production rate vs. QGI (MMSCF/d)]

- **Diminishing Returns**
Based on the production decline curve, the cumulative production can be determined.

Use material balance or reservoir model to predict reservoir pressure.
Gas Lift Design – Operating Range

- **P1 = 5000 psia**
  - WC = 20%

- **P2 = 3500 psia**
  - WC = 60%

Operating Range
Gas Lift Design – Operating Depth

P1 = 5000 psia
WC = 20%

P2 = 3500 psia
WC = 60%

Depth Range

Injection Depth (ft)

Injection Rate (MMSCF/d)
Gas Lift Design - Procedure

When you click the *Design* button

**First:**
- The temperature profile is calculated using the model selected
- *Objective tubing flowing gradient* is computed top down
- The gas is “forced” at the computed MD of injection

**Second:**
- Space unloading valves and define operating valves. Below operating valve space dummy valves according to minimum spacing
Gas Lift Design – Flow Parameters

• Design Conditions
  ➢ Kick off Pressure
  ➢ Maximum Casing Head Pressure

• Design Rates
  ➢ Liquid Rate
  ➢ Gas Injection Rate

• Gradients
  ➢ Static Fluid Gradient
  ➢ Injection Gas Gravity

• Extended Spacing Gradient
Gas Lift Design – Design Options

- Valve Type (IPO / PPO)
- Valve Manufacturer / Model
- Casing Pressure Drop
- Deepest Point of Injection
- Valve differential pressure
- Min. Valve Spacing
- Valve Positioning
- Round-off Valve Depth
Gas Lift Analysis Workbench (AWB)

- Management By “Exception”
- Monitor Well Production
- Integration with Analysis Tools
- User Customizable
- Well and Network Optimization
Gas Lift AWB

Injection Depth

Inferred vs. Measured

Q_o
Q_g
Q_w

CHP
QGI
THP
WHT
Gas Lift AWB

- Monitor Real-Time Data
- Accurate Well Tests
- Compare Production

Maintain Production
Gas Lift AWB: Maintaining Production

Test Parameters
- Well Head Pressure
- Well Head Temperature
- Lift Gas Injection Rate
- Injection Pressure
- Flow Rates
  - $Q_o$
  - $Q_w$
  - $Q_g$
Gas Lift AWB: Maintaining Production

- Verify Model Date and Accuracy
- Check Operating Point
- Verify Flow Correlation Factor
- Check Valve Status
- Check Injection Depth
- Check Gas Lift Performance
Gas Lift AWB : Tuning Well Test

• Determine flow correlation factor
  ➢ Based on Well Test Data
  ➢ Based on Flowing Gradient Survey

OR

• Determine Reservoir Pressure and Productivity Index by Regression
  User will select from the well tests (1 to 5) to perform the regression.
Gas Lift AWB : Tune Flow Correlation
Gas Lift AWB : Tune IPR

- Average Reservoir Pressure
  - Material Balance or Reservoir Simulator

- Productivity Index
  - Fractured reservoir model
  - Parameters:
    - Fracture Width, Height and Half Length
    - Fracture Permeability
    - Skin Factor (Damage, Choke)
Gas Lift AWB: Maintaining Production

Unloading Valve Behavior

- Orifice Flow
- Transition Flow
- Throttling Flow

Gas Passage

Downstream Pressure → Upstream Pressures
Weatherford Artificial-Lift Systems is the only service company to fund a joint industry project called the Valve Performance Clearing House (VPC). It therefore has the license to use the VPC dynamic valve performance data.
Gas Lift AWB : Maintaining Production

• Thornhill – Craver
  ➢ Easy to use, Highly Inaccurate

• API Simplified
  ➢ Based on API RP 11V2

• Winkler Eads
  ➢ Modifies T-C for the flow area

• VPC Correlation (Valve Performance Clearing House JIP)
  ➢ Most Accurate, Based on dynamic flow testing
Gas Lift AWB : Maintaining Production

Analog Alarms

- CHP
- WHT
- THP
- QGI
Gas Lift AWB: Maintaining Production

Intelligent Alarms

- Multi Point Injection
- Tubing Hole Alarm
- Tubing Hole Warning
- Shallow Injection Depth
- May be Slugging
- Custom
Gas Lift AWB: Maintaining Production

- Multi Point Injection Based on Nodal Analysis
- Tubing Hole Alarm Lo Lo CHP, Hi QGI
- Tubing Hole Warning Lo CHP, Hi QGI
- Shallow Injection Depth Lo CHP
- May be Slugging Lo or Hi THP, Lo or Hi CHP
Gas Lift AWB: Maintaining Production

- Calculate inferred production
  - Show injection status
    - No injection point found
    - Multi point injection
    - Shallow valve injection
    - Deepest valve injection
  - Delta Q chart
    - Historical trend of production difference between inferred and actual values
Gas Lift AWB : Lift Gas Optimization

• Equal slopes optimization
  – Distributes the available gas optimally
  – Easy to implement
Gas Lift AWB : Lift Gas Optimization

- Equal slopes optimization
  - Methodology:
    - Compute LGR curves for daily avg. THP
    - Compute slope \( \frac{dQ_{go}}{dQ_{gi}} \)
    - Get cumulative curve
    - Determine optimum slope
    - Derive individual well optimum rates
Gas Lift AWB : Lift Gas Optimization
Gas Lift AWB : Lift Gas Optimization

**dQo/dQGI vs. Cumulative QGI**

- **Slope**
  - Current Available Gas

**QGI**
- 0
- 200
- 400
- 600
- 800
- 1000
- 1200
- 1400
- 1600
- 1800

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Gas Lift AWB: Lift Gas Optimization

Total production from the asset is the sum of Qo for all wells.
Gas Lift AWB: Lift Gas Optimization

Composite Curve (Cum Qo vs. Cum QGI)

Does it make sense to inject more gas to increase production?
Gas Lift AWB: Lift Gas Optimization

Price $ Qo vs. Cost $ QGI

Cost includes cost of injection gas + compression costs
Price includes price of crude oil produced – transportation costs

Does it make economic sense?
Gas Lift AWB: Lift Gas Optimization

- Surface network optimization
  - Models compressors, chokes and pipelines
  - Detailed optimization method
Gas Lift AWB : Lift Gas Optimization
Gas Lift AWB : Lift Gas Optimization

• Advantages
  – Detailed model will recommend choke settings
  – Accounts for pressure losses in pipelines

• Disadvantages
  – Detailed model is required and needs to be updated
  – Actual behavior of chokes different than analysis results