Innovating Gas-Lift for Life of Well Artificial Lift Solution

“The Unconventional Solution!”

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Unconventional Oil & Gas Resources
Unconventional Oil & Gas Resources

<table>
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<th>Huge Conventional Fracture Stimulation</th>
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- Unconventional Oil & Gas
- Huge Conventional Fracture Stimulation
## Unconventional Oil & Gas Resources

<table>
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<th>Slick Water Fracture Stimulation</th>
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![Image of oil and gas wellhead](image)
Unconventional Oil & Gas Resources

Horizontal Drilling
Unconventional Oil & Gas Resources

Horizontal Drilling With Multi-Stag Fracture
Unconventional Oil & Gas Resources

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Horizontal Drilling With Multi-Stag Fracture
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Conventional Facility & Artificial Lift Design
Unconventional Oil & Gas Resources

Unconventional Facility & Artificial Lift Design
Re-circulative Gas Lift
Re-circulative Gas Lift Benefits

1. No down hole equipment other than tubing
   – Eliminates all down hole maintenance
   – Accommodates low cost cleanout
Re-circulative Gas Lift Benefits

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2. Accommodates all fluids
   - Liquids, Solids, High GOR
Re-circulative Gas Lift Benefits

1. No down hole equipment other than tubing
   – Eliminates all down hole maintenance
   – Accommodates low cost cleanout

2. Accommodates all fluids
   – Liquids, Solids, High GOR

3. Provides deep depletion
An Unconventional Artificial Lift Solution For Liquids Rich Gas?
An Unconventional Artificial Lift Solution For Liquids Rich Gas?

1. Free Flowing well as long as possible!
An Unconventional Artificial Lift Solution For Liquids Rich Gas?

1. Free Flowing well as long as possible!
   • Install compression
How Does Compression Impact The Critical Rate To Lift Liquids
3 1/2” Tubing 12000ft Vertical well

**Graph:**

- **Title:** LGR vs Critical Rate (mcf/d)
- **X-axis:** LGR (bbls/mmcf water 1.1 SG)
- **Y-axis:** Critical rate to Lift Liquids (mcf/d)
- **Legend:**
  - 1250psi
  - 1000psi
  - 750psi
  - 500psi
  - 350psi
  - 200psi
  - 100psi
  - 1 psi

The graph illustrates the relationship between LGR and the critical rate required to lift liquids for different pressures, showing how critical rate increases as LGR increases.
3 1/2" Tubing 12000ft Vertical well

LGR vs Critical Rate (mcf/d)

Critical rate to Lift Liquids (mcf/d)

LGR (bbls/mmcf water 1.1 SG)

- 1250psi
- 1000psi
- 750psi
- 500psi
- 350psi
- 200psi
- 100psi
- 1 psi
How Does Compression Impact The Bottom Hole Flowing Pressure
3 1/2” Tubing 12000ft Vertical well

BHFP vs LGR

LGR (bbls/mmcf Water SG 1.1)

BHFP (Psi)

1250 psi
1000 psi
750 psi
500 psi
350 psi
200 psi
100 psi
1 psi
3 1/2” Tubing 12000ft Vertical well

BHFP vs LGR

BHFP (Psi)

LGR (bbls/mmcf Water SG 1.1)

1250 psi
1000 psi
750 psi
500 psi
350 psi
200 psi
100 psi
1 psi
Unconventional Compressor Design
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1. Capable of Using All HP
Unconventional Compressor Design

1. Capable of Using All HP
2. Can accommodate all Suction / Discharge pressure combinations
150 HP - 800 Psi Discharge

Gas Rate (MMcf/d) vs. Suction Pressure (psi)
Unconventional Compressor Design

1. Capable of Using All HP
2. Can accommodate all Suction / Discharge pressure combinations
3. Annual Maintenance
An Unconventional Artificial Lift Solution For Liquids Rich Gas?

1. Free Flowing well as long as possible!
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An Unconventional Artificial Lift Solution For Liquids Rich Gas?

1. Free Flowing well as long as possible!
   - Install compression
   - Install Tubing
Unconventional Wellbore Design
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1. Design Tubing for optimum depletion
Unconventional Wellbore Design

1. Design Tubing for optimum depletion
   - The larger the better!
Unconventional Wellbore Design

1. Design Tubing for optimum depletion
   - The larger the better!
   - Install friction reducing coatings
Unconventional Wellbore Design

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   - The larger the better!
   - Install friction reducing coatings
   - Eliminate upsets to reduce turbulence
Unconventional Wellbore Design

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2. Install Surface Flow control valve to allow annular production
Unconventional Wellbore Design

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3. Eliminate all downhole equipment!
The Difficulties of Well Startup

- Gas Column in Casing
- High Casing Pressure
- Full Column of Liquid
- Zero Tubing Pressure
Well Startup Without GL Valves

Push liquids back into The Formation
Well Startup Without GL Valves

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Push liquids back into The Formation
Well Startup Without GL Valves

Break Circulation With Minimal HP
Unconventional Wellbore Design

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2. Install Surface Flow control valve to allow annular production

3. Eliminate all downhole equipment!

4. If necessary provide capability to store gas in the wellbore
Concentric Tubing Gas Storage

2 7/8" Production tubing

Gas Storage

4 1/2 " Csg

7 " Csg

4.5" liner
Parallel Tubing Gas Storage

- 2 3/8” Injection tubing
- Gas Storage
- 2 7/8 “ Production Tubing
- 7 “ Csg
- 4.5” liner
An Unconventional Artificial Lift Solution For Liquids Rich Gas?

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   - Install compression
   - Install Tubing
An Unconventional Artificial Lift Solution For Liquids Rich Gas?

1. Free Flowing well as long as possible!
   - Install compression
   - Install Tubing

2. Installation of re-circulative Gas lift system.
Unconventional Gas Lift Design
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1. Re-Circulative Gas Lift Control System
Unconventional Gas Lift Design

1. Re-Circulative Gas Lift Control System
   - Well site intelligence
Unconventional Gas Lift Design

1. Re-Circulative Gas Lift Control System
   - Well site intelligence
   - Real time Critical rate determination
Unconventional Gas Lift Design

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   - Real time production optimization
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2. Low Maintenance control valve design
Unconventional Gas Lift Design

1. Re-Circulative Gas Lift Control System
   ▪ Well site intelligence
   ▪ Real time Critical rate determination
   ▪ Real time production optimization

2. Low Maintenance control valve design

3. Blanketed Blow Case providing safe depletion into a deep vacuum.
Vessel Design
Vessel Design
Gas Flow Path
Gas Flow Path
Gas Flow Path
Liquid Flow Path

Level Switch
Liquid Flow Path

Level Switch
Liquid Flow Path

Level Switch
Liquid Flow Path

Level Switch
Liquid Flow Path

Level Switch
Liquid Flow Path

Level Switch
3rd Generation
PROTOTYPE
Gas Lift Case Study
Gas Lift Case Study

- Vertical Gas Well
Gas Lift Case Study

- Vertical Gas Well
- Perforations 1799m – 1819m
Gas Lift Case Study

- Vertical Gas Well
- Perforations 1799m – 1819m
- 3 ½” tubing landed @ 1800 m
Gas Lift Case Study

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- Gas relative density – 0.8
Gas Lift Case Study

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- Condensate Gravity – 54 deg API
Gas Lift Case Study

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- Cum Gas 14.6 BCF
Gas Lift Case Study

- Vertical Gas Well
- Perforations 1799m – 1819m
- 3 ½” tubing landed @ 1800 m
- Gas relative density – 0.8
- Condensate Gravity – 54 deg API
- Cum Gas 14.6 BCF
- Reservoir pressure – 100 psi
Pool Cumulative Gas
Pre Gas Lift Production Rates
Downsize Tbg 3 1/2” -> 2 3/8”

October 1999

Log Calendar Day Rate vs Time

Cal Dly Gas: 216.28 mcf/d
Date: Jan 2015
December 2002
Change Wellhead from 3 1/2” -> 2 3/8”
Install Plunger lift
March 2003
Upsize Tbg
2 3/8” -> 3 1/2”
Install Plunger Lift

Log Calendar Day Rate vs Time

Cal Dly Gas: 216.28 mcf/d
Date: Jan 2015

Cal Dly Gas (mcf/d) Cal Dly Wtr (bbl/d) Cal Dly Cnd (bbl/d) VWT (%)
October 2014
Gas lift Compressor Installed

Fluid Rate
5 bbls/d
Competing Well Production Rates after installation of Gas lift compressor
Critical Rate
1 psi Tbg – 25 bbls/mmcf liquids

• Predicted
Critical Rate
1 psi Tbg – 25 bbls/mmcf liquids

• Predicted
  – Hagedorn Brown 310 mcf/d
Critical Rate
1 psi Tbg – 25 bbls/mmcf liquids

• Predicted
  – Hagedorn Brown 310 mcf/d
  – Beggs & Brill 466 mcf/d
Critical Rate
1 psi Tbg – 25 bbls/mmcf liquids

- Predicted
  - Hagedorn Brown 310 mcf/d
  - Beggs & Brill 466 mcf/d

- Actual 350 mcf/d
Bottom Hole Pressure
1 psi Tbg – 25 bbls/mmcf liquids

• Predicted
Bottom Hole Pressure
1 psi Tbg – 25 bbls/mmcf liquids

• Predicted
  – Hagedorn Brown  93 kPa
Bottom Hole Pressure

1 psi Tbg – 25 bbls/mmcf liquids

• Predicted
  – Hagedorn Brown 93 kPa
  – Beggs & Brill 241 kPa
Bottom Hole Pressure
1 psi Tbg – 25 bbls/mmcf liquids

• Predicted
  – Hagedorn Brown  93 kPa
  – Beggs & Brill   241 kPa

• Actual          320 Kpa
Questions....