High Pressure Gas-Lift: Is Industry Missing a Potentially Huge Application to Horizontal Oil Wells?

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- **Encline Artificial Lift Technologies LLC**

What is High Pressure Gas-Lift

- Operating at Elevated Surface Pressures
  - Surface injection pressures up to ~4000 psi
    - CNG compressor cylinders, 5000# casing ratings
  - Injection pressure simply the producing BHP when gas head and friction calculated
  - Similar to unloading well with coiled tubing and nitrogen
  - Practiced to a degree offshore

What is High Pressure Gas-Lift

- Possible elimination of Gas-Lift Valves
  - If producing BHP below 4500 psi, can inject through orifice above packer
    - Otherwise known as single point injection
    - No gas-lift valve required
  - One valve increases this to ~6000 psi

What is High Pressure Gas-Lift

- Presence of gas throughout entire flow string, not just from the gas-lift valve to surface
  - Increases the efficiency and effectiveness of injected gas
- As well declines, injection pressure declines to that of conventional gas-lift
  - High Pressure only present when needed due to higher BHP
  - Limited downside

What is the Application for Horizontal Oil Wells?

- Makes annular gas-lift possible using small tubing
- Can potentially eliminate expensive and failure prone ESP’s as initial form of artificial lift
- Allows Gas-Lift to be the single and only form of artificial lift needed
  - “Life Cycle” of Artificial Lift ?

Gas-Lift Training Video (Youtube – Diker)

Traditional Gaslift / Continuous Gas Circulation

- Traditional gaslift utilizes designs that begin in the 1000 psi injection pressure range
  - As flowing BHP falls, injection drops to lower valves, and ultimately an orifice just above the packer
  - Injection pressures steadily decrease while working way down to orifice
  - FBHP's around 500 psig possible for 10000 Foot depth for liquid rates below 50 BPD

Traditional Gaslift / Continuous Gas Circulation

- **As fluid volumes fall, GOR increases to the point that the well essentially behaves as a gas well**
  - **Concept of CGC (Continuous Gas Circulation – Jim Hacksma at 2008 Gas Well Deliquification Workshop) comes into play**
  - **Efficiency can be improved by adding plunger (Eric Perner / Stan Lusk at 2015 Gas Well Deliquification Workshop) and handle rates of 200-250 BFPD**
  - **FBHP's around 300 psig possible for 10000 Foot depth**
- ***Gas-Lift can be a cradle to grave operation***

Limitations of Traditional Gaslift

- **Normal tubing diameters pose a restriction at rates above 500 BFPD, as gas occupies a large percentage volume inside the tubing**
  - **Hence, only large tubing or reverse flow can lift high volumes**
  - **Many operators utilize submersible lift for new horizontal wells, where external energy is used to offset the friction of flowing up these small tubing diameters**

Limitations of Traditional Gaslift

- Alternative of Reverse Flow solves problem of friction loss, as cross-sectional area is up to 3 times greater
  - 5-1/2” 23# casing with 2-1/16” IJ tubing has annular capacity of .0957 ft3/ foot
  - 2-7/8” 6.5# , the largest size for 5-1/2” casing, has capacity of .0325 ft3/ foot
  - Annular area is 2.95 times the tubing area
  - High Pressure Gas-Lift enables large volumes to be transported to the bottom of the well through a small conduit such as 2-1/16” IJ tubing

High Pressure Gas-Lift History

- Apparently has been used offshore with large tubing diameters
  - Conventional flow direction used due to safety valves
  - Schlumberger Xlift Valve developed for High Pressure
    - Originally designed for deepwater gas-lift
    - Provide deeper injection points, 5000 psi injection
- Literature scan showed injection pressures of 1600 to 1850 psig, but hearsay says up to 5000 psi common offshore
- This is nothing new…

High Pressure Gas-Lift History

- SPE 14347 by R.J. Dickens of Exxon in 1988: High-Pressure Gas Lift for Deep, Sour Production
  - High Pressure Gas-Lift used to produce sour Smackover formation at 15,200 feet in Jay Field in Florida by Exxon
  - Although 7000 psi available, 3000 psi injection pressure with "two or three" mandrels chosen due to casing integrity concerns

" A deep gas-injection depth minimizes the injection gas volume required to reach the minimum flowing gradient, providing for the maximum drawdown at the perforation depth."

High Pressure Gas-Lift

- Why is it applicable now?
  - Operators desire to produce new horizontal oil wells at high rates to improve their profitability
    - Traditional gas-lift up tubing underperforms submersible lift in this application
  - With annular lift, frictional losses are born by the compressor, and formation does not see them (similar to ESP’s)
  - ESP’s have short operating life, and are expensive to replace

High Pressure Gas-Lift

- **Example: Cat 3512 4 Stage 1000 HP Compressor**
  - **Capable of moving 3.6 MMCFPD from 45 to 4000 psi**
  - **10,000 feet of 2-1/16" IJ tubing**
  - **4000 psi surface injection pressure**
    - **Frictional loss of 300 psi**
    - **Gas head adds 1000 psi depending on temperature (Z factor)**

$$P_v = P_s \, e^{\frac{.01875 \, \gamma_g \, D}{T_{avg} \, Z_{avg}}}$$

- **Potentially 4700 psi BHP**

High Pressure Gas-Lift

- **Takeaways:**
  - Can dead lift fluid if BHP 4700 psi or less
  - For 2000 BPD well, 3.6 MMSCFPD is an 1800 GOR boost
  - Coiled tubing looks even better, with continuous exterior OD eliminating turbulence around joints
  - Once well has depleted, can go to traditional gas-lift

Evaluating a Candidate Well

- **Suggested Exercise:**
  - Prepare family of IPR curves for candidate wells
  - Prepare outflow curve for ESP
  - Prepare outflow curve for High Pressure Gas-Lift
  - Compare difference and costs, especially submersible lift anticipated failure and operating costs
- **Results of a single analysis: 80/20 Rule**
  - 80% of the production with 20% of the cost

Chicken or the Egg?

- Obviously four stage compressors are not presently available
  - This is because E&P operators are not asking for them
  - If there is a demand for them, compressor industry will eventually get there, but initially operators will have to purchase some until this is a proven practice
- So, be willing to sign a long term contract to get the machine built
  - The compressor will also be able to meet lower pressure gaslift requirements if designed well

Compressor Performance at both 4000 psi and 600 psi discharge

Ariel Performance

ARIEL 7.7.2.2

Company:	McClung Energy Services	Customer:	[redacted]
Quote:	Will Nelle	Inquiry:	Bill Elmer
Case 3:	Mid Flow Option	Project:	High Pressure Gas Lift

McCLUNG ENERGY SERVICES LLC

Compressor Data: / **Driver Data:**

Elevation,ft:	1500.00	Barmtr,psia:	13.906	Ambient,°F:	105.00	Type:	Unselected
Frame:	JGA/4	Stroke, in:	3.00	Rod Dia, in:	1.125	Mfg:	
Max RL Tot, lbf:	20000	Max RL Tens, lbf:	10000	Max RL Comp, lbf:	11000	Model:	
Rated RPM:	1800	Rated BHP:	560.0	Rated PS FPM:	900.0	BHP:	0
Calc RPM:	1800.0	BHP:	398	Calc PS FPM:	900.0	Avail:	0

Services	Service 1					
Gas Model	VMG					
Stage Data:	1 (SG)	2	3	---	4	---
Target Flow, MMSCFD	1.500	1.500	1.500	---	1.500	---
Flow Calc, MMSCFD	1.461	1.461	1.455	---	1.450	---
BHP per Stage	92.0	95.0	111.3	---	88.2	---
Specific Gravity	0.6500	0.6504	0.6479	---	0.6479	---
Ratio of Sp Ht (N)	1.2513	1.2465	1.2585	---	1.2649	---
Comp Suct (Zs)	0.9885	0.9768	0.9412	---	0.8450	---
Comp Disch (Zd)	0.9846	0.9721	0.9475	---	0.9761	---
Pres Suct Line, psig	45.00	N/A	N/A	---	N/A	---
Pres Suct Flg, psig	44.41	146.17	410.21	---	1362.01	---
Pres Disch Flg, psig	151.17	419.88	1375.95	---	4040.14	---
Pres Disch Line, psig	N/A	N/A	N/A	---	4000.00	---
Pres Ratio F/F	2.831	2.710	3.277	---	2.946	---
Temp Suct, °F	80.00	130.00	130.00	---	130.00	---
Temp Clr Disch, °F	130.00	130.00	130.00	---	130.00	---
Cylinder Data:	Throw 1	Throw 3	Throw 2	Throw 4	Throw 2	Throw 4
Cyl Model	8-7/8JG	5-3/4M	3-3/4SG-CE	3-3/4SG-CE	1-3/4SG10-HE	1-3/4SG10-HE
Cyl Bore, in	8.875	5.500	3.750	3.750	1.750	1.750
Cyl RDP (API), psig	340.9	436.4	2318.2	2318.2	5545.5	5545.5
Cyl MAWP, psig	375.0	480.0	2550.0	2550.0	6100.0	6100.0
Cyl Action	DBL	DBL	CE	CE	HE	HE
Cyl Disp, CFM	383.5	145.4	31.4	31.4	7.5	7.5
Pres Suct Intl, psig	40.81	136.06	380.05	380.05	1351.82	1351.82
Temp Suct Intl, °F	86	135	135	135	134	134
Pres Disch Intl, psig	161.27	445.65	1464.94	1464.94	4138.89	4138.89
Temp Disch Intl, °F	229	282	321	321	289	289

1.46 MM from 45 PS to 4000 PD, using 398 HP

Ariel Performance

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Company:	McClung Energy Services	Customer:	[redacted]
Quote:	Will Nelle	Inquiry:	Bill Elmer
Case 4:	Mid Flow Option - Min Pd	Project:	High Pressure Gas Lift

McCLUNG ENERGY SERVICES LLC

Compressor Data: / **Driver Data:**

Elevation,ft:	1500.00	Barmtr,psia:	13.906	Ambient,°F:	105.00	Type:	Unselected
Frame:	JGA/4	Stroke, in:	3.00	Rod Dia, in:	1.125	Mfg:	
Max RL Tot, lbf:	20000	Max RL Tens, lbf:	10000	Max RL Comp, lbf:	11000	Model:	
Rated RPM:	1800	Rated BHP:	560.0	Rated PS FPM:	900.0	BHP:	0
Calc RPM:	1800.0	BHP:	248	Calc PS FPM:	900.0	Avail:	0

Deactivated

Services	Service 1					
Gas Model	VMG					
Stage Data:	1 (SG)	2	3	---	4	---
Target Flow, MMSCFD	1.500	1.500	1.500	---	1.500	---
Flow Calc, MMSCFD	1.519	1.519	1.517	---	*BlowThru*	---
BHP per Stage	89.6	79.7	66.5	---	0.0	---
Specific Gravity	0.6500	0.6504	0.6500	---	0.6456	---
Ratio of Sp Ht (N)	1.2521	1.2482	1.2597	---	1.2359	---
Comp Suct (Zs)	0.9885	0.9780	0.9533	---	0.9165	---
Comp Disch (Zd)	0.9848	0.9740	0.9494	---	0.9167	---
Pres Suct Line, psig	45.00	N/A	N/A	---	N/A	---
Pres Suct Flg, psig	44.41	137.30	315.98	---	614.11	---
Pres Disch Flg, psig	140.46	320.98	620.92	---	610.00	---
Pres Disch Line, psig	N/A	N/A	N/A	---	600.00	---
Pres Ratio F/F	2.647	2.215	1.924	---	0.993	---
Temp Suct, °F	80.00	130.00	130.00	---	130.00	---
Temp Clr Disch, °F	130.00	130.00	130.00	---	130.00	---
Cylinder Data:	Throw 1	Throw 3	Throw 2	Throw 4	Throw 2	Throw 4
Cyl Model	8-7/8JG	5-3/4M	3-3/4SG-CE	3-3/4SG-CE	1-3/4SG10-HE	1-3/4SG10-HE
Cyl Bore, in	8.875	5.500	3.750	3.750	1.750	1.750
Cyl RDP (API), psig	340.9	436.4	2318.2	2318.2	5545.5	5545.5
Cyl MAWP, psig	375.0	480.0	2550.0	2550.0	6100.0	6100.0
Cyl Action	DBL	DBL	CE	CE	HE	HE
Cyl Disp, CFM	383.5	145.4	31.4	31.4	7.5	7.5
Pres Suct Intl, psig	40.81	127.74	292.66	292.66	613.39	613.39
Temp Suct Intl, °F	85	134	133	133	130	130
Pres Disch Intl, psig	150.02	341.64	666.41	666.41	613.39	613.39
Temp Disch Intl, °F	220	253	239	239	130	130

1.519 MM from 45 PS to 600 PD, using 248 HP. Load decrease of only 38%. Improve loading by raising PS

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