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**
    - **Did not have these 35 years ago for onshore**
  - **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**
    - **Packer and orifice are optional (trade offs)**
  - **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**
  - **May still be circulating gas at 300 psi with a plunger, whether gas-lift valves installed or High Pressure compressor**
  - **Limited downside**

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 History

- **SPE 80531 in 2003: Comparative Evaluation of Single vs. Multi-Mandrel Gas Lift System for an India Offshore Field**
  - **Operators of Mumbai High field performed comparison of single point gas lift to conventional gas lift**

"Hence, it is concluded that the single point gas-lift system is not feasible at this stage in Mumbai High because of huge investment involved. However, the system can be planned in new fields.."

What is the Application for Horizontal Oil Wells?

FIRST APPLICATION

- **Conventional gas-lift via injection down casing, with flow up the production tubing *without any problematic gas-lift valves***
  - **Can be done with a packer and a single orifice to prevent casing pressure swings when lateral unloads**
  - **Can be done without a packer when casing pressure swings are not a concern**
- **Requires injection pressures high enough to lift a full column of liquid**

What is the Application for Horizontal Oil Wells?

Do high pressure compressors exist?

- Yes, but most of them are in fire-flood service, or CNG (compressed natural gas) service, and have been purpose-built

Can you rent one?

- No, because the rental compressor industry does not believe there is a market for such a compressor
- Until this changes, operators will have to build them
- Once many have been built, and High Pressure Gas-lift becomes proven, you will be able to rent them

What will these compressors look like?
Here is an example:

Ariel Performance Run

- Based on industry standard JGQ -2 gas-lift package
- Industry standard Cat 3306 engine
- Rich gas has temps all below 325 degrees
- 588 MSCFPD at 4000#

Ariel Performance

ARIEL

7.7.2.2

Company: Ariel Corporation
Quote:
Remarks:

Customer: [redacted]
Inquiry:
Project: Eagleford Ga

Compressor Data:

Elevation,ft:	500.00	Barmtr,psia:	14.429	Ambient,°F:	100.00
Frame:	JGQ/2	Stroke, in:	3.00	Rod Dia, in:	1.125
Max RL Tot, lbf:	20000	Max RL Tens, lbf:	10000	Max RL Comp, lbf:	11000
Rated RPM:	1800	Rated BHP:	280.0	Rated PS FPM:	900.0
Calc RPM:	1782.0	BHP:	142	Calc PS FPM:	891.0

Disch Event

Services	**Gas Lift**		
Gas Model	Hall		
Stage Data:	**1 (SG)**	**2**	**3**
Target Flow, MMSCFD	0.600	0.600	0.600
Flow Calc, MMSCFD	0.588	0.588	0.586
BHP per Stage	48.8	46.5	40.2
Specific Gravity	0.7500	0.7499	0.7504
Ratio of Sp Ht (N)	1.2380	1.2469	1.2685
Comp Suct (Zs)	0.9809	0.9461	0.8344
Comp Disch (Zd)	0.9725	0.9440	0.9702
Pres Suct Line, psig	80.00	N/A	N/A
Pres Suct Flg, psig	78.00	348.19	1194.37
Pres Disch Flg, psig	354.69	1205.80	4040.14
Pres Disch Line, psig	N/A	N/A	4000.00
Pres Ratio F/F	3.994	3.365	3.354
Temp Suct, °F	80.00	130.00	130.00
Temp Clr Disch, °F	130.00	130.00	160.00
Cylinder Data:	**Throw 1**	**Throw 2**	**Throw 2**
Cyl Model	5-1/8M	3-3/4SG-CE	1-3/4SG10-HE
Cyl Bore, in	5.125	3.750	1.750
Cyl RDP (API), psig	454.5	2318.2	5545.5
Cyl MAWP, psig	500.0	2550.0	6100.0
Cyl Action	DBL	CE	HE
Cyl Disp, CFM	124.6	31.1	7.4
Pres Suct Intl, psig	72.24	319.10	1184.09
Temp Suct Intl, °F	86	135	134
Pres Disch Intl, psig	375.28	1294.85	4149.42
Temp Disch Intl, °F	268	320	313

Transition from High Pressure to Traditional Gaslift?

- As BHP drops down below 1000 psi
  - The same compressor can be used, but gas will be blowing through the third stage
  - This is not creating a significant inefficiency
  - Similar to what you have now with conventional gas-lift compressors when pressures drop to 500 psi (does not seem to bother anybody now)
- High pressure capability remains in case:
  - Offset fracs or re-fracs result in producing BHP increase requiring high pressure
  - Reduce potential damage from “Frac Hits”

Protection from Frac Hits?

- **From April 2017 JPT : Oil and Gas Producers Find Frac Hits in Shale Wells a Major Challenge**
- Another idea is to recharge the offset wells using gas, either natural gas or carbon dioxide, neither of which should lead to well damage. Though Barree is not aware of any companies that have tested this approach, he said “there is a good chance that it could help.”
- If gas compression facilities are available, operators could continuously pump natural gas into offset wells to increase their local pore pressure to ward off an oncoming fracture.
- Barree said the potential of this approach is supported by instances where wells have been shut in prior to an offset hydraulic fracturing operation and were shown to have built up enough pressure to reduce the frequency or severity of frac hits.

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 could be a cradle to grave operation if there were a way to lift high volumes on initial completion***

Limitations of Traditional Gaslift

Why isn’t gas-lift capable of being a cradle to grave artificial lift method?

- 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

What is the Application for Horizontal Oil Wells?

SECOND APPLICATION

- High Pressure makes annular flow gas-lift possible by injecting high pressure gas down 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 ?
  - Save your money

High Pressure Gas-Lift

- Operators desire to produce new horizontal oil wells at high rates to improve their economics
- 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

Can they be eliminated by High Pressure Annular Gas-Lift?

Limitations of Traditional Gaslift

- **Alternative of Reverse Flow addresses 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

- **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 (where flow up tubing is practical friction-wise), can go to annular injection with either traditional gas-lift or High Pressure 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**

Compressor Performance at 4000 and 600 psi discharge

85% drop in Discharge Pressure results in only 38% load drop, as HP related to compression ratios

Ariel Performance

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

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

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

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

Chicken or the Egg?

- **Obviously high pressure 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**
- **Or, 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**

Insist on Better Gas-Lift Compressors for your wells

Should you wish to discuss these ideas in further detail, please contact:

Bill Elmer, P.E.

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bill.elmer.pe@gmail.com 903-530-6032

Also founding member and VP of Engineering R&D at Encline Artificial Lift Technologies LLC (enclinelift.com)