Improving the Design of Wellhead Gas-Lift Compressors

- Bill Elmer, P.E.
- Encline Artificial Lift Technologies LLC
History of Gas-Lift Compressors

• 20th Century Compression: Operator Owned and Maintained
  – Operators staffed with engineers and mechanics
  – Rental compressors utilized minimally for short term needs
  – Large unitized fields with massive compressor stations
    • Examples: Conroe Field, Delhi Field, King Ranch
    • Clarks, Cooper Bessemer, Ingersoll-Rand SVG’s
  – Gas Plant stripped liquids from gas stream prior to reinjection or sale of gas
History of Gas-Lift Compressors

- In the 90’s came “Outsourcing” and “Alliances”
  - Loss of control did not bother most E&P companies
  - Indicator driven E&P industry favored spending capital on the drill bit instead of compression equipment
  - Compression experts retiring

The Result:

Transition to 3rd Party Owned and Operated
No control over compressor design
The Advent of the 21st Century

- Barnett Shale caused need for many more wellsite gas-lift compressors
  - Packaging industry geared up to meet the huge demand
  - Eventually rental industry caught on to what operators wanted

- Resurgence of Gas-Lift
Development of Horizontal Rich Oil Plays

• Gas-Lift results in producing BHP’s competitive with other forms of artificial lift ( < 500 psi at 10000 feet)

• Gas-Lift combined with plunger lift has demonstrated ability to achieve producing BHP’s near 300 psi, using less lift gas
  • Eric Perner / Stan Lusk at 2015 Gas Well Deliquification Workshop
    – ability to handle rates of 200-250 BFPD

• Offset fracs, frac sand production, and deviation plague other forms of lift

• Primary downside of Gas-Lift is compressor downtime
Industry 3 Stage Gas-Lift Compressor Design

- Designed for Multiple Applications, not specifically Gas-Lift
- Temperature control through process irrelevant
- Industry needs a Gas-Lift Only Design
Factors Impacting the Design for Horizontal Rich Gas Plays

• Surface Separation Equipment Conditions Differ
  – High Volumes and Slugging Tendencies Present
  – Elevated pressures assist in moving fluid to downstream treating equipment
  – Primary gas separation occurs at first separator, and commonly at pressures exceeding 100 psig

• Gas-Lift Supply Pressure of 100 psig regularly available
  – Makes 2 stage preferable to 3 stage compression
### Horsepower Comparison Using Web Calculator based on GPSA

<table>
<thead>
<tr>
<th>Suction Pressure (psig)</th>
<th>30</th>
<th>(must not be less than -14 psig.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge Pressure (psig)</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>Capacity (MMSCFD)</td>
<td>0.400</td>
<td></td>
</tr>
</tbody>
</table>

- **Pressure Ratios**: 22.7
- **Number of Compression Stages**: 3
- **Pressure Ratios per Stage**: 2.83
- **Estimate Discharge Temp (Deg F)**: 290.17
- **Compressor Horsepower Estimation**: 82.23
- **Auxiliary Horsepower Estimation**: 8.22
- **Total Horsepower Estimation**: 90.45

90 HP for 3 Stage

### Suction Pressure (psig) | 80 | (must not be less than -14 psig.) |
<table>
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<tr>
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<td>0.400</td>
<td></td>
</tr>
</tbody>
</table>

- **Pressure Ratios**: 10.71
- **Number of Compression Stages**: 2
- **Pressure Ratios per Stage**: 3.27
- **Estimate Discharge Temp (Deg F)**: 315.71
- **Compressor Horsepower Estimation**: 62.22
- **Auxiliary Horsepower Estimation**: 6.22
- **Total Horsepower Estimation**: 68.44

68 HP for 2 Stage

25% Less
Factors Impacting the Design for Horizontal Rich Gas Plays

- Rich components condense in coolers
  - Freezes dump lines when flashing to low pressure
  - Causes environmental issues when dumped to atmospheric tanks, or excessive VRU duty
  - Results in hydrates in aftercooler and downstream piping
  - Compressor company answer is methanol and pumps
  - Enhances likelihood of paraffin formation in wellbore, wellhead, and flowline (equilibrium related)

More expense and downtime!
Factors Impacting the Design for Horizontal Rich Gas Plays

- These problems can be prevented by designing the compressor to keep temperatures high enough to prevent fluid condensation.

- To prove this, a two compressor pilot project was undertaken. The next graphs are results of this project.
Factors Impacting the Design for Horizontal Rich Gas Plays

- To prevent scrubber dump lines from freezing, condensation can be prevented by keeping temperatures above dewpoint temperatures.
Factors Impacting the Design for Horizontal Rich Gas Plays

• This compressor has aggressive temperature control using coolers with individual VFD driven fan motors with PID control. High winds were present on February 23.

Temperatures of 125 degrees prevented fluid condensation.
Factors Impacting the Design for Horizontal Rich Gas Plays

• Below weather information shows 25 MPH sustained winds with 40 MPH gusts the afternoon of February 23.
Manual Bypass Installation

• Pneumatic temperature controller in red
  – Measuring 3rd stage discharge temp, which was doing little work

• Despite closed louvers and methanol pumps, hydrate issues resulted in installation of manual bypass
Manual Bypass Installation: Lack of proper design resulted in vibration related failure at threads, resulting in fire that destroyed compressor.
Factors Impacting the Design for Horizontal Rich Gas Plays

- When your compressor company blames the “heavy” constituents in your natural gas for freezing your dump line, or causing hydrates
- Just say “No”
  - It is the lack of proper temperature control that allows hydrocarbon condensation
Factors Impacting the Design for Horizontal Rich Gas Plays

• So much for ideal interstage temperatures. What is an ideal Gas-Lift Discharge Temperature?
  – 180 degrees is temperature rating of normal valves
  – Higher temperature valves can be specified
  – Wellhead elastomers typically rated at 250
  – Temperatures above 150 degrees can present safety issues, requiring insulation

Suggest Discharge Setpoint of 150 to 160 degrees F, unless paraffin problems severe
### 3 Stage Compressor Performance at 1000 and 500 Discharge Pressures

#### Ariel Performance

<table>
<thead>
<tr>
<th>Company:</th>
<th>Ariel Corporation</th>
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<tbody>
<tr>
<td>Quote:</td>
<td>ALRDC Gas-Lift</td>
</tr>
<tr>
<td>Project:</td>
<td>ALRDC</td>
</tr>
</tbody>
</table>

#### Compressor Data:
- **Elevation, ft.** | 50.00
- **Barrnl, psia:** | 14.669
- **Ambient, °F:** | 100.00
- **Frame:** | JGP/2
- **Stroke, in:** | 3.30
- **Rod Dia, in:** | 1.125
- **Max RL Tot, Ibf:** | 12000
- **Max RL Tens, Ibf:** | 6600
- **Max RL Comp, Ibf:** | 7000
- **Rated RPM:** | 1900
- **Rated BHP:** | 170.0
- **Rated PS FPM:** | 900.0
- **Calc RPM:** | 1775.0
- **BHP:** | 129
- **Calc PS FPM:** | 887.5

#### Services

<table>
<thead>
<tr>
<th>Gas Model</th>
<th>Gathering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hall</td>
<td>Hall</td>
</tr>
</tbody>
</table>

#### Stage Data:
- **Target Flow, MMSCFD:** 1.000
- **Flow Calc, MMSCFD:** 0.635
- **BHP per Stage:** 49.5
- **Specific Gravity:** 0.7200
- **Ratio of Sp Ht (N):** 1.2397
- **Comp Sct (Zs):** 0.9909
- **Comp Disch (Zd):** 0.9870
- **Pres Sct Line, psig:** 30.0
- **Pres Sct Flg, psig:** 146.35
- **Pres Disch Line, psig:** 160.00
- **Pres Ratio F/F:** 3.065
- **Temp Sct, °F:** 130.00
- **Temp Clnr Disch, °F:** 100.00

#### Cylinder Data:
- **Cyl Model:** 6M
- **Cyl Bore, in:** 7.500
- **Cyl ROP (API), psig:** 150.0
- **Cyl MAWP, psig:** 175.0
- **Cyl Action:** DBL
- **Cyl Disp, CFM:** 262.9
- **Pres Sct Intl, psig:** 26.18
- **Temp Sct Intl, °F:** 66
- **Pres Disch Intl, psig:** 158.37
- **Temp Disch Intl, °F:** 262

### Additional Data

- **Barl. psia:** 14.669
- **Ambient, °F:** 100.00
- **Frame:** JGP/2
- **Stroke, in:** 3.30
- **Rod Dia, in:** 1.125
- **Max RL Tot, Ibf:** 12000
- **Max RL Tens, Ibf:** 6600
- **Max RL Comp, Ibf:** 7000
- **Rated RPM:** 1800
- **Rated BHP:** 170.0
- **Rated PS FPM:** 900.0
- **Calc RPM:** 1775.0
- **BHP:** 109
- **Calc PS FPM:** 887.5

### Notes:

- **+3.7%**

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May 16 – 20, 2016

2016 Gas-Lift Workshop
Factors Impacting the Design for Horizontal Rich Gas Plays

- Dropping Discharge pressure for 3 Stage machine:
  - Reduces Stage 3 to only 12 HP out of 109 total HP (11%)
  - Stage 3 Discharge Temperature drops 73 degrees to a cool 179, assuming inlet temp was 130. This would be unusual other than summertime.
  - Gas volume increases paltry 3.7% due to VE improvement
  - Engine load drops 20 HP, or 15.5%
Factors Impacting the Design for Horizontal Rich Gas Plays

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<tr>
<td>Elevation, ft:</td>
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<tr>
<td>Frame:</td>
<td>JGQ/2</td>
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<tr>
<td>Max RL Tot, lbf:</td>
<td>20000</td>
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<tr>
<td>Max RL Tens, lbf:</td>
<td>10000</td>
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<tr>
<td>Rated RPM:</td>
<td>1800</td>
</tr>
<tr>
<td>Calc RPM:</td>
<td>1792.0</td>
</tr>
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</table>

| BHP per Stage: | 72.5 |
| Specific Gravity: | 0.7200 |
| Ratio of Sp Ht (N): | 1.2576 |
| Comp Suct (Zs): | 0.9845 |
| Comp Disch (Zd): | 0.9812 |
| Pres Suct Line, psig: | 80.00 |
| Pres Di Sch Flg, psig: | 80.00 |
| Pres Di Sch Line, psig: | N/A |
| Pres Ratio F/F: | 4.232 |
| Temp Suct, °F: | 80.00 |
| Temp Cyl Di Sch, °F: | 130.00 |

<table>
<thead>
<tr>
<th>Cylinder Data:</th>
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<tr>
<td>Cyl Model:</td>
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<td>Cyl Bore, in:</td>
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<td>Cyl RDP (API), psig:</td>
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<td>Cyl Disp, CFM:</td>
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<td>Pres Di Sch Intl, psig:</td>
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<td>Inquiry Project</td>
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<tr>
<td>EOG Resources:</td>
<td>Eagleford Gas Lift</td>
</tr>
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</table>

**Note:** +12%
Factors Impacting the Design for Horizontal Rich Gas Plays

• Dropping Discharge pressure for 2 Stage machine:
  – Stage 2 at 27 HP doing 25% of total work, not 11%
  – Stage 2 Discharge Temperature drops 80 degrees, but still at relatively high level of 207
  – Gas volume increases 12% due to VE improvement
  – Engine load drops 22 HP, or 17.2%

• Takeaway:
  – When discharge pressure drops:
    • 2 stage moves 8.3% more gas using 1.7% less HP than 3 stage
Factors Impacting the Design for Horizontal Rich Gas Plays

• For Gas-Lift Application, besides being 2 Stage with precise temperature control, compressors should:
  – Automatically start and stop, as facility shut-ins for high separator levels, high tank levels, or high pressures are common
    • Technology allows this to be done for either gas engine or electric motor drive
  – Receive speed signals from operators gas-lift volume control system
    • Practice of compressing gas to a high pressure, and recycling excess volumes is wasteful and causes hydrates in the bypass
    • Control of engine or motor speed to obtain desired rates will result in the lowest discharge pressure, and highest efficiency
Factors Impacting the Design for Horizontal Rich Gas Plays

- For Gas-Lift Application, Compressors should:
  - Be designed with a full flow bypass to allow no-load startup without blowing down the compressor to atmosphere
  - Have vessels, piping, and cylinders of ample pressure ratings to allow this bypass to open on shutdown without exceeding any pressure rating
    - Much safer practice than blowing down the compressor
    - Far more environmentally friendly practice
    - Rich gas compressors without aggressive gas temperature control often blow liquids when blown down
Factors Impacting the Design for Horizontal Rich Gas Plays

- For Gas-Lift Application, Compressors should:
  - Be driven by electric motor if power is available
    - Less downtime (or we should be outfitting pumping units with engines)
    - More conducive to automating
    - Greater speed turndown capabilities
    - Better for cold weather climates such as Bakken
Reasons that Industry Gas-Lift Compressor Design may not change

- Desire to maintain standard unit design that personnel are familiar with
- Existing packages not conducive to re-design
- Rightfully question whether operators understand their compression needs
  - For the most part this is true
  - The reason that this presentation was created
Reasons that Rental Gas-Lift Compressor Design may not change

• Operators don’t know to push back on the liquid condensation issue being a “gas quality” issue, when it is a lack of proper gas cooling control.

• Experience shows compression companies that operators will rent the existing design, as they are left with little choice in boom times.

• Educating operators and compression companies on the importance of a better designed gas-lift compressor is the solution.
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