A New Approach to The Differential Valve

- Steve Long – Weatherford Gas Lift PLM
Introduction – Background Information

- First differential valves used widely in 1930’s & 40’s
- 1944 King Injection Pressure Operated Valve (IPO)
- New differential valve designs - 1990’s & 2000’s
- 2012 Weatherford development for Shell HPHT
- 2014 Weatherford New 1.5” Differential Valve
- 2016 Weatherford RH-2 XHP IPO Valve (5000 psi)
Why Bother with Differential Valves?

- Can operate at varying injection gas pressures
- No Bellows
- Not temperature sensitive
- Good flow characteristics
- Simplicity in design and handling
New Weatherford 1.5” Differential Valve

- Complete redesign similar to a velocity type safety valve
- Positive results from flow testing
- Closes on predetermined differential pressure
- Reopens at lower differential pressure than original closing differential
- Considerations
  - Specific unloading and kick-off procedures
  - Surveillance and planning
New 1.5” Differential Valve Flow Path
New 1.5” Differential Valve

- Flow Through Latch
- Check Valve
- Spring
- Choke
- Flow Tube
- Inlet Ports
- Sealing Head

Patent Pending
New 1.5” Differential Valve Mechanics – Open Position

Differential Closing Pressure = \[\frac{\text{Spring Force}}{\text{ID Area of flow-tube} - \text{ID area of choke}}\] \[\times \text{Friction Factor}\]

Where:

\[\text{Differential Closing Pressure} = \text{Casing Pressure} - \text{Tubing Pressure}\]
New 1.5” Differential Valve Mechanics – Closed Position

Differential Reopening Pressure = \[
\text{Spring Force} \div \text{ID Area of flow-tube}
\]

Where:

Differential Reopening Pressure = Casing Pressure – *Tubing Pressure

Note: If check is spring loaded check valve and the sealing head with a positive seal is used, then trapped pressure inside the flow-tube instead of tubing pressure applies.
Weatherford Gas Lift Valve Test Skid at R&D Lab
New 1.5” Differential Valve – Test #57 Close

- .313” Choke
- ~1520 upstream/casing
- Closed at 680 psi downstream
- 840 psi differential closing pressure
- 2.9 MMSCF/Day at close

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New 1.5” Differential Valve – Test #57 Reopen

- Patent Pending
- .313” Choke
- 450 psi Reopen
## Example Well Data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tubing Size</td>
<td>5.5”</td>
</tr>
<tr>
<td>Mid Perforations</td>
<td>10,000’</td>
</tr>
<tr>
<td>Static BHP</td>
<td>5000 psi</td>
</tr>
<tr>
<td>Completion Fluid Gradient</td>
<td>.500 psi/ft</td>
</tr>
<tr>
<td>Productivity Index</td>
<td>5</td>
</tr>
<tr>
<td>Water Cut</td>
<td>50%</td>
</tr>
<tr>
<td>Water Specific Gravity</td>
<td>1.07</td>
</tr>
<tr>
<td>Formation GOR</td>
<td>200:1</td>
</tr>
<tr>
<td>Wellhead Back Pressure</td>
<td>200 psi</td>
</tr>
<tr>
<td>Injection Pressure</td>
<td>1500 to 2000 psi</td>
</tr>
<tr>
<td>Injection Gas Specific Gravity</td>
<td>.70</td>
</tr>
<tr>
<td>Injection Gas Volume Requirement</td>
<td>3 to 5 MMSCF/Day</td>
</tr>
<tr>
<td>Production Rates**</td>
<td>*10,000 BFPD with 1500 psi injection pressure</td>
</tr>
<tr>
<td></td>
<td>*12,000 BFPD with 2000 psi injection pressure</td>
</tr>
</tbody>
</table>

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# Example Well Differential Valve Design

<table>
<thead>
<tr>
<th>True Vertical Depth (feet)</th>
<th>Valve Type</th>
<th>Choke Size (inches)</th>
<th>Differential Close (psi)</th>
<th>Differential Reopen (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2800’</td>
<td>Differential</td>
<td>16/64”</td>
<td>1050</td>
<td>650</td>
</tr>
<tr>
<td>4800’</td>
<td>Differential</td>
<td>20/64”</td>
<td>750</td>
<td>450</td>
</tr>
<tr>
<td>6200’</td>
<td>Differential</td>
<td>22/64”</td>
<td>750</td>
<td>400</td>
</tr>
<tr>
<td>7600’</td>
<td>Differential</td>
<td>24/64”</td>
<td>750</td>
<td>400</td>
</tr>
<tr>
<td>9000’</td>
<td>Orifice</td>
<td>24/64”</td>
<td>NA</td>
<td></td>
</tr>
</tbody>
</table>

*The above spacing is based on minimum of 1500 psi injection pressure and maximum 2000 psi*
Stage 1 – New 1.5” Differential Gas Lift Valve Unloading

- Well is loaded with completion fluid.
- All differential valves are open
- The orifice valve remains open at all times
Stage 2 – New 1.5” Differential Gas Lift Valve Unloading

- **Injection gas** is started to unload well
- **Differential valves** open

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Stage 3 – New 1.5” Differential Gas Lift Valve Unloading

- Injection gas enters top differential valve at 2800’
Stage 4 – New 1.5” Differential Gas Lift Valve Unloading

- Fluid level in casing continues to drop as gas is injected in top differential valve at 2800’
Stage 5 – New 1.5” Differential Gas Lift Valve Unloading

- Injection gas enters 2^{nd} differential valve at 4800’
- Top and 2^{nd} differential valves will be injecting gas simultaneously
- Sufficient injection gas volume will have to be maintained

1500 psi

- 2800’
- 4800’
- 6200’
- 7600’
- 9000’

Open
Open
Open
Open
Always Open

1050 \Delta P close
750 \Delta P close

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Stage 6 – New 1.5” Differential Gas Lift Valve Unloading

• Differential valve at 2800’ closes

• Injection point is at 4800’ as unloading continues
Stage 7 – New 1.5” Differential Gas Lift Valve Unloading

- Injection gas enters 3rd differential valve at 6200’
- 2nd and the 3rd differential valves will be injecting gas simultaneously
- Sufficient injection gas volume will have to be maintained
Stage 8 – New 1.5” Differential Gas Lift Valve Unloading

- The differential valve at 4800’ closes
- The injection point stabilizes at 6200’
- Production rate of ~10,000 BFPD
Stage 9 – Unloading Complete for 2000 psi Injection Pressure

- The differential valve at 7600’ closes
- Injection point stabilizes at 9000’
- Production rate is ~12,000 BFPD
Questions?
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