Update on Plunger Fall Velocity
New Testing

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Rick Nadkrynechny
Bill Hearn
What do we know?


1. Measured plunger fall velocities for grooved, ultra seal, dual pad and brush type are much less than **1000 ft/min**.

2. Two-Piece & Bypass Plungers are fast! (Generally > 1000 ft/min)

3. Worn 2 3/8 brush type plungers (408-477 ft/min). New brush plungers fall slow. Fall Velocity changes w/ wear.

4. 2 3/8” Dual pad type plungers (259-265 ft/min).

5. Increasing the diameter from 2.375” to 2.875” resulted in the pad type plunger falling slower (>200 ft/min).

6. Improving the seal on a dual pad plunger (Ultra Seal) results in even slower fall velocities (159 ft/min).

7. Solid Plungers are “fast” 300-400 Ft/Min.

8. In the same well new plungers fall slower when compared to the same type of older/worn plunger.
Plunger Falls Faster Through Gas than Liquid

- 201 Ft/min Gas
- 38 Ft/min Liquid

Plunger Hits Liquid

Plunger on Bottom

Only Shut-in Time Period Shown
Plunger Depth and Fall Velocity

Normally, Velocity Decreases as Plunger Falls Deeper into Well

Begin - 250 ft/min

End - 131 ft/min

Faster

Slower

Normally, Velocity Decreases as Plunger Falls Deeper into Well
Actions by the Plunger Displayed in the Tubing Pressure Increase in Gas Flow Rate into Tubing Results in Plunger Slowing Down...

Tubing Pressures - (psi)

-500.0 -400.0 -300.0 -200.0 -100.0 0

Spunger Velocity - (ft/min)

-160.0 -140.0 -120.0 -100.0 -80.0 -60.0 -40.0 -20.0 0 20.0 40.0 60.0

Standing Valve Open

Increase in Gas Flow Rate

Plunger Slows Down

Plunger Velocity - (ft/min)

-500.0 -400.0 -300.0 -200.0 -100.0 0

Elapsed Time - minutes


Tubing Gas Flow Rate - (Mscf/D)

-160.0 -140.0 -120.0 -100.0 -80.0 -60.0 -40.0 -20.0 0 20.0 40.0 60.0

Elapsed Time - minutes

Fall Velocity Slows in Deviated Well

Plunger Slowed from 200 ft/min once plunger goes past Kick off Point 8234 Ft

What Effect Does Wellbore Deviation Have on Plunge Fall Velocity?
Plunger Fall Velocity Slows Past Hole

Plunger Slowed from 217 ft/min When Falls Past Hole@ 5050’

Liquid in the bottom of the tubing provides a pressure seal
Fall Velocity – Bypass Valve Closes

Plunger Slowed from 950 ft/min to 366 ft/min due to Valve Premature Closing

@ 3016' Bypass Valve Closed

By-pass Plungers Just don’t Work in my wells. Why?
Bumper Spring Falls Fast ~ 1658 ft/min
1st Tracked Spring to bottom and then slower Plunger
Paraffin Stops Plunger Fall
Plunger “Knocked” Loose by Acoustic Pulse

Blast from Gas Gun Re-Starts Fall

Tubing Pressure Signal Becomes Flat when Plunger Sticks
Chemical Treatment Down Tubing Tends to Slow/Stops Plunger Fall

Plunger Does Not Reach Bottom...
Fast Plunger Arrivals are a Symptom of Sticking Plunger
**NEW TEST**: Demonstrate Impact of Various Features on Performance of Different Types of Plungers.

- Acoustic fluid level instruments can be used on plunger lifted wells to record the acoustic signal produced as the plunger falls down the tubing.
- Measured Acoustic signal, Tubing & Casing Pressures
- Determine Fall velocities for eight different types of plungers in the same well.
- Test each cycle under very similar conditions
<table>
<thead>
<tr>
<th>Plungers Tested in 2 3/8” Tubing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company B pad w/ seal</td>
</tr>
<tr>
<td>Company B dual pad</td>
</tr>
<tr>
<td>Company A dual pad seal</td>
</tr>
<tr>
<td>Company B single pad</td>
</tr>
<tr>
<td>Company B solid pad combo</td>
</tr>
<tr>
<td>Company C solid</td>
</tr>
<tr>
<td>Company B solid</td>
</tr>
<tr>
<td>Company C Padded By-pass</td>
</tr>
</tbody>
</table>
Plunger Testing

- Performed by Rick Nadkrynechny on 8 different types of plungers – 3 different manufacturers.
- Plungers ran at different times in the same well.
- Acquired data using a Well Analyzer, plus measured gas and liquid produced volumes at various times during each test with portable tester.
- Clock times of the flow measurements were recorded and times were annotated on the plunger lift data.
- Purpose was to gather data and make the data available to those who are involved with the design and operation of plunger lift wells.
TESTPROCEDURE

• Record for each plunger:
  – Manufacturer, description, exact weight, compressed and uncompressed diameters, pictures of plunger

• Flow well through test separator and acquire accurate gas and liquid production rates throughout test

• Prior to plunger start up shoot tubing fluid levels

• Collect data over a representative cycle.
### Pressures During Normal Well Cycle

**Plunger from Company A w/ dual pads & seal**

<table>
<thead>
<tr>
<th>Time</th>
<th>Event Description</th>
<th>Casing</th>
<th>Tubing</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>Valve Closes, Shut-in Begins and Tubing Pressure Starts Increasing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Plunger hits Liquid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Plunger on Bottom</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Valve Opens, Unloading Begin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Liquid Arrives, Tubing Pressure at Minimum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Plunger Arrives, After-flow begins</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Tubing Pressure Maximum Spike</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Valve Closes, Cycle Repeats</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Time - Minutes**

- [A]: 10.966
- [B]: 38.744
- [C]: 66.522

**Figures:**
- Casing
- Tubing
WELL SELECTED for TESTING

• Had stable flow characteristics
• Effort made to not change the plunger control settings
• Normal functioning standing valve
• Tubing Intake of 8080.71 ft.
• One set of perforations 8121.92-8151.44 feet
• 2 3/8” Tubing, 5.5” Casing, and No packer
• Produced 0.63 BPD water and no condensate
• Able to run on timer control in order to control the flowing environment
## Fall and Rise Velocities

<table>
<thead>
<tr>
<th>Plunger Desc</th>
<th>Average Fall Velocity Ft/min</th>
<th>Casing Pres. Psig</th>
<th>Tubing Pres. Psig</th>
<th>Line Pres. Psig</th>
<th>Load Factor</th>
<th>Average Rise Velocity Ft/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company B pad w/ seal</td>
<td>-236.6</td>
<td>208.3</td>
<td>198.2</td>
<td>110.3</td>
<td>0.1031</td>
<td>1333.3</td>
</tr>
<tr>
<td>Company B dual pad</td>
<td>-239.5</td>
<td>203.9</td>
<td>188.4</td>
<td>111.8</td>
<td>0.1683</td>
<td>1041.6</td>
</tr>
<tr>
<td>Company A dual pad seal</td>
<td>-289.8</td>
<td>204.7</td>
<td>195.1</td>
<td>112.1</td>
<td>0.1037</td>
<td>1245.0</td>
</tr>
<tr>
<td>Company B single pad</td>
<td>-335.0</td>
<td>216.4</td>
<td>202.7</td>
<td>122.3</td>
<td>0.1456</td>
<td>1343.9</td>
</tr>
<tr>
<td>Company B solid pad combo</td>
<td>-372.9</td>
<td>209.0</td>
<td>192.5</td>
<td>111.4</td>
<td>0.1691</td>
<td>1362.0</td>
</tr>
<tr>
<td>Company C solid</td>
<td>-385.4</td>
<td>204.9</td>
<td>192.3</td>
<td>109.5</td>
<td>0.1321</td>
<td>1503.5</td>
</tr>
<tr>
<td>Company B solid</td>
<td>-445.3</td>
<td>212.4</td>
<td>189.3</td>
<td>113.9</td>
<td>0.2345</td>
<td>1122.4</td>
</tr>
<tr>
<td>Company C Padded By-pass</td>
<td>-1121.3</td>
<td>214.8</td>
<td>196.6</td>
<td>102.9</td>
<td>0.1626</td>
<td>1260.0</td>
</tr>
</tbody>
</table>

**Notes:**
- E - Determined Using Echometer Well Analyzer
- M - Acquired Using Echometer Well Analyzer
3 Times More Liquid Measured than When Plunger Hit

Company A dual pad seal – Shut-in Time Period Only

Load Factor = \( \frac{(Cp-Tp)}{(Cp-Lp)} \) = 0.1037
Liquid Load in Tubing \( (Cp-Tp) \) = 0.0857 BBLs
Liquid Measured @ Surface = 0.1497 BBLs

Liquid Efficiency 174.8%

@ 40.634 Minutes
Tubing Pressure = 185.1
Casing Pressure = 190.8
Pressure Diff. = 4.7
Percent Liquid = 21.96
Height (Gassy) = 59.95'
Liquid = 0.051 BBLs

@ 61.683 Minutes
Tubing Pressure = 195.1
Casing Pressure = 204.7
Line Pressure = 112.1
Pressure Diff. = 9.6
Percent Liquid = 100%
Height (Gas Free) = 22.7'
Liquid = 0.086 BBLs
## Liquid and Gas Volumes

### Relationship between load factor and rise velocity

<table>
<thead>
<tr>
<th>Plunger Desc</th>
<th>Average Fall Velocity Ft/min</th>
<th>BBLs of Liquid Load Tbg (Cp-Tp)</th>
<th>BBLs of Liquid Tbg Meas. @ Surface</th>
<th>Liquid Effic. %</th>
<th>Gas Flow Volume Calc. Scf /Cycle</th>
<th>Gas Flow Volume Meas. Scf /Cycle</th>
<th>Gas Volume Slips By Plunger Scf</th>
<th>Average Rise Velocity Ft/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company B pad w/ seal</td>
<td>-236.6</td>
<td>0.0901</td>
<td>0.1541</td>
<td>171.0%</td>
<td>4416.0</td>
<td>4304.8</td>
<td>311.9</td>
<td>1333.3</td>
</tr>
<tr>
<td>Company B dual pad</td>
<td>-239.5</td>
<td>0.1383</td>
<td>0.2359</td>
<td>170.6%</td>
<td>5548.0</td>
<td>5446.2</td>
<td>421.0</td>
<td>1041.6</td>
</tr>
<tr>
<td>Company A dual pad seal</td>
<td>-289.8</td>
<td>0.0857</td>
<td>0.1497</td>
<td>174.8%</td>
<td>9424.0</td>
<td>11007.9</td>
<td>437.0</td>
<td>1245.0</td>
</tr>
<tr>
<td>Company B single pad</td>
<td>-335.0</td>
<td>0.1222</td>
<td>0.1069</td>
<td>87.5%</td>
<td>3335.0</td>
<td>3859.5</td>
<td>144.7</td>
<td>1343.9</td>
</tr>
<tr>
<td>Company B solid pad combo</td>
<td>-372.9</td>
<td>0.1472</td>
<td>0.1069</td>
<td>72.6%</td>
<td>5703.0</td>
<td>6585.9</td>
<td>280.1</td>
<td>1362.0</td>
</tr>
<tr>
<td>Company C solid</td>
<td>-385.4</td>
<td>0.1124</td>
<td>0.0516</td>
<td>45.9%</td>
<td>7519.0</td>
<td>8947.8</td>
<td>430.1</td>
<td>1503.5</td>
</tr>
<tr>
<td>Company B solid</td>
<td>-445.3</td>
<td>0.2061</td>
<td>0.1767</td>
<td>85.8%</td>
<td>4795.0</td>
<td>5495.5</td>
<td>506.6</td>
<td>1122.4</td>
</tr>
<tr>
<td>Company C Padded By-pass</td>
<td>-1121.3</td>
<td>0.1624</td>
<td>0.1981</td>
<td>122.0%</td>
<td>3028.0</td>
<td>2897.4</td>
<td>451.3</td>
<td>1260.0</td>
</tr>
</tbody>
</table>

### Notes:

- **E** - Determined Using Echometer Well Analyzer
- **T** - Measured with Tester
Company A dual pad seal – Gas Volumes

- Gas Volume (scf/cycle) Calculated VERSUS Measured during cycle for all 8 plungers:
  - Average Error 9.9% of the measured scf/cycle.
  - Maximum Error of 16%
  - Minimum Error of 2.6%
Observations

- New Plunger Fall Velocities are in the same Range of Fall Velocities as Previous Testing
- Solid plunger that fell the 2nd fastest also had the most gas that slipped past the plunger – probably due to poorest seal.
- Solid Plungers were less than 100% Efficient
- Padded Plungers fell slower and tended to have the highest liquid efficiencies
- Good Seal resulted in liquid measured at the surface higher than the liquid at the bottom of the tubing above plunger when surface valve opened
  - Most likely due to liquid below the SN in the casing being brought into the tubing when unloading begins.
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