Plunger Fall Velocity Considerations

Rick Nadkrynechny

Lynn Rowlan

Cell: (780) 831-5038
Fax: (780) 402-2808
Email: t-ram@telusplanet.net
RR2, Site 17, Box 13 Grande Prairie, AB T8V 2Z9
Plunger Fall Velocity Impacted BY:

1. Diameter of Plunger
2. Effectiveness of Seal between Plunger and Tubing
3. Brush stiffness and seal
4. Increased friction due to contact with the tubing
5. Plunger Age or wear
6. Faster If Valve Opens To Bypass Gas Through The Plunger
7. Faster if Tubing is Worn OR Slower if Tubing is Sticky
8. Wellbore Deviation
9. Gas Flow Rate Into The Tubing
10. PRESSURE OF GAS
How: Listen to Plunger Signals During Shut-in

1) 3 Channel High Frequency (30Hz or greater) Data Acquisition

2) Tubing
   a) Pressure
   b) Acoustic signal

3) Casing pressure

Pressure sensor & microphone
Pressure sensor
Just Listen To Plunger
**Velocity:** Plunger Fall Speed Between Two Consecutive Counted Collars

Plunger Velocity @ Joint 22 equals the change in depth divided by the change in elapsed time.

Velocity = \( \frac{D_i - D_{i-1}}{T_i - T_{i-1}} \) = -230.9 ft/min

- \( D_{i-1} = 676.2 \)
- \( D_i = 708.4 \)
- \( T_{i-1} = 5.663 \)
- \( T_i = 5.802 \)

Looking at this Minute Falling through Gas Each Joint
Pressure Goes Up ~ Plunger Slows Down

Falling through Gas Gradually Slows from 240 ft/min to 135 ft/min

Normal Fall Velocity Profile Starts Off Fast and Gradually Slows Down

1) Tubing is OK
2) Liquid in Bottom

Falling thru Liquid

During Shut-in

Click on Any Point

Click on Any Point

Faster

Slower
What has been Published?


1. Measured plunger fall velocities for grooved, ultra seal, dual pad and brush type are much less than published 1000 ft/min.
2. Two-Piece & Bypass Plungers 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 quickly 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. New plungers slower than same type of older/worn plunger.
Plunger Fall Velocity by Williams Study Presented in 2009 Plunger Lift School

- Three Vertical Straight wells
  - Tubing Condition
    - 2 wells tubing < 1 year old
    - 1 well tubing 7 years old
  - Different fields
- 26 plungers were evaluated
  - 8 manufacturers
  - 6 designs/styles
    - Pads
      - Single, Double, Triple
    - Brushes
      - Drift, Cut-Down, Oversized
    - Barstocks
Plunger Fall Velocity – Barstock
Solid Plungers are “fast” 300-400 Ft/Min
William’s 2009 Conclusions

- Adjusting cycle times to a specific plunger will yield more efficient plunger operation and increased gas production
- Various styles of plunger types fall at different velocities
  - i.e. single pad vs. double pad
- Different manufacturers fall at different velocities
  - i.e. FB Brush vs. Mega Brush
- Age of tubing did not seem to have an affect?
- Fall Velocities Similar to Other Studies
<table>
<thead>
<tr>
<th>Plunger Type</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company B pad w/ seal</td>
<td><img src="image1" alt="Company B pad w/ seal" /></td>
</tr>
<tr>
<td>Company B dual pad</td>
<td><img src="image2" alt="Company B dual pad" /></td>
</tr>
<tr>
<td>Company A dual pad seal</td>
<td><img src="image3" alt="Company A dual pad seal" /></td>
</tr>
<tr>
<td>Company B single pad</td>
<td><img src="image4" alt="Company B single pad" /></td>
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<tr>
<td>Company B solid pad combo</td>
<td><img src="image5" alt="Company B solid pad combo" /></td>
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<tr>
<td>Company C solid</td>
<td><img src="image6" alt="Company C solid" /></td>
</tr>
<tr>
<td>Company B solid</td>
<td><img src="image7" alt="Company B solid" /></td>
</tr>
<tr>
<td>Company C Padded By-pass</td>
<td><img src="image8" alt="Company C Padded By-pass" /></td>
</tr>
</tbody>
</table>

Same Well Plungers Tested in 2 3/8” Tubing One Well
Observations

• Fall Velocities Similar to Other Studies
• 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.
Plunger Falls Slower Through Liquid than Gas

201 Ft/min
Gas

38 Ft/min
Gaseous Liquid

Plunger Hits Liquid
Plunger on Bottom

Only Shut-in Time Period Shown
What Effect Does Wellbore Deviation Have on Plunger Fall Velocity?

Viper Plunger Fall Slowed Down from 344 to 280 ft/min After going past Kick off Point

3861.55'}
Horizontal Well Impacts Velocity

Dual Pad Plunger Increased Speed from 230 to 450 ft/min once Plunger Goes Past Kick Off Point

Solid Plungers Decrease Speed VS Padded Plungers Increase Speed?
Plunger 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.
Increase in Gas Flow Rate Past Plunger Results in Plunger Slowing Down...

- Increase in Gas Flow Rate
- Plunger Slows Down
- SV Opens
Paraffin Sticks Plunger During 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 Forms Gunk and Tends to Slow/ Stops Plunger Fall

Plunger Does Not Reach Bottom...

Fast Plunger Arrivals are a Symptom of Sticking Plunger
Fall Velocity Increases as Pressure Drops

Plunger Fall Velocity Changes as a function of Pressure Change

Dual Pad Plunger Fall Velocity Faster 1.75 Ft/Min with Each 1 Psi decrease in Pressure

Fall Velocity (Ft/Min) = -539.28 + 1.75(Avg Tbg Psi)
Fall Velocity Increases as Pressure Drops

\[ \text{Fall Velocity (Ft/Min)} = -367.95 + 0.2504(\text{Avg Tbg Psi}) \]
More Data Shows Fall Velocity Change is Non-Linear

Could say “Viper Plunger falls @ 350 ft/min
Changes speed 1 ft/min per 1 psi, and does not fall much slower than 180 ft/min @ High Gas Pressure

Viper Plunger - Fall Velocity as Function of Pressure

Fall Velocity (Ft/Min) = -0.0006485x^2 + 0.949(Avg Tbg Psi) - 520.8

1 Psi = 1 Ft/Min at Low Pressures
2 7/8 inch Bypass Plunger w/ Standing Valve
Hits at Bottom **Very** Hard ~ almost 60 Mile/Hr

- Fell 5339 Ft in 1.73 Min
- 3083 ft/min
- Rise Velocity 556 Ft/Min
- Gas Flow Rate: 5000 m3/D
- 176.6 Mscf/D
- Line Pressure 30 Psia
- Gas Velocity = 44.7 ft/sec
- Near Critical
2 7/8 inch Bypass Plunger
Fall Velocity Range 5000-1000 ft/min

Fall Velocity Averaged 3654 Ft/Min

Fell 5339 Ft in 1.73 Min
3083 ft/min

60 MPH

Bottom of Tubing - 5339.24 Ft
Plunger Hits Liquid - 5242.71 Ft
“Select Correct Plunger for the Well”

Some wells need fast plungers and some wells casing pressure builds slowly.

Choose the appropriate plunger type based on the casing pressure buildup and the rate of liquid flow.

- **By-pass**
- **By-pass w/Pads**
- **Padded w/ Seal**
- **Solid or Padded**

Foss & Gaul

PcMax

Casing Pressure vs. Elapsed Time Graph

- Casing Pressure - Psig - Plunger too Much Liquid
- Casing Pressure - Psig Normal
- Casing Pressure - Psig - School Canada
- Casing Pressure - Psig - Plunger 4 Cycles
Recommendation

1) "DETERMINE PLUNGER FALL VELOCITY" - accurately measure using an acoustic fluid level instrument.

2) "DETERMINE MINIMUM SHUT-IN TIME" to maximize the number of cycles per day.

3) "DON’T WASTE TIME GUESSING" - Track plunger fall to ensure plunger reaches fluid at bottom of the tubing by the end of the shut-in period.

4) "MAXIMIZE PRODUCTION" from plunger lift installations by using the shortest possible shut-in time equal to the time required for the plunger to reach bottom.

5) "Select Correct Plunger for the Well" some wells need fast plungers and some wells casing pressure builds slowly.
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