Acoustically Determining Plungers Fall Velocity For Different Type Plungers

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**Plunger Lift System**

**Controller:** Electronic-based system with control parameters to determine under what conditions to exert control by opening/closing the motor valve

**Transducer:** Electronic device that emits an electronic signal to be converted within controller to engineering units

**Motor Valve:** Diaphragm-operated device controlled by controller to open/close sales/tank line

**Lubricator/Catcher:** Uppermost stopping point for plunger; acts as shock absorber; catcher is mechanical device that locks plunger in lubricator for removal and for inspection

**Arrival Sensor:** Magnetic device strapped around lubricator to detect plunger arrivals... Vibration sensors have been used

**Bumper Spring:** Shock absorber at plunger’s deepest stopping point

**Plunger:** Pig-type device that provides a seal between gas and liquid inside tubing to deliver fluid and gases to surface with differential pressure. The plunger travels entire length of tubing from catcher to bumper spring.
Plunger Cycle

Plunger lift operation cycle can be divided into three parts:

1) **Shut-in**: Surface valve closed, flow shut-in, plunger falls down thru gas and liquid in the tubing. Goal of the operator or controller is to try to achieve Shut-in of the well for the shortest amount of time possible, But short enough for plunger to reach bottom. And long enough for the casing pressure to build high enough to bring the plunger back to surface.

2) **Unloading**: Surface valve open and pressure stored in the casing lifts the accumulated liquid and plunger to the surface.

3) **After-flow**: Surface valve open and well continues to flow after plunger reaches the surface. Plunger held at surface by differential pressure from flow of gas up the tubing. Well is producing gas. Most liquid produced from the formation tends to fall back, accumulating at the bottom of the tubing. The goal of the operator or controller is to Flow the well only until the well begins to load with liquids.
Pressures During Normal Well Cycle

1. Plunger hits Liquid
2. Plunger on Bottom
3. Liquid Arrives, Tubing Pressure at Minimum
4. Plunger Arrives, After-flow begins
   Tubing Pressure Maximum Spike

[C] Valve Closes, Cycle Repeats

\[ A \]
- Valve Closes, Shut-in Begins and Tubing Pressure Starts Increasing

\[ B \]
- Valve Opens, Unloading Begins

\[ C \]
- CP: Casing Pressure
- TP: Acoustic Signal
- LP: Tubing Pressure

Time - Minutes
Shoot Fluid Levels

1) Shoot Fluid Level Down Tubing to Top of Plunger

2) Tubing
   a) Pressure
   b) Acoustic Signal

Pressure sensor & microphone
Plunger fall speed between two consecutive shots Calculation:

\[
S = \frac{(D_i - D_{i-1})}{(T_i - T_{i-1})}
\]

where:

- \(S\) = Plunger fall speed, ft/sec
- \(D_i\) = Distance to the Plunger, ft, at the time of the current shot, \(T_i\)
- \(D_{i-1}\) = Distance to the Plunger at the previous time, ft, at time of the previous shot, \(T_{i-1}\)

Given:

- \(T_{i-1} = 10:55\)
- \(T_i = 11:00\)
- \(D_{i-1} = 1972.6\)
- \(D_i = 2860.1\)

Plunger Speed equals the difference between the depth to the plunger divided by the difference between the elapsed time.

\[
S = \frac{(2860.1 - 1972.6)}{5} = 177.5 \text{ Ft/Min}
\]
Shoot Fluid Level to Top of Plunger to Determine

1) Depth to the Plunger
2) Fall Velocity of a Various Type Plungers
3) If the shut-in time for the well is the shortest time possible
4) Is shut-in time long enough for the plunger to fall to the bottom.

Plunger Goes by Collar

Plunger Top @ 5001'
Worn Brush Plunger 477 fpm Fall

Time of Day on 08/24/2000

Valves Close Plunger
Begins Fall 10:07:00

Plunger Hits Fluid 260 Ft Above
Tubing Bottom at 10:22:00

Valves Opens Plunger Begins
Rise to Surface 10:25:00

Avg Plunger Fall Velocity 477 Ft/Min

Depth to Liquid in Tubing 7140 Ft
Standing Valve Depth 7400 Ft
Passive Recording

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

2) Tubing
   a) Pressure
   b) Acoustic signal

3) Casing pressure

Just Listen To Plunger
Plunger Falls Slower Through Liquid than Gas

201 Ft/min Gas

Plunger Hits Liquid

38 Ft/min Liquid

Plunger on Bottom

Only Shut-in Time Period Shown
Where’s the Plunger [During Shut-in]

Click on Any Point

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

Normal Fall Velocity Profile
1) Tubing is OK
2) Liquid in Bottom

Falling thru Liquid

Slower

Faster

Click on Any Point
Fall Velocity Increases as Pressure Drops

Plunger Fall Velocity Changes as a function of Pressure Change

Dual Pad Plunger Increases with Increasing Pressure

Fall Velocity (Ft/Min) = -539.28 + 1.75(Avg Tbg Psi)
Various Plunger Manufacture Features Affecting Fall Velocity

1) Diameter of Plunger
2) Effectiveness of Seal between Plunger and Tubing
3) Increased friction due to contact with the tubing
4) If the plunger falls straight or spins
5) How age/wear effects plunger
6) Valve Opens on Fall to Bypass Fluids
2 3/8” Plungers Types Monitored:

- Brush
- Grooved
- Clean-out
- Dual Pad
- Ultra Seal
Comparison of Plungers Falls 2 3/8” Tubing

<table>
<thead>
<tr>
<th>Field Test</th>
<th>Acoustic Velocity (Ft/sec)</th>
<th>Plunger Type</th>
<th>Tubing Depth (Feet)</th>
<th>Height of Liquid (Feet)</th>
<th>Average Fall Velocity (Ft/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1424</td>
<td>Brush</td>
<td>7400</td>
<td>260</td>
<td>477</td>
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<tr>
<td>2</td>
<td>1269</td>
<td>Pad 2 3/8</td>
<td>4008</td>
<td>608</td>
<td>265</td>
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<td>3</td>
<td>1216</td>
<td>Pad 2 3/8</td>
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<td>232</td>
<td>259</td>
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<td>4</td>
<td>1280</td>
<td>Ultra Seal</td>
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<td>41</td>
<td>159</td>
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<tr>
<td>5</td>
<td>1242</td>
<td>Grooved</td>
<td>3042</td>
<td>13</td>
<td>408</td>
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<tr>
<td>6</td>
<td>1320</td>
<td>Clean Out</td>
<td>9896</td>
<td>1400</td>
<td>326</td>
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<tr>
<td>Date</td>
<td>Well</td>
<td>Description</td>
<td>Condition</td>
<td>Tbg Length (FT)</td>
<td>Fall Speed Ft/Min</td>
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<td>--------------------------------------------------</td>
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</tr>
<tr>
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<td>B3</td>
<td>Brush Plunger</td>
<td>New</td>
<td>10123</td>
<td>150</td>
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<tr>
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<td>Dual Pad Plunger</td>
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<td>162</td>
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<tr>
<td>09/13/01</td>
<td>B12</td>
<td>Dual Pad Plunger</td>
<td>Existing</td>
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<td>179</td>
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<td>187</td>
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<tr>
<td>06/05/01</td>
<td>B9</td>
<td>Dual Pad Plunger</td>
<td>Existing</td>
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<td>200</td>
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<td>09/13/01</td>
<td>B12</td>
<td>Solid, Grooved, Tapered End</td>
<td>Repeat</td>
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<td>364</td>
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<tr>
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<td>368</td>
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<tr>
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<td>By-pass Valve, Dual Pad</td>
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<td>10235</td>
<td>1690</td>
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</tbody>
</table>
What do we know?


1. Measured plunger fall velocities for grooved, ultra seal, dual pad and brush type are much less than $1000 \text{ ft/min}$.
2. Two-Piece & Bypass Plungers are fast! (Generally $> 1000 \text{ ft/min}$)
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 ($>200 \text{ ft/min}$).
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.
Three wells
  - Vertical section
    • 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 - Barstocks

Fall Velocity (ft/min)

- Mega Lift Barstock
- PCS 16" Barstock
- Weatherford Barstock
- Sand Viper
- Superior Sand Barstock

Well 1, Well 2, Well 3
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?

- Tubing gas flow into tubing?
**Plungers Tested in 2 3/8” Tubing**

<table>
<thead>
<tr>
<th>Plunger Type</th>
<th>Image</th>
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</thead>
<tbody>
<tr>
<td>Company B pad w/ seal</td>
<td><img src="image1.png" alt="Image" /></td>
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<tr>
<td>Company B dual pad</td>
<td><img src="image2.png" alt="Image" /></td>
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<tr>
<td>Company A dual pad seal</td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td>Company B single pad</td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td>Company B solid pad combo</td>
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</tr>
<tr>
<td>Company C solid</td>
<td><img src="image6.png" alt="Image" /></td>
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<tr>
<td>Company B solid</td>
<td><img src="image7.png" alt="Image" /></td>
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<tr>
<td>Company C Padded By-pass</td>
<td><img src="image8.png" alt="Image" /></td>
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</tbody>
</table>
Observations

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

What Effect Does Wellbore Deviation Have on Plunger Fall Velocity?
Plunger Slowed from 217 ft/min When Falls Past Hole@ 5050' 

Liquid in the bottom of the tubing provides a pressure seal
Actions by the Plunger Displayed in the Tubing Pressure Increase in Tubing Pressure and/or Gas Flow Rate Past Plunger Results in Plunger Slowing Down…

Increase in Gas Flow Rate

Plunger Slows Down
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
2 7/8 inch Bypass Plunger w/ Standing Valve
Hits at Bottom Very Hard

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

Below Critical,
Gas Velocity
44.7 ft/sec

Line Pressure 30 Psia

Tubing

Casing

Gas Velocity
44.7 ft/sec

Line Pressure 30 Psia
2 7/8 inch Bypass Plunger Fall Velocity Range 5000-1000 ft/min

Plunger Fall Velocity - Ft/Min

Fell 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

Elapsed Time - Mins

Depth to Plunger - Feet
Plunger Slowed from 950 ft/min to 366 ft/min due to Valve Premature Closing. At 3016’ Bypass Valve Closed.

By-pass Plungers Just don’t Work in my wells. Why?
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.
Questions?