PLUNGER FALL VELOCITY CONSIDERATIONS

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1. Data used to correlate construction features of plungers to fall velocity
2. Some features cause a plunger to fall rapidly, while other features cause a plunger to have a slower fall velocity.
3. Well conditions (gas flow rate and pressure) have significant impact on plunger fall velocity.
4. Use plunger fall velocities to determine shut-in time
   a. 1 Velocity not accurate
   b. Impacted by many parameters
5. Setting controller to the shortest shut-in time will maximize oil and gas production
Less Accurate: Determine Fall Velocity by Shooting Fluid Level to Plunger Top

1. BECAUSE, Pressure Wave from Shot Pushes Plunger
2. Can Shoot to Top of the Plunger
3. Echo off Top of Most Plungers (Not Two Piece)
4. See If the Plunger Falls Below Liquid at Bottom
**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

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Just Listen To Plunger
Equipment on Well
Plunger Cycle

Plunger lift operation cycle can be divided into three parts:

1) **Shut-in**: Surface valve closed, flow shut-in, plunger falls down 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 long enough for the plunger to reach bottom. And long enough for the pressure to build high enough to bring the plunger back to surface.

   *How long does it take plunger to get to bottom during shut-in?*

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.

Thanks: Dan Phillips and Scott Listiak
Conventional Plunger Cycle

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

[B] Valve Opens, Unloading Begins

[C] Valve Closes, Cycle Repeats

[2] Shut-in Valve Closed, w/ Pressure Increasing

### Plunger Cycle Events

- **[A]** Valve Closes (Shut In Begins)
  - Elapsed Time: 2.267 minutes
  - Tubing Pressure: 137.0 psi (g)
  - Casing Pressure: 192.7 psi (g)

- **[1]** Plunger Hits Liquid
  - Elapsed Time: 47.467 minutes
  - Tubing Pressure: 235.5 psi (g)
  - Casing Pressure: 273.1 psi (g)

- **[2]** Plunger On Bottom
  - Elapsed Time: 59.283 minutes
  - Tubing Pressure: 235.5 psi (g)
  - Casing Pressure: 290.7 psi (g)

- **[B]** Valve Opens (Unloading Begins)
  - Elapsed Time: 69.267 minutes
  - Tubing Pressure: 272.8 psi (g)
  - Casing Pressure: 306.0 psi (g)

- **[3]** Liquid Arrives
  - Elapsed Time: 79.550 minutes
  - Tubing Pressure: 126.3 psi (g)
  - Casing Pressure: 235.1 psi (g)

- **[4]** Plunger Arrives
  - Elapsed Time: 80.717 minutes
  - Tubing Pressure: 206.2 psi (g)
  - Casing Pressure: 231.5 psi (g)

- **[C]** Valve Closes (Shut In Begins)
  - Elapsed Time: 91.333 minutes
  - Tubing Pressure: 126.2 psi (g)
  - Casing Pressure: 171.4 psi (g)
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.
Manufacturer Designed Brush Stiffness and Seal Impact Fall Velocity

New Brush Fall Velocity Ranges from 160 – 425 Ft/Min
Acoustic Signal During Shut-in Period

- Shut-in Begins = 34.4 Min
- Plunger Hits Liquid = 70.0 Min
- Plunger on Bottom = 78.4 Min

Tubing Pressure
Count Signals from Plunger Falling thru Collar:
Acoustic/Pressure Signal During Shut-in (1 minute)

1800 Data Points in the Acoustic Signal During 1 Minute
Passive Monitoring Requires High Resolution Pressure & Acoustic Data

Signals Show Plunger Falls Past 80th and 81st Tubing Collar

2568 Ft Deep

0.1 PSI
**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.

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

Looking at this Minute Falling through Gas

Each Joint
Normal Fall Velocity [During Shut-in]

Click on Any Point

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

Falling thru Liquid

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

Slower

Faster
Take Guess Work Out of Setting Shut-in Time

- 201 Ft/min Gas
- 38 Ft/min Liquid
- Plunger Hits Liquid
- Plunger on Bottom
- Only Shut-in Time Period Shown

Fall Velocity in Liquid
- Gassy Fluid: 38 Ft/min
- Surfactant: 80 Ft/min
- High Pressure: 23 Ft/min
When Shut-in Begins the Tubing Pressure Instantly Drops when Plunger Starts to Fall

Pressure Drop = \( \frac{\text{Weight}}{\text{Area}} \)

Plunger weight (8 lbs) / Area of 2-3/8”
Identify When Plunger Becomes Stuck
Pressure Increases By ~3 psi

Blast from Gas Gun Re-Starts Fall

Plunger Sticks
Paraffin Stops Plunger Fall
9 Shots Used to Push Plunger to Bottom

Pressure Pulse Sent Down Tubing from Gas Gun Applies Force to Top of Plunger to Push & Re-Start Fall

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

Plunger Hits Liquid - 1937.01 Ft

Plunger Does Not Reach Bottom

Fast Plunger Arrivals are a Symptom of Sticking Plunger
Increase in Gas Flow Rate Past Plunger Results in Plunger Slowing Down…

Tubing Pressures - (psi)

Plunger Velocity - (ft/min)

Increase in Gas Flow Rate Past Plunger
Results in Plunger Slowing Down

SV Opens

Increase in Gas Flow Rate
Plunger Slows Down
2 3/8” By-Pass Shut-in Period Notice Pressure and Acoustic Signals

- After Flow
- Shut-in

Tubing Pressure
- Average Fall Velocity: 911 Ft/Min

- 3 Psi Step
- Tight Spot in Tubing Plunger Sticks at 60th Joint (1866 ft)

Acoustic
Count Signals from Plunger in Collar:
Acoustic Signal During Shut-in (1 minute)

Average Fall Velocity 911 Ft/Min
Fall Velocity – Bypass Valve Closes

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

By-pass Plungers Just don’t Work in my wells. Why?
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 Velocity = 44.7 ft/sec Near Critical
- Line Pressure 30 Psia
- Gas Flow Rate: 5000 m3/D 176.6 Mcf/D
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
Tubing Pressure Helps to Identify Downhole Problems

Plunger falls Past Hole at 1872 feet and Pressure from Casing Flows Into Tubing

Rapid Tubing Pressure Increase if Plunger has Sudden Stop

~ 3 psi Drop when Released from Catcher

Hole in Tubing 59th Joint

Suddenly Starts Suddenly Stopped

Plunger’s Weight is Supported by Tubing
Hole in Tubing

1) Hole was 156 jts from surface or 5054' based on 32.4' joint lengths

2) Hole measured with micrometer to be 0.160” by 0.125”.
Pressure Increases as Plunger Falls Past Hole

Plunger Fall in Well with Hole in Tubing - Tubing and Casing Pressure Equalized

Notice Tubing Pressure Drops approx 3 psi when Plunger Begins Fall
Pressure Drop Begins to Equalize When Plunger Falls Past Hole

Pressure Drop due to:
- Weight/Area = 2.31 Psi
- Terminal Velocity Force
- Friction on Plunger

Hole Depth: 5050 Feet
Plunger Fall Velocity Slows Past Hole

Liquid in the bottom of the tubing provides a pressure seal.
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?
Horizontal Well Impacts Velocity

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'

ore Deviation Have on Plunger Fall Velocity?
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?
Pad Plunger in Deviated S-Curve

- Pad Plunger Looses Seal
- @ 20 Deg of Inclination
- Speeds Up from 220 ft/min to 360 ft/min
Brush Plunger in Deviated S-Curve

When Inclination > 20 Deg
Extra Friction Slows Down from 500 ft/min to 425 ft/min
Solid Plunger in Deviated Well

When Inclination > 20 Deg
Extra Friction Slows Down from 500 ft/min to 425 ft/min
Fall Velocity is Faster at Low Pressures
Slows as Pressure Increases

Dual Pad Plunger

Fast

Slower
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)
Bypass Slow at High Pressure
Shut-in Time needs to be 2.66 Hours

2.375” Dual Pad Bypass
Plunger when Tubing
Pressure 1732 to 2213 Psig

Avg Velocity
78.4 ft/min

Normally Dual Pad Bypass Plunger Fall > 1000 Ft/Min
Fall Velocity Change is Non-Linear with Pressure

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

Vel (Ft/Min) = 2432.3 Psig^{-0.3779}

1 Psi = 1 Ft/Min at Low Pressures
New Fall Velocity Model Based on Gas Density

Viper Plunger Fall Velocity Calculation Based on Gas Density Model at Pressure and Temperature
Control Fall Velocity with Orifice Size

![Graph showing fall velocity in gas vs. tubing pressure average during fall for orifice sizes 8 mm, 10 mm, and 4.7 mm. The graph includes a label for Viper Barstock.]
Plunger Fall Velocity
Determined by Orifice Selection

10 mm  8 mm  4.7 mm  0 mm
“Select Correct Plunger for the Well” some wells need fast plungers and some wells casing pressure builds slowly.
Plunger Fall Velocity Impacted By:

1. Diameter of Plunger – Larger Diameter Falls Slower
2. Effectiveness of Seal between Plunger and Tubing – Better Seal Plunger Falls Slower
3. Brush stiffness – If the Bristles do not provide a effective seal then the plunger falls faster
4. Increased friction due to contact with the tubing – Plunger Falls Slower
5. Old age/increased wear – as the plunger wears out the worn plunger falls faster
6. If Gas can pass through plunger (i.e. Bypass) – then a plunger falls faster
7. When the plunger becomes stuck and stops – usually indicated by a 3 psi increase in pressure
8. If the Tubing is Sticky – the plunger falls slower
Plunger Fall Velocity Impacted By:

9. Wellbore Deviation – more than 20 degrees of deviation impacts plunger fall velocity
   a. Padded Plungers Faster due to Loss of Seal
   b. Solid Plungers Slower due to Increased Friction

10. Gas Flow Rate Into The Tubing – gas flow into tubing reduces plunger fall velocity

11. Pressure or Density of Gas
   a. High Pressure and plunger fall is Slow
   b. Low Pressure and plunger fall is Fast

12. Liquids increase density – plunger falls slow
   a. Surfactant lightens gradient and plunger falls faster, but more time may be required
   b. High pressure also causes plunger to fall more slowly through liquid
Plunger Life Cycle

1. Well is flowing above critical with all flow in Mist flow, no liquid gradient at any time.
2. Well begins to bubble and slug (Usually high speed bypass candidate if +15 ft/s velocity is available.)
3. Well begins to have difficulty maintaining seal due to velocity getting below 15 ft/s (usually good application for padded bypass plunger)
4. Well requires shut-in time to build pressure to maintain velocity of plunger (quick-drop application).
5. Well requires build time (conventional plunger lift applicable as fall time is not important)
6. Well requires substantial build time (high efficiency seals require more fall time but have a better seal).
7. Economics need to be reviewed for rod pump, compression, chamber lift or other forms of lift.
Questions?