Test Results from Plunger Well Simulator

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Constructed A Large Scale Plunger Lift Well Model

• Model Used to simulate how plungers behave in tubing with compressed air and water.
• Studied the performance 31 different plungers of different types and metallurgy.
• Gas flow rate required to float each type of plunger in dry gas was determined.
• Gas and liquid flow rate required to float each type of plunger in gassy fluid was determined.
• Fall velocity of each type of plunger through gas free water was determined.
• Pressures and gas flow rates measured during test
Results From Testing Will Be Presented

• Procedures used to perform each type of test will be discussed.
• Videos acquired while conducting each test will be shown.
• Plunger Float gas flow rates were determined by processing the high speed pressures recordings and measurements of gas and liquid flow rates.
• For fall velocity through water, the pressure changes at the moment the plunger hit the water and the when the plunger hit bottom be precisely determined.
• Data shows how plunger type and density of fluids impact plunger performance.
Float Each Plunger In Dry Gas

- Test was designed with the intent of determining the minimum flow rates required to lift and float each plunger type in a dry well.
- Each plunger was made to float at three separate heights within the tubing column and the flow rates were recorded as well as the pressures.

1. Measure and mark liquid column height up the tubing in metric. Ground zero is at the bottom collar.
2. Set up video camera so the whole height of tubing may be viewed.
3. Hook up the well analyzer to pressure tap located at the bottom of the tubing column.
4. Set up TWM. Put the well in to the group “Shop” and call the well “Testing Model”. Select plunger test.
Procedure for Float Each Type of Plunger in Dry Gas

5. Make sure well is dry.
6. Drop plunger into tubing. Close all unions.
7. Write name of plunger on whiteboard and set it in view of the camera.
8. Turn video on. Start acquiring Echometer data.
9. Slowly increase gas flow rate. Record flow rate and time when plunger remains afloat at the 0.5m, 1.75m and 3.0m marks.
10. Reduce the flow rate until the flow is shut off, controlling the plungers fall as to not damage bottomhole equipment.
11. Repeat steps 9 and 10 two more times, recording any observations.
12. Turn off video camera and stop acquiring data. Describe that data set as the name of the plunger being tested.
13. Remove plunger using the appropriate fishing tool.
14. Repeat steps 5-13 with each plunger being tested.
Video of Floating venturi bypass steel plunger in Dry Gas
Venturi Bypass Steel Plunger Floating from High Gas Velocity

27 Measured Data Points Recorded for Each Plunger

<table>
<thead>
<tr>
<th>Trial</th>
<th>Height</th>
<th>Flow Rate - Mcf/D</th>
<th>Pressure - Psig</th>
<th>Temp - Deg F</th>
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</table>
**Required Dry Gas Flow Rate to Float Plunger at 3 Specified Heights**

| Flow Rate (MscfD) | Brush Pad Style #3 | Dual Pad Style #1 | Venturi Long Plug | Venturi Titanium Plug | Single Pad Long Style #1 | Single Pad Short Style #1 | Venturi Long 4.7mm | Venturi Titanium 4.7mm | Cleanout Steel | Cleanout Steel w/o holes | Mini Cleanout Steel | Mini Cleanout Steel w/ holes | Solid Round Plunger | Solid Bypass 8.0mm | Venturi Bypass 8.0mm | Venturi Bypass 4.7mm | Titanium 8.0mm | Venturi Long 8.0mm | Sliding Sleeve 8.0mm | Venturi Long 10mm | Worn Venturi 2.0mm | Worn Venturi 1.86mm | Worn Venturi 1.73mm | Worn Venturi 1.50mm | Worn Venturi 1.38mm | Worn Venturi 1.26mm | Worn Venturi 1.14mm | Worn Venturi 1.02mm | Worn Venturi 0.90mm | Worn Venturi 0.78mm | Worn Venturi 0.65mm | Worn Venturi 0.53mm | Worn Venturi 0.41mm | Worn Venturi 0.29mm | Worn Venturi 0.17mm | Worn Venturi 0.05mm | Worn Venturi 0.00mm |
Dry Gas Pressure Required to Float Plunger at Required Gas Flow Rate

Sorted by Pressure
Dry Gas ~ Calculated Terminal Plunger Fall Velocity at Floating Gas Rate

Sorted by Calculated Plunger Fall Velocity

Plunger Terminal Fall Velocity - Ft/Min

- Brush Pad
- Triple Pad Style #3
- Single Pad Style #1
- Venturi Long Plug
- Cleanout Long 4.7mm
- Venturi Steel Plug
- Single Pad
- Venturi Titanium 4.7mm
- MIni Cleanout Steel
- Solid Round Plunger
- Venturi Long 8.0mm
- Solid Spinal
- Venturi Wide Ring
- Cleanout 4.7mm Steel
- Mini Bypass
- Venturi 8.0mm Steel
- Solid Worn Venturi 1.80"
- Sliding Long 10mm
- Venturi Bypass Steel 10mm
- Worn Venturi 1.73"
Plunger Falling Through Gas Free Liquid

- Test was designed to determine the fall velocity of various plungers through a gas free constant liquid column height.
- Each plunger was dropped into a liquid column and the time required to fall to the bottom was recorded.

1. Measure and mark liquid column height up the tubing in metric. Ground zero is at the bottom collar.
2. Hook up the well analyzer to pressure tap located at the bottom of the tubing column.
3. Set up TWM. Put the well in to the group “Shop” and call the well “Testing Model”. Select plunger test.
5. Add water until liquid column reaches 2.5m high.
6. Start acquiring data.
7. Drop plunger into tubing from top. Cover opening as soon as plunger is dropped to avoid water splashing out.
8. Record the time it takes between the plunger hitting water and hitting standing valve at bottom.
10. Pull plunger out with appropriate fishing tool.
11. Repeat steps 4-9 with each plunger being tested.
Elapsed Time for Triple Pad Plunger to Fall thru Gas Free Water

- Fall Velocity: 8.2 ft/13.93 Sec = 0.589 ft/sec = 35.3 ft/min
- Plunger Hits Liquid: 10.37 Seconds
- Plunger on Bottom: 24.30 Seconds
- Plunger on Bottom: 13.93 Seconds
Plunger Fall Velocity Through Gas Free Water

Fall Velocity thru Water - Ft/Min

Feb. 19 – 22, 2012
Plunger Weight Impacts Fall Velocity Through Gas Free Water

- Venturi Bypass Steel: 3.13 Lbs
- Venturi Bypass Titanium: 1.78 Lbs
- Venturi Cleanout 4.7mm Steel: 2.82 Lbs
- Venturi Cleanout 4.7mm Titanium: 1.11 Lbs
Plunger Weight & Bypass Impact Fall Velocity Through Gas Free Water

**Steel Weight 1.90 Lbs**

**Titanium Weight 0.71 Lbs**

<table>
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<tr>
<th>Venturi Steel 10mm</th>
<th>Venturi Titanium 10mm</th>
<th>Venturi Steel 8.0mm</th>
<th>Venturi Titanium 8.0mm</th>
<th>Venturi Steel 4.7mm</th>
<th>Venturi Titanium 4.7mm</th>
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<td>8 mm</td>
<td>4.7 mm</td>
<td>4.7 mm</td>
<td>Plugin</td>
<td>Plugin</td>
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Fall Velocity thru Water - Ft/Min

Feb. 19 – 22, 2012
Float Each Plunger In Gaseous Liquid Column

- Determine the minimal flow rates required to lift a liquid column, lift the plunger and keep the plunger suspended within a tubing column.
- Each trial started by recording the flow rate of gas when the liquid column is able to lift itself to 3.0m.
- Record flow rate when plunger lifted off the standing valve and when it remained suspended in the tubing.

1. Measure and mark liquid column height up the tubing in metric. Ground zero is at the bottom collar.
2. Set up video camera so the whole height of tubing may be viewed.
3. Connect well analyzer at the bottom of the tubing column.
4. Set up TWM. Put the well in to the group “Shop” and call the well “Testing Model”. Select plunger test.
Float Each Plunger In Gaseous Liquid Column

5. Drop plunger into tubing to standing valve. Close all unions.

6. Write name of plunger on whiteboard and set it in view of camera.

7. Add a 1m liquid column into the tubing.

8. Turn video on. Start acquiring Echometer data.


10. Reduce the flow rate until the flow is shut off, controlling the plungers fall as to not damage equipment.

11. Shut off the water pump.

12. Stop the recording on the video camera and stop acquiring data. Name the data file “water – “ followed by name of plunger.

13. Repeat steps 5-12 for each plunger being tested.
5. Conducting Test

a) Make sure the ball valve is open.

b) Slowly increase flow rate using globe valve. Record the flow rate and time when the liquid column reaches the t-union (3m).

c) Next, record the flow rate and time when the plunger lifts off the standing valve and remains off.

d) Take two separate recordings of the flow rate and time, one minute apart while the plunger remains afloat anywhere from 1m to 2.5m (For bypass plungers, record once when it is afloat and again when it is cycling freely).

e) Take note of the flow rate of the water coming into the tubing and the average temperature.
Video of Plunger Triple Pad Plunger Floating in Gaseous Liquid Column
Fluctuating Pressure Data During Float in Gaseous Liquid Column

Triple Pad Plunger

~ 40 Pressure Swings Per Minute

+7 psi Pressure Swings

~ 40 Pressure Swings Per Minute
Gas Flow Rate Required to Support Plunger in Gaseous Liquid Column

Flow Rate (Mscf/D)

- Venturi Long Plug
- Venturi Titanium Plug
- Venturi Long 4.7mm
- Triple Pad
- Dual Pad Style #1
- Venturi Steel Plug
- Single Pad
- Venturi Steel 4.7mm
- Venturi Titanium 4.7mm
- Venturi Long 8.0mm
- Venturi Titanium 8.0mm
- Venturi Steel 10mm
- Cleaning Steel
- Venturi Long 10mm
- Mini Bypass Titanium
- Venturi Cleanout 4.7mm Steel
- Venturi Steel 10mm
- Venturi Bypass Steel
Observations

• Float velocity in dry gas and gassy fluid showed different results between suspending a plunger in a dry gas or a plunger in gassy water.

• Water with gas created a better seal between the plunger and the tubing walls (restricting the flow of gas pass the plunger)
  – When Liquid Present, Less Gas is required for the plunger to lift and travel up the tubing.

• Slugging when both Liquid and Gas in Tubing make Steady State Measurements Difficult

• This was an Interesting Project!
Plunger Fall Velocity Impacted By:

1. Effectiveness of Seal between Plunger and Tubing – Better Seal Plunger Falls Slower

2. Increased wear – as the plunger wears out a worn plunger falls faster

3. If Gas can pass through plunger – then a plunger falls faster

4. Gas Flow Rate Into The Tubing – gas flow into tubing reduces plunger fall velocity ~ Possible to Float Plunger

5. Density of Fluids Impacts Plunger Fall Velocity

6. High Density and plunger fall is Slow

7. Light Density and plunger fall is Fast

8. As Fluid Density Increases – plunger falls slower
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