Selection, optimization and safe operation of bypass plungers

Set up for success

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History

• The first use of a bypass plunger may have been as early as 1927 by Hughes (now part of Baker Hughes) however it was used for oil and in the 1950's it was mentioned as a way to "remove water and increase gas well productivity" in Brown's Book “The Petroleum Engineer”. At the time the use was limited as there were no controllers available so optimizing the velocity of the plunger was difficult and damage often occurred.

• They come in various names including continuous/free fall/freecycle and bypass plungers

• Designed to fall against flow
Bypass Plunger Examples

IPS Pacemaker

FB Super Flow

Weatherford Rapidflo with Trip Rod

T-Ram Venturi Bypass

WMC Venturi Eagle

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Potential/historical problems

• There is the potential for dangerously high plunger velocities depending on pressures, flow rates and falling against no flow. Often this is the biggest mental barrier.

• Surface facilities must be designed in such a way as to accommodate tool behaviour.

• Bottom hole assembly (BHA) must be designed to withstand potential harsh impact.

• BHA best designed in such a way as to hold liquid [standing valve].

• Best if BHA is sumped as added protection against harsh impacts.

• Large amounts of liquid are NOT required to “cushion” at EOT.

• “Freewheeling” should be avoided in low liquid cases.
Reasons for Expanding Bypass Use

- Recent understanding of conventional plunger fall velocities can be crossed over to bypass plungers as well.
- Programs such as ProdOP are available to assist in setup.
- High speed data acquisition equipment such as the Echometer can assist in setup and monitoring.
- Improvements to lubricators and BHA's.
- Control systems allow more sophistication so automatic chokes and multiple valve arrangements are feasible.
- Better understanding regarding material selection/heat treat processes for improved equipment durability.
So what are the “minimum” requirements?

- At least 8-10 ft./sec gas velocity at end of tubing (EOT) and flow above critical rate at surface under continuous conditions
- GLR/well specific understanding so as to allow proper set up
- Lubricator/piping arrangements at surface that will guarantee proper tool behaviour
- Proper BHA that can support possible harsh impact
- Understanding of gas velocities at surface to mitigate potential risk
- Field staff training about continuous application
- Physical construction and control logic selection that “wont be fooled”
- Inspection program – potentially modified for bypass plungers
- Understanding of how long the well’s life cycle will support continuous application and when shut in time will be required (change to “quick drop” plunger)
Gas velocities – top to bottom

- Use EOT as minimum requirement and surface as risk assessment

From ProdOp – Dr. J. Lea, PLTECH

Superficial Gas Velocity - Pressure with Gray (Mod)

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Depth (1000 ft MD)</td>
<td>Pressure</td>
<td>Flow Rate</td>
</tr>
<tr>
<td>Ptwh</td>
<td>Hi-Angle Critical Velocity</td>
<td>14.0 ft/s</td>
</tr>
<tr>
<td>Formation Gas Rate</td>
<td>94 psig</td>
<td>377 Mscf/d</td>
</tr>
<tr>
<td>Condensate</td>
<td>1.0 bbl/MMscf</td>
<td>1.0 bbl/MMscf</td>
</tr>
<tr>
<td>Water</td>
<td>3.0 bbl/MMscf</td>
<td>3.0 bbl/MMscf</td>
</tr>
<tr>
<td>Tubing String 1</td>
<td></td>
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</tbody>
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Surface velocity suggests potential high velocities - consider mass during tool selection.

Velocity at EOT meets minimum requirements.
Venturi Plunger Selection Tool

Is the well flowing above critical rate at surface?

YES

Is there at least 10ft/s at the bottom of the well?

YES

Does the well produce sand/wax/paraffin?

YES

Consider the use of a standard Venturi plunger with a variable orifice to minimize fall time based on build rate.

YES

Consider a full-port bypass plunger.

NO

Is there a b-valve present?

YES

Consider a quickdrop with a speed reducing orifice as a method of risk reduction to minimize bottomhole impact.

NO

Consider the use of a conventional plunger that fails fast (i.e. 8mm or 10mm Venturi variable orifice).

NO

Consider the use of titanium as a method of risk reduction due to its lighter mass.

NO

Consider the use of a standard grade steel bypass plunger.

YES

Consider the use of a full-port bypass plunger with an orifice option.

NO

Is the velocity greater than 30ft/s at surface?

YES

Consider the use of a standard Venturi with a variable orifice to match build rates.

NO

Consider the use of a standard grade steel bypass plunger.
Bottom hole impact – minimal liquid at bottom of the well
Bottom hole impact – with liquid at the bottom of the well
Trip rod considerations

Trip rods can cause pressure drops, could be a significant restriction in low pressure cases.

Can help solve wax and debris issues.

Need to be inspected.
Trip rods to address wax/sand
Trip rod to help with sand production issues on HZ well

Well begins to load
Bypass plunger installed
Trip rod installed

Flow Rate (e3m3/d)
Tubing Kpa
Sep Oct Nov Dec Jan 2012
Using bypass plungers to clean tubing

- There are *misconceptions* regarding plungers and wells that produce wax/sand debris etc.
- Many wells currently use chemicals as methods to keep tubulars clean when in fact *plungers could be used*
- Cycle frequency may require *special set up* as you may find liquid will not be present
- Special valving may be required in order to *mitigate potential high velocities*
- *Continuous applications* may be required depending on cycle frequency
Risk from not following minimum requirements
Considerations when no additional valves or control to be used

• Best if line pressures are consistent
• Most likely requires a trip rod or positive plunger valve shift mechanism
• May require a variable orifice or other plunger fall velocity control means
• Most likely to have problems associated with fast travel times both on fall and arrival
Sample no valving arrangement

No added valving may prevent proper tool behaviour.

Be sure pressure transmitters do NOT have water traps.
Considerations when adding manual valves to lubricator outlets

- Works best with consistent line pressures
- Valves provide throttling (choking) of flow to control rise velocity of plunger
- Throttling is set at a fixed point, therefore preventing free flow of gas – may limit production
- Still may require a trip rod or auto catch to effect positive opening of the plunger valve
Sample with manual valves

Simple modifications can be made to accommodate a bypass plunger.

Make alternate plans rather than running fuel gas over extended lengths.
Limitation of manual valves

Difficult to maintain consistent travel times with fixed valve settings. “Pinched” valves add back pressure, limit flow rate and force debris around and through plungers.
Considerations for additional Automatic Valves

- Requires logic capability of controller to operate multiple solenoids or variable choke
- Allows greatest amount of control over the whole system
- Provides best performance and best safety
- Permits matching flow rate control with plunger characteristics for best optimization
Example with Automatic Choke

Continuously variable control valve operating from EFM flow rate data is used to shut-in or reduce flow for plunger fall, control rise velocity and operate fully open after plunger arrival.
Example with automated valves

Utilization of globe valve can address extreme velocity environments

Auto catch/main valve are engaged during the lift. This promotes proper tool behavior.

“B” valve opens upon plunger arrival. This promotes no added back pressure.
What does a cycle look like with high speed data?

Well was started 10/26/09 as a conventional well.

“Normal” looking conventional cycle

The well did meet the minimum gas velocity at time of start up but did not have the proper surface piping to support a continuous application

“Liquid” had to become part of the “logic” to manage arrival speeds.
Shift forward with same well and small modification

Addition of a bolt on actuator onto the ball valve to promote tool behaviour.
Confirm gas requirements

- Caution: gas rates at surface might indicate plunger not required – look at EOT critical rate!
Gas velocities – top to bottom

- Use EOT velocity for minimum rate requirement and surface velocity for fast arrival risk assessment

**Superficial Gas Velocity - Pressure with Gray (Mod)**

- Velocity at EOT meets minimum requirements
- Surface velocity suggests potential high velocities – consider mass during tool selection

From ProdOp – Dr. J. Lea, PLTECH
What does the cycle look like now?

Notice minimal pressure increase in the csg during the 1 minute of shut in – 2 psi as opposed to 107 psi (graph is in kPa)
Logic suddenly becomes “easier”
No longer using liquid as a mechanism to control arrivals. GLR suggested 240 litres/day during free flowing period.
Slug sizes are now minimal – 5 litres/trip. 48 trips/day = 240 litres/day (=0.03 bbl/trip, 1.5 bbls/d)
Detailed cycle analysis – static fall

- Total **round trip** arrival of 21.16 minutes
- Well is shut in for 1.1 minutes to drop past high velocity upper section of the well. Plunger falls at 1758.7 ft./minute - **total depth fallen thus far is 1703.09 ft**
Detailed cycle analysis – fall during flow

- Total round trip arrival of 21.16 minutes
- Well is shut in for 1.1 minutes. Plunger falls at 1758.7 ft./minute - total depth fallen thus far is 1703.09 ft
- Well opens up – plunger continues to fall at 682 ft./minute at a gas rate of 413mcf. Rate determined by manual joint frequency recognition at surface. Confirmed with Echometer pressure data sampling csg pressure at 120 times/second.
- Plunger on bottom CAN be detected
Detailed cycle analysis – liquid and plunger arrival

• Total round trip arrival of 21.16 minuets
• Well is shut in for 1.1 minuets. Plunger falls at 1758.7 ft./minuet - total depth fallen thus far is 1703.09 ft
• Well opens up – plunger continues to fall at 682 ft./minuet at a gas rate of 413mcf. Rate determined by manual joint frequency recognition at surface. Confirmed with echometer pressure data sampling csg pressure at 120 times/second.
• Plunger on bottom CAN be detected
• Small liquid slug – 3.06 seconds
• Average rise velocity of 780 ft./minute
Detailed cycle analysis summary

- After 30 minutes of after flow well is shut in based on critical rate cutoff criteria for 1.1 minutes
- Plunger falls in a static condition at 1758.7 ft./min
- Plunger falls 1703 ft. prior to opening sales valve
- Main sales valve is opened and plunger continues to fall at 682 ft./minute at a gas rate of 413 mcf/d while B valve remains closed and flow is restricted through pinched upper valve.
- Plunger on bottom is easily detected by an Echometer thus verifying fall rate during the on period
- Average rise velocity of 780 ft. minute based on confirmation of plunger on bottom with Echometer
- 3 seconds of fluid brought to surface
- On plunger arrival, B valve is opened and full gas flow occurs until cutoff criteria reached and cycle repeats
- 48 trips per day equals 240 liters of liquid (1.5 bbls) production which agrees with previous GLR data during mist flow regime of well life cycle
Casing pressure trend as seen on scada

- Average flowing csg pressure decrease equalled a net production gain of 53mcf/day
Static fall considerations

- During any part of the fall period – consideration must be given to static fall with bypass plungers. Tool selection and the BHA needs to be “matched” for worst case scenario’s. The BHA must be able to accommodate a dry trip at maximum velocity – mass and fall velocity must be a primary consideration.

- Static fall sometimes required in order to get the tools deep enough into the well to get out of extreme velocities thus allowing the plungers to continue downward travel.

- Static fall can trigger arrival sensors.

- Some shift pin designs can close during rapid fall decent – need to know maximum velocity a particular plunger design can fall against.
Controller/logic considerations

- Controller may need to accommodate multiple solenoids – auto catch/B valve
- Fast trip protection needs to be considered
- Arrival history can detect tool behavior problems
- If auto tuning is to be used – be cautious of how to adjust for slow and fast conditions. Sometimes a slow arrival may be due to the slow decent part of the cycle, which therefore may mean fast upward travel
- Drastic gathering system pressure variation can greatly effect fall and arrival speeds
- Gathering system pressure swings can greatly effect high perm wells and therefore arrival times. This is due to no storage issues as with conventional systems.
- Numerous trips common with continuous applications can be a handful for batteries on stand alone controllers and scada systems.
Conclusions

• There are many wells operating as conventional plunger wells that could be converted to continuous applications with minimal modifications – sometimes no modifications are needed

• Initial construction should include the ability to use continuous plunger technology

• Most new plunger installs should be continuous candidates as a starting point

• Recent tool designs are supporting the need to minimize bottom hole impact
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