Plunger Lift Algorithms – A Review

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Learning Points

- What is an algorithm?
- Continuous vs conventional plunger lift
- Well production goal
- Plunger stage objectives & variation
- Plunger driver
- How do algorithms relate?
**What is an Algorithm?**

*algorithm*

/ˈælɡəˌraɪðəm/

*noun*

a process or set of rules to be followed in calculations or other problem-solving operations, especially by a computer

For plunger lift, an algorithm:
- Tells the well when to open and close
- Records data (Ex: Flow rates, pressures, arrivals)
- Initiates receiving and/or transmitting data
What is an Algorithm?

Open Condition Examples

<table>
<thead>
<tr>
<th>Timer &gt; or = set point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tubing pressure &gt; or &lt; set point</td>
</tr>
<tr>
<td>Casing pressure &gt; or &lt; set point</td>
</tr>
<tr>
<td>Line pressure &gt; or &lt; set point</td>
</tr>
<tr>
<td>CP-TP &gt; set point</td>
</tr>
<tr>
<td>CP-LP &gt; set point</td>
</tr>
<tr>
<td>TP-LP &gt; set point</td>
</tr>
<tr>
<td>CP-LP AND TP-LP &gt; set point</td>
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Open Condition Examples

<table>
<thead>
<tr>
<th>Slug size &gt; set point</th>
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<tbody>
<tr>
<td>Load factor &lt; set point</td>
</tr>
<tr>
<td>Load factor &lt; set point (1) AND CP &gt; LP (1)</td>
</tr>
<tr>
<td>Maintain plunger velocity within user selected range</td>
</tr>
<tr>
<td>Throttle control valve to maintain down stream pressure or flow rate</td>
</tr>
<tr>
<td>Manual open</td>
</tr>
</tbody>
</table>

(1) For user defined time period

Which to choose??

Open conditions are in play after allowed plunger fall time elapses
## What is an Algorithm?

**Close Condition Examples**

<table>
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<th>Condition</th>
<th>Example</th>
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<tbody>
<tr>
<td>Afterflow timer &gt; set point</td>
<td>Flow rate &lt; (Turner CFR * multiplier) AND (CP-LP) &lt; set point</td>
</tr>
<tr>
<td>Tubing pressure &gt; or &lt; set point</td>
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Close conditions are in play after the arrival sensor confirms the plunger surfaced.

Adjustments if max allowed plunger rise time expires before plunger arrives.

Additional settings for gas assisted plunger lift & plunger assisted gas.
Continuous Cycle Plunger Lift

- Plunger falls against flow rate
- At bottom, plunger valve closes
- Plunger rises. Valve opens at surface.
- Afterflow (if desired)

Plunger falls when:
- Flow rate is insufficient (bypass adj) OR
- Well closed for short period of time OR
- Well closed until plunger hits bottom

Monitor expected vs actual RTT.
Can use many algorithms to end afterflow. If afterflow, consider an auto-catcher.

Know & monitor SAFE plunger velocity for the equipment utilized.
Consider surface impact velocity sensor.
Conventional Cycle Plunger Lift

Stage 1  Plunger fall (gas, liquid)
Stage 2  Casing pressure build
Stage 3  Plunger rise
Stage 4  Production stage

Optimize each stage!
Well Production Goal

- **DAILY PRODUCTION**
- **LOST PRODUCTION**
- **NATURAL DECLINE CURVE**
- **CASING PRESSURE**
- **LIQUID LOADED DECLINE CURVE**
- **LOST PRODUCTION**

FLOW RATE (mcf)

PRESSURE (psi)

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Flowing Bottom Hole Pressure

- Line pressure
- Liquid
- Scale / Paraffin
- Chokes
- Valve trim size
- Orifice plate
- 90 degree elbows

Low Backpressure
- Produces
- FBHP
- Ensures
- Production

Most Production
Well Production Goal

IPR CURVE

ABSOLUTE OPEN FLOW!

High Pressure Well
Low Pressure Well

Flowing Pressure, PSIA

Rate, MCFD

100 psi

~ 80 Mcf/d
~ 20 Mcf/d

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Denver, Colorado
## Plunger Stage vs Variation

<table>
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<tr>
<th>Stage</th>
<th>Objective</th>
<th>Contributors to Variation</th>
<th>Tools</th>
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</table>
| Plunger Fall    | Fall time expires when plunger hits the BHS. Too long is costly!          | Height of gas column  
                    |                                                                             | Mfr’r data  
                    |                                                                             | Echometer  
                    |                                                                             | Wellmaster |
| CP Build        | Lowest CP required to surface plunger                                     | CP typically not the same after a set close time               | Foss and Gaul’s CP req’d          |
| Plunger Rise    | Don’t stall plunger. Don’t damage equipment. Optimize production!         | CP, TP, LP, restrictions, plunger efficiency.                   | Liquid load  
                    |                                                                             | Lift pressure  
                    |                                                                             | Surface vel.  
                    |                                                                             | sensor     |
| Production Mode | Desired volume of liquid in tubing on every cycle                         | Liquid load typically not the same after a set open time interval | Critical flow  
                    |                                                                             | rate, CP  
                    |                                                                             | increase    |
Plunger Lift Driver

**Control Valve**

**DOWNWARD FORCE**
- Liquid Load (CP-TP)
- Line Pressure Restrictions

**PLUNGER EFFICIENCY**
- Best – Brush or Pad
- Worst – Bar Stock

**UPWARD FORCE**
- Casing Pressure

**LIFT PRESSURE = (CP- LP)**

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How do Algorithms Relate?

Stabilize liquid load and lift pressure on every cycle, then optimize!

**Considerations**

- Actual production vs goal? Decline & IPR curve.
- Operating at Minimum Open OR Minimum Close?
- Packer in well? Can’t use casing pressure algorithms
- Line pressure varies? Pipeline pressure or flow limitation?
- Casing pressure varies given a set close time?
- Liquid in tubing varies given a set open time?

Select an algorithm that accommodates variations and drives to, then maintains the production goal.
How do Algorithms Relate?

- **Plunger Fall**
  - Time
  - Tubing pressure > / = set point
  - Casing pressure > / = set point
  - Tubing / Casing > / = set point
  - Tubing – Line > / = set point
  - Casing – Line > / = set point
  - Casing_{req'd} > / = Foss and Gaul
    - > / = Multiplier X F&G
  - Load Factor < / = Set point
  - Time
  - Tubing pressure < / = set point
  - Casing pressure < / = set point
  - Casing_{req'd} > / = Increase psi
  - Flow rate < / = set point
  - Delay Timer < / = Critical flow
  - Multiplier X CFR

- **Pressure Build**

- **Plunger Rise**

- **End Production**
Layered conditions

- Open or close on multiple conditions.
- Ex: Close when (CP Rises) or (Flow Rate = Critical) or (Time) expires

Auto cycle algorithms (Initially developed for wells with packers)

- Controller self adjusts to maintain a preselected plunger velocity.
- User must select “best” plunger velocity for each well.
- Algorithm may not directly relate to producing at the lowest FBHP.
- When plunger wears, program adjusts to maintain velocity. Production?

Casing pressure rise - can indicate liquid in tubing

Load Factor or Lift Factor

- Load Factor = Liquid load / Lift pressure (Industry guideline = / < 0.5)
- Lift Factor = Lift pressure / Liquid load (Industry guideline = / > 2.0)
- Lift Factor same: LP = 100; LL= 50 AND LP = 50; LL = 25. Lowest FBHP??
- Maintains production, yet may not drive well to lowest FBHP
Adjustments if missed arrival

- Add close time or build to a higher pressure set point before next open.
- Some algorithms allow selecting # of sequential misses before shut-in.

If using LP, dump valves must not stick open!

Stabilization time or minimum open is important when liquid follows the plunger

( Horizontal well or EOT above perf’s)
1. Optimize each plunger stage
2. Select an algorithm for each stage that:
   - Best achieves the objective for that stage
   - Adjusts for known well variations
   - Drives to the lowest flowing bottom hole pressure
   - Maintains production on the natural decline curve

“Which to choose”

Operator knowledge is the #1 factor influencing production

Stabilize, then optimize!

Optimize production!
Monitor plunger velocity.
Don’t tear up anything!
John Wooden: "When you improve a little each day, eventually big things occur... Not tomorrow, not the next day, but eventually a big gain is made. Don't look for the big, quick improvement. Seek the small improvement one day at a time. That's the only way it happens — and when it happens, it lasts."

UCLA Basketball Coach (1948 to 1975)
Won 82.5 % of conference games
10 NCAA Championships in 12 years
“Problems are nuggets to be mined, not garbage to be buried”

“Getting the Right Things Done” by Pascal Dennis

Linkedin Group

“Plunger Lifted Gas Wells”
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