Gas Well Deliquification Workshop

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Plunger Lift Algorithms – A Review

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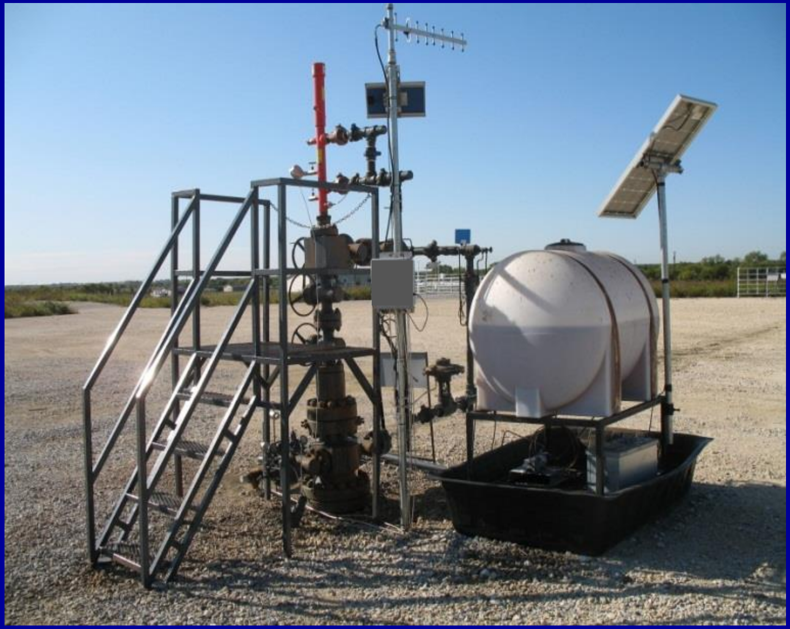


Learning Points

- 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 ?

al·go·rithm
/ˈalgəˌriT͟Həm/

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
Timer > or = set point
Tubing pressure > or < set point
Casing pressure > or < set point
Line pressure > or < set point
CP-TP > set point
CP-LP > set point
TP-LP > set point
CP-LP AND TP-LP > set point

Open Condition Examples
Slug size > set point
Load factor < set point
Load factor < set point (1) AND CP > LP (1)
Maintain plunger velocity within user selected range
Throttle control valve to maintain down stream pressure or flow rate
Manual open

(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
Afterflow timer > set point
Tubing pressure > or < set point (1)
Casing pressure > or < set point (1)
Line pressure > or < set point (1)
CP-TP > set point
CP-LP > set point
Slug size > set point
DP across orifice plate < set point (1)

Close Condition Examples
Flow rate < (Turner CFR * multiplier) AND (CP-LP) < set point (1)
Maintain plunger velocity within range
Manual close

(1) For user defined time period

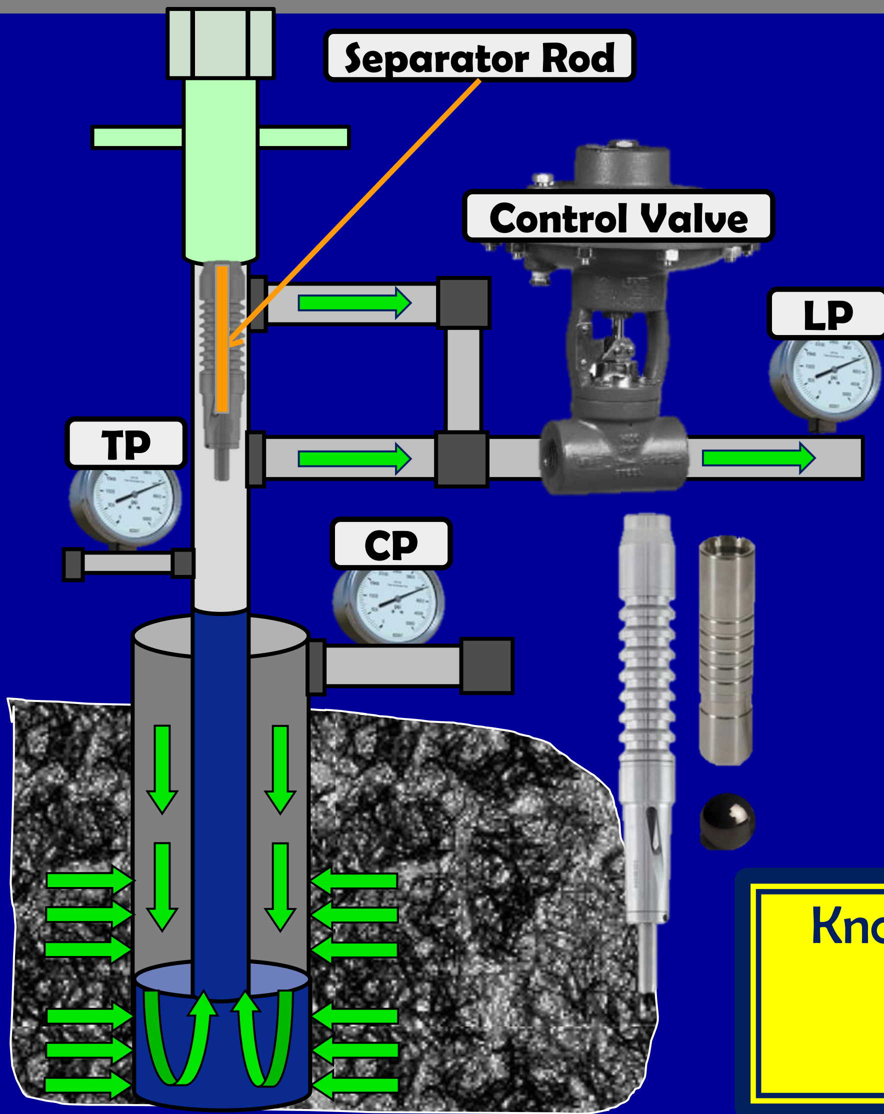
Which to choose ??

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.

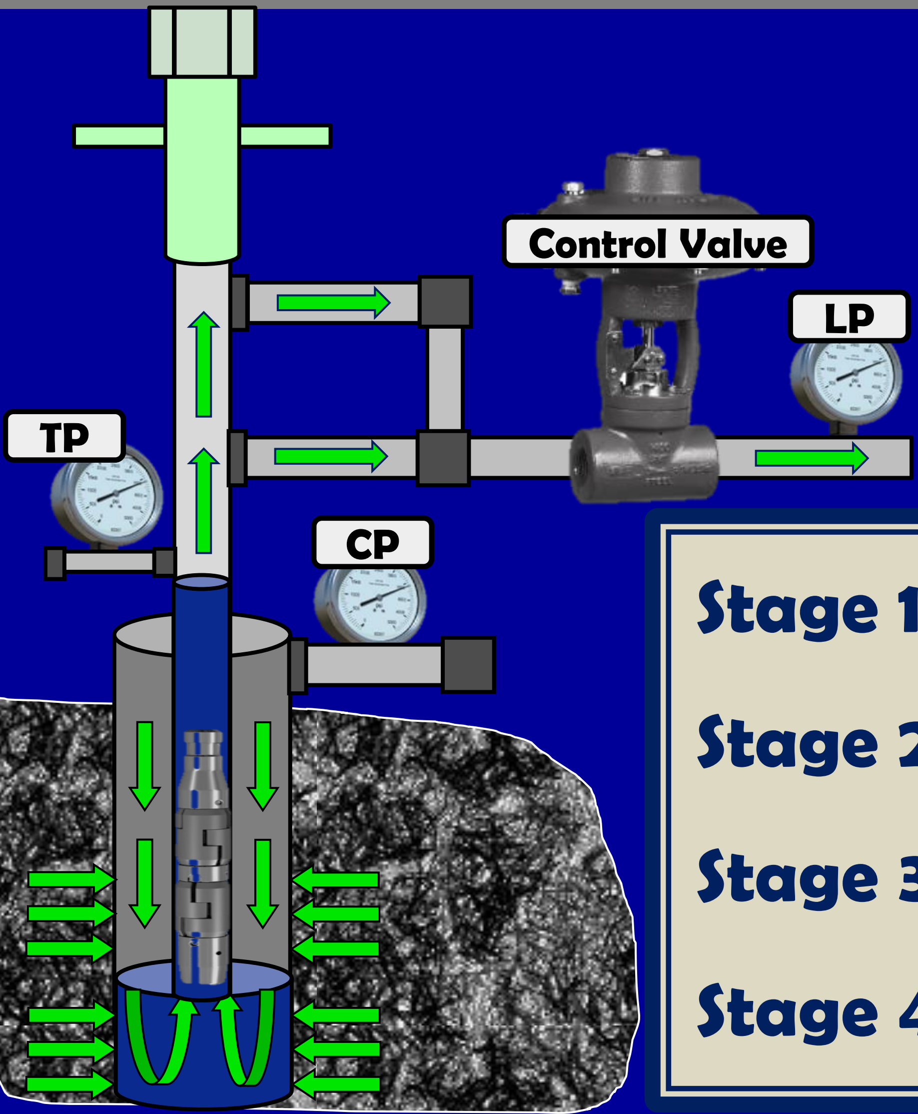
Can use many algorithms to end afterflow.

If afterflow, consider an auto-catcher.

Know & monitor ***SAFE*** plunger velocity for the equipment utilized.

Consider surface impact velocity sensor.

Conventional Cycle Plunger Lift



Optimize each stage!

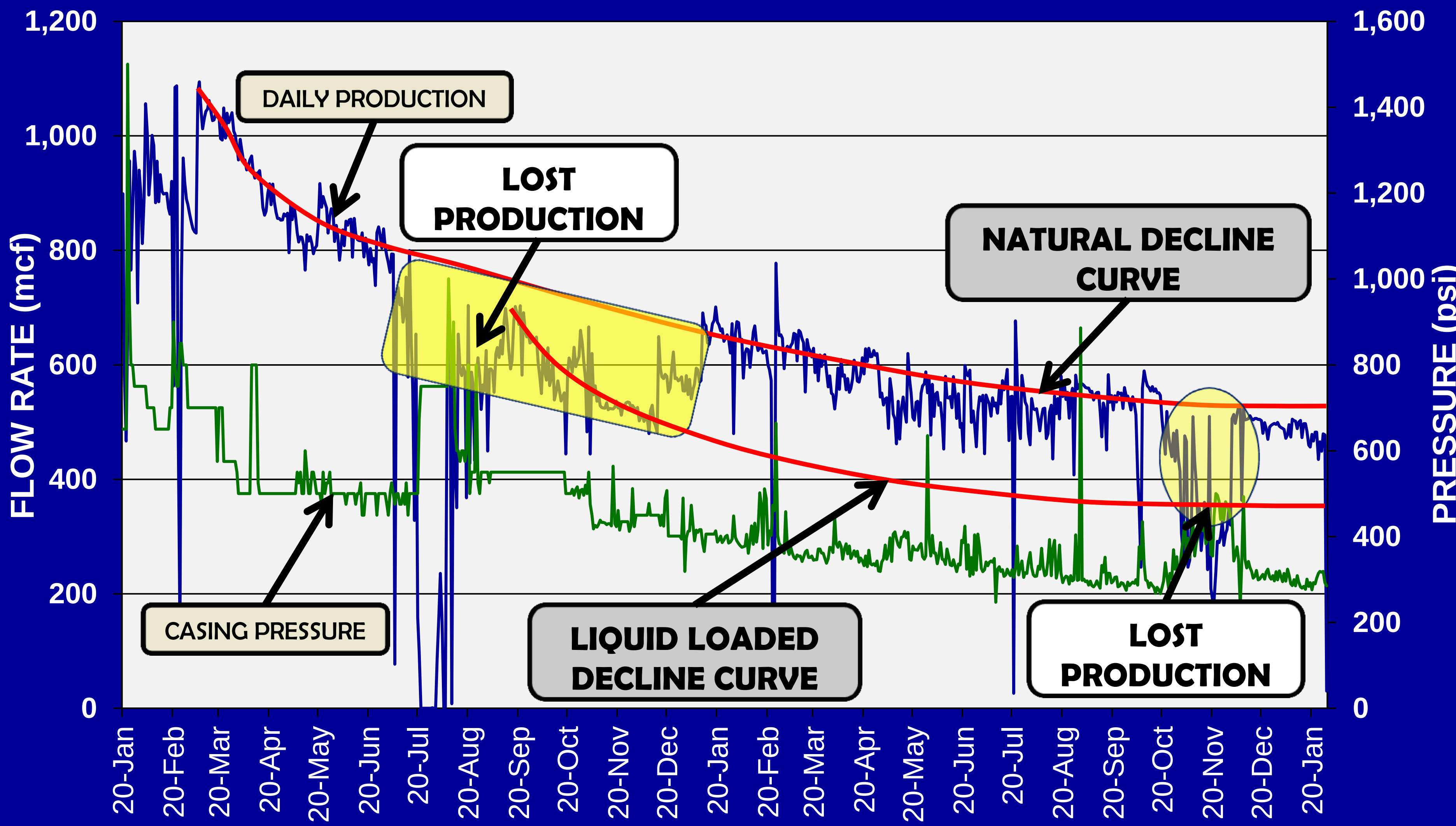
Stage 1 Plunger fall (gas, liquid)

Stage 2 Casing pressure build

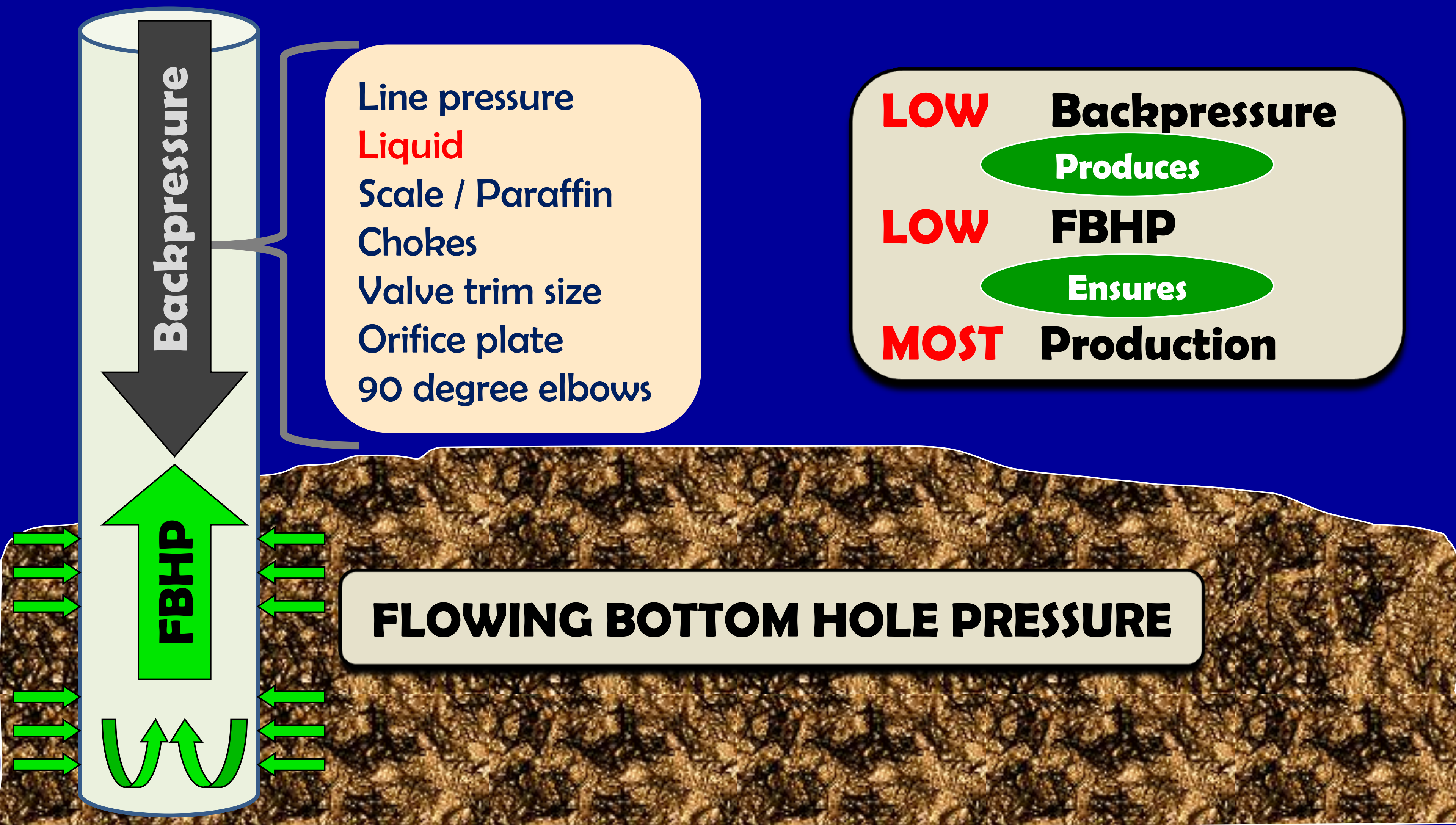
Stage 3 Plunger rise

Stage 4 Production stage

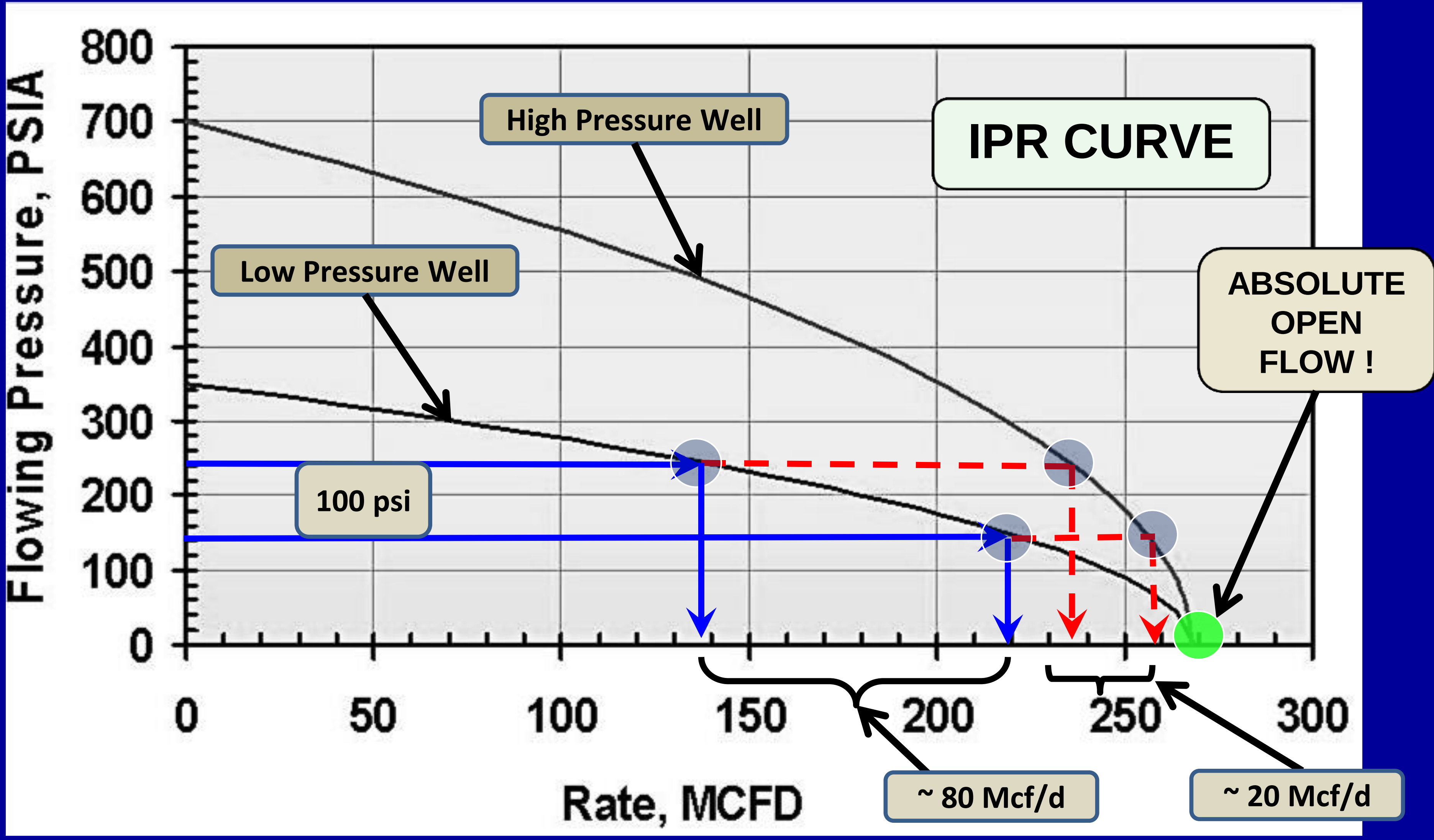
Well Production Goal



Well Production Goal



Well Production Goal

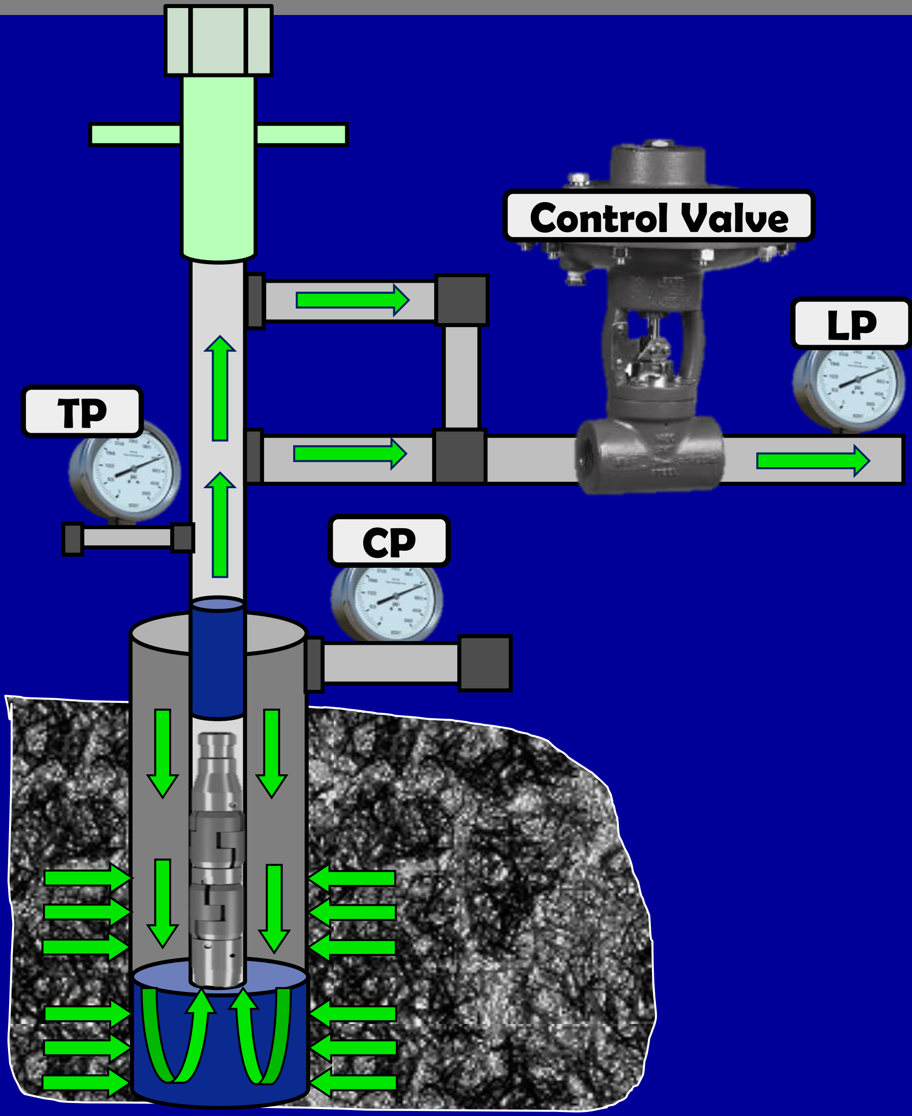


Plunger Stage vs Variation

Optimize each stage!

Stage	Objective	Contributors to Variation	Tools
Plunger Fall	Fall time expires when plunger hits the BHS. Too long is costly!	Height of gas column Height of liquid column Actual fall velocity	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



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)

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

Pressure Build

- Time > / = set point
- 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

Plunger Rise – Time

End Production

- Time > / = set point
- Tubing pressure < / = set point
- Casing pressure < / = set point
- Casing pressure > / = Increase psi
- Flow rate < / = set point
  < / = Critical flow
  < / = Multiplier X CFR

Delay Timer

How do Algorithms Relate?

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

How do Algorithms Relate?

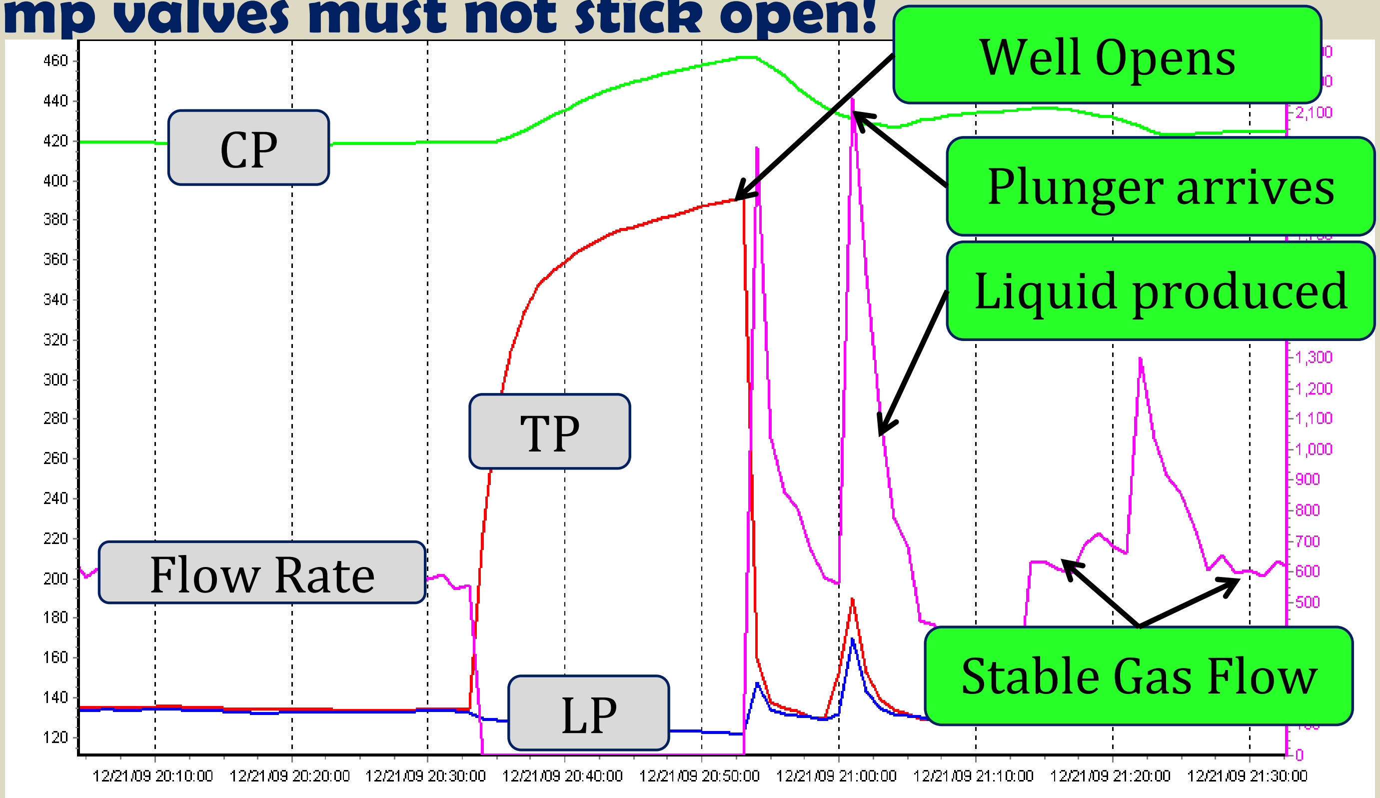
Adjustments if missed arrival

- 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)



Summary

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"

Stabilize, then optimize !

Operator knowledge is the # 1 factor influencing production

Optimize production!

Monitor plunger velocity.

Don't tear up anything!

Continuous Improvement

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

Continuous Improvement

"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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