10 Steps to Optimized Production

David Cosby, P.E.
Shale Tec LLC
Learning Points

- What is an optimized well?
- 10 Steps to optimizing production
**Why Optimize?**

**What is an optimized well?**

- Meets daily production goal?
- No missed plunger cycles?
- Produces at or above 80% of AOF?
- 20% production increase?
- 500 to 1000 fpm plunger cycle?
- Rapid payback?

“An optimized plunger lift well is a well that is operating at the maximum number of cycles necessary to generate the lowest average flowing bottom hole pressure with the available reservoir energy.”

ALRDC Guidelines and Recommended Practices

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Why Optimize?

IPR CURVE

ABSOLUTE OPEN FLOW!

High Pressure Well

Low Pressure Well

100 psi

150

200

250

300

0

100

200

300

400

500

600

700

800

Flowing Pressure, PSIA

Rate, MCFG

~ 90 Mcf/d

~ 20 Mcf/d

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10 Steps to optimizing production

1. Develop an artificial lift strategy
2. Install AL before production is lost
3. Standardized PL configuration
4. Set meaningful production targets
5. Remove restrictions
6. Prioritize wells daily
7. Optimize
8. Troubleshoot with DATA!
9. Preventative maintenance
10. Continuous improvement

Be Proactive!
Lowest FBHP!
Train Wide and Deep!
Real Time DATA!
1. Artificial Lift Strategy

Guidelines & Recommended Practices
Selection of Artificial Lift Systems
for Deliquifying Gas Wells

Lessons Learned
from Natural Gas STAR Partners

Options for Removing Accumulated Fluid and
Improving Flow in Gas Wells

Artificial Lift Type Considerations:
- Operating depth, volume, temperature
- Ability to handle corrosion, gas, solids
- Fluid gravity, build angle, servicing
- Energy source, system efficiency

Free Flowing Well

Foaming Agent

Velocity Strings

Compress

Swab or Intermit Well

2 Stage Plunger Lift

Gas Assisted Plunger Lift

Plunger Assisted Gas Lift

Beam Pump

ESP

High Cap X

Often, only Short Term Solution

Monthly Chemical Expense

Not Environment Friendly

Liquid Loading

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1. Artificial Lift Strategy

**Plunger Lift Zone**

- A.L. **GENERALLY NOT REQUIRED**
- **BEST** (GLR = 10)
- **GOOD** (GLR = 5)
- **WILL WORK** (GLR = 3)

**Minimum Gas Volume Required**
- (7500 ft TVD)
  - 400 scf / Bbl / 1000 ft of Lift
  - 3 Mcf per BBL or GLR = 3

- Higher GLR wells are easier to keep running, resulting in less non productive time
- Down hole liquid loading will be different for Horizontal Wells!
- Well may benefit at 1 MMcf/day

**CONSIDER:**
- 2 Stage Plunger Lift,
- Gas Assisted Plunger Lift,
- Plunger Assisted Gas Lift
1. Artificial Lift Strategy

Barnett Shale Artificial Lift Experience
Heather Burnham
Operations Engineer
XTO Energy

Artificial Lift Selection Process

Guidelines
- > 8 GLR plunger lift
- < 4 GLR gas lift or rod pump

Further Evaluation
- Between 4 and 8 GLR evaluate options
  - Multistage plunger
  - GAPL
  - Gas lift
- > 450 bbls consider AL alternatives or water shut off

Barnett Shale AL Selection (~150 psi FWP)

June 4 - 6, 2012
2. When to install

Install artificial lift before production is lost!

Production Type Curve

Horizontal Wells
Consider liquid in lateral line

High Flow Wells
Sweep liquid off tubing wall
Some improve with 1 MMcf +

Install AL Here!

Typically installed here

Downhole Critical Flow Rate
2. When to install

### CHK Play Comparison

- **9 months**: Fayetteville Barnett
- **22 months**: Marcellus
- **41 months**: Haynesville Colony Wash

Sample Critical Flow Rate

**Graph Details:**
- **Axes:** Miles per day, Month
- **Curves:** Haynesville Type Curve, Colony Wash Type Curve, Marcellus Type Curve, Barnett Type Curve, Fayetteville Type Curve

**Timeline:**
- **Feb 29 - Mar 2, 2016**
- **2016 Gas Well Deliquification Workshop Denver, Colorado**
3. Standardize!

- Dual master valve
- Dual outlet lubricator
  (Except if no afterflow)
- Platform to reach lubricator
- Pressure transducer type, location
- Pressure gauge type, locations
- Solenoid supply – clean / dry gas!
- Control valve type, trim, material
- Ball valve model number
- Hammer union locations

45 degree vs 90 degree elbows can reduce restrictions

Controller location and attachment
Connection to EFM - trench or radio?
Communications with office
Lightening suppression

Emergency shut off
Sand cut probe
3. Standardize!

Plunger Types for Well Condition

- Continuous Flow Plunger
- Rapid Fall Plunger
- Sand or Clean-out Plunger
- Brush
- Pad and / or Viper
- Surface retrieval tools
- Retrieval Plungers

Data Required for Each

1. Liquid volume removal rating
2. Fall velocity in gas
3. Fall velocity in gaseous liquid
4. Fall velocity adjusted for TP
5. Optimal rise velocity
6. What to inspect
7. When to inspect
8. When to replace
9. Material. NACE compliant?
10. For continuous run
    - Max/Min Gas Flow Rate
    - Fall velocity vs flow rate
11. Maximum **SAFE** impact velocity

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4. Meaningful Production Target

Set a meaningful production target for each well

Operating at:
- 40% of Absolute Open Flow?
- 80% of Absolute Open Flow?

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5. Remove Restrictions

- Scale, Paraffin – Drift and broach tubing
- Bottom hole spring hold down – size, debris
- Motor valve trim – full port opening
- Orifice plate at flow meter
- Well head – Sleeve if needed
- Chokes

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<td>1.227 inch$^2$</td>
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<td>1 ½ inch</td>
<td>1.767 inch$^2$</td>
<td>194.0 %</td>
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</table>
5. Remove Restrictions

- **Flow Rate**
- **Casing Pressure**
- **Tubing Pressure**
- **Line Pressure**

**Tubing and Line are same.**
No restriction. High Flow Rate

**Tubing higher than Line.**
Restriction. Low Flow Rate.

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6. Prioritize Wells Daily

Prioritize wells daily

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Prioritize wells daily

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Leading indicators of future problems:

- Missed arrivals
- Fast or slow arrivals
- Low battery voltage
- Increasing close times
- Pressures trending higher
- Ignored preventative maintenance
- Reliance on Trial and Error

“Lifting costs reduced up to 75% with automation”

GWD Denver 2011

XTO / Ferguson Beauregard presentation

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7. Optimize Production

FLOWING BOTTOM HOLE PRESSURE

Line Pressure
Liquid
Scale / Paraffin
Chokes
Valve Trim Size
Orifice Plate
90 Degree Elbows

LOW Backpressure
Produces
Ensures
MOST Production

LOW FBHP
Select plunger based on:
- Life stage of well
- \( \text{H}_2\text{S}, \) sand, paraffin, scale
- Gas to Liquid Ratio
- Required CP build time

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Figure 4 – Sample Decline vs. Plunger Type Graph
(Independent upon velocity available through the tubing string)
7. Optimize Production

Continuous Flow

Fall Time Options
1. Plunger falls off trigger rod based on flow rate
   o Plunger responds solely to well conditions
   o Surface velocity sensor recommended for safety
   o By pass valve can provide some adjustment
2. Operator closes well for short time to initiate plunger fall
   o Adjust fall time to align actual with target cycle time
3. Operator closes well until plunger reaches the bottom
   o Operator has full control of plunger cycle times and enjoys benefit of short fall time

After Flow
If afterflow is desired, consider an auto-catcher.
   o Operator initiates plunger fall stage.
   o Can ensure liquid in tubing.
   o Reduces backpressure.
   o May reduce plunger wear.

CP Build
Begins when plunger bottoms, closing plunger inner valve.
If insufficient casing pressure exists, consider a slow falling plunger.

Rise Time
Avoid unsafe surface plunger velocities! KE = \( \frac{1}{2} mv^2 \)
When start of rise is unknown, average rise time is unknown.
Consider surface velocity arrival sensor.

- Natural decline curve
- Lowest flowing bottom hole pressure
- Maintain target round trip times
7. Optimize Production
Continuous Flow

Calculate Round Trip Time

EXEMPLARY
- 2 3/8 Dart 3-Slot Plunger
- 10,000 ft to bottom hole spring
- 500 Mcf/d; 30 bbls/d

FALL TIME
- 10,000 ft / 1200 fpm = 8.33 min
  (Against Flow Rate!)

RISE TIME
- 10,000 ft / 1000 fpm = 10 min
- 10,000 ft / 750 fpm = 13.3 min
- 10,000 ft / 500 fpm = 20

CALCULATIONS
Round Trip Time = Fall Time + Rise Time
RTT = FT + RT

Slowest RTT = 8.33 min + 20 min
Slowest RTT = 28.33 min

Desired RTT = 8.33 min + 13.33 min
Desired RTT = 21.7 min

Fastest RTT = 8.33 min + 10 min
Fastest RTT = 18.33 min
7. Optimize Production

Continuous Flow

Calculate Round Trip Time

**FIRST RUN -**
- Use auto or manual catcher
- Start with plunger at bottom of well
- Check actual vs req’d casing pressure
  - Avoid unsafe speed on arrival
- Open well, record rise time
- Catch plunger
- Close well and release plunger
- After drop time expires, open well
- Record round trip time

**EXAMPLE:**
- 2 3/8 Dart Plunger 3-Slot
- 10,000 ft to bottom hole spring
- 500 Mcf/d; 30 bbls/d

**FIRST RUN -**
- Recorded Rise Time = 12 min
- Recorded Round Trip Time = 22 min
- RTT = RT + FT
- 22 min = 12 min + Fall Time
- Fall Time = 10 min or 1000 fpm
- Published Fall Time = 1200 fpm
Monitor on every cycle

Round trip time
- Lower limit
- Upper limit
- Target
- Actual

After flow time
7. Optimize Production

Conventional Plunger

Fall Time
- Plunger fall times are not the same for all wells
- Too little fall time can result in fast arrivals & liquid loading
- Too much fall time can result in less production
- **Know actual plunger fall time in each well!**

Rise Time
- Avoid unsafe plunger velocities!
- $KE = \frac{1}{2} mv^2$
- Optimize production.
- Don’t tear anything up!
- “No arrival” - 250 to 400 fpm.

CP Build
- Operate at the lowest casing pressure possible
- Lift small volumes of liquid on each cycle (1/4 bbl)
- Match the plunger fall time with CP build rate

After Flow
- Same volume of liquid in tubing on every cycle
- At start-up, no afterflow until CP build is zero.
- Use critical velocity and CP rise as indicators
- Allow the lateral leg to fully unload, if possible
7. Optimize Production

Conventional Plunger

- Produce at natural decline curve
- Produce at lowest flowing bottom hole pressure
- Maintain safe plunger velocity

Minimal close time (Plunger fall and CP build)
- Stronger well with good pressure and quick recovery
- CP Build time not required
- Consider a rapid fall or continuous run plunger
- Optimize by adjusting after flow

OR

Minimal open time (Plunger rise and after flow)
- Weak well or well with lot of liquid
- Well requires CP Build Time. Little to no after flow time.
- Optimize by using best sealing plunger and removing restrictions

Guidelines & Recommended Practices
Use of Plunger Lift for Deliquifying Gas Wells
www.ALRDC.com
7. Optimize Production

Operate at lowest flowing bottom hole pressure
- Low liquid load AND Low lift pressure
- If too much liquid enters well at low pressure, operate at a higher pressure

Optimize production! Maintain safe plunger velocity!

Scenario 1:
- Plunger Fall Time = 60 min
- Total Close Time = 90 min
- Afterflow = 20 min
- Plunger Velocity = 1500 fpm

Scenario 2:
- Plunger Fall Time = 60 min
- Total Close Time = 60 min
- Afterflow = 20 min
- Plunger Velocity = 1200 fpm

Scenario 3:
- Plunger Fall Time = 60 min
- Total Close Time = 90 min
- Afterflow = 20 min
- Plunger Velocity = 400 fpm

Scenario 4:
- Plunger Fall Time = 60 min
- Total Close Time = 60 min
- Afterflow = 0 min
- Plunger Velocity = 350 fpm

Adjustments
- Fast run with CP build time
  - Less lift pressure
- Fast run without CP build time
  - Faster falling plunger, then add liquid load
- Slow run with afterflow
  - Less liquid load
- Slow run without afterflow
  - Add lift pressure

Operate at lowest flowing bottom hole pressure
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Optimize production! Maintain safe plunger velocity!

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Adjustments
- Fast run with CP build time
  - Less lift pressure
- Fast run without CP build time
  - Faster falling plunger, then add liquid load
- Slow run with afterflow
  - Less liquid load
- Slow run without afterflow
  - Add lift pressure
1. DETECT RAPIDLY
   - Real time alarms (Cry-out)
   - E-mail, text

2. DIAGNOSE WITH DATA
   - Then prescribe!

3. LOOK FOR VARIANCE

4. SOLVE ROOT CAUSE
   - Formal brainstorming, Pareto, Fishbone, 5 Why

5. BECOME A LEARNING ORGANIZATION
   - Reduce time between occurrence, detection and return to full production

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8. Troubleshoot

On Site Observation
- Plunger impact velocity at surface
- Did plunger arrive
- Plunger inspection
- Plunger stuck in lubricator

Trend Charts
- Casing
- Tubing
- Line
- Flow Rate

Cycle History

Downhole Camera

Analysis Software
- ABB
- T-Ram Report Card
8. Troubleshoot

Casing Pressure
Tubing Pressure
Line Pressure
Flow Rate

Casing & Tubing equalize while closed
8. Troubleshoot

TP decline when closed and flow rate spikes.
## Costs of Down Time

<table>
<thead>
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<th>Time to detect problem</th>
<th>Time to implement</th>
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<tr>
<td>Time to diagnose problem</td>
<td>Time to restart well</td>
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<tr>
<td>Time to prescribe solution</td>
<td>Time to prevent reoccurrence</td>
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<tr>
<td>Time to acquire parts / services</td>
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## Track monthly

- **Non productive time**
  - % of available time in which wells flow below the target
- **Unplanned downtime**
  - % of available time in which wells are closed due to an unscheduled event
9. Preventative Maintenance

Preventative maintenance program

- What to inspect
- When to inspect
- Who will inspect
- How to inspect – Method / Tools; Pass / fail criteria

Plunger lift inspection points

- Plungers (Replace BEFORE production is lost)
- Lubricator (Spring, catcher, “o” ring, connection to WH)
- Bottom hole spring (Blockage?, Worn?)
- Control and dump valves (No leaks!)
- Arrival sensor, pressure transducers, wiring
- Drip pot or gas scrubber (Check daily, drain)
- Supply gas to solenoid valves (Clean, dry gas!)
- Battery, solar panel, wiring
- Master and wing valves
- Orifice plate; Flow meter
- Tubing integrity (Echometer or pressure test)

Broken bottom hole springs are very difficult to retrieve!
10. Continuous Improvement

**Current Condition**

March 1 –
- The Rattle Snake 4H is missing arrivals again! Every couple weeks seems like this happens.
- I’ll add more off time to build pressure – but last time this just caused fast plunger arrivals.
- And it takes several hours to adjust.
- Joe’s worked plungers for a long time - he says all we can do is just keep tweaking it every week or so.
- Maybe I’ll get a different route soon.

**Desired Condition**

Sept 1 -
- Production is on target for the RS 4H!
- Plunger is running at 750 fpm, 15 trips a day, every day.
- I’ll have to replace the plunger when it gets close to 30,000 miles – should be in another couple weeks.
- Softball practice at 4 today – no problem getting there on time!

**How do we get there?**
10. Continuous Improvement

“The Seven Habits of Highly Effective People”
By Stephen Covey

Circle of Concern

Be Proactive

Circle of Influence

Begin with the End in Mind

Sharpen the Saw

Put First Things First

Seek first to Understand

then to be Understood

Think Win / Win

Synergize
10. Continuous Improvement

PROBLEM -> ACT -> REPEAT

PLAN – Understand the problem
1) Is the problem statement clear and accurate
2) Has the root cause been identified?

DO – Implement the plan
3) Has irreversible corrective actions been implemented for all root causes?

CHECK – Follow-up
4) Has a plan been identified to verify the effectiveness of all corrective actions?

ACT – Adjust
5) Has a plan been identified to standardize and save all lessons learned across all groups?

PDCA

“Getting the Right Things Done” by Pascal Dennis

The problem, improvement activity, opportunity for improvement, project goals and customer requirements

The process performance

The process to determine root cause of variation, poor performance

The process performance by addressing and eliminating root causes

The improved process and future process performance

10. Continuous Improvement

Pareto Diagram

Wells producing below production target

Cost per month or per year for each?

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<th>Frequency of Occurrence</th>
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10. Continuous Improvement

Fishbone Diagram

Why are we missing production targets?

- Man
  - Adequate quantity?
  - Right abilities?
  - Right training?
  - Motivated?

- Method
  - Time per well
  - Standard processes?
  - Correct data?
  - Optimized Wells?

- Material
  - Recently Frac'd into?
  - Liquid loaded?
  - Drill rig on site?
  - Sand/Salt/Scale?

- Well Conditions
  - Compressor down?
  - Significant restrictions?
  - Good control methods?
  - Reliable equipment?

- Machine

- Equipment

- Management
  - Goals?
  - Culture?
  - Resources?
  - Training?
10. Continuous Improvement

5 Why’s!

1. **WHY** are the wells liquid loaded?
   - Artificial lift was not installed prior to lost production

2. **WHY** was artificial lift not installed prior to lost production?
   - We did not know the wells were liquid loading

3. **WHY** didn’t we know the wells were liquid loading?
   - We were not looking at them - all of our resources are focused on existing plunger wells

4. **WHY** are we spending so much time on existing plunger lift wells?
   - Operators are traveling to every well every day – only 10-15 min / well is possible

5. **WHY** don’t we invest in automation and prioritize problem wells?
10. Continuous Improvement

Knowledge (what to, what to)

Habits

Skills (how to)

Desire (want to)

What’s the Process?

How can we tell it’s working?

What are we doing to improve it?

Build new habits

“Tear down old habits”

“The Seven Habits of Highly Effective People”

By Stephen Covey

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10. Continuous Improvement

What are your plunger lift goals for 2016?

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10 Steps to optimized production

1. Develop an artificial lift strategy
2. Install AL before production is lost
3. Standardized PL configuration
4. Set meaningful production targets
5. Remove restrictions
6. Prioritize wells daily
7. Optimize
8. Troubleshoot with DATA!
9. Preventative Maintenance
10. Continuous Improvement

Be Proactive!

Train Wide and Deep!

Lowest FBHP!

Real Time DATA!
"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."

John Wooden

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”
ADDENDUM

Feb 29 - Mar 2; 2016

2016 Gas Well Deliquification Workshop
Denver, Colorado
Principle 1
Base your management decisions on a long range philosophy, even at the expense of short term financial goals.

Principle 2
Create a continuous process flow to bring problems to the surface.

Principle 3
Use “Pull” systems to avoid overproduction.

Principle 4
Level out the workload.

Principle 5
Build a culture of stopping to fix problems, to get quality right the first time.

Principle 6
Standardized tasks are the foundation for continuous improvement and employee empowerment.

Principle 7
Use visual controls so no problem are hidden.

Principle 8
Use only reliable thoroughly tested technology that serves your people and processes.

Principle 9
Grow leaders who thoroughly understand the work, live the philosophy and teach it to others.

Principle 10
Develop exceptional people and teams who follow your company’s philosophy.
Principle 11
Respect your extended network of partners and suppliers by challenging them and helping them improve.

Principle 12
Go and see for yourself to thoroughly understand the situation.

Principle 13
Make decisions slowly by consensus; thoroughly considering all options; implement rapidly.

Principle 14
Become a learning organization through relentless reflection and continuous improvement.
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