Optimize and Troubleshoot Plunger Lift Wells

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Shale Tec LLC
CONTENTS

Why optimize
Planning
Line-out and optimize
Detect & troubleshoot
Sustain peak production
Why Optimize?

What is an optimized well?

- Meets daily production goal?
- No missed plunger cycles?
- Produce 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
Why Optimize?

Why is it important?

DAILY PRODUCTION

480 – 350 = 130 mcf/d
130 mcf/d X 30 days X 12 months = 46,800 mcf
46,800 mcf X $ 3.50 / mcf = $ 163,800 / year

$ 163,800 / yr X 100 wells = $ 16.38 Million / yr

LOST PRODUCTION

LIQUID LOADED DECLINE CURVE

CASING PRESSURE

NATURAL DECLINE CURVE

LOW PRODUCTION

FLOW RATE (mcf)

PRESSURE (psi)


February 18 – 20, 2013
2013 Gas Well Deliquification Workshop
Denver, Colorado
**Why Optimize?**

Why is it important?

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**Inflow Performance Relationship**

- 60 psi
- 138 ft of water

46% of AOF

79% of AOF

42 mcf/d

ABSOLUTE OPEN FLOW!

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42 mcf/d X 30 days X 12 mo X $ 3.5 / mcf = $ 52,920

$ 52,920 X 100 wells = $ 5.29 Million / yr

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"Gas Well Deliquification" by Lea, Nickens, Wells

"Natural Gas Engineering Handbook" by Guo, Ghalambor

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February 18 – 20, 2013

2013 Gas Well Deliquification Workshop

Denver, Colorado
**Why Optimize?**

How does plunger lift help?

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**Free Flowing Well**

**Plunger Installed**

**Daily Production**

**Critical flow rate area**

**Horizontal Barnett Shale Well**

**Production stabilized and increased**

---

**MCF / D**

- 0
- 200
- 400
- 600
- 800
- 1000
- 1200
- 1400
- 1600
- 1800

**Dates**

- 19-Apr-09
- 3-May-09
- 17-May-09
- 31-May-09
- 14-Jun-09
- 28-Jun-09
- 12-Jul-09
- 26-Jul-09
- 9-Aug-09
- 23-Aug-09
- 6-Sep-09
- 20-Sep-09
- 4-Oct-09
- 18-Oct-09
- 1-Nov-09
- 15-Nov-09
- 29-Nov-09
- 13-Dec-09
- 27-Dec-09
Why Optimize?

How does plunger lift help?

Plunger Installed

Rapid Fall Plunger

Daily Production

Critical flow rate area

Horizontal Barnett Shale Well

Production stabilized and increased

MCF / D

0
500
1000
1500
2000
2500

February 18 – 20, 2013
“Problems are nuggets to be mined, not garbage to be buried”

“Getting the Right Things Done” by Pascal Dennis

“Creating a Lean Culture” by Dennis Mann

“The Toyota Way” By Jeffery K. Liker
Planning

Where are we now?
Where do we need to go?
How do we get there?

1. Define True North
2. Develop the plan
3. Deploy the plan
4. Monitor the plan
5. Solve the problems
6. Improve the system

Understand the mess!

1. What is the gap?
2. What prevents us from meeting our target? (fishbone)
3. What are the causes in order of importance? (pareto)
4. What actions will address the most important causes? (A3)

What is the Process?
How can you tell it’s working?
What are you doing to improve it?
Why are we missing production targets?

Planning

What are the causes? Fishbone!

Man
- Not enough people
- Absenteeism
- Training
- Motivation

Method
- Time per well
- No standard processes
- Insufficient data
- Non-Optimized Wells

Material
- Well Frac’d into
- Liquid loaded
- Drill rig on site
- Sanded in

Machine
- Line pressure issues
- Restrictions
- Limited technology
- Equipment failures

Management
- Equipment
- Poorly defined goals
- Fire fighting culture
- Inadequate resources
Planning

What are the causes in order of importance - Pareto

Wells Producing below production target

- Liquid Loading: $500,000 / yr
- Not optimized: $350,000 / yr
- Surface Equipment: $120,000 / yr

Pareto Frequency of Occurrence
1. WHY are the wells liquid loaded?
   - Artificial lift was not installed prior to lost production

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

3. WHY didn’t we know the wells were liquid loading?
   - All of our resources are focused on operating existing plunger lifted wells

4. WHY are we spending so much time on existing plunger lift wells?
   - Our operators are untrained and we only have on-site control

5. WHY don’t we train our operators and invest in automation?
Planning

What engine drives a solution? PDCA!

**ACT**
Adjust

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

**CHECK**
Follow-up

4) Has a plan been identified to verify the effectiveness of all corrective actions?

**PLAN**
Understand the problem

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

**DO**
Implement the plan

3) Has irreversible corrective actions been implemented for all root causes?

“A problem well defined is a problem half solved”

1. Define True North
2. Develop the plan
3. Deploy the plan
4. Monitor the plan
5. Solve the problems
6. Improve the system
Planning

What’s the plan? A3 – one 11” X17” page!

FOCUS: Production

Performance, Gaps, Targets
✓ Show last years results
✓ Are we getting better or worse?
✓ Show 1, 3, 5 year targets
Tell the story with a chart!

Reflection on 2012 activities
✓ Assess 2012 activities.
✓ What worked, what did not?
✓ Please explain!

Rationale for 2013 activities
✓ How does last year affect this year?
✓ Any new factors to consider?
✓ What are our 3-4 areas of emphasis?
✓ How will these benefit us?

2013 Action Plan

<table>
<thead>
<tr>
<th>Goals</th>
<th>Activities</th>
<th>J</th>
<th>F</th>
<th>M</th>
<th>A</th>
<th>M</th>
<th>J</th>
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<th>S</th>
<th>O</th>
<th>N</th>
<th>D</th>
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<tbody>
<tr>
<td>Identify Liquid Loaded Wells</td>
<td>Review decline curves</td>
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<td>Check critical flow rate</td>
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<td>Determine AL type required</td>
<td>Low Gas to Liq Ratio</td>
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<td>Plunger Lift Supplier</td>
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<td>SCADA, Wireline, etc</td>
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<td>Select and train operators</td>
<td>Determine org structure</td>
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<td>Train operators</td>
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<tr>
<td>Begin installation</td>
<td>Install 1-5 systems</td>
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<td>Install 6-10 systems</td>
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</tbody>
</table>

Follow-up, Unresolved issues
✓ How will we check and report?
✓ Any unresolved issues, questions, support needed?
✓ What will we do about it?

SIGNATURES:

Author:  
Version and Date:  

February 18 – 20, 2013
Line-out and optimize
Line-out and Optimize

Install AL BEFORE production is lost!
Considerations

- Maximum liquid to remove
- Gas to liquid ratio
- Critical velocity – When does loading begin?
- Available gas injection supply
- Operator skills. Organizational structure.
- Vendor support
- Preventative maintenance requirements
- Expected future AL needs
- Capital & LOE

Develop a specific, proactive plan for your field!
Set realistic targets
✓ Actual production vs target
✓ Green, Yellow, Red

Prioritize wells daily
✓ Milk run – reactive, trial and error
✓ Manage by exception – allows more time to focus on problem wells
✓ Requires telemetry

“Lifting costs reduced up to 75% with automation”
GWD Denver 2011
XTO / Ferguson Beauregard presentation

Line-out and Optimize
Set goals, prioritize daily
Line-out and Optimize

Plunger Cycle

Produce at Lowest Flowing Bottom Hole Pressure!

Minimum “ON” well

CP build time required? YES! Little to no afterflow

Improve plunger seal efficiency and well conditions to operate at lower pressure

Minimum “OFF” well

CP build time required? NO! Allow afterflow

Select plunger with appropriate fall speed and seal. Optimize by modifying afterflow

“Simple on/off controllers are not effective for optimization of a plunger system.”

Guidelines & Recommended Practices
Use of Plunger Lift for Deliquifying Gas Wells
ALRDC

FOUR STAGES
✓ Fall (Gas, Liquid)
✓ CP Build
✓ Rise
✓ Production

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2013 Gas Well Deliquification Workshop
Denver, Colorado
Fall Time (Gas, Water)

- Plunger fall times are not the same for all wells
- Too little fall time can result in fast arrivals and loading
- Too much fall time could result in less production
  - 15 plunger runs per day and 300 mcf
  - Fall time is 10 min too long on each cycle
  - 10 min X 15 cycles per day = 150 min wasted each day (1.6 cycles per day)
  - 300 mcf/d / 15 cycles = 20 mcf / cycle.
  - 20 mcf X 1.6 = 32 mcf/d X 30 days = 960 mcf/mo X $ 3.5 = $ 3,360 / mo
  - $ 3,360 / mo X 12 months X 100 wells = $ 4.03 M / year
- Know actual plunger fall time in each well!
  - Chase plunger with wireline or use EchoMeter
CP Build Time

- **Objective** – *Operate at lowest CP practical (i.e., backpressure)*
  - Lift small amounts of liquid on each cycle (Ex: 1/4 to 1/3 barrel)
  - Select the proper plunger for the well!
- **Use Foss and Gaul equation to estimate CP required**

Rise Time

- **Objective** – “Fast enough to avoid stalling, slow enough to avoid damage”
  - **Guideline** – 500 to 1000 fpm
- **Focus on production, using plunger velocity as an indicator**
- **Set initial no arrival at 250 to 400 fpm**

Afterflow

- **Objective** – *Same amount of fluid in tubing on every cycle*
- **Line-out** – Little to no afterflow until CP build time is zero
- **Use critical velocity to indicate when to close well**
- **Allow lateral leg to unload for stronger horizontal wells**
Track on each cycle

### WHEN WELL CLOSES

<table>
<thead>
<tr>
<th>Run #</th>
<th>Time</th>
<th>Casing</th>
<th>Tubing</th>
<th>Line</th>
<th>Casing - Tubing</th>
<th>Tubing Liquid</th>
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<td>314</td>
<td>253</td>
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<td>251</td>
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<td>313</td>
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<td>310</td>
<td>251</td>
<td>132</td>
<td>59</td>
<td>0.53</td>
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### WHEN WELL OPENS

<table>
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<th>Time</th>
<th>Casing</th>
<th>Tubing</th>
<th>Line</th>
<th>Casing - Tubing</th>
<th>Tubing Liquid</th>
<th>Casing - Line</th>
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### RESULTS

<table>
<thead>
<tr>
<th>Run #</th>
<th>Time</th>
<th>Velocity</th>
<th>Arrival</th>
<th>Open</th>
<th>Fall</th>
<th>Close</th>
<th>Production</th>
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<td>00:38</td>
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<td>00:07</td>
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<td>00:39</td>
<td>5.3</td>
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</tbody>
</table>
**TRADITIONAL**
- Fall time
  - Gas – 7750 ft @ 180 fpm
  - Liquid – 250 ft @ 40 fpm (1 bbl)
  - Total = 43 min + 6 min
  - Total = 49 min + 10%
  - Total = 54 min
- CP Build
  - 30 min to reach req’d pressure
  - Higher pressure req’d to lift 1 bbl
- Rise Time
  - 600 fpm = 13 min
- Production mode (afterflow)
  - 60 min
- Total cycle = 2.6 hours or 9 trips / day
- Total Production time = 9 hours
  (Partially in liquid loaded tubing)

**FREQUENT TRIPS**
- Fall time
  - Gas – 7937 ft @ 800 fpm
  - Liquid – 63 ft @ 40 fpm (¼ bbl)
  - Total = 10 min + 1.5 min
  - Total = 11.5 min + 10%
  - Total = 12.5 min
- CP Build
  - Open when plunger reaches bottom
  - Less pressure req’d to lift ¼ bbl
- Rise Time
  - 600 fpm = 13 min
- Production mode (afterflow)
  - 15 min
- Total cycle = 40.5 min or 35.5 trips / day
- Total Production time = 8.875 hours
  (Clear tubing, lower flowing pressure)

**Many trips a day lifting small amounts of liquid!**
Very short close time (Ex: 1 to 5 min)

Plunger falls against flow

Only round trip times recorded

Excessive plunger velocities possible

UNCONVENTIONAL PLUNGER EXAMPLE

Very short close time
(Ex: 1 to 5 min)

Plunger falls against flow

Only round trip times recorded

Excessive plunger velocities possible

Plunger free cycling

February 18 – 20, 2013

2013 Gas Well Deliquification Workshop
Denver, Colorado
Troubleshoot
1. DETECT RAPIDLY
   o Real time alarms (Cry-out)
   o E-mail, text

2. DIAGNOSE WITH DATA
   o Then prescribe!

3. LOOK FOR VARIANCE

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

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

## Common Problems

### Plunger fails to surface
- Stuck in lubricator
- Worn plunger
- Not enough pressure
- Too much liquid
- Bad arrival sensor or cable
- Plunger stuck in tubing
- Grease in tubing from WH valves
- Rapid fall plunger – shift rod stuck

### Slow arrivals
- Worn plunger
- Not enough pressure
- Too much liquid
- Tubing restrictions
- Wrong plunger type

### Fast arrivals
- Fall time too short
- Plunger hung in WH
- Tight spot in tubing
- Too much pressure
- Not enough liquid

### Control valve will not close
- Liquid in gas supply line
- Debris in solenoid valve
- Solenoid valve malfunction
- Solenoid vent line plugged

### Control valve will not open
- No gas supply pressure
- Clogged gas supply filter
- Liquid in gas supply line
- Debris in solenoid valve
- Solenoid valve malfunction
- Hole in Motor Valve diaphragm

### Motor valve leak
- Obstacle in Motor Valve trim
- Cut, worn trim (sand, particulates)
- Consider ceramic trim
## Troubleshoot

### Common Problems

<table>
<thead>
<tr>
<th>Short battery life</th>
<th>Catcher will not trap plunger</th>
<th>Lubricator top seeps / leaks</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Inspect battery</td>
<td>✓ Inspect / replace spring and or ball</td>
<td>✓ Lubricate threads</td>
</tr>
<tr>
<td>✓ Inspect wires to solar panel</td>
<td>✓ Flow longer</td>
<td>✓ Inspect “O” ring</td>
</tr>
<tr>
<td>✓ Inspect solar panel</td>
<td></td>
<td>✓ Grease “O” ring</td>
</tr>
<tr>
<td>✓ Clean</td>
<td></td>
<td></td>
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<tr>
<td>✓ 45 Degree angle</td>
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<tr>
<td>✓ Facing south</td>
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<tr>
<td>✓ Radio malfunction (amps)</td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Plunger fishing neck mushroomed</th>
<th></th>
<th>Fast, dry plunger runs. Liquid in tubing on each cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Lubricator spring worn, stuck or too stiff</td>
<td></td>
<td>✓ Fall time too short</td>
</tr>
<tr>
<td>✓ Excessively fast plunger runs</td>
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<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Fall time elapsed, CP not rising, OFF time remains</th>
<th></th>
<th>Missed run every 6 weeks or so – no other issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Reduce shut-in time or open at a lower lift pressure</td>
<td></td>
<td>✓ Meter tech on site - shut in meter run</td>
</tr>
</tbody>
</table>

- **Radio malfunction (amps)**
  - Catcher will not trap plunger
    - Inspect / replace spring and or ball
    - Flow longer
  - Motor valve closed, flow rate not zero
    - Motor valve leak
    - Calibrate flow meter
  - Flow rate increasing at end of afterflow
    - Flow longer

- **Plunger fishing neck mushroomed**
  - Lubricator spring worn, stuck or too stiff
  - Excessively fast plunger runs

- **Fall time elapsed, CP not rising, OFF time remains**
  - Reduce shut-in time or open at a lower lift pressure

**2013 Gas Well Deliquification Workshop**

**Denver, Colorado**

February 18 – 20, 2013
Troubleshoot

Common Problems

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

Control Valve Closed
- Tubing declines
- Flow rate observed

Control Valve Leak!

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Troubleshoot

Common Problems

Control Valve Closed
- Line pressure declines
  Possible Dump Valve Leak!

Line pressure declines
Possible Dump Valve Leak!
Troubleshoot

Common Problems

- Control Valve Open
  - Well closed when flow rate is increasing
  - Flow longer!
Common Problems

Troubleshoot

- Control Valve Closed
  - Casing and tubing equalize
  - Pushing liquid out of tubing
  - Shorten close time or add a standing valve
Sustain peak production
**Training is not enough!**

- Develop skill sets required for each critical position. Train and evaluate skill. PDCA!

<table>
<thead>
<tr>
<th>Skill</th>
<th>Operator A</th>
<th>Operator B</th>
<th>Operator C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well site safety</td>
<td>Complete</td>
<td>Required</td>
<td>Complete</td>
</tr>
<tr>
<td>Basics of liquid loading</td>
<td>Complete</td>
<td>Required</td>
<td>Complete</td>
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<tr>
<td>Basics of plunger lift</td>
<td>Required</td>
<td>Required</td>
<td>Complete</td>
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<tr>
<td>Well requirements for plunger lift</td>
<td>Required</td>
<td>Required</td>
<td>Complete</td>
</tr>
<tr>
<td>Surface and sub-surface equipment</td>
<td>Required</td>
<td>Required</td>
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<tr>
<td>Preventative maintenance</td>
<td>Required</td>
<td>Required</td>
<td>Complete</td>
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<tr>
<td>Controller and graphical user interface screens</td>
<td>Required</td>
<td>Required</td>
<td>Complete</td>
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<tr>
<td>Optimizing plunger lift wells</td>
<td>Required</td>
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<td>Complete</td>
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<tr>
<td>Troubleshooting plunger lift wells</td>
<td>Required</td>
<td>Required</td>
<td>Complete</td>
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<tr>
<td>Formal problem solving processes</td>
<td>Required</td>
<td>Required</td>
<td>Complete</td>
</tr>
<tr>
<td>EchoMeter - Track / locate plunger, tubing integrity, fluid levels</td>
<td>Required</td>
<td>Required</td>
<td>Complete</td>
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<tr>
<td>Formal team building skills</td>
<td>Required</td>
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<td>Complete</td>
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<tr>
<td>E-mail, text, excel, etc ....</td>
<td>Complete</td>
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<td>Complete</td>
</tr>
</tbody>
</table>
Develop and implement an optimization strategy

- When to install, what plunger to use, standardize WH configuration
- What is the production target? Who will line-out
- Minimum “On” well or Minimum “Off” well?

Define and communicate clear responsibilities

- Central optimizer (Example)
  - Selects plunger lift algorithm and plunger
  - Selects set points
  - Monitors pressures, plunger cycles and production
  - Notifies field operator of current and potential issues

- Field operator (Example)
  - Well site safety
  - Coordinates all on site activities
  - Preventative maintenance and repairs
  - Occasionally monitors plunger arrivals

Who’s responsible for production?

BOTH are critical to sustained peak production!
Develop and implement a preventative maintenance program

- Inspection point, pass/fail criteria, technique, frequency for:
  - Plunger (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
  - Orifice plate
  - Flow meter
  - Tubing integrity (EchoMeter or pressure test)

Guidelines & Recommended Practices
Use of Plunger Lift for Deliquifying Gas Wells
ALRDC
“Problems are nuggets to be mined, not garbage to be buried”

Sustain peak production

“Good To Great: Why Some Companies Make the Leap .... And Others Don’t” by Jim Collins
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