Gas Well Deliquification Workshop

Sheraton Downtown Denver Hotel

Denver, Colorado

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Optimize and Troubleshoot Plunger Lift Wells

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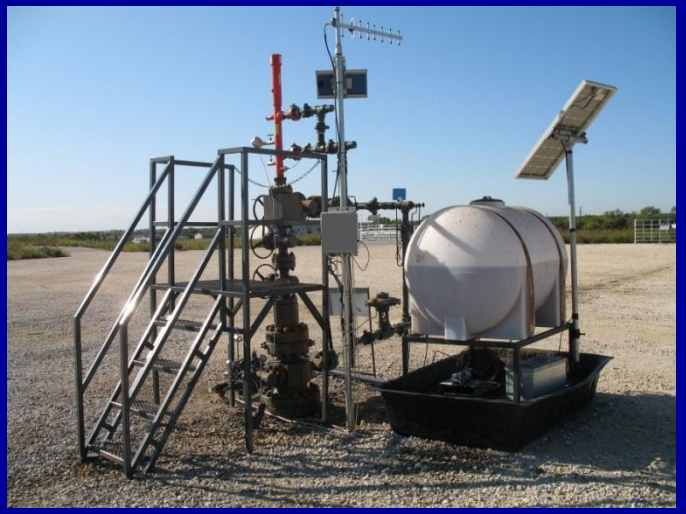


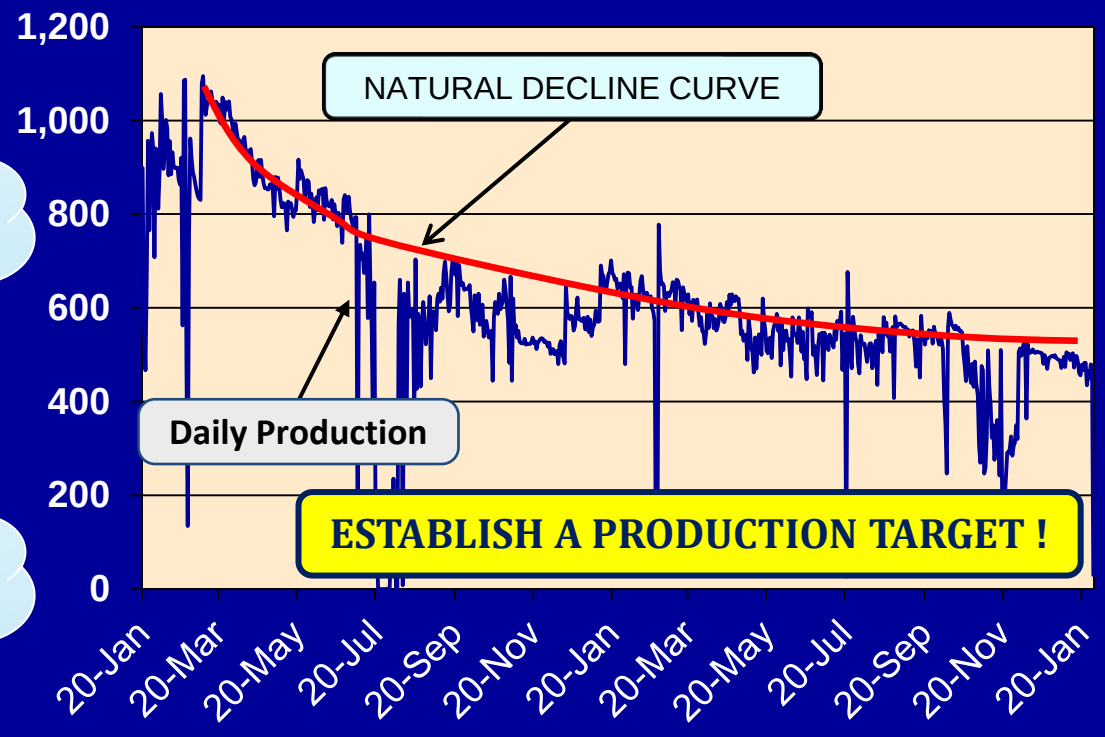
CONTENTS

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

Why Optimize?

What is an optimized well?

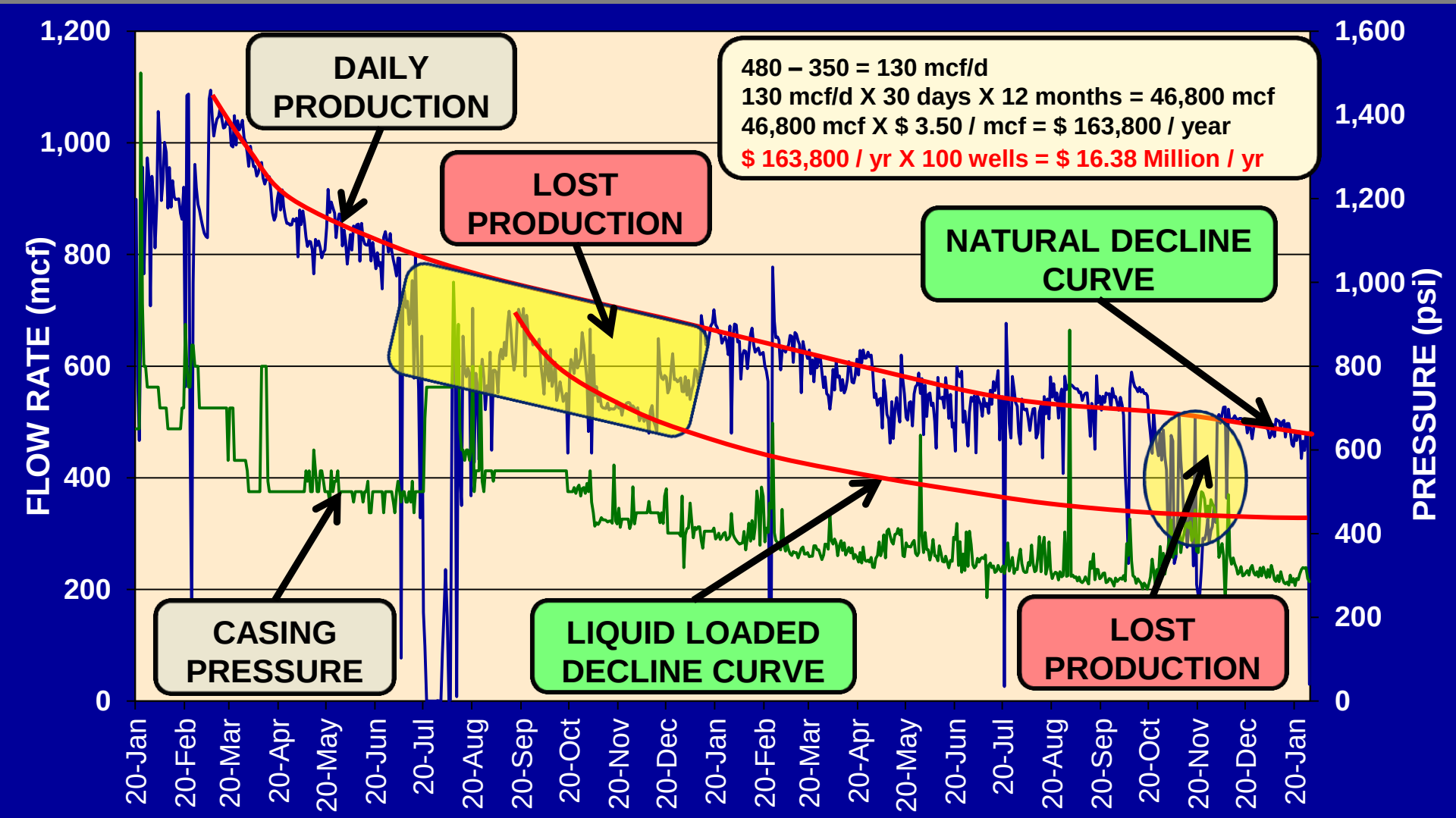
- Meets daily production goal ?
- No missed plunger cycles?
- Produce at or above 80 % of AOF?
- 20% production increase?
- 500 to 1000 fpm plunger cycle ?
- Rapid payback ?



"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?



Why Optimize?

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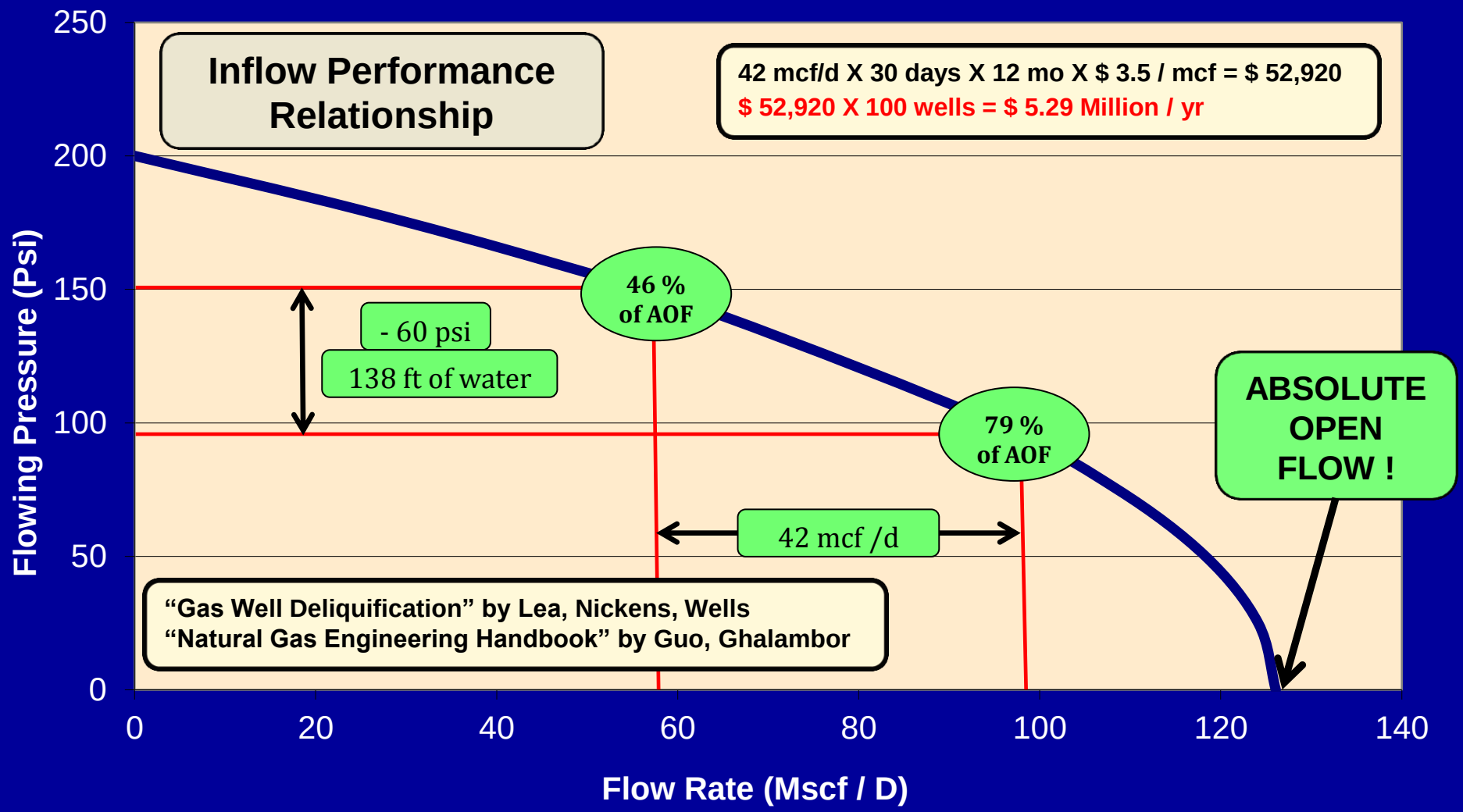
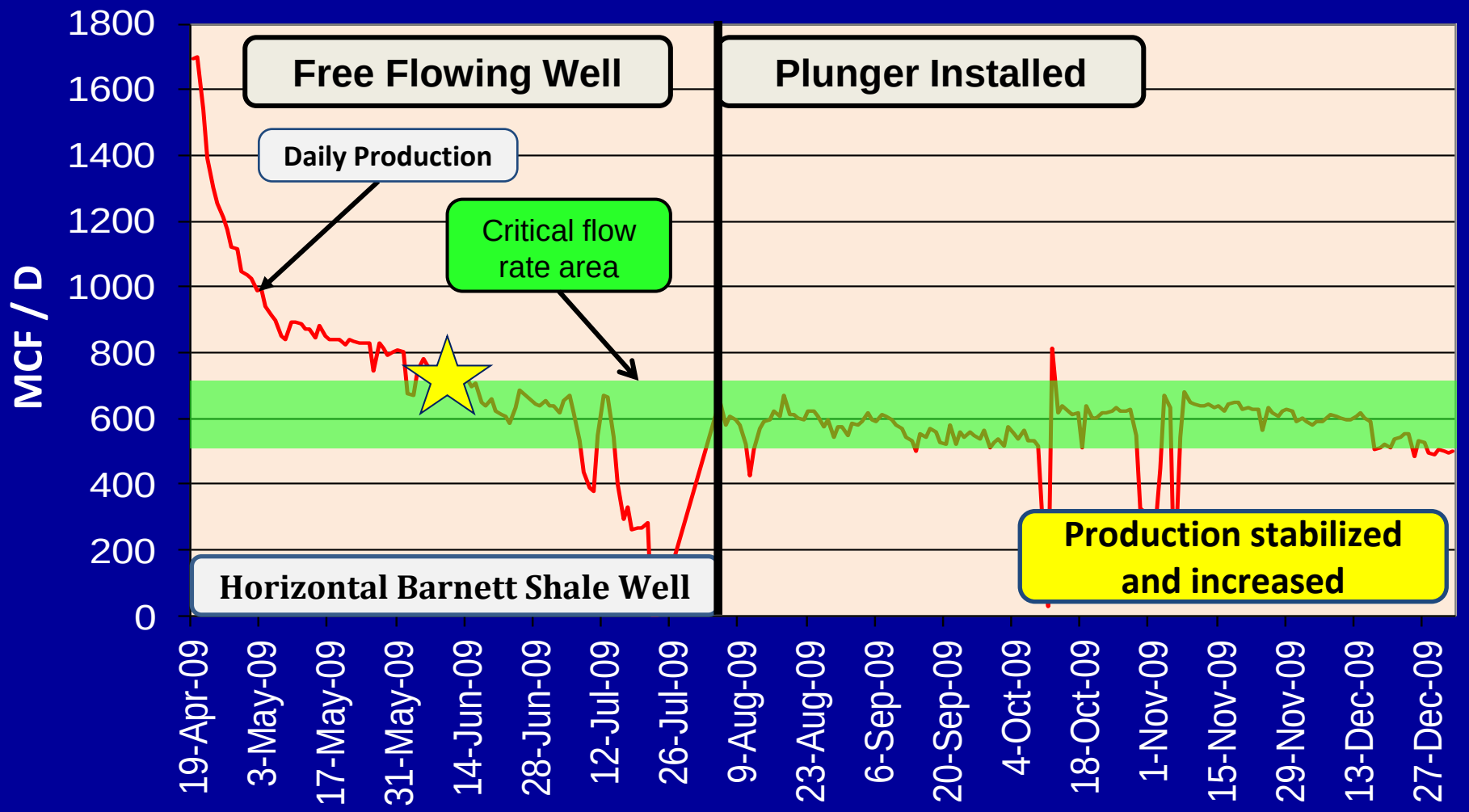


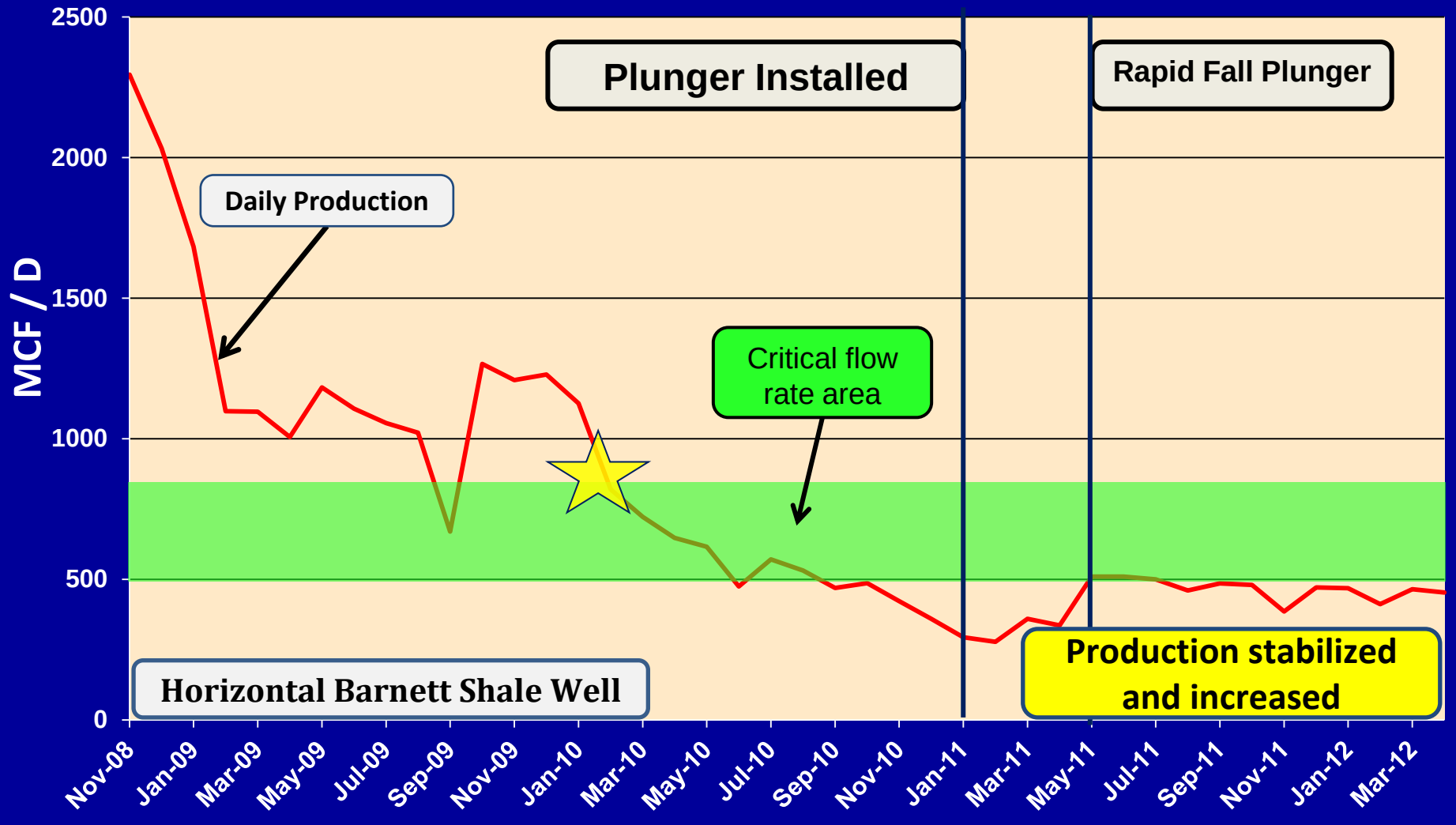
Why Optimize?

How does plunger lift help?



Why Optimize?

How does plunger lift help?



Planning

"Getting the Right Things Done" by Pascal Dennis

"Creating a Lean Culture" by Dennis Mann

"The Toyota Way" By Jeffery K. Liker

Planning

Understand the mess!

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

What is the Process?

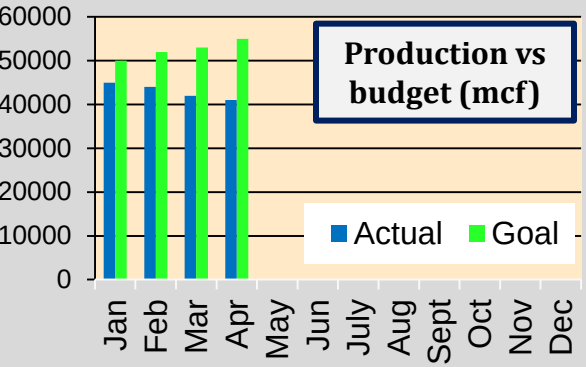
How can you tell it's working?

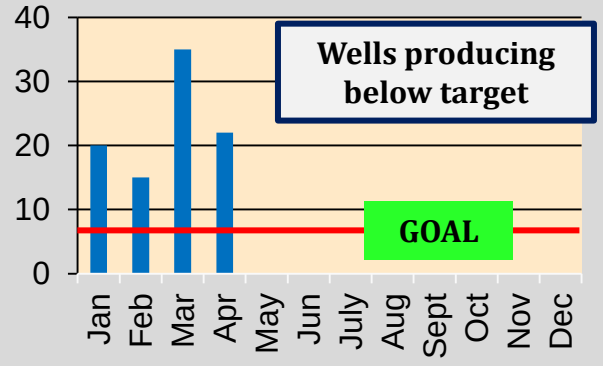
What are you doing to improve it?

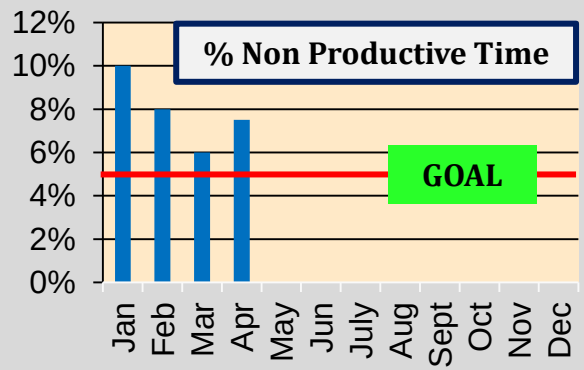
1. What is the gap?
2. What prevents us from meeting our target? (fishbone)
3. What are the causes in order of importance? (pareto)
4. What actions will address the most important causes? (A3)

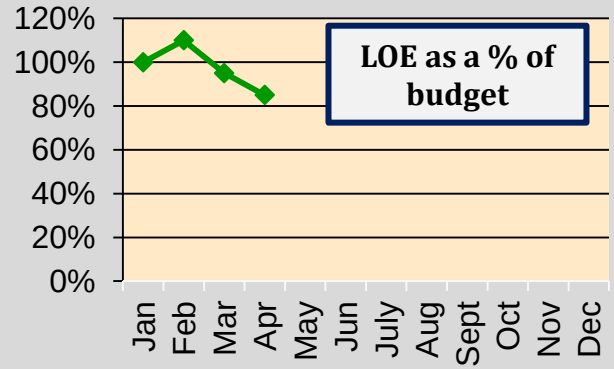
Planning

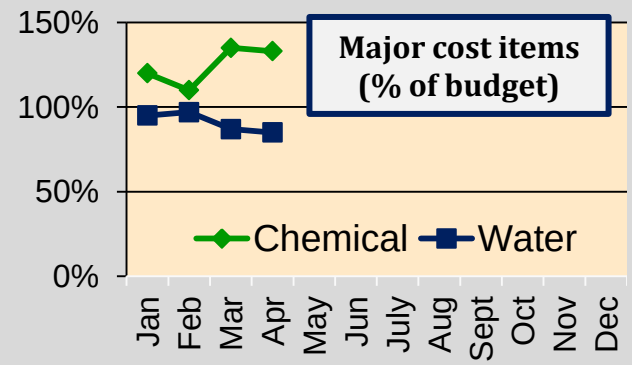
What is the gap ? Dashboard – one 11” X 17” page

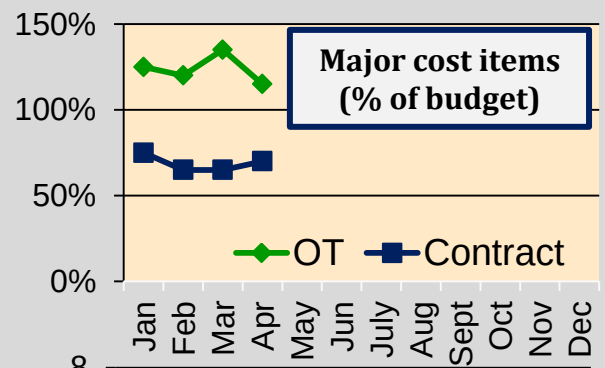


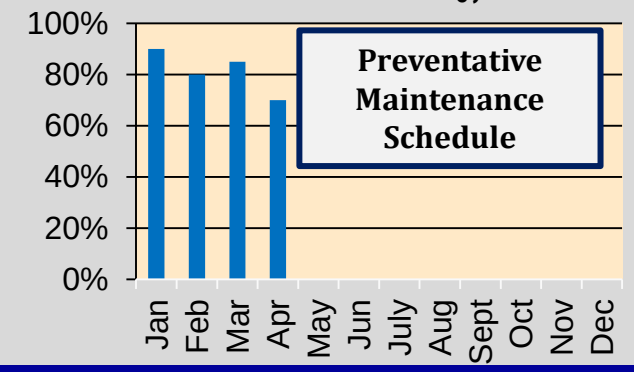


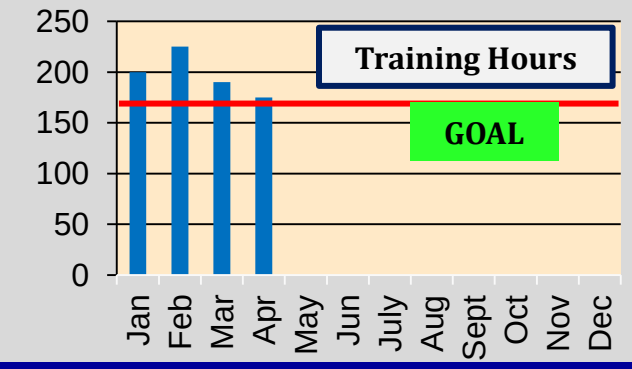


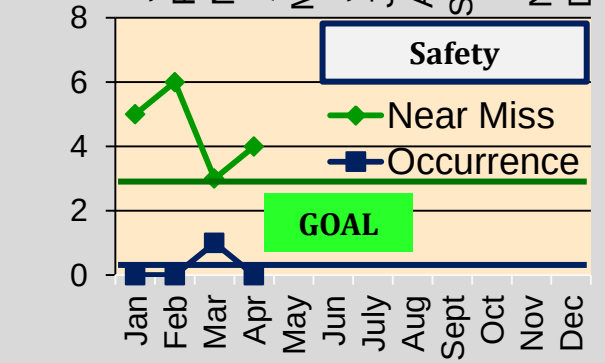






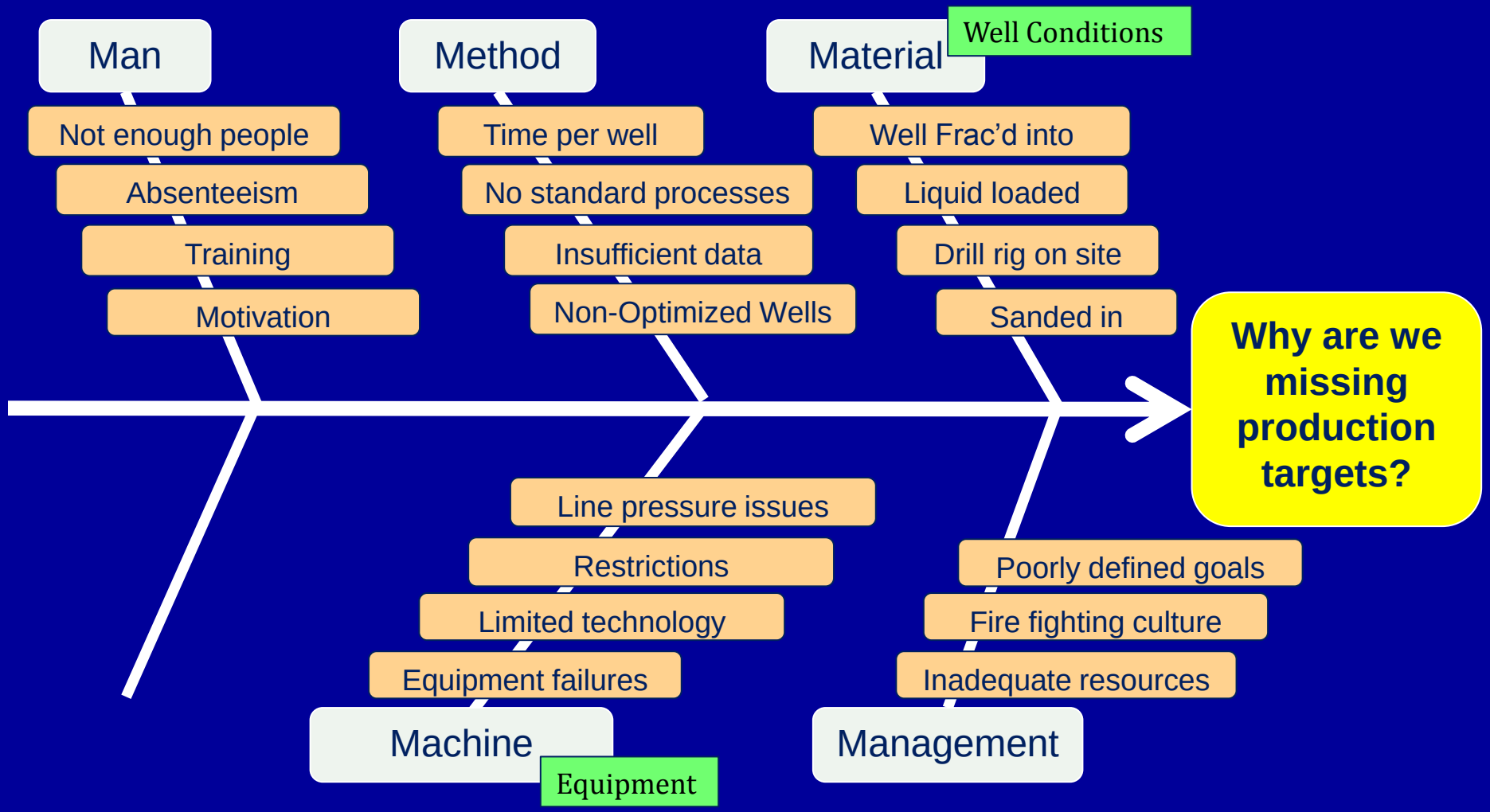






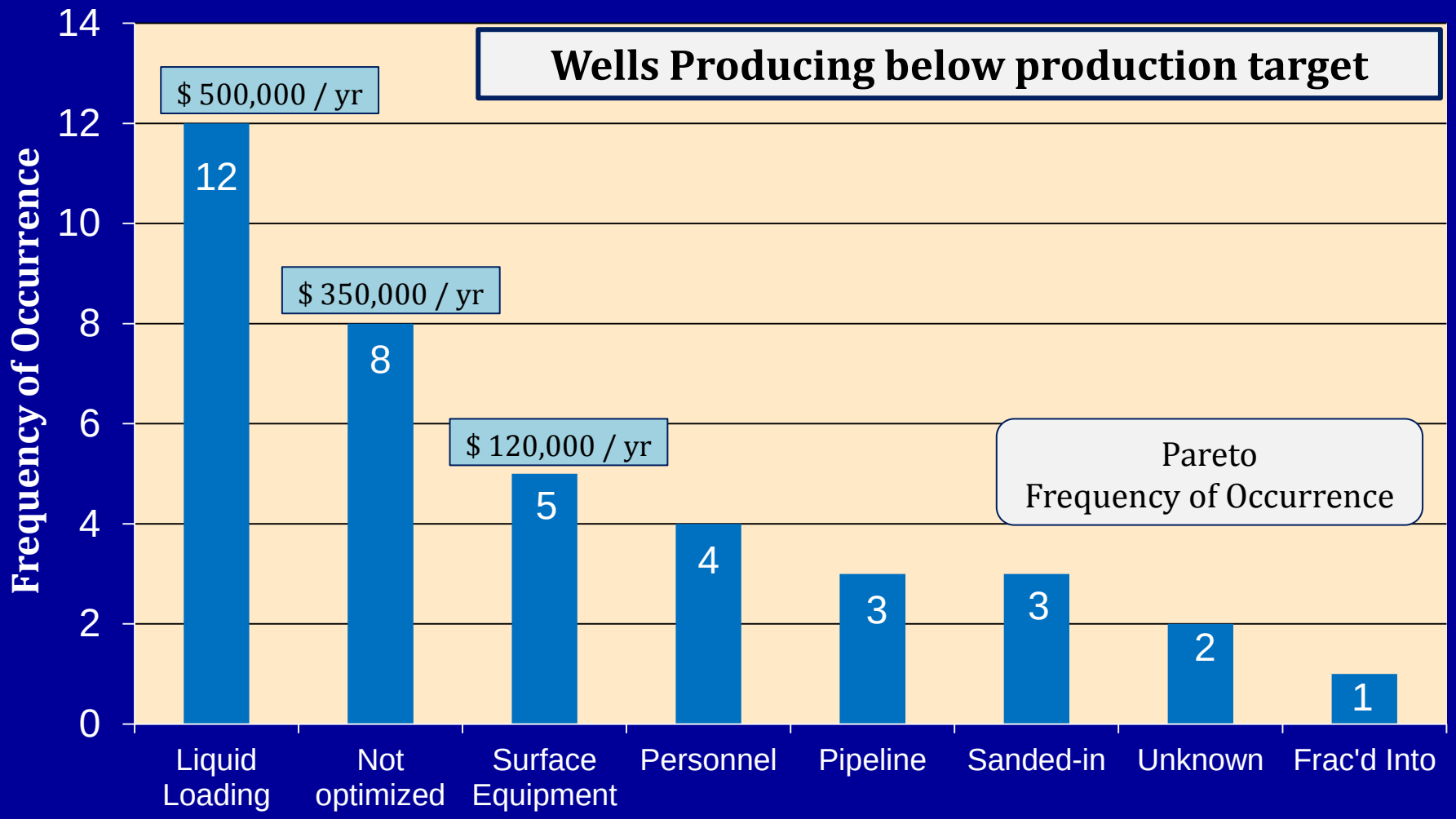
Planning

What are the causes? Fishbone !



Planning

What are the causes in order of importance - Pareto



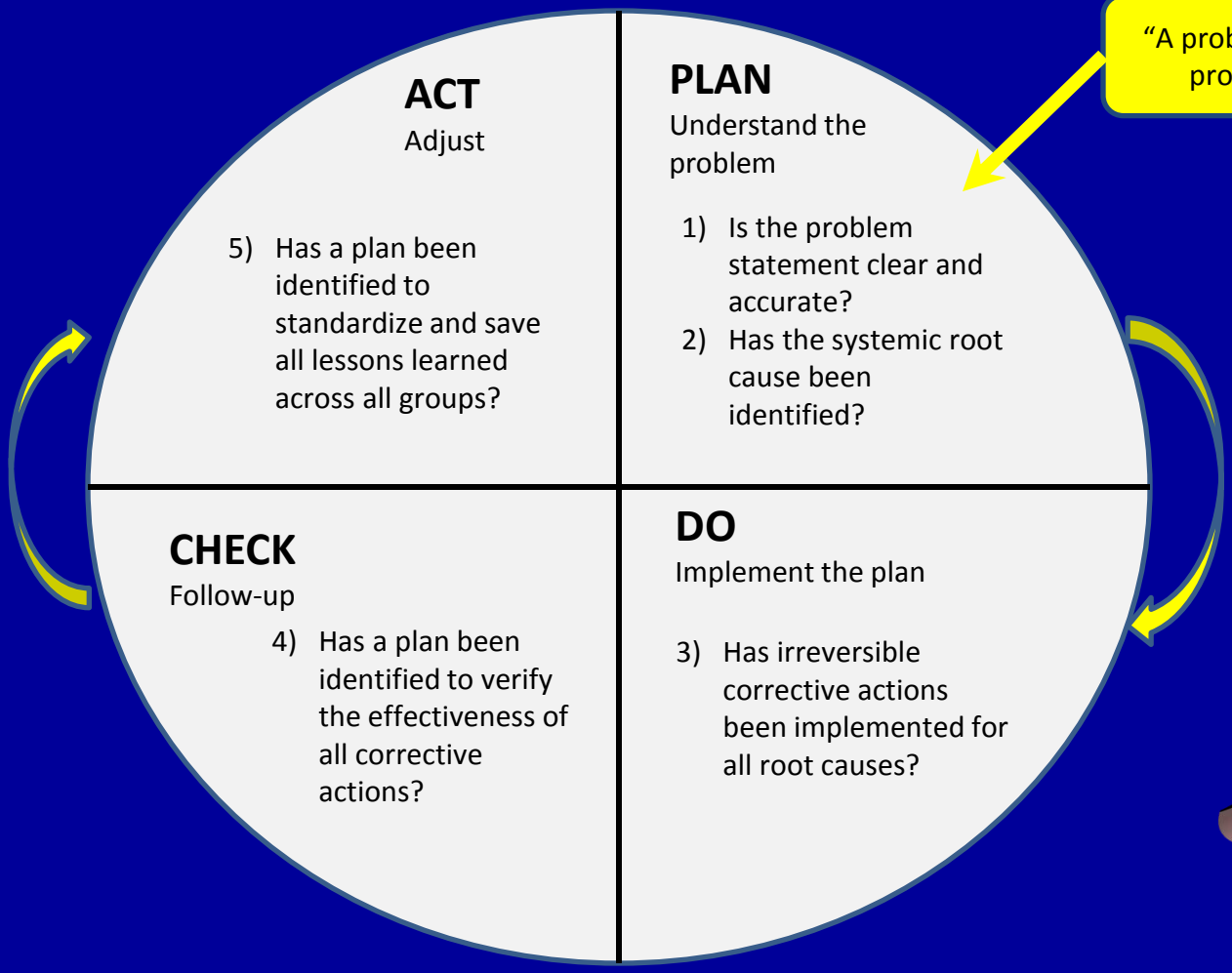
Planning

What is the root cause? 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 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 !



"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

Goals	Activities	J	F	M	A	M	J	J	A	S	O	N	D
Identify Liquid Loaded Wells	Review decline curves	■											
	Check critical flow rate	■	■										
	Determine GLR		■										
Detemine AL type required	Low Gas to Liq Ratio	■	■	■									
	High Gas to Liq Ratio	■	■	■									
Select vendors	Gas Lift Supplier			■	■								
	Plunger Lift Supplier			■	■	■							
	SCADA, Wireline, etc				■	■	■						
Select and train operators	Determine org structure						■	■					
	Select operators						■						
	Train operators							■	■				
Begin installation	Install 1-5 systems								■				
	Install 6-10 systems											■	

Follow-up, Unresolved issues

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

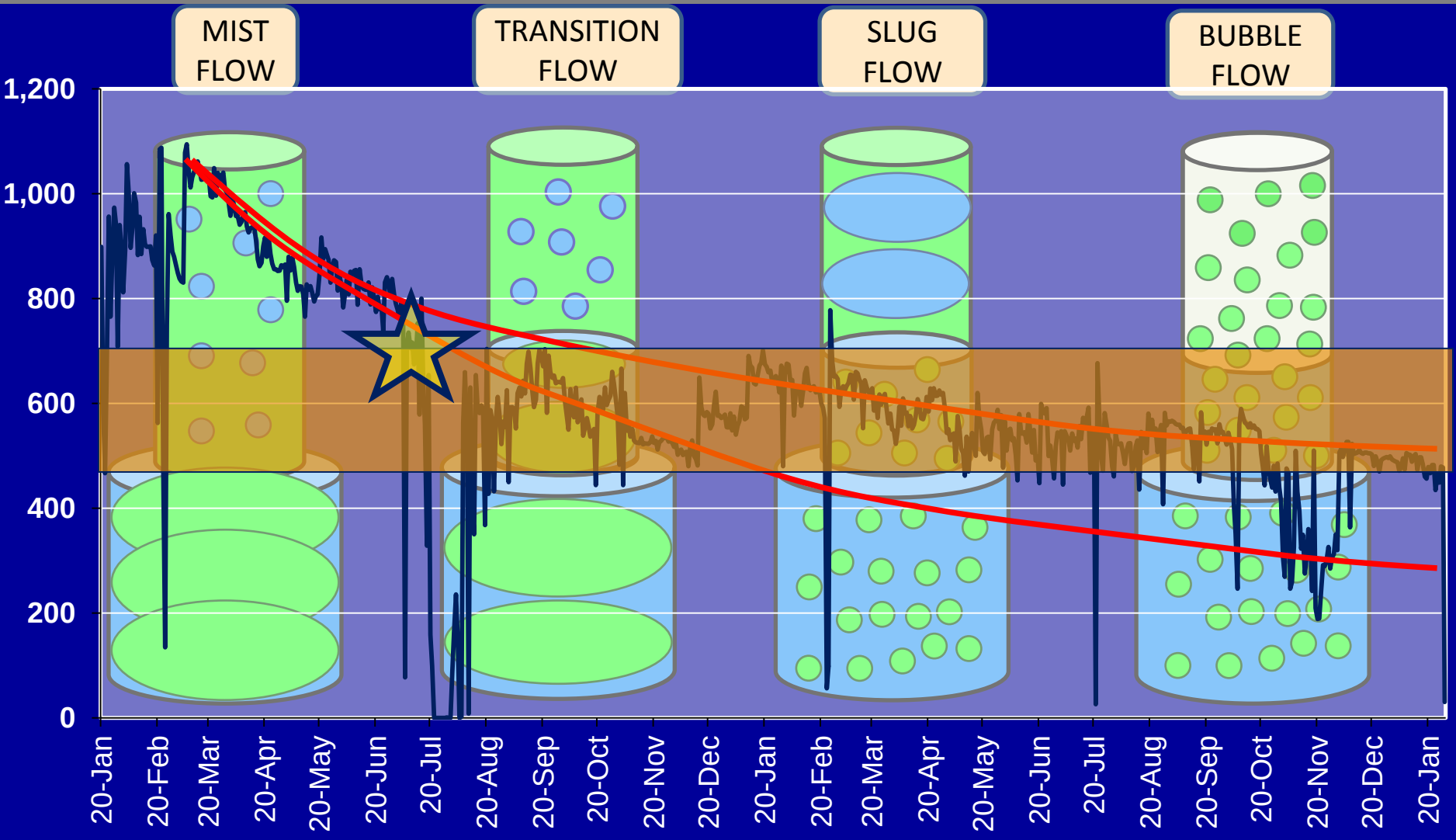
SIGNATURES:

Author:
Version and Date:

Line-out and optimize

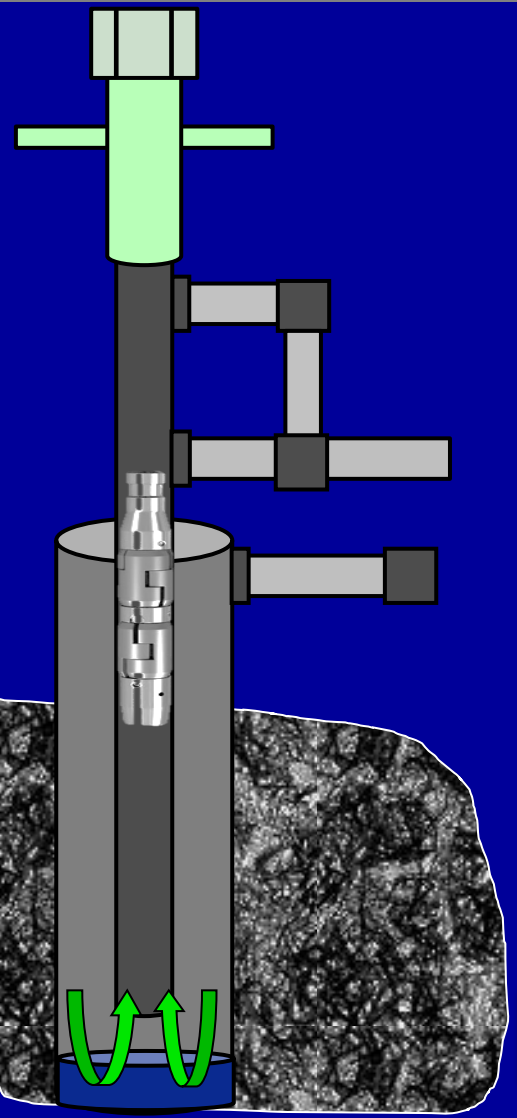
Line-out and Optimize

Install AL BEFORE production is lost!



Line-out and Optimize

Select the "Best" AL Type



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!

Line-out and Optimize

Set goals, prioritize daily

Set realistic targets

- ✓ Actual production vs target
- ✓ Green, Yellow, Red

"Lifting costs reduced up to 75% with automation"

GWD Denver 2011
XTO / Ferguson Beauregard presentation

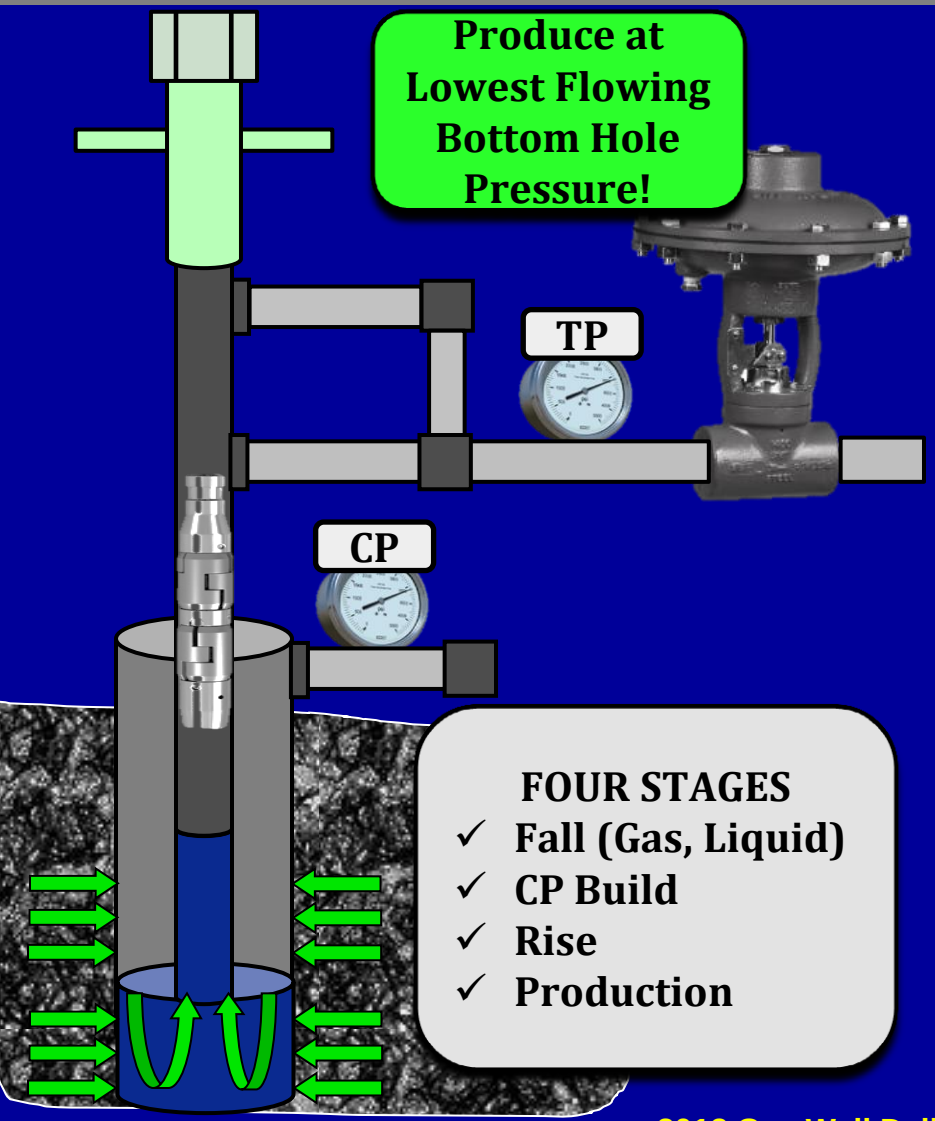
Prioritize wells daily

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

Well Name	Last Polled		Batt Volts	Plunger Stage	Time Remain	Pressures			Flow Rate	Plunger Velocity	Today			Yesterday			Production Target	
	Date	Time				CP	TP	LP			Gas	Good	Miss	Gas	Good	Miss	Gas	%
Well 1	1/10/2013	08:42:07	12.8	Falling	00:06:15	375	350	150	0	650	45	8	0	450	18	0	420	107%
Well 2	1/10/2013	08:39:16	12.3	Rising	00:03:09	450	350	160	269	437	33	5	0	323	12	0	380	85 %
Well 3	1/10/2013	10:21:02	11.2	Produce	00:45:15	375	165	150	335	1211	75	12	0	650	40	0	630	103%
Well 4	1/10/2013	18:39:15	10.2	Shut in	00:00:00	450	350	500	269	437	0	0	0	0	0	0	390	0%

Line-out and Optimize

Plunger Cycle



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

Line-out and Optimize

Plunger Cycle

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

Line-out and Optimize

Plunger Cycle

CP Build Time

- Objective – Operate at lowest CP practical (ie 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

Line-out and Optimize

Plunger Cycle

Track on each cycle

Run #	WHEN WELL CLOSES						
	Time	Pressures					
		Casing	Tubing	Line	Casing - Tubing	Tubing Liquid
503	11/17/2012 4:36:00 AM	314	253	135	61	0.54
504	11/17/2012 5:21:00 AM	312	254	135	58	0.52
505	11/17/2012 6:07:00 AM	314	256	133	58	0.52
506	11/17/2012 6:51:00 AM	311	251	134	60	0.54
507	11/17/2012 7:39:00 AM	313	256	133	57	0.51
508	11/17/2012 8:21:00 AM	310	251	132	59	0.53

Run #	RESULTS						
	Plunger Data			Time			Production
	Time	Velocity	Arrival	Open	Fall	Close	Gas
503	5.83	1029	Y	00:06	00:25	00:38	6.0
504	4.58	1310	Y	00:05	00:25	00:40	5.5
505	6.03	995	Y	00:07	00:25	00:36	5.8
506	5.12	1172	Y	00:06	00:25	00:41	5.3
507	6.00	1000	Y	00:07	00:25	00:35	6.4
508	4.93	1217	Y	00:05	00:25	00:39	5.3

Run #	WHEN WELL OPENS							
	Time	Pressures						
		Casing	Tubing	Line	Casing - Tubing	Tubing Liquid	Casing - Line	Foss and Gaul
503	11/17/2012 5:15:00 AM	355	326	134	29	0.26	221	213
504	11/17/2012 6:02:00 AM	354	337	134	17	0.15	220	191
505	11/17/2012 6:44:00 AM	353	326	133	27	0.24	220	209
506	11/17/2012 7:33:00 AM	354	331	134	23	0.21	220	204
507	11/17/2012 8:14:00 AM	351	321	132	30	0.27	219	215
508	11/17/2012 9:01:00 AM	352	330	132	22	0.20	220	202

DOWNWARD FORCE

PLUNGER EFFICIENCY

UPWARD FORCE

Line-out and Optimize

Plunger Cycle

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!

Line-out and Optimize

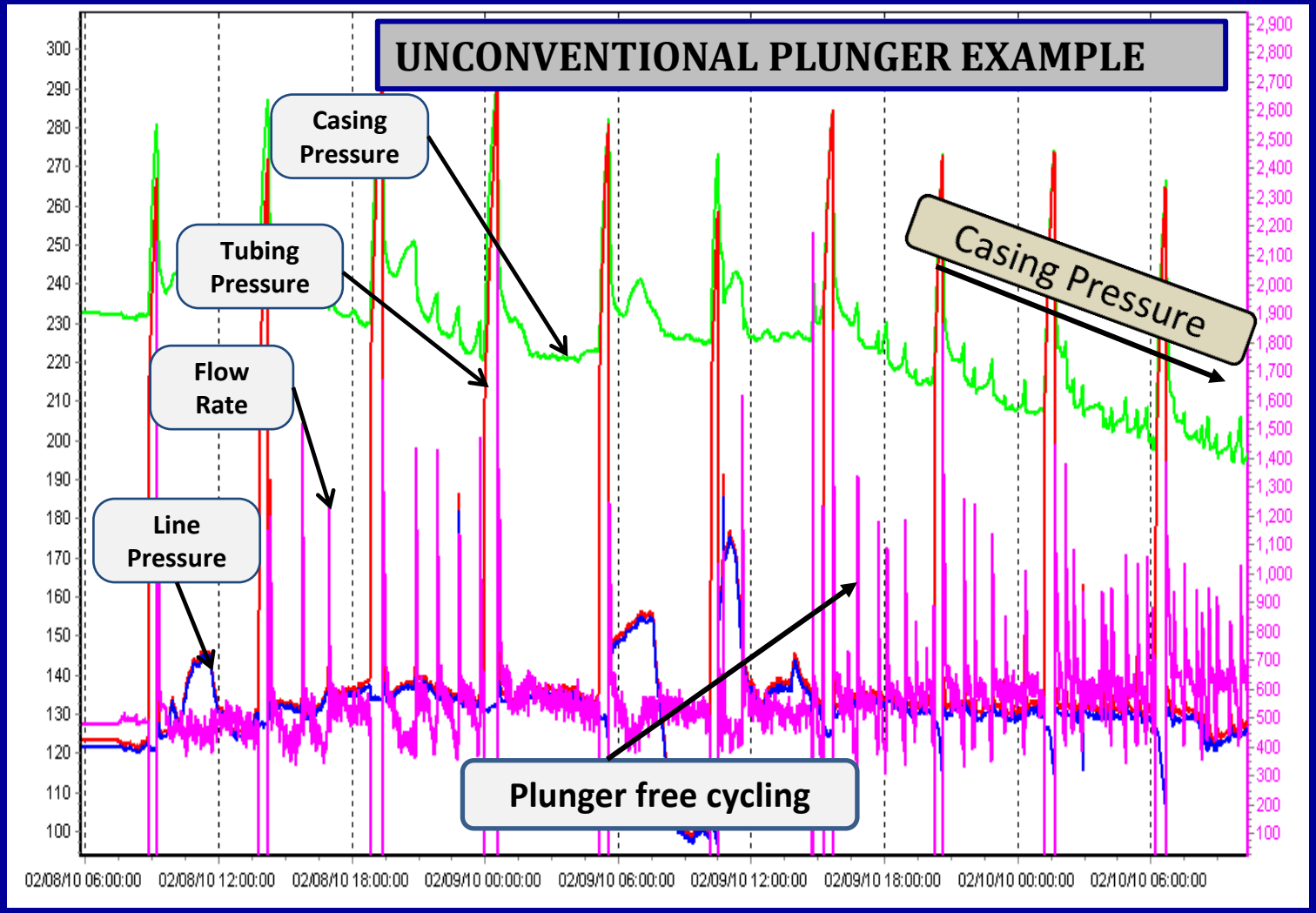
Plunger Cycle

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

Plunger falls against flow

Only round trip times recorded

Excessive plunger velocities possible



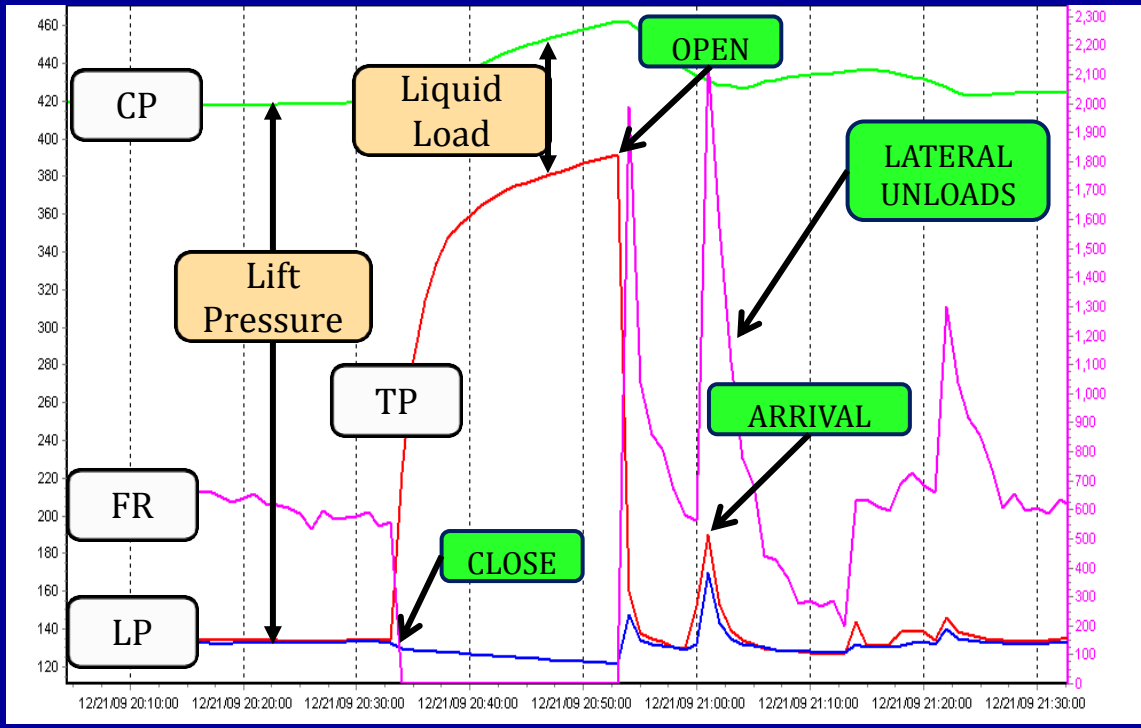
Troubleshoot

Troubleshoot

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

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

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

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

Motor valve leak

- ✓ Obstacle in Motor Valve trim
- ✓ Cut, worn trim (sand, particulates)
- ✓ Consider ceramic trim

Troubleshoot

Common Problems

Short battery life

- ✓ Inspect battery
- ✓ Inspect wires to solar panel
- ✓ Inspect solar panel
  - ✓ Clean
  - ✓ 45 Degree angle
  - ✓ Facing south
- ✓ Radio malfunction (amps)

Plunger fishing neck mushroomed

- ✓ Lubricator spring worn, stuck or too stiff
- ✓ Excessively fast plunger runs

Catcher will not trap plunger

- ✓ Inspect / replace spring and or ball

Flow rate increasing at end of afterflow

- ✓ Flow longer

Motor valve closed, flow rate not zero

- ✓ Motor valve leak
- ✓ Calibrate flow meter

Lubricator top seeps / leaks

- ✓ Lubricate threads
- ✓ Inspect "O" ring
- ✓ Grease "O" ring

Fast, dry plunger runs. Liquid in tubing on each cycle

- ✓ Fall time too short

Missed run every 6 weeks or so – no other issues

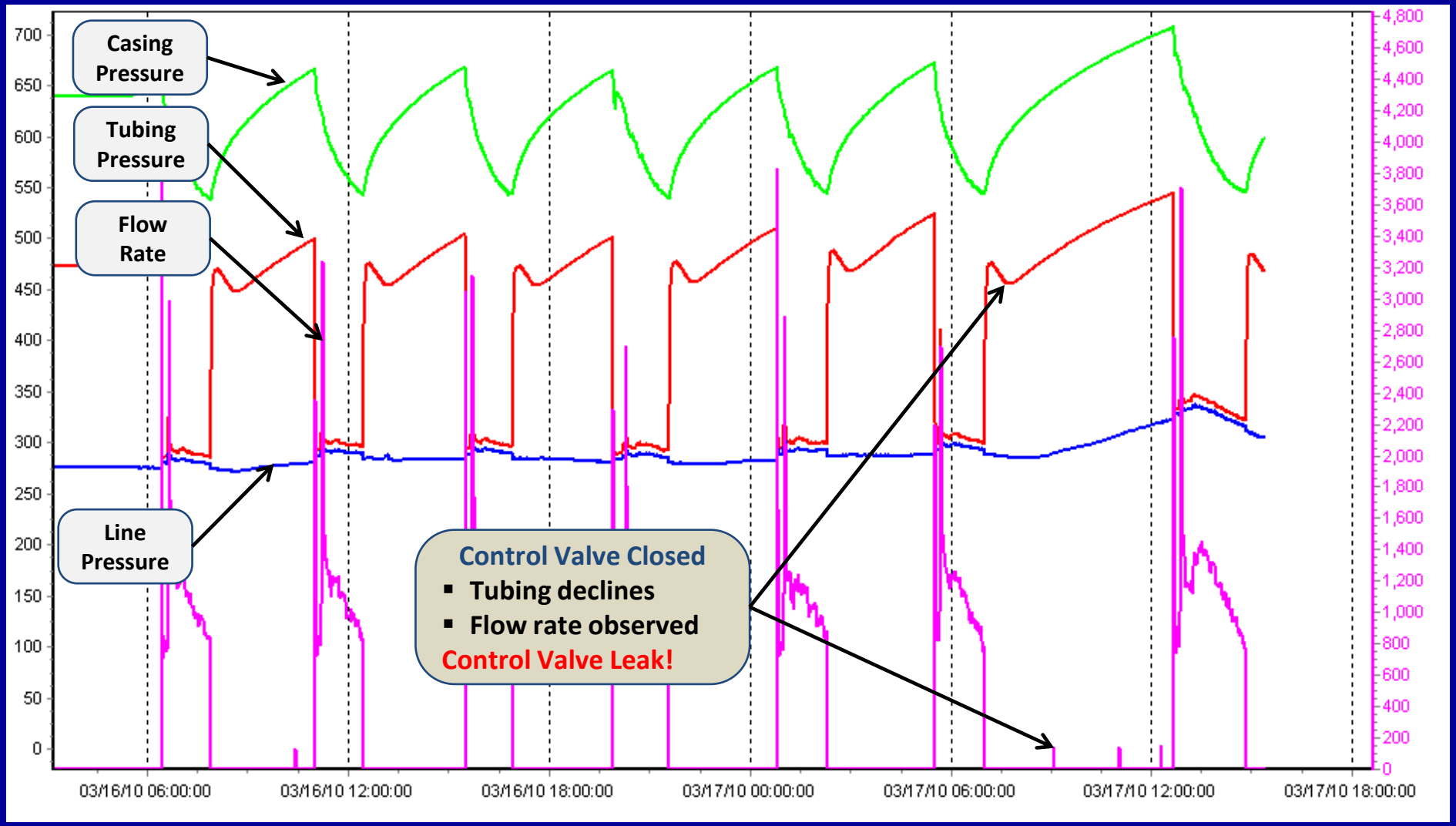
- ✓ Meter tech on site - shut in meter run

Fall time elapsed, CP not rising, OFF time remains

- ✓ Reduce shut-in time or open at a lower lift pressure

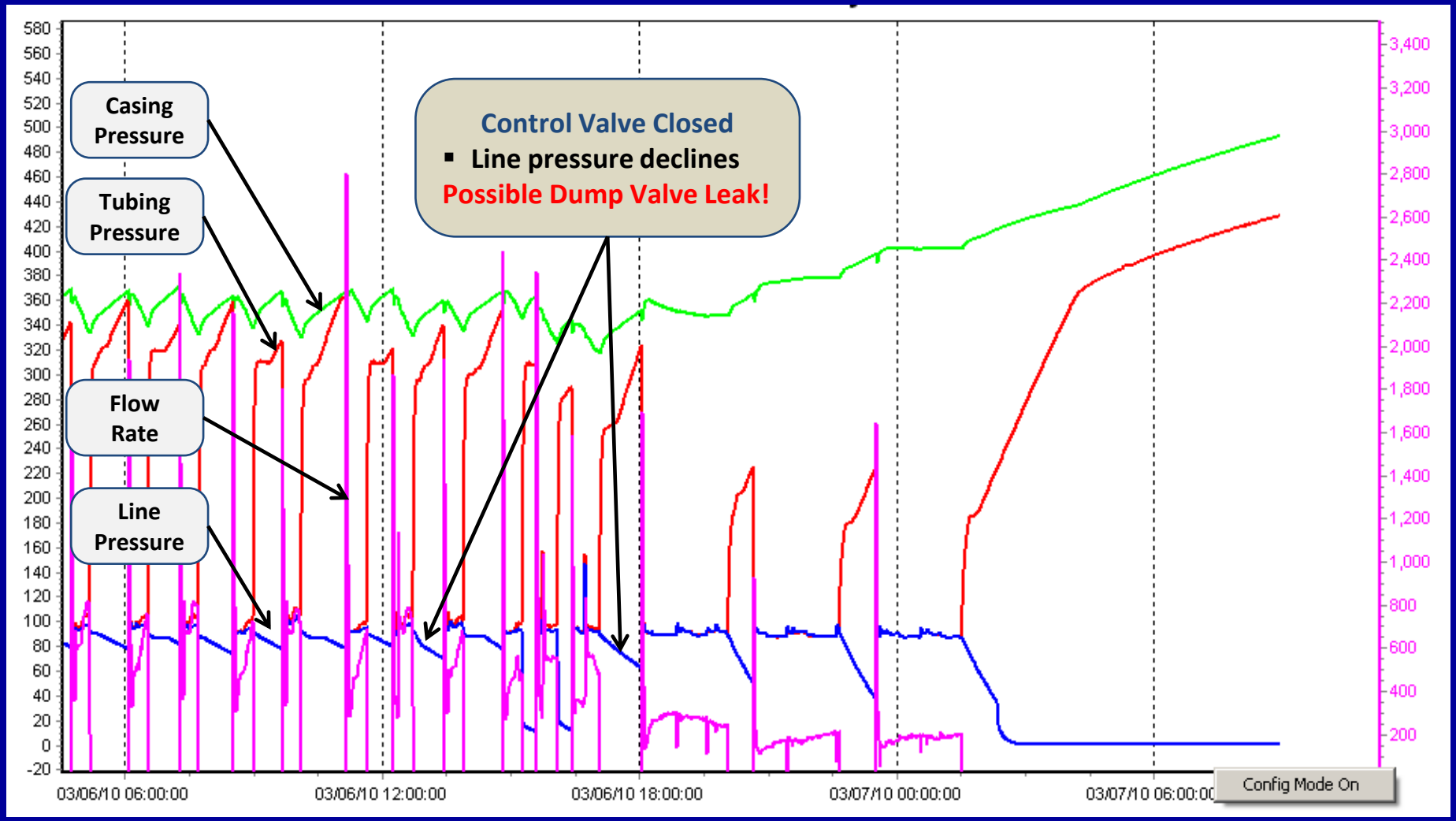
Troubleshoot

Common Problems



Troubleshoot

Common Problems



Troubleshoot

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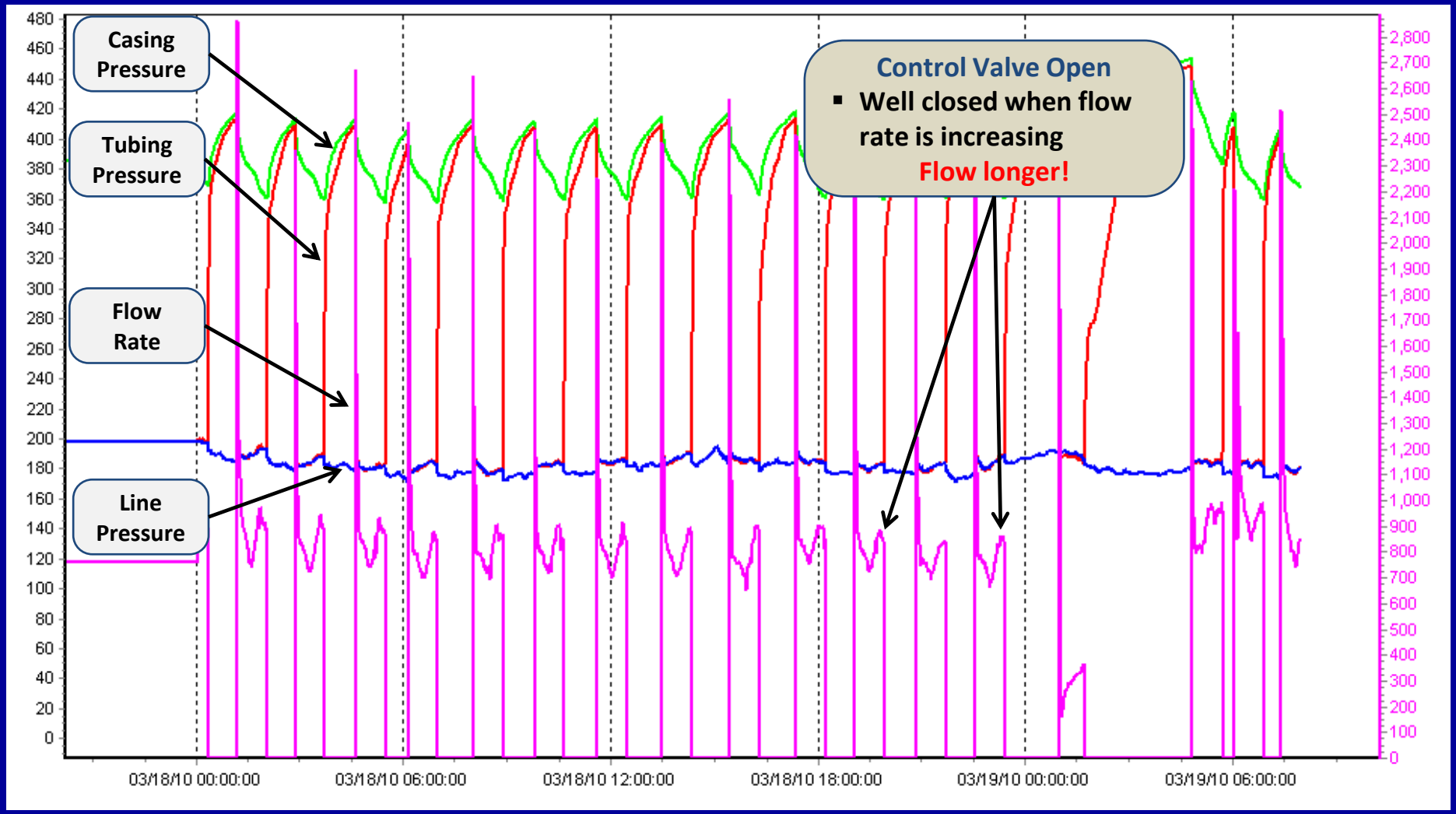

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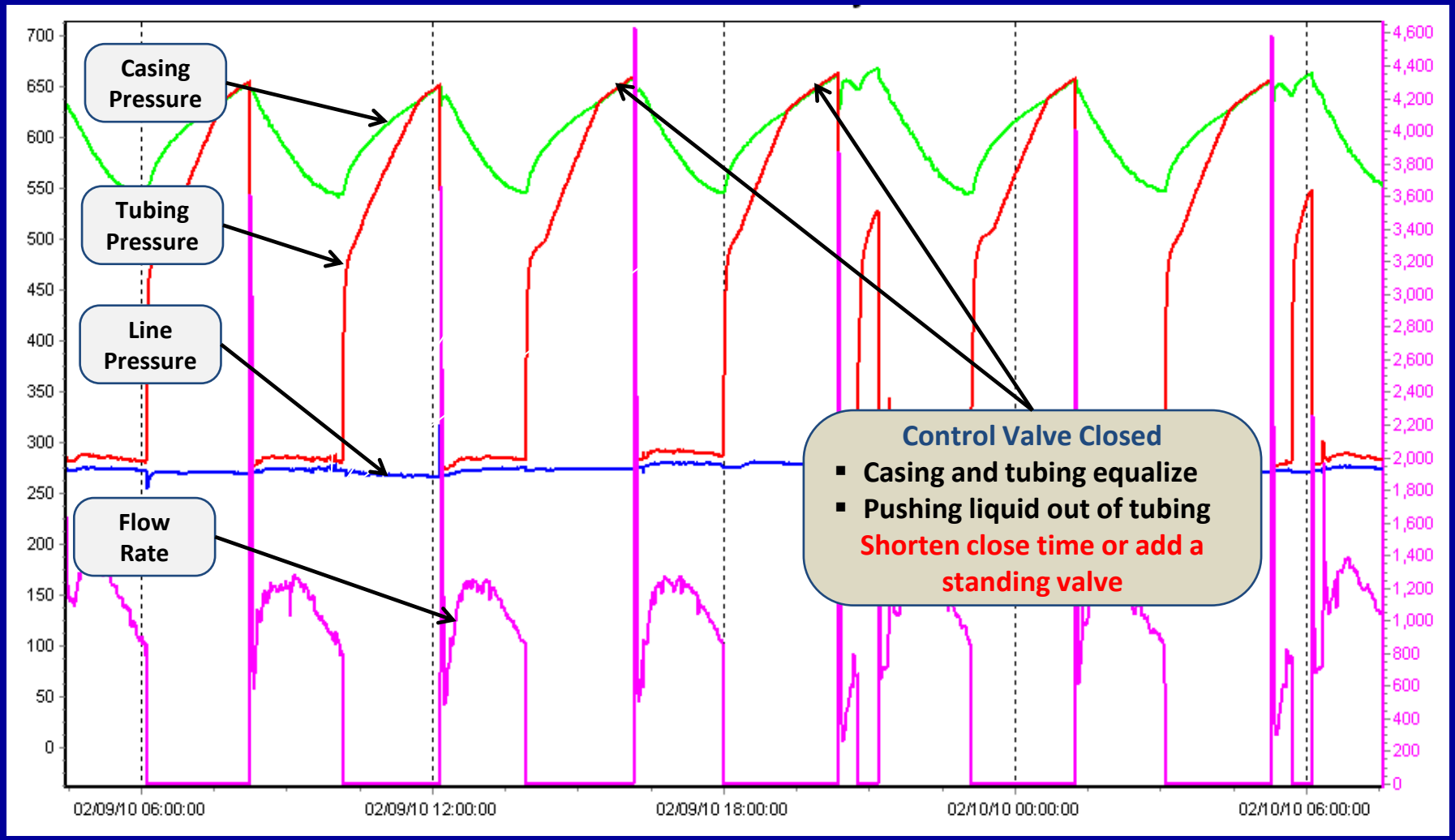


Sustain peak production

Sustain peak production

Training is not enough! Demonstrated Learning

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

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

Sustain peak production

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

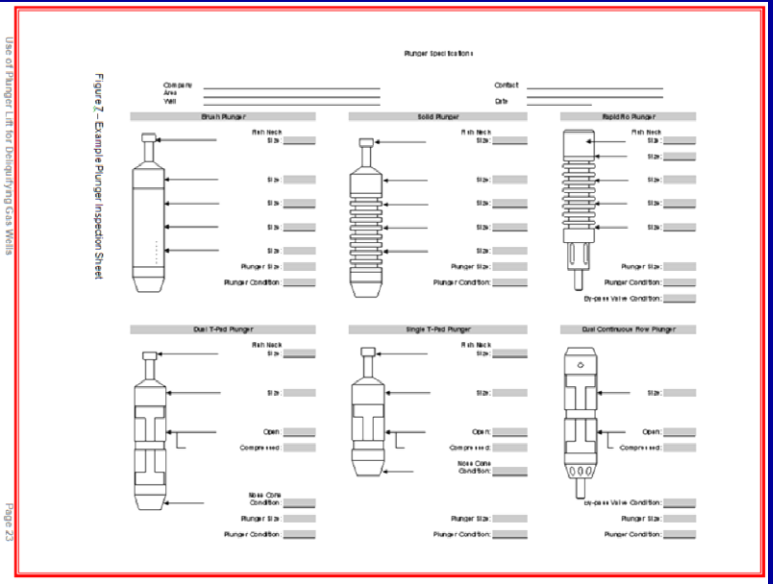
Who's responsible for production?

BOTH are critical to sustained peak production!

Sustain 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

Sustain peak production

"Problems are nuggets to be mined, not garbage to be buried"

Linkedin Group

"Plunger Lifted Gas Wells"

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