Gas Well Deliquification Workshop
Sheraton Denver Hotel
Denver, Colorado
February 29 – March 2; 2016

10 Steps to Optimized Production

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Shale Tec LLC

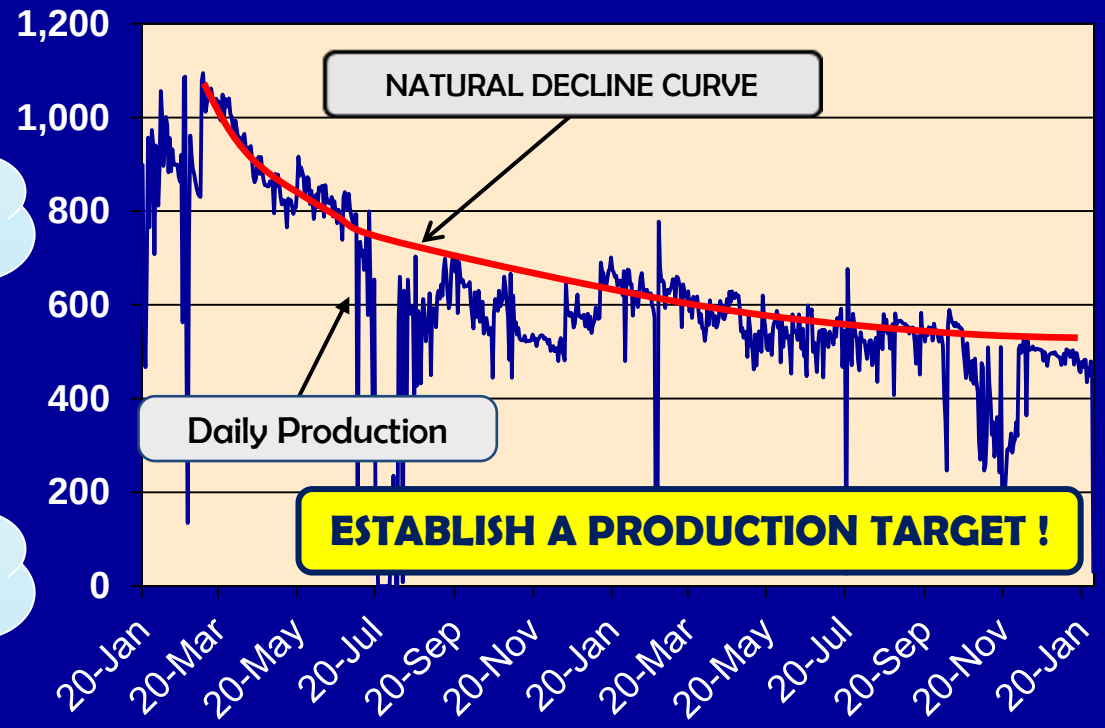
Learning Points

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

Why Optimize?

What is an optimized well?

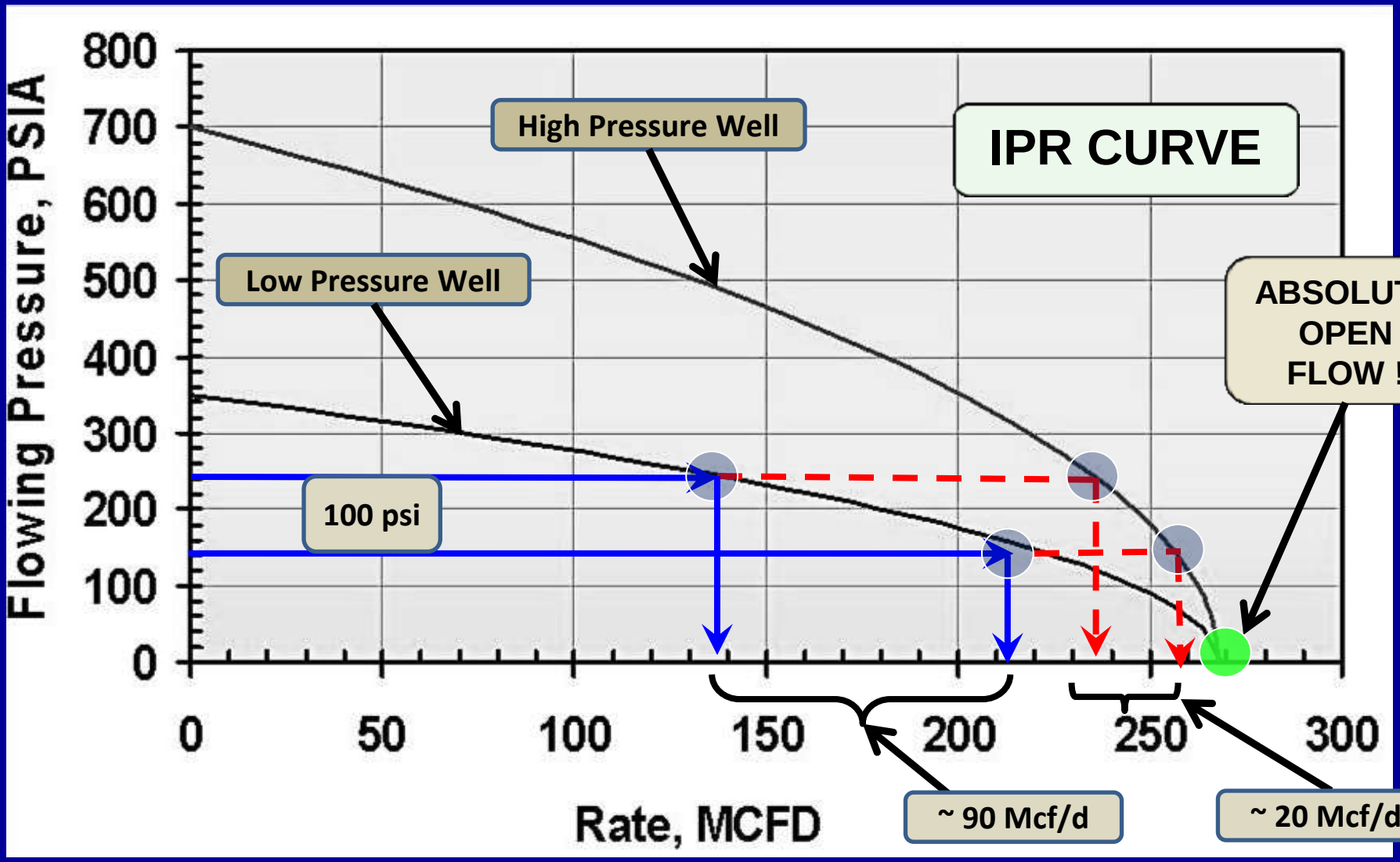
- Meets daily production goal ?
- No missed plunger cycles?
- Produce at or above 80 % of AOF?
- 20% production increase?
- 500 to 1000 fpm plunger cycle ?
- Rapid payback ?



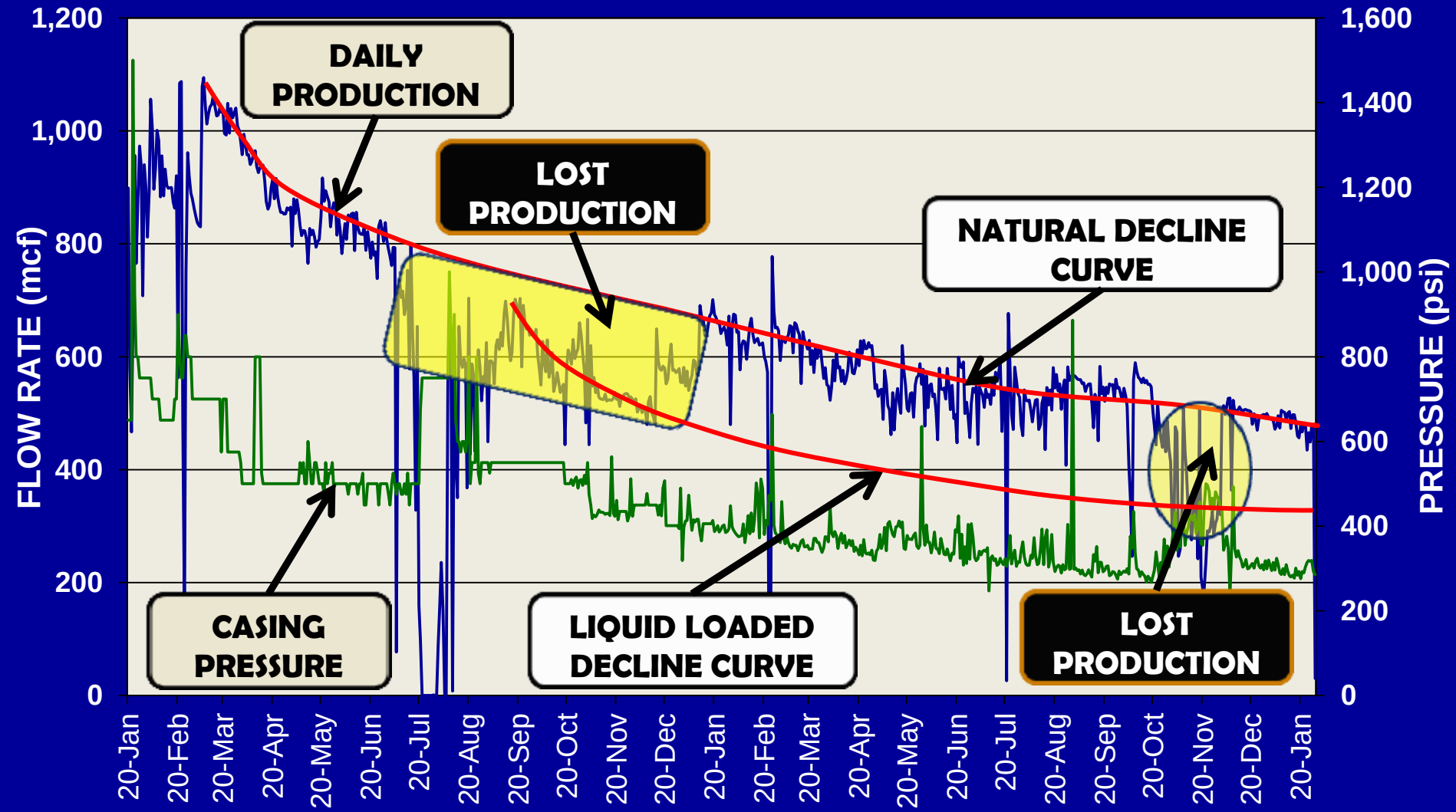
"An optimized plunger lift well is a well that is operating at the maximum number of cycles necessary to generate the lowest average flowing bottom hole pressure with the available reservoir energy."

ALRDC Guidelines and Recommended Practices

Why Optimize?



Why Optimize?



10 Steps!

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 !

Train Wide and Deep !

Lowest FBHP !

Real Time DATA !

1. Artificial Lift Strategy

ESP

Beam Pump

Plunger Assisted Gas Lift

Gas Assisted Plunger Lift

2 Stage Plunger Lift

Plunger Lift

Compression

Velocity Strings

Foaming Agent

Swab or Intermit Well

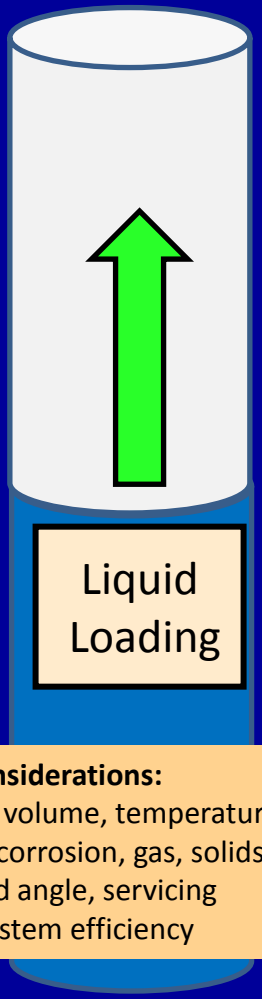
Free Flowing Well

High Cap X

Often, only Short Term Solution

Monthly Chemical Expense

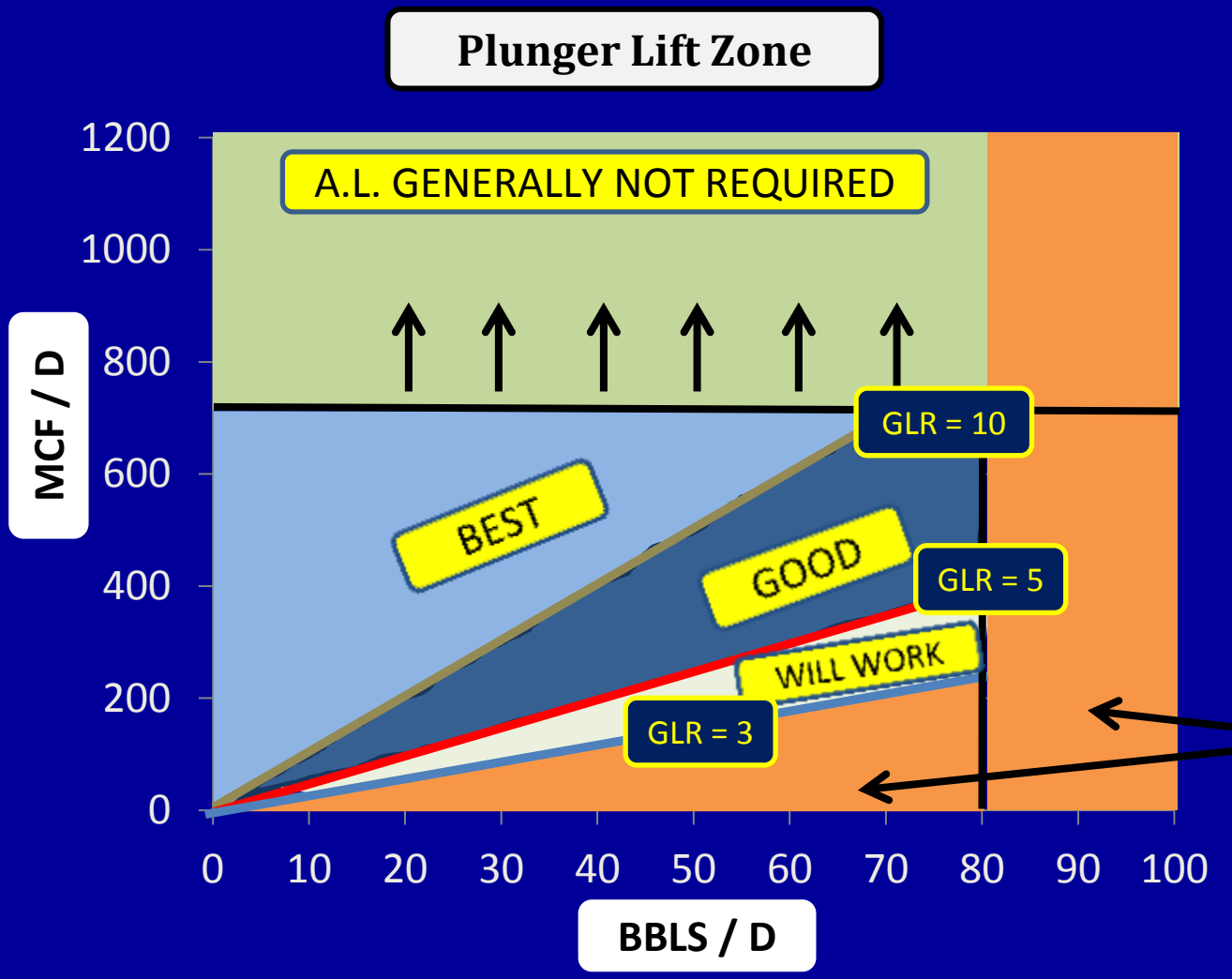
Not Environment Friendly



Artificial Lift Type Considerations:

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

1. Artificial Lift Strategy



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

3rd Annual Appalachian Basin
Gas Well Deliquification Seminar
Marietta College, Marietta, Ohio
June 4 - 6, 2012

Barnett Shale Artificial Lift Experience

Heather Burnham
Operations Engineer
XTO Energy

XTO ENERGY a subsidiary of ExxonMobil

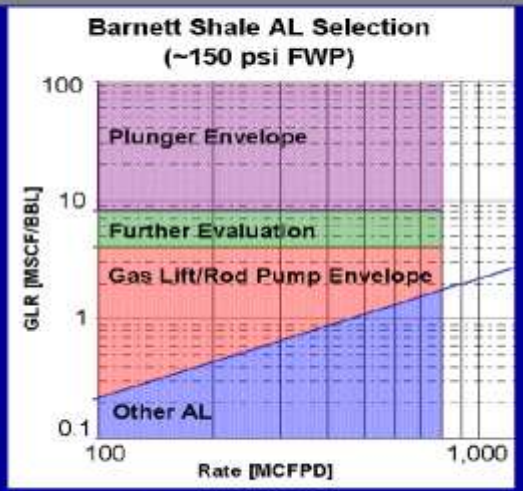
Artificial Lift Selection Process

Guidelines

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

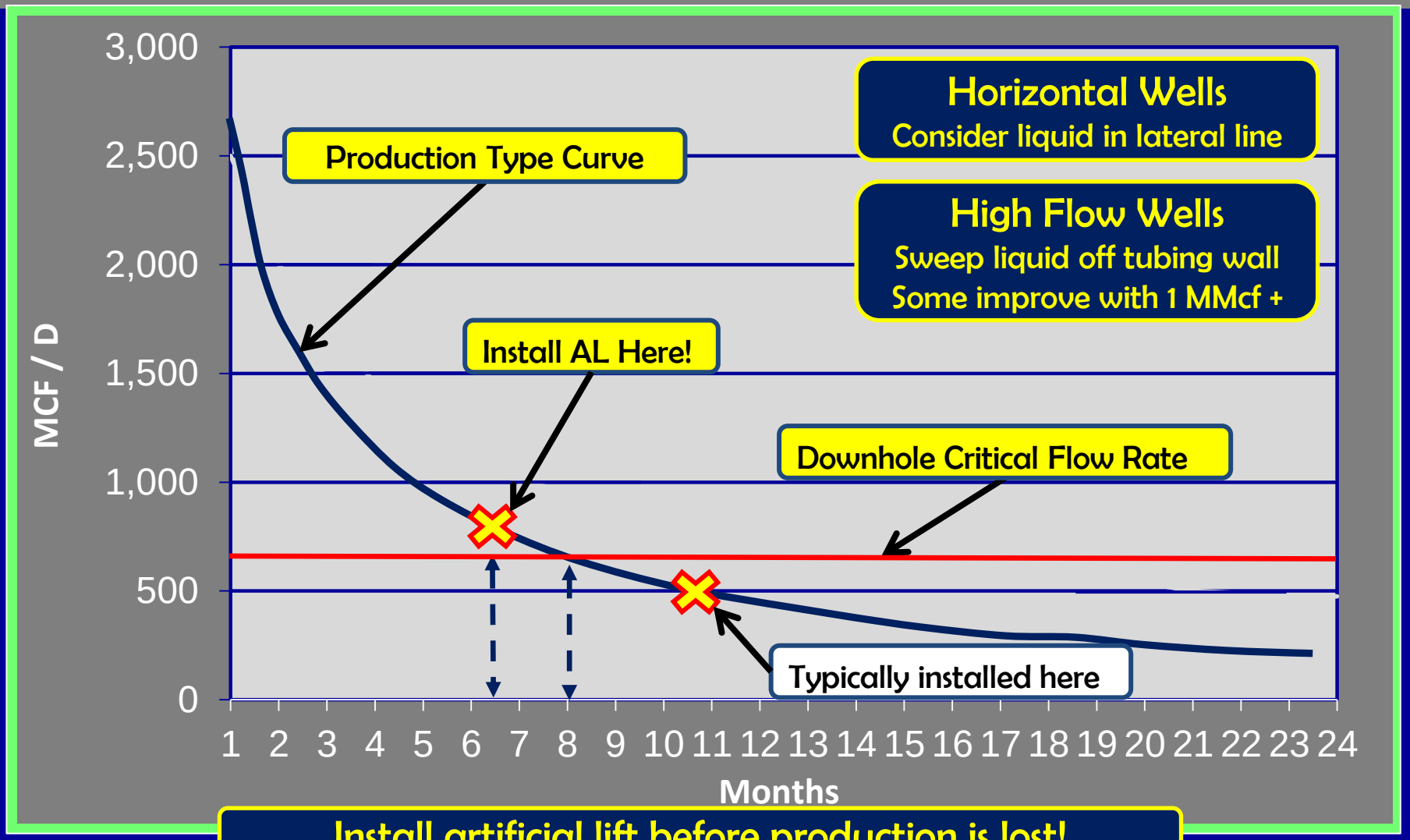
Further Evaluation

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



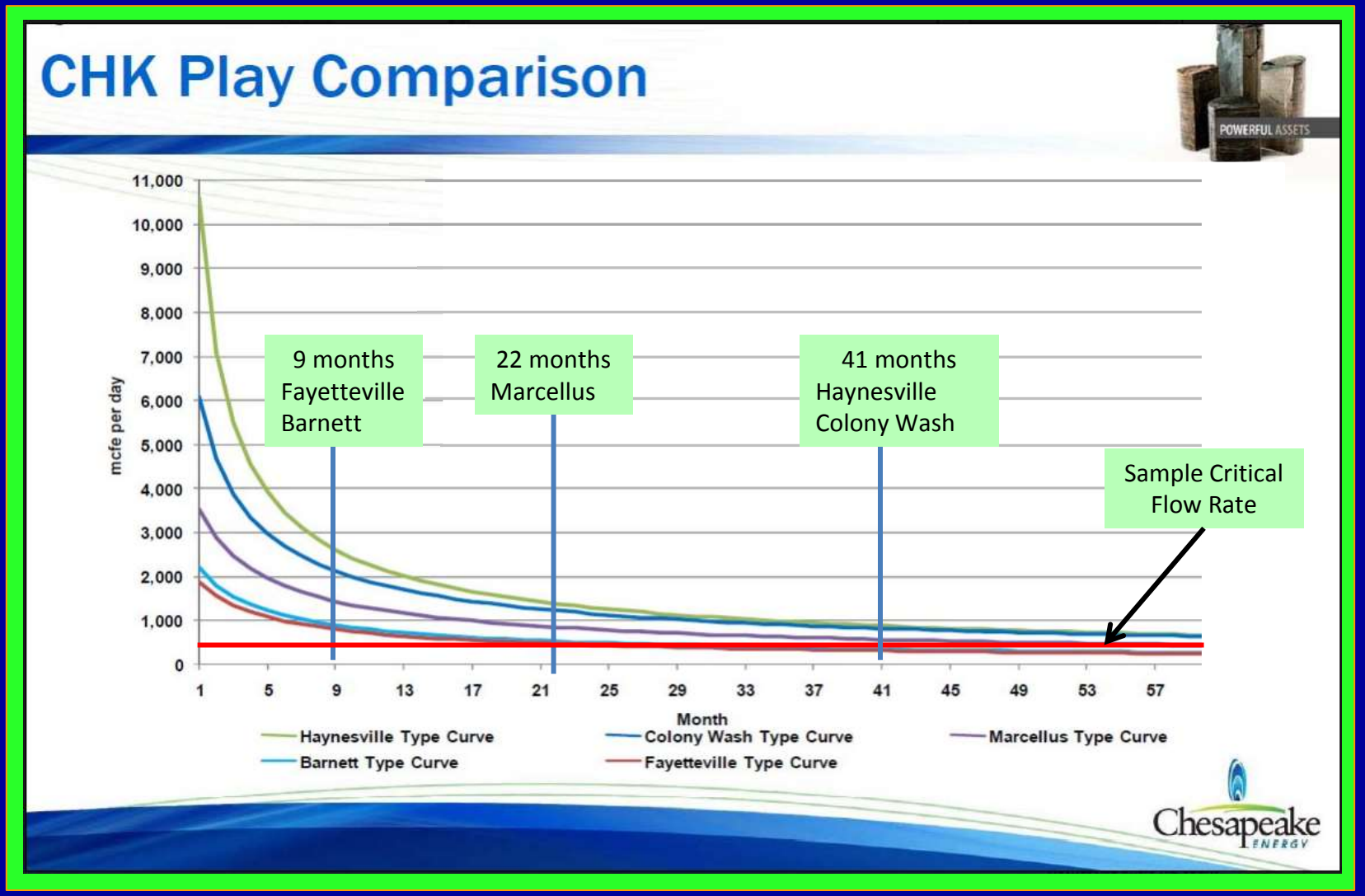
June 4 - 6, 2012 — 2012 Appalachian Basin Gas Well Deliquification Seminar, Marietta, Ohio — 4

2. When to install

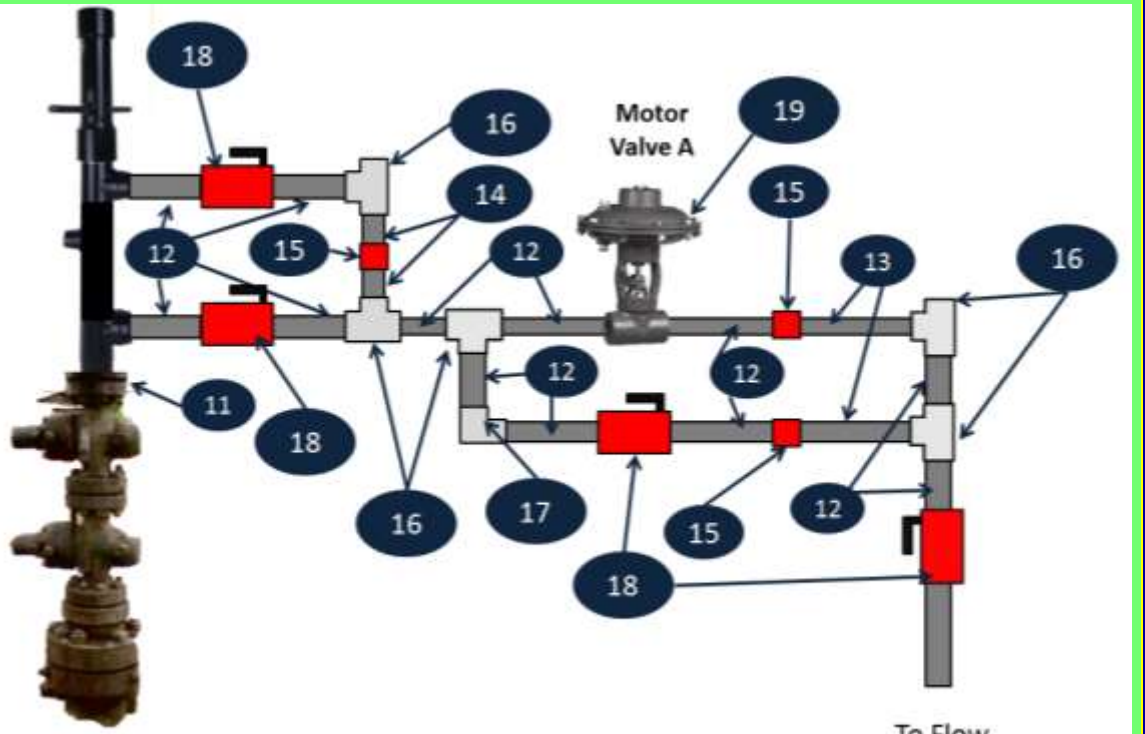


Install artificial lift before production is lost!

2. When to install



3. Standardize !



45 degree vs 90 degree elbows can reduce restrictions

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

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

Emergency shut off
Sand cut probe

3. Standardize !

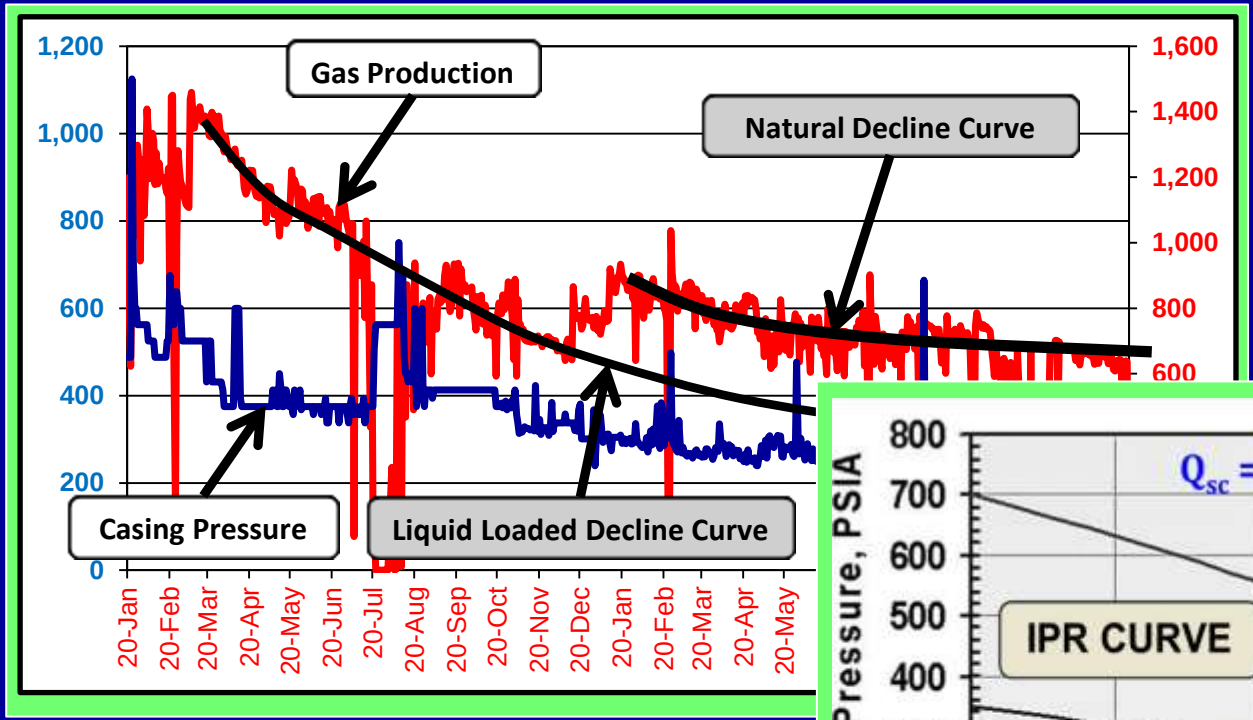
Plunger Types for Well Condition

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

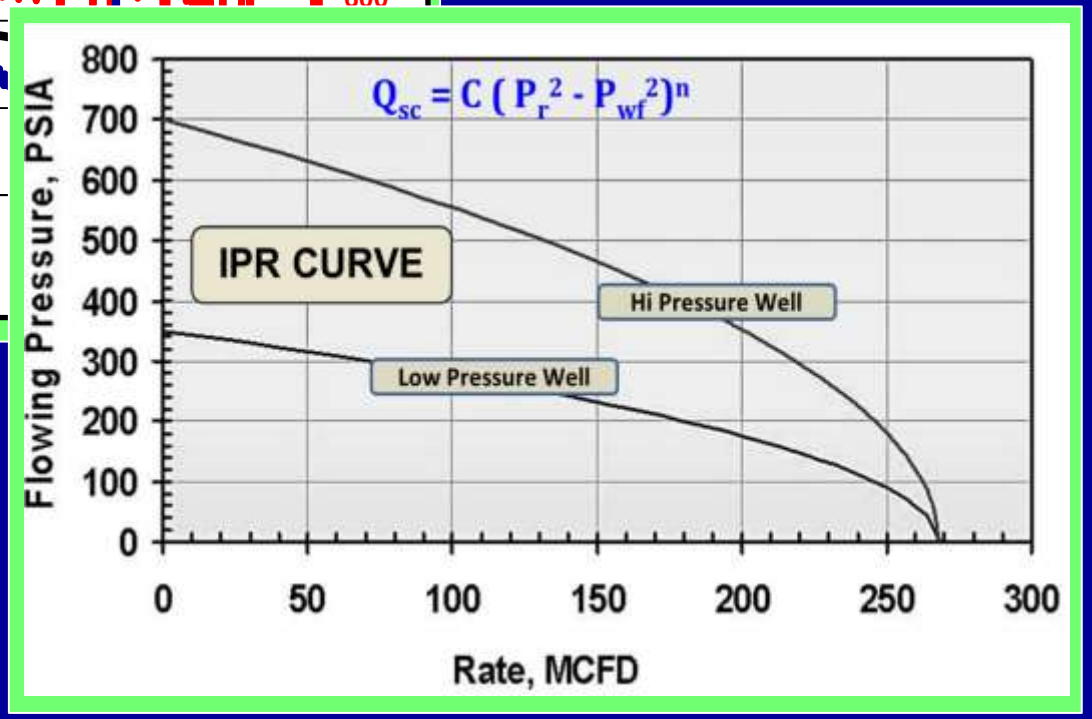
Data Required for Each

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**

4. Meaningful Production Target



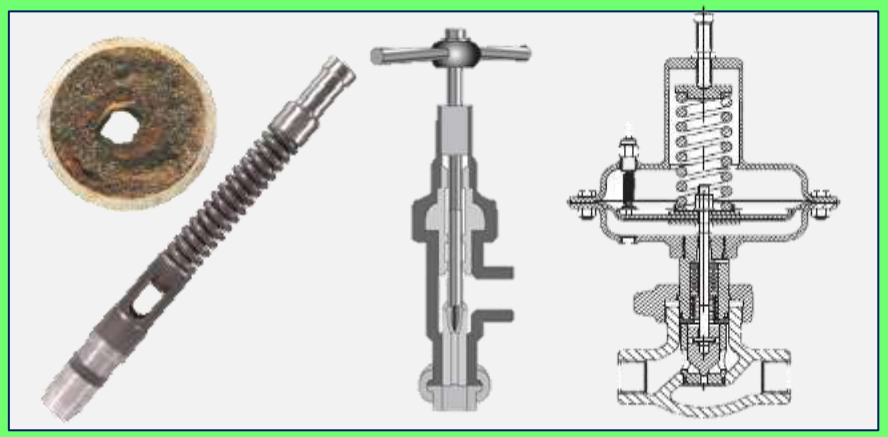
Set a meaningful production target for each well



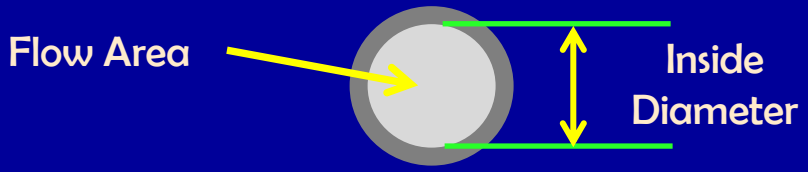
Operating at :

- ❑ 40 % of Absolute Open Flow?
- ❑ 80 % of Absolute Open Flow?

5. Remove Restrictions

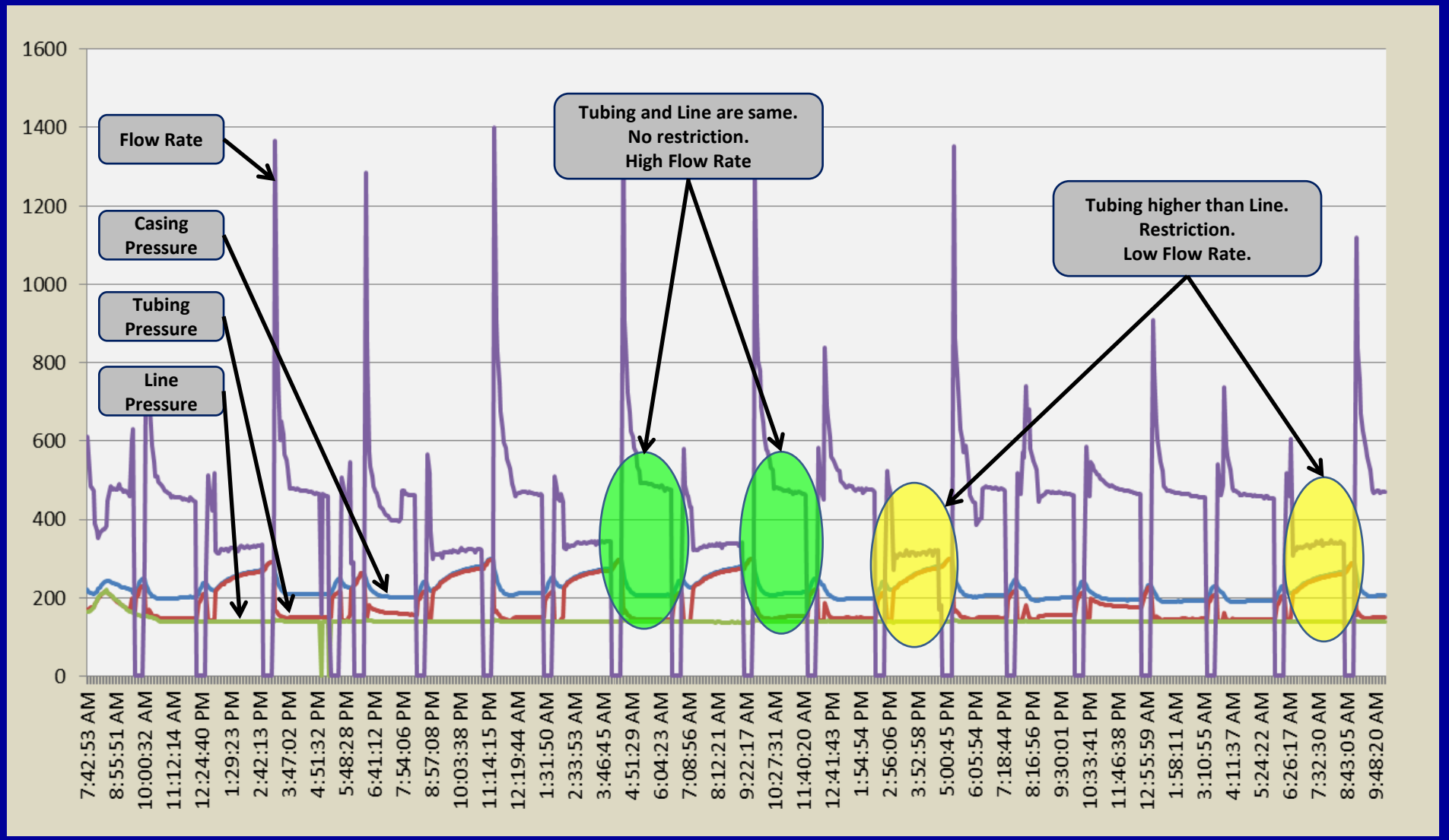


- ✓ Scale, Paraffin – Drift and broach tubing
- ✓ Bottom hole spring hold down – size, debris
- ✓ Motor valve trim – full port opening
- ✓ Orifice plate at flow meter
- ✓ Well head – Sleeve if needed
- ✓ Chokes



Diameter	Area	% Difference
7/8 inch	0.601 inch^2	0 %
1 inch	0.785 inch^2	30.6 %
1 ¼ inch	1.227 inch^2	104.2 %
1 ½ inch	1.767 inch^2	194.0 %

5. Remove Restrictions



6. Prioritize Wells Daily

Well Names

Well Name	Last Polled		Batt.	State	Time	Pressures (psi)			Flow	Velocity	Today			Yesterday			Target	
	Date	Time	Volts		Remain.	Tube	Case	Sales	Rate	(ft/min)	Gas	Arr.	Fails	Gas	Arr.	Fails	Gas	%
	01/26/11	08:42:07	12.8	Plunger Falling	00:06:06	437	497	154	0	477	26	8	0	362	18	0	320	113.1
	01/26/11	08:41:26	11.9	Plunger Falling	00:10:23	354	369	151	0	194	40	4	0	291	13	0	450	64.6
	12/22/10	09:29:58	11.8	Manual Mode	00:00:00	1	478	0	0	0	0	0	0	0	0	0	0	0.0
	01/30/11	19:09:24	13.1	Manual Mode	00:00:00	-4	465	82	0	0	0	0	0	0	0	0	450	0.0
	01/31/11	08:52:38	12.9	Production Mode	01:48:00	63	174	75	575	529	63	4	0	509	10	0	700	72.7
	01/31/11	09:24:49	13.1	Manual Mode	00:00:00	542	542	56	0	0	3	9	3	350	13	0	0	0.0
	01/28/11	13:39:10	14.1	Plunger Falling	00:20:35	485	641	94	0	887	19	5	1	227	15	3	360	63.0
	01/26/11	08:42:50	13.6	Manual Mode	00:00:00	461	882	53	0	0	0	0	0	0	0	0	340	0.0
	01/31/11	08:51:14	12.8	Plunger Rising	00:34:19	103	482	105	964	1269	78	20	0	693	47	0	700	99.1
	01/26/11	08:41:12	14.5	Production Mode	00:45:19	133	315	147	475	983	71	7	0	588	17	0	775	75.9
	01/26/11	08:40:55	14.1	Plunger Rising	03:44:17	115	205	125	512	0	58	0	2	500	0	6	700	71.4
	01/26/11	08:41:04	14.0	Plunger Falling	00:11:01	218	238	76	0	867	36	6	0	309	16	0	550	56.3
	01/26/11	08:40:22	13.7	Production Mode	00:25:42	60	168	78	467	1143	51	4	0	422	11	0	600	70.3
	01/26/11	08:42:10	13.5	Plunger Rising	00:36:16	94	625	104	352	253	12	3	0	117	8	0	180	65.3
																		105.5
																		93.0
																		82.9
																		83.2
																		79.5
																		0.0
																		0.0
																		71.8
																		80.1
																		0.0
																		81.0
																		69.4
																		46.4

Prioritize wells daily

Production

- Address shut-in wells first
- Then, wells below target

Leading indicators of future problems

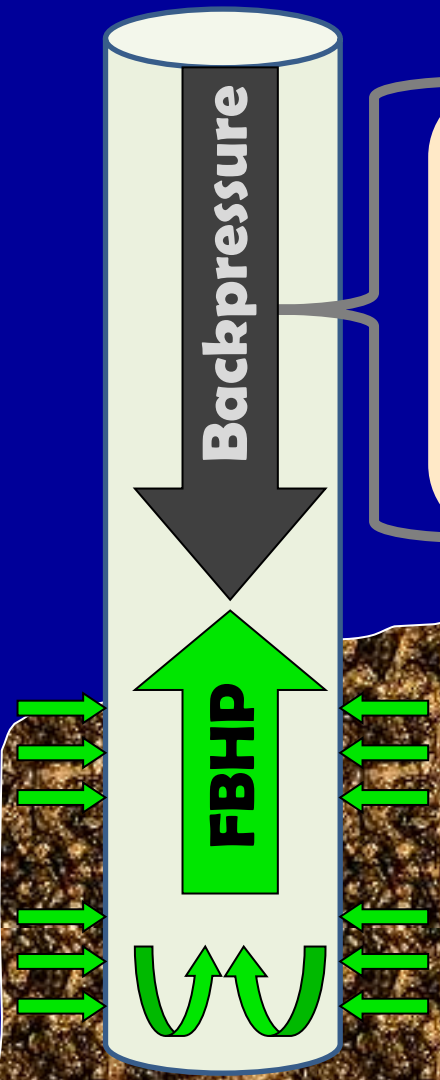
- Missed arrivals
- Fast or slow arrivals
- Low battery voltage
- Increasing close times
- Pressures trending higher
- Ignored preventative maintenance
- Reliance on Trial and Error

"Lifting costs reduced up to 75% with automation"

GWD Denver 2011

XTO / Ferguson Beauregard presentation

7. Optimize Production



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

LOW Backpressure

Produces

LOW FBHP

Ensures

MOST Production

FLOWING BOTTOM HOLE PRESSURE

7. Optimize Production

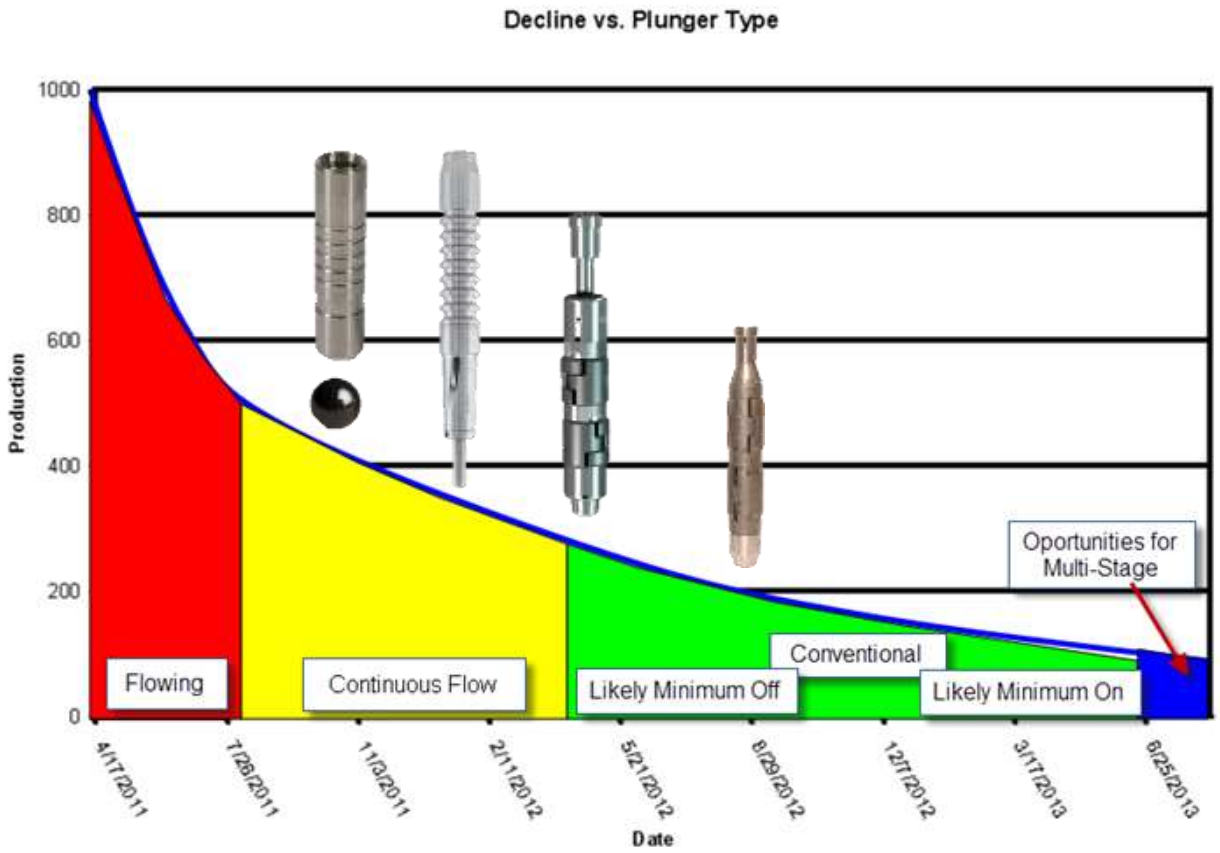


Figure 4 – Sample Decline vs. Plunger Type Graph
(Dependent upon velocity available through the tubing string)

Select plunger based on:

- Life stage of well
- H_2S, sand, paraffin, scale
- Gas to Liquid Ratio
- Required CP build time

7. Optimize Production

Continuous Flow

Fall Time Options 1

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

After Flow 4

If afterflow is desired, consider an auto-catcher.

- Operator initiates plunger fall stage.
- Can ensure liquid in tubing.
- Reduces backpressure.
- May reduce plunger wear.

CP Build 2

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

Rise Time 3

Avoid unsafe surface plunger velocities! KE = ½ mv²
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

EXAMPLE

- 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

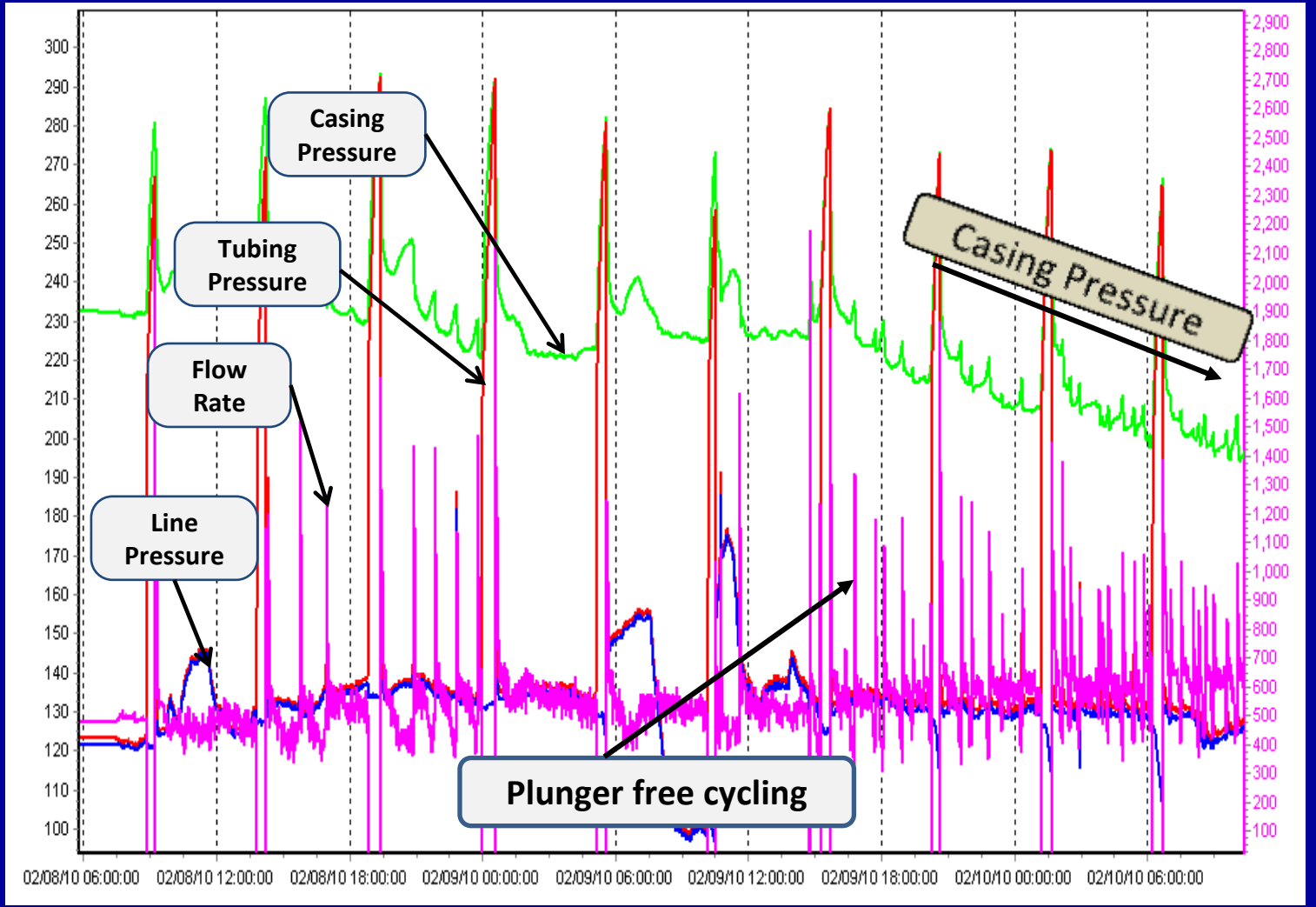
7. Optimize Production

Continuous Flow

Monitor on every cycle

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

After flow time



7. Optimize Production

Conventional Plunger

Fall Time 1

- 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!**

CP Build 2

- 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

Rise Time 3

- Avoid unsafe plunger velocities!
- KE = ½ mv^2
- Optimize production.
- Don't tear anything up!
- "No arrival" - 250 to 400 fpm.

After Flow 4

- Same volume of liquid in tubing on every cycle
- At start-up, no afteflow 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**

Avoid unsafe plunger velocity on first few runs (Know CP req'd)

OR

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

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**

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

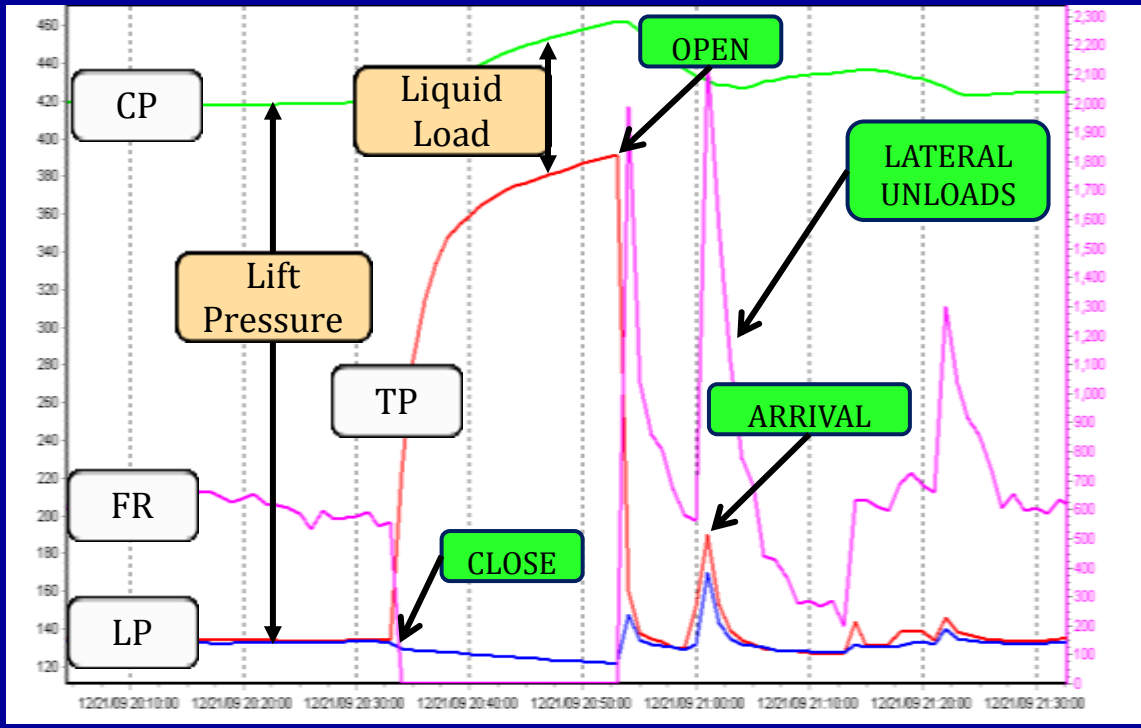
Slow run wihtout afterflow
- Add lift pressure

8. 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

8. Troubleshoot

On Site Observation

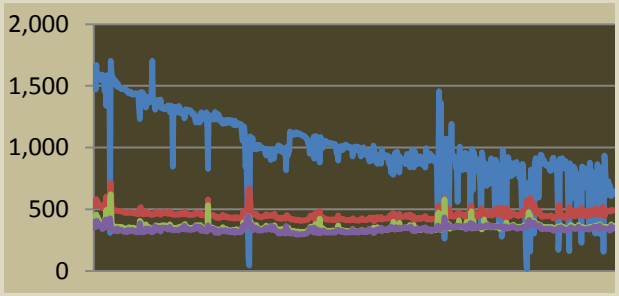
- Plunger impact velocity at surface
- Did plunger arrive
- Plunger inspection
- Plunger stuck in lubricator

Echometer

Smart Plunger

Trend Charts

Casing
Tubing
Line
Flow Rate



Cycle History

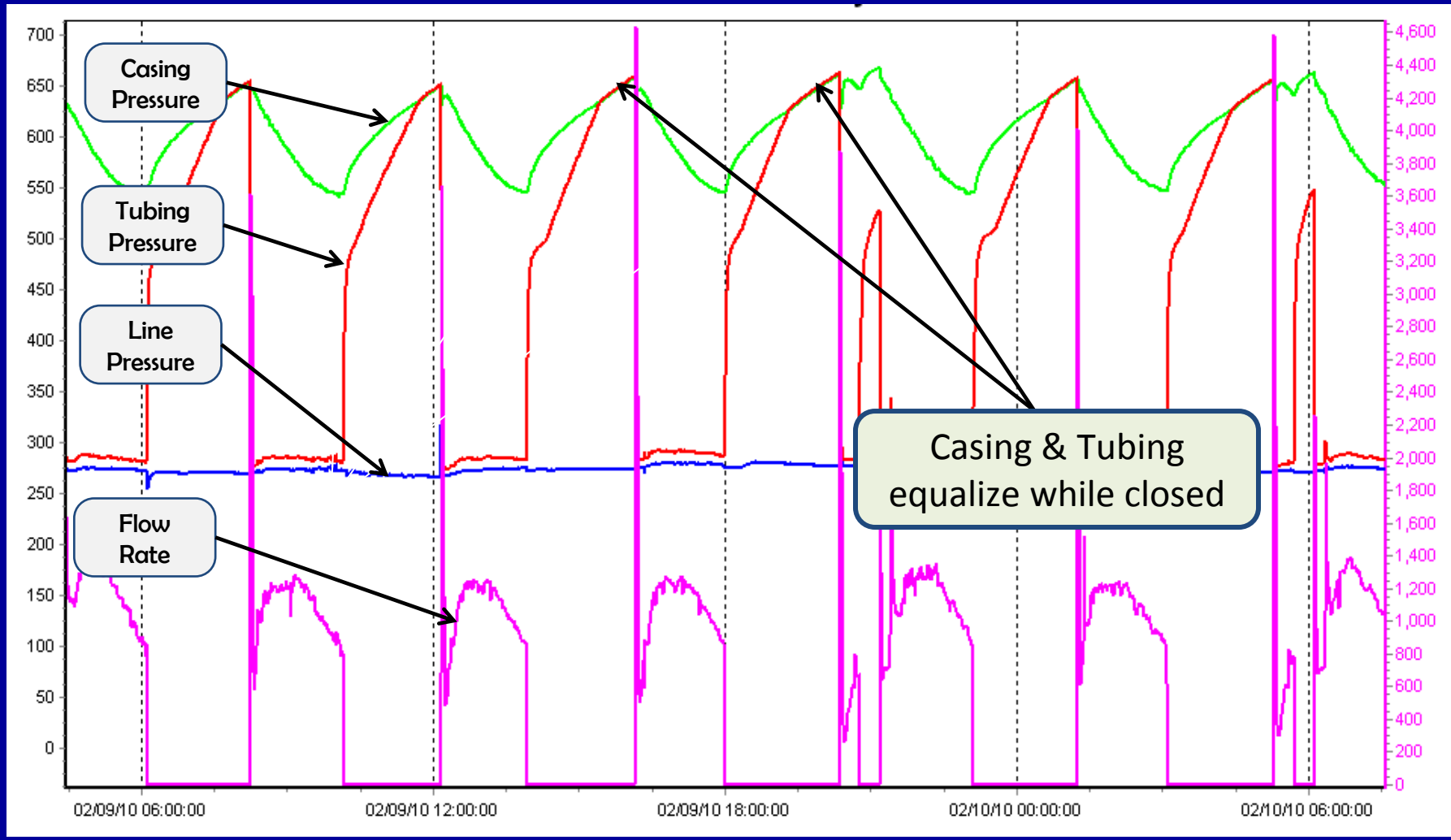
Downhole Camera

www.evcam.com

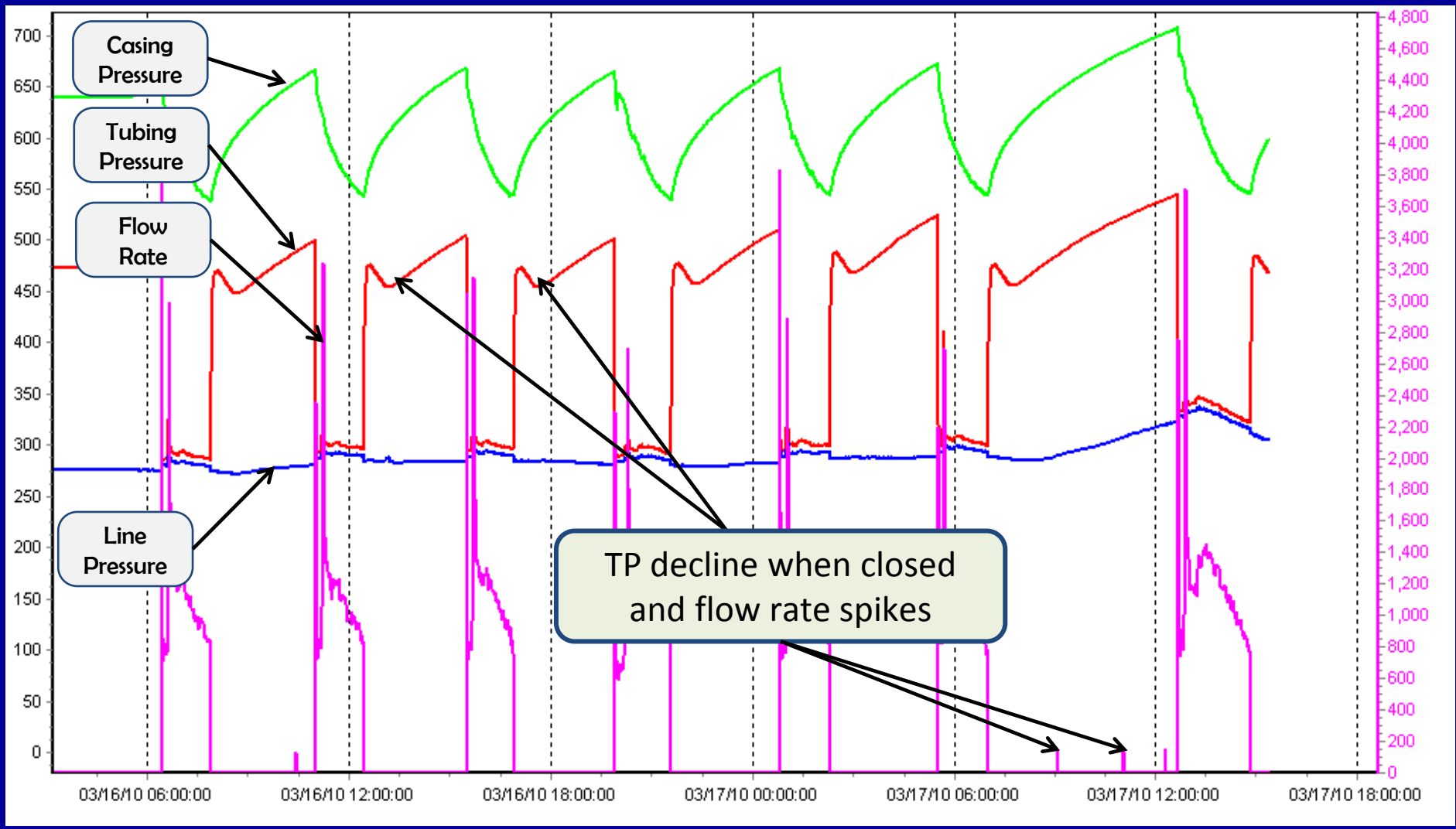
Analysis Software

- ABB
- T-Ram Report Card

8. Troubleshoot



8. Troubleshoot



9. Preventative Maintenance

Costs of Down Time

- Time to detect problem
- Time to diagnose problem
- Time to prescribe solution
- Time to acquire parts / services
- Time to implement
- Time to restart well
- Time to prevent reoccurrence

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

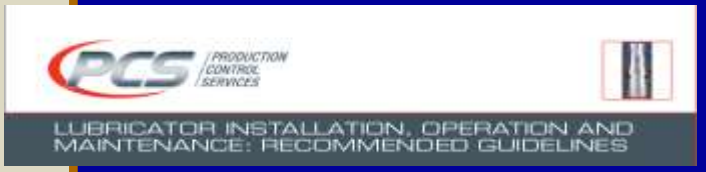
9. Preventative Maintenance

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.

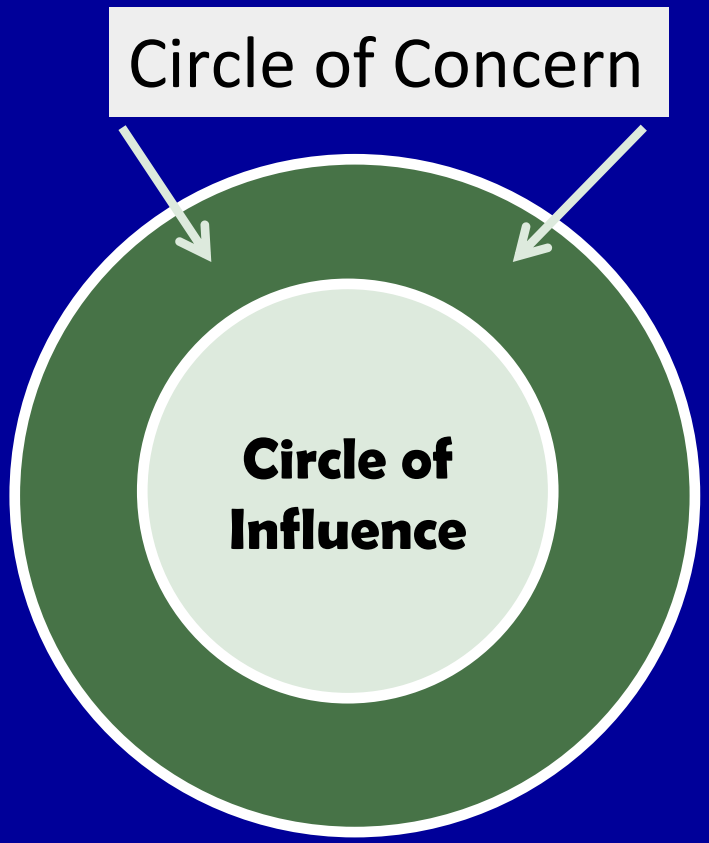
Desired Condition

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



~ Sharpen the Saw ~

Be Proactive

Begin with the End in Mind

Put First Things First

Think Win / Win

Seek first to Understand then to be Understood

Synergize

"The Seven Habits of Highly Effective People"
By Stephen Covey

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?

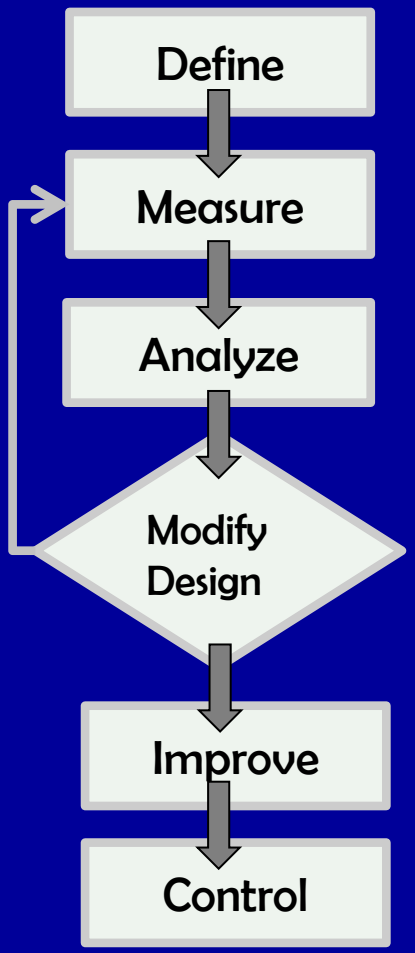
CHECK – Follow-up

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?

"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

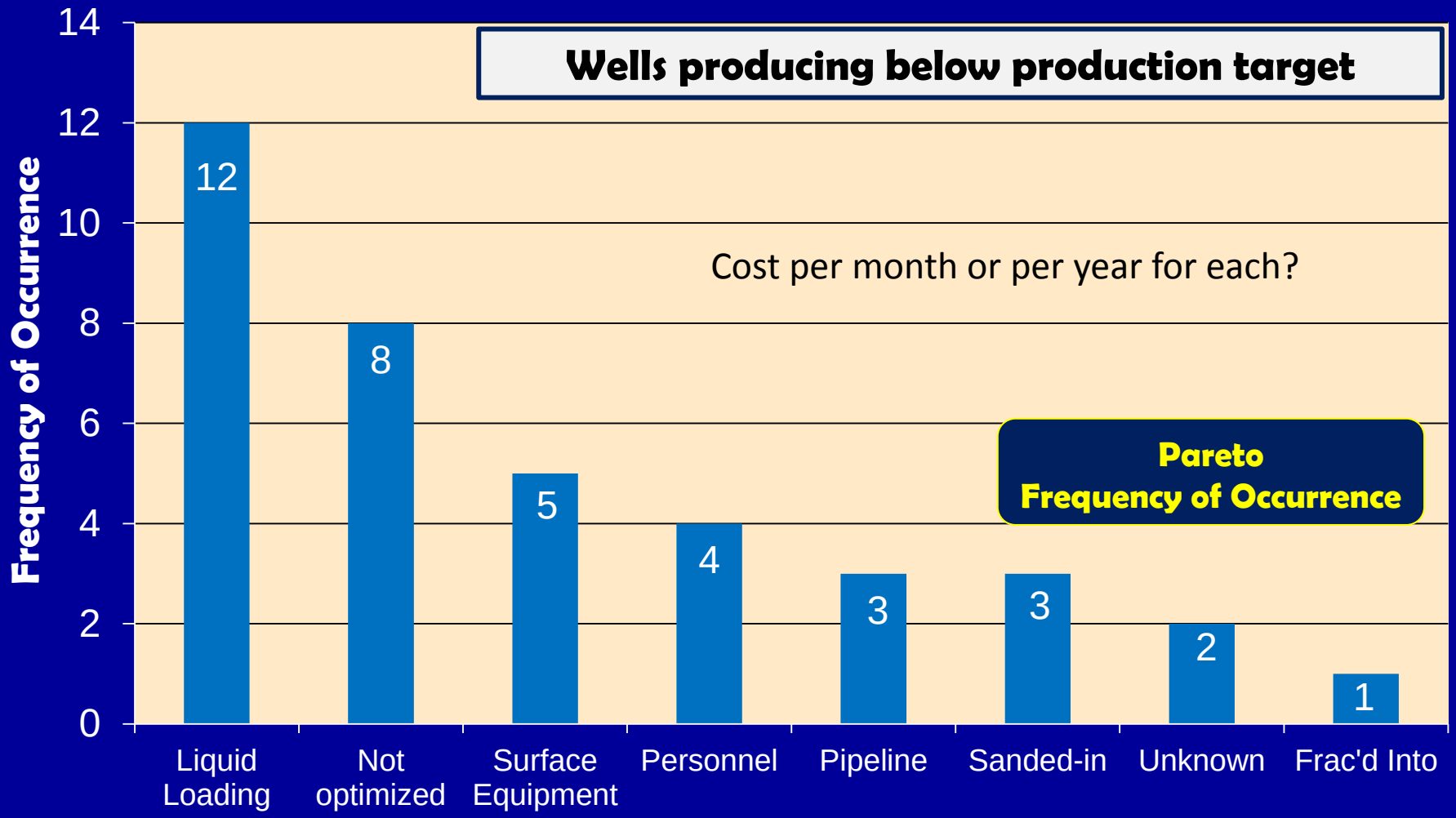
The process performance by addressing and eliminating root causes

The improved process and future process performance

"The Certified Quality Engineer Handbook, Third Edition"

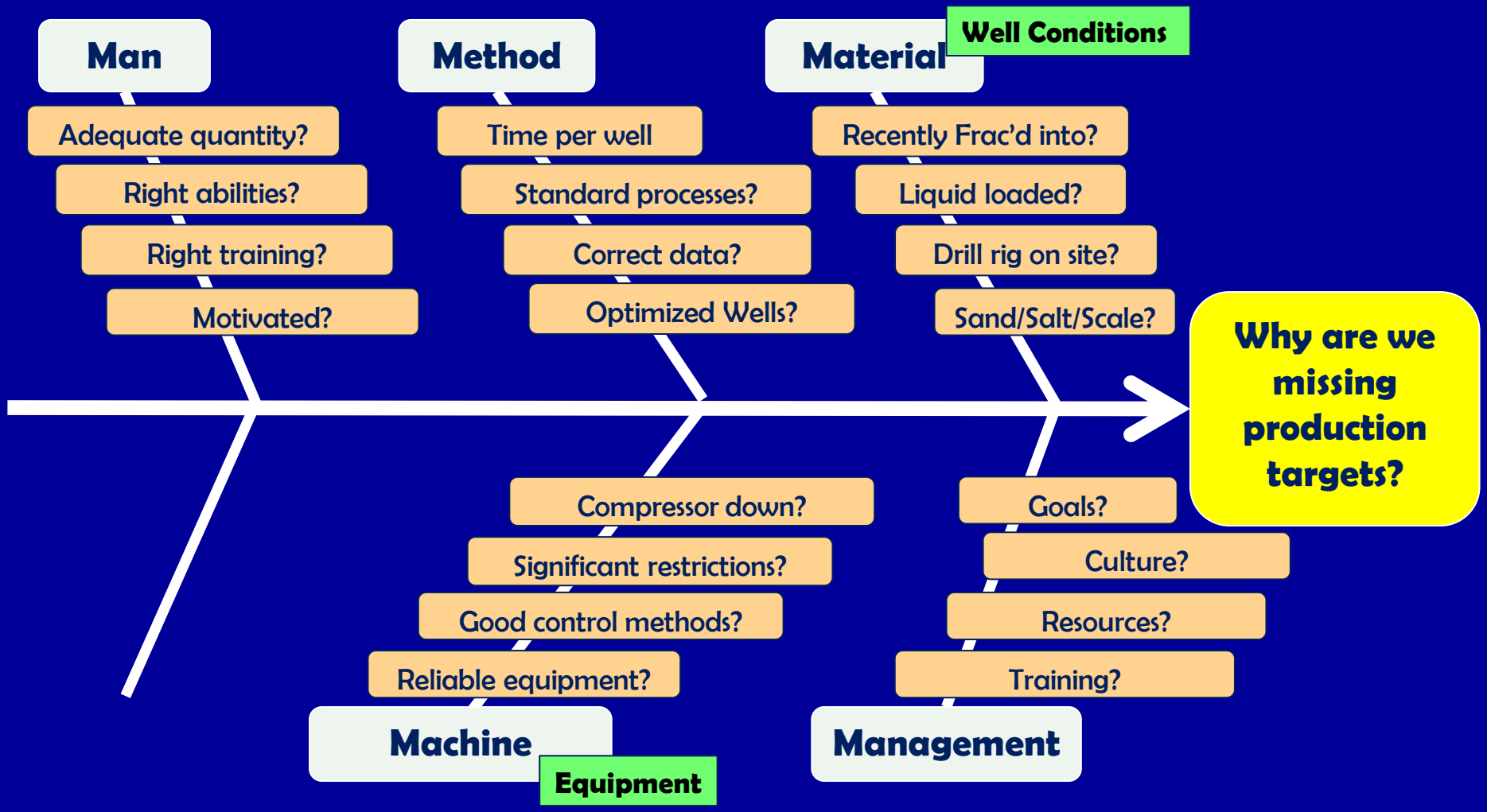
10. Continuous Improvement

Pareto Diagram



10. Continuous Improvement

Fishbone Diagram



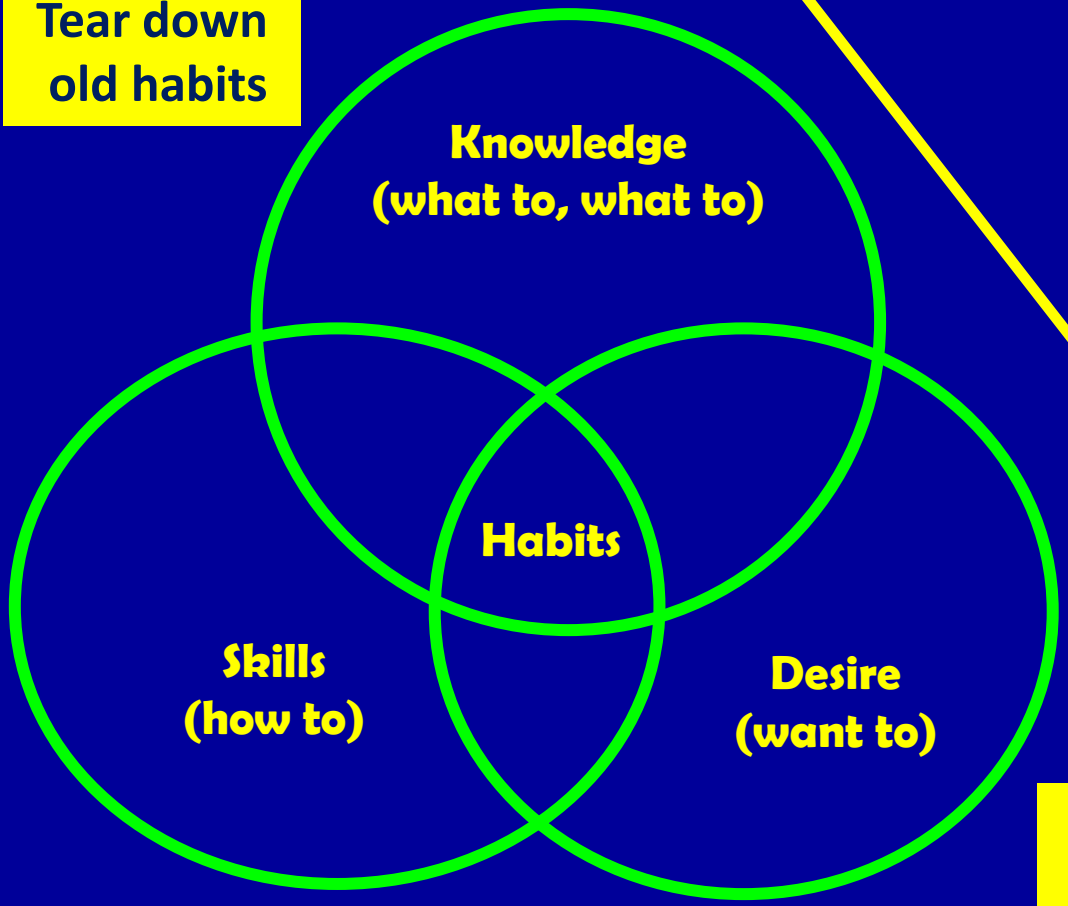
10. Continuous Improvement

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

Tear down old habits



"The Seven Habits of Highly Effective People"
By Stephen Covey

What's the Process?

How can we tell it's working?

What are we doing to improve it?

Build new habits

10. Continuous Improvement

SHALE TEC

PLUNGER LIFT IMPROVEMENT PLAN

Goal	Activities	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Goal 1	Activity 1												
	Activity 2				Plan								
	Activity 3				Complete								
	Activity 4				Late								
	Activity 5												
Goal 2	Activity 1												
	Activity 2												
Goal 3	Activity 3												
	Activity 4												
	Activity 5												
Goal 4	Activity 1												
	Activity 2												
	Activity 3												
	Activity 4												
	Activity 5												
Goal 5	Activity 1												
	Activity 2												
	Activity 3												
	Activity 4												
	Activity 5												

What are your plunger lift goals for 2016 ?

10 Steps!

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 !

Final Comments

"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

Final Comments

"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

"The Toyota Way" by Jeffery K. Liker

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.

"The Toyota Way" by Jeffery K. Liker

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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