Artificial Lift R&D Council

Whatever Happened to Pump Stroke Optimization?

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ENCLINE

History of Pump Stroke Optimization

- Concept and data from two pilot wells first presented to industry at ALRDC Sucker Rod Pumping Workshop in September 2015
- Case Study of 20 Well Eagle Ford pilot presented at Southwestern Petroleum Short Course in April 2016, and in peer reviewed SPE Paper 181228-PA
- Four well Bakken pilot presented in September 2016 at ALRDC Sucker Rod Pumping Workshop

What is Pump Stroke Optimization?

- Part 1: For wells with excess pump capacity, preferentially slowing pumping speed on downstroke
  - Results in less slippage and better pump fillage
  - Referred to as **Slow Downstroke Mode** or SDSM
- Part 2: Address the problem of wave and slug flow in horizontal wells that mislead RPC's into cycling between max and min speeds
  - Results in poor pump fillage and rod buckling
  - Requires setting max pumping speed near average

PSO Part 1: "Slow Downstroke Mode"

Two ways to run at 3 SPM

- Old School Method for 3 SPM
  - Total stroke duration is 20 seconds
  - Upstroke duration is 10 seconds, as is downstroke
- Slow Downstroke Mode (SDSM)
  - 6 SPM on upstroke, a 5 second duration
  - 2 SPM on downstroke, a 15 second duration
  - Total stroke duration still 20 seconds but upstroke duration only 25% of each stroke, not 50% (5/20 instead of 10/20)

SDSM Example: Pumping at 3 SPM

Use of the Pump Slippage Equation to Design Pump Clearances (Rowlan, McCoy, Lea)

Pump Slippage

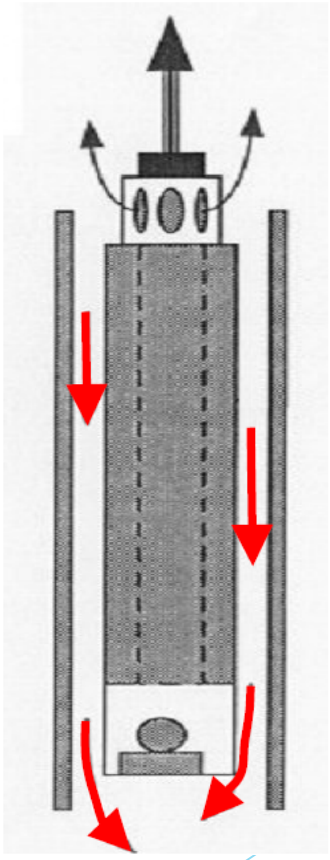
1) Fluid that leaks back into pump between the Plunger OD and the Barrel ID
2) Leaks into the pump chamber between the standing valve and traveling valve
3) When traveling ball is on Seat.

Pump Efficiency =
BPD Tank / BPD Pump

Slippage % =
Slippage BPD / BPD Pump

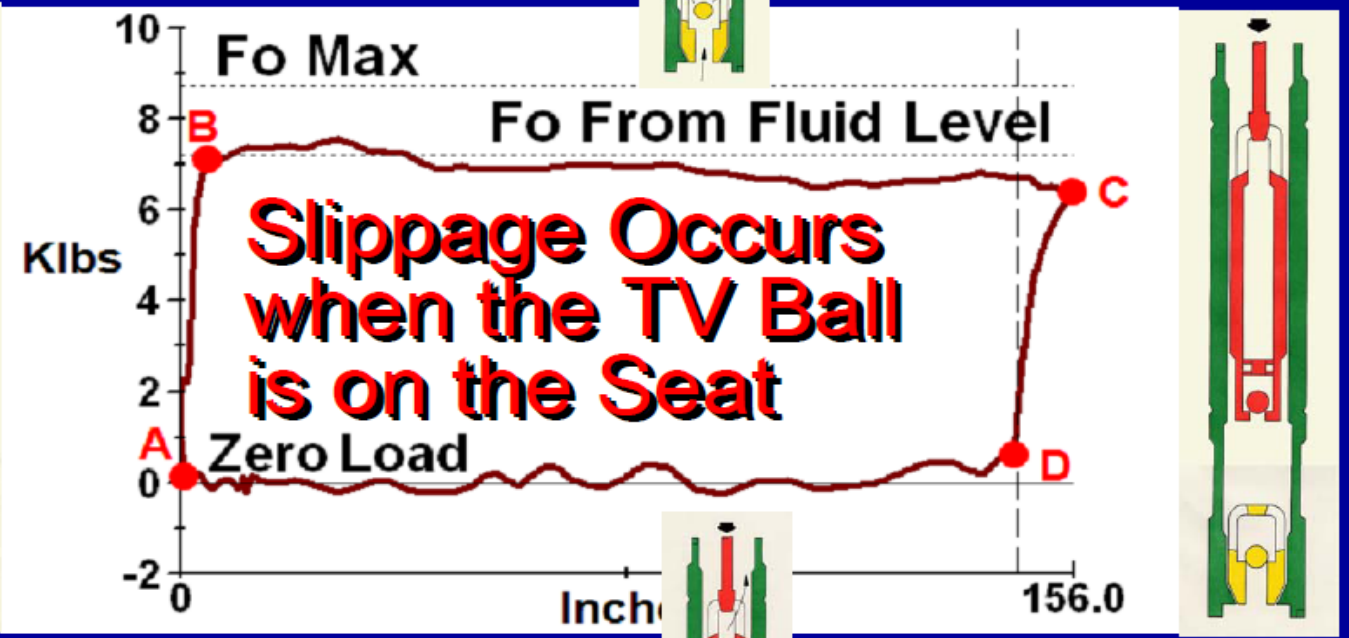
Sept. 25 - 28, 2012 2012 Sucker Rod Pumping Workshop

BPD Tank = BPD Pump - Slippage



1) Point A to B pressure acting on closed SV gradually transferred from tubing at point A to be fully carried by the Closed TV at point B.

2. Point B to C, plunger carries full differential pressure across Closed TV



4) Point D to A, TV open as fluid in the pump is displaced through the traveling valve on the down stroke

3) Point C to D pressure across closed TV gradually transferred from rods to be fully carried by the Closed SV at point D.

Observations about Pump Slippage

- Pump Slippage during the Upstroke reduces system efficiency
  - Since standing valve is open, slippage replaces fluid that would normally enter pump
  - Less Time on Upstroke = Less pump slippage
- Pump slippage during the Downstroke does not impact system efficiency, but improves fillage
  - Since standing valve closed during downstroke, new well fluids not entering the pump anyway
  - Slippage fluids fill pump, opening travelling valve sooner
    - Pump fillage increased, reduced rod buckling

From SPE 181228: Pump Slippage Equation Correction

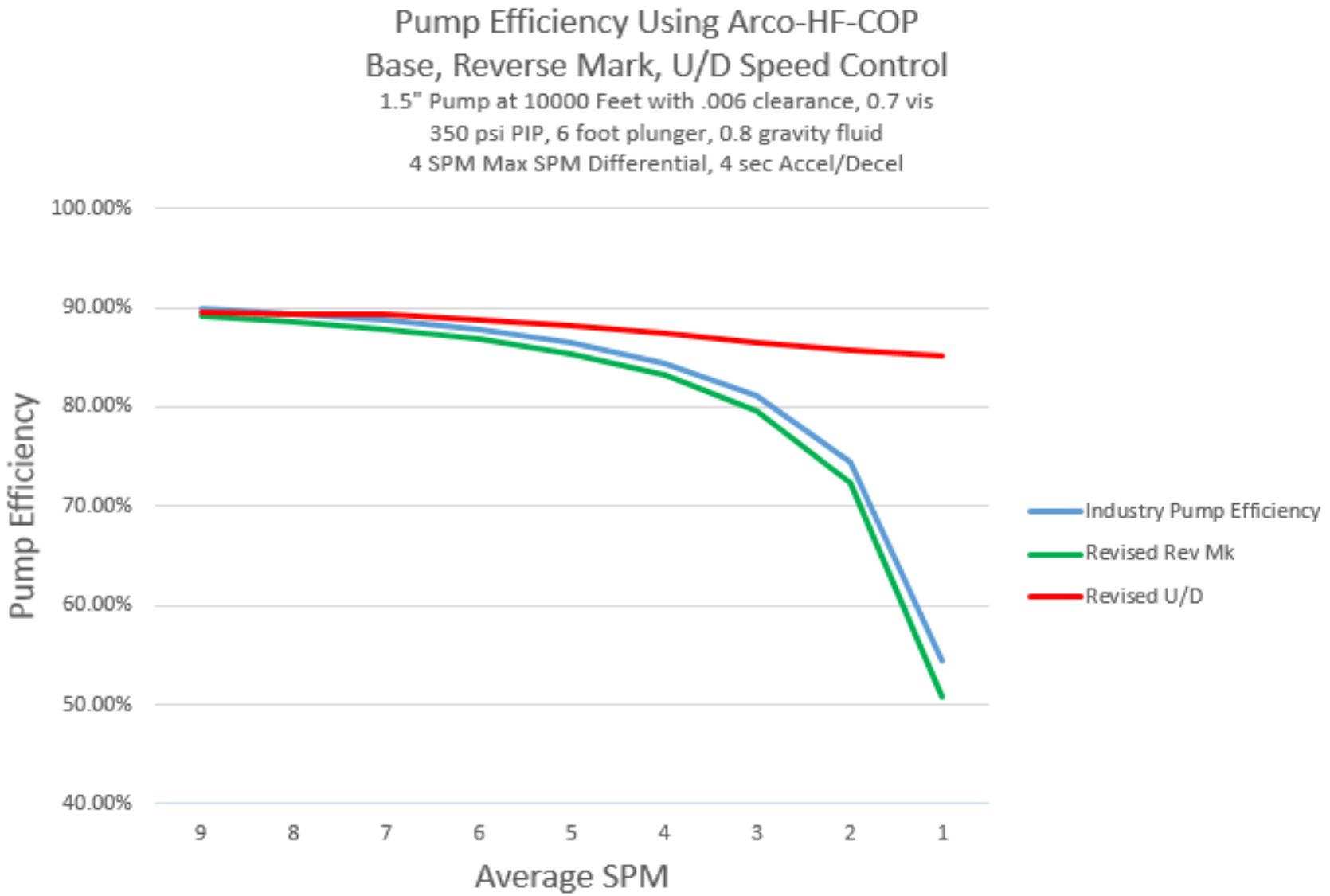
- 2001 Thesis by Chambliss submitted to Texas Tech: “Plunger Leakage and Viscous Drag for Beam Pump Systems”
  - Pump slippage greater for alternative geometry pumping units that had unequal upstroke and downstroke travel time

$$B_{Adjusted} = \frac{Degrees_{UP}}{180} B_{Calculated}$$

  - However, Chambliss did not consider variation in pumping speed induced travel time differences. A revised equation that considers both is presented:

$$B_{Adjusted} = (2 \times T_{Upstroke} \times B_{Calculated}) / (T_{Downstroke} + T_{Upstroke})$$

Patterson slippage formula modified for % Upstroke Duration



PSO Part Two: Setting Pumping Speeds

The result: Poor pump fillage.

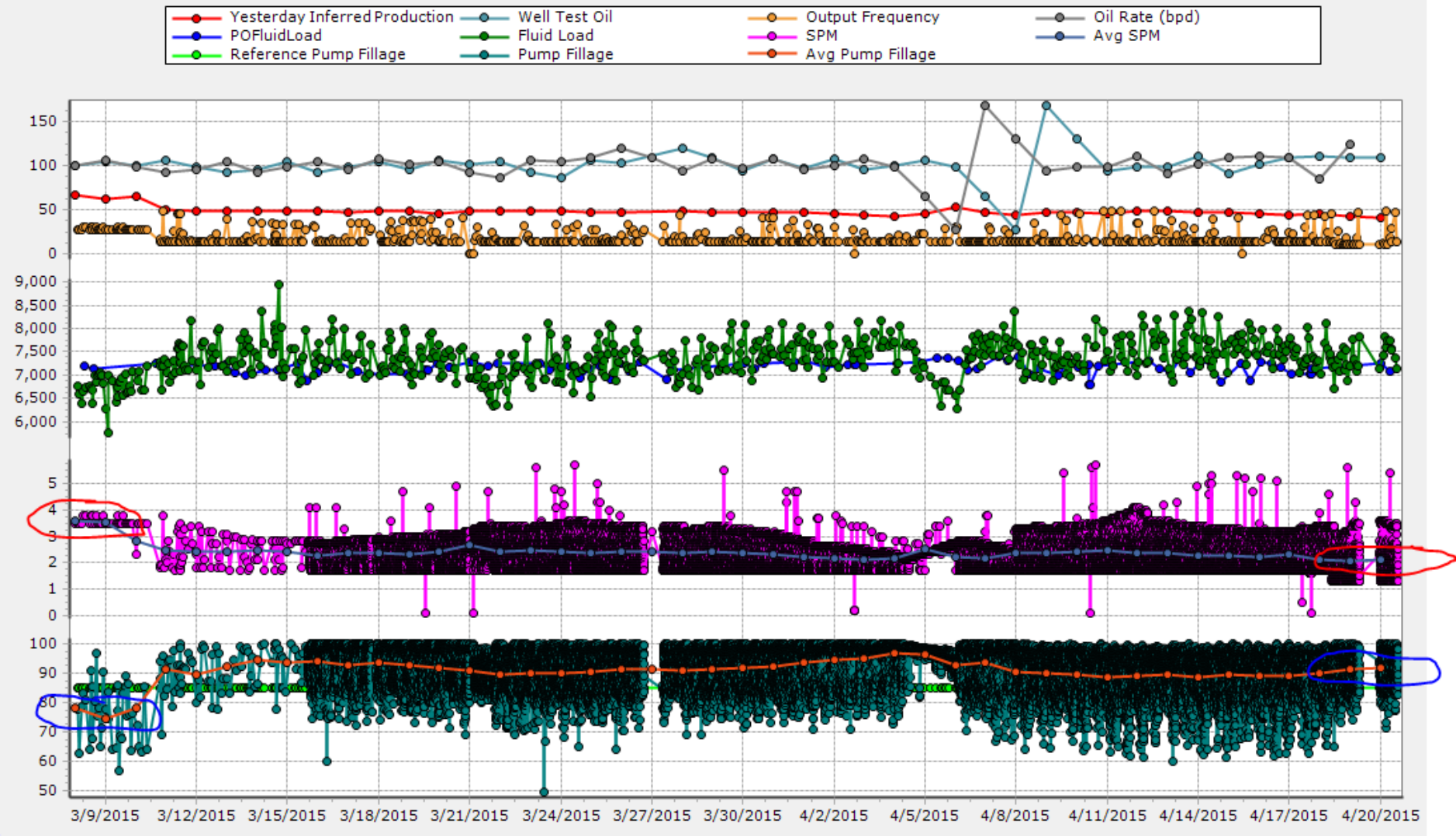
How do operators address poor pump fillage due to horizontal well slugging?

- By manually setting pumping speed
  - Limiting maximum pumping speed
  - Reducing the minimum pumping speed
- The current approach requires
  - Regular monitoring by personnel
  - Resetting pumping speeds as wells continue to deplete
- PSO Part 2 is autonomous setting of these speeds

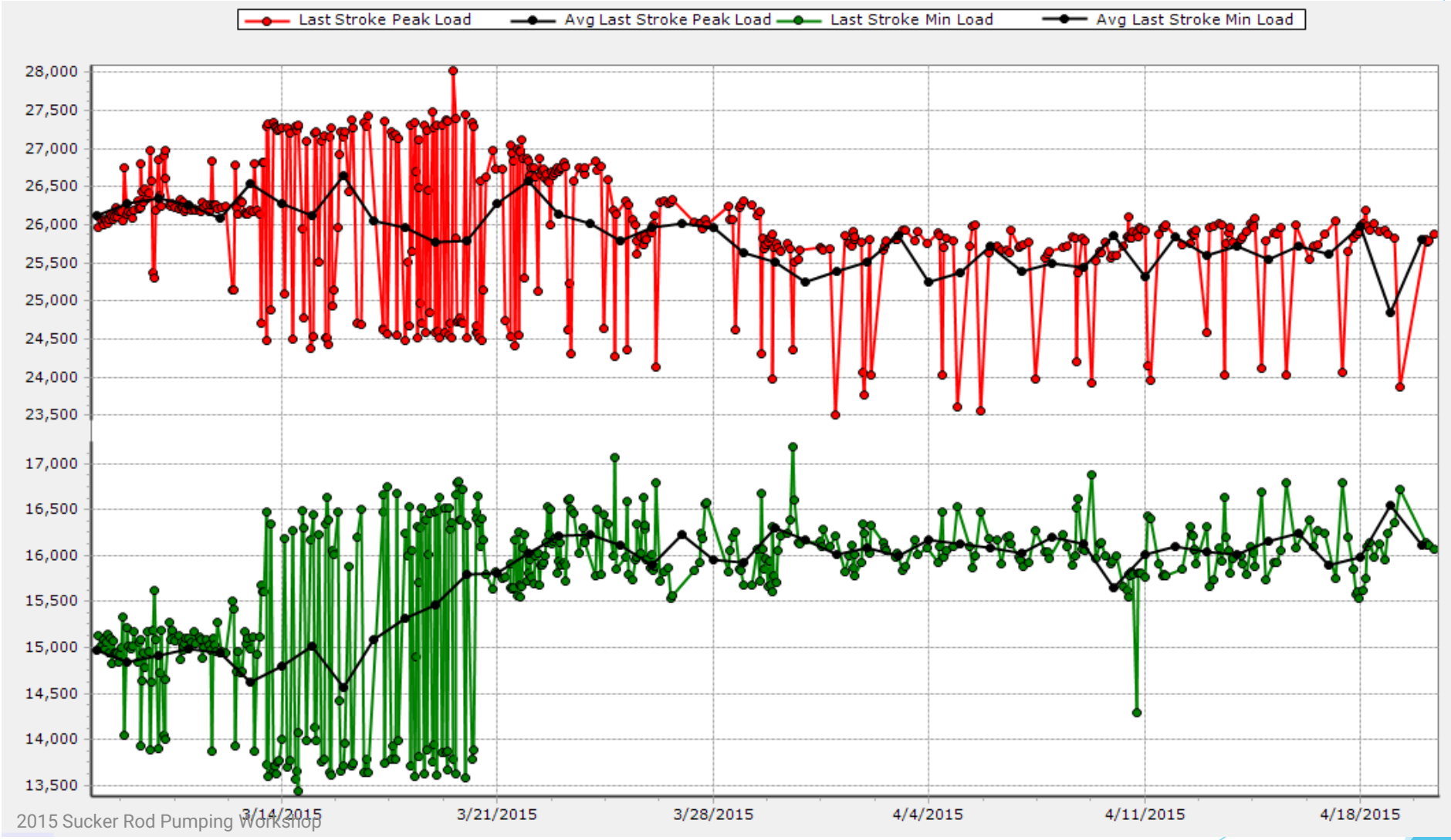
SDSM (PSO Part 1) decreases slippage and increases pump fillage, increasing efficiency

- Also more time for evolving gas to exit gas anchor
  - Less gas enters pump, more liquid
- Higher minimum rod loads due to slow downstroke/ less gas
  - Reduces buckling tendencies
  - Allows higher maximum rod loads
- **Has nothing to do with setting pumping speeds**
  - That is PSO Part 2

Well #1: 35% reduction in strokes per day, oil production not significantly affected



Well #1: Minimum load increased by 1000 pounds, maximum load same



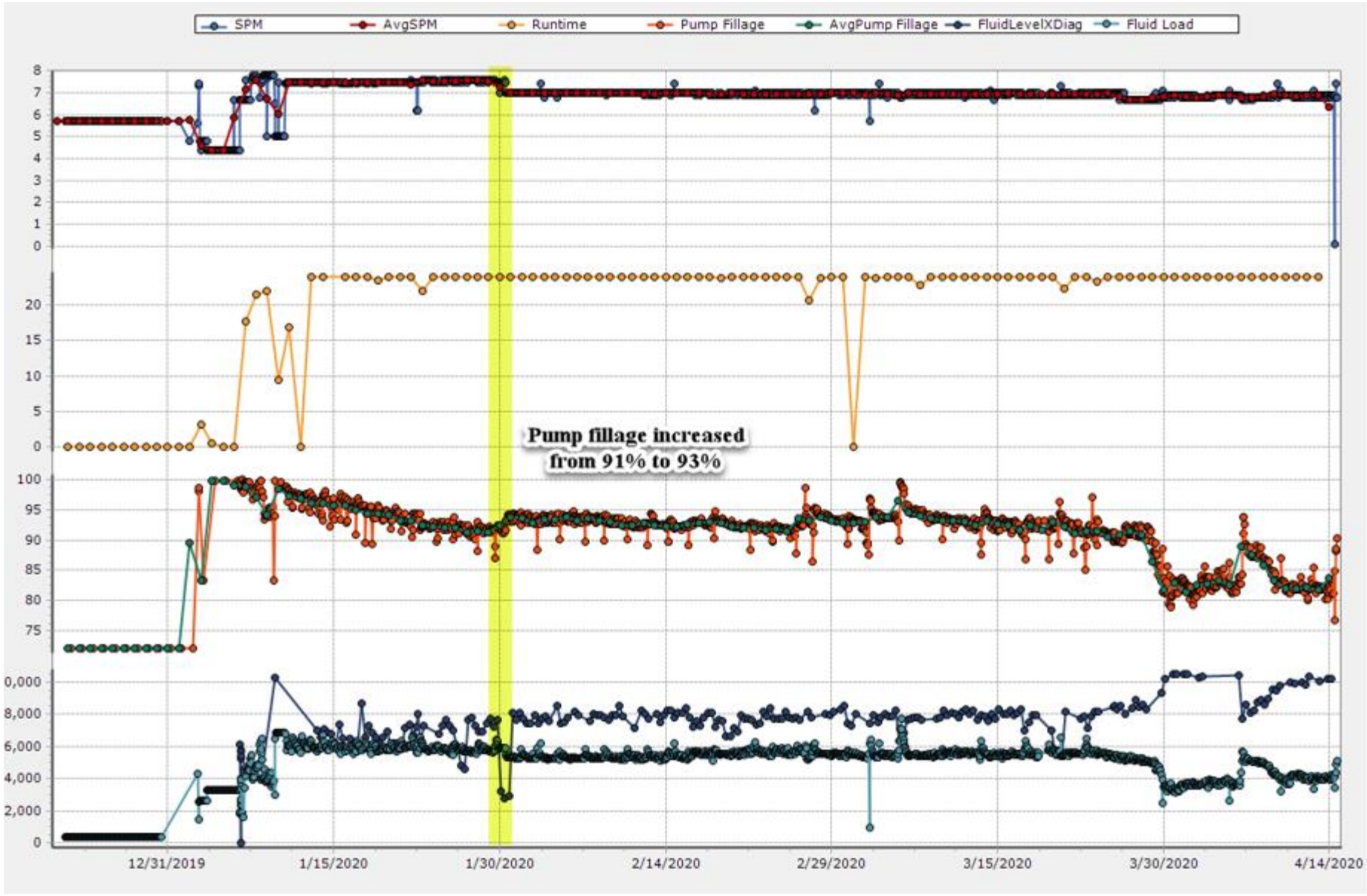
Why PSO Part 2 works

- PSO Part 2 does what you would do, create maximum working speed setpoints that are better aligned with the average production rate
- This prevents over-reacting to high pump fillages often seen at the beginning of a slug event
- Keeping the maximum pumping speed slightly higher than average pumping speed helps avoid low pump fillage events and rod buckling

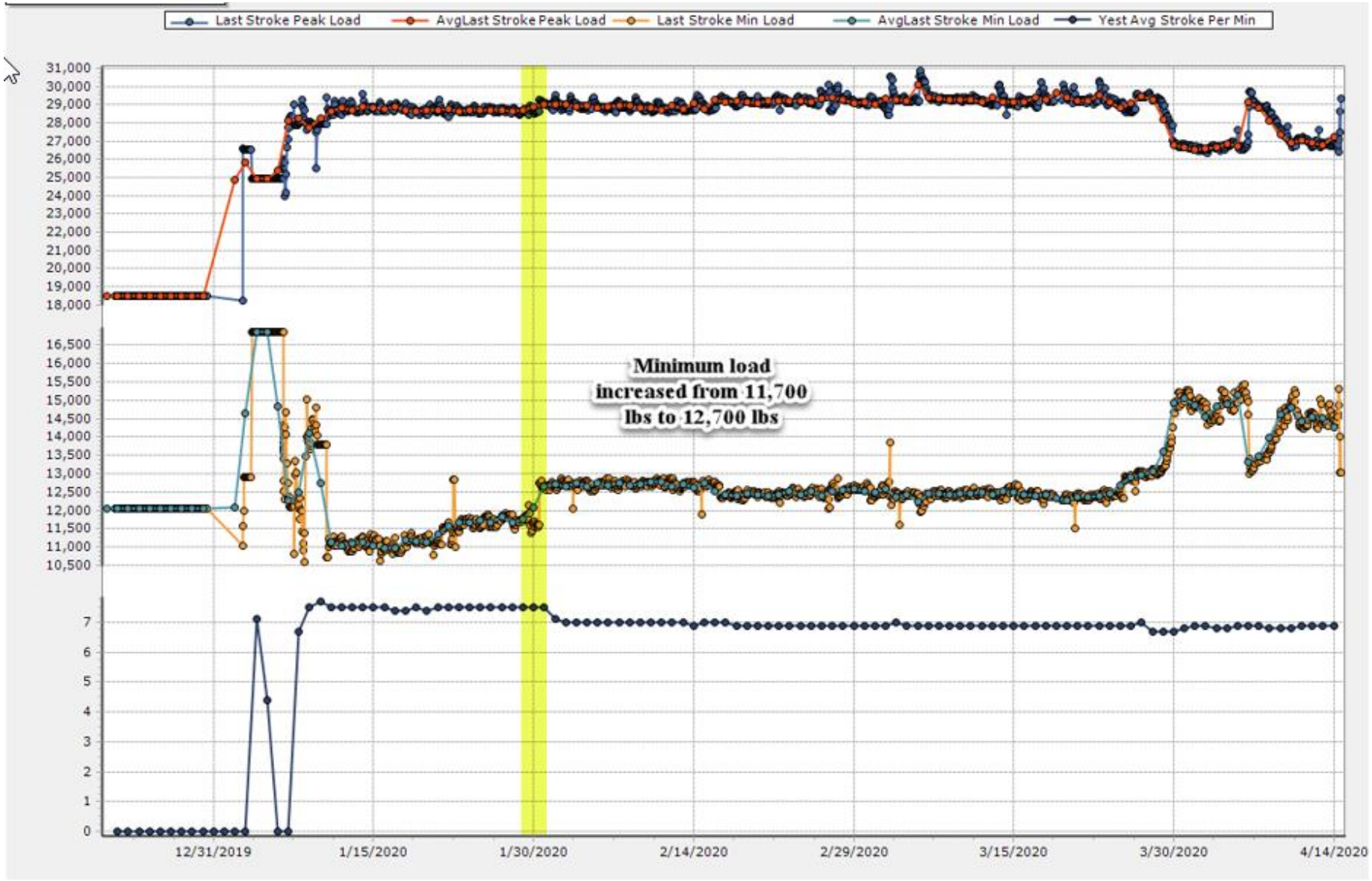
Some operators are using SDSM today

- Continental Resources using SDSM in Bakken
  - No hardware modifications needed
  - Using Scada to load SDSM settings into RPC's
- EOG Resources using SDSM in Eagle Ford
  - Working towards applying PSO Part 2 via Data Analytics

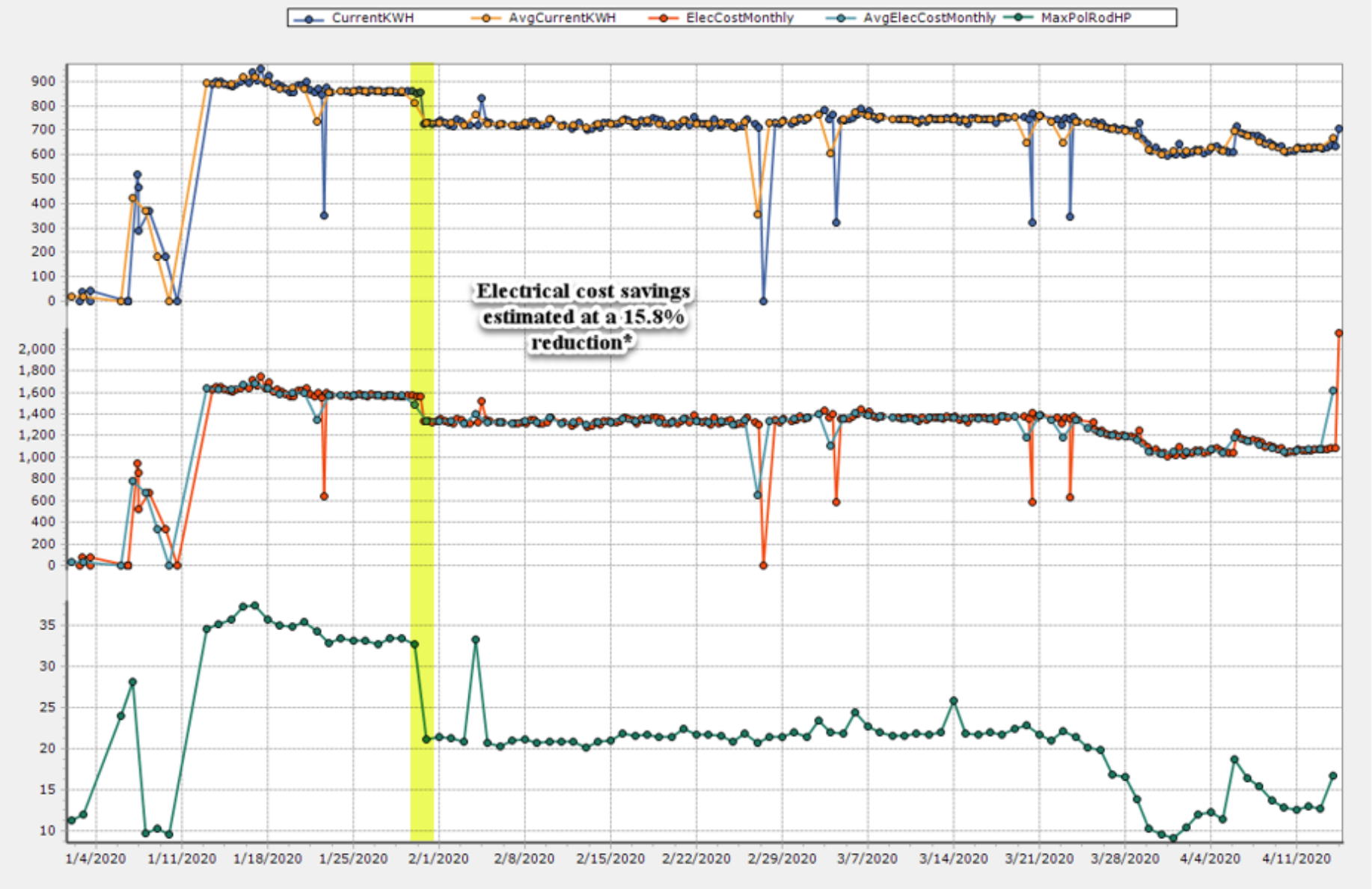
Continental Resources SDSM Results



Continental Resources SDSM Results



Continental Resources SDSM Results



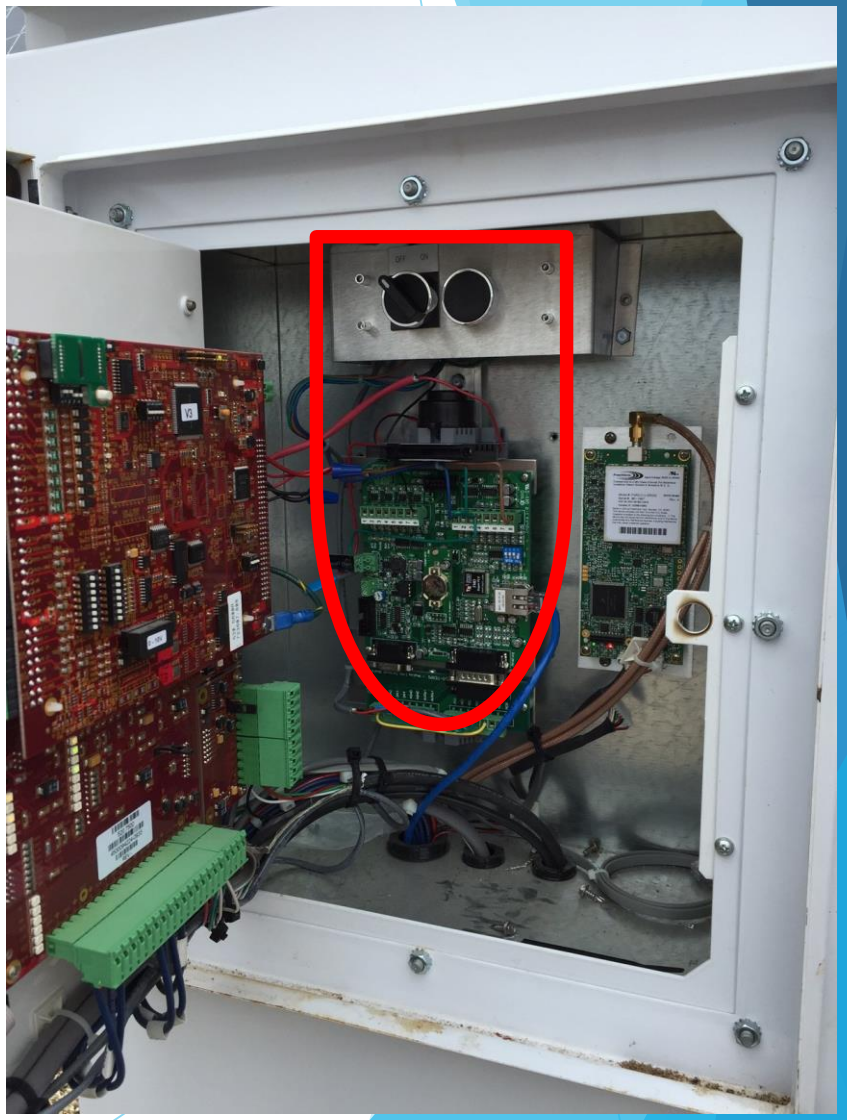
Continental Resources SDSM Results

Factors Working Against PSO Adoption

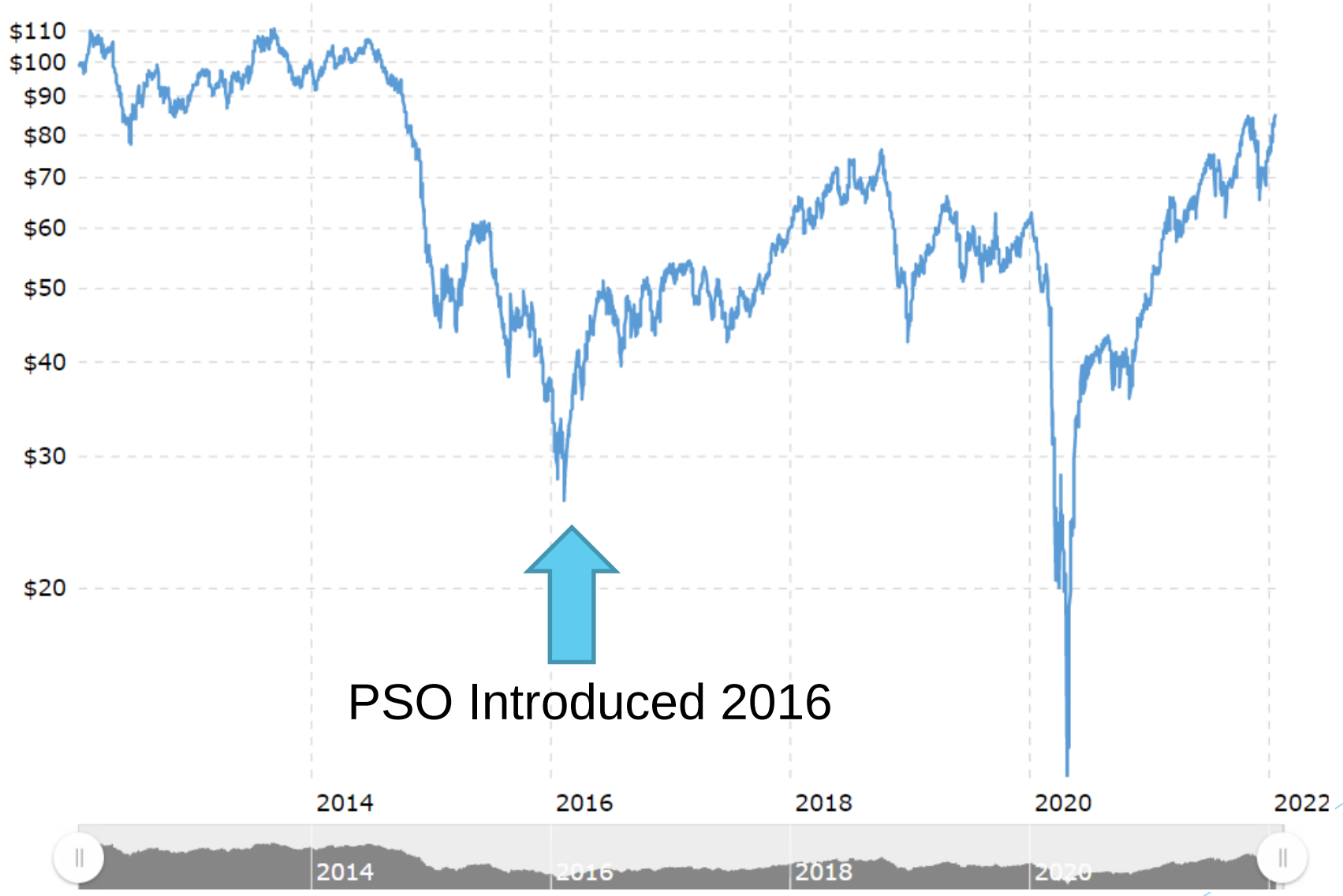
- SDSM / PSO doesn't increase production
  - Makes same production with less strokes (less wear)
  - Lower power consumption documented
  - Neither were home run reasons
- Could not prove that less strokes and higher minimum rod loads would result in less failures
  - No long-term failure studies performed
- Pumps with leaking standing valves lost production
  - 5% of pilot test wells saw this

Factors Working Against PSO Adoption

- Is major change in operation
  - Simulation programs can't handle it
  - Unrealized fears about equipment failures
  - Required PLC to be inserted in RPC cabinet
- RPC companies felt threatened
  - Wasn't invented by them
  - Hardware could not perform PSO Part 2
  - Encline had applied for a patent
  - Result: Warranty voided if operator tried
- Oil price dropped and spending stopped



Factors Working Against PSO Adoption



Factors Working Against PSO Adoption

- Gas Lift became popular for horizontals
  - Less industry interest in rod pumping
  - Introduction of HPGL in 2016 shifted Encline resources from PSO due to idea importance
- Slow Downstroke Mode and PSO are not plug and play
  - SDSM requires routine parameter review
  - PSO sets all parameters, but requires periodic algorithm evaluation
  - Neither simple enough for busy operator personnel
  - Opportunities for Machine Learning?

The Future?

- Encline dropped all patent efforts years ago when it became clear that adoption would be difficult
- RPC manufacturers are free to incorporate PSO
- Operators are free to incorporate PSO into Data Analytics / Machine Learning efforts
  - Let the cloud tell the RPC upstroke and downstroke pumping speeds

Acknowledgements/Thanks & Questions

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