Artificial Lift R&D Council

Whatever Happened to Pump Stroke Optimization?

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ENCLINE

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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

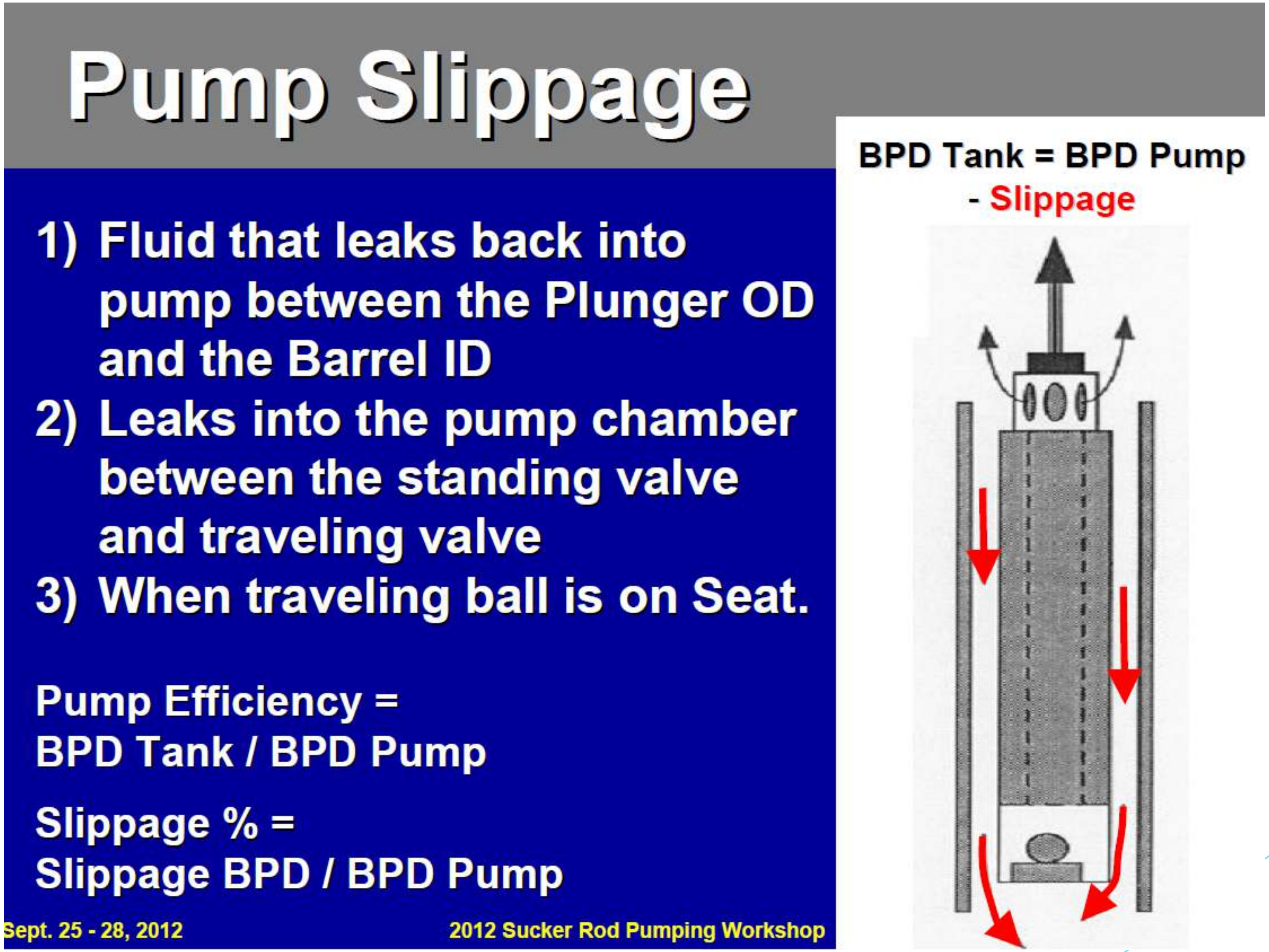
PSO Part 1: “Slow Downstroke Mode”

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)

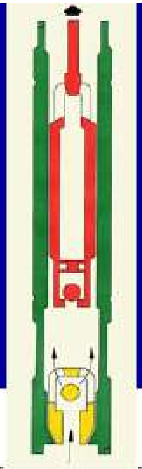
SDSM Example: Pumping at 3 SPM

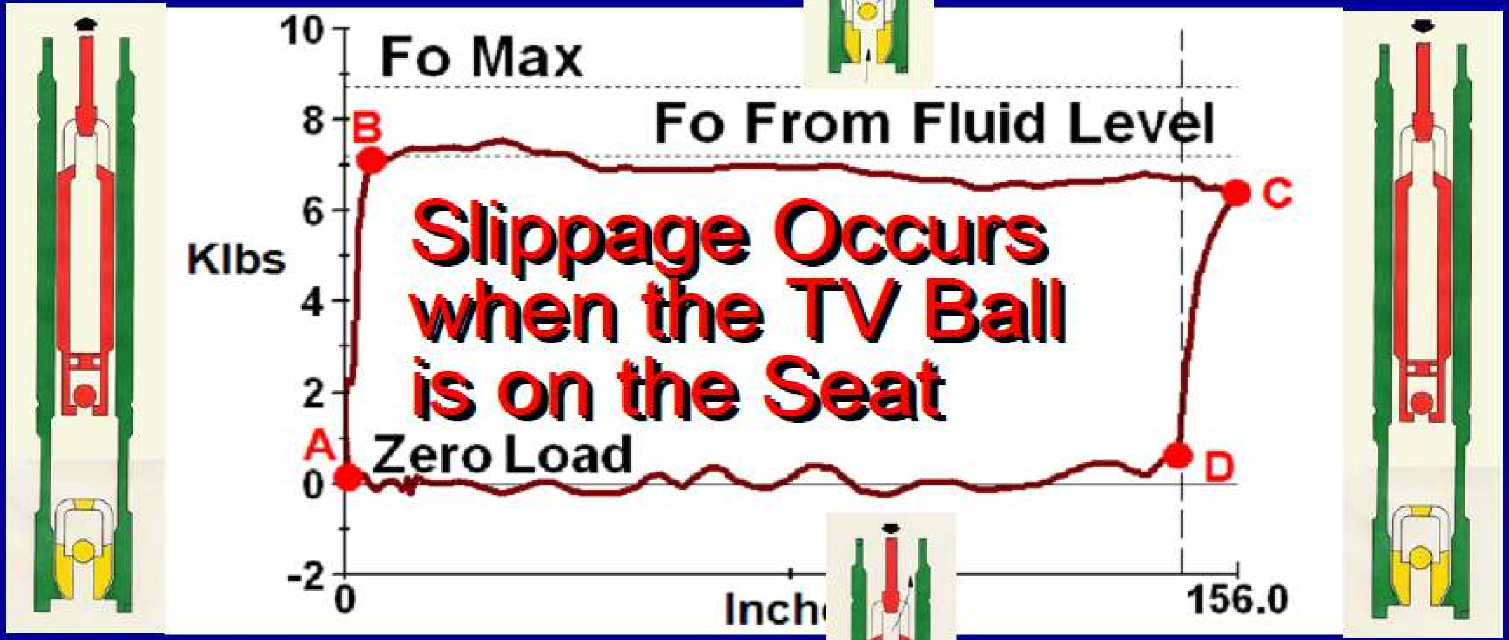
Use of the Pump Slippage Equation to Design Pump Clearances (Rowlan, McCoy, Lea)

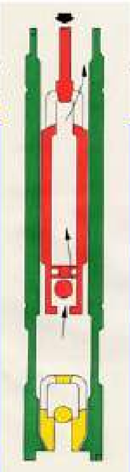


1) **Point A to B** pressure acting on closed SV gradually transferred from tubing at point A to be fully carried by the Closed TV at point B.

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

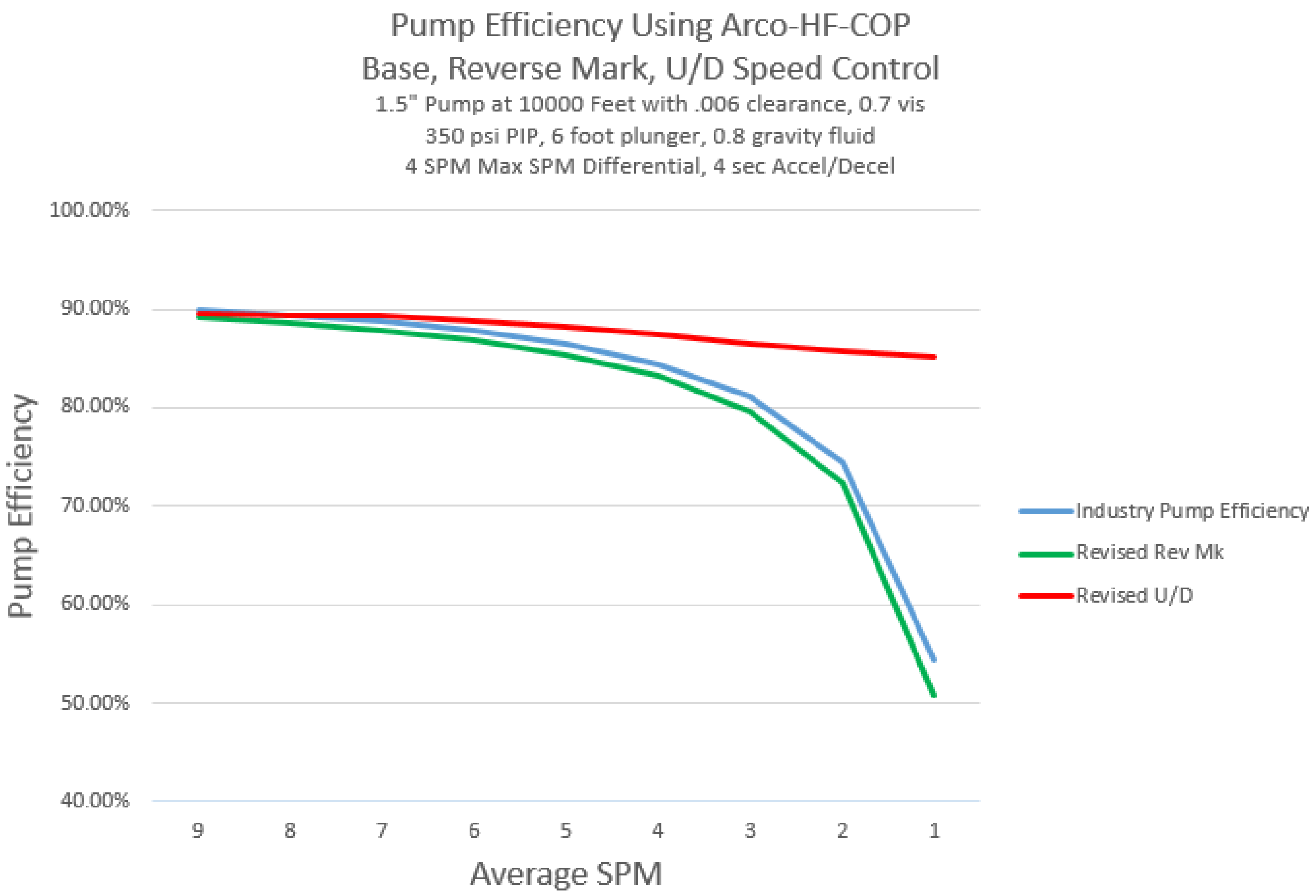
- 2001 Thesis by Chambliss submitted to Texas Tech: “Plunger Leakage and Viscous Drag for Beam Pump Systems”
  - Pump slippage greater for alternative geometry pumping units that had unequal upstroke and downstroke travel time

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

  - 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

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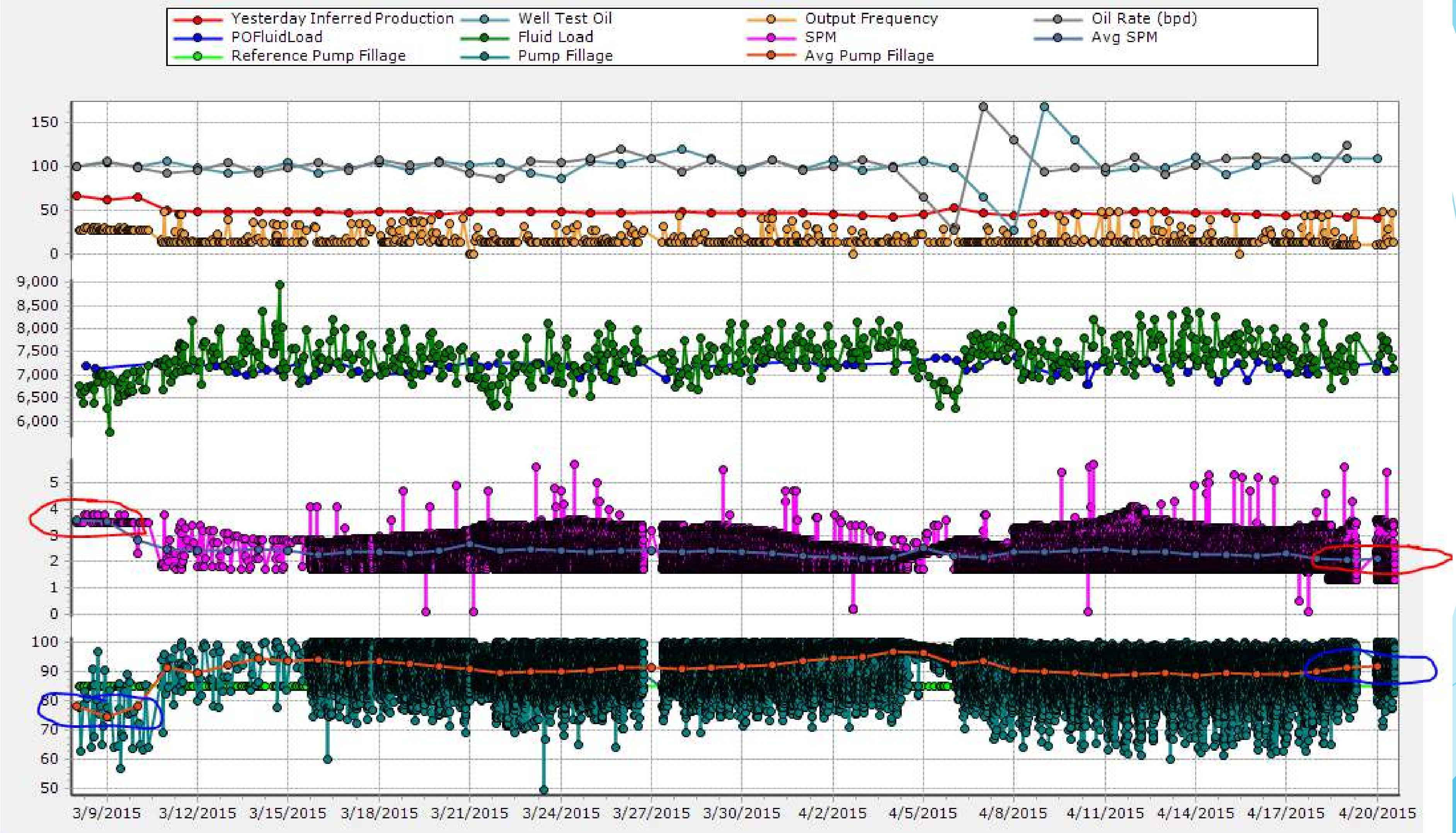

Well #1: Minimum load increased by 1000 pounds, maximum load same

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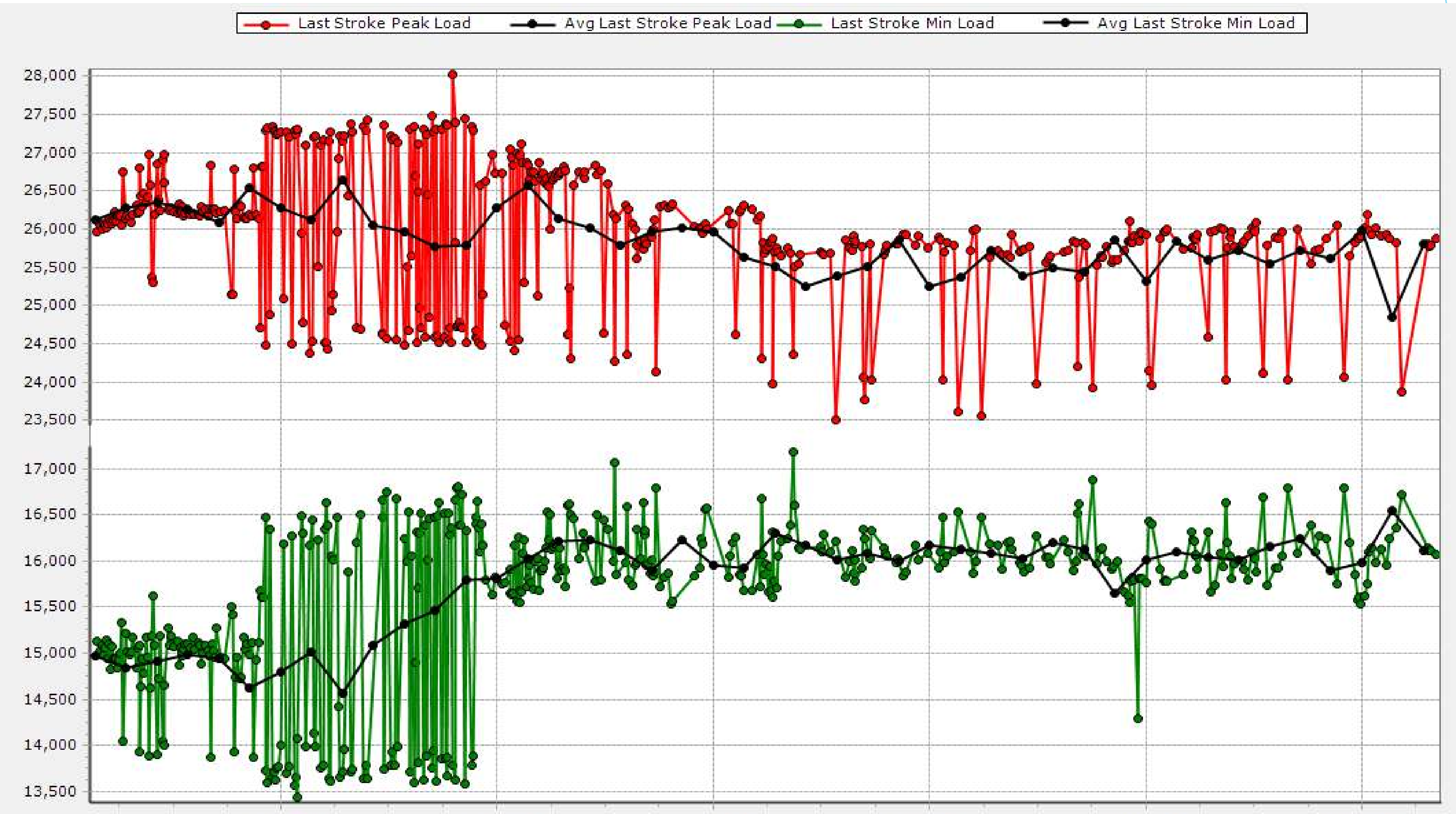


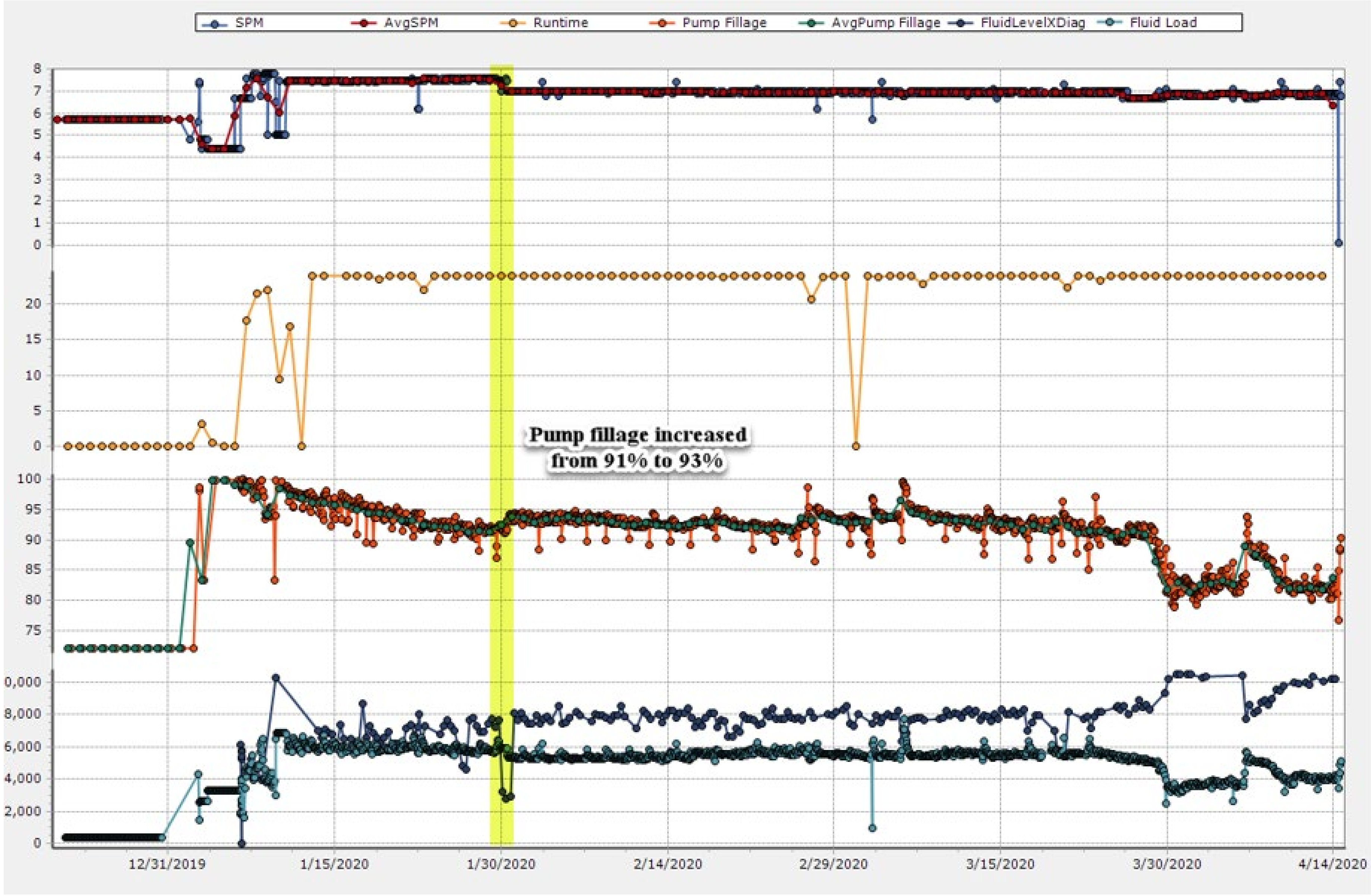
Why PSO Part 2 works

- 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

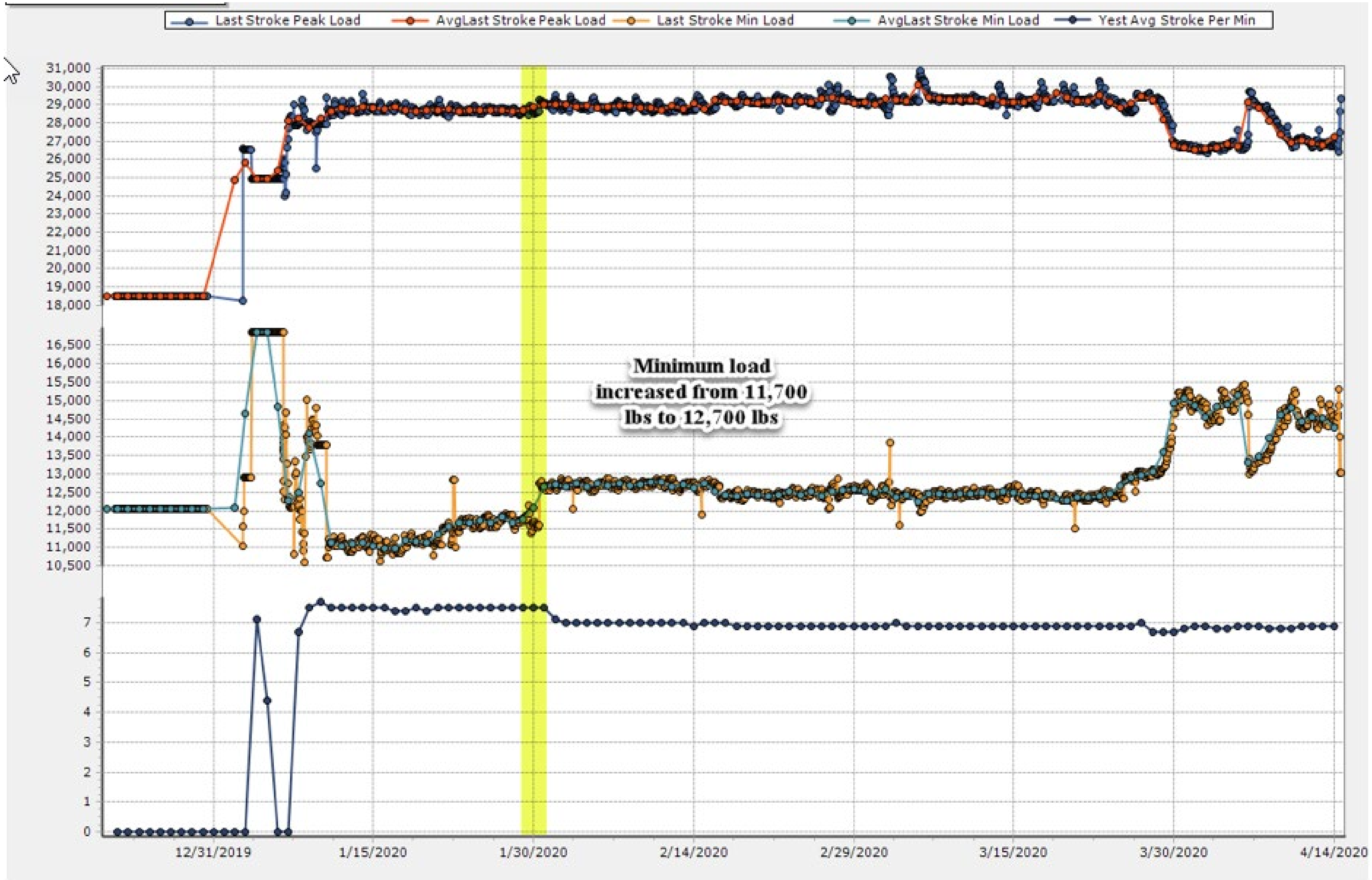
Some operators are using SDSM today

- Continental Resources using SDSM in Bakken
  - No hardware modifications needed
  - Using Scada to load SDSM settings into RPC’s
- Operator in Eagle Ford using SDSM on 400+ wells
  - Working towards applying PSO Part 2 via Data Analytics

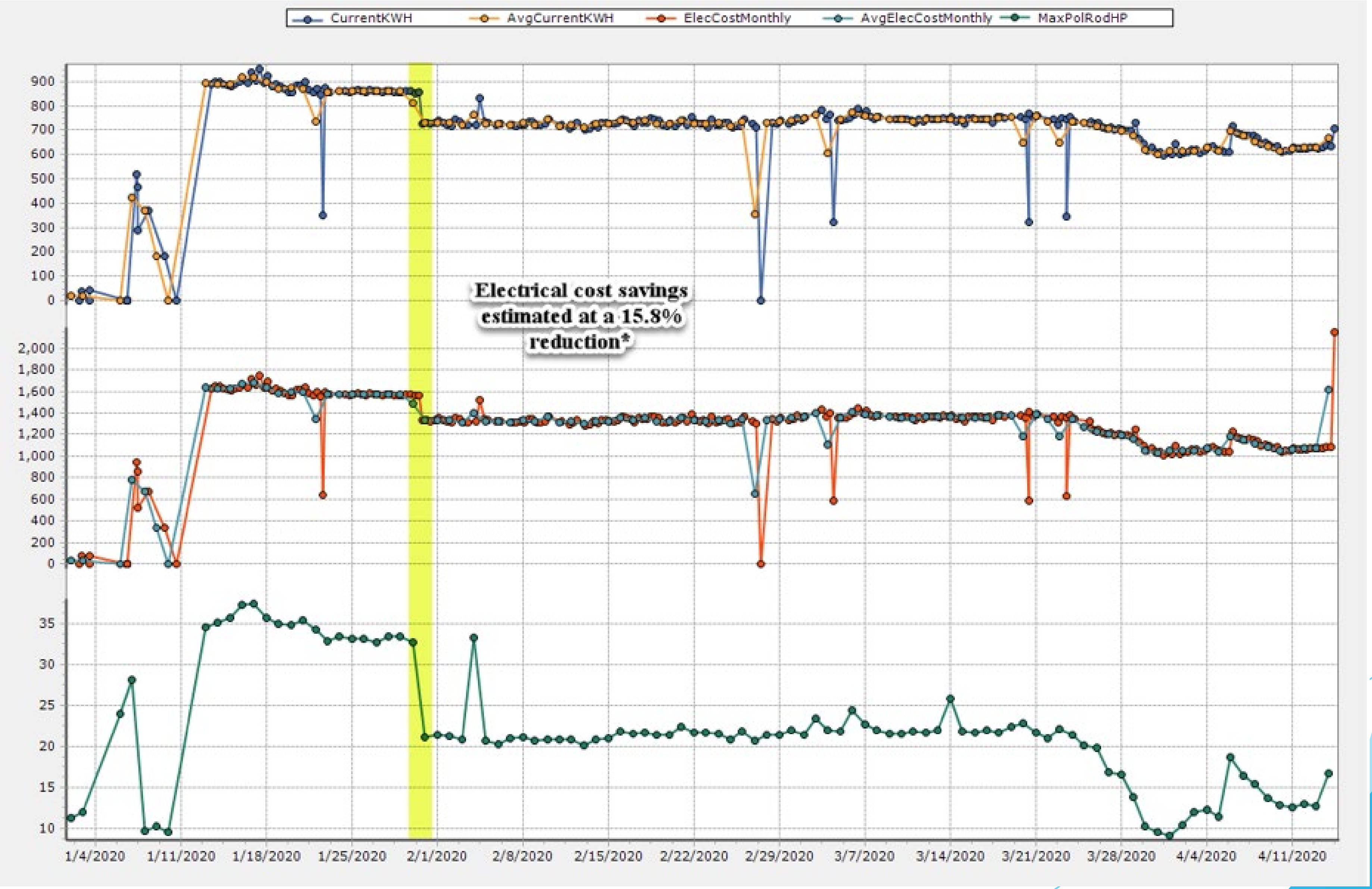
Continental Resources SDSM Results



Continental Resources SDSM Results



Continental Resources SDSM Results



Continental Resources SDSM Results

Factors Working Against PSO Adoption

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- 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

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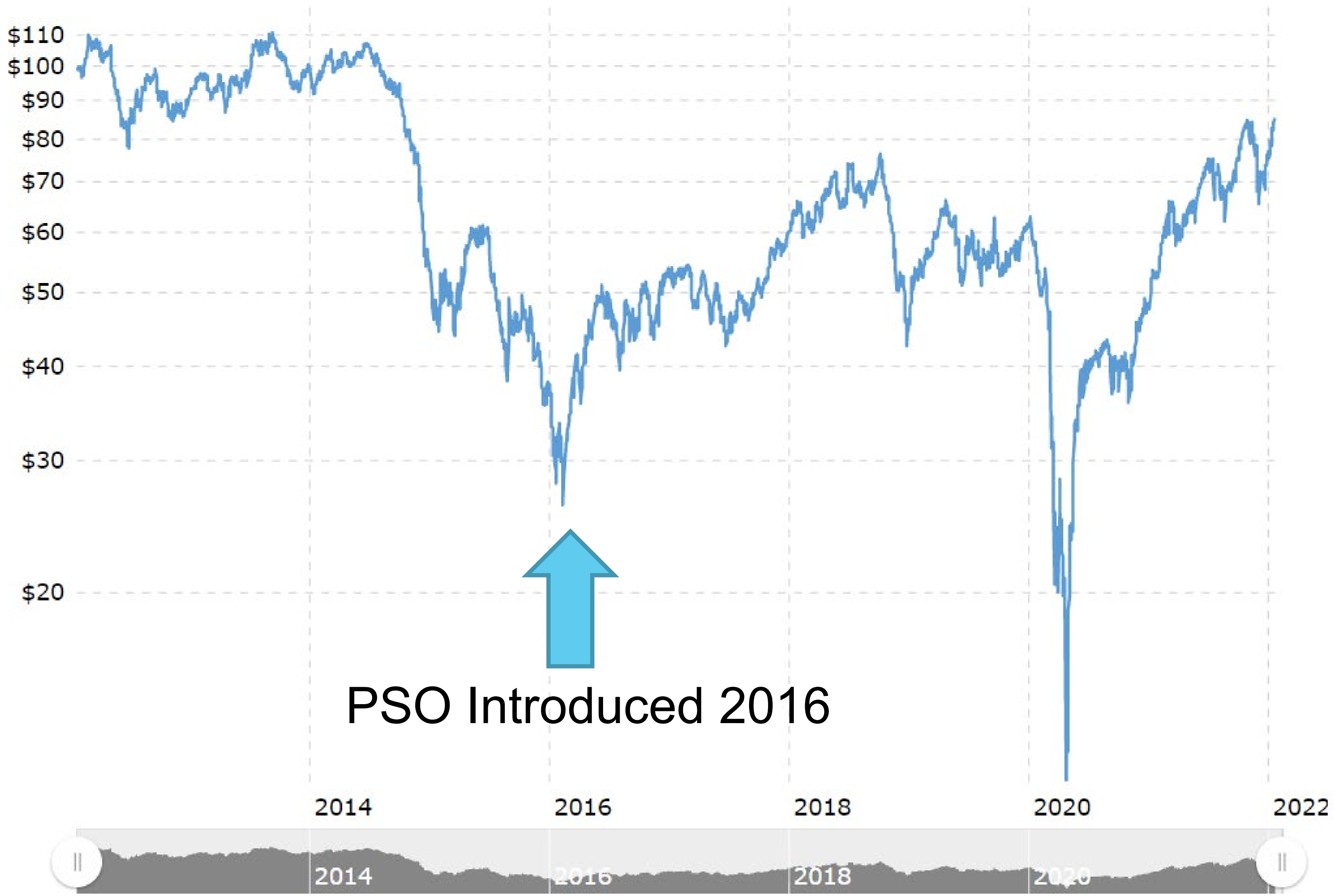

Factors Working Against PSO Adoption

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- 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
- Encline has free guide to SDSM setup. Visit enclinelift.com and request in contact section

Acknowledgements/Thanks & Questions

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