Unpacking the Myths: Continuous Pumping is Not Continuous Fracturing

2025 AADE National Technical Conference & Exhibition

AADE-25-NTCE-033

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Pump Efficiency is a Poor Operational Metric

1. Pump efficiency is a **poor operational metric**
   - Non-standard
   - Includes Non-Productive Pumping (NPP)
2. Some methods of Continuous Pumping exacerbate NPP

For Your Consideration: The Perfect Job

The perfect frac job would “break rock” at the design rate, every minute of every day, for the entire job.

“Continuous Pumping” Intent vs Reality

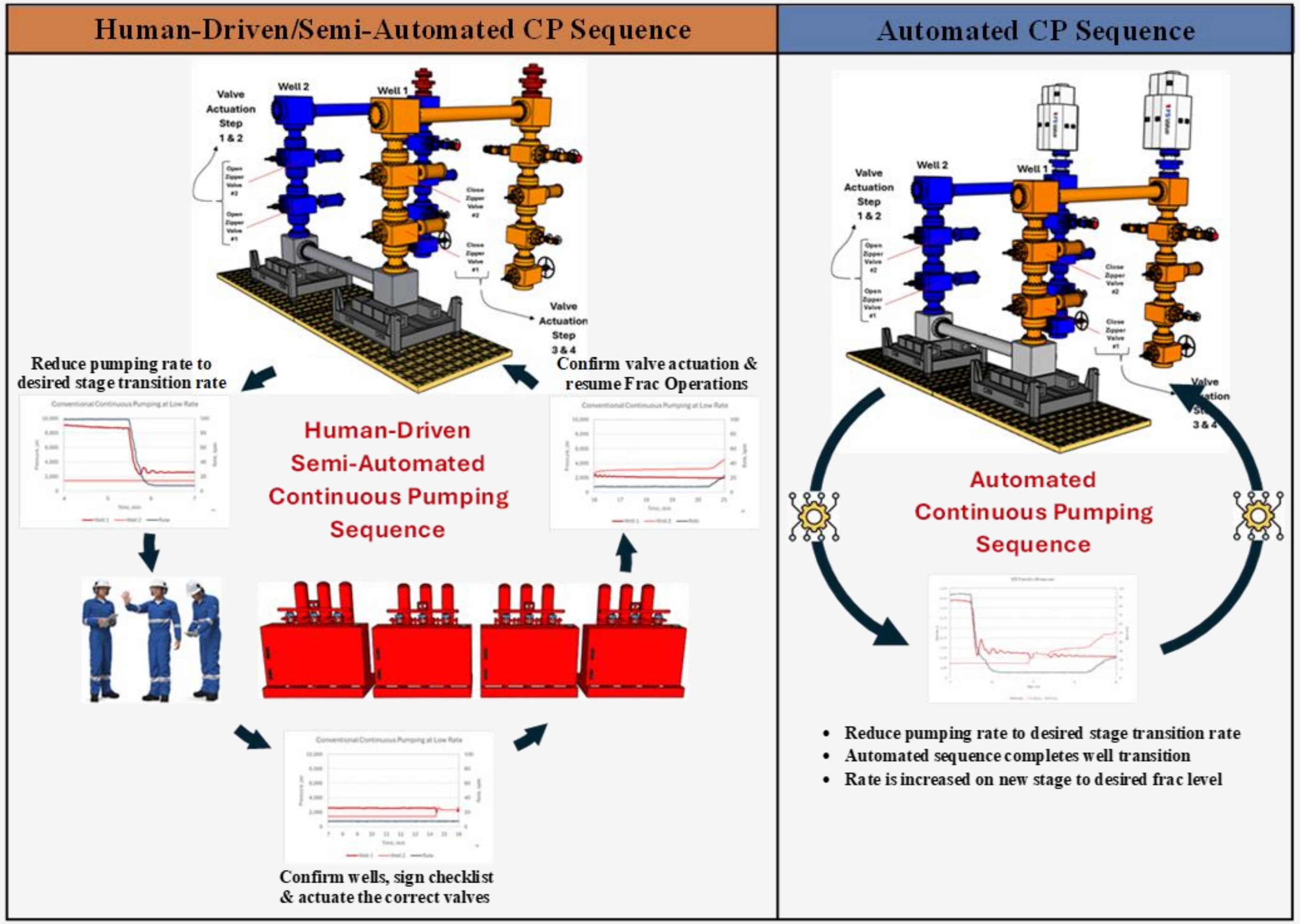
Original Definition…

- *Continuous Pumping* introduced in 2020
- At the time, pumps slowed to 20 bpm
- Automated workflow transitions zipper valves within 40 seconds
- Sensors verify transition completion and valve positions
- Pumps quickly start ramp back up to design rate
- **Rapid transitions, maximizing fracturing**

What is happening…

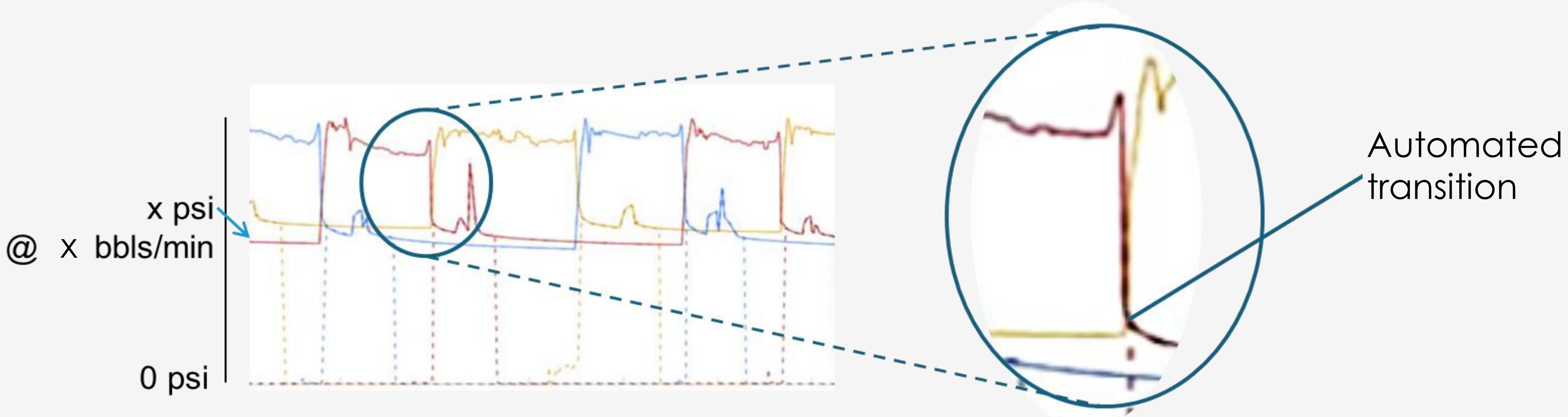
- *Continuous Pumping* morphed into continuing to pump at a low rate while manually transitioning
- Pumps slowed to 5 bpm
- Valves transitioned with semi-automated or manual system, taking significant time.
- Verification, checklists, communication need to be completed before pumps ramp back up to design rate
- **Slow transitions, maximizing pumping, maximizing cost**
- **Issues:**
  - **Appearance of efficiency**
  - **“If you think you are efficient, why seek further gains?” -> Inhibits seeking further efficiency gains**
  - **Operators paying for non-productive pumping (NPP)**

Contrasting Continuous Pumping (CP) Methods



Human-Driven CP	Automated CP
Rate: swaps at 5 bpm	**Rate**: swaps up to 50 bpm
Process Steps: human interaction with most steps	**Process Steps**: Single click, computer-driven workflow and sensors
Verification: Checklists & handshakes	**Verification**: Sensor feedback
Redzone Exposure: Yes	**Redzone Exposure**: No
Deadhead prevention: Human verification	**Deadhead prevention**: Data-driven lockout

~~Continuous Pumping~~ "Continuous Fracturing" Redefined



Limited Flat Time Transitions. Eliminates Significant Time between Stages. Increased Average bbls/min.

- Pumps are slowed, not stopped
- Currently, transitions take place up to 6,000 psi differential and up to 50 bbl/min*
- Limited flat time during transition
- Automation provides path to eliminate "invisible lost time"
- Eliminates significant time during pressure down, pressure up and transition.

*** Reservoir dependent**

Continuous Pumping Taxonomy and Implications

Popular Pumping metrics (i.e. pumping time, swap time) mask inefficiencies

- **Invisible Lost Time** (ILT)
  - Process time components lost in metrics.
- Workflow and semi-automated solutions include ILT:
  - Decision time pre-swap
  - Multiple manual workflow steps requiring human intervention
  - Slower transitions

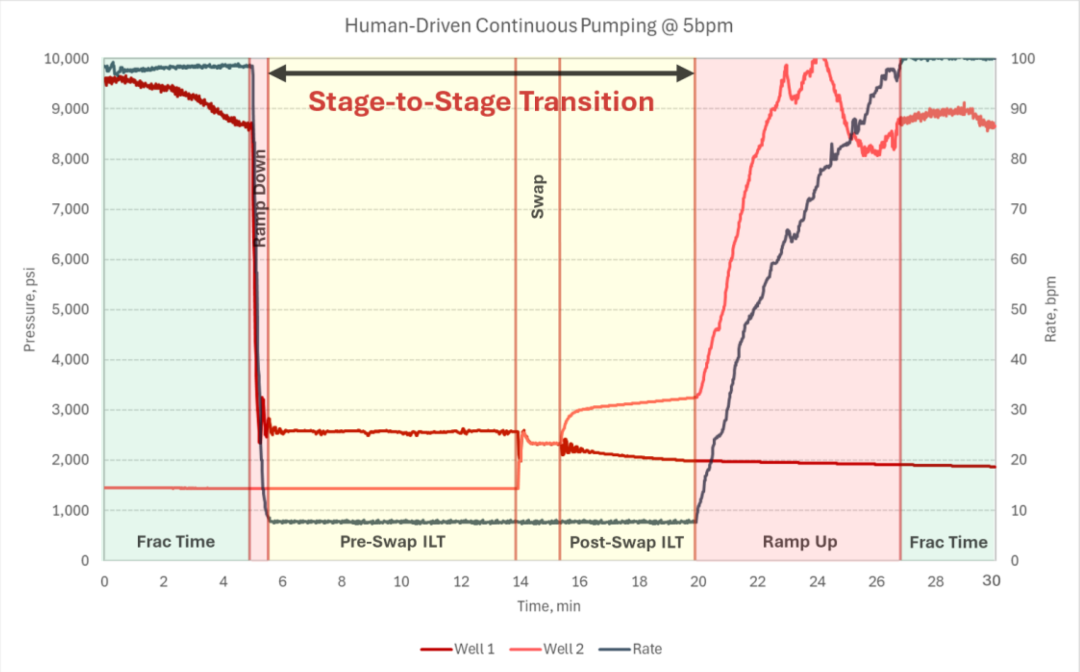
New Metric to Drive Efficiency: Effective Fracturing %

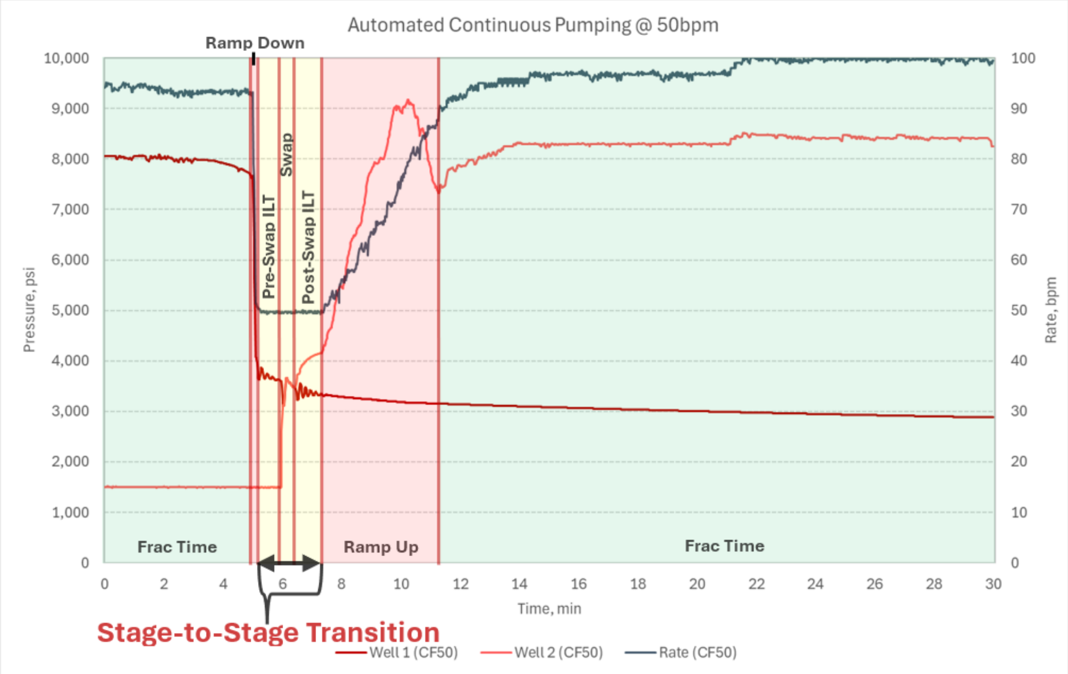
Component	Definition
Continuous Fracturing	Time pumps are actively stimulating frac stages. Time "Breaking Rock".
Effective Fracturing%	Percentage of clean fluid volume (CFV) injected during operations dedicated to stimulation stages. $\left(\frac{CFV_{Stages}}{Design\ Rate\ x\ 1440}\right)x100$

- **Summary**
  - In continuous pumping operations, Pump Efficiency **includes all time** pumping, regardless if you are "breaking rock".
  - Continuous Fracturing is time you are **"breaking rock".**
  - Effective Fracturing % measures the % of time stimulating each day at your design rate.
- **Why** does this matter?
  - **If you believe there is little room to improve your operation, you will not spend time or money to improve.**

A Close Look at Continuous Pumping (CP) Swaps

Human Driven CP at 5 bpm pump rate	**Automated CP at 50 bpm pump rate**
Total Stage-to-Stage Transition: ~15 min	Total Stage-to-Stage Transition: ~2 min





0.8	**8.5**	**1.5**	**5.0**
RD	Pre-Swap ILT	Swap	Post-Swap ILT

0.3	**<1**	**0.6**	**1**
RD	Pre-Swap ILT	Swap	Post-Swap ILT

24hr Continuous Pumping: Pump Hours vs Fracturing Hours

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Human Swaps: longer transitions, lower barrels, less stages per day, more risk

Human swaps @ 5 bpm

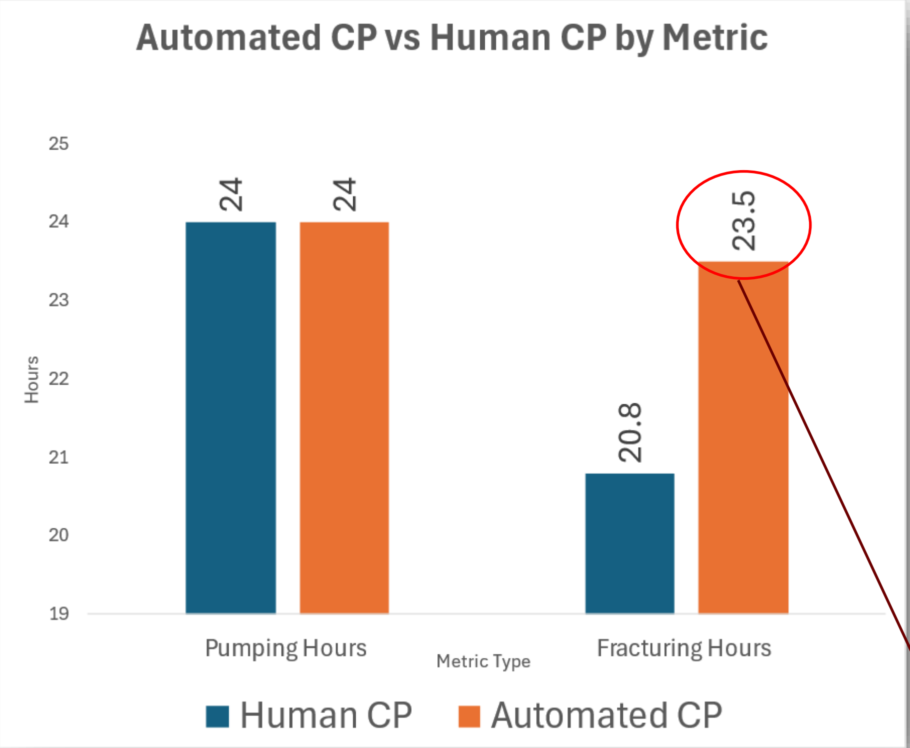
Human-Driven Continuous Pumping @ 5 bpm				
Event	Time Period	Stages	Cumulative Time Period	CFV Pumped
Stage	1.58 hrs	1.0	1.58 hrs	9,231 bbl
Transition	0.25 hrs		1.83 hrs	75 bbl
Stage	1.58 hrs	2.0	3.41 hrs	9,231 bbl
Transition	0.25 hrs		3.66 hrs	75 bbl
Stage	1.58 hrs	3.0	5.24 hrs	9,231 bbl
Transition	0.25 hrs		5.49 hrs	75 bbl
Stage	1.58 hrs	4.0	7.07 hrs	9,231 bbl
Transition	0.25 hrs		7.32 hrs	75 bbl
Stage	1.58 hrs	5.0	8.91 hrs	9,231 bbl
Transition	0.25 hrs		9.16 hrs	75 bbl
Stage	1.58 hrs	6.0	10.74 hrs	9,231 bbl
Transition	0.25 hrs		10.99 hrs	75 bbl
Stage	1.58 hrs	7.0	12.57 hrs	9,231 bbl
Transition	0.25 hrs		12.82 hrs	75 bbl
Stage	1.58 hrs	8.0	14.40 hrs	9,231 bbl
Transition	0.25 hrs		14.65 hrs	75 bbl
Stage	1.58 hrs	9.0	16.23 hrs	9,231 bbl
Transition	0.25 hrs		16.48 hrs	75 bbl
Stage	1.58 hrs	10.0	18.06 hrs	9,231 bbl
Transition	0.25 hrs		18.31 hrs	75 bbl
Stage	1.58 hrs	11.0	19.89 hrs	9,231 bbl
Transition	0.25 hrs		20.14 hrs	75 bbl
Stage	1.58 hrs	12.0	21.72 hrs	9,231 bbl
Transition	0.25 hrs		21.97 hrs	75 bbl
Stage	1.58 hrs	13.0	23.55 hrs	9,231 bbl
Transition	0.25 hrs		23.80 hrs	75 bbl
Stage	0.20 hrs	13.1	24.00 hrs	957 bbl
Total		Stages Completed	Time Period	CFV Pumped
		13.1 stgs	24.00 hrs	121,937 bbl
		EF% @ 84.0%		

13.1 stgs | **121.9k bbls**

Automated swaps @ 50 bpm

Automated Continuous Pumping @ 50 bpm				
Event	Time Period	Stages	Cumulative Time Period	CFV Pumped
Stage	1.54 hrs	1.0	1.54 hrs	9,064 bbl
Transition	0.03 hrs		1.58 hrs	100 bbl
Stage	1.54 hrs	2.0	3.12 hrs	9,064 bbl
Transition	0.03 hrs		3.15 hrs	100 bbl
Stage	1.54 hrs	3.0	4.69 hrs	9,064 bbl
Transition	0.03 hrs		4.73 hrs	100 bbl
Stage	1.54 hrs	4.0	6.27 hrs	9,064 bbl
Transition	0.03 hrs		6.30 hrs	100 bbl
Stage	1.54 hrs	5.0	7.85 hrs	9,064 bbl
Transition	0.03 hrs		7.88 hrs	100 bbl
Stage	1.54 hrs	6.0	9.42 hrs	9,064 bbl
Transition	0.03 hrs		9.46 hrs	100 bbl
Stage	1.54 hrs	7.0	11.00 hrs	9,064 bbl
Transition	0.03 hrs		11.03 hrs	100 bbl
Stage	1.54 hrs	8.0	12.57 hrs	9,064 bbl
Transition	0.03 hrs		12.61 hrs	100 bbl
Stage	1.54 hrs	9.0	14.15 hrs	9,064 bbl
Transition	0.03 hrs		14.18 hrs	100 bbl
Stage	1.54 hrs	10.0	15.73 hrs	9,064 bbl
Transition	0.03 hrs		15.76 hrs	100 bbl
Stage	1.54 hrs	11.0	17.30 hrs	9,064 bbl
Transition	0.03 hrs		17.34 hrs	100 bbl
Stage	1.54 hrs	12.0	18.88 hrs	9,064 bbl
Transition	0.03 hrs		18.91 hrs	100 bbl
Stage	1.54 hrs	13.0	20.45 hrs	9,064 bbl
Transition	0.03 hrs		20.49 hrs	100 bbl
Stage	1.54 hrs	14.0	22.03 hrs	9,064 bbl
Transition	0.03 hrs		22.06 hrs	100 bbl
Stage	1.54 hrs	15.0	23.61 hrs	9,064 bbl
Transition	0.03 hrs		23.64 hrs	100 bbl
Stage	0.36 hrs	15.2	24.00 hrs	1,995 bbl
Total		Stages Completed	Time Period	CFV Pumped
		15.2 stgs	24.00 hrs	139,456 bbl
		EF% @ 95.8%		

15.2 stgs | **139.5k bbls**



Automated: 2.7 hrs (13%) more fracturing

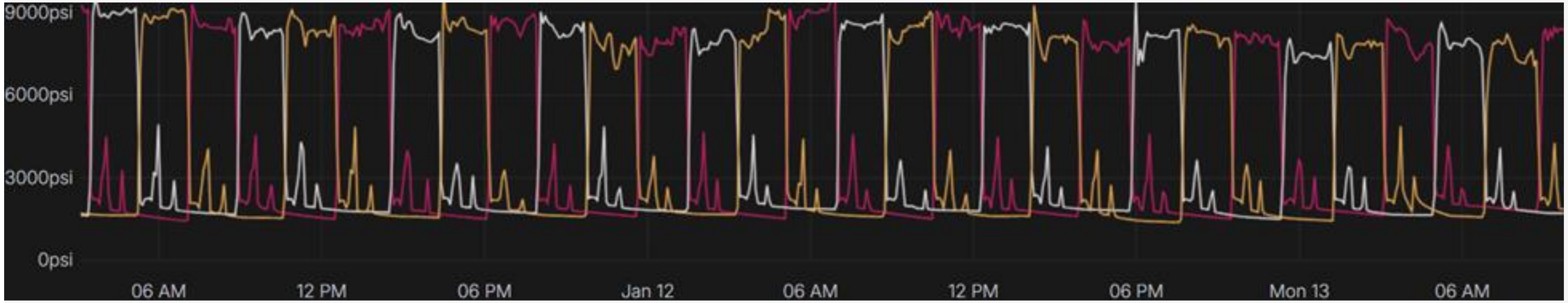
Example: Same Pump Hours, Same Design, More Stages, Higher Volume

Continuous Pumping ≠ Continuous Fracturing: Same Pump Hours, Increased Stages with Automation

Continuous Pumping: Human / Semi-Automated Workflow-driven

60 pump hours
25.3 stages
2.37 hrs/stage

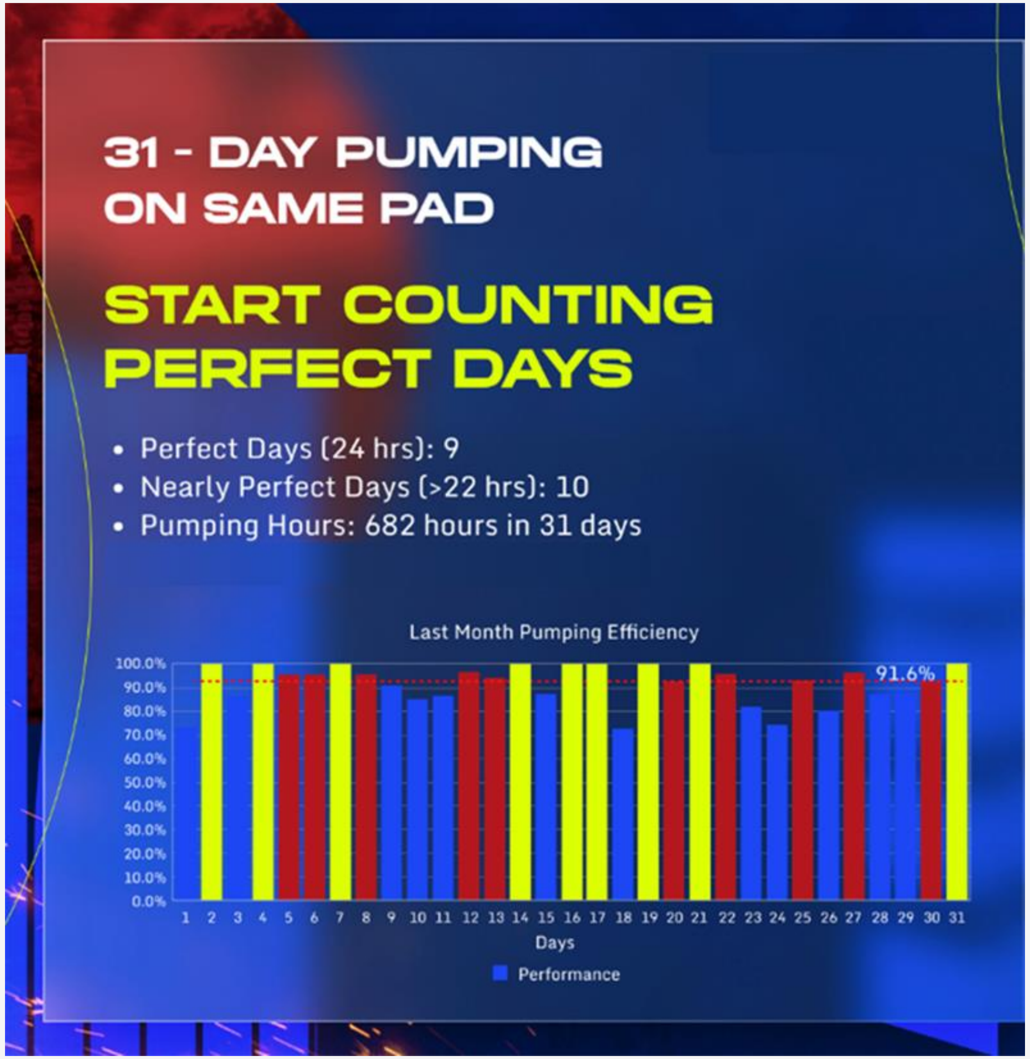
Continuous Fracturing: Automation with limited pre- and post-ILT



60 pump hours
29.7 stages
2.02 hrs/stage

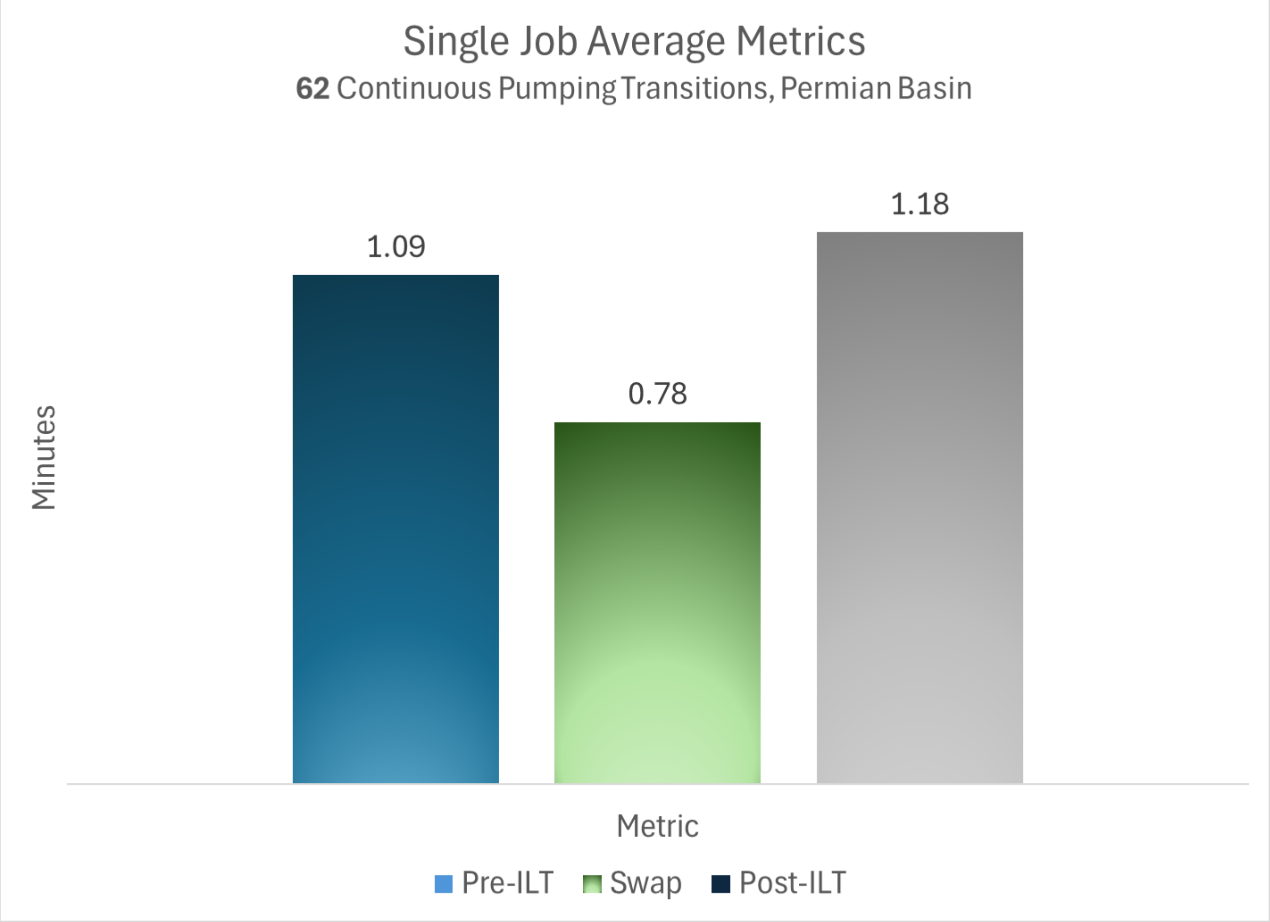
Permian Basin Case History #1

- **Results**:
  - **Utilizing Automated Transitions and Pump Swapping Technology**
  - **Perfect Days**: goal is to fracture 100% of day
    - **100% effective** fracturing is 1,440 min/day x 100bpm = **144,000 bpd** pumped
    - **9 "Perfect Days"** – fractured all day with rapid, high bpm transitions.
    - 140,175 bpd (actual) / 144,000 bpd (possible) = **97.3% effective fracturing**.
  - **31 Day Overall Effective Fracturing%:** 89.2%
    - 128,445 bpd (actual daily avg) / 144,000 bpd (possible)
    - Note pump efficiency at 91.6% (includes NPP)

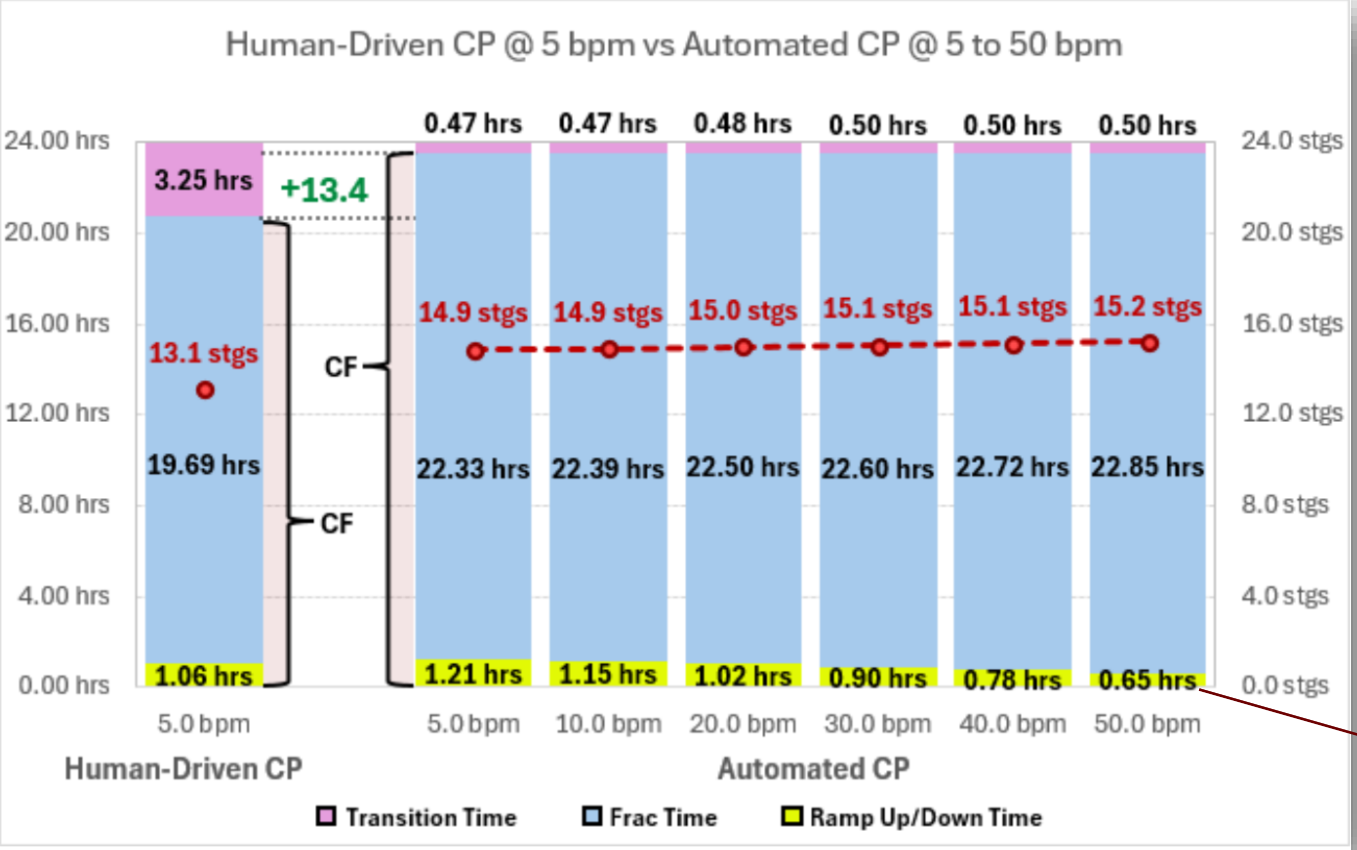


Permian Basin Case History #2

- **Results**:
  - Delaware Basin
  - 62 Continuous Pumping Swaps
  - Average time:
    - Pre-ILT: 1.1min
    - Swap: 0.8 min
    - Post-ILT: 1.2min
  - Fastest Transition: 1.4min
    - Pre-ILT: 0.4min
    - Swap: 0.6min
    - Post-ILT: 0.4min
  - Human-Driven: Can a human get out to the valves, verify valve positions & wireline out of the hole, finish checklist, get buy-in, safely transition all valves, and verify positions before ramping up in <1.5 min?



Automated Transitions at Higher BPM -> More Fracturing



- Human-Driven CP is **slower**, **riskier**, and occurs at lower BPM.
- Automated CP is **faster** and **safer**.
- Pushing CP to higher pump rates increases your effective fracturing%.

Note the ramp time decreases as transition bpm increases.
Result: More fracturing time.

Key Takeaways

1. Pump Efficiency Calculations hide **inefficiencies**
2. "Continuous Pumping" is NOT "Continuous Fracturing", dependent on the continuous pumping method.
3. In continuous pumping operations, **operators pay** for pumping hours even if these hours are not fracturing (i.e. operators are paying for slow transitions)
4. Pre-Swap and Post-Swap time is **LOST** within swap metrics.
5. **Automation** provides path to reduce & eliminate "invisible lost time".
6. Fast transitions at high pumping rates **eliminate time** during pressure down, pressure up, and swap.
7. **Call to Action**: Measuring Effective Fracturing % represents true operational efficiency. Provides the incentive to ask: "How do we cost-effectively get to 100%?"

Questions?

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