Back to the Basics - Process Control Diagnostics Improves Refinery Performance

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Emerson Process Management

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James Beall

- Principal Process Control Consultant, Emerson Process Management
- 26 Years experience in process control
  - 7 Years Emerson Process Management
  - 19 Years at Eastman Chemical Company
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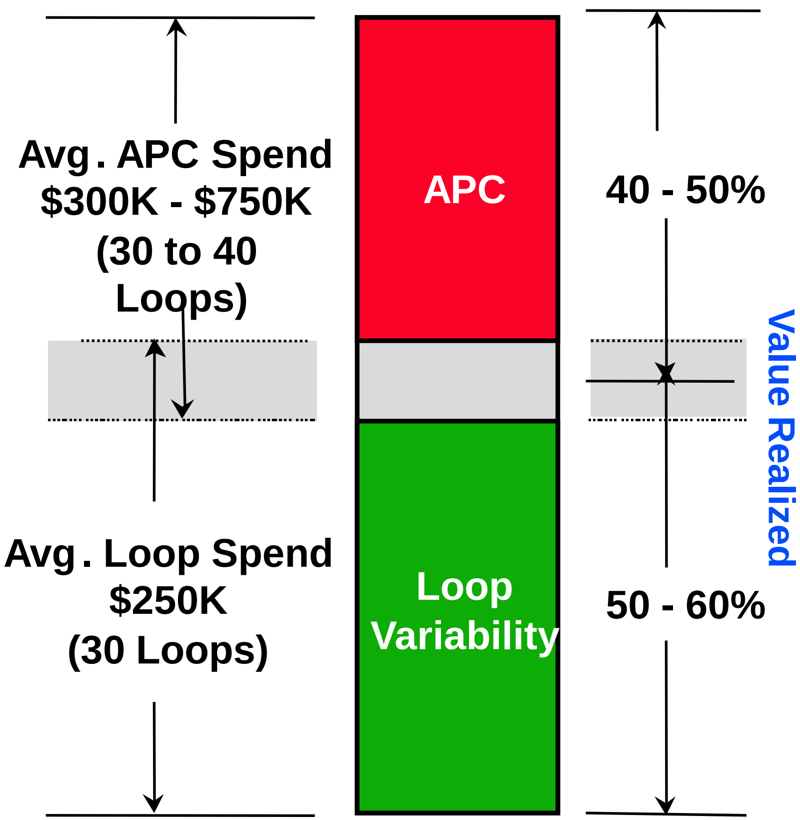
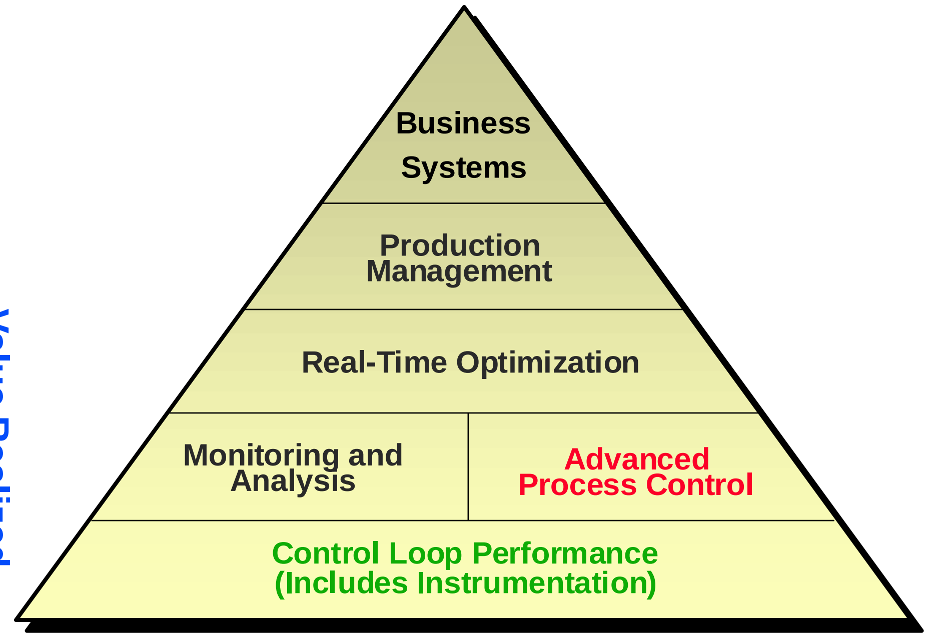
A Solid Control Foundation is Essential to the Success of Any APC project

- The core of a solid foundation is good measurements and final elements.
- Deficiencies in the measurement and final element can increase the time required for process testing and identification by a factor of 5 or more and can significantly reduce the improvement in process capacity and efficiency provided by APC.
- Significant economic benefit can be obtained from a good control foundation!

A Winning Combination



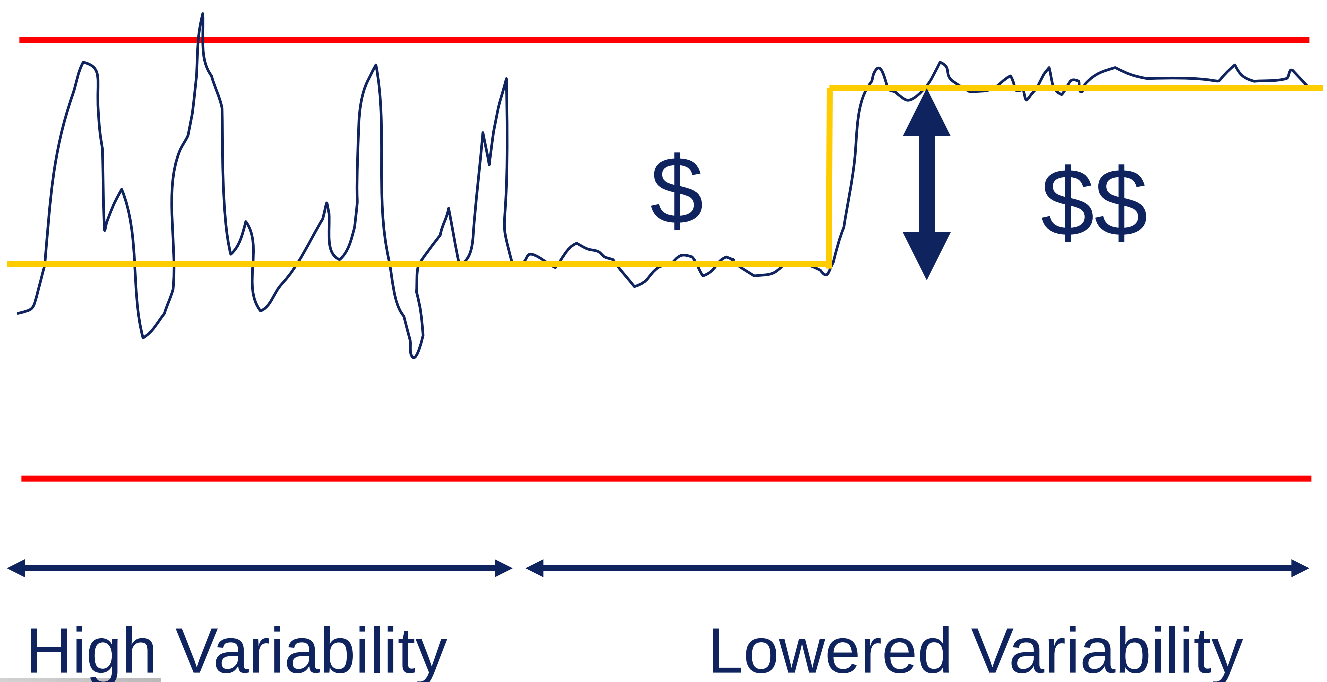
McKinsey Study June 97



When Performed Together,
Loop Optimization and APC
Yield The Best Financial Return
(Add ~25% APC Budget)

Key Take-Away Message

- Control key process parameters with less variability
- Operate closer to constraints with less variability



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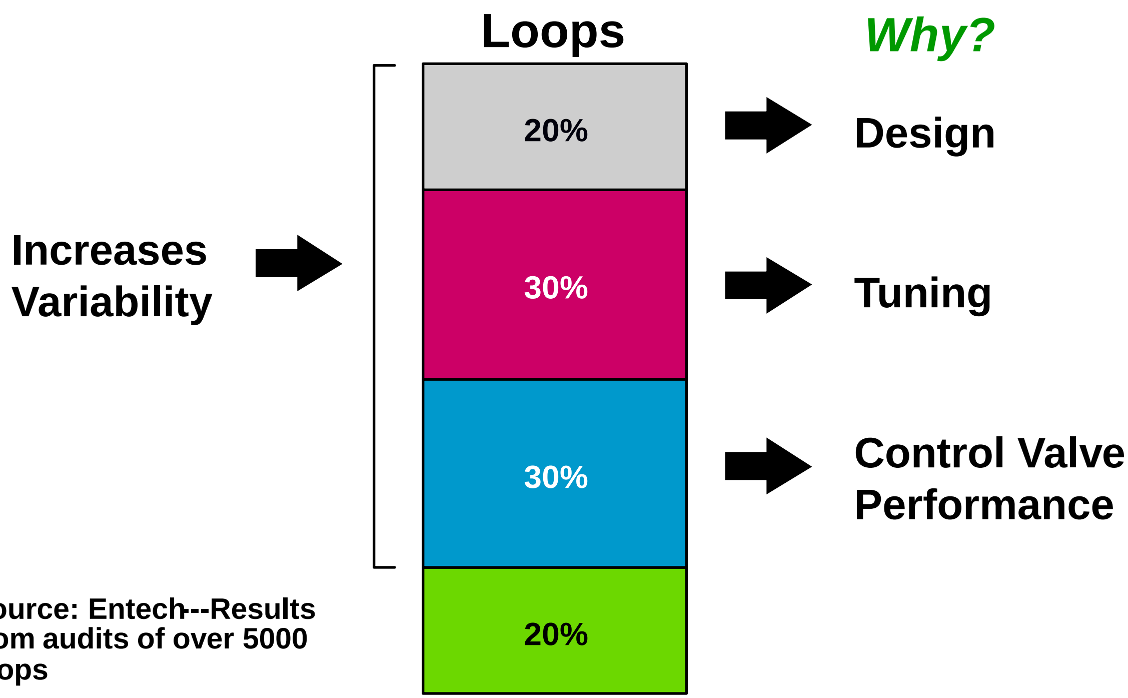
Largest and Most Frequent Opportunities in Basic Control

- Eliminate variability at the source
- Tune the controllers to meet control objectives
  - Coordinate Tuning Speed Based on Operating objectives
  - Attenuate Variability with Control/Equipment
- Utilize cascade and feed forward control
- Use a process analysis system to diagnose problems and tune loops

EnTech Statistic -: Control Loops with Excessive Variability



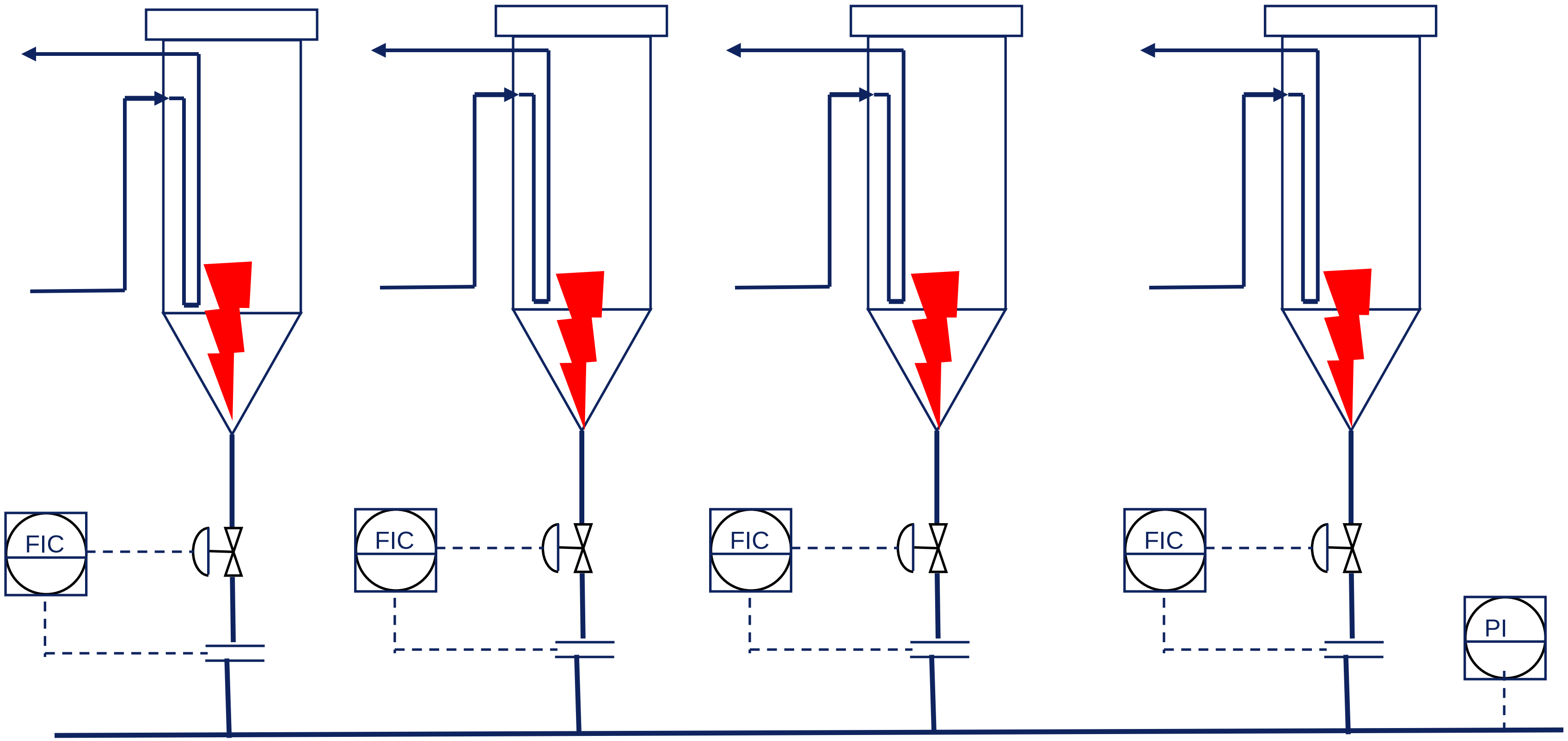
Source: Entech---Results from audits of over 5000 loops

- **“The undesirable behavior of control valves is the biggest contributor to poor loop performance and the destabilization of product uniformity”.**

W. L. Bialkowski, President
EnTech Control Engineering

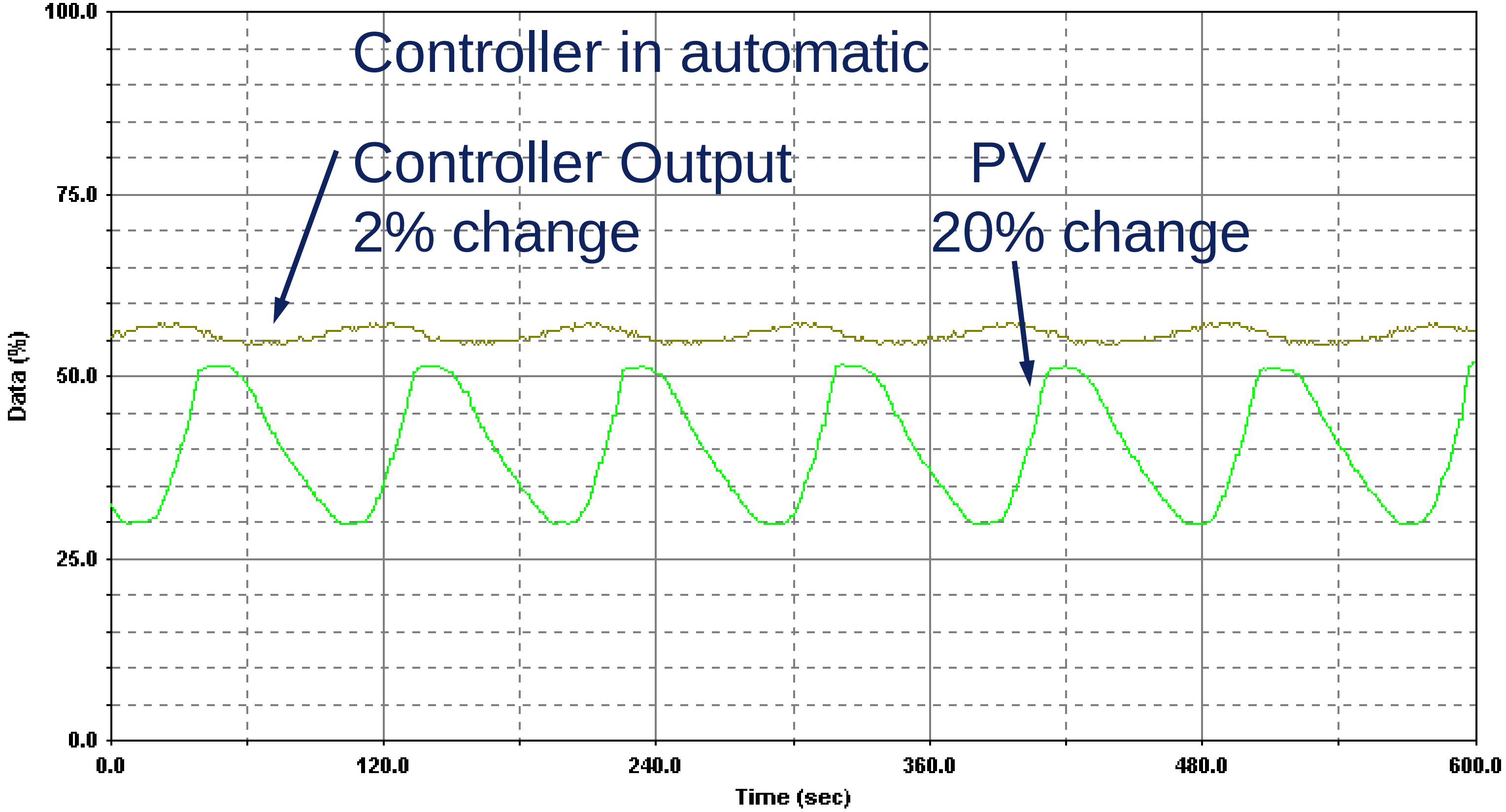
Eliminate Sources of Variability: Valve Problems

Process Heaters

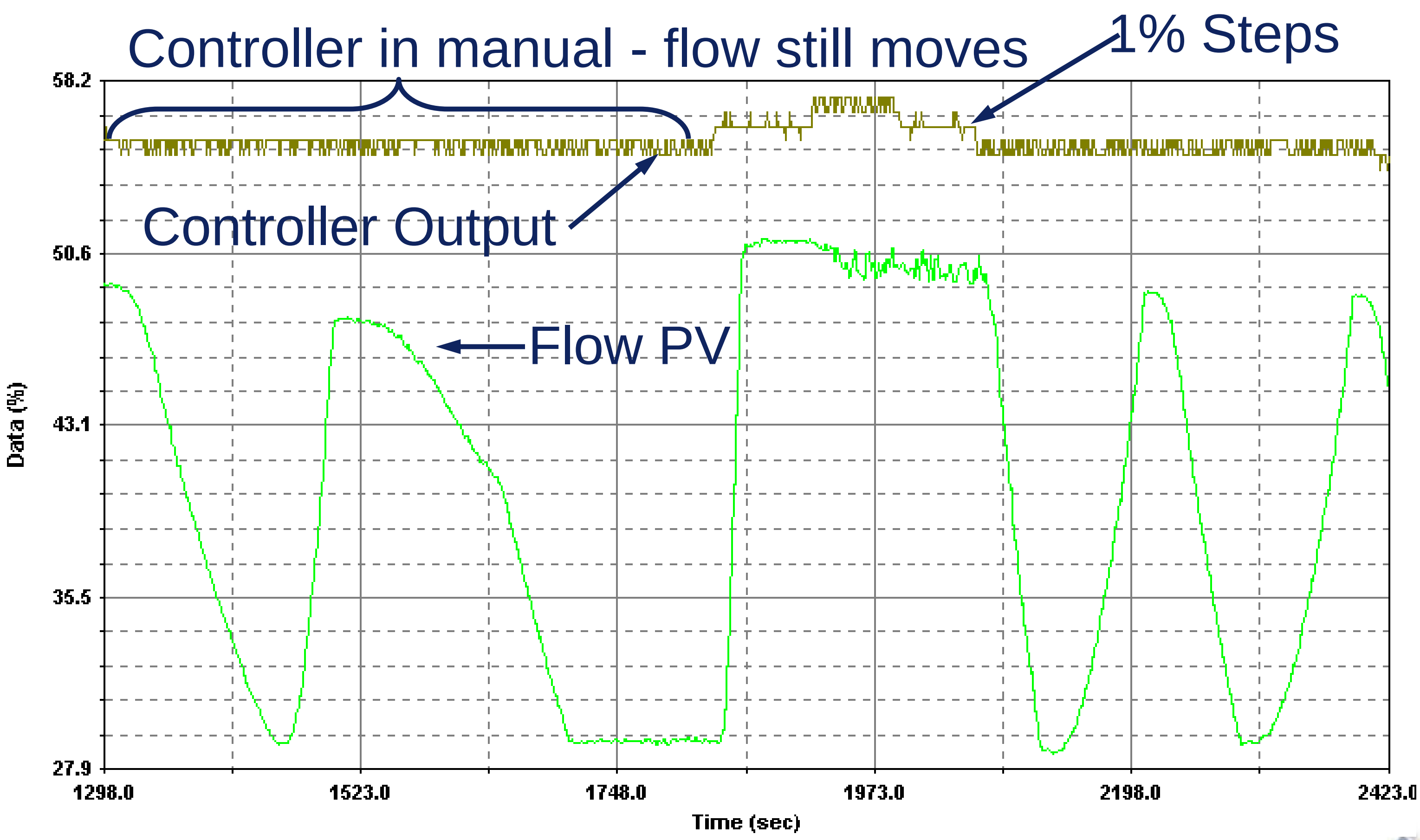


Methane Header

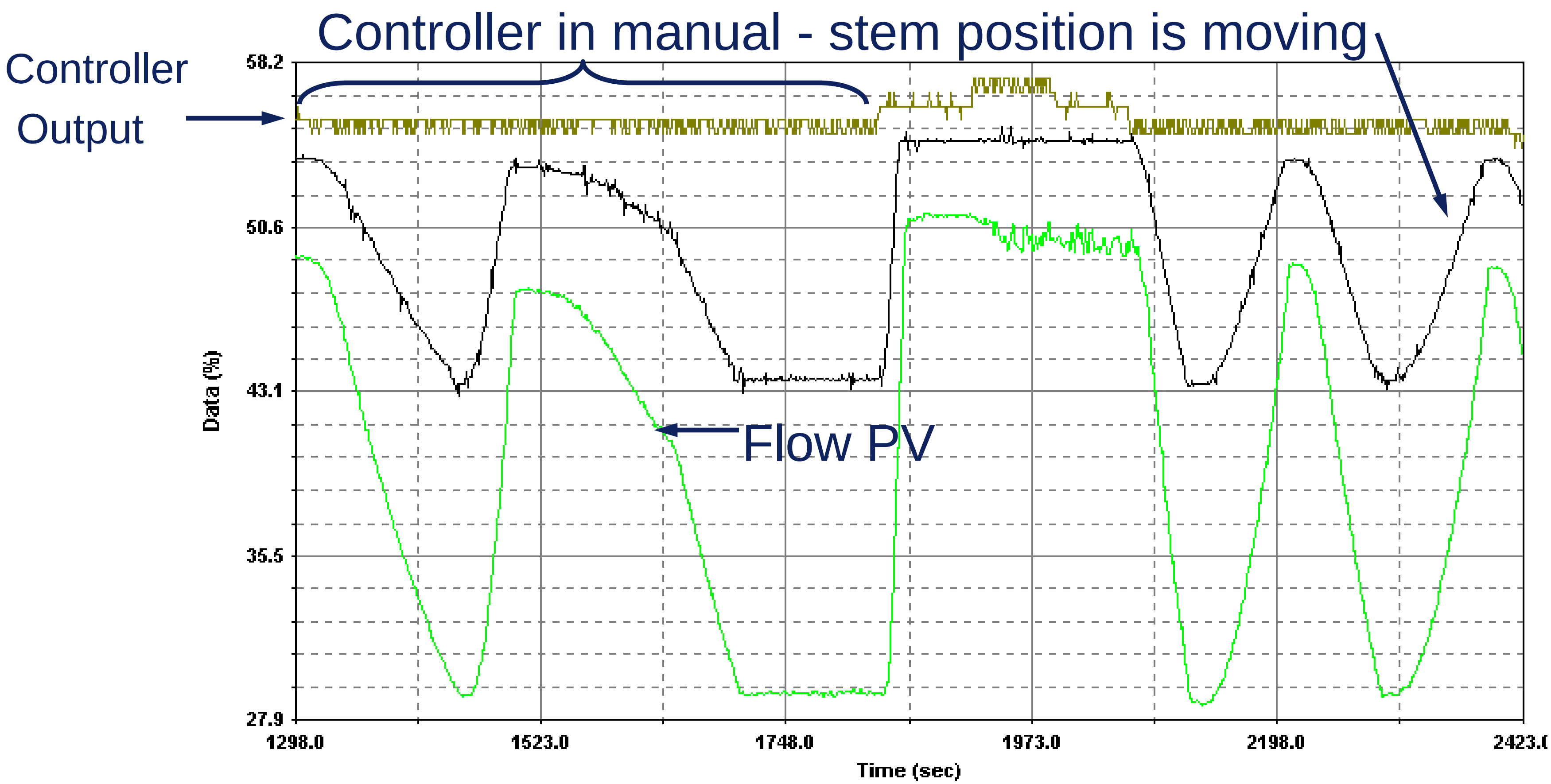
Eliminate Sources of Variability: Valve Problems - Flow Control Loop



Eliminate Sources of Variability: Valve Problems - Flow Control Loop

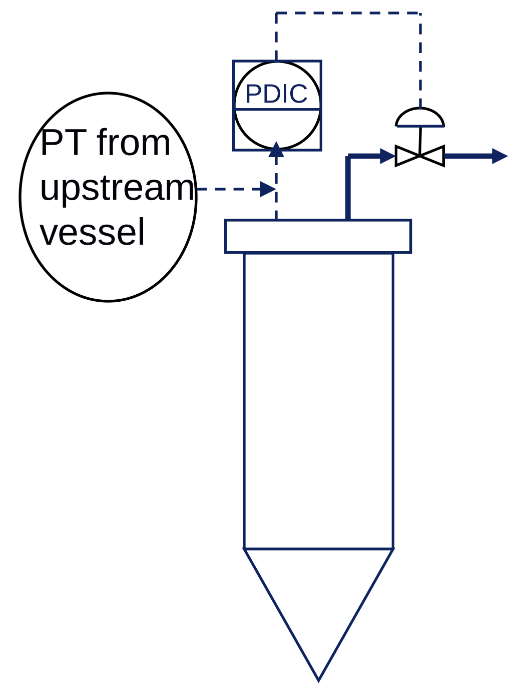


Eliminate Sources of Variability: Valve Problems - Flow Control Loop



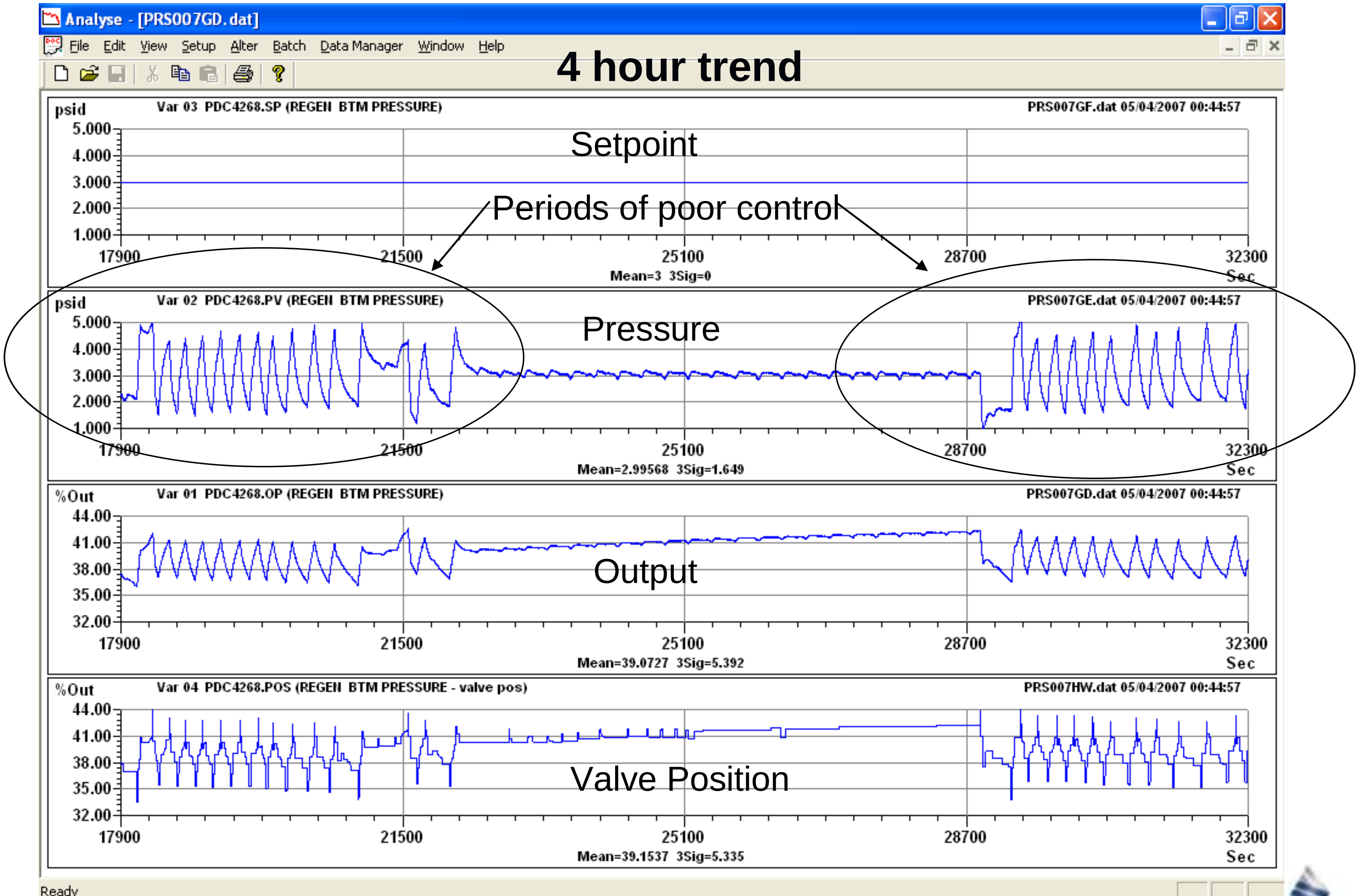
Eliminate Sources of Variability: Valve Problems – Regenerator Pressure Valve

- New facility, new valve
- Periods of good and back control performance
- The valve was a rotary "tight shutoff" made for on-off service but was "adapted" to continuous control



Regenerator

Eliminate Sources of Variability: Valve Problems – Regenerator Pressure Valve



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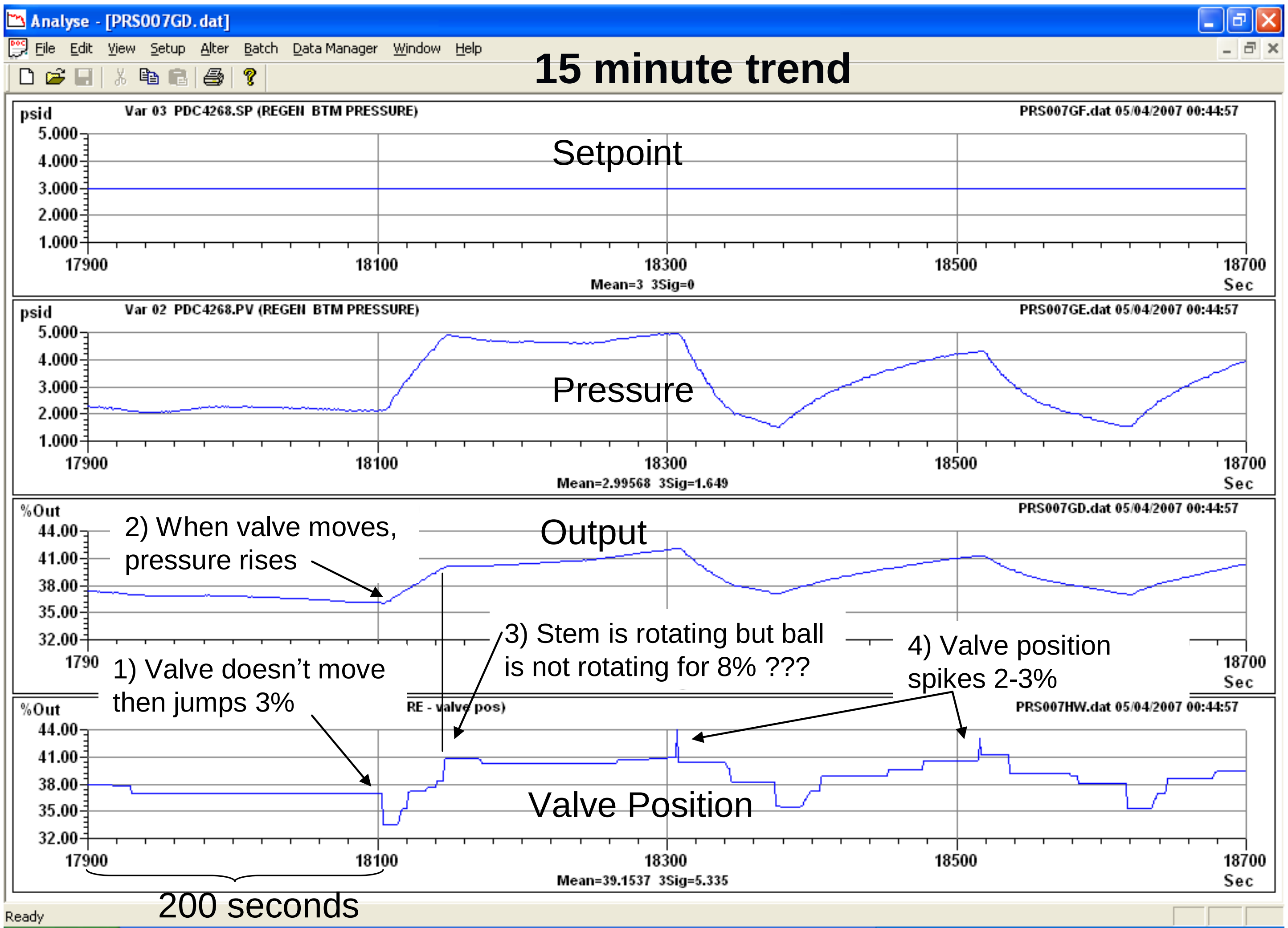
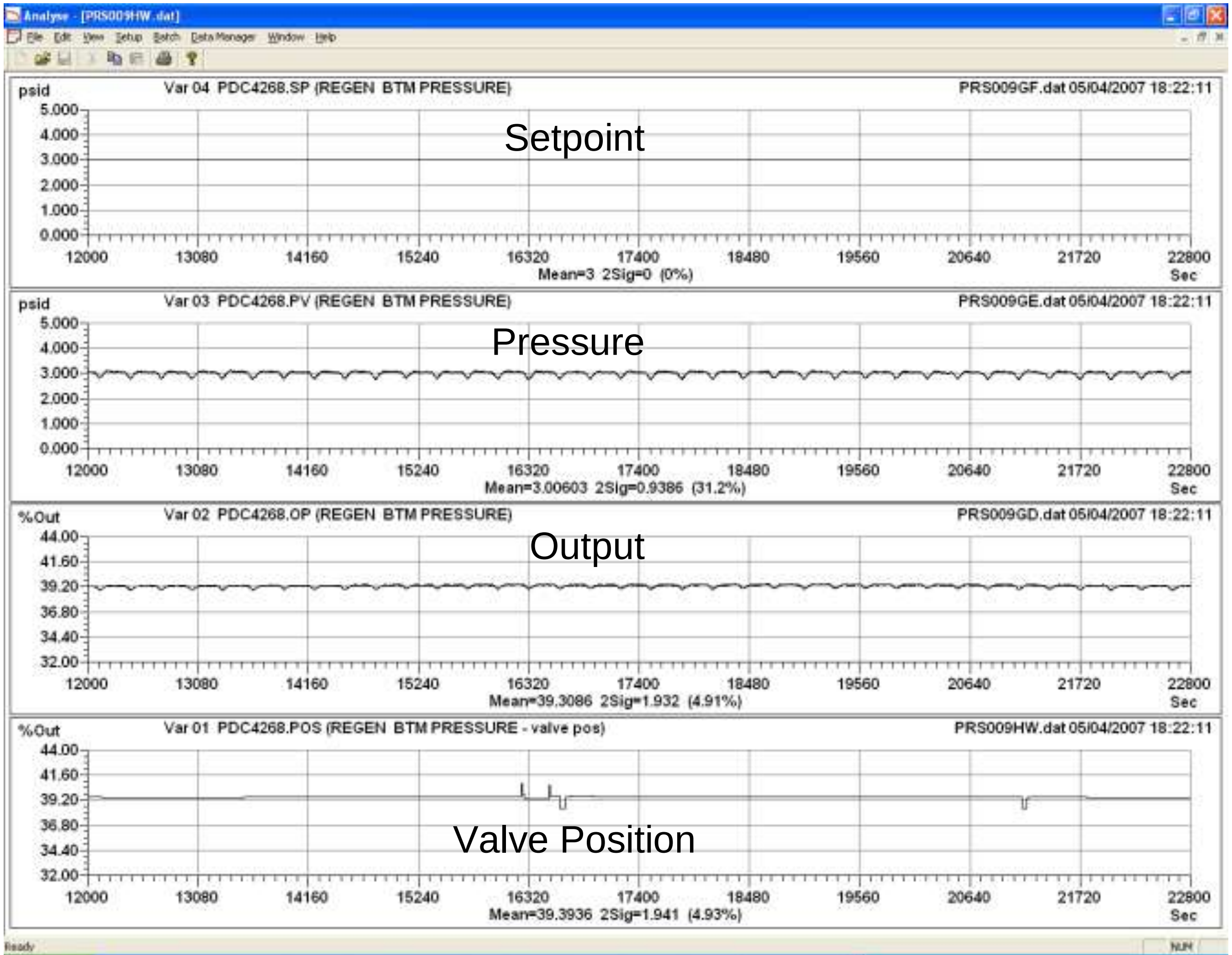
Eliminate Sources of Variability: Valve Problems – Regenerator Pressure Valve

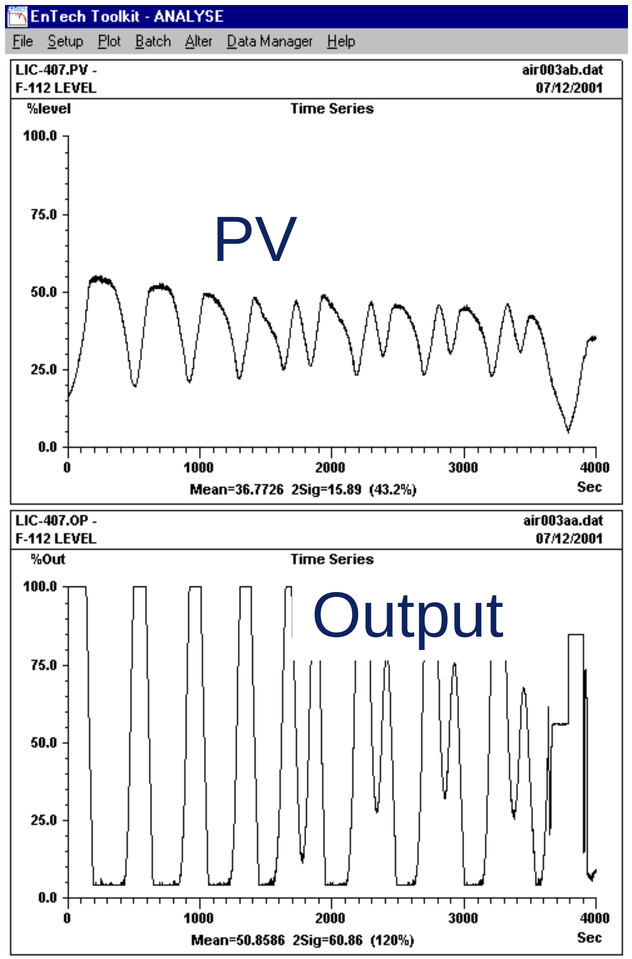


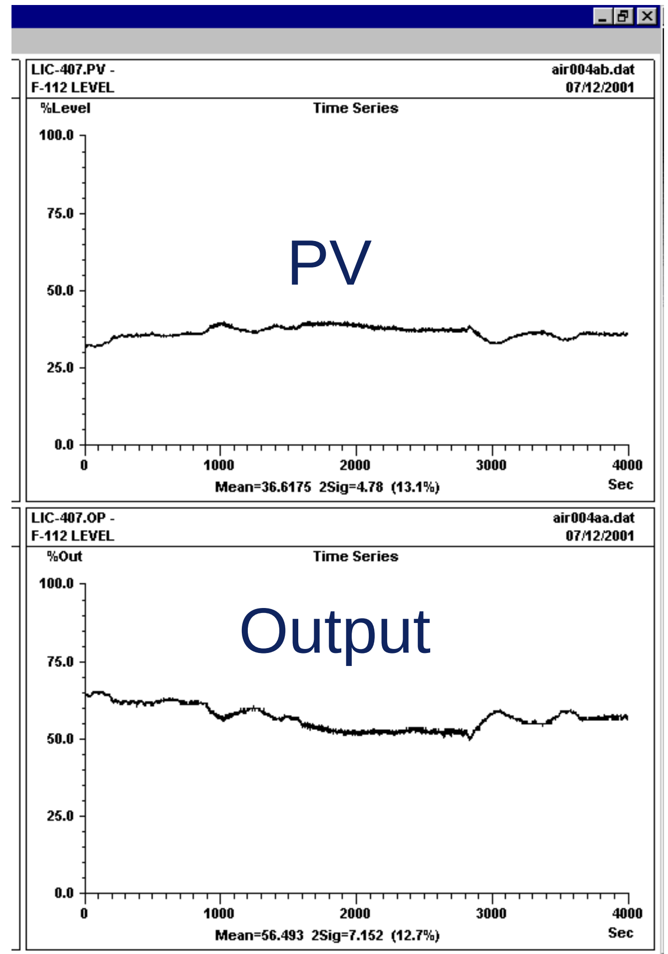
Eliminate Sources of Variability: Valve Problems – After Improvements



Eliminate Source of Variability: Poor Tuning

Before | **After**





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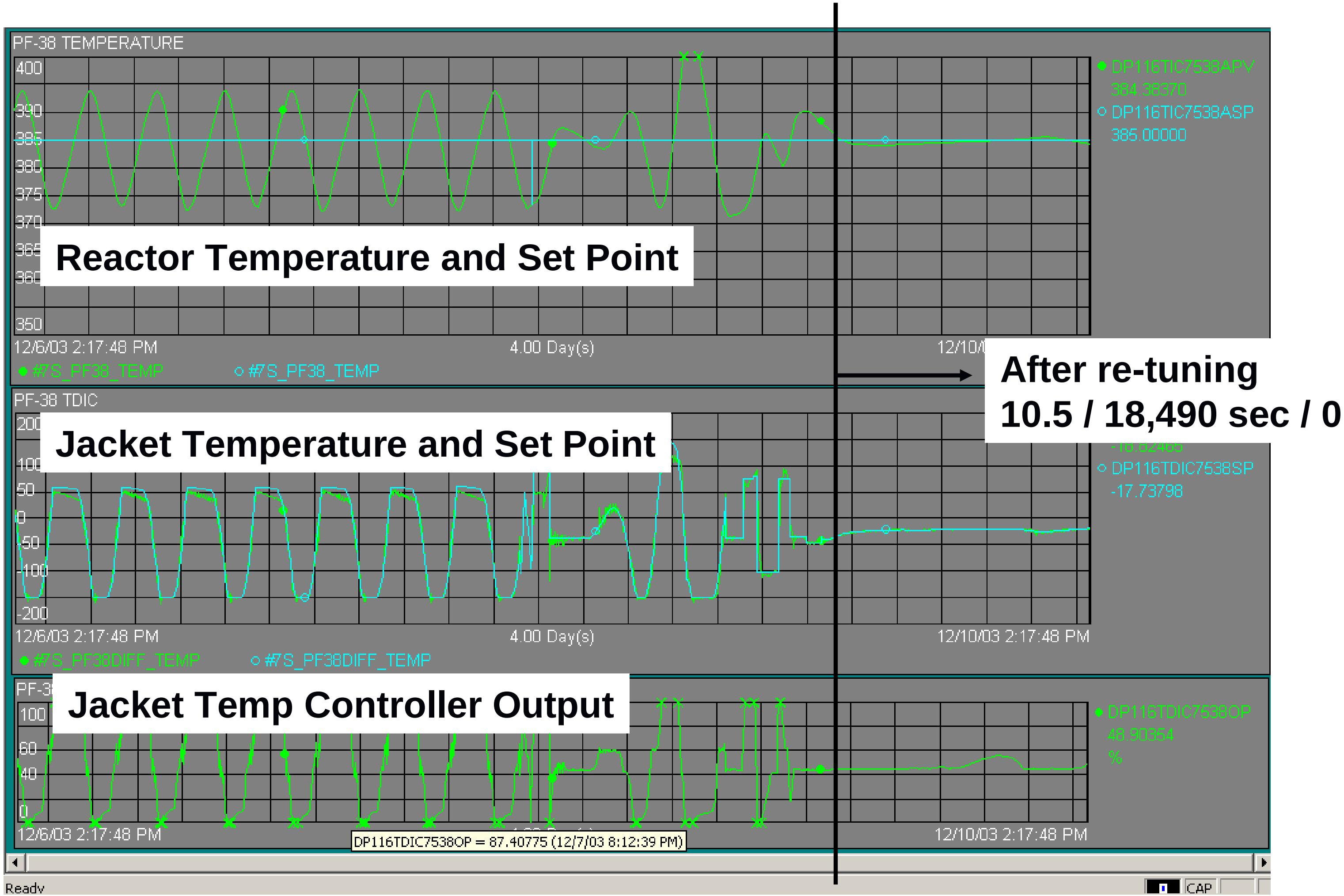


Setting the Control Foundation - Tuning

- Utilize tuning methodology as a TOOL to coordinate tuning of all loops as a system
  - Methodical selection of the closed loop time constant of each loop, considering all interactions
  - Attenuate variability with control/equipment
  - Tuning to minimize resonance or “disturbance amplification” of lower level loops

Tuning Methods

- First tuning method due to Ziegler & Nichols (1942)
  - Called Quarter-Amplitude-Damping (QAD)
- "little black books"
- Default tuning (gain=1.0, Reset=1 min)
- Many people still do not use any method preferring to "tune-by-feel"
  - Classical control skills now rare
- Most older tuning methods try for "as fast as possible"
- Net result is each loop tuned independently
  - process dynamics not coordinated

Tuning Issues

- More aggressive – less robust – more resonance - less change in the process dynamics to cause instability
- Some loops require aggressive tuning for disturbance rejection – must be sure process dynamics are “constant” and carefully coordinate tuning in other loops in the system.
- Most loops benefit from the none-oscillatory tuning- allows coordinated tuning of all loops in the unit and minimizes resonance.

Tuning Issues

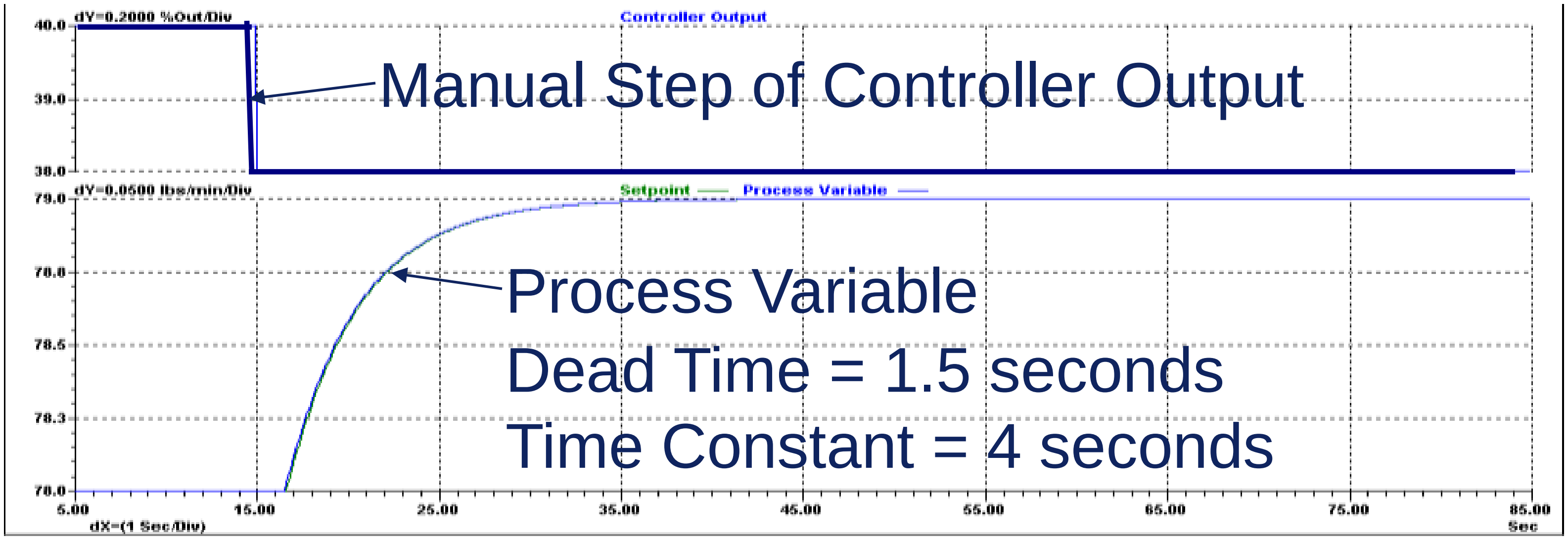
- "In addition, optimized tuning procedures for unaided feedback controllers have limited practical value for continuous processes; they yield results that are far inferior to those obtainable with well damped feedback controls with simple feedforward and override control."*

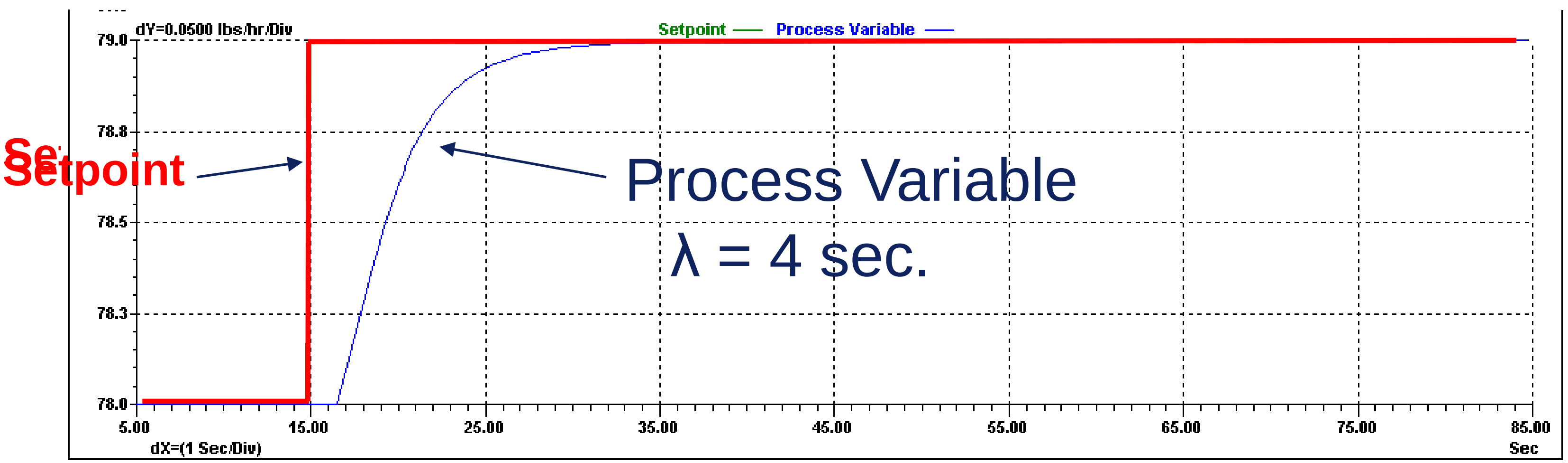
*Buckley. P.S.. "Override Controls on a Chemical Reactor," in Proceedings of Texas A&M Instrumentation Symposium, Jan. 1970.

Coordinated Loop Tuning

- Manipulate the closed loop time constant, Lambda, (λ) to:
  - reject disturbances while ensuring stability
  - separate the break frequency of cascaded or interacting loops
  - treat all the loops in a Unit Operation as a SYSTEM
  - control variability pathways
- Allows optimization aimed at manufacture of uniform product more efficiently

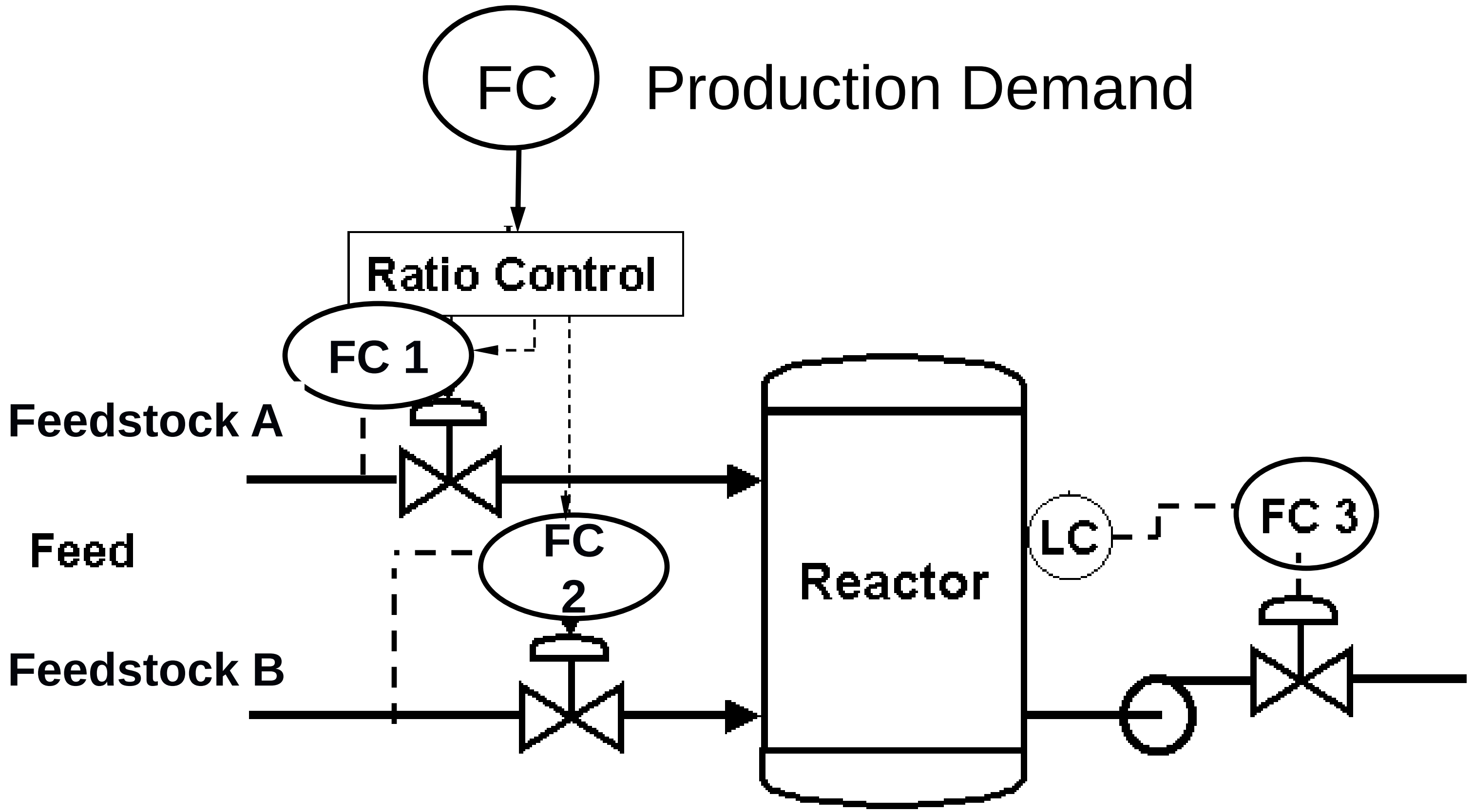
Coordinated Tuning – Select Speed of Response



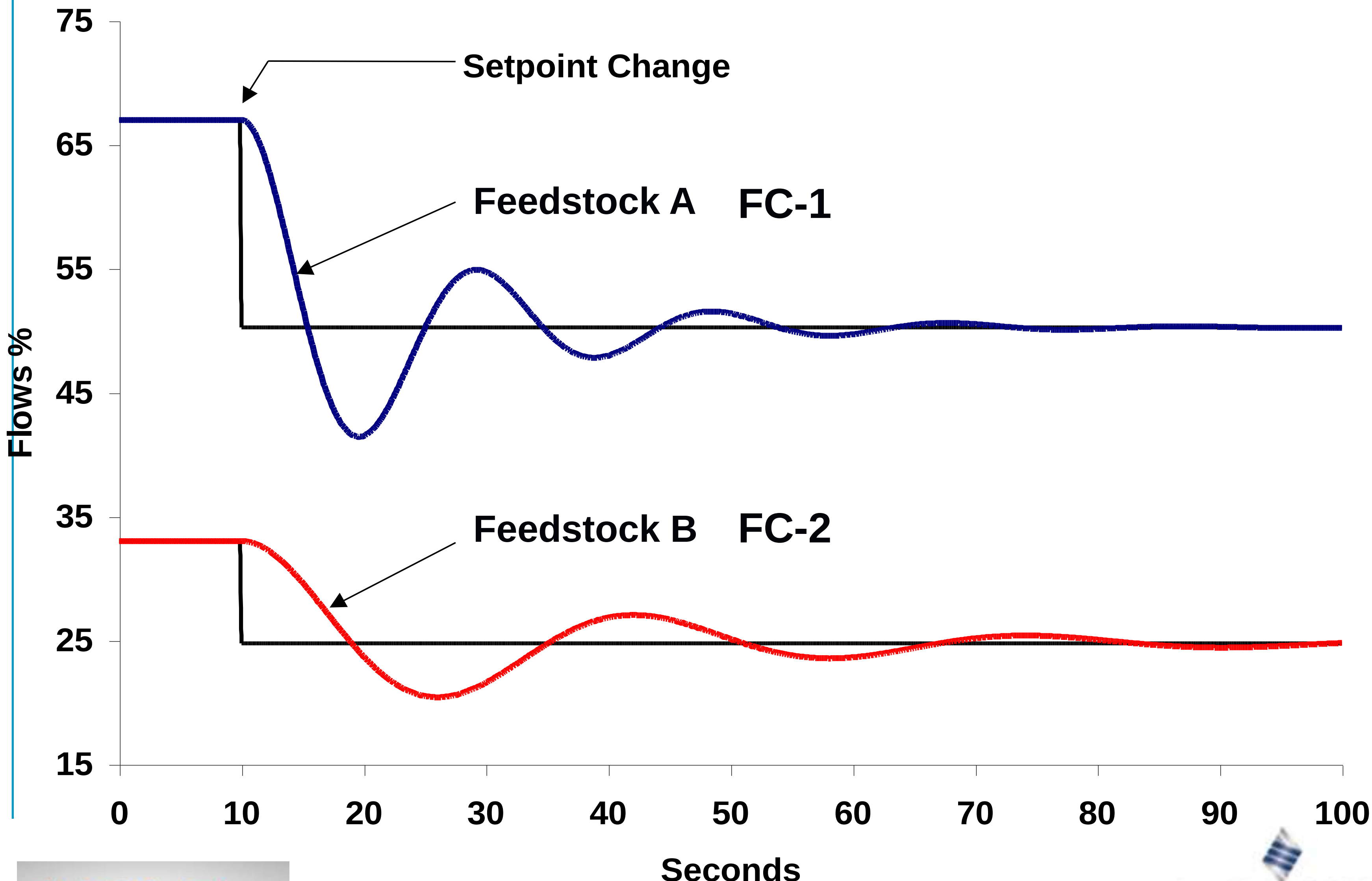


Coordinated Tuning of all Loops as a System

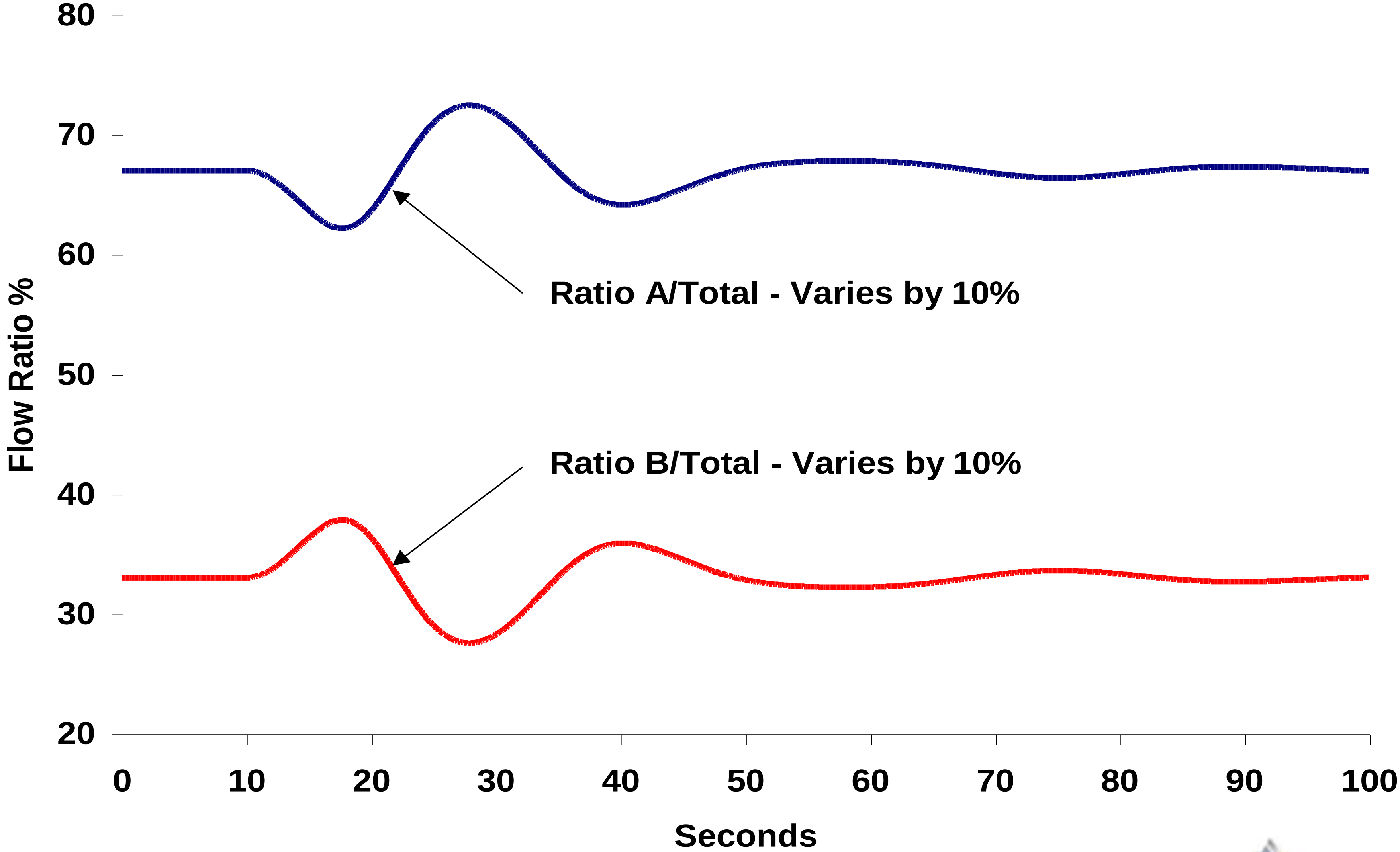
→ Reactor feed Process Goal: constant feedstock ratios



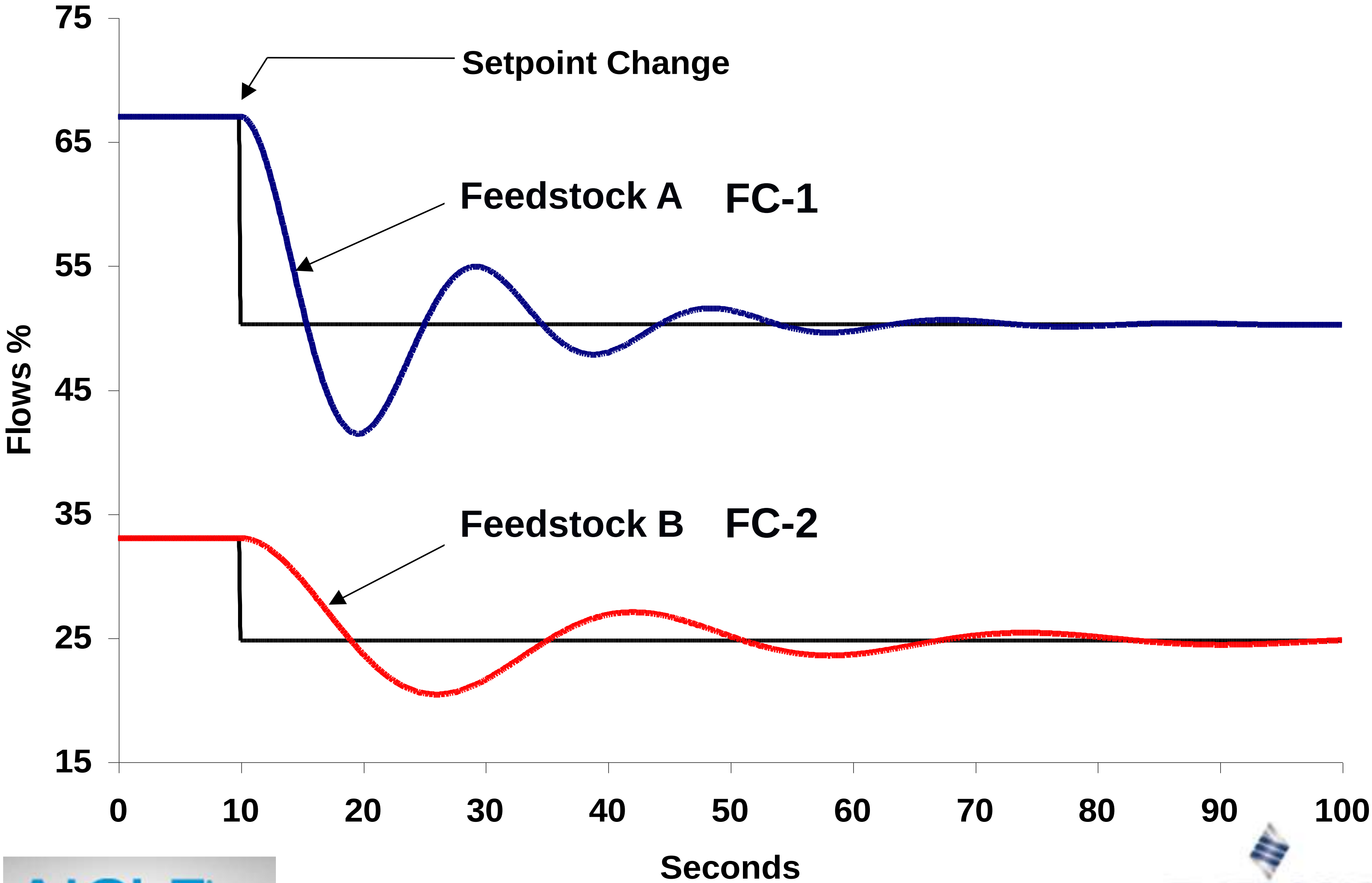
Ziegler-Nichols Tuning



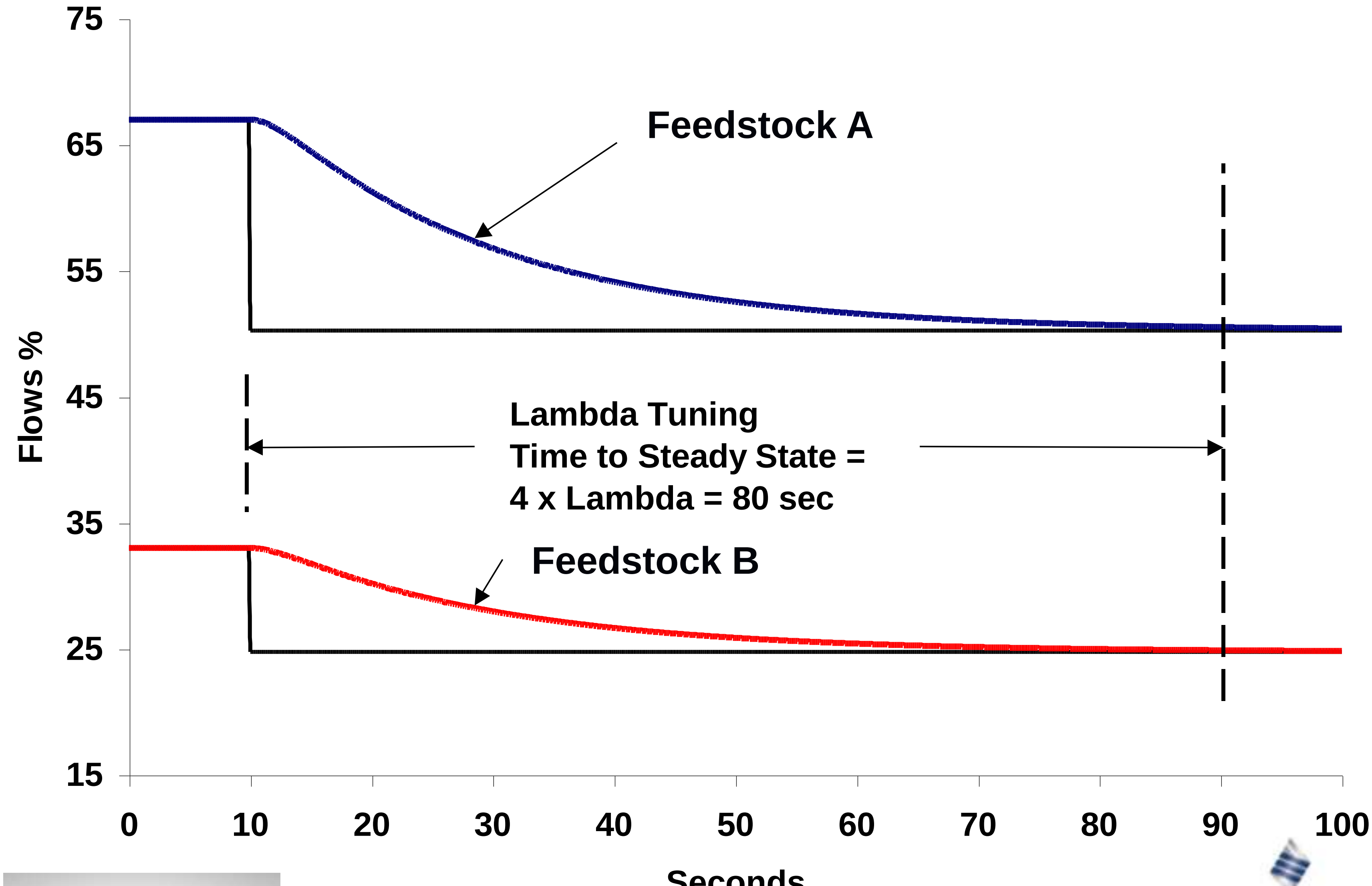
Impact of Z-N Tuning - Feedstock Ratios Upset



Ziegler-Nichols Tuning



Lambda Tune Both Loops for Identical Response



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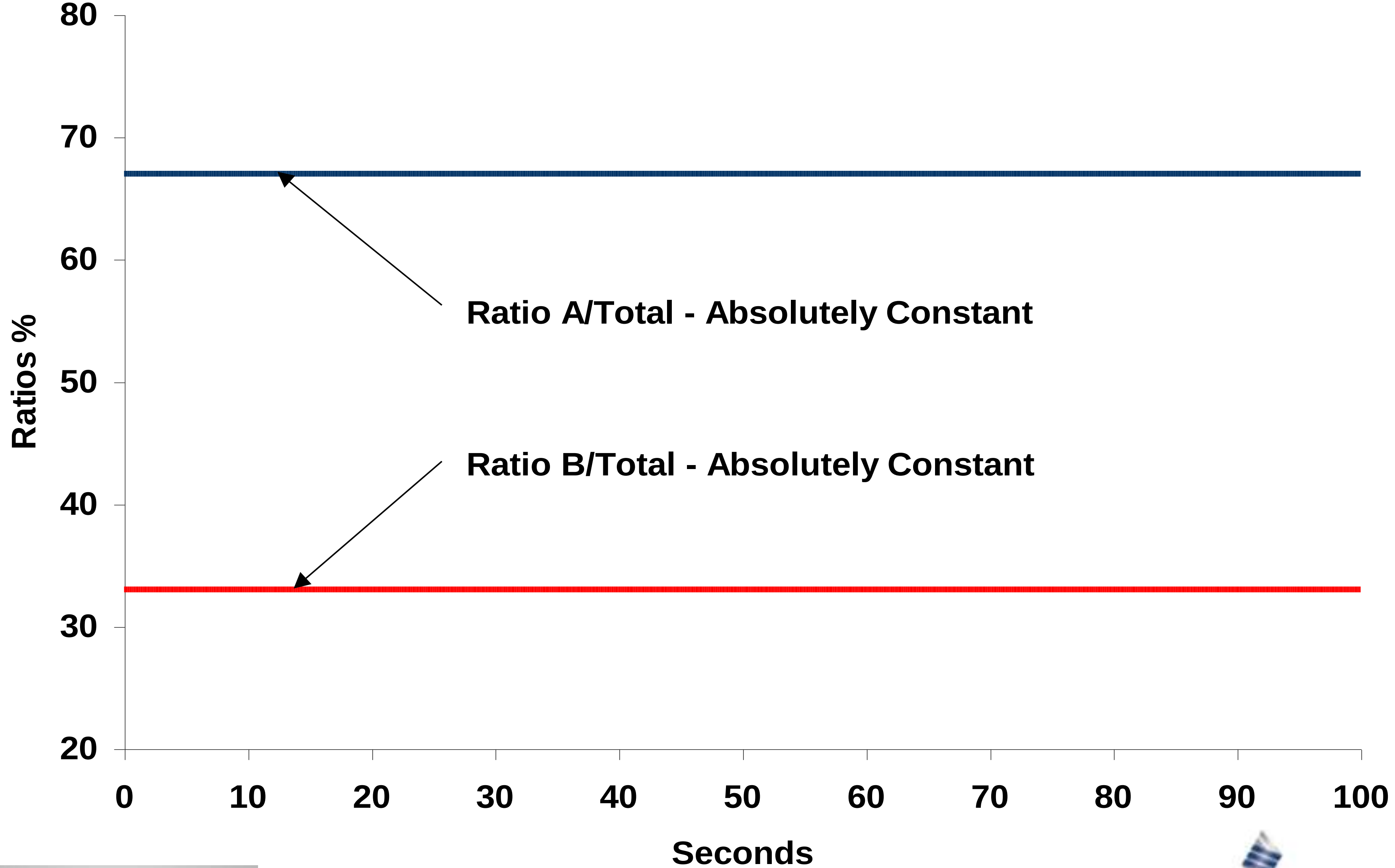
Impact of Lambda Tuning - Feedstock Ratios Constant



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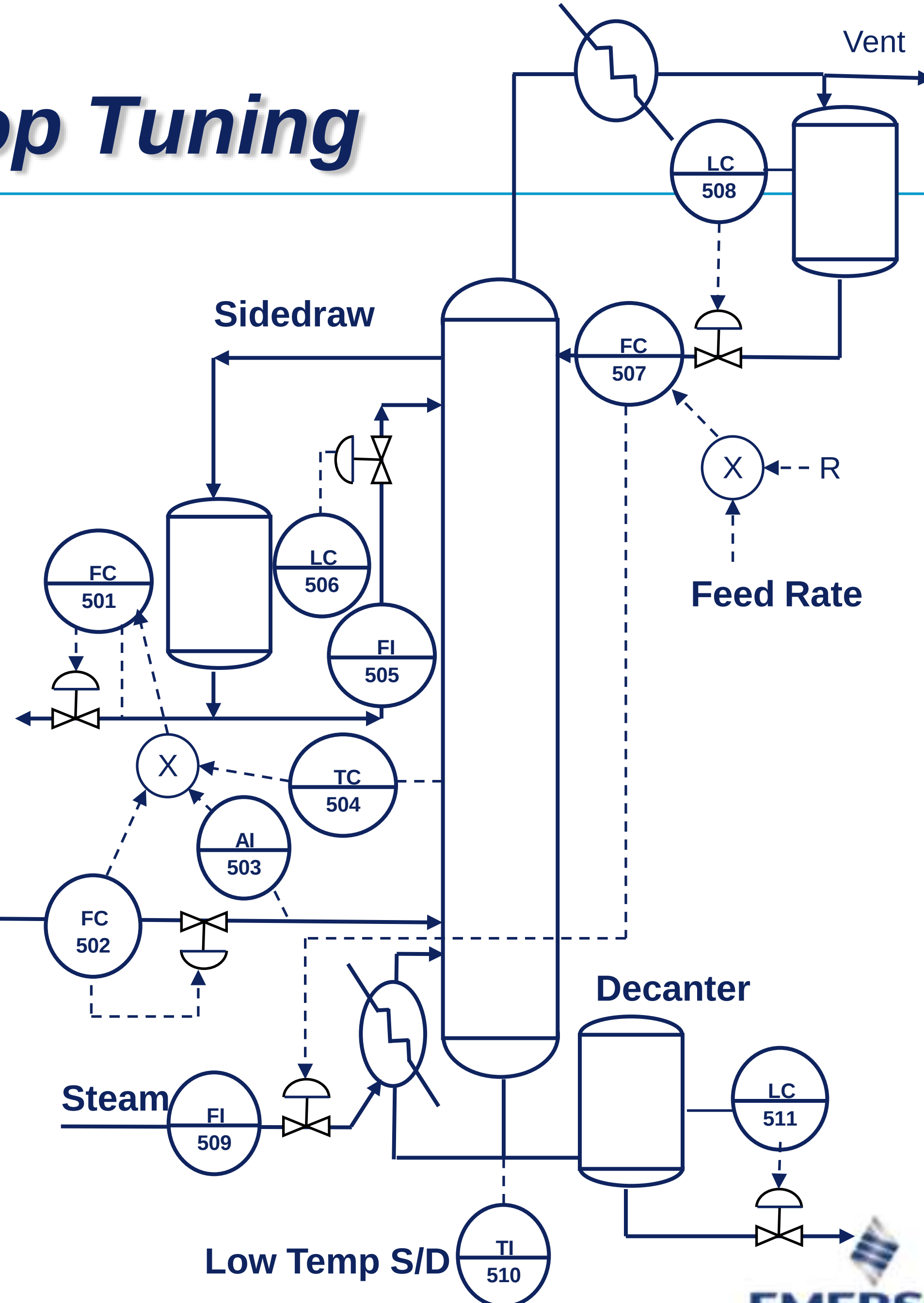
Coordinated Loop Tuning

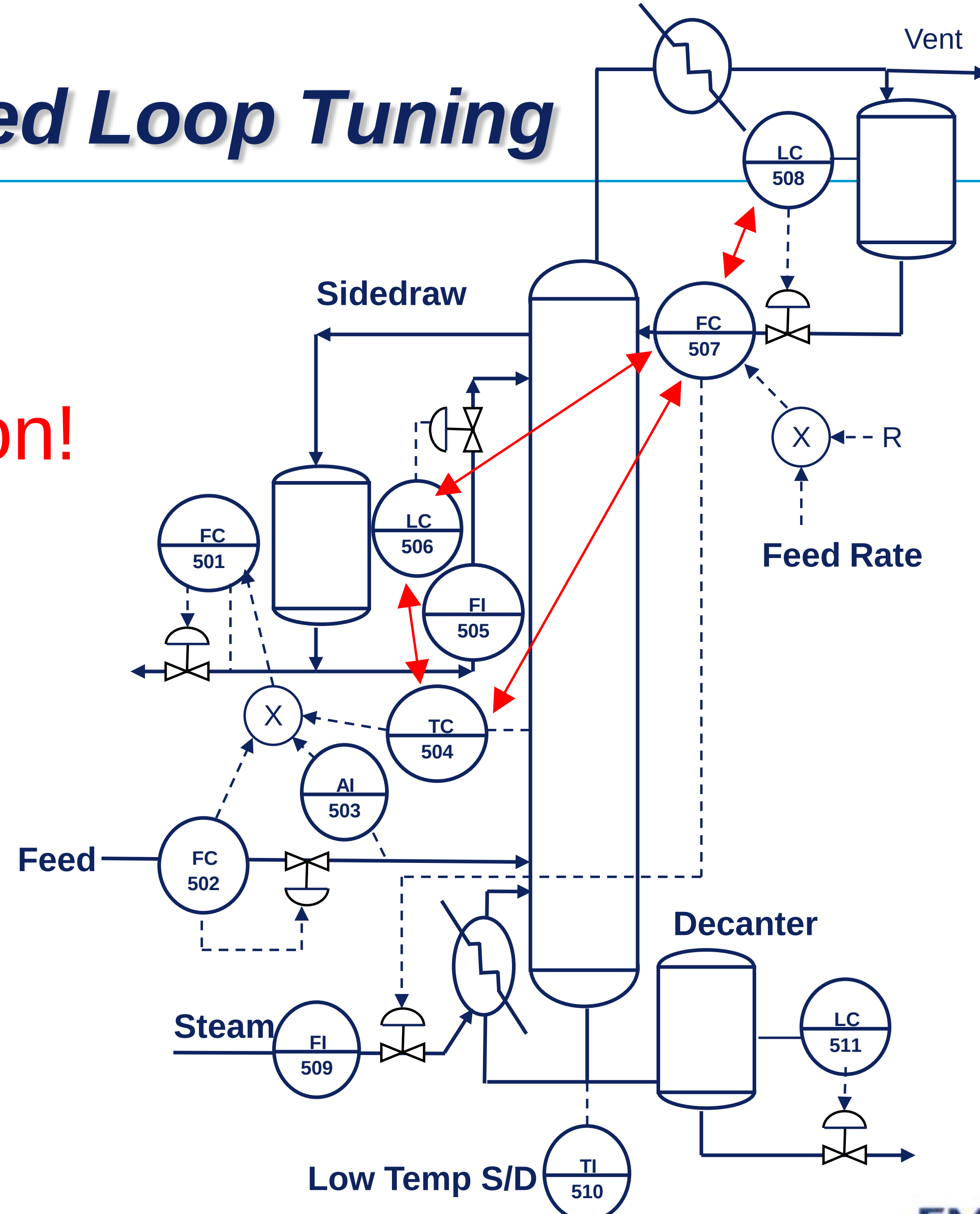
Goal: Reduce Steam Usage

Issues: When the reflux was reduced, the steam was reduced and the product was on spec. However, the column control variables started to oscillate and the column tripped on low base Temp.



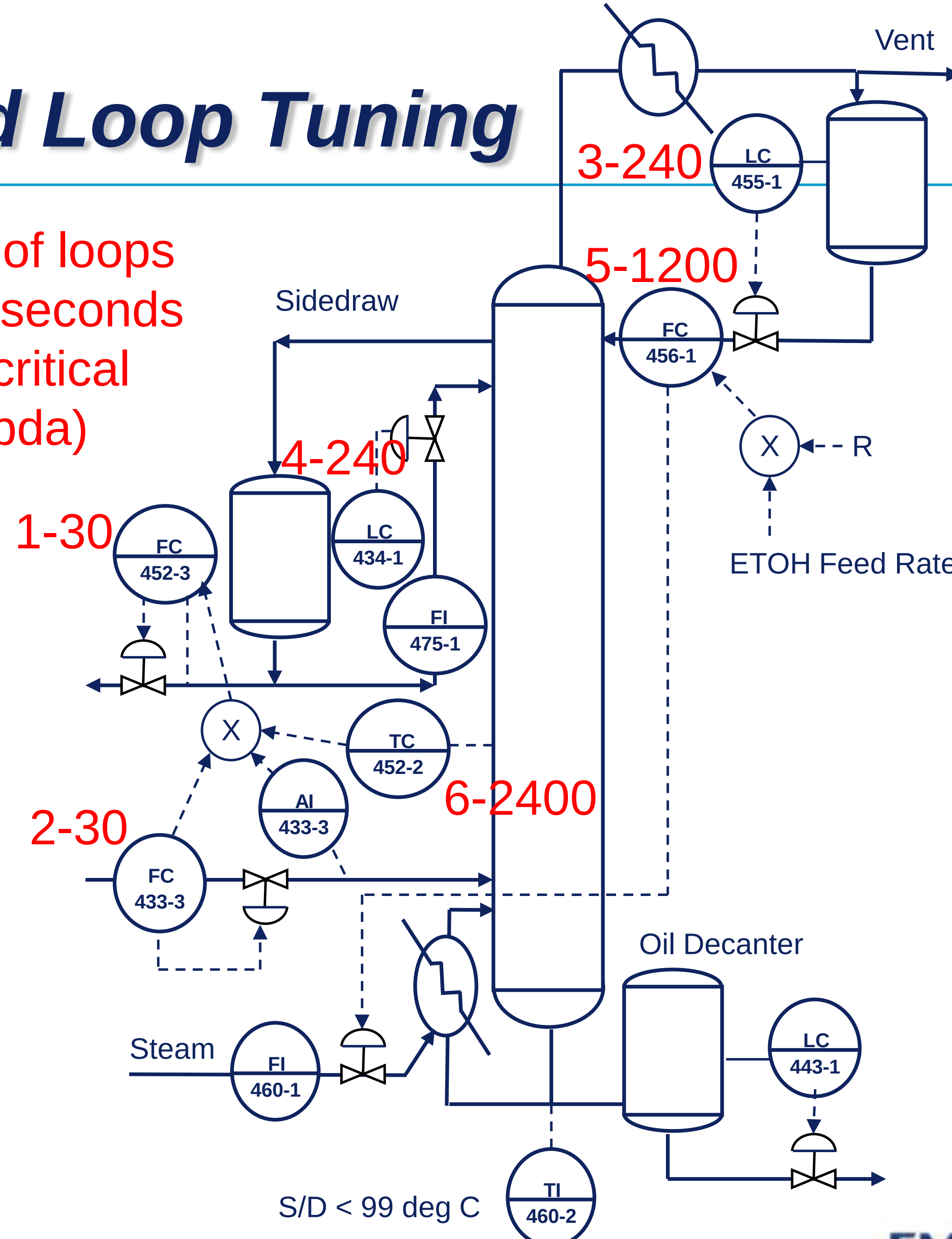
Coordinated Loop Tuning

Interaction!



Coordinated Loop Tuning

Coordinate speed of loops
Lambda shown in seconds
Tuning sequence critical
(Sequence – Lambda)



Results of Coordinated Loop Tuning

- Less varability of key process variables which reduced low base temperature shutdowns
- Reduced reflux from 275 lbs/hr to 200 lbs/hr
- Reduced steam usage by 25%

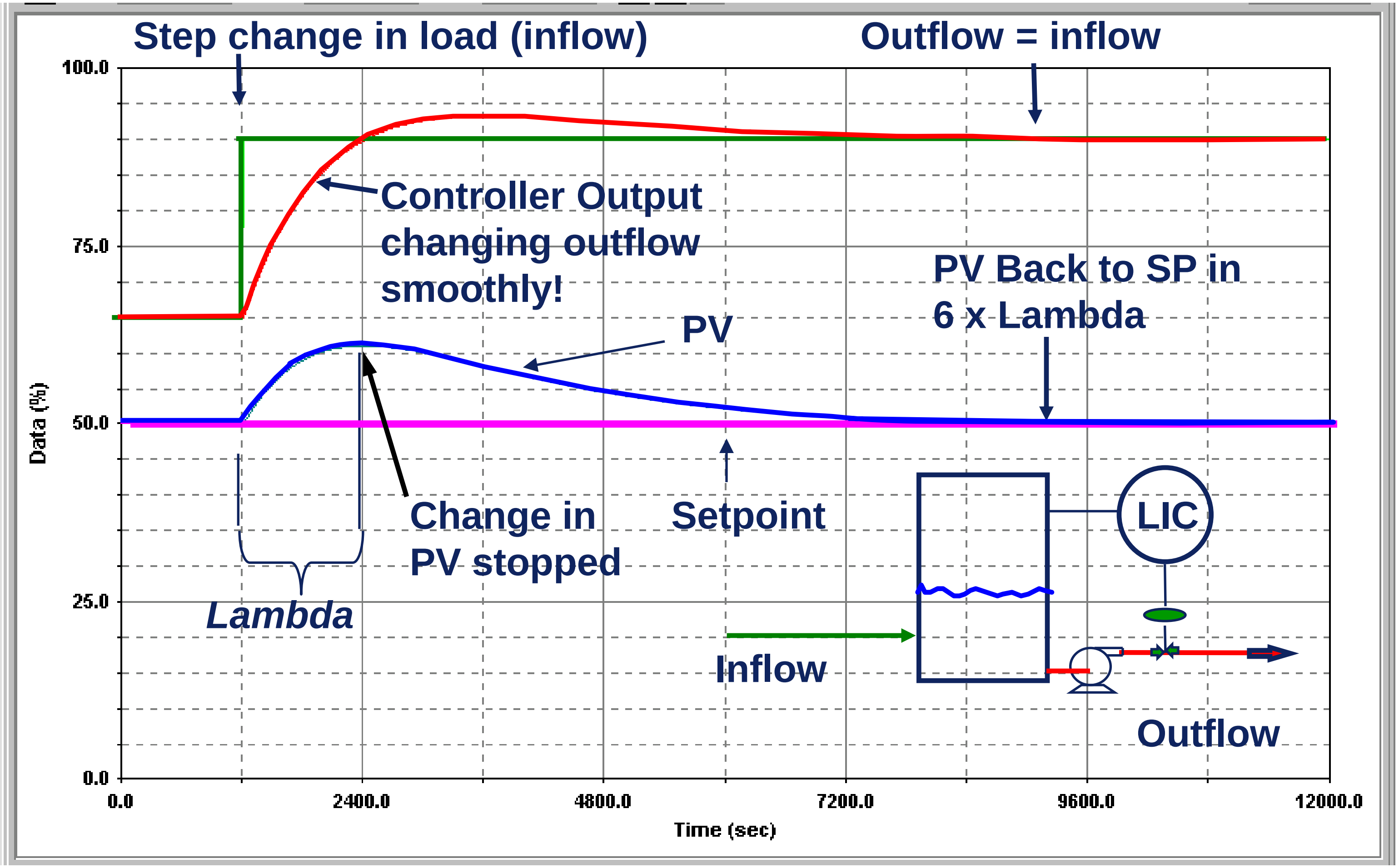
Attenuate Variability with Control/Equipment

- "Capacity" in the process can be used to attenuate or absorb variability

- Primary source of process capacity is level control

- To utilize level control as a capacity tune the controller as slow as possible but still "fast" enough to hold the PV within the allowable level deviation (ALD) for a maximum load change

Lambda Tuning for Integrating Processes - Load Disturbance Response

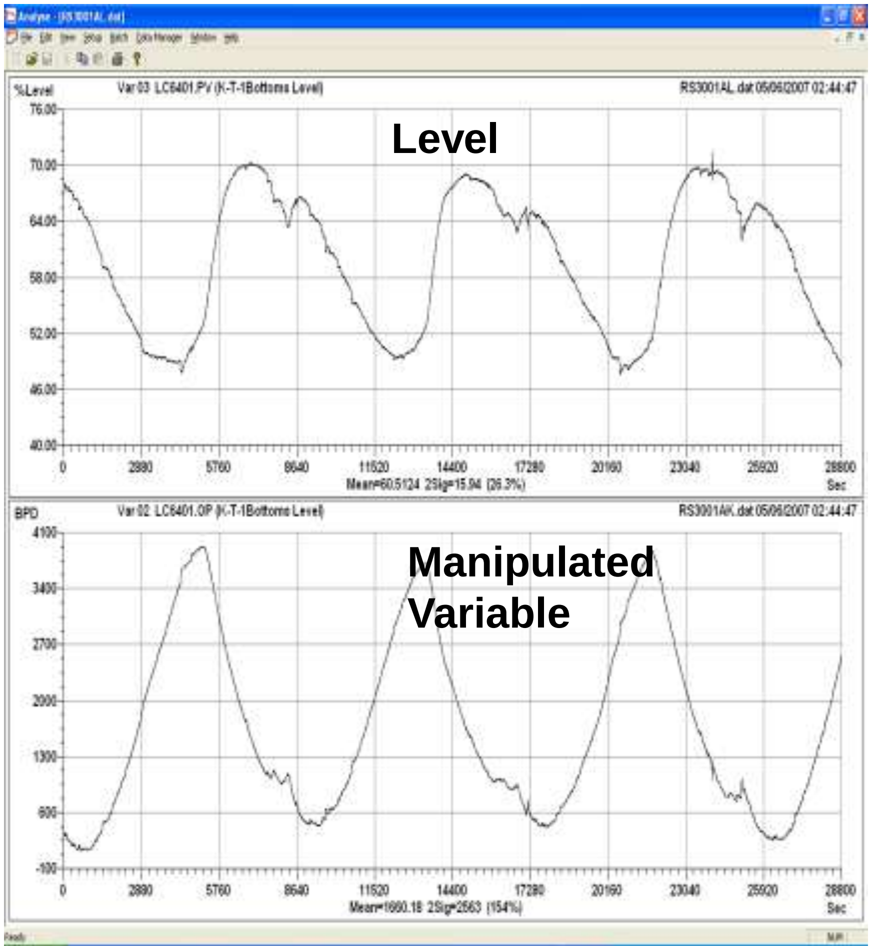


Utilize Level Control as Variability Sinks

- Choose the arrest time (Lambda) “slow” enough to provide a variability sink yet maintain level within the allowable variation
- Lambda = f (ALV / (Kp * MLD)
  - ALV = Allowable Level Variation
  - Kp = Integrating process gain
  - MLD = Maximum Load Disturbance

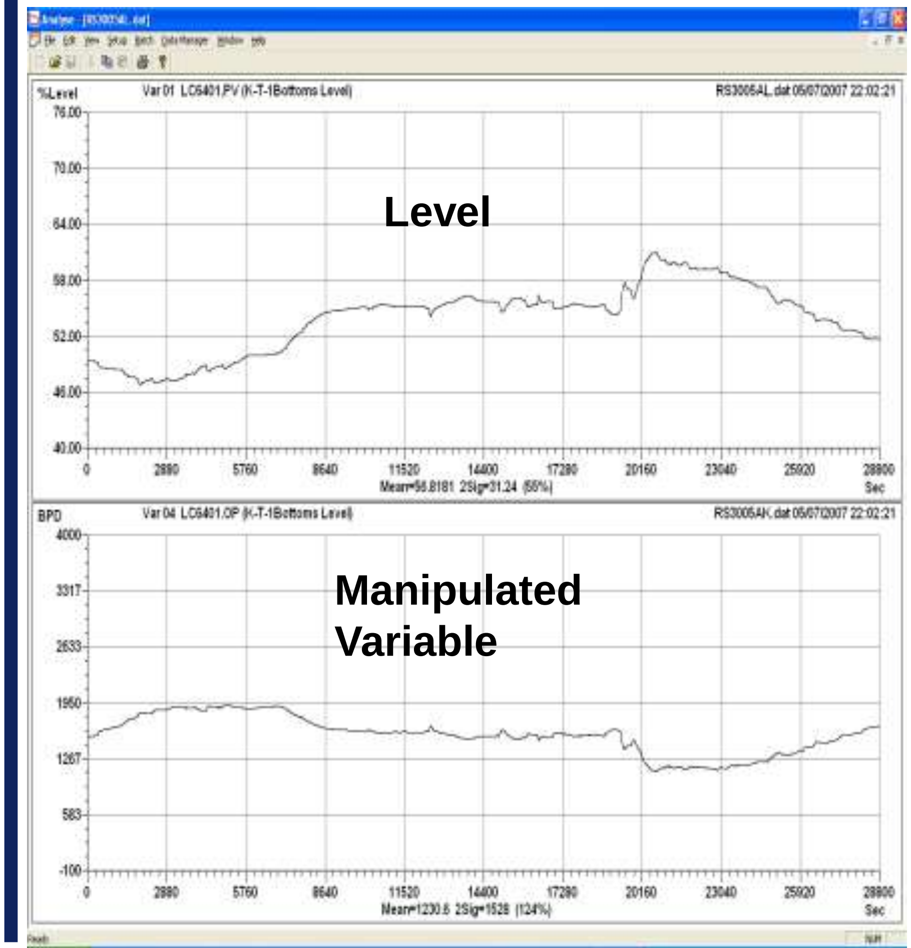
Level Tuning – Results Coker Tower

Before



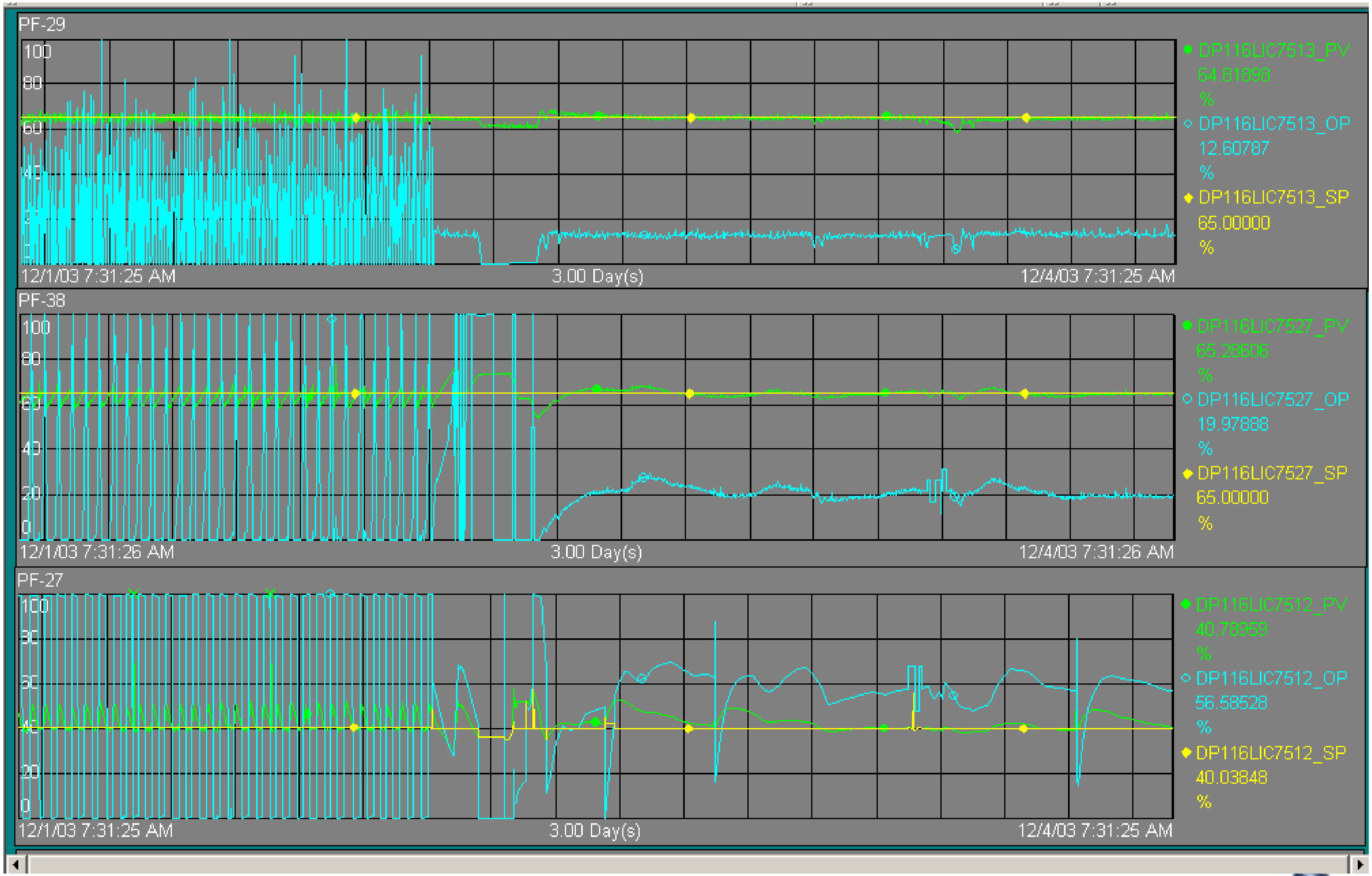
8 hours

After



8 hours

Reactor Levels and Outflows



Utilize Cascade and Feedforward

"In addition, optimized tuning procedures for unaided feedback controllers have limited practical value for continuous processes; they yield results that are far inferior to those obtainable with well damped feedback controls with simple feedforward and override control."*

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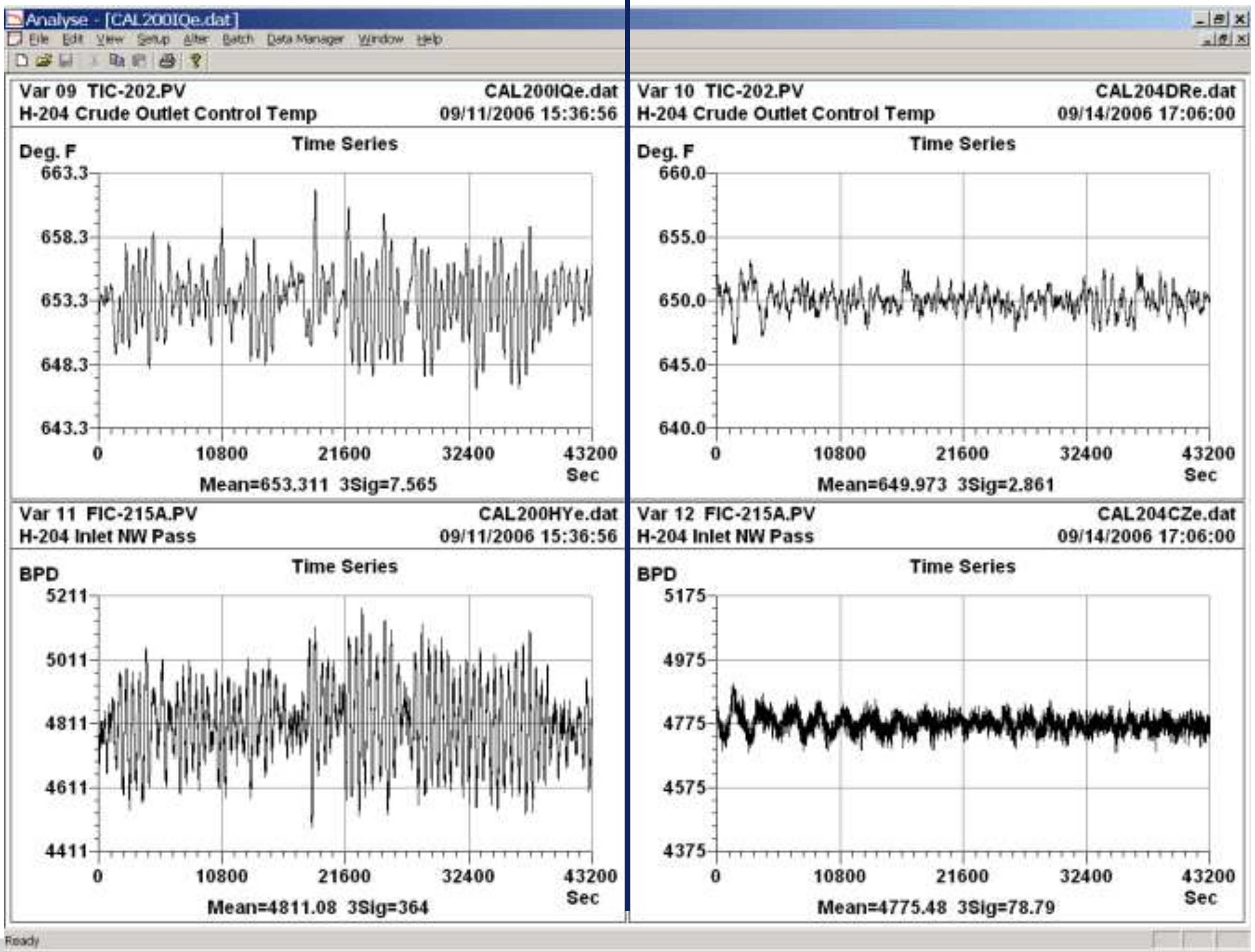
Utilize Cascade and Feedforward

Before | **After**

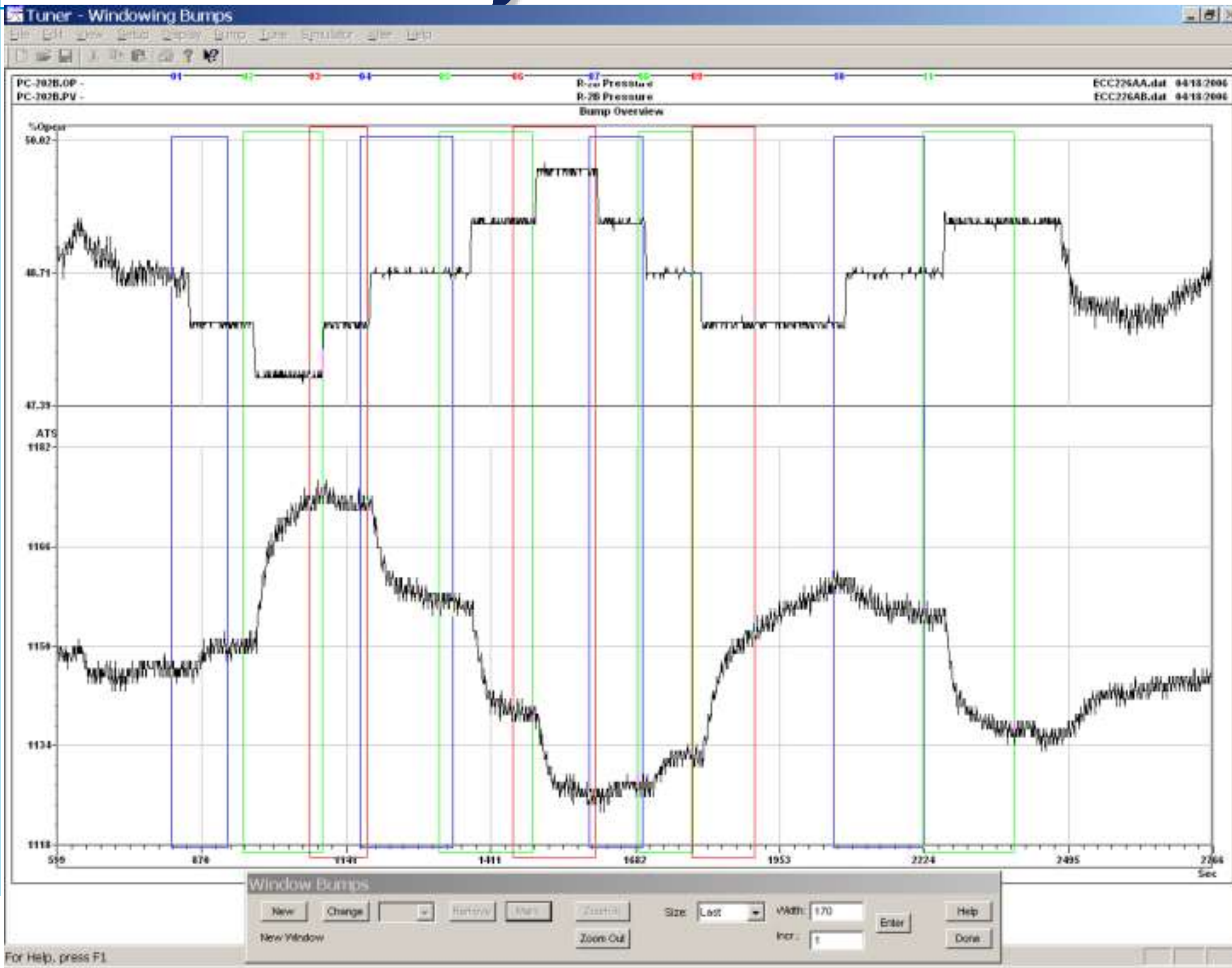


Process Analysis Toolkit

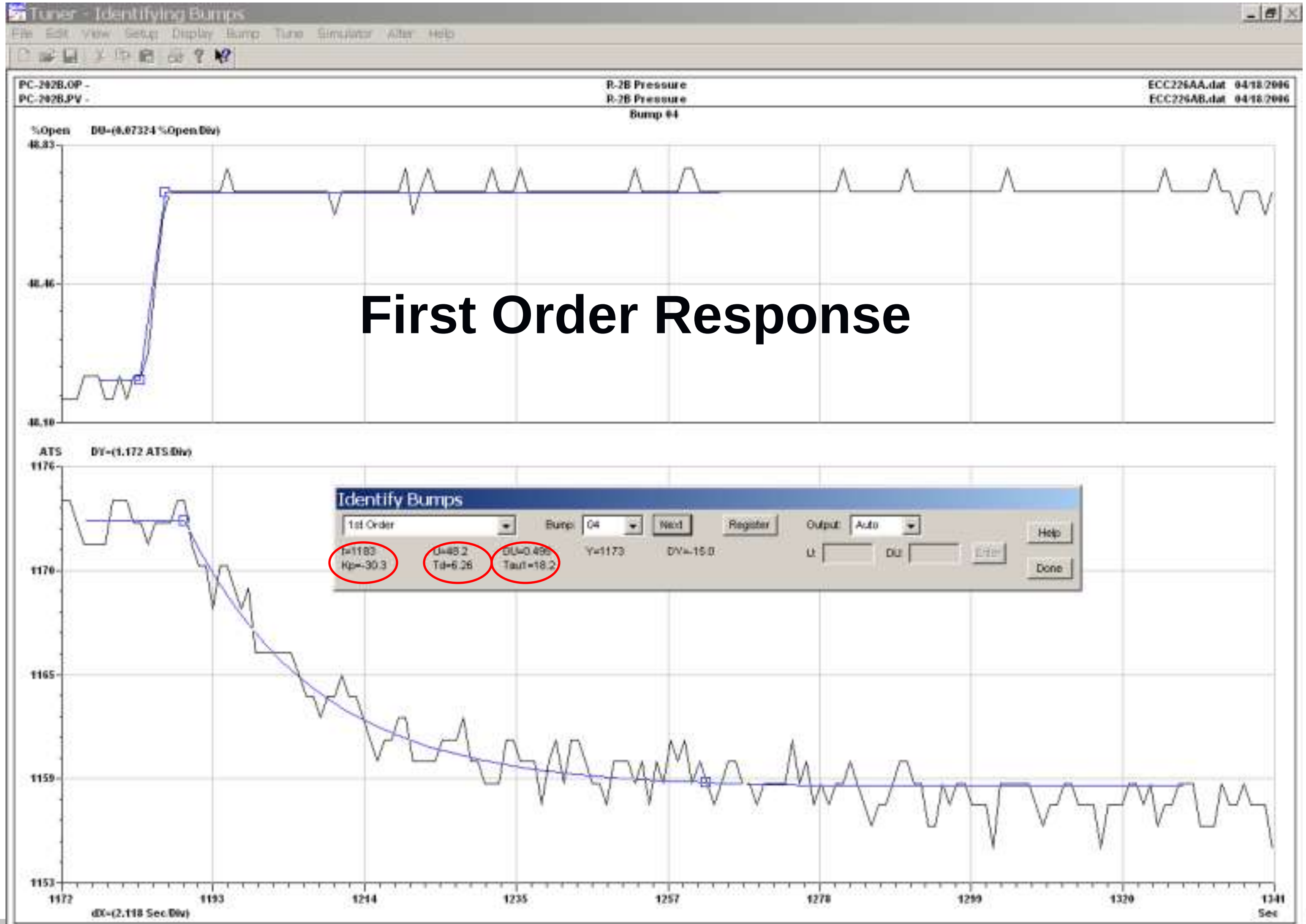
- You MUST have a process dynamics analysis and diagnostic toolkit of some type!

- If you don't have process analysis toolkit, you are leaving a TON of money on the basement floor!

Process Analysis Toolkit



Process Analysis Toolkit



Process Analysis Toolkit

Bump Summary

Model: 1st Order

	Bump	DU	DY	Kp	Td	Tau1
*	01	-0.498	4.02	-8.06	7.73	11.1
	02	-0.546	21.8	-39.9	6.01	22.6
*	03	0.488	-1.87	-3.84	8.15	13.2
	04	0.495	-15.9	-32.1	6.26	25.6
	05	0.500	-17.7	-35.3	4.66	21.5
	06	0.500	-13.9	-27.8	0.258	24.8
*	07	-0.503	1.83	-3.65	23.3	10.1
*	08	-0.498	5.49	-11.0	16.3	16.4
	09	-0.501	20.0	-39.9	3.54	23.1

Discard

Reset

Bump Table Summary

	Kp	Td	Tau1
Low Spread(%)	12.8	93.5	8.58
Average	-35.4	3.95	23.5
High Spread(%)	21.6	58.4	8.59

Suggested Values ◉ Auto Discard ○ Man. Discard

	Kp	Td	Tau1
Nominal	-35.4	3.95	23.5
Spread	21.6	58.4	8.59

Calc

Actual: -35.4 | 3.95 | 23.5

Units: DU in %Open, DY in ATS, Kp in ATS/%Open,
Time Parameters in Sec

Done Help

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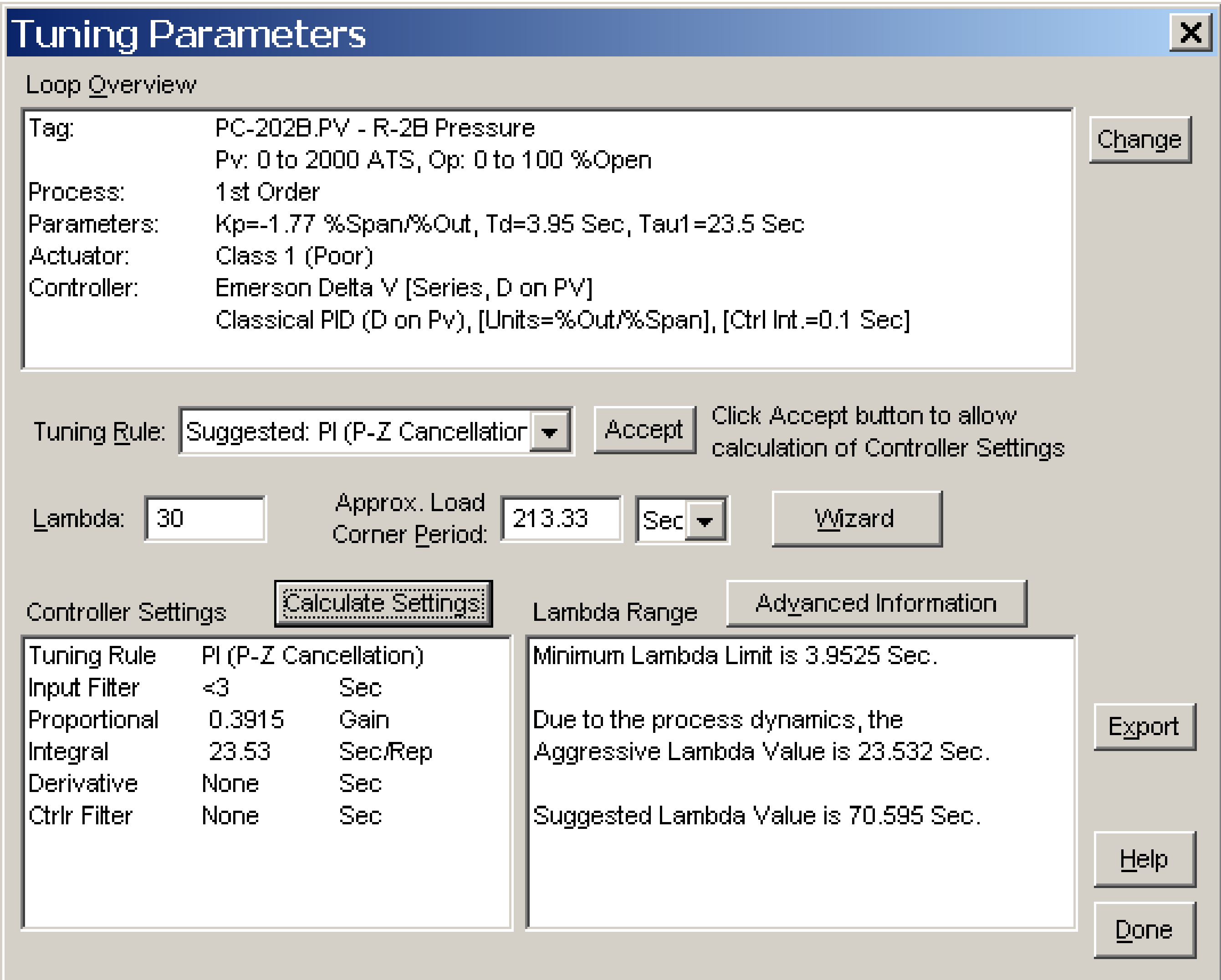
Process Analysis Toolkit



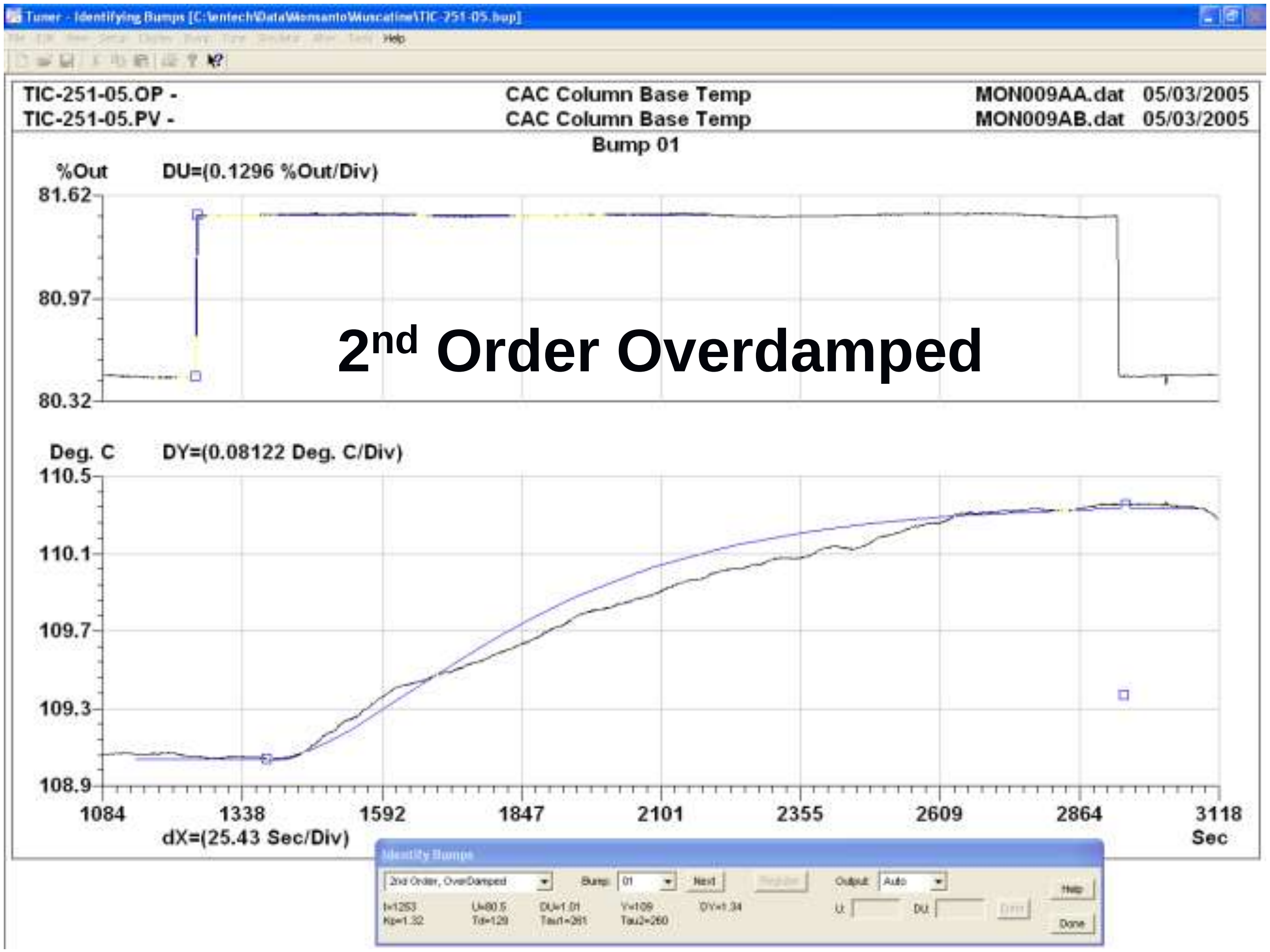
Process Analysis Toolkit

Identifying Bumps

Response | Bump | Register | Help

- A Pure Gain
- B 1st Order
- ✔ C 2nd Order, OverDamped
- D 2nd Order, UnderDamped
- E 2nd Order, Lead
- F 2nd Order, Lead with Overshoot
- G 2nd Order, Non-Minimum Phase
- H Integrator
- I Integrator, 1st Order Lag
- J Integrator, 1st Order Lead
- K Integrator, Non-Minimum Phase

Emerson's EnTech Toolkit



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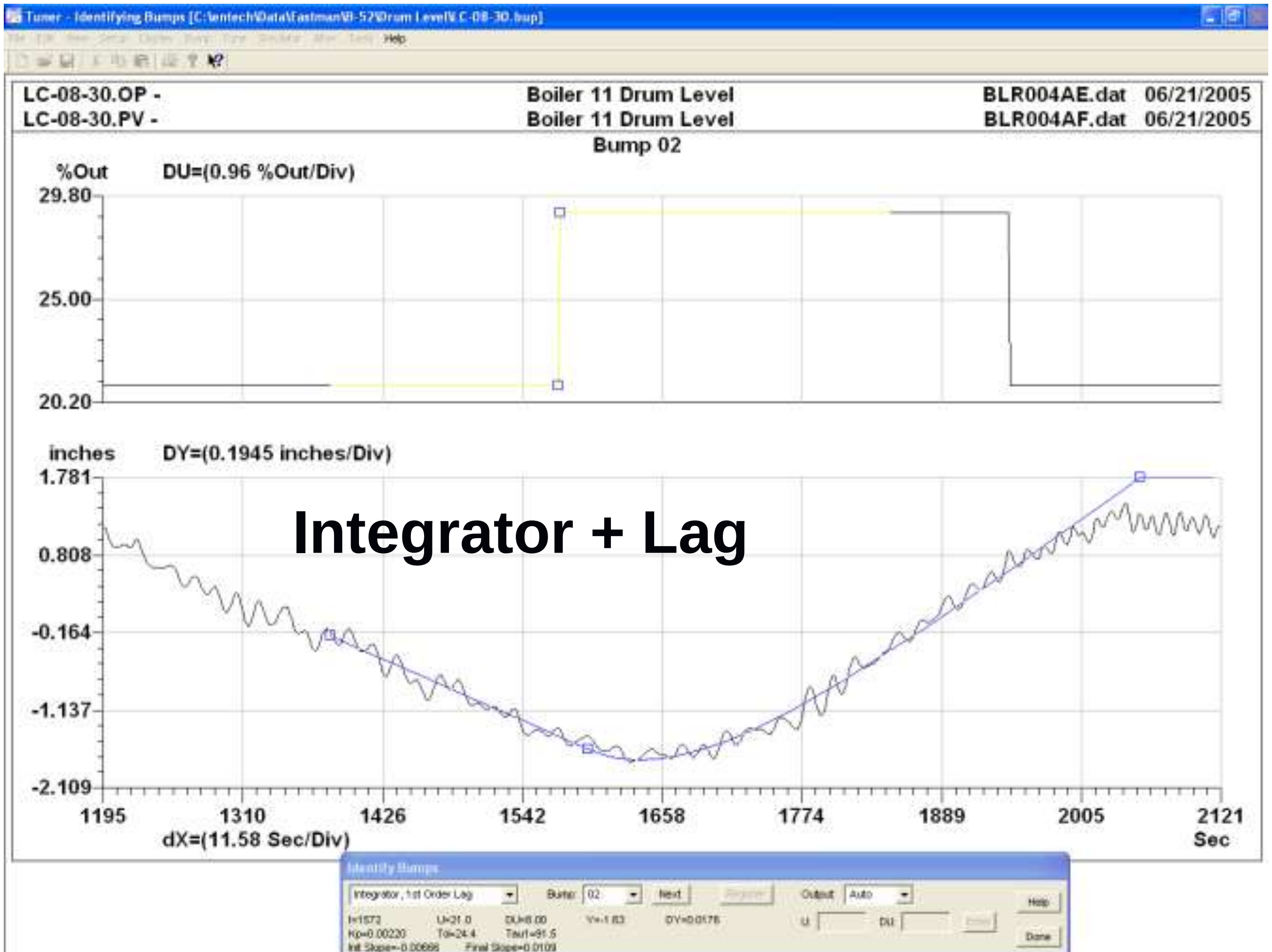

Summary

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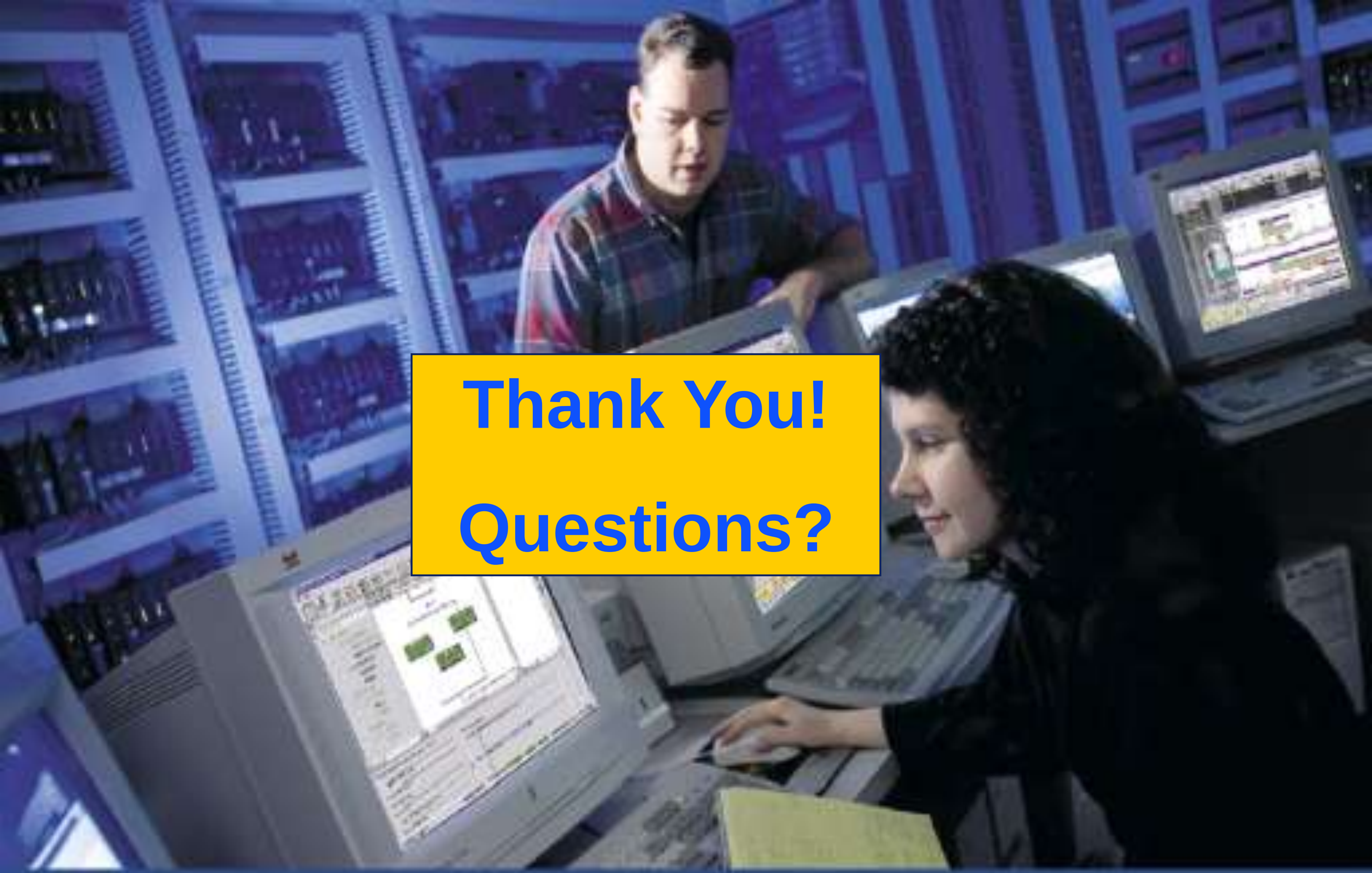
- Tune the controllers to meet control objectives
  - Coordinate Tuning Speed Based on Operating Objectives
  - Attenuate Variability with Control/Equipment
- Utilize cascade and feed forward control
- Use a process analysis system to diagnose problems and tune loops

Process Control Foundation Courses

- Course 9030, PCE I – Process Dynamics, Control and Tuning Fundamentals - 4.5 days
- Course 9031, PCE II – Process Analysis and Minimizing Variability – 4.5 days
- Course 9032, MLT – Modern Loop Tuning – 4 days, can be taught onsite or at LBP office



Thank You!

Questions?