Process Dynamics and Advanced Loop Tuning

Identification of Common Process Dynamics and Loop Tuning Techniques for Difficult Dynamics

EMERSON EXCHANGE

Presenter

- James F. Beall IV

EMERSON.
Process Management

EMERSON EXCHANGE

Speaker Introduction – James Beall

- Native East-Texan (translator available)
- 19+ Years at Eastman Chemical Company
  - 9 years E&I Engineer
  - 10+ years DCS Group Leader (PROVOX, DeltaV)
  - Last 8 years process control diagnostics and optimization
- 22 years experience in process control
- Foundation Fieldbus Experience - 3 years, 3 boilers, portion of acetaldehyde

Introduction

- Identification of the dynamics of the process (the “process model”) is key to developing proper tuning for process controllers
- Topics
  – Overview of Process Dynamics
  – Tuning based on Process Dynamics
  – Coordinated Tuning Techniques
- Good performance of the control foundation provides great economic return and greater results from Advanced Process Control.

EMERSON EXCHANGE

Types of Process Dynamics

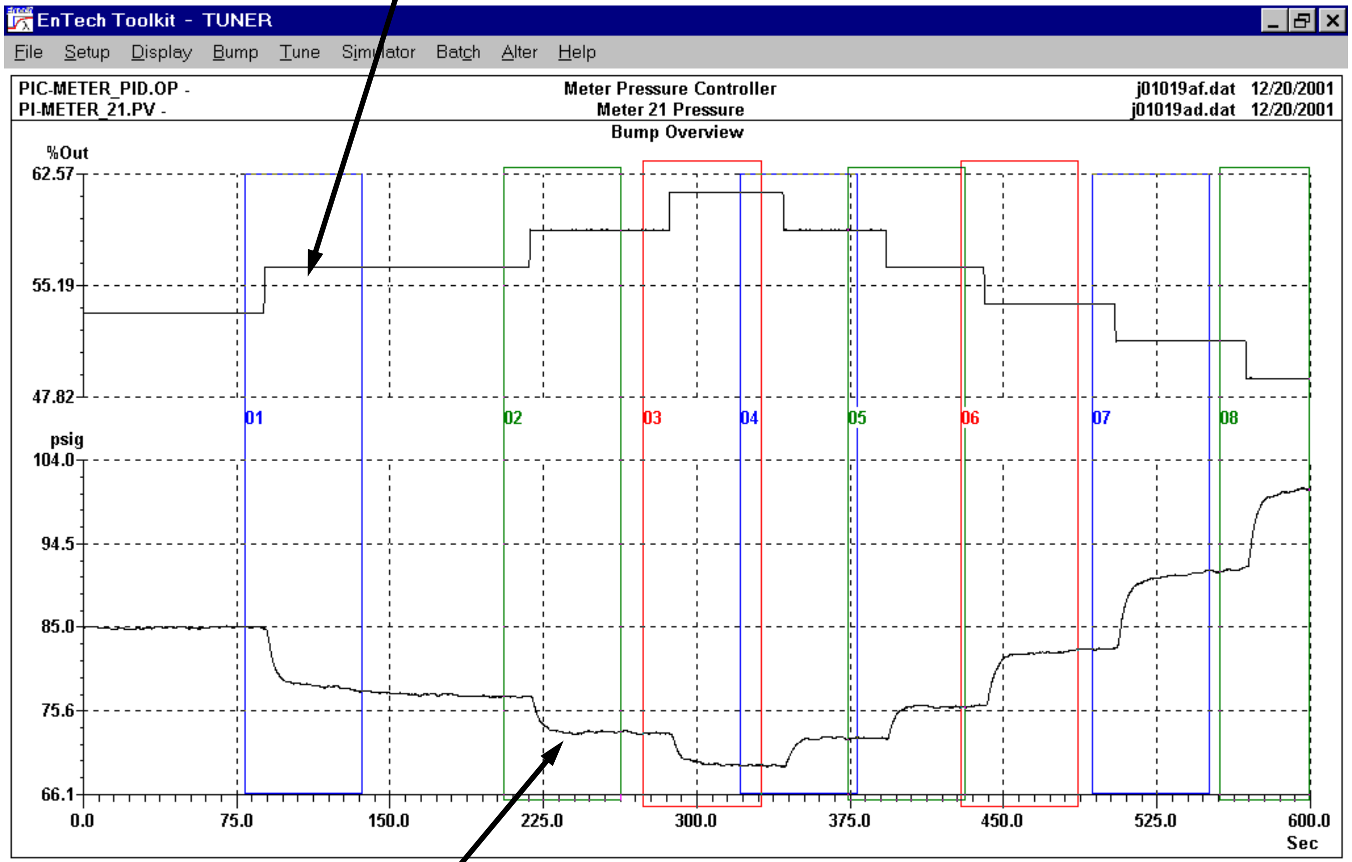
- Self Regulating

- Integrating

- Positive Feedback - “run away”

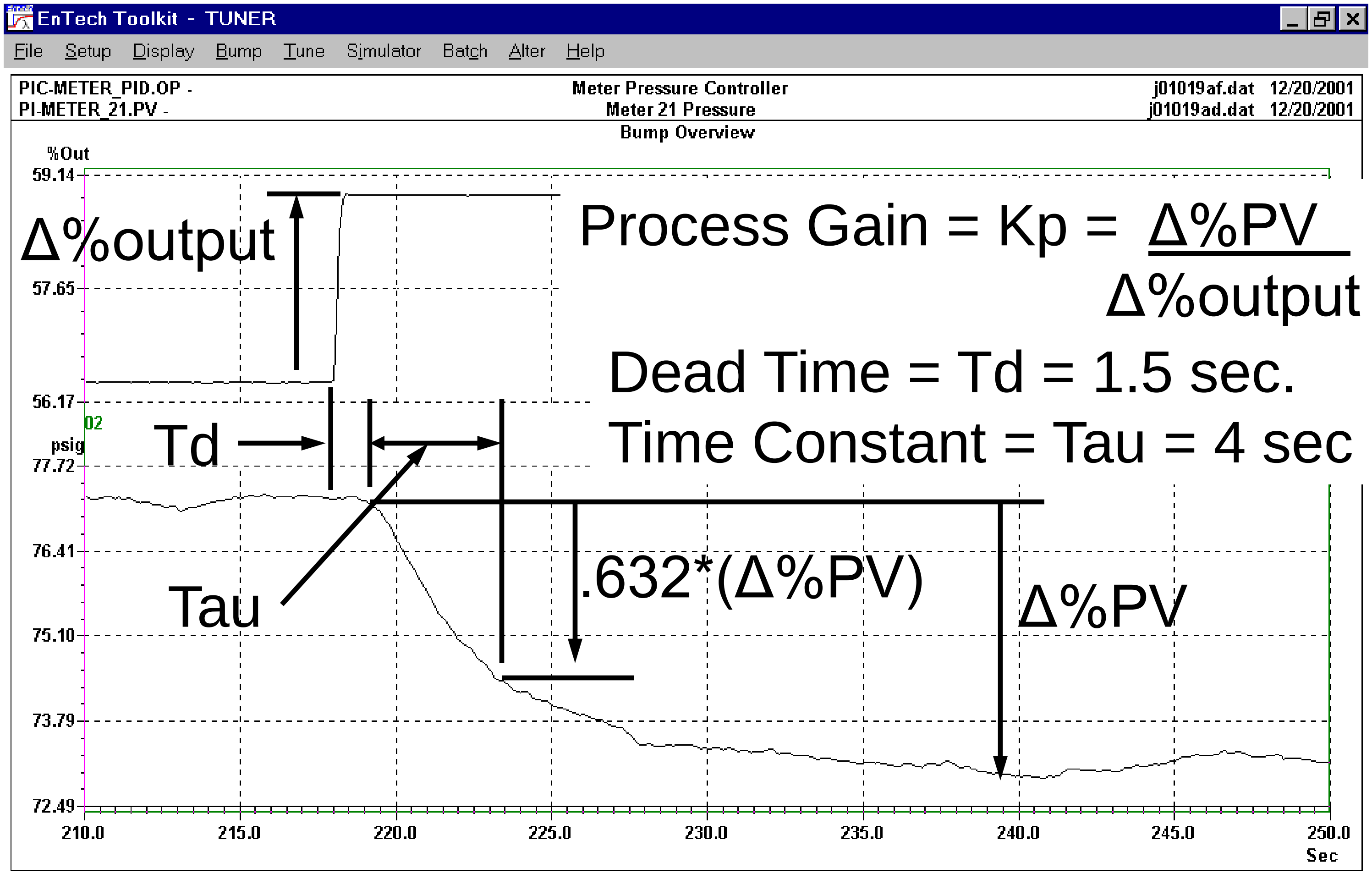
Self-Regulating Dynamics

Controller Output in manual



Process Variable

Self-Regulating – 1st Order +DT



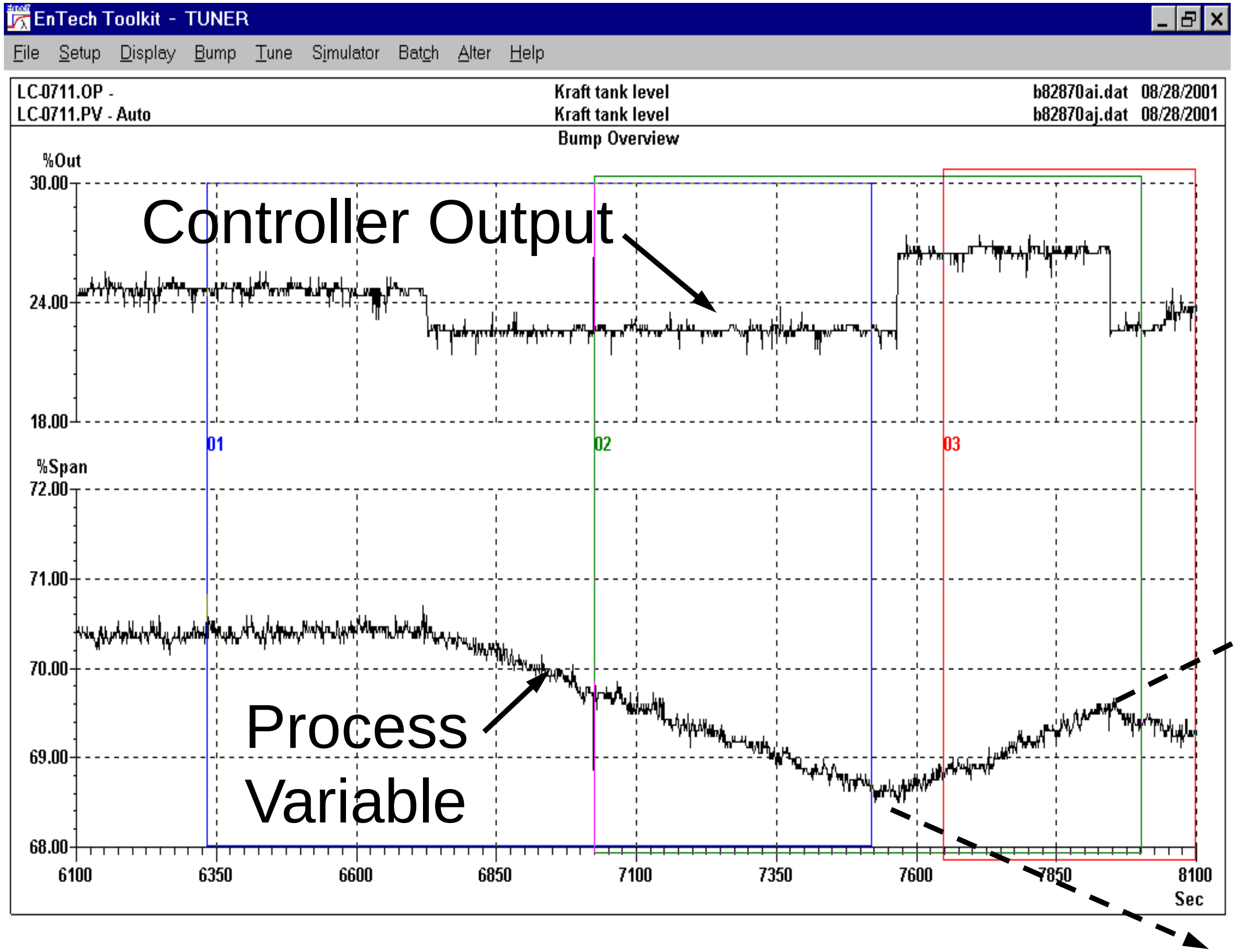
Process Gain = Kp = $\frac{\Delta\%PV}{\Delta\%output} = \frac{1\%}{2\%} = 0.5$

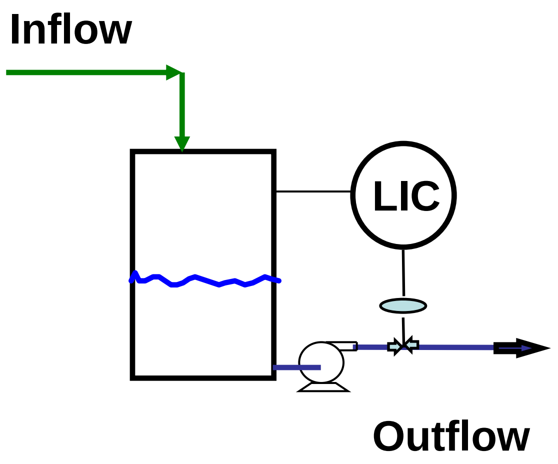
Dead Time = Td = 1.5 sec.

Time Constant = Tau = 4 sec

EMERSON EXCHANGE

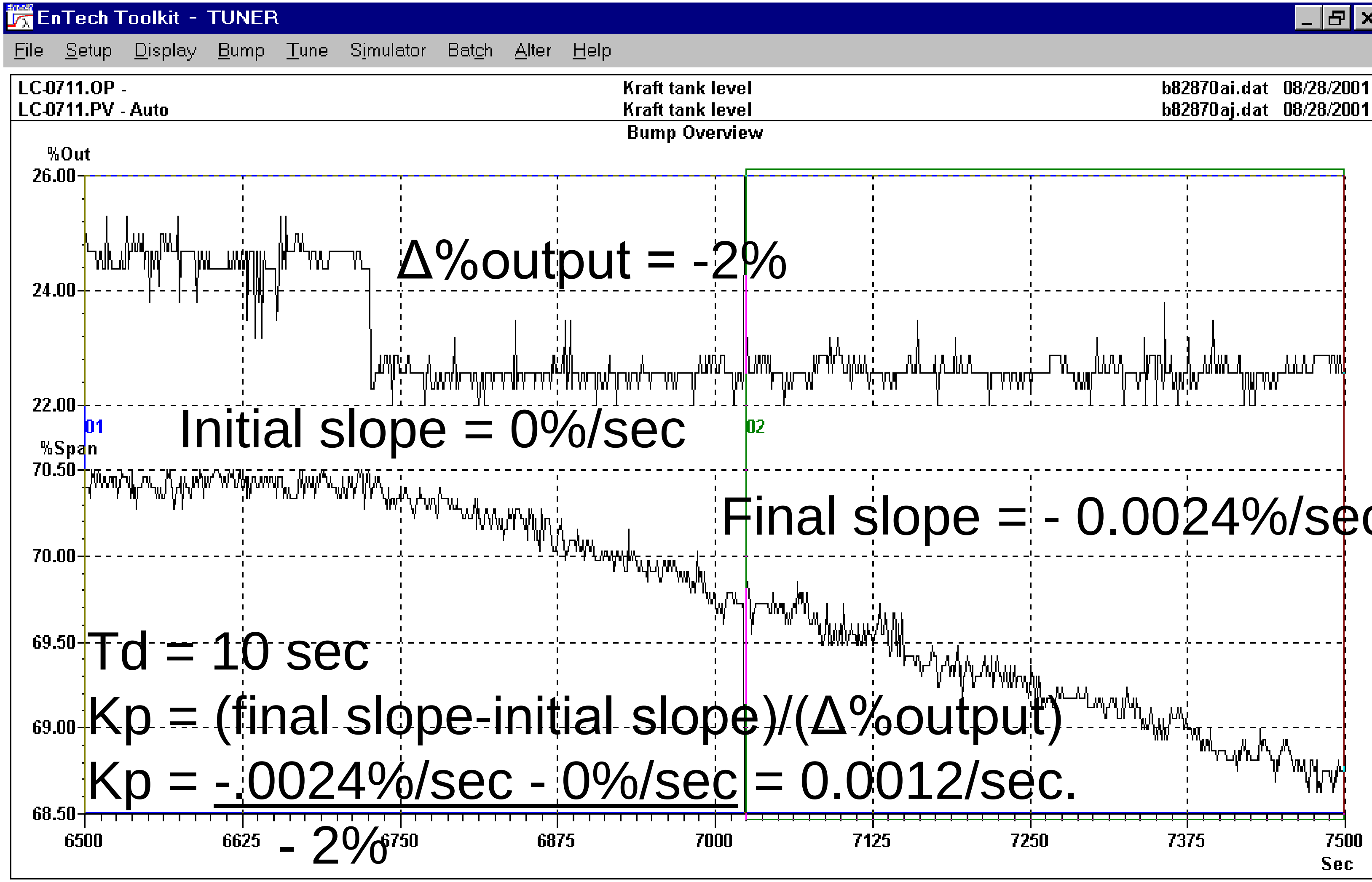
Integrating Dynamics





EMERSON EXCHANGE

Integrating + Dead Time



Δ%output = -2%

Initial slope = 0%/sec

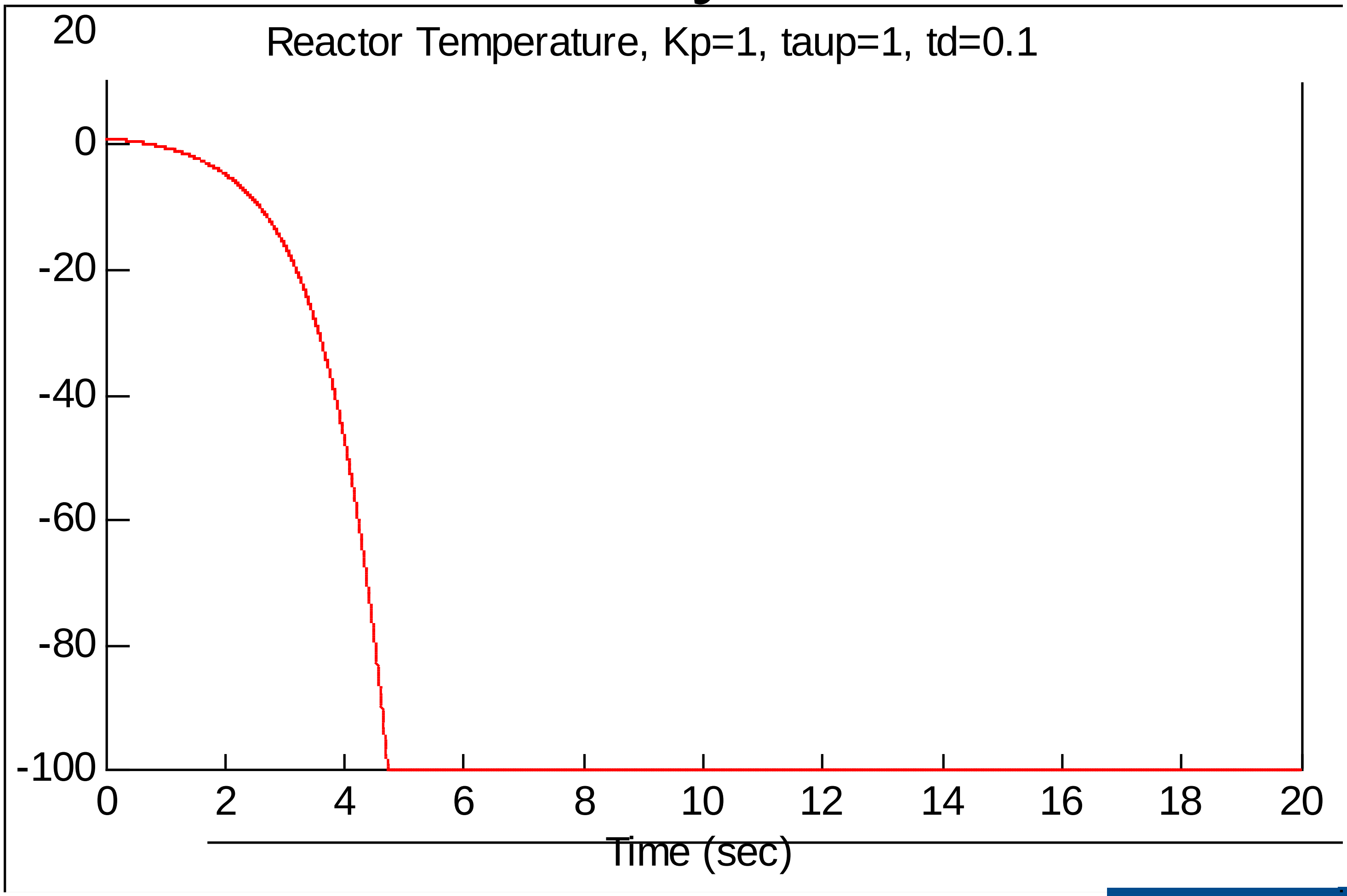
Final slope = - 0.0024%/sec.

Td = 10 sec

Kp = (final slope-initial slope)/(Δ%output)

$$Kp = \frac{-.0024\%/sec - 0\%/sec}{-2\%} = 0.0012/sec.$$

Positive Feedback Dynamics– “Runaway” Process



Coordinated Loop Tuning

- Manipulate the closed loop response 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
  - Manage loop resonance
- Allows optimization aimed at manufacture of uniform product more efficiently

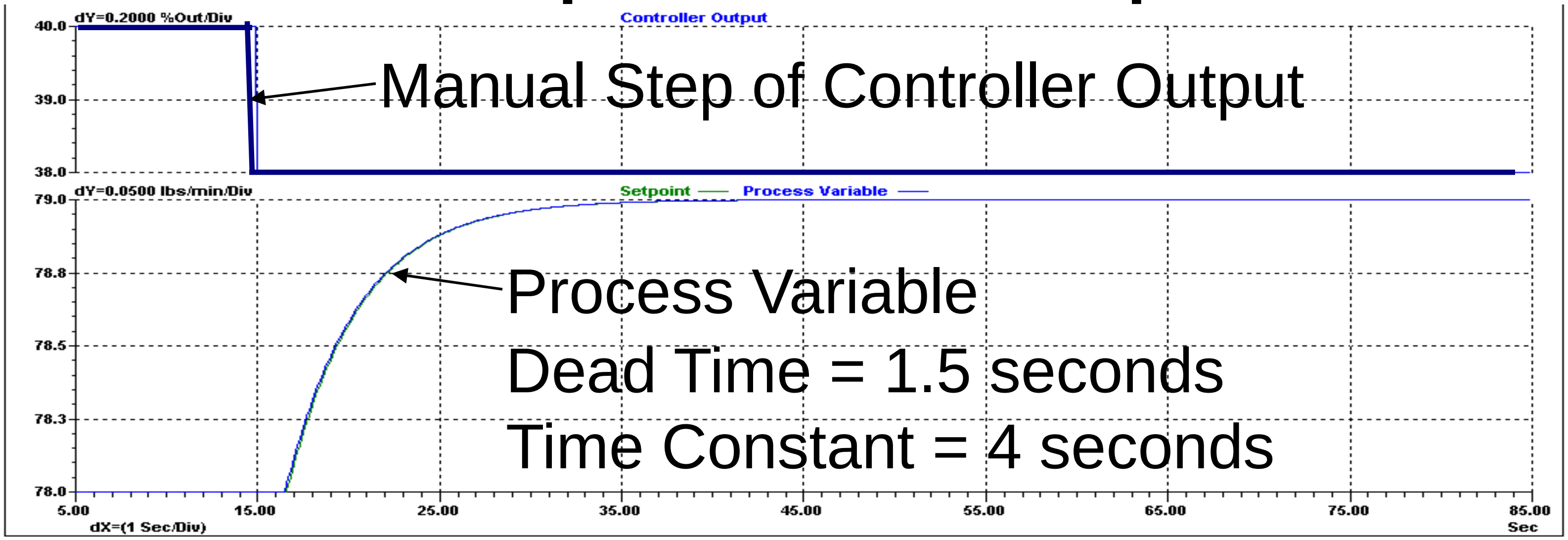
EMERSON EXCHANGE

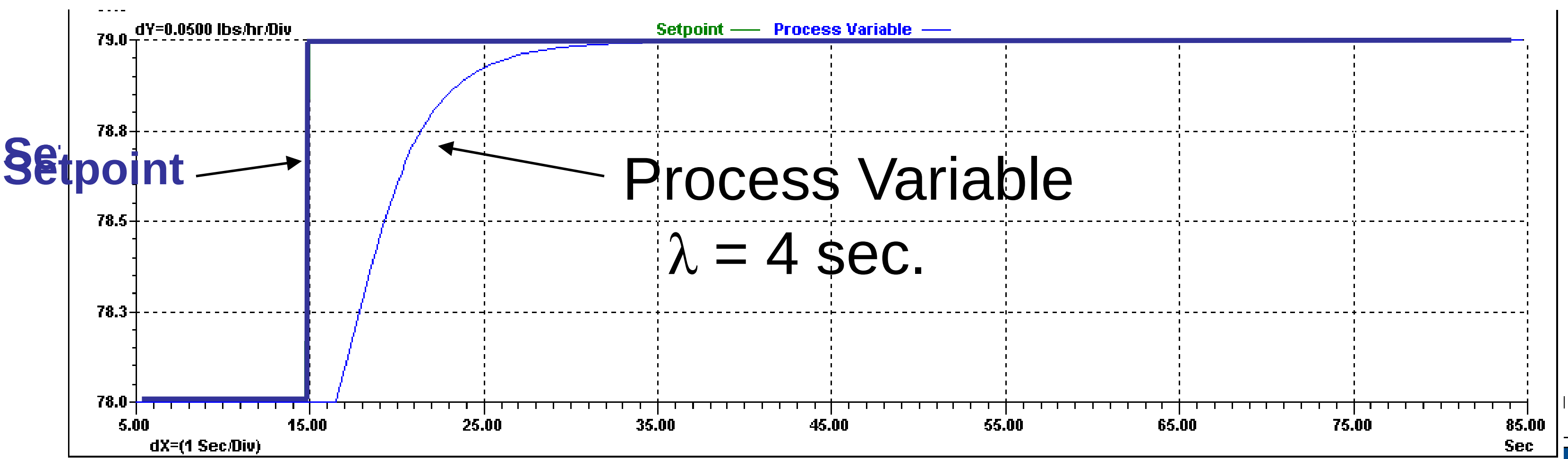
IMC Tuning – Self Regulating

- 1st Order + Dead Time
- Choose "closed loop time constant" or Lambda (λ).
  - A recommended starting point to ensure robustness is 3 * (larger of Td or Tau).
  - Since the process is rarely a pure first order, Lambda is approximated by "Time to Steady State" / 4 = TSS / 4
- Tr = Reset Time = Tau (units are time/repeat)
- Kc = Controller Gain = $\dfrac{Tr}{Kp\,(\lambda + Td)}$

(for Standard and Series (Classical) PID Forms only)

Select Speed of Response





IMC Tuning – Integrating

- Choose Lambda (λ)

- $Tr = (2^* \lambda) + Td$

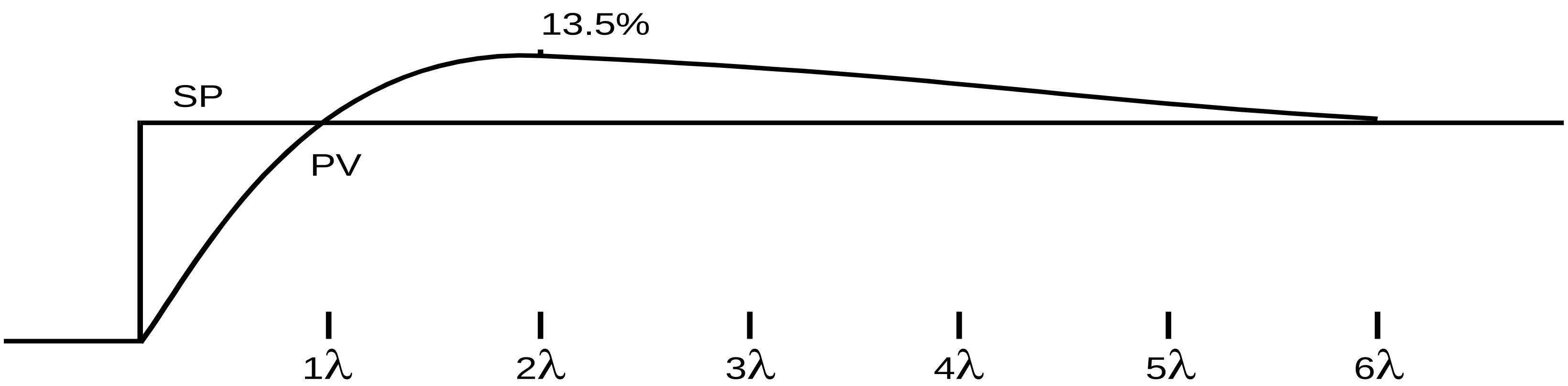
- $$Kc = \frac{Tr}{Kp(\lambda + Td)^2}$$

(for Standard and Series (Classical) PID Forms only)

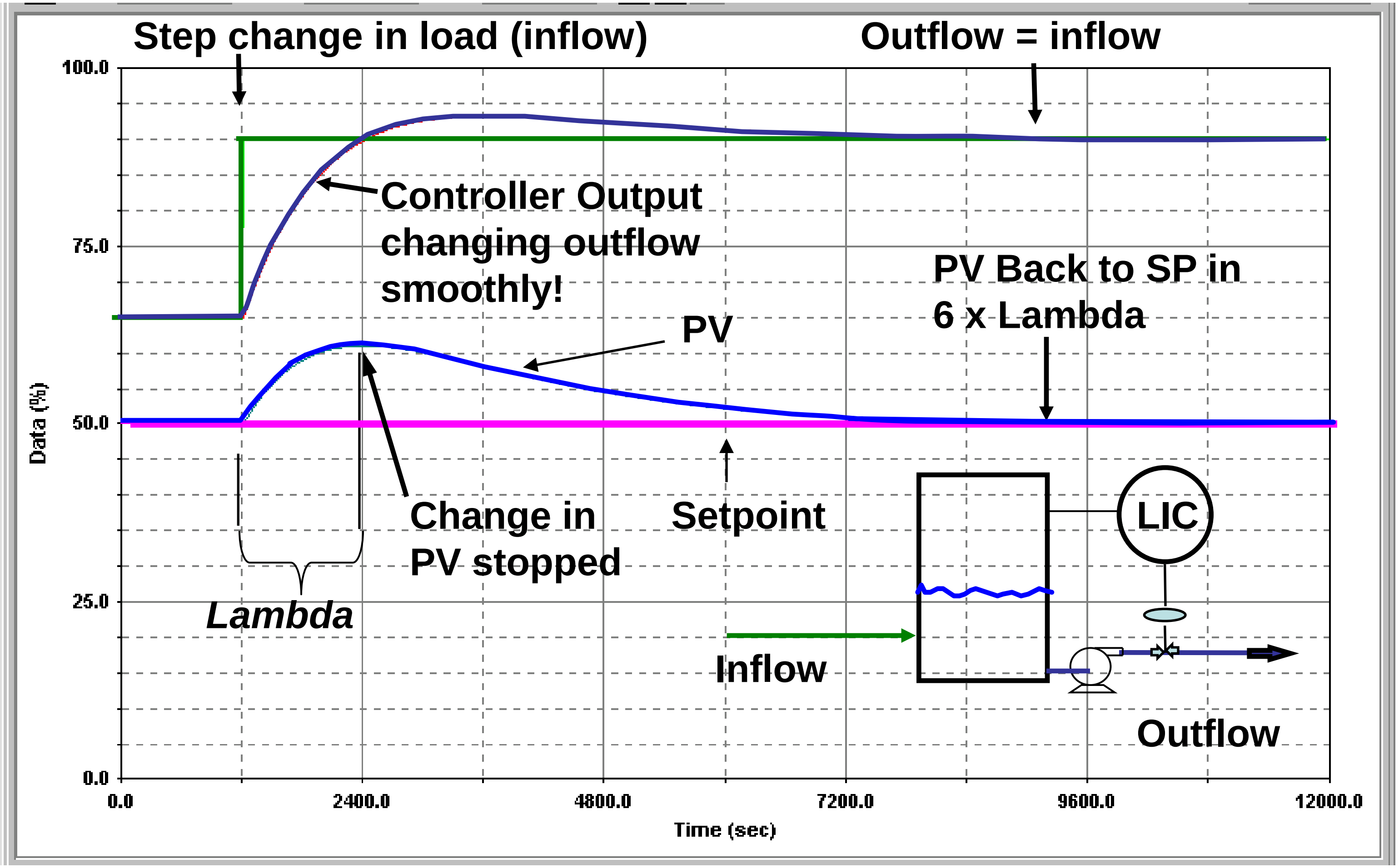
EMERSON EXCHANGE

IMC Tuning for Integrating Processes

Integrating process - 1*Lambda to Set Point but 6*Lambda to settle



IMC Tuning for Integrating Processes - Load Disturbance Response

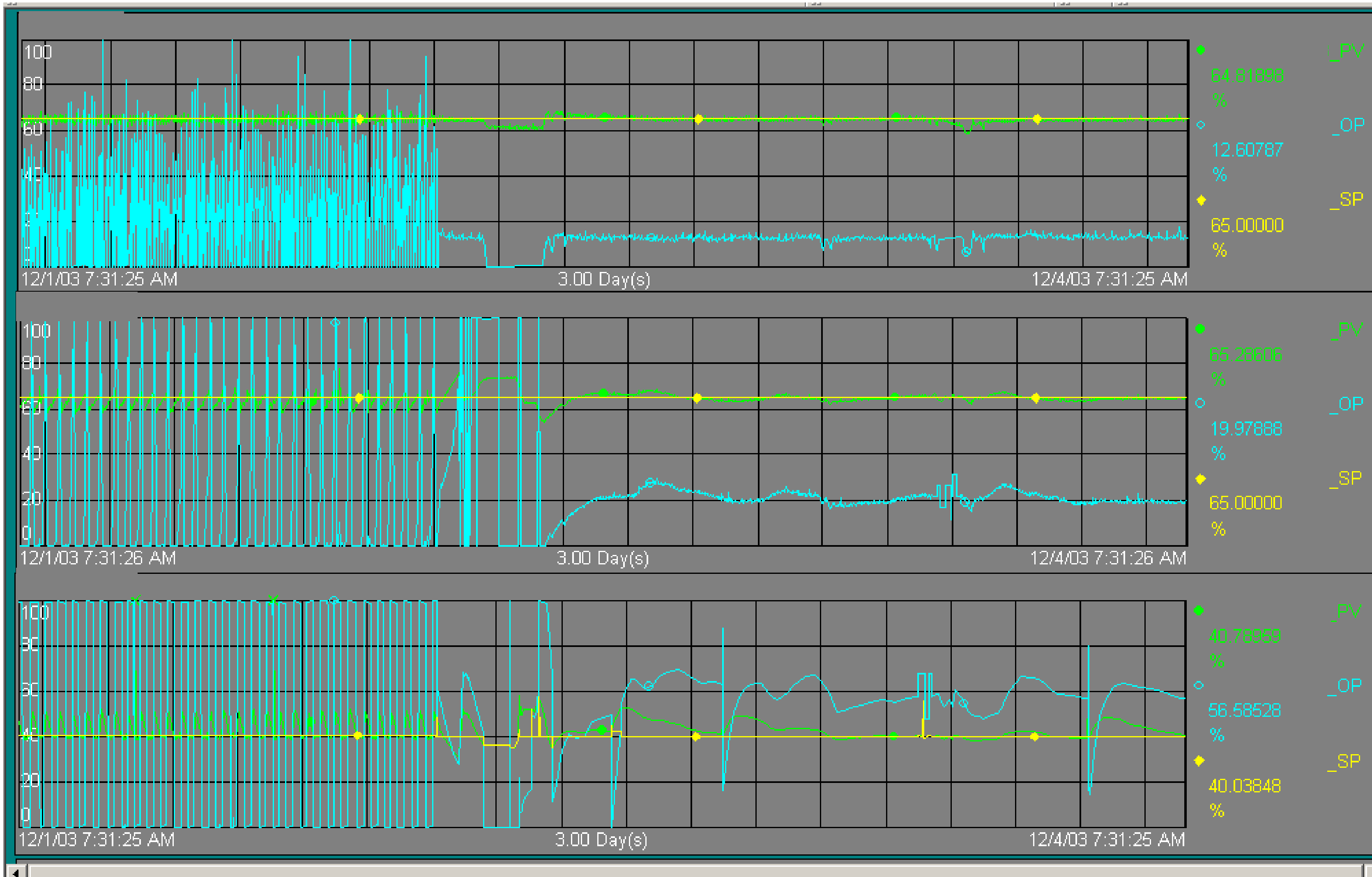


EMERSON EXCHANGE

Attenuate Variability with Control/Equipment

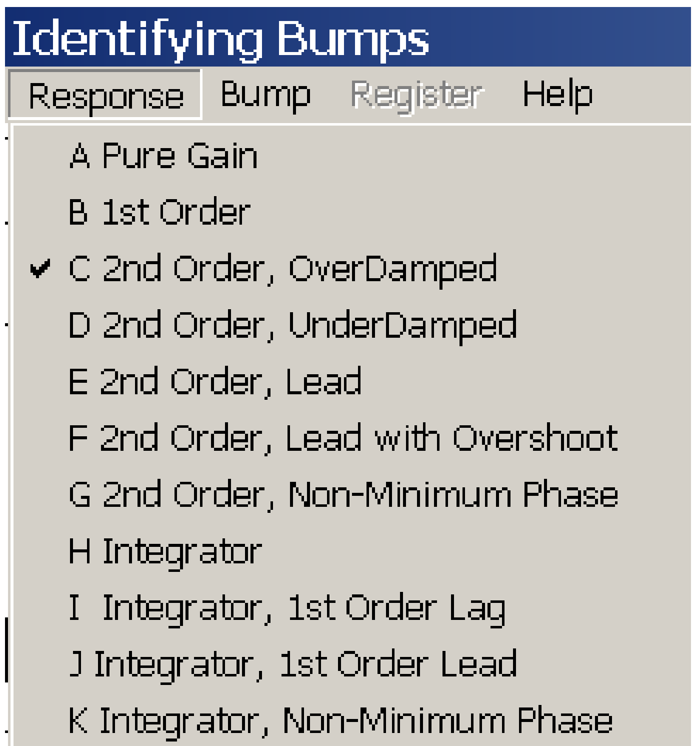
- “Capacity” in the process can be used to attenuate or absorb variability
- Primary source of process capacity is level control
- To utilize level control as a capacity tune the controller as slow as possible but still “fast” enough to hold the PV within the allowable level deviation (ALD) for a maximum load change

IMC Tuning on Integrating Processes



Difficult Dynamics

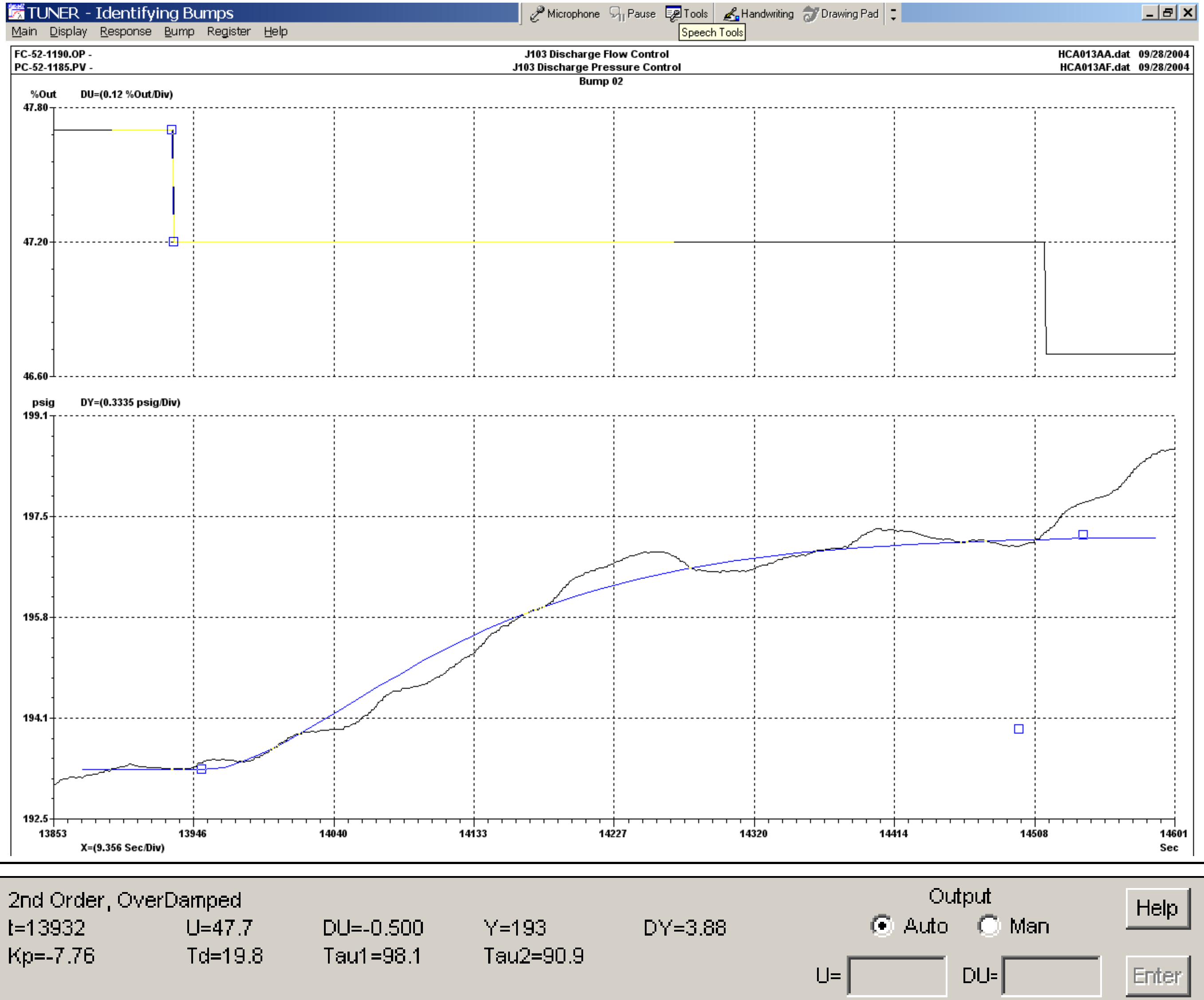
- Utilize Emerson's EnTech™ Toolkit to identify process dynamics, select controller structure and tune controller.



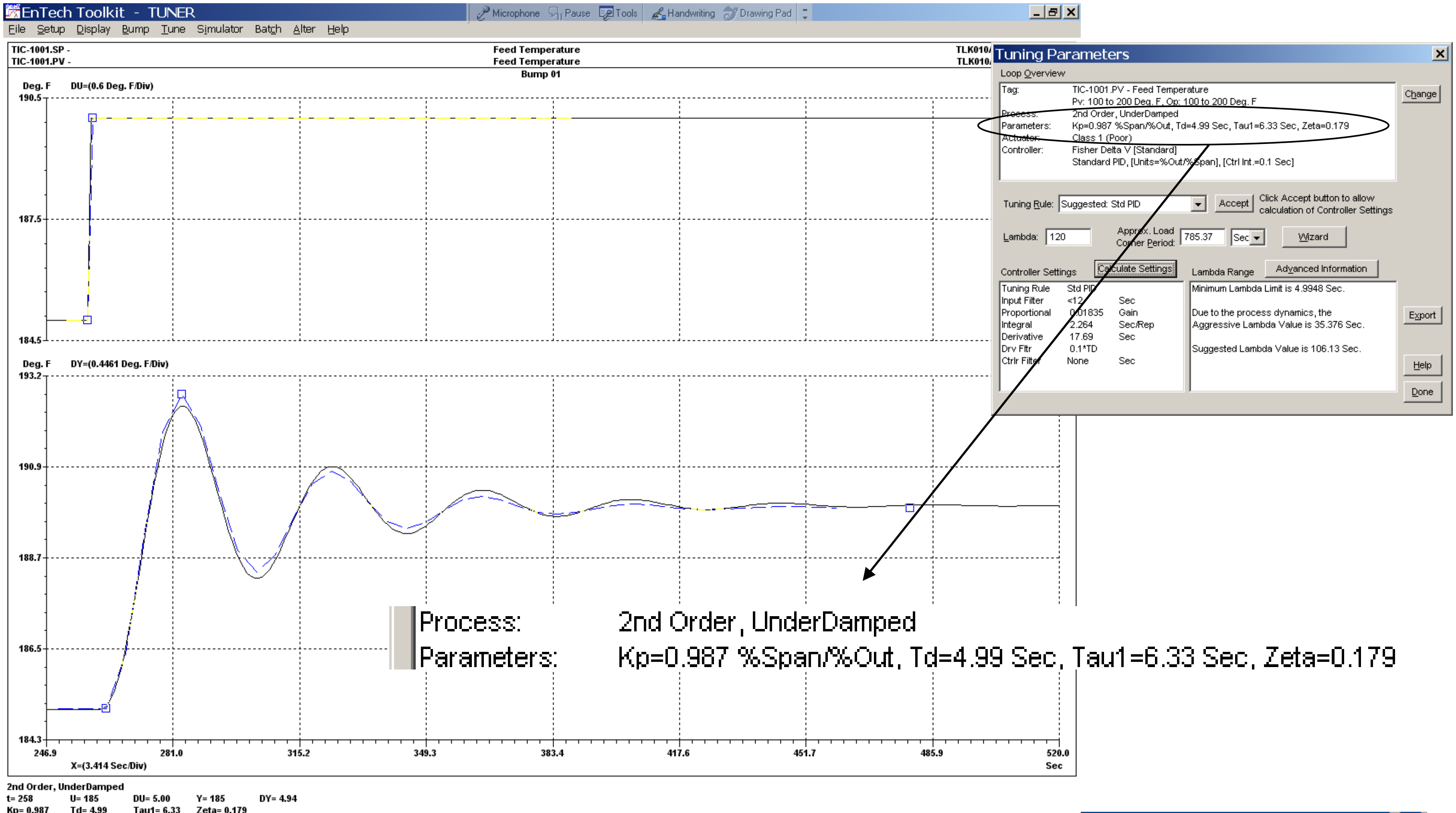
Difficult Dynamics – Real Examples

- Second Order- Over damped
- Second Order – Under damped
- 2^{nd} Order Non-Minimum Phase
- Integrating + lag
- Integrating + lead
- Integrating Non-Minimum Phase
- Runaway or Positive Feedback

Second Order – Over Damped



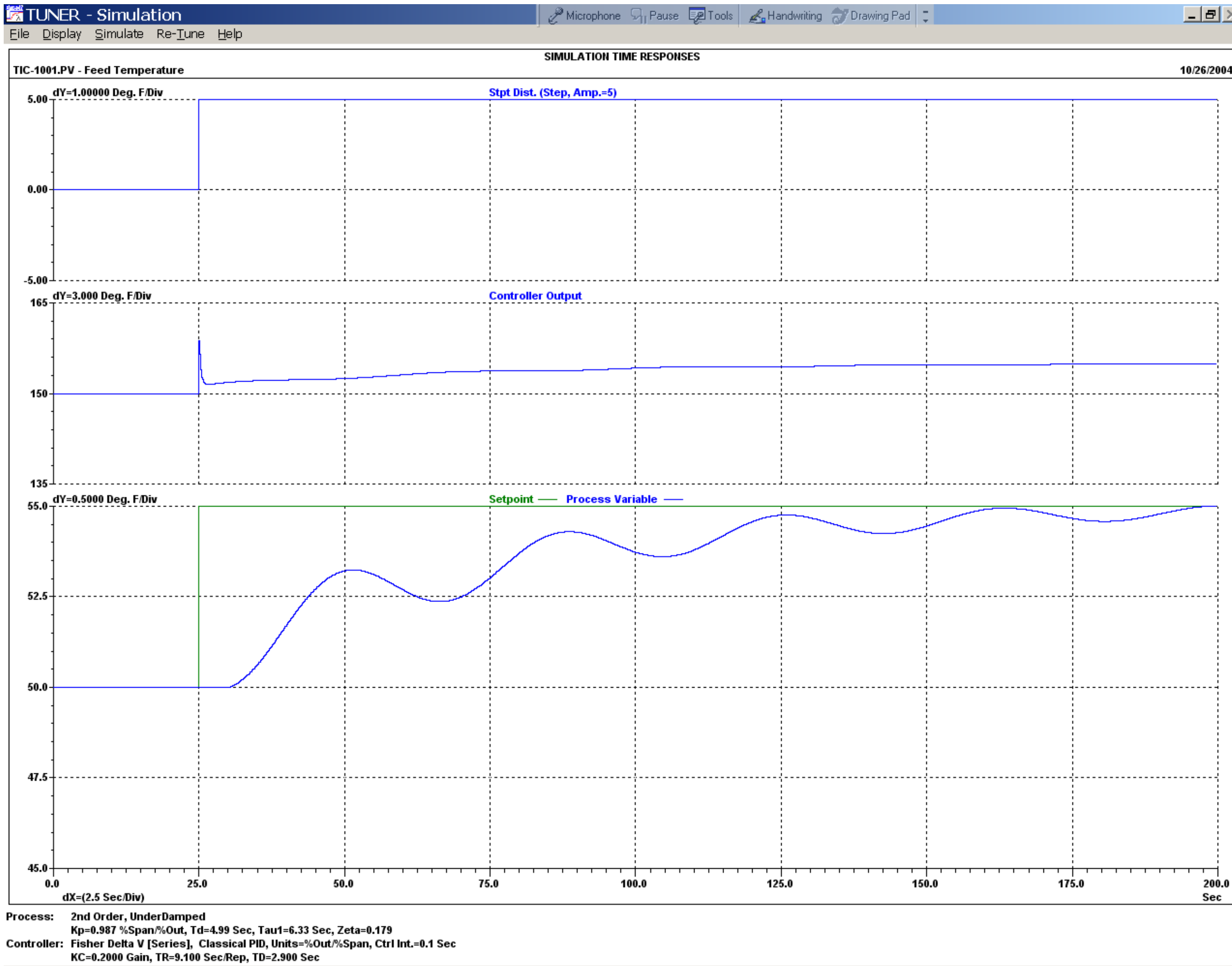
Second Order – Under Damped



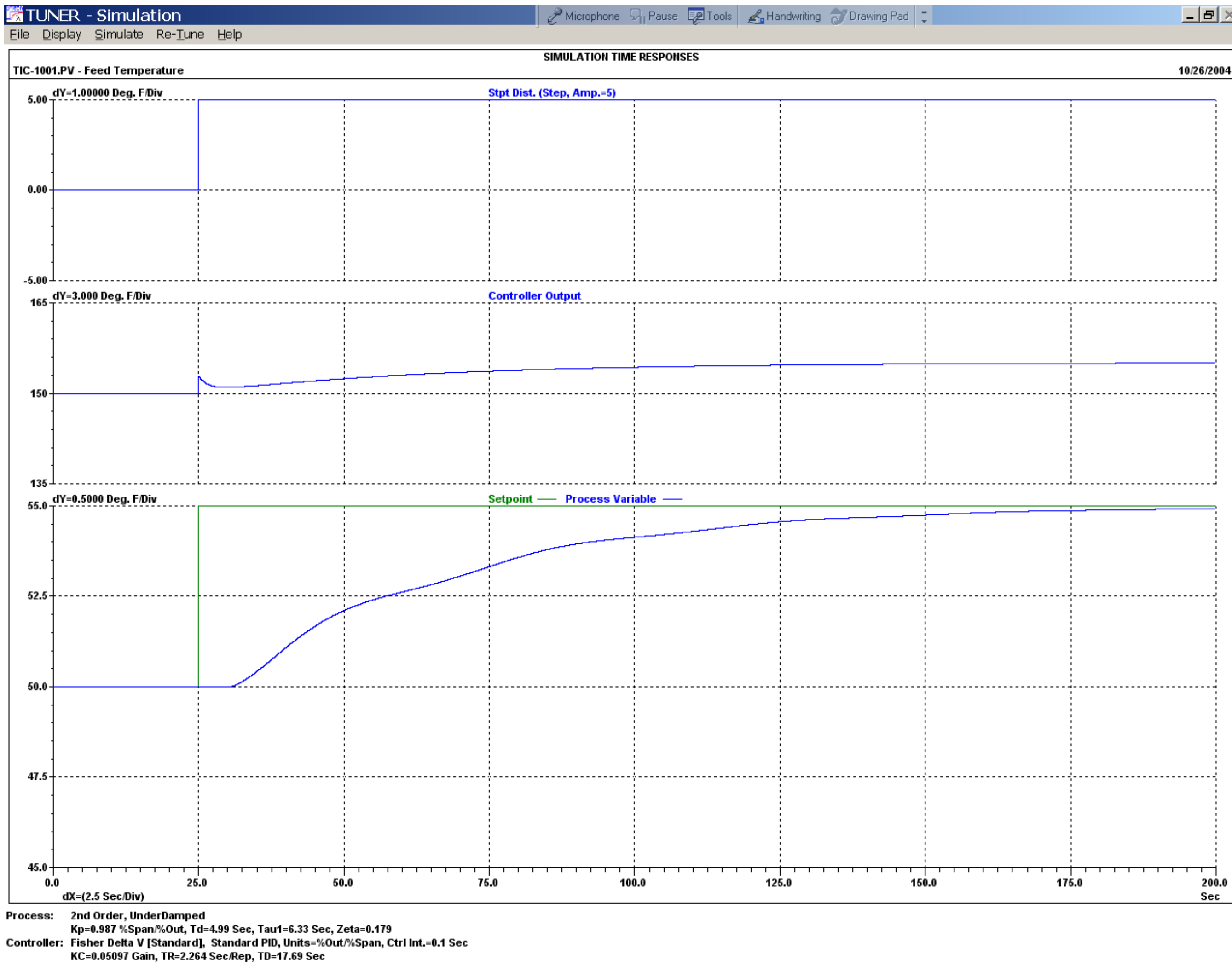
Process: 2nd Order, UnderDamped

Parameters: Kp=0.987 %Span/%Out, Td=4.99 Sec, Tau1=6.33 Sec, Zeta=0.179

Second Order – Under Damped Response to “Series” PID

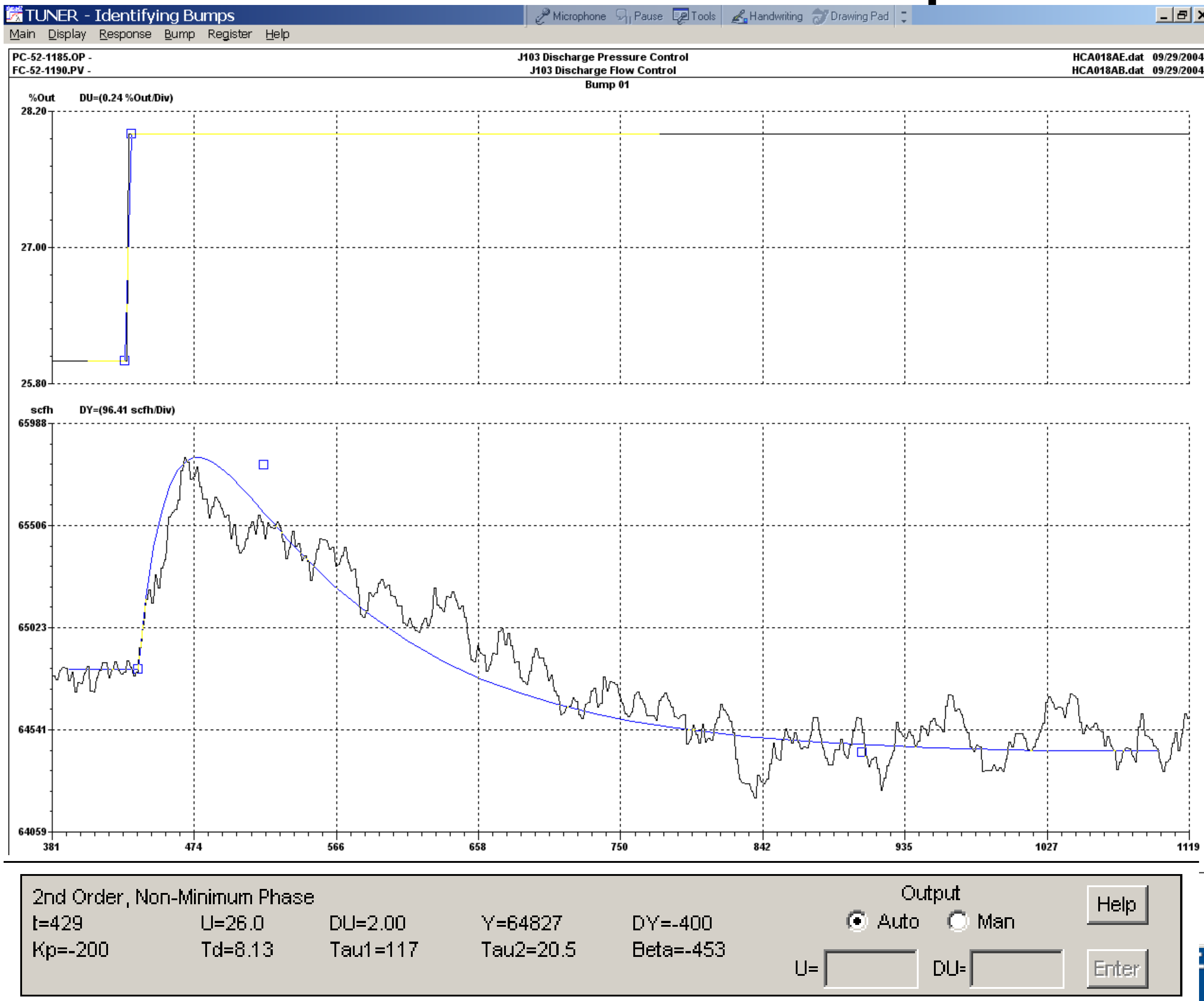


Second Order – Under Damped Response to “STD” PID

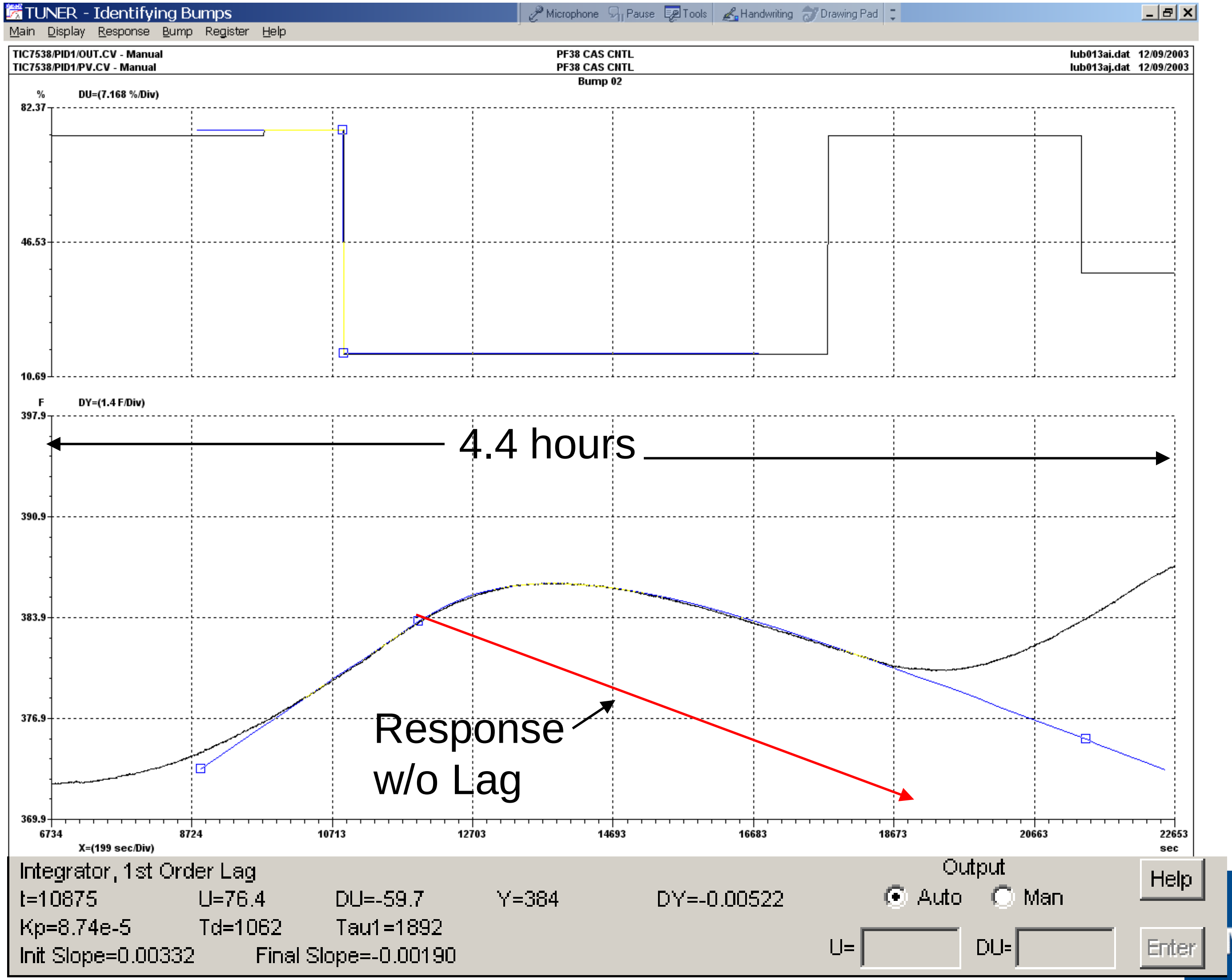


EMERSON EXCHANGE

Second Order Non-Minimum Phase "Inverse SR Response"

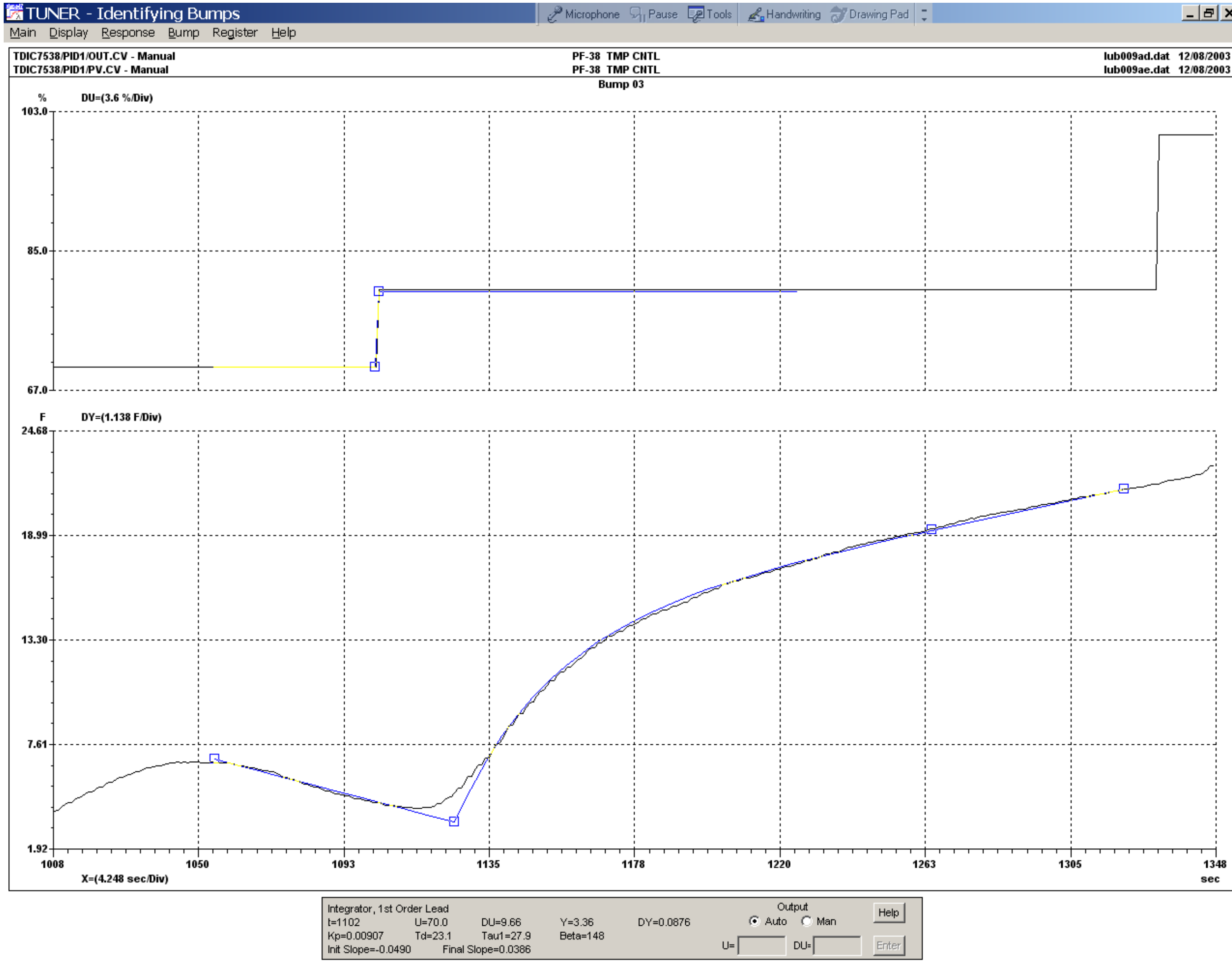


Integrating + Lag



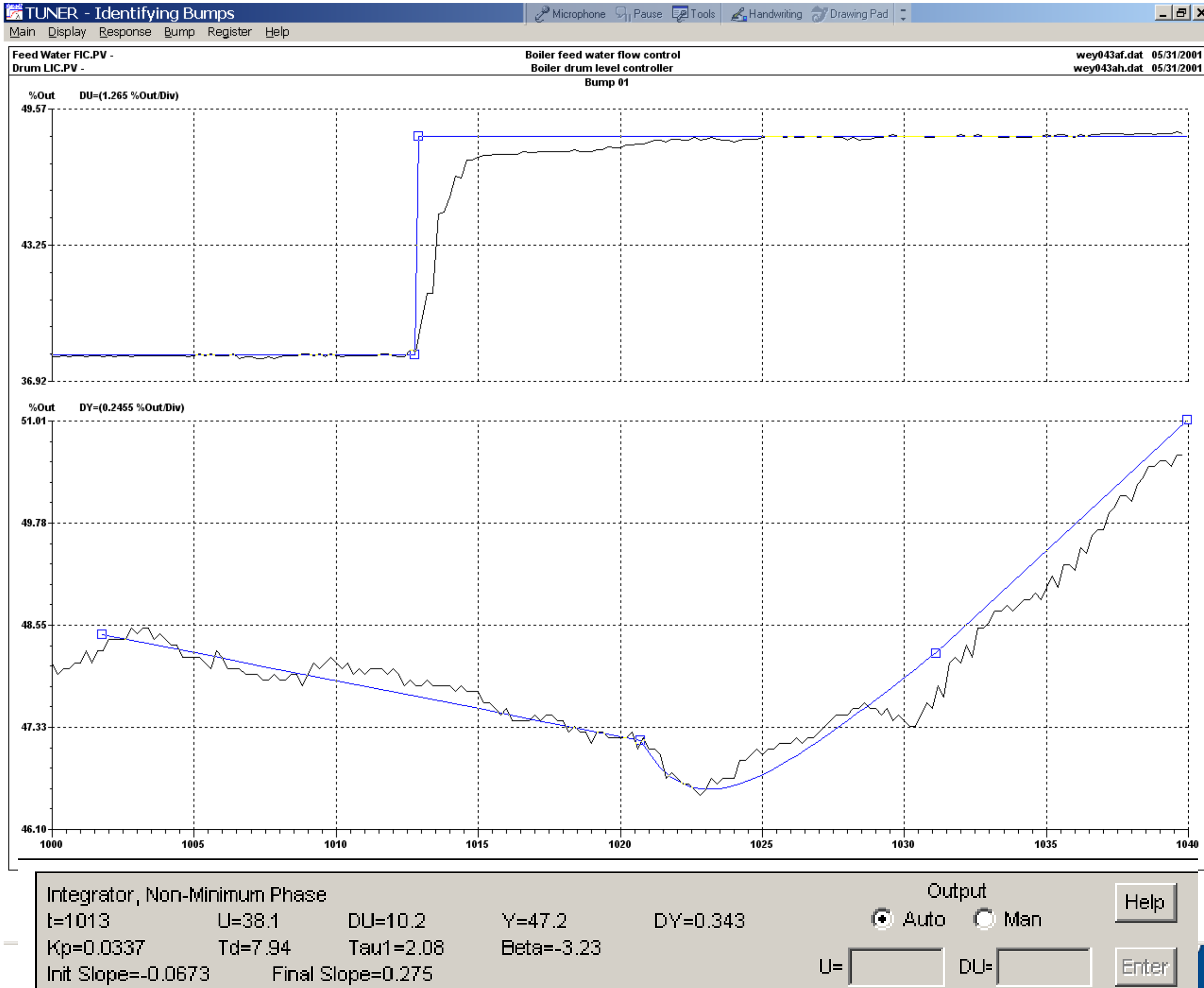
MERSON EXCHANGE

Integrating + Lead



EMERSON EXCHANGE

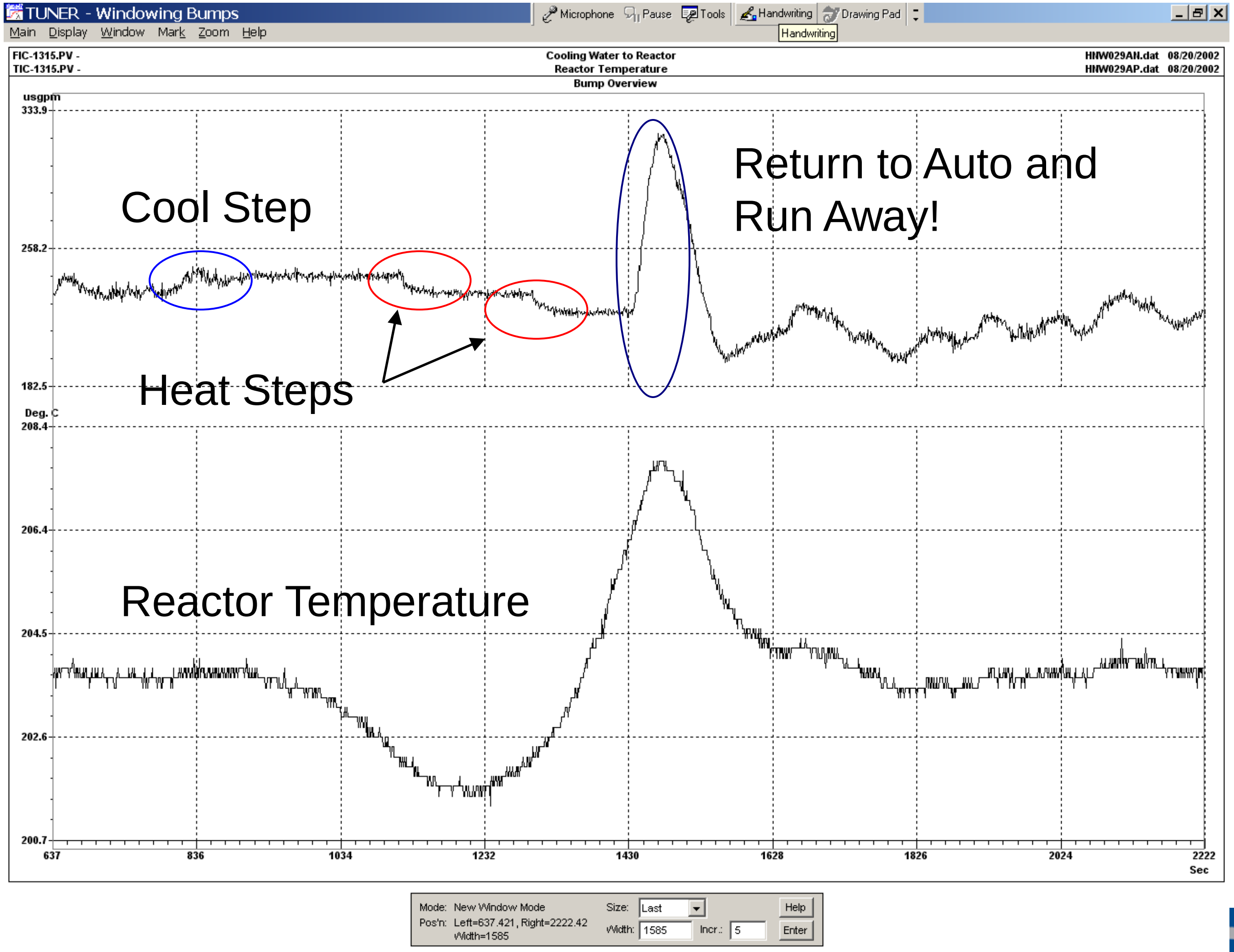
Integrating Non-Minimum Phase "Inverse Integrating Response"



Runaway aka Positive Feedback

- Run Away!!!
- Difficult to identify dynamics
- Use closed loop techniques for identification of process dynamics
- Tuning can be calculated from these dynamics

Runaway aka Positive Feedback

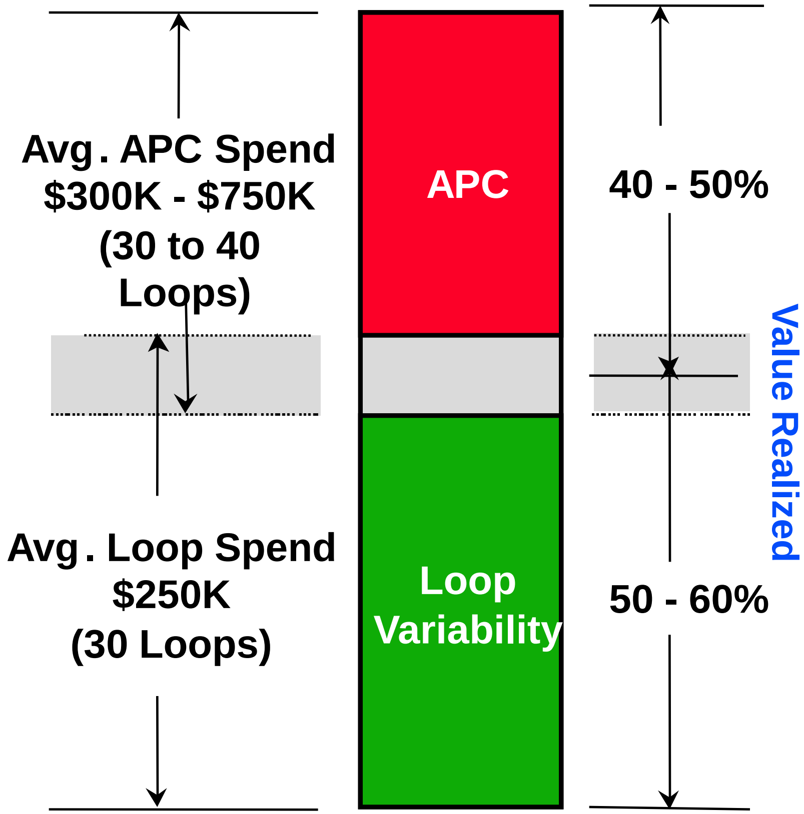


EMERSON EXCHANGE

Coordinated Loop Tuning

- Cascade Loops
- Interacting Process – incompressible fluids
- Columns
- Reactor Control

Benefit of Control Performance



McKinsey Study June 97

Business Results Achieved

- Millennium- Increased production 45%, increased profit by $1,000,000/year, reduced maintenance by $900,000/year
- Synthetic Rubber Reactor – reduced variability of product properties by 90%
- Olefins distillation – reduced variability of products by 90%, increased distillation capacity by 2%
- Batch distillation-reduce “cut” time 25%
- CO2 Plant – reduce unplanned shutdowns from 1-1/2 per week to virtually none
- Alcan – Increased production by 12% worth $1,000,000/year profit

Summary

- Understanding process dynamics is key to better process control
- Difficult process dynamics can be analyzed with good analytical tools
- There is economic benefit in using a tuning method that allows you to coordinate the response of all the loops in a unit

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**

EMERSON EXCHANGE

Predict and other DeltaV Advanced Control Products?

Overview - *Courses 7201, 7202, 7203 & 7204*

- These courses, beginning with the 7201, overview all of the major DeltaV advanced control tools. Courses 7202, 7203 & 7204 each drill deeper into a specific advanced control product and its application.

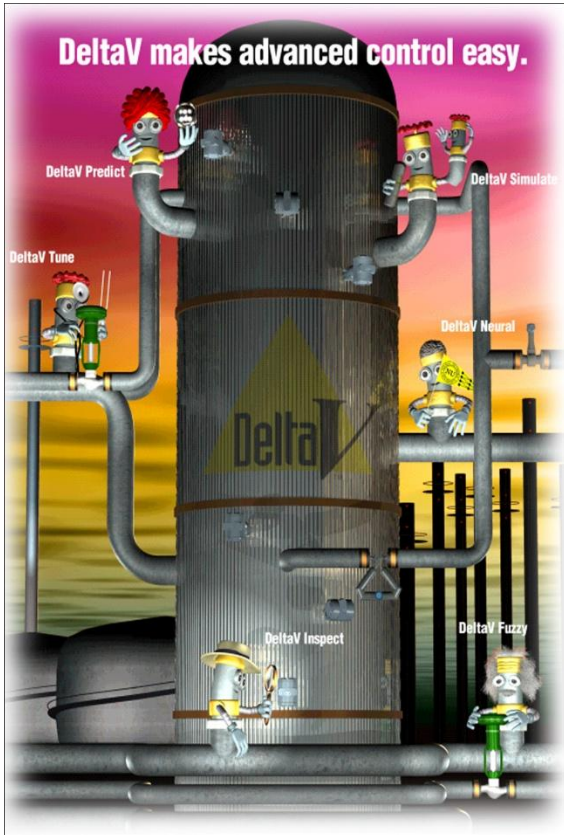
- DeltaV advanced controls are unique in the process control industry, in that users do not need detailed knowledge of the underlying mathematical principles to successfully apply the DeltaV advanced controls technology.

Course # 7201
DeltaV Advanced Controls Overview

Course # 7202
DeltaV Predict MPC Implementation

Course # 7203
DeltaV Neural Implementation

Course # 7204
RTO+ Optimize Implementation



DeltaV Advanced Control Overview

Course 7201 ***CEU's: 3.5***

Overview

This 4-1/2 day course introduces students to the **advanced control tools** available within DeltaV and how they may be used to improve plant operations. The principal technology that is utilized in each product will be discussed. The areas of improvement that may be achieved will be detailed. Also, each student will gain hands on experience with these tools in class exercises based on realistic process simulations.

Prerequisites Courses 7008 (DeltaV Intro.), 7009 (DeltaV Operate Implem.) or 7010 (DeltaV Implem.), or equivalent field experience.

Topics

The Control Foundation in DeltaV
- Traditional tools e.g. override, cascade, ratio
- Improvements provided by advanced control

DeltaV Inspect
- Detection of abnormal conditions
- Variability index, utilization

DeltaV Tune
- Tuning response, robustness
- Expert options e.g. Lambda, IMC

DeltaV Fuzzy
- Principals of fuzzy logic control
- FLC function block, tuning

DeltaV Neural
- Creation of virtual sensor
- Data screening, training

DeltaV Predict
- MPC for multi-variable control
- Model identification, data screening
- Simulation of response, tuning

DeltaV Simulate
- Operator training and engineering
- Using High fidelity process simulation

RTO+ Optimize
- Real time optimization
- Example applications

Location
Austin, TX

Registration Information
Phone: 800-338-8158
or 641/754-3771

Duncan Says-
"Enroll Today!"

Price: $2,195

e-mail: education@emersonprocess.com
website: www.emersonprocess.com/education

Questions

- James.Beall@emersonprocess.com

- 903-235-7935

EMERSON EXCHANGE