Achieving Operational Excellence on a Continuous Process with Severe Disturbances: A DeltaV APC Project

Leveraging Embedded APC Technology and SmartProcess Applications

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Thank you!

Presenters

- Eric Wheatcroft
- James Beall
- John Ward

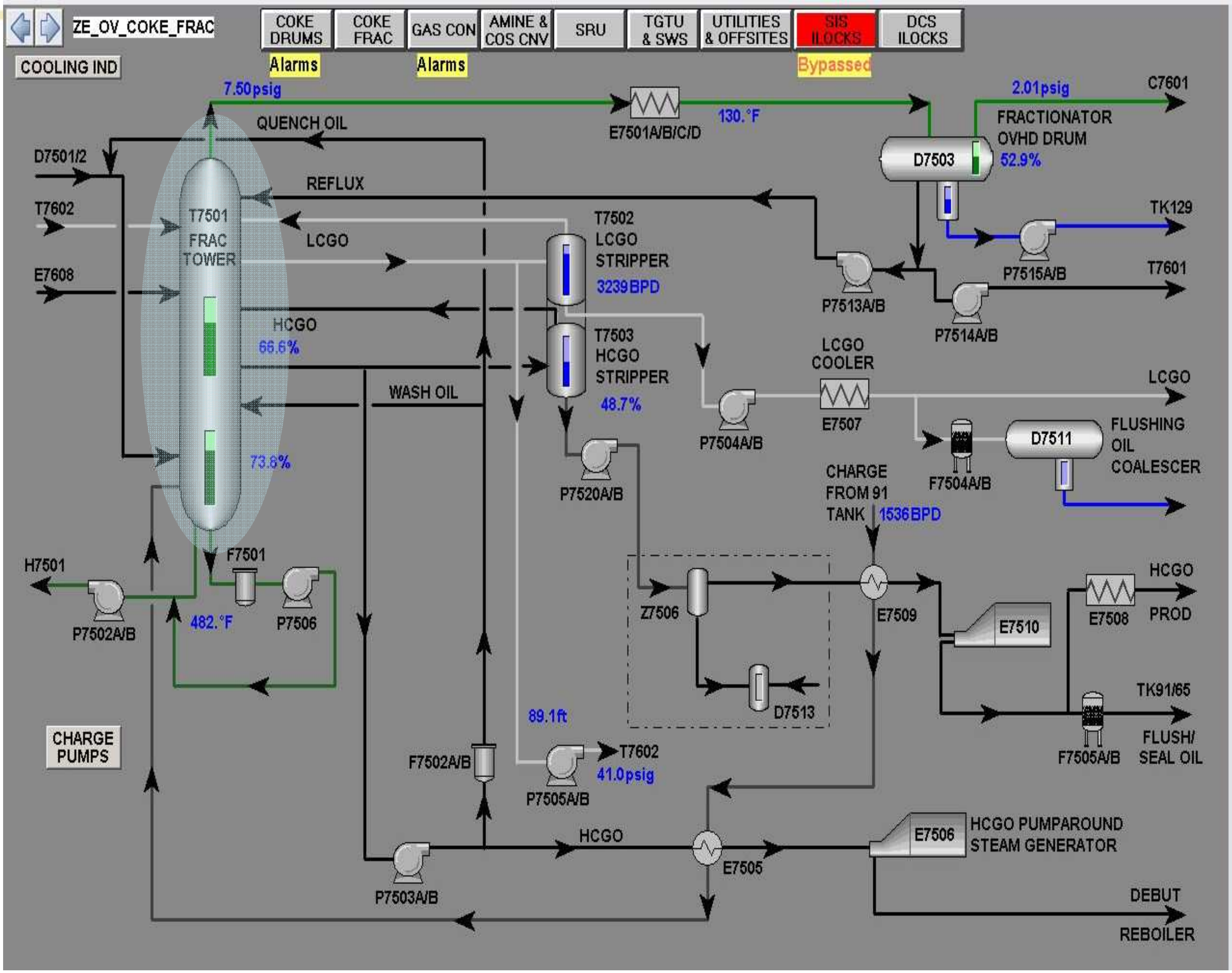
Introduction

- Process Overview
- Successful APC Execution Plan
- Business Results Achieved
- Summary
- Where To Get More Information

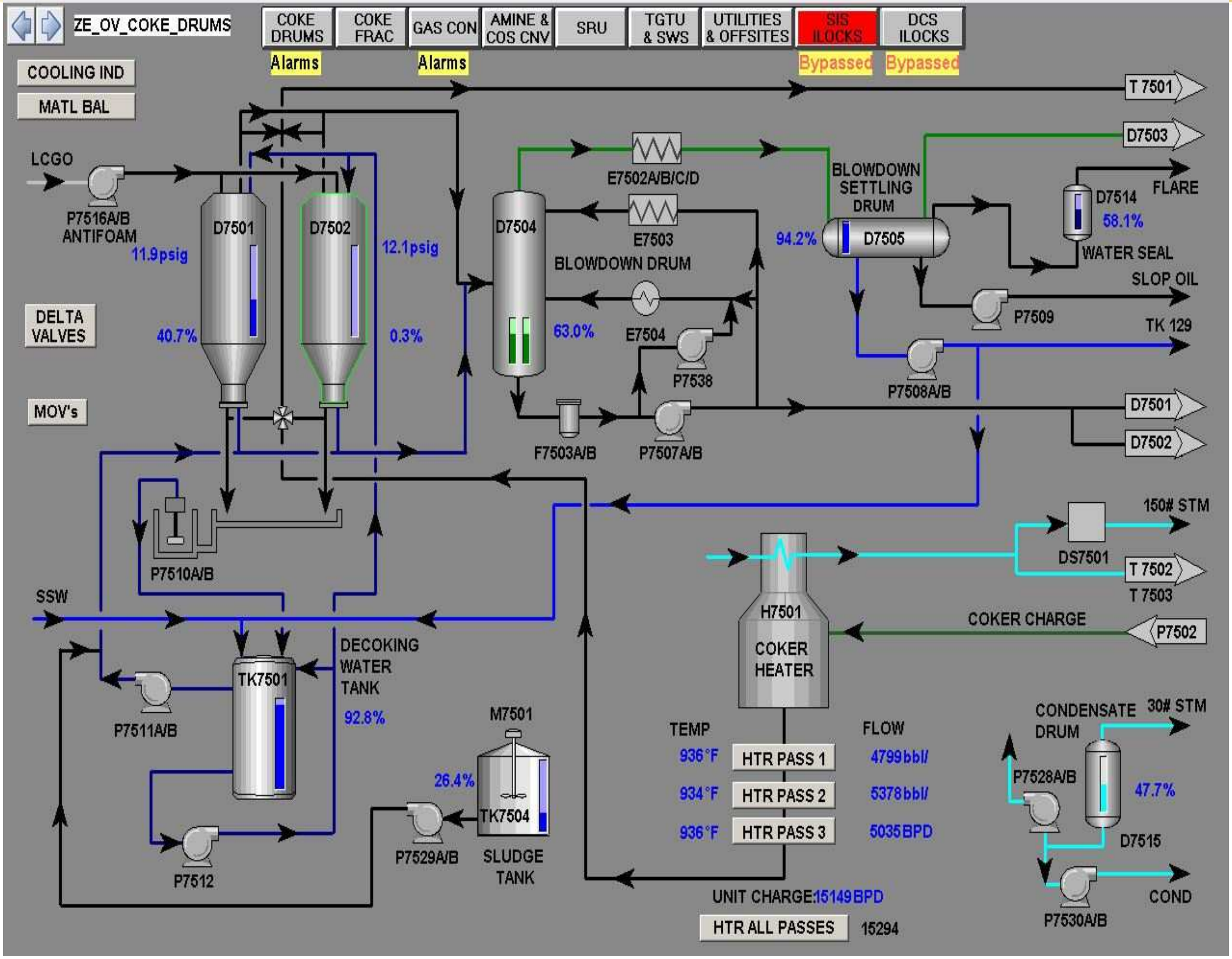
Process Overview – Delayed Coking

- Thermal process, Vacuum Resid rapidly heated and contained in a coke drum.
  - Process is endothermic (heat of reaction supplied by furnace)
- Three Distinct Steps
  - Partial vaporization and mild cracking of feed in furnace
  - Cracking of vapors as flow passes through coke drum
  - Successive cracking and polymerization of hydrocarbons in coke drum
- Yields and Product Quality are a function of temperature, pressure, and throughput ratio (fresh feed + recycle)/fresh feed
- Increase in coking temp decreases coke production

Process Overview - PFD



Process Overview - PFD



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Process Overview – Disturbances

- Process Unmeasured & Unquantified Disturbances
  - Drum Cycles
    - Backwarm
    - Drum Switches
  - HCGO Pall Filter Switches
    - HCGO pumparound integrated into the product circuit
    - Amplified the effects of HOURLY Pall filter switches
- Control Induced Variability
  - Feed pump spillback pressure control valve
  - Tower reflux flow control valve

Continuous Process with Severe Disturbances

- What would you do if your fractionator is in equilibrium and the V/L, feed rate, feed composition, heat input, suddenly changed by 20% – 30%?
- Leave and go fishing!
- Effects
  - Tray Weeping
  - Equilibrium disturbances (Vapor Liquid Mass Transfer)
  - Off Spec Product and less yield
  - Major compensation moves by operators

Process Overview Summary

- Challenges:
  – Continuous process with significant cyclic disturbances
    - Inconsistent operator response to process disturbances
    - Product quality and yield variation
- Project Objectives:
  – Compensate for disturbances
  – Maximize LCGO production
  – Minimize product quality (Naphtha, LCGO) variation
- APC facilitates:
  – Automates and optimizes “Best operator responses”
  – Control loops in desired modes
  – Minimize operator intervention

APC Development

- Justification
  - Internal Sponsorship
  - ROI Assessment
- System Preparation
  - Control Foundation Analysis & Improvement
- APC Execution
  - Embedded MPC and SmartProcess® Composites
  - Model Identification & Validation
  - Optimizer Objective Function Definition
- Quantify Benefits

APC Justification- ROI Assessment

- Extensive review of process, equipment, problems, and project objectives
- Estimate Yield and Financial results achievable with APC
- APC Implementation Plan including valve/instrument repairs
- Obtain support of operations and management

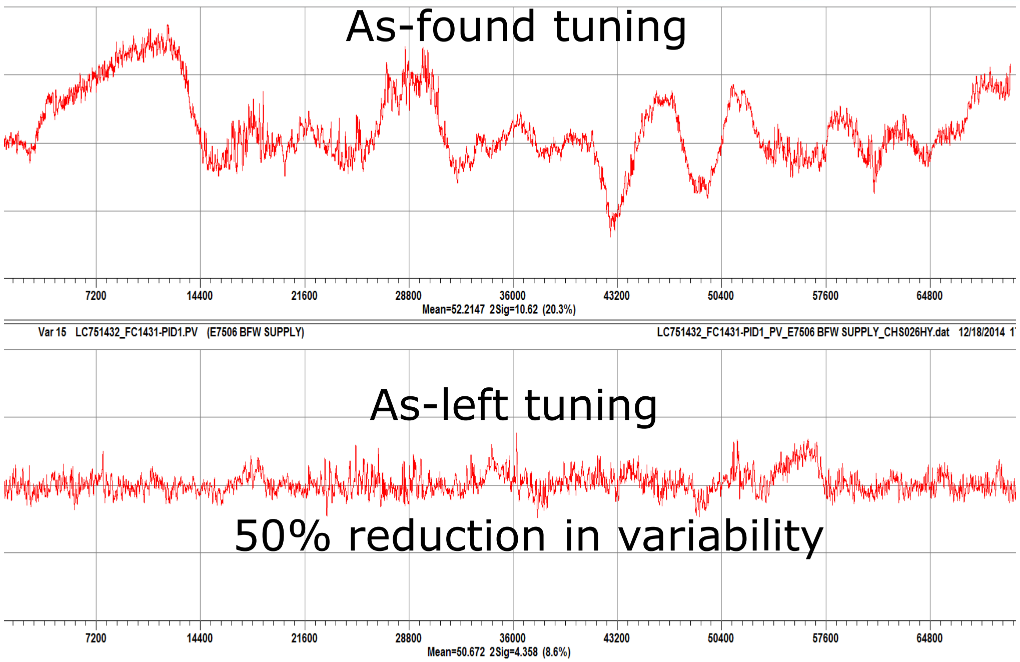
System Preparation – Control Foundation

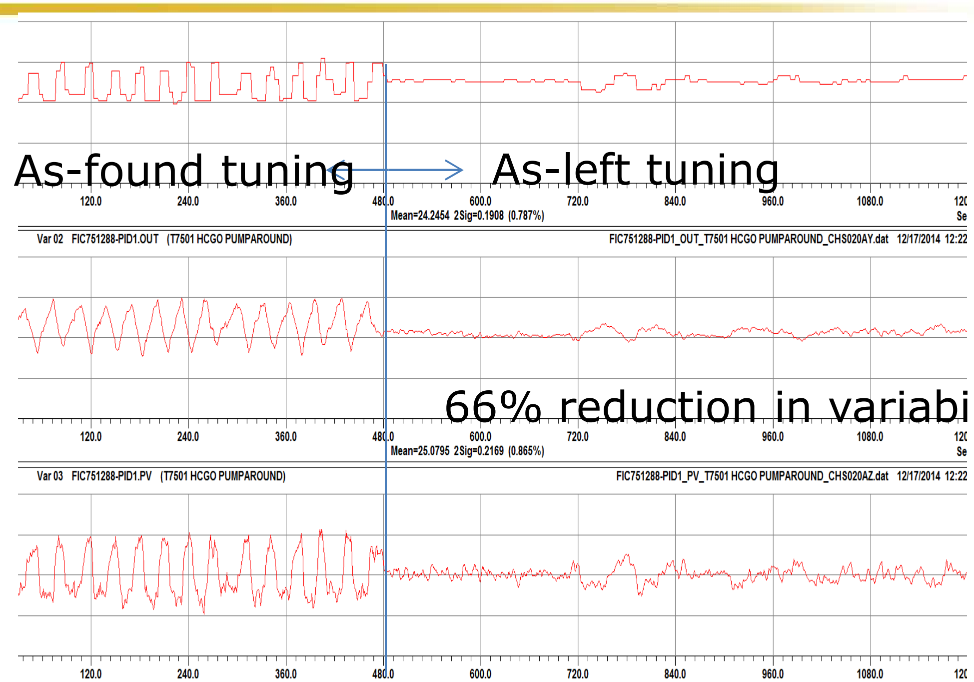
- Analyze key control loops, not just tune loops!
- Goal to improve PROCESS performance not just "LOOP" performance
- Review control metrics with DeltaV InSight
- Review control configuration and scheme
- Maximize PROCESS performance

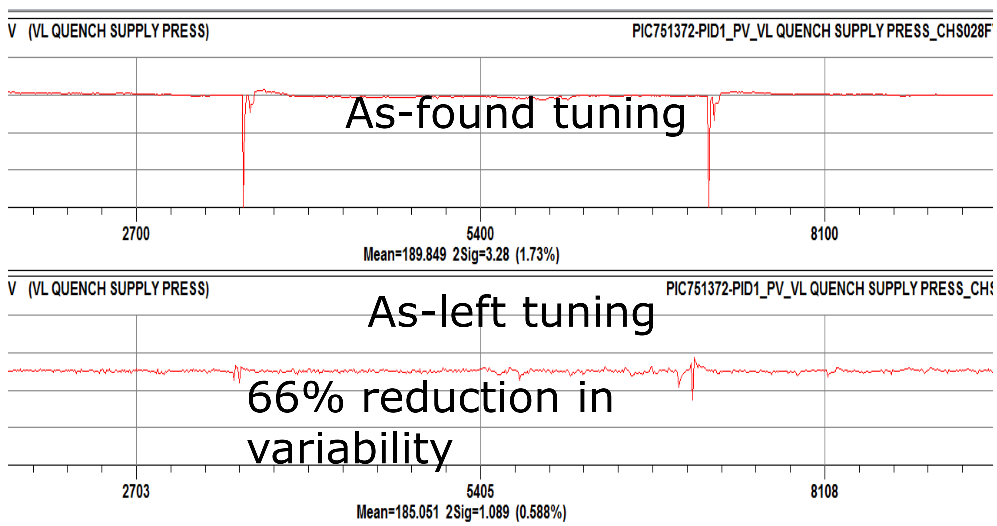
System Preparation – Control Foundation

- Field walk down
  - Assess equipment installation against best practices
  - Assess general type and condition of control valves and instrumentation
- Operator interviews
  - Facilitates better understanding of the process
  - Understand control problems and operator responses
- Scope for APC Project
  - Reviewed and analyzed 30 key loops
  - Found issues with 3 key instrument and 2 critical valves
  - "Significant" (>30%) tuning changes on 27 of 30 loops
  - Recommended new control scheme on critical equipment

System Preparation – Control Foundation



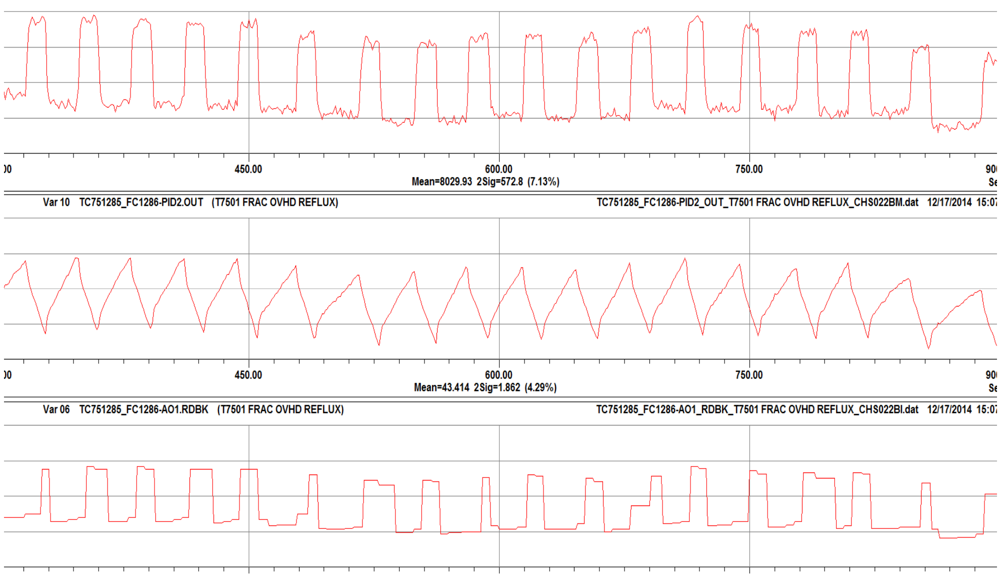


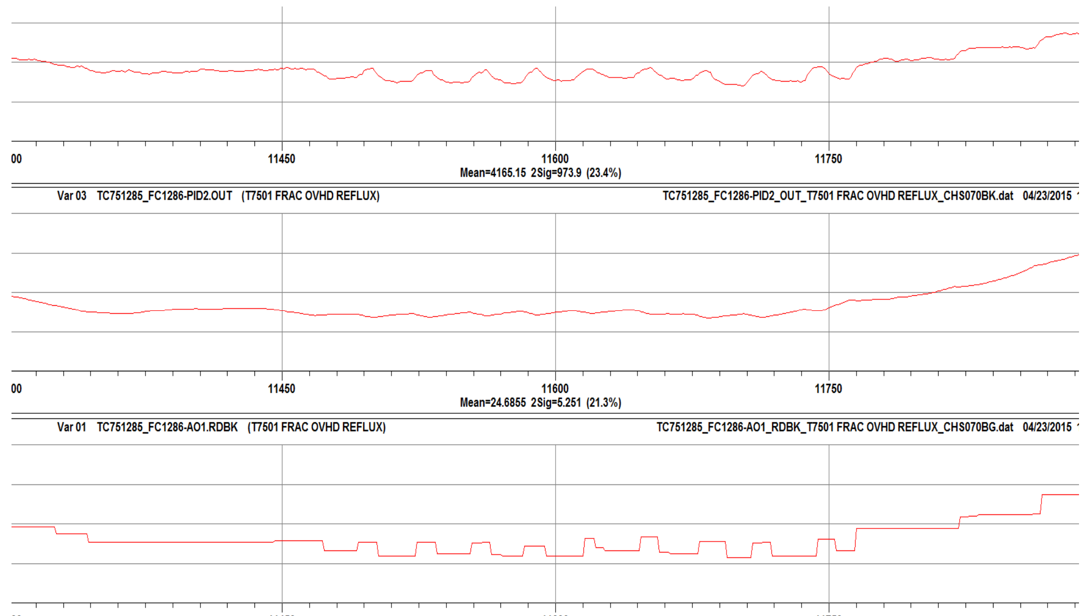


System Preparation – Control Foundation

Before Repair Valve Readback

After Repair Valve Readback





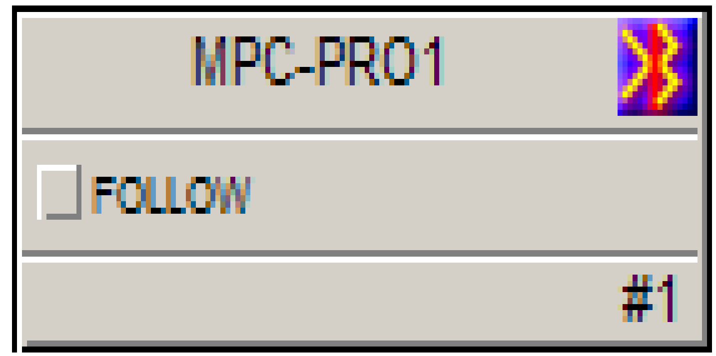
Fractionator Reflux Control Valve (Temp to Flow Cascade)

APC Execution – Control Foundation

- Results
  - Significant (>30%) reduction in variability on 10/30 of the loops
  - Found opportunity for small MPC to increase waste heat recovery - $70K/year benefit!
  - Identified critical valves that required maintenance
- Reduces time required to implement APC
- Increases benefit of APC projects
  - Coordinated control loop responses contribute to project success
- Provides 25-50% of benefit of total APC project!

APC Execution – Embedded Model Predictive Control

- MPC - Model Predictive Control
- Special control block in DeltaV
  - Multiple inputs
  - Multiple outputs
  - Dynamic matrix controller
  - Linear Program Optimizer
- Uses models to predict future trajectory of the controlled variables
- Optimizer achieves process/economic objectives



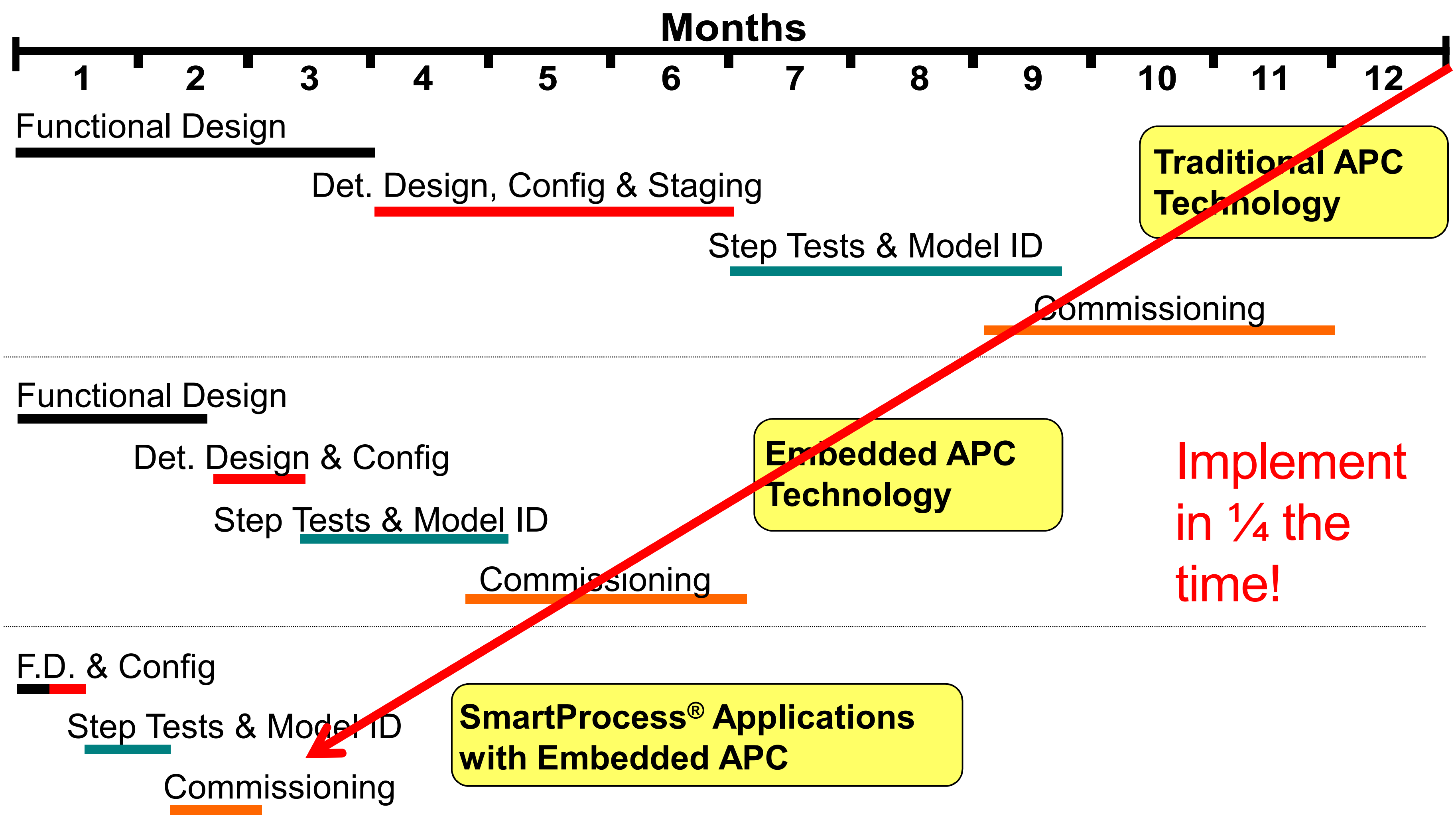
Embedded MPC - Types Of Process Variables

- ***Manipulated Variables* (MV)** – Valves or controller setpoints written to by the MPC.
- ***Disturbance Variables (DV)*** - Measured variables which may also affect the value of controlled variables
- ***Controlled Variables* (CV)** - Process variables which are to be maintained at a specific value; i.e., the setpoint
- ***Constraints (Limit) Variables (LV)*** - Variables which must be maintained within an operating range (a special type of CV)

APC Execution - SmartProcess® Applications

- Pre-Engineered APC Applications
- MPC and NN licenses
- Application specific calculations
- KPI's
- Regulatory control configuration
- Simulated process and example APC solution
- Configuration guide
- Implementation services (optional)

APC Execution - SmartProcess®



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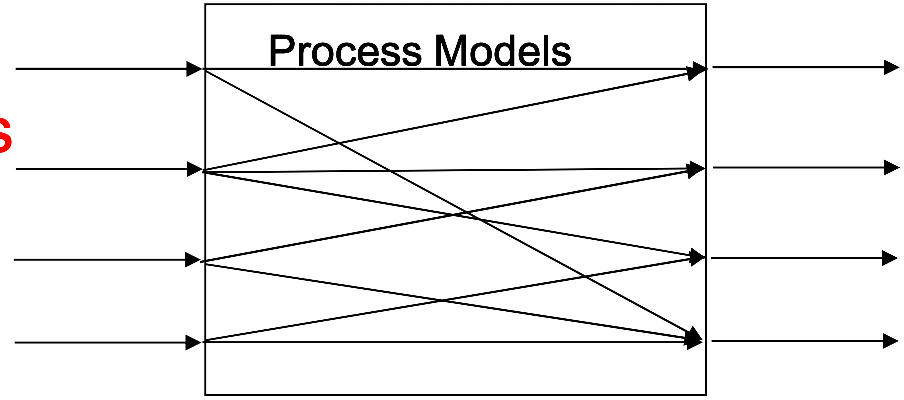
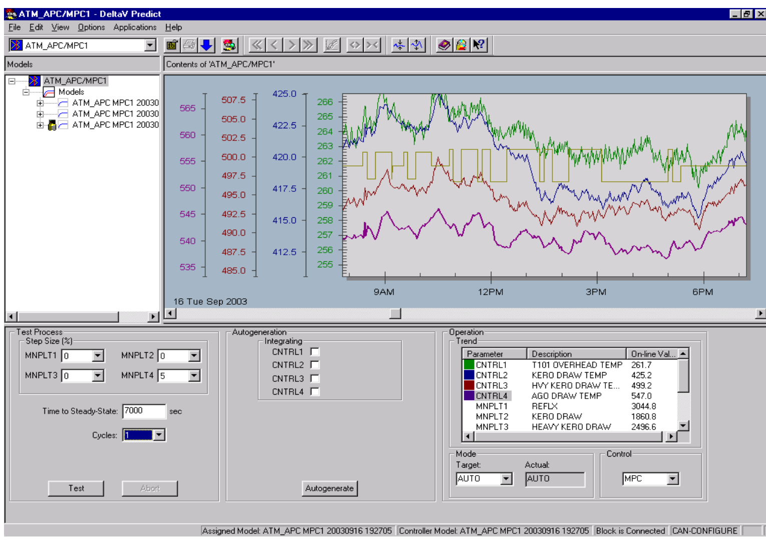
APC Execution – MPC Process Models

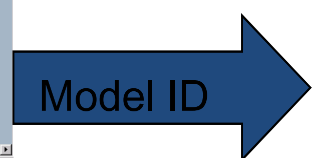
“Process” Inputs
MV’s & DV’s

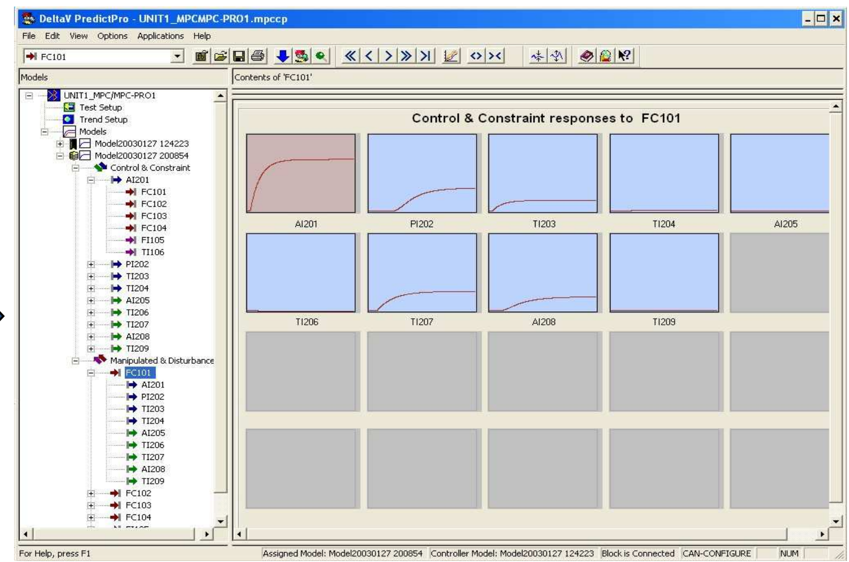


“Process” Outputs
CV’s & LV’s

Process models, input to output, are derived from observed step tests of







APC Execution – MPC Process Models

- DeltaV PredictPro - Automate MV step testing routine and determine models
- Emerson's EnTech Toolkit determine models very accurately
  - Many models were available from the control foundation project, so we continued full model analysis with Toolkit
- PredictPro validate models from any source

APC Execution – CHS MPC Variables

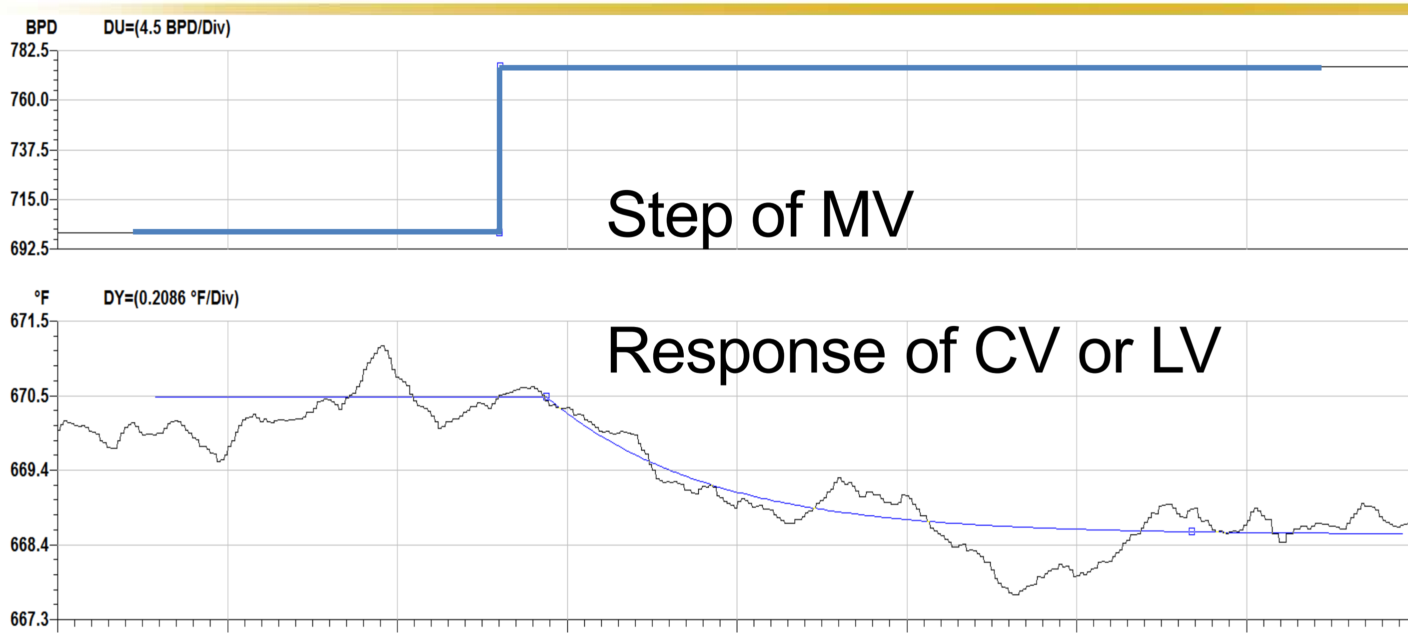
- ***Controlled Variables* (CV)** - Process variables which are to be maintained at a specific value; i.e., the setpoint
  - Naphtha Draw Comp Temp
  - LCGO Draw Comp Temp
  - HCGO Draw Comp Temp

- ***Manipulated Variables* (MV)** – Controller setpoints written to by the MPC.
  - Ovhd Temp (TC751285)
  - Net LCGO (FIC751349)
  - Lean Oil to E7610 (FIC
  - HCGO P/A (FIC751288)
  - Total Wash Oil (FC75

- ***Constraints (LV)*** - Variables which must be maintained within an operating range (a special type of CV)
  - Debut Reboiler Bypass Valve
  - Frac Ovhd Rec LIC Out
  - Sponge Oil Static Head
  - LCGO To Strpr Vlv
  - Etc.

- ***Disturbance Variables (DV)*** - Measured variables which may also affect the value of controlled variables
  - Backwarm (calculated)
  - Drum Switch (calculated)
  - Fresh Feed
  - Reflux Flow
  - Reflux Temp
  - Coke Drum Quench Temp
  - Etc.

APC Execution – MPC Process Models

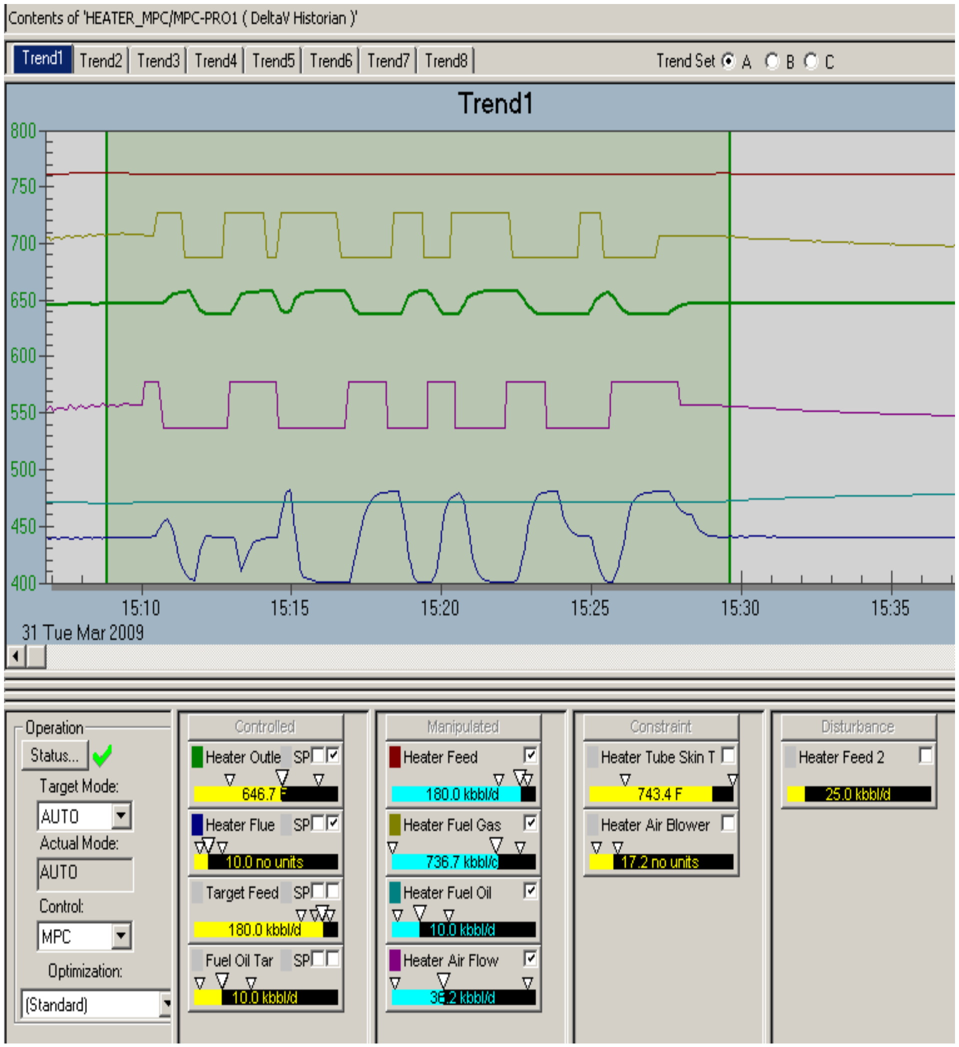


Tag:	TI751279-AI1.PV
Desc:	T7501 HCGO VAPOR TEMP
Process:	*Unknown*
Response:	1st Order
Parameters:	Kp=-0.03542 %Span/%Out, Td=259.7 Sec, Tau1=327.2 Sec

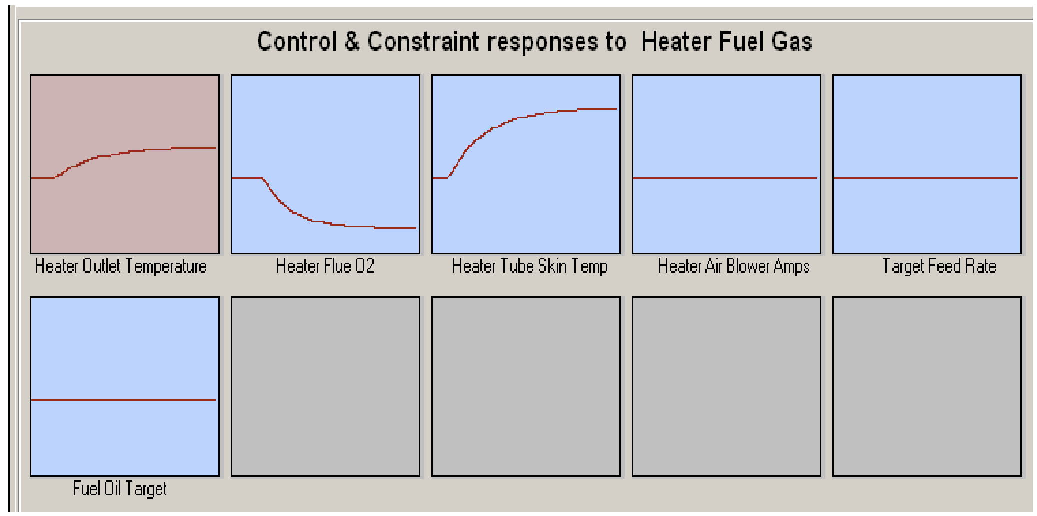
Process Model

APC Execution – MPC Process Models

PredictPro Automated Step Testing



Process Models in MPC block



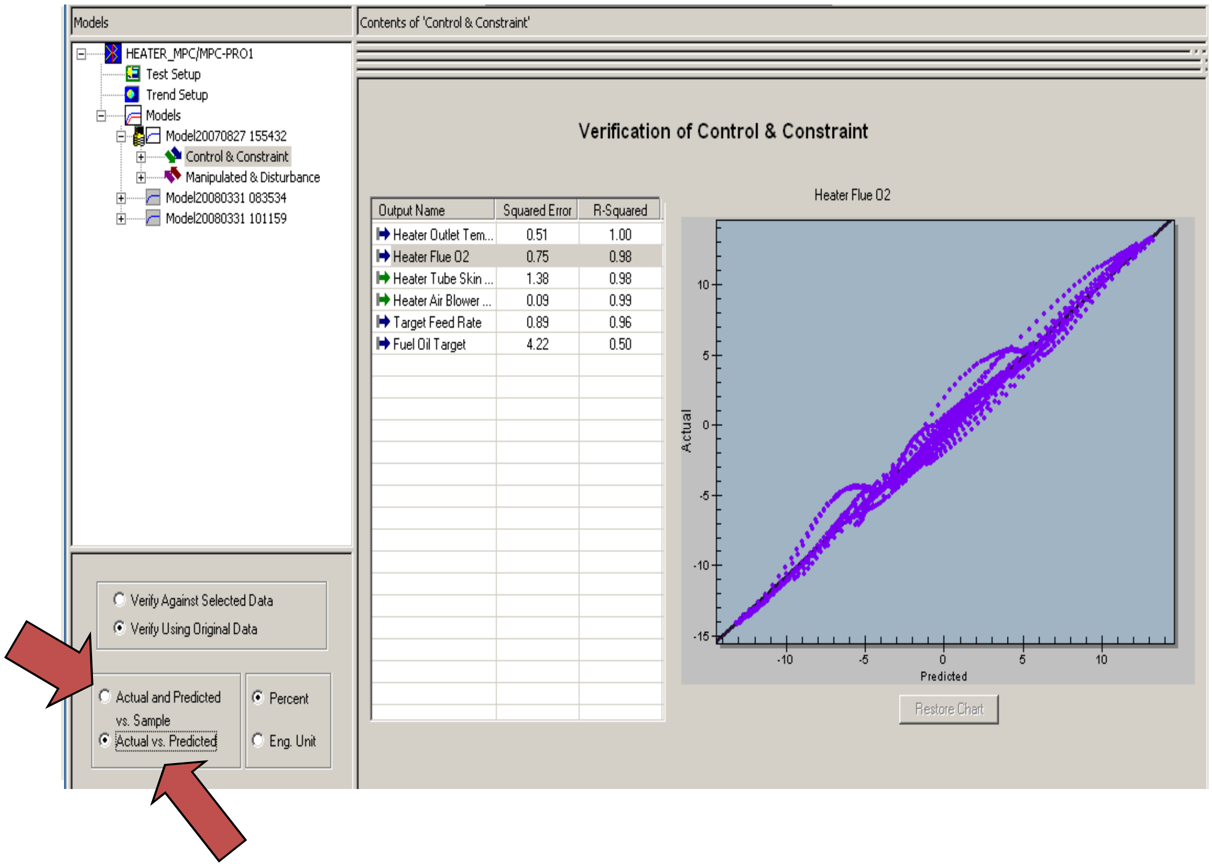
APC Execution – MPC Process Models

- Measurements are not available for Backwarm and Drum Switch
- Created “calculated” DV’s for Backwarm and Drum Switch
- Backwarm
  – Reduction in heat input to the Fractionator
  – Change in composition to the Fractionator
  – Created a DV with scale 0-100%, reduce from 100 to 80 when triggered
- Drum Switch
  – Reduction in heat input to the Fractionator
  – Minor change in composition to the Fractionator
  – Created a DV with scale 0-100%, reduce from 100 to 70

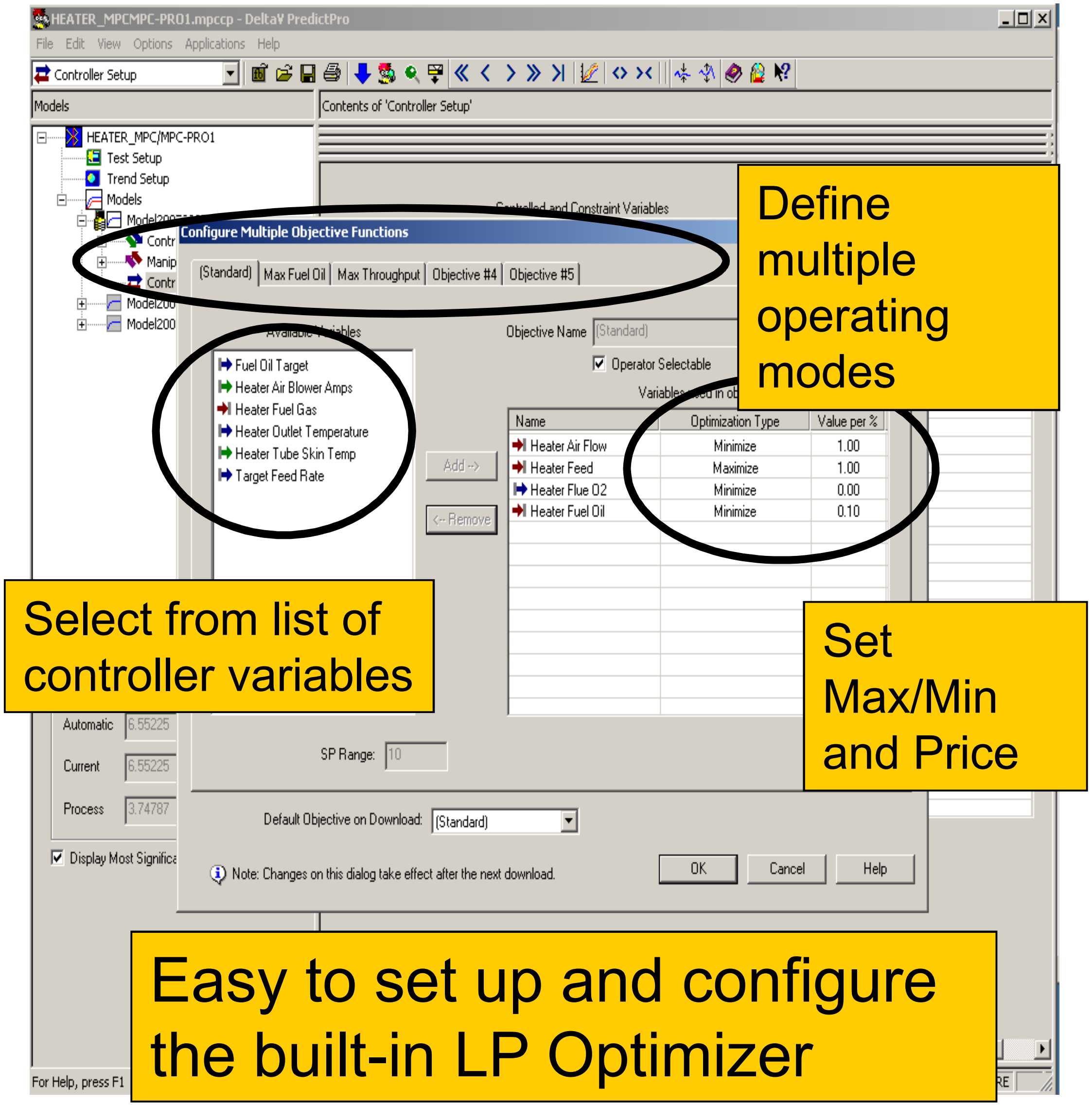
APC Execution – MPC Process Models

- Each DV triggered with key process variables and associated switching valves
- DV’s ramped slowly back to 100% after event to “re-arm”
- Calculated the models for both DV’s
  - Knowing approximately how much key MV's would move to compensate for the heat and composition change
  - Use the opposite amount of MV move, multiplied by know MV to CV/LV models to obtain the model from the calculated DV’s

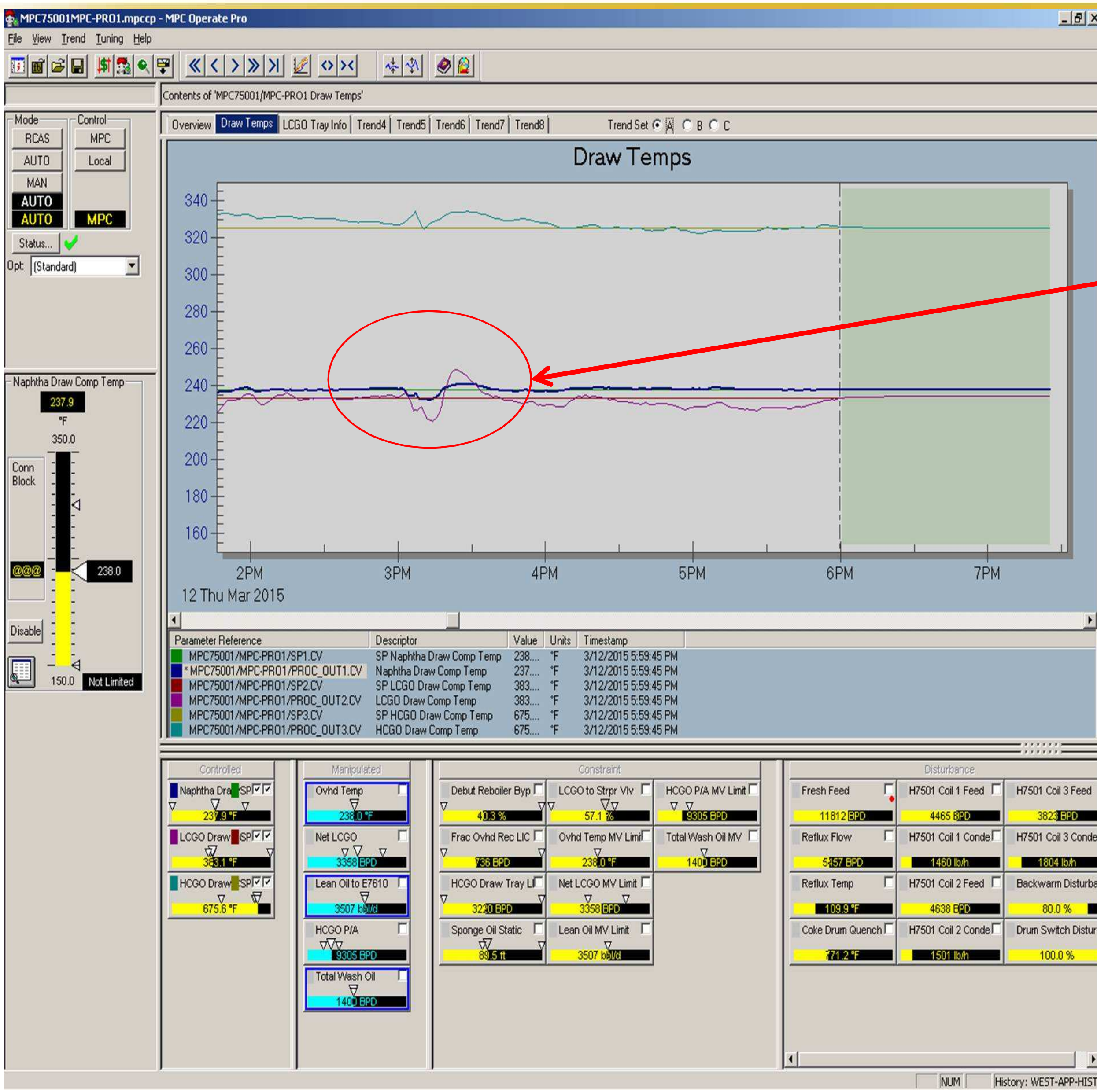
APC Execution – Validate MPC Process Models



APC Execution – MPC Optimizer – Linear Program



APC Execution – Performance



Minimal deviation during major disturbance!

Business Results Achieved

- Eliminated operator intervention during coke drum backwarm and drum switch operations!
- The average LCGO production was increased by almost 5% of rate which resulted in a payback of 6 months for the project!
- Reduced downstream unit constraint
  - Shifted HCGO production to LCGO - Right barrels in the right place!
- Reduced Naphtha quality exceedances by 32%, LCGO by 40%
- ROI < 6 months!
- Management & Operators gained confidence in

Summary

- APC can be successful on process with large unmeasured disturbances
- Implementation plan ensures success
  - Project Sponsor
  - Benefit Assessment
  - Control Foundation Improvement
  - Embedded MCP and SmartProcess® Application Package saves time
- Reduced product quality exceedances by >32%
- ROI on project was 6 months!
- Identified other opportunities
- Questions

Where To Get More Information

- Other EGUE Sessions
  – TBD
- Information
  – **Advanced Control Foundation: Tools, Techniques and Applications ;** Terrence L. Blevins, Gregory K. McMillan, Willy K. Wojsznis, Mark Nixon.
  – **Advanced Control Unleashed: Plant Performance Management for Optimum Benefit;** Terrence L. Blevins, Gregory K. McMillan, Willy K. Wojsznis, Michael W. Brown
- Consulting Services
  – Emerson Process Management, Industry Solutions Group
  – James Beall, James.Beall@emerson.com
  – John Ward, John.W.Ward@emerson.com

Thank You for Attending!

Enjoy the rest of the conference.