FCC Advanced Process Control
What's it worth?

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PETROCONTROL
A leader in inferential control technology

Workshop Objectives

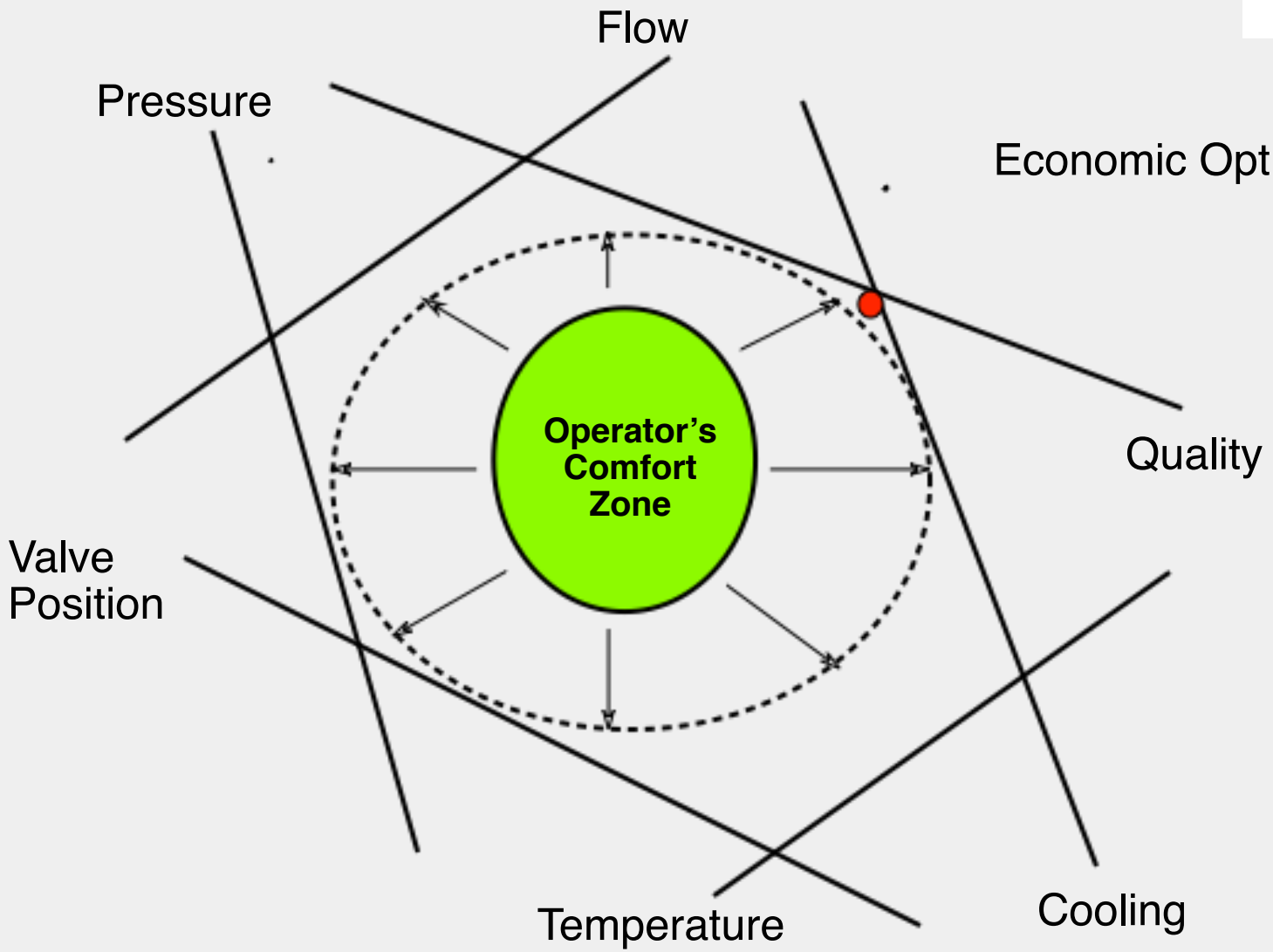
- Educate/Advocate APC Technology
- FCC APC Functionality
  - Typical FCC
  - Today's biggest opportunities
- What FCC APC is worth?
- Finding opportunities in your FCC
  - Audits
  - Benchmarking

Show seminar participants potential options to maximize profitability in FCC's with APC

APC Technology

- APC is a tool to help operators control and optimize the process
- APC for FCC's typically consist of:
  - Multivariable Control
  - Inferential Models

The Good Operator: Pushes Multiple Constraints



The Problem with Operating Near the Optimum

- The active constraints can change several times a shift.
- PID control is not adequate for controlling process at several constraints.
- Operators can't be expected to monitor dozens of process variables and make adjustments every minute.

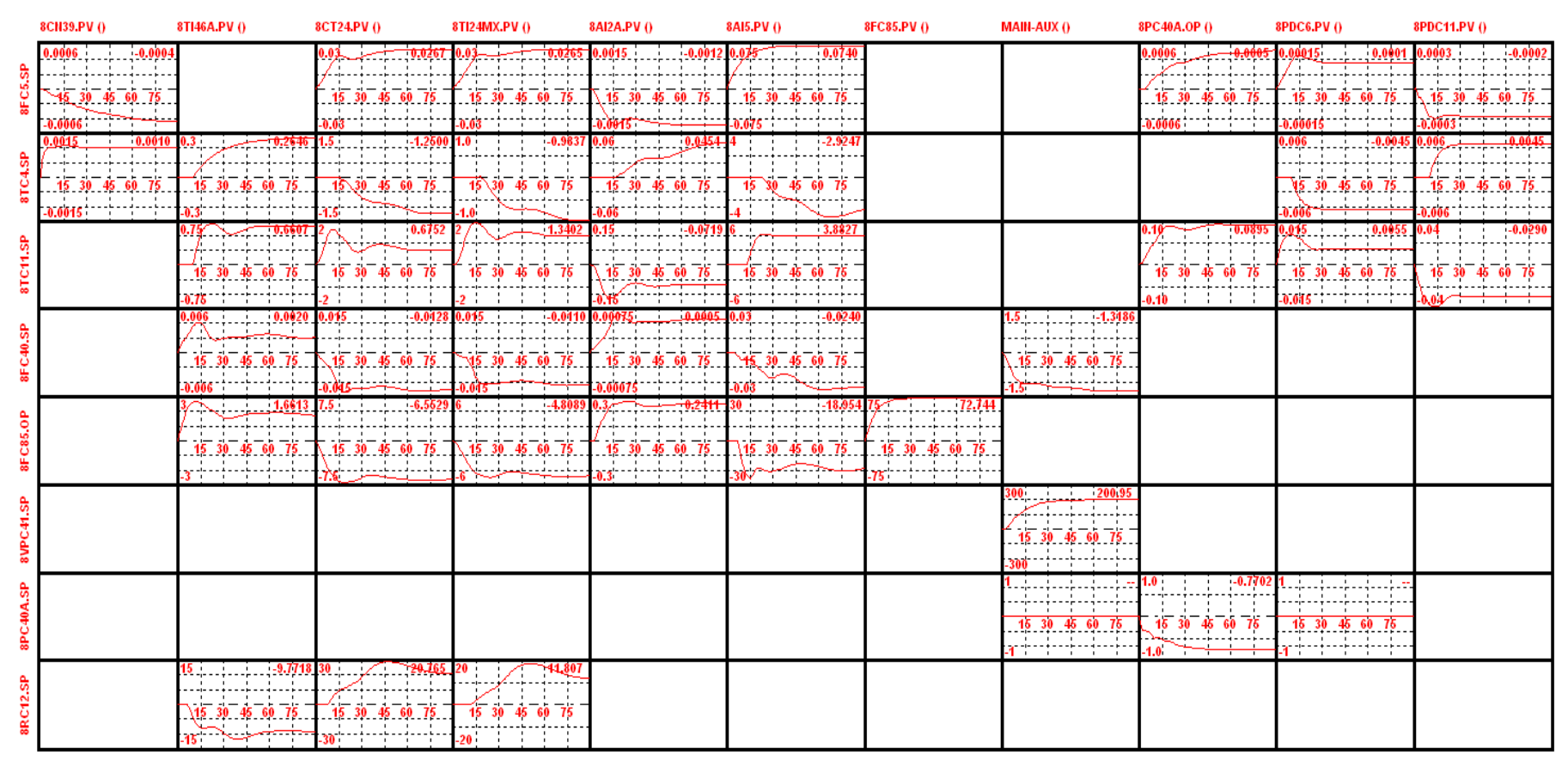
This is why APC and multivariable controllers are needed!

Multivariable Controller Features

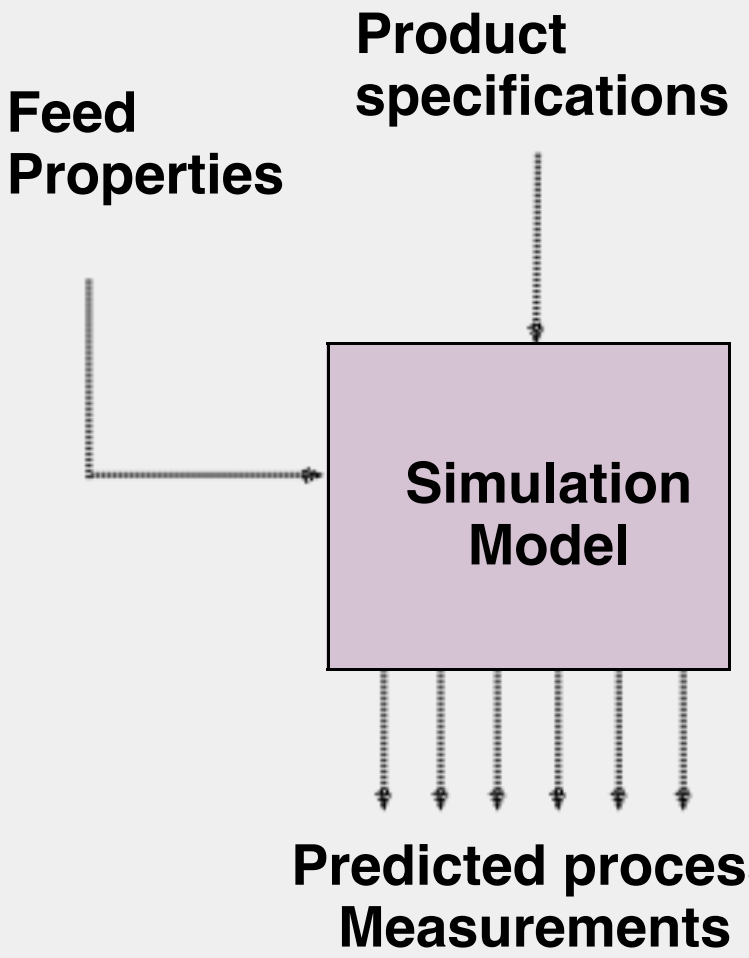
- Allows operation at multiple constraints
- Model based to deal with slow dynamics
- Can handle interactions between variables
- Optimization features to push plant towards most profitable operation
- Makes adjustments once per minute

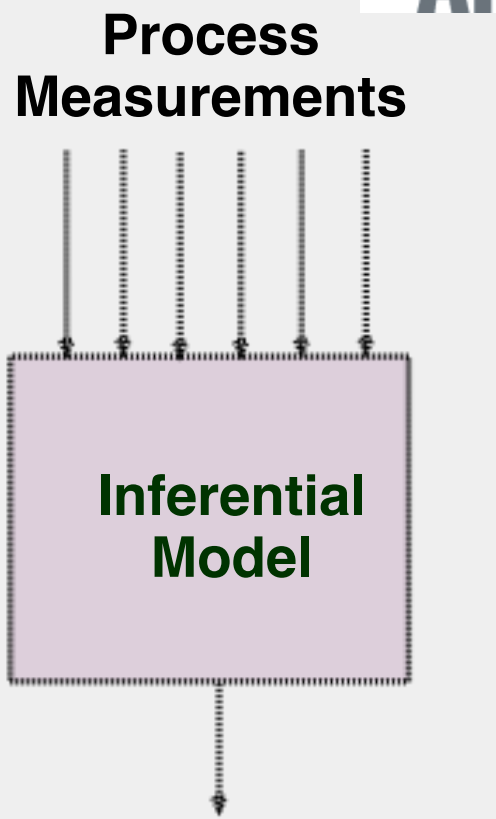
- MVPC been around since 1970's but became popular in 1980's.
- Used extensively in refining and petrochemical industries.
- Sold as industrial software products: Major players are:
  - AspenTech's DMCplus®
  - Honeywell's Profit®
  - Emerson's DeltaV Predict

Model Matrix



Inferential Modeling (1)





Inferential Modeling (2)

- Typical FCC inferences
  - Naphtha 90% point
  - HCN 90% point, sometimes flashpoint
  - LCO 90% point
  - Propane C2 and C4 content
  - Butane C3 and C5 content
  - Naphtha RVP or (preferably) C4 content
  - Loading of key trays
  - Reactor inferences: catalyst circulation rate, coke make, CTO ratio, severity
- ≈ 75% of APC benefits are tied to inferences

Inferential Modeling (3)

- Multi-variable controllers use inferences as control variable to optimize
  - Gasoline cut
  - LCO recovery
  - Stripper C2 penetration (and indirectly – loss of propylene to fuel)
  - Gasoline C4 content
  - Alky olefin feed flow and quality
  - Propylene recovery

Inferential Modeling (4)

- Quality of inferences makes a difference in our ability to capture the APC benefits
- Best inferential models are:
  - Based on process engineering and API procedures
  - Input a set of measurements that have the inferential information
  - Calibrated well, to the point that there is no need for daily changes of bias
  - Trusted by the operators

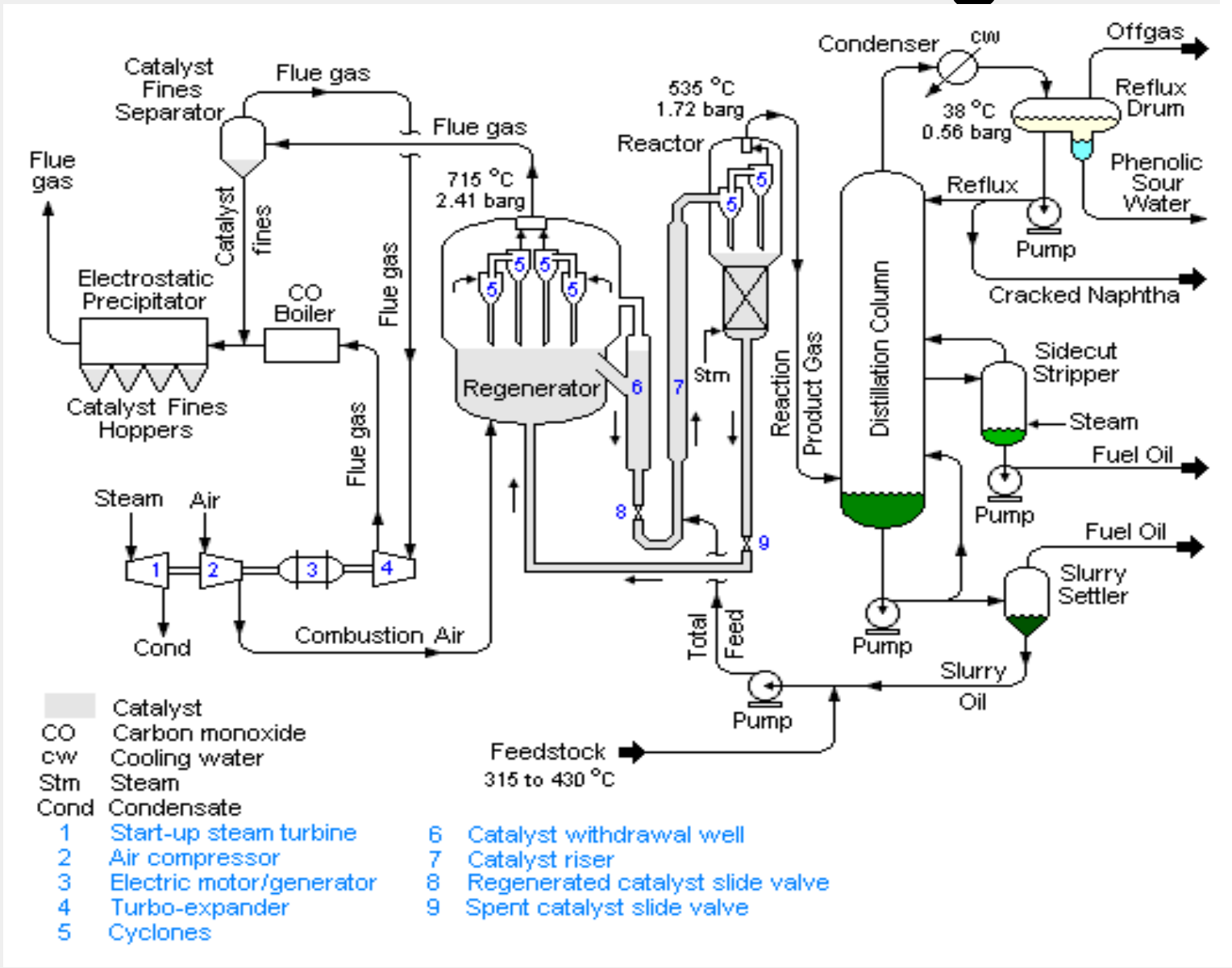
APC Functionality in a FCC (1)

- Reactor/Regenerator
  - Maintain the desired feed rate/reactor temperature from the production plan
  - Maximize catalyst circulation by minimizing preheat subject to regenerator limits (dense phase temperature), blower capacity limit or slide valve opening
  - Subject to compressor constraints, minimize wet gas compressor suction to improve main column fractionation
  - Regulate combustion air to control flue gas oxygen and prevent CO excursions

APC Functionality in a FCC (2)

- Fractionator and Gas Plant
  - Optimize Naphtha production – Cut naphtha on target (heavy or light) per current economics
  - Maximize LCO – Reach endpoint targets and improve fractionation to maximize LCO and minimize slurry
  - Avoid loss of C3 to fuel gas while keeping C2 out of propylene
  - Maximize C4 in Alky feed while minimizing C5 slippage
- Additional control and optimization objectives for FCC are:
  - Maximize throughput if economics dictate
  - Improve energy conservation

FCC Process Flow Diagram



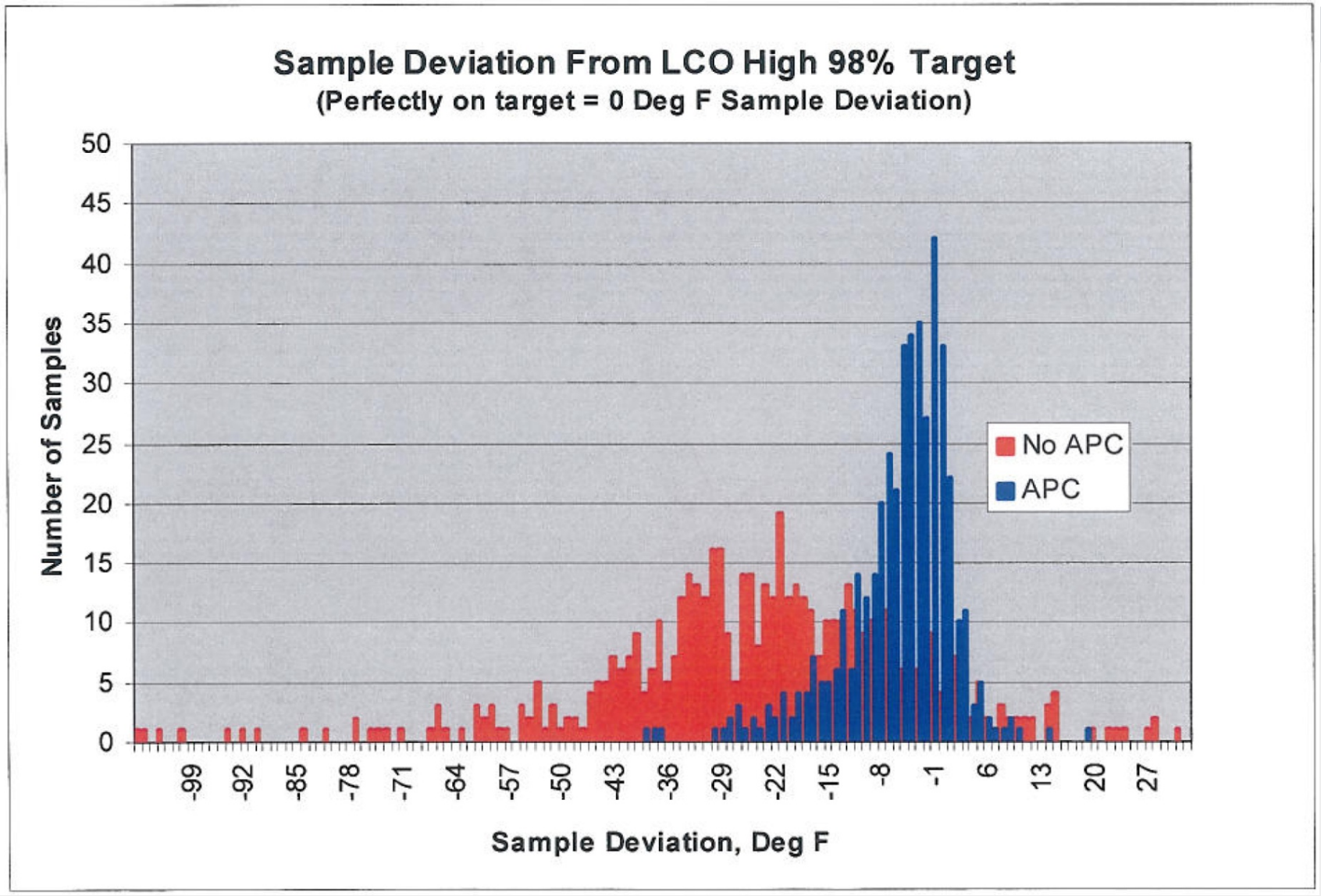
Today's biggest opportunity: LCO Maximization

- Optimize Naphtha production – Cut naphtha on target (heavy or light) per current economics
- Maximize LCO – Reach endpoint targets and improve fractionation to maximize LCO and minimize slurry

LCO Maximization

- Optimize Naphtha production – Cut naphtha on target (heavy or light) per current economics
  - 3-5 Yield %
- Maximize LCO – Reach endpoint targets and improve fractionation to maximize LCO and minimize slurry
  - 1-2 Yield %
- Getting this correct is Big $

LCO Maximization audit



What FCC APC is Worth?

0.40 to 0.60 $/BBL

- Multivariable controller(s) on the Reactor/Regenerator, Fractionator, and Gas Plant.
- MVC objective function reflects current economics, controller is pushing the profitable constraints.
- APC engineer regularly monitors and supports the advanced control performance. He/she is the owner for the APC. Problems are addressed and opportunities are captured.
- Operators are trained and supported.
- APC engineer supports inferential property models. When the inferences diverge from lab data, it is investigated and reconciled. Inferential models have meaningful inputs.

Value of APC Project Methodology

Additional benefits from:

- Engineering analysis/focus on operation
- Unit test and modeling
  - Uncover a better way to operate the process/ Disprove some process myths
  - Identify instrumentation problems
  - Create a high quality rich data set for inferential product quality calculation development
  - Educate the control engineers on the process

Identifying Opportunities
APC Audit

- Benchmark – Compare Refinery's APC applications and performance to industry
- Audit – Evaluate Refinery's approach to APC
- Gap Analysis – Identify performance gaps and opportunities
- Future Projects – Identify "quick hit" opportunities with short-term payback and future capital projects.

Example
APC Post Audit – 1

- Driving force $/BBL
- Increase LCO recovery 0.44
- Increase HCO recycle 0.03
- Decrease oxygen purchases 0.03
- Total evaluated 0.50

- Additional non-evaluated benefits next page

Example
APC Post Audit – 2

Not evaluated fully

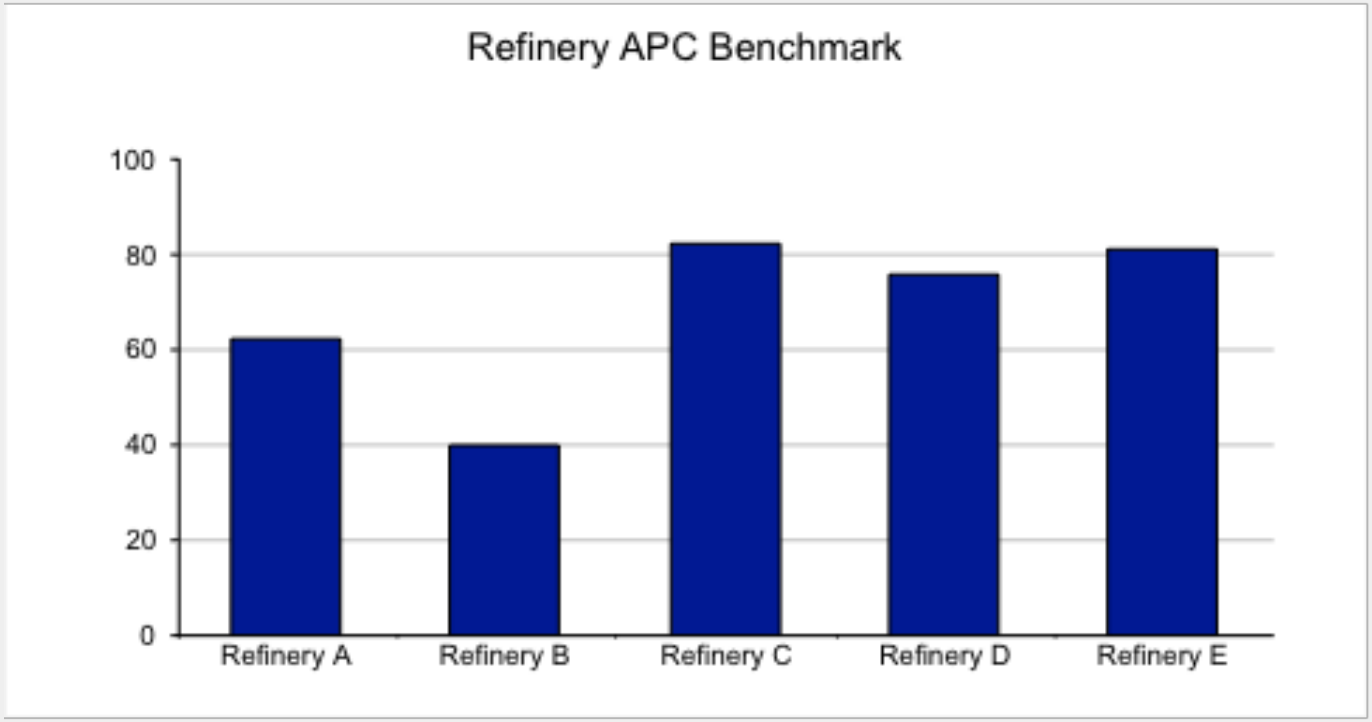
- Better gasoline RVO control
- Higher cat circulation rate (higher conversion)
- Avoid C2 contamination of propane

Example FCC Control Audit
SCORECARD

Opportunity Matrix

	REFINERY A		REFINERY B	
	CURRENT	RECOMMENDATIONS	CURRENT	RECOMMENDATIONS
GENERAL APC				
RX/RG MVPC EXISTS	YES	YES	YES	YES
FRACTIONATOR MVPC EXISTS	YES	YES	YES	YES
GAS PLANT MVPC EXISTS	YES	YES	YES	YES
PERFORMANCE APC	NEEDS IMPROVEMENT	VARIOUS	GOOD	FINISH COMMISSIONING
PERFORMANCE INFERENTIALS	NEEDS IMPROVEMENT	BETTER INPUT SET	GOOD	FINISH COMMISSIONING
SUPPORT APC	NEEDS IMPROVEMENT	MORE RESOURCES	GOOD	CONTINUE - ESPECIALLY THE NEXT 3-6 MONTHS
SUPPORT INFERENTIALS	NEEDS IMPROVEMENT	BETTER MONITORING INFERENCES AND INPUTS	GOOD	CONTINUE
RX/RG				
FEED MAXIMIZATION FUNCTION	NEEDS IMPROVEMENT	ADD CV/USE GAS PLANT MV'S FIRST	YES	VERIFY MODELS, LINEARIZE VALVES, ADD CV'S FOR FEED/RX TEMP
RX/RG PRESSURE BALANCE	YES	NONE	YES	NONE
FRACTIONATOR				
NAPHTHA QUALITY CONTROL	YES	MODIFY MATRIX AND INFERENCE TO ALLOW DISTILLATE MODE	YES	NONE
LCO YIELD OR QUALITY CONTROL	NEEDS IMPROVEMENT	REVIEW LCO HOT REFLUX AND LCO INFERENCE	YES	IMPROVE LCO INFERENCE
SLURRY HEAT MANAGEMENT	NEEDS IMPROVEMENT	ADD MV'S TO ALLOW SOLUTION TO OVERCOOLING, CV FOR HCO VAPOR TEMP	YES	NEED STRATEGY FOR PART LOAD OPERATION
GAS PLANT				

APC Benchmarking



Tips for FCC Seminar

- APC can be worth big dollars
  - Projects are low capital expenditure/ returns are large
  - Make sure you get your LCO maximization function correct; ability to switch between gasoline and LCO
  - APC project methodology often finds big wins
- Don't miss out
  - Use audit scorecard to evaluate your unit
  - Benchmark your FCC