Refinery Crude Unit

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Division

EMERSON
Process Management
Topics

→ Why Do Crude / Vacuum Units Need Advanced Controls?
→ What Advanced Controls Do We Implement?
→ What’s New And Different With Emerson APC Tools?
→ Case Study
Crude Unit Product Variability

Date

7/5/00
7/6/00
7/7/00
7/8/00
7/9/00
7/10/00

Diesel 90%
Crude Unit Characteristics

- Conditions Are Often Changing
  - Changing Crude Feed Compositions
  - Changing Targets For Sidestream Qualities
    - Product Qualities Measured by Laboratory Samples or Online Analyzers with a lot of delay

- One Of The Largest Consumers Of Energy In The Refinery

- One of the most INTERACTIVE units in the refinery – difficult to control

- Primary Yields Set Overall Refinery Yields
## Typical Benefits

<table>
<thead>
<tr>
<th>Unit</th>
<th>PredictPro Benefit USc/ bbl Feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmospheric Crude Units</td>
<td>5</td>
</tr>
<tr>
<td>Vacuum Distillation Units</td>
<td>5</td>
</tr>
<tr>
<td>FCCU Main Fractionator</td>
<td>4</td>
</tr>
<tr>
<td>Coker Main Fractionator</td>
<td>8</td>
</tr>
</tbody>
</table>
APC Improves Quality

- Removes process variability
- Provides real-time predictions of unmeasured qualities
- Compensates for dead-time and analyzer delays

Typically 40-80% reduction in quality variation.
APC Increases Throughput

- Ideal for managing multiple constraints
- Predicts limit violations before they occur
- Push equipment and plant limits every minute of every day

Typically 3-10% increase in throughput.
APC Reduce Operations & Maintenance Costs

→ Automation of routine tasks increases the loop count per operator

→ “Safe Park” applications lowers risks during process upsets

→ More stable operation reduces wear-and-tear on machinery

Typically 0-4% reduction in O&M costs.
APC Reduce Incidents

- Prediction and control against actual equipment limits
- Automated action on instrument or equipment failure
- More stable operation reduces opportunity for excursions

Typically 10-20% reduction in safety or environmental incident risk.
APC Minimize Energy Costs

- Designed to minimize energy when possible.
- Maximize equipment efficiency and heat recovery.
- Optimize tradeoffs in the site utility and fuel balance.

Typically 2-6% reduction in energy costs.
APC Reduces Off-spec and Rework

→ Real-time prediction and control of key product qualities
→ Stable operation yields consistent, predictable qualities
→ On-spec blends every time leads to lower inventories and component costs

Typically 5-10% reduction in product inventories.
Hierarchy of Performance Control

- Loop Performance
- Process Control DCS
- Advanced Control
- Enterprise Control
Improving Control Performance
Reducing Input Disturbances – Fuel Gas

<table>
<thead>
<tr>
<th>Heat Combustion</th>
<th>Kcal/mole</th>
<th>Kcal/gm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>191.76</td>
<td>11.95</td>
</tr>
<tr>
<td>Ethane</td>
<td>341.26</td>
<td>11.35</td>
</tr>
<tr>
<td>Propane</td>
<td>488.53</td>
<td>11.08</td>
</tr>
<tr>
<td>Butane</td>
<td>635.38</td>
<td>10.99</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>57.79</td>
<td>28.77</td>
</tr>
</tbody>
</table>

Conclusion: Measure and control by mass – not by volume!
Reducing Variability – Remove Disturbances - Heater Controls

Fuel Gas with Mass Control and Density Feedforward
Heater Excess Air Control
Main Crude Unit

→ Main feed valve deadband was 5-7%. This caused pressure fluctuations to the desalter units in the preheat train. A lower pressure setpoint was necessary to avoid lifting relief valves.

→ The main feed valve was replaced with a 12” V300 control valve assembly and tuned using Lambda Tuning methodology (avoid interaction with the desalter pressure controller).

→ Pressure fluctuations were reduced to a +/- 1 psi allowing a higher pressure setpoint.

→ Throughput increases have averaged 2000 BPD with a desalter pressure controller setpoint increase.

→ This optimization is presently valued at $1,900,000 annually.
DeltaV Advanced Control - PredictPro
Yesterday’s Technology...

...required you to have a really big one!
DeltaV: Removing Obstacles To APC Implementation & Maintenance

DeltaV APC Projects are 25-50% Faster and Less Costly than traditional APC Projects

Team of consultants
**Embedded APC Tools – What’s new?**

- NO extra databases
- NO database synchronization issues
- NO watchdog timers
- NO fail/shed logic design
- NO custom DCS programming
- NO interface programming
- NO operator interface development

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**Traditional Advanced Control**

**Embedded APC:**

- Can run in DCS controllers
- Redundant and fast (1/sec)
- Integrated operator user interface
- Configured in DeltaV environment
- Automated step testing and Model ID
Typical APC Project Timeline

Months

1  2  3  4  5  6  7  8  9  10  11  12

Functional Design

Det. Design, Config & Staging

Step Tests & Model ID

Commissioning

Traditional APC Technology

Embedded APC Technology
Classical Feedback Control

Setpoint → Error → PID Algorithm to make Error zero → Move single manipulated variable → Plant → Current measured value for single controlled variable

Control Moves Based on Current Measurement
Multivariable Predictive Constraint Control

Uses Information from The Past To Predict The Future
Multi-Variable Control Problem

Controller

Temperature

Controller

Temperature

Reflux

Reboil

Distillation Process
Multi-Variable Control Problem

Controller

Temperature

Reflex

Controller

Reboil

Temperature
Multivariable Predictive Constraint Control

Benefits: Reduction in Standard Deviation of 30 to 70%
Historically, Advanced Control Was Done in Supervisory Computers

Advanced Process Control

- Not redundant
- Not real-time (1 minute)
DeltaV Predict in the Controller

Advanced Process Control
- Not redundant
- Real-time (1 minute)

Proprietary Bus

DCS Controller
- PID
- APC

LAN

Open Bus
- Redundant and Fault Tolerant
- Real-time (1 second)
- Communicates data throughout enterprise

Fieldbus

PID

LAN

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MPC Implementation Sequence

1. PreTest and Variable Selection
2. Configure
3. Process Testing
4. Model Building and Validation
5. Controller Simulation
6. Build Operator Interface
7. Controller Download
8. Controller Operation
Step 2 - Graphical Configuration - MPCPro
Function Block
Configure the MPCPro by Selecting Properties
Attributes for Control, Manipulated, Disturbance and Constraint Parameters
Step 3 - Automated Step Testing

Manipulated inputs selected for test are changed in a pseudo-random fashion during the test based on the step size and initial starting manipulated input value.
Step 4 – Model Validation - Process Model Displays Produced
Model Validation
Step 5 - Controller Simulation
Step 6: Automatic Operator Display

- Trend Window
- Past
- Future

Trend Window

- CVs
- MVs
- LVs
- DVs
Built-in LP Optimization

Minimized Energy

- 80 deg F
- 50 psi
- 0% position

- 120 deg F
- 100 psi
- 100% position
DeltaV Neural

– Create real-time “virtual sensors” for periodic lab measurements

– Easy to understand and use

– Easy to update and maintain
Property Estimation

→ When critical measurements are slow to reflect process changes or only lab analysis is available, then parameter estimation can often be used to improve the performance of control and monitoring applications.

→ Measured process inputs their relationship to the property of some process output is used to infer an estimate of the output.
Example: Crude Column Product Quality

Crude Column

→ Predict product qualities from temperature / pressure profile
  - Distillation properties (IBP, 90, EP)
  - Pour, cloud, SUS

Updated from lab measurements
Real-time estimate used for control
Distillation Control Module

- Standard Distillation Calcs
- Module Library
- Predict Pro Block
- Preconfigured Neural Blocks

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SmartProcess Implementation

Months

1 2 3 4 5 6 7 8 9 10 11 12

Functional Design
Det. Design, Config & Staging
Step Tests & Model ID
Commissioning

FDS & Config
Step Tests & Model ID
Commissioning

Traditional APC Technology

Embedded APC Technology

SmartProcess Applications
Implementing Advanced Control
Refinery APC Example

Ergon, West Virginia
Ergon Project Scope

- Atmospheric Crude and Vacuum Units
- 2 Model Predictive Controllers – 4 x 4, 3 x 3
- 3 Neural Networks
  - SR Naphtha 95% point
  - AGO 95% point
  - Wax distillate 95% point
Atmospheric Column
4 Controlled Variables

- Crude
- Fuel Gas
- Naphtha
- Kero
- Hvy Kero
- AGO
- Resid to VAC Column

MPC
Atmospheric Column
4 Manipulated Variables

Crude
Fuel Gas

Naphtha
Kero
Hvy Kero
AGO
Resid to VAC Column

MPC

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Atmospheric Column
3 Disturbance Variables

Crude → Fuel Gas

FC

TC

MPC

Naphtha
Kero
Hvy Kero
AGO
Resid to VAC Column
Atmospheric Column Neural Network Predictions

Column Temps & Yields

Naphtha

Kero

Hvy Kero

AGO

Resid to VAC Column

Crude

Fuel Gas

Predicted NA End Point

Predicted AGO End Point

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Vacuum Column
Controlled Variables

- VGO
- Wax Dist
- Hvy Wax Dist
- VAC Resid
- Atm Btms
- Fuel Gas

Controlled Variables:
- VAC P/A
- FC
- TC
- PC
- LC
- TI
- PCT

MPC
Vacuum Column
Manipulated Variables

- VGO
- Wax Dist
- Hvy Wax Dist
- VAC Resid

Atm Btms
Fuel Gas

MPC
**Vacuum Column Disturbance Variables**

- VGO
- Wax Dist
- Hvy Wax Dist
- VAC Resid
Vacuum Column
Neural Network Prediction

Column Temps & Yields

Predicted Wax Distillate 95% Point

Atm Btms
Fuel Gas

VAC Resid

VGO
Wax Dist
Hvy Wax Dist

Wax Distillate 95% Point
Column Temps & Yields
Atm Controller Performance

Controller ON

Crude Change

- CV
- SP
- MV
- Lab
- Spec

Naphtha

Hvy Kero

Kero

AGO
Neural Results – Naphtha 95% Point

Crude Switch

07-Aug-03 09-Aug-03 11-Aug-03 13-Aug-03
00:00:00 00:00:00 00:00:00 00:00:00

Lab
NN Prediction
Filtered
# Variability Reduction

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th></th>
<th>After</th>
<th></th>
<th>Reduction in Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>St. Dev.</td>
<td>Average</td>
<td>St. Dev.</td>
<td></td>
</tr>
<tr>
<td><strong>Atm Column</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR NAPHTHA EP</td>
<td>349.55</td>
<td>14.89</td>
<td>347.10</td>
<td>4.30</td>
<td>71.1%</td>
</tr>
<tr>
<td>AGO EP</td>
<td>636.32</td>
<td>10.54</td>
<td>634.41</td>
<td>6.22</td>
<td>41.0%</td>
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<tr>
<td>OVERHEAD TEMP</td>
<td>253.18</td>
<td>5.01</td>
<td>260.91</td>
<td>1.80</td>
<td>64.1%</td>
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<tr>
<td>KERO DRAW TEMP</td>
<td>362.59</td>
<td>4.60</td>
<td>366.60</td>
<td>1.86</td>
<td>59.5%</td>
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<tr>
<td>HVY KERO TEMP</td>
<td>459.37</td>
<td>5.65</td>
<td>462.72</td>
<td>2.60</td>
<td>54.0%</td>
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<tr>
<td>AGO DRAW TEMP</td>
<td>528.14</td>
<td>5.60</td>
<td>530.77</td>
<td>2.55</td>
<td>54.5%</td>
</tr>
<tr>
<td><strong>Vacuum Column</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WAX DIST 95% POINT</td>
<td>934.36</td>
<td>12.28</td>
<td>933.78</td>
<td>8.56</td>
<td>30.3%</td>
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<tr>
<td>VGO CHIMNEY TEMP</td>
<td>358.58</td>
<td>7.32</td>
<td>365.74</td>
<td>3.23</td>
<td>55.8%</td>
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<tr>
<td>WAX VAP TEMP</td>
<td>542.47</td>
<td>5.99</td>
<td>599.50</td>
<td>2.29</td>
<td>61.8%</td>
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<tr>
<td>H WAX VAP TEMP</td>
<td>651.77</td>
<td>5.39</td>
<td>671.75</td>
<td>3.74</td>
<td>30.7%</td>
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### Crude/Vac Unit APC Project Timeline

<table>
<thead>
<tr>
<th>Activity</th>
<th>Timeframe</th>
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</thead>
<tbody>
<tr>
<td>Functional Design Specification</td>
<td>3 weeks</td>
</tr>
<tr>
<td>Application Configuration</td>
<td>&lt; 1 day</td>
</tr>
<tr>
<td>Step Tests</td>
<td>10 days</td>
</tr>
<tr>
<td>Commissioning</td>
<td>1 week</td>
</tr>
</tbody>
</table>

DeltaV APC Projects are 25-50% Faster and Less Costly than traditional APC Projects

**Scope:** Two 4x4 MPC controllers, 3 Neural Nets
Standard Operator Display
Summary

- APC has a large value for Crude Units
- DeltaV Embedded APC dramatically lowers implementation costs
  - Less need for expensive consultants
  - Quicker implementation
  - Easier to maintain
- Can be used with other DCS platforms
- Simple Optimization can be done in APC layer
Learning More About DeltaV Advanced Control

- Book was inspired by DeltaV Advanced Control Products. This book was introduced at ISA2002 may also be ordered through ISA, Amazon.com or at EasyDeltaV.com/Bookstore

- The application sections include guided tours based on DeltaV Advanced Control Products

- CD provides an overview video for each section and examples. Copies of the displays, modules, and HYSYS Cases are included on the CD.
Questions? Comments?

Questions? – contact

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(512) 834-7262
Thank You!

Questions?