FCCU Advanced Control at Chevron Pembroke Refinery

ERTC
8th to 10th May 2006
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Zak Friedman Petrocontrol
Steve Park AMT
FCC at Pembroke Refinery

- Initial Hydro skim refinery commissioned in 1967
- Cracking facilities commissioned in 1983 (Texaco side by side Rx/Rg unit, with a main fractionator and gas concentration section)
- Can process over 35% resid of total throughput of over 100,000 BPSD (600m3/hr - One of the Biggest FCC in Europe)
- Feed mix variation is in the region of 0.908 to 0.92 SG
- Last major turn around is during 2003
History of APC at Pembroke

- Pembroke Refinery has a long history of APC since 1987
- First MVC controller on FCC – 1988 (DMC) – with separate controller for Rx/Rg, and Mainfrac
- 2001, RMPCT replaced DMC, retained original structure, and added deeth, debut, napsplit
- Very limited success at each time (mainfrac didn’t work, lack of co-ordination between applications, tray damage)
- First Principle Inferentials first used in early 1990’s and have been deployed across most refinery units
FCCU APC Reengineering

• Potentially US$ 4millions/yr yet to be captured (carried a study on FCC APC during 2004) - Need to completely revamp FCC APC
• Scope of the revamp to cover reactor, regenerator, mainfrac, deeth, debut
• Main focus of the application and this paper is the Fractionator section due to major difficulties in managing this section of the unit
• Major feed limiting constraints are mainly in the Fractionator section
• RMPCT is the control technology used
• New FCCU application commissioned in July 2005
Operating within Constraints

**True Economic optimum**
- Max Tot. feed, Max Resid, ROT
- Max prod: LCGO (up-grade more HCGO)
- Max HHCN (match ULSG Capacity)
- Max Ole (match Alky Capacity)
- Min usage Air, Min C3 loss to offgas

**MVC Operating Region**
- WGC Anti-surge
- Airblower anti-surge
- HP steam limitation

**WGC & others**

**System Pressure**
- Eg. Rx/Rg DP.
- Mainfrac top P
- SCSV/RCSV – DP
- And OP
- Mainfrac OVHD P

**Rx/Rg Temperature**
- Eg. Rx bed Temp.
- Rg flu gas Temp.
- Excess O2,
- Cyclone Vel

**Hydraulic Const.**
- Eg. Control valve
- Saturation OP – reflux & cooling system

**Column fouling/flooding limitation**
- LCGO draw TY DP, Level,
- Glitsch grid flow,
- TPA DP, ICGO wash down
- Mainfrac bottom Temp.

**Operator's Preferred Operating Region**

**Product Purity**
- HCN90 & EP
- HHCN90 & EP
- LCGO Flash
- Slurry Density
- C2 spec in Ole

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FCCU application overview

- Applications are as follows:
  - Rx_Rg/mainFrac/Deeth (better integration and optimisation) – 55CVs, 22MVs, 11DVs
  - Single application to cover Debutaniser (8CVs, 4MVs, 6DVs)
- Large scope application with sub controllers deployed for ease of maintenance and operator intervention. *(Sub controller switch AM/CL code supplied by AMT)*
- Customised Operator displays developed by CVX and AMT
  - Easy monitoring and operated upon (by panel operators)
  - Accommodation for switching access
- First principle Inferential model based on GCC (PetroControl)
Overview of Revamp Design

FCCU Block Flow Diagram

- Waste Heat Boiler
- PRT & Flue Gas
- PRT MTR GEN FOWAR
- Primary
- Secondary
- Feed Heaters
- Airblower anti-surge
- Stack
- HP Steam
- Wet Gas Compressor
- WGC Anti-surge
- HP STM limitation
- Main Frac Overheads
- Reactor / Regenerator
- Mainfrac OVHD P
- Eq. Rx/Rg DP
- Mainfrac top P
- SCSV/RCSV - OP And OP
- Excess O2, Cyclone Val
- Cooling Capacity
- Main frac draw DP & Level
- Glitsch grid flow, TPA DP, ICBO wash down, MF BTM T, cooling duty
- HHCN90 & EP
- Preheat Abs Sponge Abs
- HCGO Prod
- Refinery F/Gas
- Olefin Market
- HSCG prod
- Downstream units limitation
- Reboil capacity from LCGO PA / Reflux
- HCGO PA / Reflux
- ICBO PA / Reflux
- Typical Constraints
- Typical prod. & spec.
- Petrocontrol
- AMT
Schematic of Main fractionator

Cold Feed → TPA

TPA → LCGO PA

LCGO PA → ICGO PA

ICGO PA → Reactor Effluent

Reactors to Min Tray Wash

Max lvl 93%

Min Tray Wash → Min Grid Flow

Max btm temp

Min Grid Flow → Max velocities

Max velocities → Max yield on resid feed

Lean Oil to Absorber

90% Dist

HHCN Product

90% Dist

Flash point spec

Max to min traywash

LCGO Product

Max lvl

Wet Gas

HHCN Product

Max yield on resid feed
Project details Schedule and contract

- Project was completed in a 8 month window.
- Inferential model provided by PetroControl, and implemented and subsequent re-calibrated by CVX (VBA-model for easy maintaining and calibration)
- APC model jointly developed and implemented by CVX and AMT (one engineer each)
- Operator training package jointly developed by CVX and AMT (computer based self-learning, interactive)
- Project completed under budget with benefits higher than expected
FCCU APC Application Success Factors

• New FCCU application commissioned in mid-June 2005
• High operator acceptance
• Good average controller uptime (>95% when process available)
• Fractionator control now much improved, this is a key issue for the FCCU unit operations.
• Payback achieved within a month
Feature – inferentials/Specs Control

- **Fractionator:**
  - LCGO Flash Point
  - HHCN ASTM 90% & End point
  - HCN ASTM 90% & End point

- **Gas Plant**
  - Deeth bottom % C2 slippage
  - Olefin % C5
  - LCN RVP

- **Note:** no analyser or lab updates used for biasing inferences
Highlight - Inferential models

CVX VBA model
Based on GCC

AMCL model
## Sample Model – Spec Control

<table>
<thead>
<tr>
<th>MF Top-T</th>
<th>MF OVHD-T</th>
<th>LCGO prod.</th>
<th>HCGO PA</th>
<th>LCGO RBL</th>
<th>Deeth RBL</th>
<th>Ambient-T</th>
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<tbody>
<tr>
<td>HCN pt90</td>
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<td>HCN EP</td>
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<td>HHHCN 90pt</td>
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<td>HHHCN EP</td>
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<tr>
<td>LCGO FP</td>
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<tr>
<td>Deeth Bottom C2</td>
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</table>

**Petrocontrol**

**AMT**
Highlight - LCGO Flash Point control

LCGO Flash Point Control

- Infer LCGO FP
- Lab LCGO FP
- Infer LCGO FP Sdev

- Inferential recalibrated & new controller commissioned
- Average Standard deviation is reduced by 1DegC
Highlight – HCN90 spec control

Average Standard deviation is reduced by 1DegC
Feature – mainfrac control

- Optimise where possible the Fract bottoms heat removal
  Control Fractionator bottom temperature
- Prevent Fractionator flooding
- Maximise heat removal and balance duty around the column
- Ensure column packed sections are kept wet
- Ensure Slurry oil density remain on control within tight limits
- Minimise fouling probabilities in Slurry system
- Sustains Debutaniser on control even though reboiler (HCGO) exchanger fouling occurs
Sample Model – Main Frac control

<table>
<thead>
<tr>
<th>MainFrac Bottom Temp.</th>
<th>Feed</th>
<th>ROT</th>
<th>MF Top-T</th>
<th>LCGO prod.</th>
<th>HCGO PA</th>
<th>ICGO PA</th>
<th>HHCN prod</th>
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<tbody>
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<table>
<thead>
<tr>
<th>Packed Section</th>
<th>Feed</th>
<th>ROT</th>
<th>MF Top-T</th>
<th>LCGO prod.</th>
<th>HCGO PA</th>
<th>ICGO PA</th>
<th>HHCN prod</th>
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<tbody>
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<th>ICGO Wash</th>
<th>Feed</th>
<th>ROT</th>
<th>MF Top-T</th>
<th>LCGO prod.</th>
<th>HCGO PA</th>
<th>ICGO PA</th>
<th>HHCN prod</th>
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<tbody>
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<table>
<thead>
<tr>
<th>LCGO Draw</th>
<th>LVL</th>
<th>Feed</th>
<th>ROT</th>
<th>MF Top-T</th>
<th>LCGO prod.</th>
<th>HCGO PA</th>
<th>ICGO PA</th>
<th>HHCN prod</th>
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<th>LCGO Draw</th>
<th>DP</th>
<th>Feed</th>
<th>ROT</th>
<th>MF Top-T</th>
<th>LCGO prod.</th>
<th>HCGO PA</th>
<th>ICGO PA</th>
<th>HHCN prod</th>
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<table>
<thead>
<tr>
<th>HCGO Visc</th>
<th>Feed</th>
<th>ROT</th>
<th>MF Top-T</th>
<th>LCGO prod.</th>
<th>HCGO PA</th>
<th>ICGO PA</th>
<th>HHCN prod</th>
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<table>
<thead>
<tr>
<th>HCGO Density</th>
<th>Feed</th>
<th>ROT</th>
<th>MF Top-T</th>
<th>LCGO prod.</th>
<th>HCGO PA</th>
<th>ICGO PA</th>
<th>HHCN prod</th>
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<tbody>
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</tbody>
</table>
Highlight - LCGO Section dP Sensitivity to Flood
Highlight - LCGO Draw Tray Level

LCGO Draw Self Regulating Level

- Tray Full, LCGO section flooded
- Project KO and Pretest and dynamic test Phase
- Controller Commissioned
- Unit being pushed

Draw tray level
Level stdev

50 60 70 80 90 100
12/12/04 12/02/05 12/04/05 12/06/05 12/08/05 12/10/05 12/12/05 12/02/06

0 2 4 6 8 10 12 14 16 18 20

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Highlight - Fractionator BTM T Critical Unit imitation

Fractionator bottom temperature

355°C is High Operating Limit

Controller Commissioned
Feature – Optimisation direction

- Maximise Total Feed (match scheduling)
- Max Resid processing to Regen limitations
- Minimise load on Blower and expander
- Stay in safe system delta P range (slide valves) – max cat circulation
- Maximise Conversion
- Run to minimum Regen excess O2 (>1%)
- Max LCGO draw against MIN internal reflux
  - Significant operator issue
- Minimises the Deethaniser C3’s loss to offgas subject to C2 content at bottom (ole prod)
Sample Model – Rx/Rg optimisation
Unit Feed and Yields in M3/HR
Shows increase in recovery of LCGO whilst sustaining bottom conditions

Feed rate conditions dictated by refinery and plant issues, Application ran at >95% from start of application

Increased recovery of LCGO at expense of internal reflux (traywash) and hence Slurry yield - Gain of 1
Highlight – Excess O2 optimisation

Excess O2 regen flu gas

Controller Commissioned

Unit is pushed to the limit
Highlight – Deeth Optimisation

Deeth Offgas minimisation

Controller
Commissioned

DEETH OFF GAS
C2 IN LPG
02DC2C2V.PV.stdev

Petrocontrol
Feature – operator Acceptance

- Easy & user friendly APC monitoring display
- Comprehensive operator’s training
## Highlight – Customised Operator Display

### Abilities

- **Able to switch on/off** the whole controller
- **Able to drop** any CVs or MVs
- **Able to change** Low/High Limit
- **Able to see which** are the critical variables
- **Able to switch on/off**, between Sub-controller

### Table

<table>
<thead>
<tr>
<th>MV Desc.</th>
<th>Status</th>
<th>Value</th>
<th>Move</th>
<th>LOLIM</th>
<th>HILIM</th>
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<tbody>
<tr>
<td>TC1967 Prim</td>
<td>ON</td>
<td>117.0</td>
<td>117.0</td>
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<tr>
<td>TC075 MF/TQ</td>
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<td>131.5</td>
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<tr>
<td>FC2612 LCGO</td>
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<td>110.0</td>
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<tr>
<td>FC2368 CHIL</td>
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<td>55.0</td>
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<tr>
<td>FC044 HCGO</td>
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<td>-0.04</td>
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<td>494.7</td>
<td>0.01</td>
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<tr>
<td>FC2175 HCGO</td>
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<td>214.9</td>
<td>-0.68</td>
<td>190.0</td>
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</table>

<table>
<thead>
<tr>
<th>CV Desc.</th>
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<th>SSVAL</th>
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<th>HILIM</th>
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<td>FC044.OF HC</td>
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<td>41.62</td>
<td>10.00</td>
<td>85.00</td>
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<tr>
<td>FC067.OF LCG</td>
<td>46.68</td>
<td>46.91</td>
<td>0.00</td>
<td>90.00</td>
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<tr>
<td>FC2175.OF HCGO</td>
<td>94.85</td>
<td>94.85</td>
<td>0.00</td>
<td>94.00</td>
</tr>
</tbody>
</table>

**Note:**
- The table above shows the status and values of various process variables.
- The customised operator display allows for detailed monitoring and control of these variables.
Highlight – sample training slide
Thank you

Questions