FCCU Advanced Control at Chevron Pembroke Refinery

ERTC
8th to 10th May 2006
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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

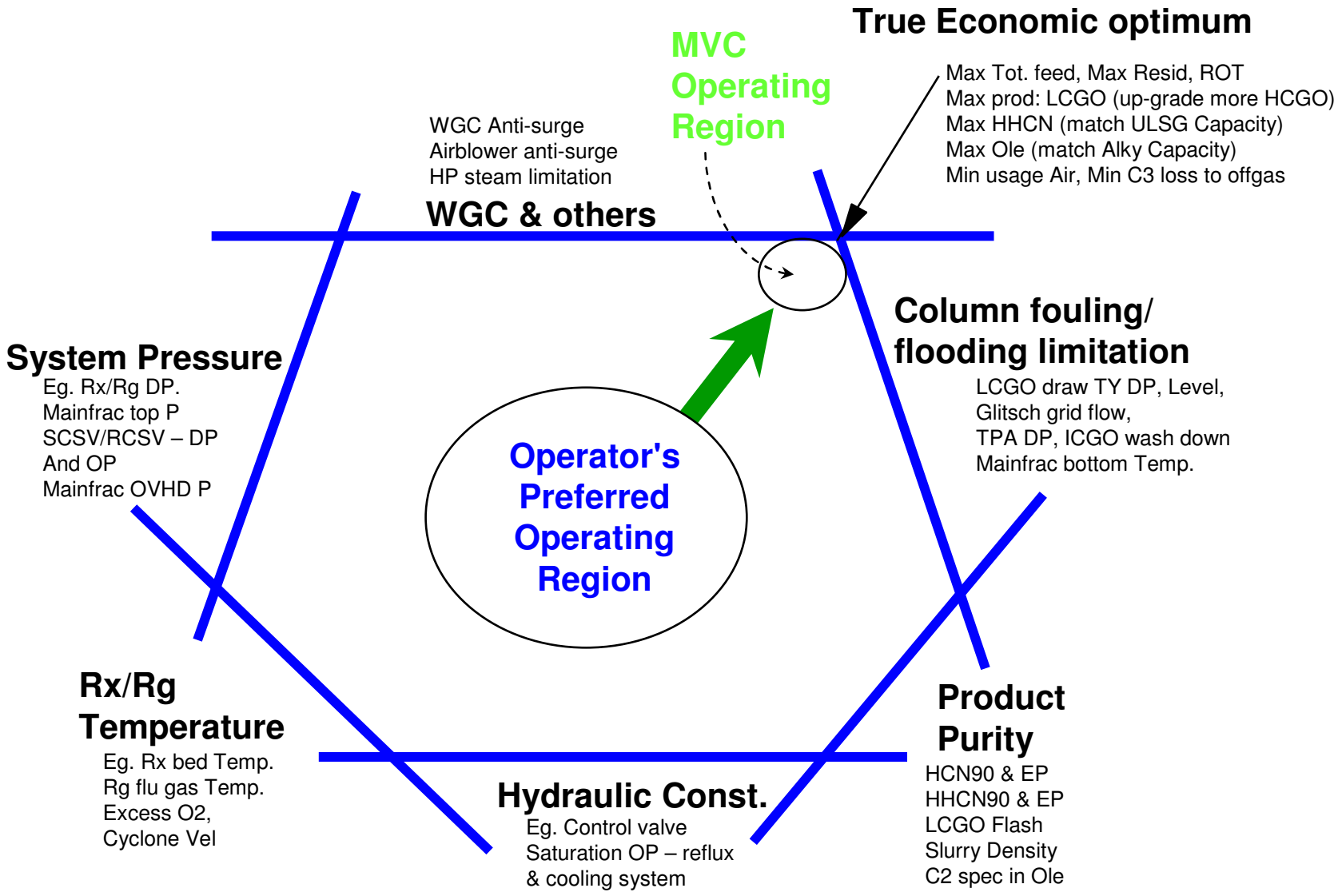
History of APC at Pembroke

- 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



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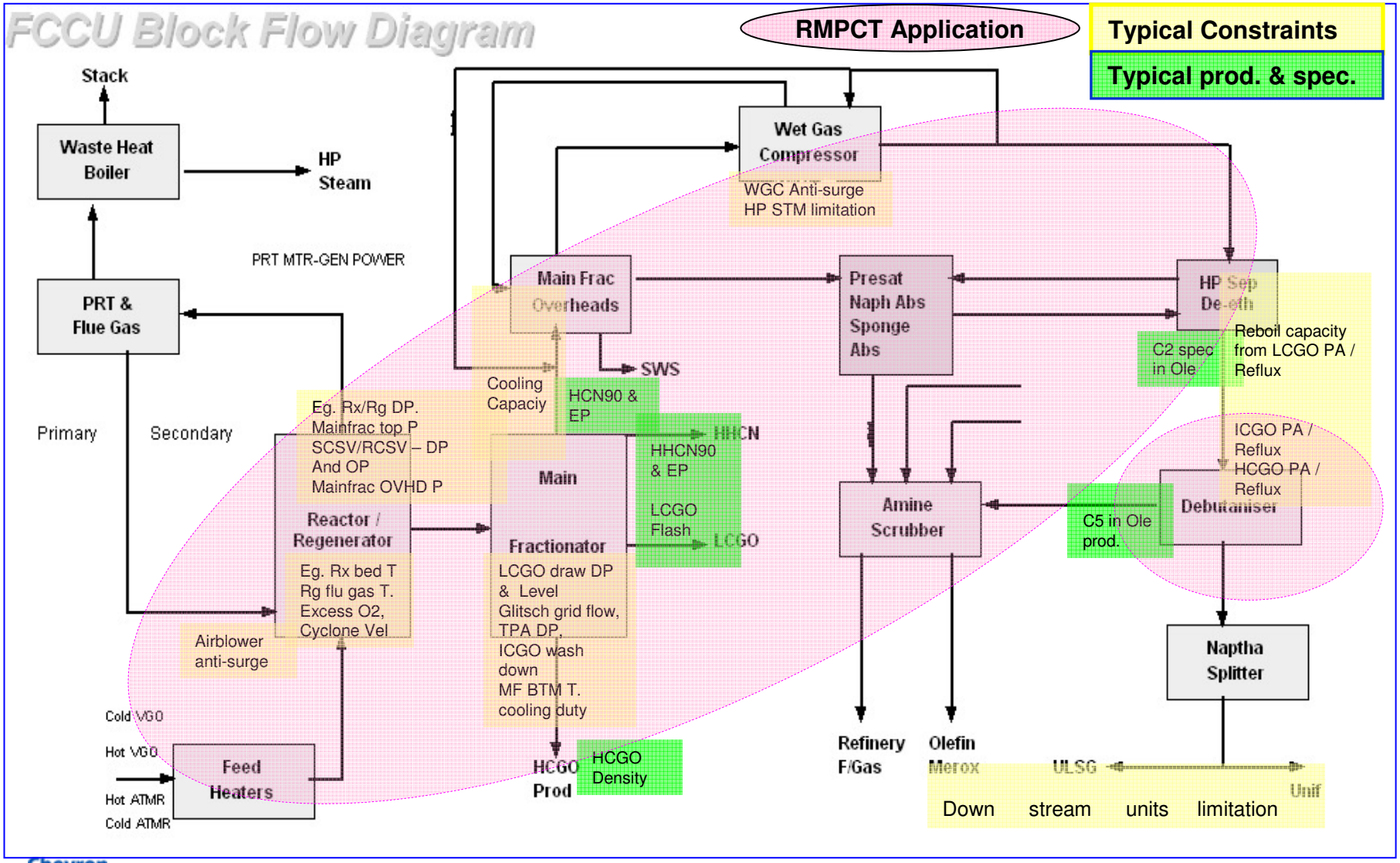
FCCU application overview

- 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



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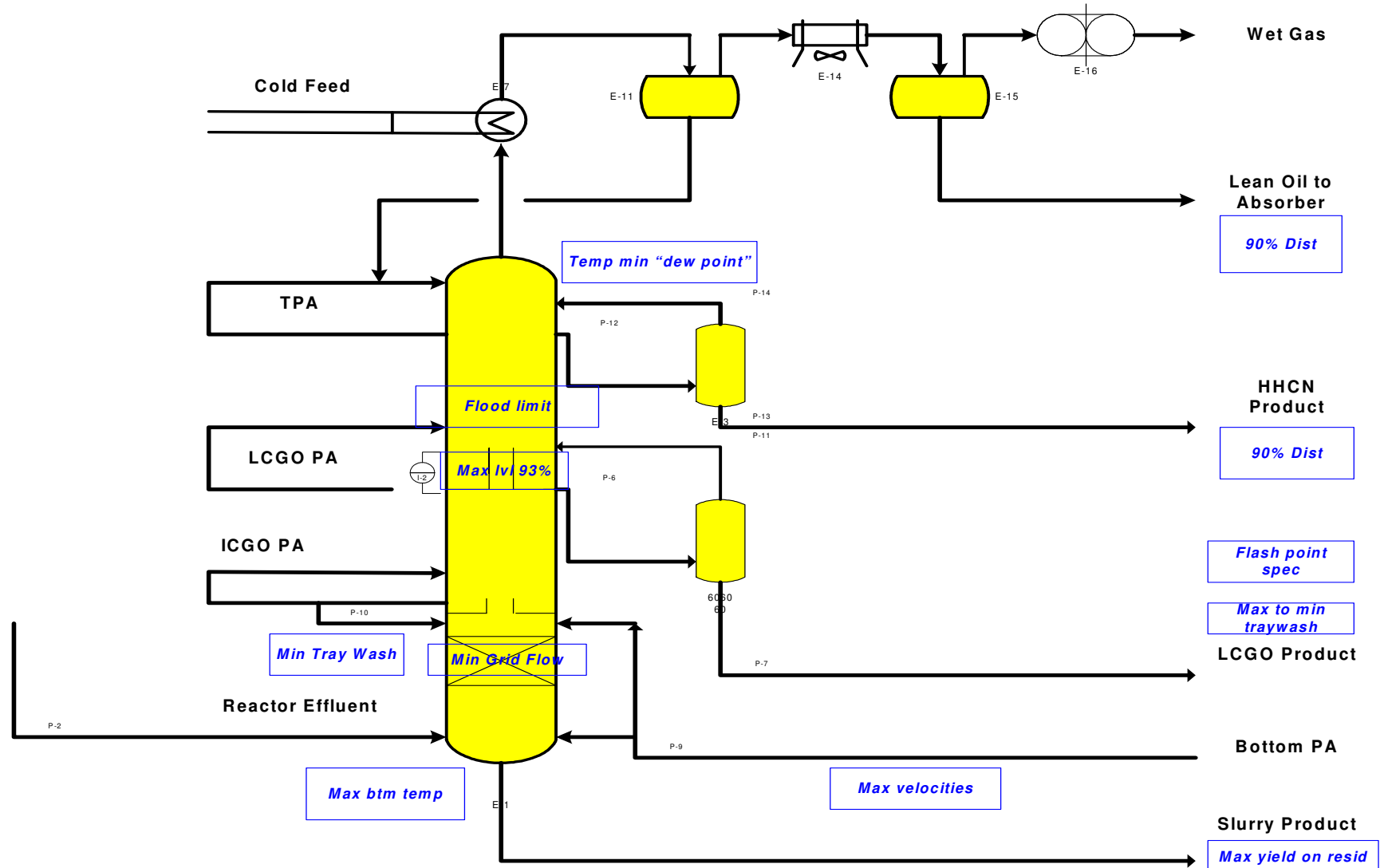
Schematic of Main fractionator



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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

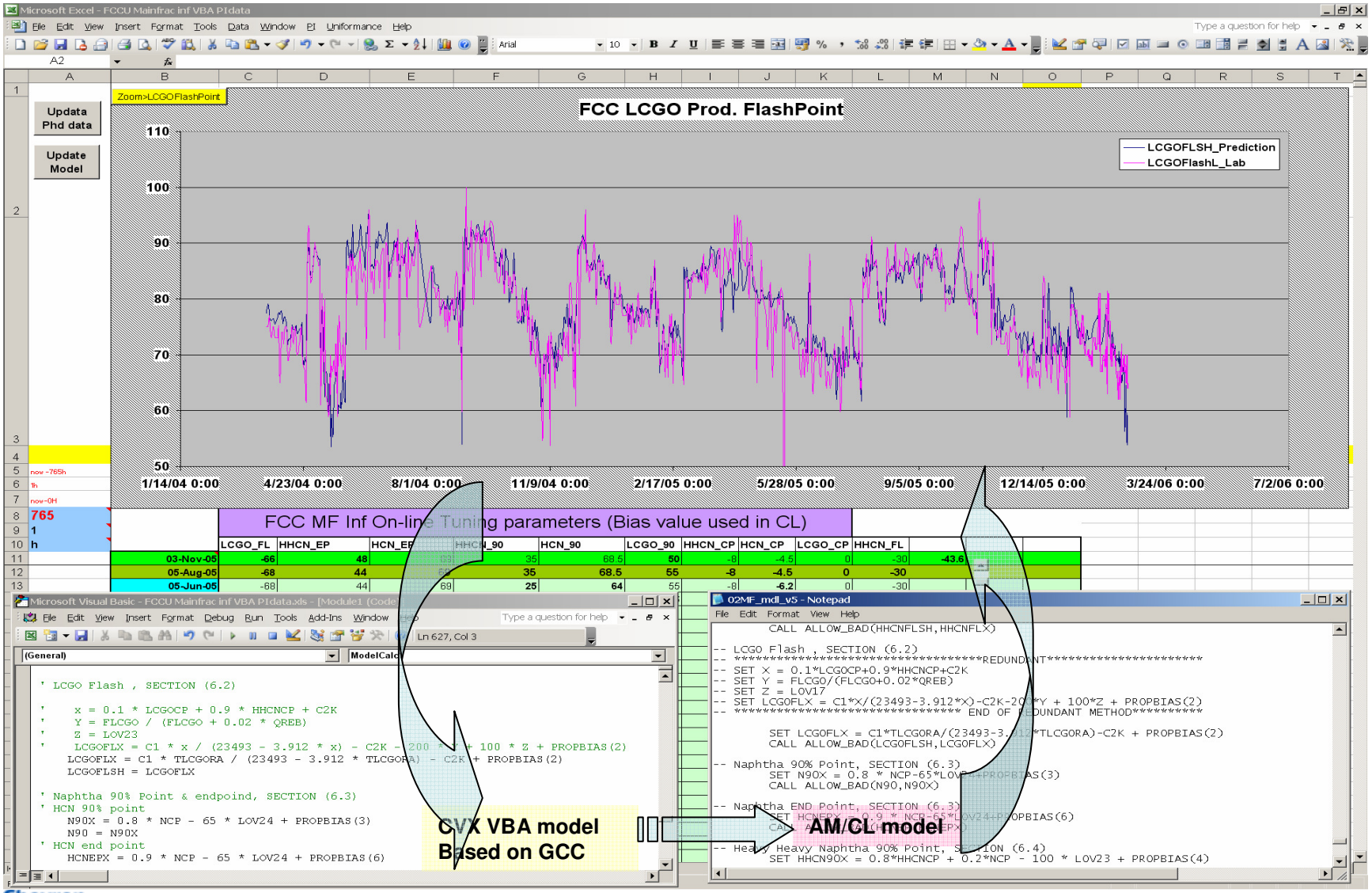
FCCU APC Application Success Factors

- 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



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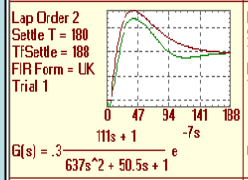
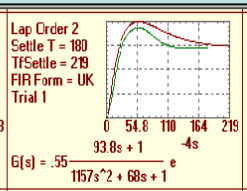
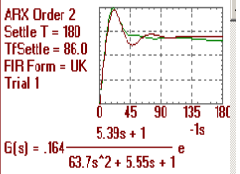
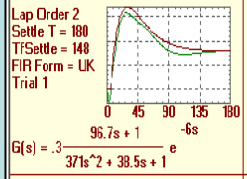
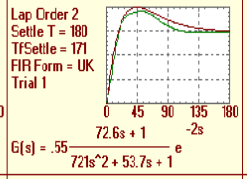
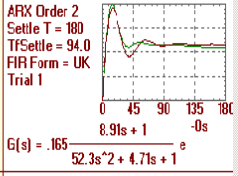
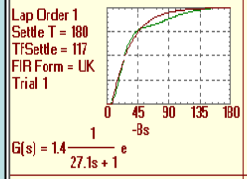
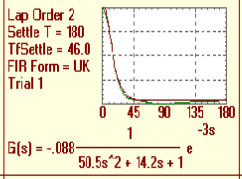
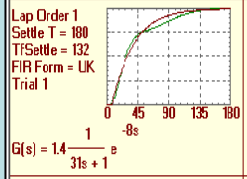
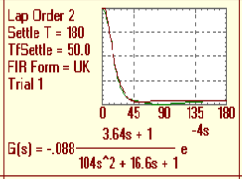
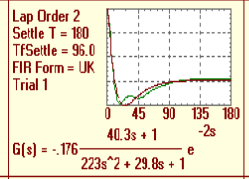
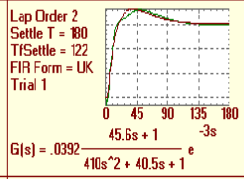
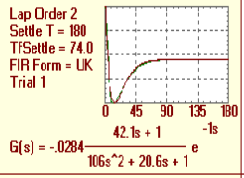
Sample Model – Spec Control

	MF Top-T	MF OVHD-T	LCGO prod.	HCGO PA	LCGO RBL	Deeth RBL	Ambient-T
HCN pt90							
HCN EP							
HHCN 90pt						
HHCN EP						
LCGO FP							
Deeth Bottom C2							

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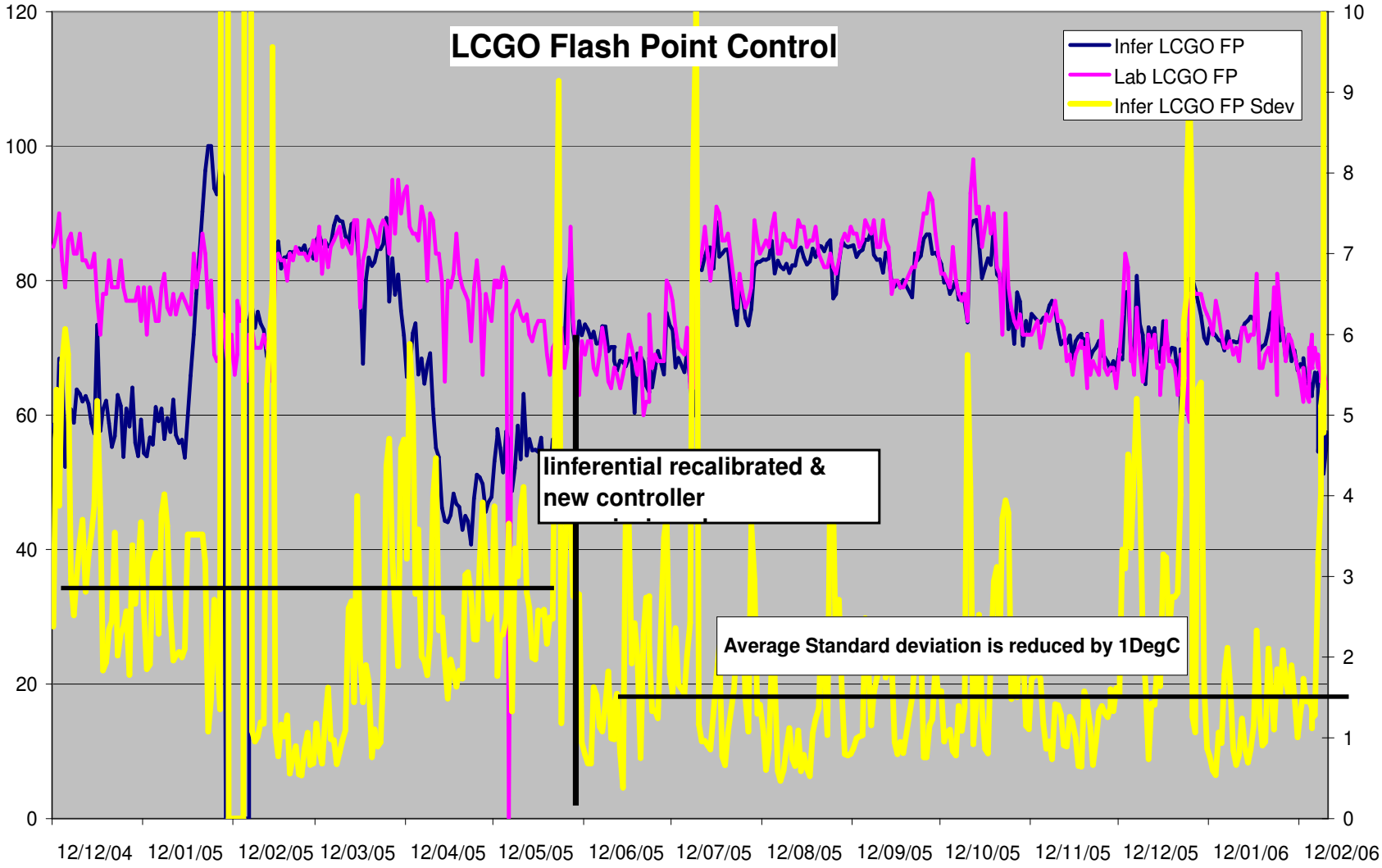
Highlight - LCGO Flash Point control



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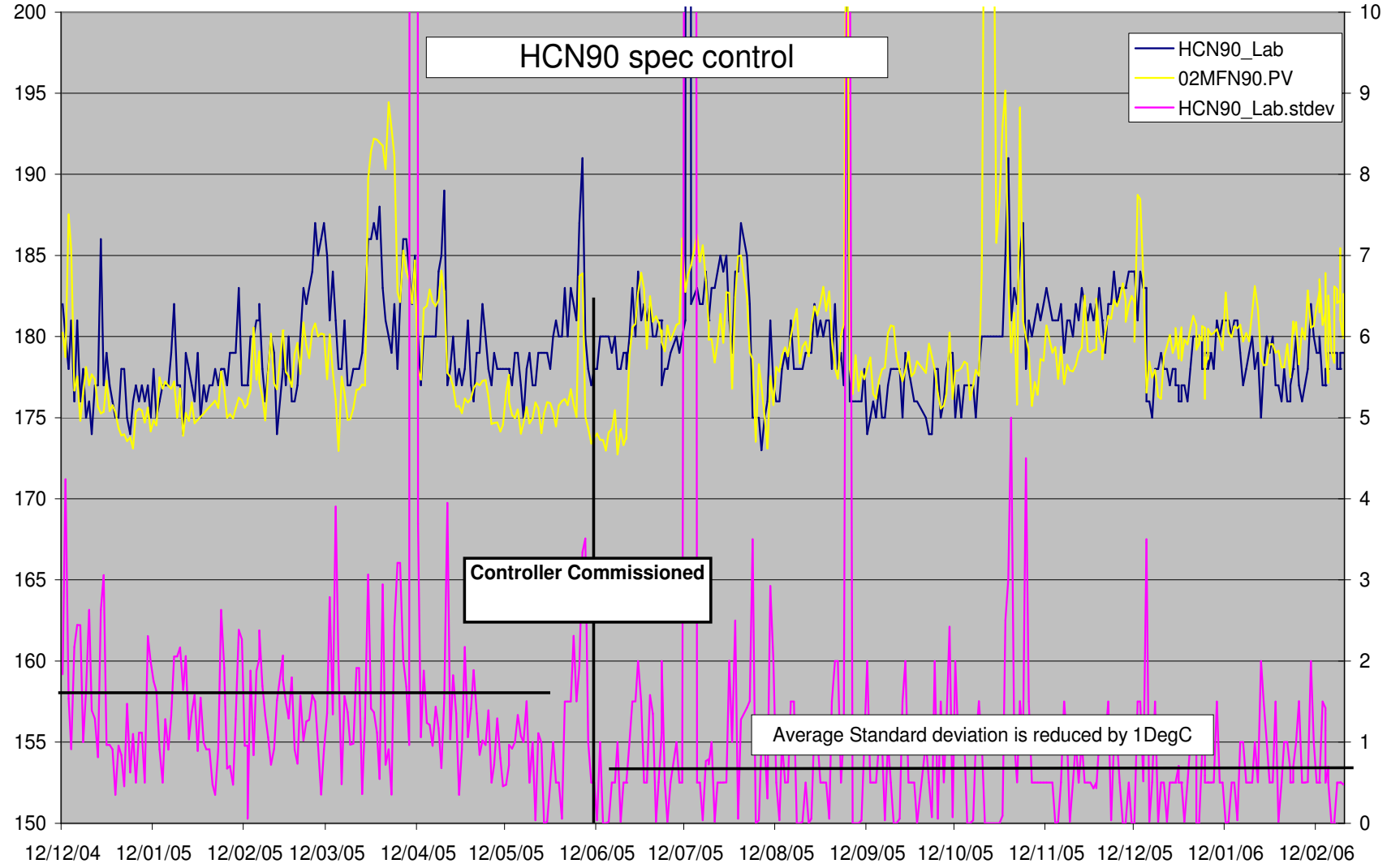
Highlight – HCN90 spec control



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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

	Feed	ROT	MF Top-T	LCGO prod.	HCGO PA	ICGO PA	HHCN prod
MainFrac Bottom Temp.	Lap Order 2 Settle T = 180 TfSettle = 82.0 FIR Form = UK Trial 1 $G(s) = .05 \frac{1.32s + 1}{53.8s^2 + 4.67s + 1} e^{-0s}$	Lap Order 2 Settle T = 180 TfSettle = 15.0 FIR Form = UK Trial 1 $G(s) = .3 \frac{-.745s + 1}{5.66s^2 + 4.76s + 1} e^{-0s}$					
Packed Section	ARX Order 2 Settle T = 180 TfSettle = 68.0 FIR Form = UK Trial 1 $G(s) = .76 \frac{8.7s + 1}{130s^2 + 23.7s + 1} e^{-7s}$	Lap Order 1 Settle T = 180 TfSettle = 34.0 FIR Form = UK Trial 1 $G(s) = -1.4 \frac{1}{8s + 1} e^{-1s}$		Lap Order 2 Settle T = 180 TfSettle = 228 FIR Form = UK Trial 1 $G(s) = -1 \frac{30s + 1}{338s^2 + 68.7s + 1} e^{-9s}$	Lap Order 2 Settle T = 180 TfSettle = 27.0 FIR Form = UK Trial 1 $G(s) = 1 \frac{8.96s + 1}{28.9s^2 + 7.88s + 1} e^{-0s}$		
ICGO Wash	Lap Order 2 Settle T = 180 TfSettle = 45.0 FIR Form = UK Trial 1 $G(s) = .85 \frac{.4s + 1}{39.6s^2 + 8.53s + 1} e^{-7s}$	Lap Order 2 Settle T = 180 TfSettle = 45.0 FIR Form = UK Trial 1 $G(s) = -.914 \frac{15.8s + 1}{33.6s^2 + 6.63s + 1} e^{-1s}$	Lap Order 2 Settle T = 180 TfSettle = 77.0 FIR Form = UK Trial 1 $G(s) = -1 \frac{3.32s + 1}{81.8s^2 + 8.87s + 1} e^{-5s}$	Lap Order 2 Settle T = 180 TfSettle = 74.0 FIR Form = UK Trial 1 $G(s) = -1 \frac{13.8s + 1}{120s^2 + 26.1s + 1} e^{-9s}$	Lap Order 2 Settle T = 180 TfSettle = 75.0 FIR Form = UK Trial 1 $G(s) = -.3 \frac{17s + 1}{265s^2 + 33.8s + 1} e^{-2s}$		Lap Order 2 Settle T = 180 TfSettle = 85.0 FIR Form = UK Trial 1 $G(s) = -1 \frac{23.3s + 1}{190s^2 + 36s + 1} e^{-5s}$
LCGO Draw LVL	Lap Order 1 Settle T = 180 TfSettle = 70.0 FIR Form = UK Trial 1 $G(s) = .16 \frac{1}{16.7s + 1} e^{-3s}$	Lap Order 2 Settle T = 180 TfSettle = 102 FIR Form = UK Trial 1 $G(s) = .2 \frac{64s + 1}{201s^2 + 28.4s + 1} e^{-0s}$	Lap Order 2 Settle T = 180 TfSettle = 57.0 FIR Form = UK Trial 1 $G(s) = -.2 \frac{3.33s + 1}{121s^2 + 16.5s + 1} e^{-5s}$	Lap Order 1 Settle T = 180 TfSettle = 163 FIR Form = UK Trial 1 $G(s) = -.3 \frac{1}{40s + 1} e^{-2s}$	Lap Order 2 Settle T = 180 TfSettle = 48.0 FIR Form = UK Trial 1 $G(s) = -.04 \frac{1}{51s^2 + 15.1s + 1} e^{-0s}$	Lap Order 2 Settle T = 180 TfSettle = 115 FIR Form = UK Trial 1 $G(s) = -.0601 \frac{24s + 1}{409s^2 + 46.6s + 1} e^{-1s}$	Lap Order 1 Settle T = 180 TfSettle = 136 FIR Form = UK Trial 1 $G(s) = -.189 \frac{1}{33.6s + 1} e^{-1s}$
LCGO Draw DP	Lap Order 2 Settle T = 180 TfSettle = 80.0 FIR Form = UK Trial 1 $G(s) = .0006 \frac{37.3s + 1}{248s^2 + 47.5s + 1} e^{-2s}$	Lap Order 2 Settle T = 180 TfSettle = 92.0 FIR Form = UK Trial 1 $G(s) = .00069 \frac{75.8s + 1}{139s^2 + 23.6s + 1} e^{-0s}$		Lap Order 1 Settle T = 180 TfSettle = 159 FIR Form = UK Trial 1 $G(s) = -.0012 \frac{1}{38.4s + 1} e^{-5s}$	Lap Order 2 Settle T = 180 TfSettle = 33.0 FIR Form = UK Trial 1 $G(s) = -.0002 \frac{.32s + 1}{29s^2 + 7.39s + 1} e^{-0s}$	ARX Order 2 Settle T = 180 TfSettle = 133 FIR Form = UK Trial 1 $G(s) = -.0001 \frac{31.5s + 1}{157s^2 + 48.5s + 1} e^{-3s}$	Lap Order 1 Settle T = 180 TfSettle = 141 FIR Form = UK Trial 1 $G(s) = -.000512 \frac{1}{34.4s + 1} e^{-3s}$
HCGO Visc	Lap Order 2 Settle T = 180 TfSettle = 76.0 FIR Form = UK Trial 1 $G(s) = -.03 \frac{4.1s + 1}{112s^2 + 15.6s + 1} e^{-16s}$	Lap Order 2 Settle T = 180 TfSettle = 27.0 FIR Form = UK Trial 1 $G(s) = .1 \frac{1}{18.5s^2 + 8.85s + 1} e^{-0s}$	Lap Order 2 Settle T = 180 TfSettle = 122 FIR Form = UK Trial 1 $G(s) = .06 \frac{43.5s + 1}{507s^2 + 45s + 1} e^{-0s}$	Lap Order 2 Settle T = 180 TfSettle = 80.0 FIR Form = UK Trial 1 $G(s) = .03 \frac{15.5s + 1}{429s^2 + 35.5s + 1} e^{-12s}$	Lap Order 2 Settle T = 180 TfSettle = 70.0 FIR Form = UK Trial 1 $G(s) = .02 \frac{1}{130s^2 + 23.1s + 1} e^{-0s}$		ARX Order 2 Settle T = 240 TfSettle = 81.0 FIR Form = UK Trial 1 $G(s) = .0299 \frac{16.1s + 1}{440s^2 + 37.2s + 1} e^{-12s}$
HCGO Density	Lap Order 2 Settle T = 180 TfSettle = 86.0 FIR Form = UK Trial 1 $G(s) = -.09 \frac{7.8s + 1}{145s^2 + 17.8s + 1} e^{-21s}$	Lap Order 2 Settle T = 180 TfSettle = 29.0 FIR Form = UK Trial 1 $G(s) = .3 \frac{.224s + 1}{21s^2 + 6.66s + 1} e^{-1s}$	Lap Order 2 Settle T = 180 TfSettle = 62.0 FIR Form = UK Trial 1 $G(s) = .18 \frac{22.4s + 1}{120s^2 + 21.9s + 1} e^{-0s}$	Lap Order 2 Settle T = 180 TfSettle = 72.0 FIR Form = UK Trial 1 $G(s) = .09 \frac{1}{118s^2 + 21.8s + 1} e^{-7s}$	Lap Order 2 Settle T = 180 TfSettle = 60.0 FIR Form = UK Trial 1 $G(s) = .06 \frac{1}{100s^2 + 20s + 1} e^{-0s}$		Lap Order 2 Settle T = 240 TfSettle = 72.0 FIR Form = UK Trial 1 $G(s) = .0306 \frac{1}{117s^2 + 21.6s + 1} e^{-7s}$

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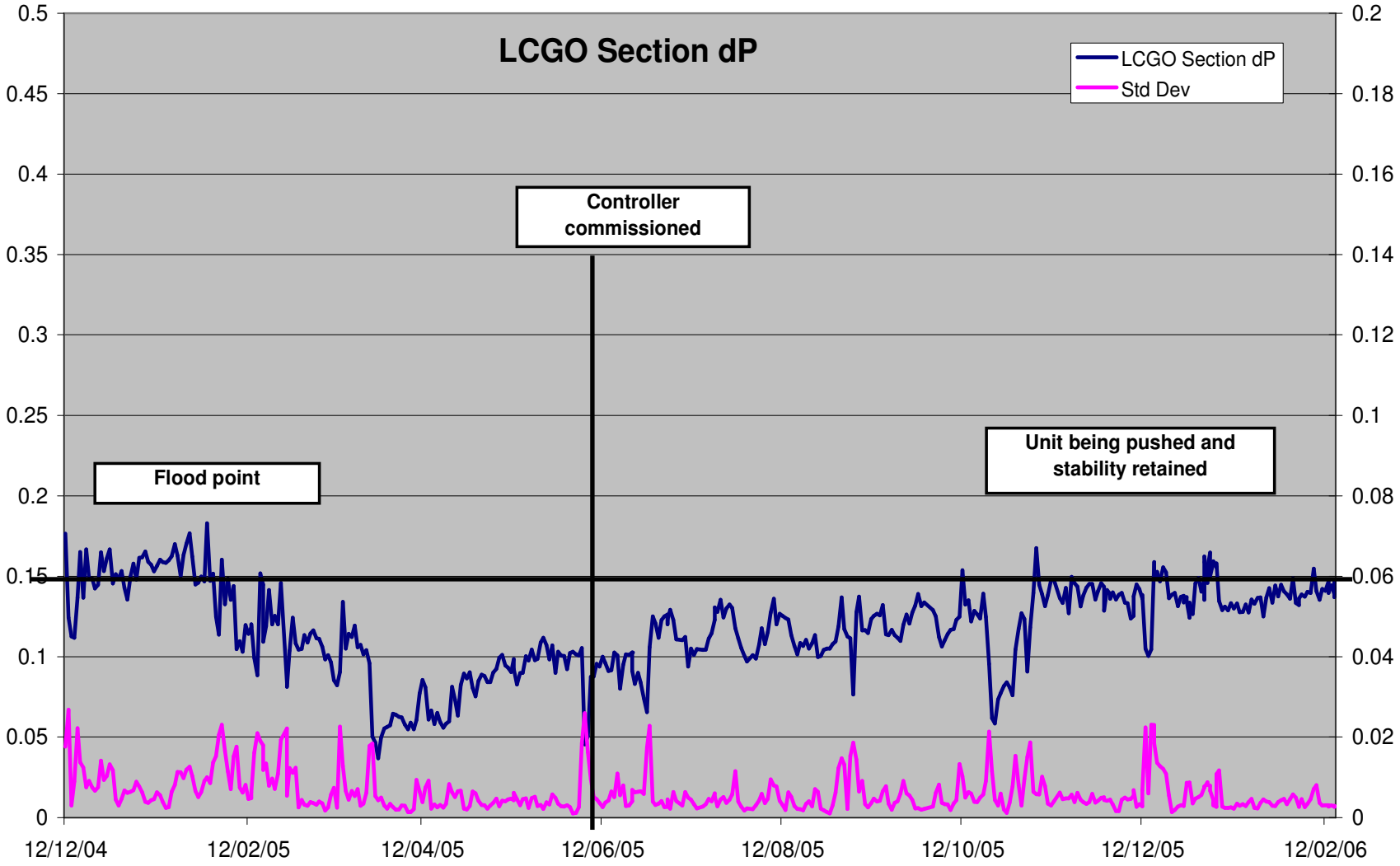
Highlight - LCGO Section dP Sensitivity to Flood



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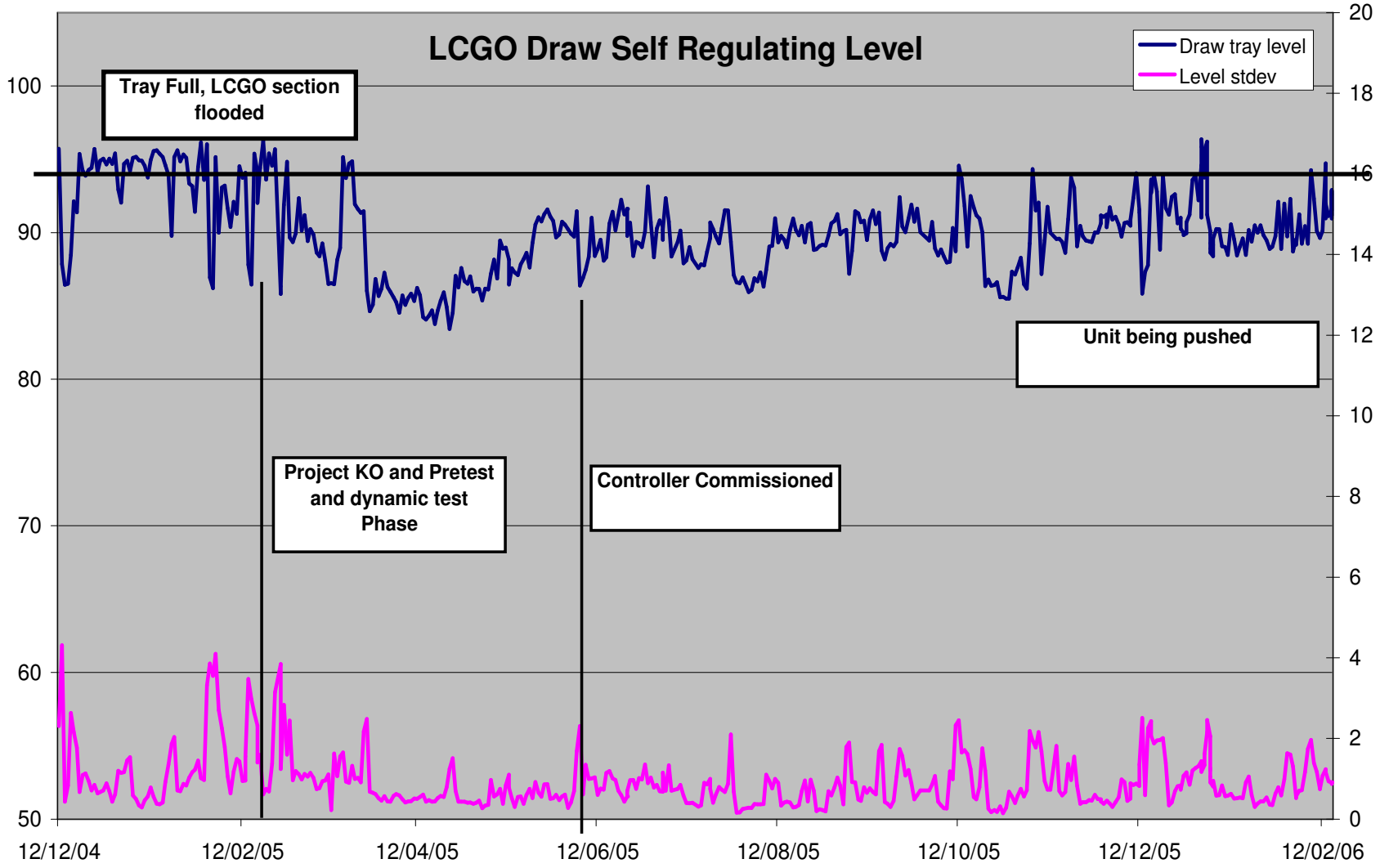
Highlight - LCGO Draw Tray Level



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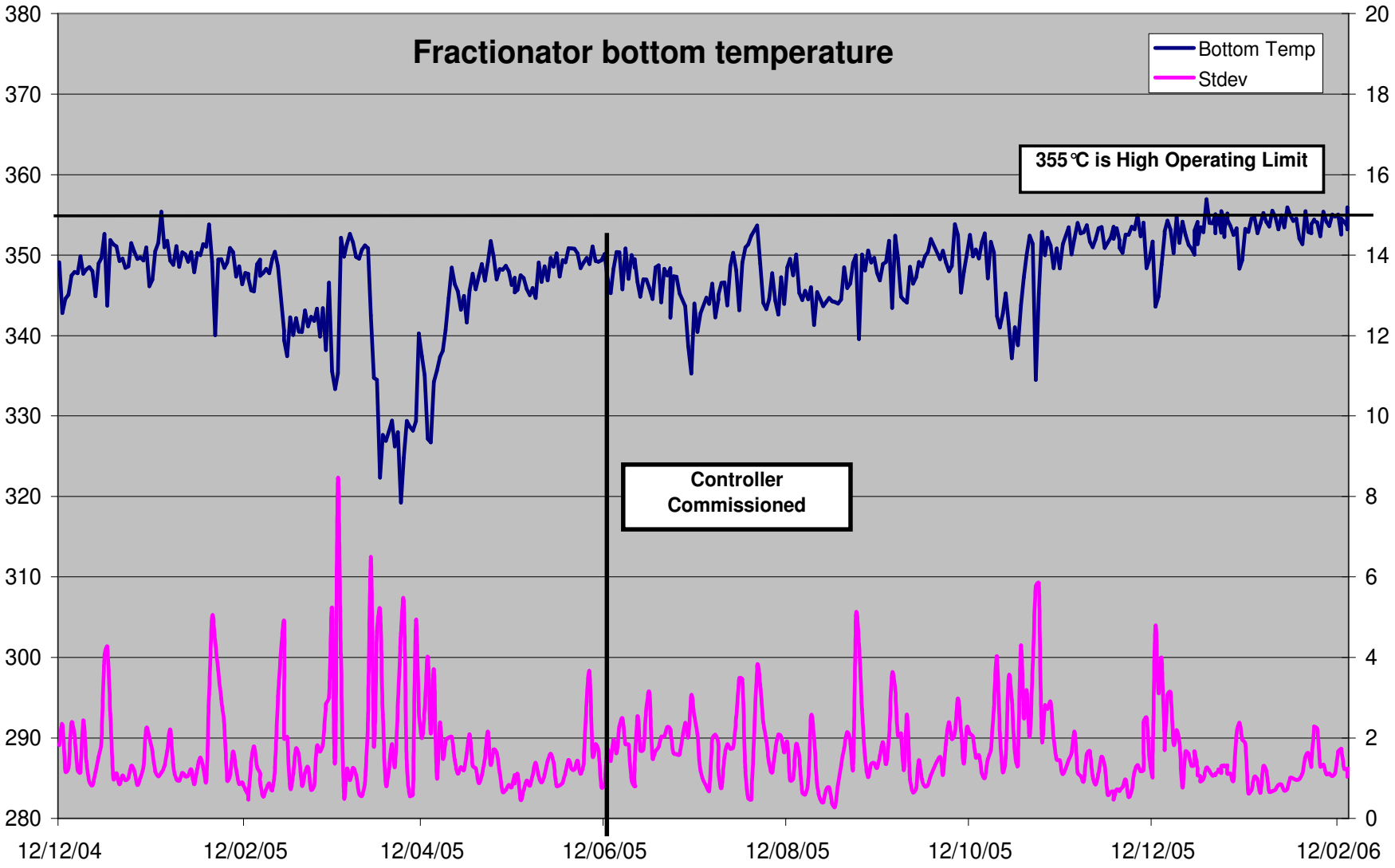
Highlight - Fractionator BTM T Critical Unit limitation



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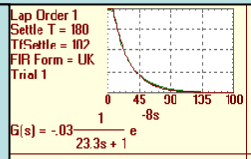
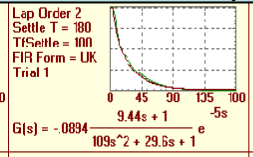
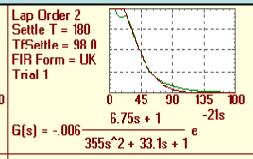
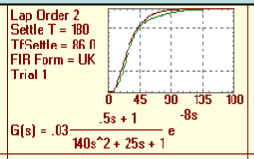
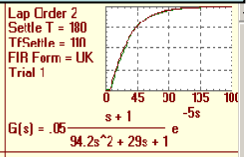
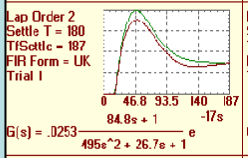
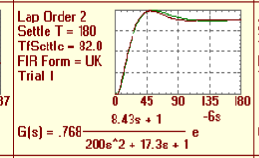
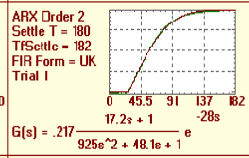
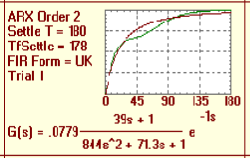
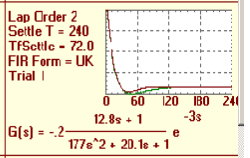
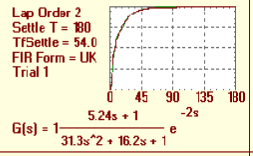
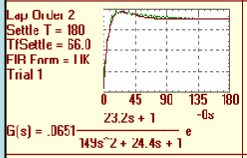
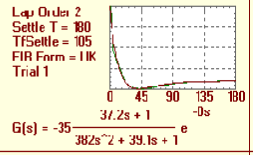
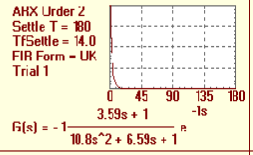
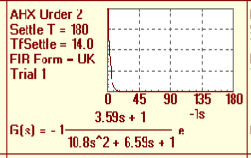
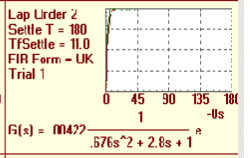
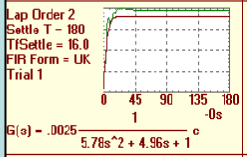
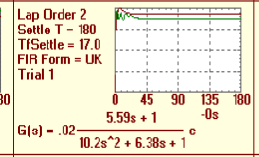
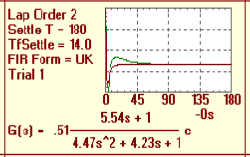
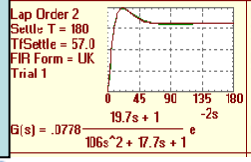
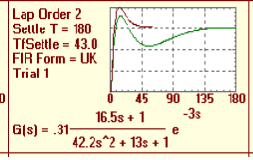
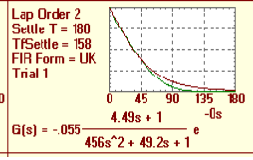
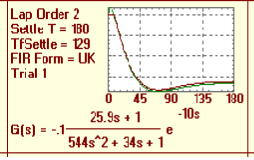
Feature – Optimisation direction

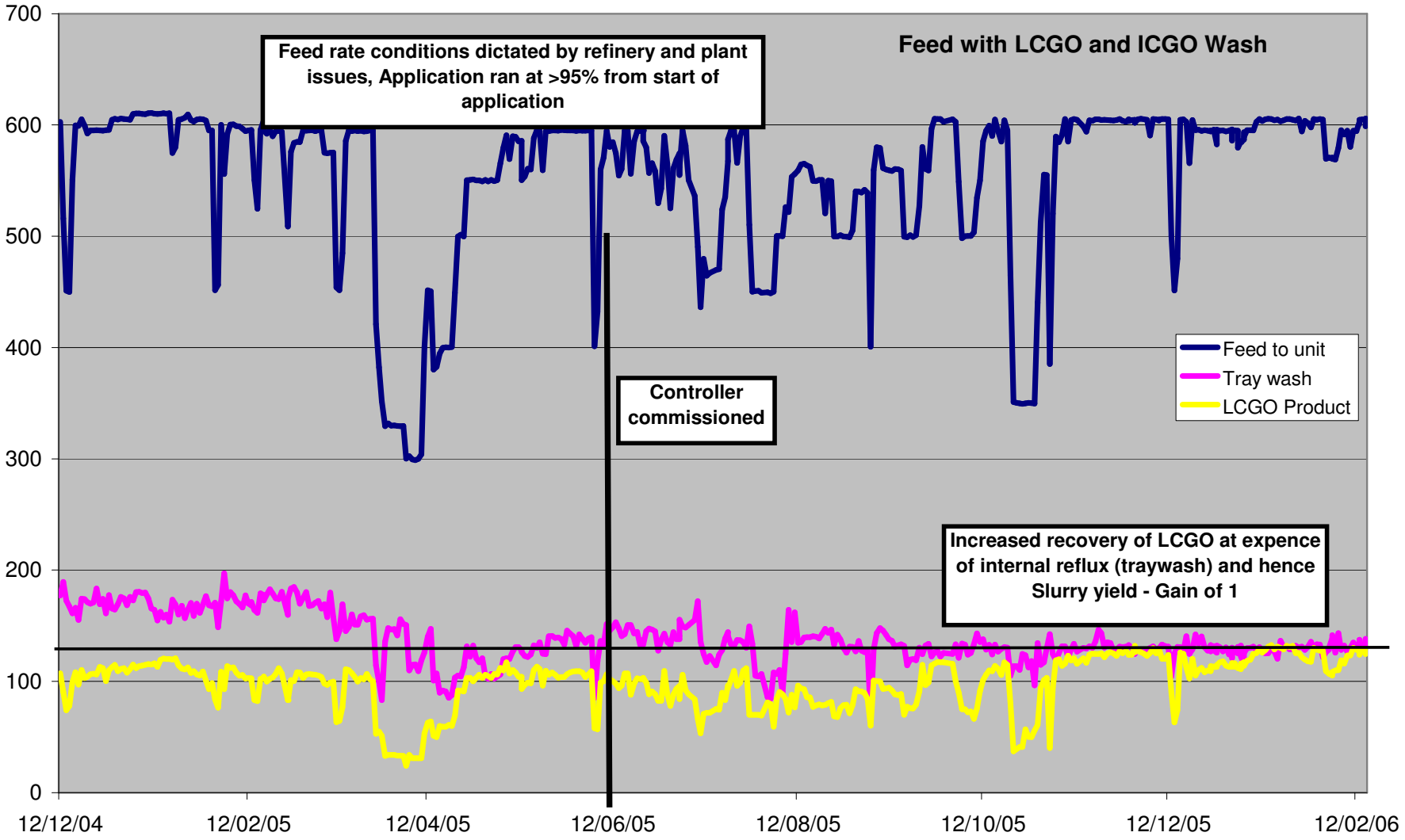
- Maximise Total Feed (match scheduling)
- Max Resid processing to Regen limitations
- Minimise load on Blower and expander
- Stay in safe system delta P range (slide valves) – max cat circulation
- Maximise Conversion
- Run to minimum Regen excess O2 (>1%)
- Max LCGO draw against MIN internal reflux
  - Significant operator issue
- Minimises the Deethaniser C3's loss to offgas subject to C2 content at bottom (ole prod)

Sample Model – Rx/Rg optimisation

	Tot-Feed	Reactor-Temp	Resid-Feed	Rx/Rg-DP	Feed-Preheat	MF Top-P	Air-blower
Excess O2							
Rx bed Temp							
RCSV DP							
RCSV OP							
Airblow Anti-srg							
WGC Anti-srg							
Cat. Circ.							

Petrocontrol

Unit Feed and Yields in M3/HR
Shows increase in recovery of LCGO whilst sustaining bottom conditions

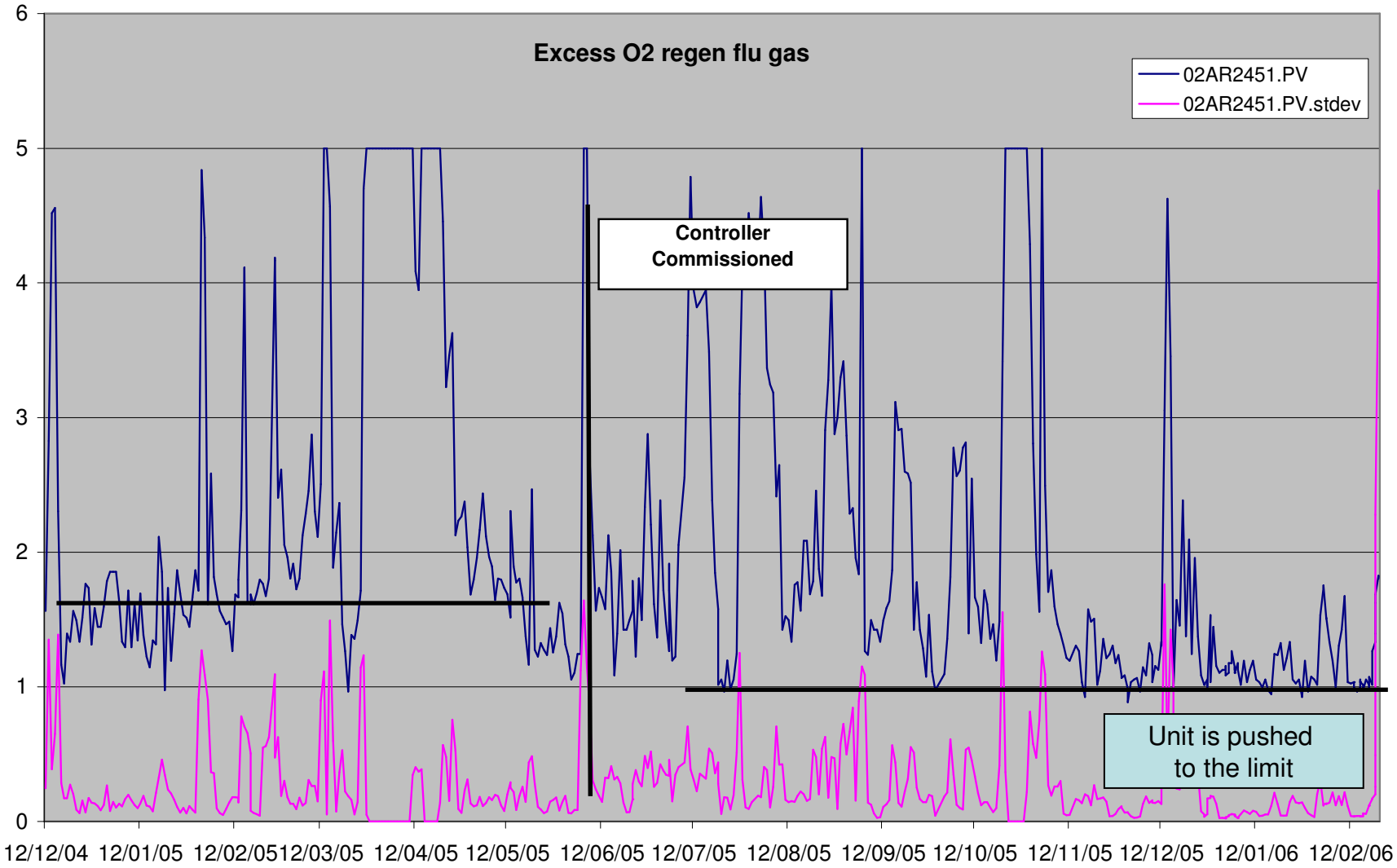


Chevron

Petrocontrol

AMT

Highlight – Excess O2 optimisation

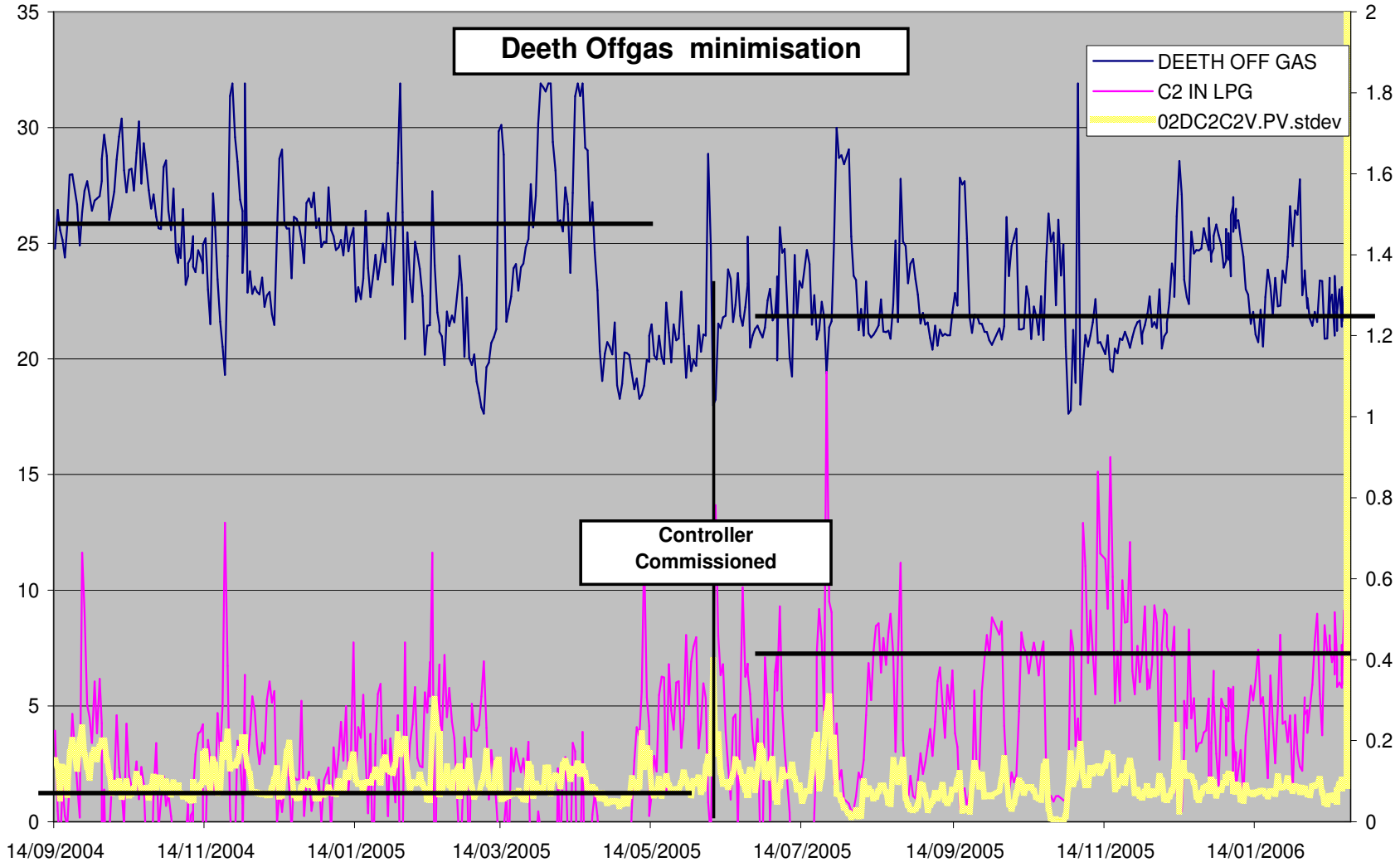


Chevron

Petrocontrol

AMT

Highlight – Deeth Optimisation



Chevron

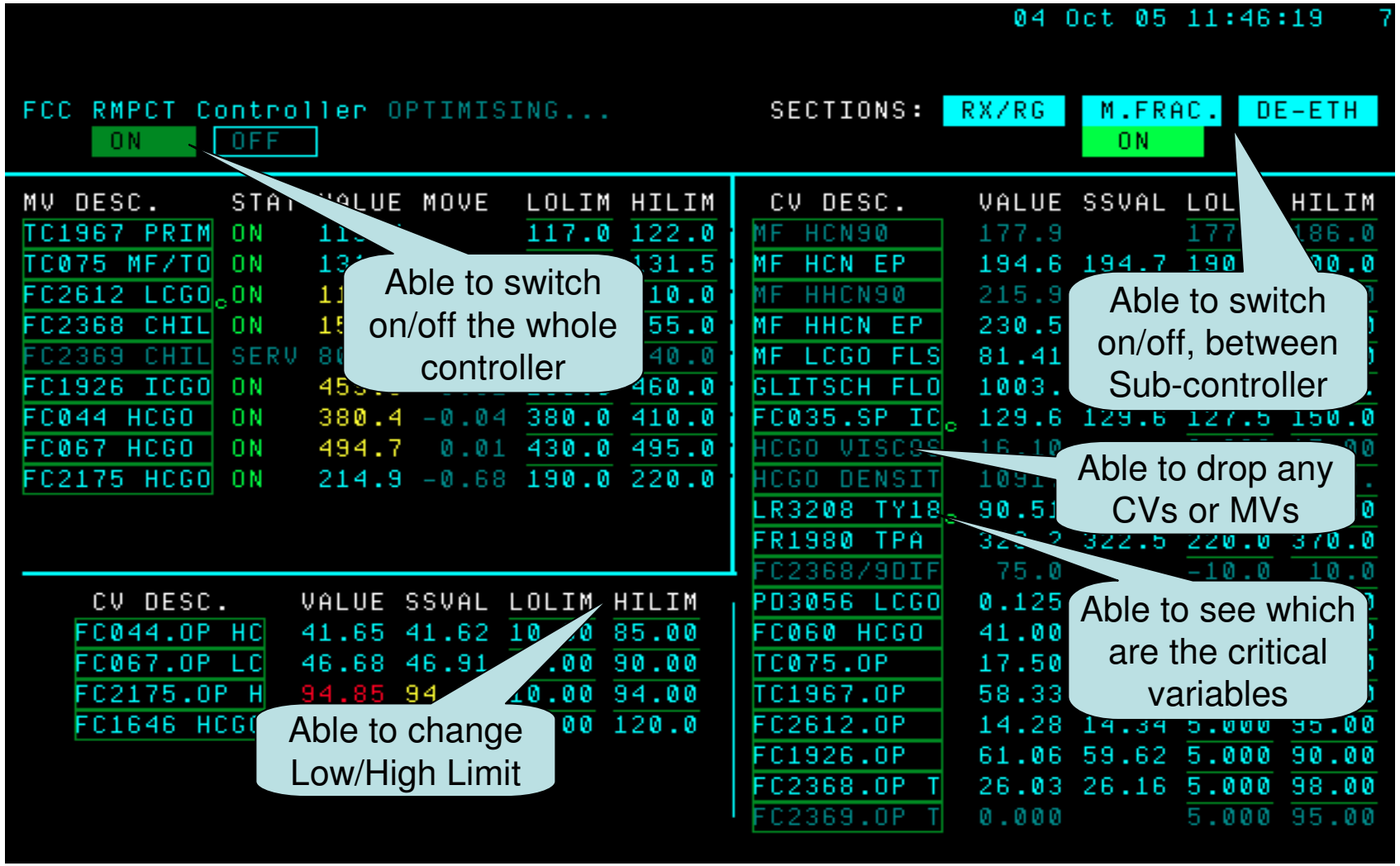
Petrocontrol

AMT

Feature – operator Acceptance

- Easy & user friendly APC monitoring display
- Comprehensive operator's training

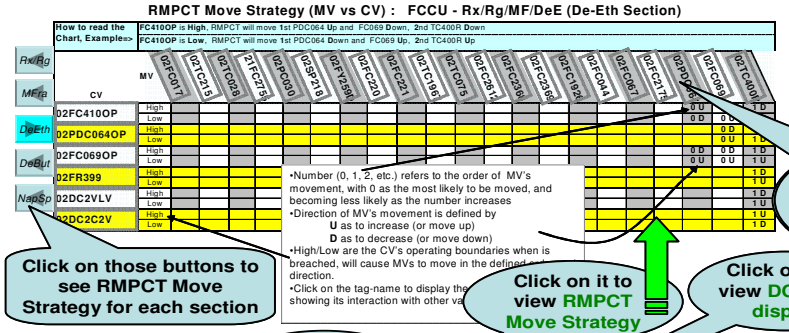
Highlight – Custimised Operator Display



Highlight – sample training slide

Overview – How to navigate through the Training

FCCU De-Eth RMPCT Move Strategy (MV vs CV)



De-ethaniser Operator Screen

Click on those buttons to see RMPCT Move Strategy for each section

Click on any of the MV or CV tags to view detail schematic

Click on those buttons to see DCS Ops RMPCT display for each section

Click on it to view RMPCT Move Strategy

Click on it to view DCS Ops display

Click on it to view next slide

Click on it to view previous slide

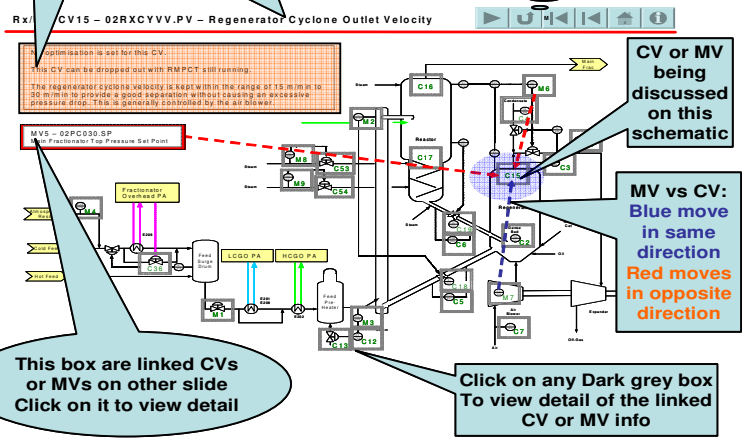
Click on it to view this HELP slide

Click on it to view control hints

Control hint on this CV or MV

Slide title, eg. CV, MV etc.

Navigating buttons



CV or MV being discussed on this schematic

MV vs CV: Blue move in same direction Red moves in opposite direction

This box are linked CVs or MVs on other slide Click on it to view detail

Click on any Dark grey box To view detail of the linked CV or MV info

Help Instructions (click on "here" boxes to see more):

Each CV and MV is presented by a set of 3 standard slides :

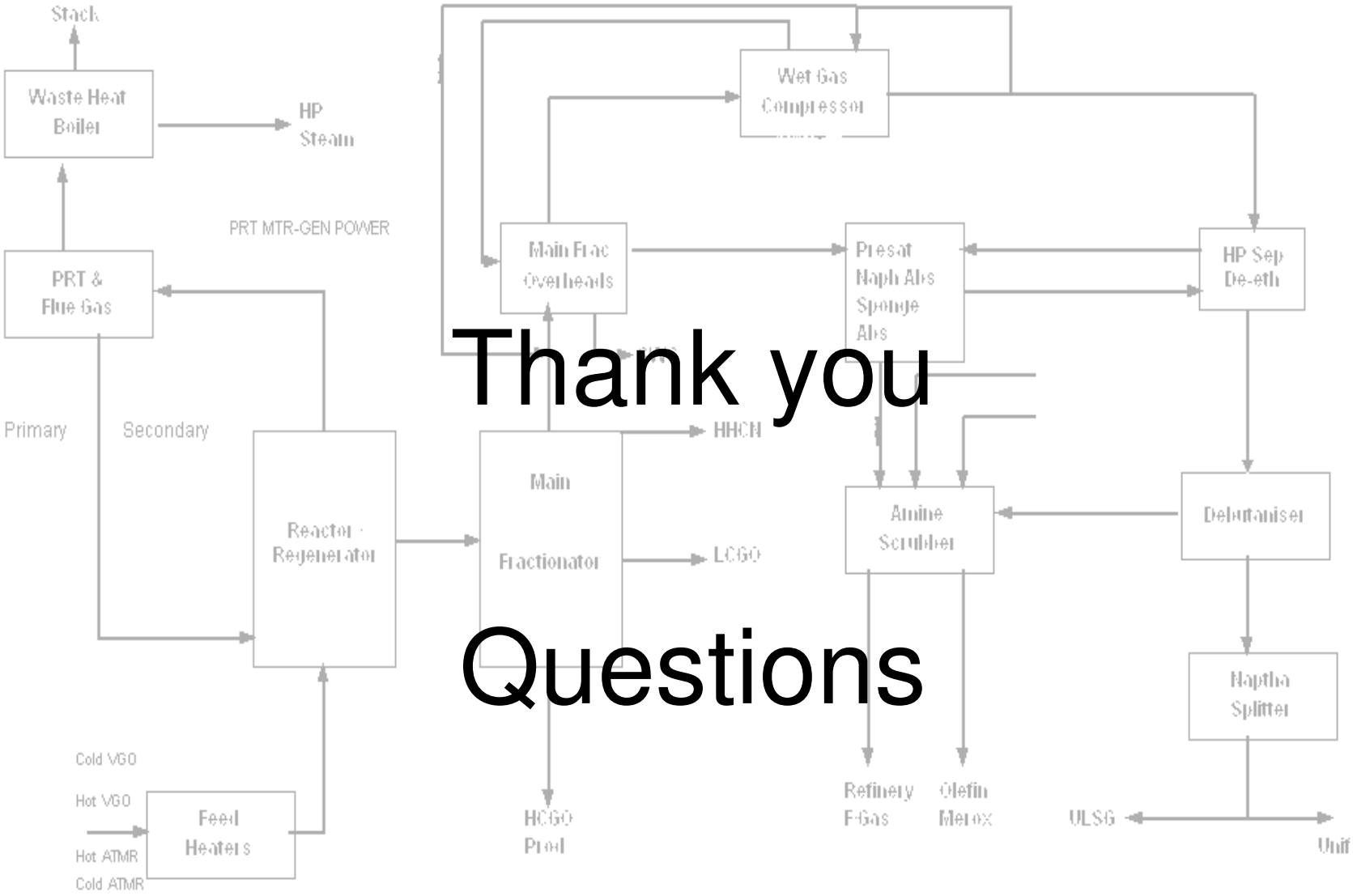
1. **DCS Ops display**,click Here-1 to see live DCS screen shot. Normally Ops performs actions such as turn on/off RMPCT, change Hi/Lo limit of CV or MV, drop off CV or MV on this display. Click Here-2 to see more.
2. **Process Schematic**, click Here-3 to see FCC process flow diagram with CV and MV labels. Click Here-4 to see more
3. **RMPCT Move Strategy Matrix**: click Here-5 to see typical MV's move when at CV constraint. Click Here-6 to see more.

At top right corner of every slide, there are 6 navigating buttons Here-7 to aid user to navigating through out this presentation.

On every slide, click : to show / hide more control information for the CV or MV in discussion, click : to see the related DCS Ops Display, click M to view the related RMPCT Move Strategy Matrix, click : to return to the CV or MV in discussion, click : to advance to next slide. If not how to navigate through, click : to view this HELP slide

At any time to exit from the training, press the ***Esc*** key on the keyboard

Ready to start…..then click Here-8 to begin the tutorial



Thank you

Questions