

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 Inferenceals first used in early 1990's and have been deployed across most refinery units

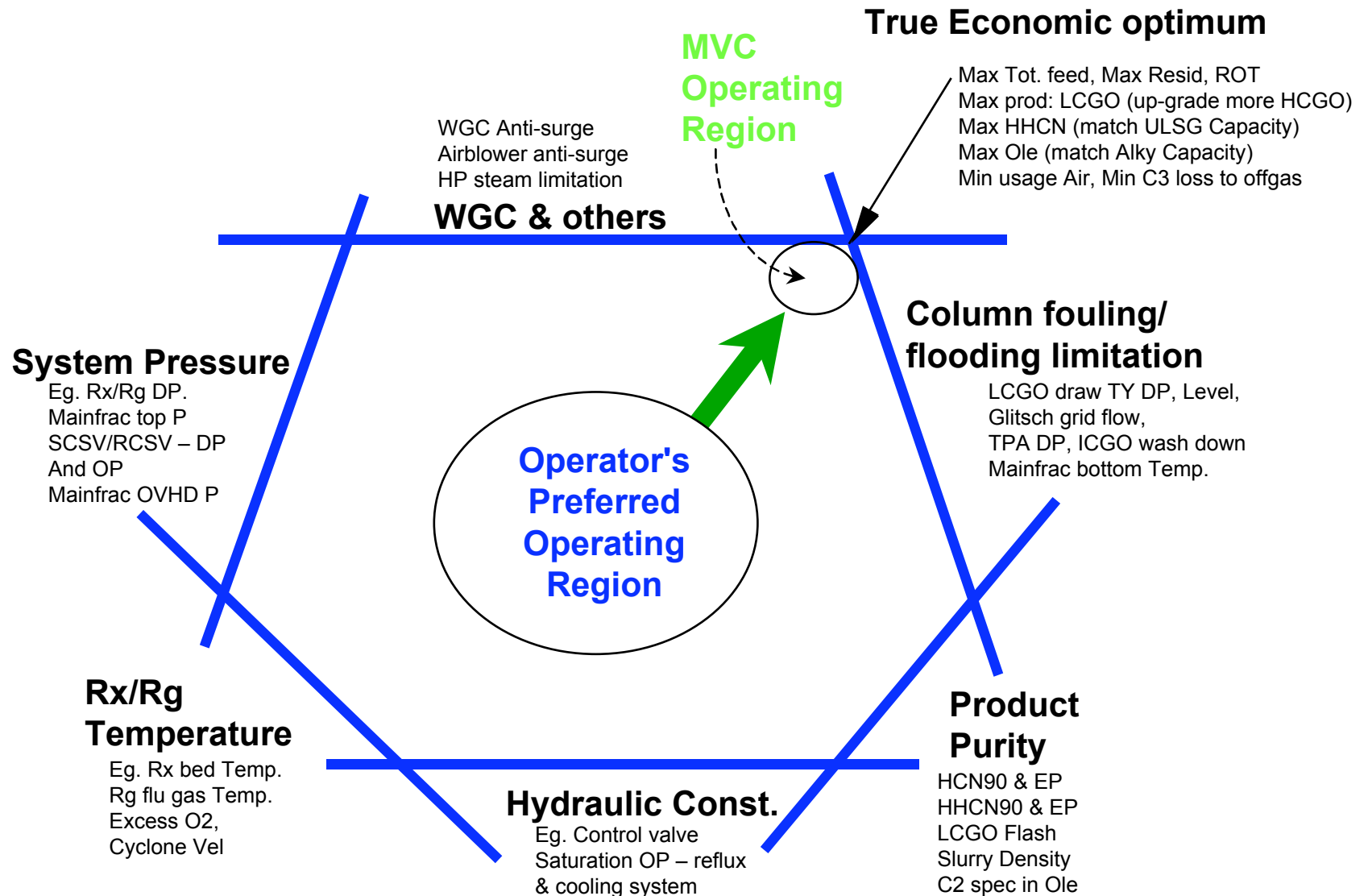


FCCU APC Reengineering

- 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



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)

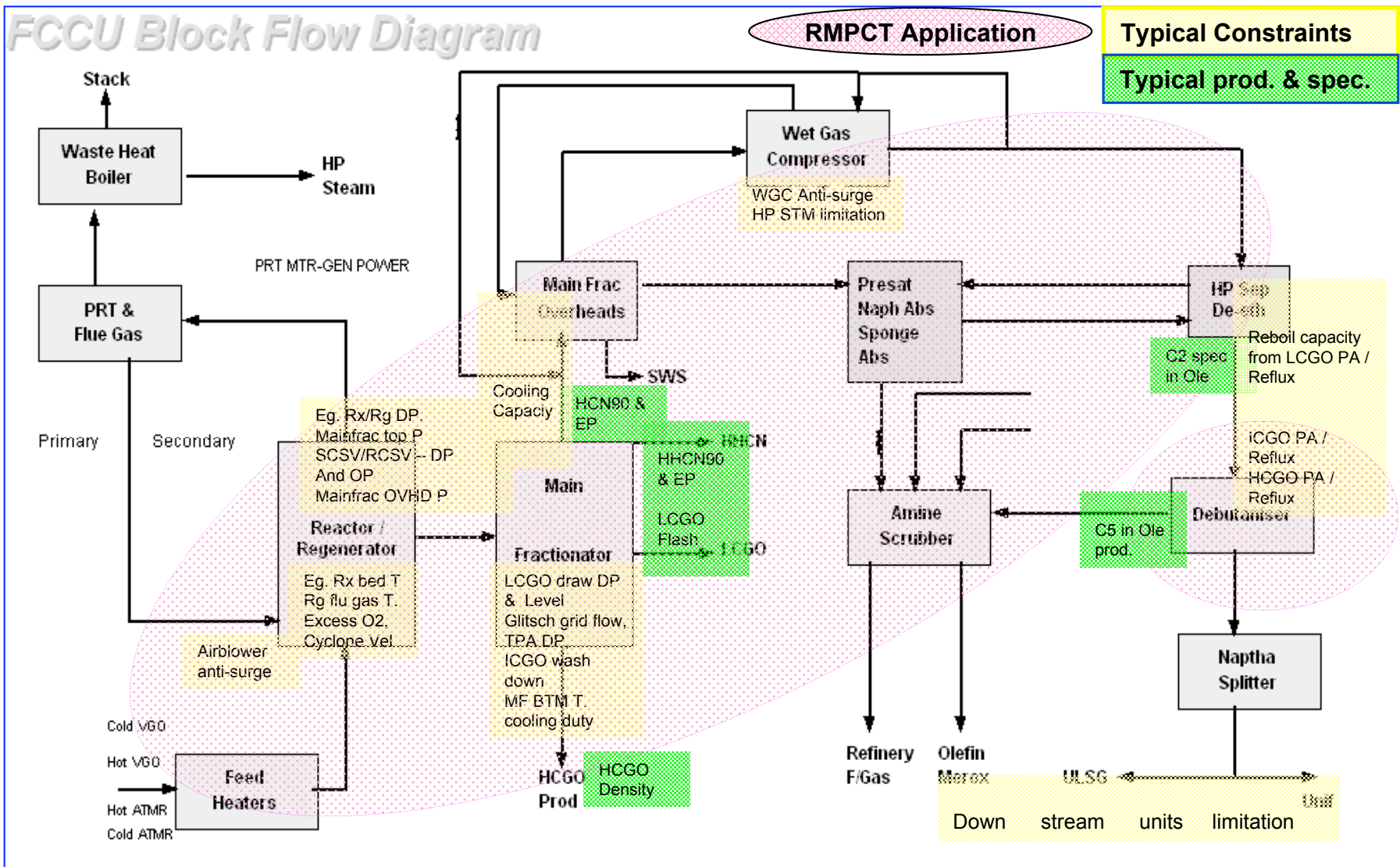


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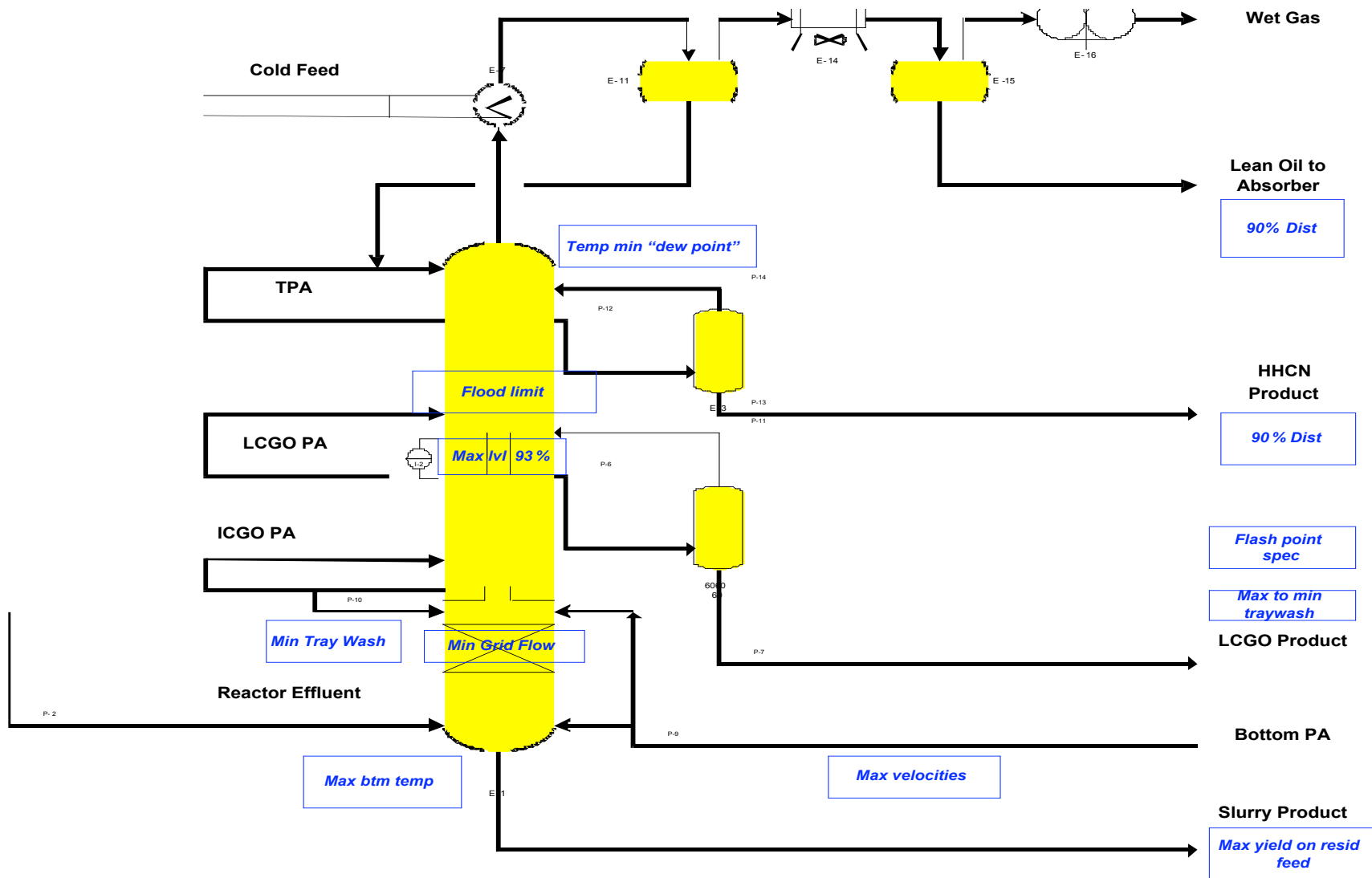
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Overview of Revamp Design

FCCU Block Flow Diagram



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



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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

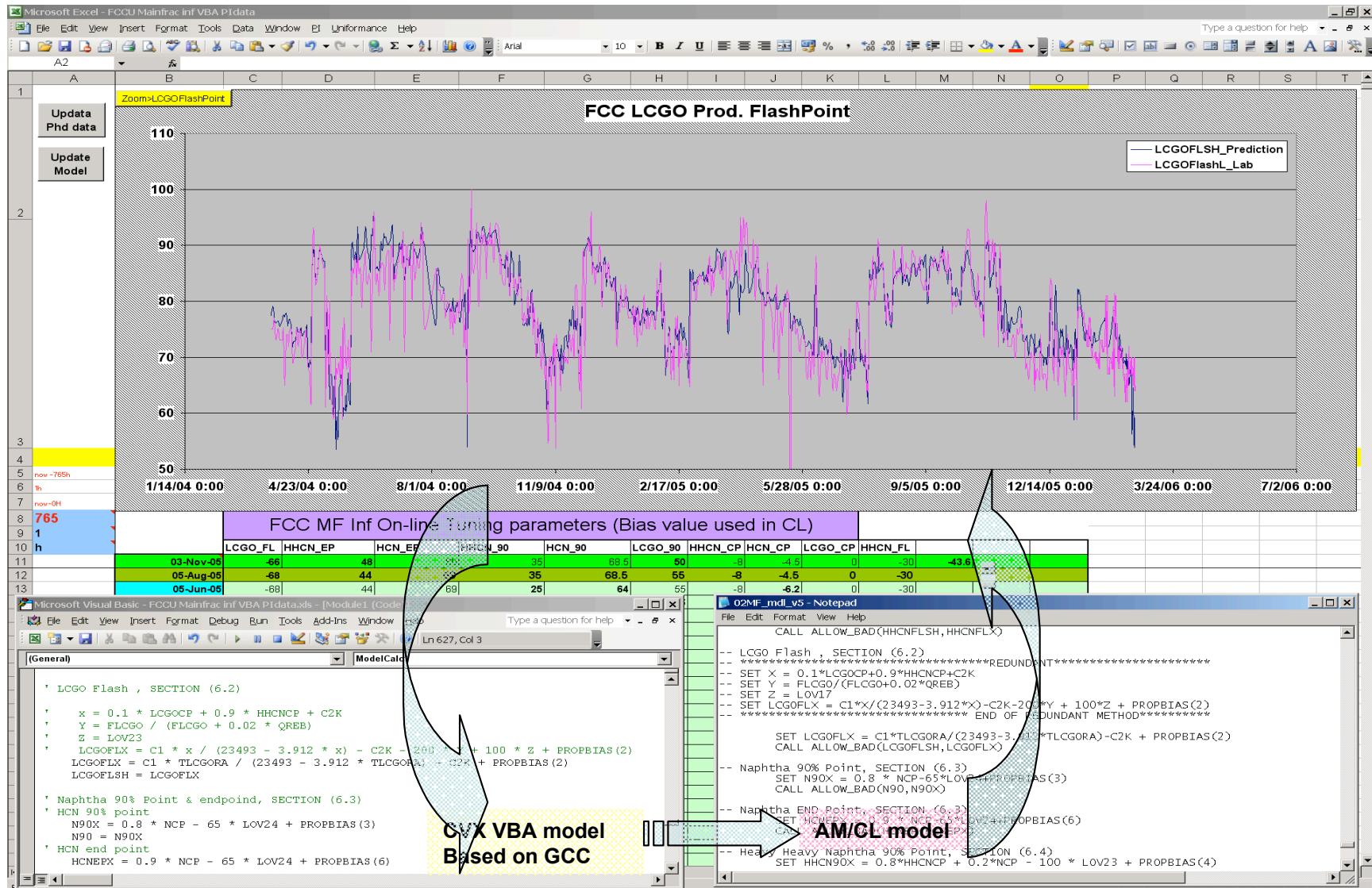


Feature – inferentials/Specs Control

- 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

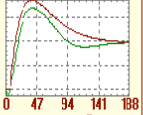
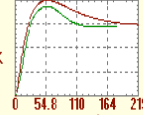
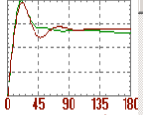
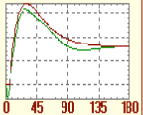
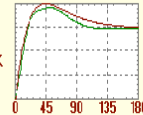
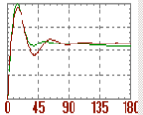
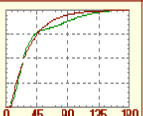
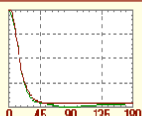
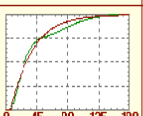
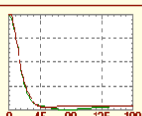
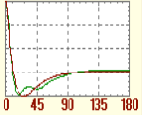
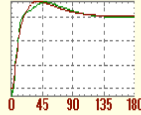
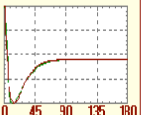


CX VBA model Based on GCC

AM/CL model

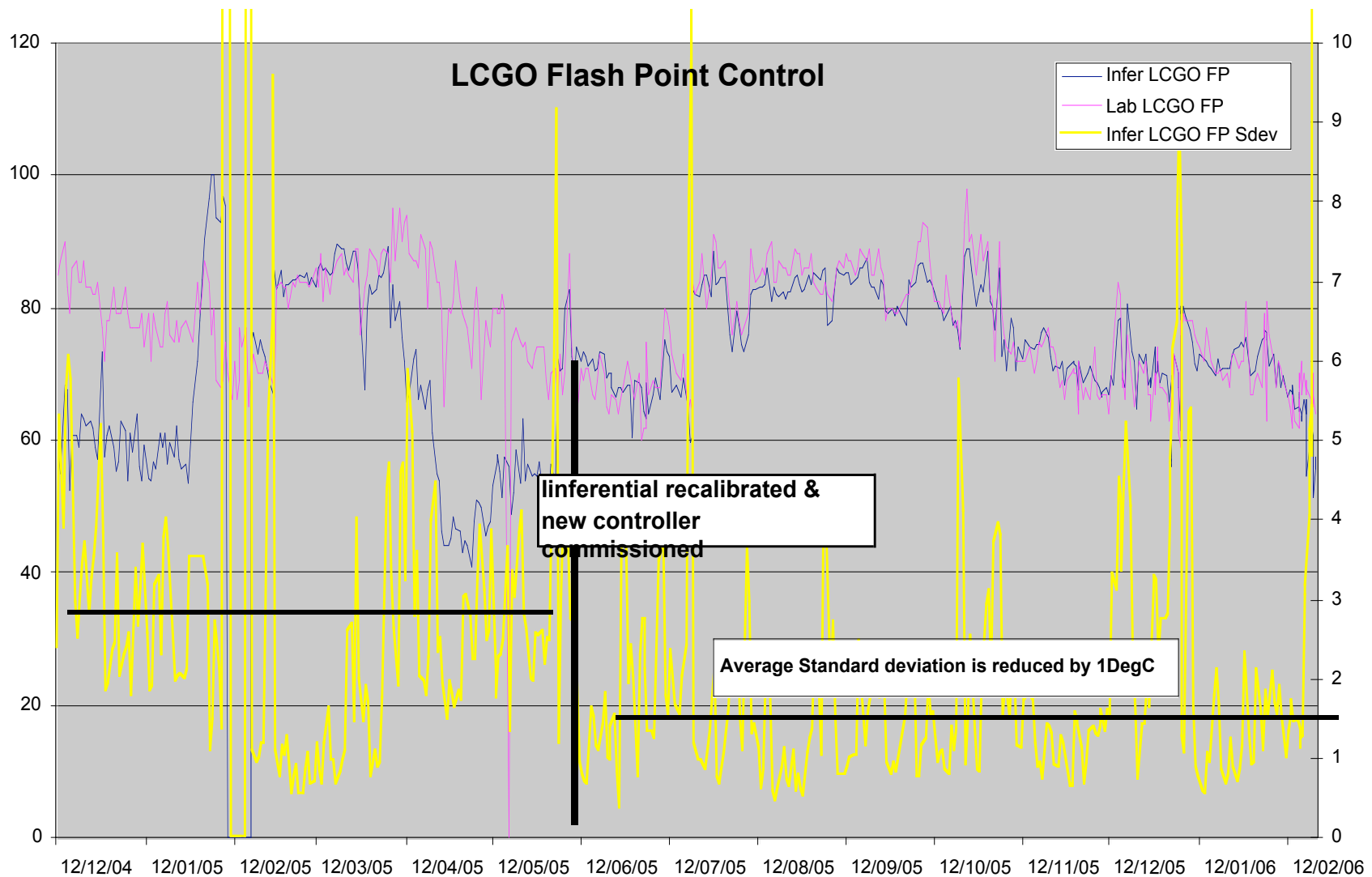


Sample Model – Spec Control

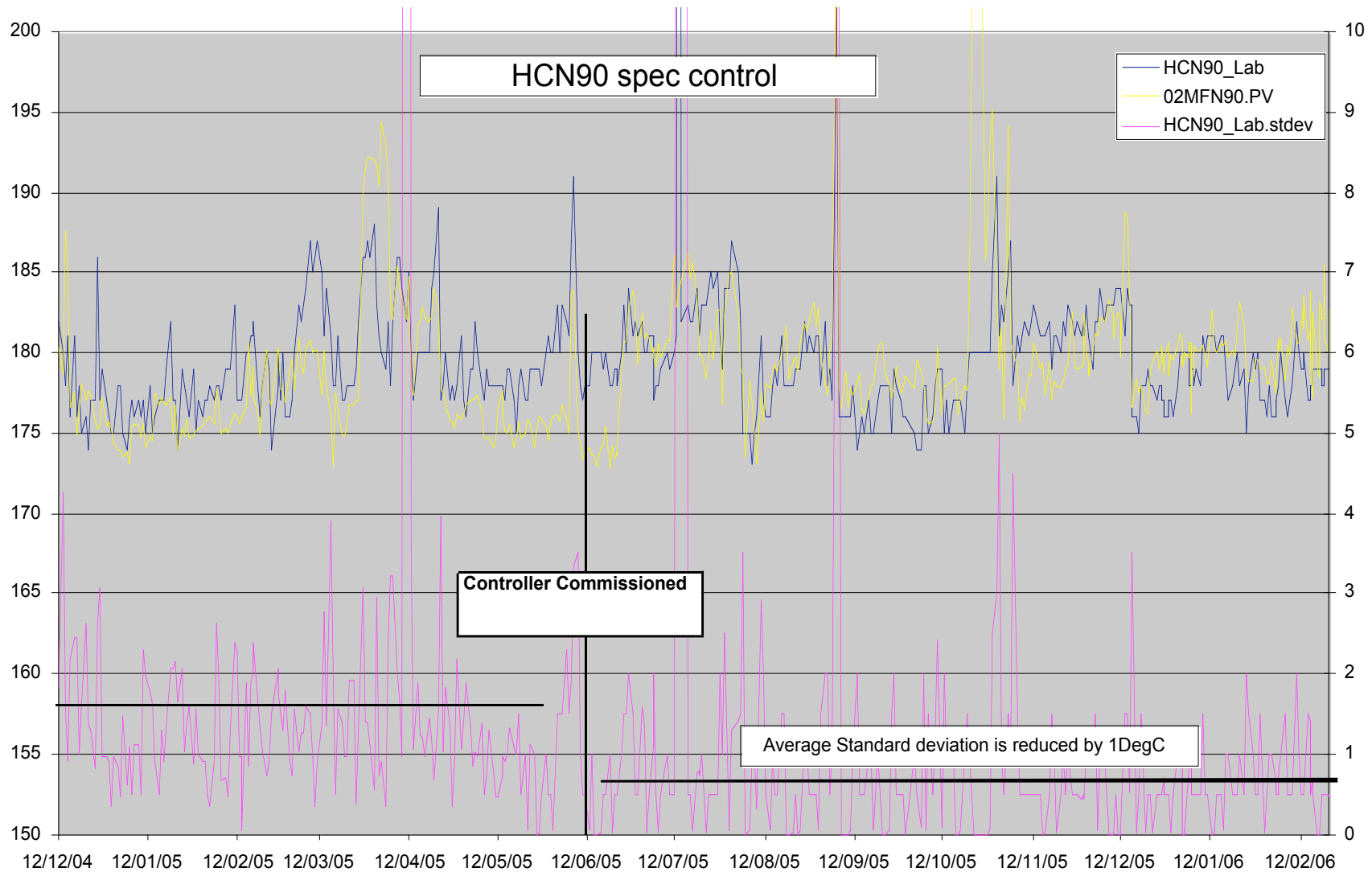
	MF Top-T	MF OVHD-T	LCGO prod.	HCGO PA	LCGO RBL	Deeth RBL	Ambient-T
HCN pt90	<p>Lap Order 2 Settle T = 180 TFSettle = 188 FIR Form = UK Trial 1</p>  <p>$G(s) = -.3 \frac{111s + 1}{637s^2 + 50.5s + 1} e^{-7s}$</p>	<p>Lap Order 2 Settle T = 180 TFSettle = 219 FIR Form = UK Trial 1</p>  <p>$G(s) = .55 \frac{33.8s + 1}{1157s^2 + 68s + 1} e^{-4s}$</p>					<p>ARX Order 2 Settle T = 180 TFSettle = 86.0 FIR Form = UK Trial 1</p>  <p>$G(s) = .164 \frac{5.39s + 1}{63.7s^2 + 5.55s + 1} e^{-1s}$</p>
HCN EP	<p>Lap Order 2 Settle T = 180 TFSettle = 140 FIR Form = UK Trial 1</p>  <p>$G(s) = -.3 \frac{96.7s + 1}{371s^2 + 38.5s + 1} e^{-6s}$</p>	<p>Lap Order 2 Settle T = 180 TFSettle = 171 FIR Form = UK Trial 1</p>  <p>$G(s) = .55 \frac{72.6s + 1}{721s^2 + 53.7s + 1} e^{-2s}$</p>					<p>ARX Order 2 Settle T = 180 TFSettle = 94.0 FIR Form = UK Trial 1</p>  <p>$G(s) = .165 \frac{8.91s + 1}{52.3s^2 + 4.71s + 1} e^{-0s}$</p>
HHCN 90pt	<p>Lap Order 1 Settle T = 180 TFSettle = 117 FIR Form = UK Trial 1</p>  <p>$G(s) = 14 \frac{1}{27.1s + 1} e^{-8s}$</p>			<p>Lap Order 2 Settle T = 180 TFSettle = 46.0 FIR Form = UK Trial 1</p>  <p>$G(s) = -.088 \frac{1}{50.5s^2 + 14.2s + 1} e^{-3s}$</p>			
HHCN EP	<p>Lap Order 1 Settle T = 180 TFSettle = 132 FIR Form = UK Trial 1</p>  <p>$G(s) = 14 \frac{1}{31s + 1} e^{-8s}$</p>			<p>Lap Order 2 Settle T = 180 TFSettle = 50.0 FIR Form = UK Trial 1</p>  <p>$G(s) = -.088 \frac{3.64s + 1}{104s^2 + 16.6s + 1} e^{-4s}$</p>			
LCGO FP			<p>Lap Order 2 Settle T = 180 TFSettle = 96.0 FIR Form = UK Trial 1</p>  <p>$G(s) = -.176 \frac{40.3s + 1}{223s^2 + 29.8s + 1} e^{-2s}$</p>		<p>Lap Order 2 Settle T = 180 TFSettle = 122 FIR Form = UK Trial 1</p>  <p>$G(s) = .0392 \frac{45.6s + 1}{410s^2 + 40.5s + 1} e^{-3s}$</p>		
Deeth Bottom C2						<p>Lap Order 2 Settle T = 180 TFSettle = 74.0 FIR Form = UK Trial 1</p>  <p>$G(s) = -.0284 \frac{42.1s + 1}{106s^2 + 20.6s + 1} e^{-1s}$</p>	



Highlight - LCGO Flash Point control



Highlight – HCN90 spec control



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

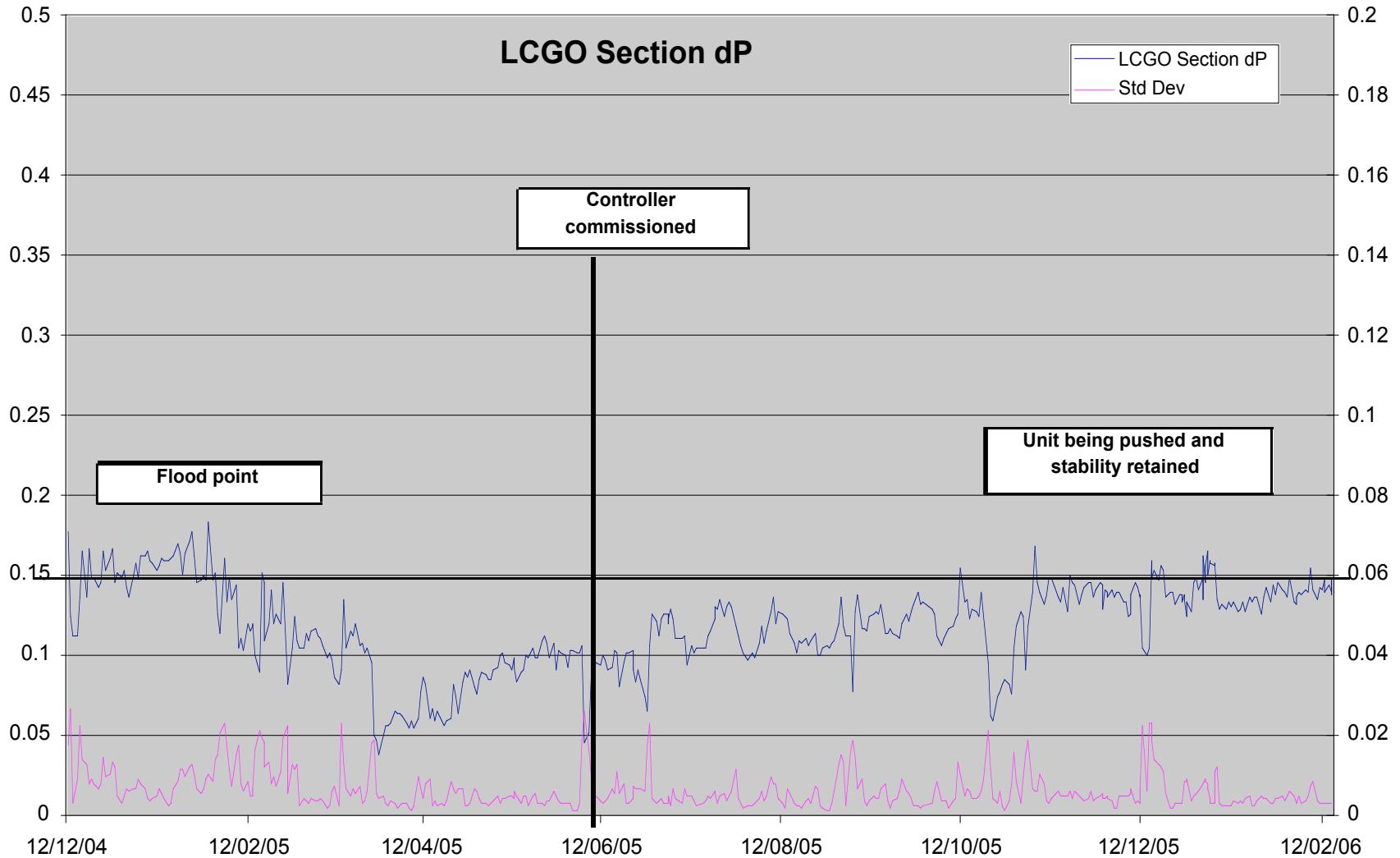


Sample Model – Main Frac control

	Feed	ROT	MF Top-T	LCGO prod.	HCGO PA	ICGO PA	HHCN prod
MainFrac	 Lap Order 2 Settle T = 180 TFSettle = 82.0 FIR Form = UK Trial 1 $G(s) = .05 \frac{1.32s + 1}{53.8s^2 + 4.67s + 1}$	 Lap Order 2 Settle T = 180 TFSettle = 15.0 FIR Form = UK Trial 1 $G(s) = .3 \frac{-745s + 1}{5.66s^2 + 4.76s + 1}$					
Bottom Temp.							
Packed Section	 ARX Order 2 Settle T = 180 TFSettle = 69.0 FIR Form = UK Trial 1 $G(s) = .76 \frac{8.7s + 1}{130s^2 + 23.7s + 1}$	 Lap Order 1 Settle T = 180 TFSettle = 34.0 FIR Form = UK Trial 1 $G(s) = -1.4 \frac{1}{8s + 1}$		 Lap Order 2 Settle T = 180 TFSettle = 228 FIR Form = UK Trial 1 $G(s) = -1 \frac{30s + 1}{338s^2 + 687s + 1}$	 Lap Order 2 Settle T = 180 TFSettle = 27.0 FIR Form = UK Trial 1 $G(s) = 1 \frac{8.96s + 1}{28.9s^2 + 7.88s + 1}$		
ICGO Wash	 Lap Order 2 Settle T = 180 TFSettle = 45.0 FIR Form = UK Trial 1 $G(s) = .05 \frac{.4s + 1}{39.5s^2 + 8.53s + 1}$	 Lap Order 2 Settle T = 180 TFSettle = 45.0 FIR Form = UK Trial 1 $G(s) = -.914 \frac{15.3s + 1}{33.8s^2 + 6.53s + 1}$	 Lap Order 2 Settle T = 180 TFSettle = 57.0 FIR Form = UK Trial 1 $G(s) = -1 \frac{3.32s + 1}{81.8s^2 + 8.87s + 1}$	 Lap Order 2 Settle T = 180 TFSettle = 77.0 FIR Form = UK Trial 1 $G(s) = -1 \frac{13.8s + 1}{120s^2 + 261s + 1}$	 Lap Order 2 Settle T = 180 TFSettle = 74.0 FIR Form = UK Trial 1 $G(s) = -.3 \frac{17s + 1}{265s^2 + 33.8s + 1}$		 Lap Order 2 Settle T = 180 TFSettle = 85.0 FIR Form = UK Trial 1 $G(s) = -1 \frac{23.3s + 1}{190s^2 + 36s + 1}$
LCGO Draw LVL	 Lap Order 1 Settle T = 180 TFSettle = 70.0 FIR Form = UK Trial 1 $G(s) = .15 \frac{1}{16.7s + 1}$	 Lap Order 2 Settle T = 180 TFSettle = 102 FIR Form = UK Trial 1 $G(s) = .2 \frac{64s + 1}{201s^2 + 28.4s + 1}$	 Lap Order 2 Settle T = 180 TFSettle = 57.0 FIR Form = UK Trial 1 $G(s) = -.2 \frac{3.33s + 1}{121s^2 + 16.5s + 1}$	 Lap Order 1 Settle T = 180 TFSettle = 163 FIR Form = UK Trial 1 $G(s) = -.3 \frac{1}{40s + 1}$	 Lap Order 2 Settle T = 180 TFSettle = 49.0 FIR Form = UK Trial 1 $G(s) = -.04 \frac{1}{51s^2 + 15.1s + 1}$	 Lap Order 2 Settle T = 180 TFSettle = 115 FIR Form = UK Trial 1 $G(s) = -.0601 \frac{1}{409s^2 + 46.6s + 1}$	 Lap Order 1 Settle T = 180 TFSettle = 136 FIR Form = UK Trial 1 $G(s) = -.189 \frac{1}{33.6s + 1}$
LCGO Draw DP	 Lap Order 2 Settle T = 180 TFSettle = 80.0 FIR Form = UK Trial 1 $G(s) = .0006 \frac{37.3s + 1}{248s^2 + 47.5s + 1}$	 Lap Order 2 Settle T = 180 TFSettle = 92.0 FIR Form = UK Trial 1 $G(s) = .00069 \frac{75.8s + 1}{139s^2 + 23.6s + 1}$		 Lap Order 1 Settle T = 180 TFSettle = 159 FIR Form = UK Trial 1 $G(s) = -.0012 \frac{1}{38.4s + 1}$	 Lap Order 2 Settle T = 180 TFSettle = 33.0 FIR Form = UK Trial 1 $G(s) = -.0002 \frac{1}{29s^2 + 7.39s + 1}$	 ARX Order 2 Settle T = 180 TFSettle = 133 FIR Form = UK Trial 1 $G(s) = -.0001 \frac{31.5s + 1}{157s^2 + 48.5s + 1}$	 Lap Order 1 Settle T = 180 TFSettle = 141 FIR Form = UK Trial 1 $G(s) = -.00052 \frac{1}{34.4s + 1}$
HCGO Visc	 Lap Order 2 Settle T = 180 TFSettle = 75.0 FIR Form = UK Trial 1 $G(s) = -.03 \frac{4.1s + 1}{112s^2 + 15.6s + 1}$	 Lap Order 2 Settle T = 180 TFSettle = 27.0 FIR Form = UK Trial 1 $G(s) = .1 \frac{1}{18.5s^2 + 8.85s + 1}$	 Lap Order 2 Settle T = 180 TFSettle = 122 FIR Form = UK Trial 1 $G(s) = -.06 \frac{43.5s + 1}{507s^2 + 45s + 1}$	 Lap Order 2 Settle T = 180 TFSettle = 80.0 FIR Form = UK Trial 1 $G(s) = .03 \frac{15.5s + 1}{429s^2 + 35.5s + 1}$	 Lap Order 2 Settle T = 180 TFSettle = 70.0 FIR Form = UK Trial 1 $G(s) = .02 \frac{1}{130s^2 + 23.1s + 1}$		 ARX Order 2 Settle T = 240 TFSettle = 81.0 FIR Form = UK Trial 1 $G(s) = .0299 \frac{1}{16.1s + 1}$
HCGO Density	 Lap Order 2 Settle T = 180 TFSettle = 86.0 FIR Form = UK Trial 1 $G(s) = -.09 \frac{7.8s + 1}{145s^2 + 17.8s + 1}$	 Lap Order 2 Settle T = 180 TFSettle = 29.0 FIR Form = UK Trial 1 $G(s) = .3 \frac{.224s + 1}{21s^2 + 6.66s + 1}$	 Lap Order 2 Settle T = 180 TFSettle = 62.0 FIR Form = UK Trial 1 $G(s) = .18 \frac{22.4s + 1}{120s^2 + 21.9s + 1}$	 Lap Order 2 Settle T = 180 TFSettle = 72.0 FIR Form = UK Trial 1 $G(s) = .09 \frac{1}{118s^2 + 21.8s + 1}$	 Lap Order 2 Settle T = 180 TFSettle = 60.0 FIR Form = UK Trial 1 $G(s) = .06 \frac{1}{100s^2 + 20s + 1}$		 Lap Order 2 Settle T = 240 TFSettle = 72.0 FIR Form = UK Trial 1 $G(s) = .0906 \frac{1}{117s^2 + 21.6s + 1}$



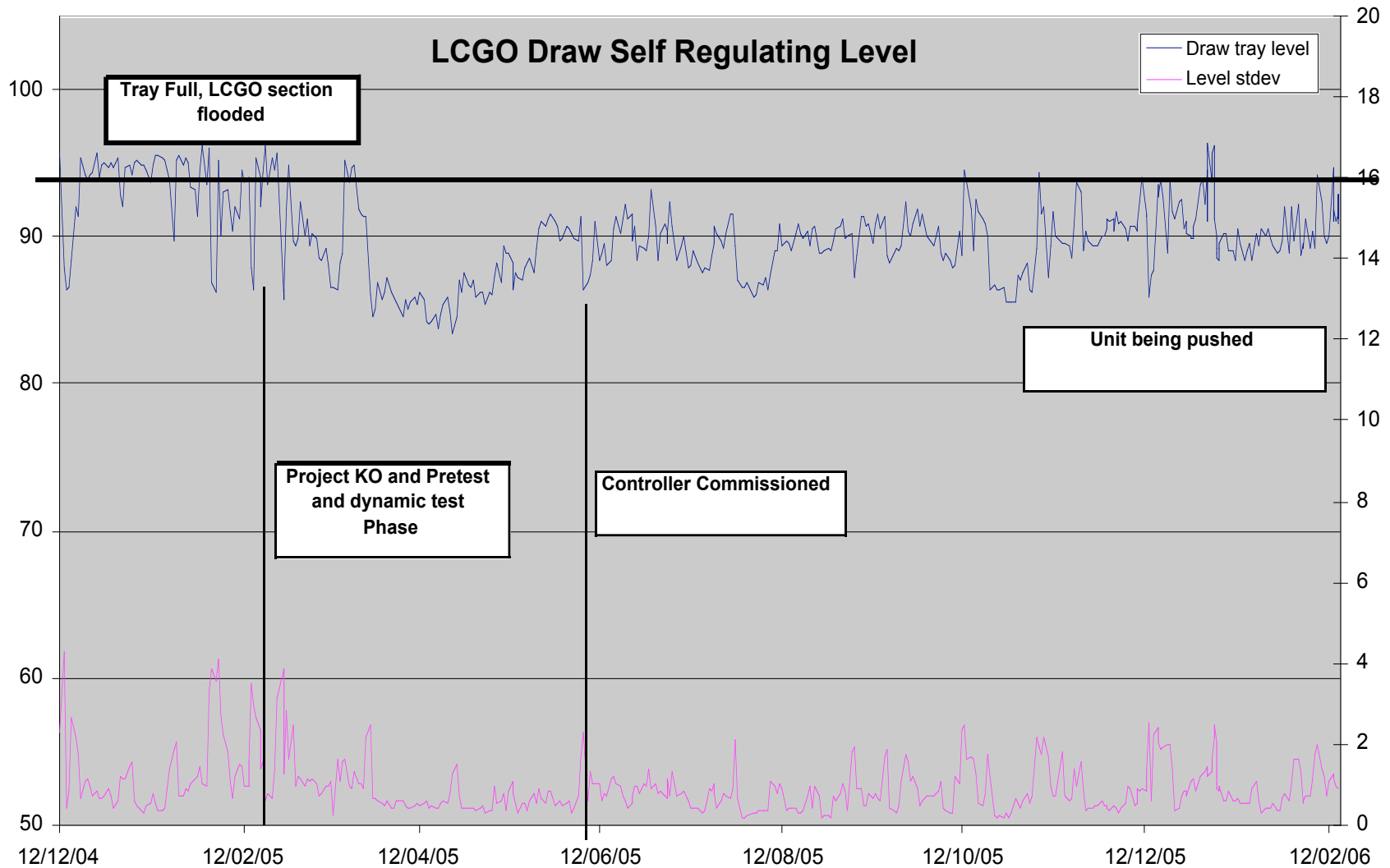
Highlight - LCGO Section dP Sensitivity to Flood



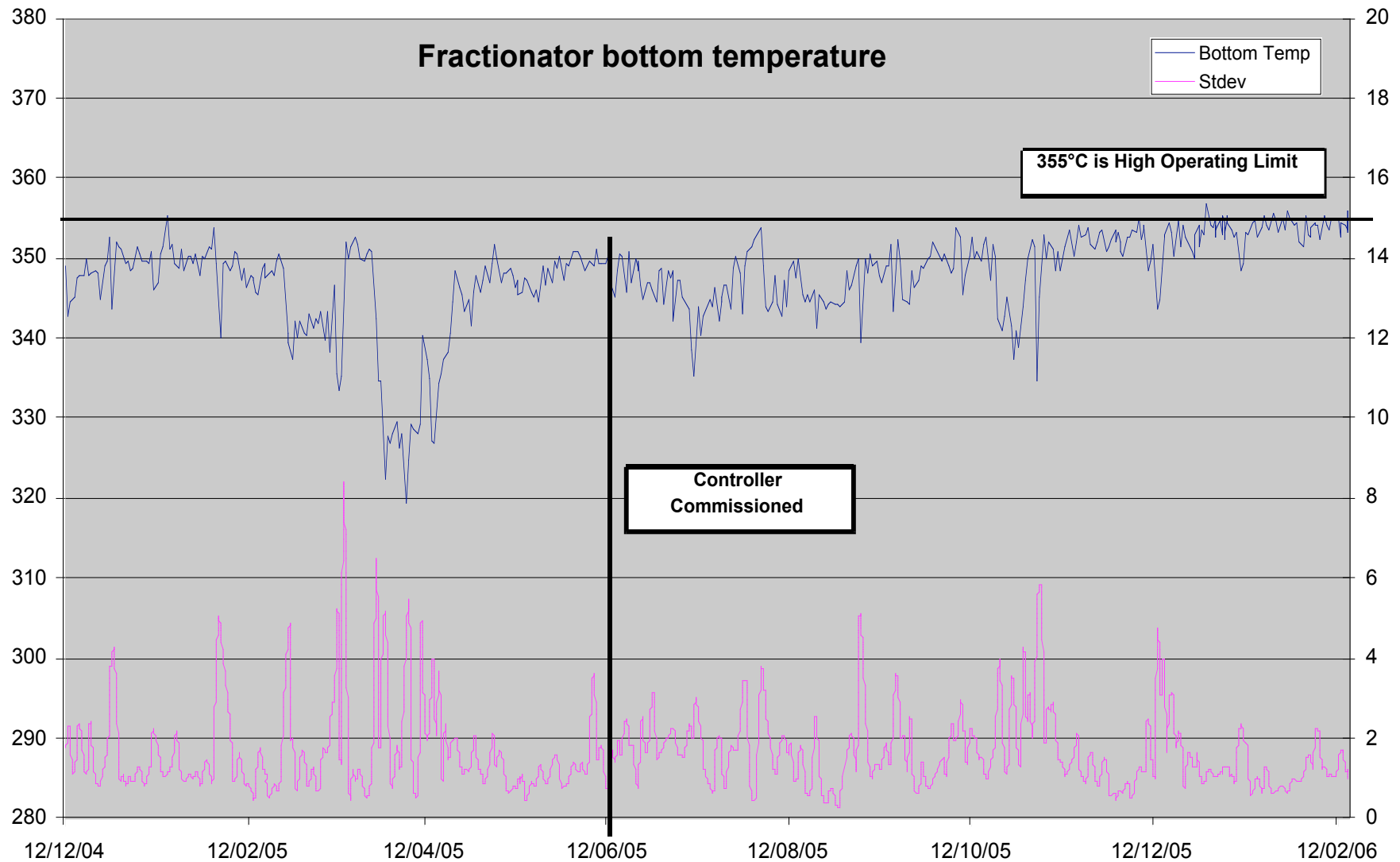
Petrocontrol



Highlight - LCGO Draw Tray Level



Highlight - Fractionator BTM T Critical Unit imitation



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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)



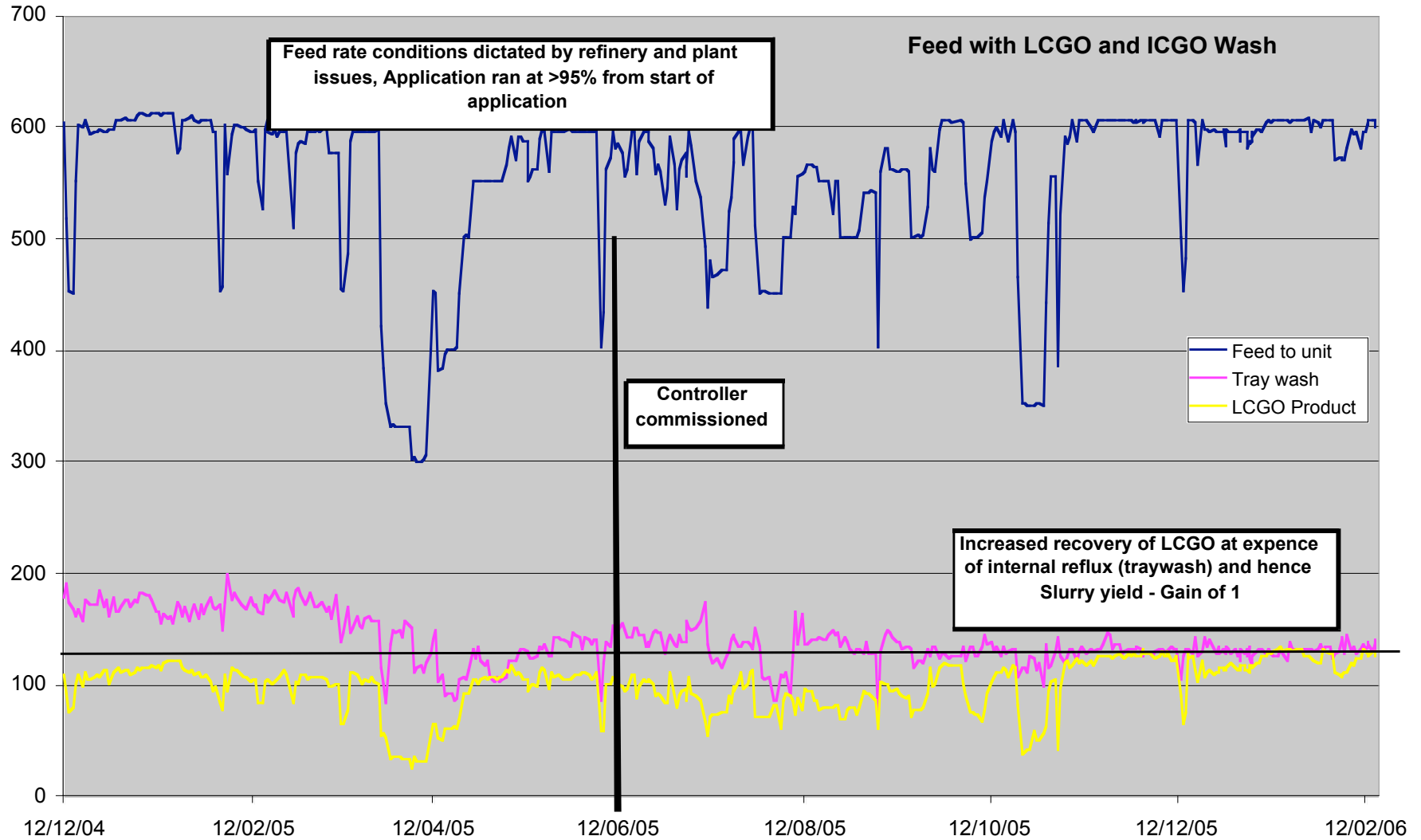
Sample Model – Rx/Rg optimisation

	Tot-Feed	Reactor-Temp	Resid-Feed	Rx/Rg-DP	Feed-Preheat	MF Top-P	Air-blower
Excess O2	<p>Lap Order 1 Settle T = 180 TFSettle = 102 FIR Form = UK Trial 1</p> <p>$G(s) = \frac{-0.03}{23.3s + 1} e^{-8s}$</p>	<p>Lap Order 2 Settle T = 180 TFSettle = 100 FIR Form = UK Trial 1</p> <p>$G(s) = \frac{-0.0894}{109s^2 + 29.6s + 1} e^{-5s}$</p>	<p>Lap Order 2 Settle T = 180 TFSettle = 98.0 FIR Form = UK Trial 1</p> <p>$G(s) = \frac{-0.006}{355s^2 + 33.1s + 1} e^{-21s}$</p>		<p>Lap Order 2 Settle T = 180 TFSettle = 86.0 FIR Form = UK Trial 1</p> <p>$G(s) = \frac{.03}{140s^2 + 25s + 1} e^{-8s}$</p>		<p>Lap Order 2 Settle T = 180 TFSettle = 100 FIR Form = UK Trial 1</p> <p>$G(s) = \frac{.05}{94.2s^2 + 29s + 1} e^{-5s}$</p>
Rx bed Temp	<p>Lap Order 2 Settle T = 180 TFSettle = 187 FIR Form = UK Trial 1</p> <p>$G(s) = \frac{.0253}{495s^2 + 26.7s + 1} e^{-17s}$</p>	<p>Lap Order 2 Settle T = 180 TFSettle = 82.0 FIR Form = UK Trial 1</p> <p>$G(s) = \frac{.768}{200s^2 + 17.3s + 1} e^{-6s}$</p>	<p>ARX Order 2 Settle T = 180 TFSettle = 182 FIR Form = UK Trial 1</p> <p>$G(s) = \frac{.217}{925s^2 + 48.1s + 1} e^{-28s}$</p>		<p>AFX Order 2 Settle T = 180 TFSettle = 178 FIR Form = UK Trial 1</p> <p>$G(s) = \frac{.0779}{844s^2 + 71.3s + 1} e^{-1s}$</p>		<p>Lap Order 2 Settle T = 240 TFSettle = 72.0 FIR Form = UK Trial 1</p> <p>$G(s) = \frac{-2}{177s^2 + 20.1s + 1} e^{-3s}$</p>
RCSV DP				<p>Lap Order 2 Settle T = 180 TFSettle = 54.0 FIR Form = UK Trial 1</p> <p>$G(s) = \frac{1}{31.3s^2 + 16.2s + 1} e^{-2s}$</p>			
RCSV OP	<p>Lap Order 2 Settle T = 180 TFSettle = 56.0 FIR Form = UK Trial 1</p> <p>$G(s) = \frac{.0651}{149s^2 + 24.4s + 1} e^{-0s}$</p>			<p>Lap Order 2 Settle T = 180 TFSettle = 105 FIR Form = UK Trial 1</p> <p>$G(s) = \frac{-35}{382s^2 + 39.1s + 1} e^{-0s}$</p>			
Airblow Anti-srg				<p>ANX Order 2 Settle T = 180 TFSettle = 14.0 FIR Form = UK Trial 1</p> <p>$G(s) = \frac{-1}{10.8s^2 + 6.53s + 1} e^{-1s}$</p>		<p>ANX Order 2 Settle T = 180 TFSettle = 14.0 FIR Form = UK Trial 1</p> <p>$G(s) = \frac{-1}{10.8s^2 + 6.53s + 1} e^{-1s}$</p>	<p>Lap Order 2 Settle T = 180 TFSettle = 11.0 FIR Form = UK Trial 1</p> <p>$G(s) = \frac{0.0477}{.576s^2 + 2.8s + 1} e^{-0s}$</p>
WGC Anti-srg	<p>Lap Order 2 Settle T = 180 TFSettle = 16.0 FIR Form = UK Trial 1</p> <p>$G(s) = \frac{-.0025}{5.78s^2 + 4.96s + 1} e^{-0s}$</p>	<p>Lap Order 2 Settle T = 180 TFSettle = 17.0 FIR Form = UK Trial 1</p> <p>$G(s) = \frac{-.02}{10.2s^2 + 6.38s + 1} e^{-0s}$</p>				<p>Lap Order 2 Settle T = 180 TFSettle = 180 FIR Form = UK Trial 1</p> <p>$G(s) = \frac{.51}{4.47s^2 + 4.23s + 1} e^{-0s}$</p>	
Cat. Circ.	<p>Lap Order 2 Settle T = 180 TFSettle = 57.0 FIR Form = UK Trial 1</p> <p>$G(s) = \frac{.0778}{106s^2 + 17.7s + 1} e^{-2s}$</p>	<p>Lap Order 2 Settle T = 180 TFSettle = 43.0 FIR Form = UK Trial 1</p> <p>$G(s) = \frac{.31}{42.2s^2 + 13s + 1} e^{-3s}$</p>	<p>Lap Order 2 Settle T = 180 TFSettle = 158 FIR Form = UK Trial 1</p> <p>$G(s) = \frac{-0.055}{456s^2 + 49.2s + 1} e^{-0s}$</p>		<p>Lap Order 2 Settle T = 180 TFSettle = 129 FIR Form = UK Trial 1</p> <p>$G(s) = \frac{-1}{544s^2 + 34s + 1} e^{-10s}$</p>		



Unit Feed and Yields in M3/HR

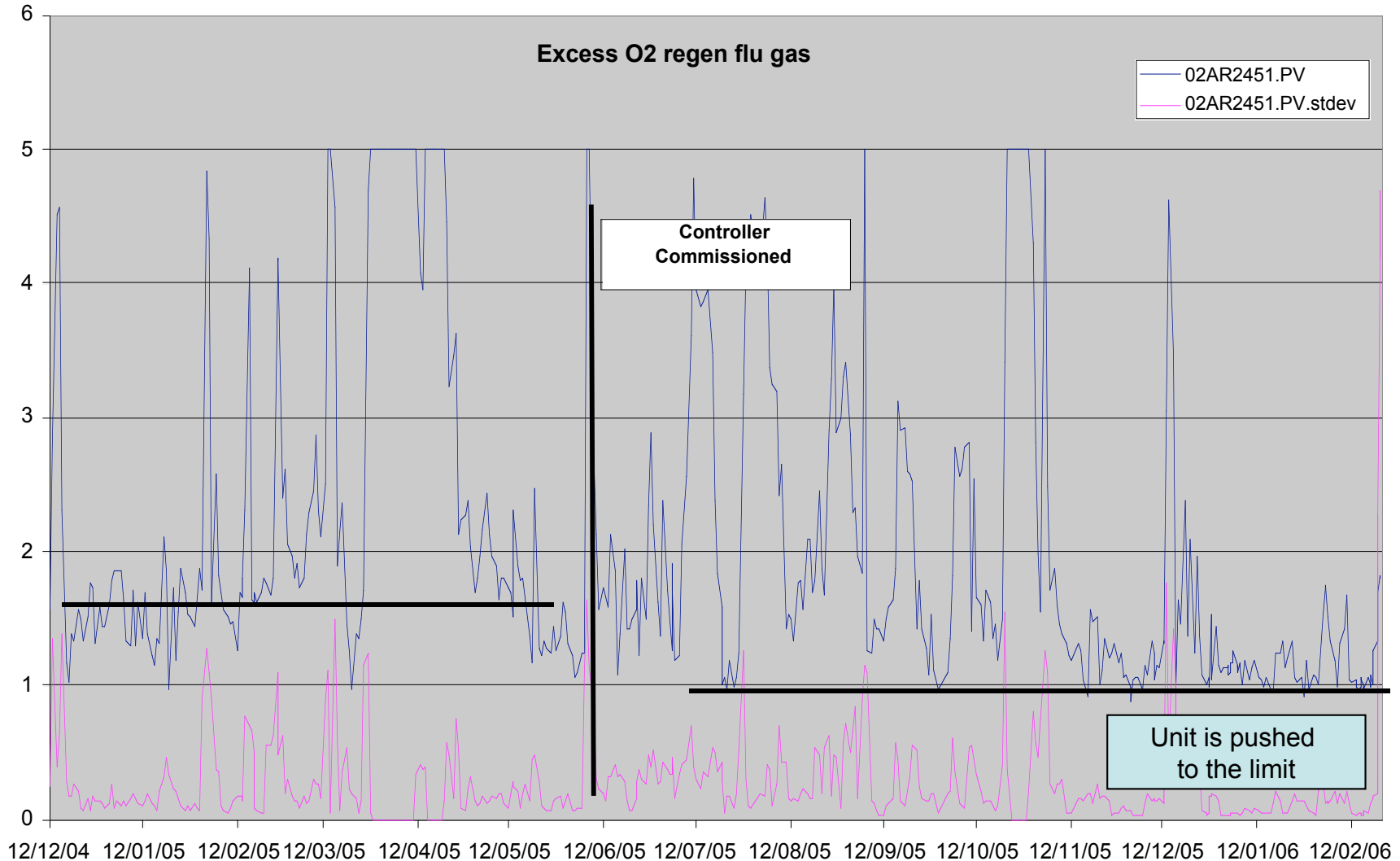
Shows increase in recovery of LCGO whilst sustaining bottom conditions



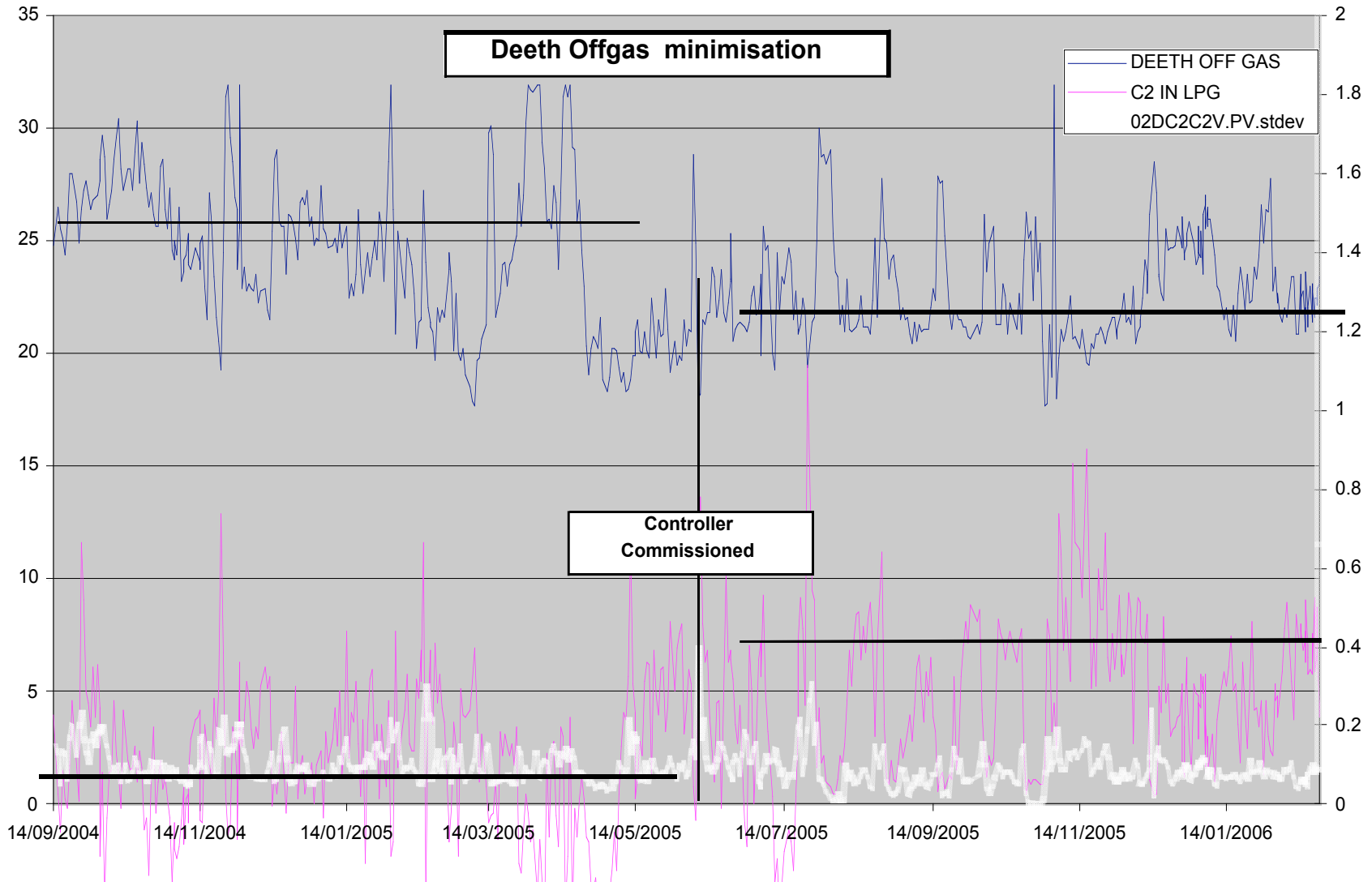
Petrocontrol



Highlight – Excess O2 optimisation



Highlight – Deeth Optimisation



Feature – operator Acceptance

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



Petrocontrol

AMT

Highlight – Customised Operator Display

04 Oct 05 11:46:19 7

FCC RMPCT Controller OPTIMISING...
 ON OFF

SECTIONS: RX/RG M.FRAC. DE-ETH
 ON

MV DESC.	STAT	VALUE	MOVE	LOLIM	HILIM
TC1967 PRIM	ON	117.0		117.0	122.0
TC075 MF/TO	ON	131.5			131.5
FC2612 LCGO	ON	11.0			10.0
FC2368 CHIL	ON	15.0			55.0
FC2369 CHIL	SERV	80.0			40.0
FC1926 ICGO	ON	450.0			460.0
FC044 HCGO	ON	380.4	-0.04	380.0	410.0
FC067 HCGO	ON	494.7	0.01	430.0	495.0
FC2175 HCGO	ON	214.9	-0.68	190.0	220.0

CV DESC.	VALUE	SSVAL	LOL	HILIM
MF HCN90	177.9		177.0	186.0
MF HCN EP	194.6	194.7	190.0	200.0
MF HHCN90	215.9			
MF HHCN EP	230.5			
MF LCGO FLS	81.41			
GLITSCH FLO	1003.0			
FC035.SP IC	129.6	129.6	127.5	150.0
HCGO VISCOS	16.10			
HCGO DENSIT	1091.0			
LR3208 TY18	90.51			
FR1980 TPA	322.2	322.5	220.0	370.0
FC2368/9DIF	75.0		-10.0	10.0
PD3056 LCGO	0.125			
FC060 HCGO	41.00			
TC075.OP	17.50			
TC1967.OP	58.33			
FC2612.OP	14.28	14.34	5.000	95.00
FC1926.OP	61.06	59.62	5.000	90.00
FC2368.OP T	26.03	26.16	5.000	98.00
FC2369.OP T	0.000		5.000	95.00

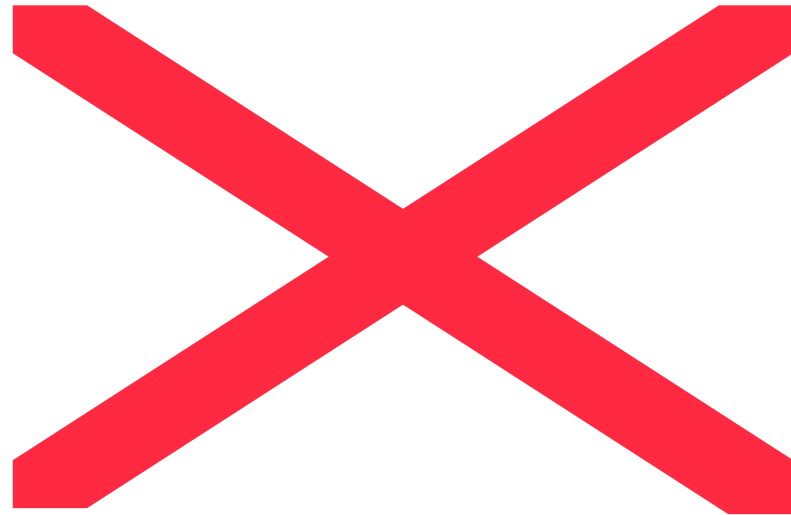
CV DESC.	VALUE	SSVAL	LOLIM	HILIM
FC044.OP HC	41.65	41.62	10.00	85.00
FC067.OP LC	46.68	46.91	0.00	90.00
FC2175.OP H	94.85	94.00	10.00	94.00
FC1646 HCGO			00	120.0

Annotations:

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

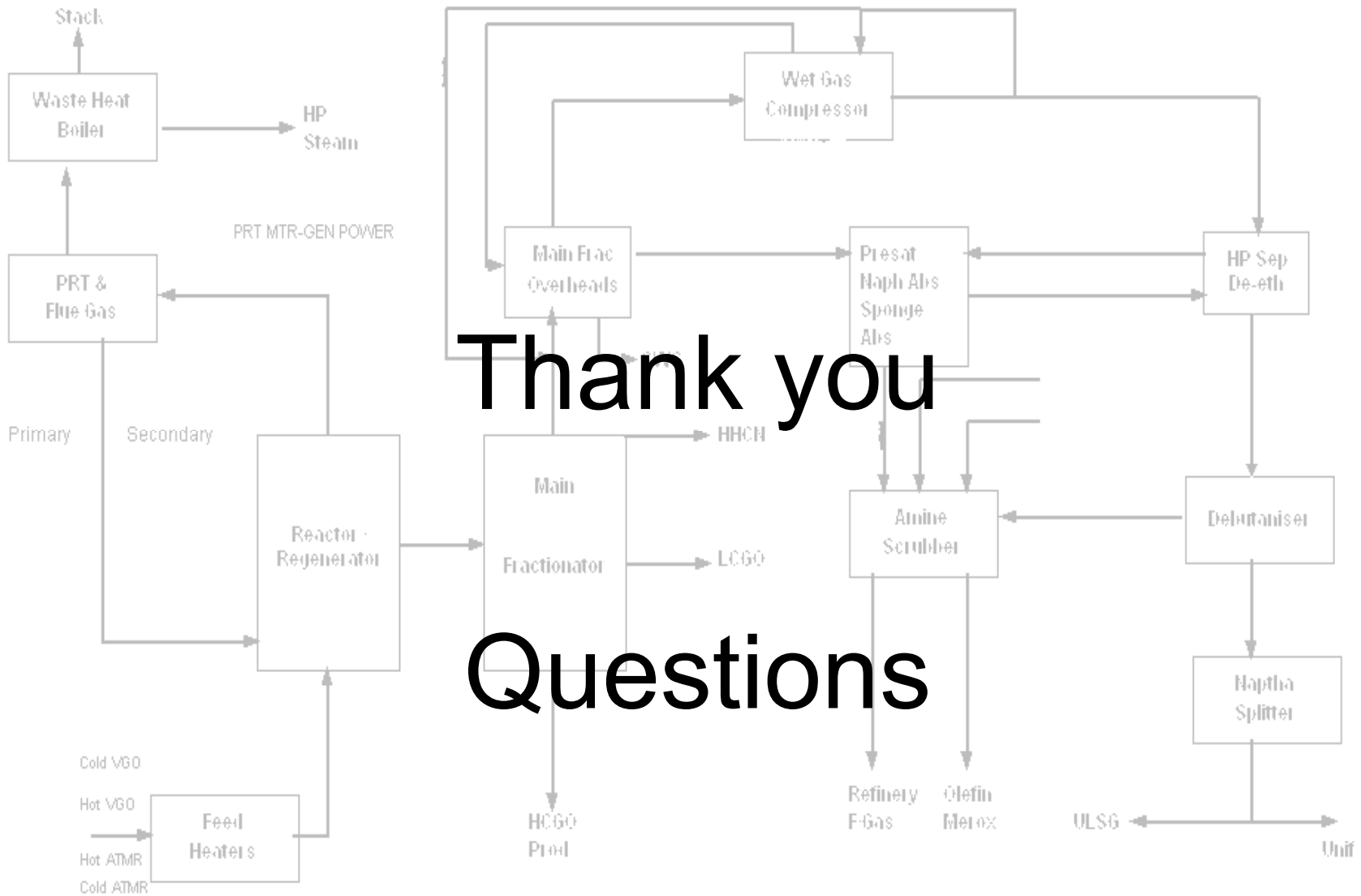


Highlight – sample training slide



Petrocontrol

AMT



Thank you

Questions

