

# BENEFIT CALCULATION of APC APPLICATIONS

**László Nagy**

*Team leader of PA*



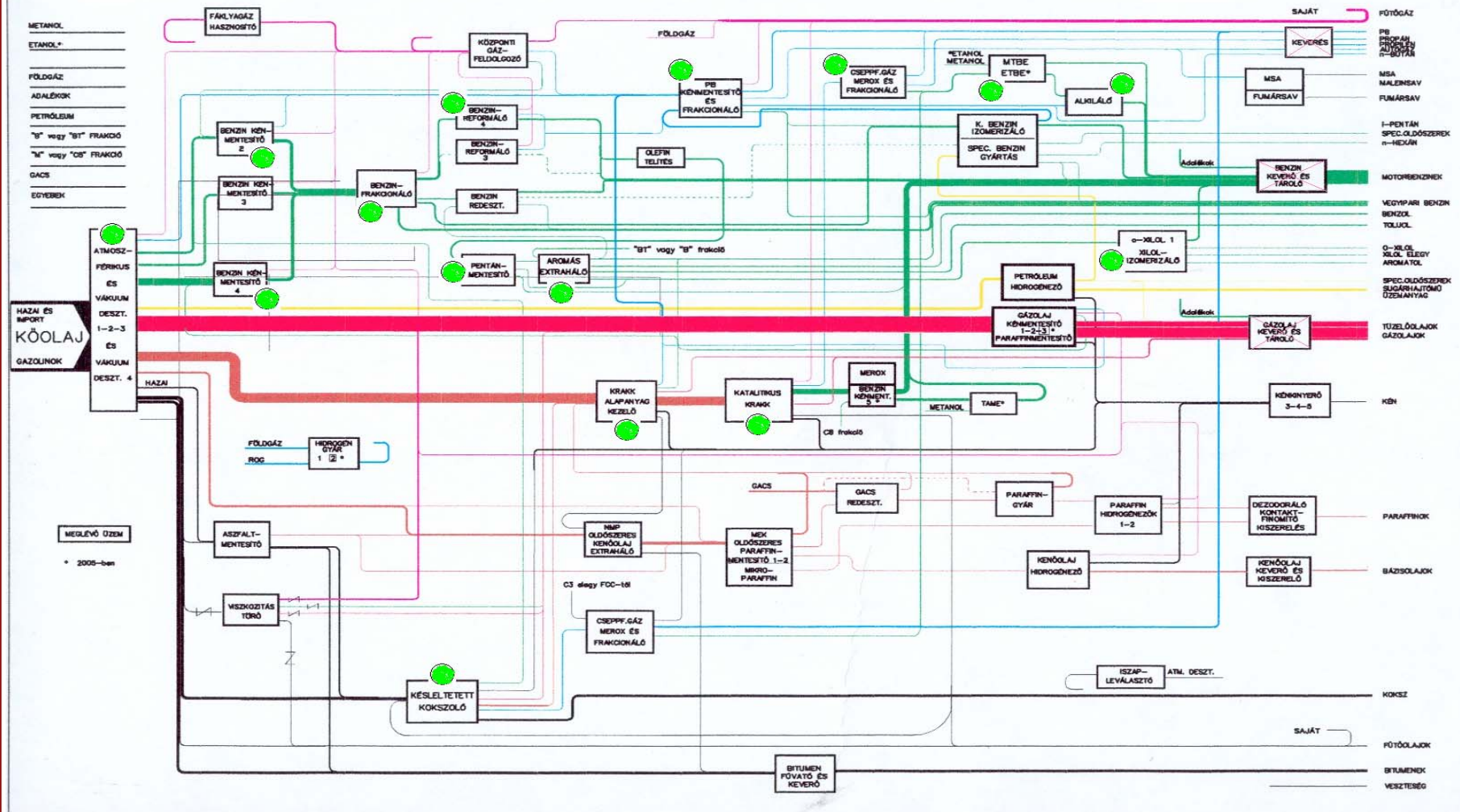
▶ **MOL GROUP**

# DANUBE REFINERY



# APC APPLICATIONS in MOL

A MOL DUNAI FINOMÍTÓ TECHNOLÓGIAI FOLYAMATA



# APC DMC CONTROLLERS

FCC	BI1	LPG fractionator	VD3	DMN_FRAC	Main column
	CI1	Reactor / regenerator		DMN_H111	Atmospheric heater
	CI2	Main column		DMN_H112	Atmospheric heater
	GI1	PP Stripper		DPD	Primary distillation column
	GI2	Debuthanizer		DST	Stabilization column
ALK	DC3	Depropanizer	GFR	DVC	Vacuum column
ETBE	IST	Izostripper		C4S	C4 Splitter
	M1	Reactor / fractionator		DC2	Deethanizer
MHC	M2	Ethanol recovery		DC3	Depropanizer
	HRX	Reactor		DC4	Debuthanizer
VD1	HDP	Main column	CCR4	FRACT	Benzene
	AMN	Main column		HYDRO	Reactor
VD2	APD	Primary distillation column		PLATFM	Platforming
	ATS	Stabilization column	NDH2	BEK2	Stabilization column
	CMN_FRAC	Main column	AROMATIC	BEN	Benzene column
	CMN_H108	Atmospheric heater	TOL	Toluene column	
	CMN_H109	Atmospheric heater	XOX	Ortho-xylene column	
VD2	CMN_H230	Atmospheric heater	XK1	Predestillation	
	CPD	Primary distillation column	XK2	Xylene column	
	CST	Stabilization column	DC	CMF	Main column
	CVC	Vacuum column		CHT	Heater
				GDB	Debutanizer
				GDP	Depropanizer
				PPS	PP Splitter

# APC FEASIBLE BENEFITS

- ✓ Energy saving
- ✓ Maximise most valuable product
- ✓ Quality control
- ✓ Maximise feed



REALIZABLE PROFIT 1 - 2 Billion Ft / year !!!!

4 – 7 mill EUR / year

# FAIRY TALE BEGINS

Once on a time there was a dear little girl who was loved by every one who looked at her, but most of all by her grandmother, and there was nothing....

**MEASURE THE PROFIT  
OF APC (HISTORY)**

# A METHOD FROM LAST CENTURY

WWW.BBC.COM



**Evaluation of APC operation:**

**EXCEL table was sent through outlook:  
Why the controller was switched off?**

**Report about up-time of APC controllers**

# WHERE TO GO?

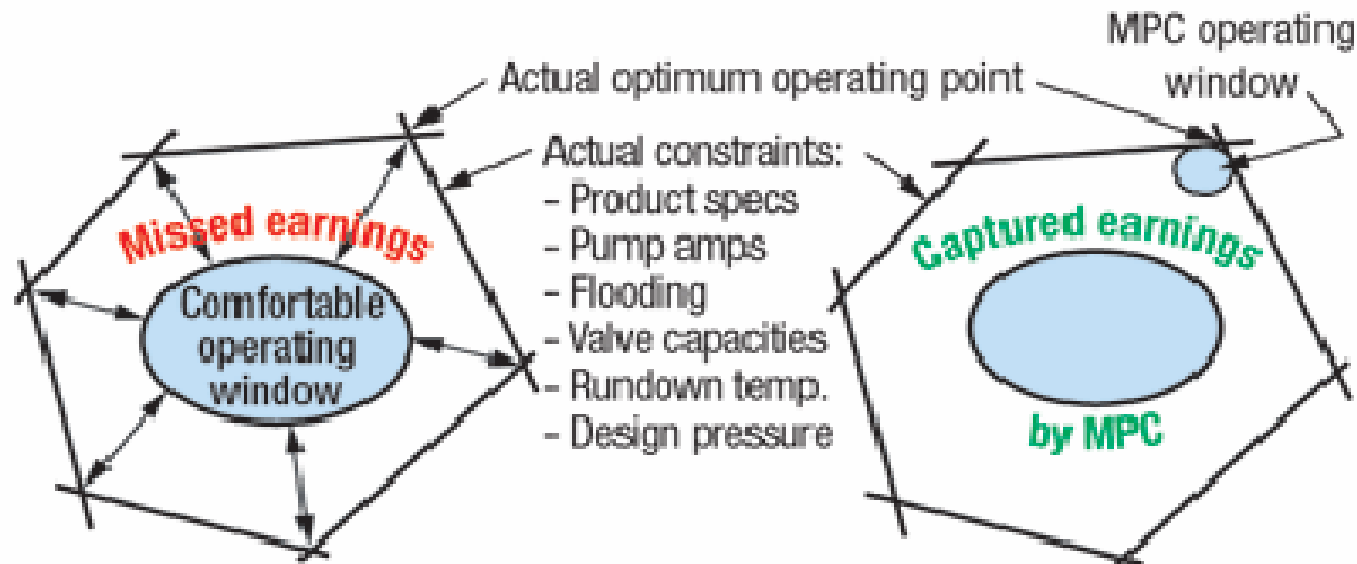


**IDEA !!!**

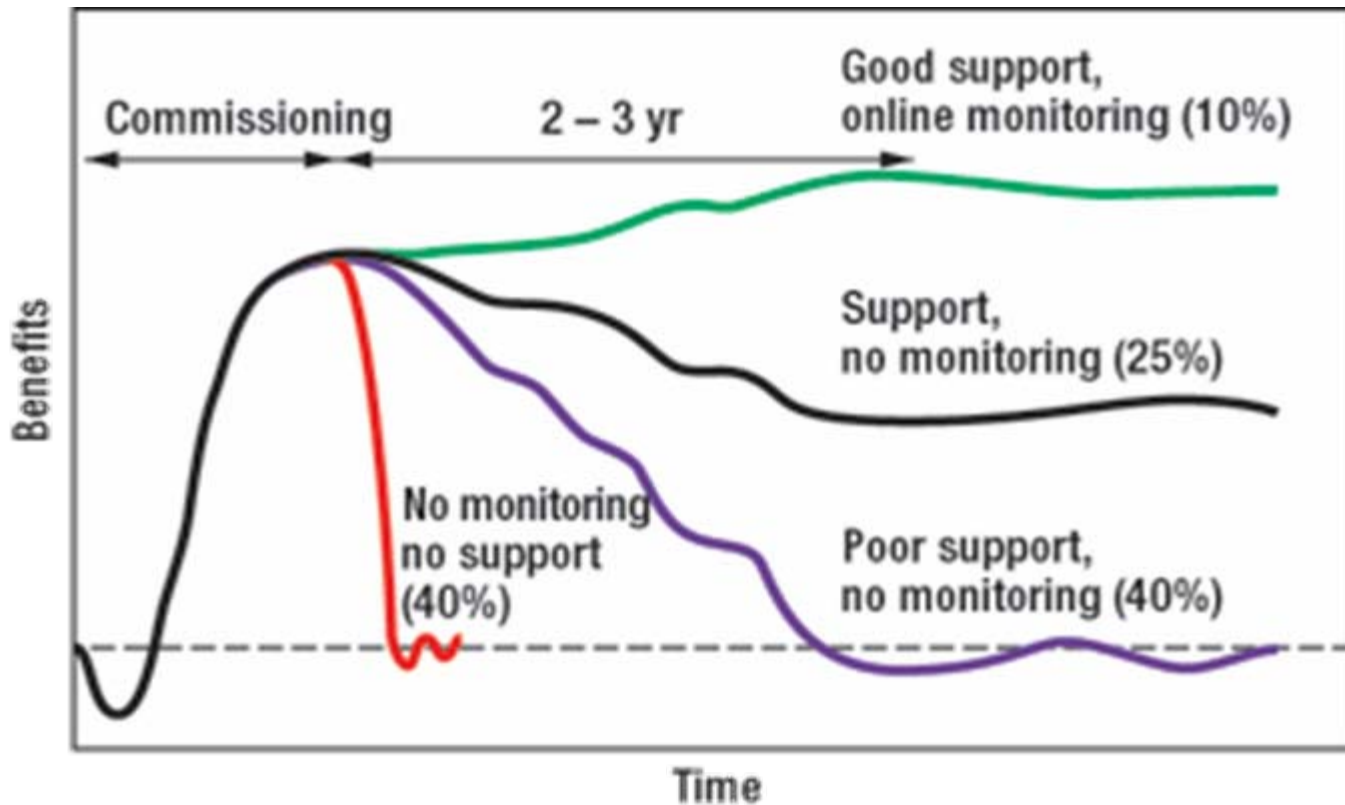
# APC vs OPERATOR

**Without MPC**  
Operation stays in a  
"comfort zone," away  
from constraints.

**With MPC**  
Process is controlled at  
the real optimum, capturing  
additional earnings.



# NEED of ONLINE MONITORING



# KPI DEVELOPED by KERN

## KPI for MPC utilization

$$UI = CVA / MVD * 100$$

UI = Ideal *MPC* utilization

CVA = number of *CVs* at active constraints

MVD = number of *MVs* in controller design

Hydrocarbon Processing October 2005

A. G. Kern On-line monitoring of multivariable control utilization and benefits

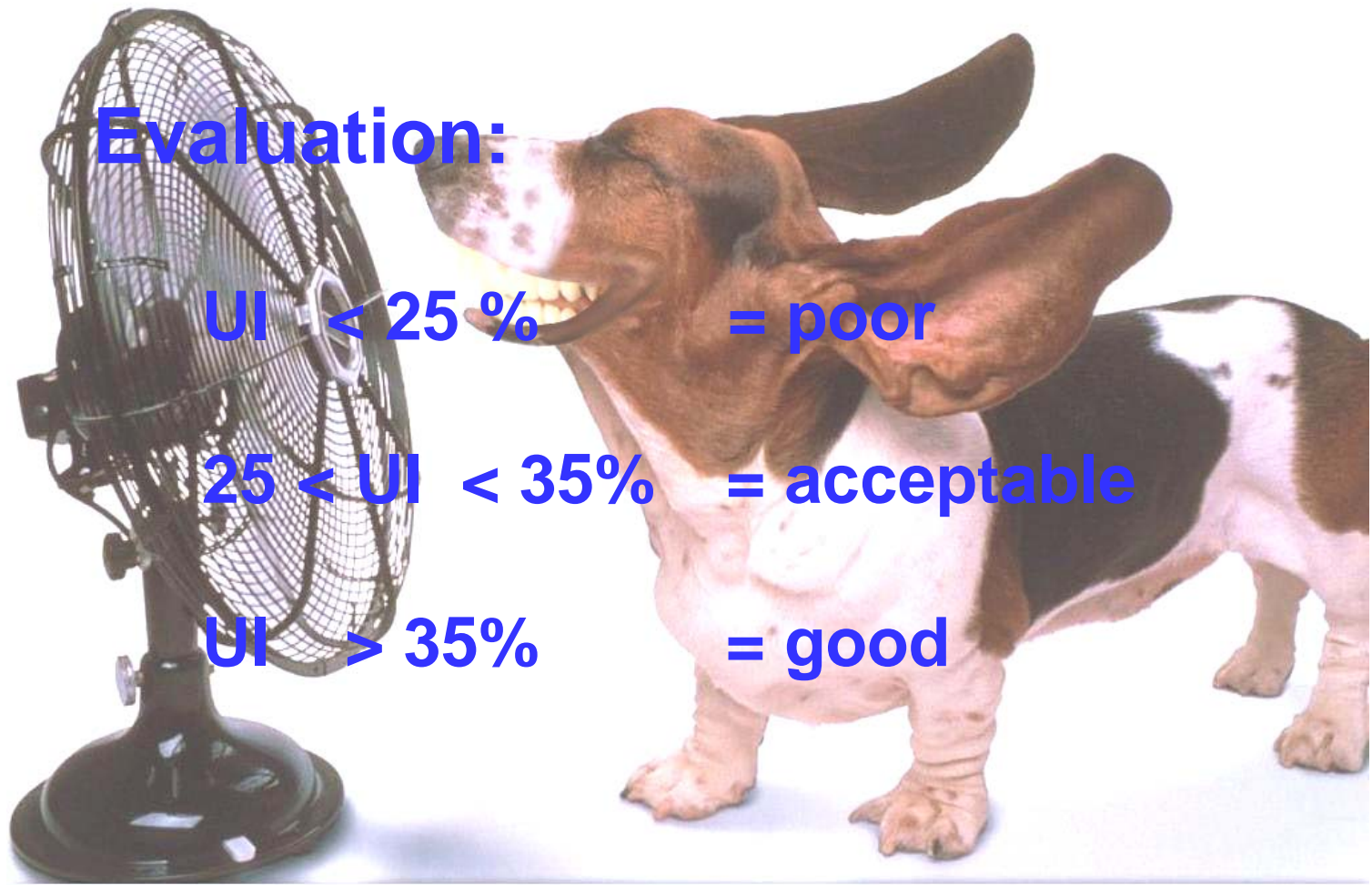
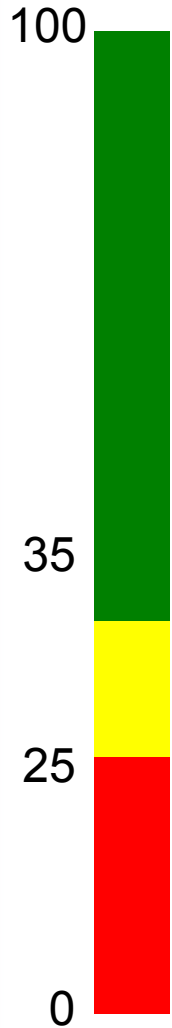
# IMPROVED KPI

Actually we have applied the following real equation:

$$UI = (CV_{hi} + CV_{lo} + CV_{sp} + MV_{hi} + MV_{lo}) / (MV_d - MV_{pr} - MV_{et}) * 100$$

CV <sub>hi</sub>	= CV on upper active constraint
CV <sub>lo</sub>	= CV on lower active constraint
CV <sub>sp</sub>	= CV with clamped setpoint
MV <sub>hi</sub>	= MV on upper active constraint
MV <sub>lo</sub>	= MV on lower active constraint
MV <sub>d</sub>	= total number of MV
MV <sub>pr</sub>	= total number of predicted MV
MV <sub>et</sub>	= number of MV with external target

# EVALUATION CRITERIA



Evaluation:

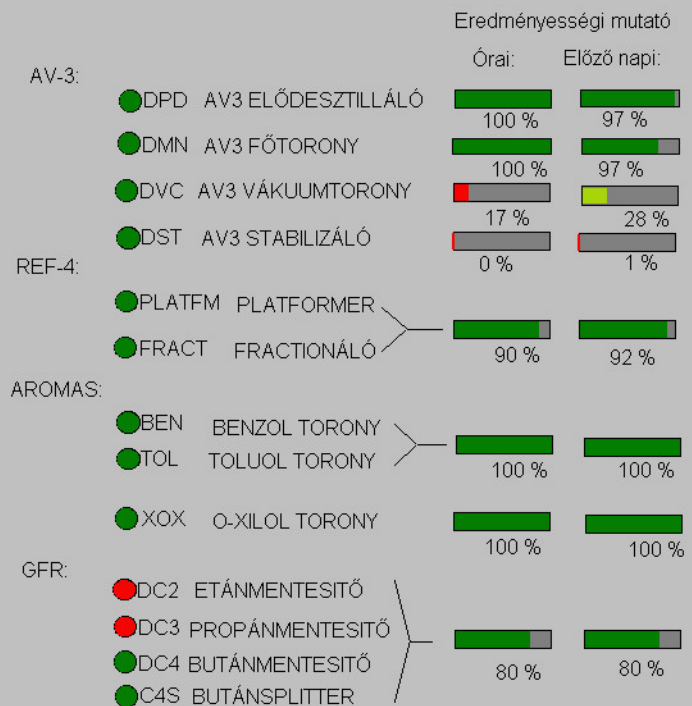
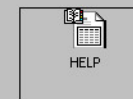
$UI < 25\%$  = poor

$25 < UI < 35\%$  = acceptable

$UI > 35\%$  = good

# AROMATIC AREA

## AROMÁS ÜZEMCSOPORT



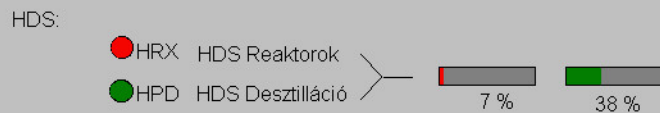
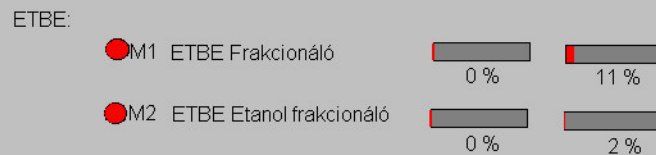
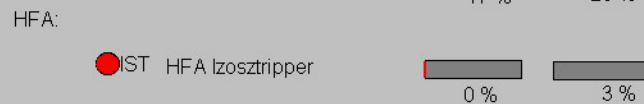
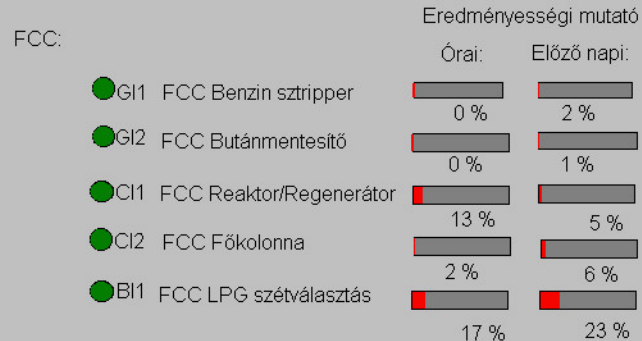
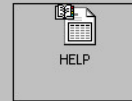
APC futás:	2008.02.28	2008.02.22 - 2.29.
	Tegnapi	Heti
AV3 ELŐDESZTILLÁLÓ	100,00	100,00 %
AV3 FŐTORONY	100,00	97,88 %
AV3 VÁKUUMTORONY	100,00	100,00 %
AV3 STABILIZÁLÓ	100,00	97,52 %
REF4 PLATFORMER	100,00	100,00 %
REF4 FRACTIONÁLÓ	100,00	100,00 %
BENZOL TORONY	100,00	91,87 %
TOLUOL TORONY	100,00	92,01 %
O-XILOL TORONY	99,93	98,65 %
ETÁNMENTESITŐ	0,00	0,00 %
PROPÁNMENTESITŐ	0,00	0,00 %
BUTÁNMENTESITŐ	100,00	100,00 %
BUTÁNSPLITTER	100,00	100,00 %

- APC bekapcsolva
- APC kikapcsolva

- > 35% Jó kihasználtság
- > 25% < 35% Megfelelő
- < 25% Gyenge kihasználtság

# MOTOR FUEL AREA

## MOTORHAJTÓANYAG ÜZEMCSOPORT



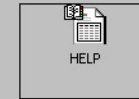
- APC bekapcsolva
- APC kikapcsolva

- > 35% Jó kihasználtság
- > 25% < 35% Megfelelő
- < 25% Gyenge kihasználtság

APC futás:	2008.02.11	2008.02.05 – 2.12.
	Tegnap	Heti
FCC Benzin sztripper	100,00	74,77 %
FCC Butánmentesítő	100,00	71,73 %
FCC Reaktor/Regenerát	100,00	64,80 %
FCC Főkolonna	100,00	66,76 %
FCC LPG szétválasztás	100,00	71,70 %
HFA Izosztripper	0,00	0,00 %
ETBE Frakcionáló	0,00	0,00 %
ETBE Etanol frakcionáló	0,00	0,00 %
HDS Reaktorok	0,00	0,00 %
HDS Desztilláció	100,00	85,64 %

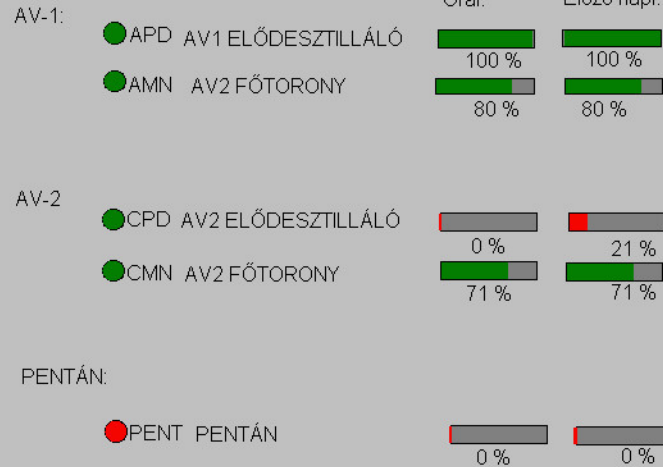
# BASE OIL AREA

## BÁZISOLAJ ÜZEMCSOPORT



Eredményességi mutató

Órai: Előző napi:



APC futás:	2008.02.11	2008.02.05 – 2.12.
	Tegnap	Heti
AV1 ELŐDESZTILLÁLÓ	100,00	99,95 %
AV1 FŐTORONY	100,00	99,99 %
AV2 ELŐDESZTILLÁLÓ	100,00	100,00 %
AV2 FŐTORONY	100,00	100,00 %
PENTÁN	0,00	0,00 %

- APC bekapcsolva
- APC kikapcsolva

- > 35% Jó kihasználtság
- > 25% < 35% Megfelelő
- < 25% Gyenge kihasználtság

# PROPAGATION of OUR METHOD

We proudly presented what we have done.

Reactions:



# APC EVALUATION

AROMATIC UNIT		1/101 BENZENE TOWER APC RATING		Extrapolated annual benefit		50 775 545 Ft
<b>Period</b>		2009.08.07 to 2009.09.07				
<b>Parameters</b>						
DMC Objective	Energy Cost Reduction					
DMC On/Off Switch	APCDAR1BEN.LSTDMCON					
Feed	DARBRFC001.PV					
Reflux	DARDRFC002.PV					
Heat price	Ft/kcal	0.014679				
Impurity on top(Toluene)	PPM	DAR2R101TTOP.PVA				
Impurity upper limit		DAR2R101TTOP.HI				
Average reflux ratio without APC		0.65				
Simulated S/S optimal reflux ratio		0.48				
$\Delta H$	kcal/m <sup>3</sup>	90500				
Specific heat	kcal/m <sup>3</sup> /°C	416				
Top temperature		DARDRT093.PV				
Reflux temperature		DAR1RT084.PVA				
Target Std. Deviation		0,5				
<b>DMC ONLINE TIME</b>		<b>80%</b>		<b>TOTAL SCORE</b>		<b>79%</b>
<b>Energy cost reduction</b>						
Theoretical cost reduction possibility	Target Profit*	Actual Profit	Score	Weighting	Weighted average	
6 910 650 Ft	5 528 520 Ft	3 773 452 Ft	68,3%	60	41%	
*target profit = 80 % of theoretical cost reduction						
<b>Steady product quality and operation</b>						
Valuable product	Target Std. Deviation	Actual Std. Deviation	Score	Weighting	Weighted average	
Impurity in benzene (PPM)	0,50	0,54	86,07%	10	9%	
<b>Technological bottleneck/operator mishandling</b>						
Profitable Manipulated Variable on Constraints	Target Constraints	Actual Constraints	Score	Weighting	Weighted average	
Benzene product on HI LIMIT	0%	0,0%	100,00%	15	15%	
Reboiler steam on LO LIMIT	0%	0,4%	99,15%	15	15%	

- ❖ Multicomponent distillation - energy savings
- ❖ Crude distillation - correspond to PIMS optimization
- ❖ Maximize feed or valuable product
- ❖ Stabilize quality of product ( no giveaway )

# DETAILED REVIEW

## AROMATIC UNIT

### Period

2009.08.07 to 2009.09.07

### Parameters

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DMC ONLINE TIME **80%**

## 1/101 BENZENE TOWER APC RATING

Extrapolated annual benefit **50 775 545 Ft**

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TOTAL SCORE **79%**

# DETAILED REVIEW

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DMC ONLINE TIME

**80%**

TOTAL SCORE

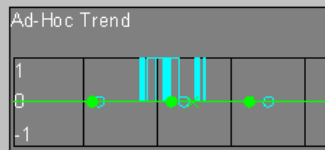
**79%**

# MV-S ON LIMIT

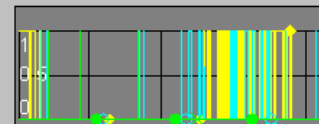
## AROMATIC UNIT MV-s (Manipulated Variables) ON LIMIT

### BENZENE MV-s

Benzene product 0,02%  
Steam 9,56%



### XK1 MV-s



K1 reflux 0,93%

K1 heating 5,58%

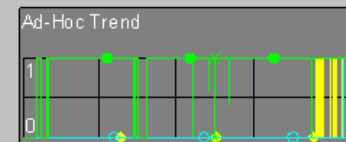
Naftene 19,43%

### TOLUENE MV-s

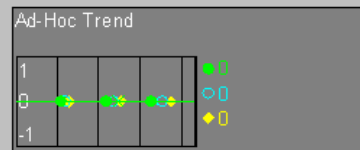
Toluene product 0,06%  
2/101 fuel gas 1,66%



### XK2 MV-s



### XOX MV-s



K2A reflux 89,33%

K2B bottom product 0,03%

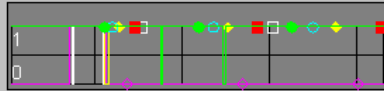
K2B bottom product 2,10%

Ortoxylylene product 0,00%  
Aromatol product 0,00%  
3/104 fuel gas 2,22%

# MV-S ON LIMIT

## FCC UNIT MV-s (Manipulated Variables) ON LIMIT

### Rx-Rg MV-s



Reaktor hőfok  
99,35%

Aag. előmelegítés  
99,35%

PRS levegő  
9,87%

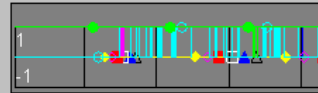
MCB riserbe  
99,35%

400 V5 nyomás  
98,28%

Alapanyag  
98,07%

410 V3 nyomás  
99,19%

### Main column MV-s



400 V1 fej hőfok  
99,85%

Mosóolaj 510 V5-be  
27,69%

LCO kitárolás  
0,00%

Nafta 400 E1-re  
0,00%

MCB cirk. 400 E5A-ra  
18,49%

400 V1 quench  
0,00%

MCB cirk. 400 E5B-re  
0,00%

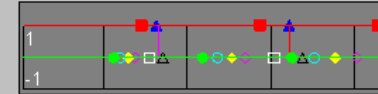
410 V6 mosófolyadék  
0,04%

MCB cirk. 400 E4-re  
17,68%

Benzin 410 V5-be  
0,03%

MCB cirk. 400 E11-re  
0,00%

### C3 splitter MV-s



430 V1 reflux  
0,03%

430 V1 37.t. hőfok  
0,00%

430 E6 nafta  
0,00%

430 V1 nyomás  
0,06%

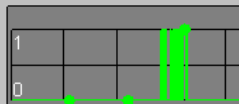
430 E8A propilén  
99,99%

430 V6 betáp  
0,00%

430 E8B propilén  
99,99%

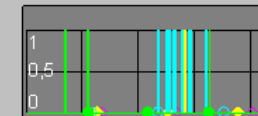
430 V9 nyomás  
0,00%

### Benzine stripper MV



410 V7 lefűjt gáz  
5,84%

### Debutaniser MV-s



410 V8 nyomás  
0,89%

410 V8 32. t. hőfok  
0,51%

Nafta 410 e15-re  
0,50%

410 V8 reflux  
1,33%

Kikapcsolt szabályzó

# DETAILED REVIEW

## AROMATIC UNIT

### 1/101 BENZENE TOWER APC RATING

Extrapolated annual benefit **50 775 545 Ft**

#### Period

2009.08.07 to 2009.09.07

#### Parameters

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$\Delta H$ kcal/m <sup>3</sup>	90500
Specific heat kcal/m <sup>3</sup> /°C	416
Top temperature	DARDRT093.PV
Reflux temperature	DAR1RT084.PVA
Target Std. Deviation	0,5

#### Energy cost reduction

Theoretical cost reduction possibility	Target Profit*	Actual Profit	Score	Weighting	Weighted average
6 910 650 Ft	5 528 520 Ft	<b>3 773 452 Ft</b>	68,3%	60	41%

\*target profit = 80 % of theoretical cost reduction

#### Steady product quality and operation

Valuable product	Target Std. Deviation	Actual Std. Deviation	Score	Weighting	Weighted average
<b>Impurity in benzene (PPM)</b>	<b>0,50</b>	<b>0,54</b>	<b>86,07%</b>	<b>10</b>	<b>9%</b>

#### Technological bottleneck/operator mishandling

Profitable Manipulated Variable on Constraints	Target Constraints	Actual Constraints	Score	Weighting	Weighted average
Benzene product on HI LIMIT	0%	0,0%	100,00%	15	15%
Reboiler steam on LO LIMIT	0%	0,4%	99,15%	15	15%

DMC ONLINE TIME **80%**

TOTAL SCORE **79%**

# CALCULATIONS

Basic reflux ratio without APC (Rat)= 0,65

Heat loss ( $\Delta H$ ): 90500 Kcal/<sup>3</sup>m

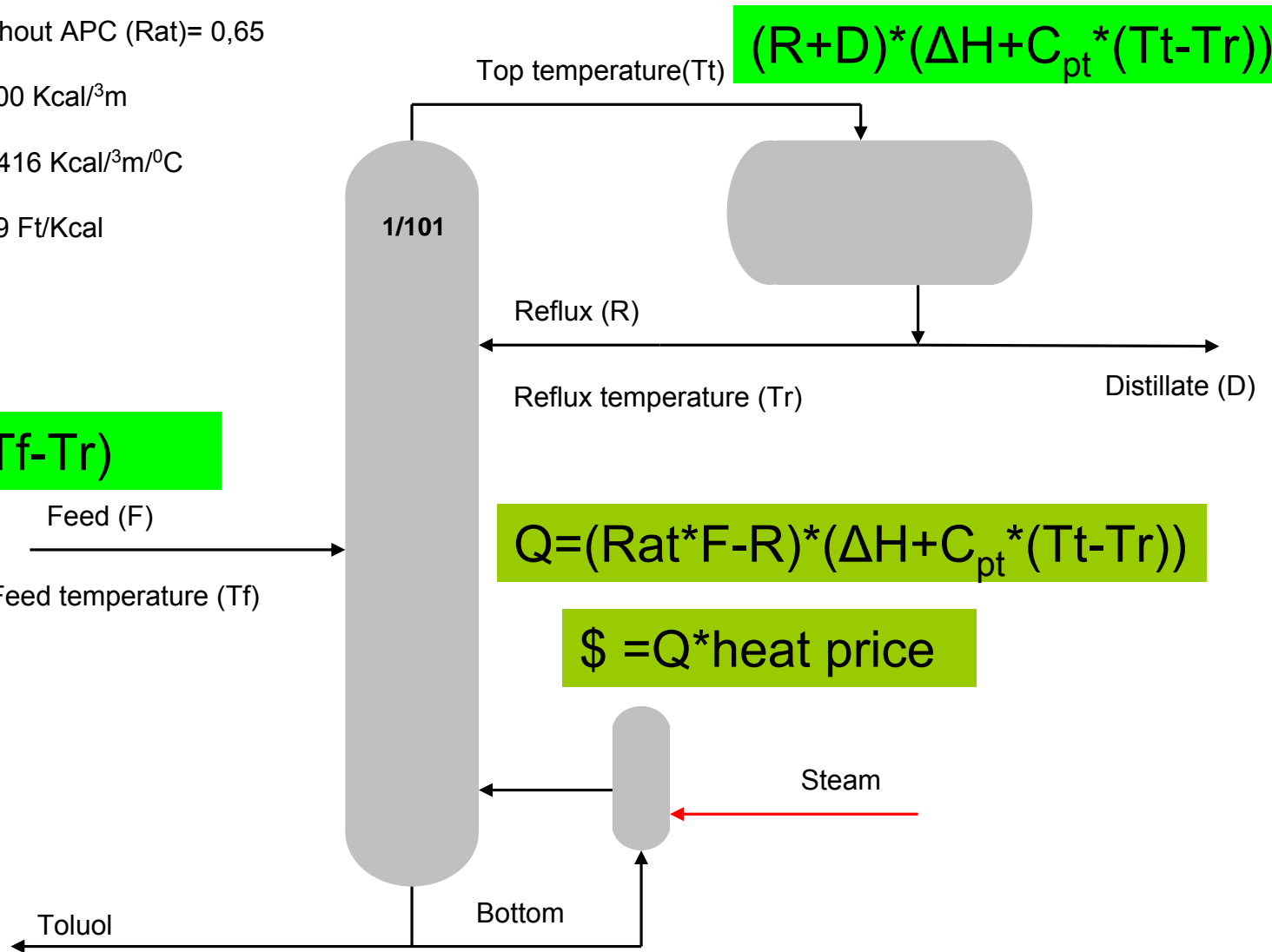
Specific heat (C<sub>pt</sub>): 416 Kcal/<sup>3</sup>m/<sup>0</sup>C

Heat price: 0.014679 Ft/Kcal

$$F \cdot C_{pf} \cdot (T_f - T_r)$$

Feed (F)  
Feed temperature (T<sub>f</sub>)

$$(F - D) \cdot C_{pb} \cdot (T_b - T_r)$$



$$(R + D) \cdot (\Delta H + C_{pt} \cdot (T_t - T_r))$$

$$Q = (Rat \cdot F - R) \cdot (\Delta H + C_{pt} \cdot (T_t - T_r))$$

$$\text{\$} = Q \cdot \text{heat price}$$

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TOTAL SCORE **79%**

# BENEFIT-COST RATIO

Period

2008.01.01      2009.01.01

## ROUGH ESTIMATION OF ANNUAL ENERGY COST AND SAVING

Average reflux	Benzene product		Annual energy cost	Saving ratio
	DAR2RF029.PV			
m3/h	kg/h	m3/h	480 571 800 Ft	13,9%
18,6	15570,7	17,7		

2008 Average reflux without APC	2008 Average feed without APC	Ratio	Number of days without APC
m3/h	m3/h	0,7	78
21,3	31,5		

# GLOBAL OPTIMUM

## CRUDE UNITS:

Cut point targets given by PIMS global optimum

Sensitivity of the PIMS model show us how the profit is decreasing with every one °C cut point difference.

There is a swing between heavy naphta stream and kero stream. This stream is about 15 °C wide range and the yield of swing is 1,5%. According to this, 1 °C difference causes 0,1 % change in yields.

If we calculate with amount of annual REB crude oil (5,8 million tons in 2010 at MOL side), we will get 5800 t difference per year. In these days there is 20 USD price difference between import naphta and import 0,2 gasoil, which means 1°C difference can cause 116 000 USD losses in every year.      ~ 22 mill Ft / 1°C

If we suppose 1°C difference means 5800t/year change between gasoil and vacuum gasoil as well, the loss can be even 500 000 \$/year, because the price difference is higher there (it can be 100-150 USD/t).      ~ 30 mill Ft / 1°C

# BENEFIT OF ACCURATE CUTTING

( Specified cutting point - cutting point controlled by operator ) = 6.5 C°

M(Inf) - Mean value of inferential calculation

$\sigma_{INF}$  - Standard deviation of ( Lab measurement - Inferential calculation )

$\sigma_{ASTM}$  - Standard deviation of ASTM measurement

SpecT - Specified cutting point

Profit - Benefit mill Ft / 1°C

$$(6,5 - (SpecT - M(inf))) * Profit * Corr$$

$$Corr = \begin{cases} 1, & \text{if } \left( \frac{1,5 * \sigma_{ASTM}}{\sigma_{INF}} \right)^2 > 1 \\ \left( \frac{1,5 * \sigma_{ASTM}}{\sigma_{INF}} \right)^2, & \text{if } \left( \frac{1,5 * \sigma_{ASTM}}{\sigma_{INF}} \right)^2 < 1 \end{cases}$$

THANK YOU FOR YOUR KIND ATTENTION!

*APC*

*OTS*

*DCS*

