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A Yokogawa Company

Using Simulation as a Tool for Coker Troubleshooting – the KBC Approach

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KBC India

SUPERIOR RESULTS. **SUSTAINED.**

Agenda

- KBC Introduction
- Coker Case Studies
- KBC Software Portfolio
- Petro-SIM™ and Rx-SIM
- DC-SIM™ and Drum Modelling

KBC Advanced Technologies

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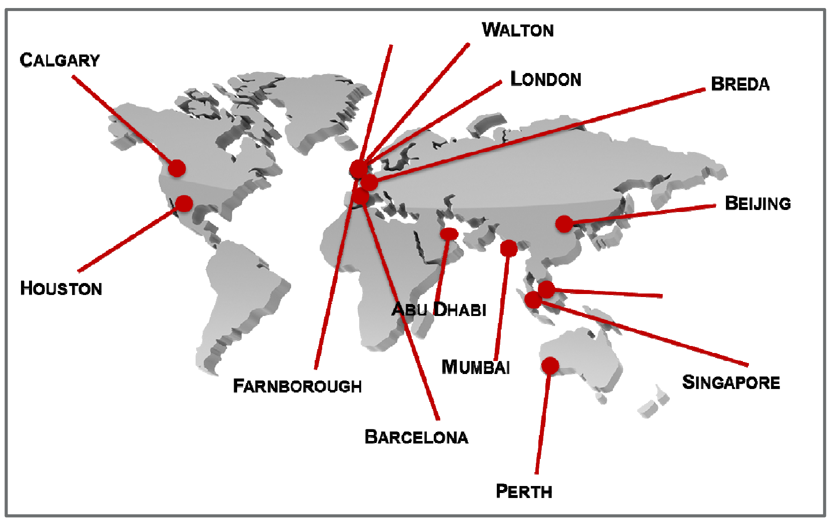
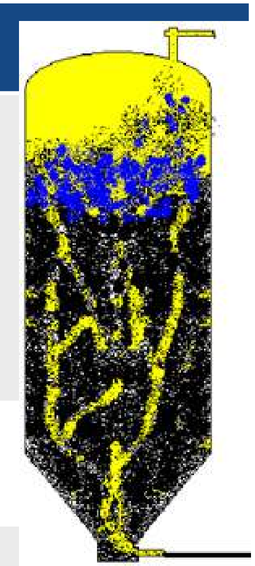
- KBC is now a Yokogawa company
- KBC is a UK based leading independent consulting and technology group established in 1979
- We deliver competitive advantage in the Oil and Gas industry through business performance improvements/asset value recognition, strategic solutions and **Petro-SIM** software



Case Study 1: Drum Pressure Optimisation

Client Situation Indian Refinery Coker heavy distillate was high in CCR limiting refinery capacity..

Project Implementation Approach



- Unit operating at +125% of design feed
- High CCR in HCGO > 1.5 wt%
- Downstream Hydrocracker constrained by feed filtration cycles
- Internal drop of HCGO increased unit CFR, dropped unit feed rate and ultimately reduced Crude throughput to refinery

Key Findings from Simulation Model

$$C_S = u_S \sqrt{\frac{\rho_V}{\rho_L - \rho_V}}$$

- High Vapor Velocities in drum
- High ‘C’ factor of drum. ‘C’ factor is a ratio of Vapor and liquid densities and Vapor Velocities
- Vapor and Liquid densities depend on Unit operating capacities, Drum temperature, Pressure
- ‘C’ factor is also feed quality dependent, foamover tendency and cycle time
- Typically drum vapor velocities should be limited to **0.5 ft**/s and ‘C’ factor should be limited to **0.3 ft/s**
- Tendencies to push that ‘last bottom of the barrel’ in Cokers lead to new operating challenges

KBC Kinetic model of Coker drum helps in identifying these new constraints

Case Study 1: Drum Pressure Optimisation

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Client Situation	Indian Refinery Coker heavy distillate was high in CCR limiting refinery capacity

Use of Model for Recommendations

- Calibrated base case model was used to run over 2 dozen Predict cases were compared by varying independent variables such as Drum Pressure, Heater COT (Every Coker is limited here!), unit capacity, recycle ratio…
- Optimum Drum pressure was selected such that it limits loss of yield (high coke make) and reduction of GRM within agreed envelope
- Drum pressure was increased by 30% by changing WGC suction pressure. This saw HCGO CCR reduction by 80% and helped to stabilise HCR bed DP. There was a debit in terms of increased Coke make
- Refinery crude processing rate was normalised *(Revenue!!)*
- Subsequently Fractionator internals were modified (Changeover to Packing from Shed deck trays) as advised by KBC. At higher throuputs packings help to reduce entrainment with optimum ‘wash and wetting rates’

Results	Improved refinery reliability and accrued refinery revenue by 20-25 million USD over 6 months

Case Study 2: Velocity Steam and Heater Optimisation

Client Situation Client had high tube fouling rate on a newly commissioned Coker heater

Project Implementation Approach

- Skin temperatures rise per day was double at 4ºF
- High Fouling rates reduced run length between decoking from 6 to 3 months
- Refining constrained on crude capacity

Key Findings from Simulation Model

- Velocity steam rate is feed quality, heater tube length, radiation box design, injection point and heater *'ΔP'* dependent
- Feed Asphaltenes (SARA) along with KBC proprietary *'Colloid Instability Index' factor* (part of Heater model) was used for tuning
- Velocity steam optimisation reduces 'Peak Oil Temperatures' in outlet preceding coils. But very high rates can imply Foam over & Fractionator overhead cooling limitations
- Client implemented KBC recommendations of Velocity steam variation and temperature measurement source

Results Increase in Heater run length and reduction in Skin Temperature rise by 2ºF

Case Study 2: Velocity Steam and Heater Optimisation

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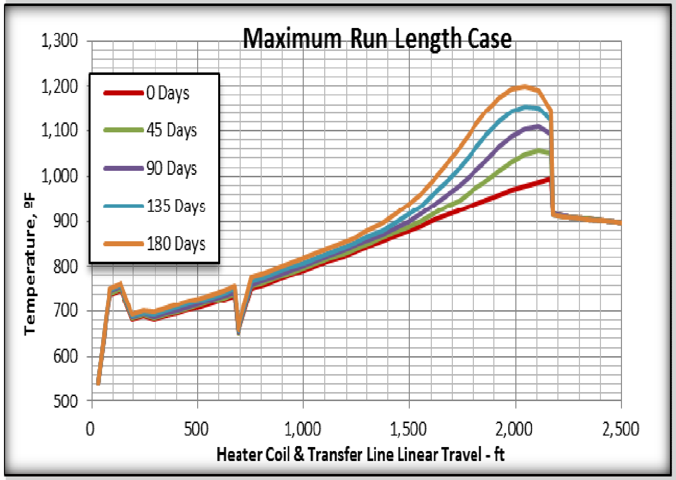
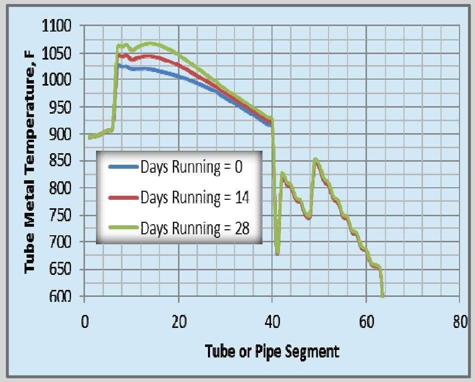
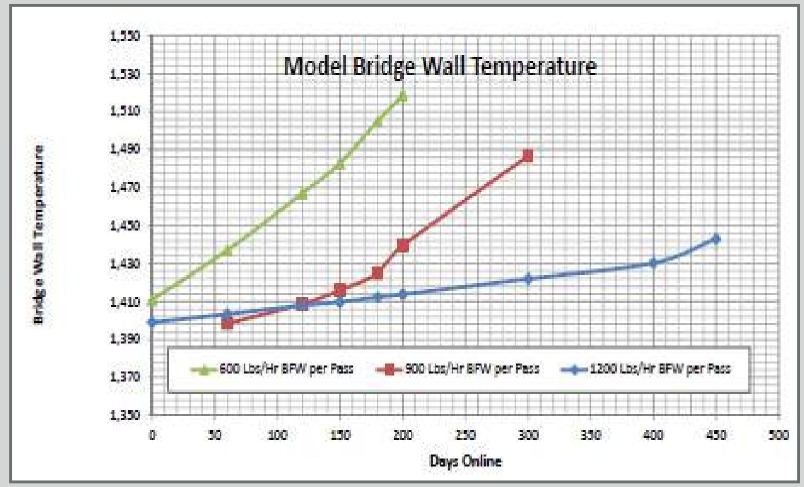
Client Situation	Client had high tube fouling rate on a newly commissioned heater







Simulation Aid

- Such and similar conclusions (graphs) are easy to plot and review using Coker heater simulation model.
- Heater model Calibration and tuning is based on operating and engineering data
- Variation of operating conditions in predict mode defines process optimisation

Case Study 3: Reducing Coker Recycle

DC-SIM ability to predict Quality and quantity of 'Column Recycle stream'

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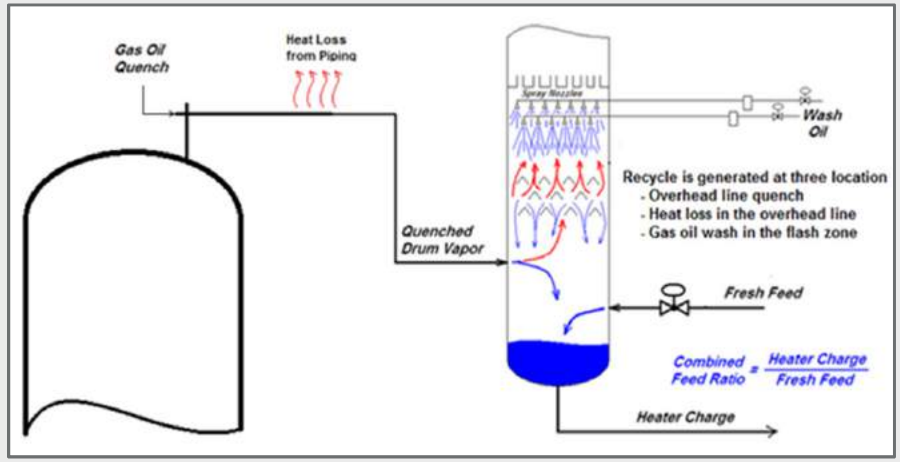
Client Situation A Middle East Refiner Coker heavy distillate had high overlap with recycle stream

Project Implementation Approach

- Overhead 'Quench', Heat loss in overhead line and tower Wash zone design all contribute to recycle
- Processing heavy Refinery Slops in fractionator also contributes to higher recycle
- Excessive drop in temp of drum vapor adds by quenching adds to additional recycle.
- Overhead quench liquid contributes to 30% of Recycle with rest coming from Wash Zone of fractionator
- Processing heavy Blowdown liquid in fractionator flash zone also adds to higher recycle
- Flash zone Packing v/s sieve and/or Shed deck influence Recycle



- Having large number of Trays in flash zone wash section requires additional wash too keep trays wet and avoid coking. This contributes to Recycle

All scenarios can be Simulated coupled with Kinetic Model

Case Study 3: Reducing Coker Recycle

DC-SIM ability to predict Quality and quantity of 'Column Recycle stream'

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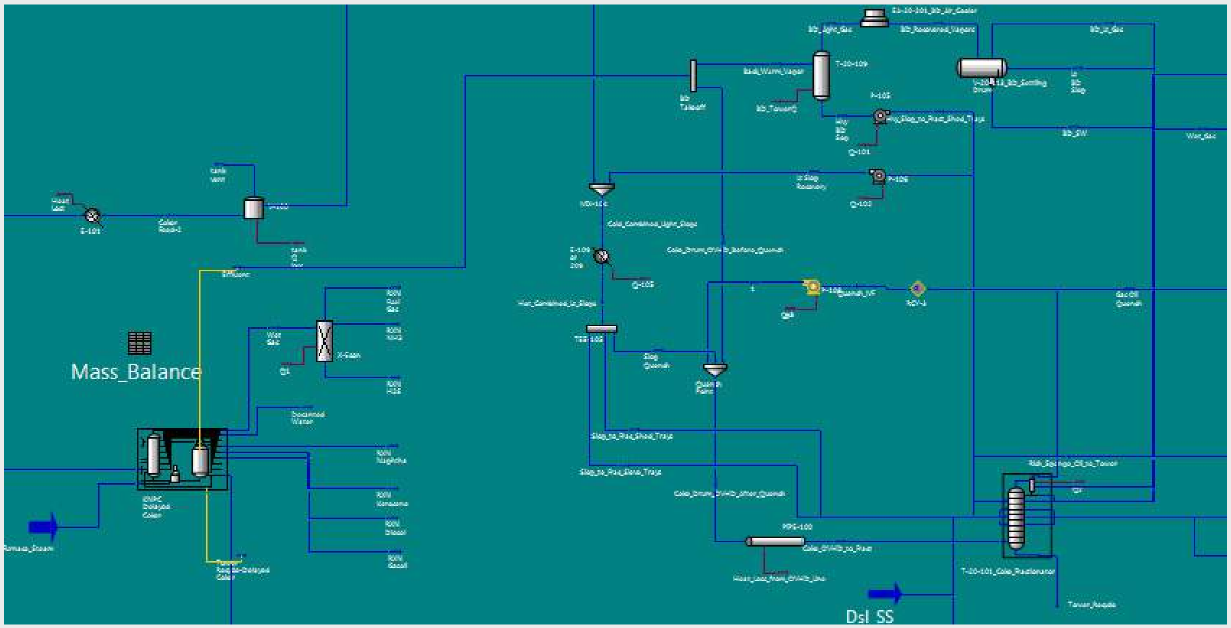
Client Situation | A Middle East Refiner Coker heavy distillate has high overlap with recycle stream

Key Findings and Recommendations



- DC-SIM reactor model and Petro-SIM flowsheeting techniques were used to model
  - Blowdown system,
  - Overhead vapor pipe segment
  - Quench stream
- Petro-SIM fractionator bottoms recycle stream quality can be easily compared with Kinetic model generated recycle stream quality gives confidence of a good base case

Results | Setting up Base model is key to success of simulation application to actual operations

Case Study 3: Reducing Coker Recycle

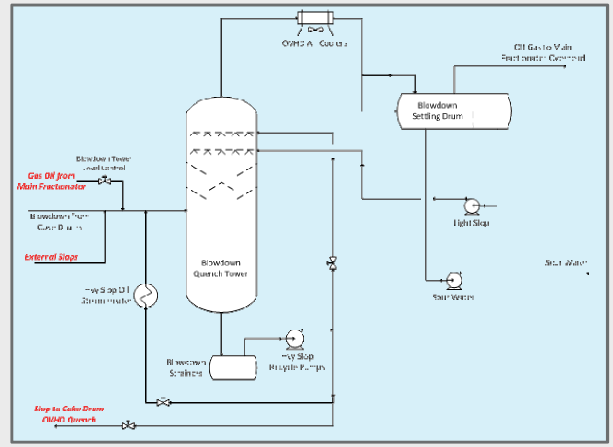
DC-SIM ability to predict Quality and quantity of 'Column Recycle stream'

A Yokogawa Company

Client Situation A Middle East Refiner Coker heavy distillate has high overlap with recycle stream

Key Findings and Recommendations

- Simulating flash zone conditions using combination of Drum vapor stream + Quench helped in minimising 'Wash' to trays. However it can runs into risk of Trays or packing coke up, use Tray designer guidelines to optimise
- Delta changes in Drum Vapor properties (post quench) and recycle stream properties as output from simulation help in correctly representing Flash zone.
- Drum overhead line model, MF flash zone section model, PA adjustments for improved Vapor – Liquid traffic, all helped to optimise & reduce CFR with reduction in overlap
- KBC suggested
  - Slops diversion to Blowdown tower rather than Fractionator
  - Flash zone modification with part open spray chamber & reduction in number of shed deck trays



Recycle Reduction	**2-3%**
Delta Coke Reduction	**0.8%**

Results Expected refinery wide benefit was 5.0 m$/y. Client will be implementing it as a part of Revamp

KBC Software Portfolio

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Petro-SIM™
- Steady-state and dynamic process simulator for unit operations

SIM Reactor Suite™
- Reactor Kinetic modelling in refining and petrochemicals

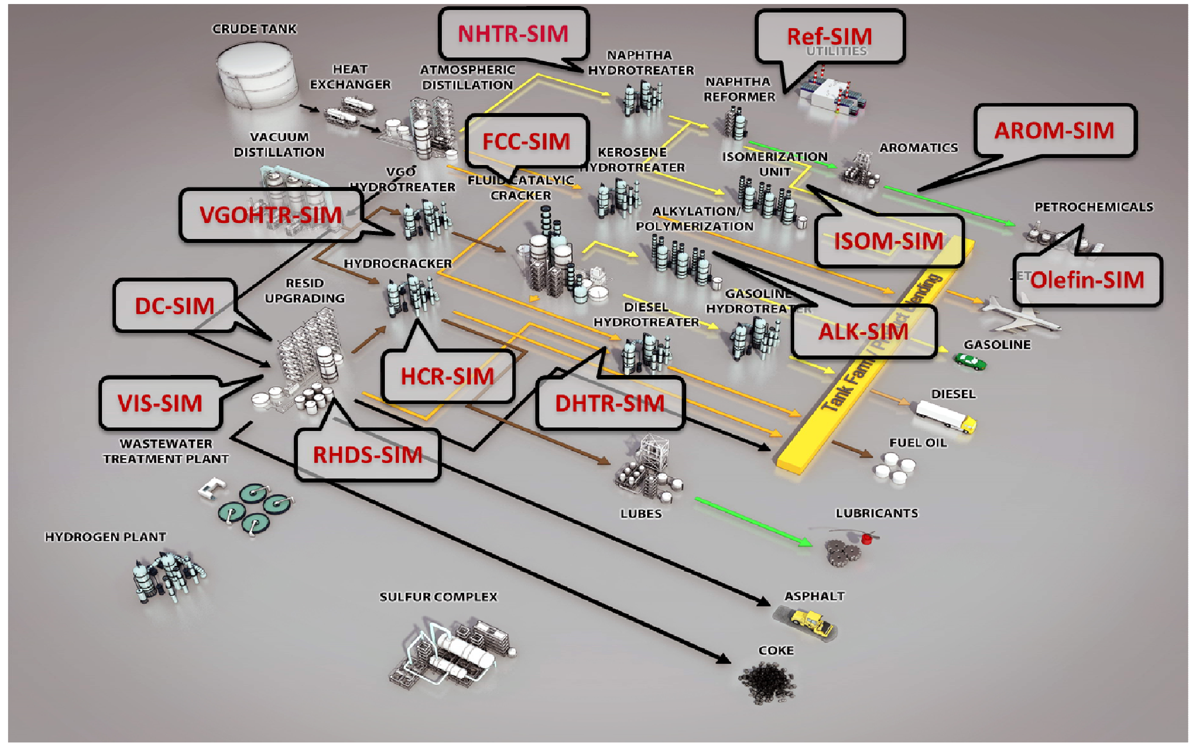
Energy-SIM™
- For Utility system modelling

Multiflash™
- Comprehensive Phase behavior, PVT and flow assurance package

Maximus™
- Thermal and hydraulic network simulator for Oil & Gas fields

KBC Petro-SIM and Rx-SIM

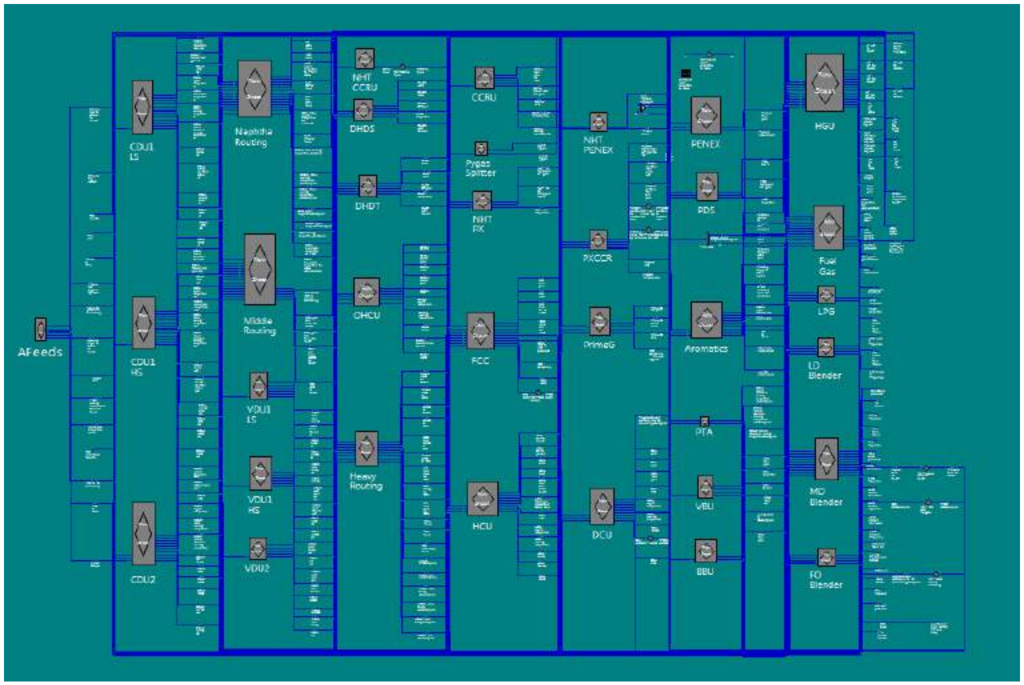
- Full function process simulation platform backed by KBC consulting experience
- Refinery wide flowsheet modelling
- Integrated with other technologies, historians, databases
- Leader in reactor kinetics modelling
- Backbone for profit improvement studies, LP vectors generation



Regular version updates with improved reactor kinetics and features using client feedback

V.7.0 release next year

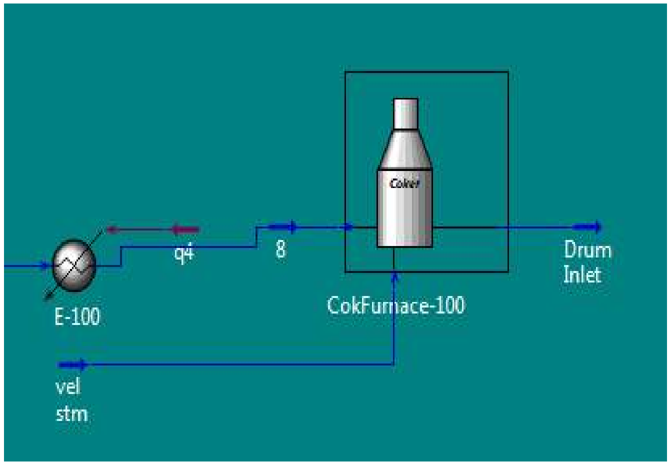
KBC Petro-SIM and Rx-SIM



Sample Economics Summary	Basis	Price		Base case Rev 7	4. DCU	Delta	K$/day	Base case Rev 7 (4)	1.1 Deep cut (5)	2.1 Increase Reformate RON (6)	2.3 Optimize Severity in PX-CCR (7)	2.4 Reduce NSU2 Heavy Naphtha IBP (8)
Margin ($m/yr)				727.9	782.9	54.99						
Gross Margin ($/bbl)				6.50	6.99	0.49	158					
				4	13			4	5	6	7	8
Feeds												
Crude	MT	848	tonne/h	1868.7	1868.7	0.0	0	1868.7	1868.7	1868.7	1868.7	1868.7
PFO ex PNC	MT	783	tonne/h	11.7	11.7	0.0	0	11.7	11.7	11.7	11.7	11.7
Oxygen	MT		tonne/h	180.3	180.8	-0.5	0	180.3	180.3	179.3	185.5	182.9
PX FEED NAPHTHA FROM MR	MT	879	tonne/h	20.0	20.0	0.0	0	20.0	20.0	20.0	20.0	20.0
PNCP Pygas C7-C8	KL29	821	m3/h	23.7	23.7	0.0	0	23.7	23.7	23.7	23.7	23.7
PNCP Heavy aromatics C9+	KL29	821	m3/h	6.0	6.0	0.0	0	6.0	6.0	6.0	6.0	6.0
PNCP C4	KL29	1030	tonne/h	21.8	21.8	0.0	0	21.8	21.8	21.8	21.8	21.8
Total Cost of Feedstocks			US$MM/Day	39.8	39.8							
Products												
Light Ends												
HYDROGEN to PNCP	MT	3506	tonne/h	0.1	0.1	0.0	0	0.1	0.1	0.1	0.1	0.1
PROPYLENE	MT	1258	tonne/h	9.1	9.0	-0.1	-2	9.1	9.0	9.0	9.2	9.1
LPG	MT	1030	tonne/h	82.0	82.0	-0.1	-1	82.0	82.1	85.3	81.3	82.0
Light Distillates												
PNCP Naphtha	MT	876	tonne/h	143.8	142.1	-1.6	-35	143.8	146.4	140.1	150.7	146.7
MS, EURO-III	KL29	821	m3/h	222.0	222.0	0.0	0	222.0	222.0	221.5	214.7	216.8
MS E - IV	KL29	833	m3/h	33.0	32.9	0.0	-1	33.0	32.9	32.7	32.8	32.9
Middle Distillates												
ATF	KL29	833	m3/h	183.1	183.1	0.0	0	183.1	183.1	183.0	183.1	183.1
SKO	KL29	851	m3/h	115.0	118.2	3.3	67	115.0	115.2	115.0	115.0	115.0
MTO	KL29	926	m3/h	0.7	0.7	0.0	0	0.7	0.7	0.7	0.7	0.7
HSD, EURO-III	KL29	856	m3/h	775.6	778.8	3.2	66	775.6	773.8	775.5	775.5	775.5
HSD, EURO-IV	KL29	857	m3/h	248.1	248.2	0.0	1	248.1	248.2	248.1	248.1	248.1
Heavies												
HPS	MT	783	tonne/h	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0
Fuel oil product	MT	693	tonne/h	17.5	17.5	0.0	0	17.5	17.1	17.5	17.5	17.5
BITUMEN (TOTAL)	MT	529	tonne/h	59.8	59.8	0.0	0	59.8	59.8	59.8	59.8	59.8
Coke	MT	107	tonne/h	108.3	117.2	8.9	23	108.3	107.3	108.3	108.3	108.3
SULPHUR (TOTAL)	MT	132	tonne/h	30.2	30.7	0.4	1	30.2	30.3	30.2	30.2	30.2
PetChem												
BENZENE	MT	1141	tonne/h	2.5	2.5	0.0	0	2.5	2.5	2.6	2.3	2.9
PARAXYLENE	MT	1489	tonne/h	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0
PTA	MT	1134	tonne/h	58.2	58.3	0.2	4	58.2	58.2	57.8	59.9	59.0
Fuel / Intermediate												
Fuel Gas	MT	710 711	tonne/h	44.7	45.7	1.0	17	44.7	44.6	46.1	43.0	44.6
IFO	MT	589 589	tonne/h	44.3	45.5	1.2	17	44.3	44.1	44.3	44.3	44.3
FCC Coke	MT		tonne/h	4.9	4.9	0.0	0	4.9	4.9	4.9	5.0	4.9
Total Value of Products			US$MM/Day	41.9	42.0							

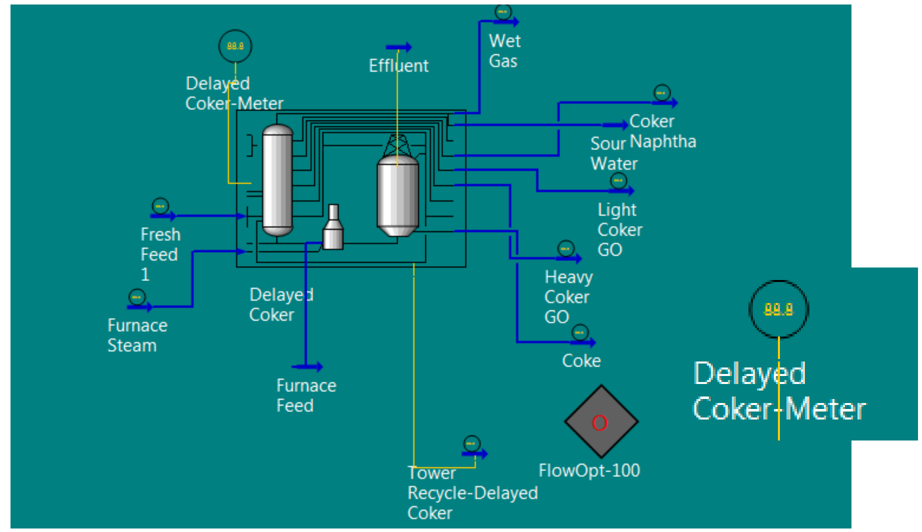
Refinery units integration into flowsheet and transition into workbook makes it a powerful case comparison tool

DC-SIM and Coker Heater Set-up



Heater Model

- Rigorous tube by tube calculations
- Can be calibrated to match Coker reactor heater effluent stream
- Tuning by Heat flux, tube dimensions, skin T, metallurgy….



Tube Heat Balance Closure
- Calculate equal fluxes in all tubes
- Specify tube by tube heat flux: Fixed Values
- Specify tube by tube heat flux: Flux Profile (selected)
- Specify tube by tube heat fractions

☑ Inlet Tube T initialisation only

Update Flux

Check All

	Temperatures [C]	Pressures [inHg(60F)_g]	Heat Fluxes [Btu/hr-ft2]	Adjust?	K1-Values
1	482.2	81.68	-350.0	☐	1.330
2	<empty>	<empty>	-350.0	☐	1.330
3	<empty>	<empty>	-350.0	☐	1.330
4	<empty>	<empty>	-350.0	☐	1.330
5	<empty>	<empty>	-350.0	☐	1.330
6	<empty>	<empty>	-350.0	☐	1.330
7	<empty>	<empty>	-350.0	☐	1.330
8	493.3	<empty>	1.197e+004	☑	1.330
9	<empty>	<empty>	1.196e+004	☑	1.330
10	<empty>	<empty>	1.196e+004	☑	1.330
11	<empty>	<empty>	1.198e+004	☑	1.330
12	<empty>	<empty>	1.199e+004	☑	1.330
13	<empty>	<empty>	1.202e+004	☑	1.330
14	<empty>	<empty>	1.207e+004	☑	1.330
15	<empty>	<empty>	1.211e+004	☑	1.330
16	<empty>	<empty>	1.217e+004	☑	1.330
17	<empty>	<empty>	1.225e+004	☑	1.330
18	<empty>	<empty>	1.234e+004	☑	1.330
19	<empty>	<empty>	1.239e+004	☑	1.330
20	<empty>	<empty>	1.255e+004	☑	1.330
21	<empty>	<empty>	1.267e+004	☑	1.330
22	<empty>	<empty>	1.279e+004	☑	1.330
23	<empty>	<empty>	1.290e+004	☑	1.330
24	<empty>	<empty>	1.305e+004	☑	1.330

- Drum model has in-built rigorous fractionator Bottom ckt that helps to predict correct quality and quantity of CFR
- Although steady state, but works on snapshots at time intervals of drum cycle
- ‘Foam-over’ tendency, ‘Drum C-factor’, ‘Vapour Velocity’, ‘Coke Outage level’ assessment are some critical parameters that can be correctly predicted

DC-SIM Data Input, Calibration and Results

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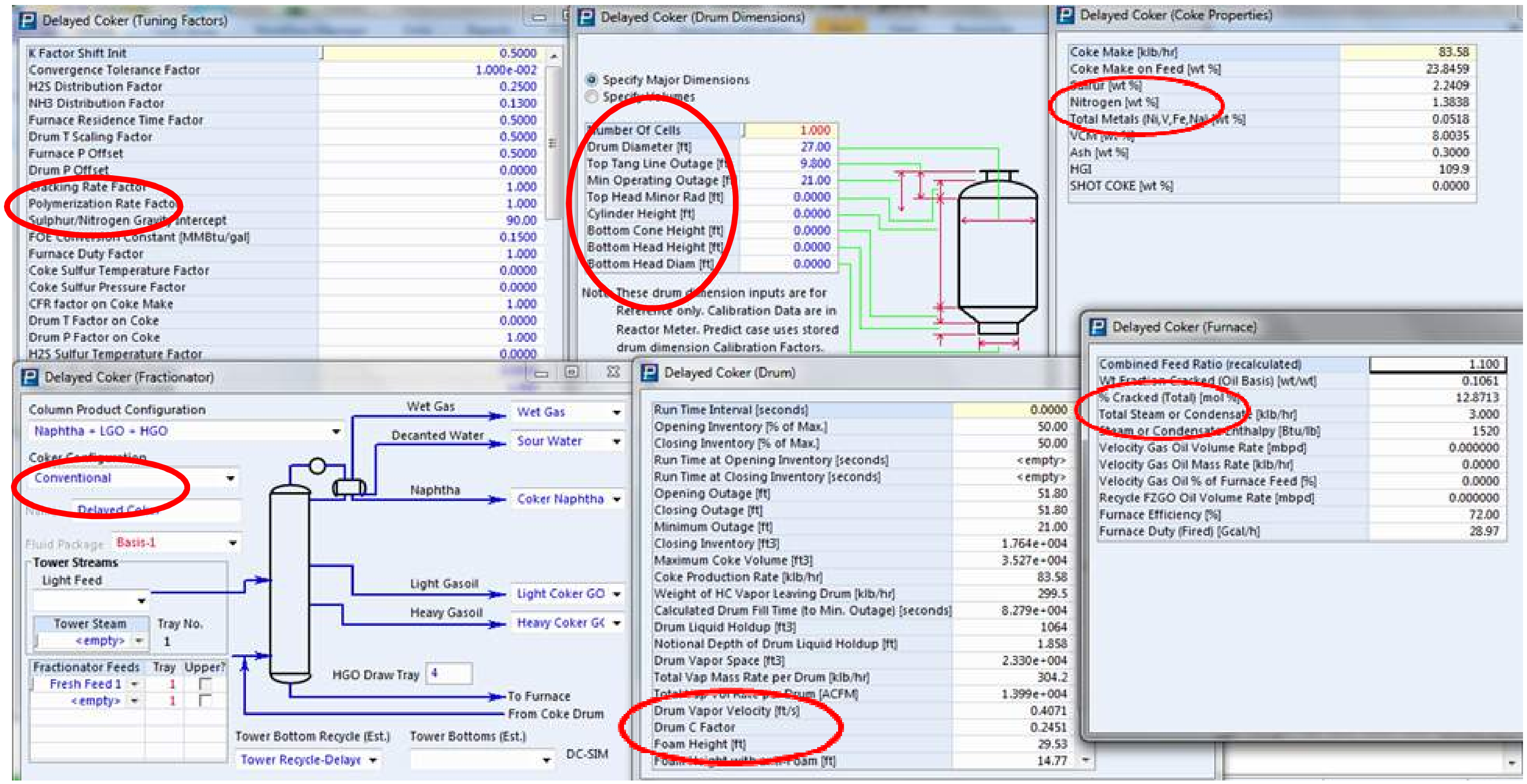
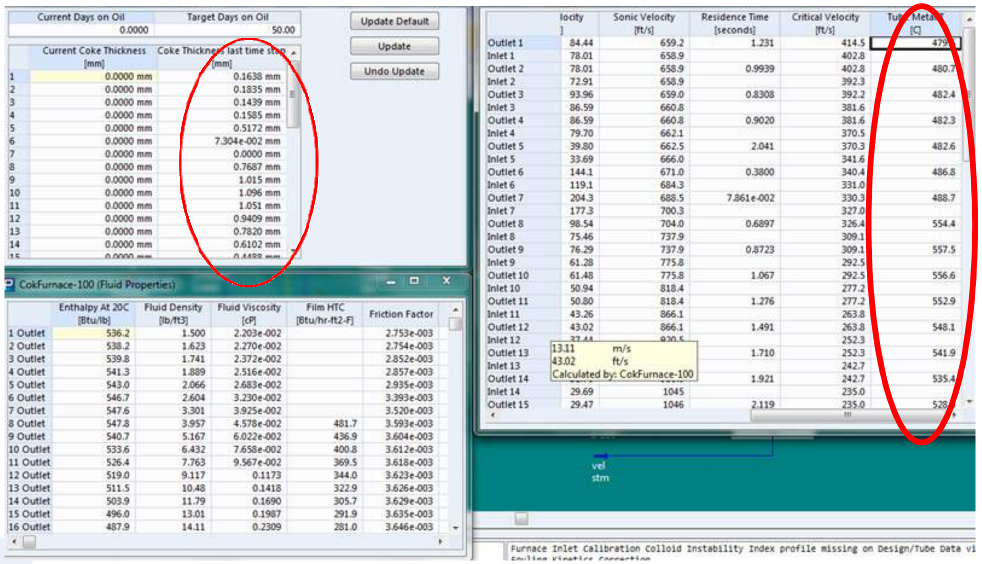
- 'Once through' and conventional designs can be modelled
- Predicts % cracking at end of heater transfer line
- Flexibility to model 'extra low recycle' operation
- Feed and impurities distributed within 50F pseudo components
- Model estimates coke 'S' & 'N' from balance. Coke quantity from feed CCR
- 1ST Order reaction kinetic rates separately for cracking and coking using 'Arhenius equation'

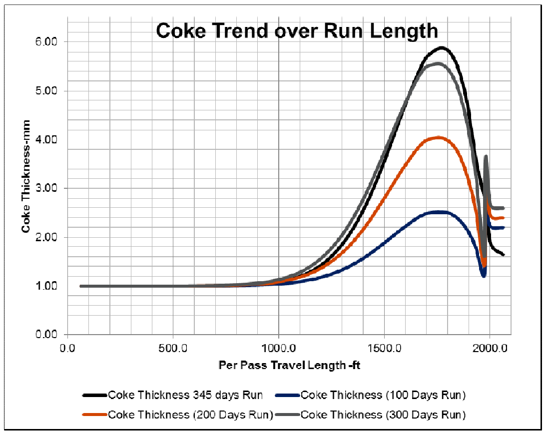


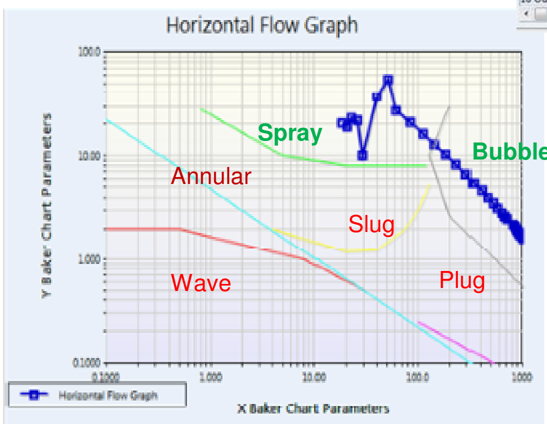
- Drum Liquid hold-up results provides insight into vapour/liquid equilibrium over the coke surface that ultimately helps to predict correct VCM & HGI properties of Coke
- Drum foaming tendency predictions is another feature to troubleshoot operations

Coker Heater Modelling

- Based on actual geometry, tube-by-tube heat balance, pressure drop, coke laydown in tubes and transfer line and run-length predictions
- Coke formation is a function of bulk and film temperatures
- Tube flow regime helps in optimising ‘Velocity Steam’, extending de-coking cycle time, reducing peak oil temperatures of tubes







- Pressure drop calculations are based on widely accepted *‘Beggs & Brill’* method
- Heat flux calculations are based on *‘Boltzmann-Levans’* method that uses flue gas temperature to iterate and provide radiant flux

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We are continuously developing and upgrading our skills and evolving our tools.

KBC is there to help you!