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Coker Heater Design and Evaluation

KBC

DRIVING EXCELLENCE

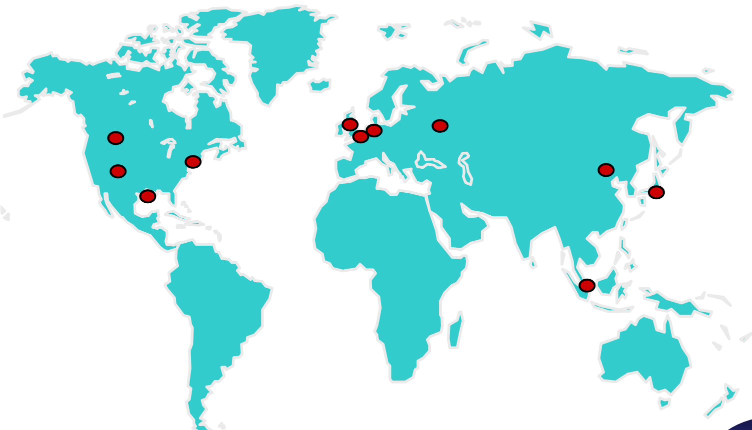
Coker Heater Optimization & Revamp

- Heater often unit limit
- Coker often refinery limit
  - Refinery throughput
  - Refinery crude slate
- Getting more from heater can be very valuable
- Refiner will look to optimize or revamp the heater
  - In house heater evaluation may be beyond refinery capability
  - Refiner may need to utilize third party engineering

Getting Your Heater Evaluation Done

- Coker heater unique in refinery
  - Reactor coil
  - Worst feeds
  - Shortest run lengths
- Unique properties make coker heater evaluation complexity
- KBC to outline how we handle the unique features
- Reference point for when heater revamp becomes refinery goal

KBC Background

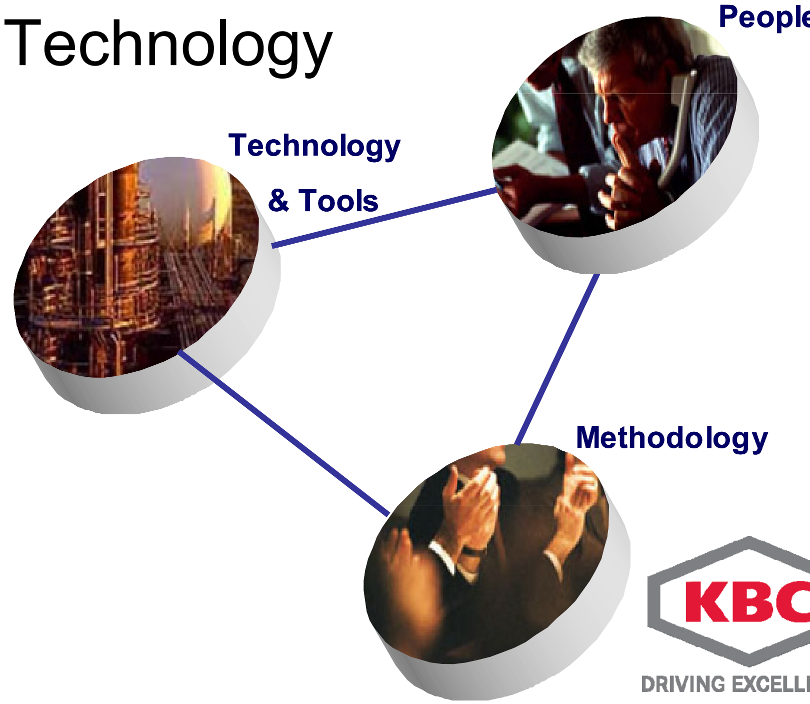


KBC Office Locations

- **2006** Acquires **TTS Performance Systems** for Human Performance improvement services and **Veritech** to extend Energy services
- **2004** **Petro-SIM™** – Plant-Wide Flowsheet Simulation Software released
- **2002** Acquired PEL for Oil and Gas market analysis and **Linnhoff March** to enhance Energy services
- **2000** Created **Petrochemical**, **Gas Processing** and **Energy Industry** services
- **1996** Developed **Reliability, Availability & Maintenance** services
- **1995** Created **On-site Implementation Services**
- **1986** Developed **Petrofine** simulation software
- **1979** KBC founded as **independent consulting company**, specialising in energy improvement in refineries

What We Do

- Provide Independent, Objective Advice
- Enhance Capital & Asset Effectiveness
- Improve Operational Performance
- Increase Competitive Advantage
- Meet Individual Client Needs with Consulting + Implementation + Technology



KBC Background in Coking

- Have performed operations reviews/profit improvement evaluations on over 60 cokers, in over 50 sites, representing over 1.5 MM BPD of coking capacity.
- Over course of last three years, participated in licensor selection process on 10 grass-roots cokers

Design/Revamp Challenges

- Actual inlet stream to the heater probably unknown
- Modeling heater for potential revamp not straightforward
  - Outlet stream is not inlet stream
    - Different composition
    - Different physical and thermal properties

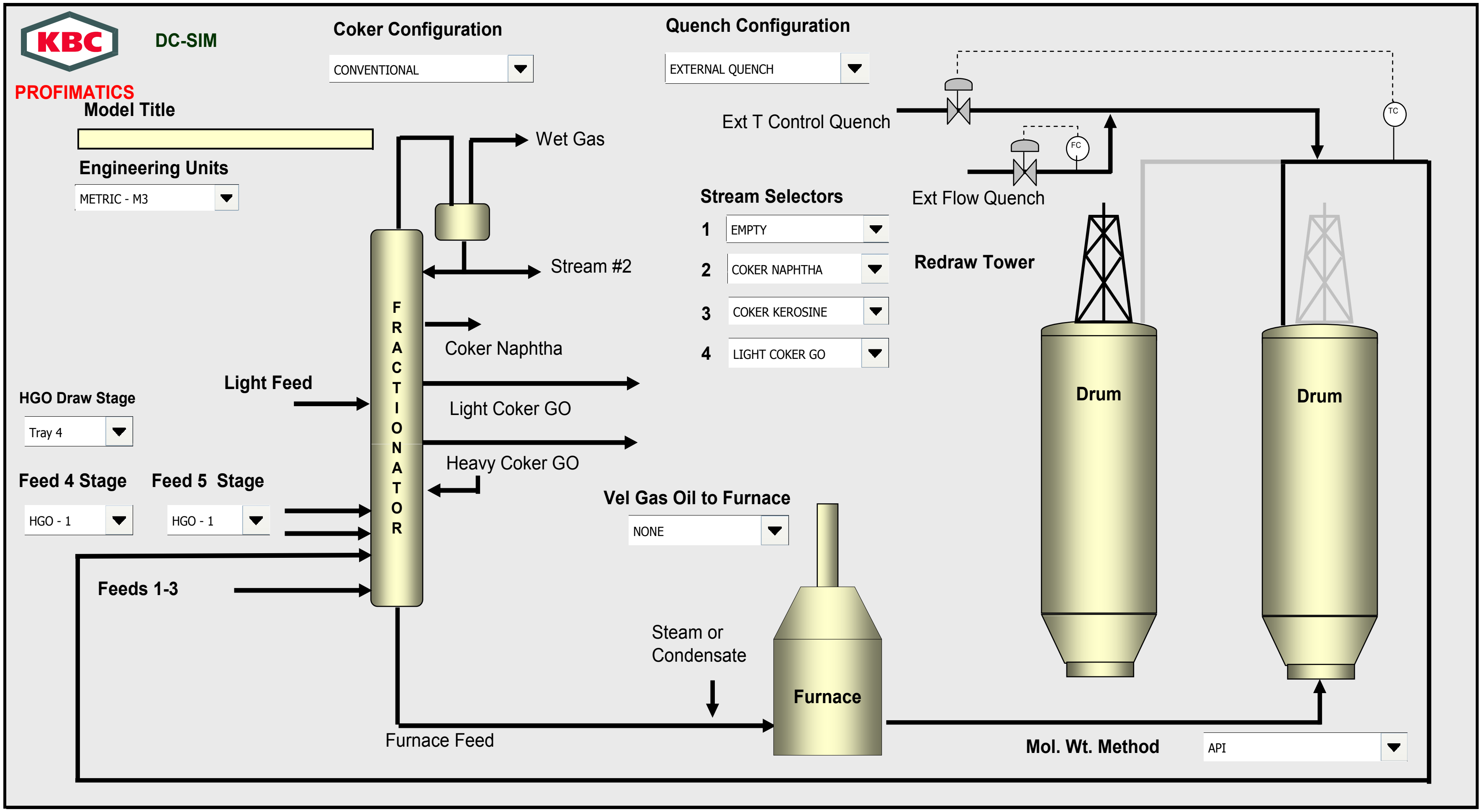
How do you?

- Characterize the feed to the heater?
- Account for the reaction occurring within the coil?
- Project the impact of process/heater configuration changes on heater run length?
- Assess impact of feed quality changes?

Defining Heater Inlet Stream

- Defining the recycle feed to heater
  - Generate recycle stream in kinetic model
    - KBC uses DC-SIM
    - DC-SIM can generate both recycle and heater feed streams
  - Generate recycle stream by heat and material balance around column flash zone
  - DC-SIM can be imbedded into PetroSIM flowsheet

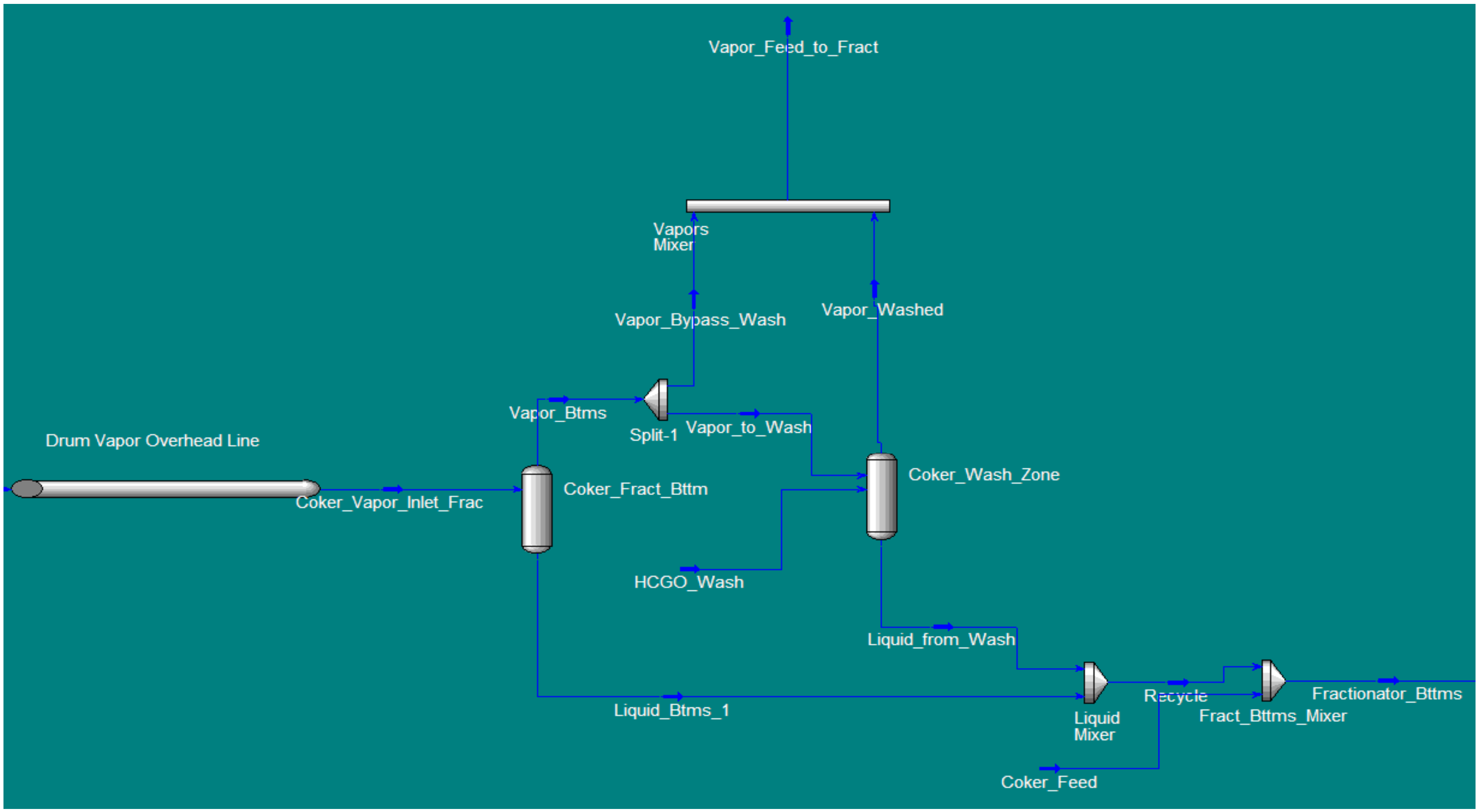
DC-SIM Overview Page



DC-SIM Tower Bottoms

	A	C	D	E	F
323	-Tower Bottom Mass Rate	**lb/hr**			410315
324	-Tower Bottom Volume Rate	**bbl/d**			26212
325	-Tower Bottom Temperature	**°F**			584
326	-Tower Bottom API Gravity	**°API**			0.52
327	-Tower Bottom Specific Gravity	**60/60 deg F**			1.0718
328	-Tower Bottom Sulfur	**wt %**			5.1115
329	-Tower Bottom Nitrogen	**wt %**			0.5191
330	-Tower Bottom ConCarbon	**wt %**			29.68
331	-Tower Bottom Metals	**ppmwt**			789
332	-Tower Bottom TBP 00% Point	**°F**			600.3
333	-Tower Bottom TBP 10% Point	**°F**			1049.1
334	-Tower Bottom TBP 30% Point	**°F**			1183.4
335	-Tower Bottom TBP 50% Point	**°F**			1283.9
336	-Tower Bottom TBP 70% Point	**°F**			1404.0
337	-Tower Bottom TBP 90% Point	**°F**			1522.1
338	-Tower Bottom TBP 99% Point	**°F**			1584.8
339	-Tower Bottom K-Factor	**---**			11.27
340	-Tower Bottom Mol Wt	**---**			754

Coker Flash Zone H&MB



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Characterizing Oil thru Coil

- Defining oil through the heater
  - Requires understanding conversion through the heater
  - KBC uses VIS-SIM
    - Tube by tube kinetic visbreaker model for heater process side
    - As coker heater, reaction tuning factors typically left at default values
    - Performs reaction and pressure drop calculations

KBC VIS-SIM

Anonymous Coker Heater

Design
- Connections
- **Tube Data**
- User Variables
- Notes

	Outside Diam [ft]	Thickness [ft]	Pass	Length [ft]	Coke Thickness [ft]	Spacing [ft]	Header K-Values
1	0.3333	2.650e-002	4.000	32.92	0.0000	0.5833	0.0000
2	0.3333	2.650e-002	4.000	32.92	0.0000	0.5833	0.7500
3	0.3333	2.650e-002	4.000	32.92	0.0000	0.5833	0.7500
4	0.3333	2.650e-002	4.000	32.92	0.0000	0.5833	0.7500
5	0.3333	2.650e-002	4.000	32.92	0.0000	0.5833	0.7500
6	0.3333	2.650e-002	4.000	32.92	0.0000	0.5833	0.7500
7	0.3333	2.650e-002	4.000	32.92	0.0000	0.5833	0.7500
8	0.3333	2.650e-002	4.000	32.92	0.0000	0.5833	0.7500
9	0.3333	2.650e-002	4.000	32.92	0.0000	0.5833	0.7500
10	0.3333	2.650e-002	4.000	32.92	0.0000	0.5833	0.7500
11	0.3333	2.650e-002	4.000	32.92	0.0000	0.5833	0.7500
12	0.3333	2.650e-002	4.000	32.92	0.0000	0.5833	0.7500
13	0.3333	2.650e-002	4.000	32.92	0.0000	0.5833	0.7500
14	0.3333	2.650e-002	4.000	32.92	0.0000	0.5833	0.7500
15	0.3333	2.650e-002	4.000	32.92	0.0000	0.5833	0.7500
16	0.3333	2.650e-002	4.000	32.92	0.0000	0.5833	0.7500
17	0.3333	2.650e-002	4.000	32.92	0.0000	0.5833	0.7500
18	0.3333	2.650e-002	4.000	32.92	0.0000	0.5833	0.7500
19	0.3333	2.650e-002	4.000	32.92	0.0000	0.5833	0.7500
20	0.3333	2.650e-002	4.000	32.00	0.0000	3.500	0.7500
21	0.3333	2.650e-002	4.000	15.00	0.0000	0.5833	1.000
22	0.3333	2.650e-002	4.000	2.000	0.0000	0.5833	0.5000
23	0.3333	2.650e-002	4.000	2.000	0.0000	0.5833	0.5000
24	0.3333	2.650e-002	4.000	35.00	0.0000	0.5833	0.7500
25	0.3333	2.650e-002	4.000	35.00	0.0000	0.5833	0.7500
26	0.3333	2.650e-002	4.000	35.00	0.0000	0.5833	0.7500
27	0.3333	2.650e-002	4.000	35.00	0.0000	0.5833	0.7500
28	0.3333	2.650e-002	4.000	35.00	0.0000	0.5833	0.7500
29	0.3333	2.650e-002	4.000	35.00	0.0000	0.5833	0.7500
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31	0.3333	2.650e-002	4.000	35.00	0.0000	0.5833	0.7500
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33	0.3333	2.650e-002	4.000	35.00	0.0000	0.5833	0.7500
34	0.3333	2.650e-002	4.000	35.00	0.0000	0.5833	0.7500
35	0.3333	2.650e-002	4.000	35.00	0.0000	0.5833	0.7500
36	0.3333	2.650e-002	4.000	35.00	0.0000	0.5833	0.7500
37	0.3333	2.650e-002	4.000	35.00	0.0000	0.5833	0.7500
38	0.3333	2.650e-002	4.000	35.00	0.0000	0.5833	0.7500
39	0.3333	2.650e-002	4.000	35.00	0.0000	0.5833	0.7500
40	0.3333	2.650e-002	4.000	3.000	0.0000	0.5833	0.7500
41	0.3333	2.650e-002	4.000	3.000	0.0000	0.5833	0.7500

Design | Operating Data | Calibration Factors | Worksheet | Results | Calibration

Delete | OK | Ignored

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KBC VIS-SIM Heater Profile

Anonymous Coker Heater

Results
- Operating Summary
- **Detailed Tube Profil**
- Tube Specifications
- Coil T And P Profile
- Fluid Properties
- Two Phase Regime
- Mass Bal Summary
- Residue Properties
- Conversion Summary
- Viscosity Summary
- P Drop Summary
- Diagnostics
- Residence Time Graph
- Horizontal Flow Graph
- Vertical Flow Graph

	Fluid P [psig]	Fluid T [F]	Oil Film T [F]	LV% Vaporised [vol %]	Fluid Velocity [ft/s]	Sonic Velocity [ft/s]	Residence Time [seconds]
Outlet 1	64.00	915.0	962.4	10.27	50.92	775.7	0.6813
Outlet 2	66.88	907.6	958.1	8.498	45.71	809.0	0.7608
Outlet 3	70.57	899.8	953.5	6.901	40.83	849.5	0.8466
Outlet 4	73.87	891.8	948.5	5.586	36.94	893.9	0.9303
Outlet 5	76.85	883.7	943.1	4.514	33.83	941.8	1.011
Outlet 6	79.59	875.4	937.4	3.647	31.32	992.5	1.087
Outlet 7	82.14	867.1	931.5	2.949	29.28	1045	1.158
Outlet 8	84.52	858.1	924.7	2.382	27.59	1101	1.223
Outlet 9	86.77	850.2	918.8	1.947	26.24	1154	1.283
Outlet 10	88.92	841.2	911.8	1.585	25.07	1208	1.339
Outlet 11	90.98	833.0	905.4	1.318	24.12	1255	1.388
Outlet 12	92.97	824.0	898.1	1.084	23.31	1306	1.449
Outlet 13	94.90	801.8	878.0	0.5938	22.12	1451	1.504
Outlet 14	96.80	792.8	870.4	0.5319	21.65	1476	1.536
Outlet 15	98.67	784.5	863.5	0.4794	21.23	1498	1.567
Outlet 16	100.5	775.5	856.0	0.4289	20.79	1519	1.599
Outlet 17	102.3	766.5	848.6	0.3836	20.39	1539	1.629
Outlet 18	104.1	757.5	841.2	0.3427	20.01	1557	1.660
Outlet 19	105.9	748.5	833.8	0.3060	19.65	1574	1.690
Outlet 20	107.6	739.5	826.5	0.2729	19.30	1589	1.672
Outlet 21	109.7	732.2	732.2		6.121		2.450
Outlet 22	110.1	732.2	732.2		6.121		0.3267
Outlet 23	110.2	732.2	732.2		6.121		0.3267
Outlet 24	110.3	732.2	765.6		6.121		5.724
Outlet 25	110.9	728.6	761.5		6.108		5.736
Outlet 26	111.5	725.1	751.0		6.095		5.747
Outlet 27	112.0	722.4	748.3		6.086		5.756
Outlet 28	112.6	719.6	777.8		6.076		5.771
Outlet 29	113.2	713.4	772.7		6.054		5.792
Outlet 30	113.8	707.1	750.8		6.032		5.810
Outlet 31	114.3	702.5	746.8		6.016		5.826
Outlet 32	114.9	697.8	730.7		6.000		5.839
Outlet 33	115.5	694.4	727.9		5.988		5.851
Outlet 34	116.0	690.9	716.0		5.976		5.861
Outlet 35	116.6	688.2	713.8		5.968		5.869
Outlet 36	117.2	685.6	704.8		5.959		5.877
Outlet 37	117.7	683.6	703.2		5.952		5.884
Outlet 38	118.3	681.6	696.5		5.945		5.890
Outlet 39	118.9	680.0	695.2		5.940		5.895
Outlet 40	119.4	678.5	678.5		5.935		0.5055
Outlet 41	119.6	678.5	736.8		5.935		0.5056
Inlet 41	119.8	678.0	736.4		5.933		

Design | Operating Data | Calibration Factors | Worksheet | **Results** | Calibration

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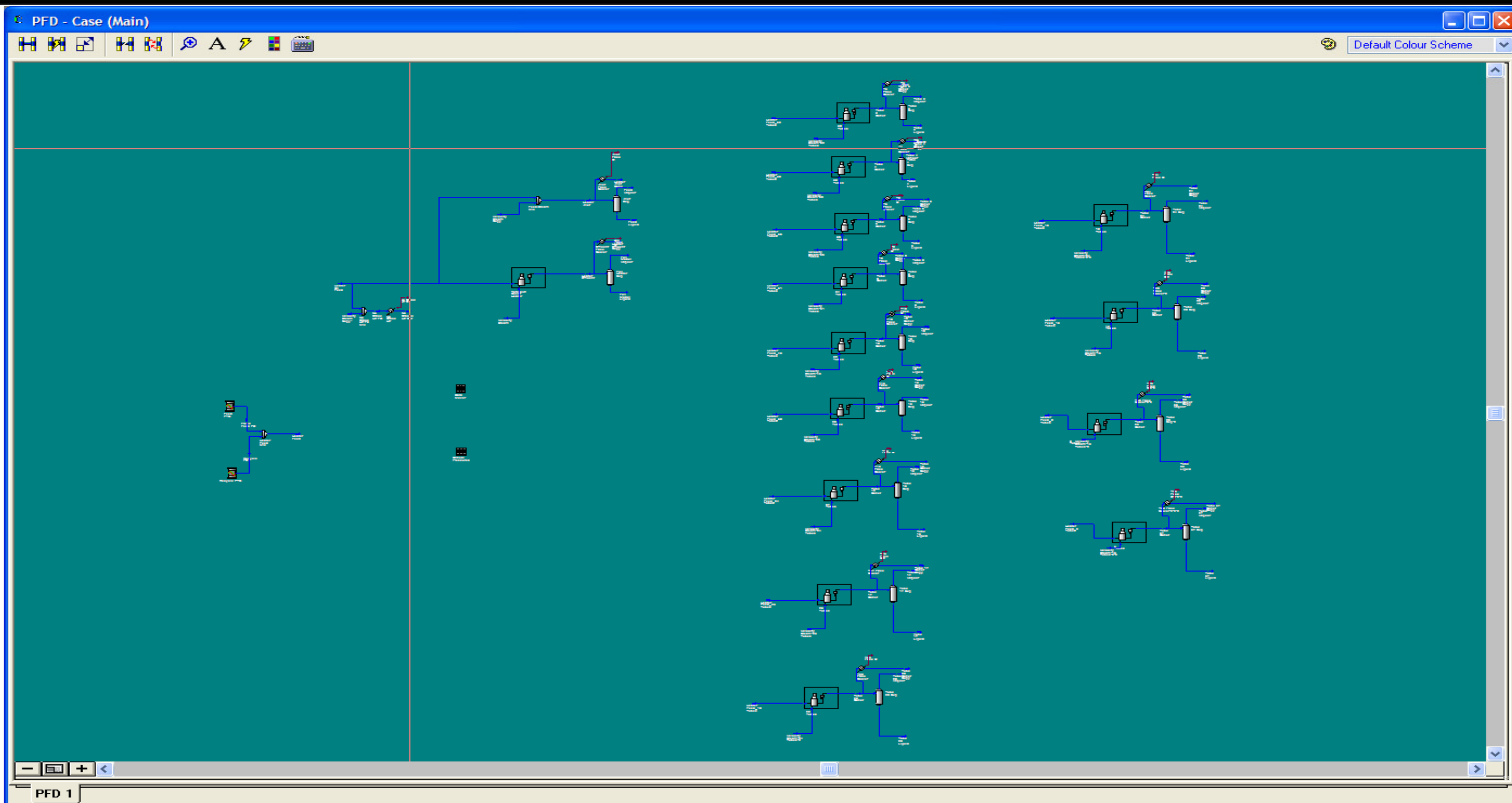
Generating Fluid Properties



Solving Overall Furnace

Properties Matrix for a given Heat Flux

Petro-SIM™

- Details heavy oil physical properties
- Delayed coker yields for heat balance in the tower flash zone
- Thermal cracking in heater radiant coils
- Heater process side hydraulics

Heat Flux

Must Be Equal

Firebox Simulation

- Detailed tube-by-tube radiant heat transfer
- Detailed tube-by-tube convective heat transfer
- Fire box flue gas hydraulics

Heat Flux for a given Properties Matrix

Converging Kinetic/Firebox Models

- PetroSIM used to generate:
  - Liquid and vapor properties of coil fluid
    - % vapor, densities, heat capacities, thermal conductivities, viscosities, surface tension
  - Properties transferred to commercial firebox simulator via property grid input
- Commercial firebox simulation used to generate heat fluxes, transferred to VIS-SIM
- Models run iteratively until no change in fluxes

Step Out Cases

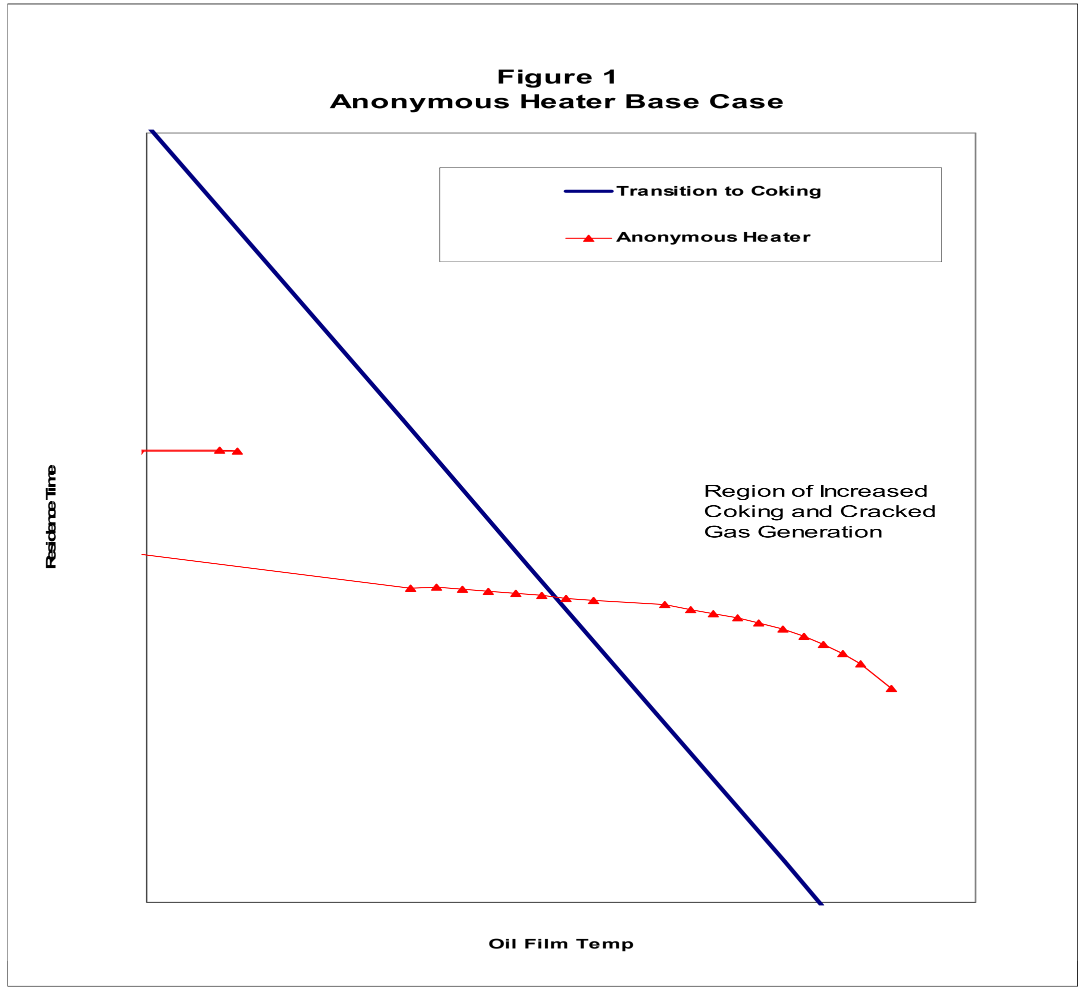
- Once the base case model developed, can be used to evaluate
  - Velocity steam strategy
    - Quantity, injection location
  - Heater configuration
    - Tube diameter, tube length, number of tubes
  - Other operating variables
    - Feed changes, light recycle, etc

Step Out Cases—Heater Fouling

- Addressing changes in heater fouling
  - Coking tendency
    - Performance versus KBC coking curve
  - Projected run length
    - Using KBC coking rate equation
  - Feed quality impacts
    - Evaluating potential for asphaltene precipitation in the coil

Coking Tendency: Coking Curve

- From series of heavy oil heater analyses, KBC developed coking correlation between residence time and film T
- In “anonymous” heater, 13 tubes operating on coking side of coking curve



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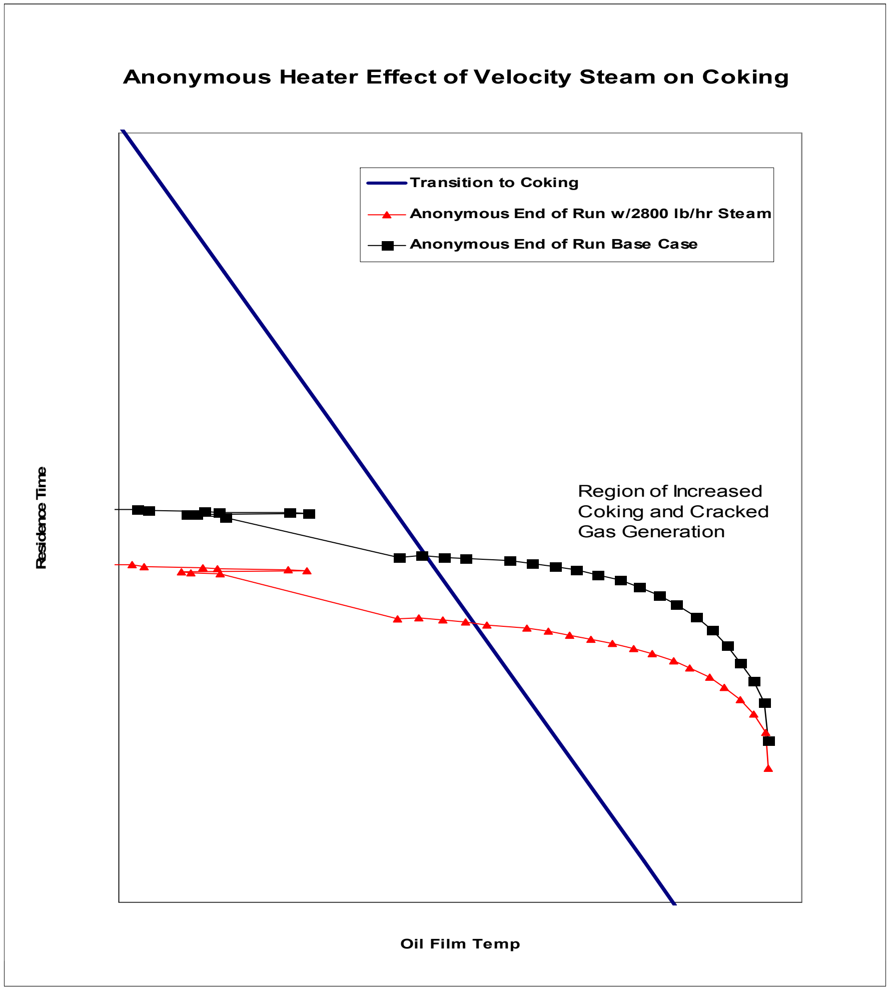
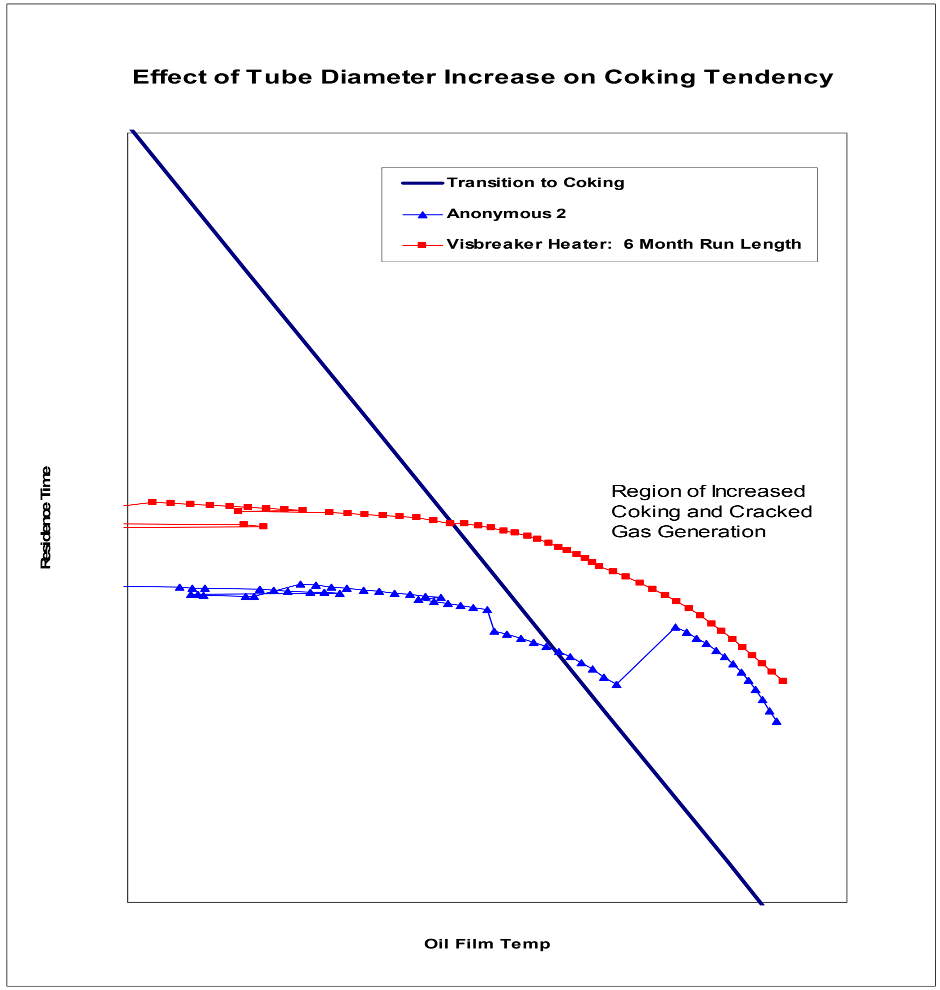
Coking Tendency: Examples





KBC Coking Rate Calculation

- From the coking curve, KBC derived coking rate equation

- Form of the Arrhenius equation:

$$\text{Relative Coking Rate} = (\text{Constant})^{(\text{Base T} - \text{Case T})} * (\text{Case Time} / \text{Base Time})$$

Asphaltene Precipitation

- KBC has developed physical property called Aromatic Blending Number (ABN)
- ABN is a function of BMCI (Bureau of Mines Correlation Index

$$EMCI = 473.7SG + \frac{87552}{ABP} - 456.8$$

where:

$BMCI$ = calculated BMCI value

SG = SG of stream ABP = Mo

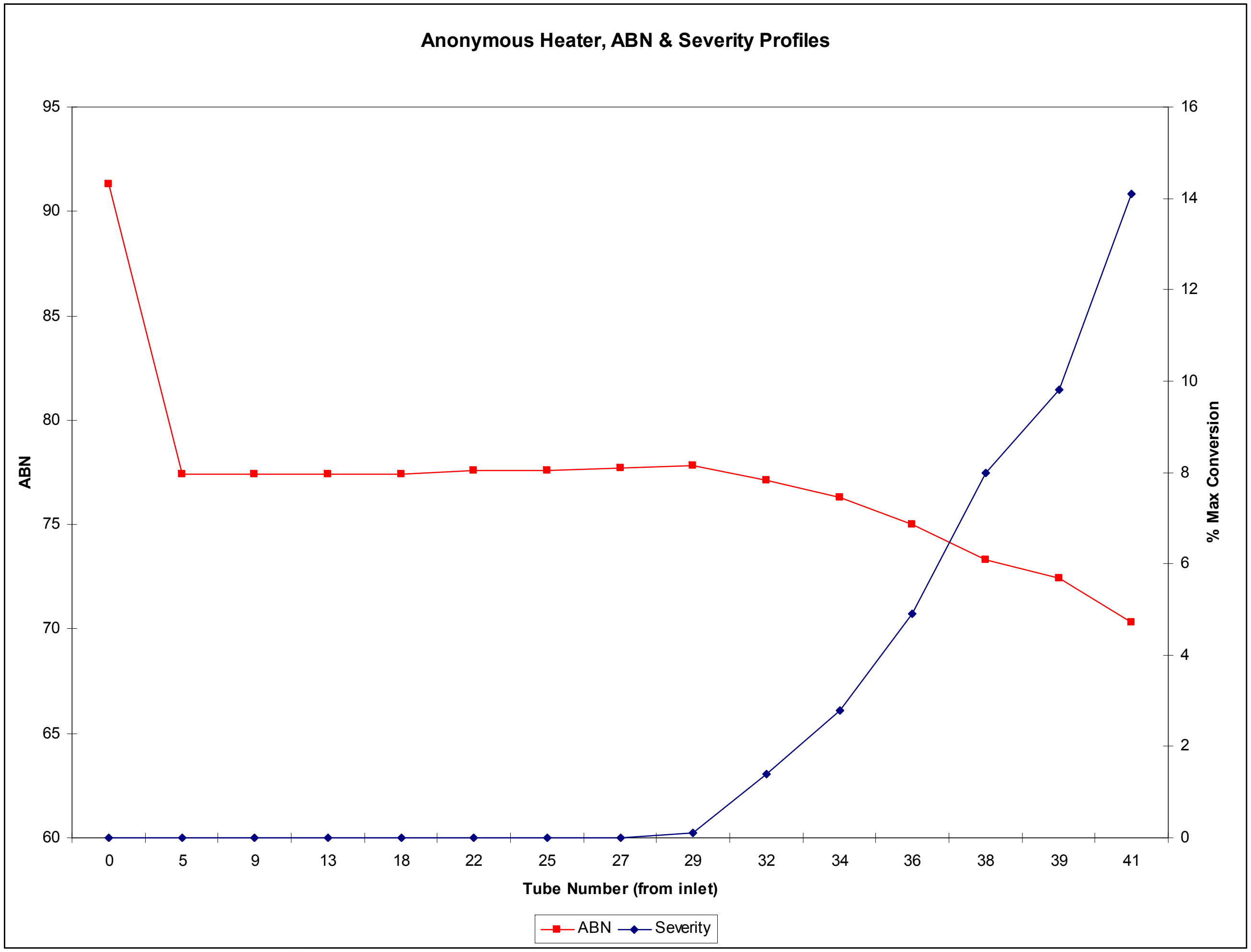
ABP pf stream, °R.

- ABN is a primary indicator of oil stability & oil's capability as asphaltene solvent
- For streams with asphaltenes, ABN = 40 times p-value (or p-value = ABN/40)

Heater Cracking Severity

- As part of visbreaker modeling technology KBC has developed physical property called Maximum Visbreaker Conversion
- Maximum visbreaker conversion a function of asphaltenes and BMCI (Bureau of Mines Correlation Index)
- Maximum visbreaker conversion is the 400- conversion at which the visbroken pitch product reaches minimum stability target
- Heater severity is the conversion/maximum visbreaker conversion

Tracking ABN and Heater Severity



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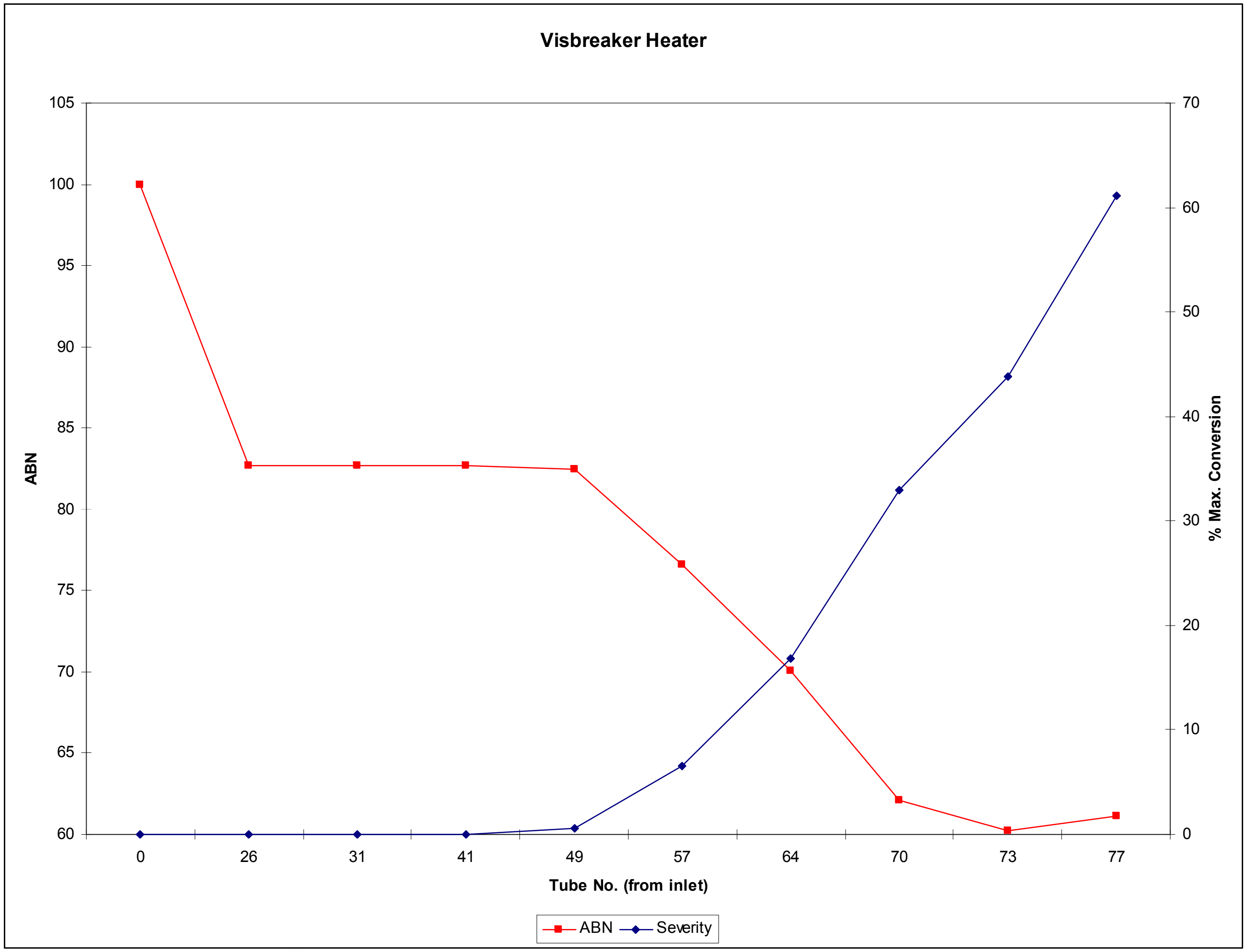
ABN and Heater Severity (2)



Coker Heater Design Considerations

- Feed characterization
  - How is recycle accounted for/characterized?
- Oil characterization through coil
  - How is change of composition addressed?
- How are run length projections made?
- How are effects of feed quality changes assessed?

KBC Contact Information

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