Sustaining Olefins Production Through Optimization And Effective Feed Management

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MANAGING CHANGING FEEDSTOCK

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Punch Line and Challenges for Operations

PUNCH LINES

- ❑ Keep Producing…No Matter What..!
- ❑ Stay Efficient…! (Energy, Chemicals, Raw Materials)
- ❑ Reduce losses..! (Flaring, Waste Water)

Challenges

- ❑ Dynamic Nature of the plant
- ❑ Change in availability of feedstock
- ❑ Change in equipment health
- ❑ Unavailability of equipment due to maintenance or reliability
- ❑ Resources

Everyday decision making involves evaluating multiple parameters (process, mechanical, operations) to run the plant with the targets set.

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NEED for Effective Feed Management

- Critical challenge for operating plants in the region is uncertainty in availability of feed
- More the flexibility in feed more the uncertainty faced by the unit
- Primary target for any plant is to keep producing the most with available feedstock
- Various aspects to consider –
    - Plant Infrastructure
    - Type of Feed processing know-hows
    - Use of economics in coordination with business plan
    - Customer requirement at downstream
- Optimizing the plant within these constraints to achieve a particular objective function becomes important

Decision Process – Feed Management

Decision Making Process for Plant Manager – Feed Management

1. Available of alternate feedstock
2. Evaluation of all the hard constraints in the plant
3. Setting up of an appropriate target for 100% asset utilization
4. Develop a solution with calculation of set points
5. Attempt to work around the constraints to implement the plan
6. Maximized Production

   Meet the target

- ❑ Time for decision making is short and critical increasing chances of missing on an important constraint; resulting in suboptimal plan
- ❑ Conclusive role of Plant Operation Engineer is essential in decision making
- ❑ Lower supply of a particular feedstock should not be an obstacle in achieving the production goal
- ❑ Instead, optimized processing aiming maximum asset utilization enables leveraging of different feedstocks available

Leveraging the availability of alternate feeds open window for optimized operation through utilization of data intelligence tools

Decision Support Tool - Conceptualization

- Automating the decision making process ensures all constraints are accounted for while achieving global optima on the target set
- Easier, faster way of developing a plan to manage various situations with feedstock availability
- Allows what-if to simulate and plan for situations that may arise in the future and also allows audit of the situations in the past to allow better understanding and learning
- A simple uncomplicated tool would make decision making in operations easier but at the same time more accurate

- A tool was developed to address this need for a Ethylene Plant
- Excel is easy to use; every engineer can use excel without much training; also allows user to modify the UI for his own need
- Allows various objective function to simulate variety of targets set for operations
- All mechanical, equipment, business aspects included in form of constraints
- Allows optimization to achieve target within the boundaries set for each manipulated variable

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Decision Support Tool - Features

- **Objective function**: Allows various objective functions to be optimized
  - Maximum or Specified Ethylene Production rate
  - Maximum Ethylene while achieving specified/planned Propylene
  - Maximum or Specified Propylene Production rate
  - Maximum Ethylene and Propylene Production rate (E+P)
  - Maximum Plant Contribution USD
  - Maximum or minimum byproduct flows apart from Ethylene and Propylene such as C4M, 1,3 BD, recycle flow, residue gas keeping plant contribution high.

- **Configurational Inputs**: Allows specifying configurational aspects of the plant based on mode of operation or availability of major equipment
  - Number of furnaces in operation
  - Feed conversion
  - Losses in recycle or products
  - Plant Contribution
  - Cost of raw material and products

- **Constraints**:
  - Upper and Lower limit of various critical parameters to indicate the capability of each equipment and business case for the plant
  - Limits are estimated based on design data, data analytics, plant operating cases and users' operation experience.

Decision Support Tool - Development

- Analysis of the Design Data for the plant to develop configurational constraints
  - PFD, PID
  - Equipment Datasheets
  - Design & Operating Data - HMB
- Furnace Effluent Prediction Model (Statistical)
  - Data from yield Prediction model
  - Design data
  - Actual Online/Lab analysis data
- Define and estimate unit constraints
  - ✓ Involves statistical approach and plant operational inputs based on the way how plant was operated/some identified boundaries/limits
- Plant recovery model based on available cases
- Estimation of major stream flow rate –wherever required
- Products balancing and validation with actual
- Product and raw material pricing
- Defining Objective Functions
- Use of solver (GRG Nonlinear) with objective function
- Validation of optimized variables

Decision Support Tool – Using the Tool

- Define Inputs –
  - Feed composition wt% -Each stream
  - External Feed/Supplementary feed and composition
  - Recycle or losses or key component loss in products
  - Selectivity/conversion of reactors
  - No of furnace on specific feed

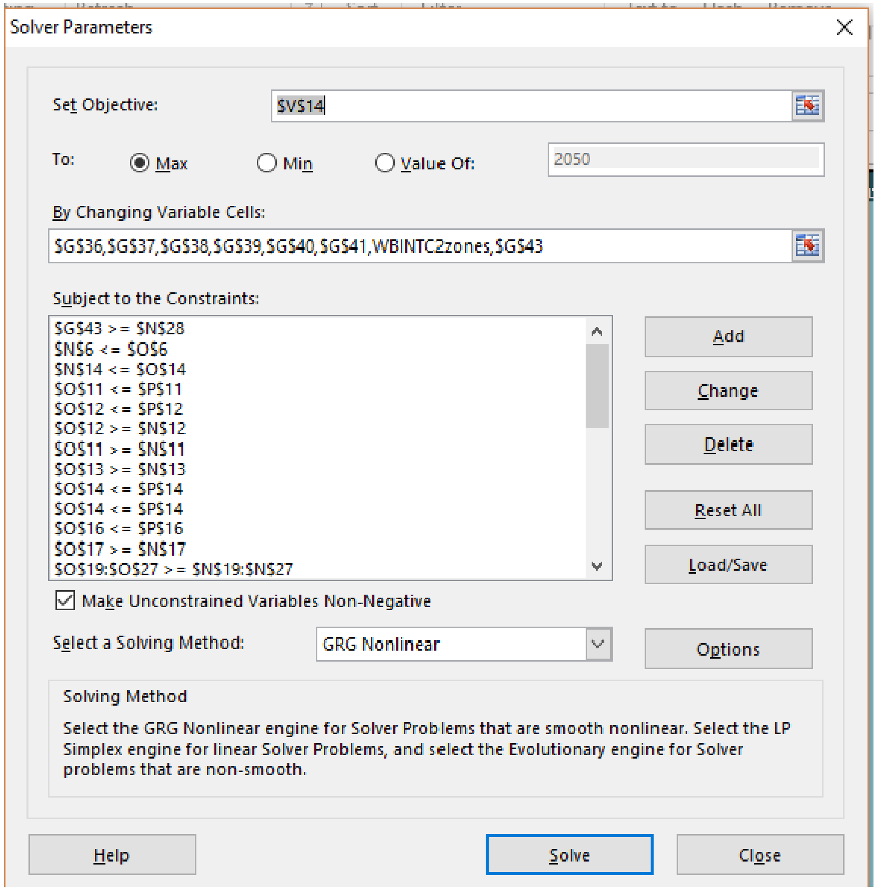
OLEFINS INPUT DATA

	Feed Characterization				Operating conditions		
	NGL FEED	400	TPD				
		16667	Kg/h		No. of furnaces	7	
Analyzer/Lab	Composition	Nor Comp					
0.96	Methane	1.0	wt%		Passes on Ethane	6.0	
67.41	Ethane	67.4	wt%		Flow per Pass	9453	kg/hr
24.67	Propane	24.7	wt%				
3.8	i-C4	3.8	wt%		Passes on Propane	36	
2.89	n-C4	2.9	wt%		Flow per Pass	7809	kg/hr
0.27	C5	0.3	wt%				
100.00							
	PURE PROPANE	5750.7	tpd		Conversion %		
		239611	kg/hr		Ethane	65.0%	
Analyzer/Lab	Composition	Nor Comp					
0	Methane	0	wt%		Propane	87.0%	
0.5	Ethane	0.5	wt%				
98	Propane	98	wt%				
0.7	i-C4	0.7	wt%		Hydrogenation		
0.8	n-C4	0.8	wt%		C2 hdn selectivity	50.0%	
0	C5	0	wt%		C3 hdn selectivity	60.0%	
0	Propylene	0	wt%		MAPD conversion	90.0%	
100.00							
	PURE ETHANE	199.1	tpd		Recovery model		
		8297	kg/hr		Ethylene loss in R.G.	2000	ppmv
Analyzer/Lab	Composition	Nor Comp			Ethylene in C2 spl bot	3	wt%
0	Methane	0	wt%		Ethane in ethylene	100	ppm w
100	Ethane	100	wt%		C4 loss in DP o/h	1.5	wt%
0	Propane	0	wt%				
0	i-C4	0	wt%		Propane in propylene	5000	ppm w
0	n-C4	0	wt%				
100.00	C5	0	wt%				

Decision Support Tool – Using the Tool

- ❑ Define Constraints and Objective Function in the Solver

OLEFIN PLANT CONSTRAINTS		Minimum	Desired value-Present	Maximum
Furnaces				
Flow per Pass for Ethane	Kg/h	3500	9453	9500
Flow per Pass for Propane	Kg/h	3500	7809	9500
No. Passses on Ethane	No	6	6	6
Ethane conversion	%	45.0%	65.0%	65.0%
Propane conversion	%	80.0%	87.0%	87.0%
NGL Feed	Kg/h	0	400	400
Pure Propane Feed	Kg/h	0	5751	7193
Pure Ethane Feed	Kg/h	0	199	400
No of furnace to be operat	No	7	7	7
Compressor 3rd Stage disc '	°C			
CGC molar flow	KgMol/	2500	15009	15009
Total Propane	Kg/h	0	281123	350000
CGC Mass flow	Kg/h	100	337942	361477
DMS+DM Bottom	Kg/h	0	250857	275204
H2 mole % in Residue Gas	Mol%	30.0%	40.0%	40.0%
Methane mole % in Residue	Mol%	50.0%	59.7%	70.0%
C2 splitter Feed	Kg/h	0	155396	177170
Depropanizer feed	Kg/h	0	105590	172205
Propylene Splitter Feed	Kg/h	0	84431	120000
Debutanizer	Kg/h	0	21219	25000
Condensate Stripperbtm flo	Kg/h	0	5718	70000
Gasoline fractionator	Kg/h	0	14580	20000
Propylene in C3 spl bottom	Kg/h	0	0.0	10
DP Flooding		40	55.6	80
Products				
Max. Ethylene		0	119326	123000
Max. Propylene		0	46579	58000
Max. Mixed C4 product		0	11777	12000
Max. Residue gas		0	76634	85000



Decision Support Tool – Using the Tool

- Tool Output
  - Optimize Objective Functions
  - Limiting constraints values/status
  - Product Flows

PRODUCTS FLOWS (Kg/h)		
Fuel gas generated	78638	
CH4 product	250	
Ethylene	**120352**	Obj Funct
Ethane recycle	32282	
Propylene	**45723**	Obj Funct
Propane recycle	36055	
C4 mix product	11999	
Rich Aromatic	12067	
Mixed oil	3339	
Ethylene+Propylene	**166075**	Obj Funct
Contribution MUSD	**213.62**	Obj Funct

DESIRED OPTIMIZING VARIABLES		
NO OF FURNACE OPR	7	UNIT
NGL FEED INTAKE	0	TPD
PURE PROPANE INTAKE	6041	TPD
PURE ETHANE INTAKE	400	TPD
ETHANE CONV	68.0%	%
PROPANE CONVERSION	88.0%	%
PASSES ON ETHANE	6	UNIT
PROPYLENE IN C3 SPL BOT	2.0	wt%
TOTAL CONTRIBUTION	213.6	**M USD**

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Products				
Max. Ethylene		0	119326	123000
Max. Propylene		0	46579	58000
Max. Mixed C4 product		0	11777	12000
Max. Residue gas		0	76634	85000

Model-Results- Example-1

Model has estimated highest consumption of Propane feed based on feed and product pricing

Objective Function- Highest Ethylene		
INPUT	TPD	% CONV
NGL Feed	0	-
Pure Ethane Feed	477	65
Pure Propane Feed	5878	88

Case-1

Fuel gas generated	77007
CH4 product	250
Ethylene	120308
Ethane recycle	35892
Propylene	44648
Propane recycle	35126
C4 mix product	11836
Rich Aromatic	11833
Mixed oil	3232
Contribution (MM USD)	**206.84**

Objective Function- Highest E+P		
INPUT	TPD	% CONV
NGL Feed	0	-
Pure Ethane Feed	413	65
Pure Propane Feed	5861	84

Case-2

Fuel gas generated	74510
CH4 product	250
Ethylene	116678
Ethane recycle	35110
Propylene	50039
Propane recycle	48381
C4 mix product	11243
Rich Aromatic	10785
Mixed oil	2727
Contribution (MM USD)	**200.80**

Objective Function- Highest Contribution		
INPUT	TPD	% CONV
NGL Feed	0	-
Pure Ethane Feed	0	65
Pure Propane Feed	6557	85.7

Case-3

Fuel gas generated	81086
CH4 product	250
Ethylene	116343
Ethane recycle	27733
Propylene	52761
Propane recycle	47490
C4 mix product	12000
Rich Aromatic	11770
Mixed oil	3169
Contribution (MM USD)	**227.81**

Feed & Product **Dummy** Pricing USD/mt	
Feed	
NGL Feed	394
Pure Propane	366
Pure Ethane	338
Recycle/Purge	563
Wash Oil in CGC	394
Products	
Fuel gas	155
Fuel gas export	296
H2	634
Methane	634
CH4 product	577
Ethylene	465
Propylene	493
C4 mix	324
1,3 BD	254
LPG	169
Rich AromaticS	254
Benzene	408
Tolune	310
MXS	423
Raffinate	254
Mixed oil	352

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Model-Results- Example-2

Limiting feed. Preferred Operation -Case-3 Estimating highest contribution

Objective Function- Highest Ethylene		
INPUT	TPD	% CONV
NGL Feed	0	-
Pure Ethane Feed	400	65.1
Pure Propane Feed	6000	88

Case-1

Fuel gas generated	77983
CH4 product	250
Ethylene	119951
Ethane recycle	34461
Propylene	45428
Propane recycle	35814
C4 mix product	11926
Rich Aromatic	11942
Mixed oil	3281
Contribution (MM USD)	**211.11**

Objective Function- Highest E+P		
INPUT	TPD	% CONV
NGL Feed	0	-
Pure Ethane Feed	400	68
Pure Propane Feed	6000	86.8

Case-2

Fuel gas generated	77522
CH4 product	250
Ethylene	119249
Ethane recycle	32400
Propylene	47268
Propane recycle	39883
C4 mix product	11795
Rich Aromatic	11690
Mixed oil	3148
Contribution (MM USD)	**210.45**

Objective Function- Highest Contribution		
INPUT	TPD	% CONV
NGL Feed	0	-
Pure Ethane Feed	400	68
Pure Propane Feed	6000	88

Case-3

Fuel gas generated	78128
CH4 product	250
Ethylene	119635
Ethane recycle	32139
Propylene	45433
Propane recycle	35814
C4 mix product	11939
Rich Aromatic	12009
Mixed oil	3318
Contribution (MM USD)	**212.14**

Feed & Product **Dummy** Pricing USD/mt)	
Feed	
NGL Feed	394
Pure Propane	366
Pure Ethane	338
Recycle/Purge	563
Wash Oil in CGC	394
Products	
Fuel gas	155
Fuel gas export	296
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Conclusion

- 100% Asset utilization is important and Feed management essential to achieve this; Dynamic nature of the plant and availability of the feed requires evaluation and calculation of many parameters to achieve operation excellence within the given constraints of the plant
- Time is of essence during such situation and hence an automated decision support tool adds immense value
- A simple uncomplicated excel tool allowed Ethylene manufacturer to take decision to cope with changing feed availability and managing alternate feed
  - Increase and sustain plant production
  - Identification of bottlenecks
  - Optimize product yields
  - Increase gross contribution
- Tools allows -
  - Predict Cracker Yield- Optimize cracking severity- conversion of feedstock
  - Consumption Rate of each Feedstock
  - Plant Production Comparison - Present v/s Predicted
  - Monetary contribution if cost database is available
  - Margin available in identified plant constraints
  - First debottleneck identification from listed constraints

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Regression for Furnace Effluent Prediction

- ***Preparing regressed equations to predict the furnace effluent.***

In absence of kinetics/dynamic model, a fine tuned *"Plant Optimizer"* and *"Yield Predictor"* can be a better solution in plant feed and production management. This can be prepared by regressing plant big data or PFD data

✓ For preparation of regressed equation, furnace actual operating data (Furnace effluent composition- Detailed full analysis) with component mole% and operating conversion is required for each feed slate.

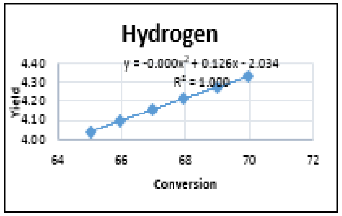
	Ethane						Propane									N-BUTANE					
Comp/Conv %	65	66	67	68	69	70	84.9	86.0	87.1	87.8	88.0	88.3	89.0	89.8	90.0	0.95	1.00	1.05	1.10	1.14	1.20
Hydrogen	4.04	4.10	4.15	4.21	4.27	4.33	1.47	1.50	1.52	1.52	1.52	1.66	1.77	1.68	1.59	0.98	0.95	0.95	0.99	1.01	1.02
Methane	5.08	5.21	5.65	6.01	6.16	6.50	20.44	20.92	21.75	22.06	22.08	20.93	20.30	21.44	22.61	19.42	19.86	20.28	20.37	20.63	20.88
Ethylene	49.94	50.59	51.13	52.14	52.95	53.63	32.97	33.61	34.42	34.65	34.68	35.57	36.53	36.51	36.05	32.88	33.31	33.59	34.49	34.84	35.17
Ethane	34.36	33.35	32.41	30.98	29.89	28.82	5.05	5.29	4.83	4.72	4.70	7.15	8.90	7.87	5.87	5.35	5.44	5.51	5.19	5.24	5.14
Propane	0.18	0.18	0.19	0.19	0.19	0.20	14.10	12.93	12.07	11.48	11.38	10.53	9.50	9.14	9.45	0.48	0.44	0.31	0.29	0.21	0.20
Propylene	1.40	1.42	1.47	1.49	1.60	1.64	16.01	15.62	15.50	15.54	15.54	14.47	13.50	13.77	14.56	20.89	19.87	19.35	18.68	18.07	17.56
Other Comp	4.99	5.15	4.99	4.97	4.92	4.89	9.96	10.12	9.99	9.99	9.99	9.70	9.50	9.58	9.88	20.00	20.13	20.00	20.00	20.02	20.02
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

In absence of furnace actual operating effluent results, material balance based on different PFD cases as provided by licensor can be utilized.

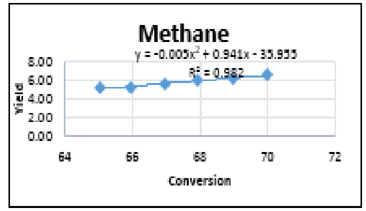
✓ From the good plant operating data, estimation of regressed equations can be done for all the components in the furnace effluent (estimation of components other than Olefins is necessary to calculate heavier stream flows)

Regressed Equations-Olefins in Furnace Effluent

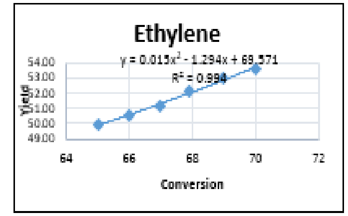
❑ *Regressed equations-Ethane Feed-Example*



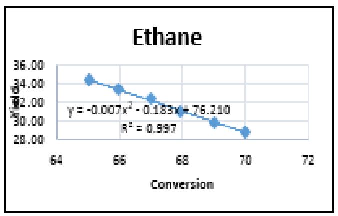
	-5E-04	0.1259	-2.033833
	Actual	Predicted	
65	4.0389	4.0392	0.0000001
66	4.0969	4.0962	0.0000005
67	4.1549	4.1564	0.0000022
68	4.2129	4.211	0.0000036
69	4.2709	4.2725	0.0000028
70	4.3289	4.3284	0.0000002



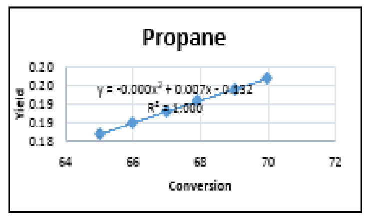
	-0.00478	0.9411	-35.95525
	Actual	Predicted	
65	5.082964	5.0291	0.0029002
66	5.214085	5.3261	0.0125430
67	5.650541	5.6353	0.0002318
68	6.005571	5.9119	0.0087758
69	6.161807	6.2189	0.0032555
70	6.499093	6.4928	0.0000397



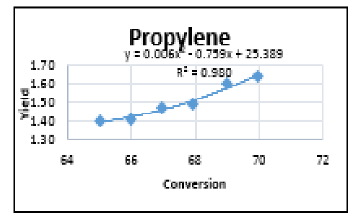
	0.0152	-1.294	69.571068
	Actual	Predicted	
65	49.939	49.906	0.0010866
66	50.585	50.57	0.0002361
67	51.131	51.312	0.0328166
68	52.14	52.024	0.0133512
69	52.954	52.874	0.0064366
70	53.627	53.69	0.0039741



	-0.007	-0.183	76.210385
	Actual	Predicted	
65	34.36	34.401	0.0016469
66	33.355	33.355	9.452E-08
67	32.414	32.218	0.0382896
68	30.983	31.156	0.0301796
69	29.895	29.924	0.0008303
70	28.817	28.77	0.0022135



	-2.6E-05	0.0065	-0.13241
	Actual	Predicted	
65	0.18	0.1817	0.0000000
66	0.18	0.1847	0.0000000
67	0.19	0.1878	0.0000000
68	0.19	0.1906	0.0000000
69	0.19	0.1938	0.0000000
70	0.20	0.1967	0.0000000



	0.006	-0.759	25.389487
	Actual	Predicted	
65	1.4035	1.3991	0.0000196
66	1.4177	1.4244	0.0000460
67	1.4684	1.4635	0.0000238
68	1.495	1.5105	0.0002398
69	1.5999	1.5772	0.0005189
70	1.6412	1.651	0.0000964

Hydrogen
Methane
Acetylene
Ethylene
Ethane
MA/PD
Propylene
Propane
Butadiene
Other C4s
C5S
C6-C8 NA
Benzene
Toulene
EB+XY+STY
C9 to 200
Fuel Oil
CO
CO2

Similar regressed equations for Propane, Butane, Naphtha feed can be estimated for other component as show in above table. By using regressed equations and recovery model, the individual component flows in furnace effluent and for all in-out streams across columns/sections can be estimated.