Optimizing a World-Scale Petrochemical Plant

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Agenda

• The need for Optimization

• RPMS Project Implementation Methodology

• RPMS Solution Blue Print

• RPMS Model Development

• RPMS Model Validation & Calibration

• Benefits

• Next Steps
Petrochemical Complex - Process Flow Diagram

Oxygen

Ethane MMSCFD

Propylene KBD

:5 Cut (Recycle)

Olefin Cracker

Ethane Conversion
- Fu1: 0.30 Mt/day
- Fu2: 0.30 Mt/day
- Fu3: 0.30 Mt/day
- Fu4: 0.30 Mt/day
- Fu5: 0.30 Mt/hr

Ethylene Conversion
- 0.00 Mt/hr

Ethylene

HDPE

LLDPE

Butene-1 Product

Butene-1 Separation

Fuel Gas Mix Drum (FMD)

Py Gas

BTX Extraction

C6-C8 Raffinate

BEI

Toluene/Xylenes

Butene-1

Ethylene

0 Mt/day

0 Mt/day

0 Mt/day

0 Mt/day

0 Mt/day

0 Mt/day

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Olefins Unit – Feedstock Slate

- Propane, 34%
- Ethane, 28%
- Ethane Recycle, 19%
- Propane Recycle, 16%
- C5 Recycle, 1%
- Mix C4 Recycle, 1%
Petrochemical – Product Profile

- Benzene: 5%
- MTBE: 0%
- Butene-1: 1%
- Toluene/Xylenes: 5%
- C6-C8: 1%
- PP: 14%
- LLDPE: 19%
- HDPE: 17%
- EG: 42%
Why Do We Need an Optimization Model?

Flexibility

- Different Feedstocks
- Many Furnaces

Constraints

- Equipment limits
- Furnace availability
- Product demand
- Feedstock availability

Price Volatility

- Ethane
- Propane
- Naphtha

Graph showing price volatility over time.
The RPMS Planning Model Captures the Synergy between the Olefins Unit and Downstream Constraints
Project Goal

- Lower unit manufacturing cost
  - Improve feedstock selection and evaluation
  - Explore variable feedstocks

- Improve plant asset utilization
  - Furnace severity optimization
  - Physical and quality constraints
  - Recycles
  - Inventory management

- Reduce losses
  - Performance monitoring (Plan versus Actual)

- Planning for market positioning
  - Strategic planning, budgeting
  - Identify highest margin products / Make the right product at the right time
Agenda

• The need for Optimization

• **RPMS Project Implementation Methodology**

• RPMS Solution Blue Print

• RPMS Model Development

• RPMS Model Validation & Calibration

• Benefits

• Next Steps
RPMS Project Implementation Methodology

• Phase I - RPMS Model Building
  – RPMS Solution Blue Print
  – Develop RPMS Model

• Phase II - RPMS Model Fine Tuning
  – RPMS Model Validation & Calibration
  – RPMS Commissioning
Agenda

- The need for LP Optimization
- RPMS Project Implementation Methodology
- **RPMS Solution Blue Print**
- RPMS Model Development
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• To work with the Customer ‘s resources to define & describe in a common data repository all the activities relevant to the Petrochemical Facility that may have an economic impact in the RPMS LP model

  – Inputs / Outputs
  – Furnaces : Hot & Cold Section
  – Downstream Processing : EG-1, HDPE, LLDPE, PP, Butene-1, and BTX
  – Utilities

• The RPMS Solution Blue Print contains the “Plant Knowledge” used to built the RPMS model for the Olefin Complex, Downstream Processing and Utilities
### RPMS Solution Blue Print - Furnaces

#### Ethane Operation

**C2 Fresh Feed**
- RPMS Stream Code: C2S
- Composition: Methane, Ethane, Propane

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<th>Composition</th>
<th>RPMS Material Code</th>
<th>RPMS Property Code</th>
<th>RPMS Description</th>
<th>RPMS Position</th>
<th>Value (mol%)</th>
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**C2 Composition Mix**
- RPMS Stream Code: C2M
- Composition: Methane, Ethane, Propylene, Propane

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**Base Case Discussion**
- 845 SOR
- 853 EOR
- 849 Fully loaded (52 Tons/hour)
- 0.35 S/H Constant
- 65% Conversion (Ethane)
- 70% Max Conversion Limit (Ethane)
- 85 COP Constant

**Operating Parameters**
- COT: 830 - 850
- S/H: 0.35 - 0.72
- COP: 72 - KPA

**Capacity**
- 52 Tons/hour (This includes re-cycle)
- 54 Max
- 26 Min
Agenda

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- **RPMS Model Development**
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RPMS Model Development

- How should actual petrochemical activities be represented in the LP model?
  - A model matching current operations and production may be grossly inadequate as a decision support tool
  - Model structure must be sufficiently robust to generate a good economic representation over a practical range of operations

- All "real" physical petrochemical limitations should be modeled explicitly
  - Model it, if it has an economic impact, such as any operating characteristic limit or quality affecting unit economics

- Start simple and add complexity later if needed and understand what you are doing
Use of SPYRO

- Yield prediction program that provides a simulation software for modeling the ethylene Pyrolysis reactors
  - It accepts any hydrocarbon feedstock from ethane through distillates up to 350 °C (662 °F) ASTM D-86 endpoint
  - Produces an accurate, detailed analysis of product yields, furnace performance and coking rates for any feedstock or mixture (co-cracking)

- SPSL – SPYRO for Planning and Scheduling Optimization
  - Extension to SPYRO
  - Allows the reactor model to be called directly from a third-party optimization tool such as RPMS
  - The model is accessed via a FORTRAN subroutine call
    - SPSL(FNAM,SPYIN,DSPYIN,SPYOUT,DSPYOUT,IRET)

- SPSL must be configured with furnace geometry prior to using it
Furnace Model Development Using SPYRO SPSL

- Define Furnaces Operation Modes (e.g. ethane or propane) and Mapping of SPSL Effluent Yields & RPMS

- Create BASE Vector – Using SPSL
  - BASE Detailed Feed Composition
  - BASE Operating Conditions (Conversion, COT, LOAD, S/HC, COP)

- Create DELTA Vectors (Partial Derivatives) – Using SPSL
  - Provide perturbation step size for a Detailed Feed Composition variable in the corresponding input array of DSPYIN
  - Provide perturbation step size for Operating Conditions variables (Conversion, COT, LOAD) in corresponding input array of DSPYIN

- Define / Model Operating Range for Operating Conditions – Conversion, COT, LOAD, ....

- Model Furnaces Capacities & Utilities (Fuel, Steam)
SPSL Effluent & RPMS Mapping

- From 128 components in effluent exiting the furnaces to 40 consolidated components in RPMS
- Material and properties codes corresponding to each component in RPMS are defined and mapped to SPYRO codes
- Properties are automatically tracked and error is distributed properly
# RPMS – Furnace Model Development

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### RPMS – Furnace Model Development

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</table>

**Variables:**
- S: FNAM, SPYIN, DSPYIN, DSPYOUT, IRET
RPMS Olefins Unit Furnaces

- Represented based on SPYRO SPSL simulation runs and Customer technical knowledge as discussed in the RPMS Solution Blue Print
  - Effluent furnaces yields are dynamically adjusted as a function of changes in the feed composition and conversion simultaneously
RPMS Dynamic & Static Model Structures

**INPUTS**

Supply Data:
- Feedstocks Availability, cost & composition

Demand Data:
- Products Demand, price & specifications

Other Input
- Inventory
- Process Unit Capacities
- Planned shutdowns / slowdowns

**OUTPUT**

Profit
Product Mix & Marginal Values
Incremental Opportunities
Process Units Utilization & Operating Parameters – Conversion
Blending Recipes

```
Olefin Cracker
```

Inputs:
- Oxygen
- Ethane MMSCFD
- Propane KBD
- PG Gas

Outputs:
- EG-1
- HDPE
- LLDPE
- PP
- Butene Separation
- BTX Extraction

Utilities
Inventory
Agenda

• The need for Optimization

• RPMS Project Implementation Methodology

• RPMS Solution Blue Print

• RPMS Model Development

• **RPMS Model Validation & Calibration**

• Benefits

• Next Steps
RPMS Model Validation & Calibration

- To confirm that the RPMS model structure represents the Customer operating facilities in terms of key operating variables and economic drivers

- To verify that the model's structural integrity remains intact when subjected to expected and reasonable deviations from typical operation
Model Validation & Calibration Approach & Objective

• **Approach:** Use of the Backcasting Technique
  – To investigate LP process unit variances against actual plant data
  – To understand and determine whether these variances are due to poor actual data or an inaccurate LP model so that “corrective actions (e.g. recovery factors and yields correction, etc) can be taken”

• **Objective**
  – The LP should perform with accuracy of +/- 3% versus Actual Petrochemical Complex data
Model Validation & Calibration - LP vs. Actual Results

- Ethylene production within 1.024% of actual data
- Propylene production within 0.70% of actual data
- MC4 Mix within -0.31% of actual data
- Derivates production within the overall +/- 3% of actual data
Agenda

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• Next Steps
How Are Benefits Achieved

- The RPMS LP model quickly and effectively provides optimal plans that respect operational constraints while meeting market supply and demand constraints
  - Compare actual and planned plant performance to improve planning
  - Enable business investment decisions to be evaluated and compared
Economic Benefits

• Feedstock Selection
  – Flexibility in feed stock purchase alternatives provides a high margin return

• Operations Planning
  – Furnace severity optimization
  – Constraint and recycle optimization
  – Utility consumption/production optimization

• Unit Optimization
  – What is the value of being 5% off on yield predictions?
  – What is the value of being off 1% on optimum conversion?
  – What is the value of being off on fractionation targets?
Benefits

- Realization that is more economically to operate the ethane and propane furnaces at a lower conversion than a higher conversion as it was done previously by operations
  - Saving of around 5% of the Objective Function

- Understanding of the economics implications when re-routing streams to a lower value disposition
  - Sending MC4 to Fuel implies a decreased of 0.6% of the Objective Function

- Change in “operational philosophy” from Tons/day to $/day

- Customer on the proper path to increase the site variable margin by a minimum of 2% - this value shall ensure a project payback well under one year
Agenda

• The need for Optimization
• RPMS Project Implementation
• RPMS Solution Blue Print
• RPMS Model Development
• RPMS Model Validation & Calibration
• Benefits
• Next Steps
Further Expand Solution - The Supply Chain Challenges
Next Steps

- Improve the Technical and Financial Level knowledge of the company personnel.

- Increase the available tools to check in forecasted financial values and operational plants targets against real complex data to maximize net profits – Performance Monitoring using Production Analyst

- Marriage between APC applications and LP software package could improve further financial benefits

- Increase the level of understanding of the overall SABIC complexes from a technical, operational and financial perspective - SABIC global optimization