Advances in Aromatics Technology:
Lowers Paraxylene Cost of Production
Global PX Supply Demand

- The commissioning of new complexes in 2014 led to oversupply of PX
  - Operating rates <80%
  - 10 Million ton surplus capacity
- Steady demand growth combined with a slow down in supply addition has begun consume this excess capacity
  - Utilization rates steadily climbing out of 2014 trough
- China PX import will continue to drive global demand
  - > 10 million ton per year import
Recent PX Technology Advancements by UOP

• Since 2010 UOP has commercialized significant breakthroughs in PX purification technology (2 highlights):

  • Energy Efficient Aromatics Complex (EEAC) – UOP introduced EEAC in 2010, as a novel, proprietary heat integration flowscheme that dramatically reduced energy consumption across the PX complex by 20-40%  
  – This was readily adopted by the industry, now in practice in 3 world-scale commercial plants in operation since 2014 and included in the design in 3 others
  – Unmatched by competitors

  • ADS-47 adsorbent – In 2011 UOP introduced ADS-47 which has dramatically higher capacity than any other commercially used UOP adsorbent, an improvement by 20-25% relative to previous generation UOP adsorbents  
  – Readily adopted by the industry, now ADS-47 is in use in 11 commercial plants

• Light Desorbent (LD) Parex™ Process is here…
Advancements in CCR Platforming Technology
Increase Yield and Reduce CAPEX

Increased Yield and Reduced CapEx Increase IRR by 2 - 6%

**CCR Section**

**ImpX™ Reactor Section**

- CatMax™ Internals

**Recovery Section**

- Enhanced Recovery ($C_5^+, LPG, H_2$)

**CycleMax™ III CCR**

**High Yield Catalyst**

**Integrated Heater Design**

**CFE**

- Reactor Effluent

- Recycle Gas

- Naphtha Feed
CatMax™ Reactor Internals

-8%

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Conventional High-Strength Scallops</th>
<th>CatMax Internals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength vs. D-shaped</td>
<td>Up to 10 times higher</td>
<td>Up to 10 times higher</td>
</tr>
<tr>
<td>Number of Scallops</td>
<td>Base</td>
<td>Base</td>
</tr>
<tr>
<td>Catalyst Volume</td>
<td>Base</td>
<td>Base</td>
</tr>
<tr>
<td>Total Reactor Stack Height</td>
<td>Base</td>
<td>Base - 8%</td>
</tr>
<tr>
<td>Total Transfer Pipe Length</td>
<td>Base</td>
<td>Base - 6%</td>
</tr>
</tbody>
</table>

>1 MM USD Total Installed Cost Savings for New 50,000 BPSD Reformer
Convective Charge Heater Design

• Features
  – Charge heater moved to convection section, displacing portion of steam generation
  – Enables 1 less heater box

• Benefits
  – 15% heater ISBL EEC reduction
  – 4% overall reduced plot space
  – 20% less fuel fired
  – 20% lower emissions

• Builds on UOP Platforming Experience
  – 200+ Fixed Bed units with CFE to convection section using trim radiant heat
  – 30+ CCR Units with one or more column reboilers in the convection section
  – 2+ CCR Unit with Interheater 1 or 3 using convection section heat
  – Supplemental heat for NHT Charge Heater in heater convection section

$5MM Savings for a 50,000 BPSD Unit & 20% Lower Emissions
UOP Heater Design for Larger Units (>50,000 BPSD)

Platforming Unit Interheater #1

### Integrated Heater Designs Reduce Plot Space & Capital Cost

<table>
<thead>
<tr>
<th>Heater Type</th>
<th>Heater in Parallel</th>
<th>Heater in Series</th>
<th>Twin-U Heater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Box Depth, m</td>
<td>Base</td>
<td>More</td>
<td>Base</td>
</tr>
<tr>
<td>Box Width, m</td>
<td>Base</td>
<td>Less</td>
<td>Less</td>
</tr>
<tr>
<td>Plot Area, m²</td>
<td>Base</td>
<td>More</td>
<td>Less</td>
</tr>
<tr>
<td>Manifold Length, m</td>
<td>Base</td>
<td>Double</td>
<td>Base</td>
</tr>
<tr>
<td>Number Burners</td>
<td>Base</td>
<td>Base</td>
<td>Less</td>
</tr>
</tbody>
</table>
CAPEX and OPEX Trade-off

Utilities Savings Typically Achieved at the Expense of Additional Capital Investment

UOP's Latest Generation Design Enables 20-40% Utilities Savings with 15-20% Capital Savings

UOP’s Latest Generation Design Enables 20-40% Utilities Savings with 15-20% Capital Savings

LD Parex Process Shifts the Paradigm of Energy Efficiency Trade-off with CAPEX
Heavy Desorbent Has Been the Primary System Used for Selective PX Adsorption

History

- Both heavy (HD) and light (LD) desorbent systems were used when UOP introduced the Parex process in the 1970s
  - Adsorbents were available developed for both systems
  - Units were designed for either HD or LD, based on preference of the owner
- HD systems had an energy advantage over LD systems with adsorbent technology available at the time
  - Since the late 1970’s, virtually all new Parex designs have used HD

Modern

- By 2010, improvements in adsorbent technology have enabled designs with LD to have equivalent energy consumption as those with HD
- LD offers significant opportunities to reduce CAPEX by eliminating equipment
  - ADS-47 adsorbent is well proven as providing a step-change in performance

What if we take the knowledge we now have of the HD system adsorbent and apply it to an LD system?
Commercial Demonstrations ADS-47 Adsorbent Prove the Step-change Increase in Performance

Relative Requirement to Process Same Amount of Feed

Parex Design Benefits from ADS-47
- Adsorbent chamber reduced by 35%
- Desorbent circulation reduced by 32%
- Highest commercially proven reliability
- Successful operation in 11 units starting in 2011

Significant Breakthrough in Paraxylene Separation Adsorbent Technology Provides Ability to Improve Light Desorbent Economics
Continuous Innovation Translates Across Both Heavy & Light Desorbent Systems

In 45 years, All Production Capacity & Product Quality Guarantees Achieved
Compared to a heavy desorbent system, using light desorbent enables separation efficiencies that allow for an optimized fractionation flow scheme, enabling high energy efficiency at a significantly reduced cost.

- Uses Heavy Desorbent (p-DEB)
- Desorbent taken as Raffinate & Extract Column Bottoms
- Xylene Fractionation requirements set by $A_9$ limit in Xylene Column overhead
- Energy reduced 20-40% by evaluating overall complex as a “system” and rearranging heat integration
The 3 main components of the LD Parex Aromatics Complex system are all commercially proven & reliable:

1. Desorbent
2. Adsorbent
3. Heat Integration

- Uses Light Desorbent (Toluene)
- Desorbent taken as Raffinate Column overhead & Extract Column sidedraw
- Α limit in XC overhead no longer a design constraint
- Overall complex still evaluated as a “system” to increase heat integration and reduce energy input
## Independent Cost Savings Analysis by Major Western EPC

### Process Unit Comparison (1200 KMTA PX)

<table>
<thead>
<tr>
<th>Process Unit</th>
<th>Next Best Alternative</th>
<th>LDPX Delta (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extractive Distillation</td>
<td>Base</td>
<td>+12%</td>
</tr>
<tr>
<td>B-T Fractionation</td>
<td>Base</td>
<td>-0%</td>
</tr>
<tr>
<td>Transalkylation</td>
<td>Base</td>
<td>-6%</td>
</tr>
<tr>
<td>PX Purification</td>
<td>Base</td>
<td>-2%</td>
</tr>
<tr>
<td>Isomerization</td>
<td>Base</td>
<td>-39%</td>
</tr>
<tr>
<td>Xylene Fractionation</td>
<td>Base</td>
<td>-46%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>-17%</strong></td>
</tr>
</tbody>
</table>

**1,200 kMTA pX complex; USGC basis:**
- Equipment Cost Savings = 17%
- Total Installed Cost Savings = 15%

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### Equipment Cost Comparison, Breakdown by Unit

#### Next Best Alternative
- Extractive Distillation
- B-T Fractionation
- Transalkylation
- PX Purification
- Isomerization
- Xylene Fractionation

#### LD Parex Aromatics Complex
- Extractive Distillation
- B-T Fractionation
- Transalkylation
- PX Purification
- Isomerization
- Xylene Fractionation

17% equipment cost savings

20% Reduction in Equipment Results in 15-17% Capital Savings, as Confirmed by a Major Western EPC
**Light Desorbent Commercial Experience**

<table>
<thead>
<tr>
<th>Year</th>
<th>Service</th>
<th>Status</th>
<th>Capacity kMTA</th>
<th>Region</th>
</tr>
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<tbody>
<tr>
<td>1972</td>
<td>Parex process</td>
<td>Operation</td>
<td>120</td>
<td>Europe</td>
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<tr>
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<td>Parex process</td>
<td>Operation</td>
<td>90</td>
<td>Americas</td>
</tr>
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<td>1998</td>
<td>MX Sorbex™ process</td>
<td>Operation</td>
<td>50</td>
<td>Americas</td>
</tr>
<tr>
<td>1998</td>
<td>MX Sorbex process</td>
<td>Operation</td>
<td>50</td>
<td>Asia</td>
</tr>
<tr>
<td>1998</td>
<td>MX Sorbex process</td>
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<td>Operation</td>
<td>50</td>
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<td>Operation</td>
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<td>2007</td>
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<td>2008</td>
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<tr>
<td>2012</td>
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<tr>
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<tr>
<td>2017</td>
<td>LD Parex process</td>
<td>D&amp;C (o/s 3Q2020)</td>
<td>800</td>
<td>EMEA</td>
</tr>
</tbody>
</table>
UOP Continuous Innovation in Aromatics Technologies

LD Parex Units
- 6 Design/Construction

EEAC
- 3 in operation
- 3 Design/Construction

Conventional

2011

15-17% CAPEX Reduction
20-25% Energy Consumption Reduction

2015

1971 - 2010

20 – 40% Energy Consumption Reduction

OPEX Reduction and CAPEX Reduction

LD Parex Process Lowers the Cost of pX Production
Where is LD Parex Process on the PX Cost Curve?

Global ParaXylene Variable Cost Curve
Oil 50 $/BBL, Natural Gas (NEA) 7$/MM BTU

- UOP LD Parex Process in Asia
- UOP LD Parex Process in the Middle East
- Competing Technology in Mid-East

Annual PX Supply (Million Tons)

UOP LD Parex Process Provides Substantial Cost Advantage
Leveraging Historically Proven UOP Technology for Your Future Success

- UOP’s 45 years of experience with adsorption-based separation technology in >100 operating units enables us to lead the market in innovation.

- Recent breakthroughs by UOP in adsorbent development capability make light desorbent separation technology economically superior relative to any other PX purification process.

- The 3 major components of the LD Parex Aromatics Complex design—desorbent, adsorbent and heat integration—are all commercially proven & reliable.
  - 6 LD Parex Complexes are now in Design and Construction.

- LD Parex Process enables a step-change improvement in capital efficiency while still maintaining the industry-leading energy efficiency.

LD Parex Process is the lowest cost UOP Technology available for PX production and provides greater return on your investment.