Recent Advances in Cumene/Phenol/Acetone Technology:

Energy Efficient Versalis/Lummus Cumene - Phenol Technology for Minimizing Operating Costs

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versalis technology conference: value to compete
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Bangkok, Thailand
Agenda

- Overview
- Cumene
- Phenol-Acetone
- Acetone Recycle
- Summary
• Producing cumene and phenol since 1964
• Started liquid-phase cumene operation in 1996
• Plant operations at two sites
  – Mantova, Italy – 300,000 MTA
  – Porto Torres, Italy – 200,000 MTA (recently shutdown)
• One phenol licensee plant in operation
  – Domo, Germany – 160,000 MTA

Over 45 years of cumene and phenol plant operations experience

More than 98% on-stream factor
<table>
<thead>
<tr>
<th><strong>Technology Licensing</strong></th>
<th>CB&amp;I</th>
<th>Versalis</th>
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<tbody>
<tr>
<td>Marketing and licensing</td>
<td>✓</td>
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<tr>
<td>Process design</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Training</td>
<td>✓</td>
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<tr>
<td>Start-up assistance</td>
<td>✓</td>
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<td>Catalyst supply</td>
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<td>✓</td>
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<tr>
<td>Follow-up technical service</td>
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<tr>
<th><strong>Technology Maintenance</strong></th>
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<td>Process enhancements</td>
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<td>Catalyst R&amp;D</td>
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<tr>
<td>Technology Development</td>
<td>✓</td>
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<tr>
<td>Company</td>
<td>Capacity (mta)</td>
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<td>------------------------------</td>
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<td>FCFC, Taiwan (Expansion)</td>
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<td>GE Plastics, USA</td>
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<td>Herdillia Chemicals, India</td>
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<td>Georgia-Gulf, USA</td>
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<td>Texaco Chemical, USA</td>
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<td>BTL of Illinois, USA</td>
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**Three new Versalis/Lummus technology projects:**
- Petronas, Malaysia – 203 kMTA phenol
- FCFC, China - 450 kMTA cumene/300 kMTA phenol
- Essar, India - 270 kMTA cumene/200 kMTA phenol
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• State-of-the-art, liquid-phase, zeolite technology
• Highly experienced Versalis/Lummus partnership
  – Versalis: leading petrochemical company with production plants based on PBE-type proprietary zeolite catalyst
  – CB&I: long history of development and commercialization with zeolitic aromatic alkylation processes, both cumene and ethylbenzene
• Superior PBE-1 zeolite catalyst based technology
• High quality products suitable for all requirements
• Low investment and plant operating cost
Alkylation

\[ \text{C}_3\text{H}_6 \quad + \quad \text{(Propylene)} \quad \text{(Benzene)} \quad \rightarrow \quad \text{CH(CH}_3)_2 \quad \text{(Cumene)} \]

\[ \text{C}_3\text{H}_6 \quad + \quad \text{CH(CH}_3)_2 \quad \rightarrow \quad \text{[CH(CH}_3)_2]_2 \quad \text{(Diisopropylbenzene)} \]

Other side products: n-propylbenzene, non-aromatics, heavies,

Transalkylation

\[ \text{[CH(CH}_3)_2]_2 \quad + \quad \text{[CH(CH}_3)_2]_2 \quad \leftrightarrow \quad 2 \quad \text{CH(CH}_3)_2 \quad \text{(Cumene)} \]

Other side products: EB, butylbenzene, heavies
• Versalis PBE-1 Proprietary Beta Zeolite
  – Alkylation and transalkylation
• Superior yield
• Superior catalyst formulation
  – Unique morphology
  – Optimum zeolite acidity and porosity
  – Demonstrated superior stability/durability
  – Ease of regeneration
• Non-detectable catalyst deactivation rate
  – Extended catalyst life
  – Unique catalyst performance tracking system
  – Proprietary catalyst rejuvenation procedure
• High mono selectivity and negligible formation of coke
• 99.7 wt% product yield
• 100% propylene conversion throughout entire run
• Ultra high cumene product purity of 99.95 wt%
  – N-propylbenzene (<300 wppm)
  – low Bromine Index (< 1) without clay treatment
• Water injection allows for higher reactor operating temperatures without increasing impurity make
• Efficient LP steam production which is utilized in the phenol unit
• All carbon steel construction
• Simple operation and low maintenance
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• **State-of-the-art technology**
  – Safe and reliable wet oxidation technology based on gas lift reactors
  – Optimized cleavage technology based on loop reactors
  – Glycol based extractive distillation technology

![Diagram of the process flow](image-url)
**Process Chemistry**

- **Cumene**
  - $\text{CH}_3\text{-C-CH}_3$
  - $\text{O}_2$ → **Cumene Hydroperoxide**
  - **Acetophenone**
  - $\text{CH}_3\text{-C-CH}_3$
  - $\text{O}_2$ → **Dimethyl benzyl alcohol**
  - $\text{H}_2$ → **Alpha-Methylstyrene**
- **Acid** → **Phenol**
  - $\text{CH}_3\text{-C-CH}_3$
- **Acid** → **Acetone**
  - $\text{O}_2$
- Oxidation
- Cumene stripping
- Cleavage
- Neutralization

- Acetone fractionation
- Phenol extraction
- AMS hydrogenation
- Dephenolation
• High yield
  – Cumene consumption of < 1.31 kg/kg of phenol

• Highest quality products
  – Only phenol/acetone process commercially proven to produce pharmaceutical grade acetone

• Low environmental impact of air and water emissions

• Low energy consumption
  – Glycol based extractive distillation
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Over 90% of world’s phenol production currently via cumene hydroperoxide route that produces acetone as a by-product.

Phenol and acetone produced in fixed ratio:

- 0.62 ton of acetone per ton of phenol

Market demands for phenol and acetone not in same ratio.
• Two new Versalis/Lummus technology solutions:
  1. Alternate product
     – Acetone to isopropyl alcohol (IPA)

  2. Propylene feedstock reduction
     – Acetone recycle to cumene (under development)
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• New technology solutions to minimize acetone byproduct
• State of the art commercially proven technologies
• Only licensor/operator with over 45 years of operating experience
• Unique position to offer full range of phenolic technologies for green polycarbonate production