CB&I’s Advanced Alkylation Technologies: CDA/ky® and AlkyClean®

SCAQMD Working Group Meeting
Diamond Bar, California
August 2, 2017
This presentation contains forward-looking statements regarding CB&I and represents our expectations and beliefs concerning future events. These forward-looking statements are intended to be covered by the safe harbor for forward-looking statements provided by the Private Securities Litigation Reform Act of 1995. Forward-looking statements involve known and unknown risks and uncertainties. When considering any statements that are predictive in nature, depend upon or refer to future events or conditions, or use or contain words, terms, phrases, or expressions such as “achieve”, “forecast”, “plan”, “propose”, “strategy”, “envision”, “hope”, “will”, “continue”, “potential”, “expect”, “believe”, “anticipate”, “project”, “estimate”, “predict”, “intend”, “should”, “could”, “may”, “might”, or similar forward-looking statements, we refer you to the cautionary statements concerning risk factors and “Forward-Looking Statements” described under “Risk Factors” in Item 1A of our Annual Report filed on Form 10-K filed with the SEC for the year ended December 31, 2016, and any updates to those risk factors or “Forward-Looking Statements” included in our subsequent Quarterly Reports on Form 10-Q filed with the SEC, which cautionary statements are incorporated herein by reference.
Agenda

- CB&I Overview Snapshot
- Introduction – Alkylation Technologies
- CB&I’s Solid Catalyst Alkylation Technology - AlkyClean
- CB&I’s Advanced Low Temperature Sulfuric Acid Alkylation Process - CDAIky
Corporate Overview

- Leading provider of technology and infrastructure for the energy industry
- 125+ years of experience and expertise in reliable solutions
- $18.5 billion backlog (Dec. 31, 2016)
- More than 40,000 employees worldwide
- Relentless focus on safety: 0.01 LTIR for 2016
Introduction: Non-HF Options for Alkylation Processes

- **Solid Acid Catalyst Alkylation**
  - Inherently safer than liquid acid technologies, particularly HF
  - CB&I and Albemarle successfully commercialized the first solid acid alkylation technology in China in 2015 using AlkyClean technology (capacity 2,700 BPD)
  - AlkyClean technology is the first and only commercialized solid acid alkylation technology in the world

- **Ionic Liquid Alkylation**
  - Ionic Liquid alkylation was commercialized in a 2,400 BPD unit in China (2013).
  - Capital intensive: $130 MMUSD for 2,400 BPD (complex IL/HC separation)
  - High utility consumption: 50% more than sulfuric acid alkylation
  - Chlorides in the alkylate product: Post-treatment unavoidable
  - Reported alkylate quality falls short of a technology breakthrough

- **Sulfuric Acid Alkylation**
  - CDAlky has become the *technology of choice* for sulfuric acid alkylation due to its innovative design.
  - Commericially proven since 2013
  - 13 awards, 8 of which occurred during the past year, 1 in the US on C5 olefins
AlkyClean Technology
AlkyClean Process: Simplified Block Flow Diagram

Make-up i-Butane

Olefin Feed

Feed Pretreatment

Reaction Section

Product Fractionation Section

Hydrogen Rich Fuel Gas

i-Butane

n-Butane Product

Alkylate Product

Hydrogen

Catalyst Regeneration
AlkyClean technology …

- Reduces the client’s operational risk by eliminating safety and chemical process hazards associated with handling liquid acid.
- Is now commercially proven and is easy to operate thanks to an innovative solid catalyst and process combination.
- Employs a fixed-bed reactor system with a zeolite-based particulate catalyst.
- Regenerates the catalyst on a cyclical basis, fully restoring catalyst activity.
- Requires no post-treatment or product washing, further reducing its environmental footprint.
- Produces a high octane, low RVP alkylate on par with other technologies.
- Has been optimized for low to average capacities.
The world’s first and only commercial scale solid acid catalyst alkylation unit was successfully started up in August 2015 at Shandong Wonfull Petrochemical Group Co, Peoples Republic of China.

- Capacity: 2,700 BPD of Alkylate production.
- The startup of the unit, employing AlkyClean technology, went smoothly and safely.
- Performance test successfully completed within four (4) months. All guarantees met.
- The unit has been in operation for nearly two (2) years producing an excellent quality alkylate product.
CB&I and Albemarle received the Presidential Green Chemistry Award from the U.S. Environmental Protection Agency on 6/13/16, in recognition of AlkyClean technology in the category of 'Providing Greener Synthetic Pathways.'
CDAAlky Technology
CB&I’s innovative and advanced sulfuric acid alkylation technology, ‘CDAlky,’ offers the refiner

- Low operating costs
- Low capital investment requirement
- Ease of operation, and feed flexibility
- Interval for major turn expected to be 6 years or more
- Excellent alkylate product quality

‘Breaking the low temperature barrier’
CDA/ky Process: Simplified Block Flow Diagram

- Olefin Feed
- Isobutane Make-up

Olefin Feed → CDA/ky → Acid-HC Coalescers → Refrigeration

- Acid
- Fresh Acid
- Spent Acid

Refrigeration → Propane → iC4 recycle

Post Treatment is Eliminated

- Acid
- Caustic Water

Acid-HC Coalescers → Effluent

- Post Treatment
- Waste Water

Effluent → Fracation

- n-Butane
- Alkylate Product

- Alkylate Product
CDA/ky Key Advantages vs ‘Conventional’ Sulfuric Acid Alkylation Technology: Process Simplification

- Innovative Reactor Design
  - Vertical down-flow packing easy to scale-up
  - No moving parts, minimal maintenance
  - Low temperature operation
  - Boiling point operation - direct cooling
  - Controlled acid/olefin ratio with innovative distributor
  - Small footprint – single reactor up to 12,500 BPD

- Effective and Controlled Acid/ Hydrocarbon Separation
  - Controlled acid droplet size
  - Higher sulfuric acid utilization rate
  - Elimination of alkylate post treatment unit
  - Dry reactor effluent – lower corrosion

- Key to Success - Proprietary Design
CDAlky Key Advantages vs ‘Conventional’ Sulfuric Acid Alkylation Technology: Low Temperature

CDAlky Breaks the Low-Temperature Barrier Through Innovative Reactor Design:

- Maximizes selectivity, octane value, and yield (1,2)
- 30-50% lower acid consumption! (1,2)
- Lower corrosion rate

CDA/ky Key Advantages vs ‘Conventional’ Sulfuric Acid Alkylation Technology: Acid/ HC Separation

Innovative CDA/ky Design for Improved Acid/Hydrocarbon Separation:

- Droplet Size & Distribution Controlled with CDA/ky

Mechanically Agitated Reactors

Sulfur Content of Alkylate Product: 5,000 BPD CDA/ky Unit

- 2 ppmw sulfur in alkylate on average
- More than 110% of design capacity achieved with S < 5ppmw

CDAlky Improvements:
- Increased Acid Utilization
- Dry Effluent to Fractionation
- Elimination of Post-Treatment Steps and Associated Process Equipment
- Elimination of Downstream Fouling
CDAlky Commercial Experience List

- CDAlky has become the sulfuric acid alkylation Technology of Choice
- Approximately 130 kBPD alkylate capacity to be commissioned by 2020

<table>
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<tr>
<th>Licensee</th>
<th>Capacity</th>
<th>Start-up</th>
<th>Awarded</th>
<th>Feedstock</th>
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Footnotes:
(1) Licensed CDAlky Unit exceeded all process performance guarantees
(2) Client operates competitor’s conventional sulfuric acid alkylation technology – CDAlky technology selected over incumbent technology. Projects now in engineering phase.
CDA/ky Technology: Key Takeaways

- Consumes 30-50% less acid compared to ‘conventional’ sulfuric acid alkylation technologies.
  - Less acid to transport, handle, store, or regenerate.
- Requires no post-treatment or product washing, further reducing its environmental footprint.
- Requires conventional and less frequent maintenance, thereby reducing operator and maintenance craft exposure to acid, relative to ‘conventional’ sulfuric acid technology.
- Is ideal for sites with limited plot space.
  - Single vertical reactor scalable to 12,500 BPD.
- Is commercially proven.