CD*Alky*® Alkylation Technology

MCDERMOTT TECHNOLOGY

Overview

The CD*Alky* technology is the most advanced, proven sulfuric acid alkylation process for the production of motor fuel alkylate. It reacts light olefin streams from refinery and petrochemical sources with iso-paraffins to produce motor fuel alkylate. Central to the CD*Alky* process is an innovative contactor/reactor design that significantly reduces mass transfer resistance relative to conventional contactors. The CD*Alky* process operates at significantly lower temperatures than conventional alkylation processes providing improved alkylate quality and yield. The CD*Alky* process is available for license to the petroleum refining and petrochemical industries.

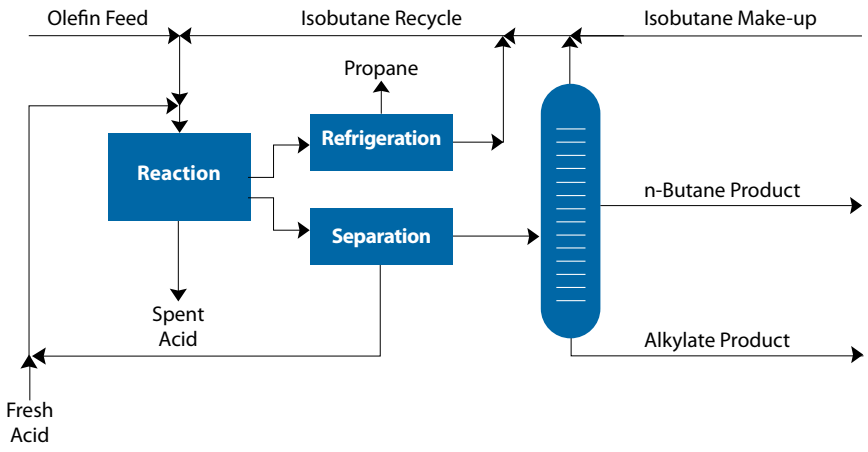
Alkylation for Motor Fuel

The process flow diagram shows the basic configuration to process a mixed C_4 olefin feed and produce a bright, clear, high-quality motor fuel alkylate. The CD*Alky* process yields a higher quality product while consuming significantly less acid than conventional technologies. The flow scheme is also less complex than conventional designs, which reduces capital and operating costs.

The CD*Alky* process requires no rotating mixers or effluent post-treatment, which further improves reliability and on-stream time. Lummus Technology has developed a novel contactor that takes advantage of our unique expertise in mass transfer technologies to lower operating temperature and to reduce acid consumption by up to 50 percent or more.

The CD*Alky* process has been successfully proven in commercial service since 2013. Four units are now in commercial operation with more in construction or design.

CDAlky Process Flow Diagram



Process Advantages Breakthrough Alkylation Technology

The CD*Alky* process is the most advanced sulfuric acid alkylation technology. The technology is simple, innovative, flexible and robust with respect to both feedstock and operation. Until now, sulfuric acid alkylation is one of the few refinery processes that remained essentially unchanged since its introduction in the early 20th century. The CD*Alky* process represents the first step change in sulfuric acid alkylation technology.

Proven Chemistry and Reactor Technology

The CD*Alky* technology is based on commercially proven sulfuric acid alkylation chemistry that has been practiced in the industry for more than 60 years. Lummus Technology has paired this well understood chemistry with its proven innovative reactor designs.

Higher Octane Alkylate and Lower Acid Consumption

The CD*Alky* process's simple innovative design enables operation at significantly lower temperatures than conventional alkylation processes. Low reaction temperatures inhibit unwanted side reactions and increase C_8 selectivity to produce a higher value, higher octane (RON 97-98), finished alkylate product at higher yield while reducing acid consumption by up to 50 percent compared to conventional technology.

Simplify the Alkylation Process

The CD*Alky* process reduces both the equipment piece count and the operational complexity by eliminating rotating mixers and post reactor water/alkaline wash, as well as the operating issues that these processes create. Plot space is significantly lower than that required by conventional technology.

No Rotating Mixers

The CD*Alky* process utilizes static internals in a scalable, vertical reactor to achieve hydrocarbon/acid contacting. This reduces maintenance, downtime and operating cost. In addition, by eliminating rotating mixers, the CD*Alky* process is able to operate at very low temperatures.

No Reactor Acid Wash or Alkaline Water Wash

By eliminating rotating mixers, emulsion drop size is optimized which eliminates the need for a reactor effluent acid wash and alkaline water wash typical of conventional alkylation processes. The CD*Alky* process uses high performance coalescers to allow for a quick, clear separation of the acid emulsion from the hydrocarbon product. This reduces maintenance and chemical costs as well as the environmental impact of the alkylation process. Also, since no additional water is added to the alkylate product, corrosion is significantly reduced in the product fractionation section.

Lower Capital and Operating Costs

The CD*Alky* process offers a simpler route to high quality alkylate. Compared with conventional alkylation processes, the CD*Alky* technology offers greater economies of scale and a lower piece count to reduce the installed cost. Elimination of rotating mixers and the elaborate effluent wash system reduces long-term maintenance costs.

Commercialized Technology

Commercial operations of the CDAlky technology since the first unit started up in 2013 have demonstrated high octane alkylate product (RON 98+) and low acid consumption along with feedstock flexibility and robust operation.

Maintenance Findings

Bottom of the CDAlky reactor at Sincier

Maintenance inspections were conducted at two commercial CD*Alky* units. Findings confirm corrosion rates and fouling propensity are greatly reduced with CD*Alky* technology relative to conventional technology.

Shandong Sincier shut down their FCC unit for a planned turn-around in October 2014 and took the opportunity to also inspect the alkylation unit which was a year-and-a-half into its run. No signs of corrosion, damage, pitting, or hydrogen grooving were found during this inspection.

Piping in acid service at Sincier

Ningbo Haiyue shut down their CD*Alky* unit in late July, 2017, due to local safety regulations. The inspection revealed, as with the Sincier unit, no visible signs of corrosion or fouling in the reactor section, coalescers, or fractionation system. All proprietary equipment was in good condition thus requiring no replacement. Three years of operation demonstrates robust operation with no underlying or fundamental fouling or corrosion issues.

DIB reboiler bundle at Haiyue

Design Philosophy and Low Corrosion

CD*Alky*'s innovative reactor design mitigates corrosion and fouling issues.

- Better droplet size control increases acid utilization and limits acid droplets leaving the reactor.
- Eliminates acid wash and alkaline wash typical for conventional processes.
- Elminates downstream corrosion and fouling problems as the CD*Alky* reactor effluent is dry and absent of acid carryover. Corrosion rates, associated maintenance costs and safety risks are greatly reduced.
- The unit operates in an acid to olefin regime that minimizes the formation of stable, hydrocarbon soluble sulfates resulting in very low sulfur in the alkylate product.

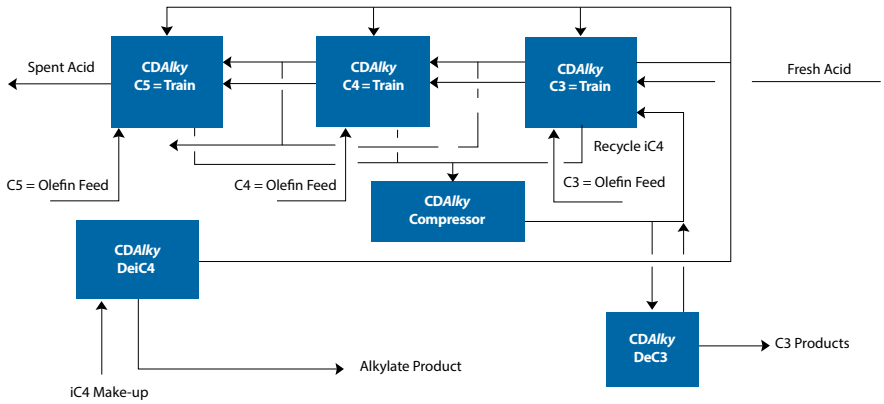
Processing of Opportunity Feeds

Processing opportunity feedstocks, such as propylene, butylenes from dehydrogenation units, and C_5 olefins, can significantly enhance revenue for the refiners and petrochemical producers with an optimized processing strategy.

Although alkylation of propylene, isobutylene, and amylene has been long practiced in North America, technical challenges have constrained the economic benefits to the refiner, and thus limited a broader acceptance of these opportunity feedstocks. CD*Alky* technology addresses all of these challenges employing an innovative and optimized processing scheme as shown in the figure below, that enable all olefins to react at optimum conditions.

The sulfuric acid and hydrocarbon streams are cascaded, for example, from the propylene reactor to the butylene reactor. The alkylate product from the propylene reactor, which is rich in isobutane and untreated (no post treatment), can be fed directly to the butylene reactor. Other technologies cannot cascade alkylate product because of the high degree of back-mixing. The stable propyl sulfate intermediates generated in the propylene alkylation reactor will further react in the low temperature butylene reactor enhancing the overall product yield and decreasing acid consumption. Utility, capital costs and acid consumption are reduced, and alkylate quality is improved. The cascading can be continued with a C_5 olefins reactor.

CD*Alky* technology is also eminently suitable for employing iso-pentane as the iso-paraffin.



References

Licensee	Capacity BPD	Capacity KTA	Year Award	Year Start-up	Feedstock
Sincier, PRC (1)	5,000	200	2012	2013	C_4 Raffinate
Haiyue, PRC (1)	15,000	600	2011	2014	C_4 Raffinate
Tianheng, PRC (1)	5,000	200	2012	2014	C_4 Raffinate
YuTianHua, PRC	6,800	265	2014	2017	C_4 Raffinate
S-Oil, Korea (2)	16,000	625	2014	2018	C_4's
Pertamina, Indonesia (2)	7,400	290	2016	2019	FCC C_4's
Valero, USA (2)	23,000	900	2016	2020	FCC olefins
Zhejiang Pet Co (ZPC), PRC	14,000	555	2016	2018	C_4 Raffinate
Yanchang, PRC	5,000	200	2016	2019	C_4 Raffinate
PetroChina Dalian, PRC	9,000	350	2017	2018	C_4 Raffinate
PetroChina Urumqi, PRC	5,000	200	2017	2018	C_4 Raffinate
PetroChina Jinzhou, PRC	6,500	250	2017	2018	C_4 Raffinate
PetroChina Jilin, PRC	9,000	350	2017	2018	C_4 Raffinate

(1) Licensed CD*Alky* unit exceeded all process performance guarantees

(2) Client operates conventional sulfuric acid alkylation technology. CD*Alky* technology selected over incumbent technology.

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