KBR Solid Acid Alkylation Technology
K-SAAT℠

While global gasoline demand trends will vary by region over the coming decades, a universal trend towards cleaner burning, higher octane fuels is expected to continue. KBR's Solid Acid Alkylation Technology, K-SAAT, produces an ideal low RVP, clean-burning and high-octane gasoline blend component, alkylate.

Technological improvements to increase gasoline engine fuel economy require high octane gasoline to prevent engine knock. At the same time, a tightening of gasoline sulfur limits results in loss of octane from some blend stocks. With strict limits on aromatics and oxygen content of gasoline, reformate and oxygen do not offer a complete solution.

The potential of alkylate is only limited by the costly concentrated liquid acid technology that, until now, was required to produce it. KBR has developed a new refinery alkylation process that overcomes this challenge.

K-SAAT has the flexibility to process a variety of light olefinic feedstocks to produce higher quality alkylate than conventional liquid acid alkylation.

A Simpler, Safer and More Sustainable Alternative for High-Quality Alkylate Production

COMMERCIALLY PROVEN AND CLEANER BY DESIGN

Gasoline is a combination of several refinery-produced components – reformate, FCC gasoline, alkylate, isomerate, etc. – that are blended to meet strict gasoline specifications. With its high octane number, low Reid vapor pressure (RVP) and absence of aromatic and olefinic compounds, alkylate is an ideal fuel that burns clean. It especially aids in reducing RVP impact due to ethanol blending and increases dilution of aromatics from reformate to benefit octane and still meet tighter gasoline specifications.

Technologies traditionally used to produce alkylate require concentrated liquid acid – either hydrofluoric acid or sulfuric acid – as catalyst. Both of these processes have high capital costs and inherent HSE hazards. KBR introduces K-SAAT℠, an engineering process and service, and next-generation alkylation technology capable of processing light olefins (C2-C5) with isobutane to produce high-quality alkylate using a unique non-precious-metal solid catalyst. The key to K-SAAT technology is its revolutionary catalyst, engineered to overcome traditional solid-catalyst stability limitations and produce high-quality alkylate with higher alkylate yield than traditional alkylation technologies. A commercial K-SAAT unit has been operating successfully since 2018. Following this success, further projects are in design.

Licensee	Location	Awarded	Type	Status
Haike Ruilin Chemical Co. Ltd	Shandong, China	2016	Grassroots	Operating
Luoyang Refinery Aoyou Chemical Industry CO.,LTD.	Henan, China	2017	Grassroots	Refinery Project on hold
CVR Energy	Wynnewood, OK, USA	2018	HF Revamp	Modular EP Supply
Confidential	USA	2019	Sulfuric Acid Revamp	FEED
Confidential	Confidential	2021	HF Revamp	Engineering

ENGINEERED CATALYST

Solid catalysts have long-promised safer and cleaner alkylation. However, the short lifetimes of most solid catalysts have resulted in expensive processes with complex reactors and large catalyst inventories, making them uncompetitive with liquid-acid technologies.

The solid-acid catalyst used in K-SAAT has been engineered to outperform liquid-acid catalysts and other solid-acid catalysts on multiple levels. The strength and distribution of the active catalyst sites have been tuned to promote formation of high-octane trimethylpentanes.

The catalyst pore structures of K-SAAT have been optimized to enhance the diffusion of high-octane C_8 alkylate product. The result is a catalyst that produces higher quality alkylate than sulfuric acid and HF acid alkylation technologies with any feedstock. The robust catalyst has a five year guaranteed lifetime.

VALORISATION OF FCC & COKER OFF GAS

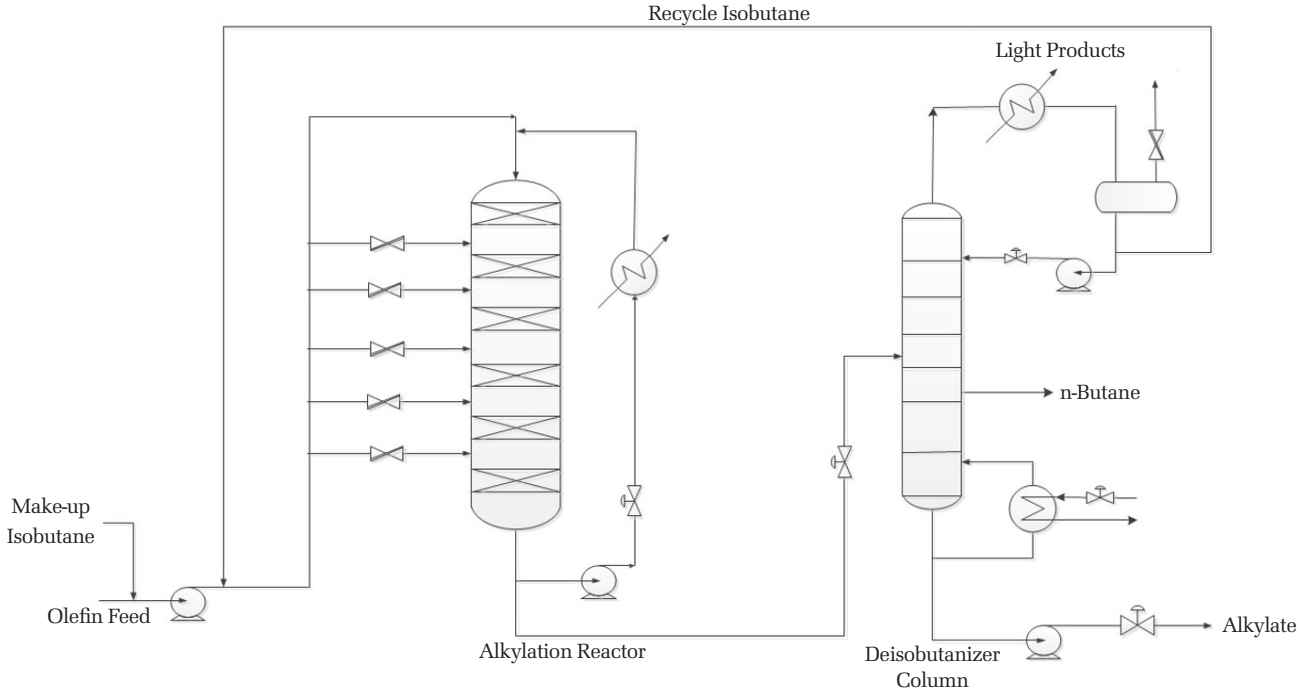
KBR offers K-SAAT, with integrated ethylene recovery from dry gas, to deliver high road octane, low RVP, alkylate with more than double the yield of conventional dry gas to liquid technologies. This scheme utilizes moderate ethylene recovery conditions to reduce energy consumption and deliver greater economic value, while making better use of valuable resources and decarbonizing the fuel gas network.

SIMPLE PROCESS – LOW CAPEX

The design and performance of the solid acid catalyst allows a simple process design to be employed. No catalyst additives are used so no catalyst separation and product treatment equipment is needed. Due to low equipment count and no exotic materials, K-SAAT is the lowest CAPEX technology for grassroots and revamp projects.

K-SAAT uses three fixed-bed reactors. While two reactors are in alkylation mode (24 hours), the third undergoes regeneration (12 hours). The K-SAAT process operates at a reactor temperature of (120°F/50°C) in a liquid-phase environment. No refrigeration is required.

The catalyst is completely regenerated with hydrogen at 525°F/275°C after each cycle. Oligomers and contaminants are removed during the regeneration process, restoring the catalyst activity for the next alkylation cycle.



K-SAAT Process Diagram

PROCESS BENEFITS

Sustainability: The K-SAAT process has lower carbon intensity than liquid-catalyst alkylation and produces no liquid waste effluents.

Safety: The K-SAAT catalyst is safe to handle and environmentally benign.

Product Yield and Octane: K-SAAT produces up to 99 RON alkylate and no acid soluble oils (ASO/conjunct polymer) byproduct.

Maintenance: The K-SAAT process uses no corrosive liquids and has fewer equipment items, reducing maintenance cost and complexity.

Feed Flexibility: K-SAAT offers the unique ability to convert ethylene to 99 RON, C_8 alkylate in a single step.

ECONOMIC BENEFITS

The K-SAAT process design is simpler than liquid catalyzed alkylation, with fewer equipment items and no exotic metallurgy. K-SAAT requires no refrigeration, acid storage, acid separation, neutralization or product treatment equipment. K-SAAT is the lowest-CAPEX technology for grassroots and revamp applications.

K-SAAT offers higher operating margins than liquid ctalyzed processes due to higher alkylate yield and octane, lower operating costs, and lower maintenance costs.

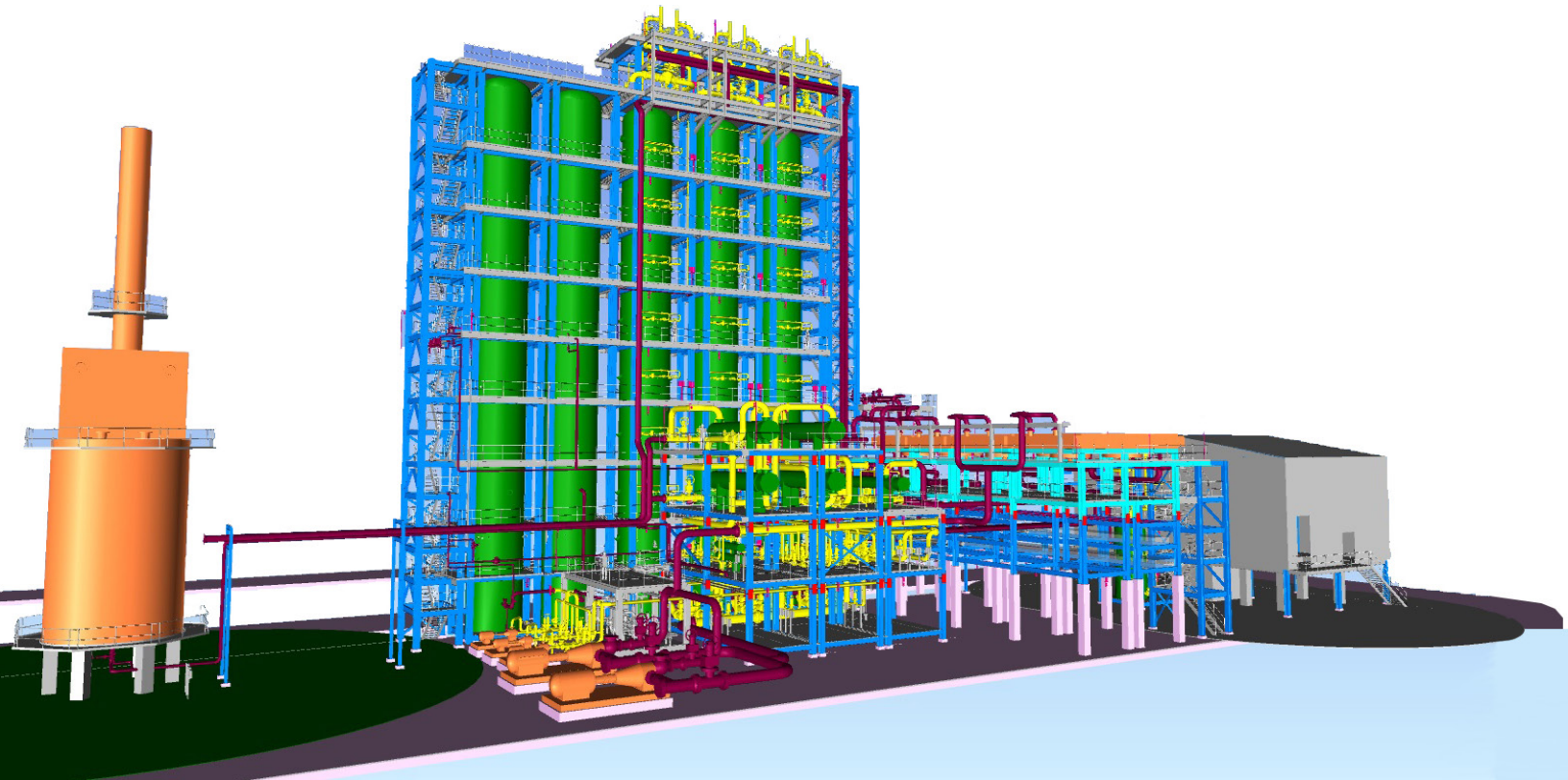
MODULAR SUPPLY

KBR offers modular supply of K-SAAT alkylation units for both revamp and grassroots applications. KBR modularized units offer many benefits:

High-end Design: KBR's integrated modularized K-SAAT units optimally unite efficient technology and superior engineering services with flawless design and seamless execution.

Quality and Reliability: One-stop shop offering quality and reliability of shop manufactured modules, removing site construction inconsistencies.

Safety: Systematic and planned fabrication in a shop environment enhances efficiency while reducing the occurrence of accidents on site by reducing on-site scope.



REVAMP OPPORTUNITIES

Revamp projects offer the opportunity to benefit from the safety, sustainability and economic advantages of K-SAAT technology while retaining and reusing some of the existing assets. While some revamp projects will be primarily driven by safety and sustainability goals, margin improvement is also a significant driver due to maintenance cost reduction and alkylate yield and octane gains.

Liquid-acid alkylation units can be revamped to K-SAAT by replacing the reaction section with three fixed-bed reactors and a regeneration loop. The fractionation section is retained. The cost to revamp a liquid acid alkylation unit is about 60% of the cost of a new K-SAAT unit with the same capacity.

CVR has selected K-SAAT technology to revamp its Wynnewood HF alkylation unit in the USA with modular supply by KBR. KBR has seen increasing interest from refiners around the world.

K-SAAT offers lower capital and operating costs compared to sulfuric acid alkyation.

K-SAAT is a highly adaptable technology with a high rate of return that is suitable for many applications.

	K-SAAT Solid Acid	Sulfuric Acid	Ionic Liquid
Alkylate RON (C4 Feed)	**97 – 99**	96 – 98	94 – 98
Relative CAPEX	**Base**	1.3 x Base	1.5 x Base
Relative OPEX	**Base**	1.3 x Base	1.8 x Base
Relative Equipment Count	**Base**	1.8 x Base	1.8 x Base
Special Metallurgy Required?	**No**	Yes	Yes
Catalyst Properties	**Non-corrosive, Solid**	Corrosive Liquid	Corrosive Liquid
Relative Catalyst Consumption*	**Base**	500 x Base	1.2 x Base
Relative Carbon Intensity (Emissions)	**Base**	1.3 x Base	2.0 x Base
Feed Impurity Limits	**< 20 ppm Sulfur < 20 ppm Moisture**	< 20 ppm Sulfur	< 20 ppm Sulfur < 1 ppm Moisture

*K-SAAT catalyst is replaced every 5 years with no ongoing make-up.

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Contact us for more information:
technology@kbr.com