Converting low-value feed to high-value products

The toughest challenge facing refiners today is how to optimize the production of cleaner products from a broad range of feeds. Refiners tend to choose technologies that deliver higher conversion to lighter products and have fewer operating problems, regardless of feed quality.

Chevron, a leading refiner and innovator of hydroprocessing technologies, combined resources with Lummus Technology, a leading technology and engineering company, and formed Chevron Lummus Global (CLG). CLG has a depth of experience in designing, building and operating hydroprocessing units. Today, the company offers a full suite of technologies and catalysts designed for optimizing production of the cleanest products from all types of feeds. CLG has designed thousands of projects in more than 70 countries. In fact, the company says that more than half of the world's hydroprocessing capacity uses its technologies.

Residuum hydroprocessing technologies

CLG offers a family of residuum conversion technologies and catalysts that can be tailored to help refiners optimize product quality, product yield, run length, capital investment and operating costs.

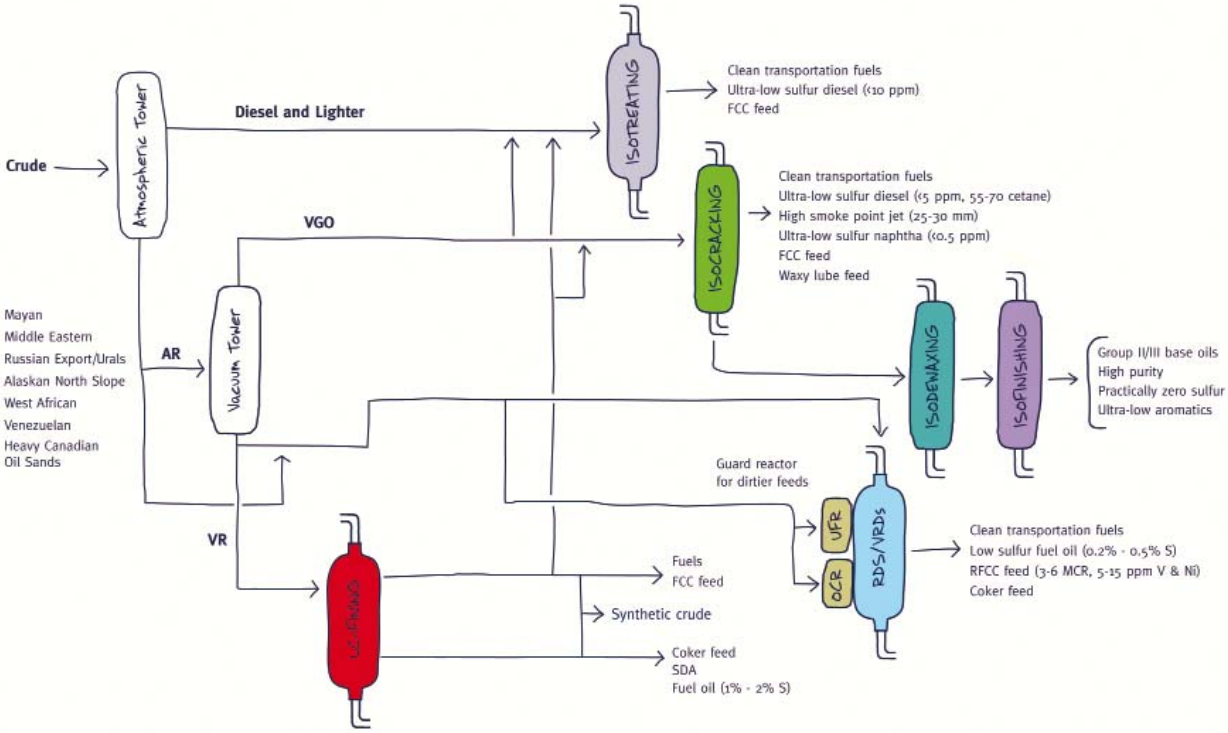
- LC-FINING is well-suited for hydrocracking extra-heavy residuum, bitumen and vacuum residuum feedstocks into low sulphur products.
- RDS removes sulphur, nitrogen and metals from residuum, producing clean Residuum Fluid Catalytic Cracking (RFCC) feedstocks for conversion into clean fuels and base oils.
- UFR and OCR guard-bed technologies enable refiners to increase feed throughput and/or process heavier feeds with higher levels of contaminant metals while maintaining excellent product qualities.

LC-FINING: Ebullating bed process

Efficiently hydrocracks extra-heavy residuum, bitumen and vacuum residuum feedstocks to high-quality transportation fuels and fuel oils

CLG's ebullating bed process, LC-FINING, provides high distillate product yields while concurrently removing metals, sulphur, Conradson Carbon Residuum (CCR) and asphaltenes from difficult feedstocks. Only CLG's LC-FINING process reduces both capital investment and operating expenses when upgrading to produce cleaner products from difficult feeds.

Its integrated onstream catalyst addition and withdrawal system eliminates the need to shut down for catalyst replacements. The catalyst, and its addition rate, are customized for optimally converting the refinery's crude source into the desired product slate.



The proprietary hydrogen recovery system is tailored to be either low or high pressure depending upon the refinery's economics. The low-pressure recovery system eliminates most of the high-pressure equipment required downstream of the reactors in other processes, while the high-pressure recovery system reduces power consumption by 0,25 hp/bbl. In every project, equipment pricing versus utility savings is evaluated so that production of the desired product slate is optimized. When LC-FINING is integrated with coking and deasphalting, distillate liquid yields as high as 92% can be achieved.

Advantages of LC-FINING

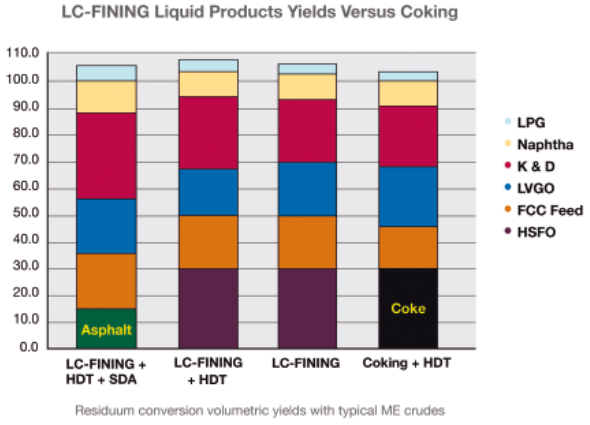
- Ability to handle most difficult feeds with metals content up to 600 ppm
- Higher conversion of residuum to lighter distillates
- Can be integrated with hydrotreating and hydrocracking on the same processing platform
- Higher reliability
- Can run continuously for four years
- Lower catalyst consumption
- Lower operating costs.

How LC-FINING works

The LC-FINING ebullating-bed process efficiently converts petroleum bottoms and other heavy hydrocarbons into high quality fuel oils, or prepares them for more efficient conversion into ultra-low sulphur distillate products.

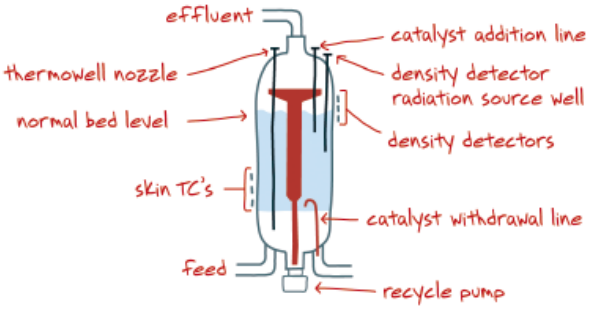
Feed from extra-heavy residuum, deasphalted oil or bitumen from oil sands is mixed with hydrogen and reacted with catalyst in an ebullating bed reactor. The back mixing in the ebullated bed reactor produces an efficient isothermal operation, eliminating the need for quenches within the reactor. Product quality is maintained at a consistently high level because fresh catalyst is intermittently added and spent catalyst removed while the reactor is onstream.

Reactor products flow to the high-pressure separator, low-pressure separator and then to product fractionation. Recycled hydrogen is separated and purified. Depending on refinery economics, the commercially proven low-pressure hydrogen recovery system can be utilized for purification of the recycle gas, which requires lower capital investment and a residuum product from the LC-FINING process can be used as fuel oil, synthetic crude or as feedstock to a coker or a solvent de-asphalter. With conversion rates of 80% and higher, LC-FINING delivers high yields and high removal of contaminants in a safe, reliable, easy-to-operate plant at low investment.



Ultra-low sulphur diesel and gas oil from the LC-FINING process

LC-FINING technology can be easily integrated with distillate hydrotreating or hydrocracking processes to produce high quality middle distillate products. Unlike coking, clean products can be produced without building an additional plant. By eliminating the need for additional downstream processing, refiners who choose LC-FINING have a more economical upgrade path for meeting the global demand for cleaner fuels. With more than 350 000 BPSD of difficult feed being converted to clean product using LC-FINING technology, its reliability is being proven day after day.



LC-FINING maximizes sulphur and metals removal.

RDS/ VRDS: Fixed-bed residuum hydrotreating

Pre-treats residuum from heavy crudes for ultra-low sulphur fuel oil production and for RFCC conversion into high quality, ultra-low sulphur transportation fuels

CLG's fixed-bed residuum hydrotreating technologies, RDS for atmospheric residuum hydrotreating and VRDS for vacuum residuum desulfurization, provide a short, economical processing path for producing higher-value products from difficult feeds. RFCC is the most popular processing route for the complete conversion of residuum oils. Without a pre-treating system in place, refiners must process atmospheric residuum from expensive crudes that are low in metals, carbon residuum and sulphur to avoid operating problems. Pre-treating RFCC feed with CLG's hydrogenefficient RDS/VRDS technologies sufficiently saturates even the most difficult feeds so that no further processing is necessary to produce high-value, light products.

CLG invented the technology in 1966. Detailed operating data on feed and processing results have been collected and analyzed. With that information the reactor internals and catalyst systems have been continually refined and upgraded so that every unit is optimized for product quality, yield, run length, capital investment and operating costs.

Customized catalyst and superior internals

After completing a thorough analysis of feed characteristics relative to operating kinetics and chemical reaction, CLG tailors the catalyst system for optimal performance. Every catalyst system is unique to the

refiner's particular need. As a result of a robust catalyst grading system and ISOMIX® internals, 12 months or longer cycle lengths are achieved while meeting targeted specifications for demetallization, desulphurization, carbon residuum reduction, denitrification and increased cracking conversion.

With a CLG RDS/VRDS residuum hydrotreating unit in the processing scheme, refiners have more flexibility in feed selection, achieve higher product yields and have fewer feed-related operating problems.

Fixed-bed residuum hydrotreating units can readily process feedstocks containing as much as 150 ppm metals (Ni + V). Adding a UFR or OCR guard-bed reactor enables refiners to process feeds with as high as 400 ppm metals (Ni + V).

UFR/OCR

Guard-bed technologies economically increase capacity from RDS units

UFR

CLG's Upflow Reactor (UFR) process technology uses an upflow guard-bed reactor that is added to the processing scheme before the fixed-bed RDS reactors. It enables refiners to increase capacity, process heavier feeds or improve product quality from a fixed-bed RDS unit. With a UFR in the processing scheme, refiners can increase feed throughput and/or process heavier feeds that have higher levels of contaminant metals while maintaining excellent product qualities. The UFR has lower pressure drop across the reactor than when a traditional down-flow, fixed-bed guard reactor is used. Consequently, capacity of the system can be increased by as much as 50%.

The principle advantages of the UFR are:

- Low pressure drop
- Prevention of guard-bed plugging problems thanks to the slightly expanded catalyst bed
- In case of RDS retrofits, no need to change out recycle gas compressors
- Opportunity to increase capacity as much as 50% in limited plot space
- Ability to add catalyst transfer system later
- Longer life of downstream fixed-bed catalyst.

Plus, it provides refiners with the greatest flexibility if they want to process heavier feeds at a later date.

OCR

CLG's Onstream Catalyst Replacement (OCR) process technology employs a countercurrent, moving-bed reactor. Like UFR, it enables refiners to significantly increase capacity or improve product quality from a fixed-bed RDS unit where a small fraction of spent OCR® catalyst is withdrawn and replaced with fresh OCR® catalyst on a weekly basis. When adding an OCR reactor in front of the

RDS unit, refiners can increase feed throughput and/or process heavier feeds with higher levels of contaminant metals, while maintaining excellent product qualities and long fixed-bed run lengths. OCR enables refiners to process residuums with up to 400 ppm metals (Ni + V) or to achieve deeper desulphurization when processing low-metal feeds. In either case, the life of the downstream catalyst is improved substantially and problems from pressure drop buildup are reduced.

Converting heavy feeds into high-value light products is a challenge for any processing scheme. CLG's catalyst system is designed to maximize the refiner's operating objectives.

ISOCRACKING

Processing technology and catalysts for producing clean fuels and ultra-low sulphur diesel

CLG's hydrocracking experience began with Chevron's invention of modern hydrocracking more than 50 years ago. Since then, CLG and Chevron have spent hundreds of millions of dollars developing hydrocracking technologies and catalysts that optimize the production of cleaner fuels.

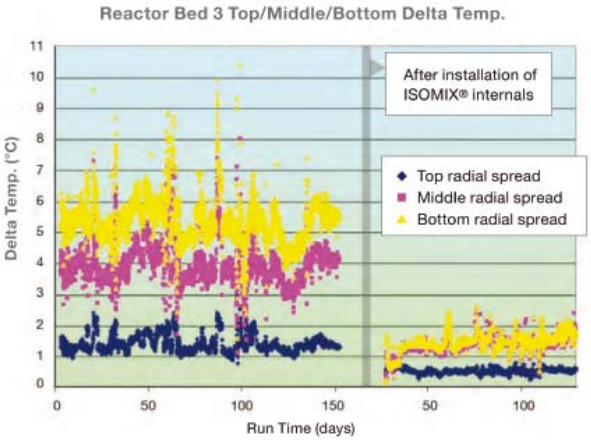
Refiners today are finding that the increased demand for high-quality transportation fuels is forcing them to convert a higher percentage of crude oil to lighter products. For many, that means adding hydrocracking capacity to meet more stringent product specifications. To maintain profitability, it is essential that these quality improvements be made without sacrificing product yield. CLG's ISOCRACKING technology is a flexible upgrade path to lighter products — a path that can help refiners reach a balance between stringent product specifications, product yield, cycle run length, capital investment and operating costs. CLG has helped refiners working with difficult feeds, such as heavy coker gas oils, deasphalted oils and material with a high end point (>538 °C) to efficiently produce clean fuels.

Around the world, the allowable limit for sulphur in transportation fuels is becoming lower. In California, where CLG's headquarters are located, it went to 15 ppm in 2006. In Europe it went to 10 ppm in 2009. Through the years, CLG has most often been the first to introduce technologies and catalysts that enable refiners to economically, safely and reliably meet tough new standards for cleaner transportation fuels.

ISOMIX® inside

High-performance reactor internals provide uniform distribution and prevent hot spots

With CLG's ISOMIX® reactor internals for fixed-bed hydroprocessing reactors, refiners can maximize catalyst utilization from high-activity catalysts and improve clean-product yields from more difficult feeds. ISOMIX® internals consist of ISOMIX® nozzles for flow distribution and the ISOMIX® mixing box. The ISOMIX® mixing box provides thorough inter-bed mixing and quenching which prevents propagation of temperature maldistribution from bed to bed. This minimizes hot spots and provides better operating control. The ISOMIX® flow nozzles uniformly distribute gas and



Reactors retrofit with ISOMIX® internals have better temperature stability with significant reduction in hot spots and temperature mal-distribution

liquid to the catalyst bed providing good gas-liquid mixing and heat exchange. Given the even flow, over a range of flow rates, the performance is less affected by distributor tray out-of-levelness. Plus, the spray pattern produced minimizes the catalyst depth needed for uniform and complete wetting. Consequently, there is greater catalyst utilization and higher reactor volume efficiency.

ISOMIX® internals have been used in reactors as large as 4,6 m in diameter and have proven to be highly safe and reliable. They take less reactor space, extend catalyst life and increase yields over other internals.

ISOTREATING

Refineries can convert up to 99% of straight-run and cracked feeds to ultra-clean diesel and kerosene

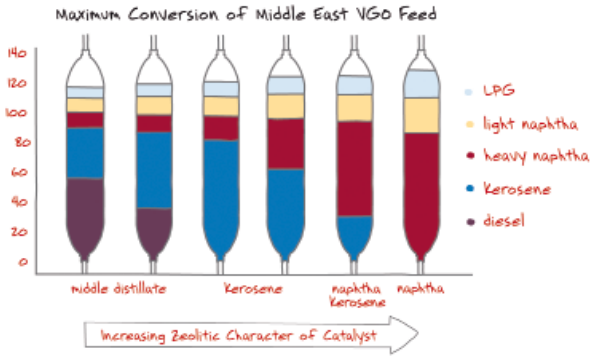
The function of the ISOTREATING process is the removal of sulphur and other contaminants (such as nickel and vanadium) from the feed, and to saturate molecules, so refiners can transform more difficult feeds into higher-value products. Highly flexible, the ISOTREATING process can be added either downstream from a residuum hydroprocessing unit, such as LC-FINING, or integrated with any hydrocracking processing scheme to improve product quality and yield.

With more than ten units in operation, it has been demonstrated that integrating a reactor for ISOTREATING requires 40% lower investment to achieve a given processing objective. The reaction section requires 50% fewer pieces than that of a stand-alone unit. Additionally, when processing feed from an LC-FINING unit, the hydrotreating reactors share the same high-pressure hydrogen loop, utilizing the excess hydrogen remaining in the LC-FINING effluent. The success of the ISOTREATING process is a combination of science and experience. Every processing scheme is unique, so, based on its experience, CLG customizes the catalyst selection and layering in the reactor to optimize production of the desired product slate. As a result, CLG has enabled refiners to upgrade heavy refractory feeds into high-value products with minimal capital expense and operating costs.

ISOCRACKING® catalysts: Tailored catalyst systems

With the demand for cleaner and cleaner fuels growing rapidly, proper catalyst selection is more important than ever

With more than 50 years of experience developing both hydrocracking catalysts and technologies, CLG has learned that optimizing production is best achieved by layering one or more hydrodenitrification and hydrocracking catalysts and creating a catalyst system unique to the refiner's operating environment and processing objectives. CLG designs layered (and even blended) catalyst systems because the feedstock changes chemical properties along the reaction pathway.



CLG experts tailor catalyst systems to optimize a refiner's processing objectives.

With a layered/blended system, refiners achieve maximum conversion and throughput while meeting more stringent product quality specifications. It starts with assessing feedstock type, operating conditions, the desired product specifications and unit operating objectives. That data is then compared to the information accumulated from our work with the operators of more than half of the hydrocracking units in operation today. Given the wide variety of feedstocks, processing conditions and tightening product specifications, there is seldom a perfect match, but the library of actual operating data is so large, analytical iterations with a high degree of confidence can be done. CLG knows how to formulate and combine catalysts for optimum synergy between components. The end result is a catalyst system that optimizes the balance of cracking activity, hydrogenation activity, yield selectivity and catalyst life.

Ongoing catalyst development

The need to get more productivity, more flexibility and more profitability from the hydrocracking process is an ongoing challenge for refiners. CLG's ISOCRACKING® catalyst development team has been addressing that challenge for more than 50 years. In the '60s, the focus was on the production of transportation fuels using amorphous catalysts. In the '80s, the portfolio was expanded to zeolitic catalysts for maximizing the production of naphtha and jet fuel. Since then, the investment in R&D and pilot plant facilities has continued to grow as CLG tackles the primary challenge of today, how to process the highest quality products from the broadest range of feed, without compromising yield or operating safety.

ISODEWAXING technology and catalysts

The world of base oil manufacturing was revolutionized when CLG introduced ISODEWAXING technology and catalysts in 1993. Environmental and regulatory groups were demanding cleaner-burning, more fuel-efficient engines, but engine manufacturers were constrained by insufficient capacity of high-quality lubricants that could produce the required performance.

Manufacturing vehicles with improved engine performance requires widespread availability of millions of gallons of low-volatility, low-viscosity lubricants. CLG's ISODEWAXING technology and catalysts made this possible, and, in the process, improved manufacturing operations and ROI for refiners.

High-quality lubricants require high-quality base stocks. Producing high-quality base stocks requires chemically transforming undesirable compounds in the feed. Prior to the introduction of the ISODEWAXING technology, solvent processing was used to remove the undesirable compounds. Many impurities were left in the oil. Alternatively, ISODEWAXING technology catalytically transforms waxy feed molecules into highly stable base oil molecules that can be tailored to meet the needs of almost any lubricant application.

These molecules have high VI, low-pour points and excellent resistance to oxidation. Further, because the process preserves the base oil's paraffinicity, it can produce higher product VI and/or higher yields than other dewaxing processes. Today, more than 60% of the world's premium base oil is produced using CLG's technology. Those base oils are being used worldwide to produce lubricants that meet stringent performance specifications.

CLG's technical team can help refiners optimize production of premium base oils from a broad range of feeds including vacuum gas oil (VGO); refinery process streams such as hydrocrackate or deasphalted oil (DAO), raffinates, foots oil and slack wax produced in existing solvent base oil facilities; or other waxes. Even feeds with close to 100% wax, such as slack wax, hard wax and Fischer-Tropsch-derived wax, can be converted to high-value premium base oils in a once-through process without recycling unconverted wax. Using ISODEWAXING technology, base oils with VIs ranging from 95 to 140 and higher can be produced from any of these feeds. Pour points may range from low (-9 to -15 °C) to ultra-low (<-40 °C).

Conclusion

CLG has spent more than 50 years developing refining technologies, catalysts and processes that enable refiners to transform the most difficult crudes into the cleanest, safest products possible. The company continues to invest millions of dollars annually in research on ways to do it better. Working together we can help protect the environment around us.

This article was extracted from a Chevron Lummus Global brochure on converting low value feed into high value products. To learn more, visit www.chevronlummus.com.