

GTL Transforming

by Peter Fairley

the Future of Lubricant Production

Gas-to-liquids synthesis promises an abundance of high-performance lubricants, but is the technology viable?

The collapse of Enron sent shudders through the oil, gas and power industries, eroding confidence and depressing investment. Few sectors of the energy

1923

Franz Fischer and Hans Tropsch produce Synthol from alkalized iron catalyst.

1925

Fischer and Tropsch convert syngas to oxygenated and liquid hydrocarbons.

1932

Fischer-Tropsch process commercialized.

1939

Germany operates nine Fischer-Tropsch plants, producing 12,000 barrels per day.

1950

Sasol forms.

1973

Shell begins GTL developing technology in response to oil crisis.

1993-1997

GTL experiences resurgence in United States.

2002

BP opens demonstration plant in Nikiski, Alaska.

2003

ConocoPhillips opens demonstration plant in Ponca City, Oklahoma.

industry were left unscathed, least of all the lubricants business, for Enron's collapse undermined the only engineering project on the drawing boards designed to mass produce synthetic lubricants from natural gas—high-performance lubricants that promise to boost automobile fuel efficiency and cut the frequency of visits to the service station.

But while the project that Enron backed, led by independent technology firm Syntroleum, is sunk, oil majors such as Royal Dutch/Shell, ExxonMobil, and ChevronTexaco are busy touting similar gas-to-liquids (GTL) projects that could generate billions of barrels of high-performance GTL lubricant base oils. That prospect has transfixed the lubricants business, for base oil production from just one of the large-scale GTL plants envisioned by the oil majors could exceed current worldwide demand for high-performance lubricants.

"Any substantial production from a plant that size would overwhelm the market," says John Boepple, a senior consultant with consulting firm Nexant, Inc./Chem Systems (White Plains, N.Y.).

HISTORY

The chemistry behind this lubricant revolution is hardly new. GTL plants employ the Fischer-Tropsch synthesis, invented in Germany in the early 1920s. Nor is the exploration of GTL technology beyond Germany novel. At the end of World War II Allied scientists studied Germany's GTL fuels plants and laboratory data, and, after the oil crises of the 1970s, oil majors and governments throughout the world began investing in GTL research. GTL is poised for widespread application today thanks to environmental pressures and the discovery of immense natural gas reserves around the world.

By transforming natural gas into easily shipped liquids, GTL plants provide a means for bringing far-flung natural gas to international markets. Environmental pressures are contributing to GTL's rebirth because GTL fuels burn clean. Crude oil is a complex mix-

ture of hydrocarbons and other elements—including volatile aromatic compounds such as benzene that contribute to urban smog and sulfur that generates soot and interferes with pollution controls. In contrast, GTL fuels are a homogenous, sulfur-free hydrocarbon liquid that burns clean. According to Shell, using GTL diesel in light-duty vehicles cuts tailpipe emissions of particulates, hydrocarbons and carbon monoxide by 20-40%. Shell says GTL diesel use in heavy-duty vehicles cuts these pollutants, as well as smog-forming nitrogen oxides, by 10-20%.

GTL plants could similarly clean up lubricant base oils. GTL plants running the Fischer-Tropsch synthesis process produce an ultra clean synthetic paraffin wax in addition to fuels, and that wax can be processed to generate lubricant base oil that is free of the sulfur, metal and aromatic contaminants found in refined base oils. As a result, GTL base oils have a lower viscosity, run cleaner and last longer.

"You're starting at the lowest common denominator, which is a single carbon atom, and then you're building up a molecule from there, as opposed to refining a crude oil where you try to separate or extract out the best molecules that you can and then try to modify them," says STLE member Ernest Henderson, a former director of refining technology and product development for Syntroleum and now an independent Tulsa, Oklahoma-based consultant in petroleum products and refining technology.

GOOD TIMING

GTL base oils are a perfect fit for the lubricants market, which is rapidly moving to higher-performance base oils. Automakers are shipping their cars and trucks with longer-lived automatic transmission and power steering fluids to reduce warranted maintenance costs, and they are specifying motor oils with lower viscosities to meet CAFE (Corporate Average Fuel Economy) standards. Heavy-duty engine oils are also

moving up the performance curve thanks to new emissions limits on nitrogen oxides or NOx. Low-NOx engine designs generate extra soot, requiring high-performance base oils to preserve lubricity and avoid premature engine service.

The net result is a shift in demand away from Group I base oil — the workhorse of the lubricants industry — which is produced by solvent extraction of refinery-generated waxes.

“You cannot make a GF-3 passenger car motor oil with just a Group I base oil,” says STLE member Geeta Agashe, who directs the petroleum and energy practice at Little Falls, N.J.-based consulting firm Kline & Co.

To meet tighter specifications, lubricant marketers are moving toward Group II and III base oils, which are the product of a variety of catalytic refining steps that selectively convert low viscosity index aromatic molecules into lower viscosity hydrocarbons, and Group IV base oils, a synthetic polyalphaolefin (PAO) lubricant produced by polymerizing a chemical feedstock.

The Group II, III and IV base oils offer progressively higher performance thanks to a reduction in volatile components and sulfur, and lower viscosities characterized by a higher viscosity index.

According to, Agashe motor oil producers are spiking Group I oils with these higher performance base oils and, in some formulations, abandoning Group I base oil altogether.

According to research by Kline, global base oil demand was 690,000 barrels per day in 2000, of which 91% was Group I, 6% was Group II, and 3% was high-end Group II, III and IV. By 2015 Kline projects that base oil demand will rise to 831,500 barrels per day, but the share served by Group I base oils will drop to 69% while Group II will grow to 21% and the highest performance grades' share will more than triple to 10%.

In barrels per day, the volume of high-performance lubricant base oil would quadruple. GTL lubricants, with essentially zero sulfur and nitrogen, excellent oxidation stability and low viscosity even at low temperatures, are well positioned to capture that growing demand for performance.

FIXING THE BED

GTL lubricants have outstanding perform-

ance characteristics because, like PAOs, they are a synthetic product. But unlike PAOs, they are produced from cheap natural gas rather than a pricy chemical feedstock.

Here's how it works: The GTL process begins with a fairly routine chemical step that breaks the natural gas into a 'synthesis gas' of carbon monoxide and hydrogen. The synthesis gas is then fed to a Fischer-Tropsch catalyst (commonly a doped particle of cobalt) under pressure and heat and the catalyst assembles the components into straight chain hydrocarbons of varying



Photo courtesy Eagle Eye Helicopter

BP's GTL demonstration plant in Nikiski, Alaska, is expected to operate for five years to complete commercial tests of its new compact gas reformer design. BP claims the new reformer is one-fortieth of the size of reformers now being used on GTL plants.

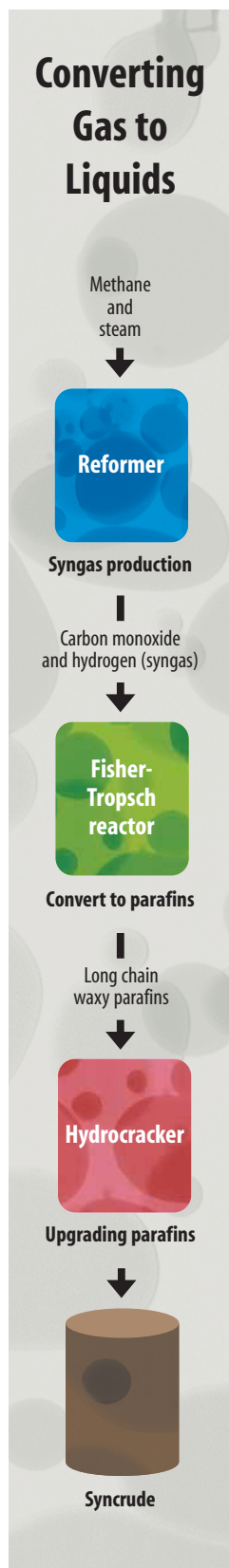
lengths, from short chains less than 20 carbons in length, which are suitable for fuels, to longer-chained paraffin waxes that can be converted into base oils. To make GTL base oil, the long waxy chains are extracted and isomerized to add hydrocarbon side chains to the straight carbon chains, just as refinery-derived wax is converted into Type II and III base oils.

Reactor configuration, catalyst composition and process conditions determine the distribution of chain lengths generated, which is expressed as an 'alpha' value between zero (all short chains) to 1.0 (all wax).

Bob Freerks, Syntroleum's manager for product development and technical support, says reactor configuration has both the most critical impact on carbon chain length and the largest impact on how much the plant will cost to build. That's because the

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reactor's design will determine how the plant handles the enormous heat released from the growing carbon chains during synthesis, which Freerks describes as one of the chief engineering challenges in a GTL plant.

Two reactor designs are common: fixed bed reactors, which employ a solid layer of catalyst-lining narrow pipes, and slurry bed reactors which temporarily suspend catalyst particles in the reactor's liquid hydrocarbon product.

The slurry process is cheaper to build. "A slurry process with vast amount of liquid can absorb that heat of reaction much better than a fixed tube process where the heat has to diffuse through solid reactor walls," says Freerks. But there's a price to pay: slurry reactors generally give an alpha value from 0.85 to 0.90, meaning that no more than approximately 20% of the resulting carbon chains will be candidates for lubricant base oil.

Fixed bed reactors offer greater control over the Fischer-Tropsch synthesis and can generate the longer, waxier hydrocarbons required to produce base oils. Most of the lubricant industry's experience with GTL base oils derives from two GTL plants—a Syntroleum pilot plant at Tulsa and Shell's semi-commercial plant at Bintulu, Malaysia—and both employ fixed-bed reactors.

Shell has operated its 12,500-barrel-per-day Bintulu plant since 1993. The plant ships enough waxes to a Shell refinery in Japan to produce about 100 barrels per day of lubricants, according to Agashe. Consultants say Shell uses the product in passenger car motor oil and automatic transmission fluid sold in Japan. "It's very high quality material," says Boepple at Nexant/Chem Systems. However, there is little published data available on Shell's material.

Syntroleum, in contrast, has widely publicized the performance of lubricants produced at its \$2.5 million pilot plant in Tulsa, which began running in December 2000 and can produce two barrels of fuels per day or one barrel per day of lubricants. Henderson says GTL lubricants produced in Tulsa passed key engine tests, notably the Sequence IIIF test sponsored by General Motors which focuses on oil thickening, oil consumption and engine wear, and the

Sequence VIB fuel economy test sponsored by Ford.

These tests are used in North America by the International Lubricant Standardization and Approval Committee (ILSAC), an association of lubricant suppliers and auto makers, to set standards for motor oil performance. ILSAC's tough GF-3 standard came into force in 2001 and further tightening is expected as early as 2004 with the approval of ILSAC GF-4.

The Sequence IIIF test subjects motor oil to an 80-hour continuous engine run, during which the oil is periodically tested for viscosity; at the end of the run the engine is stripped down and examined for wear and deposits. Thickening is a common cause of failure, as simultaneous punishment from heat, oxygen and acidic molecules boils off short-chain components and chemically alters other components.

Syntroleum's GTL oil aced the test, leaving only limited deposits on the engine and increasing in viscosity by only 36% (the pass/fail limit is 275%). Henderson, who oversaw the tests during his time at Syntroleum, says the performance was comparable overall to that of a PAO.

Syntroleum's GTL performed equally well in the Sequence VIB test, easily meeting ILSAC's fuel economy expectations. The VIB test examines an engine oil's impact on fuel economy relative to a reference oil, and the GF-3 standard requires a 0W-20 motor oil (the grade that Syntroleum tested) to boost fuel economy 2.0% over the reference when the oil is fresh, and 1.7% after a simulated 7,500-mile run. Henderson says the Syntroleum GTL-based lubricant delivered a 2.42% fuel boost when fresh and a 2.16% boost when aged, easily meeting GF-3 and even besting the expected requirements for GF-4: "Viscometrically, we're already there."

Furthermore, Henderson says there is simply no performance downside to GTL lubricants. Even limited solvency for conventional lubricant additives, the bugbear that used to afflict highly saturated hydrocarbon lubricants like the GTL base oils, has evaporated in recent years. "Over 50% of the base stocks made in North America are hydrocracked with much higher saturates content, so the additive companies are

already adjusting their additive systems," says Henderson.

MAKING THE BUSINESS CASE

The only potential cloud on the GTL base oils horizon that Henderson can see is their cost. Here analysis by Kline is clearing the air. Agashe says Kline's analyses show that GTL base oils will not only be competitive with the synthetic PAO base oils, which currently sell for between \$4.50-\$8 per gallon, but also with the Group III oils which sell for \$1.60-\$2.50 per gallon and possibly even with cheaper Group II oils.

"GTL will compete first head-on with polyalphaolefins, because they're going to say, look our material is as good in most performance categories. Then if there's more volume they will absolutely compete with Group IIIs. We've done a lot of manufacturing economics work in which we've concluded that they are very, very competitive from a manufacturing cost standpoint," says Agashe.

Nonetheless, Agashe expects GTLs to be applied first in passenger car motor oil, automatic transmission fluid and power steering fluids. She sees market penetration beginning in Europe, then spreading to North America and finally Japan before finding broader use throughout Asia. However, if several large plants come on-stream at once, the GTL base oils could be applied immediately worldwide and in a wide range of lubricants, replacing conventional base oils in such commodity products as hydraulic fluids and railroad engine oil.

The slippery question that dogs such excited prognostication is when and where the first big GTL plant will be built. The demise last fall of Syntroleum's proposed plant, the only one that was directly aimed at seizing the GTL base oils opportunity, has added urgency to the GTL waiting game.

Syntroleum's plant, code-named Sweetwater, was to convert stranded natural gas in Western Australia into 11,500 barrels of synthetic hydrocarbon liquids per day. About a third of the output from the plant's fixed-bed reactor would have been base oils, with synthetic fuels, wax and a range of specialty chemicals making up the balance. Syntroleum invested \$25 million in the

project, completing engineering designs, negotiating a 20-year natural gas supply contract, and securing a slew of permits.

Then Enron collapsed, taking \$50 million in pledged funds with it. As a result, new investors for megaprojects have been hard to find post-September 11. Plus, Syntroleum's plant was dogged by nagging doubts about its ability to earn a premium on lubricant base oils—doubts that are passing under the optimistic assessment from consultants such as Agashe. "We hit what you might call the perfect storm for trying to finance a plant," says Syntroleum's Freerks.

Analysts downplay any connection between Syntroleum's trials and the prospects for GTL lubricants. "I don't think it reflects on the underlying advantages or quality attributes of GTL base stocks. It had more to do with financing issues," says Boepple. Agashe agrees: "They have a good technology and a good product, but their economics for that plant in Australia only made sense if you assumed a premium for their GTL offerings. With Enron's debacle it was hard for Syntroleum to get the necessary financing."

Agashe is confident that GTL base oils will nevertheless begin to flow, not from dedicated fixed-bed plants but as a fraction of the output from much larger slurry-bed plants optimized for synthetic fuels. Several oil majors say they are close to beginning construction on full-scale commercial GTL fuels plants. For example, Shell says it expects to build four large GTL plants around the world by 2010, each five times larger than the Bintulu, Malaysia, plant. Not to mention, ExxonMobil says it will be

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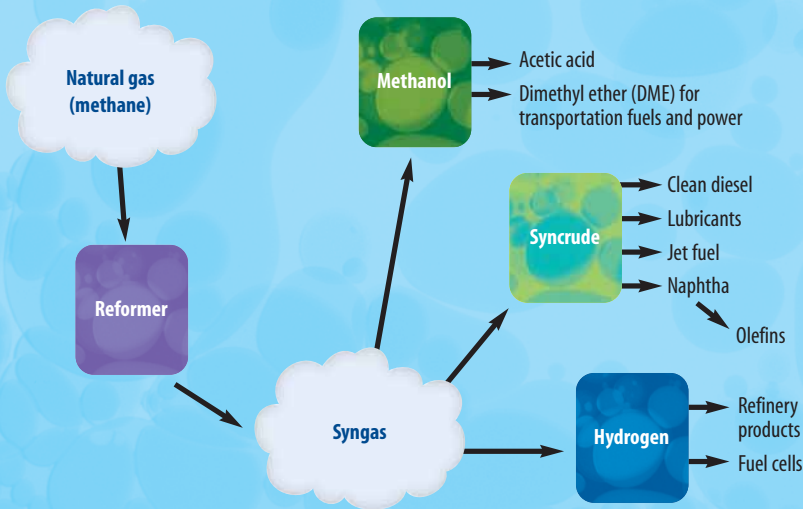


Photo courtesy ConocoPhillips

Completed earlier in the year, the ConocoPhillips demonstration plant in Ponca City, Oklahoma converts four million cubic feet per day (MMcfd) of natural gas into 400 barrels per day (bpd) of sulfur-free diesel and naphtha.

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Converting Gas to Products



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shipping 100,000 barrels per day from a GTL plant in Qatar by 2008.

What remains less clear is whether such fuel plants will convert much of any wax into base oils. GTL fuel plants inevitably produce some wax, but the plants can be designed to recirculate that wax back into the system for conversion into fuels. As Agashe puts it, "You can beat the hell out of that waxy raffinate and basically recycle it to extinction." And even if fuels plant operators choose to make lubricants instead of recycling waxes, debate over the quality of the resulting base oils is stirring friction between lubrication experts.

Agashe adds the equipment to recycle waxes is more expensive to build than a wax isomerization facility to convert the wax into finished base oils. She is confident that this advantage will convince ExxonMobil to devote as much as 20% of the Qatar plant's output to base oils, generating a massive 20,000 barrel per day flow of high-performance lubricants. "They are absolutely going to make lubricant base stocks," says Agashe.

She is even bullish about ChevronTexaco, which is partnering with South African energy firm Sasol to build a GTL plant in Nigeria but has been quiet to date about the prospects of GTL base oils. "ChevronTexaco is the largest merchant buyer of basestocks on the global marketplace," notes Agashe.

But what of the quality of the base oils from GTL fuels plants? Will its performance

match the level demonstrated by Syntroleum? According to, Agashe some of the oil majors discussing GTL projects have already begun to distribute samples of GTL base oils from pilot plants to additives makers and to independent lubricant marketers such as Fuchs and Castrol, and the feedback is gushing.

"They really love the material. It's very close to PAO quality. The viscosity index is in the 135-150 range, whereas Group IIIs have a viscosity index in the 120 to 150 range," says Agashe. She also points out that all of the GTL-derived base oils will be high quality and nearly interchangeable, unlike conventional refined oils which contain literally thousands of chemical species.

"There's a lot of difference between a Group I base oil from ExxonMobil vs. a Group I that comes out of Valero vs. a Group I that comes out of Shell Canada. They fall within certain specifications, but they're not the same. The beauty of GTL is that pretty much this material is going to look the same all over," says Agashe.

Syntroleum's Freerks offers an alternative view. Freerks argues that the interchangeability of GTL base oils is a fallacy, because base oils produced from a fuel-optimized slurry reactor will have fewer of the long carbon chains that deliver a high viscosity index or VI: "You'll get 120-130 VI base oil, whereas we've made 147 VI base oils."

He argues that GTL base oils may soon be plentiful, but says they may be forced to compete with low-end Group III base oils instead of challenging the top tier, thereby generating a lower return on investment. "You have to distinguish yourself if you're going to go after the PAO market and a higher price," says Freerks.

If Freerks is right, GTLs could provide only a marginal performance boost for the lubricants industry. If Agashe is right, GTLs could literally redraw the market, delivering the ultimate in viscosity and endurance at a very affordable price.<<

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