GTL Gas to Liquid

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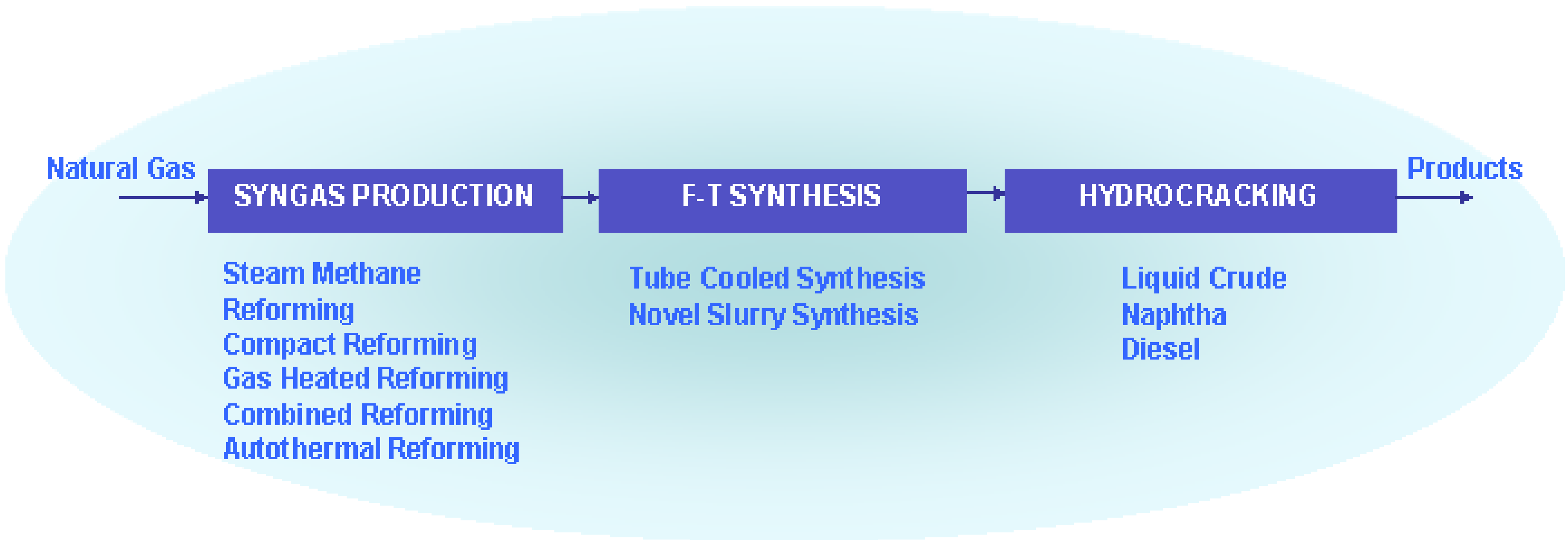

What is GTL ?

Gas-to-Liquid fuels are fuels that can be produced from natural gas, coal and biomass using a Fischer-Tropsch chemical reaction process. The liquids produced include naphtha, diesel, and chemical feedstock's. The resulting GTL diesel can be used neat or blended with today's diesel fuel and used in existing diesel engines and infrastructure. These fuels provide an opportunity to reduce dependence on petroleum-based fuels and reduce tailpipe emissions

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Natural gas can be use to produce bulk petrochemicals, including methanol and ammonia, but these are relatively small users of the gas reserves with limited markets. Liquid and other petroleum products are cheaper to transport, market, distribute to large markets. These can be moved in existing pipelines or products tankers and even blended with existing crude oil or product streams. Further, no special contractual arrangements are required for their sale with many suitable domestic and foreign markets.

GTL Gas to Liquid

New technology is being developed and applied to convert natural gas to liquids in gas to liquids technology (GTL). The projects are scalable, allowing design optimisation and application to smaller gas deposits. The key influences on their competitiveness are the cost of capital, operating costs of the plant, feedstock costs, scale and ability to achieve high utilisation rates in production. As a generalisation however, GTL is not competitive against conventional oil production unless the gas has a low opportunity value and is not readily transported.

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GTL not only adds value, but capable of producing products that could be sold or blended into refinery stock as superior products with less pollutants for which there is growing demand. Reflecting its origins as a gas, gas to liquids processes produces diesel fuel with an energy density comparable to conventional diesel, but with a higher cetane number permitting a superior performance engine design. The *Cetane Number* indicates how quickly the fuel will auto-ignite, and how evenly it will combust. Most countries require a minimum cetane number of around 45 to 50: A higher cetane number represents a lower flame temperature, providing a reduction in the formation of oxides of nitrogen (NOx) that contributes to urban smog and ground level ozone. Fischer-Tropsch diesel has a cetane number in excess of 70. Naphtha produced is sulfur free and contains a high proportion of paraffinic material suitable as cracker feedstock or the manufacture of solvents.

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Another "problem" emission associated with diesel fuel is particulate matter, which is composed of unburnt carbon and aromatics, and compounds of sulfur. Fine particulates are associated with respiratory problems, while certain complex aromatics have been found to be carcinogenic. Low sulfur content, leads to significant reductions in particulate matter that is generated during combustion, and the low aromatic content reduces the toxicity of the particulate matter reflecting in a worldwide trend towards the reduction of sulfur and aromatics in fuel.

Technology

It is technically feasible to synthesise almost any hydrocarbon from any other; and in the past five decades several processes have been developed to synthesise liquid hydrocarbons from natural gas.

There are two broad technologies for gas to liquid (GTL) to produce a synthetic petroleum product, (*syncrude*): a direct conversion from gas, and an indirect conversion via *synthesis gas (syngas)*

Aerial photo of the GTL plant at Escravos, Nigeria. Photo courtesy of Sasol Chevron

Technology

Synthesis gas is produced by reacting methane (or carbon) with steam at elevated temperatures to yield a useful mixture of carbon oxides and hydrogen. It can be produced by a variety of processes and feedstock's. It may require the indicated compositional adjustment and treatment before use in the following major applications:

Directly used for methanol synthesis. The dried syngas can be used without further adjustment since there is a net conversion of both CO and CO2 to methanol.

Ammonia synthesis gas, requiring maximum hydrogen production and removal of oxygen-bearing compounds.

Technology

Oxo synthesis gas, requiring composition adjustment and CO_2 removal to give a 1:1 H_2:CO synthesis gas.

Industrial gases, as a source of high purity CO, CO_2 or H_2,

Reducing gas, a mixture of CO and H_2 requiring CO_2 removal before being used to reduce oxides in ores to base metals.

Fuels either as a substitute fuel gas from a liquid or solid feedstock, or as an intermediate for Fischer-Tropsch or zeolite-based alternative liquid fuel technologies.

Technology

The direct conversion of methane, (typically 85 to 90 per cent of natural gas), eliminates the cost of producing synthesis gas but involves a high activation energy and is difficult to control. Several direct conversion processes have been developed but none have been commercialized being economically unattractive.

Construction at Oryx (Qatar) GTL Plant.
Photo courtesy of Sasol Chevron

Fischer-Tropsch

The discovery of F-T chemistry in Germany dates back to the 1920s and its development has been for strategic rather than economic reasons, as in Germany during World War II and in South Africa during the apartheid era. Mobil developed the "M-gasoline" process to make gasoline from methanol implemented in 1985 in a large integrated methanol-to-gasoline plant in New Zealand. The New Zealand plant was a technical success but produced gasoline at costs above $30 per barrel and required large subsidies from the New Zealand government.

Syngas

The *syngas* step converts the natural gas to hydrogen and carbon monoxide by partial oxidation, steam reforming or a combination of the two processes. The key variable is the hydrogen to carbon monoxide ratio with a 2:1 ratio recommended for F-T synthesis. Steam reforming is carried out in a fired heater with catalyst-filled tubes that produces a syngas with at least a 5:1 hydrogen to carbon monoxide ratio. To adjust the ratio, hydrogen can be removed by a membrane or pressure swing adsorption system. Helping economics is if the surplus hydrogen is used in a petroleum refinery or for the manufacture of ammonia in an adjoining plant.

Technology

The partial oxidation route provides the desired 2:1 ratio and is the preferred route in isolation of other needs.There are two routes: one uses oxygen and produces a purer syngas without nitrogen; the other uses air creating a more dilute syngas. However, the oxygen route requires an air separation plant that increases the cost of the investment.

The steam reforming process produces a syngas of $H_2:CO$ ratio of about 3:1 with the surplus H_2 that can be separated by a hollow fiber membrane process. Evaluations suggest the partial oxidation would be the preferred route when the surplus H_2 from the steam reforming process has to be disposed of at fuel value. Under these conditions, the product value of syngas by partial oxidation is lower than steam reforming. The partial oxidation process is also slightly less capital intensive.

Conversion

Conversion of the syngas to liquid hydrocarbon is a chain growth reaction of carbon monoxide and hydrogen on the surface of a heterogeneous catalyst. The catalyst is either iron- or cobalt-based and the reaction is highly exothermic. The temperature, pressure and catalyst determine whether a light or heavy syncrude is produced. For example at 330C mostly gasoline and olefins are produced whereas at 180 to 250C mostly diesel and waxes are produced.

Conversion

There are mainly two types of F-T reactors. The vertical fixed tube type has the catalyst in tubes that are cooled externally by pressurized boiling water. For a large plant, several reactors in parallel may be used presenting energy savings. The other process is uses a slurry reactor in which pre-heated synthesis gas is fed to the bottom of the reactor and distributed into the slurry consisting of liquid wax and catalyst particles. As the gas bubbles upwards through the slurry, it is diffused and converted into more wax by the F-T reaction. The heat generated is removed through the reactor's cooling coils where steam is generated for use in the process.

Commercial examples

Sasol is a synfuel technology supplier established to provide petroleum products in coal-rich but oil-poor South Africa. The firm has built a series of Fischer-Tropsch coal-to-oil plants, and is one of the world's most experienced synthetic fuels organization and now marketing a natural-gas-to-oil technology. It has developed the world's largest synthetic fuel project, the Mossgas complex at Mossel Bay in South Africa that was commissioned in 1993 and produces a small volume of 25 000 barrels per day. To increase the proportion of higher molecular weight hydrocarbons, Sasol has modified its Arge reactor to operate at higher pressures.

Commercial examples

Sasol has commercialized four reactor types with the slurry phase distillate process being the most recent. Its products are more olefinic than those from the fixed bed reactors and are hydrogenated to straight chain paraffin's. Its Slurry Phase Distillate converts natural gas into liquid fuels, most notably superior-quality diesel using technology developed from the conventional Arge tubular fixed-bed reactor technology. The resultant diesel is suitable as a premium blending component for standard diesel grades from conventional crude oil refineries. Blended with lower grade diesels it assists to comply with the increasingly stringent specifications being set for transport fuels in North America and Europe.

The other technology uses the Sasol Advanced Synthol (SAS) reactor to produce mainly light olefins and gasoline fractions. Sasol has developed high performance cobalt-based and iron based catalysts for these processes.

Commercial examples

The company claims a single module or the Sasol Slurry Phase Distillate plant, that converts 100 MMscfd (110 terajoules per day of gas) of natural gas into 10 000 barrels a day of liquid transport fuels, that can be built at a capital cost of about US$250 million. This cost equates to a cost per daily barrel of capacity of about US$25 000 including utilities, off-site facilities and infrastructure units. If priced at US$0.50/MMBtu, the gas amounts to a feedstock cost of US$5 per barrel of product. The fixed and variable operating costs (including labour, maintenance and catalyst) are estimated at a further US$5 per barrel of product, thereby resulting in a direct cash cost of production of about US$10 a barrel (excluding depreciation). These costs should however be compared with independent assessments.

Commercial examples

In June 1999, Chevron and Sasol agreed to an alliance to create ventures using Sasol's GTL technology. The two companies have conducted a feasibility study to build a GTL plant in Nigeria that would begin operating in 2003. Sasol reportedly also has been in discussions with Norway's Statoil, but no definitive announcements have been made.

Gasoline production

There are two methanol-based routes to gasoline. Mobil's methanol-to-gasoline (MTG) process based on the ZSM-5 zeolite catalyst was commercialized in 1985 in a plant now owned by Methanex in New Zealand. Commercial applications of the MTG process are now anticipated to use a fluid bed reactor with their higher efficiency and lower capital cost.

Useful Links

http://www.fischer-tropsch.org

http://www.aapg.org

http://www.spe.org/elibinfo/eLibrary_Papers/spe/1982/82UGR/00010836/00010836.htm

http://www.fischer-tropsch.org/primary_documents/patents/GB/gb309002.pdf