OIL&GAS JOURNAL

South African company commercializes new F-T process

01/10/2000

Further demonstrating its Fischer-Tropsch (F-T) prowess, Sasol Synthetic Fuels installed the last of eight new reactors using the Sasol Advanced Synthol (SAS) process in its Secunda, South Africa, plant early this year.

The SAS process converts synthesis gas into gasoline and light olefins.

More than 5,000 tcf of remote natural gas fields in the world do not lend themselves to economical LNG production or pipeline transportation. Combined with the desire to reduce the flaring of associated natural gas, the idea of converting this gas into liquid fuels, which are more easily transported, has made gas-to-liquid (GTL) a popular alternative.

The conversion of natural gas to liquid fuels consists of three major steps: the production of synthesis gas (syngas), GTL synthesis, and product work-up (OGJ, Sept. 21, 1998, p. 71).

The F-T process is one of several plausible GTL technologies gaining momentum as governments seek more environmentally friendly fuels and a disposition for natural gas located in remote areas. Although Sasol currently uses coal rather than natural gas to produce syngas, the feed to the GTL synthesis step is still syngas.

Sasol, Mossgas (Pty.) Ltd. (OGJ, Dec. 6, 1999, p. 48), and Shell are the only companies with commercial-scale F-T processes. Shell's Bintulu, Malaysia, plant, is temporarily out of commission as a result of an explosion in its air-separation plant in December 1997 (OGJ, Jan. 26, 1998).

The Bintulu plant has a liquid-production capacity of 12,500 b/d and was started up in 1993. In contrast, Sasol has produced more than 700 million bbl of synthetic fuels since the early 1980s.

In the train shown here, the old circulating fluid bed reactor *can be seen with the new SAS reactor (Fig. 2; photograph courtesy of Sasol, Johannesburg).*

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The scope of the Secunda project involved replacement of 16 existing circulating fluidized bed (CFB) Synthol reactors. The new SAS technology uses conventional fluidized bed technology.

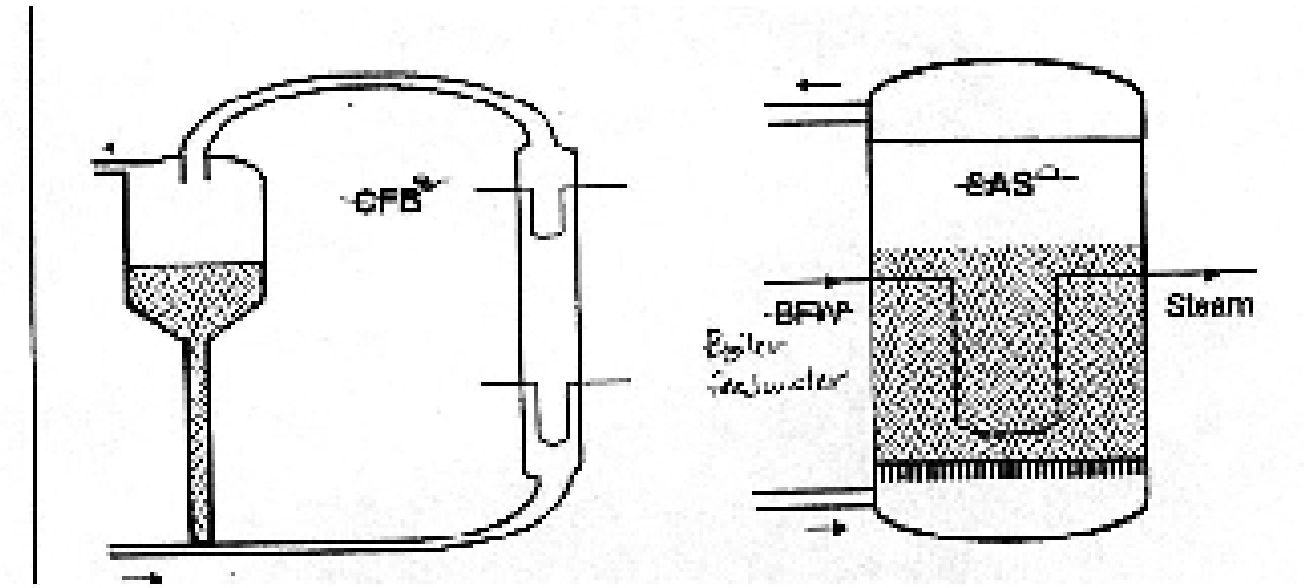

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Fig. 1 shows the difference in the new and old reactor configurations. The CFB reactors can still be seen at the Secunda plant (Fig. 2).

Sasol technologies

Sasol has two F-T technologies: a low temperature F-T (LTFT) process and a high temperature F-T (HTFT) process.

The new SAS technology is a HTFT process. The old Synthol reactors also used HTFT. The high temperature process runs at about 300-350° C. Currently, SAS uses an iron-based catalyst.

Sasol is aggressively marketing the Sasol Slurry Phase Distillate Process, which is a low temperature F-T process that uses a cobalt-based catalyst. It runs at 200-250° C. The Sasol Slurry Phase Distillate Process will be used in both the Nigeria and Qatar projects (OGJ, June 14, 1999, p. 30; July 28, 1997, p. 35).

Besides temperature, the main difference between these two technologies is the product to which the synthesis gas will be converted. HTFT produces both fuel products and chemicals, that is, gasoline as well as light olefins. LTFT focuses on clean diesel, waxes, and paraffins.

SAS development

The first CFB reactors were installed in Sasolburg, about 80 km south of Johannesburg, in 1955.

These three 1,500 b/d reactors were built to diversify South Africa's fuel supply from imported oil. Sasol One, as the complex was called, used a combination of German F-T fixed-bed technology and American fluidized-bed technology to convert coal to gasoline and diesel.

Later, in Secunda, Sasol Two and Sasol Three supplemented these three reactors. Sasol Two and Sasol Three were duplicate units, built within 2 years of each other. Sasol Two produced its first synthetic oil in 1980, and Sasol Three in 1982.

With these two projects, the Secunda complex consisted of 16 CFB reactors, each of 7,500 b/d capacity, which provided synthetic fuels to the country.

Sasol continued to perform research to develop a conventional fluidized bed reactor. In 1983, Sasol commissioned a 90 b/d, 0.8 m diameter demonstration reactor at Sasolburg; this reactor would later develop into the SAS technology.

The first commercial SAS reactor had 3,500 b/d of capacity and was 5 m in diameter. It was installed at Sasolburg in 1989. In 1995, Sasol installed and commissioned an 11,000 b/d, 8 m reactor at the Secunda plant. This was the first of four final 11,000 b/d reactors and four 20,000 b/d reactors that would be part of the 120,000 b/d project at Secunda.

SAS project scope

The SAS project replaced Sasol's 16 CFB Synthol reactors with 8 SAS reactors, one of which existed as the first commercial scale up (11,000 b/d reactor). The project changed little more than the F-T portion of the plant; syngas production and product work-up facilities remained untouched except for tie-ins to the new reactors.

According to Sasol, the new process enables smaller and simpler reactors. The simpler design manifests itself in a fewer number of reactors and lower operating costs.

Each of the three new smaller reactors was 8 m in diameter, similar to the previously commissioned one; each had a capacity of about 11,000 b/d. With the four larger 10.7 m-diameter reactors, each with a capacity of 20,000 b/d, the total capacity of the Secunda plant is 120,000 b/d-no different from the former capacity.

The new reactors were integrated into existing cooling systems. The only other major equipment outside the reactors consisted of 12 new bottom pumparound coolers and seven new steam drums. The heat generated from the exothermic F-T process is recovered by steam generation.

Fig. 1 shows the boiler feedwater lines that recover heat via steam from the reactors.

Many pieces of existing equipment were reused or relocated to minimize the project costs.

Besides new equipment within the complex, outside battery limit (OBL) equipment accounted for a modest part of the project. About 5% of the project cost, or 50 million South African rand, was for OBL equipment. Most of the OBL equipment concerned the steam integration of the new process with neighboring units.

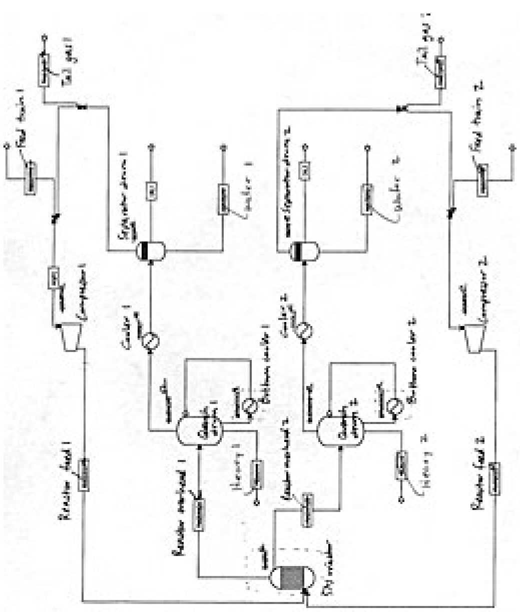

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Fig. 3 shows a simple flow diagram of one 20,000-b/d reactor train. Each of the larger reactors has two identical cooling systems; each smaller reactor has only one. Feed through the main reactor goes through an existing quench tower and new bottom pumparound coolers.

Product gas then flows through the cooling system and to the separator, which separates oil and water from the tail gas. Tail gas is recycled through the reactor.

Neither feed nor product quality and quantity significantly changed as a result of the project. The ratios of the hydrogen to carbon changed only slightly. Like the previous reactors, the new SAS reactors convert syngas to synthetic oil.

Besides gasoline and distillates, the complex produces ammonia and other chemicals. Sasol produces about 170,000 tonnes/year of alpha olefins as well as a large amount of propylene from Secunda's complex. Other high value products such as acetic acid and proprionic acid are also extracted from the aqueous stream.

The destination of Secunda's liquid fuels products remains South Africa; no change occurred as a result of this project.

Project justification

Sasol upgraded its reactors for two reasons: increased energy efficiency and lower operating costs.

The new conventional fluidized bed configuration allows for a higher syngas conversion rate than the former CFB design. The new process has higher conversion rates, which enables less recycling of tail gas through the reactor. The impact of reduced recycling is increased energy efficiency.

The additional steam drums were necessary to accommodate the increased steam production, which is exported to the rest of the plant. Before this project, the GTL process was a net importer of steam.

Operating costs are reduced mainly as a result of the change from a CFB to a conventional fluidized bed reactor. The movement of fluidized catalyst in the circulating bed takes more energy than that in a fluidized bed.

Also, the CFB enabled more erosion because it required a higher velocity; thus, maintenance has also been reduced.

Reactor operation is also more efficient in terms of catalyst usage. Three main factors contribute to lower catalyst usage: lower losses of catalyst from the reactor, less catalyst attrition as a result of lower reactor velocities, and the potential to run at increased average catalyst age.

Higher efficiency, in turn, allows reduced equipment for the same flow. Therefore, to replace the 120,000-b/d capacity with the same, Sasol was able to reduce the number of cooling trains from 16 to 12.

The final Secunda configuration has eight reactors: four with 20,000 b/d of capacity and four with 11,000 b/d of capacity. The reason for the combination of these two varying size reactors was optimum integration and space availability, says Arnold Cilliers, project manager, Sasol Technology (Pty) Ltd., Johannesburg.

The first of four 11,000 b/d, 8-m reactors had already been designed and optimized. Additional reactors of up to 13 m were considered but the cost of fabricating such a reactor made the size uneconomical. Thus, Sasol settled for four larger 10.7 m diameter reactors to optimize construction costs.

Project engineering

Along with the design of the first reactor, some of the basic engineering for the remaining reactors was started. Basic and detailed engineering for long lead-time items began in March 1996 and ran until October 1996.

Purchase orders for some long-lead equipment items were also done during this period. These items included reactors and reactor internals.

Raytheon Engineers & Constructors, Cambridge, Mass., performed all of the basic and most of the detailed engineering. A long-term relationship with Raytheon in reactor design facilitated the design of the reactors.

With some overlap, Raytheon started the detailed engineering in October 1996, which lasted for about 14 months.

Sasol also used several local South African engineering firms that had already worked in the plant:

1. Lategan & Bouwer, Secunda, for civil design.
2. Proconics, Secunda, for instrumentation design.
3. Mechem, Secunda, for interface-piping design.
4. Advanced Electrical Engineering, Secunda, for electrical design.

Cilliers says that using companies that already had a working relationship with the plant allowed increased synergies: "Although Raytheon took the lead role in detailed design, we used the knowledge of local engineering companies as well. The plant knowledge they already had facilitated those projects that required close interfaces, such as piping tie-ins, civil work, and control systems.

"This introduced cost savings in terms of manhours and quality. Because of the complexity of integration, it is vital to have people who are very familiar with the plant," says Cilliers.

Construction planning started with board approval in April 1996. The construction was done so that certain sections of the project were commissioned at different times-one reactor at a time.

Overall project management was performed by Sasol Technology. Mainly four big contractors were involved:

1. Raytheon for design and equipment procurement.
2. Group Five Civils, Ashwood, South Africa, for civil work.
3. Hitachi Zosen Corp., Osaka, and Marubeni Plant Contractor Inc., Indianapolis, consortium for reactor fabrication, transport, and erection.
4. Fluor Daniel Inc., Aliso Viejo, Calif., for mechanical, electrical, and instrumentation construction.

Civil work began in July 1997. Sasol targeted excavation for the dry winter season vs. the wet summer season. The first of the last seven reactors was commissioned in September 1998. The last reactor was up and running in February 1999.

The entire project took 2.4 million man-hr. At its peak, there were 950 construction workers onsite.

Sasol attributes smooth commissioning to careful planning, early personnel training, and thorough precommissioning checks. All seven reactors started up the first time.

Process controls

The plant uses a standard Honeywell DCS system. Although advanced controls are being considered, its implementation was not part of this project. The former plant configuration had one cooling train per reactor. Connecting two cooling trains to each of the four larger reactors was considered a huge instrumentation feat by Sasol.

Two compressors had to be designed and controlled in such a way that if one compressor failed, the associated reactor would continue to run. If one compressor tripped, there would be a 50% turndown on the reactor, which had to be designed to handle this turndown.

Mainly, plant control changed in this instance from feedback control to feed-forward control.

Environment, safety

The overall environmental effect of the project was positive. The process consumed 50% less catalyst and required 25% less in cooling trains (12 instead of 16). Thus, wastes from spent catalysts were reduced by 50% and fugitive emissions were down by 25% as a result of less equipment.

As the new process is more energy efficient, it more efficiently uses heat from the process. Previously, much wasted energy in the form of heat was sent to the atmosphere. Lower required water makeup was a direct result of this efficiency.

In addition, the project reduced the volume of "gunk," a mixture of oil and catalyst, by 75%. Noise has also been reduced from 16 db to 8 db, as the old CFB reactors were noisier.

No new permits were required for this project. After presentation of the internal scope of the project to the Department of Environmental Affairs & Tourism, Sasol received authorization to proceed.

The largest safety challenge was working in a live plant. No additional downtimes outside of those planned for regular statutory inspection were required for the project. Except for tie-ins, the new reactors were installed while the unit was operational.

In an example of the safety that had to be considered to work near the live plant, the larger reactors weighed 1,600 tons. They were placed in position in a three-lift sequence; the closure weld, which required a 600° C.+ postweld heat treatment, done onsite, was as close as 25 m from live units.

Having a live plant near the construction required more care in permit issuances and construction in general.

Economics

As the new project did not expand existing capacity, Sasol could not justify the project based on additional product revenue. Instead, its sole justification was based on increased efficiency and operating costs.

Lana van Wyk, business analyst, points out, "You have to realize how good this new technology is in comparison to the old one. To actually validate taking out all the old ones, replacing them with new technology-we aren't actually doing it to increase capacity so that illustrates the economics behind changing these reactors."

The expected initial capital investment for the eight new reactors and associated projects was 1,010 rand (US$225 million). The final project cost 1,003 rand, or 7 million rand less than originally budgeted.

Sasol expects the project to reduce operating costs by $1/bbl of liquid fuels produced.[1]

As some of the SAS reactors have run for a year now, Sasol has identified and implemented additional projects to increase capacity and efficiency.

Most of these projects were part of the medium-term, gas-expansion (MTGE) project, which was completed with a unit turnaround in September. The MTGE project increased the complex's capacity to 150,000 b/d.

Reference

1. Kleynhans, Evert, P., Matyja, Zbigniew F., and Dias, A. Paulo de Gavino, "An exercise in large scale reactor replacement," Petroleum Quarterly, Spring 1999, p. 113.