Small-scale gas to liquids

Microchannel reactor technology is on trial for the small-scale production of liquids from stranded gas

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Associated gas and stranded gas — gas reserves located far from existing pipeline infrastructure and markets — are potentially abundant sources of energy that are commonly squandered. Rather than being transported to refineries for processing, stranded gas is often just left in the ground. Associated gas produced along with oil is frequently disposed of by flaring — a wasteful and environmentally unfriendly process that is increasing subject to regulation — or by re-injection back into the reservoir at considerable expense.

According to the World Bank, 5.25 trillion cubic feet (tcf, approximately 140 billion m^3) of associated gas — the equivalent of 27% of US gas consumption — was flared in 2008. The giant gas flares that light the night sky in Russia, Nigeria, Iran, Iraq, Algeria, Kazakhstan, Libya, Saudi Arabia, Angola and Qatar are a highly visible reminder of this waste. A further 12.5 tcf of gas was re-injected. In addition, there is thought to be as much as 3000–6000 tcf of "stranded" gas — unassociated natural gas already found but without cost-effective access to the world market and, therefore, not yet being produced.[1,2] The reason? Cost-effective technologies for capturing these wasted resources are not available.

The available options for capturing the value of onshore stranded gas include liquifying or compressing the gas (to LNG or CNG), then shipping it in specially designed tankers. Both have serious drawbacks at small to medium scales, particularly in terms of cost. The economics dictate that new LNG projects are only economically viable for producing gas volumes greater than 500 mcfd over distances of 4200 km (2500 miles) or more. Although CNG is a good option for transporting smaller volumes with throughputs as low as 100 mcfd, over shorter distances in the range of 1000–2500 km (600–1500 miles) it is too expensive to be used when reserves are more remote.

A third way

For both stranded and associated gas, gas to liquids (GTL) offers a potentially attractive alternative. Like LNG and CNG, GTL densifies the energy to make it cheaper to transport. In principle, GTL products can be transported in the existing petroleum infrastructure. But in order to work efficiently, GTL plants must be designed to work on a very large scale. Conventional GTL technology is only economically viable for large-scale plants producing around 30 0000 b/d of liquid fuel and this requires a very large capital investment.

This has proved to be a considerable barrier to the progress of the GTL industry. For example, although several larger-scale plants have been developed or announced in recent years, only three have made it off the drawing board:

- Sasol's Oryx plant in Qatar was completed in 2006, but, due to an extended start-up period, did not achieve its nameplate production level of 34 000 b/d until late 2009. Costs rose from an initial estimate of $950 million to $1.5 billion
- Chevron's 34 000 b/d plant at Escravos in Nigeria will cost an estimated $6 billion and is expected to start up in 2013
- Shell's Pearl GTL plant in Qatar, the world's largest GTL project, with an ultimate capacity of 140 000 b/d and an estimated price tag of $18–19 billion, is expected to start up in 2011.

But thanks to advances in the development of technology for distributed or small-scale GTL technology, a much more flexible and economical option for capturing associated gas, both on- and offshore — in the form of modular GTL technologies — is on the horizon. These systems are designed to operate efficiently and economically when producing just 500 b/d. When combined with petroleum crude, the synthetic crude produced from associated gas can be stored on-board or could be transported to shore along with the produced oil via existing tankers and pipelines, eliminating the need for a separate logistics system to transport the gas to market. Small-scale GTL could also prove useful for capturing shale gas resources now being exploited in the US.

Shrinking the hardware and scaling down the cost

The GTL process involves two operations: steam methane reforming (SMR), to convert natural gas into a mixture of carbon monoxide (CO) and hydrogen (H_2), known as syngas, followed by Fischer-Tropsch (FT) synthesis to convert the syngas into a liquid fuel (see Figure 1). In SMR, the methane gas is mixed with steam and passed over a catalyst to produce a syngas consisting

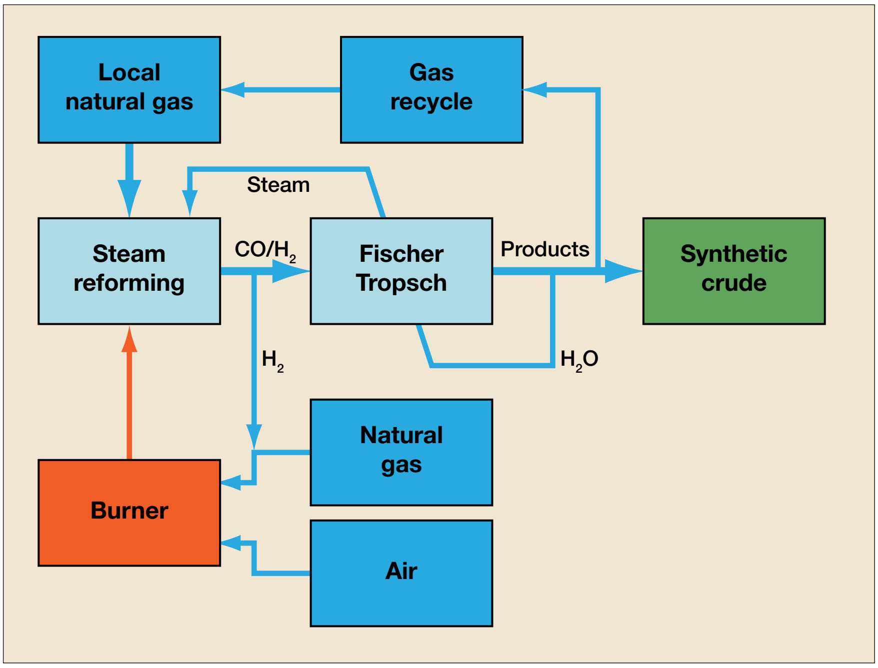

Figure 1 GTL flow diagram

of H_2 and CO. The reaction is highly endothermic, so requires the input of heat. This can be generated by the combustion of excess H_2. The syngas is then converted into various forms of liquid hydrocarbons via the exothermic (heat-producing) FT process, using a catalyst at elevated temperatures.

For small-scale GTL, the challenge is to find ways to combine and scale down the size and cost of the SMR and FT reaction hardware while still maintaining sufficient capacity. And for offshore installations, whether they are drill ships or floating production storage and offloading units (FPSOs), the equipment also needs to be able to withstand high-intensity wave motion.

Fixed or slurry bed reactors — the two conventional reactor types currently used in FT plants — only function well and economically at capacities of 30 000/day or higher, and the technology does not scale down efficiently. However, new reactor designs, such as micro- and mini-channel reactors, offer a practical way forward.

Both types of reactor consist of compact, modular fixed-bed designs with process channels that are much smaller and provide a greater surface area than conventional FT reactors. Their small size, lighter weight and lower profile are advantages in an offshore environment (see Figure 2).

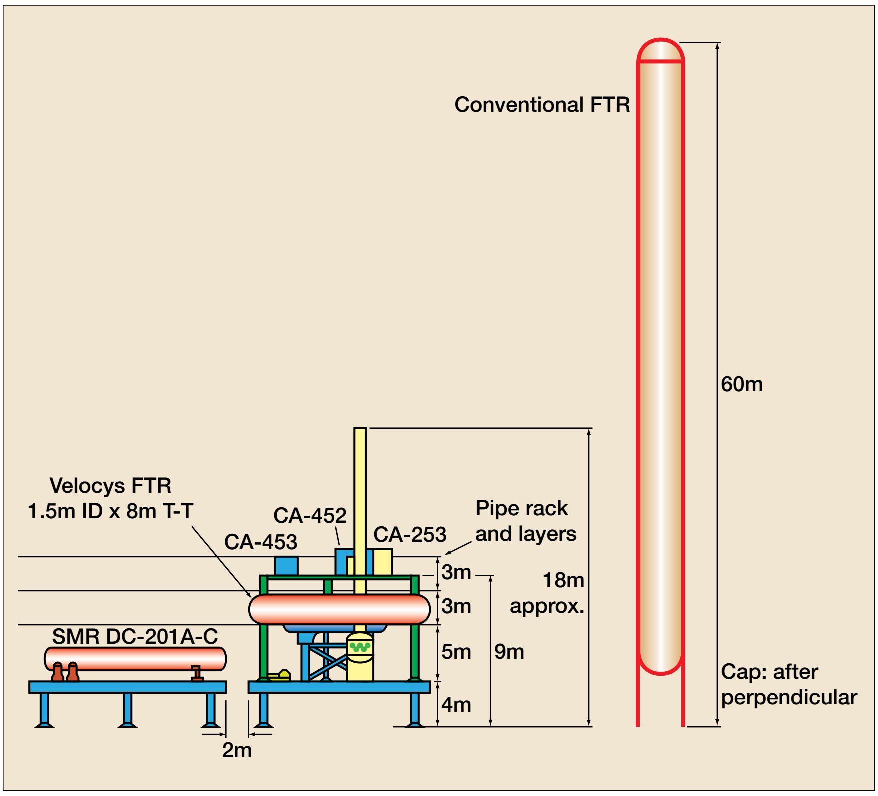

Figure 2 Profile of an FT microchannel reactor assembly compared to that of a conventional FT plant

Mini vs micro

Development of small-scale GTL depends on finding ways to intensify the SMR and FT processes. This relies on developing ways to enhance heat and mass transfer properties and increase their productivity. Since heat transfer is inversely related to the size of the channels, reducing the channel diameter is an effective way of increasing heat transfer and thus intensifying the process by enabling higher throughput. This is the basic logic behind the approaches being taken by the two main players currently working to develop offshore GTL systems, the UK-based company CompactGTL plc and the US company Velocys, a subsidiary of the UK-based Oxford Catalysts Group. Although both are developing integrated SMR/FT systems and are working on the basis of the same principles, the solutions they have come up with are different.

In essence, both companies are developing modular solutions that combine SMR and FR, and both have found ways to reduce the size of the hardware. In standard SMR and FT processes, the reactions are carried out in 2.5–5cm (1–2in)-diameter tubes or channels. In the integrated two-stage system being developed by CompactGTL — which the company says is designed to incorporate modules weighing

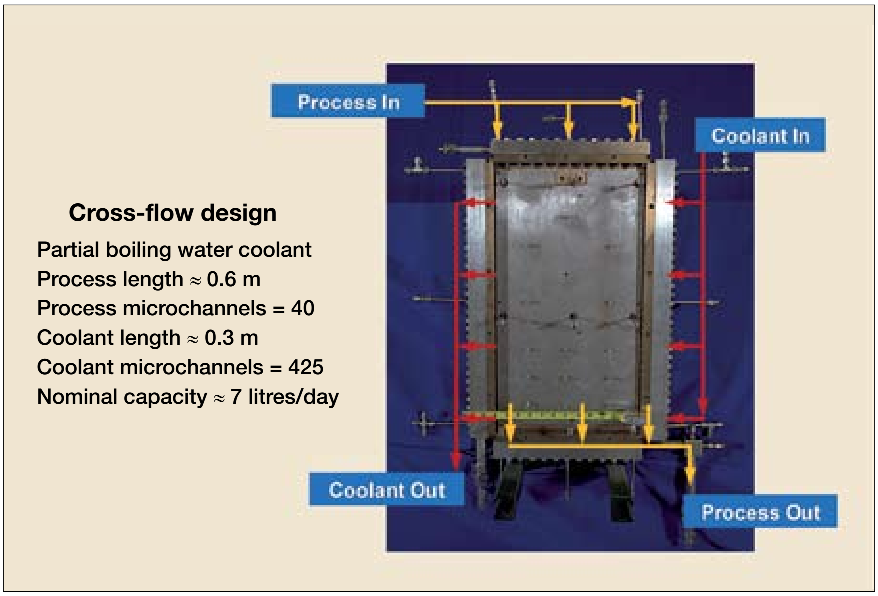

Figure 3 Schematic of the SMR microchannel reactor

less than 25 tonnes and producing 200 bbl/day of liquids per module — the SMR and FT reactions are carried out in a series of mini-channels, 1 x 0.5cm (0.39 x 0.20in).

In contrast, the Velocys combined SMR/FT system for offshore GTL takes advantage of microchannel reactor technology to shrink the hardware and intensify the processes even further. Here, reactions take place in microchannels, which have diameters in the millimetre range. For example, the microchannel FT reactor system, with a footprint of just 2.4 x 8m (8 x 25ft), has the capacity to produce around 300 b/d. Several FT microchannel reactors, with footprints of just 0.61 x 0.61cm (24 x 24in) can be combined, or manifolded, in parallel to increase production volumes.

The small size of the channels reduces the heat and mass transfer distances, thus accelerating process productivity by 10–1000 times. The enhanced heat transfer properties offered by microchannel reactors make this technology ideally suited to carrying out catalytic reactions that are either highly endothermic (such as SMR) or highly exothermic (such as FT), where heat must be efficiently transferred across reactor walls to maintain an optimal and uniform temperature to achieve the highest catalytic activity and the longest catalyst life.

In microchannel SMR reactors, the heat-generating combustion and steam methane reforming processes take place in adjacent channels (see Figure 3). The high heat transfer properties of the microchannels make the process very efficient. These properties are also used to intensify the FT process.

The basic building blocks of the Velocys microchannel FT reactors consist of reactor blocks containing parallel arrays of microchannels filled with FT catalyst interleaved with water-filled coolant channels (see Figure 4). Since the reactors are able to dissipate the heat produced by the FT reaction much more quickly than conventional systems, a more active FT catalyst can be used.

The microchannel FT reactors take advantage of a highly active FT catalyst developed by Oxford Catalysts to accelerate FT reactions by a factor of 10–15 compared to conventional reactors. As a result, the microchannel FT reactors exhibit conversion efficiencies in the range of 70% per pass, a significant improvement over the 50% or less per pass conversion rates achieved in conventional FT plants.

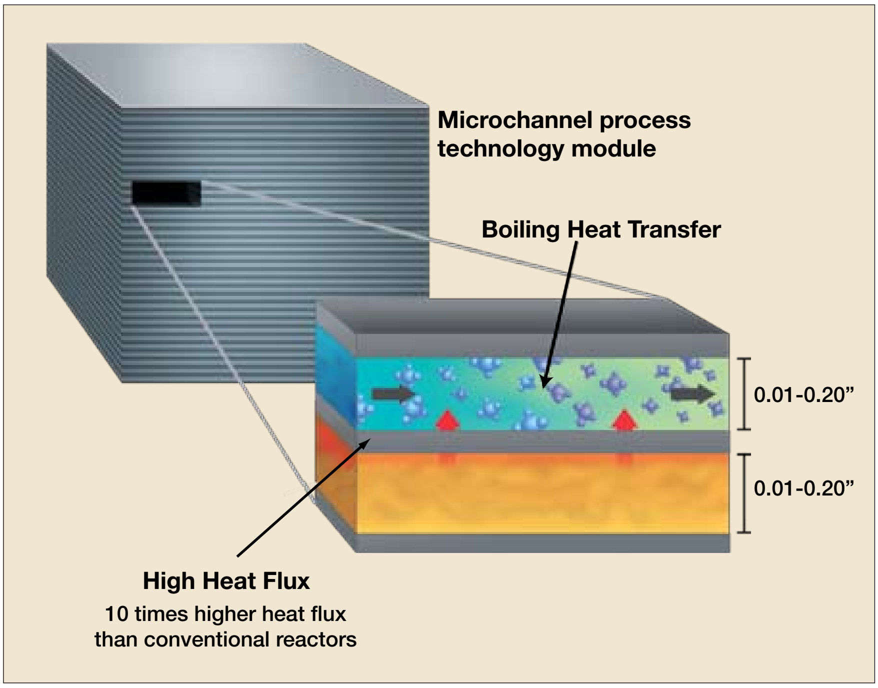

Figure 4 Microchannel reactor schematic

Catalyst key

The key to the improved performance of Oxford Catalysts' FT catalyst lies in a patented catalyst preparation method known as organic matrix combustion (OMX).

The OMX method combines the metal salt and an organic component to make a complex that effectively stabilises the metal. On calcination, combustion occurs that fixes the crystallites at a very small size and in a very narrow range. Since the calcination is quick, the metal crystallites do not have time to grow and hence remain at the ideal size for these catalytic reactions.

The OMX method produces crystallites of an optimum diameter range that exhibit a terraced surface. These are both features that enhance catalyst activity. OMX also produces fewer very small crystallites that could sinter at an early stage of operation. This results in greater catalyst stability. Less stable crystallites tend to deactivate quickly, reducing the activity of the catalysts.

Technology on trial

Both the CompactGTL and Velocys technologies have reached the trial stage. According to CompactGTL, the company entered into a joint development testing agreement in 2006 with the Brazilian state oil company, Petrobras, to deliver a 20 b/d pilot plant to be tested onshore at the Petrobras Aracaju site in Brazil. The cost of the pilot plant construction and testing project is being funded by Petrobras. The trial was due to begin during the second half of 2010. Industry reports currently suggest that although the CompactGTL skid is now *in situ* at the Petrobras site in Aracaju, it is not yet operating, although trials are expected to start soon. However, a fully integrated pilot plant at the CompactGTL site at Wilton in Teeside, UK, has been operating continuously and successfully since mid-2008 and the company expects its first commercial plant to begin operation in 2012.

Meanwhile, in March 2010, Velocys entered into a joint demonstration and testing agreement with offshore facility developer Modec, global engineering firm Toyo Engineering and Petrobras, to build and operate a 5–10 b/d microchannel GTL demonstration plant at the Petrobras facility in Fortaleza, Brazil.

Assembly is complete and the plant is due to be delivered in Q1 2011. It will be operated for nine months, starting in Q3 2011. Following a successful demonstration, it is expected that the first commercial deployment will be on an FPSO to mitigate flaring of associated gas resulting from the development of offshore oil fields. Under the terms of this agreement, the total cost, estimated at several tens of millions of dollars, will be covered by Toyo Engineering and Modec, while Petrobras will be responsible for the installation and operating costs of the demonstration plant. This demonstration plant, which is designed to accelerate SMR 200-fold and FT reactions by a factor of 10–15, is expected to be up and running during 2011.

Conclusions

The significant investments in large-scale GTL plants such as Pearl and Oryx demonstrate belief in the potential for GTL to establish itself as major technology to capture the value of large stranded gas deposits. By greatly reducing the size and cost of chemical processing hardware, micro- and mini-channel technology has the potential to extend the use of GTL to capture value from small deposits too, as well as to eliminate flaring or re-injection of associated gas. The trials being undertaken by CompactGTL and Velocys suggest that it may well be possible to reap the advantages of small-scale GTL sooner rather than later.

References

1 http://tinyurl.com/Flare-Gas-Stats

2 http://tinyurl.com/FlareGasRegsWorldBank)

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