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up in smoke

an end to wasteful flaring?

The flaring of associated and stranded gas wastes resources and money, and pollutes the environment too. But new technologies can put a stop to it, say **Andrew Holwell** and **Jeff McDaniel**

THE giant gas flares that light the night sky in countries like Russia, Nigeria, Iran, Iraq, Angola, Kazakhstan, Qatar and Venezuela are highly visible reminders of a very wasteful and environmentally unfriendly process – the flaring of associated gas (Figure 1 pictured below).

Associated gas and stranded gas – gas reserves located far from existing pipeline infrastructure and markets – are potentially abundant sources of energy commonly squandered. Rather than being transported to refineries for processing, stranded gas is often just left in the ground. Gas produced along with oil is frequently disposed of by reinjection back into the reservoir at considerable expense, or by flaring.

The amounts involved are staggering. According to the Global Gas Flaring Reduction Initiative (GGFR), a World Bank-led public-private partnership launched in 2002 [see <http://tinyurl.com/GGFR-website>], more than 134b m³ (4.7 trillion ft³) of natural gas is flared and perhaps the same amount is vented annually. This is equivalent to 25% of the gas consumption of the US, 30%

of the EU's consumption and more than the combined gas consumption of Central and South America. The annual 35b m³ (1.2 trillion ft³) of gas flared in Africa alone is equivalent to half of that continent's power consumption. And the environmental effects are serious – the GGFR estimates that flaring results in around 400m t of CO₂ in annual emissions.

Flaring is subject to increasing regulation – something the GGFR strongly supports – and the oil majors are all looking for solutions to reduce flaring. For example, Shell – a major player in Nigeria, which, according to GGFR statistics, is second only to Russia in the volume of gas flared – states on its website that “the continuous flaring of associated gas must be reduced significantly.” Total, another major operator in west Africa, notes on its website that it decided to work towards eliminating routine flaring on all new fields in 2000. It has also made a voluntary commitment to halve flaring on its sites, compared with 2005 levels.

The options for capturing the value of onshore stranded gas include liquefying or compressing it (LNG or CNG) then shipping it in specially designed tankers. LNG is an option mentioned by both Shell and Total. However, both LNG and CNG 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 500m ft³/d over distances of 4,200 km or more. Although CNG is a good option for transporting smaller volumes with throughputs as low as 100m ft³/d over shorter distances in the range of 1,000-2,500 km, it is too expensive to be used when reserves are more remote.

α third way

For both stranded and associated gas, gas to liquids (GTL) could offer an attractive alternative. Like LNG and CNG, GTL ‘densifies’ the energy to make it cheaper to transport. In principle, GTL products can be transported in existing petroleum infrastructure. Conventional GTL technology requires a very large capital investment because it is only viable for large-scale plants producing around 30,000 bbl/d of liquid fuel.

Only about 6% of the world's gas fields are large enough to sustain a GTL plant of that size, and the majority of potential undiscovered gas finds are thought to be below 1 trillion ft³, an amount too small to make conventional GTL and LNG economic. This helps to explain why, in recent years, only three GTL plants – the Sasol Oryx plant in Qatar which began full operation in 2009; the Chevron 34,000 bbl/d plant at Escravos in Nigeria, expected to start up in 2013; and the world's largest GTL project, the Shell Pearl GTL plant in Qatar, due to start up this year – have made it off the drawing board.



Emissions flare-up!

However, 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 onshore and offshore – in the form of modular GTL technologies – is on the horizon. These systems are designed to be operated efficiently and economically when producing just 500 bbl/d [see text box: Small-scale GTL – how it works]. The synthetic crude produced from associated gas can be stored on board or combined with petroleum crude and 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.

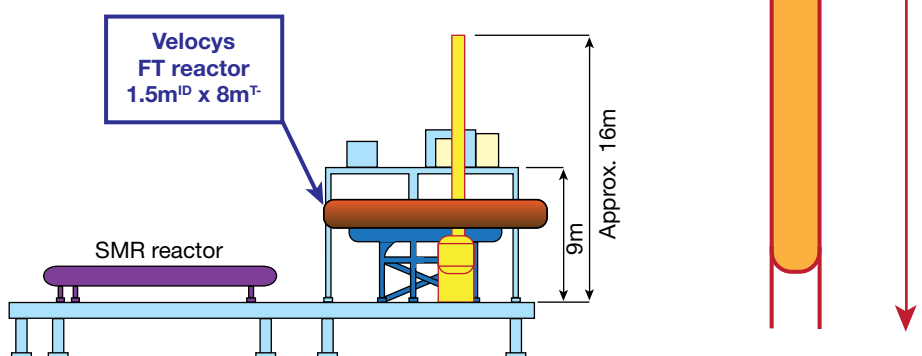
PTT, the Thai state-owned energy company, and Petrobras, the Brazilian state oil company and the largest in Latin America, are both exploring applications for small scale GTL; other international energy companies are also expressing interest. The technology could prove useful for capturing shale-gas resources now being exploited in the US, too.

shrinking the hardware and scaling down the cost

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

Fixed-bed or slurry-bed reactors – the two conventional reactor types currently used in FT plants – only function well and economically at capacities of 30,000 bbl/d or higher, and the technology does not scale down efficiently. However, new reactor designs, such as microchannel and minichannel reactors, offer practical ways forward.

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



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).

mini vs micro

Development of small-scale GTL depends on finding ways to intensify the SMR and FT processes. Achieving this relies on developing ways to enhance heat and mass transfer properties and increase their productivity. Because heat transfer is inversely related to the size of the channels, reducing the channel diameter is an effective way of increasing heat transfer, thus intensifying the process by enabling higher throughput. This is the logic behind the approaches taken by the two main players currently working to develop offshore GTL systems: the UK-based company CompactGTL plc (www.compactgtl.com) and the US company Velocys (www.velocys.com), a subsidiary of the UK-based Oxford Catalysts Group plc (www.oxfordcatalysts.com). Both are developing integrated SMR/FT systems and are working on the basis of the same principles, but their solutions are different.

In essence, both companies are developing modular solutions that combine SMR and FT and both have found ways to reduce the size

of the hardware. In 'standard' SMR and FT processes the reactions are carried out in 2.5-5 cm (1-2 in) diameter tubes, or channels. In the integrated two-stage system being developed by CompactGTL – which the company says is designed to incorporate modules weighing less than 25 t and producing 200 bbl/d of liquids per module – the SMR and FT reactions are carried out in a series of minichannels of 1 x 0.5 cm (0.39 x 0.20 in). For more information about CompactGTL technology, see http://www.compactgtl.com/download/JPT_TechUpdate.pdf.

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. In the Velocys SMR and FT microchannel reactors, reactions take place in microchannels that have diameters in the millimetre range. For example, the Velocys microchannel FT reactor system, with a footprint of just 2.4 x 8 m (8 x 25 ft), has the capacity to produce around 300 bbl/d. Several FT microchannel reactors, with footprints of just 0.6 x 0.6 m (24 x 24 inches), 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 tenfold to 1,000-fold. The enhanced heat-transfer properties offered by microchannel reactors make this technology ideally suited for 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.

The basic building blocks of the Velocys microchannel FT reactors are reactor blocks containing parallel arrays of microchannels filled with FT catalyst interleaved with water-filled coolant channels (see Figure 3). Because 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.

technology on trial

Both the CompactGTL and Velocys technologies have now reached the trial stage. According to the CompactGTL website, the company entered into a joint demonstration and testing agreement (JDTA) in 2006 with Petrobras, the largest company in Latin America, to deliver a 20 bbl/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 the

CompactGTL skid is now *in situ* at the Petrobras site and trials have already commenced. In addition, a fully integrated pilot plant at the CompactGTL site at Wilton in Teeside, UK, has been operating continuously and successfully since the middle of 2008 and, according to its website, CompactGTL expects its first commercial plant to begin operation in 2012.

Meanwhile, in March 2010 Velocys entered into a JDTA with offshore developer MODEC, the global engineering firm Toyo Engineering and Petrobras to build and operate a 6 bbl/d microchannel GTL demonstration plant at the Petrobras facility in Fortaleza, Brazil.

Assembly is now complete and it was delivered in Q1 of 2011. It will be operated for nine months, starting in Q3 of 2011. Following a successful demo, 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. This demonstration plant is designed to accelerate SMR by 200-fold, and FT reactions by tenfold to 15-fold.

The Oxford Catalysts Group is also working with PTT to develop and commercialise the group's microchannel

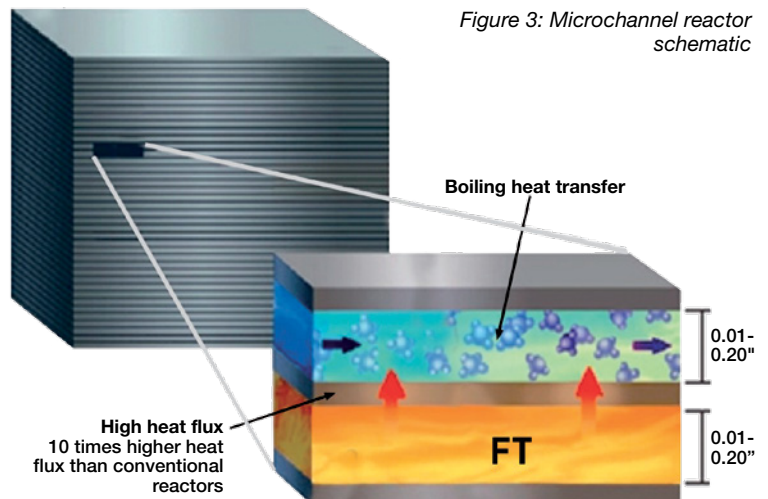


Figure 3: Microchannel reactor schematic

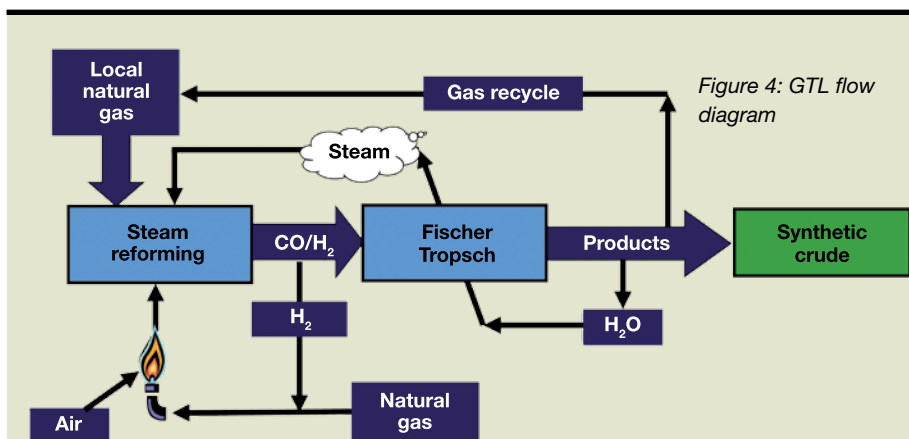


Figure 4: GTL flow diagram

SMR technology, particularly for onshore applications. Under the terms of a memorandum of understanding (MOU) signed in February 2010, PTT is providing funding of \$5m over two years to support the development. PTT is interested in the technology said Chaicharearn Atibaedya, executive vice president of the PTT Research and Technology Institute, as "we believe that small-scale GTL is a promising technology platform to utilise and create added value from flare gas, both onshore and offshore."

the threshold of success

By greatly reducing the size and cost of chemical-processing hardware, microchannel and minichannel technology have the potential to extend the use of GTL to capture value from small deposits too, as well as to eliminate flaring or reinjection of associated gas. As an environmental bonus, the Velocys FT microchannel technology can also be used for small-scale distributed production of biofuels from a variety of waste feedstocks. A demonstration biofuels plant, jointly operated by the Oxford Catalysts Group and the Portuguese incorporated holding company SGC Energia (SGCE), that includes an FT microchannel reactor and uses gasified woodchips as a feedstock, is currently operating in Güssing, Austria. So far, the plant is running well. For environmentally friendly liquid-fuel production from a wide range of conventional and biofuel sources, small-scale could soon be looming large on the environmental horizon. **tce**

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small-scale GTL – how it works

The GTL process involves two operations: steam methane reforming (SMR), to convert natural gas into a mixture of carbon monoxide (CO) and hydrogen (H₂) known as syngas, followed by Fischer-Tropsch (FT) synthesis to convert the syngas into a liquid fuel (see Figure 4).

In SMR the methane is mixed with steam and passed over a catalyst to produce a syngas consisting of H₂ and CO. The reaction is highly endothermic, so requires the input of heat. This can be generated by the combustion of the excess H₂. The syngas is then converted into various forms of liquid hydrocarbons via the exothermic (heat-producing) FT process, using a catalyst at elevated temperatures.

In microchannel SMR reactors the heat-generating combustion and SMR processes take place in adjacent channels (see Figure 5). The high-heat-transfer properties of the microchannels make the process very efficient. These properties are also used to intensify the FT process.

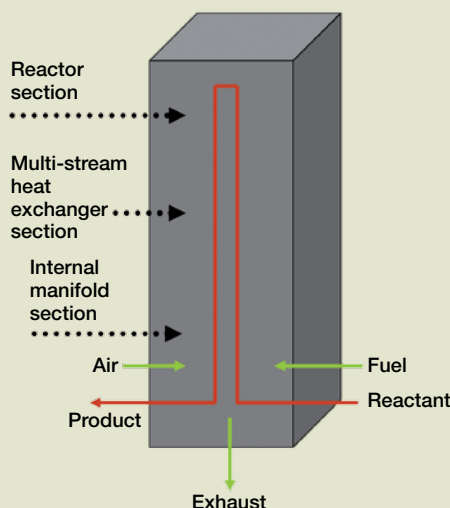


Figure 5: Schematic of the SMR microchannel reactor