Hydrogen – making the move from industrial gas to fuel

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Our sun creates energy through the fusion reaction of hydrogen to form helium: that's been going on for millions of years. Here on earth, the use of hydrogen as an energy source commenced 227 years ago when William Murdoch lit his house and office in Redruth, Cornwall from town gas – a mixture of hydrogen, carbon monoxide and carbon dioxide – which he produced in a small retort in his back yard. Over the next century, gas-works and gas distribution pipelines were built across the United Kingdom to keep the country warm and well lit.

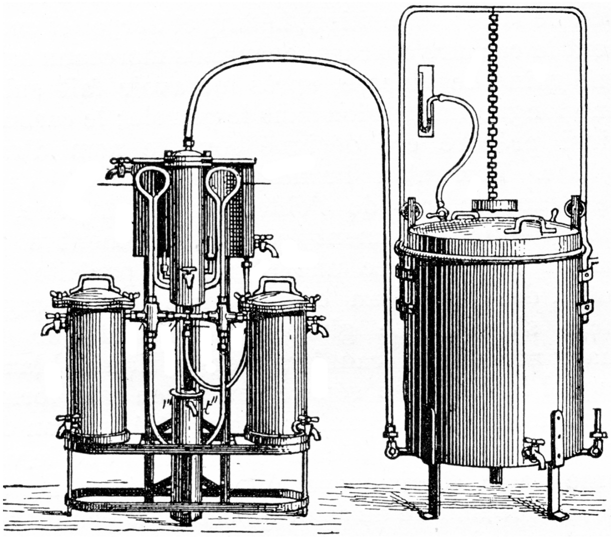
The commercialisation of natural gas from the North Sea led to a broad decline of town gas production in the UK. Natural gas reserves in Russia have also been exploited in recent decades with pipelines transporting the fuel over thousands of kilometres to markets in Europe. The more recent emergence of liquefied natural gas production, predominantly from sources in Australia, Qatar and the United States has enabled Asian consumers to benefit from natural gas and has led to a further ramp down in the use of town gas as a fuel worldwide.

Combustion of natural gas is seen as a cleaner alternative to coal for electrical power generation. It is, however, a fossil fuel and creates carbon dioxide emissions which contribute to global warming. So, the next energy transition will be the search for decarbonisation and this is the goal that will see a re-emergence of hydrogen as a gaseous fuel.

Hydrogen as an industrial gas

Despite the advent of hydrogen production, as town gas, 227 years ago, the beginnings of the modern industrial gases industry are much more recent and can be traced to 1902 when Carl von Linde built the first cryogenic air separation plant with the intent to produce oxygen.

Approximately 30 years later, industrial scale hydrogen production commenced using steam methane reformers. At this time, commercial hydrogen production was associated with the chemicals industry with names such as ICI and BASF owning many early patents. The technology was closely linked to ammonia and fertilizers production.



Early gasification reactor for town gas production

It is only in more recent decades that tonnage scale hydrogen production has become part and parcel of the industrial gases sector. From that late start, it is notable that hydrogen is now firmly established in the top three industrial gases, alongside oxygen and nitrogen. Its presence is perhaps at its most sophisticated level in the United States, where Air Products operate the 960 km-long Gulf Coast hydrogen pipeline which can supply a total of 1.5 million Nm3 per hour of hydrogen to companies along the Gulf Coast in Texas and Louisiana.

It is common to refer to 'captive' production when referring to gases that might be produced by an industrial gases company, but are pro-

Refinery hydrogen production on a Steam Methane Reformer

duced by the end-user themselves, for example a steel works that owns and operates its own ASU for oxygen production. If we were to include the vast quantities of 'captive' hydrogen production on refineries, fertilizer and chemicals plants, then hydrogen would undoubtedly become the most significant industrial gas worldwide today.

Hydrogen as a heating fuel

The UK invested heavily in natural gas distribution infrastructure to exploit the benefits of North Sea gas. This has resulted in the country having a high proportion of its heating requirements derived from natural gas. To meet the vision of a de-carbonised future, an alternative heating source must be found. Whilst electricity from renewable sources is often spoken of as a green fuel, its application for power-hungry heating would be a stretch for the renewables sector in the short term.

These are the drivers behind the H21 Leeds City Gate and the HyNet North West projects in England which aim to use hydrogen as a heating fuel in the future energy mix. The projects plan to take natural gas from the North Sea and convert that to hydrogen using steam methane reformers or auto-thermal reformers. Carbon dioxide produced in the process will be captured and stored in CCS schemes to avoid its release to the atmos-

Natural gas distribution pipeline

phere. The hydrogen can then be distributed in natural gas pipelines, leveraging the current gas distribution infrastructure.

De-carbonised Hydrogen production

One might speculate that in the future the hydrogen to be injected into the distribution grid could be produced by renewable technologies, such as electrolysis of water using solar power – thus enabling a decarbonised heating fuel supply. For this purpose, the use of polymer electrolyte membrane (PEM) technology for industrial scale hydrogen production is becoming a realistic proposition.

Under the project name 'Refhyne' a 10 MW PEM electrolysis facility built by ITM power, will produce 1,300 tonnes of hydrogen per year. It is planned to come on stream at Shell's Rheinland refinery, the largest in Germany, in 2020. The refinery requires approximately 180,000 tonnes of hydrogen per year for processes such as the production of low sulphur liquid fuels.

Hydrogen demand on refineries is anticipated to take another step up in the next few years, as marine bunker fuel join diesel, gasoline and aviation kerosene in the list of low-sulphur fuels. To comply with the latest MARPOL Annex VI regulations, ship operators may choose to burn fuel oil with 0.5% sulphur content, a big reduction from historic levels of 3.5%.

Hydrogen mobility

Much attention is currently being given to 'electro-mobility' and the need for zero emissions transportation in urban centres. At present, electrically powered cars with energy storage in lithium-ion batteries are the dominant form of electro-mobility. However, the use of hydrogen to create electrical power in a fuel-cell is an emerging alternative. Many car-makers now offer hydrogen powered fuel cell electric vehicles the fuelling infrastructure in Europe has now grown to more than 100 stations.

The hydrogen infrastructure in Germany is at the forefront of this development in Europe and a joint venture between Air Liquide, Linde, Daimler, Shell, Total and OMV plans to develop a nationwide network of 400 hydrogen refuelling stations by 2023. It is notable that the collaborators here are major energy companies and industrial gases leaders, in addition to the auto-industry. The hydrogen required in these

fuelling stations can either be produced in centralised steam methane reformers and transported to the fuelling station or generated in-situ through the electrolysis of water using solar power. So, a decarbonised production route using renewable electrical power is also possible.

Impact across the industrial gases value chain

The industrial gases majors are not the only participants in sustainable mobility space. Regional players, such as Coregas in Australia, also have skin in the game through their supply of compressed hydrogen to the refuelling station at Hyundai's Australian headquarters in New South Wales. Executive General Manager, Alan Watkins comments that "energy diversity is a huge topic in Australia. We are challenging Qatar to be the world's number one exporter of LNG and the nation has tremendous plans to play a role in the hydrogen economy. Frankly speaking, at Coregas, so do we".

Industrial gases cylinder manufacturer, Worthington Industries, sees fibre-wrapped, plastic-lined Type IV cylinders as one major trend that will continue shaping the future of the sector. "Composite cylinders with a working pres-

Fuel Cell Electric Vehicle powered by Hydrogen sure of 700 bar, are becoming the standard in the automotive sector. A car has limited space for hydrogen tanks, so, to compete with other fuel options on range, manufactures are using smaller tanks at higher pressure," said Gabi Zeilerbauer, Worthington Industries Director of European Sales for Industrial products. "An additional benefit of Type IV is weight reduction. Type IV cylinders yield a 60 percent weight reduction over Type I steel cylinders with the same volume and working pressure. Vehicles with Type IV hydrogen tanks will hence use less fuel to take drivers further".

The drive towards hydrogen is broadening the palette of players in this part of the industrial gas arena. Companies such as ThyssenKrupp and Siemens are knocking on the door with their large-scale electrolytic hydrogen production expertise. In the fuelling stations sector, smaller companies such as Hydrogenics have been able to deepen their involvement and others such as McPhy have emerged on the scene, creating tremendous impact in just over a decade of operations.

Conflict around the corner?

With their interests in hydrogen as a transportation fuel, the industrial gases companies are clearly entering a domain that has been home to the energy majors over recent years. Can we expect conflict? Through their expertise in hydrogen production and core competencies related to handling high pressure compressed gases, companies in the industrial gases value chain have a genuine contribution to make. The situation is like the application of industrial gases cryogenic technology to LNG; the extension of packaged gases logistics to the distribution of LPG and expertise in pressurised systems being stretched into CNG.

High pressure automotive CNG cylinder

Interestingly, the oil and gas sector with related downstream refining operations and petrochemical processing is one of the largest customer segments for the industrial gases industry alongside the steel making. Applications range from tonnage oxygen supply for FCC catalyst regeneration and high consumption of nitrogen for tank purging and inerting for operational safety. So, collaboration would clearly be preferred. Fortunately, in the topic of hydrogen energy, there seem to be enough niches and the sector is growing in such a dynamic fashion that all available expertise will be both welcome and required.

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