Gasification

An old technology triggering mega-scale industrial gas projects

By **Stephen B. Harrison**

Gasification is a long-established technology with a fascinating future. As an early example at industrial scale, the Seattle Gas Light Company coal gasification plant in the State of Washington came into operation in 1906. At its peak 40 years later, it was producing 7,000 Nm^3 per hour of town gas which was used for heating and lighting in nearby suburbs.

Town gas was the name given to the flammable mixture of hydrogen and carbon monoxide generated by the gasification process. In modern industrial gases terminology, this would be called syngas.

To understand the chemistry of gasification, we can consider a spectrum of processes ranging from combustion to pyrolysis. Combustion is the high temperature reaction of a hydrocarbon with an excess of oxygen. It yields primarily heat, carbon dioxide and water. It is common in electrical power generation to produce steam. At the other extreme, pyrolysis is a high temperature decomposition of a hydrocarbon to form solid carbon in the absence of oxygen. It is used to produce coke from coal in steelmaking and to create charcoal from wood. Gasification also occurs at high temperatures and fits somewhere between the two extremes of combustion and pyrolysis because a precisely controlled amount of oxygen is used.

One of the world's largest gasification projects is currently in full swing at the Jazan refinery in Saudi Arabia, where more than a dozen gasifiers built by the Spanish Company Técnicas Reunidas will produce syngas from heavy refinery residues. In total, the gasifiers at Jazan will be capable of producing 2,110,000 Nm^3 per hour of syngas: 300 times more than their forerunner in Seattle.

One of the drivers behind refinery residue gasification projects has been the IMO 2020 regulation which has led to a growth in low sulfur marine fuels. Many refineries have worked hard and invested heavily to find solutions to their heavy residuals. Furthermore, Petcoke has recently been banned in India for use as cheap feed to coal-fired power plants due to its high sulfur content. Instead, gasifying it to produce syngas and hydrogen, which is used to desulfurise fuels produced by refineries, can create value from the Petcoke.

Furthermore, the determination that exists in China to use their coal resources to produce chemicals and clean-burning liquid fuels is also clear. These factors have been key drivers behind the recent wave of solid feedstock gasification projects.

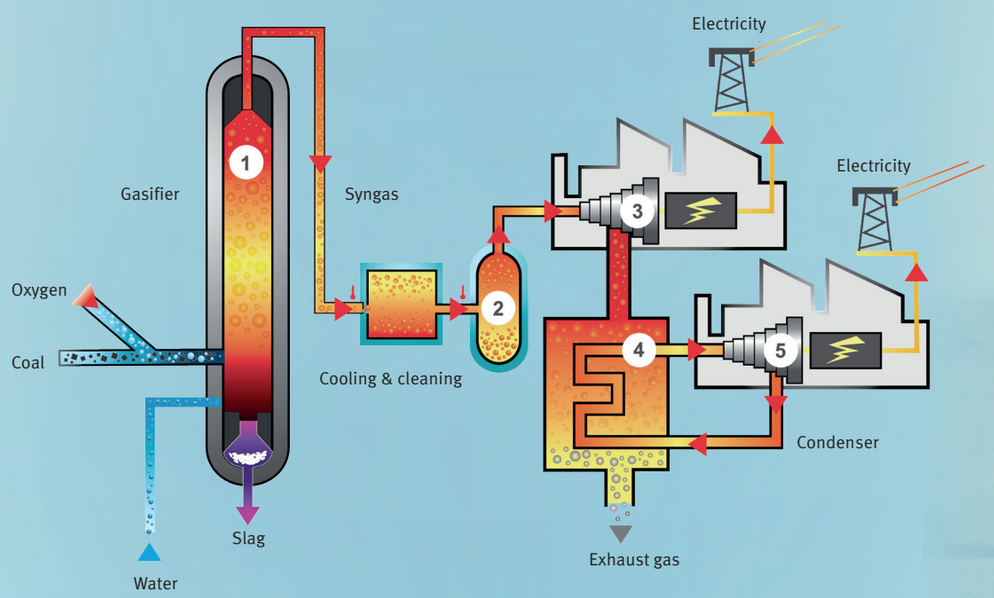
Mega-scale ASUs

At Jazan, the gasifiers will produce enough syngas to generate a total of 4 GW of power and steam. The syngas is fired directly in gas turbines which produce 2,400 MW of electricity in an integrated gasification combined cycle (IGCC) power plant. The syngas-island will also export hydrogen and steam to the refinery.

One of the interesting features of the gasification process is that it consumes vast quantities of oxygen. So, one industrial gas is used to produce another. In order to feed the hungry gasifiers at Jazan, the process requires six mega-scale ASUs from Air Products, each one rated at 3,000 tonnes per day of oxygen.

Gasification is a robust technology that can cope with oxygen at about 95% purity and the mega-scale ASUs to feed gasification projects are generally optimised on this basis. They can simultaneously produce nitrogen for refinery purging and inerting processes at a conventional ASU purity close to 99.999%. These plants

Figure 1. Gasification Sytem with Oxygen Feed (General Schematic of IGCC)



could theoretically also produce large quantities of argon or the rare gases neon, krypton and xenon.

Gaseous and liquid feedstocks

One of the most common methods of syngas production is with a steam methane reformer, or SMR. Worldwide, there are many thousands of SMRs in operation.

Some of the largest are linked to ammonia plants or for methanol production and are operated as captive units independent of the industrial gases sector. Others are linked to steelmaking, chemicals production and oil refining operations are often over-the-fence pipeline supply schemes from industrial gases companies.

SMRs are ideally suited to methane-rich natural gas a feedstock and they can be adapted to use other light hydrocarbons such as butane or naphtha. They are also available in a range of sizes covering smaller and mid-scale supply requirements. However, modern chemicals plants are being constructed at such a large scale that their requirements for syngas have simply outgrown the flow rate that an SMR can yield. For larger scale methane-fed applications, the autothermal reforming (ATR) process can be suitable. Or partial oxidation (POX) ,which is gasification of natural gas, may have a role.

The interest in ATRs as an alternative to SMRs for large-scale hydrogen production has been highlighted by the HyNet North West project, which the UK gas network company Cadent is planning. The original scheme involved SMRs to produce hydrogen for local energy and mobility applications. However, the most recent plans have evolved to replace the SMRs with two ATR units.

One of the applications for the hydrogen is injection into the gas pipeline grid network where high pressures are required. This contributed to the motivation for switching technologies because the ATR option can reduce the hydrogen gas compression power consumption; ATRs are able to operate at higher pressures than SMRs.

One of the earliest projects to use POX to convert natural gas to liquid fuels was the Shell Gas-to-Liquids (GTL) project in Binutlu, on the island of Borneo in the central region of Sarawak, Malaysia. This was the world's first commercial-scale GTL project and

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an integral aspect of the process is an Air Liquide mega-scale ASU capable of producing 3,200 tonnes per day of oxygen to feed the partial oxidation reaction. Following in the footsteps of the Bintulu project, Shell scaled up its GTL concept for the Pearl project, located at Ras Laffan Industrial City in Qatar. Since mid-2012 eight Linde ASUs have been operating to produce almost 30,000 tonnes per day of oxygen to feed the Shell GTL plant. With each ASU rated at circa 3,600 tonnes per day of oxygen, these are truly mega-scale ASUs.

Unlocking industrial gas growth

Air Products has been instrumental in the Jazan refinery heavy residue gasification project and has secured its position in coal gasification through the acquisition of both the GE Gasification business and Shell's coal gasification technology.

The stated goal of these deals was not to become a technology licensor, rather to leverage these technologies to enable the company to embrace gasification and the supporting mega ASUs and syngas processing as an integrated part of its industrial gases portfolio.

The Lu'an coal to chemicals project at Changzhi in China's Shanxi province, is one of the mega-scale coal gasification investments that Air Products has made. Four gasification reactors have been constructed to supply syngas to the chemicals complex. As part of a major de-captivation deal, Air Products took on the syngas island including the four gasification reactors when only two of them were at the stage of commissioning. Air Products then brought the four gasification reactors on-stream as part of an integrated gases supply scheme with four large ASU plants (which feed the gasifiers with oxygen) and the associated methanol-based syngas purification plant, which sits downstream of the gasifiers.

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Giving rise to new terminology: syngas islands

Jazan and Lu'an are not one-offs. In September 2019, Air Products announced that it will support Dubang Group with a coal-to-syngas project at the Xuwei National Petroleum Park in Jiangsu province. The Dubang Group will use the syngas to produce ammonia. Beyond that, Air Products will supply gases from the plant to other customers in the integrated petrochemicals cluster.

Also, in July 2019, Air Products announced that it would buy back and operate two ASUs from Jinmei Huayu's Phase One energy project in Jincheng. These two mega-ASUs have a total capacity of over 4,000 tonnes per day. The Jincheng Coal-to-Liquids (CTL) plant produces one million tonnes of fuels per year which are used as a substitute for refined diesel and gasoline for transport applications. China is long coal, short oil and making the best of the natural resources at its disposal.

Prior to these recent deals, Air Products signed a contract in 2018 to supply Jiutai New Material Company with syngas for its billion-dollar mono-ethylene glycol project at Hohhot, in China's Inner Mongolia province. Another mega-scale gasification project was announced in 2017 with Shaanxi Future Energy Group, part of China's Yankuang Group. As with Jiutai and the other projects, the agreed scope for Yankuang was to build, own and operate (BOO) an integrated air separation, gasification and syngas clean-up system – a syngas island. The ASU capacity is approximately 40,000 tonnes per day of oxygen which feeds the gasifiers that are sized to produce 2.5 million Nm^3/hour of syngas. The metrics give the project a very similar scale to Jazan. gw