POWERHOUSE HYDROGEN

Bridget Nyland, Sarah Farnand, Scott Smith, Kristin Holtz and Yu Zheng, Air Products, USA, outline solutions to a new array of challenges facing the hydrocarbon, petrochemical, and transportation industries.

Growing global demand for transportation fuels, increasing environmental regulations, and the shale gas boom in the US have all played a part in expanding hydrogen requirements in petroleum and petrochemical industries. For hydrogen users, some of these market shifts have caused new challenges that demand innovative solutions. This article discusses a variety of hydrogen related issues in the broad hydrocarbon industry and how dynamic thinking can broaden the range of solutions for hydrogen applications.

Tackling project development in emerging economies

Due to increasing global demand for clean burning transportation fuels, hydrogen demand will become further globally distributed, stretching from established markets such as North America and Western Europe to emerging and establishing markets. As hydrogen usage increases, refiners across the globe are facing a new array of problems. This section of the article will outline how two refiners in India and China have developed creative hydrogen solutions to solve some of those problems.

Creative hydrogen solutions

Challenge

Large refining unit expansions require extensive utility expansions

In a market where demand for clean burning transportation fuels is rapidly on the rise, India's Bharat Petroleum Corporation Limited (BPCL) saw a major opportunity to expand its Kochi refinery and link the refinery with a petrochemical complex. However, the proposed expansion scope far exceeded existing utility and infrastructure capacity. Paired with a need for significantly increased hydrogen production and the installation of major refining unit operations, the refinery faced a significant project effort.

Figure 1. Air Products and PetroChina recently brought onstream a steam methane reformer (SMR) that produces over 90 million ft^3/d of hydrogen and syngas to support PetroChina's Sichuan refinery and petrochemical facilities.

Figure 2. The newly installed hydrogen facility at ExxonMobil in Rotterdam improved energy efficiency over the previous hydrogen supply by over 15%. It also lowered CO_2 emissions by over 200 000 tpy.

Solution

Recognising that expanding site utilities in conjunction with the refinery would create large project strains, BPCL saw the value in outsourcing the entire industrial gas utility scope to the hydrogen provider. By outsourcing the production of hydrogen, syngas (a mixture of hydrogen and CO), nitrogen and oxygen to one vendor, the vendor could take an efficient and synergistic approach to industrial gas production and provide BPCL with a lower overall cost. BPCL also required the vendor to provide their own power to the industrial gas production complex, thereby creating a reliable utility island for crucial product supply.

On that basis, Air Products recently signed a long term agreement with BPCL to be the single industrial gas operator at the Kochi Refinery and proposed petrochemicals complex. The industrial gas site is currently scheduled for a phased start up, beginning in 2015. When complete, it will be the largest outsourced hydrogen requirement in India.

Air Products was able to integrate power production with the hydrogen producing steam methane reformers (SMRs) and design the most efficient combination of industrial gas production units to serve both Air Products' utility island and BPCL's needs. The end result is a highly reliable utility island designed to the highest efficiency standards to reduce costs for both Air Products and BPCL.

Challenge

Demands for clean fuel exceed internal hydrogen capacity

PetroChina is China's largest oil and gas producer and distributer. Forecasting quickly increasing fuel demands and seeing an opportunity to expand their petrochemical facilities, PetroChina's Sichuan refinery predicted that its hydrogen and syngas requirements would quickly grow.

Solution

PetroChina had already agreed to outsource oxygen and nitrogen supply for the refinery and petrochemical complex. Using a similar philosophy to BPCL, PetroChina decided to continue that industrial gas agreement for its hydrogen requirements, leveraging synergies in engineering and operating capacity between the air separation plant and SMR facility.

The new SMR, owned by a joint venture between Air Products and PetroChina, came onstream in 2013 and produces over 90 million ft^3/d of hydrogen and syngas for the Sichuan refinery and petrochemical complex. Significantly, this is the first time a state owned refinery in China has outsourced its hydrogen requirements.

Improving efficiencies

Operators around the world not only need additional hydrogen, they need that hydrogen to be reliable, economic, safely provided and environmentally friendly. In the following cases, operators saw value in expanding their operations but they wanted to be smart about their hydrogen use by having minimal environmental impact. A combination of new technologies and new applications allow them to meet their goals.

Challenge

Crude refining production increases limited

ExxonMobil in Rotterdam, The Netherlands, wanted to expand hydrogen production but their existing SMR was aged.

Solution

There has been tremendous improvement in SMR technology over the past 20 years, particularly on the efficiency and environmental emissions fronts. New modeling technology allows SMR designers to better integrate waste heat from furnaces and reduce flue gas emissions. For ExxonMobil, Air Products recently started up a new world scale SMR which, when compared to the refinery's previous hydrogen supply, improved energy efficiency by over 15% and lowered CO_2 emissions by 200 000 tpy, comparable to taking 90 000 cars off the road annually.

Challenge

Waste oil recycling requires high pressure, high flow hydrogen to upgrade used oil

Waste oil rerefining requires high pressure, high flow hydrogen to upgrade used oil. However, the process scale often makes capital investments for a hydrogen generator and compressor difficult and varying production demands require a high degree of hydrogen flow rate flexibility.

The waste oil rerefining industry has recently taken off in the US, particularly in response to increasing demand for higher quality grades II and III base oil. When recovered, waste oil contains a large amount of nitrogen, sulfur and metallic impurities from added detergents and mechanical use. Hydrotreating is one of the key ways oil rerefiners can remove impurities and upgrade the recovered oil's quality.

Solution

Increased flexibility does not have to mean sacrificing efficiency. One solution many US waste oil rerefiners have adopted is to use liquid hydrogen and cryogenic hydrogen compressor (CHC) technology. Modern advances in hydrogen compression technology allow for flexible and reliable liquid hydrogen supply without large hydrogen vent losses. Air Products' patented pump can pump both liquid and gaseous hydrogen to virtually eliminate vent losses. It can also follow a plants' load demand precisely so plants receive all product necessary during high production periods and don't waste any product during low production periods.

Challenge

Recovering valuable hydrogen from waste streams

Forecasting favourable ethylene market conditions due to economic shale gas, a leading petrochemical processor needed a process expansion. However, with that expansion, they would generate a large quantity of ethylene off gas that contained a high percentage of hydrogen. This off gas stream would usually be sent to the complex's fuel gas system but the processor recognised that, if recovered, the hydrogen could be used more effectively in their process rather than as a fuel.

Solution

After reviewing several options for hydrogen purification, the petrochemical processor decided to use a membrane to recover and purify the hydrogen. In this case, the processor was able to recover a hydrogen stream of 93% hydrogen purity from a feed stream of 77% hydrogen purity with high reliability, minimal maintenance and high adaptability to changing market conditions.

Membrane separators, such as Air Products' patented PRISM membranes, are compact bundles of hollow fibers contained in a coded pressure vessel. The pressurised feed enters the vessel and flows on the outside of the fibers (shell side). Hydrogen selectively permeates through the membrane inside of the hollow fibers (tube side) which is at lower pressure. The hydrocarbon rich non-permeate product is returned at nearly the same pressure as the feed gas for use as fuel gas, or in the case of synthesis gas applications such as a carbon monoxide enriched feed to oxoalcohol, organic acid, or Fisher-Tropsch synthesis.

Figure 3. A PRISM® hydrogen recovery membrane installed at a refinery. Hydrogen recovery membranes can return hydrogen streams of up to 98% and in some cases 99.9% hydrogen purity.

Various PRISM Membrane separator configurations are possible to optimise purity and recovery, such as adding a second stage membrane separator and pretreatment steps.

Expanding supply and accessibility

As new opportunities emerge, petrochemical and refining operators cannot be limited by infrastructure designed for the past. With an eye to taking every market advantage possible, these operators developed solutions to get a leg up on competition and develop future markets.

Challenge

Flexible supply modes to meet new production lines

A leading multinational manufacturer needed an economic and reliable onsite gas generation system to supply hydrogen to a new high valued added production line with varying demand. Conditions at the plant presented several challenges to this company regarding their gas supply. Existing plant infrastructure was unsuited for storing large amounts of gaseous hydrogen, the site was located in an area with limited liquid hydrogen availability, and the distance to a pipeline made that supply source economically unfeasible.

These challenges are common to many industries including petrochemical and refinery operations. Onsite gas generation can often provide the optimal low cost solution for reliable hydrogen supply. Air Products' onsite modular concept of multiple hydrogen generators provided a favourable alternative solution in this situation and also addressed the need for flexibility and minimal impact to existing plant operations.

The compact and modular equipment design of onsite hydrogen generators also allows for quick installation, fast startup, and minimises disruption to existing plant operations. Using the PRISM® Hydrogen Generator technology, this customer was able to operate at flow rates from 50 - 100% and could adjust production schedules easily due to the fast turn down and start up capabilities of each

Figure 4. One of more than 160 hydrogen fuelling stations installed worldwide to provide over 850 000 hydrogen fuel fills per year to cars, trucks, vans, buses, scooters, forklifts, planes, cell towers, material handling equipment and even submarines.

generator. The system is designed to operate at the required capacity even when one of the generators is offline: enabling the remaining modules and backup storage to provide reliable, uninterrupted service. Backup storage can be provided by both bulk gaseous and liquid hydrogen storage depending on both region and process requirements.

Delivering the right solution requires not only the right hydrogen technology but also experienced technical support. Proprietary Air Products SMR technology is applied to a containerised unit that enables a more efficient and economic conversion of steam and methane into hydrogen and carbon monoxide. This technology permits increased production and lowers the carbon footprint compared to other industrial gas supply modes.

Challenge

Temporary needs in high value markets during hydrogen outages

A chemicals manufacturer wanted to take advantage of favourable market conditions but their onsite hydrogen reformer had a tube failure. Without reliable hydrogen supply, the manufacturer could not continue production.

Solution

Advances in liquid hydrogen pumping technology and delivery systems have increased the range of temporary hydrogen supply capabilities. For many refiners and petrochemical manufacturers, temporary supply can provide much of the hydrogen needed to keep production moving while repairs are made to onsite hydrogen reformers.

In this case, as the chemicals manufacturer evaluated the extent of SMR repairs required, Air Products dispatched a team of specialists to evaluate and prepare the site in case the customer decided to proceed with the temporary hydrogen supply. When the customer's internal repairs were unsuccessful, preliminary work allowed for quick mobilisation and temporary hydrogen supply so chemicals production could continue. The temporary hydrogen supply helped this manufacturer bridge the gap between having new SMR parts fabricated, delivered, and installed and wanting to take advantage of the booming market for their product.

The benefit of temporary hydrogen supply crosses industries and can be utilised for any manufacturer who would like to continue production during onsite hydrogen generator maintenance or repairs, either scheduled or unscheduled. Supply rates of 5 million ft^3/d and pressures greater than 2000 psi are achievable using Air Products supply trucks that utilise cryogenic hydrogen compressor (CHC) technology.

Future needs in hydrogen fueling infrastructure

In addition to making conventional fossil fuels and products cleaner, hydrogen is an attractive alternative fuel in a wide range of applications including transportation, power generation, and material handling.

Global auto manufacturers are gearing up to launch their hydrogen fuel cell electric vehicles (FCEV) within the next two years. Toyota unveiled its first commercial FCEV in 2013 at the Tokyo Motor Show and announced intentions to mass produce it by 2015. Honda showcased its FCEV vehicle at the 2013 Los Angeles Auto Show and expects product launches in the US and Japan in 2015. Hyundai announced their plan to produce a hydrogen fuel cell crossover vehicle, intending to build and lease 1000 by the end of 2015. FCEVs are over two times more efficient than comparable gasoline vehicles and an important part of future energy conservation and sustainability.

Challenge

Limited access to hydrogen fuelling infrastructure

To make the hydrogen economy a reality, hydrogen must be readily available as a fuel. Gasoline, diesel and even electric power have much broader existing infrastructures creating high barriers to entry. To compete as a fuel, industry players must find a way to economically distribute hydrogen including fueling stations and delivery mechanisms.

Solution

A key element of the hydrogen economy is having the hydrogen readily available as a fuel. Air Products has developed SmartFuel™ products, a comprehensive suite of hydrogen fueling infrastructure solutions from supply to dispensing to meet customers' needs. The SmartFuel™ advanced retail hydrogen fuel dispenser mirrors traditional consumer gasoline fueling and payment practices and can conveniently meet consumer expectations of refilling hydrogen powered fuel cell vehicles in a safe, fast, reliable and familiar manner.

Conclusion

Within markets ranging from crude oil refining to hydrogen energy, the drivers behind hydrogen usage are expanding and hydrogen suppliers must develop innovative solutions to meet evolving market needs. Whether it is integrating an industrial gas complex or calling for temporary hydrogen, teaming with a far reaching and diverse hydrogen provider can open up new solutions that can benefit the hydrocarbon and broader chemical and transportation industries.