Maximising hydrogen production on SMRs

With process control and gas analysis

By Stephen B. Harrison

Steam methane reformers (SMR) are the most common large-scale hydrogen production technique in use today. Much of the installed base of SMRs is linked to refinery operations, with the balance being associated with syngas, methanol and ammonia production in the chemicals and fertiliser sectors.

Hydrogen consumption on refineries has increased significantly in recent decades to treat heavy feedstocks, produce clean burning low sulfur fuels and for the hydrogenation of biofuels. The most recent uptick in demand has been driven by the IMO 2020 changes which have increased the demand for low sulfur marine fuels. In this context, anything that could be done to squeeze a few percent more hydrogen out of an existing SMR has been desirable. Strategies that SMR operators can use to increase hydrogen output include:

1. Maximising the catalyst performance with adequate replacement
2. Use of reformer and shift reactor catalysts with high conversion yields
3. Minimising hydrogen losses through optimising the PSA hydrogen purification system bed sizing and operation
4. Preventative maintenance to ensure that the plant equipment remains functional to ensure maximum up-time of the SMR
5. Turn-around maintenance for future operation at maximum capacity
6. Installation of additional reformer tubes within the SMR to increase the catalyst volume and consequently the plant capacity
7. Adding a pre-reformer or post-reformer
8. Adjusting the steam-to-carbon ratio in the feed to the SMR
9. Process control improvements
10. Implementation of SMR operating best practices.

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Focus adds value

For many refiners the 10-point SMR optimisation plan above might theoretically be achievable. However, it may represent a distraction from their core focus on processing crude oil to produce a marketable palette of refined products and maximise refinery margins.

In recognition of the principle that focus adds value, industrial gases producers have developed expertise in SMR operations over many decades and have taken on the operation of 'captive' refinery SMRs, converting them to 'over the fence' (OTF) or pipeline hydrogen supply schemes.

Speaking for Taiyo Nippon Sanso's US subsidiary Matheson, Dr. Marco A. Márquez, Director of Business Development – Refining, says that "through our hydrogen OTF supply service we often get involved in supporting refiners. Such was the case


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recently in North America where a refinery SMR was converted to an OTF supply."

"Using our technical and operational expertise, we identified and resolved major issues affecting the plant capacity and efficiency. After the first stage retrofit was completed, the plant capacity was increased, and the efficiency was improved. The operating cost savings were significant, being in the order of several millions of dollars per year."

Economies of scale have tremendous advantages for industrial gases hydrogen producers. Márquez affirms, "We own and operate SMRs worldwide. We have cases where customers over time have come back to us for a second or third SMR in one location, for example in our Ohio Cluster. This clustering has some advantages: improving the overall reliability and ensuring optimal performance of each SMR. Customers hooked up to clusters or pipelines have the security of a back-up supply if one of the SMRs needs to be taken out of service for maintenance or catalyst replacement."

"Furthermore, to leverage Taiyo Nippon Sanso's international presence the SMRs are digitally connected to our Remote Operations Centre (ROC) in Texas, from where we can monitor and operate them. Our tools allow us to continually observe and control what is happening. Panel operators can run specialised simulations to visualise what should be happening, or get support from our experts at headquarters. This means they can intervene before minor issues escalate to become major problems. It adds up to better safety, improved reliability and enhanced energy efficiency thus maximising hydrogen availability for all our customers."

Process control drives

Whether the panel operators are local to the SMR or work remotely, the fundamentals of SMR operational economics are universal: maximise the hydrogen production and minimise hydrocarbon consumption.

However, optimising the process to achieve these goals is not quite so simple. If we could see inside the box, we could adjust parameters based on what we observe, but that's easier said than done. The SMR is heated to 1,000°C and thick metal tubes obscure the view. So, we use instrumentation to measure temperature, pressure and analyse gas compositions. A picture of the process emerges through these key parameters.

Production of hydrogen on an SMR consumes methane or other feedstocks in the reaction to produce hydrogen. These hydrocarbons are

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also used as supplemental fuel to generate the heat that is required to drive the SMR reaction kinetics forwards. Efficient hydrogen production minimises the amount of fuel and feedstock required. In addition to better process economics, this results in environmental benefits with fewer emissions of CO_2, NOx, SOx and particulate matter. So, the process control instrumentation has an essential role to play. Some of the most fundamental gas analysis requirements on an SMR are:

1. Calculation of the calorific (BTU) value of the incoming feedstock
2. Monitoring methane slip through the SMR
3. Controlling the steam-to-carbon ratio in the SMR
4. Measurement of the final hydrogen product purity
5. Measurement of the reformer burner flue gas oxygen concentration.

For these diverse requirements, a wide range of gas analysers will be required. Steve Gibbons, Head of Product Management for the continuous gas analyser product range within ABB's Measurement & Analytics business line, says that, "A key factor in selecting the right analyser is to decide what the most essential functionality is. Perhaps the priority is continuous and instantaneous measurement of a specified molecule. Or, the critical issue may be simultaneous measurement of a diverse mix of gases, for which a small delay in receiving the signal may be acceptable."

"For example, the BTU value of the natural gas coming into the SMR is best measured using a rapid response process GC-TCD such as the PGC1000 which is optimised for natural gas BTU analysis. This instrument can analyse and characterise a gas mixture sample every two minutes."

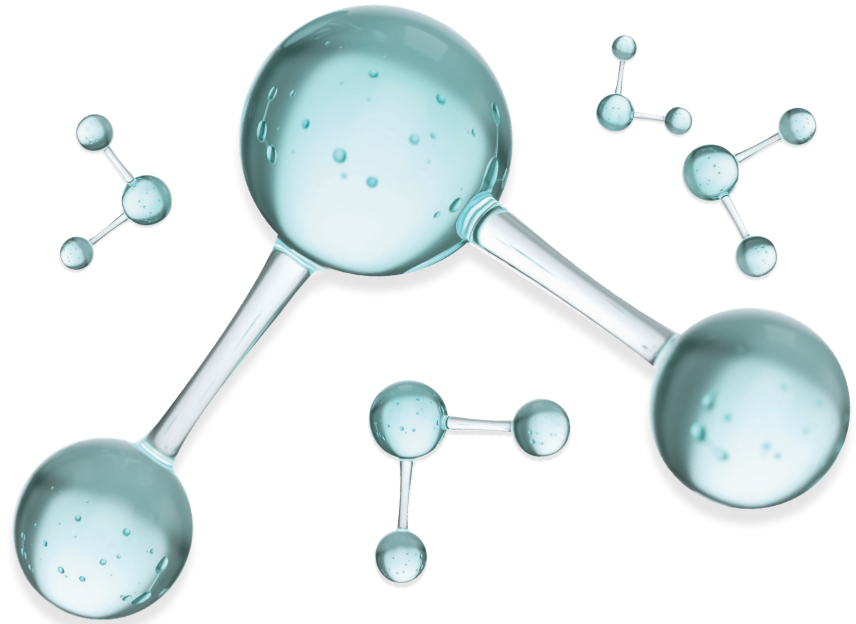
From a precise analysis of the gas composition it is possible to calculate its BTU value using formulae described in ISO 6976:1995 Natural gas — Calculation of calorific values, density, relative density and Wobbe index from composition.

Diversity of composition

In the case of BTU value determination, a process GC is required to analyse the mixed composition of the natural gas stream which can contain a variety of light hydrocarbons such as ethane and propane in addition to the base of methane. Or, in some instances, the SMR is fed with refinery gas which can contain a highly diverse mix of fuel gases.

Direct read techniques good for looking at individual components, but do not have the flexibility of a GC which is able to see across a broad range of species. However, the advantage of direct read gas analysers is that they provide continuous information. There are no blind spots in the intervals between samples. Every tiny change in the process can be observed and reacted to within seconds to ensure continuous optimisation.

Gibbons adds, "Methane slip from the SMR is a perfect case for a direct read gas analyser. Methane is IR active and can be detected with high accuracy using a non-dispersive infra-red (NDIR) analyser such as the Uras26.



Methane should be reacted to CO_2, carbon monoxide (CO) and hydrogen in the SMR and if excessive amounts of methane slip through the process it is a clear sign that something is sub-optimal. For example, it could indicate that the catalyst needs replacement, or it could be caused by low temperatures in the SMR which can be corrected by increasing the amount of fuel gas supplied to the burners."

"Some of these changes, such as catalyst performance, are longer term. Others, such as temperature changes can happen quickly, and a direct read instrument will help to fix the issue with minimal delays meaning that the operation returns to its optimum as soon as possible."

NDIR analysers are also ideal for measurement of the final hydrogen purity. Gibbons points out an irony here, "To measure hydrogen, a TCD analyser such as our Caldos27 is often used. Hydrogen is not IR active and is not detected on an NDIR. So, why do SMR operators choose an NDIR instrument to measure the final hydrogen gas purity? It's generally taken for granted that the gas coming off the SMR will be hydrogen but what really matters is the absence of CO and CO_2. These two gases are poisons to the hydro-treating catalysts in the subsequent processes where the hydrogen is used in the refinery."

"Typically, the final hydrogen product specification will have a maximum total combined CO and CO_2 content of 10 parts-per-million by volume (VPM). Simultaneous measurement of these two components is right in the sweet spot for the Uras26." gw

ABOUT THE AUTHOR

Stephen B. Harrison is celebrating 30 years involvement in industrial gases this year. He was previously global head of Specialty Gases & Equipment at Linde Gas, and spent more than 15 years with BOC Gases. He is now a consultant.