Maximising hydrogen production on SMRs

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 IMO2020 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. Turnaround 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 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 USD per year."

Economies of scale have tremendous advantages for industrial gas hydrogen producers. Márquez again commented, "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: improve the overall reliability and ensure 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."

Operational economics, environmental benefits

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 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 needs 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.


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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."

Diversity of composition versus direct response

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 are 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.