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.

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...”
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 Sansó’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 hydrocarbons in the reaction to produce hydrogen. These hydrocarbons are also used as supplemental fuel to generate the heat that is required...”

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Methane should be reacted to CO₂, 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 CO₂. 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 CO₂ content of 10 parts-per-million by volume (VPM). Simultaneous measurement of these two components is right in the sweet spot for the Uras26.”

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.