Temperature measurement

Asset protection in hydrogen generation

Thomas Fortinberry, Business Development Manager – Industrial Gas at AMETEK Land, discusses fixed thermal imaging for steam methane reformers and how improved access to data on process temperatures can optimize and extend operations.

Worldwide demand for hydrogen is rising and expected to continue to grow at 5% annually. Hydrogen is increasingly sought for petroleum refineries, chemical manufacturing and in industrial markets.

Steam methane reforming of natural gas is among the largest and most commonly used thermal methods for hydrogen generation and, in the US, for example, accounts for 95% of hydrogen produced. A need to enhance the inspection and diagnostics for creating hydrogen and other gases is driven by many factors, including an increasing focus on operator safety, reduction of downtime, improved cost efficiency, and greater asset management.

During the hydrogen production process, natural gas is combined with steam and heated at high temperatures (700–1,000°C) under pressure in the presence of a catalyst. The result is carbon monoxide, hydrogen and a small amount of carbon dioxide (CO_2). In the next step, carbon monoxide from the reforming reaction interacts with steam, again using a catalyst, to produce additional hydrogen. Finally, CO_2 is removed, leaving pure hydrogen. Throughout the process, the heat resulting from the combustion of fuel gas in a furnace box is transferred to catalyst tubes by radiation.

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Hydrogen plant steam reformers are complex and energy intensive. The monitoring of Tube Wall Temperatures (TWT) helps to optimize catalyst tube life and ensure longevity, energy efficiency and productivity. Tubular steam reformers can be top-fired or side-fired, where catalyst tubes are arranged in parallel rows with the burners between rows at the top or bottom of a furnace box, which are heated from 1,000 to 1,100°C.

In comparison, the tubes in side-fired reformers are arranged in single rows between opposing furnace walls. The reaction occurs through the tubes at 900°C, exiting the bottom. There are established TWT upper limits, based on tube design temperature and high temperatures in the interior of the box, which causes the tubes to expand.

Meeting the challenges

The most frequent challenges that plant operators face are issues with the burner, flue gas distribution and catalyst. These can directly affect TWT and lead to premature tube failure.

To prevent those challenges, most operators tend to be overly cautious on TWT and the plant, therefore, loses valuable production output every year. A 10°C drop in temperature, for example, can result in 1% decrease in productivity.

Even with a cautious approach, tube failures may still occur, due to hot spots on tubes and hot areas within the convection box, so even those producers running at a reduced rate are still not guaranteed to have a balanced reliable reformer. Reformer tube failure and process flow problems result when temperatures are too high. Even at only 20°C above the design temperature, a tube's lifetime may be cut in half. Maintaining optimum temperatures is therefore critical.

The challenges inherent in a steam reformer environment range from the basic difficulty of obtaining TWT, right through to the catastrophic failure of tubes. Adding to that difficulty is the ability of operators to conduct measurements in extremely harsh environments, in which the flue gas at the outer surface of reformer tubes is around 960°C and the inner-surface process gas ranges from 450 to 900°C.

Temperature-related issues with reformers include bulging, stress cracking, extrusion rupture and overheating. A thermal gradient through the tube wall is more significant at the bottom or close to the bottom of the tube, causing differential creep strain, which is a primary cause of damage. A fifth of all incidents in hydrogen generation involve tube cracking. Human error, however, is the main reason for catastrophic failure.

In this environment, operators are not only required to have an in-depth understanding of reformer behavior, but must also analyze data and make rapid decisions to avoid major issues. Significant operator experience is necessary to fully understand basic reformer construction, process flow, heat transfer principles, background radiation, emissivity and cooling effects that occur when the peep door is opened. Regular opening of the peep doors can result in increased stress on the tubes and potential cooling of the tubes up to 30°C. Ultimately, reliable TWT measurements are critical to asset management.

Reformer tubes are highly valuable assets, so extending tube life is essential. By continually monitoring temperature readings, operators receive early warning about increasing tube wall temperatures and can counteract potential catastrophic failure. That monitoring also allows an operator to safely and confidently increase temperatures, with a view to improving production levels.

Measurement methods

What is clear is that to meet the demands for greater safety and production, continuous 24/7 monitoring is required. Whilst there are several different temperature measurement methods involved, the most effective are:

- Handheld spot pyrometers that enable routine spot measurements to be taken. These pyrometers are highly accurate and represent an industry standard for measuring tube wall temperature.
- Fixed thermal imaging provides a more accurate and repeatable result than hand-held pyrometers as they are less liable to human error and enable optimization of the TWT to ensure a long tube life. Here, the thermal imaging cameras are inserted into the reformer, with the end of the imager ¼” from the inside reformer wall refractory. Imagers are water and air-cooled, ensuring accuracy in the hot atmosphere of the reformer.

Fixed thermal imagers

Temperature measurement accuracy must take into account emissivity. Within the reformer environment, several items may reflect off the surface. Handheld pyrometers and visual inspection can wrongly interpret the reflections as real data, causing errors in temperature measurement. Thermal imaging cameras, such as the AMETEK Land NIR-B 3XR, do not allow this to happen, especially as they can be mounted strategically within the reformer.

This fixed thermal imager delivers a high-resolution image, with accurate real-time measurements of both the tube skin and refractory surface. That image, combined with the 90° angle field of view, allows for multiple parallel tubes to be measured simultaneously. This can dramatically enhance efficiency and safety, as well as provide better asset management and furnace optimization.

With fixed thermal imagers, hot and cold areas within the furnace are easily identified and uneven heating becomes visible in real time. Incorrectly operating burners are identifiable, as are the effects of impinging flames. The use of a short wavelength minimizes errors associated with varying emissivity, so that highly accurate temperature measurement point data can be taken, stored and fully analyzed over the lifetime of the reformer. Use of fixed thermal images also allows the plant to monitor temperature during start-ups and shutdowns, in order to optimize efficiency and energy usage.

Among the major benefits of fixed thermal imagers is the rapid response time. The accompanying software sounds an alarm the moment the tube wall reaches the maximum temperature in any region, identifying the problem area and allowing the operator to take corrective measures to fix the issue, therefore reducing the risk of catastrophic events.

All the data collected can be used for many tasks, including creating TWT trending charts that identify problem areas that can be corrected during operation or planned for during the next shutdown. Data capture also is useful to enable remaining life assessments on tubes to be carried out to help plan for tube replacement during upcoming shutdowns.

Air Liquide, a world leader in gases, technologies and services for industry and health, has implemented AMETEK Land's Near Infrared Borescope (NIR-B) 3XR enhanced thermal imager, and, now, is gaining in knowhow by continuously measuring tube wall temperatures within its steam methane reformers.

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“Our main drivers for investing in AMETEK Land's NIR-B 3XR were to extend tube and catalyst life, which, as a result, we are achieving. Along with that, we are continuously learning about our reformer, balancing it correctly, and following online our main and critical asset,” commented Gonzalo Navarro, Production Manager at Air Liquide Ibérica de Gases. “The software allows us to spot and respond immediately to problems such as hot spots and bands on the tubes along with refractory damage and any flame impingement,” adds Mr Navarro. More information on this case study can be found on the AMETEK Land website.

Summary

As hydrogen demand continues its current growth pattern, pressure will continue on plants to increase safety, control costs and reduce downtime.

There has been increased interest recently in the use of fixed thermal imaging cameras for improved, continuous temperature measurement of reformer tubes. Asset management is an essential part of why continuous temperature monitoring is so important.

Fixed thermal imaging in hydrogen and other industrial gas applications is a major development in temperature measurement that helps significantly improve production monitoring and optimize operating efficiency. Thermal imaging goes a long way towards enabling plants to meet the challenges involved with steam methane reforming, whilst providing accurate data that allows operators to respond quickly to better protect assets, enhance tube life and reduce operator risks.

Article originally published in the October 2017 issue of gasworld (global) magazine.