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Fixed Thermal Imaging Enhances Hydrogen Steam Reforming Safety

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There is a burgeoning demand for hydrogen, spurred by such rapidly growing applications as fuel cells, petroleum refining, ammonia production, metal production, aerospace and chemical processing. Research and Markets, in a recent report, Hydrogen Generation Market by Generation & Delivery Mode, Technology, Application & Region—Global Forecast to 2021, estimates that the hydrogen generation market will grow from $117.94 billion in 2016 to $152.09 billion by 2021. During those five years, the petroleum-refining segment will continue as the top hydrogen growth area, with methanol in second palace, followed by ammonia; the development of fuel cell technology and the effect of tighter global regulations governing sulfur content of petroleum products. The worldwide growth of hydrogen generation is driving the increased use of steam methane reformers, and the desire to make the process as productive as possible.

There is a simultaneous movement to enhance the inspection and diagnostics used in the creation of hydrogen, methane, ammonia and so forth, driven by many factors, including an increased need for safety for operators, greater safety for the process, reduction and downtime and curtailing of cost.

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Industry Overview

Based on the availability of methane, steam methane reforming of natural gas is one of the largest and commonly used thermal methods for hydrogen generation. Natural gas reforming, for example, accounts for 95% of the hydrogen produced in the United States. Within the process, easily available and inexpensive methane and water react in the presence of a catalytic converter.

Steam methane reforming represents the least expensive method of hydrogen production and the one most commonly used. During the production process, natural gas is combined with steam and heated at high temperatures (700° C – 1,000° C), under pressure in the presence of a catalyst. The result is carbon monoxide, hydrogen and a small amount of carbon dioxide. In the next step, carbon monoxide from the reforming reaction interacts with steam, again using a catalyst, to produce additional hydrogen. Finally carbon dioxide 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.

The steam reformer used in hydrogen, ammonia and methanol plants is complex and energy intensive. The monitoring of Tube Wall Temperatures (TWT) provides the maximum level of catalyst tube life to ensure energy efficiency and productivity. Varieties of tubular steam reformers include top-fired and bottom-fired reformers, where catalyst tubes are arranged in parallel rows with burners between rows at the top or bottom of a furnace box heated from 1000° C to 1,100° C. In comparison, the tubes are arranged in single rows between opposing furnace walls in side-fired and terrace-wall-fired reformers. 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 cause tubes to expand. Creep damage, coke

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formation, tube failure and process flow problems result when temperatures are too high. And, at only 20° C over the design temperature, a tube's lifetime may be cut in half. Conversely, when the TWT is too low, there is a decrease in production output. Maintaining optimum temperatures is therefore critical.

Industry Challenges

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

Temperature-related incidents include bulging, cracking, stress cracking, extrusion rupture, overheating and over-temperature occurrences. 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 damage mechanism. A fifth of all incidents involve tube cracking, yet human error is the primary cause of catastrophic failure.

Not only do operators need to have an in-depth understanding of a reformer's dynamic behavior, they must also analyze data and make rapid decisions in the face of catastrophic failure. Significant operator experience is necessary to fully understand basic reformer construction, process flow, heat-transfer principles, background radiation, emissivity and cooling effects that occur by merely opening the peep door. Ultimately operators need to know if the data provided is real or false.

Most overheating can be traced to human error. Plant reliability is increasing, so there is a longer gap between serious problems causing operators to be unfamiliar with how to mitigate challenges rapidly enough. In addition, staff turnover happens and long-term knowledge leaves with the employees.

In spite of the challenges, it is critical to improve monitoring and temperature measurement, reduce operator exposure and risk, and provide increased productivity, reduce energy consumption, increase tube operating life span and handle potential catastrophic failure. A lot rides on the ability. A change of only 10° C below design temperature, for example, results in a 1% productivity efficiency loss. For a typical ammonia plant, that translates to ~$3 million in product sales. A shutdown and tube change post-failure can range between $250,000 to $500,000 per day in production loss and material cost.

Measurement Methods

What is necessary to meet the demands for greater safety and production is a way to provide for continuous 24/7 monitoring where required. While there are several temperature measurement methods involved, the two most effective are:

- Hand held spot pyrometers that enable routine spot measurements are highly accurate and represent an industry standard for measuring tube wall temperature. They can be used to optimize steam reformers by maintaining operation closer to design temperatures, and in many situations, they are sufficient for accuracy. However, the operators are only viewing a local spot on the tubes and may be missing hot spots in other locations.
- Fixed thermal imaging is a result of a desire to increase productivity and efficiency by optimizing tube wall temperature to ensure long tube life. It provides a more accurate and repeatable result than human operators as it operates irrespective of operator expertise, while it improves efficiency and minimizes the risk of catastrophic failure.

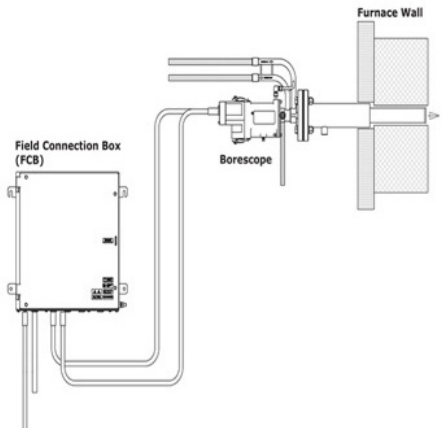

Figure 1. The Thermal imaging cameras are inserted into the reformer, with the end of the imager ¼" from the inside reformer wall refractory. Imagers are water and air-cooled, ensuring accuracy in the hot atmosphere of the reformer. Source: AMETEK Land

Emissivity is also an important factor for temperature accuracy. Within the reformer environment, several items may reflect off of the surface. Spot pyrometers and visual inspection can wrongly interpret the reflections as real data, causing errors in temperature measurement. The optimal solution would combine a thermal imaging camera capable of temperature correction and operating 24/7, that could be mounted strategically within the reformer, and that would dramatically enhance efficiency and safety.

The NIR-B 3XR Thermal Imager

The Near Infrared Borescope NIR-B 3XR by AMETEK Land for continuous temperature measurement, and furnace optimization and monitoring, provides that solution. It delivers a high-resolution thermal image with accurate real-time measurements of both the tube skin and refractory surface.

The image, combined with the 90°-angle field of view, allows for multiple parallel tubes to be measured simultaneously.

Hot and cold areas within the furnace are easily identified, and uneven heating becomes visible in real-time.

The real-time continuous data monitoring of the reformer with the NIR-B 3XR improves accuracy through automation, and lowers the risk to operators who can now view results from a safe control room. 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.

The image also allows the user to monitor and optimize furnace performance, easily identifying hot and cold areas and unbalanced burners or gas mix, with corrections viewed in real-time. Burners operating incorrectly are identifiable as are the effects of impinging flames.

Thermal imager response time of 0.14 seconds is faster by more than 40x when compared with a traditional tube thermocouple. Thermocouples also drift with time when operating at high temperatures and so must be replaced on a routine basis. The NIR-B 3XR rapid response time allows the triggering of alarms when there is a sudden temperature rise. Operators can respond almost instantaneously, alleviating catastrophic events.

An industrial Ethernet output connects to a local field connection box (FCB) that provides electrical power to the imager and an interface for fiber-optic Ethernet connections to the server. Image processing software enables the transfer of up to 100 data points via Ethernet TCP/IP to the DCS. Software records streams of data in video and individual frames for further analysis using profiles, points and areas of interest. There is an option for alarms for use in control and automation, and a playback facility of any pre-alarm event.

Data from the thermal imager can also be used to monitor catalyst activity in the reformer in the form of carbon margin and opportunities for recovering lost production through the reformer.

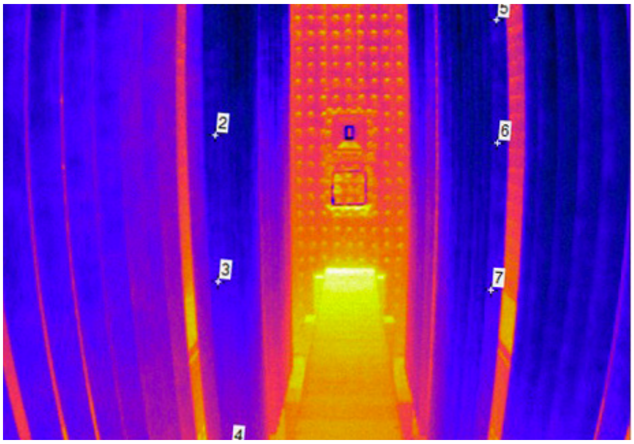

Figure 2. Thermal View inside and Reformer Tube Furnace with data points.
Source: AMETEK Land

The NIR-B 3XR prolongs reformer tube life, optimizes production throughput and reduces energy consumption. Typical applications for the NIR-B 3XR include primary steam reformers, ethylene cracker TWT measurement and delayed coking operations. It is approved for use in Zone 2 gas atmospheres, and the instrument can remain in situ during operation, plant maintenance, shutdowns and in plant start-up.

The use of hydrogen will continue to grow in the near term, and the corresponding need for safety, cost containment, reduction of downtime, and increased production and efficiency will continue. The introduction of the enhanced fixed thermal imaging features of the NIR-B 3XR will go far to improve temperature measurement within hazardous environments, delivering all of the above-mentioned necessities to the rapidly evolving industry.

AMETEK LAND

Stubley Lane
Dronfield, S18 1DJ
United Kingdom

ENGINEERING 360 MEDIA SOLUTIONS

30 Tech Valley Drive, #102
East Greenbush, NY 12061
Tel: +1 518 880 0200

ABOUT AMETEK LAND

AMETEK Land is a global supplier of non-contact temperature measurement instrumentation, process imaging solutions and combustion and environmental analyzers. Founded in 1947, LAND has been the premium supplier of temperature measurement solutions and combustion emissions monitoring.

AMETEK Land has facilities in the United Kingdom, China, France, Germany, India, Italy, Japan, Singapore, Spain and the United States.

The full range of non-contact temperature products includes high accuracy hand-held portables, fixed system spot temperature sensors, thermal line scanners, process thermal imagers and calibration sources. Many application specific systems solutions are available