TECHNICAL ARTICLE

STEAM METHANE REFORMER (SMR) OUTLET SYSTEM THERMAL IMAGING

James Cross, Global Industry Manager, Hydrocarbon and Petrochemical Industries (HPI)

A steam methane reformer (SMR) operates near material temperature and pressure design limits, creating significant reliability challenges creep rupture and cracks caused by high pressures, temperature fluctuations, and mechanical loads are common and regular physical inspection and monitoring is required despite the safety risks beneath the reformer.

The surface temperature of the outlet tubes, manifolds, sub-headers, and cross-headers (terminology seems to differ slightly based on region and technology) is a good indicator of the gas exit temperature and insulation or refractory (where present) condition. It is therefore an important variable to monitor in ammonia, methanol, hydrogen, and steel industries (where reducing gases are used in the production of Direct Reduced Iron (DRI)) - ammonia plant furnaces tend to run at lower temperatures and high pressures versus methanol and hydrogen applications, whilst reducing gas processes use lower pressures but higher temperatures than methanol and hydrogen applications[i].

Technology licensors and furnace designers have produced multiple designs over the decades, each with their unique design features, advantages, and disadvantages. A hot outlet system is defined as such because the outlet pigtails and manifolds operate at syngas temperature. These components are made from similar materials to the catalyst tubes and can belocated either inside the furnace itself or insulated on the outside. Where pigtails and manifolds are *inside the furnace*, the skin surfaces temperatures can be monitored, and welds/joints can be inspected through access ports using a thermal imaging borescope. For example, at least one producer has successfully used this system to monitor for temperature excursions, and to understand the relationship between Tube Wall Temperatures and manifold temperatures as show in the thermal image in figure 5.

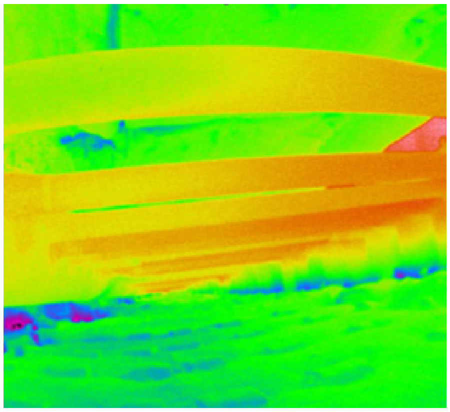


Figure 1. A hot outlet thermal image using an AMETEK Land NIR-B

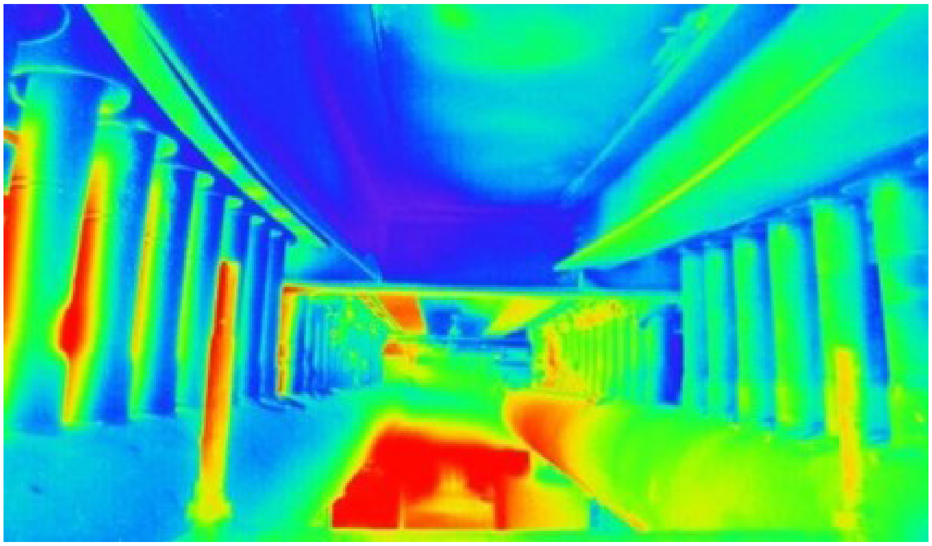


Figure 2. Cameras are installed between tube rows, in line with burners, on top fired furnaces, to provide detailed coverage of the outlet system.

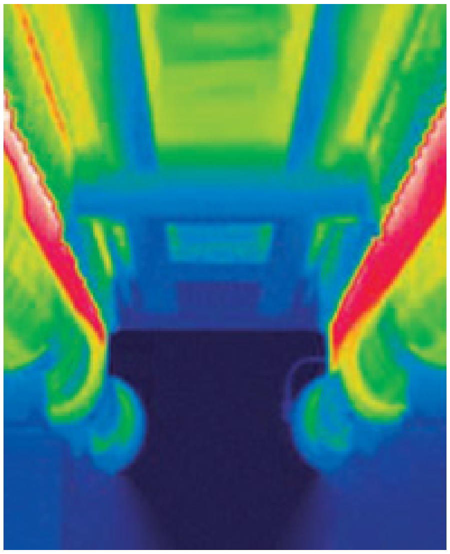


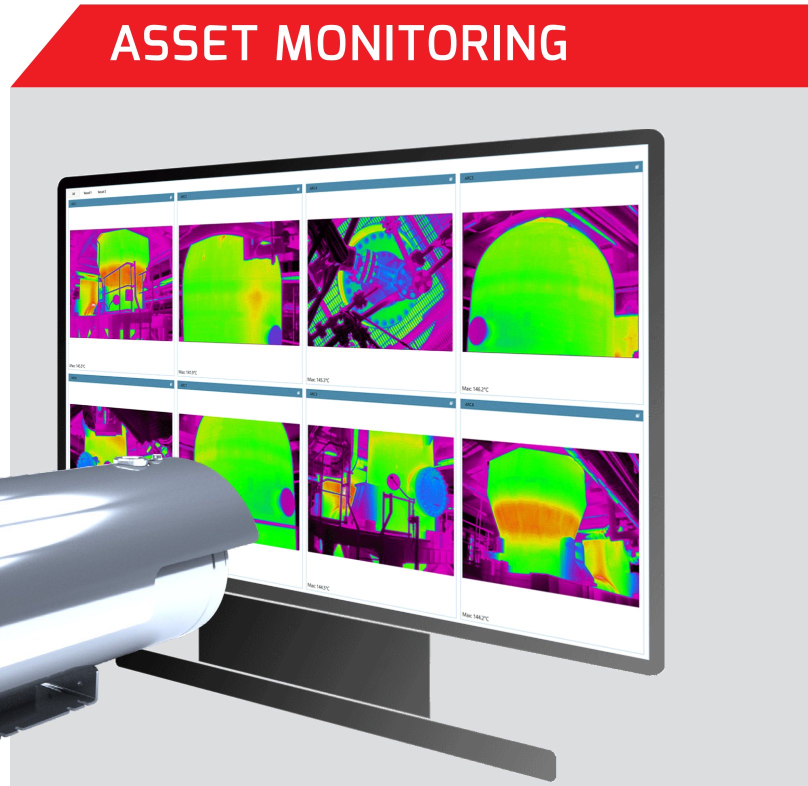
Figure 3. Outlet manifold system thermal image captured by ThyssenKrupp Industrial Solutions.

A cold outlet system uses internal insulation and eliminates hot pigtails and manifolds entirely; reformed gas is collected in a refractory lined manifold as shown in figure 3. A cold outlet system has advantages (including the suitability of lower alloys), but temperature fluctuations caused by flue gas maldistribution or other tube/furnace related temperature, combustion, process chemistry phenomena can still place additional stress on materials.

Outlet system temperatures are monitored throughout the industry visually, and periodically/manually using handheld pyrometers or portable thermal imaging cameras. Fixed/continuous monitoring solutions include:

- **Thermal sensitive paints** that indicate if a temperature excursion has occurred by changing temperature. These paints can be difficult to apply and maintain, so a colour change could indicate a failure of the paint versus a temperature excursion. Repainting is possible if the paint has faded, or has otherwise been damaged, but is not advisable on a running furnace due to the safety conditions beneath a SMR.
- **Contact thermocouples or temperature sensing cables** have also been used that provide temperature measurement and alarms at single points. Neither is particularly suitable for long pipe-lengths where large surface areas require measurement. Therefore, continuous monitoring, recording, alarming using thermal imaging is something we are increasingly asked to install.

Challenges of fixed solutions include high ambient temperatures, presence of hazardous gases, stringent certification requirements, dusty environments, and multiple obstructions causing difficulty with installation. The ambient temperature beneath a furnace can exceed 150 °C / 302 °F , so a cooled housing is often required. One positive here is that any cooling water required will likely not require lagging in colder climates to protect from freezing. So, careful consideration should be taken when specifying the solution, the protection concept, and any requirements for cooling media, including the availability of water and air at the instrument location.



LWIR-640-EX EXSH housing IMAGEPro-Asset Monitor AM

Figure 4. The AMETEK Land suite of products for asset monitoring includes the new LWIR-640-EX

AMETEK Land's fixed thermal imaging solution – utilising the LWIR-640-EX camera, the new EXSH housing, and the powerful IMAGEPro-Asset Monitor AM – continuously monitors outlet systems to provide automatic alarming, recording, and archiving which improves safety, furnace reliability, whilst reducing operating and maintenance costs.

Safety and asset integrity are critical factors in the monitoring of the outlet system. The area beneath a furnace is particularly unsafe due to high surface temperatures, limited access, and the presence of hazardous, flammable gases. Therefore, autonomous monitoring should only be considered with instruments certified for Ex environments such as the LWIR-640-EX and EXSH cooled housing. The outlet system can then be monitored from the control room to protect both the operator/inspector and the integrity of the plant.

SYSTEM INSTALLATION

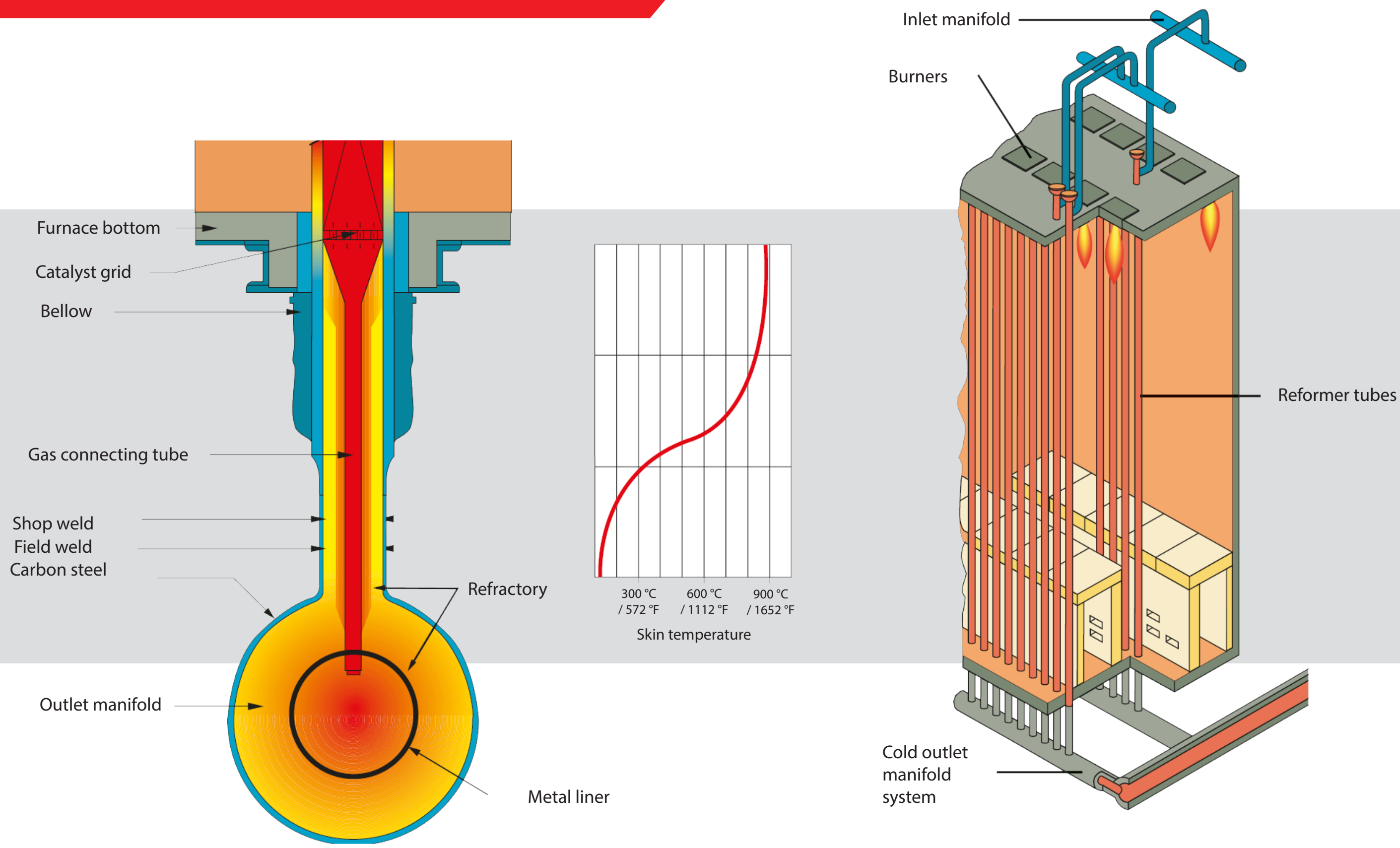


Figure 5. A cold outlet system design and the skin surface temperature profile as the gas exits the hot tube and enters the outlet manifold. Images courtesy of ThyssenKrupp/Uhde.

Each system is specified according to the design of the furnace and after detailed field of view (FoV) studies are conducted to ensure that optimal coverage is achieved with the lowest number of cameras possible. In the example shown in figures 6 and 7, cameras, with a variety of lens options, are positioned at the end of each row to provide coverage of outlet pigtails, manifolds, and the cross header. Exact positioning of the cameras can be tuned on site due to adjustable stand. Figure 8 shows a typical architecture that divides the supplied equipment between hazardous and non-hazardous areas.

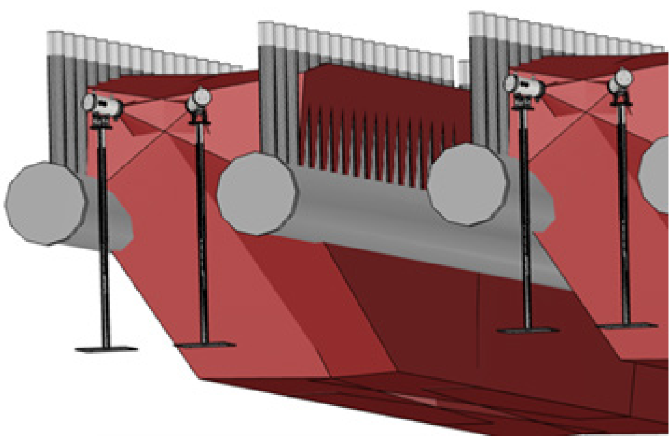


Figure 6. Cameras are positioned in between tube rows and adjusted to achieve more perpendicular viewing angles.

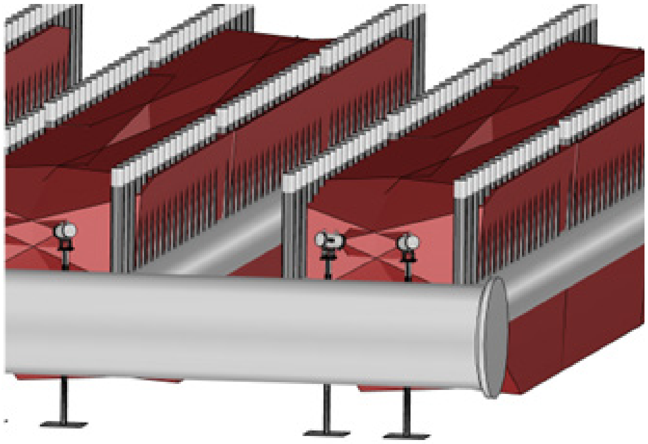


Figure 7. To avoid grazing angles on the tubes farthest from the camera, additional cameras can be installed mid-row or against the cross-header looking back toward the opposite cameras.

SYSTEM ARCHITECTURE

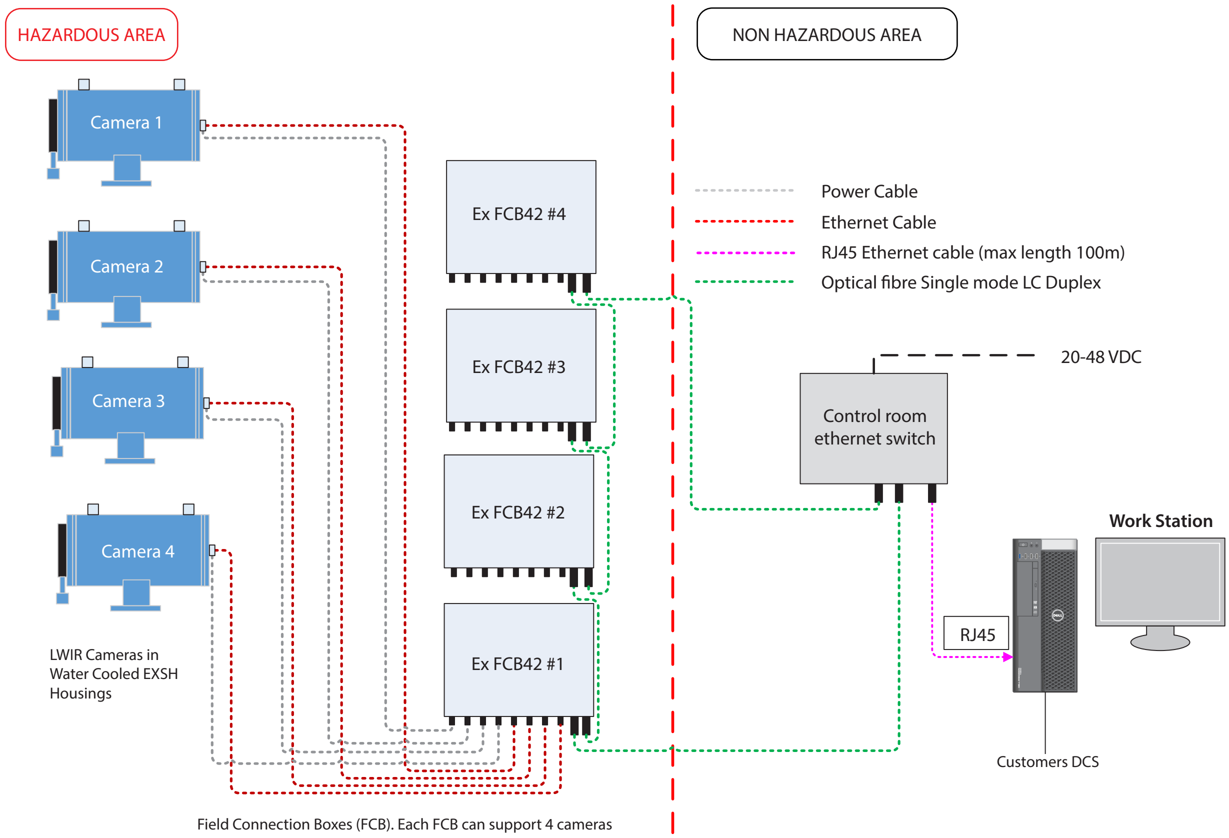


Figure 8. System architecture for automated outlet system monitoring for 16 cameras (4 cameras shown)

A fixed, automated temperature monitoring system can alarm when outlet temperatures begins to increase above the normal maximum temperature, e.g., +5 °C / +51 °F above the normal temperatures. By the time a manual inspection of an outlet system has taken place, the hot spot temperature may have risen to significantly over the material design temperatures. If a hot spot is detected by the imaging system, mitigating actions can be taken to reduce the hot spot (e.g., temporarily cooling with steam) and to identify the cause of the refractory degradation. Implementing corrective measures as early as possible in the failure mode can reduce the likelihood of disruptions, incidents, or emergency shutdowns.

The table in figure 8 demonstrates the extent to which temperature related phenomena can contribute to component failures . Even failure modes not exclusively caused by temperature and highly affected by temperature cycling and excursions, e.g., creep and material deformation.

The proposed AMETEK Land solution is made possible by the development of more affordable, higher resolution thermal imaging cameras that can be housed in cooled Ex enclosures. These advancements in capabilities are opening the door to new applications and assisting industry with its progress toward safer, more efficient, more autonomous plants.

[i] SMR Furnace Outlet Systems, Design Considerations, Emergency Repair, and Enhanced Reliability, Daniel Barnett and Joe Price, BD Energy Systems

[ii] Hydrogen: Key to any Refinery, ThyssenKrupp Industrial Solutions.

[iii] Mechanical Integrity of Syngas Outlet Systems, Asia Industrial Gases Association (AIGA)

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