Refractory detection system and floating roof protection

New refractory detection system monitors skin temperatures in Claus or thermal oxidisers as well as SMRs, gasifiers, and emissions from floating roof tanks

Bob Poteet and Andrea Biava **WIKA**
Haytham Al-Barrak and Mahendran Sella **Saudi Aramco**

There are many applications in the process industries where detecting a hotspot on the outside of an operating unit can bring safety and protection of valuable assets, such as the refractory detection system (RDS) under discussion. This technology can be used in a variety of applications, such as in the Claus section of a sulphur recovery unit (SRU).

An installation was recently completed at the Aramco gas plant. The results Aramco saw in its investigation after six months of run-time (now 12 months running) will be discussed, in addition to some other applications. The device's potential applications are only limited by the processor's imagination (see **Figure 1**). So, what exactly is this technology?

The heart of the system is a special sheath (typically 4.5mm or 3/16in) made of 316SS that only reads out the highest temperature anywhere along the sheath. To install the system on a Claus unit, first divide the unit into zones, which are areas designated for sensing. As illustrated, there can be anywhere from one to six zones in most Claus units, depending on the licensor or operator's preference. The readout from each zone will resemble a type K thermocouple, but it indicates the hottest area in a zone. You will not know where the hotspot is in the zone, but you will be aware that one exists so that appropriate action can be taken (see **Figure 2**). This technology has been successfully running on a Claus unit for more than 12 years at a major refinery in Italy.

Refractory problems in Claus or thermal oxidisers

For many operators of SRU plants, detecting refractory problems in the Claus unit can keep them up at night. If the refractory starts to fail, a situation may occur where the hot gasses hit the carbon steel shell and damage or lead to failure of the wall of the reactor. Many ways to detect this have been tried, but they all have limitations. Some have tried thermal imaging, but the problem with rain shields, cowlings, and insulation can be a real barrier.

A couple of points should be noted:

- This is not a thermocouple. Modern transmitters have self-diagnostics built in, and readings below 120°C are not reliable. While we can prove the system is working at installation, you will have to start the unit without a stable reading. Older transmitters can be used that read below 0°C, but careful consideration would need to be made in the evaluation process
- Above 400°C, the readings will lose their reliability again, but they have done their job. No damage will occur to the system until it reaches 900°C.

Uncertainties

The industry standard has been to attach thermocouples, but nobody knows how many to install. As a result, many installations do not have any thermocouples at all. Thermocouples can indicate the temperature of a specific point, but temperature excursions in other areas will go undetected. If a reactor with thermocouples could be covered, costs increase substantially.

The American Petroleum Institute (API) states that an operator should have a system so that an 'accurate shell temperature measurement system under the shroud should be included in the ETPS design.' They also request routine thermal imaging of the external shell to spot-check the thermocouples. This can be a maintenance headache if followed as it is intended.



Figure 1 Refractory failures at high temperatures are difficult to pinpoint.

Temperature values sensed by CTLS (WIKA) just two months after installation						
	Time stamp	ΔP - kPa	TC/PYRO	IR Survey °C	CTLS°C	Observation
1	Feb-11, 5:30pm	7.1 kPa		1. 203 2. 206 3. 208 4. 203 5. 201 6. 208	1. Faulty 2. 213 3. 235 4. 233 5. 248 6. 242	CTLS is working
2	Feb 15, 6:30pm	7.6	1074	1. 213 2. 213 3. 218 4. 211 5. 213 6. 217	1. Faulty 2. 232 3. 244 4. 233 5. 239 6. 221	CTLS is working
3	Feb 16, 6:30pm	7.5	1090	1. 194 2. 196 3. 204 4. 196 5. 204 6. 211	1. Faulty 2. 213 3. 228 4. 221 5. 235 6. 213	CTLS is working
4	Feb 17, 7:30pm	7.5	1084	1. 178 2. 183 3. 188 4. 183 5. 195 6. 201	1. Faulty 2. 210 3. 222 4. 217 5. 234 6. 211	CTLS is working
5	Feb 18, 9:30pm	7.5	1083	1. 200 2. 204 3. 212 4. 202 5. 205 6. 211	1. Faulty 2. 228 3. 240 4. 232 5. 240 6. 221	CTLS is working

Table 1 Temperature values sensed by CTLS (WIKA) just two months after installation closely represent the true values as cross-verified by an IR camera survey

Throughput vs burner ΔP vs reaction temperature vs outer shell temperature			
% Acid gas throughput	Burner Δp, kPa	Hot face (firebrick) temperature, °C	Shell outer skin temperature, °C
25	0.8	~ 1000	210 ± 15
35	1.07	~ 1033	212 ± 15
45	2.13	~ 1067	216 ± 15
55	3.2	~ 1100	218 ± 15
65	4.3	~ 1133	221 ± 15
75	5.3	~ 1167	225 ± 15
85	6.4	~ 1200	229 ± 15
95	**7.5**	**~ 1233**	**234 ± 15**
100	8.8	~ 1250	238 ± 15

Table 2

Aramco findings

In an effort to resolve technical challenges, Saudi Aramco (SA) piloted a newly developed RDS to monitor the skin surface temperature of SRU thermal reactors (reaction furnace).

Since 90% of SA SRU units are shrouded (weather-shielded), measuring the surface temperature online becomes challenging. Without the correct monitoring device in place, catastrophic failures could occur, affecting plant throughput. Deployment of this technology aims to detect repetitive refractory failures early by sensing hot spots on the reactor surface, even with the presence of a shroud. Maintenance and shutdown will be planned and timed accordingly.

Collaboration between the technology provider, WIKA, and SA began in March 2022 with the installation of the thermocouple on one of Saudi Aramco's gas plant SRUs. In October 2022, the CTLS installation was completed and successfully tested.

The plant continued monitoring the unit, keeping a close eye on the measured skin temperature to confirm continuous and reliable outputs (see **Table 1**). Upon testing performance, the new linear thermocouple technology proved to be working well. The CTLS coils' peak

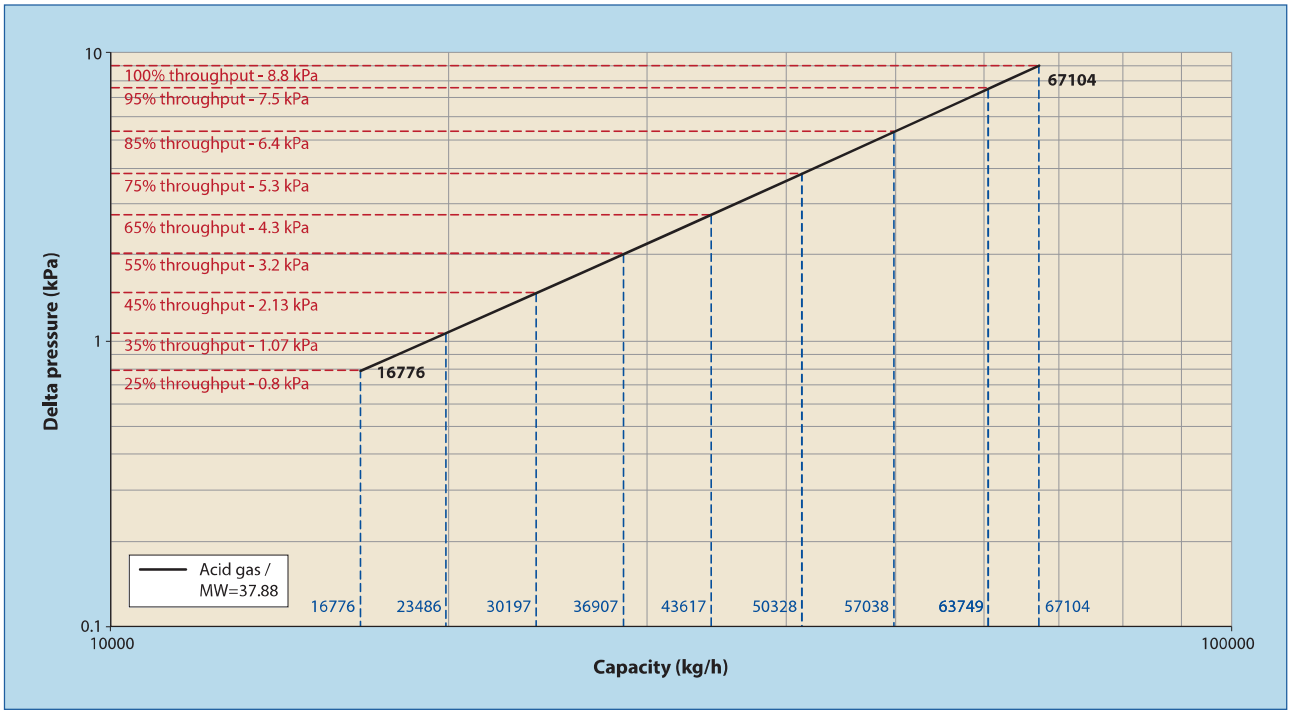


Figure 2 Burner capacity curve showing the capacity vs ΔP



Figure 3 RDS unit installed outside reactor by a trained crew



Figure 4 Close-up view of Nelson studs applied to reactor

temperature readings were recorded at 10 different time stamps over the course of eight months of operation since the coils were first put into operation.

This is a great tool, but based on our first use, we believe the way forward is if we had the ability and freedom to move the thermocouple CTLS while the unit is running without the need to weld on the reactor casing. We are jointly evaluating the use of magnets to facilitate this feature.

Installation

The RDS is installed by a trained field crew. Nelson studs are applied to the reactor, and the system is held down by galvanised steel channels attached to the Nelson studs. This system ensures good contact between the RDS and the reactor shell. On a larger Claus, it took a three-man crew five to six days to completely install a six-zone unit (see **Figures 3** to **5**).

Industry feedback

An Italian refiner who had this bespoke system installed 12 years ago agreed to provide feedback, reporting that he knew of no other system that could provide the required coverage, particularly the need for system reliability. While two of the four zones were lost after contractors cut components, a high level of reliability was still maintained. We enquired if the system had ever alarmed during the 12-year period and he reported that it had only done so twice. In neither case did the hotspot reach the point where he had to shut down. However, during the next routine maintenance, they could see that in the zones where the alarm occurred there were indeed some refractory problems.

Other applications

Other applications include:

- **Gasifier applications:** Gasifier applications are very similar to the Claus but in a much larger way with more



Figure 5 Multi-zoned RDS unit installation

zones. The sensors are run vertically over the full unit and at the top.

- **Steam methane reformers (SMRs):** The outlet header in an SMR is a refractory line piping that requires constant monitoring of the outside temperature by operators. Some use thermocouples, while others just do scanning. A common question related to thermocouples is how many are needed to give complete coverage while the scanning is a real Opex cost. For this solution, we can simply wrap the pipe with the RDS and monitor for any refractory failures. This can be easily installed with a clamping system or even magnets.
- **Floating roof oil storage:** There have always been concerns about the possibility of generating a fire in a floating roof tank (see **Figure 6**). For their conformation, these tanks have a mobile roof that slides along the vertical axis of a metallic structure fixed cylindrically. To avoid product leaks during the sliding of the roof, a scraping and sealing system (seal) is installed. The seal, made of rubber, undergoes continuous mechanical vertical movement and is exposed to corrosive agents contained in the product, usually hydrocarbons. Over time, it deteriorates and emits vapours released by the stocked product, which is normally maintained in the tank at a variable temperature between 70°C and 90°C.

Under certain climatic conditions, this escape of vapours can trigger fires that cause significant damage to plants, the environment, and staff. Protecting these tanks with fire detection systems is therefore essential. However, deterioration of the coating material of the linear heat detection



Figure 6 Installed scraping and sealing solution for a floating roof tank

cable (thermowire) can often generate false alarms. This uncertainty is a sign of low sensor reliability and creates a challenge for operators, who must decide when and how to intervene.

It is important to decide whether the system should be turned off immediately or, if a false alarm is suspected, the field cause of the alarm should be verified. In the former case, restoration of the area under consideration would result in high costs.

Over time, multiple false alarms can cause staff to consider a system unreliable and, therefore, of little use. The third option would mean, in case of ignition, a delay in activating the fire extinguishing system with its related consequences. To avoid these problems, it is therefore necessary to maintain detection systems with technical features that are immune to false alarms and can respond immediately.

Moreover, by continuously monitoring the temperature near the seal, valuable information about the wear of the seal can be provided to the operator, allowing for intervention prior to a critical situation arising. Advantages include:

- Increased level of security
- Increased functional efficiency and durability
- Programming of maintenance interventions
- Self-recovery sensor after the intervention of the alarm
- Reduced cost of insurance premiums, as the provision of prevention systems reduces the level of risk, thus increasing the level of security.

Bob Poteet is Director of Business Development for the Global Project Business group at WIKA, Houston, Texas. He graduated from Texas A&M University. He has four patents in temperature sensing areas used in the process industries.

Andrea Biava is Business Development Manager for Electrical Temperature and Services at WIKA Italia.

Haytham Al-Barrak is a Fired Equipment Engineering Consultant at Saudi Aramco. He holds an MS in mechanical engineering from University of Southern California. He has two patents in fired equipment monitoring.

Mahendran Sella is a Heat Transfer and Combustion Engineer at Saudi Aramco. He holds a BS degree in mechanical engineering from Institute of Engineers, India.