How to perform temperature profiling in hazardous environments

Instrumentation is available to perform temperature profiling in oil & gas, refining and petrochemical applications, but care must be taken during installation and use

By Keith Riley, Pressure+Temperature Product Marketing Manager, Endress+Hauser and Tim Schrock, Americas Area Manager, Endress+Hauser

Measuring temperature across a process unit—such as a furnace, desalter, hydrofiner, fixed-bed reactor or hydrocracker in refineries, or similar process units in chemical plants—leads to improved process control, increased catalyst life, more efficient production, fewer process upsets, and decreased emissions.

Known as temperature profiling, this technique allows acquisition of temperature data from multiple sensors, then transmits the data to an automation system where control and monitoring software analyze the data and take action. This article covers the sensing devices used to acquire temperature profile data.

Although the sensing equipment shown in the examples is from Endress+Hauser, similar equipment may be available from other instrumentation suppliers.

Profiling a hydrofiner

A hydrofiner is a typical application for temperature profiling. New environmental standards for low sulfur fuels are driving the need for temperature profiling in the refining industry. This set of new regulations requires plants to reduce air pollution emissions, particularly NOx, leading to equipment retrofits and upgrades.

For example, the sulfur content in mineral oil products has to be limited, and this is typically achieved by catalytic desulfurization in a hydrofiner. Heated to 572-752°F (300-400°C) and raised to a pressure of 362-870 psi (2.5 to 6 MPa), the oil is mixed with hydrogen and reacts with the catalyst. The sulfur molecular connection is then converted to H2S and hydrogen carbides.

One of the issues with this process is performing temperature profile monitoring at the different catalyst layers of a hydrofiner (Figure 1). Only a limited number of access points are available in a hydrofiner, so multiple sensors have to be inserted at each access point across the layers.

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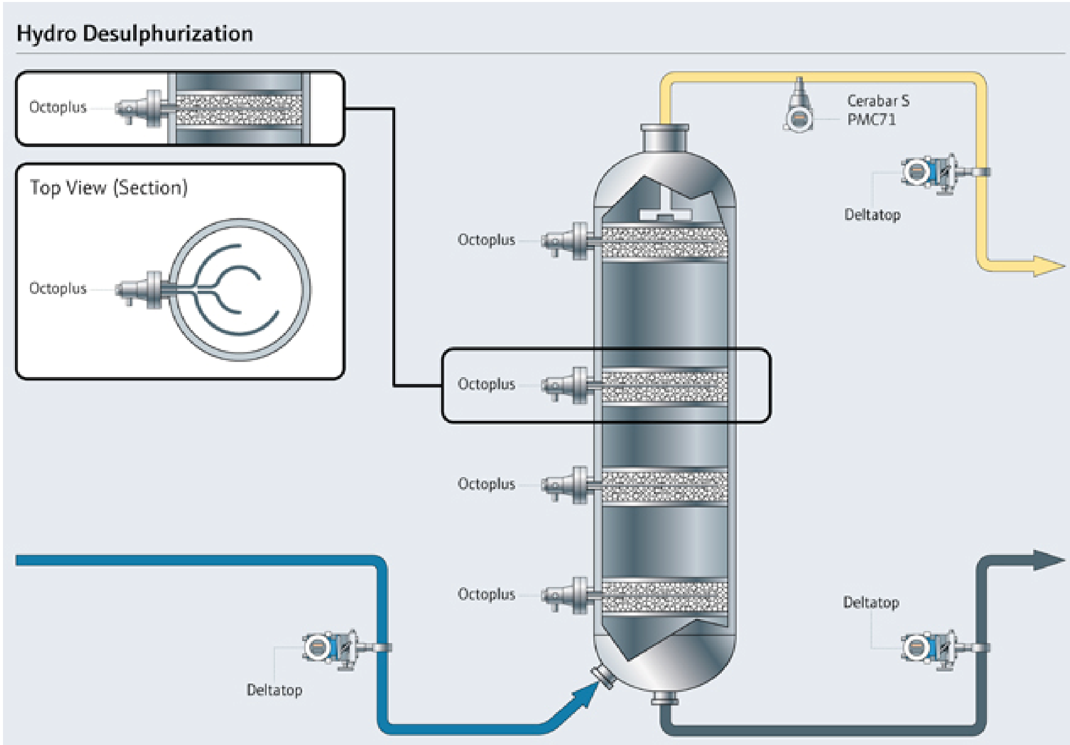

Figure 1: Temperature profiling at the different catalyst layers in a hydrofiner. Note the multiple sensors (top left) inserted at each access point.

One way is to insert a special "sensor array" with multiple sensors, all connecting to a single transmitter. The Endress+Hauser Octoplus (seen in the top left corner of Figure 1) has multiple sensors as needed based on the application; individual thermocouples mounted in a single nozzle. The unit's "tentacles" can be positioned within the reactor as needed to monitor the layer. Using data from multiple sensors, the control and monitoring software can construct a 3D image of the catalyst layer.

Temperature sensing elements can be replaced individually to minimize maintenance. The sensing elements are encased in a guiding tube that remains in the reactor. This allows a faulty insert to be easily exchanged for a new one (Figure 2).

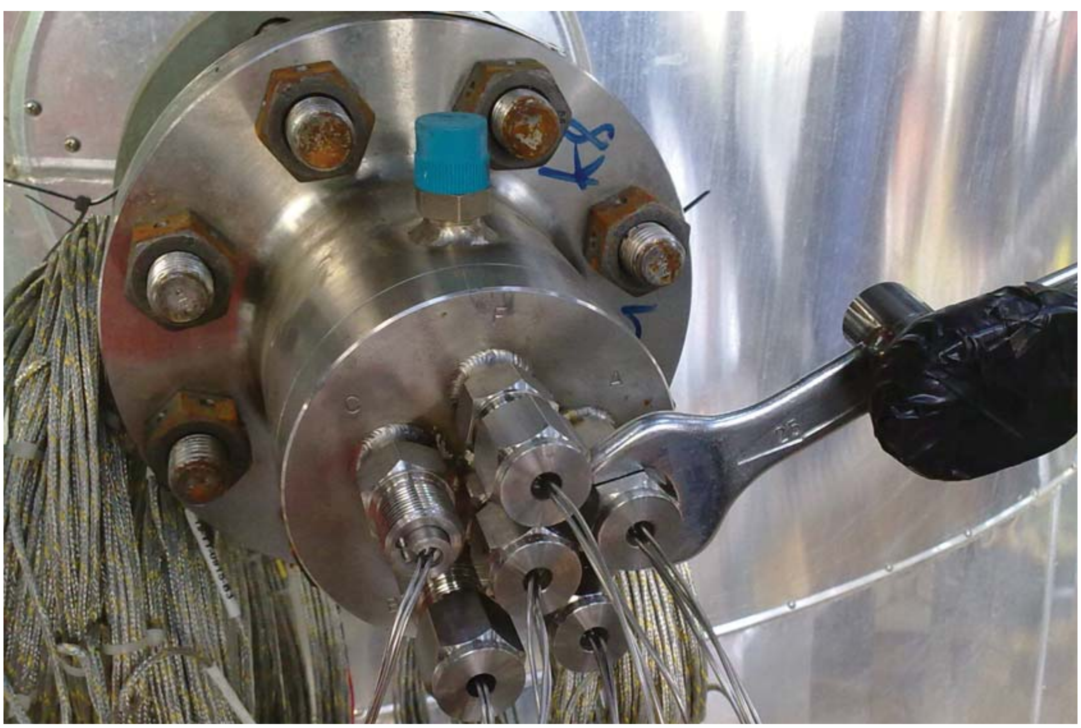

Figure 2: Individual temperature sensors can be quickly replaced.

Temperature profiling with a sensor array is also useful in fixed-bed reactors. Due to the solid state of the catalyst, it may not be possible to achieve a homogeneous reaction mixture. Formation of hot spots and cold spots may occur, and coke formation can quickly lead to deactivation of the catalyst.

With multiple measuring points per process connection, sensors can be freely positioned in the reactor to detect problems. As a result, operations can quickly become aware of a degrading process situation and take appropriate action.

Sensors are routed to a process transmitter or terminal block that can accept multiple sensors and then output 4-20 mA signals or thermocouple signals to the control system. Either the terminal block or the transmitter are typically housed in an enclosure (Figure 3).

Figure 3: An enclosure contains either a terminal block that sends sensor data via the thermocouple cable to the control system or a transmitter that sends sensor data via 4-20 mA signals to the control system.

Multipoint thermometers

Another method for creating a temperature profile is with a multipoint thermometer, a temperature sensor with a long thermowell containing multiple sensors. The Endress+Hauser iTHERM TM911 (Figure 4), for example, contains multiple sensors, arranged along the length of the thermowell. The thermowell can be longer than 100 ft, allowing it to extend vertically through a reactor or process vessel.

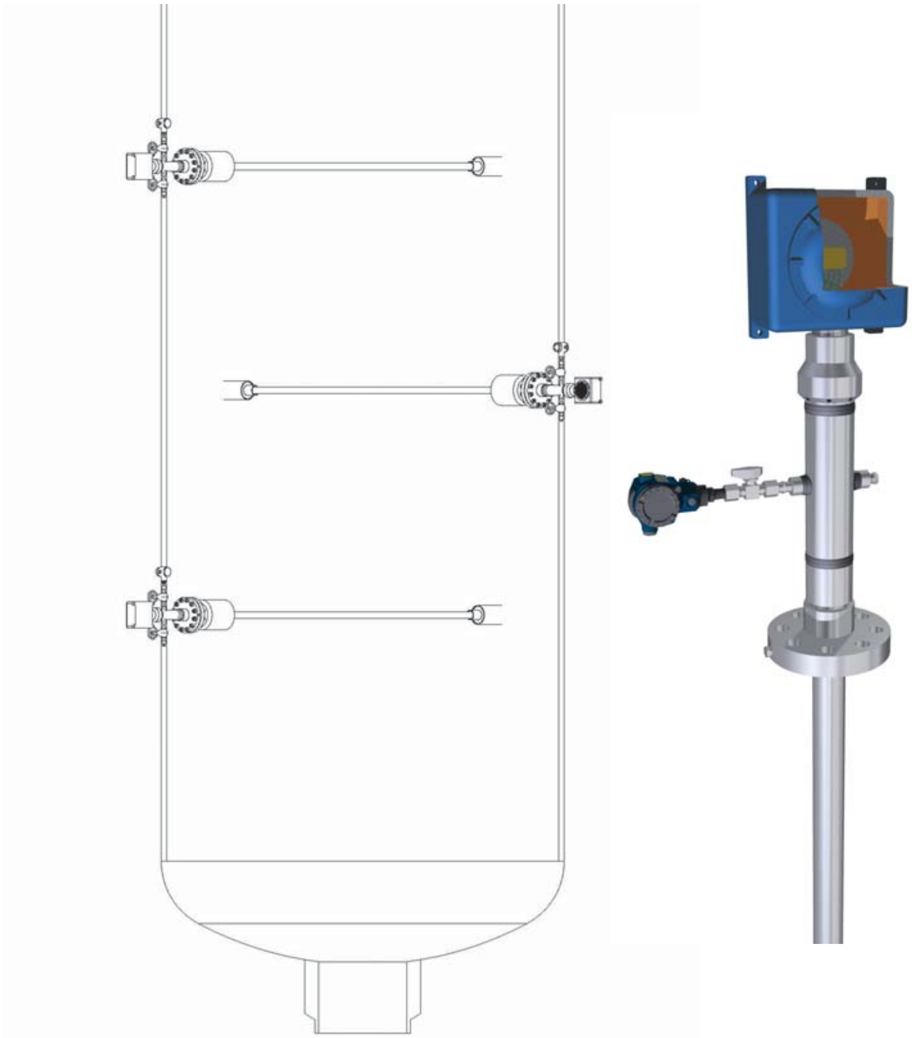

Figure 4: A multipoint sensor, such as the Endress+Hauser iTHERM TM911 (right), has multiple temperature sensors arranged along the length of its thermowell. The sensor can be placed so that it spans a reactor.

While Figure 4 shows the sensor mounted across a reactor vessel, the sensor can also be mounted vertically or at an angle as needed to obtain different temperature profiles. Theoretically, the maximum immersion length of each individual multipoint thermometer can be equal to the reactor's internal diameter. Supports may be necessary to reinforce the end of the multipoint thermowell at the opposite side of the process connection.

Measuring safely

In the oil & gas, refining and chemical industries, safety is always a priority. Therefore, great care has to be taken when making multiple sensor connections because in almost all cases the measurements are being made in a hazardous area, and/or the contents of the vessel are hazardous. In the case of the sensor array, all of the process connections are potential leak points as they leave the vessel. With multiple connections, this can pose a problem.

For both the sensor array and multipoint thermometer, one solution is to install a safety chamber (Figure 5) between the flange and junction box. This prevents process gases and liquids from escaping the vessel if any of the process connections leak.

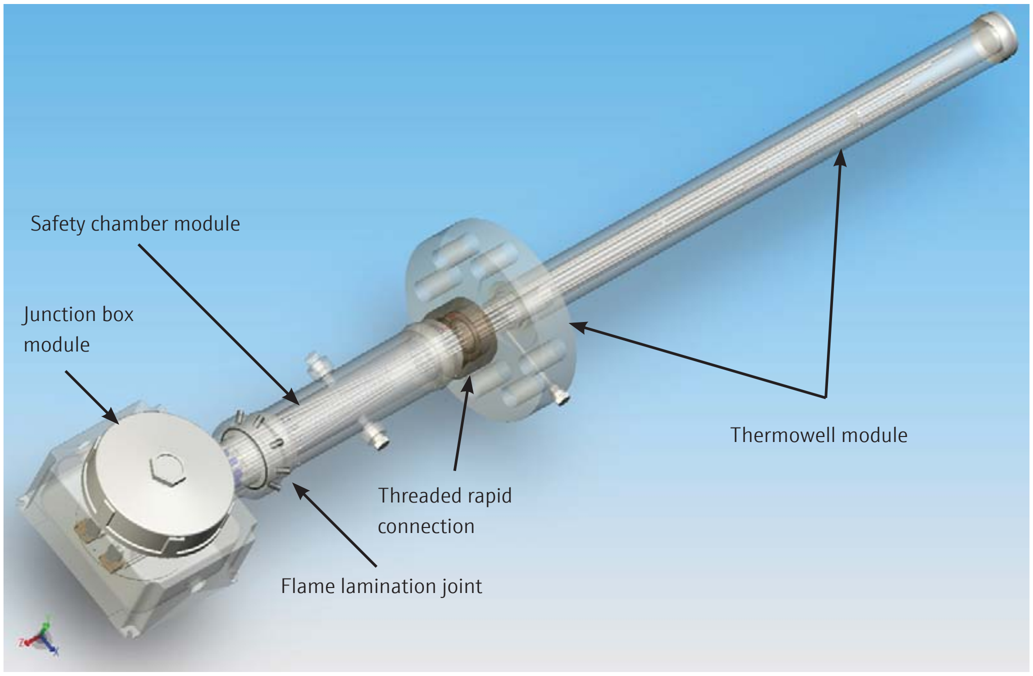

Figure 5: A safety chamber between the flange and junction box prevents process fluid or gas from escaping from the vessel if a leak occurs.

After long term usage under demanding process conditions such as high corrosion rates, pressures and temperatures—combined with a series of known and unpredictable process phenomenon such as turbulence, highly exothermic local chemical reactions and others—a crack in the thermowell wall might occur, allowing the process media to fill the internal volume of the thermowell. In such a case, the process media can be contained by second and third barriers (Figure 6).

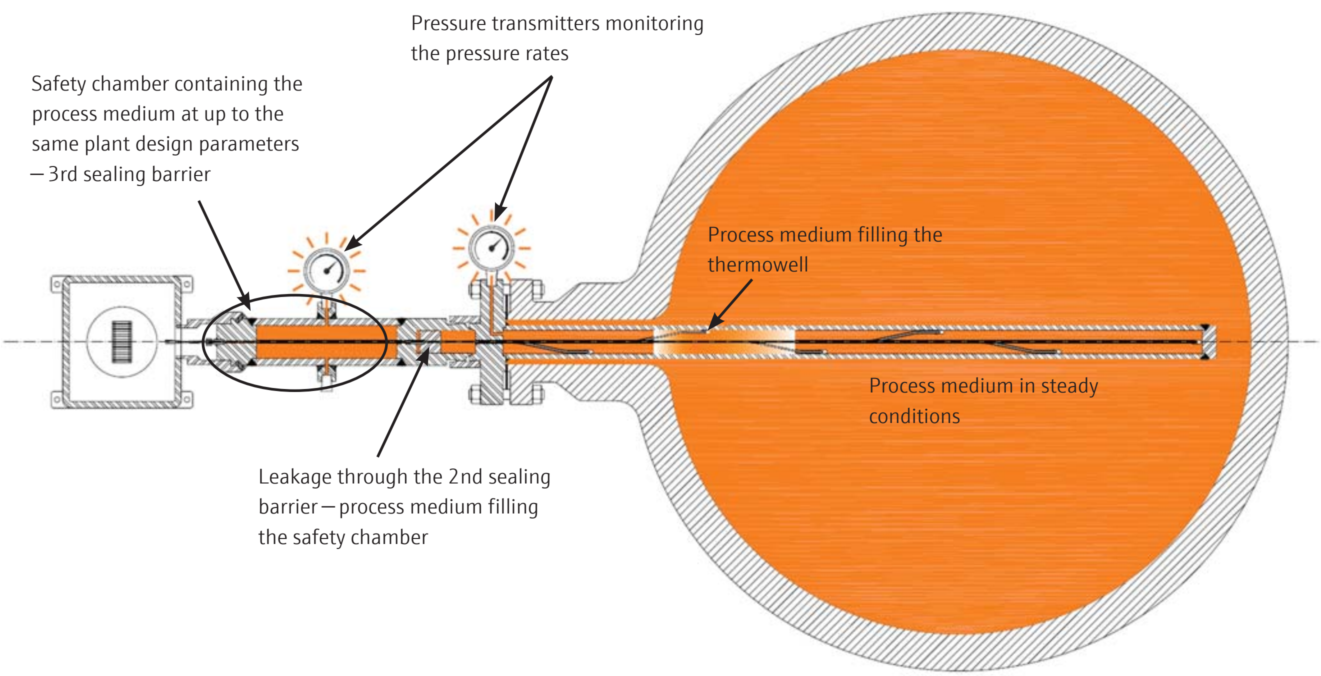

Figure 6: For extra safety, pressure transmitters can detect a leak.

By using a pressure vent on the multipoint flange, the leak can be detected and monitored via a pressure transmitter. The second barrier protects the safety chamber from any attack by highly corrosive process media, as well as from high process pressures or temperatures.

Even after a breakthrough of the second safety barrier, there is no need for a plant shutdown as the safety chamber is in accordance with PED/ABSA pressure directives and their harmonized rules and calculation codes. This allows it to still safely operate until the next planned downtime.

Summary

Modern flow technologies provide instrument engineers with vital self-monitoring information. The format of such Applications for temperature profiling in the oil & gas and petrochemical industries are characterized by demanding process conditions in term of hazardous media with high pressures and temperatures—combined with elevated corrosion rates, turbulence and vibration. Specialized instrumentation such as array sensors and multipoint thermometers are available to make required measurements, but care must be taken during installation and use.

Notes

Keith Riley has been a Product Business Manager with Endress+Hauser since April 2008. Prior to this, he was a Product Manager and Regional Sales Manager with L.J. Star Incorporated as well as a Product Manager for Penberthy (Tyco Valves). Overall, he has over 20 years of sales, marketing and instrumentation experience in the process industry.

Tim Schrock, Area Manager for the Endress+Hauser temperature production center has 5+ years of experience in the instrumentation field. He started his career at Endress+Hauser and has held various roles such as Technical Support Engineer, Inside Sales Engineer, and Outside Sales Representative. In his current role, he works closely with the sales centers located in the US, Canada, Mexico, Brazil, and Chile on temperature applications, while also providing commercial and marketing support.

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Endress+Hauser, Inc.
2350 Endress Place
Greenwood, IN 46143
Tel: 317-535-7138
888-ENDRESS (888-363-7377)
Fax: 317-535-8498
info@us.endress.com
www.us.endress.com

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