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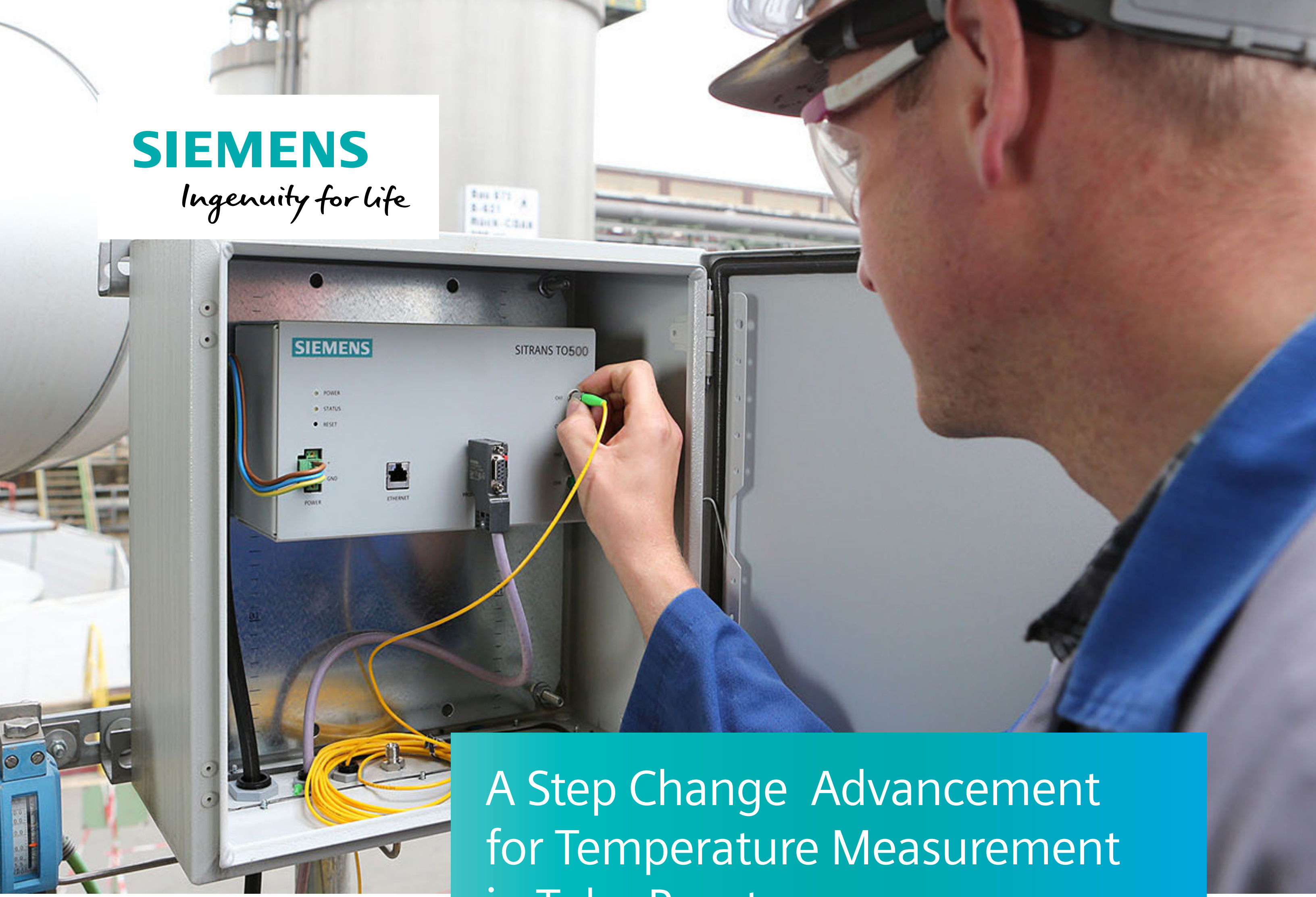

A Step Change Advancement for Temperature Measurement in Tube Reactors

Accurate determination of temperature in the catalytic conversion of gases and liquids is a critically important task that often presents many operational challenges. This is particularly the case in applications featuring tube and tube-bundle reactors, where spatial limitations place special demands on measurement technology. In these applications, a high priority is placed on being able to reliably detect hotspots within the reactor so that adjustments can be made in order to ensure the quality of the substance conversion and aging of the process catalyst.

Historically, thermowells made up of resistance temperature detectors (RTDs) or thermocouples (TCs) have been the solution of choice for determining temperature profiles in tube and tube-bundle reactors. The bulkiness of these thermowells, however, which is largely a product of each RTD or TC's need for individual wires, coupled with limited available space inside reactors, means that the overall number of measuring points has to be kept relatively low, thereby hampering process optimization efforts. Fortunately for operators, a new solution based on fiber-optic sensing now exists that solves many of these problems and -- for the first time -- provides a detailed look into the interior of tube-bundle reactors: the SITRANS TO500.

Temperature Measurement in Tube-bundle Reactors

Tube-bundle reactors consist of externally cooled reaction tubes in which a gas mixture is chemically converted with the help of a catalyst at temperatures ranging from 250 – 600 degrees Celsius. The tubes are several meters long and between 2 – 5 centimeters (cm) in diameter. Temperature changes along the length of the reaction volume depending on variables, such as the specific location where the gas enters the reactor and the amount that is allowed to flow in.

To measure temperature at different points and develop a profile, a protective tubular fitting or thermowell containing multiple RTDs or thermocouples is placed into the reactor tube. As each sensor requires a separate component and as many as two to four wires, the thermowell often has to be several centimeters wide, even if only a few measuring points are needed. In processes where a higher number of measuring

The multipoint measurement system SITRANS TO500 transmits temperatures and temperature profiles reliably and fast. By indicating the spatial temperature distribution, the system improves visibility into operating conditions to optimize quality, yield and lifetime

points is required, the thermowell can become large enough and heavy enough to present logistical and operational challenges, particularly during installation and when it needs to be removed from the reactor for scheduled maintenance. In most applications, the number of sensors is kept as low as possible to avoid this problem; however, fewer sensors translates into less measuring points, which means that processes have to be controlled on the basis of theoretical modeling, making process optimization virtually impossible to achieve.

Changing the Status Quo

Recognizing the need for a solution that could improve the efficiency of temperature profiling in applications with space restrictions, Siemens developed the SITRANS TO500 – a fiber-optic measuring system that enables operators to record a high number of temperature measuring points using a single sensor fiber that is less than 2 millimeters (mm) in diameter.

SITRANS TO500 technology is based on fiber Bragg gratings (FBGs), which are arranged at individually defined points on the sensor probe. The transmitter sends light waves to the fiber-optic sensors and evaluates the reflected portions. In the transmitter, light is generated in the wavelength of 1500 - 1600 nanometers (nm) and outputted to the sensor measuring probe via a continuously tunable laser light. Each fiber Bragg grating reflects light of a defined wavelength. The wavelength reflected by the grating varies depending on the temperature. The reflection at the FBGs is thus a measure of the temperature at the respective measuring point. A gas cell with fixed absorption line serves as a reference in the system and the wavelength determination is continuously adjusted by it.

Because the reflection of the light takes place in the same fiber, no additional cables are necessary, which results in a much smaller cross section of the protective tube being taken up by the measurement setup within the reactor. This creates more available reaction space, which positively impacts throughput. Moreover, the sensors response times are shortened because of the damping effect of the air gap between the fiber in which the gratings are inscribed, which means that the tube walls can be reduced to a minimum.

In order to adapt fiber-Bragg grating technology to industrial applications, Siemens engineers had to make the inherently brittle fiber somewhat flexible, as this is the only way the sensor could be inserted into a reactor and extracted again when, for example, a facility is undergoing scheduled maintenance. Flexibility also enables the meter-long sensor to be rolled up for transport.

The SITRANS TO500 comes equipped with a transmitter, and measuring lance, which can each be connected to up to 48 temperature sensors on the transmitter at four channels. With up to four measuring probes, as many as 192 measuring points can be processed simultaneously. The system can also be integrated with any programmable logic controller (PLC), distributed control system (DCS), or SCADA system via a Profibus DP interface, providing operators with the ability to gather and analyze temperature profile data and leverage digitalization to optimize reactor operation.

The fast and gap-free detection of temperature profiles provided by the SITRANS TO500 enables plant operators to reliably monitor catalytic conversion processes and more precisely control the quality of end products. Local overheating is quickly and accurately detected, thereby minimizing the risk that the product has to be discarded, while at the same time ensuring integrity of the process, plant, and environment. The system is particularly well suited when the user needs to install a very large number of measuring points in a tight space and with low thermal mass, such as in tube and tube-bundle reactors or in capillaries or microreactors.

Optimizing Temperature Measurement in the Performance Polymers Industry

The benefits of using fiber-optic technology for temperature measurement have been on display in Evonik Industries high-performance polymer plant in Marl, Germany. The plant uses tube-bundle reactors in the production of Laurolactam -- a starting material for a high quality polyamide named Vestamid®.

Evonik faced the challenge of having to install a sufficient number of temperature measurement points in a small space within a single tube reactor in order to quickly detect high temperatures and undertake countermeasures. In this way, they could prevent destruction or the accelerated aging of the catalyst due to overheating. This avoids a plant shutdown, which would otherwise be required due to the complicated procedure for replacing a catalyst.

Due to the small diameter of the reactor tubes, the necessary number of measurement points and the demands on the speed of data acquisition, it was not possible to use a conventional thermowell made up of RTDs or thermocouples. As a result, Evonik made the decision to conduct a pilot test with the SITRANS TO500.

"With the SITRANS TO500, our plant personnel can detect the development of hotspots or the effectiveness of the catalyst in good time with the detailed recording and visualization of the complete temperature profile in the reactor," said Matthias Hüning, a specialist in electrical measurement and control technology for Evonik Industries. "We use this information to initiate measures to reduce the temperature, for example, in the first scenario. In the second scenario, we can perform maintenance procedures, such as replacing the catalyst when necessary due to its age."

Both applications extend the life of the catalyst in the reactor, which means cost-effective, preventative maintenance procedures are performed based on need. Evonik is also able to capitalize by coupling the SITRANS TO500 to optical signals. During the installation, Siemens used a glass fiber coupler to connect the sensing fiber in the reactor and the transmission line to the transmitter. The coupler can easily be disconnected for maintenance purposes, for example, when the reactor cover needs to be opened. The measuring probe can be pulled out before revision of the reactor or before replacing the catalyst and rolled onto a spindle. The latter also enables it to be easily and safely transported.

Redundancy Ensures Fail-safe Operation

Inline measurements of temperature profiles in spatially confined applications place special demands on the measurement technology. This especially applies for determination of the temperature changes in tube and tube-bundle reactors. In such applications, there is significant opportunity to improve quality and achieve process optimization through enhanced visibility of internal temperature profiles. Doing so enables reactions to be controlled in such a way that catalytic converters age as slowly as possible, resulting in a diminished need for replacements.

The SITRANS TO500 was developed specifically for this purpose and provides many operational advantages over conventional RTDs and thermocouples. In highly critical chemical processes, where failure or inoperability of a single temperature sensor can have far-reaching impacts both operationally and financially, the installation of two SITRANS TO500's offers a means to ensure temperature profile visibility at all times, resulting in fail-safe operation.

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