Tube skin temperature measurement

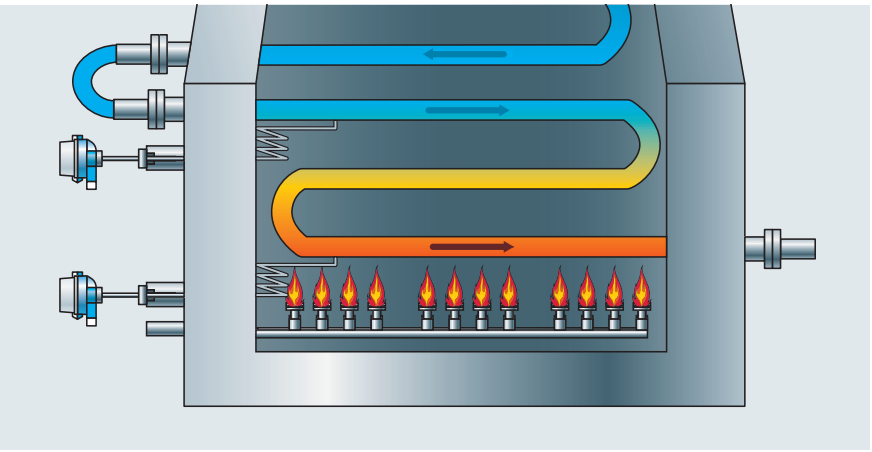
in a steam-cracking furnace for ethylene production

Benefits at a glance

- Overheating detection
  - Preventing the accumulation of coke in pipes and its negative effects
  - Increased life span of the tubes
- Regulation of the burners feeding based on temperature measurements leads to substantial energy savings
- Increased process efficiency & product quality

Process conditions

- Ambient or negative pressure
- Ambient process environment temperature: 1260 °C (2300 °F)
- Surface temperature of the tube: 1150 °C (2102 °F)
- Acid gases (SO2 + NOx), concentration of OS2
- Simultaneous oxidation and carburization



One of the main processes in the petrochemical industry is the steam cracking, which is used to produce light olefins, like ethylene or propylene, by splitting large hydrocarbons into smaller and lighter molecules through the reaction with steam. This chemical reaction converts gaseous or liquid-heavy hydrocarbons (e.g. ethane, naphtha) into smaller ones by heating them at extremely high temperatures and mixing them with superheated steam in tube furnaces. The heart of the process is the cracking furnace, where high amounts of energy are given to tube coils by the burners in two main sections (convection and radiation) and where highest temperatures are reached on the skin tubes. This fundamental step is key to produce ethylene, an essential raw material for the chemical industry, and to produce polymers, solvents, synthetic fibers or plastics with the right quality and efficiency in terms of energy consumption. Due to inaccessibility, high temperatures and potential damage, a conventional direct temperature measurement of the medium inside the tube is not possible. A tube skin thermocouple assembly enables the accurate measurement of the outer tube surface in a steam cracking furnace or in other applications such as heat exchangers, heat recovery and steam generator units (HRSG) steam treatment reactors, fired heater applications or boilers.

The challenge An important factor for accurate measurement inside a furnace is to protect the sensor from external thermal effects, mainly the heat coming from the burners. As the sensor is placed on the outer surface of the tube, it is important to ensure that only the effective tube surface temperature is measured and not the

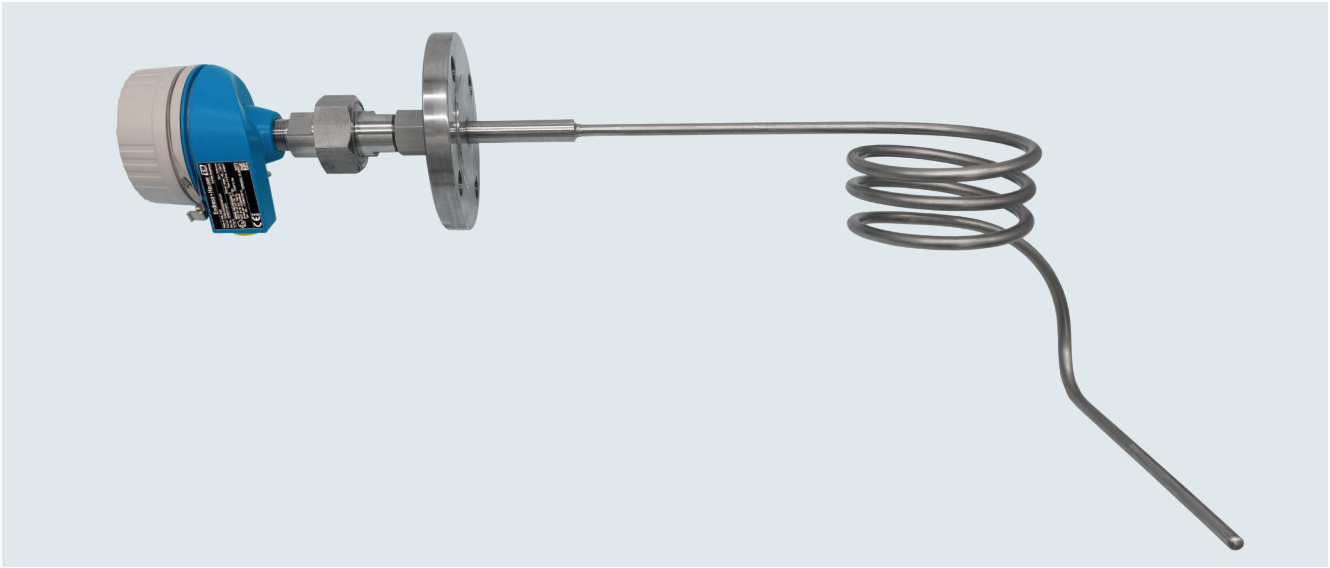
Endress+Hauser

People for Process Automation

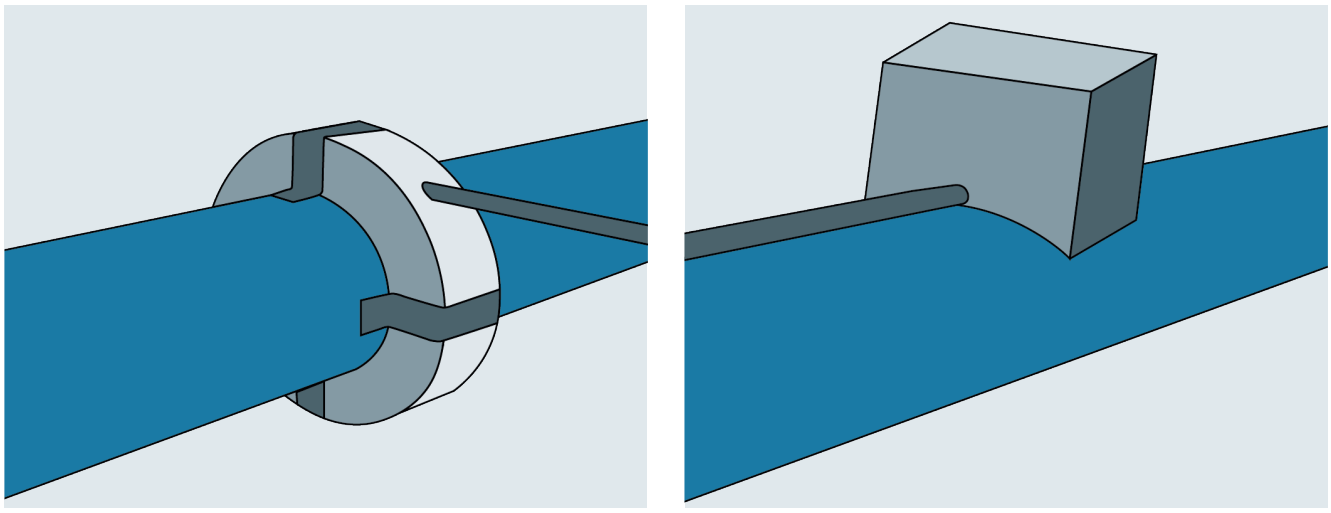
internal furnace temperature where all the tubes are installed. The needed thermal expansion of the heated tubes places the highest demands on the instrumentation used in terms of material selection, thermometer design and the connection of the thermometer to the pipe's surface and to the furnace's walls.
The second thing to consider is the build-up of a coke layer on the inner tubes' surface. This layer forms when the steam and hydrocarbons in the convection sections are not heated to the correct temperatures and not diluted in the nominal ratio to obtain the correct carbonization rate. The ratio of steam to hydrocarbons depends on the composition of the feedstock.
As a result, the high temperature of the cracking process in the radiant section of the furnace would result in a higher rate of coke formation. When coke deposits accumulate on the inner tube walls, this phenomenon impedes heat transfer between the furnace environment and the tube coil. This can raise the tube skin temperature above the maximum allowable temperature, without achieving the desired cracking temperatures for the desired product quality.
Basically, accurate temperature measurements at multiple points in the furnace sections allow continuous monitoring of furnace performance in terms of energy consumption compared to heat transferred to the process fluids, and tube life monitoring for predictive maintenance.

Our solution For every application, the pipe surface thermometer needs to be designed and specifically customized according to customers' requirements to ensure optimal continuity between the sensor and the process fluid and the least influence from the environmental temperature of the furnace.

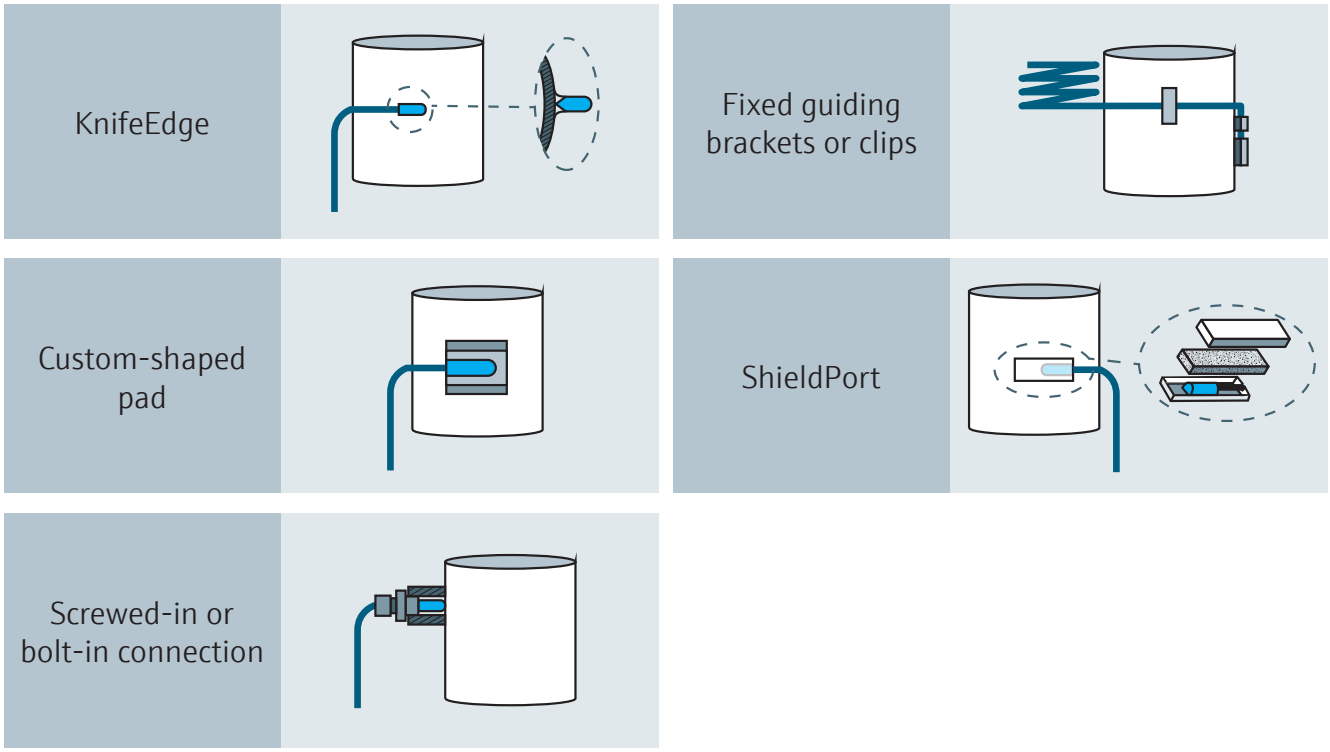
TC65 thermocouple thermometer
All the different executions and technical details are part of the individual consultation and customization.



Highest accuracy through optimized heat transfer between the sensor and the process fluid
- Heat shield fabricated and coated with advanced materials for proper insulation between tube and external environment
- Different types of pipe connections
- Ideal positioning of the measuring point in relation to the burners



Customized heat shield in different shapes



Types of pipe connections

Longevity in harsh operating conditions such as strong vibration, corrosion or relative displacements due to differential thermal expansions

- Advanced alloys for the sheathing of MI cables and special ceramics
- Adjusted sensor diameter (MI cable) depending on wall thickness
- Sensor routing from furnace wall to tube outer surface considering MgO expansion coils

Modular assembly allows for easy installation from inside and outside the furnace

- Sensor welding performed separately from heat shield
- Separate IEC Ex compliant components such as process connection, insert, heat shield etc., can be assembled in the field to provide a complete IEC Ex certified instrument at the end of the installation
- Threaded connections for normal process conditions, welded connections for harsh process conditions

Result The unique design and engineering of the thermometer allows the process temperature of the reacting fluid to be calculated from the surface temperature of the tube.

This, in turn, ensures that the burners produce the right amount of heat to reach the exact temperature on the outer tube surfaces, allowing a regulated power supply and substantial energy savings. At the same time, the risk of overheating both the tube and the fluid is significantly reduced, which helps to prevent adverse effects on the process efficiency that could result from coke build-up and reduced flow in the tube.

Ultimately, the result is a significant extension of the life of the pipe and associated instruments, while securing product quality and process efficiency.

www.endress.com

A01391T/09/EN/01.24

Endress+Hauser

People for Process Automation