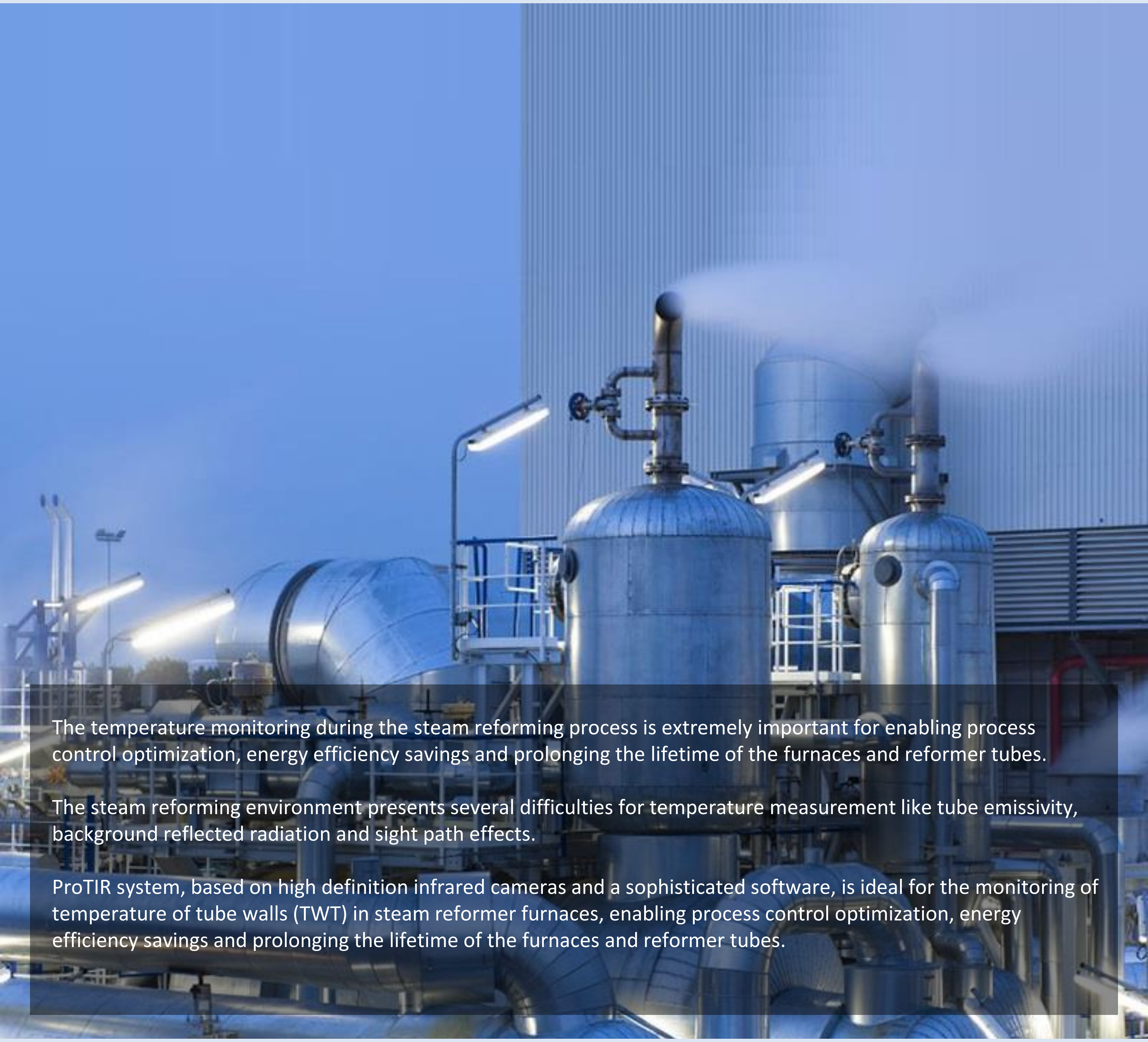
Steam Reformer Tube Wall Temperature Monitoring

Application Note



The temperature monitoring during the steam reforming process is extremely important for enabling process control optimization, energy efficiency savings and prolonging the lifetime of the furnaces and reformer tubes.

The steam reforming environment presents several difficulties for temperature measurement like tube emissivity, background reflected radiation and sight path effects.

ProTIR system, based on high definition infrared cameras and a sophisticated software, is ideal for the monitoring of temperature of tube walls (TWT) in steam reformer furnaces, enabling process control optimization, energy efficiency savings and prolonging the lifetime of the furnaces and reformer tubes.

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Steam Reforming

Steam reforming is a method for producing gases, specially hydrogen, methanol and ammonia, by reaction of hydrocarbons with water.

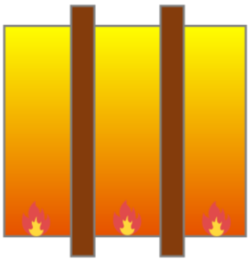
Commonly natural gas is the feedstock. The main purpose of this technology is normally the production of hydrogen, an essential material for such processes as desulfurization at petroleum refining plants, ammonia synthesis for fertilizer production, methanol production, and direct reduced iron production.

The reaction is conducted in a huge furnace where high-temperature steam (700°C–1.000°C) is used to produce hydrogen from a methane source, such as natural gas.

The furnace heats a large number of tubes containing a catalyst (typically nickel). Methane reacts with steam under 3-25 bar pressure in the presence of the catalyst to produce synthetic gas (syngas) composed of hydrogen (H_2), carbon monoxide (CO), and a relatively small amount of carbon dioxide (CO_2).

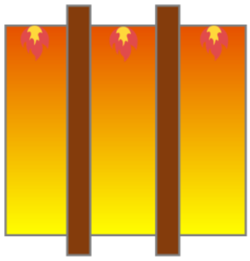
Steam reformer tubes

Bottom Fired



The bottom-fired type has an almost constant heat flux profile along the length of the tube. The furnace approaches a counter-current design resulting in high metal temperatures at the outlet.

Top Fired



The top-fired reforming is characterized by a peak in the tube wall temperature in the upper part of the reformer, and it has the highest heat flux where the metal temperature is at its maximum.

Side Fired

The side-wall fired design allows a better adjustment and control of the tube wall temperature. This alternative offers more flexibility in design and operation, and a higher average heat flux.

Terrace Fired

The terrace-wall fired reformer is a modification of the bottom fired design, having slightly lower tube wall temperatures.

Steam Reformer Designs

There are several factors that are of fundamental importance in the reformer design. The tube geometry is a key factor in the reformer and its design must consider a number of interrelated parameters: the tube length, the feed flow, the reformer duty, the number of tubes, the tubes' diameter, the average heat flux, and the space velocity.

Increasing the length of the tubes is more economical than increasing the number of tubes, because when many reforming tubes are used the inlet and outlet systems in the plant become very complicated. However, the tube length is limited by the risk of tube bending and by restrictions in pressure drops across the catalytic bed.

For large tube diameters the wall thickness must be increased.

In general, the total cost of the reformer tends to increase with the increase of the tubes' diameter above a minimum where the tube wall thickness must be kept constant.

By reducing the tube wall thickness, the operating temperature can be also reduced, thus providing considerable energy savings. In addition, with higher heat flux to the catalyst, the production requirements of a particular unit can be met with a lower number of tubes.

Tube Walls Temperature (TWT) Monitoring

Monitoring the temperature of the tube walls is critical for the control of the reforming reaction. The goal is to keep the temperature high enough to ensure an efficient process without wasting energy.

On the other hand, the service life of the reformer tubes is limited since they continually degrade due to the harsh and high temperature environment of the furnace.

The tubes suffer the combined effect of creep, alternating thermal and mechanical stresses, external and internal oxidation and carburization. The reformer tubes have a maximum temperature of operation.

Exceeding this temperature causes damage that can reduce the life of the tube, requiring expensive early tube replacement and the associated downtime.

To avoid the reformer tubes damaging because of overheating it is extremely important to control the temperature.

Tube wall temperatures range from 700°C to 1.200°C, and industry rule of thumb is that a 20°C increase in tube wall temperature above its maximum allowable temperature will halve the tube life. So, plants maximize production by operating as close as possible to the temperature limits of the pipes without exceeding them.

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Tubes Lifetime as a function of Temperature

Temperature	Tube Lifetime
860°C	10 years
880°C	5 years
900°C	2.5 years
925°C	11 months
950°C	4.5 months
975°C	2 months
1000°C	4 weeks
1050°C	5.5 days
1100°C	1 day

Temperature Measurement Problems

Tubes emissivity

Emissivity varies widely for different materials, and also for the same material at different temperatures and with time on-line. In addition, surface conditions such as roughness and scale deposits can result in a significant variation in emissivity over a small area of target surface.

The most effective method to minimize such an error is actually to measure the emissivity directly. With the use of laser pyrometers there are practical difficulties, which result in concerns about the measurement obtained in this way.

Measurements in typical steam reforming furnaces have shown that the range of tube emissivity is generally confined to narrow band in a given reformer.

Traditionally, a reformer tube was assumed to have a constant emissivity of 0.85.

Measurements carried out using a laser pyrometer showed that in the top-fired furnace studied, the tube emissivity varied between 0.96 - 0.98; and in the terraced-wall furnace (in which the tubes are several years older) between 0.90-0.94. These results after analysis are found to to be high.

Laser pyrometers

Reflected radiation

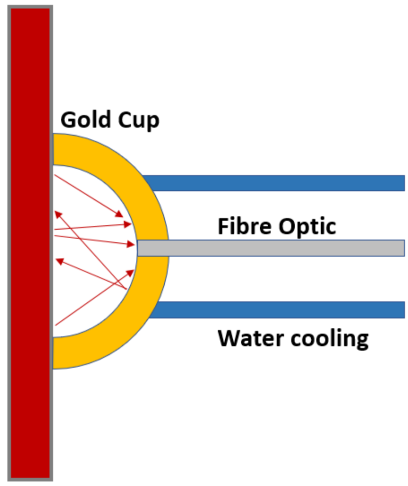
Conventional pyrometers cannot distinguish between radiation emitted by the target tube and radiation emitted by the walls of the furnace, luminous flames or near-by tubes and reflected from the surface of the target tube.

All non-contact radiation pyrometers in fact measure the sum of the two, the reflected radiation superimposing itself on the thermal self-emission of the target, masking its true value.

Gold cup pyrometer

Another contact method of tube wall temperature measurement is the gold cup pyrometer. This eliminates all reflected radiation by forming an enclosure around the target spot.

In this way no correction for reflected radiation is required. In addition, since the internals of the gold cup pyrometer approximate well to a black body, the emissivity can be taken as unity.



Gold cup pyrometer diagram

As a result, this method represents a more accurate way of measuring tube wall temperatures than laser pyrometers.

However, the Gold Cup is a large device and, once filled with cooling water, becomes very heavy. There is also a limit to the distance that it can be inserted into the furnace.

These reasons together with its relatively high price makes this option not practical enough to use for continuous temperature monitoring measurements.

The information from the gold cup can be used to eliminate inherent errors and modify infrared thermal imagers and pyrometers in order to make these non-contact measurements devices more accurate.

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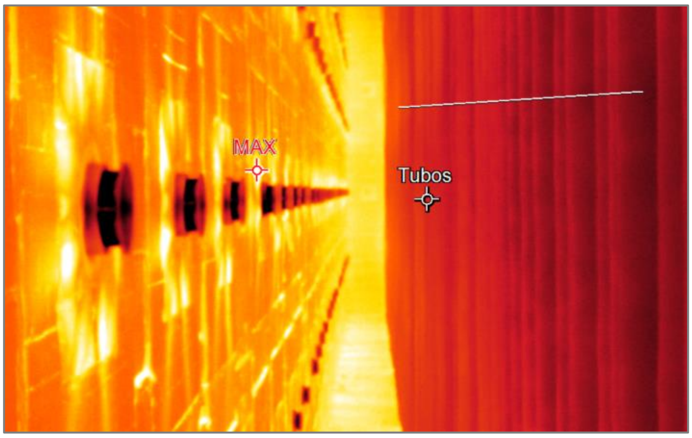
Sight Path Effects

This phenomenon refers to absorption and emission of radiation by the intervening furnace gases between the target and the instrument. In particular, this is due to carbon dioxide and water molecules.

The high temperature combustion gases are partially opaque over large portions of the infrared spectrum.

In terms of meaningful temperature measurement, it is essential to choose a measurement device with an operating wavelength at which the furnace atmosphere is effectively transparent to the radiation.



ProTIR tube walls temperature monitoring inside the furnace

ProTIR | Temperature Monitoring Inside the Furnace

To adapt these needs, VisionTIR has developed ProTIR, a continuous temperature monitoring system to measure high temperatures in real time, based on high definition infrared cameras and a sophisticated software.

ProTIR is ideal for the monitoring of temperature of tube walls (TWT) in steam reformer furnaces, enabling process control optimization, energy efficiency savings and prolonging the lifetime of the furnaces and reformer tubes.

With 86° viewing angle optic, our system provides accurate temperature information (from any of 367.000 live data points) of an extensive area with just a narrow opening in the wall.

Protected by a rugged housing and using a high-performance water-cooling system, ProTIR system resists up to 2.200ºC (3.992ºF).

In addition, this thermal imaging solution provides a wide temperature measurement range of 450 – 1800ºC (842 – 3272ºF).

ProTIR software provides accurate data analysis along with automated alarm outputs and control for 24/7 monitoring, to instantly alert the user of any problems from the control room.


ProTIR retractable system

ProTIR Main Features

Real time inspection at the highest resolution
86° angle for maximum inspection details. 764*480 pixel resolution, giving 367.000 data points.

Protection mechanisms
Different protection mechanisms available against overheating (automatic retraction system and wall fixing device) for long-term trouble-free use.

Range of housing dimensions and mounting options
There are different lengths and diameters available to provide the best solution for every installation.

Full feature software
It provides accurate data analysis, configuration of different areas, temperature trends, automated alarm outputs and control for 24/7 monitoring, in order to instantly alert the user of any problem from the control area.

Communications via Profinet / Profibus / OPC Client
Data integration and communication to the different levels of the factory (SCADA, data bases, communications with PLC and sensors).

ProTIR Main Benefits

- ✓ High-definition thermal images
- ✓ Radiometric images with accurate temperature information
- ✓ Temperature range: 450 – 1800ºC (842 – 3.272ºF)
- ✓ Operating temperature: up to 2.200ºC (3.992ºF)
- ✓ Frame Rate: 80 Hz
- ✓ Spectral range: 0,92 – 1,1 µm
- ✓ Process control optimization
- ✓ Energy efficiency savings
- ✓ Long term reliability
- ✓ Minimal maintenance

Conclusions

- Monitoring the temperature of the tube walls in a steam reforming furnace is critical for the control of process. The goal is to keep the temperature high enough to ensure an efficient process without wasting energy and without reducing the life of the tubes.
- ProTIR is a continuous temperature monitoring system, based on high definition infrared cameras and a sophisticated software, ideal for temperature monitoring of tube walls (TWT) in steam reformer furnaces, enabling process control optimization, energy efficiency savings and prolonging the lifetime of the furnaces and reformer tubes.

Benefits of ProTIR Temperature Monitoring System

- ✓ Allows operating at high temperature without reducing the lifetime of the tubes.
- ✓ Energy efficiency savings.
- ✓ Real time temperature monitoring.
- ✓ Simultaneous and multiple measurement points, areas or targets.
- ✓ Minimum maintenance.
- ✓ Temperature range: 450 – 1800ºC (842 – 3.272ºF)
- ✓ Operating temperature: up to 2.200ºC (3.992ºF)
- ✓ Automated alarms outputs.
- ✓ Long time reliability.
- ✓ Data integration and communication to SCADA System.

VisionTIR
Multispectral Vision Technology

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