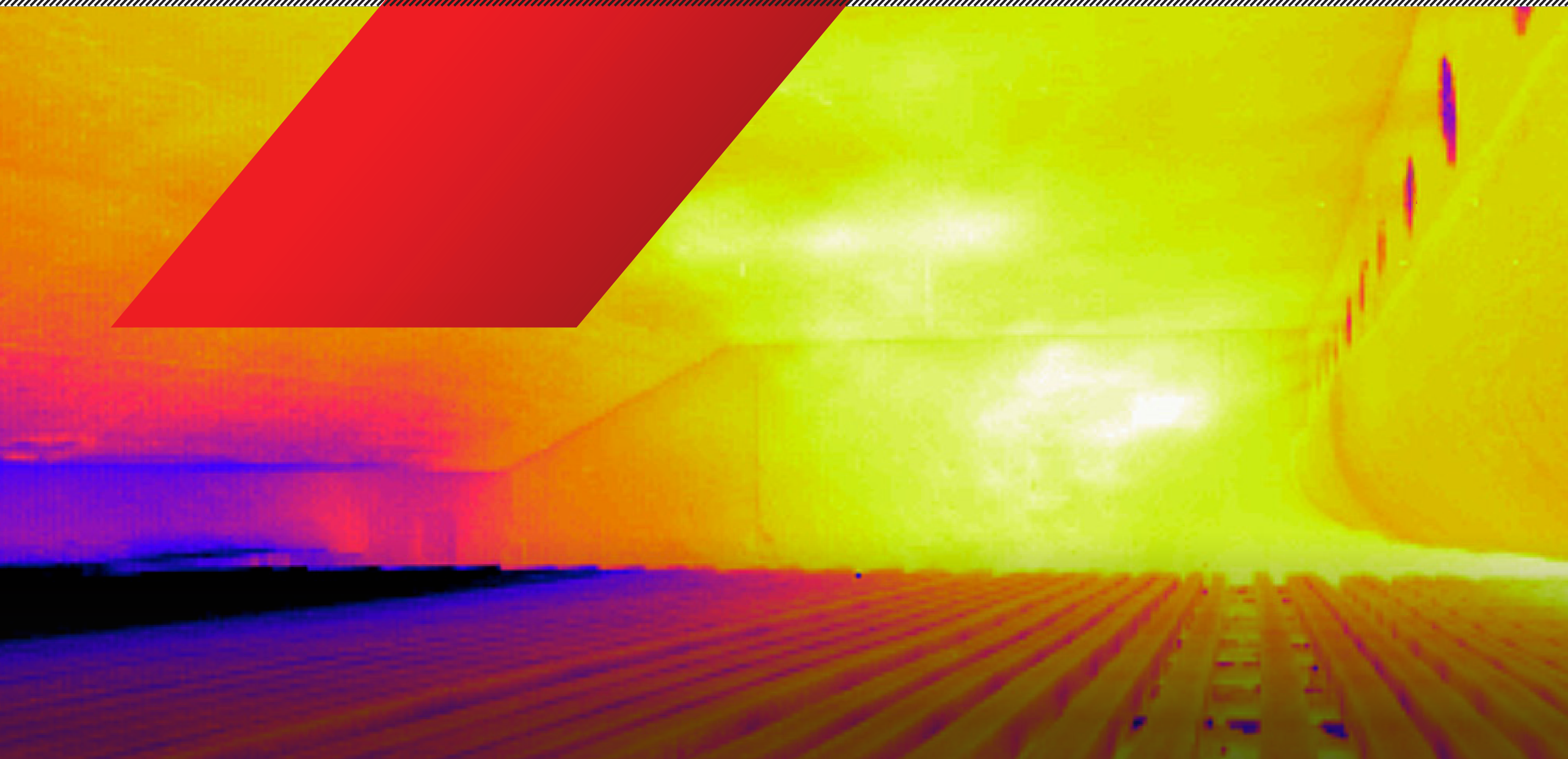
PROCESS OPTIMISATION IN METAL REHEAT FURNACES

APPLICATION NOTE



Reheat furnaces bring cold metal to the correct temperature for rolling, extruding or forging. For optimum quality, and to reduce wastage, the temperature should be uniform throughout the product, which requires accurate temperature monitoring.

In addition, temperature measurements are key to providing optimised heating trajectories for the metal, which results in consistent metallurgical properties and minimal surface scaling as well as significant energy savings and a reduction of CO_2 emissions.

The most effective and accurate method of achieving these measurements is through thermal imaging and combustion efficiency.

REHEAT FURNACES

Most steel mills and metal forging operations rely on reheat furnaces to ensure that metal slabs or billets reach a uniform and repeatable temperature prior to being sent to their rolling mills and forge presses and further processing.

The purpose of the reheat furnace is to bring the product temperature up to the working level so that it can be rolled, extruded or forged at the correct working temperature for the entirety of the process.

There are two major types of reheat furnaces – continuous and batch. Each can use various heating methods, but the most common uses either natural gas/methane, or natural gas with oxygen enrichment.

APP NOTE

Typically, a reheat furnace in a hot rolling mill for steel has to raise the metal temperature from ambient to around 1200 °C (2192 °F).

CONTINUOUS REHEAT FURNACES

Continuous reheat furnaces have evolved from simple pusher furnaces – where stock is sequentially pushed through the furnace as each new product is added – to the more advanced walking beam furnaces.

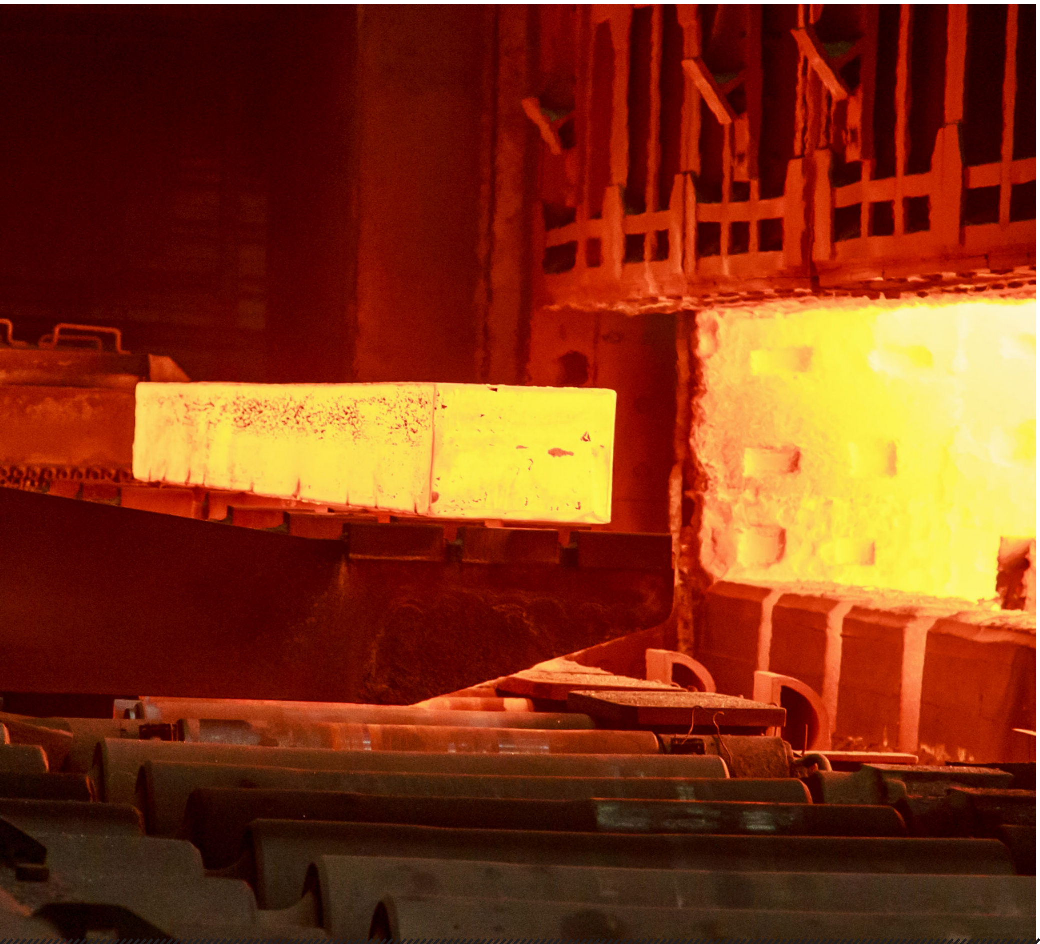
The walking beam design – where stepping, alternating skids 'walk' the product through the process – produces a much more uniform underside temperature that results in higher-quality finished products.

Continuous reheat furnaces are typically used in hot rolling mills. The slab or billet is loaded into the cool end of the furnace, then passes through pre-heat, heating and soaking zones before being discharged for rolling.

In this system, the pre-heat zones warm up the material, then the heating zone delivers the main heating for the product. The soaking zone allows the heat to homogenise throughout the steel, so that when it is discharged it has a uniform temperature distribution throughout its thickness, length and width.

The aim of this method is to create a tightly controlled heating trajectory as the stock travels through the furnace. For maximum fuel efficiency, the stock should achieve the desired temperature shortly before discharge.

However, in many cases, the steel is heated too quickly, particularly in the pre-heat zone. This is very fuel inefficient, and so wastes energy and increases costs. It can also affect the metallurgical properties of the steel and increase surface scaling.



BATCH REHEAT FURNACES

Batch reheat furnaces are commonly used in forging operations, where the metal is hammered to improve its density and strength.

If the metal drops to a certain temperature, it can damage the forging machinery and negatively affect the forging quality. To prevent this, the part needs to be returned to the batch reheat furnace and brought back up to temperature for further forging.

Once the reheated part is ready, it is quickly transported back to the forge for further work. This pattern of heating, forging, and return to the furnace for reheating, can be repeated several times during the forging process.

Again, the heating needs to be uniform to ensure that the entire product is at the correct temperature for forging to continue.

INDUSTRIAL DECARBONISATION

THE ROAD TO CO_2 INDUSTRIAL DECARBONISATION

Decarbonisation trends will change how industrial operators work – forcing end-users, technology licensors, and instrument manufacturers to continuously seek incremental and radical improvements to process efficiency.

For many heavy industrial processes, increasing energy efficiency can be a serious challenge. The key aims are to minimise energy use, maximise combustion efficiency, achieve optimum quality, reduce emissions, and capture waste heat sources to be reused.

Many tasks require only slight behavioural changes – for example, switching equipment off rather than leaving it on standby can significantly reduce energy usage over time.

However, the extremely aggressive nature of many industrial processes due to the process media, the surrounding environment, or both – can make other energy-reducing measures, such as optimising combustion, or thermal processing, challenging to achieve.

These measures require precise measurement particularly in combustion optimisation, where changing fuel sources or quality can impact the reaction and useable energy.

In addition, ever-increasing demand for high-specification products means that achieving quality goals becomes a never-ending race. Products that fail to meet the necessary criteria may be rejected, scrapped, or require rework, all of which can double emissions.

TRADITIONAL TEMPERATURE MEASUREMENTS: THERMOCOUPLES

Historically, thermocouples were installed through the furnace roof or walls to measure the furnace temperature in each zone. The furnace temperature was controlled based on those readings.

However, thermocouples do not measure the stock temperature – the temperature of the metal being passed through the furnace. Instead, they only measure the furnace atmosphere and surroundings. Mathematical heating models are then used to infer the stock temperature.

This historical 'blind' method of temperature profiling provides an approximation of the metal's surface and bulk temperature during its movement through the furnace, assuming that movement is steady and repeatable.

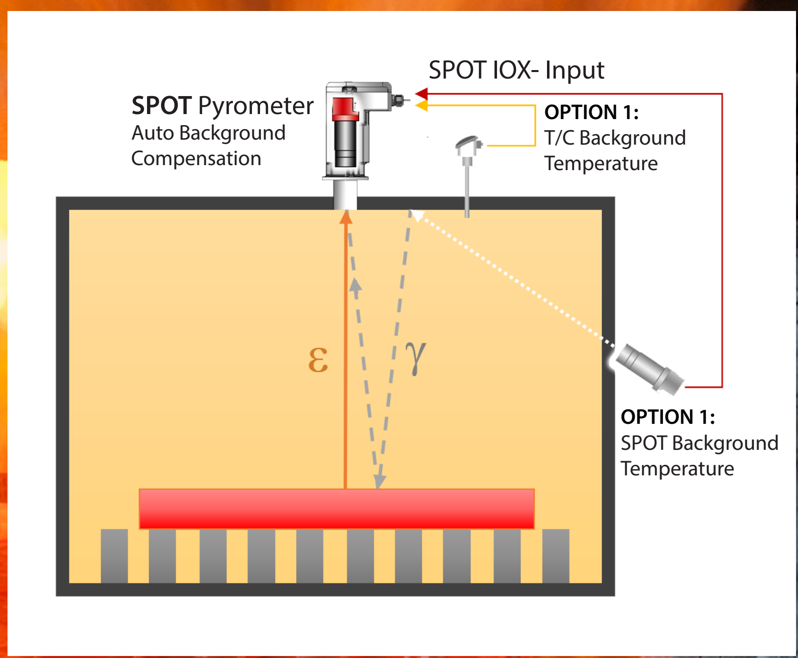
Whenever the product is delayed in the furnace or environmental conditions change, this method becomes highly unpredictable. It is also affected by mixing a variety of products with different sizes or emissivities. Sophisticated modeling is required to accommodate these factors.

There are other problems with using thermocouples. They need to be checked on a regular basis and replaced when they become out of specification or broken. This may happen quite often, as the protective sheath around the thermocouple can be damaged when the refractory surface expands or contracts.

In addition, when thermocouples operate at elevated temperatures for an extended period of time, their accuracy degrades due to tip migration – this is when the alloys at the tip start to combine rather than remain as two separate metals.

Some operators compensate for the problems of thermocouple measurement by overheating the product, leaving it in the soaking zone for longer. This is seen as more desirable than having to completely reheat the product.

However, this wastes energy and often affects the metallurgical properties of the product, causing additional scaling on the surface.



TRADITIONAL TEMPERATURE MEASUREMENTS:

THERMOMETERS

Non-contact radiation thermometers, also referred to as infrared pyrometers, have been used for many years to measure actual stock temperatures directly.

Readings from pyrometers are a sum of the emitted and reflected radiation from the stock and furnace background. To determine the correct stock temperature, the background temperature must be measured and its effects subtracted from the pyrometer reading.

A thermocouple can be used to measure the background temperature. The AMETEK Land Furnace Thermometers provide this measurement, as do SPOT+ thermometers which have a secondary input as standard.

Once the correct pyrometer system is chosen, accurate stock temperature values can be fed to the furnace control model to improve quality and reduce fuel costs.

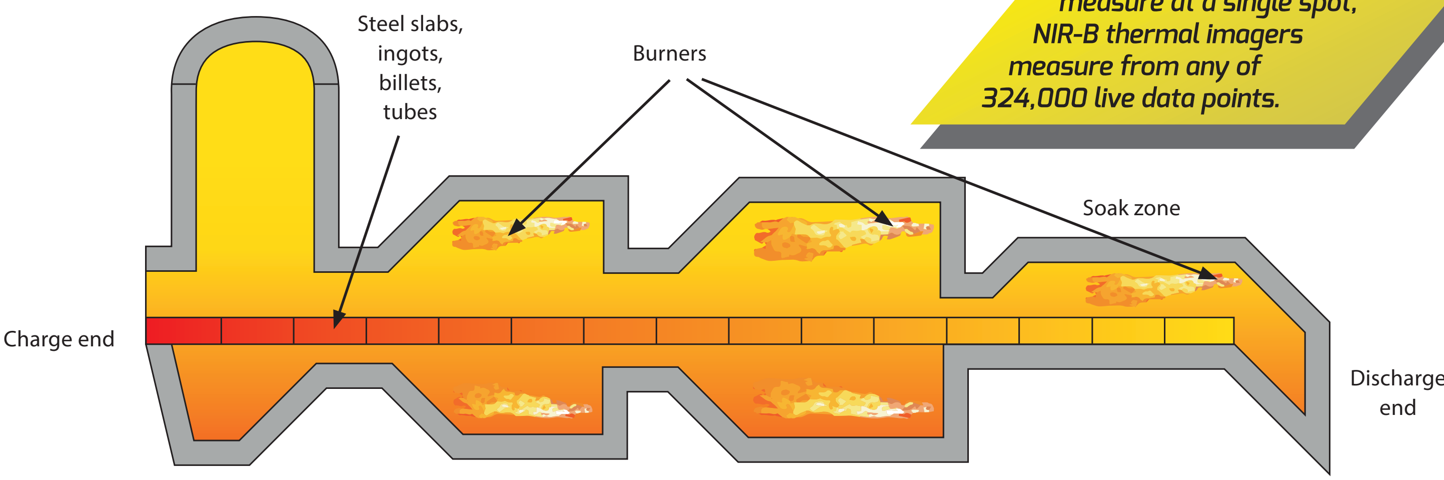
The one disadvantage of using this method is that the pyrometer only measures a single spot. This limits usage to locations where the target is in a known position and it is acceptable to measure a small area on the surface of the metal. A complete picture of the surface temperature is not provided.

TYPICAL CONTINUOUS REHEAT FURNACE – CROSS-SECTION

The product proceeds through pre-heat, heating and soaking zones before being discharged for rolling.

APP NOTE

While thermometers only measure at a single spot, NIR-B thermal imagers measure from any of 324,000 live data points.

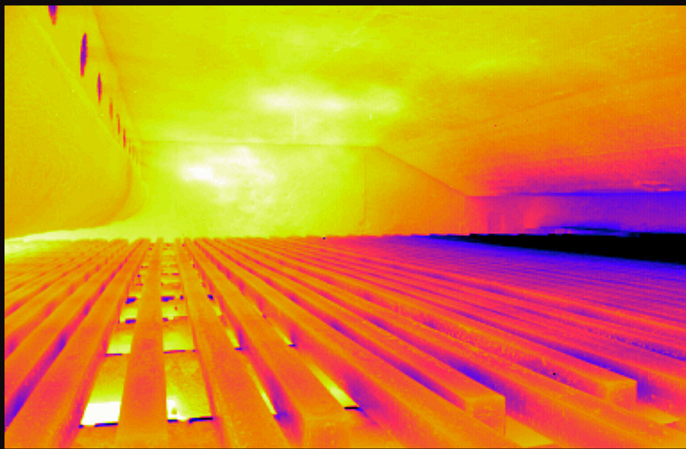


SPOT+ PYROMETER FAMILY

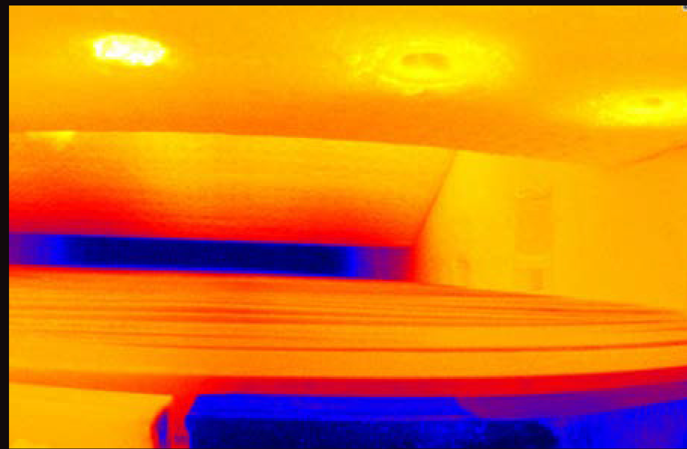
FULLY-FEATURED, HIGH-PERFORMANCE PYROMETERS FOR FIXED, NON-CONTACT INFRARED SPOT TEMPERATURE MEASUREMENTS IN REHEAT FURNACES.

SPOT+ Pyrometers are non-contact infrared temperature measurement devices used in reheat furnaces. With high accuracy, fast response time, and a wide temperature range, these pyrometers provide reliable monitoring and control.

They are easy to install and integrate, offering flexibility and durability in harsh industrial environments. By using SPOT+ pyrometers, operators can optimise furnace performance, improve product quality, and enhance energy efficiency.



Billets/slab in a walking beam furnace.



Pusher approaching multiple billets approaching the furnace exit.

THERMAL IMAGING

With increasing quality requirements, companies are switching to process thermal imaging systems to provide temperature measurements of the entire metal stock and the furnace interior. The starting point for higher product quality is knowing that the temperature is homogeneous – the same throughout the product – not just at single points.

These systems deliver a highly detailed image and are fully radiometric, enabling accurate temperature readings within their entire field of view.

Measurement points, areas of interest and profiles can be configured to measure multiple areas on multiple targets within the scene.

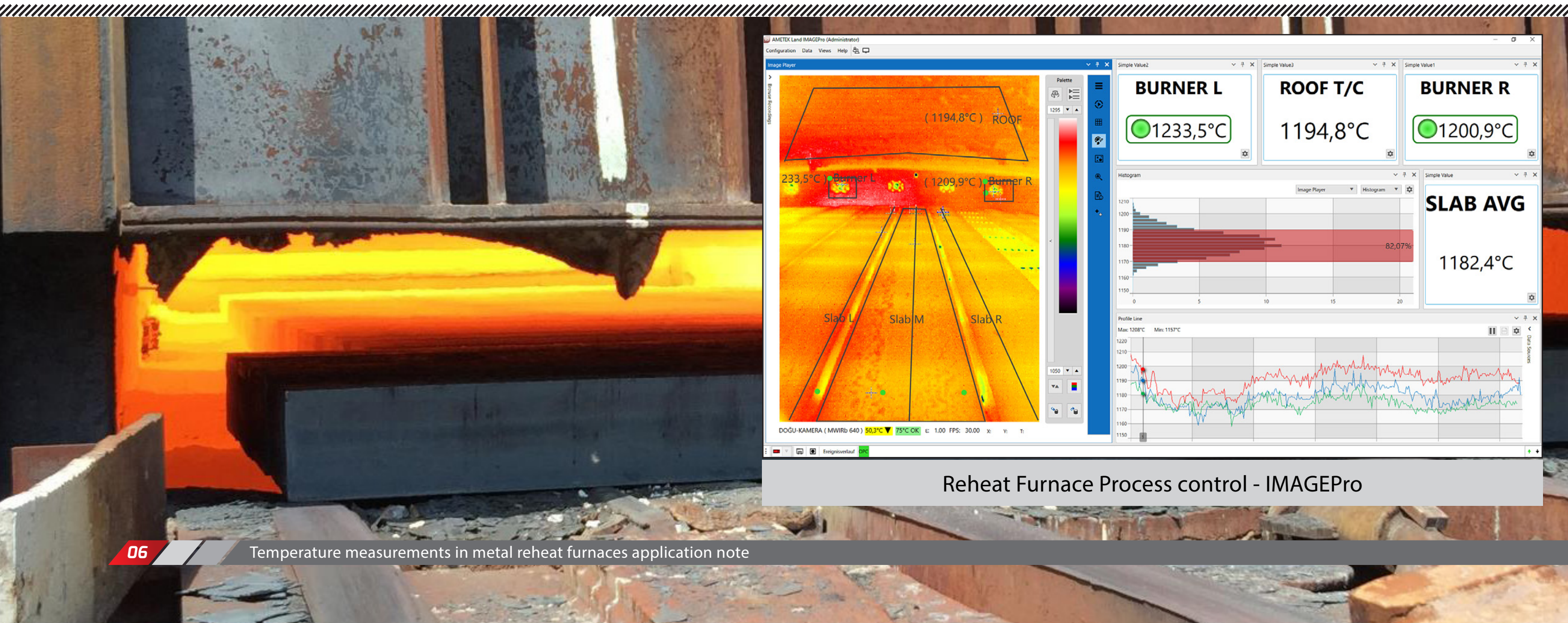
In this way, thermal imaging cameras allow the measurement of loads which are varied in quantity, size and location in the furnace.

The thermal imaging camera can measure the entire product in the reheat furnace, identifying any erroneous or anomalous measurements. It also provides a live visual image, which is particularly advantageous compared to other temperature monitoring methods.

For example, when reheating billets, the steel may be heated correctly, but it could have a bent end (known as a hooked billet) which is likely to hinder the movement of the billet out of the furnace.

Based on live thermal imaging ,the burners and their operation can be monitored, controlled and optimised continuously.

Traditional thermal imaging cameras require a large hole to be cut in the furnace wall to provide a viewing window for the camera. This results in costly heat wastage, while the heat can also damage the camera itself. In addition, the required viewing window requires frequent cleaning and maintenance, and introduces an additional source of error to the system.



Reheat Furnace Process control - IMAGEPro

NEXT GENERATION: BORESCOPE FURNACE CAMERAS

To overcome the issue of heat loss, the AMETEK Land furnace thermal imagers and systems feature through-the-furnace-wall borescope optics that allow a wide-angle view inside the furnace. This requires only a very small insertion hole through the wall, making it very easy to install and significantly reducing heat loss.

The furnace camera systems can survive in conditions where the inside furnace temperature might be 1600 ˚C, and also features an online compensation of the hotter furnace background radiation to achieve the correct stock temperatures. This allows the imager to subtract the effects of background reflections, providing the most accurate surface temperature measurements of the stock.

Once installed, the furnace thermal imaging systems operates 24 hours a day for continuous monitoring. Generally, this information is output into a control system while operators take advantage of real temperature measurements, its deviation and the live image.

IMAGEPro advanced thermal imaging software, with up to 16 cameras working in one system gives both quality control and process improvement.

Optional auto-retraction systems are available, moving the camera out of the furnace whilst retaining the position in case of water cooling or purging air failure. For temperatures up to 13000 °C, air cooled furnace borescope are available.

THE INFORMATION FROM THE FURNACE CAMERA SYSTEMS ALLOW THE PRODUCT TO BE PRE-HEATED, HEATED AND SOAKED FOR PRECISELY THE RIGHT TIME, WHICH IS SUITABLE FOR DIFFERENT FIRED FURNACES TYPES AND ATMOSPHERES

- SAVE ENERGY THROUGH REDUCED FUEL USE
- REDUCE CO2 AND GAS EMISSIONS BY COMBUSTION CONTROL AND OPTIMISATION
- INCREASE THROUGHPUT AND REDUCE DOWNTIME
- IMPROVE PRODUCTION YIELDS AND FURNACE LIFE BY REDUCING FURNACE TEMPERATURE
- PROTECT DOWNSTREAM PROCESSING MACHINERY FROM UNDER-TEMPERATURE PRODUCTS

Fixed Installation of a process thermal imaging borescope

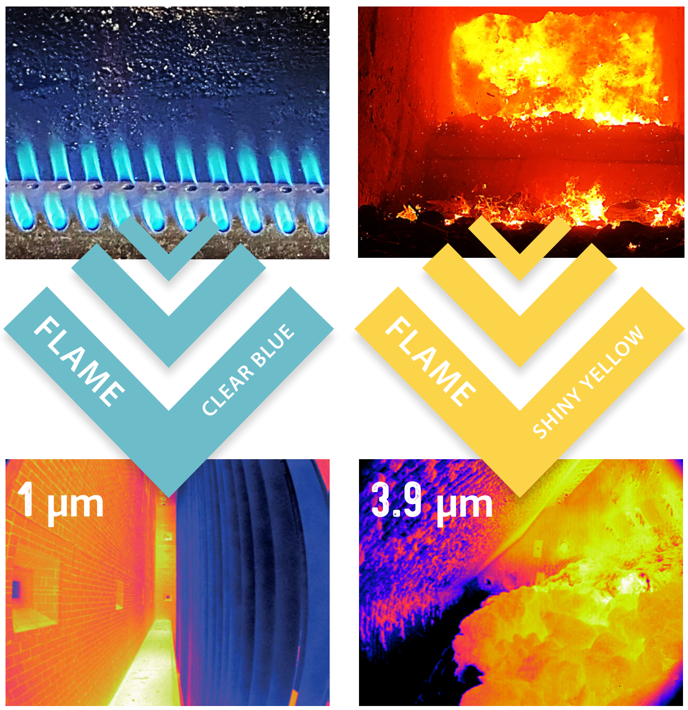
FEATURES

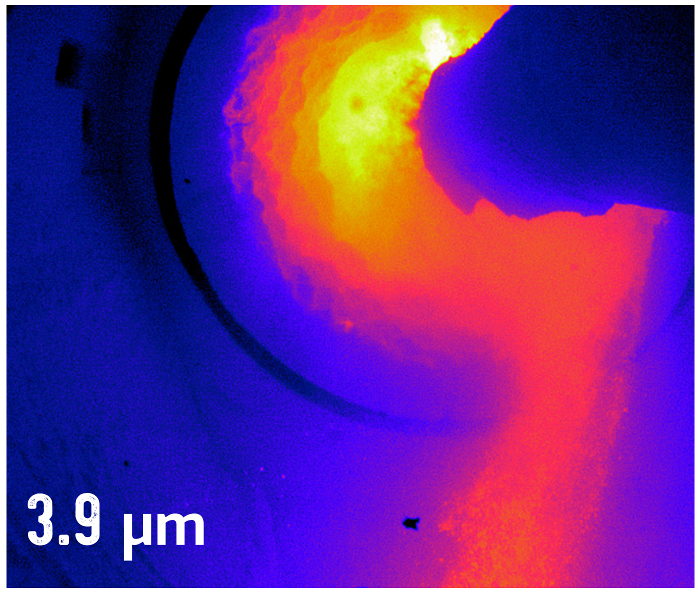
- High temperature measurement accuracy
- Short wavelength sensor
- Optimised spectral response for different fuels
- Dedicated IMAGEPro software packages
- Different cooling options
- Multiple interfacing
- Optional auto-retractions systems
- Two-year warranty

BENEFITS

- 24/7 Optimum process and furnace control
- Simple installation and ease of use
- Energy saving and emission reductions
- IMAGEPro advances thermal imaging monitoring and control
- Low running costs even in the highest temperatures
- Water and air cooled versions available
- Confidence in product reliability
- Open data interfacing

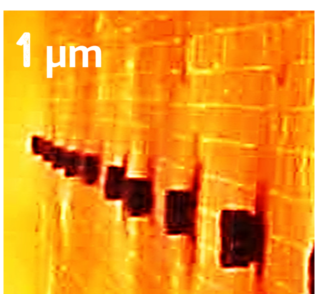
FURNACE MONITORING: SHOULD A 1 µm OR 3.9 µm BORESCOPE BE USED





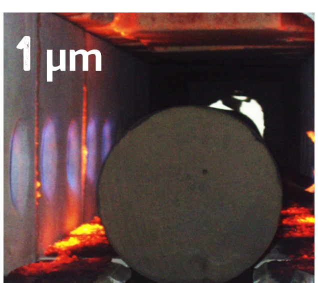
CEMENT ROTARY KILN

A 3.9 µm borescope is recommended to provide a wide and clear view through smoky and dusty atmospheres.

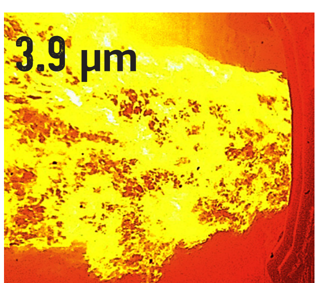


Reformer - Clear flames

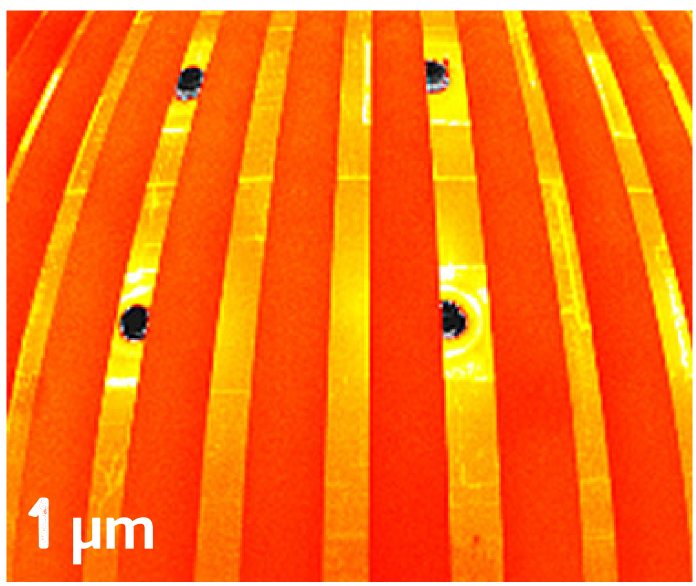
Waste - Dirty-shine flames



Heating - Clear flames



Coal - Dirty-shine flames

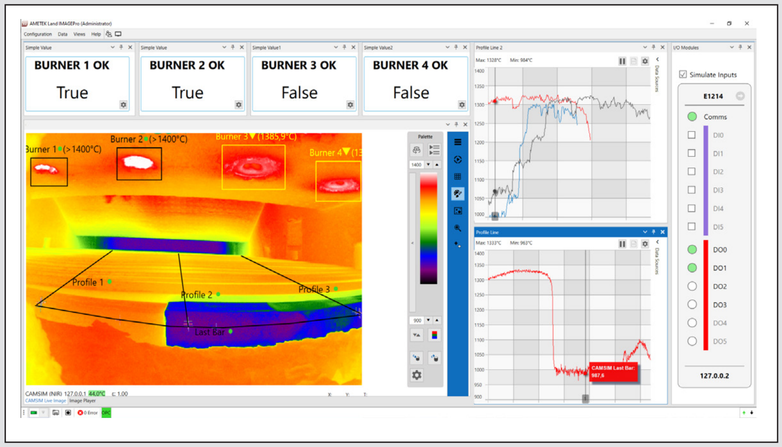


INDUSTRIAL FURNACES

A 1 µm borescope is recommended for oxy and hydrogen flames.

APPLICATION SOFTWARE:

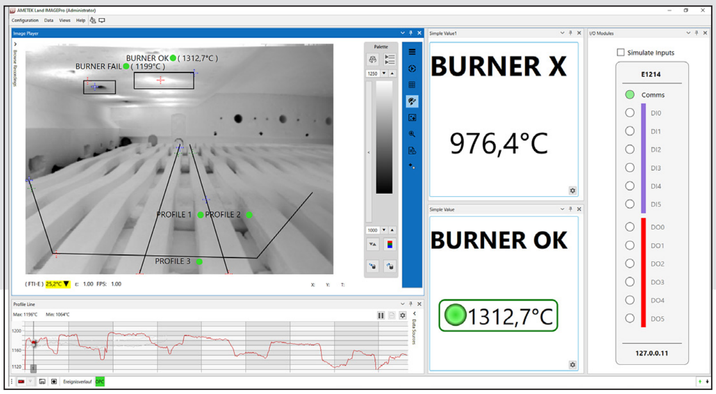
IMAGEPRO

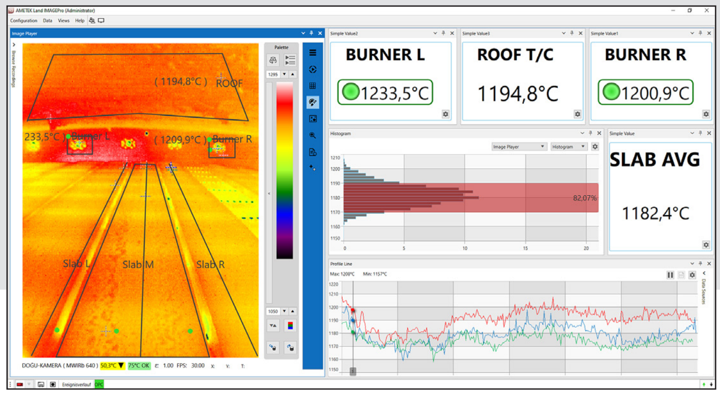


The innovative IMAGEPro is advanced image processing software for process control, monitoring, analysing and capturing temperature measurement data.

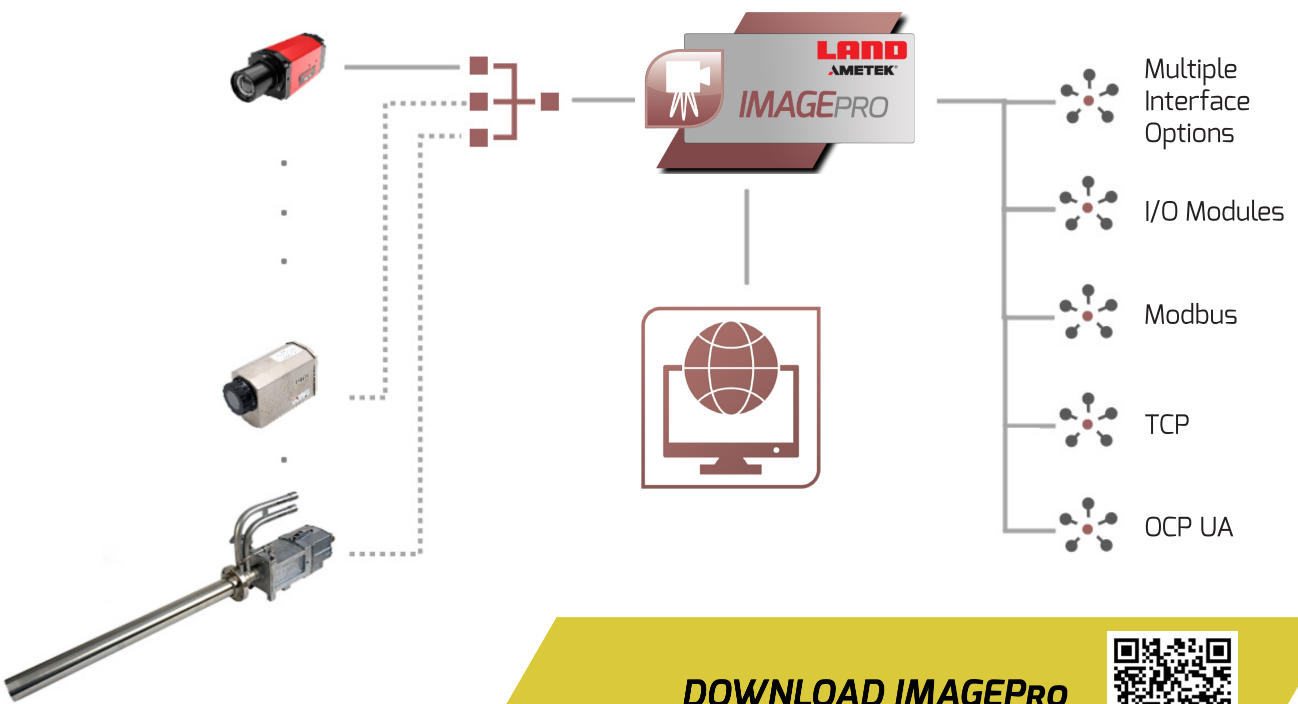
IMAGEPro is a Windows PC software system providing full imager configuration, enhanced thermal process views and advanced temperature analysis options.

Able to monitor and control up to sixteen of AMETEK Land's thermal imagers, IMAGEPro offers real-time analysis and clear visualisation of critical process parameters enabling precise thermal imaging enhanced application control.





IMAGEPRO OVERVIEW



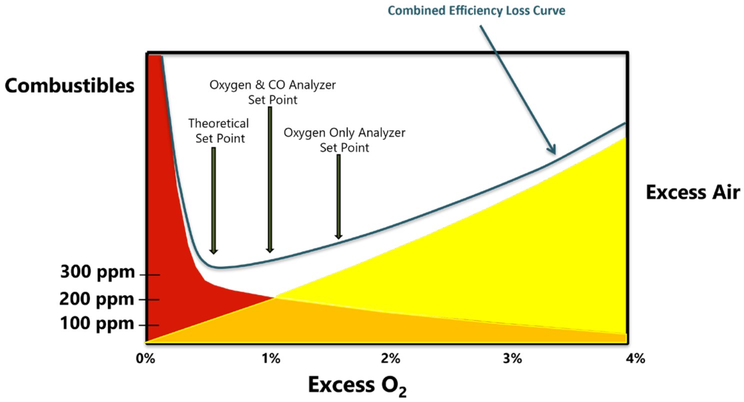
DOWNLOAD IMAGEPRO

REDUCING CO AND NOX

Combustion efficiency can also be improved by optimizing the fuel/air ratio inside the furnace. For a furnace that burns natural gas under ideal conditions, all the fuel and oxygen in the air will be consumed and the products generated would be water vapor (H2O) and carbon dioxide (CO2), a condition called stoichiometric combustion.

Actual combustion processes are inevitably more complicated and stoichiometric conditions cannot be achieved in a real furnace. Because of this, the exhaust contains residual oxygen (O2) and carbon monoxide (CO) in addition to CO2 and H2O.

The mechanisms of loss are shown in graph below.



Mechanisms of loss

Fuel-rich conditions, with very little oxygen in the flue gases, are an obvious source of loss because not all the fuel is burned. Excess air conditions allow the fuel to burn completely, but the additional air flow draws a lot of heat from the furnace. The blue line shows the total heat loss. The ideal operating condition has a very small amount of excess air, although the need for flame stability means that it is preferable to operate with an additional safety margin.

Measuring the oxygen concentration alone generally usually results in a larger amount of excess air than would be ideal, because the risks associated with flameout caused by a fuel-rich condition are severe. Adding a CO measurement to the combustion chamber allows for more precise control of the fuel/air ratio, as it gives a clear indication that a fuel-rich condition has been reached.

This is because the furnace operator can reduce the amount of excess air to a low level but can be sure that all the fuel is being consumed. A combination analyzer that measures both oxygen and carbon monoxide simplifies installation, calibration and maintenance. In general, it is not possible to place sensors inside the high-temperature furnace, so an extractive analyzer is preferred. The user must choose between fully extractive and closed-coupled extractive analyzers, each of which has its advantages and disadvantages.

The AMETEK Land FGA 930E is fully extractive system for measuring CO and O2. It has a probe inserted into the furnace, but the analyzer is located some distance away, in a lower temperature zone. The FGA 930E is a fully-integrated analyzer which includes sample conditioning and analysis along with the user interface and calibration system in a single 600 mm square enclosure. It has QAL1 approval so it is suitable for both environmental compliance and combustion efficiency measurements.

The next requirement is to minimize emissions of oxides of nitrogen (NOx) as this is a regulated pollutant. Based on Zeldovitch's theory, any parts of a flame that are above 1600 °C will form thermal NOx. Excess air not only causes a reduction in efficiency, but also causes additional NOx formation, since the reactions that form NOx depend on the availability of oxygen molecules. Therefore, minimizing the amount of excess oxygen also reduces the formation of NOx. The FGA 950E adds an NO sensor to the FGA 930E, so one instrument can be used to optimize all aspects of the combustion process, resulting in better efficiency and lower pollutant emissions.

AMETEK Land can provide an furnace thermal imaging systems consisting of an infrared borescope camera, air- or water-cooled housing, auto-retract system, power supply, connecting cables and ImagePro software for 24/7 operation and furnace monitoring.

The FGA 930E and FGA 950E gas analyzers are supplied complete with sample probe and 15 m connecting tubes for both sample and calibration gas.

Using the above techniques to measure process conditions inside a reheat furnace allows the operator to accurately measure furnace temperatuires and conduitions, reduce CO2 and NOx emissions, improve product quality and save fuel.

AMETEK Land FGA 950E

CONCLUSION

The AMETEK Land advanced furnace thermal imaging systems offer significant benefits over more traditional single point pyrometers or thermocouples for Metal Reheat applications.

ADVANTAGES OF BORESCOPE FURNACE THERMAL IMAGERS:

- **24/7 monitoring and control of furnace operation and performance**
- **Allows simultaneous measurement of multiple objects in different locations**
- **Measures temperature profile over the entire furnace metal stock**
- **Monitors the interior furnace condition and from existing thermocouples**
- **Minimises furnace heat loss - long borescope lens penetrates thick furnace refractory walls and requires require only a small opening**
- **Saves energy and fuel and reduces CO_2 and gas emissions**
- **Easy integration into new or existing furnace controls**

By providing the most accurate measurements for temperature of the entire metal stock, the furnace thermal imaging systems deliver significant benefits in cost savings and product quality.

AMETEK LAND SOLUTIONS FOR METAL REHEAT FURNACES:

SPOT+ Pyrometers

Fully-featured, high-performance pyrometers for fixed, non-contact infrared spot temperature measurements.

FGA SERIES

FGA provides accurate measurement of carbon monoxide, nitric oxide and oxygen in flue gases.

NIR-B-2K

A short-wavelength radiometric infrared borescope imaging camera with a wide dynamic range, designed to measure temperatures and furnace interiors for natural gas heated furnaces (clear flames).

MWIR-B-640

A mid-wavelength radiometric infrared borescope imaging camera, delivering a clear image of the stock and furnaces temperatures even in smoky and dusty furnace atmospheres.

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