

## REDUCING EMISSIONS AND IMPROVING COMBUSTION EFFICIENCY IN REHEATING FURNACES

Among the most pressing issues for the global steel industry is the need to reduce its environmental footprint. Air pollution control regulations around the world require producers to measure and control emissions of carbon monoxide, oxides of nitrogen and particulate matter in the steelmaking process and downstream operations such as rolling mills.

In addition, widespread public awareness of climate change is putting pressure on the supply chains of many consumer goods to reduce their emissions of greenhouse gases, such as carbon dioxide. Fortunately, there are a number of technologies available that can be used to improve combustion efficiency and reduce pollution emissions.

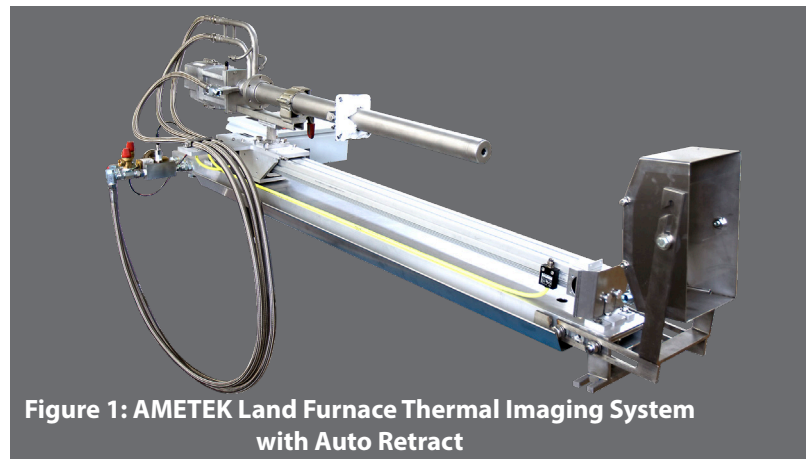
This article will focus on two measurement techniques that can improve the efficiency of reheat furnaces in rolling processes.

### Furnace Thermal Imaging Systems

The large amount of fuel used in a reheat furnace means that small improvements in furnace operation can result in large reductions in cost and emissions. The AMETEK Land NIR-B and MWIR-B are infrared borescope imagers which provide full radiometric thermal images and videos inside the furnace. This allows the furnace operator to monitor the temperatures of the stock or billet and optimize the temperatures inside the reheat furnace by balancing the air-fuel ratio. Benefits include reducing emissions of toxic gases such as carbon monoxide (CO) and oxides of nitrogen (NO<sub>x</sub>), reducing fuel consumption and emissions of greenhouse gases such as carbon dioxide (CO<sub>2</sub>) and to improve product quality. Temperature measurements have traditionally been made using thermocouples mounted on the roof and walls of the furnace, or by means of a single-point infrared thermometer, but both have limitations:

- Thermocouples measure the temperature of the furnace walls and the furnace atmosphere, but not the billet itself, so mathematical models are used to estimate its temperature. These tend to be conservative, so there is a tendency to overheat the material, resulting in wasted fuel.
- A SPOT furnace thermometer can measure the temperature of the billet, saving fuel and improving the quality of the product. However, the temperature of the billet is generally lower than the temperature of the furnace walls, so reflections from the billet surface can cause a significant error in the measured temperature. Because of this, an accurate measurement requires a correction for the effects of reflections from the billet surface.

The high temperature means it is impractical to place a camera inside the oven, so we need a method that allows

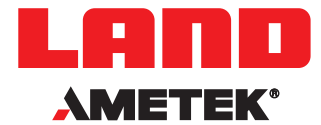


**Figure 1: AMETEK Land Furnace Thermal Imaging System with Auto Retract**

the sensitive electronics to be mounted outside the oven whilst forming an image of the inside. This is achieved using a borescope – a series of lenses which forms a wide-angle image. Because the lenses are the only components that penetrate the furnace wall, it only requires a small-diameter hole for access. The lens system is protected from the harsh environment of the furnace by a water-cooled and air-purged housing.

AMETEK Land offers near- and mid-wavelength infrared borescopes. Both designs provide radiometric images, that offer multiple temperature points within the image that have an accuracy that is comparable to a conventional spot pyrometer. The NIR-B near infrared borescope provides high-resolution images with up to 3 million image pixels and is ideal for furnaces burning natural gas. The MWIR-B mid-wavelength infrared borescope uses a specific wavelength which does not respond to luminous flames, so it can be used in furnaces fuelled by process gas and solid fuels. Both provide a clear view through these different furnaces atmospheres.

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The borescope lenses will suffer catastrophic damage if the cooling water fails, so an automatic retraction system withdraws the borescope from the furnace if it detects excessive temperature at the probe tip or if the purge air supply fails. Thermal imaging provides a wealth of information, not offered by traditional temperature measurement techniques such as thermocouples or spot infrared thermometers. For furnace temperatures below 1300 °C AMETEK Land also provides air cooled furnace thermal imaging systems, without the need to supply water cooling to the instrument.

The IMAGEPro image processing software allows the user to measure and display the temperature at any point of the image. This includes the billets, wall, ceiling, rollers, etc. IMAGEPro can determine the maximum, minimum and average temperatures for each region of interest (ROI). A background temperature correction can be made for each selected region of interest (ROI), based on the measured temperature of the furnace wall, furnace and refractory conditions. Improved knowledge of the temperature distribution within the furnace, including an accurate measurement of the billet temperature allows the furnace operator to save fuel, reduce emissions and improve product quality.

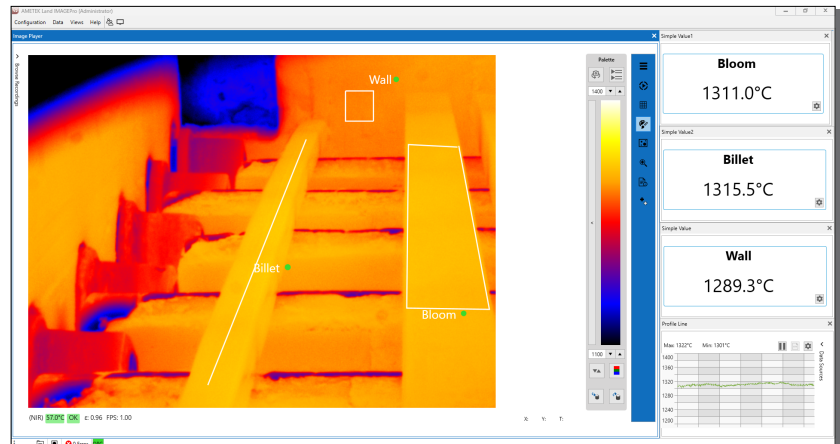


Figure 2: AMETEK Land IMAGEPro in a reheat furnace application

The large amount of fuel burned in a reheating furnace means that small improvements in efficiency bring big benefits. A gas furnace typically consumes 25 m<sup>3</sup> of fuel per metric ton of processed steel. Better measurement of material temperature can reduce fuel consumption by up to 10%, saving money and reducing greenhouse gas emissions. For a typical 100 t/h oven the savings can be tens of thousands of Euros per month.

## 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 (H<sub>2</sub>O) and carbon dioxide (CO<sub>2</sub>), 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 (O<sub>2</sub>) and carbon monoxide (CO) in addition to CO<sub>2</sub> and H<sub>2</sub>O.

The mechanisms of loss are shown in Figure 3.

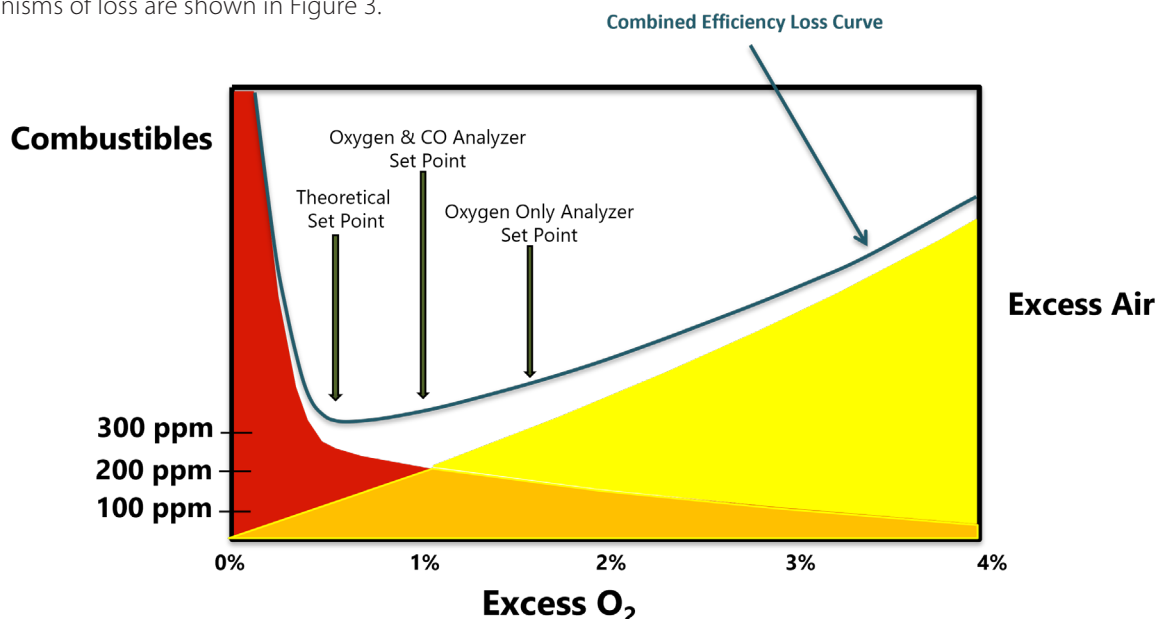
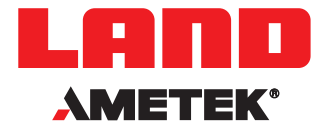


Figure 3: Combustion Efficiency

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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 O<sub>2</sub>. 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 (NO<sub>x</sub>) as this is a regulated pollutant. Based on Zeldovitch's theory, any parts of a flame that are above 1600 °C will form thermal NO<sub>x</sub>. Excess air not only causes a reduction in efficiency, but also causes additional NO<sub>x</sub> formation, since the reactions that form NO<sub>x</sub> depend on the availability of oxygen molecules. Therefore, minimizing the amount of excess oxygen also reduces the formation of NO<sub>x</sub>. 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.



Figure 4: AMETEK Land FGA950E

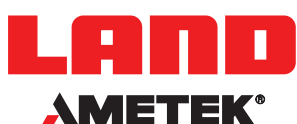
## Conclusion

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 temperatures and conditions, reduce CO<sub>2</sub> and NO<sub>x</sub> emissions, improve product quality and save fuel.


For more information, go to [www.ametek-land.com](http://www.ametek-land.com)



## CONTACT US

 [www.ametek-land.com](http://www.ametek-land.com)

 [land.enquiry@ametek.com](mailto:land.enquiry@ametek.com)

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