

HOT 'N' COLD

Derek Stuart and Manfred Hayk, AMETEK Land, look at new techniques for temperature measurement in cement manufacturing.

Controlling a cement kiln is a challenging task. The efficient and consistent production of high-quality cement with the lowest environmental impact requires careful attention to the raw mix feed rate, the fuel/air ratio, and the temperature distribution throughout the kiln. The task is

made more complicated because conditions within the kiln make it difficult to measure many of the key operational parameters.

Temperature measurements within the kiln are especially challenging. Kiln rotation, high temperatures, and the movement of the sintering material along the kiln make thermocouples and



other contact temperature sensors impractical. Radiation thermometers, also known as pyrometers, allow non-contact temperature measurement, but their effectiveness is limited by the high dust loading, especially within the burning zone. Nevertheless, the burning zone temperature (BZT) is an important measurement because it shows whether there has been a complete transformation from C_2S to C_3S , which occurs in the region of $1300^{\circ}C - 1450^{\circ}C$ ($2372^{\circ}F$ to $2642^{\circ}F$).

Ratio pyrometers

Many kilns use a ratio pyrometer to measure the BZT. This is much less susceptible to errors caused by obscuration from dust because it uses the ratio between the radiation intensity at two wavelengths, instead of the absolute intensity at a single wavelength. Combined with a peak-picker algorithm, it can give an accurate temperature measurement even when there is 95% obscuration of the field-of-view. A viewing port within the firing hood located below and to the side of the burner allows the best measurement of clinker temperature, as shown in Figure 1. This is a very aggressive location, so the pyrometer generally has to be installed with a water-cooled

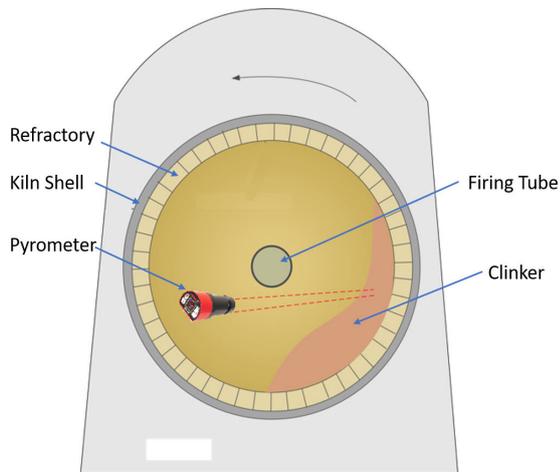


Figure 1. Viewing port within the firing hood.



Figure 2. Installation of borescope mounted adjacent to the firing tube.

jacket to prevent damage to the electronics, as well as an air purge to protect the delicate optical surfaces from hot and dusty process gases.

The main disadvantage of the ratio thermometer is that it gives only a single measurement value from a small part of the kiln, so its readings can be deceptive if the target area is not optimised. A short-wavelength thermal image, made using a near-infrared sensor and borescope probe, gives a lot more information about the conditions within the burning zone. Figure 2 shows a typical installation with the borescope mounted adjacent to the firing tube. As with the pyrometer, it needs water cooling and air purge.

Borescopes

The borescope is only 61 mm (2.4 in.) dia., including the water-cooled jacket, so it can be inserted through a small viewing port. To minimise exposure to the aggressive process conditions, the borescope tip should be slightly recessed onto the wall of the process. This does not affect its function and the large 90° by 67° field of view enables it to form an image of the relevant parts of the process.

An additional safety precaution is the automatic retraction system, which withdraws the entire instrument from the process, if either purge air or cooling water should fail. Both electrical and pneumatic retractions are available. The pneumatic system can tolerate higher ambient temperatures and offers better reliability in the most aggressive applications.

A wide-angle image with high spatial resolution allows accurate temperature measurements and important information about the process conditions within the burning zone. Figure 3 shows an image taken with an AMETEK Land NIR-Borescope. Image processing software continually assesses the temperatures of the clinker, burner flame, and refractory. The image also provides valuable qualitative information, such as the flame propagation and formation of ash rings within the kiln. Because of its wavelength in the near-infrared, the image suffers less scattering from particles within the field of view than a conventional video camera or borescope operating at visible wavelengths.

Although the borescope is a powerful tool for measurements in the firing zone, it cannot measure temperatures further along the kiln in the heating and calcining zones. An elegant non-contact method for temperature measurements in these areas is to mount a thermowell through the refractory and view it with a pyrometer mounted close to the kiln. This measurement allows accurate measurements without the drawbacks associated

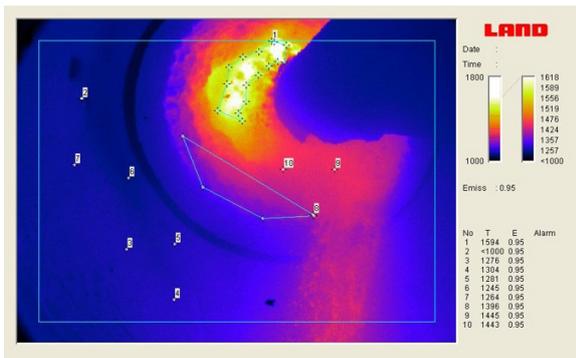


Figure 3. AMETEK Land NIR-Borescope thermal image.



Figure 4. AMETEK Land LSP-HD linescanner mounted in an industrial enclosure.

with mounting a thermocouple inside the kiln. The pyrometer can easily be accessed for calibration or adjustment, even while the kiln is in operation.

Kiln shell temperature

Another parameter of great importance to plant reliability is the kiln shell temperature. The steel shell of the kiln has a melting point of 1300°C (2372°F) and the maximum practical temperature is less than 500°C (932°F). This means it needs to be protected from the hot feed and the gases within by a thick layer of refractory bricks. Along with their low thermal conductivity, which protects the kiln shell, the refractory bricks are used for their physical stability and resistance to abrasion, as well as the highly basic chemistry of the clinker. Over time, chemical changes in the surface of the refractory bricks can lead to spalling. The bricks will rapidly deteriorate, if they are exposed to overheating in the burning zone. Sudden mechanical damage is also possible, especially if the kiln shell distorts because of uneven rotation. No matter what the underlying cause is, deteriorating refractory bricks cause an increase in the kiln shell temperature.

Measuring the shell temperature allows the operator to monitor the long-term changes in the refractory and detect loss or damage to individual refractory bricks.

There are several ways to measure the kiln shell temperature. Point measurements can

be made using thermocouples with wireless transmitters, but it is impractical to install enough sensors to detect the condition of individual refractory bricks. A handheld pyrometer can be used to make repeated measurements with good coverage, but the results depend on the skill of the operator and real-time measurements are not possible. A handheld thermal imager allows the operator to visualise the kiln shell and identify hot spots, but it is also non-continuous. A fixed industrial thermal imager is another option, but it is difficult to get a satisfactory image of a long, thin object, such as a kiln using a conventional image sensor. This is because a wide-angle lens is needed to cover the whole length of the kiln. For a 70 m (230 ft) long kiln, a 640 x 480 pixel image sensor gives a resolution of only 110 mm (4.3 in.), so it is difficult to detect damage to an individual refractory brick.

The most effective tool for continuous measurements of kiln shell temperature is a line-scanning infrared sensor. This uses a single detector with a scanning mirror to repeatedly scan along the length of the kiln, giving the equivalent of 1000 pixels along the kiln. Rotation of the kiln allows the scanner to build up an image of the kiln shell. Using a single sensor allows for excellent consistency of measurement when compared to a thermal imager. Even the best image sensors exhibit considerable pixel-to-pixel variability, whereas the scanner uses the same sensor for every point in the measurement. It is important to limit the scan angle to 90° or less. A wider angle allows the scanner to be mounted closer to the kiln, but the surface emissivity of the kiln decreases rapidly at high angles and the imaged spots become elliptical, leading to degraded spatial resolution. If it is not possible to set the scanner back far enough to obtain a full view of the kiln, image processing software can stitch the output of multiple scanners to give a single display. This approach also allows enhanced spatial resolution, as it effectively doubles the number of pixels in each scan.

Conclusion

Modern temperature measurement techniques give many insights into all aspects of cement kiln operation, allowing for improvements to product quality, reduced fuel consumption, and improved reliability. Borescope images of the firing zone are especially valuable, as they provide insights that are not accessible using other techniques. ■

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