HYDROCARBON ENGINEERING

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SOLVING THE OCCLUSION PROBLEM

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consider the advantages of two-wavelength pyrometry temperature measurement in Claus thermal reactors.

Achieving long-term temperature measurement accuracy using pyrometers in Claus thermal reactors has proven to be problematic. Pyrometers determine temperature by measuring the light radiating from the object. However, operation problems occur as sulfur deposits build up on the viewport window and form in the pyrometer mounting nozzle, as shown in Figure 1. Sulfur accumulation causes an ever-increasing deterioration of accuracy in this critical temperature measurement, and often requires continuous maintenance involving removal of the instrument and cleaning of the nozzle or viewport to restore accuracy.

It is well-established that most of these problems can be eliminated by the installation of steam jacketed lens assembly type instruments where the window, valve, and nozzle operate at a temperature high enough to minimise the build up of the sulfur deposits in the

sight path. This practice also removes the need for a high-volume nozzle purge. Such purges can cool the nozzle, promoting material deposition further down the sight path and causing corrosion of the nozzle.

Despite the use of steam jacketed lens assembly technology, certain operating conditions still allow sight path occlusions to occur. Process upsets, interruptions to the steam supply (keeping the lens and nozzle hot), unusual feed gas compositions, and certain gas flow patterns within the reactor, etc. can potentially transport occluding material into the sight path.

To better understand how two-wavelength pyrometry eliminates the effects of occlusions,

Figure 1. Occlusions in viewport window and process nozzle.

a review of how occlusions affect measurement and the functionality of one-wavelength pyrometry is in order.

Single-wavelength pyrometer

Figure 2 shows a schematic representation of a one-wavelength pyrometer measuring the temperature of a Claus thermal reactor. A broad spectrum of light is emitted by the refractory hot face of the reactor. This light passes through the reacting process gases that absorb and emit light in various wavelengths and amounts, depending on gas composition, concentration, and temperature. The light then passes down the vessel nozzle and through a window. The optical filter passes a narrow band of wavelengths to a sensor that amplifies the output. This non-linear amplified sensor output is then processed to calculate the temperature (Figure 3, upper graph).

Any occlusion in the vessel nozzle, or on the window, reduces the sensor voltage proportionally by the amount of visible area that is occluded, and results in a corresponding reduction in the reported calculated temperature.

Ratiometric two-wavelength pyrometer and occlusion detection

Figure 2 also shows a typical scheme for a two-wavelength pyrometer. In this case, two separate narrow bandpass filters pass different wavelengths of light to two sensors. Each output is then amplified.

The non-linear sensor output as a function of temperature is shown in in the middle graph in Figure 3. Because differing wavelengths are used, the two curves are not the same. The processor then calculates the ratio of the two voltages using the following formula, where reduction in V1 and V2 is caused by occlusion:

$$R(T, \lambda_1, \lambda_2) = \frac{Occ \bullet V1(T, \lambda_1)}{Occ \bullet V2(T, \lambda_2)}$$

A ratio neutralises any attenuation caused by occlusion, as illustrated by the lower graph in Figure 3, and the ratio does not change regardless of how much the output signal is attenuated by material in the sight path (through the vessel nozzle and window). Assuming that a measurable amount of light reaches both sensors, the ratio is used to calculate the reactor temperature.

Therefore, two-wavelength pyrometry offers a considerable advantage over single-wavelength pyrometry in the Claus thermal reactor. By measuring light at multiple wavelengths, it is possible to accurately determine temperature even if the sight path is partially blocked by debris in the mounting nozzle or has material build-up on the lens window surface. Portable two-wavelength pyrometers can be used to spot check temperatures, especially through partially clouded sight ports.

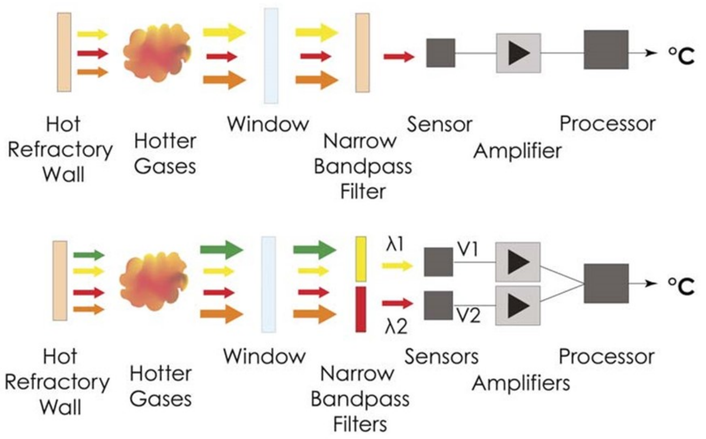

Figure 2. Schematics of a typical one-wavelength pyrometer and of a two-wavelength pyrometer.

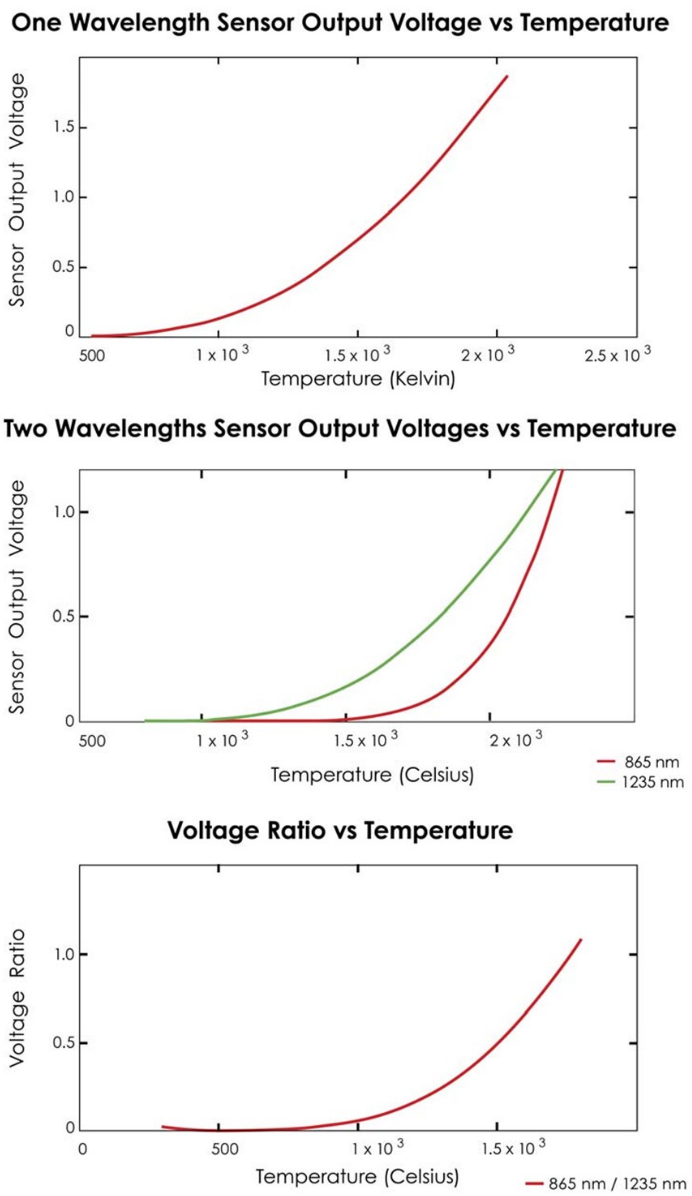

Figure 3. Comparing sensor voltage outputs and sensor output ratio to temperature.

The amount of occlusion existing in the sight path can be calculated by comparing the two-wavelength pyrometer temperature to a theoretical temperature value based on sensor voltage calculated as if there is no occlusion. This can allow an alarm to be tripped if the occlusion exceeds a certain amount, alerting an operator to the need to investigate the nature of the occlusion and to schedule appropriate maintenance. It should be noted that this alarm should be set to trip well before occlusion has progressed far enough to compromise temperature measurement accuracy.

Limitations of ratiometric two-wavelength pyrometry

The ratiometric measurement method negates the occlusion effect, as illustrated in Figure 3, assuming that attenuation of both wavelengths is the same. In most situations this is fine – the occluding material is generally thick enough to be opaque at both measured wavelengths. However, if the occlusion blocks one wavelength more than the other, the occlusion-cancelling effect is incomplete and can result in measurement errors. Depending on which wavelength is more attenuated, the errors can cause a positive or negative charge. Translucent coatings or a different type of glass used during calibration are examples of potential error causes. These errors typically occur far less often than single-wavelength errors.

Two different bands of atmospheric transparency are used with the ratiometric two-wavelength pyrometry method. The minimum measured temperature is determined by the detection threshold of the shortest wavelength sensor and by the amount of occlusion. The ratiometric measurement can only be made if there is a measurable amount of light at both wavelengths. At lower temperatures, the amount of light at the shorter wavelength may fall below the measurement threshold, even though the longer wavelength still has a measurable amount of light. In those cases, the two-wavelength pyrometer reverts to a single-wavelength measurement using the longer wavelength.

Using dual wavelengths to measure refractory and flame temperature

Another use of multiple wavelengths is to improve the accuracy of flame temperature measurement. Hot gases radiate and absorb light in discrete wavelengths, as opposed to the refractory wall, which radiates over a broad range of wavelengths. Refractory temperature is measured by choosing wavelengths where the

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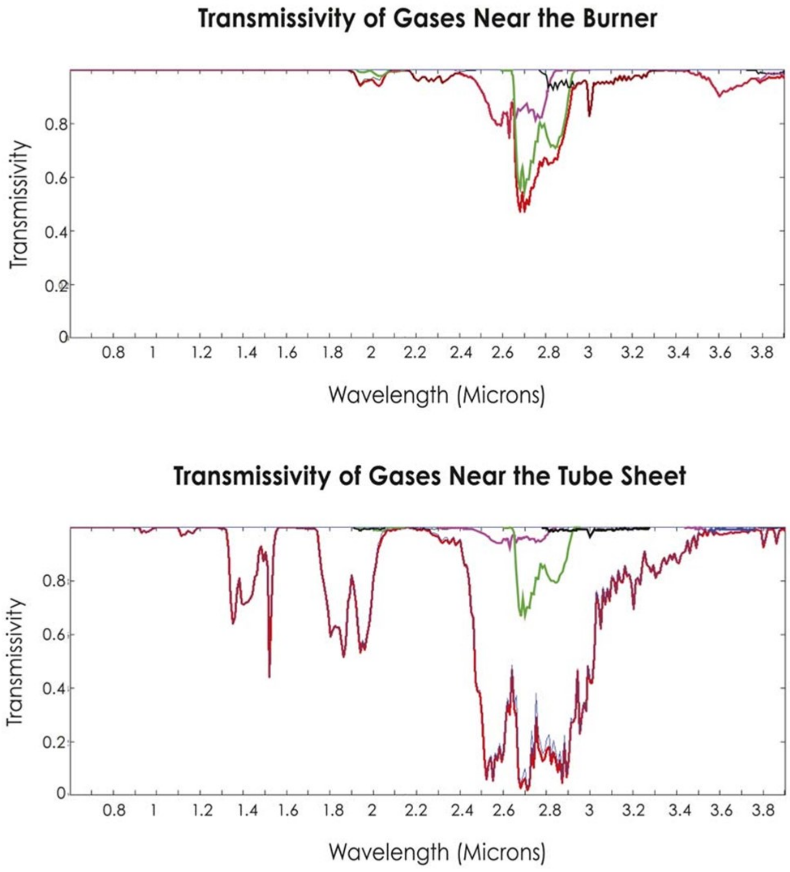

Figure 4. Transmissivity of Claus thermal reactor gases at two different locations.

process gases are highly transparent, thus ignoring the light radiated by the gases. By choosing a wavelength at which process gases radiate, the pyrometer is sensitive to the temperature of the gases. However, since the refractory also radiates at these wavelengths and because the gases are partially transparent, the sensor observes some light from the gas and some light from the refractory. A two-wavelength pyrometer can separate out the gas temperature from the refractory temperature by measuring refractory light at a specific wavelength that ignores the gas while simultaneously measuring the light from the gas (which includes some light from the refractory). Then, by entering a factor related to the gas transparency, the pyrometer can remove the effects of refractory temperature from the gas temperature measurement.

For example, Figure 4 (upper graph) shows the transmissivity of a typical mixture of gases near the burner of a Claus thermal reactor with a feed gas that is largely un-reacted.[1] The atmosphere is mostly transparent at much of the near and mid-infrared wavelengths except around 2.7 μm, where the atmosphere transmits about half of the light passing through it. A single-wavelength pyrometer operating at 2.7 μm reads roughly halfway between the gas temperature and the hot-face temperature. By knowing that the transmissivity is approximately 0.5, and by concurrently measuring refractory temperature at a wavelength unaffected by the gas, a two-wavelength pyrometer removes the effect of the refractory radiation and calculates the actual gas temperature.

Limitations of two-wavelength flame temperature pyrometry

For pyrometers intended to measure gas temperature, gas composition can affect the temperature measurement. Figure 4 (lower graph) shows the transmissivity of the same gases from the same reactor as Figure 4 (upper graph), but near the tube sheet. The gas composition changes considerably during the course of the reaction and thereby the transmissivity also changes. A flame pyrometer with a 0.5 transmissivity setting overcompensates for the gas composition, as seen in Figure 4. The figures shown are for a constant feed gas composition. Changes in feed gas composition and flow rate further affect the transmissivity at all points along the reactor. Therefore, while it is possible to compensate for the transmissivity for a given set of operating conditions, accuracy suffers as soon as operating conditions change.

Conclusion

Two-wavelength pyrometer technology can significantly reduce the negative impacts of occlusion as compared to single-wavelength pyrometer technology. In addition to accurately determining reactor temperature when occlusion occurs, the amount of occlusion can be detected by comparing the single-wavelength temperature measurement to the ratiometric two-wavelength measurement. This information can be used to alert plant personnel and trigger an investigation or the need to schedule appropriate maintenance, thus creating an additional operational benefit not found with single-wavelength pyrometer technology.

Reference

1. SAMES, J., PASKALL, H., BROWN, D., CHEN, M., and SULKOWSKI, D., 'Field Measurement of Hydrogen Production in an Oxygen- enriched Claus Furnace', in *Sulphur Recovery*, 12^{th} edition, Sulphur Experts (2009), pp. 224 – 228.