Pyrometer verification and calibration methods

It is possible for infrared pyrometers in service on a Claus thermal reactor to read incorrect values due to miscalibration or misalignment. **T. Keys** of Delta Controls Corporation discusses the advantages and drawbacks of different options for pyrometer verification and calibration, including both in place calibration and uninstalled calibration.

Infrared pyrometers in service on a Claus thermal reactor are in an extreme environment. It is possible for the pyrometer to read incorrect values for a number of reasons including miscalibration or misalignment. Miscalibration can be caused by slight drift of the electronics among other factors. If the accuracy of the unit is in question, action must first be taken to verify that the optical sight path is not occluded by the build-up of material and that the lens of the pyrometer is not obscured. Subsequently, the optical alignment of the pyrometer must be verified to be concentric with the bore. The pyrometer can become misaligned due to severe vibration, improper installation or mishandling. Once actions have been taken to verify the alignment and optical sight path, the calibration of the unit must be verified. A number of options exist for pyrometer verification and calibration including both in place calibration and uninstalled calibration, each with both advantages and drawbacks.

Calibration methods

Prior to removal of any component of a Claus reactor pyrometer, an assessment must be made as to the ability of the nozzle block valve to provide a gas tight seal when closed. A malfunctioning or leaking valve, usually due to build-up of solid sulphur, will limit the choices of calibration methods to comparison of other permanently installed temperature measurement devices or the use of a handheld pyrometer.

Factory calibration

The pyrometer can be sent to the factory for recalibration and recertification. This option can be costly due to the time required to uninstall the unit, shipping/handling, calibration costs, and having a standby instrument on hand. The advantage is that the factory can accurately recalibrate the pyrometer in a blackbody calibrator traceable to a NIST standard.

Black body calibrator

Commercially available black body calibrators (Fig. 1) can be maintained in an instrument shop for calibration. The pyrometer would be removed from service, brought to the shop and calibrated using the black body. The black body calibrators that can reach the high temperatures used in Claus thermal reactors are extremely expensive, finicky, and require training to operate and maintain making this a less than ideal option.

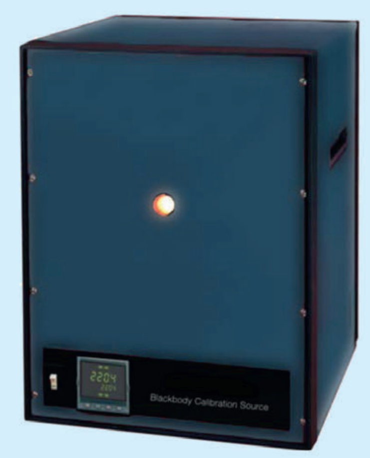
Outside contractor

Contractors can be employed to periodically perform calibrations on-site. This can be costly and the pyrometer may have to be removed for calibration. Also, the effectiveness of the calibration method must be evaluated.

Insertion thermocouple

A specially designed insertion thermocouple can be temporarily mounted in place of the pyrometer's lens assembly. Using a sliding gland seal fixture, a stainless steel sheathed thermocouple is inserted into the pyrometer nozzle to the closed block valve. The sealing gland is then tightened to minimise leakage but permits the thermocouple to be inserted to a pre-determined distance to measure the temperature just beyond the refractory hot face (see Fig. 2). This method

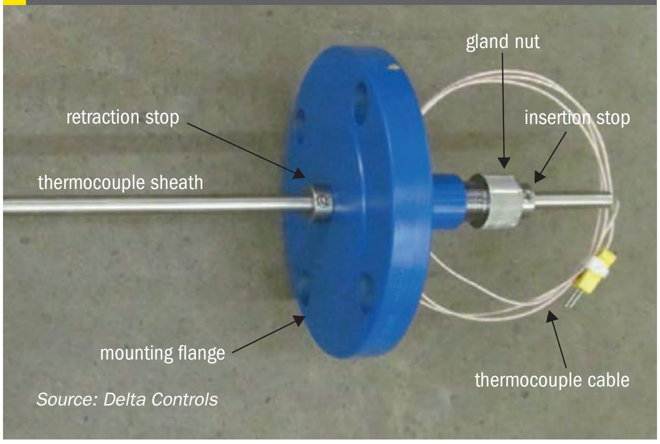
Fig 1: **Commercially available blackbody calibrator**



Source: Delta Controls

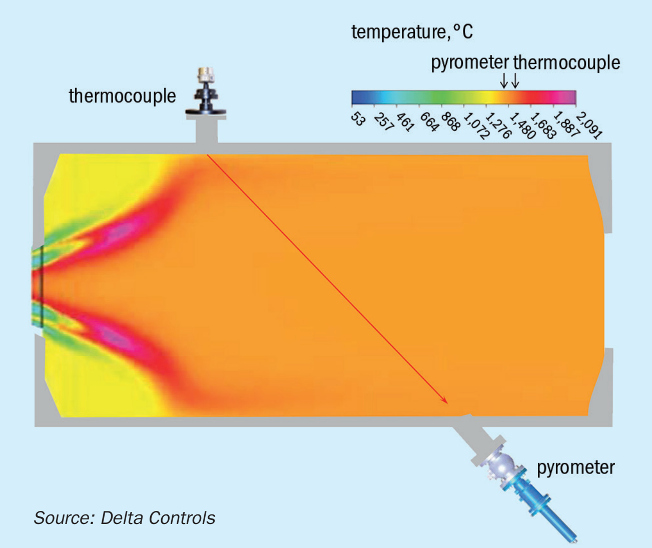
has some distinct disadvantages. The temperature that is measured at this point may not accurately represent the temperature measured by the pyrometer. This is due to the pyrometer measuring infrared light from the far side of the thermal reactor, as well as other reflected light from within the reactor. This causes the pyrometer to read a more average temperature as opposed to the point temperature measurement obtained by the inserted thermocouple. This is explained in more detail below. There are also safety considerations when carrying out this operation. Due to the sliding seal, slight leakage of reactor gases is possible, normally requiring that the operation be carried out under supplied air. Another consideration is that many Claus thermal reactors operate at a temperature higher than

Fig 2: **Insertion thermocouple**



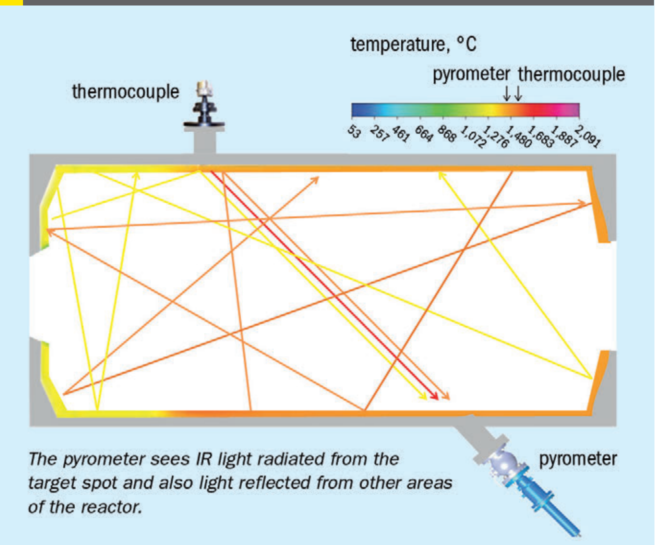
Source: Delta Controls

Fig 3: **CFD model: the burner zone of a Claus thermal reactor with the pyrometer aimed directly at the thermocouple**



Source: Delta Controls

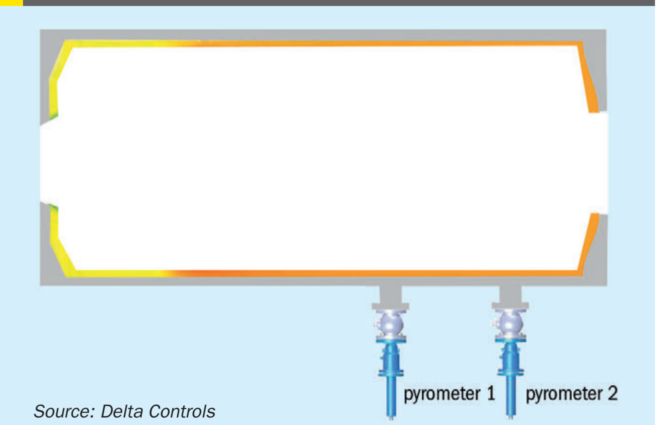
Fig 4: **IR light detected by the pyrometer**



The pyrometer sees IR light radiated from the target spot and also light reflected from other areas of the reactor.

Source: Delta Controls

Fig 5: **Side by side pyrometer calibration**



Source: Delta Controls

a stainless steel thermocouple sheath can withstand. At high temperature the stainless steel sheath can become deformed to the point that it cannot be withdrawn from the thermal reactor through the sliding gland to the point where the block valve can be closed. After the thermocouple measurement is taken, the thermocouple is then removed and the pyrometer adjusted to the thermocouple's measured value. All factors considered, using an insertion thermocouple to verify the accuracy of the infrared pyrometer should only be performed when no better options are available.

In place calibration

It is possible to calibrate the pyrometer in place without removing it from service. These methods use other instruments on the thermal reactor as references for calibration. Some options are as follows.

Calibrate using the nearest permanent thermocouple

If the thermal reactor has a nearby permanently installed thermocouple, it can be used to verify or calibrate the pyrometer. This is an improvement over the insertion thermocouple, since there is no risk of leakage, overheating, or extraction problems.

A disadvantage of this method is that the thermocouple may not be located in the same area as the pyrometer and will not read the same temperature. In fact, even if the pyrometer were pointed directly at the thermocouple, the two instruments might read different values.

Fig. 3 depicts a typical temperature profile of the front section of a Claus thermal reactor. This profile was created via computational fluid dynamics (CFD). A thermocouple is positioned close to the burner and a pyrometer further down the reactor is aimed directly at the thermocouple. Note the elevated temperature at the thermocouple created by the burner flame while the rest of the downstream thermal reactor section temperature is uniform.

In this example the pyrometer is aimed directly at the thermocouple. The hot infrared energy around the area of the thermocouple is easily viewed by the pyrometer and one would expect the two instruments to read about the same temperature. However, this would not be incorrect. The thermocouple measures the temperature of the refractory hot face at one small point. In this model, the spot temperature at the tip of the thermocouple is considerably above the average temperature of the refractory due to the direct impingement of hot combustion gases.

The pyrometer detects the hot radiated energy from the area around the thermocouple, but due to the relatively low emissivity and high reflectivity of the refractory brick, between 50% and 80% of the light detected by the pyrometer is actually reflected light radiated from surrounding surfaces, as noted in Fig. 4. In Fig. 3, the nearby surfaces are considerably cooler than the target spot of the pyrometer; the pyrometer will therefore report a temperature less than the temperature of the thermocouple.

Calibrate using a nearby permanently installed pyrometer

Some thermal reactor installations have multiple pyrometers mounted in the same zone for redundancy (see Fig. 5). In this case, it may be possible to use one pyrometer to calibrate the other.

This is only possible if the following conditions are met:

- both pyrometers are looking at the same area of the thermal reactor;
- the pyrometer being used as a reference is known to be in good working condition.

Calibrate using a handheld pyrometer

The foremost recommended method to calibrate a pyrometer is with a handheld Claus reactor pyrometer. The process pyrometer is temporarily removed and replaced with a portable pyrometer that has matching optical characteristics. After reading the thermal reactor temperature, the process pyrometer is placed back in service and adjusted to match the portable pyrometer reading. In many cases, nearby viewports may be used instead of removing the process pyrometer.

Note that the portable pyrometer must be one that is specifically designed for the Claus thermal reactor. A general purpose portable infrared pyrometer typically has too wide a viewing angle to accurately see down the narrow aperture of the valve, nozzle, and borehole into the thermal reactor. It is very likely that a general purpose portable infrared pyrometer may detect wavelengths that are sensitive to changes in the composition of the process gases, causing erroneous readings. Such an instrument may also be sensitive to attenuation by coatings on the viewing window or partial occlusions in the bore.

Fig 6: **Delta Controls model HIP handheld pyrometer**

Source: Delta Controls

A portable pyrometer designed for use in a Claus thermal reactor (Fig. 6) will have the appropriate narrow field of view, will detect the same wavelengths of light as the permanent pyrometer, and will ignore the attenuation of the window or any partial bore occlusion.