HANDLING THE HEAT

Ted Keys and Matt Coady, Delta Controls Corp., USA, discuss the proper placement of temperature instruments in a Claus thermal reactor in order to obtain accurate readings.

Measuring temperatures within a Claus thermal reactor is very difficult. Plagued with extreme heat, thermal shock, vibration, corrosion, shifting refractory, errant flame patterns and quenching, even instruments specifically designed for the reactor may fail prematurely, suffer from accuracy problems, or require excessive maintenance. Following handling and installation procedures properly, and correctly applying and operating the protection systems (purges and steam heating) for the instruments can vastly improve the chances of making an accurate and reliable measurement. But before the measurement systems are installed, the vessel must be designed with the mounting nozzles placed in the most suitable locations. The highly-specialised sensors used in this application are subject to a number of limitations, which make placement critical for accurate and reliable readings.

The operating temperature inside the thermal reactor is measured to ensure that the maximum refractory design temperature is not exceeded. Refractory hot-face temperature is a reliable measurement that is most commonly taken. For this reason, it is imperative that the instruments are not placed in a

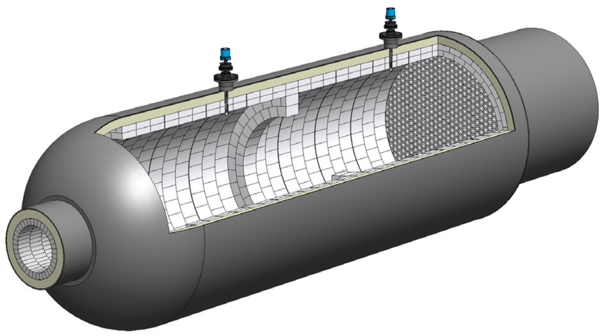

Figure 1. Thermocouples placed two-thirds to three-quarters from the burner to choke ring in zone 1 and from the choke ring to tube sheet ferrules in zone 2.

position of direct burner flame as impingement will normally occur. Some instruments attempt to measure the reaction gas temperature, and while this would be ideal, achieving reliable and accurate measurement of the gas temperature is difficult.

Types of temperature equipment

The extreme conditions and corrosive environment inside the Claus reactor limit the types of devices that can be used to measure the temperature effectively. Currently, the only viable types of temperature measurement devices for a Claus thermal reactor are pressure purged ceramic thermocouples and optical pyrometers, both of which must be designed specifically for the Claus reactor.

Thermocouples

Claus reactor thermocouples are purged noble-metal types (typically type R, S, or B) enclosed in ceramic thermal wells. The thermocouple is purged with nitrogen to sweep out any process gases that can diffuse through the thermowell at high temperatures. To insure against intrusion of reaction gases, the purge must be maintained at a slightly elevated pressure and provide a constant very low N_2 flow. If the thermowell becomes broken, process gases will quickly corrode and destroy the thermocouple junction. It is important to remember that a thermocouple measures the temperature at only a singular point within the reactor.

Pyrometers

Pyrometers measure the infrared light emitted by the hot refractory walls to determine temperature. The pyrometer is aimed at a spot on the refractory, however the indicated temperature is not necessarily the temperature of the target spot. Because of the reflectivity of the refractory brick, about half of the measured infrared (IR) energy is emitted by the target spot, and the other half is reflected light that was emitted from other parts of the reactor. Thus, a pyrometer indicates a weighted average of the target area and the surrounding temperatures.

Nozzle placement locations

When considering the positioning of thermocouples and pyrometers in a Claus reactor, the goals should be to accurately measure a representative temperature of the reactor and to maximise reliability, given the inherent vulnerabilities of the devices.

Thermocouple placement

The nozzle for mounting thermocouples should be as short as possible. Nozzles operating below the freezing point of sulfur (120˚C or 248˚F) will tend to form and collect solidified sulfur, which could press against the ceramic thermowell and break it under subsequent expansion and contraction. Short nozzles are preferable as they keep the thermowell and nozzle hot enough to prevent sulfur from forming and solidifying. Preferably, the nozzle flange should be positioned beneath the external thermal protection system shroud.

The insertion length is usually specified so that the thermocouple junction is positioned against the refractory hot-face. Shorter insertion may cause a lower reported temperature. Longer insertion would place more of the ceramic thermowell out into the gas stream, which risks damage to the thermowell due to exposure to thermal shock during rapidly changing process conditions.

Positioning the nozzle on the top centreline of the reactor, straight vertically downwards is the ideal position. Positioning a nozzle closer to the sides of the vessel subjects the thermocouple to a greater chance of damage due to shifting refractory. Radial shifting is most prevalent at the sides of the vessel and is nearly non-existent at the top centreline. Longitudinal shifting is usually checked by the use of expansion joints at multiple intervals.

Refractory bricks are usually installed to fit somewhat loosely so that they are not crushed by thermal expansion during start up. As the reactor heats up, bricks expand and are pushed outward and upward, moving to fill gaps that were intentionally left for this purpose. Upward movement of bricks on the side of the vessel could potentially break the ceramic thermowell of any side-mounted thermocouple. Therefore, to minimise the risk of breakage from shifting refractory, thermocouples should be installed on the top centreline of the thermal reactor vessel. Mounting the thermocouple on top of the vessel also makes installation easier and reduces the chance that the thermocouple will be broken during installation.

Thermocouples should not be installed in an area of direct flame impingement as this could cause cracking of the ceramic thermowell due to thermal shock. Unfortunately, this region is likely to be where one is most interested in making a temperature measurement. A pyrometer may be a better choice for measuring in these areas.

The thermocouple location should not be directly downstream of any bypass nozzle, as temperatures there may not be representative of the overall reactor temperature. The optimum thermocouple location along the length of the vessel is best determined by computational fluid dynamic (CFD) modelling of the thermal reactor and burner. Lacking that, for a typical two-zone thermal reactor, it is common to place one thermocouple two-thirds to three-quarters of the way into zone 1 and another thermocouple two-thirds to three-quarters of the way into zone 2 (Figure 1).

Pyrometer placement

Unlike thermocouples, pyrometers are not prone to damage due to refractory shift. However, they are susceptible to inaccuracy due to blockages of the sight path. This could be caused by deposition of sulfur or another material in the nozzle bore or on the viewport window, or by significantly shifting firebricks that might partially obscure the view through the borehole into the reactor. Because of the potential for sight path blockage, the pyrometer should be placed in a location that allows easy access for inspection of the sight path, verification, calibration, cleaning, and alignment while the reactor is in operation. The side of the vessel is usually the most convenient mounting location.

The nozzle should slope slightly downward to allow any condensed sulfur or other materials to fall out of the nozzle into the vessel. The pyrometer nozzle does not have to be near the target spot; it could be anywhere within a line of sight of the target spot. The pyrometer is aimed at a specific spot in the reactor but, due to reflectivity, the indicated temperature is a weighted average of the target area and the surrounding temperatures, as previously mentioned. However, the temperature of the target spot does affect the measurement and so the target spot should not be directly downstream from a bypass nozzle or on some other location whose temperature is not representative of the overall temperature. If the nozzle is to be mounted at an angle to the vessel to, for example, aim towards the tube sheet or checker wall, the angle should not be less than 45˚ from the long axis of the reactor. Shallower angles create a large elliptical hole in the refractory that can cause hot spots at or around the nozzle.

Like the thermocouple, the target spot for a pyrometer is best determined using a CFD simulation of the reactor. And likewise, lacking such a simulation, it is common to position a pyrometer two-thirds to three-quarters of the way into zone 1 and another two-thirds to three-quarters of the way into zone 2.

Nozzle design

For both thermocouple or pyrometer installations, the ideal nozzle should be as short as possible, leaving sufficient space beneath the flange to remove frozen studs at turnaround time. The shorter nozzle will operate at a much higher temperature, minimising the possibility of sulfur forming in the nozzle, or in the case of a pyrometer, forming on the inside of the viewport glass, which has historically required frequent cleaning to restore accuracy. The added heat will also minimise the possibility of corrosion. Although impossible to attain, the ideal nozzle would operate at the same temperature as the vessel shell and remain corrosion free. In spite of the benefits of a short nozzle, it is essential to consider the equipment manufacturer's maximum ambient and nozzle temperature ratings.

Placing multiple instruments

In a typical two-zone reactor, the use of at least one temperature instrument in each zone is recommended, since there is often a difference in temperature between the zones. Additional instruments may be desired for redundancy. The use of both thermocouples and pyrometers in each zone will provide improved reliability by protecting against common-cause failures.