CLAUS REACTION FURNACE TEMPERATURE MEASUREMENT – AN OVERVIEW

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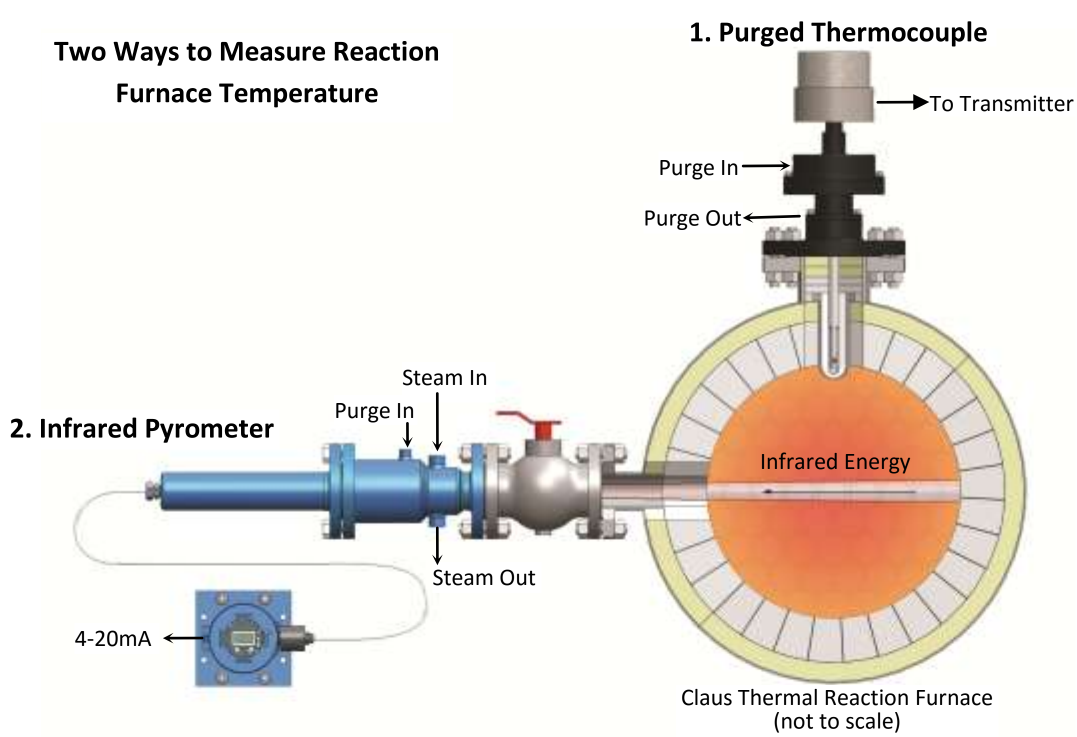
We want to monitor the temperature in the Claus Furnace and to protect it from damage, minimize costly shutdowns, and improve safety and efficiency. There are currently two ways to do this: the Thermocouple and the Infrared Pyrometer. The question of which is better is not simply answered, since both offer advantages as well as drawbacks.

Over the years, thermocouples were generally thought to be unreliable in Claus furnaces, which they were. They had a tendency to fail and when they did, they could not be easily repaired or replaced until the unit was shut down. So, the thermocouple gave way to the Infrared device, which did not succumb fatally to the harsh conditions of the furnace and when it did malfunction, it could be serviced while the unit remained in operation.

However, the high maintenance requirements of the IR units created a demand for something better. So, a special thermocouple was designed for the Claus furnace. And, although problems became more infrequent, there was still a need for more thermocouple reliability.

Careful examination of thermocouple failures revealed that problems we not so much in the design, but in the installation technique, or more accurately, the lack thereof. It was found that the primary reasons for failure were of a mechanical nature and not of the process conditions, harsh as they are. Failure was generally breakage of the thermowell, usually because of improper installation. In more than one instance it has been observed that the installer breaks the thermocouple during insertion and then goes ahead and connects it up. It will work for a month or so, but it will fail and the result is another unreliable thermocouple. And, when they are broken, the resulting exposure to the reaction gases causes sudden failure by corrosion. So, with all this, the solution was to design a thermocouple that did not succumb to the stresses of refractory movement and design installation tools and fixtures that make installation



simple, safe and foolproof. In addition, installation tools and proper installation insure the thermocouple is positioned properly so as to insure an accurate reading of temperature at the refractory hot face.

So, why bother with the thermocouple and all of its apparent vulnerabilities? The reason is that it is the most accurate device to measure temperature; it is the world standard.

Let's compare them:

Thermocouple advantages are:

- Relatively low cost,
- Little or no maintenance,
- High accuracy,
- Unaffected by changing gas conditions.

Thermocouple drawbacks are:

- Subject to damage due to thermal shock, high-temperature excursions, severe shifting refractory, mishandling, and improper installation.
- Must be purged.
- Cannot be repaired until furnace shutdown.

Infrared Pyrometer advantages:

- Mechanical isolation using the nozzle valve. This permits service or replacement while the furnace remains in service, a distinct advantage.
- Not easily broken by mishandling or improper installation and will withstand severe system upsets. Normally not harmed by moderate over-temperature conditions and normally are immune to shifting refractory.

Infrared Pyrometer Drawbacks are:

- Vulnerability to sulfur condensing and clogging the nozzle bore and of sulfur coating the viewport glass window. Both conditions cause an attenuation of the Infrared energy reaching the sensor, resulting in an ever-increasing inaccurate low measurement.
- Sensor drift requires frequent recalibration.
- Some IR pyrometers contain mechanical choppers that reduce reliability.

So, what specifically has been done to make both of these two technologies more suitable for Claus furnaces?

For the thermocouple…

1. Installation of the large outer refractory thermowell. This thermowell rests on the refractory and moves with it relative to the vessel shell. It is not attached to the thermocouple assembly, but fits loosely in the hole bored through the refractory. This permits shifting firebrick relative to the insulating refractory as well as shifting insulating refractory to the vessel shell.

2. Installation tools that provide simple and easy installation minimizing the risk of breakage or improper installation. These tools are a "refractory stop" that is mounted to the nozzle prior to refractory work that keeps castable material from entering the base of the nozzle. This is important because any material that collects at the base of the nozzle upsets the critical mounting dimensions, to which each thermocouple is uniquely built. A refractory drilling kit insures that the correct bore is created in the refractory, on center and perpendicular to the mounting flange. This insures that the proper clearances are established permitting refractory movement without damage. Another valuable tool is the installation mounting bar kit that permits safe installation in other than the recommended vertical top centerline nozzle location. In these non-vertical locations, it is difficult for the installer to insert a heavy thermocouple into the nozzle and simultaneously keep the unit perfectly on center to avoid any side loads on the

ceramic thermowell. If the installer relaxes his grip on the horizontal unit during installation, it will become broken due to a combination of gravity and the heavy flanged headworks. The mounting bar kit supports the full weight of the unit, keeping the thermowell centered during insertion until it is solidly bolted in place.

3. Thermocouples must be continually purged to insure against contamination. To survive the conditions, the use of ceramic materials is necessary. However, at the high operating temperatures, these materials are not as "gas-tight" as needed to prevent corrosion by reaction gas elements that migrate though the ceramic wall, collect inside and eventually contaminate the metallic thermocouple elements. To eliminate this problem, the use of a continual purge flow at elevated pressure is needed. Typical flow rates of 0.5 SCFH are sufficient to protect the thermocouple and do not cool the thermocouple more that 1-2 degrees. Thermocouples can eventually fail if the purge and pressure are not maintained over the long term. To eliminate the purge issues, simple easy to install purge controls panels have been developed. In addition, these purge control units also serve as excellent diagnostic tools to determine the causes of thermocouple accuracy issues and mode of failure.

Nitrogen is the recommended purge gas; Clean dry instrument air may be suitable, but only if it contains *no* hydrocarbons; trace quantities of oil in the purge gas have been known to collect and burn inside the thermowell, leaving deposits that eventually damage the thermocouple.

For the Infrared Pyrometer…

1. Implementation of the heated lens assembly minimizes the buildup of sulfur in the refractory bore, nozzle and even the block valve. The steam jacketed lens housing generates sufficient heat that when combined with the furnace heat, keeps sulfur from solidifying and obstructing the IR energy pathway to the sensor. Elimination of the high purge flow into the nozzle also removes a source of the creation of sulfur. To prevent accumulation of dust or ash on the lens window surface, a very small purge is introduced in front of the lens window to create a swirl path. In addition the low flow purge is pre-heated to avoid any cooling effect that would encourage sulfur to condense on the glass.

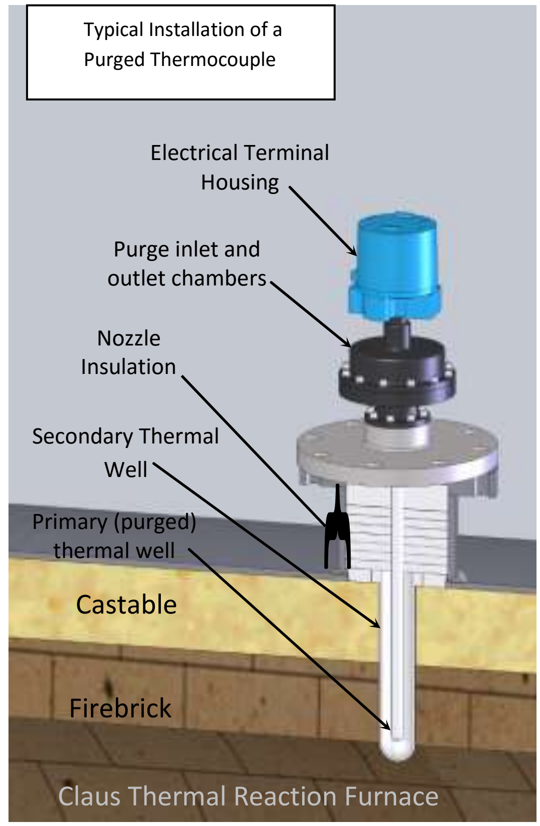
2. Early IR instruments attempted to measure the entire range of temperatures from startup through operation. This required the use of sensor materials that were subject to aging and drift, resulting in the need for frequent recalibration. The measurement of low temperatures also required the use of a mechanical chopper motor. This mechanical system reduced the reliability of the instrument.

Modern IR pyrometers forego measurement of the low end of the temperature range (ambient to about 300 °C). This allows the use of high stability semiconductor sensors that do not exhibit the aging effects of early designs, and eliminates the need for a mechanical chopper motor. These sensors are unable to measure the very low temperatures needed for refractory dry-out, but the resulting reliability and freedom from maintenance warrants their use.

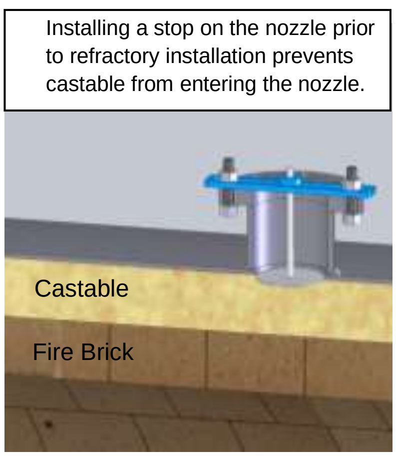
Thermocouple Installation Criteria

The thermocouple performs most reliably when installed on the vessel top centerline in the vertical down position. This is because it is the easiest position to make the physical installation and minimizes the risk of breakage during insertion. Also, movement or shifting of the refractory at the top centerline is normally limited to separation of the firebrick from the castable materials and occasional separation of insulting brick from the vessel shell. There is little shear motion at the top and any that occurs is along the horizontal axis. Mounting at the side positions, although acceptable, makes installation more difficult and, in addition, refractory shifting can also be of a radial shear motion. This refractory movement can cause breakage, particularly if any refractory dust/chips settle around the outer refractory thermowell and fill the space needed to permit refractory movement.

Larger nozzle sizes (4” or 6”) permit easy installation of nozzle insulating materials that minimize the buildup of sulfur in the nozzle, which could place stresses on the inner “gas-tight” element thermowell, again causing damage. Also larger nozzles permit refractory movement without causing the outer refractory thermowell well to press against the ID of the nozzle. The minimum ID of the hole through the vessel shell should be at least 3.5” and be centered relative to the nozzle flange.



Nozzles should be as short as practical. Shorter nozzles maintain heat closer to that of the vessel shell, minimizing corrosion. Taller nozzle are cooler and require the thermocouple be of a longer insertion length needlessly increasing the cost (platinum/rhodium wire is expensive). Shorter thermocouples are also easier to install and are less vulnerable to physical damage during handing and insertion. It is quite acceptable to have the thermocouple mounting flange positioned beneath the rain shield/shroud. Nozzles should not be purged as this encourages the deposition of sulfur, destroying the protective capability of the specially designed nozzle insulating materials. Weld neck flanges make ideal nozzles since they have no weld beads in the ID that often restrict insertion of solid insulating rings.



The most critical detail of thermocouple installation is the creation of the bore hole through the refractory. For maximum reliability, this hole must be of the proper diameter, centered, and be perpendicular to the nozzle mounting flange. Although this seems simple, logistical issues often result in incorrect bore hole creation. A bore hole that does not meet the specification causes undue needless expense repairing the refractory for another drilling exercise, and loses valuable time. It is important to protect against castable material entering the base of the nozzle. Should this occur, the nozzle depth dimension will be altered, preventing installation of the outer refractory thermowell that rests on the cold face of the refractory. If material is found to have entered the nozzle above the inside surface of the vessel shell, it must be removed leaving a level surface on the refractory even with the inside surface of the vessel shell. The easiest and simplest means to protect against this is to use the refractory stops supplied by the thermocouple manufacturer. But, someone must take responsibility of assuring that these stops are fitted to the nozzles prior to the beginning of refractory installation.

A thermocouple installed in a nozzle / refractory bore that does not meet specification often results in failure during startup and the failure will not become evident until the furnace is in service. The drilling of the refractory cannot be performed “free style” without guide fixtures; doing so guarantees failure. The easiest, safest and simplest means is to utilize the drilling kit furnished with the thermocouple.

Infrared Pyrometer Installation Criteria

The pyrometer, contrary to the thermocouple, is usually installed in a side position on the vessel. This is to provide for easy access, since it can be serviced while the unit is in operation. Keeping the nozzle location above the 9:00 and 3:00 o’clock position prevents the accumulation of particulate and molten sulfur, which would block the IR energy path to the sensor. Gravity and vibration provide cleaning assistance as long as there is some downward angle of the nozzle toward the vessel centerline. Remote electronics type units may be installed in a vertical downward position, but consideration must be given to the limited length of interconnecting cable from the lens to the electronics.

Nozzle design must be in accordance with the IR manufacturer's recommendation. As with the thermocouple, the nozzle should be short. Again, this is to maintain heat that helps to prevent corrosion and the buildup of sulfur. For IR units featuring remote electronics and steam jacketed lens assemblies, no nozzle purge should be used and the nozzle, block valve and IR lens should be insulated to maintain higher temperature. This minimizes corrosion and discourages the formation of solid sulfur and coating of the lens window glass, preventing expensive routine maintenance. Remote electronics type IR units require that 50 - 75# steam be fed to the steam jacketed lens housing in order to realize the benefits of immunity to sulfur build up.

With integral IR units whereby the electronics and lens are mounted directly to the nozzle, consideration must be given to the manufacturer's installation instructions regarding nozzle purging and any cooling requirements. No insulation would normally be recommended for these units.

Nozzles are usually 2 or 3" and it is important to assure that the bore hole through the refractory is aimed at the desired target area. The bore hole should be centered and perpendicular to the mounting nozzle flange to assure a clear pathway to the interior of the vessel. The creation of this bore hole through the refractory is most easily performed using the drilling kit furnished with the IR pyrometer.

Refractory Dry-Out Temperature Measurement

The curing of refractory can be critical to successful long term refractory performance. Failure to adhere to the contractor's recommendations may cause early refractory failure and invalidate warranties.

Accurate measurement of the critical and relatively low temperatures during dry-out is a challenge. Generally, IR pyrometers and thermocouples that are suitable for measuring reaction temperatures are unable to accurately measure the critical low temperatures. But, there are a couple of ways to accomplish this.

One is to utilize Claus Reaction Thermocouples that are fitted with an auxiliary thermocouple element that is suitable for accurate measurement of ambient temperatures up to the low end of reaction temperatures. These thermocouple are fitted with an extra set of terminals to conveniently connect them to a transmitter or for wiring to a convenient location for local observation. Although this is a convenient method, the single drawback is that when the operating temperature exceeds that of the dry-out thermocouple element, it will melt away. It then becomes a convenient accurate single use thermocouple. So, if it becomes necessary to shut down for additional refractory work, this thermocouple would no longer be available.

If multi-use is deemed desirable, a more suitable method would entail the use of the insertable "calibration" thermocouple that is an option on Infrared Pyrometers. This provides an excellent means to monitor this dry out profile. However, it requires that the IR unit remain out of service until the refractory dry-out cycle is complete, but it normally is of little use anyway. Upon reaching the end of the dry out cycle and before going on line, the insertable thermocouple is withdrawn and the IR device fitted into its operating position and placed in service. A point of interest… at least one refinery has chosen to prohibit opening of any Claus Furnace port during operation, including that of utilizing thermocouples and cleaning devices fitted with a mounting gland and an operable block valve.

Use of Both IR and Thermocouple

Use of both technologies provides redundancy and protection from common-cause failures; i.e., conditions that affect one technology will likely not affect the other technology.

Since thermocouples are the accuracy standard, they provide a constant means for calibration of IR units in actual service. Thermocouples cannot read erroneously high. They can be inaccurate only in low reading. Any suspicion of thermocouples reading too low because of purging can be validated by temporarily shutting off the purge flow (purge flow may actually be removed for short intervals without harm, but must be maintained for the long term). If temperature rises, then the purge rate is too high. Most Claus furnace thermocouples are fitted with dual measuring elements, mounted side by side but in differing fashions. The Operating element is exposed inside the purged element well; the Reference element is mounted in the same position but sealed in a cavity with ceramic material. The reason for this is that in the event of breakage of the element well, only the exposed Operating element would come in direct contact with the corrosive reaction gases; the Reference element, sealed in ceramic, would remain in accurate service for a considerably longer period. The disparity between the signals of the two elements would very quickly and clearly indicate failure.

Thermocouples succumb to extreme over-temperature conditions causing failure (3320°F melting point of “B” type), loss of long term purge, severe shifting refractory or severe thermal shock. None of these conditions would normally have any detrimental effect on IR units.

IR units, as mentioned above, may fail because of other problematic issues. Setting aside the remote units designed to eliminate the problems of blockage of the IR sight path due to build up of sulfur and coating of the lens glass, these are common problems. Although these issues may be corrected by opening the nozzles and cleaning them out, it is a costly procedure. With IR units that suffer these problems or that require frequent calibration due to sensor drift, the thermocouple can be used to determine when IR maintenance should be performed.

This cleaning maintenance work on the IR can only be performed however, when the nozzle block valve is operable and not frozen in the open position. Means to prevent this are the selection of a proper fireproof valve and keeping it at elevated temperature. Also, periodically operating the valve handle may prevent it from freezing.

Recommendations:

- Use both thermocouple and IR technology to reduce susceptibility to common-cause failures.
- Use thermocouples designed specifically for Claus service and insure that proper purge specifications are carefully followed.
- Consider IR pyrometer designs that are heated to protect against sulfur build-up in the optical path.
- Follow the details of installation instructions and use the proper tools and fixtures for installation.
- Span Instruments to read higher than the maximum expected temperatures.