
Question 6: The use of infrared pyrometers for monitoring tube temperatures in steam reformers is a well known practice. What is your recommended frequency for use of these devices (how many times per week)? Can you offer any recommended alternate devices or methods available such as fixed infrared pyrometer skin thermocouples or infrared imaging?

Brian Slemp (CITGO)

CITGO's operating philosophy is to monitor our tubes with an optical pyrometer every shift. We monitor the tubes from multiple locations on each level of our terraced wall furnace. This method has been extremely effective in extending the life of the furnace tubes and catalyst. The original load of catalyst lasted in excess of 15 years and the original tubes were in service nearly 20 years.

I am unaware of any alternate devices used for this purpose at this time. A vendor has identified an experimental effort to insert a new technology, internal tube temperature. This technology may provide more reliable continuous temperature monitoring.

Praveen Gunaseelan (Vantage Point Energy Consulting)

The typical monitoring frequency with hand-held infrared (IR) pyrometers is at least once per shift during normal operation. Additional monitoring beyond this would be needed during abnormal operating scenarios. Due to differences in steam reformer designs, it is prudent to consult with your technology provider or their recommended engineering contractor for specific recommendations on this issue.

The alternate approaches mentioned are useful to supplement hand-held IR monitoring.

- IR imaging (camera) is useful for screening broader sections of the furnace at a time, and can help to identify potential concerns for more detailed follow-up with hand-held IR pyrometers.
- Skin thermocouples have a reduced life in SMR furnaces due to the high temperatures, and are thus not used as a primary method for monitoring. When functioning, they are relatively accurate and useful for remote monitoring.
- Fixed IR pyrometers are potentially useful for continuous monitoring of a specific location.

Randy Peterson (STRATCO)

The isobutane recycle sample can be neutralized at the sample location using a chamber filled with alumina or KOH pellets. If using a KOH chamber, it is best to add a filter downstream to filter out any fines.

Alternately, the sample may be neutralized in the lab upstream of the GC by the same method. In some refineries, KOH pellets have been added directly to sample bombs prior to sampling.

The iso recycle from the side draw of an isostripper typically contains about 1% HF. However, if the tower is refluxed and the iso recycle stream comes from the tower accumulator, the sample may contain more HF.

Josh Siegel (Johnson Matthey Catalysts)

The tubes in a steam methane reformer (SMR) operate close to the limits of materials technology. Stresses induced as a result of very high temperatures, combined with large differential pressures across the tube, mean that tubes undergo irreversible creep and therefore only have a limited life before they fail. Operation at tube wall temperatures significantly above design can result in a rapid increase in the number of tube failures. Inversely, an operator wants to avoid operating a reformer with tube temperatures below design will result in the full capacity of the reformer not being realized. An operator must therefore have confidence in the temperatures measured.

If the hydrogen plant is running at a fixed rate, then tube wall temperature measurements are generally taken for maintenance purposes anywhere from once a week to once a month. This frequency of measurement allows data for tracking tube wall temperatures over time and to verify that design conditions are not exceeded. Typically the measurements would be taken when the plant is running at high rates, as this is normally when the tubes would exhibit their hottest temperatures. For reformers in which the tubes are running hot, have hot spots, giraffe necking, or another indication that something is causing non-optimal operation, we recommend more frequent measurements. When these conditions are present, it is good practice to conduct spot checks once per shift to keep an eye on the known hot spots in the reformer. During times where the plant is ramping up and down in feed rates or changing feedstocks, it is also a good idea to do spot checks to ensure no heat imbalances or hot spots exist.

While infrared pyrometry for monitoring tube temperatures in SMRs is a well-known practice, it is important to understand the proper methodology of measuring the tube temperature as well as understanding what effects the readings. Infrared pyrometers read the level of radiation from a target that, in this case, would be the SMR tube. However, the tubes in a SMR receive other radiated energy within the reformer. This radiation can be from sources such as the refractory, flames, or even adjacent tubes. In order to account for this extra radiation, the proper background corrections need to be performed to get an accurate tube wall temperature measurement. If no background correction is used, temperatures close to 60°F higher than actual temperatures can be measured for a top-fired reformer. For a side-fired reformer, the reading can be up to 90°F higher.

Laser pyrometers are also used for tube wall temperature measurement. Laser pyrometry operates by sending out a low powered pulsed laser of known energy at the target. The return signal is detected with a conventional infrared signal to quantify the background radiation. To fully account for the background radiation this method requires impact of the target to be at right angles. This is not achieved with cylindrical reformer tubes, creating some concern about the accuracy of the measurements. This error in measurement can contribute to a high estimate of the target temperature.

Manual infrared imaging has been receiving much more attention over the last decade. This imaging does allow good trending analysis of SMR tubes, in that it is able to see multiple tubes in the image at

one point in time compared to the more targeted analysis of a pyrometer. This trending enables awareness of hot and cold areas of the reformer as well as tube wall temperatures at a single point in time. Technology also exists where infrared imaging cameras are installed on the reformer providing a live feed to the control room. This technology has provided value during transient and start-up conditions, a time where severe tube damage is most likely to occur. Operators can see the burners and their flame patterns without being on the reformer. With both types of infrared imaging, it is still difficult to correct for the radiation effects, so the temperatures measured are a high estimate.

One technique that can be used for measuring tube wall temperatures that eliminates the background radiation is a Gold Cup pyrometer. The Gold Cup pyrometer is an infrared radiation detector on a water-cooled probe that is placed squarely on the tube thus eliminating the reflected radiation. While this technique provides very accurate tube wall temperature measurements, it is limited by line of site access from the reformer portholes. In addition, it is labor intensive requiring a practiced team of two operators.

Skin thermocouples provide a continuous measurement of tube wall temperatures. Skin thermocouples, when installed correctly, can give accurate tube wall temperatures, however, under typical conditions they have been known to have short and unpredictable lifetimes. Another issue for skin thermocouples is how they are attached to the tube. If the tubes are slotted to attach the thermocouple it weakens the tube wall. One way to get around this would be spray welding. However, this technique has a drawback in that it will not provide an accurate indication of the tube wall temperature at much above 1,100°F.

Monitoring of tube wall temperatures is an important practice. Tube wall temperature measurement should be a weekly part of plant monitoring, increasing in frequency as the severity or performance of the SMR dictates. Infrared pyrometers are the most well-known means of conducting tube wall temperature measurements. However, the accuracy of those measurements requires background radiation correction. Gold Cup pyrometry provides accurate tube wall temperature measurements, but is laborious in its technique. Correction methodologies for infrared pyrometry provide a means to get close to Gold Cup measurements. Alternative technologies are available for use and while providing good qualitative results, still need improvement to address the accuracy of the temperature measurements.

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