Question 3: Please discuss your best strategies to prevent overheating of steam reforming furnaces?

Praveen Gunaseelan (Vantage Point Energy Consulting)

The question is general; however, there are a variety of steam reformer designs with different operating and control strategies used industrially so a general answer is provided. Operators are urged to consult with their technology providers or qualified engineering contractors for specific guidance on this issue. For simplicity, it is assumed that natural gas is the hydrocarbon feed being reformed with steam. Steam reforming of methane (natural gas) is an endothermic reaction which requires heat input that is typically provided by the combustion of process off-gas and make-up natural gas. A number of scenarios can result in furnace overheating, including:

•Loss of feed flow (resulting in reduced transfer of heat from the furnace)

•Over-firing

•Hot spots in the reformer tubes (e.g. due to catalyst maldistribution, poisoning, deactivation, etc.)

•Flame impingement on reformer tubes, resulting in stress failures

•Inadequate heat removal during start-up

Accordingly, there are a number of strategies to prevent overheating of SMR furnaces that address potential overheating scenarios, and which need to be used in combination to minimize the possibility of an occurrence. Typical strategies are listed below:

•Increased surveillance, both visual and with devices such as pyrometers, during start-up as well as during normal operation

•Minimize the possibility of hotspots (e.g. closer monitoring of catalyst loading, etc.)

•Reduce the occurrence of poor flame patterns

•Implement advanced control schemes to reduce the possibility of or recover from overheating situations

Brian Moyse (Haldor Topsoe)

First of all regular measurements of reformer tube temperatures and inspection of the radiant side of the reformer is very important.

New hydrogen plants will often be designed with software that allows continuous control of the firing duty with proper adjustments made as function of the hydrogen capacity. All the PSA off-gas is used as primary fuel and the firing control is handled by the secondary fuel.

Obviously a proper catalyst loading with only a minor variation of tube pressure drops is mandatory for proper flow distribution through the tubes. Maldistribution may cause individual tubes to overheat.

Proper catalyst selection and operating conditions should be adopted to avoid carbon formation on the process side, which will lead to hot-banding and tube overheating.

Burner operation should be checked regularly to avoid flame impingement on the tubes.

The Haldor Topsoe reformer furnace is designed to allow for profiling of heat input from burner rows, resulting in catalyst tubes operating at a higher average temperature and heat flux at lower peak tube temperature. This profiling of heat input in itself reduces the risk of overheating of the furnace, but also the measurements of the tube skin temperature made on a regular basis will prevent from operating the reformer with too high tube skin temperatures.

However, the biggest threat to the tubes is a sudden over-heating, which will damage the tubes very rapidly. This could in principal be due to:

•Loss of cooling (feed)

•Too high fuel input (overfiring). Fuel is controlled with a duty controller, summarizing all fuel duty input.

To prevent from such sudden over-heating, the reformer is protected by low feed and steam flow trips, and the fuel is controlled with a duty controller, summarizing all fuel duty input, to prevent overfiring.

Further, as secondary protection, the reformer is protected by flue gas temperature measurement. This is the fastest indicator of over-firing, as process gas in a cold collector can increase in 15-30 seconds if the firing is increased rapidly and a high temperature trip is initiated.

Brian Slemp (CITGO)

The best strategies to prevent overheating steam methane reformer tube:

1)Ensure the catalyst tubes are pressure drop balanced. Reformer furnaces have an inlet manifold to evenly distribute the feed. An increase in pressure drop from an improperly loaded catalyst tube will reduce the flow of the reactants in that tube increasing the tube temperature and potentially leading to coking and overheating.

2)Routinely monitor the skin temperatures and balance the fire box heat distribution to prevent localized hot spots.

3)Prevent direct flame impingement.

4)Routinely monitor catalyst activity with your vendor to prevent operating in the carbon deposition region and generating internal thermal insulation thereby overheating a tube.

5)Maintain proper steam to carbon ratio.

6)Monitor feed composition to ensure potential coke precursors are not introduced above allowable limits.

7)Ensure high purity steam is used to prevent catalyst poisoning and coke generation.

8)Closely monitor tube temperatures and nitrogen flow during startup.

Tina Moss (Johnson Matthey Catalysts)

If not monitored properly, a variety of operating issues can lead to high steam reformer furnace tube wall temperatures. High tube wall temperatures are most often due to poor catalyst loading, problems during start-up operations, or carbon formation due to poisoning. Therefore, the best strategies to prevent overheating of steam reforming furnaces are to address the operating issues that can cause high tube wall temperatures.

The first step in avoiding high tube wall temperatures is to ensure a good catalyst loading that avoids flow imbalances and large catalyst voids. The general tolerance on flow variations between tubes is ± 2.5% for a good catalyst loading, which corresponds to a pressure drop variation of ± 5%. The most common loading technique used by North American refiners is the trickle loading method. There are several trickle loading techniques available in the market and these can typically achieve between 2 to 5% pressure drop variation.

Problems that result in furnace overheating often occur during plant start-ups. Feed flow imbalances on the process side of the reformer tubes often occur during start-ups when rates are significantly less than design. To minimize the impact of the feed flow imbalances, nitrogen flow needs to be sufficient to provide a heat sink as the burners are going through a sequenced start-up. Once steam flow is introduced it provides a significant heat sink but needs to be at least 30% of, and preferably 40 to 50% of the design rate as soon as possible to allow even firing of the furnace. In addition, the operating pressure during start-up should be kept low to maximize process gas velocity and hence improve gas flow distribution as well as minimize the pressure differential across the tube walls reducing the stresses on the steam reformer tubes. While these concerns are most prevalent during start-ups, these conditions can also be present when there are significant rate fluctuations.

Another source of high tube wall temperatures is the result of catalyst deactivation. High tube wall temperatures can occur due to carbon formation caused by insufficient steam rates or poisoning of the catalyst. Insufficient steam to carbon ratios can result if steam flows are not appropriately modified following feedstock changes. Low steam flow can result in carbon deposition on the catalyst and overheating of furnace tubes. Poisoning of the catalyst that results in carbon formation is typically due to sulfur. The best strategy to prevent catalyst deactivation by poisoning is to ensure good purification operation and monitoring during operation. In the event that carbon formation has occurred, one potential strategy is to steam the catalyst to remove the carbon formed. This is most effective if the catalyst loaded in the top is alkali promoted

. Steam reforming furnaces are very expensive, complex units. Overheating of these units can result in reduction in hydrogen production and equipment failure. Creating a strategy to address proper catalyst loading and start-up procedures, as well as, transient conditions during daily operation will help to avoid steam furnace overheating.

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