INSPECTION OF THE TOP ENDS OF REFORMER TUBES

The standard adopted for the examination of Reformer Tubes in Steam Methane Reformers (SMR) has been to inspect the heated length of the tube within the furnace. The portion of the tube outside of the heated length is normally not inspected after being in service. However, recent trends have changed that perspective due to internal defects encountered in these portions of the top ends. These defects have been found in two completely different design arrangements which will be described separately as Case I and Case II.

Case I - Top Fired / Down Flow:

In these reformer designs, the burners are top fired with a down flow process. The inlet gas is injected through a pigtail into the tube above the furnace radiant box in the penthouse. The unheated tube top section is made of wrought material with metallurgies ranging from low-chrome alloy steel (1.25 Cr - 0.5 Mo) to stainless steel 304H, 347H, or similar materials while the heated length within the furnace is a centrifugally cast material mostly 25Cr/35Ni/Nb or with Micro-alloy additions. See Figure 1.

A number of tube top designs include the use of a side entry pigtail connection and an insulation plug on the blind flange of the tube top. During transient and cold weather conditions, the temperature of the tube top flange can drop below the process gas dew point resulting in condensation in the area shown in "black". The process gas dew point is typically in a range of around 300-400 °F.

The condensed liquid can then drip down into the area marked in "blue" where it can contact the inside of the tube top causing re-vaporization of the liquid and localized rapid cooling of the tube at that location. Continual dripping of liquid and vaporization of the liquid produces in a cyclic variation in temperature resulting in a damage mechanism called "thermal fatigue". The stainless steel tube top designs are most susceptible to thermal fatigue damage due to its higher expansion coefficient compared with low-chrome alloys. The higher expansion coefficient of stainless steel materials produces greater thermal stress with localized temperature cycling.

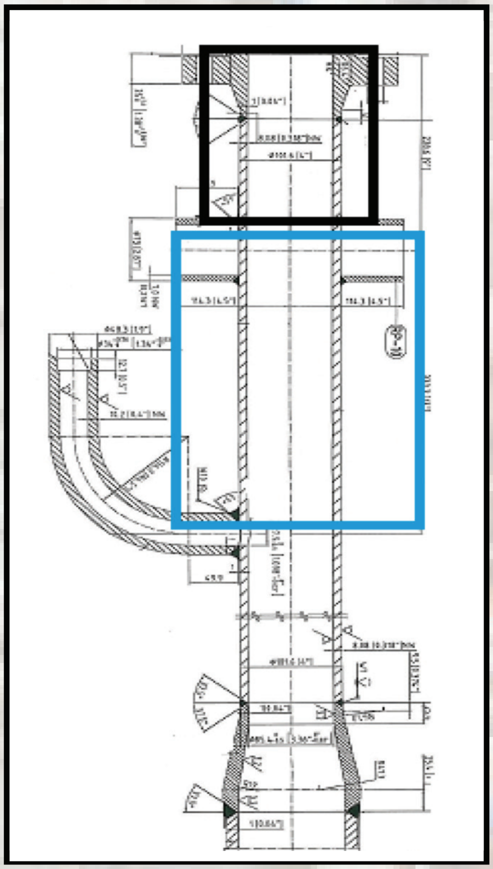

Figure 1: Top Fired / Down Flow

Case II - Bottom Fired / Up Flow:

In these reformer designs, the reformer is bottom fired with an up-flow process. The inlet gas is injected from the bottom of the tube through an inlet pigtail and the reformed gas comes out from the top of the tube through an outlet pigtail. The outlet pigtail is located on the portion of the tube outside of the heated length on an uncovered roof open to the atmosphere. The tube material is made of the same material as the heated length which is centrifugally cast length which is a centrifugally cast material mostly 25Cr/35Ni/Nb or with Micro-alloy additions. In this scenario, the process gas can also reach its dew point around 300-400 °F and cause "condensation". See Figure 2.

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However, the reasons for this are different from the previous case because the gas on the outlet side is much hotter than the inlet side. In this case, the "condensation" of the process gas inside the tube is caused by greater exposure to weather conditions due to the uncovered roof and insulation issues near the top ends. This is likely in areas where winters are extremely cold and areas where rain is predominant throughout the year.

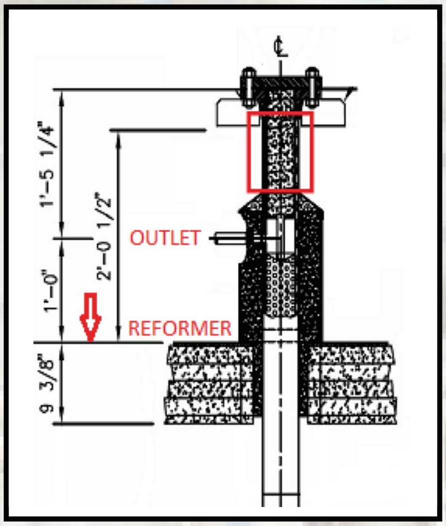

Figure 2: Bottom Fired / Up Flow

The area susceptible is marked in "red" as the insulation is often not extended up to just below the flange bolts. This insulation would prevent the low temperature conditions and rain water ingress which can affect the internal conditions of the process gas inside the tube.

The cyclic stresses brought on by these variations in temperature result in the same damage mechanism as for Case I, that is, "thermal fatigue". In both Case I and Case II, the defects manifest themselves in the form of circumferential cracks or pinhole cracks that initiate from the ID and propagate towards the OD resulting in a leak.

It is necessary to highlight that these crack defects start on the ID and propagate towards the OD offering no warning until failure occurs in service. It is also important to know that these cracks typically occur with no measurable dimension creep, therefore the inspection method must detect cracks rather than creep damage.

When failures of this type occur, it can be catastrophic in terms of fire and property damage, production losses and more importantly safety. This is related to the fact that a fire in the top ends of the reformer tubes can go unnoticed for a period of time as this area is not frequently visited, and fire at this location can overheat and cause additional failures of adjacent tube tops and/or pigtails.

Magnetische Pruefanlagen has developed a reliable technique to scan these areas of the top ends and identify cracks defects that have initiated so that timely action can be taken to prevent failures in service.

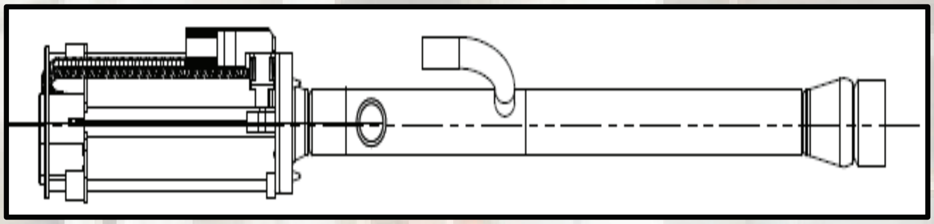

Figure 3: Schematic of the Device for Scanning of the Top Ends

The technique and fixture as shown in Figure 3, used to detect these defects, is an eddy current probe that scans the top ends for presence of defects that may have already initiated due to the above-mentioned effects of "thermal fatigue". The timely identification of these defects will ensure safe and reliable operation of the reformer and prevent fires that can result in significant damage.