

Overview of Reformer Tubes

Introduction

The Steam Methane Reformer is key to the production of blue and grey hydrogen because it is where the steam-hydrocarbons reforming reaction to produce hydrogen takes place.

Alloy tubes, typically HK-40 but micro alloys are also used, loaded with catalyst (nickel/ alumina) typically 12-14 m (40-46 ft) long with an outer diameter 0.11-0.13 m (4.3-5.1 inches), are fed at the top with the steam-hydrocarbon mixture. Leaving the tubes at the bottom is a gas stream containing 70-75 % hydrogen (dry basis), 2-6 % methane, 7-10 % carbon monoxide and 6-12 % carbon dioxide.

The main reforming reaction, being endothermic in nature, consumes a large amount of heat energy. The heat is generated at the outer surface of the tubes by burning natural gas or other hydrocarbon which then transfers through the walls of the tubes into the reacting gases

Purpose of Tubes

The tubes in a reformer perform several functions:

- Provide sufficient residence time for the reforming reactions
- Retain and carry the flow of the process gases
- Retain the catalyst
- Exclude the combustion gases
- Transfer heat from the main body of the furnace to the process gases
- Withstand temperature in the range of 700 °C to 1200 °C

Any tube failure will mean a total loss of containment and a fire in the furnace.

Tube Life

Life of a reformer tube is limited. These tubes frequently have a short life of about 5 years, as a consequence of the prolonged exposure to the aggressive environment of high temperature and high stress. The tubes are required to withstand alternating mechanical and thermal stresses, internal and external oxidation and carburization.

The main issues are degradation due to carburization and cracking due to creep. Deformation is just the visible consequence. Coke formation is also an issue, as the coke layer is thermally insulating and results in an increase in the skin temperature of the tube.

Tube lifetime is determined using the Larson-Miller Parameter. The Larson Miller Parameter is calculated using experimental lab data for a particular alloy. The Larson Miller Parameter describes the equivalence of time at temperature for a steel under the thermally activated creep process of stress rupture. It permits the prediction of the equivalent times necessary for stress rupture to occur at different temperatures.

If the operating temperature is too high there is an increased risk of damage by creep and coke formation. The life of a reformer tube can be prolonged by operating at lower temperatures but with lower rates of reaction. There is an optimum operating temperature range that can be controlled by the burner firing and the gas velocity through the tubes.

The industry rule of thumb is that for every 20 °C above the Maximum Allowable Operating Temperature (MAOT) there will be a halving of tube life. Production is maximised by operating as closely as possible to the MAOT. This is achieved by monitoring of Tube Wall Temperature (TWT). Individual tubes or the whole array can be replaced. With a desired tube life of 100,000 operating hrs (11.4 years) time-based criteria have been used to set tube life but operators are also employing a condition-based assessment in an attempt to avoid taking tubes out of service earlier than necessary.

Tube Monitoring

To avoid premature tube failure, it is important to monitor the Tube Wall Temperature (TWT) and control the firing of the furnace accordingly. A significant risk of overfiring exists during transient conditions.

Monitoring of TWT is done using an optical infrared pyrometer, a portable or fixed thermal imager or a Gold Cup pyrometer. It is also possible to perform in-tube temperature monitoring.

Other monitoring techniques are employed to try and predict tube failure including visual inspection, eddy current response, ultrasonic attenuation, wall thickness measurement, profilometry (the measurement of the outside of the pipe) and metallographic replicas.

Retube Cost

For a reformer with a capacity of 50,000 Nm³/hr of hydrogen the cost to retube is approximately 10 -20 % of the installed plant cost. Exact cost of replacement will depend on several factors including materials and labour rate. Another consideration is that the alloys used, have a high nickel and chromium content. The cost of both these metals in the long term is trending upwards.

As of writing an uninstalled HK-40 stainless steel reformer tube costs around US\$ 25,000 from the manufacturers gate.