TERRACE WALL™ Reforming Furnace

Introduction

Foster Wheeler has supplied over 200 reformers worldwide and the following describes Foster Wheeler's proprietary TERRACE WALL™ Reformer technology.

Foster Wheeler Terrace Wall ™ Reformer

The Reformer features a radiant section consisting of twin fire-boxes, each containing a single row of catalyst tubes with two terraced-burners on either side of the tubes discharging hot gas into the convection section. The convection section has several coils, which recover heat from the flue gas leaving the radiant section for various process and utility duties. The reformer is designed to recover as much heat from the flue gas as is economic, whilst avoiding dew point problems.

Reformers of this type have been in operation for many years under conditions similar to those used for this Hydrogen Plant design. This technology offers several advantages over competing technologies, namely:

- Uniform heat flux distribution giving long reformer tube life
- High reliability
- Low steam-to-carbon ratio
- Positive reformer furnace firing control
- Low maintenance requirement
- High product gas purity and low product cost

Foster Wheeler's Fired Heater Division engineers and fabricates all kinds of process furnaces including reformers for hydrogen, ammonia and methanol plants.

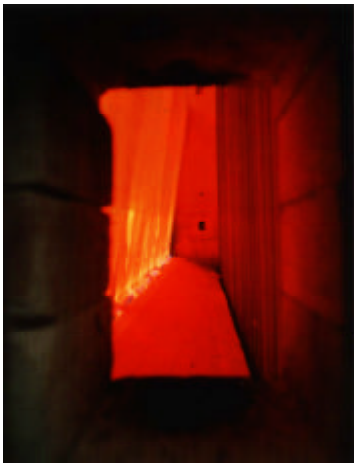
There are three types of furnace in common use today for large-scale hydrogen production, namely downfired, sidefired, and Foster Wheeler's proprietary TERRACE WALL™ arrangement.

Foster Wheeler has built a number of downfired and sidefired furnaces, including the largest downfired furnace in the world.

Special Features of the TERRACE WALL™ Reformer

The Foster Wheeler designed furnace incorporates unique design features to provide efficient, reliable and controlled heat transfer to the reformer catalyst tubes.

Terrace Wall ™ Radiant Section



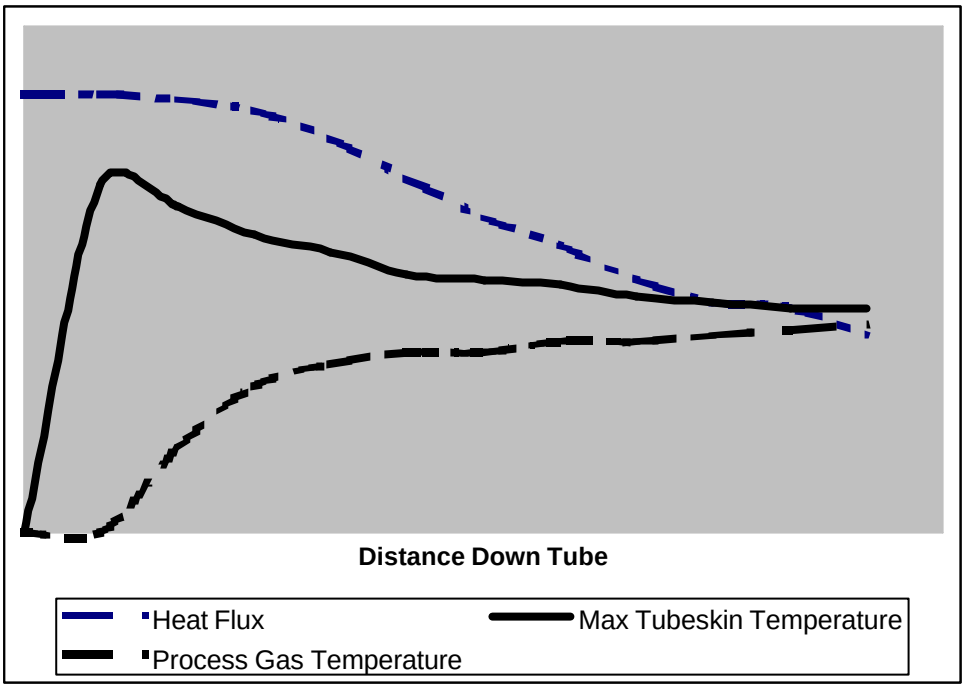
The inclined TERRACE WALLS™ are uniformly heated vertically by the rising flow of hot gases, with each terrace capable of being independently heated to provide the particular heat flux desired in its zone. This allows the operator to match the vertical heat flux to the process heat demand within the catalyst tube, thereby avoiding tube hot spots and prolonging tube life. This principal is illustrated in Figures A & B.

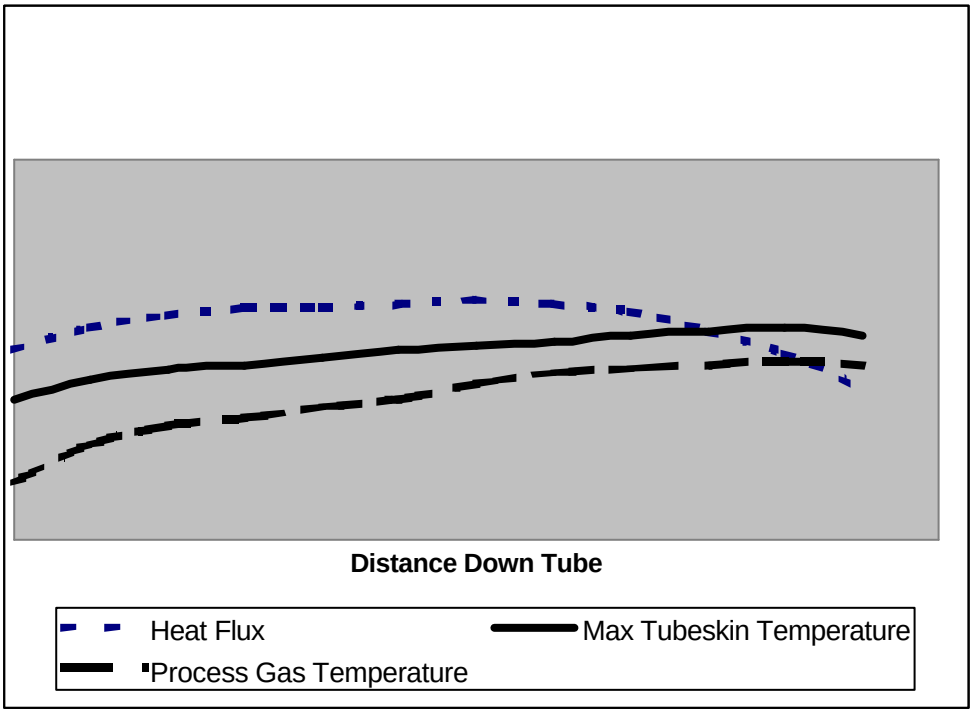
The controlled delivery of heat to the reformer catalyst tubes is essential because the process heat demand within the catalyst tubes varies significantly from inlet to outlet, shifts progressively along the tube during the life of the catalyst and also changes with different feedstocks. A hotspot 20°C above design temperature can halve the design life of the tube.

The incline of the wall also localizes the effectiveness of the terrace to that portion of the heat-absorbing surface directly opposed to it. Actual experience has shown that the TERRACE WALL™ design accomplishes this to a far greater degree than is possible with any flat wall construction, and is distinctly better than in downfired designs.

Uniform heat distribution is also required along the length of the furnace and circumferentially around each tube.

Uniformity of heat distribution along the length of the furnace is assured by the special burner design, which provides for a continuous arrangement with no marked





discontinuity. Development work by Foster Wheeler makes it possible to achieve this with both gas and oil firing. Flame impingement on catalyst tubes is practically impossible in the TERRACE WALL™ design.

Uniform heat flux distribution around the circumference of each tube is ensured in the TERRACE WALL™ design by provision of ample spacing between the tubes so as to utilize the tube surface to the highest degree of effectiveness without excessive metal temperature.

Even with the most conservative furnace design it should be accepted that a tube failure may occasionally occur. The normal tube failure mode is small cracks or pinholes, which over a number of hours coalesce into a large hole. The resultant

flame must be isolated before flame impingement damages adjacent tubes or walls of the furnace causing an emergency shutdown.

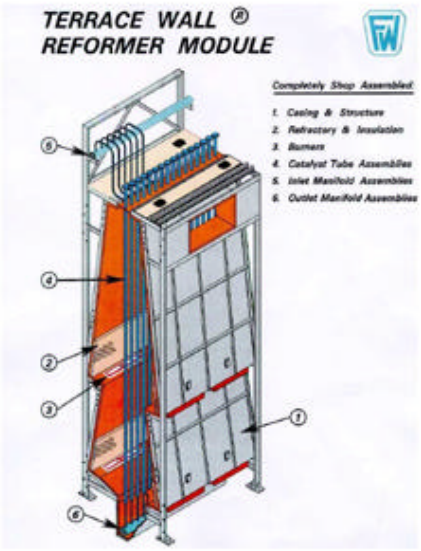
Unlike downfired furnaces, the Foster Wheeler design incorporates a system where the inlet and outlet of individual pigtails can be nipped on-line. (Nipping is basically squeezing flat a short section of piping to stop flow through the damaged tube)

Additional Design Features

Additional significant design features are listed below:

- Catalyst tubes are supported by top counterweights. Virtually all of the loaded catalyst tube weight is supported.
- The inlet manifold/inlet pigtail system is designed to minimize applied stresses to all components in this area.
- The single row tube arrangement with heating from both sides at two levels eliminates any tendency for tube bowing, thus further minimizing applied stresses to the outlet pigtail/manifold system.
- Use of ceramic fiber insulation to the greatest practical extent (rather than firebrick) maximizes reliability and minimizes field erection costs and maintenance.
- The plot area is minimized for a given size as a result of mounting the convection section, induced draft fans, and stacks above the radiant section.
- During routine maintenance, the removal of one burner gun has minimal effect on furnace operation owing to the wall radiation effect in the TERRACE WALL™ design.
- The integrated steam system utilizes a proprietary Foster Wheeler process gas boiler, which is “close-coupled” to the reformer gas outlet headers. This proven innovative arrangement saves plot space and eliminates high temperature transfer lines.

Recent Developments in Reformer Design



Recent developments to improve the design of the TERRACE WALL ™ Reformer include:

- Modified geometry of the radiant section to tailor flux profile and improve thermal efficiency without increasing catalyst tube temperature.
- Outlet pigtails arranged vertically providing better access for ease of welding and nipping, which dispenses with the need for a cold bottom flange for catalyst removal. Vacuum type catalyst removal systems allow removal of catalyst via the tube inlet flange.
- Reduced number of burners by about 30% due to increased capacity with the new burners using staged fuel and staged air combustion techniques for lower NOx emissions.
- Modular construction is an available option to reduce site construction time. This is specifically attractive where site construction costs are high.