Installation of a New Flue Gas Tunnel Design Concept and Resulting Operation

Down-fired steam methane reformers utilize flue gas tunnels running the length of the radiant section floor to collect and transport radiant section flue gas to the convection section for heat recovery. Flue gas enters the tunnels through side wall openings which are distributed along the length of the tunnels in a pattern designed to achieve uniform flow of flue gas both in the downwards vertical direction and into the tunnel along the entire length of the tunnel. Conventional tunnels have been in use for several decades, but a new tunnel system manufactured by Blasch Precision Ceramics and designed and developed in conjunction with BD Energy Systems is now available and greatly improves upon the conventional design.

BD Energy Systems and Cherokee Nitrogen discuss the successful revamp project execution of installing the above discussed technology in an existing down-fired steam methane reformer along with operational results obtained from the reference Ammonia plant.

Joe Price
BD Energy Systems, LLC

Jason Hartsell
Cherokee Nitrogen, LLC

Introduction

Conventional tunnels incorporate physical features that constrain design efficacy resulting in non-uniform flue gas flow both along the length of the tunnels and among the tunnels. Non-uniform flue gas flow has been correlated to non-uniform catalyst tube convective heating, varied tube temperatures, and early tube failures due to localized overheating.

BD Energy Systems have developed a new patent pending Tunnel Optimal Performance (TOP) design method to achieve radiant flue gas flow uniformity and improved tube longevity/reliability. BD Energy Systems uses the Blasch Precision Ceramics designed StaBlox™ system, having mullite bonded high alumina refractory components that include unique features incorporating the TOP design within the StaBlox™ system and allowing the installation of the entire tunnel system without mortar utilizing interlocking features.

Previous articles have been written describing the design of the StaBlox™ tunnel system and the TOP designed orifice inserts engineered by BD Energy Systems that make up the new flue gas tunnel system that is the subject of this paper.[1] It is not the intention of this paper to restate all of the detailed information from the previous papers, but a summary of pertinent information is provided as a basis for further discussion.

Characteristics and Limitations of Conventional Tunnels

The following points list the inherent limitations of conventional tunnels discussed in previous papers.

- The openings in the side walls of conventional tunnels are rectangular in shape and are normally the size of a half brick. This also results in step-changes in flow area as opposed to a more fluid change in flow area.
- Conventional tunnels have buttresses to increase stability. This restricts the width of the tunnels and increases tunnel pressure drop with increased plant capacities due to the higher velocities inside the tunnels.
- The buttresses are also areas of the tunnels where flue gas flow openings cannot be supplied and create no-flow regions where flue gases must be diverted to adjacent openings resulting in increased flue gas flow to adjacent catalyst tubes.
- Conventional tunnels side walls also require expansion joints that create no-flow regions.
- Conventional tunnel slabs (covers) are simply laid on top of the tunnel wall and provide limited stability to the system. They are also a source of frequent failure due their mass.
- The mass of the tunnels is high and is a source of high temperature heat retention during cool down. The weight of the tunnel can also be detrimental to the tunnel's own stability due to deflection of the supporting floor structure.

Characteristics of the StaBlox™ Tunnels with TOP Design

- The openings in the side walls are circular and designed to accept an alumina orifice plate. There are over twenty different orifice sizes allowing fine tuning of flue gas flows.
- The StaBlox™ system does not require buttresses enabling the width of the tunnels to be maximized to reduce pressure drop.
- The system has its own floor component and all components are interlocking creating a very stable structure.
- Internal stabilizing bars are available for taller tunnels.
- There are no areas of no-flow.
- Thermal expansion allowances are designed into the components and installation. No discrete expansion joints are required.
- All components are hollow and light weight which decreases installation time, reduces mass by approximately 60%, and reduces heat retention.

Installation of New Tunnels

New TOP designed StaBlox™ tunnels were installed in 2018 at LSB's Cherokee Nitrogen facility in Cherokee, Alabama. The reformer has seven rows of 24 catalyst tubes and eight tunnels. The first step in installing the tunnels is leveling the radiant floor to receive the base pieces. Figure 1 shows the base pieces installed and ready for the remainder of the tunnel to be installed.

After the floor is leveled, installation of the base pieces and assembly of the tunnels proceeds at a much higher rate compared to conventional tunnels. The tunnels in this reformer were five feet (1525mm) high and forty feet (12,190mm) in length. Typically, three entire tunnels can be easily assembled in one 12-hour shift and at the Cherokee Nitrogen facility, one shift was able to complete four tunnels. Figures 2 and 3 depict a tunnel that is partially assembled and one that is completely assembled, respectively. Each of the tunnel components (base, bricks, and slabs) can be easily carried by one person.

Figure 1. Tunnel Base Plates Installed

Figure 2. Partially Assembled Tunnel

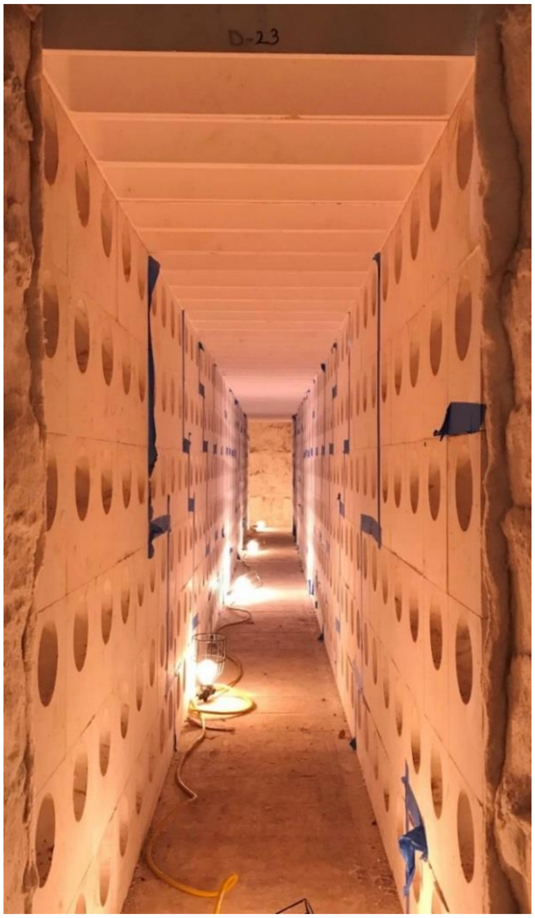

Figure 3. Completed Tunnel

For reference, Figure 4 shows an orifice insert installed in a tunnel side wall opening.

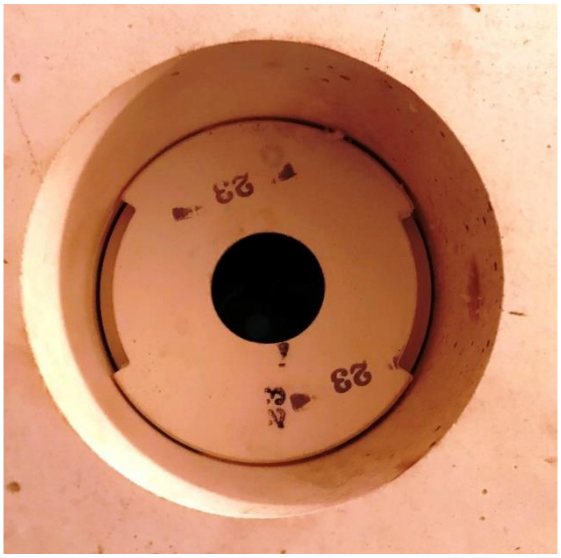

Figure 4. Tunnel Side Wall Opening with Orifice Plate Installed

Operational Data Analysis

As previously stated, the purpose of the flue gas tunnels is to assist the collection of the products of combustion in such a way as to create a uniform flow of flue gas in the vertical direction that results in uniform heating of the catalyst tubes. This goal implies that the flue gas must also enter the tunnels uniformly along the entire length of the tunnel otherwise crossflow occurs near the bottom of the radiant section as the flue gas follows the path of least resistance. The no-flow areas created by conventional tunnels create crossflows near the bottom of the catalyst tubes where the tube metal temperatures (TMTs) are the highest creating even higher temperatures compared to tubes located in front of no-flow areas.

Operating data were compared for periods of 2½ months before and 3½ months after the installation of the tunnels. Key points that were examined are catalyst tube metal temperatures and production rates.

Figures 5 and 6 show surface graphs by row and tube number of the TMTs before and after the installation of the tunnels, respectively. There is a noticeable improvement in both the temperature range and uniformity of the TMTs.

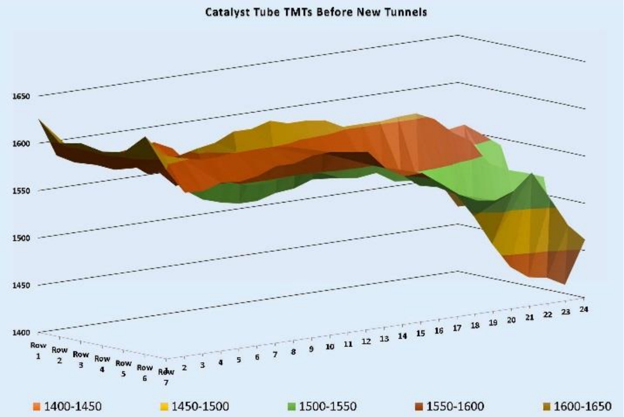

Figure 5. Catalyst TMTs Before New Tunnels

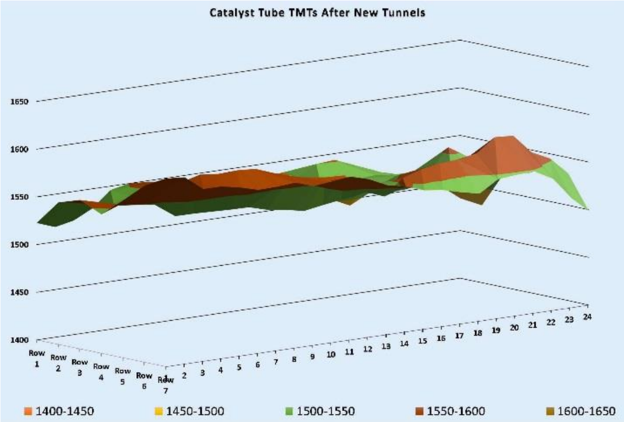

Figure 6. Catalyst TMTs After New Tunnels

Table 1 is a comparison of the TMT data.

	Avg TMT °F (°C)	TMT Std Dev °F (°C)	TMT Min to Max ΔT °F (°C)
Before	1556 (847)	42 (23.3)	222 (123)
After	1545 (841)	21 (11.7)	116 (64)

Table 1. Summary of TMT Data

It can be seen that not only did the average TMT decrease slightly but also the temperature range became narrower by approximately 50%.

The plant also experienced an increase in production of 3.3% after the installation of the new tunnels as well as an increase of 3.7% in the production/feed-rate ratio. These increases are a result of reduced methane slip from the front end of the plant due to more uniform heating of the catalyst tubes. More uniform heating of the catalyst tubes enables operators to safely increase the outlet process temperature while still maintaining the TMTs at safe levels.

The increase in production experienced at this plant is relatively high. It is estimated that larger plants would experience a smaller increase in the range of 1.3 to 1.8%.

Conclusion

The installation of the new tunnels had a positive effect on the catalyst tube metal temperatures causing the temperatures to be more uniform throughout the radiant section. This allowed an increase in production rates while maintaining the TMTs at a safe operating level.

References

1. Improving Down-fired SMR Flue Gas Flow Uniformity Using the New StaBlox™ Reformer Tunnel System, Joe Price, Tanner Howell, Joe Quintiliani, AIChE 2016, Nitrogen+Syngas 2016