IMPROVING THE flow

Jeffrey Bolebruch, Blasch Precision Ceramics, USA, describes the installation experience with a new reformer flue gas tunnel system.

For decades, down-fired steam methane reformer furnaces have used flue gas tunnels (or 'coffins') along the radiant section floor to collect and improve flue gas flow uniformity. These tunnels range from 4 – 10 ft high, 2 – 3 ft wide, and 40 – 100 ft long, depending on the unit design capacity. However, the conventional refractory firebrick or tongue- and groove-firebrick construction has always constrained the flue gas to a non-uniform flow, which has been correlated to non-uniform catalyst-tube temperatures and accelerated tube aging. Due to tunnel size and refractory volume, traditional brick design uses only basic shapes. Typical brick-and-mortar installations require several physical features that severely limit tunnel effectiveness, making uniform flue gas flow unachievable. The ability to design and construct tunnels using highly-engineered refractory shapes could be the answer to improving flue gas tunnel effectiveness and improving catalyst tube reliability and longevity.

A system to improve flue gas flow

BD Energy Systems and Blasch Precision Ceramics have co-developed an improved reformer tunnel system to achieve flue gas flow uniformity among and along the tunnels. This system combines BD Energy Systems steam methane reforming (SMR) experience with Blasch's customised refractory shapes. The result is unparalleled flue gas flow control, using the patented Blasch StaBlox^{TM} reformer tunnel system in conjunction with the

Figure 1. Conventional tunnel construction.

Figure 2. StaBloxTM reformer flue gas tunnel system.

Figure 3. Placement of base blocks.

Figure 4. Base blocks complete.

Figure 5. Building the walls.

patent pending BD Energy Systems' Tunnel Optimal Performance (TOP) system. Because of this new ability to fine-tune flue gas flow, these tunnels can be adapted to other applications and can open the door to previously unexplored SMR process possibilities.

This paper provides an overview of the first two installations of the Blasch StaBlox Tunnel System, which occurred in the summer of 2018 at a pair of unnamed US ammonia plants with the installation performed by ParFab Companies and overseen by BD Energy Systems and Blasch Precision Ceramics. Both installations involved removal and replacement of all tunnels.

As described above, conventional brick-and-mortar tunnels are typically 4 ft to 10 ft high, 2 ft to 3 ft wide, and 40 ft to 100 ft long. Nominal brick dimensions are 9 in. x 3 in. x 6 in. (L x H x W). Buttresses extend from the outer wall surface for support and stability. Discrete expansion gaps (expansion joints) are intended to accommodate thermal expansion to avoid wall distortion ('snaking'). Tunnel wall openings are created by removing ½ bricks (4½ in. x 3 in.) from the tunnel wall. Columns of openings are arranged at least 1½ to 2 brick lengths apart (centre-to-centre) and are distributed along the length of the tunnel to control flue gas flow into the tunnel. These brick tunnels have historically been a significant source of reliability concerns, with partial failure or even full tunnel collapse being common. The causes of these failures can be classified into three main sources: mass, material selection, and expansion management.

The StaBlox system uses five core tunnel construction components. The construction begins with a base component that spans the bottom of the tunnel and mates to the side wall blocks. The side wall blocks are 18 in. long x 9 in. high. Each block contains two 4.5 in. dia. openings. An orifice insert with an engineered inside diameter is installed in each opening. In addition to orifice inserts, these openings can hold ancillary parts, such as tie-rods inside the tunnels, which connect the two tunnel walls and replace buttresses as an additional support structure. These tie-rods can be easily removed and replaced during outages to allow easy access down the tunnel interior for inspection or repairs. At the top of the tunnel is a lightweight slab that mates to the side walls. In order to allow for a completely mortar-free construction, the slabs also employ a shiplap joint to prevent any gas bypass through the tunnel slabs. Every component of this system is designed to accommodate its own thermal expansion. In order to eliminate any gas bypass through the expansion joints, a fibre gasketing system is employed.

Installation procedure

Levelling the floor

Once the conventional brick tunnels were removed, the first and arguably most important task is to carefully prepare the floor for installation. The StaBlox Tunnel System requires a flat surface on which to build. Assembly tolerances and thermal expansion allowances are carefully calculated and quite tight, so any irregularities could create issues at assembly. The StaBlox Tunnel System is considerably lighter than a conventionally constructed tunnel, but if the structure under the floor of the furnace is unstable or badly warped, this should ideally be corrected prior to installation. This proved necessary at one of the sites, where a badly warped I-Beam was cut out and replaced with a straight one. Once the structure was deemed to be acceptable, a levelling castable was used to even out any low spots in the area in which the tunnels will stand. Forms were placed slightly further apart than the tunnel was wide, and the castable was poured into that space. Once that was allowed to cure, an IFB layer was put down followed by wall assembly.

Placement of base blocks

Assembly began by laying down all of the base blocks. A string was run along the desired edge of the tunnel, in order to ensure that the base blocks are laid down straight. Further, it is imperative that the base blocks be properly gapped in order to ensure that the side blocks will have the proper allowances for thermal growth. The side blocks have tight tolerances and self-align as they fit together, but if the base blocks are too close together or too far apart, the side blocks will eventually run out of room to adjust within the space allotted to them.

The first tunnel was constructed by laying down the 9 in. wide base blocks as described and gapping them at the calculated value between every other block (to mirror the anticipated expansion of the 18 in. long side blocks). It was subsequently determined when the tunnel was complete, that the gaps between the base blocks were excessive, leading to rather large gaps between the side blocks and lids. The overall assembled length of the base blocks was then measured and found to be well over the design length. In retrospect, it became clear that in the real world, there was enough debris even on a freshly swept floor to ensure that the theoretical gap was large enough. The next two attempts yielded assemblies that were actually a bit short, creating issues with side brick and lid clearances (Figure 3). Eventually, the proper gapping was determined and verified through an accurate overall length measurement of the assembly and through subsequent assembly of the tunnels (Figure 4). As most would understand, initial installations of new technology inevitably present some unknowns at the time of installation. However, assembly and disassembly of three of these walls were still completed within hours. The experience garnered in the actual assembly of these tunnels strongly suggests that they can be disassembled and moved for major maintenance and then replaced without substantial effort.

Building the walls

Once the base blocks were in place, installation began on the walls. Due to the blocks possessing a "tongue" on one side and "groove" on the other, it was important to remain mindful that all blocks were to be oriented in the same direction. The vertical groove arrives with a strip of refractory ceramic fiber cemented into place. The entire first row of side blocks were placed on the base blocks first just to ensure that the gaps between the base blocks were correct and, consequently, that the gaps between

Figure 6. Placing ceramic fiber gaskets between layers of blocks.

Figure 7. Installation speed can positively influence overall workflow.

Figure 8. Installation of the lids.

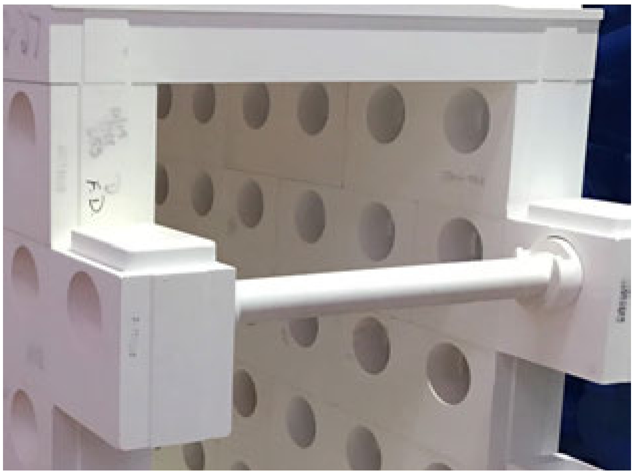

Figure 9. Removable tie rods.

Figure 10. TOP orifice inserts.

Figure 11. Nine tunnels constructed in one week.

the side blocks were consistent and of the proper thickness. Each side block covers two mating features on the base blocks and has only minimal movement end to end. The blocks were each centred on their range of limited movement (Figure 5). The installation partners, ParFab Field Services, started by assigning specific individuals to transport blocks; temporary installation of rollers proved to expedite this process considerably. The ParFab crew nominated one individual to place the horizontal ceramic fiber gaskets neatly on the blocks being placed while everyone else continued building (Figure 6). The combination of construction method and optimised task management resulted in approximately 4 hours/tunnel by the end.

In fact, it was determined that this speed will allow planners to significantly alter their work plan going forward. Usually, it is necessary to build scaffolding over and around in-progress tunnels to access the upper regions of the reformer for other work. Due to the speed of installation, the tunnels can be installed afterwards, simplifying the scaffolding. Further, the tunnel part of the job can be scheduled later to allow completion of more difficult or higher priority activities first. This sort of approach can bring greater flexibility to the installers in addition to positively impacting the overall length of the job (Figure 7).

Installation of the lids

Once the walls reach final height at one end of the furnace, it is possible to begin placing the lids. The tops of the side blocks have the same features that are present on the tops of the base blocks, so it is necessary to ensure they are all oriented the same way. The lids fit snugly onto these features with the same thermal growth allowances built in. The lids contain shiplap type features to prevent gas bypass (Figure 8). The lids also serve to tie in the tops of the walls, preventing them from moving inward or outward. Once installation of the lids began, the tunnel walls tightened up immediately, resisting efforts to rock them back and forth, even without mortared assembly. Assembly without mortar is important because it allows repeated thermal cycling without creating enough stress across the body to cause cracking. This is precisely why mortar joints crack and why stresses large enough to do real damage are able to accumulate across longer distances. At rest, the tunnel is an assembly of thousands of pieces all held together by mechanical design, and in use, at elevated temperature, it is a monolithic, leak free body.

Placing tie rods (if used)

Tie rods are easily installed. A pair of cradles are simply inserted in opposing holes and turned 90° to engage the locking cams. The tie rods simply sit in the cradles. In addition to preventing the walls from pushing inward, features in the rod prevent the walls from spreading apart (Figure 9). This sort of behaviour can be seen in the form of “snaking” in conventional tunnels, if the expansion gaps are not properly worked out during construction. As many or as few tie rods may be inserted as desired. The cradle mechanism permits easy removal and replacement should access to the inside of the tunnels be required for any reason.

Orifice inserts

The heart of the StaBlox Tunnel System, and what enables it to have a significant impact on performance, is the BD Energy Systems’ Tunnel Optimal Performance (TOP) System. This system utilises a specific algorithm to model the furnace and recommends a specific pattern of opening sizes across the entire length and height of the tunnel. Each side block contains a pair of openings containing cam locking features into which any one of 50 different sized inserts may be installed. Each opening in the entire tunnel is assigned a number from 0 to 50, and marked in some way, to ensure the proper sized insert went in the correct place (Figure 10). These inserts may be changed out in order to fine-tune tunnel performance during subsequent shutdowns. It is also possible to install and fine tune individual tunnels in order to improve furnace performance.

Conclusion

Blasch Ceramics and BD Energy Systems were able to oversee two separate installations, several hundred miles apart within two weeks. Once the existing tunnels were demolished and floor prepped, one 43 ft tunnel was assembled every 4 hours. With the installation of the Orifice Inserts and tying into the current structure at either end, approximately 3 days, start to finish, was required for completion of 9 tunnels (Figure 11). This makes it possible even during short outages to replace and fine tune individual tunnels. This fine tuning should improve performance for every tunnel so replaced. WF