Replacement of No. 4 Reheat Furnace Roof at Mittal Steel

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There comes a time when furnace roof replacement can be justified by the economics. Today's insulating and refractory materials result in energy savings at start-up and throughout the operating cycle. The results are reduced fuel consumption, reduced maintenance downtime and increased production.

In December of 2005 Mittal Steel USA in Steelton, Pa., began working with ETS Schaefer Corporation (supplier) in Macedonia, Ohio, to develop a new furnace roof for their No. 4 reheat furnace in the 35-inch mill. Mittal's (manufacturer) Steelton plant produces a variety of products including railroad rails, specialty blooms and forging-quality ingots. Processes at this facility include steelmaking, rolling and finishing. The supplier designs and builds ceramic-fiber heat-containment systems and had up to this point provided ladle preheater linings, soaking-pit cover linings and furnace doors to this plant. The existing furnace roof needed to be replaced, and, because of Mittal Steel's emphasis on fuel savings and the rising cost of natural gas, they decided it was time to look at an alternative lining material for this roof. The goals would be to reduce fuel consumption, reduce maintenance downtime and increase production, thereby increasing profitability.

As we discuss this project, there are two definitions that need to be stated for clarification. Heat Storage is the number of BTUs that are needed per square foot of furnace lining to bring that lining up to operating temperature. Heat Loss is the number of BTUs per square foot per hour that are lost through the lining.

The Furnace

The No. 4 Furnace was built in 1914 and has seen many different refractory linings over the years. The old furnace roof consisted of 10-inch thick 45P (plastic) ram suspended from 3-inch beams with hanger bricks and had approximate overall dimensions of 20.5 feet x 49.8 feet. The hot face of the middle of the roof was located approximately 3.75 feet from the hearth but angled slightly upwards at the end-burner walls. The roof also angled downward above the furnace openings to meet the back of the lintel blocks. The contours of the roof would be changed slightly with the new ceramic fiber design. This furnace is typically operated at 2350°F with the furnace pressure not exceeding 0.04"wc. There are six burners on each side of the furnace that rely on recuperative flue checkers for hot air circulation. The air flowing back into the burners from these checkers is approximately 300°F. These burners alternate firing between sides and have a horizontal flame direction, which results in some flame impingement on the hot face of the roof refractory. This was a design concern for the new lining system.

This furnace is shut down each weekend, so thermal shock had always been a major problem. The roof refractory material had been in place for at least 10 years and required frequent repair due to damage caused by thermal shock. The roof had been patched so many times that it began to look like an old quilt. The weekly cooling and heating of the roof was causing excessive failure of the refractory. This in turn created additional maintenance work and downtime.

Fig. 1. Picture of old roof

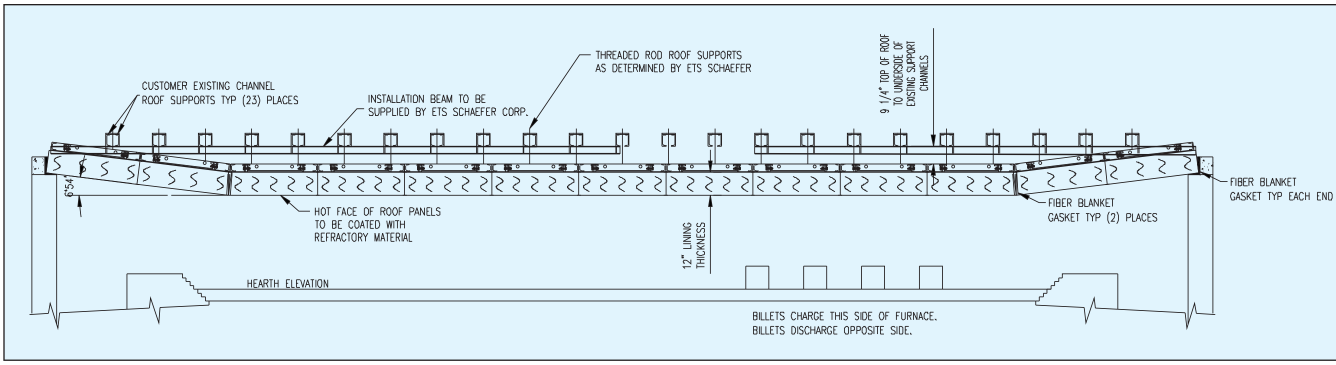

Fig. 2. AutoCAD drawing of new roof

Cold-face temperatures were measured at 400°F due to the inferior insulating qualities of ram refractory. These high temperatures were also indicative of high heat-loss values. The weekly shutdown of the furnace also created other concerns with the performance of the roof. Due to the high heat-storage values of ram, large amounts of fuel were required to bring the roof temperature back up for operation. When the manufacturer began to see rising natural gas prices, heat loss and heat storage became more important factors in the operation of this furnace.

Because of Mittal Steel's numerous concerns with this roof, they decided it was time for a change and wanted to look for something that would reduce maintenance and provide better efficiency inside the furnace. The supplier was brought in to present ideas for a new roof that would reduce fuel consumption and provide better resistance to thermal shock. Several concerns were raised including flame impingement, durability and possible mechanical impact. Moving the large roof panels into the furnace during installation would also be a challenge because there was no overhead crane available. In addition to considering all of these challenges, a theoretical fuel-savings analysis was also put together at the very beginning of this project to estimate fuel savings. This information was used to determine whether or not this project was justified.

The Project

This project actually began before the design work was completed. The manufacturer initiated the tear out of the existing refractory roof, and, once that was complete and the steel structure was exposed, the engineering work could be finished. The supplier sent in a field team to measure the furnace and to come up with a logistical plan for installation. Because of the age of the furnace, all of the dimensions on the drawings had to be confirmed to make sure they were accurate. Once all of this information was gathered, work began on the design drawings that would be used for construction (Fig. 2).

The new roof would consist of a 12-inch-thick ceramic-fiber monolithic lining mounted to a 3/16-inch-thick mild-steel-plate backing. The supplier decided to use their Perm+A+Lining panel system because of its stainless-steel anchoring system and its ability to be mounted to plate. The fiber blanket used had a maximum-use rating of 2600°F with a constant-use rating of 2450°F. This fiber blanket also had a density of 8 pounds per cubic foot. But once fabricated into the lining, which has a compression rate of 50%, the resulting finished density is 12 pounds per cubic foot. Fiber shrinkage of approximately 3% was anticipated, but, because of the monolithic design that allows no seams in the roof system, shrinkage would not create any problems. Once the panels were all installed and compressed against one another, the parallel folds would eliminate the joints between the panels. And the fact that there were no burners or flues in the roof would also help with the performance of the lining.

The overall dimensions of this new roof are 20.5 feet x 49.8 feet with the lining system consisting of 13 panels (each measuring approximately 20.5 feet x 3.8 feet). A steel structural frame was attached to the plate backing of each panel. These frames would provide support for the panels to prevent sagging and would also allow casters to be attached to each panel so that they could be tracked into the furnace. A special pallet was constructed for each panel so that a tow motor could be used to move them as needed and to provide protection from damage prior to installation.

Prior to installation, the supplier's crews arrived to "clean up" the furnace. The small steel beams and hangers used to support the ram roof were removed as well as all of the lintel blocks. Repairs were made to the tops of the brick walls to create an even surface for the roof to seal against. The jambs on either side of the furnace openings were also reconstructed using brick. The recuperative flue checkers on either side of the furnace were cleaned out and repaired to allow for proper flueing. Once all of the preparatory work had been completed, installation could begin.

Each panel was moved inside the furnace using a tow motor with extended forks to provide the necessary reach. Once in place, four casters on each panel were locked into two parallel tracks that were installed in the furnace roof structure. These lining panels could now be tracked into position. The outside panels were moved into place first with the center panel being the last one installed. Prior to lowering these panels onto the walls, a folded piece of fiber blanket was laid on top of the wall to create a gasket. Gaskets were also used between the center panels and the lintel blocks.

These gaskets would prevent any type of leak or hot spot. Once all of the panels were moved into their final positions, they were suspended from the existing furnace structure using threaded rod with fasteners. The roof panels were then welded together on the cold-face structure. The hot face of the lining was then sprayed with a refractory coating to minimize fiber erosion due to flame impingement (Fig. 4).

The Benefits

Now that the furnace is back in operation, an accurate evaluation can be made of the benefits of this roof system. Anticipated problems with flame impingement never materialized, easing any worries about fiber erosion. The maintenance headaches associated with thermal shock have been eliminated because of the fibrous nature of the new lining material. As a result, the weekly shutdown and cooling of the furnace will no longer create problems with the roof lining. Cracking and spalling have disappeared, which has reduced maintenance downtime and caused production to increase.

Fuel savings have been significant. In addition to being able to lower their set point by 125°F, the cold-face temperature of the roof has decreased to 215°F. Mittal Steel's light-off time for this furnace has also decreased from 12 hours to six hours, and fuel consumption to bring the furnace up to operating temperature has been reduced by 81%. Not only do these benefits provide reduced fuel consumption, but they also create a safer environment above and around the furnace. Last but not least, the production rate of this furnace expressed in tons per hour has increased by 15.5%. Increased operating profits associated with these benefits have more than justified the cost of this project (Fig. 3).

Roof Comparison

Roof Type	Operating Temp.	Burner Set Point	Heat Loss	Heat Storage	Cold Face Temp.	Light Off Time	Gas Consumption for Light Off
10" Thick 45P Ram	2350 °F	2325 °F	1,536 BTU/ SF/Hour	34,075 BTU/SF	400 °F	12 Hours	554,000 CF
12" Thick Ceramic Fiber Monolithic	2350 °F	2200 °F	232 BTU/ SF/Hour	3,984 BTU/SF	215 °F	6 Hours	105,000 CF

Note: Heat Loss and Heat Storage are theoretical values. All others are actual.

Fig. 3. Comparison spread sheet

Fig. 4. New roof

The Conclusion

The three primary goals of this project – reduced fuel consumption, reduced maintenance downtime and increased production – have been met due to better materials and design for this furnace roof. The ceramic-fiber lining in the roof has provided greater insulating qualities, lower heat storage values and better resistance to thermal shock. The manufacturer expects to continue to see lower fuel consumption, lower maintenance costs and greater production time inside this furnace. All of these outcomes will add money directly to the company's bottom line. **IH**

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Additional related information may be found by searching for these (and other) key words/terms via BNP Media SEARCH at www.industrialheating.com: refractory, ceramic fiber, thermal shock, fiber blanket, hot face, cold face, heat storage, heat loss