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Combustion Technologies Improve Melting-Furnace Productivity

Fig. 7. Roof-mounted Transient Heating burner directing heat downward and toward the melt bath

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New combustion technologies offer metals producers the ability to adjust the energy distribution profile and customize heat release to the requirements of a given melting operation. This article discusses how the unique capabilities of two new burners helped SDI La Farga increase productivity, decrease specific fuel consumption and significantly reduce burner maintenance time in its secondary copper-melting furnace.

SDI La Farga, LLC (SDILF) is a recycling operation that refines all types of processed copper to produce Cu-FRHC (fire-refined, high-conductivity) products. In 2014, SDILF had challenges with non-uniform heat distribution in their melting furnace, which led to uneven wear of the furnace lining and limited productivity. Their burners were also susceptible to frequent and prolonged maintenance delays from molten metal splashing and wear due to the corrosive atmosphere in the furnace.

SDILF's desire to address these challenges and achieve aggressive productivity targets led to the evaluation and implementation of unique combustion technologies capable of adapting to the diverse needs of the operation.

Forming a Baseline Using CFD Modeling

Figure 1 shows a schematic (top view) of the original configuration of the SDILF melting furnace. In the baseline operation, nearly 75% of the total energy input was delivered by two main burners (MB1 and MB2, located on the south side). The remaining energy (25%) was supplied using two auxiliary burners (A1 and A2, located on the east and west sides). The main burners used natural gas as fuel and oxygen-enriched air as the oxidizer, while the auxiliary burners used natural gas as fuel and pure oxygen as the oxidizer. All burners were aimed at the copper scrap (referred to as charge) located at the center of the furnace and introduced from the roof.

Given the single-pass flue-gas configuration (from south to north) of the furnace, it seemed logical to concentrate more energy on the south side of the furnace through the main burners. However, copper scrap is piled up at the center of the furnace during melting, which led to the main flames reflecting onto the refractory walls. The south side of the furnace was overheated, while the north side witnessed relatively colder zones, which slowed down slagging operations.

The reflection of the flames and overheated refractory required SDILF to reduce both the firing rate and oxygen-enrichment levels to minimize refractory wear – a change that lowered the production significantly below design capacity. At lower firing rates, the problem of metal splashing and wear on the burners became more serious.

Researchers at Air Products conducted computational fluid dynamics (CFD) simulations to gain an understanding of flue-gas patterns and energy distribution during the melting process. The temperature distribution calculated by the CFD modeling is shown in Figure 2. The hot spots seen on the east and west sides of the furnace matched initial feedback from SDILF about high-erosion zones in the furnace.

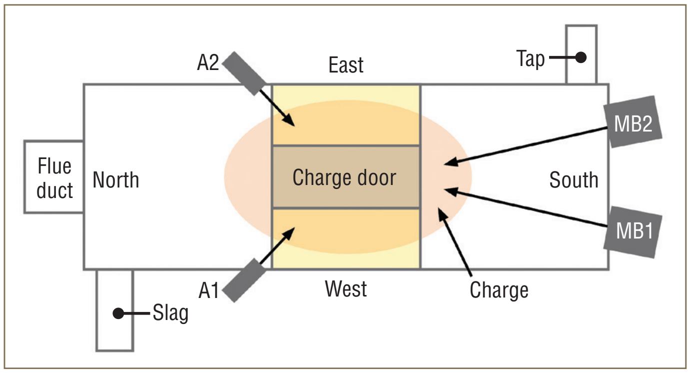

Fig. 1. Top view of the original configuration of the SDILF melting furnace

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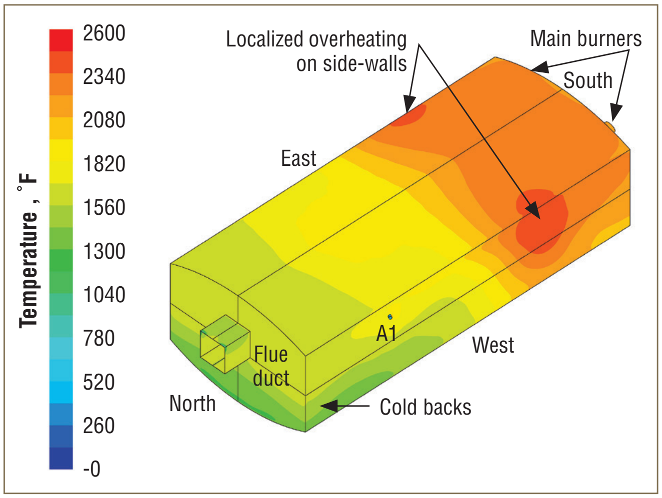
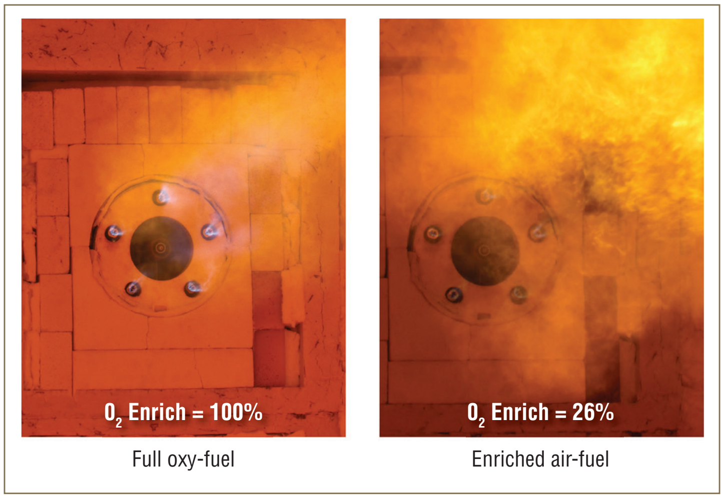


Fig. 2. CFD calculation of baseline SDILF operation (walls)



Full oxy-fuel

Enriched air-fuel

Fig. 3. Range of oxygen-enrichment operation of TEB technology

The modeling results were consistent with recurring maintenance needs experienced during operation, as well as refractory wear patterns observed during furnace outages. The flame impingement and uneven heat distribution caused aggressive refractory wear, especially on the south side of the furnace. The agreement between CFD results and observations during operation and outage gave SDILF confidence that implementing Air Products' technology could increase furnace performance.

Implementing Unique Combustion Technologies

Based on the understanding derived from CFD modeling, it was determined that the operation needed a combustion technology that provided a high degree of flexibility to adapt to the varying operating conditions within the furnace. The combustion technology needed to be capable of:

- Adjusting heat distribution to minimize overheating and limit flame reflection onto the walls and roof of the south side of the furnace
- Providing high gas velocities to minimize nozzle clogging from metal splashes
- Allowing ease of maintenance in the case of metal splashing causing blockage
- Adjusting oxygen enrichment and flame shape to allow optimal performance with both charge-pile and flat-bath conditions

Air Products' patented Tunable Enrichment Burner (TEB), which uses a combination of natural gas, air and oxygen, was selected because it addressed these requirements. The ability to adjust the oxygen enrichment to affect the flame shape is shown in Figure 3. Figure 4 shows the ability of the burner to modulate the heat-distribution profile, allowing for optimal operation both while the charge pile is being melted and at flat-bath conditions.

The burner design also minimizes direct interaction of oxygen with the melt, ensuring lower yield losses due to oxidation. The TEB is considerably smaller and easier to remove from the furnace in comparison to SDILF's original burner,

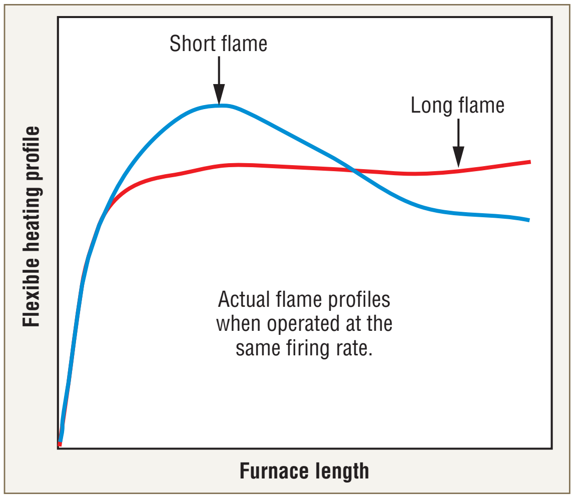


Fig. 4. Flexible heating profile of TEB technology

Fig. 5. TEB firing at Air Products' Combustion Lab in Allentown, Pa.

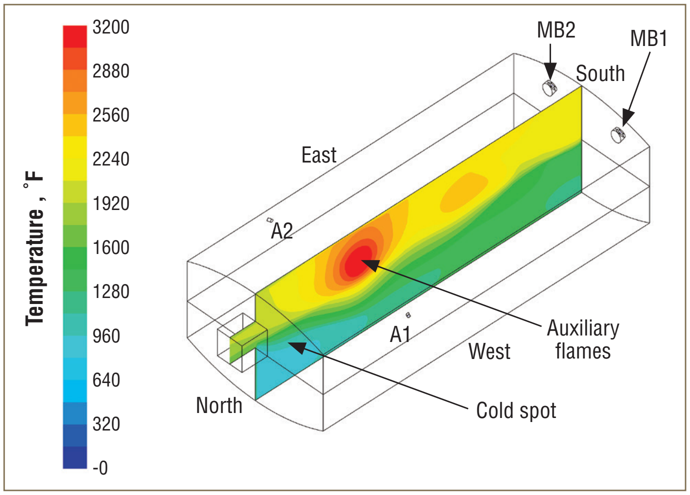


Fig. 6. CFD calculation of flue-gas temperatures inside the furnace during baseline SDILF operation

which allowed them to reduce burner maintenance downtime by 80% when splashing necessitated it. Additionally, the TEB's higher gas velocities significantly reduced the frequency of clogging due to metal splashing.

Figure 5 shows the momentum and well-defined structure of the TEB flame. Following deployment, the TEB delivered a 10% increase in overall productivity and a 15% reduction in specific fuel consumption.

SDILF originally considered a change of technology to improve the downtime associated with burner and refractory maintenance. The TEB accomplished both objectives. Burner maintenance, which was originally difficult and time consuming, turned into a 15-minute job that simply involved pulling the burner, clearing any obstruction and putting the burner back into operation.

Both SDILF and Air Products worked closely on burner modifications to create a design that facilitated easy removal and installation. The two teams worked well together to address each hurdle that arose in a timely manner. The reduction of burner maintenance time, reduced refractory wear and improved production were the key successes achieved by the TEB.

During the evolution of the TEB and installation designs, Air Products and SDILF discussed other concerns that the SDILF team had with the original auxiliary burners. These issues were related to inefficient energy utilization and high burner maintenance. With the measured success of the TEB, SDILF personnel were confident there was opportunity for further improvement.

Despite the flue being on the north side of the furnace, the baseline operation had constant problems with slag freezing and overheating of the roof of the furnace. While the orientation of auxiliary burners was effective at melting the charge pile, it did not allow SDILF to direct heat toward the north side of the furnace. The auxiliary burners also had maintenance and safety challenges because of the need for water cooling and frequent clogging from metal splashing due to their proximity to the melt bath.

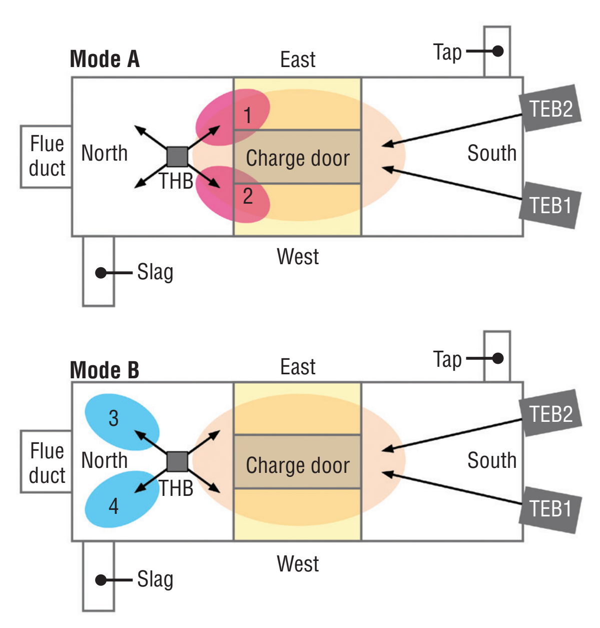


Fig. 8. Schematic of TEB and THB in operation at SDILF

The CFD modeling showed the interaction of the auxiliary flames with each other, the scrap pile and the main flames, which created localized stagnation zones (shown by the red spot in Figure 6). This drove heat to the roof and away from the melt bath on the north side of the furnace.

To address these challenges, a burner was needed that would be capable of:

- Operating without water cooling
- Being mounted away from the melt bath to reduce maintenance needs due to splashing, without compromising the performance
- Directing energy to the pile and toward the north side of the furnace
- Eliminating the stagnation zone by directing heat toward the bath and away from the furnace superstructure

Air Products selected the patented Transient Heating Burner (THB) to replace SDILF's two auxiliary burners. The THB is a roof-mounted, non-water-cooled, multi-flame oxy-fuel burner that can direct energy to different parts of the furnace as required (Fig. 7, front page).

The burner was programmed to operate as shown in Figure 8, where two flames are directed toward the centrally located scrap pile (mode A), and two flames are directed toward the north side (mode B), but always downward and toward the melt bath (Fig. 7, front page). During melting, the burner was operated sequentially with more time in mode A compared to mode B, such that 75% of the total energy was directed to the scrap pile and the rest was directed to the north side.

The TEB and THB technologies firing in tandem, combined with operational improvements made by SDILF, resulted in a significant increase in the output from the operation, with 15% higher productivity and 25% lower specific fuel consumption compared to 2014 baseline operations.

The original intent of the THB phase of the project was to replace the high-maintenance auxiliary burners (A1 and A2 in Figure 1). The THB dramatically reduced the time and effort associated with burner maintenance. Once the THB was installed, SDILF also noticed improved performance of the furnace from a melt-efficiency and slagging perspective. The auxiliary burners caused issues with furnace refractory because of their orientation and location. Replacing them with the THB alleviated this problem by removing those issues in the operation.

Additionally, Air Products collected and analyzed relevant process data during both trials by installing supplementary data-collection capability to augment what SDILF already had in place. The data analysis suggested the use of less-dense material, which influenced feedstock-material charging practices. The data also advised SDILF on how to run the burners during the changes in the feedstock material.

The information revealed by the data analysis and CFD modeling convinced SDILF to place additional sensors to optimize performance. This provided added benefit because it helped improve all aspects of the furnace operation.

Summary

SDILF had many limitations in the early years of their furnace, including inefficient use of gas, downtime of the furnace due to refractory wear and long maintenance delays due to inadequate access and ability to maintain burners.

Tunable Enrichment Burner and Transient Heating Burner technologies were proposed for implementation in SDILF's secondary copper melting furnace. Though the burners were replaced in kind, the unique capabilities of TEB and THB technologies were leveraged to address challenges and drive operational improvements.

Specifically, productivity increased by 15%, specific fuel consumption decreased by 25%, burner maintenance time decreased by 80% and furnace relines decreased by 20%. The implementation of TEB and THB technologies have made a significantly positive impact on SDILF's mill operations.

Despite the unique features of the SDILF furnace, the challenges it presented are relevant to other more-conventional reverberatory furnace operations. The TEB provided the flexibility to tune the flame and oxygen enrichment for charge-pile to flat-bath scenarios. In addition, its high gas velocities helped to minimize nozzle clogging from metal splashes, and the ease of maintenance ensured minimum downtime.

The THB also provided heat in the furnace where it was needed, eliminating cold zones. Each of these technologies enabled optimization of the overall process, proving the importance of choosing the right burner for the right application.

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