



Stephen Sherlock discusses the development and trials of an innovative combustion system that uses fewer burners, distributes the heat better and more efficiently and provides the opportunity for direct heat recovery, which cannot be achieved using pre-mix systems. The combustion control for this system offers the same accuracy of control as the best existing systems but with the potential for an even higher turn-down ratio, lower gas consumption improved safety and direct heat recovery. The burners provide improved heat distribution and more efficient combustion, resulting in optimised side heating. Real fuel savings result from the wider turn-down ratio and improved combustion efficiency, while the improved heat distribution results in enhanced thermal homogeneity of the glass leaving the forehearth.

The standard 'K type' firing system, which is the basis of most forehearth gas heating systems, is an arrangement of small pre-mix 'pencil' burners at 41/2 in centres down both sides of the forehearth channel (figure 1). This helps to control the heat losses from the slower sidewall glass flows but the heat release is still not ideal. It has been known for some time that this type of flame attains its highest temperature forward of its root, which puts the main heat release beyond the edge of the channel block. The narrow spacing between burners is therefore necessary to minimise this effect and provide, as near as possible, an even longitudinal distribution of heat to each side of the channel.

Development

For many years, Fives Stein has been working to improve and simplify the combustion system and has been successful in:

- Increasing the firing range by improvements to the air-gas mixing (from 3:1 to 6:1+ turndown ratio).
- Increasing the controllability by the use of variable speed fans.
- Improving the safety by using selfcontained zone systems.

To accomplish accurate air-gas mixing throughout the full firing range, a teemixer system has been developed using a proportioning regulator. This uses the air flow through an orifice plate to regulate the flow of gas to the mixer and offers better air-gas ratio stability over the full firing range than can be achieved with a venturi mixer. In this system, the tee-mixer is not a fundamental part of the air-gas ratio control but a means of pre-mixing the air and gas. Due to this, it was therefore possible to consider a move to nozzle mix burners.

It was also necessary to improve the distribution of the heat inside the forehearth itself, identifying the means



Figure 1: K-type forehearth firing system.

to introduce a slower flame velocity that could be distributed over a wider area. Many different arrangements of nozzle mix burners were modelled and several prototype burner blocks were created and tested to find out which of the various burner pipe/burner block combinations would correctly slow and widen the flame front to achieve the better sidewall heat release desired. The result is the PlanarTek burner block (figure 2), which replaces three premix burners with one nozzle mix burner.

The burner block has various features to promote the desired effect:

- An internal profile to generate an upwardly directed flame.
- A slotted outlet to give a wide flame front. >





Figure 3: CFD modelling results, showing temperature field in the forehearth cross-section.



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Figure 4: Prium PlanarTek burner system.

- An angled front burner block face (radiating heat to the side glass).
- A top relief (structural, to prevent loading on the slot).
- A rear sculpted shape for extra insulation.

A simulation model was built to represent a full forehearth combustion zone, approximately 8ft (2.44m) in length. The CFD modelling results (figure 3) show that the flame is lifted onto the underside of the roof, successfully concentrating heat onto the sidewall of the forehearth. The wider flame front is also slower moving and thus appears to give up more of its heat in the critical region of the forehearth. The flame is applied to the superstructure refractory via the Coanda effect and in turn, the roof radiates the heat energy to the glass. This results in more of the energy being retained in the forehearth structure and less being carried out in the flue gases. A natural lowering of temperature distribution to the centre of the forehearth with increased heating of the side walls is evident, resulting in improved cooling efficiency, where cooling air is required.

Prototype trials

In order to test this properly, a fullscale sub and superstructure heat/ cool zone was constructed. The test rig was first built with a firing system using conventional burners to establish a benchmark to compare the burner system against.

For each test run, the rig was heated up to normal forehearth operating temperature and then allowed to soak. Once temperatures were stable, a set of data was collected and then the temperature was increased. This process was repeated for a series of increasing temperature steps and then for corresponding decreasing temperature steps. Once the test was complete, the rig was cooled down and rebuilt with the PlanarTek burner blocks and the process repeated. The results showed that the nozzle mix burner provided more heat to the sidewall and did so using approximately 10% less gas.

Conclusion

An innovative forehearth combustion system has been successfully developed and proven on two independent operational installations. The combustion system distributes heat better and more efficiently and provides the opportunity for direct heat recovery.

In operation, the burner has attained its objective of providing heat closer to the forehearth channel sidewalls and it has done so using 10% less gas than the traditional pre mix/standard burner forehearth firing systems. The combination of the Prium flat flame burner blocks and nozzle mix combustion system has also shown itself to be more flexible, with the potential for further improvements in forehearth operation (figure 4).

Recuperative burner system

It has long been known that waste exhaust heat recovery can significantly improve fuel efficiency, as attested by its almost universal use on fuelfired melters. The fact that it is not used on forehearths, even when firing levels are high, is a direct result of the use of premix firing systems, where it is dangerous to use preheated air. This danger is removed with the introduction of Prium nozzle mix burners. On selected high fire zones, it has been shown that a simple



Figure 5: Prium PlanarTek recuperative burner system, with an adapted exhaust and tube in tube recuperator.

recuperative system, as illustrated in figure 5, can achieve additional fuel savings of 15% or more.

- This modern forehearth combustion technology delivers:
- A broad planar flame front at a low momentum to effectively maintain heat close to the sidewalls. Heat is then optimally transferred and focused on the slower flowing sidewall glass streams.
- The gas-air constituents are mixed and combustion takes place within the specially designed PlanarTek burner block chamber.
- The PlanarTek burner directly and evenly heats the superstructure refractories, creating a stable and consistent combustion environment.
- A 10% gas reduction in comparison to the premix burner and standard burner block for the equivalent heat input and temperature distribution.
- Prium PlanarTek combustion technology in conjunction with Prium forehearth BH-F 400 and proven zone control system significantly reduces gas consumption, while improving glass homogeneity.
- Prium PlanarTek combustion can be integrated with a heat recovery system to further reduce gas consumption.

Prium is a registered trademark of Fives.



Stephen Sherlock addresses the 41st ASEAN Glass Conference in Da Nang, Vietnam.

About the author:

Stephen Sherlock is Sales Director at Fives Stein

 Further information:

 Fives Stein Ltd, Didcot, Oxon, UK

 tel:
 +44 1235 811111

 email:
 fivesstein-uk@fivesgroup.com

 web:
 www.glass.fivesgroup.com