# Advanced Forehearth Heating system
# (Enhanced glass homogeneity and reduced fuel consumption).

Introducing the Prium® PlanarTek Forehearth Heating system
(Nozzle mix burner + planar flame burner-block).

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ABSTRACT
For many years now incremental improvements have been made to forehearth heating systems that have made them more efficient, more controllable and safer. Fundamentally; however, they are still mostly K-type firings systems, which were introduced in the 1920s. The system feeds a mixture of gas and air to rows of small pencil burners arranged down either side of the forehearth channels. The efficiency and distribution of the heat inside the forehearth is dictated and limited by this arrangement and further improvements are limited.

This paper discussesthe development and trials of an alternative combustion system that uses fewer burners, distributes the heat better and more efficiently andprovides the opportunity for direct heat recovery, which cannot be achieved using pre-mix systems. The combustion controls for this new 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, compared to the traditional K-type firing systems.

Real fuel savings result from the wider turn-down ratio and improved combustion efficiency, whilst the improved heat distribution results in enhanced thermal homogeneity of the glass leaving the forehearth.

INTRODUCTION
The control of the glass temperature in the forehearth has become critically important to the successful operation of today's high speed production lines. The ability to attain this level of control at high throughputs has been achieved by major improvements in structural design, especially relating to the application of cooling, use of superiorrefractory and mechanical components and utilisation of advanced microprocessor based control systems. The forehearth heating system too has improved, with better flow control and mixing devices. But, in the majority of cases, the final delivery of heat is still through the type and arrangement of burners first used in the 1920s. The materials may have improved but the fundamental principle of heat delivery has not.


Figure 1. K-type forehearth firing system

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 4½" centres down both sides of the forehearth channel. This helps 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 well forward of its root, which puts the main heat release beyond the edge of the channel block. The narrow spacing between burners are 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 we have been working to improve and simplify the combustion system and have:

- Increased the firing range by better air-gas mixing (from 3:1 to 6:1+)
- Increased the controllability by the use of variable speed fans
- Improved the safety by using self-contained zone systems.

To accomplishaccurate air gas mixing throughout the full firing range we have developed a tee-mixer system 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 only a means of pre-mixing the air and gas. It was therefore possible to also consider a move to nozzle mix burners.

However, none of these have overcome the fundamental issue of heat release inside the forehearth. To address this limitation we needed to look at the combustion process itself.

In addition to the advancements in control we realised we needed to improve the distribution of the heat inside the forehearth itself. In this respect we looked for a means to introduce a slower flame velocity that could be distributed over a wider area. Many different arrangements of 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 frontto achieve the better sidewall heat release we desired. The result is our new PlanarTek Burner Block, practically taking the place of 3 premix burners with one nozzle mix burner.

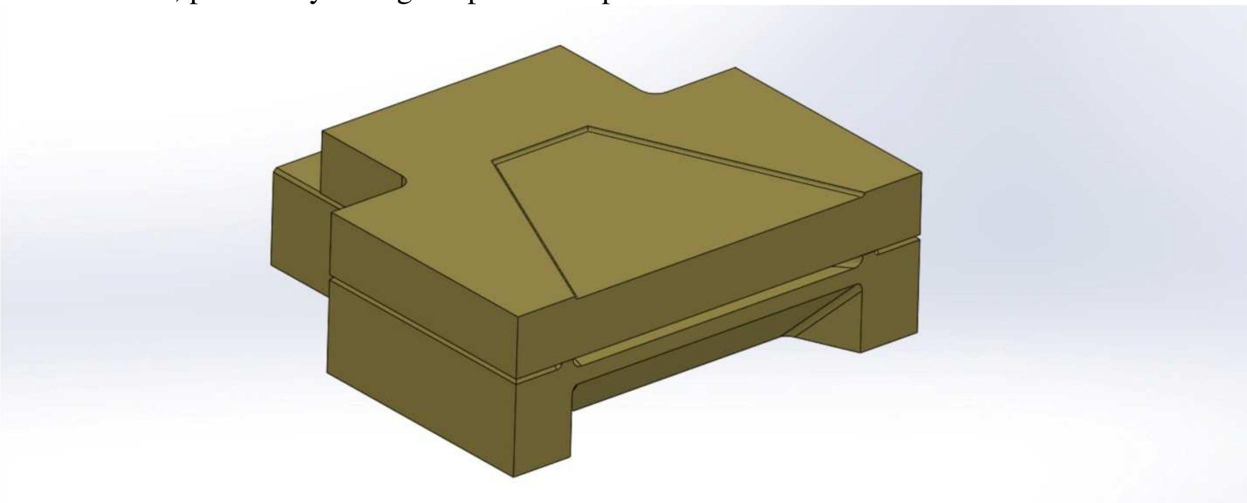

Figure 2. Model of the new PlanarTek Burner block design.

The burner block has various unique features to promote the desired effect.

- An internal profile to generate an upwardly directed flame
- A slotted outlet to give a  wide flame front
- 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 (extra Insulation)

We built a simulation model to represent a full forehearth combustion zone, approximately 8 feet (2.44m) in length. The simulation was basic at first to see if the burner block would distribute the combustion output in an even manner across the glass surface. From these initial results we gained the confidence to invest further resources into modelling studies with CelSian Glass and Solar.

PROTOYPE TRIALS

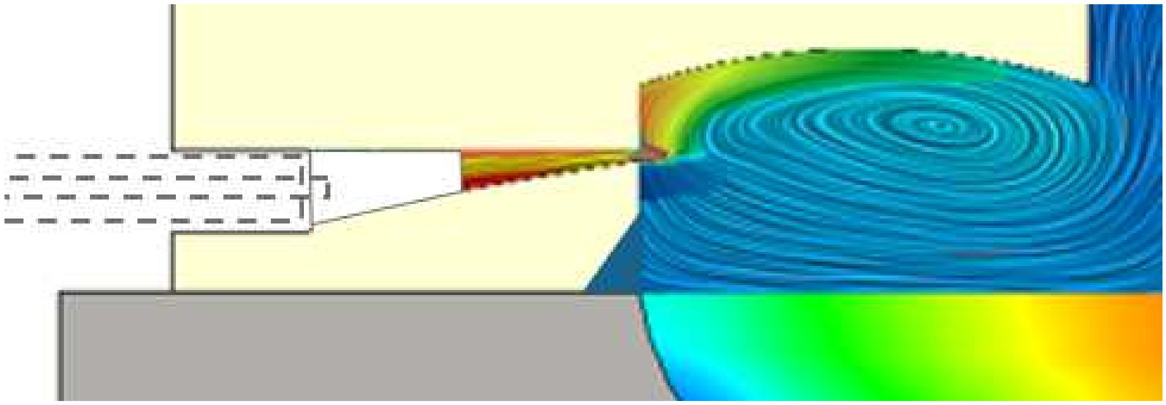

Figure 3. CFD modelling results showing temperature field in the forehearth cross-section.

The CFD modelling results, Figure 3, shows 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.

In order to test this properly, a full scale zone superstructure was constructed. The test rig was first built with firing using conventional burners to give a benchmark to compare the new 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 a corresponding decreasing temperature steps. Once the test was complete the rig was cooled down and rebuilt with the new burner blocks and the process repeated. The results showed that the new burner did provide more heat to the sidewall and actually achieved it using approximately10% less gas

Further tests and operational datahave confirmed the improvements and shown:

- The new burner provided more heat to the sidewall
- Excellent flame stability
- A wide turndown (8:1+), allowing greater flexibility
- Full clean combustion leading to a slower flow of combustion products, which causes less disturbance to the centre-line cooling.
- The use of the nozzle mix burner system has also proved to be much simpler to maintain than the conventional pre-mix system.
- The nozzle mix system is also inherently safer than a pre-mix system since no combustible mixture is being moved through the production environment.

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 theburner has attained its objective of providing heat closer to the forehearth channel sidewalls and it has achieved this 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. Prium® PlanarTek Burner system

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 fuel fired melters. The fact that it is not used on forehearths, even when firing levels arehigh, is a direct result of the use of premix firing systems where it is dangerous to use pre-heated air. This danger is removed with the introduction of the Prium® Flat Flame burners and, on selected high fire zones, we have shown that a simple recuperative system, as illustrated in Figure 5, can achieve additional fuel savings of 15% or more.

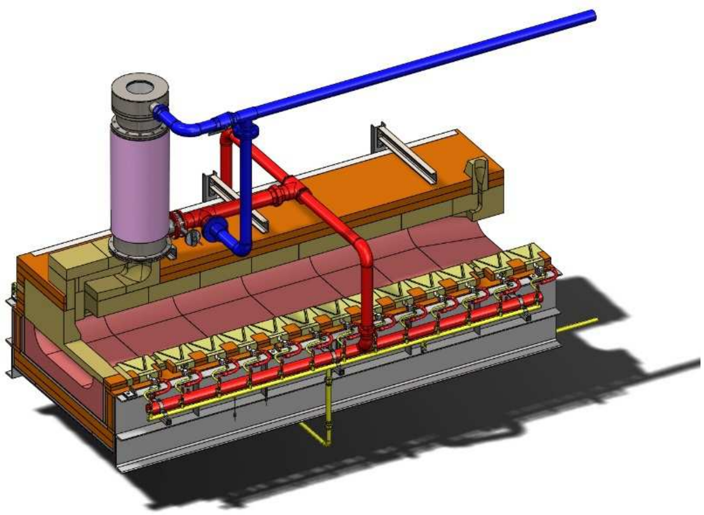

Figure 5. Prium® PlanarTek Recuperative Burner system with anadapted exhaust and tube in tube recuperator

Two full forehearth firing system using the now patented Prium® Flat Flame burner blocks and nozzle mix combustion systems are being successfully operated in the two factories in the BA Glass Group in Poland. This modern forehearth combustion technology delivers

- A broad planarflame front at a low momentum to effectively maintain heat close to theside walls. Heat is then optimally transferred and focused on the slower flowingsidewall glass streams.
- The gas-air constituents are mixed and combustion begins within thespecially designed PlanarTek burner block chamber.
- The PlanarTek burner directly and evenly heats the superstructurerefractories creating a stable and consistent combustion environment.
- A 10% gas reduction in comparison to the premix burner and standardburner block for the equivalent heat input and temperature distribution.
- Prium® PlanarTek combustion technology in conjunction with our Prium®Forehearth BH-F 400 and proven zone control system significantlyreduces gas consumption whilst improving glass homogeneity.
- Prium® PlanarTek combustion can be integrated with a heat recoverysystem to further reduce gas consumption.

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