Operations

GLASS PLANT AUDITS – THREE CASE STUDIES IN GLASS PRODUCTION PROBLEMS AND THEIR SOLUTIONS

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ABSTRACT

Over the multi-year length of a glass plant campaign, problems arise with root causes traceable to design, engineering, construction and the operational parameters which can change over time. This presentation's intent is to illustrate real-world production problems arising from those changing needs, practical solutions, and the value of non-resident process reviews such as performed by the member companies of the TECO Group. It often takes an experienced or non-routine study of the problem(s) to first determine the root cause, and then engineer how to best resolve it. Problems and solutions can include: refractory design/selection for maintenance, wear issues experienced during the campaign, hot repairs and temporary engineering solutions and operational process adjustments. This can typically result in glass quality improvements and campaign life extension through applying principles of operation optimization and improving maintenance techniques. The results are often significant improvements in glass quality, pack yields and the plant's bottom line. This presentation will discuss three problem instances - in a throated furnace, the waist area of a float furnace, and sidewall refractory replacement maintenance activities.

INTRODUCTION

Ask anyone involved in the day to day operation of making glass - sometimes it seems as if their plant is a living, breathing entity. And sometimes, they become ill…

GLASS PROBLEM ONE – FURNACE WITH A SORE THROAT

TECO was asked to assist with an increasingly evident non-conforming glass attribute from a throated furnace in Europe. The problem was a distortion line in the rolled glass sheet being called a "water mark" by plant personnel, which tested as a high density alumina-zirconia layer approximately 60-75 microns thick, shown below in Figure 1.

When first detected preliminary thinking was that it was a lamination problem (mechanical action on the glass), such as roller mark, lip issue, roller cooling problems, etc. Many initial actions were undertaken to find the root cause and eliminate this defect. These actions included:

- The cover of the lamination area was adjusted.
- Various machine positions were instituted.
- Several machine changes with different rollers were tested, smaller rollers with different cooling, etc.
- A bottom roller with chrome coating was used.
- Refractory lip was changed.

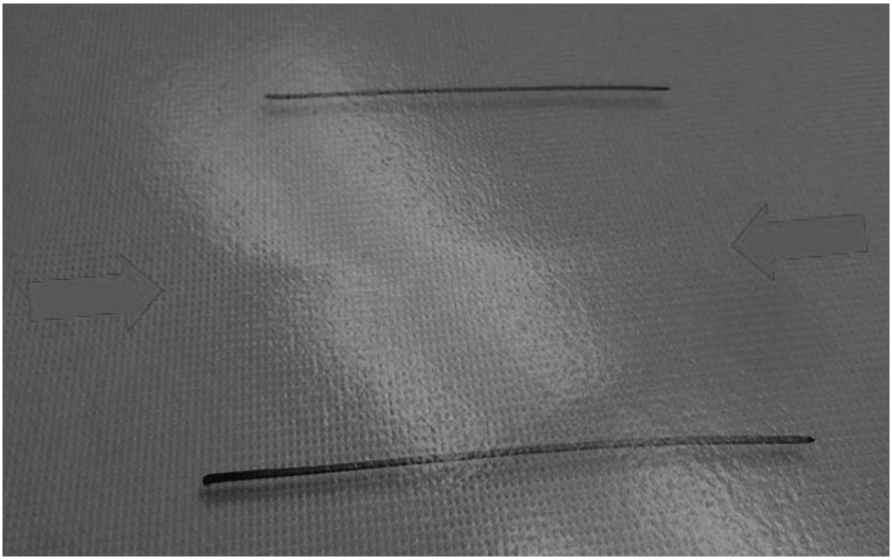
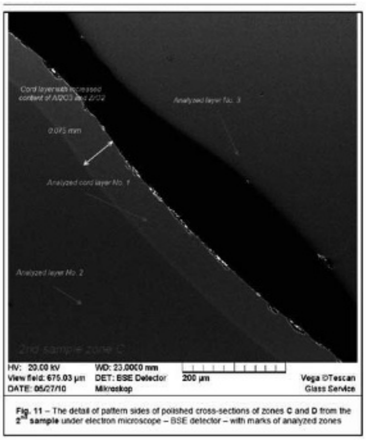


Figure 1. Optical inhomogeneity in the Ribbon

This is a typical operational progression, where the urgency of continuing glass losses force increasingly costly (in terms of lost production and/or equipment replacement) adjustments to the process in a search for improvement. Meanwhile a sample of the distortion line was sent out for laboratory analysis. The results are shown in Figure 2.

Based on the analysis report, an average of five composition measurements yielded higher levels of alumina and zircon content than what was normally found in the base glass. Therefore, increased focus was placed on the batch, the glass furnace and the forehearth operation and structures, which had been previously been operated consistently and at steady state for some period of time.

Technical service personnel from Toledo Engineering Co., Inc. (TECO) and Zedtec, Ltd. were invited to the facility to help the customer assess the situation. Together, the combined team completed several problem solving exercises and developed an evaluation plan. During this investigation, the physical inspection of the furnace interior was performed, as the viewing ports allowed. Figure 3 shows the interior of the Zedtec glass conditioning forehearth - the inspection of the forehearth provided assurance that there was no undo wear, the structure was intact and the glass level was as per the design of 50 mm below top of block.



Formula	Ox%
Na_2O	14,76
Al_2O_3	3,37
SiO_2	74,10
Ca0	7,04
ZrO_2	0,74

Figure 2. Analysis Results of the Glass Inhomogeneity.

Figure 3. Forehearth Inspection Port and Forehearth Glass Level Estimate

Finally, the inspection of the furnace interior provided that while the structure and superstructure refractory appeared to be in proper condition, the glass level as observed did not appear to be at the design level of 50 mm below top of block – there appeared to be much less glass freeboard, as shown in Figure 4. To check this observation, first a simple length of tubing was used as a water level, and when checked, showed that the furnace construction was correct, with both the furnace and forehearth top of block set to the same elevation. The actual glass level observation did not make sense, so not only was the water level used several more times, but an optical engineering level measurement was contracted locally, and these readings also verified the correct construction. Engineering 101 teaches us that liquids seek their own level, yet the visual observations appeared contrary to this. The team assembled and discussed the next steps.

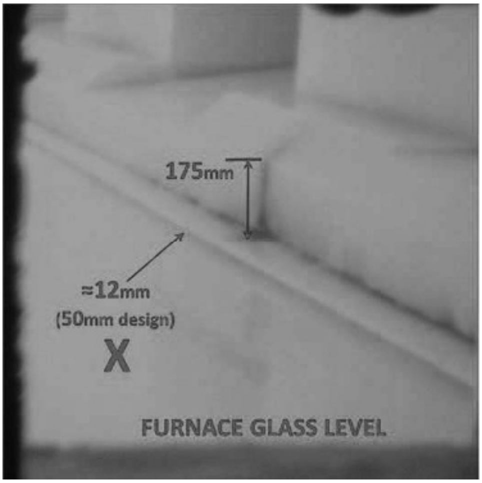


Figure 4. Furnace Glass Level Visual Estimate

Although seemingly improbable, a theory developed that perhaps there was restriction in the throat, possibly a buildup of denser glass that was ‘wicking off’ and presenting in the final product as the aforementioned watermark. The throat became the focus of the discussion, and a plan was developed to retrofit a drain onto the throat bottom, to remove a possible accumulated buildup of denser glass:

Plant management acted quickly to institute this solution. The results after draining the throat for a few hours, during which periods of inhomogeneous glass streaming were evident, was that the furnace glass level returned to the designed 50 mm below top of block. While seemingly improbable, an accumulation of denser glass in the throat area had slightly restricted the glass flow, requiring a higher furnace glass level and head pressure to maintain the operating glass level in the forehearth.

The distortion line in the glass was the presentation of this problem - a buildup of denser glass which restricted glass flow - and was solved by installation of a periodic drain capability in the bottom of the furnace throat, as shown in Figure 5.

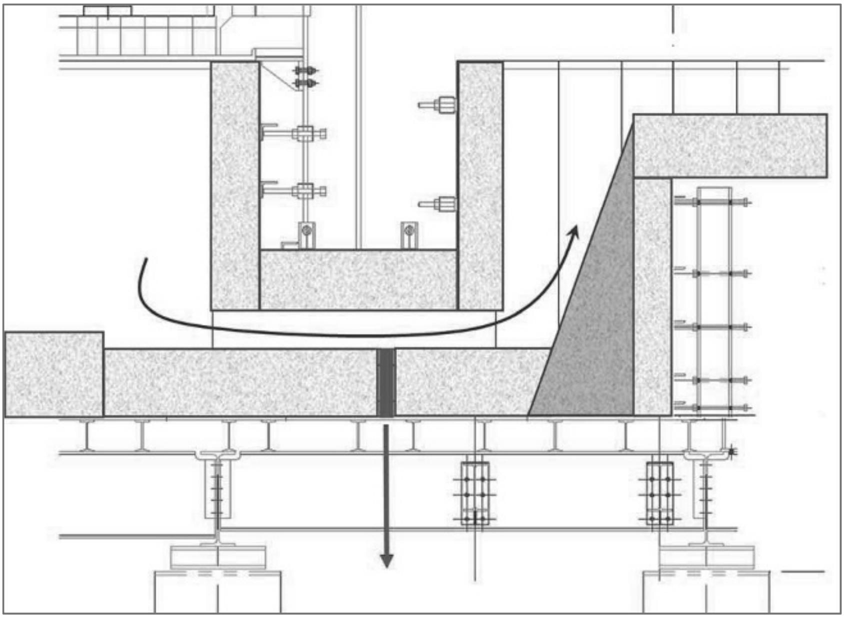
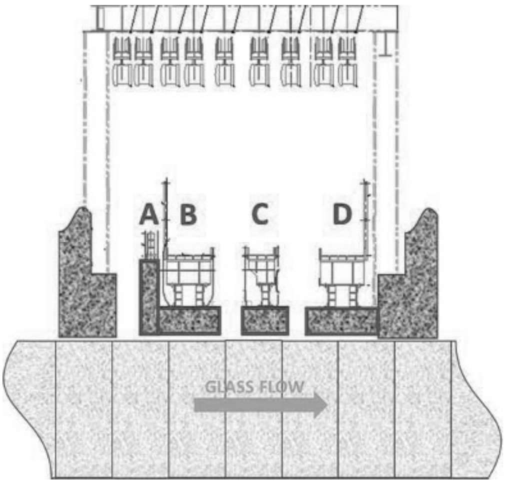


Figure 5. Representation of a Sunken Throat Bottom Drain, such as by KTG Engineering.

GLASS PROBLEM TWO – FURNACE WITH A SAGGING WAISTLINE

TECO was asked to assist a float glass manufacturer who had recently changed a large refractory structure in the waist area of their float furnace, to relieve a possible source of refractory contamination in their glass ribbon. In normal circumstances, this should be a straightforward procedure, the replacement of the A arch (see Figures 6 & 7 below).

The A arch, as can be seen in the Fig. 1, is a high and narrow design that helps shield the downstream area of the waist during normal openings of the upstream access area, in front of A, for routine maintenance in that area. The old A arch, replaced by the customer, is shown in Figure 8.



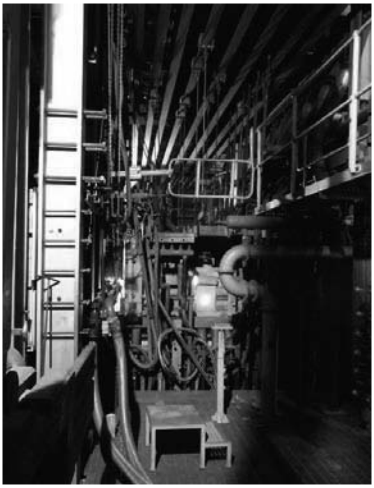


Figure 6. Layout of Waist Arches A through D

Figure 7. View of Waist, Right Side

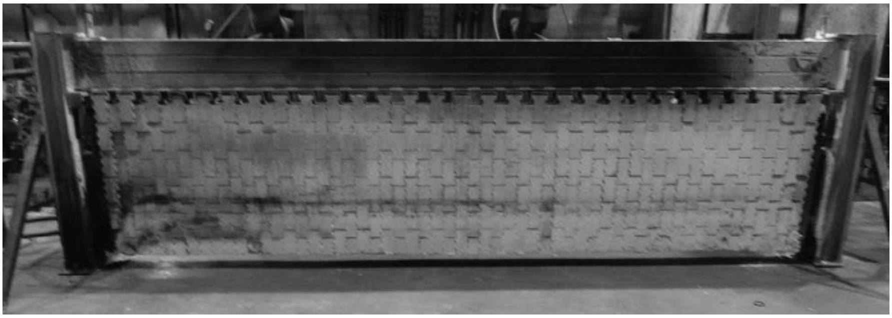
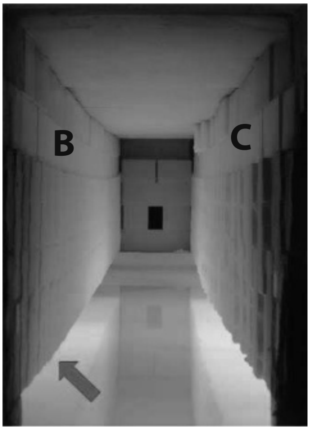


Figure 8. Old Replaced A Arch

However, during the replacement of the A arch, the support structure of the B arch was exposed to higher temperatures and radiant heat from the open A arch area. This is normally acceptable for the short period of the A arch replacement procedure, in that the B waist arch support steel is designed to be water cooled. Unfortunately, the steel assembly provided by a local supplier had developed water leaks when originally placed in service, and the B arch support beam was necessarily switched over to compressed air cooling to avoid leaking water damage to the refractory structure. Periodic inspections of the B arch had shown only slight sagging (Figures 9 and 10) while being cooled with compressed air, and it had remained stable for several years.



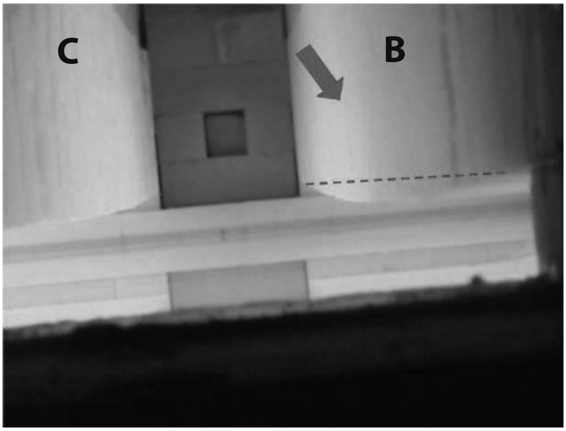


Figure 9. View from Right Side

Figure 10. View from Left Side

When the A arch was replaced, the B arch support was exposed, became overheated, and sagged severely during the replacement work, as shown in Figure 11. The B arch became a possible risk to the safe and efficient operation of the float glass process line going forward.

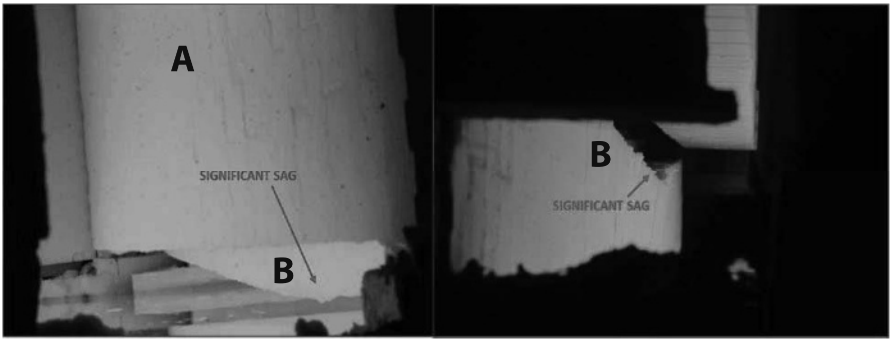


Figure 11. Views of the B Arch Maximum Sag during Replacement of the A Arch

With the discovery of the damaged B arch, TECO was asked to provide its expertise and participate in the emergency plan for the replacement of the B arch, which also supports an equipment access walkway above the arch. In general, this waist area is a fairly crowded space (see Figure 7 above). The new B arch refractory assembly had to be carefully preheated in order to sustain its introduction into the elevated temperature of its position in the furnace waist area. The procedure which was developed by the team was to transfer the new, preheated B arch into position simultaneously with the removal of the old B arch, and with the reintroduction of water cooling of the new B arch steel support structure. Therefore, the team carefully considered all aspects of personnel safety and staffing, mechanical structures, refractory heating requirements, piping, equipment logistics, and operational adjustments, along with risk assessment and contingency planning.

The new B arch was preheated in a temporary kiln built proximate on the operating floor, and when fully heated it was insulated, lifted out of the heating area, chained to the old B arch, and as the old arch was lifted and removed to the left, the new B arch followed from the right side into position. In Figure 12 below, the old B arch is shown when removed from the waist. The over-heated area of the beam is evident in the center, as well as some of the permanent sagging of the refractory that resulted. Figure 13 shows the new B arch in place.

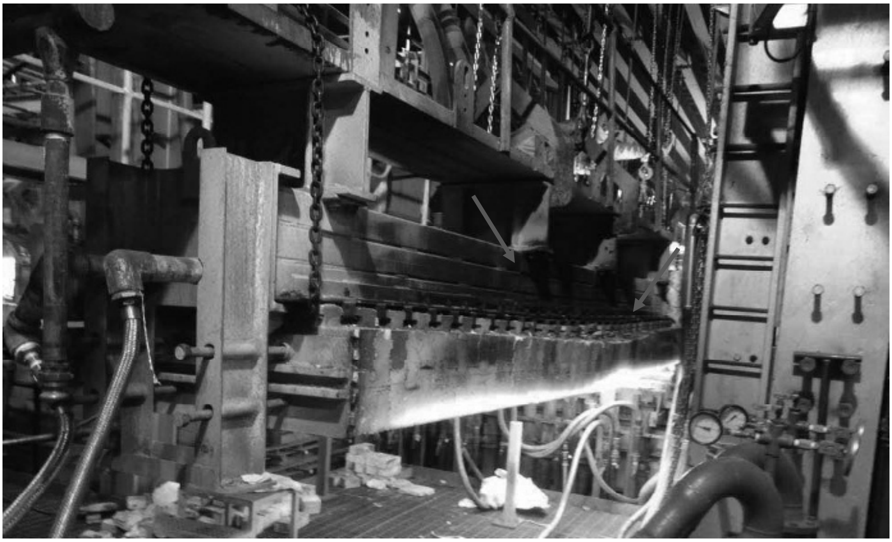


Figure 12. Old B Arch Removal from the Waist, with New B Arch being Set in Place from the Right Side

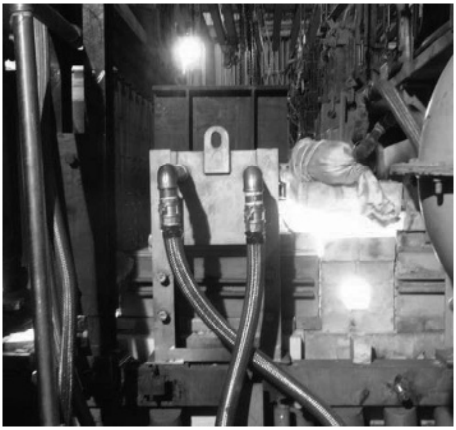


Figure 13. New B Arch in place, with Water Cooling

The procedure was executed quickly and efficiently as planned, resulting in a new, secure and stable refractory structure in the float furnace waist area. No further issues were reported afterwards.

GLASS PROBLEM THREE – FURNACE HAVING ITS BOWLS TAKEN OFF

TECO was asked to assist a float glass manufacturer with the removal of the glass level bowls in their furnace design, when it was determined that these aging structures were highly worn and a source of glass loss. The physical removal work was to be performed during a routine maintenance hot-hold of the furnace. Working as a team, a concept was jointly developed and planned in detail.

Glass level bowls (GLB) have been built into furnaces in the past, primarily for the utilization of nuclear level detectors, and even farther in the past, as a structure called a dry dock alcove when ceramic floaters were used in the waist as a skimmer, prior to the adoption and use of water cooled waist pipes, as shown in Figures 14 and 15. As can be seen in Figure 16 below, the GLBs do not contain the full depth of the glass, however, their removal and replacement with standard height furnace sidewall refractory, meant that the entire depth of the molten glass in the furnace would be exposed, and therefore needed to be reliably constrained.

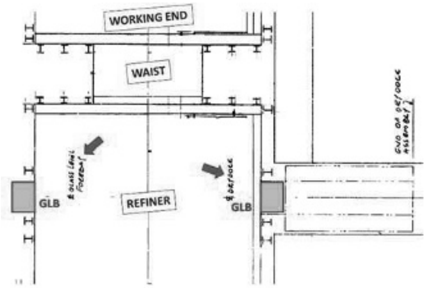


Figure 14. Typical Position of GLB Shown in an Old Furnace Drawing

Figure 15. An exterior photograph of the Old Furnace

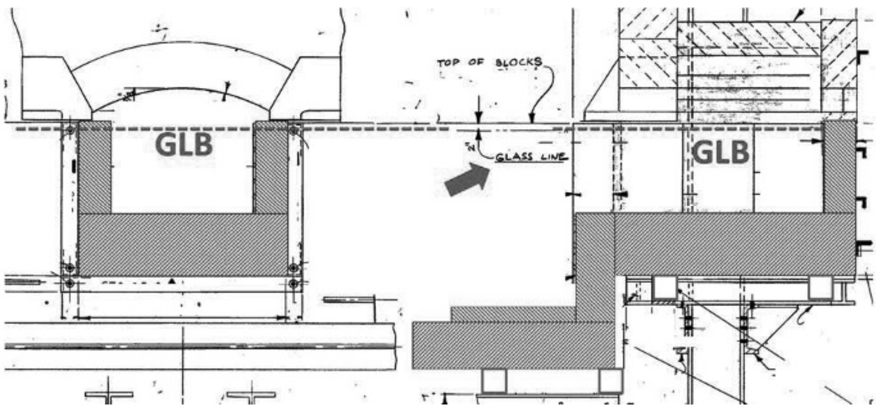


Figure 16. End View and Centerline View of a Typical GLB Construction

The glass level in the furnace was planned to be reduced only a few inches for the work, resulting in several feet of molten glass still requiring safe containment, as shown in Figure 17.

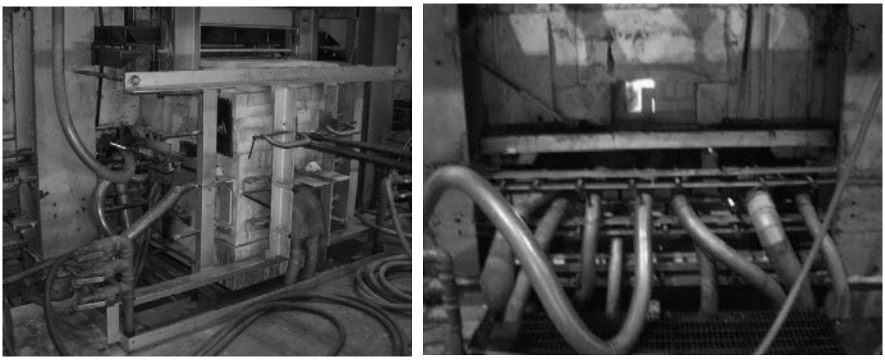


Figure 17. Left: Left Side GLB before the Work; Right: Work Nearly Finished after its Removal

To accomplish removal, a procedure to insert water lances directly into the molten glass was developed, in order to freeze the glass and secure the four to five-feet wide opening that was required. Water lances are used for similar applications in smaller furnaces, but this is atypical for a large float furnace containing approximately 1500 tons of molten glass. The application of the water lances also had to accommodate a clear working area for maximized personnel safety, and of course, facility protection from any molten glass leak. The steps of the work are highlighted in Figure 18.

Figure 18. Left: First Water Lance Readied after GLB Superstructure Removed; Right: inserted (R)

As a result of water being introduced directly into the molten glass depth, the steam being produced initially caused significant eruptions and displacement of the normally calm glass surface. The area of glass in the furnace in front of the GLB was monitored and evaluated for the planned for amount of cooling required to stabilize the area in order to contain the furnace molten glass and allow complete removal of the GLB and lower furnace sidewall blocks in this area. Once judged secure, the demolition was completed. These steps are presented in Figures 19 – 21.

Once demolition was completed, the furnace sidewall area was cleaned and prepared to accept the new replacement refiner tank wall blocks in this area. Half height blocks were utilized, in order to facilitate their safe and secure placement. Older furnace designs often used two course construction in the refiner areas, and this was judged acceptable for meeting the remaining campaign requirement.

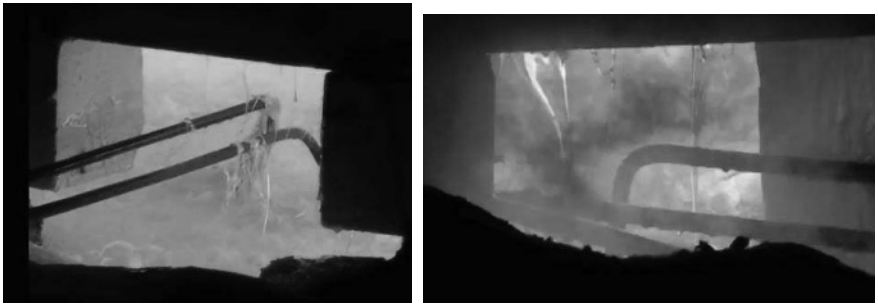


Figure 19. Second (L) and Third Lances (R) When Initially Placed

Figure 20. Water Lances Placed via. the GLB Opening

Figure 21. Left: Area of Concern in the GLB Furnace Inside Corner; Right: During Demolition. Bright orange spots of hot glass can still be seen on the right side.

After all refractory replacement work was completed and the steelwork secured, the water lances were removed and the same procedure was successfully followed once again to remove the GLB on the other side of the furnace. Figures 22-24 show the progress.

Figure 22. Left: First Block Placement; Right: Ready for the Last Sidewall Block

Figure 23. Interior View as Work Neared Completion. Note: Due to the rapid exposure of the large tank wall block into the operating furnace high temperature environment, some block corner spalls occurred.

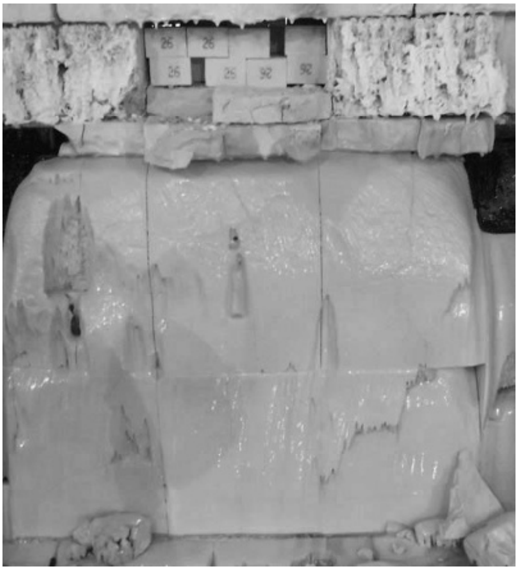


Figure 24. Secure Replacement Refractory (shown at cold repair inspection, after three full years of service)

SUMMARY

These three examples are representative of situations encountered during a glass plant's operating life. They are somewhat 'episodic' and rare at each facility, in that these types of problems occur infrequently during a long furnace campaign. Glass plant operators may wish to team with qualified glass plant engineering companies, experienced in current 'best practices', for added expertise and guidance when needing to assess and solve such problems.

ACKNOWLEDGEMENT

TECO wishes to gratefully thank their customers, who kindly granted their permission to use this information.