The influence of forehearth design on glass conditioning

Better cooling can extend tonnage, weight and temperature ranges says John McMinn.*

Glass conditioning requires the concurrent removal and addition of heat to the molten glass through relevant systems. It is one of the most influential factors in glass forming since it has a great impact on machine speed, forming process and pack rate.

In modern forming processes, the rejection rate and the requirements for faster machine speed are inherently linked to thermal homogeneity in the gob and, by extension, to the efficiency of the forehearth conditioning system.

Of the 100 or so bottle defect types identified to date about 50% can be related to the temperature and homogeneity level of the glass. Some of these defects are attributable to the forming machine, some to the feeder mechanism, some to the furnace and some to the forehearth. Those linked to the forehearth are mainly due to lack of thermal homogeneity and temperature stability.

The limited data available indicates that up to 3% of production is rejected due to poor thermal conditioning in the forehearth. Tonnage is also lost by related machine speed restrictions.

The forehearth contains a glass stream that shows three dimensional temperature variations. With the internal superstructure geometry, the heating and cooling subsystems dissipate the thermal inhomogeneity within the glass stream. The system should also produce a gob at a temperature appropriate to the forming process irrespective of instabilities in the distributor or adjacent forehearths, or of environmental changes.

Forehearth designs fall into three main categories according to how they are cooled. Muffle cooled forehearths use heat transfer plates in their superstructure above the central glass stream. The plates are covered by a longitudinal refractory muffle. The central glass stream radiates heat to the cooling plates, which are cooled by airflow through the muffle.

By automatically controlling the flow of the cooling air through the muffle, the amount of heat removed from the glass can be controlled. There is no interaction between the heating and cooling components due to their physical separation.

▸ Damper in action.

But the amount of heat in the forehearth is directly related to the number and size of the embedded heat transfer plates, and the number of plates that can be used is restricted due to structural integrity considerations. Some of the roof block area is unavailable for heat transfer limiting the responsiveness of cooling and conditioning.

Radiation cooling has been used since the forehearth was introduced. It works by exposing large portions of the central glass stream to the ambient atmosphere via openings in the forehearth roof. The main advantage of the system is the theoretical speed of response that is dictated by the Stephan-Bolzman formula. But the heat loss in such systems is large and difficult to control, with a danger of overcooling. There is also potential for external debris to enter the glass stream.

▲ Emhart's 340 forehearth offers wider ranges of ware.

Direct cooled forehearths have the cooling air injected directly into the forehearth combustion chamber. In theory all the roof area is available to the cooling system and the response time of the cooling system is much higher than that of a muffle system.

But the responsiveness of the system is limited. Only a finite amount of cooling air can be injected into the system without contacting the glass surface. There are also disadvantages for conditioning properties.

Air cooled forehearths with direct forced convection cooling have no mechanism to separate the heating and cooling components in the forehearth.

The advantages of direct and indirect forced convection forehearths have been combined to overcome their disadvantages in the Emhart Glass 340 forehearth.

The 340 employs a unique simultaneous dual cooling system which combines muffle cooling and direct forced convection cooling. Derived from a common source and operated concurrently, the relative airflow rate of the muffle and direct cooling systems is approximately four to one.

Each cooling zone has four automatically controlled side exhaust flues, an automatically controlled direct cooling air exhaust flue over the central glass stream at the end of the zone, and a static muffle cooling exhaust flue.

Control of the five-flue automatic exhaust configuration effectively determines the flow of cooling air and combustion gases both longitudinally and laterally within the forehearth chamber. This controls the relative surface temperature of the forehearth roof blocks and the glass stream, providing a powerful mechanism to ensure tight control of the thermal conditioning process allowing the selective input or removal of heat from the glass.

This configuration also provides an unprecedented degree of cooling power, not merely for large tonnage production. The ability to remove large quantities of heat from the glass allows much higher grades of insulation to be used.

Higher substructure and superstructure insulation levels reduce structural heat losses and significantly improve conditioning when operating at lower tonnages. Therefore the increased cooling capacity can be exploited to expand the tonnage range. It also extends gob temperature and entry temperature ranges.

The Emhart Glass 340 Forehearth has been successfully used in an application in which the range of ware required was 85g to 1382g. The forehearth easily and quickly responded in this weight range, and could have comfortably exceeded it.

The 340 is an important contribution to the forming process and a significant advance in forehearth technology. Glass International

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