Glass conditioning flexibility and the new Emhart Glass 340 Forehearth

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In 2002, Emhart Glass launched an advanced forehearth development programme to provide the glass container industry with a highly flexible glass conditioning system. The goal of this programme was to exceed the cooling and heating capabilities of the current crop of forehearth products. To this end, staff from the company studied the various designs that are used throughout the industry, reviewing the advantages and disadvantages of each technology. In the end, the company introduced a new forehearth product that exceeds the current standards with increased operational performance and fuel efficiency.

Cooling design review

The three types of cooling schemes are currently used in the glass container industry – free radiation, internal cooling, and muffled cooling. Each of these design concepts was evaluated to determine its relative advantages and disadvantages with respect to other methods.

Free radiation designs employ openings in the roof to allow heat from the glass to radiate to the surrounding space. These designs have the highest cooling capability, but they also proved to be the most difficult to control. As a result, free radiation designs produce the highest level of disruptive convective movement within the glass stream. This cooling method requires openings in the forehearth roof that must be highly controllable in order to provide even cooling over the entire central section of the molten glass stream. Emhart Glass designers concluded that, while free radiation cooling is a good method for dumping heat, it has limited use in an advanced thermal conditioning system.

The second design theory examined was the internal cooling method. This type of design injects a stream of air into the rear central portion of the forehearth cooling zone. The cooling air scrubs the internal central roof refractory, lowering its temperature and allowing the molten glass to radiate heat to its surface. The advantages of this method were overshadowed by one major disadvantage. The cooling gases become intrained with the side combustion gases in the forehearth, thus reducing the overall efficiency of this design. Additionally, since this method injects cooling air into the forehearth, the atmospheric mix above the

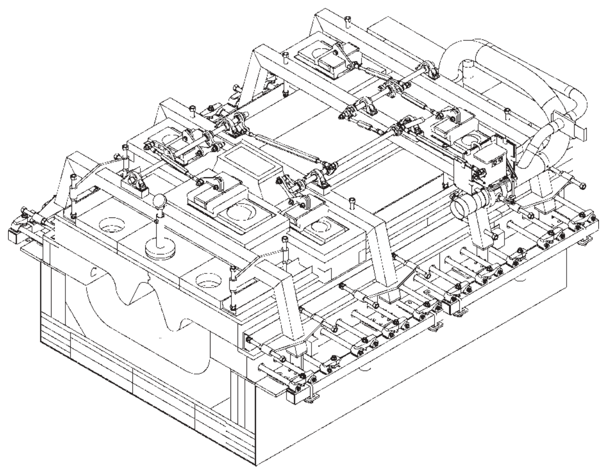

Figure 1. *The Emhart 340 Forehearth*

glass is changed, which may present a problem for amber production.

The remaining method, muffled cooling, was pioneered by Emhart Glass. It uses a thin refractory radiation plate that is set over a hole in the forehearth superstructure roof. A refractory cooling tunnel is then placed over the radiation plate and cooling air is injected into the tunnel to cool the top side of the plate. The heat is removed through the plate by the passing cooling air over the plate's surface. The advantage of this system is that the internal atmosphere is maintained, but the amount of cooling capacity is dependent upon the total surface area of the plates.

Early in our study, it was recognised that maximum cooling capability could be realised through a *combination* of cooling methods. The free radiation cooling method was eliminated quickly as it produced too many control problems for good glass conditioning. The study of the internal cooling scheme using computer simulations showed that through proper placement of the exhaust flues and control of the internal pressure within the forehearth, the problem of mixing combustion and cooling air could be overcome.

The 340 Forehearth design

The Emhart Glass 340 Forehearth was designed based on our analytical and computer studies to possess a unique dual cooling scheme that combines an advanced

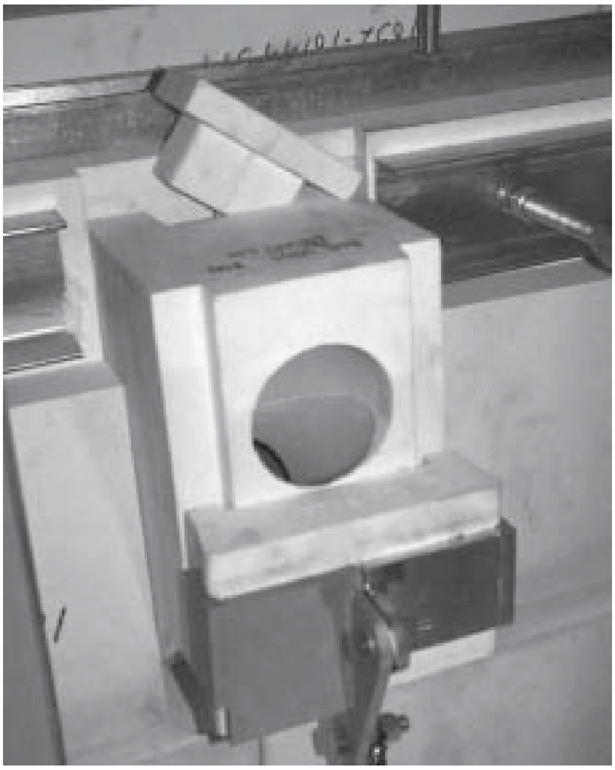

Figure 2. *Cleanable damper/flue block*

Figure 3. Range of containers produced on a Single 340 Forehearth

form of internal cooling with a muffled cooling design. Early studies indicated that this dual cooling design would provide a 20% increase in cooling capability over a typical muffled cooling design. An advanced damper control system was added to control the internal back pressure within the forehearth, and to also provide a means of heating the central glass stream. A high pressure combustion system with increased heating capacity was designed to manage the heat losses in the forehearth and provide controllable heating of the central glass stream. The new 340 design is shown in Figure 1.

The 340 Forehearth inherited many of the basic features found in the 540 Forehearth. For example, the cross sectional shape of the refractory roof is the same design as that used in the 540. This shape divides the molten glass stream into three unique areas. The two outside areas are used for heating, and balance structural heat losses while the central section cools the hotter glass stream core. This highly optimised roof design provides outstanding separation of combustion and cooling gasses within the forehearth.

As for flues, the 340 Forehearth is designed with five controllable openings. The four side exhaust flues control back pressure in the side combustion chambers, while a central damper is used to adjust the internal cooling air exhaust opening. All damper movements are regulated by a single control input that positions the cooling and combustion dampers in unison. The damper control motion also moves the control valve for the cooling air supply to provide the correct amount of cooling flow. Cooling air that is modulated by the control valve is immediately split upon exiting the valve into two feed pipes. One is a large (10– 15 cm, 4 or 6 inch) diameter pipe for the muffle cooling tunnel, and the other is a smaller (5 cm, 2 inch) diameter pipe for the internal cooling. The internal cooling pipe is fitted with a manual slide gate valve that can be used to reduce the internal cooling in the event of atmospheric issues within the forehearth.

All flue openings are fitted with cleanable damper blocks. Since damper blocks slide over the top of the flues to regulate the internal back pressure, and it is possible for condensate to form on the damper blocks, there was a concern that this foreign material might fall back into the glass and cause defects. The 340 Forehearth uses a new self cleaning damper/flue design that eliminates this problem (see Figure 2). Note that a clean out is provided to remove accumulated condensate material.

This new design's flexibility is further increased by the use of a heating control strategy. In cases where cooling is not required (e.g. low pull, or high gob temperature requirements), the side combustion damper blocks can be closed, and the central damper opened further to force hot combustion gases to the central chamber. This heating capability is highly effective in reducing job change times for low tonnage pulls with high gob temperatures.

Testing the concept

In early January 2003, the first 340 Forehearth was installed and commissioned. The forehearth was a 36 inch wide, 24 foot long unit consisting of a 6 foot equaliser and two 9 foot cooling sections. It was installed on a green furnace producing hollowware. The forehearth was sized to operate over an extremely wide tonnage and temperature range. Since its installation, the unit has consistently produced thermal efficiencies of 95% or better, and the customer has reported an increase in pack rates and faster job change times.

This 340 Forehearth has produced an impressive range of containers. The largest one produced on this

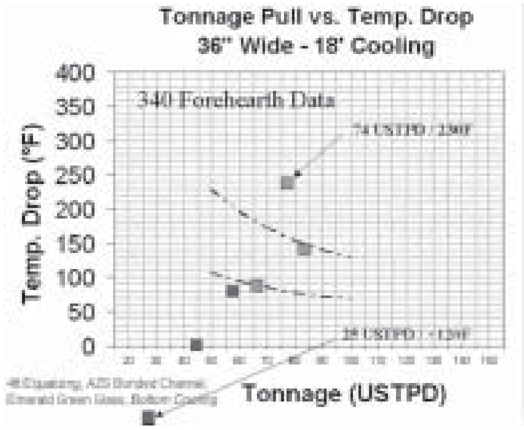

Figure 4. 340 operational ranges

line was a 1·4 kg, 4 l, handled wine jug and the smallest was an 85 g hot sauce bottle. A sampling of the containers produced on this 340 Forehearth are shown in Figure 3 below.

The tonnage and temperature ranges produced on this 340 Forehearth is also impressive. Figure 4 shows a typical 540 cooling curve range. The dashed lines indicated the predicted performance for a similar sized 540 forehearth with bottom cooling. The 340's operational data points are plotted in red and green. Red is for the heating mode, and green is for the cooling mode. Note that this 340 did not have bottom cooling.

Conclusions

The Emhart Glass 340 Forehearth system has evolved through intensive mathematical modelling and many years of experience at the cutting edge of forehearth technology. The system combines unparalleled cooling capacity with thermal conditioning, and it is capable of operating over an extended tonnage and gob temperature range.

This new design employs a unique simultaneous dual cooling system where a combination of muffled and direct-forced convective cooling is used. This configuration provides the forehearth with an unprecedented degree of controlled cooling power. In addition, the advanced flue control mechanism provides for centre heating capabilities, which extends the lower range of the 340 Forehearth – a feature that is extremely helpful for low pull, high gob temperature jobs and improving job change times.

The 340 Forehearth utilises the proven 540 cooling section roof block design to efficiently divide each cooling zone into three separate longitudinal areas. The central area is used to house the muffles cooling plates, and to contain the internal cooling airflow. The two outer areas are used to contain the combustion gases while operating in cooling mode.

Each cooling zone is equipped with five automatically controlled flue exhausts. These exhausts, in conjunction with the cooling air and combustion gas control valve, can be adjusted to direct the flow of cooling air and combustion gasses, both longitudinally and laterally, within the forehearth chamber. This control allows the mechanism to selectively input or remove heat from the glass, and it ensures tight control of the thermal conditioning process.

Whether applied to distributors or forehearths, the 340's design concept provides unparalleled thermal conditioning. It represents the future of forehearth technology – made available today by Emhart Glass.