Vital statistics of forehearth operation

According to John McMinn, in terms of forming problems and ware rejection, the design and operation of the forehearth are highly significant factors in the productivity of a glass plant. Forehearth audits determine the performance of a forehearth and its associated subsystems.

In 1976, the USA celebrated its bicentenary, Concorde introduced supersonic travel and slightly more prosaic, the author joined BGIRA (British Glass Industry Research Association) as a research physicist in the Glass Forming section to study heat transfer mechanisms in glass and to begin a life-long association with the glass industry.

After a change from research to industry, the majority of my career has been spent in the design and development of forehearth systems, being responsible for the design and implementation of several of today's leading forehearth designs, including the PSR 500 and the Emhart 340.

DESIGN OPTIONS

Throughout the 1970s, the choice of commercially available forehearth systems to container and tableware manufacturers was limited to two or three designs and the forehearth of choice for many was the BHF-400 Series. Today, with varying degrees of success and imagination, many more forehearth designs are available to the industry.

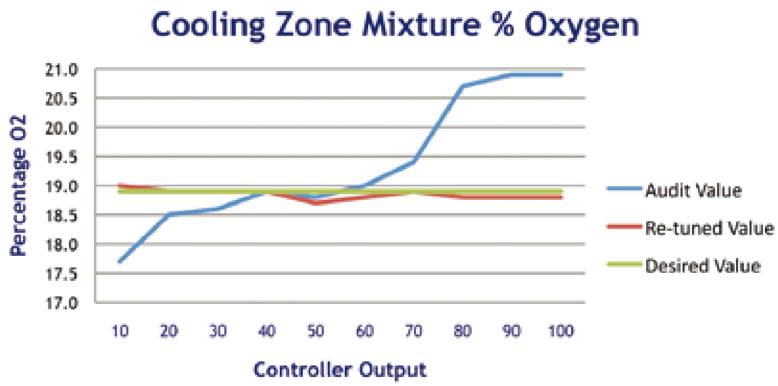
With such a choice available, how should a glass plant choose the 'best' forehearth? In practice, forehearth choice is largely dictated by budget and application. The tonnage and gob temperature range that a forehearth can accommodate is determined by individual forehearth design. The ability of the forehearth to thermally condition the glass is also very much a function of forehearth design.

However, as production tonnages increase within the confines of existing distributor and forehearth footprints, the merits of individual forehearth designs become more important. But what becomes equally, if not more important, is what happens after the design has been selected, the system installed and the commissioning engineer has gone home.

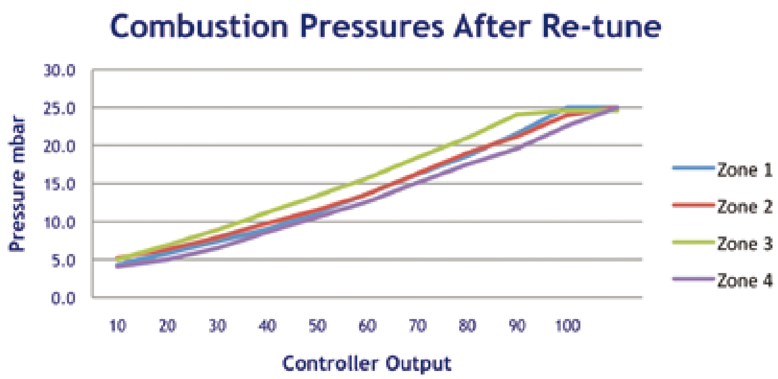
Approximately 100 types of defect have been identified, of which approximately 50% are possibly related to the temperature and thermal homogeneity of the glass and by implication to the effectiveness of the thermal conditioning properties of the forehearth design. What is patently obvious is that, in terms of forming problems and ware rejection, both design and the operation of the forehearth are highly significant factors in the productivity of a glass plant.

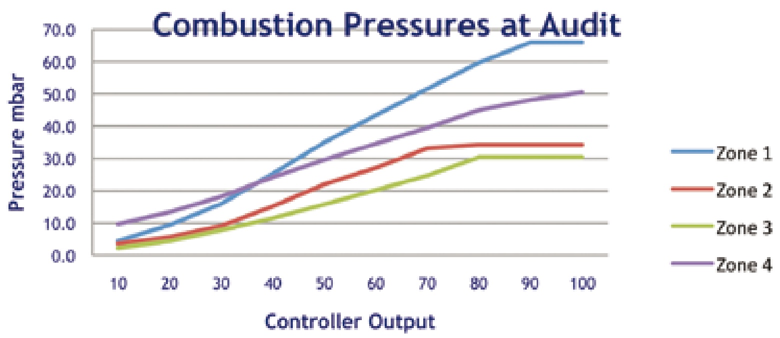
OPTIMISATION VIA AUDITS

Since its formation in January 2009, Forehearth Services has conducted audits on a variety of forehearths and forehearth designs across the globe. The first stage is to calculate and assess the maximum operational potential of the forehearth, based on the forehearth design and the capability of its cooling, control and combustion systems. The second stage is to establish the current operational status of the forehearth, while the third is to determine what steps are necessary to return the forehearth to the optimal operation and efficiency afforded by the forehearth design.



Example of audit retuning.





Another example of audit tuning.

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So, for the first vital statistic of forehearth operation – to date what percentage of the forehearths examined were found to be operating optimally? The astonishing answer is zero percent! In many cases, the forehearths were wasting fuel, unable to achieve the required setpoint, unable to accommodate the design tonnage range, producing thermally inhomogeneous glass or producing forehearth-induced defects. More importantly, the maximum achievable pack rates were lowered due to poor forehearth performance. Why does this happen?

The main reasons are normal operational de-calibration and system complexity. Forehearths are not static entities, operating via control motors and modulating equipment which have a natural tendency to de-calibrate with time. The initial settings installed by the commissioning engineer are changed to suit changing operational requirements. Unfortunately, in many cases repeated parameter setting drives the system further from optimum calibration. Maintenance routines and component replacement can also be a source of system de-calibration. Lack of maintenance or inadequate maintenance is also a common cause.

Forehearth designs have evolved in complexity to accommodate increasingly sophisticated forming requirements. Often, operators are given inadequate training from the system supplier, leaving them ill-equipped to deal effectively with system malfunctions. The introduction of new technology into a plant is often compromised by lack of proper understanding by the operator; indeed I have seen operators alter the operation of new forehearth designs so that they emulate the function of the forehearths they replaced.

CONTROL STRATEGIES

Forehearth control systems and control strategies in particular have evolved from simple discrete PID controllers to SCADA-based systems. With this increase in sophistication comes an acceptance that the data presented on a computer screen is inviolable. Few operators, it seems, question the logic of what the SCADA system presents.

It is rare to perform a forehearth technical audit and find that the system is operating sub-optimally due to a single malfunction or calibration. Usually, a variety of factors operate concurrently to compromise the efficiency of the system.

Despite the ubiquity of PID controllers in forehearth control, it is rare to find the correct PID terms being used. During forehearth audits, it was discovered that 75% of the forehearths examined were operating with inappropriate PID terms. (A recent paper suggested that of all control loops in operation, approximately 90% were operating with the wrong PID values for the process being controlled – so perhaps we in the glass industry are not so bad!) Experience gained during the audits and through past experience of forehearth troubleshooting indicates clearly that there is a basic lack of understanding of PIDs and their effect on the conditioning of the glass and the operation of the forehearth. It is clear that more operator training is required in this area.

Air/gas ratio and ratio stability are a source of recurrent problems associated with poor forehearth operation. Glass quality, forehearth control, forehearth response speed and gob thermal homogeneity are all compromised by inappropriate and unstable air/gas ratios. In many cases, this is due to the type of mixing system employed. Advances seen in cooling system and control system design have not universally been accompanied by advances in forehearth combustion technology. Many companies are still using combustion systems based on technology introduced in the 1930s. Other more advanced technology is offered by some forehearth suppliers with which it is possible to achieve and maintain a more stable and accurate air/gas ratio but at the moment, such systems are in the minority. However, assuming the system was correctly specified at the design stage, the accuracy of these systems, as with all combustion systems, relies on the calibration and maintenance of the equipment.

The amount of heat supplied to the forehearth decreases significantly as the air/gas ratio deviates from the required value. A combustion system operating with 20% excess air increases gas consumption by 4.6% and operating with 20%, excess gas increases fuel consumption by 24.8%. To add to the statistics provided by Forehearth Services technical audits, the number of forehearths found to be operating with a correct and stable ratio, ie a correct and constant ratio

Forehearth Services audit.

for all zones throughout the combustion pressure range, was zero %. However, the vast majority of forehearths were subsequently recalibrated successfully to provide fuel-efficient and accurate combustion.

A combination of inappropriate PID terms and inaccurate/unstable air/gas ratio can have a major impact on forehearth operation – and pack rates. However, it would seem that not all forehearth operators know what the actual air/gas ratio should be. The calorific value of natural gas varies significantly throughout Europe and determines the air/gas ratio, yet experience shows that only a small percentage of glass companies have calculated what the optimum air/gas ratio should be for their location, despite the fact that calculating the value is simple and the data required for the calculation readily available.

The relationship between the control system and individual zones of the forehearth is another vital link in the operation and efficiency of the forehearth system. Typically, high pressure combustion systems operate with a minimum pressure of 2.5 mbar and a maximum pressure of 50 mbar. The control and combustion system should be calibrated to ensure the linearity of each zone. It must be assumed that this link was linearised during the commissioning process. However, the post commissioning audits discovered that this link, assuming it existed, had altered greatly.

The implications of this are that the amount of heat available to each forehearth zone varied greatly with obvious detrimental effects on forehearth control and efficiency. The worst discovered had a zone deviation of 5 mbar to 50 mbar for 100% controller output and a deviation from 5 mbar to 20 mbar at minimum controller output. Again, this situation was easily remedied by careful recalibration.

ZONE SETPOINT SELECTION

Forehearth zone setpoint selection is a crucial function which massively affects the operation and efficiency of the forehearth. Unfortunately, this is another area that seems to be poorly understood.

The results of the audits indicate that almost 50% of all forehearths were operating with detrimental and inappropriate setpoint profiles. This is often made worse by the operator failing to consider the distributor setpoint profile when selecting the forehearth setpoints.

A rule of thumb often cited is that 60% of the required heat loss should be achieved in the rear zone, with the remainder in the front cooling zone. Those familiar with operating cascade control know that this maxim should not be applied blindly. Often, cascade control operates >

optimally, with the heat loss being divided equally between cooling zones. But for those without the benefit of cascade control, the setpoints should be set based on the incoming glass temperature and the temperature profile at the spout entrance. This is a vital element of forehearth control and Forehearth Services' operator training programme emphasises this subject.

Another setpoint maxim is that the setpoint profile from the throat to the spout should provide a decreasing temperature profile. At least this is universally true (and truer still if operating with amber glasses). However, the actual setpoint values and the zone-to-zone temperature decrease are crucial to both the operation of the forehearth and to the thermal homogeneity of the glass entering the spout.

Setpoint selection requires knowledge of the physical processes occurring within the forehearth as a result of a parameter change. Any change made to the forehearth by an operator should be done based on the ability to predict what effect the change will produce and the timescale within which the change will occur. Forehearth Services operator and technician training modules provide the basis to ensure correct setpoint selection.

THERMAL CONDITIONING

Thermal efficiency is a common yardstick used to quantify the ability of a forehearth to thermally condition the glass. Approximately 70% of the forehearths audited were found to have a thermal efficiency value below 85%. This is perhaps not surprising since if the efficiency value was acceptable, the forehearth would not have been selected for an audit.

Over-optimism of what the system can achieve is not uncommon. Forehearths are designed for a particular glass colour, forehearth entry temperature, tonnage range and gob temperature range. This is not to say that the forehearth will not be able to produce formable glass but the quality of the glass thermally will deteriorate as one or more of these parameters deviate from the design specification.

It is vital for forehearth designers to have accurate data regarding the above parameters but they must also make assumptions. These assumptions are normally made in collaboration with the customer but sometimes, they are wrong.

Throat or riser temperatures, forehearth entry temperatures, glass level stability and incoming glass thermal stability can determine whether or not the forehearth can function as designed. Validation of these assumptions is a critical component of the forehearth audit process.

Forehearth audits determine the performance of the forehearth and its associated subsystems. The audits provide the optimal operating performance based on the particular forehearth design and the external factors which affect it. They also provide the tools for returning the system to post commissioning status and with suitable training, can ensure the forehearth is operated optimally for the lifetime of the system. ■

Forehearth Services would like to thank the companies who commissioned forehearth audits. Thanks are also extended to the plant personnel for their valuable assistance and co-operation throughout the audit procedures. ■

ABOUT THE AUTHOR:
John J McMinn is Managing Director of Forehearth Services

FURTHER INFORMATION:
Forehearth Services Ltd, Swinton, South Yorkshire, UK
tel: +44 7850 328299
email: forehearthservices@gmail
web: www.forehearthservices.com