Forehearth control – Infra-red pyrometers or thermocouples?

John McMinn* describes how to measure forehearth performance and optimise performance.

I have been privileged enough to have spent 38 years in the glass industry and to have met and worked with glass plants in 74 countries. Apart from 12 years as a research physicist studying heat transfer in glass, I have spent the majority of my career designing a variety of new shiny forehearths including the PSR500 and the Emhart/Sorg 340.

As managing director of Forehearth Services I have spent the past six years looking at – well, shall we say less shiny forehearths.

Unfortunately forehearths don't remain shiny for long. They operate in a challenging environment hotter than the Sahara desert at noon and rained on by condensing mould dope. No surprise therefore that even the dedicated few pay infrequent visits to the forehearth platform.

Not wanton neglect exactly, but operating more on the basis of 'as needs must'. It is no surprise therefore that forehearth performance deteriorates with time. The problem is how does one measure forehearth performance? It can be hard to quantify and even more difficult to quantify and recognise deteriorating performance.

Forehearth Services has performed forehearth audits on more than 100 forehearths in more than 20 countries, and quite simply we measure forehearth performance. More importantly we identify the steps that need to be taken to return the forehearth and its combustion and control systems back to optimum performance.

Audits

Lack of performance is due to a combination of factors ranging from mechanical de-calibration to inappropriate forehearth operation – with quite a few stops in refractories, cooling systems and control equipment in between.

An audit comprises a holistic system of tests, analyses, and measurements of all functions relevant to forehearth performance including forehearth operation. When the audit data is analysed it provides a map of what needs to be done to optimise the forehearth performance.

The principal objectives of an audit are to increase pack rates, decrease energy wastage, protect plant equipment from improper operation and decrease the likelihood of a catastrophic, unscheduled shutdown.

Unsurprisingly, the overwhelming majority of clients that commission an audit do so because one or more of their forehearths is compromising production. Sometimes the reasons for poor performance are multi-causal and complex. In others the cause may be down to lack of training of forehearth personnel.

Blister is a common reason for commissioning a forehearth audit. The audit can, by a system of elimination tests, identify the origin and cause of the blister. The inability of the forehearth to maintain a stable gob weight is also high on the list of reasons for commissioning an audit. But, frankly, the problems associated with operating a forehearth optimally are abundant.

Infra-red pyrometers vs thermocouples

As an example, Forehearth Services has for a long time been advising customers operating with dark amber or green glass to avoid using infra-red pyrometers as zone control sensors. The advice is based on a great many forehearth audits where it has been shown conclusively that using an infra-red pyrometer, rather than a thermocouple, greatly compromises the control and performance of the forehearth.

Consider the two charts below that show control reactions of forehearths operating with dark amber glass. ***Fig 1*** shows the response of a forehearth zone combustion loop to a 5°C set point increase, shown in blue. Control of the

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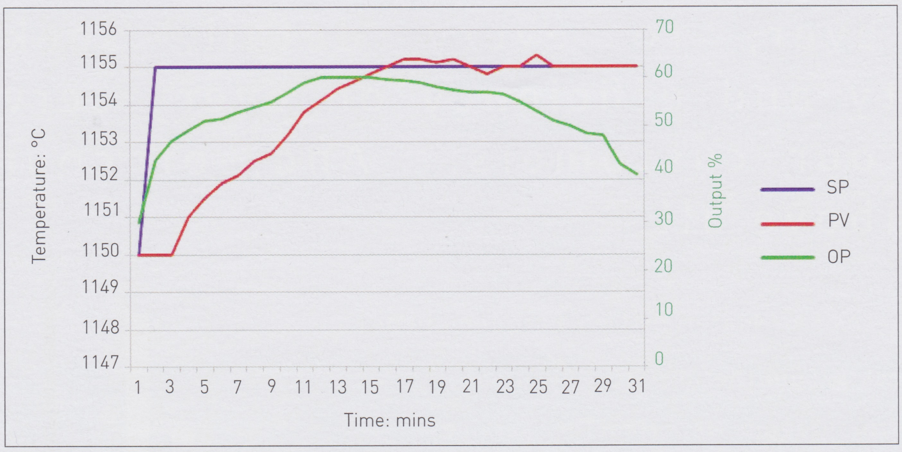

Fig 1. Thermocouple response to 5°C SP Increase.

loop is by a thermocouple positioned at the front of the zone at the standard depth of 25mm below the glass surface. The reaction of the controller output, shown in green, shows the set point increase caused a 35% increase in combustion output. This increase in output resulted in the glass temperature, shown in red, achieving the new set in 14 minutes.

By contrast, ***Fig 2*** shows the combustion loop response to the same set point increase. In this case, control of the zone is provided via a fibre-optic pyrometer positioned at the front of the zone. The 5°C set point increase results in a much smaller 4% increase in combustion output. Despite this modest increase in combustion the set point was achieved in three minutes.

It is tempting to conclude that, if you require fast, efficient forehearth control, then you should choose pyrometers in preference to the apparently slow reacting control offered by thermocouples. Unless, in addition to the forehearth combustion system, the pyrometer is mysteriously providing its own heat input there is something seriously wrong with this comparison.

The discrepancy between forehearth control and pyrometer control is due to differences in glass measurement methodology between the two instruments. The standard pyrometer used in forehearth control utilises a silicon cell operating within a narrow waveband of 0.7 to 1.1 m. This is the essence of the problem when using this type of temperature sensor in forehearths operating with dark coloured glass.

The glass depth from which the detector can receive radiation is dependent on both the wavelength over which the detector operates and the glass colour. A pyrometer operating over the above waveband can typically 'see' up to 35mm into the glass. For dark glasses however this distance is reduced to as little as 0.5mm.

From a glass control perspective the situation is made worse by the fact that the first 50% of the glass depth accounts for 80% of the signal delivered by the fibre-optic to the detector. For flint glasses this is tolerable but for dark glasses this results in 80% of the signal being derived from the top 0.25mm of the glass depth – i.e. effectively the glass surface.

By contrast the thermocouple measures some form of averaged glass temperature at a depth of 25mm – which is why the sensor took almost three minutes to react to the increase in combustion output and a further 12 minutes to achieve set point. The pyrometer however responds within one minute and achieves set point after a further two minutes.

While an increase in the combustion output takes time to affect the glass temperature 25mm below the glass surface, an increase in combustion can affect the glass surface within a short timescale. Consequently, a pyrometer reading the glass surface will quickly assume the set point has been achieved. The problem is that the signal from the pyrometer tells the controller that the zone is at the required set point temperature where, in reality, it is only the glass surface that has achieved the required temperature increase. The temperature of the bulk of the glass remains unaltered.

Case study

A recent audit was conducted on a forehearth where each zone was controlled by a pyrometer. In addition, each zone was equipped with a tri-level thermocouple approximately 650mm downstream from the pyrometer and used for glass temperature monitoring only. The set point was increased by 5°C and within a few minutes the pyrometer registered that set point had been achieved and consequently the combustion output was reduced. However, the tri-level thermocouple registered no increase in glass temperature at any level in the glass. This is a strong argument to suggest that pyrometers are inappropriate for control of dark coloured glasses.

Indeed, audits conducted on forehearths operating with dark glasses invariably identify the pyrometer as a source of control problems. That is not to say that thermocouples do not have potential for forehearth control problems. But that will have to be the topic of a future paper. ■

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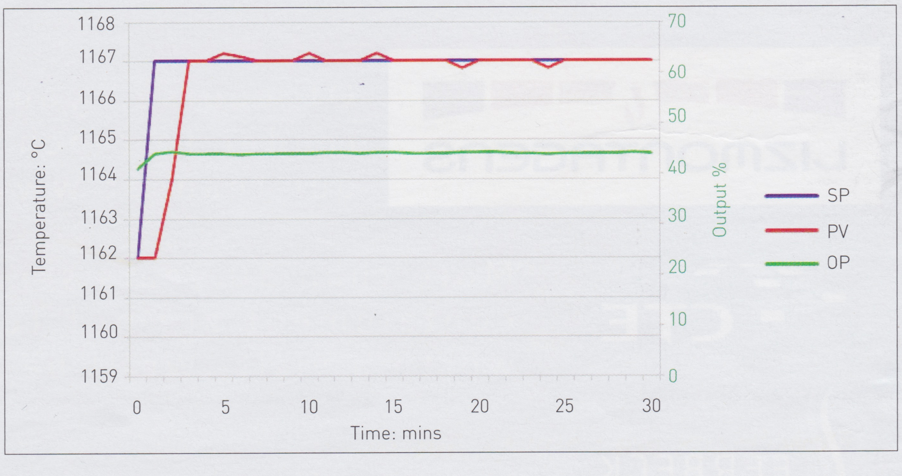

Fig 2. Pyrometer Response to 5°C SP Increase.