Gas to glass: Ensuring fuel gas quality in glass melting

Stephen Harrison* and Kim Chapman** discuss the impact fuel gas quality during the melting process has on the quality of glass, and how to automatically measure and control gas calibration.

The glass industry consumes high quantities of fuel gas from natural gas distribution grids for melting glass batches.

The quality of this fuel gas can fluctuate quickly, often within a day. It also shifts with seasonal cycles, depending on the blended composition of regionally generated biogas, the propane vaporisation to enrich the biogas and piped natural gas from the North Sea, which has a high calorific value, or Russian natural gas. In some countries, such as The Netherlands and Germany, the biogas contribution to the grid has grown recently and the mix of natural gas sources continues to diversify.

Accurate temperature control during the glass melting process is critical for production quality. Failures to control the temperature within a tight range can result in batch wastage.

It is beneficial to make feed-forward adjustments to the burner operation to mitigate for changing fuel gas quality. Burner efficiency, waste gas emissions pollution control and the life of a furnace refractory lining are also important issues that can be influenced by changes in natural gas composition.

To enable such adjustments, an automated method of feed-forward process control using a fast response micro GC-TCD arrangement can be employed. This system analyses the fuel gas quality and computes its probable thermal characteristics using methods similar to those in ISO6976 to allow the required adjustments in burner operation to be made. The analytical matrix and the overall system control loop parameters can vary from site to site and over time within the same site.

So, it is vital that the most suitable carrier gas for this application is used as well as the most appropriate calibration gas mixtures.

Natural gas composition

The composition and calorific value (similar to the Wobbe index) of piped natural gas can change rapidly, even within minutes.

It can also change throughout the course of a day and has longer term macro shifts with seasonal cycles.

A reason for this change is that various sources are mixed to create natural gas. In various countries and regions there are standards within which the natural gas composition and calorific value must remain, but these are not standardised across the world and are not even standardised across Europe where natural gas pipelines criss-cross the continent in a diversified energy supply network.

For example, in Germany, the blended composition of natural gas arriving at the user, such as a glass manufacturer, may be a mix of regionally generated biogas (methane lean, low calorific value); intermittent slugs of high calorific value vaporised propane to enrich the biogas; piped North Sea natural gas (high calorific value); or Russian natural gas (lower calorific value).

Across continental Europe, the use of Russian natural gas increased in recent decades and in some countries the biogas contribution to the grid has grown extensively. The mix of natural gas sources, therefore, continues to diversify, and the need for automated smart process control reactions to these variations is important to industrial consumers of natural gas.

Since these composition changes can take place within minutes, the furnace must be able to react to these changes within a similar time frame to ensure stable and optimum operation.

The measurement of natural gas calorific value can be performed using flame techniques and calorimetry. This is the traditional approach, but it is slow in comparison to the speed in which natural gas composition and calorific value can change. For a fast process control loop which is able to direct process responses

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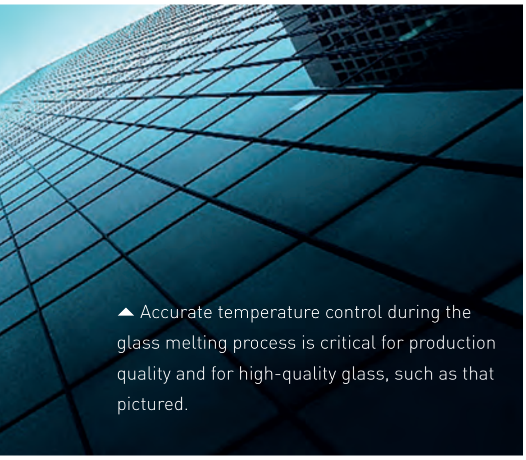
at the same rate that the natural gas composition can change, a faster method of measurment is requried.

Analysis of the fuel gas chemical composition and computation of the implied calorific value using methods similar to those in ISO6976 has, in practical application, been shown to be a good proxy for flame methods of calorific value measurement.

It does rely on a fast and accurate method of chemical species measurement. A rapid response Micro GC-TCD is suitable for the task as it can enable a process loop response time in one to three minutes.



▲ Accurate temperature control during the glass melting process is critical for production quality and for high-quality glass, such as that pictured.

Process control system

The best way to ensure optimal operation of the burner is to measure and control the amount of oxygen in the burner flue gas using a feedback control loop. This ensures there is a small residual amount of oxygen emerging in the escaping flue gases. Although this is the most economically and environmentally efficient way to run the process, plant operators should guard against having a large excess of oxygen which could impact production costs.

To achieve the right balance, oxygen should be measured in the furnace, or in the regenerator heat exchangers where the flue gases leave the furnace and pre-heat the gases coming into the furnace.

This measurment is fed into a feedback process control loop and the measurement is typically achieved using instrumentation such as a Zirconia oxygen analyser, which is reliable and robust in this hot operating environment.

The instrument's sensor requires periodic calibration, either with ambient air or with a speciality gases calibration mixture (consisting of an even percent of oxygen in nitrogen), to ensure accuracy of measurement. While a feedback control loop is essential to measure oxygen levels in the melting furnace and make adjustments to the oxygen or natural gas being fed in, the more sophisticated process control strategy is to use a feed-forward control loop in combination with the feedback control loop.

The feed-forward loop measures the chemcial composition of the natural gas (as a proxy for calorific value) coming into the furnace. It enables the automated predictive and proactive feed-forward adjustment of natural gas flow rate and associated stoichiometric oxygen flow rate. The process control loop ensures that the thermal input to the furnace remains under control, so that the temperature profile of the glass batch melt is controlled according to the optimum process requirements.

These feed-forward control loops usually incorporate gas chromatography instrumentation with a thermal conductivity detector (GC-TCD) to measure the quality of the natural gas flowing into the furnace.

This allows for feed-forward adjustments in either oxygen or the natural gas flow rates, based on the calorific or heating value of the natural gases coming in. This is a critical factor, as natural gas is fundamentally a mixture of gases whose composition changes over time, impacting on the total calorific value and furnace temperature profile.

The use of a Micro GC, in contrast to a larger general purpose conventional laboratory GC, is convenient for two reasons. Firstly, the compact design allows the instrument to be used in-situ, close to the process, to minimise sample line length and therefore achieve rapid response times.

Secondly, the purpose-built design incorporates a short GC column optimised for the natural gas composition measurement application, which also enables rapid response times for this process control loop.

5.0 grade helium (99.999%) is the most typical carrier gas for gas chromatography and is the standard choice for this application. The benefits are both ease and safety of product handling; good speed of separation, essential for this feed-forward process control loop application; and broad range of applicability. The disadvantage of using helium in this application is that the natural gas being analysed can sometimes contain helium, and so the use of helium as the carrier gas prevents the measurement of helium as a component of the natural gas.

5.0 grade hydrogen is an alternative carrier gas with a faster column velocity and separation speed than helium. However, hydrogen is highly flammable and there are safety concerns to be considered. The separation resolution is also not as good as helium for some species and matrices. However, use of hydrogen may be suitable in helium-rich natural gas streams.

5.0 grade nitrogen and argon are also potential GC carrier gases. Both are inert, easy to handle and are abundantly available at 5.0 grade chromatography purities on many industrial sites. However, their speed of separation is not ideal for rapid response applications and they give poor sensitivity to the TCD.

The recommendations from analytical instrument manufacturers should always be taken into consideration.

As with most gas chromatography applications, the carrier gas doubles up as the zero gas. Additional zero gas selection is not usually required.

The most suitable calibration gas mixture is a multi-component mixture of hydrocarbons with a similar composition to the natural gas stream. Clearly, one of the reasons for this application being important is that the composition of the natural gas stream changes. Selecting a suitable calibration gas mixture that is representative of the general fuel gas composition is recommended.

In some cases, it might be suitable to use a suite of two or three calibration gas cylinders with different 'synthetic natural gas' mixture compositions to give a breadth of calibration points across the spectrum of operation.

Since this is a process control application, not a legislatively controlled emissions monitoring application or a natural gas custody transfer application, regular certification of the synthetic natural gas mixture is highly suitable. ISO17025 or ISO Guide 34 Accredited certification for these synthetic natural gas mixtures is, of course, technically feasible and commercially available, but these accredited products are more complex to manufacture and therefore add cost, which is not generally required for this process control application.■

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