

# Thermal Imaging Enhances Today's Complex Glass-melt Process

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The move to Oxy-fuels, the establishment of global standards governing emissions, and today's inadequate measurement processes are materially impacting the glass manufacturing industry. The glass melting process used in the manufacture of glass products is extremely energy-intensive. According to the U.S. Department of Energy, approximately 40% of the energy used involves heating the batch and homogenizing batch constituents; 30% can be lost through the furnace structure, and another 30% can be lost through the exhaust gases.

Glass melting takes place in continuously operated melting furnaces or tanks where a mixture of cold ingredients, including silica sand, limestone, soda ash, dolomite and cullet are melted at 1600° C (2900° F). The process of melting the glass can take days. Typically, the higher the quality of glass produced, the longer the residence time of the glass melt to ensure complete homogenization. The batch in the tank is between two feet (600mm) and three feet (1,000mm) deep in the tank.

Key features of the furnaces are adequate insulation, good sealing to minimize air leakage, excellent heat recovery from efficient regenerators, a well-designed doghouse and charging system, and an accurate control system. In the past, thermal imaging inside refractory-lined furnaces and glass-melt tanks required large openings in the refractory to view critical areas. This results in both heat loss and wasted energy.



Figure 1. The interior of a glass furnace after a rebuild indicating undamaged refractory lining.

The process in a cross-fired furnace involves a series of ports on one side of the furnace where hot air and gas are injected, producing flames that lick across the top of the glass. At the opposite side of the furnace, there are an equal number of ports that pull the exhaust outwards. This exhaust is not released into the atmosphere, but instead enters a regenerator—an area that is produced from refractory bricks constructed with gaps between

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the bricks called checkerwork. Hot gas flows through the gaps between the bricks, heating the bricks to more than 1500° C.

After 20 minutes the firing ceases on one side, and after a few seconds of null time, firing begins from the other side. In this way, air is preheated by the energy from the bricks in the regenerator. If the process runs too long, however, refractory insulation brickwork located at the port arches will begin to melt—a process called glazing. When brickwork glazes, it loses its insulation characteristics and fails to emit energy properly (See Figure 2).

If the regenerator brickwork is overheated it can slump - restricting air flow. Not only is airflow to the port restricted, but also the checkerwork begins to crumble. All of these factors shorten the life of the furnace from a 15-year expectation to as few as 10 years.



Figure 2. Damaged refractory around the ports is caused by over temperature use.

Throughout this process, the accurate monitoring of key refractory-lined areas is challenging.

### Current Monitoring Solutions

There are several challenges facing operators. For example, within the glass-melt furnace, there are a variety of temperature measurements to be taken in different furnace locations. Trends established by temperature measurements throughout the furnace are also important, such as crown temperature and port arch long-term temperature trending, the temperature of the melt line and batch transit time recording and comparison, temperature “visualization” of cold spots in the refractory wall, indicative of air leaks caused by structural issues, and the impact of fluctuating temperatures on the process and the furnace itself.

It is still common to use a portable infrared thermometer similar to a digital camera to take measurements inside the glass furnace to gauge the time of reversal intervals and ascertain if they are too long or too short. To do so, the operator flips open a viewing port on the side of the furnace, waits for a reversal when there is no flame, and measures the temperature of the port arch on the opposite side of the tank.

However when a reversal occurs, from the moment the flame stops, the refractory surface temperature drops rapidly, many degrees per second. Therefore the timeliness, accuracy and repeatability of the measurements are questionable.

Video cameras are still used to monitor flame propagation and other processes during the melt. Should one burner not produce as much flame as the others, for example, it could be a sign that the regenerative checkerwork was collapsing in one of the ports. The batch line is also monitored to see at what point in the furnace the islands have all melted. The major downside, however, is that it is impossible to measure temperature with a visual camera.

### Controlling Emissions

Globally, there is an increased focus on emission control, and to date Europe, specifically the United Kingdom, has taken the lead on curtailing glass furnace emissions. The United Kingdom, for example, introduced several layers of legislation, including:

- The Environmental Protection Act of 1990 and 1995
- Integrated Pollution Prevention and Control Directive (IPPC) (EU) (1999)
- Climate Change Levy (CCL) & Climate Change Agreements (UK) (2001/2006)
- European Union Emission Trading Scheme (EUETS) (EU) (2003)
- Restriction of Hazardous Substances (RoHS) (EU) (2006)
- Registration, Evaluation, Authorization and restriction of Chemicals (REACH) (EU) (2007)
- Environmental Permitting Directive (UK) (2008)
- Carbon Reduction Commitment (UK) (2010)

The legislation established provisions covering the emission of pollutants and furnace specifications. While glass manufacturing involves emissions to air, wastewater and solid waste, the main emission sources of nitrogen oxides (NOx) occur via high furnace temperatures, the decomposition of nitrogen compounds in the batch materials, and the oxidation of nitrogen contained in fuels.

Legislation has resulted in two major changes in glass-melt furnaces. First, in the past, thermal imaging inside refractory-lined glass-melt tanks typically required large openings to be cut into the refractory to enable viewing of the critical area. Not only did this cause significant wasted energy from heat loss and the lack of emission control, but also it was difficult to keep the opening free from debris. Now, to curb emissions, these large holes are restricted.

The second change in response to emission legislation is a transition to the use of Oxy fuels. Oxy-fueled furnaces use pure oxygen; there is no nitrogen and hence NOx emissions are significantly reduced. The use of these fuels, however, has its own challenges. While they are not among the majority,

Oxy-fuel-based furnaces are clearly a rapidly growing trend. Given that the fuels burn hotter, thermal imagers that could keep pace and provide accuracy are gaining in importance. Running even slightly hotter affects the refractory insulation within the furnace.

This movement towards Oxy-fuels, coupled with expanding global emission-controlling standards, necessitates a different design, monitoring and measuring approach.

### Thermal Imaging

The AMETEK Land's NIR Borescope (NIR-b) delivers a new approach. The NIR-b is a short wavelength, radiometric infrared borescope imaging camera that produces high-definition (656 x 494 pixel) thermal images, and enables accurate temperature measurement from any point in the image. The camera measures temperatures from 600° C to 1800° C (1112° F to 3272° F).

There are many advantages to thermal vs. visual imaging and point temperature measurements. Using a permanently installed thermal-imaging camera that actively records all necessary and useful data after a reversal, the system can replay up to the point of a reversal start. Each of the furnace areas can be viewed, the video can be stopped at any frame, and measurements can be taken of all of the ports at the exact same point in the process so that reversals can be tuned more accurately. In addition, the beginning of any structural damage because of high temperatures can be caught rapidly. For example, if a crack is developing, it shows up as a cold area where external air is being pulled in, and it can be preventatively repaired.

With the NIR-b it is possible to accurately profile the temperature of the entire furnace with only a small opening in the wall, giving the operator access to data which would have previously been either time consuming or impossible to collect. The operator is free to focus on specific areas of interest, measure live data points and store the data for future analysis. By monitoring the live video, the operator can begin to increase melt-tank efficiency, improving product quality and reducing process costs.

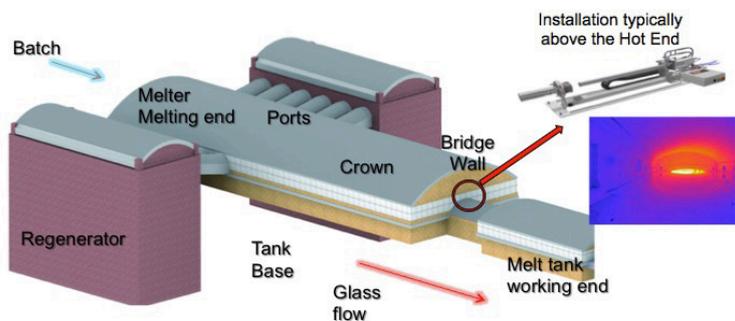


Figure 3. Typical Configuration 90° FOV lens and 900 mm Borescope Length with Auto-Retract Mechanism

The NIR-b's viewing angle of 44° or 90° provides 324,000 data points and 24-hour, 7- day monitoring. The high-quality image produced by the NIR-b allows real-time data to be streamed in time-lapse modes to process engineers so that they can visualize the flow of the glass melt batch during processing. This enables statistical levels and alarms to be set in the control equipment on optimum glass quality production.

Alarms can be set, for example, to detect air leaks and glass leaks seen by the imager as "cold" spots. By using a high-accuracy thermal-imaging device to measure, monitor and log refractory temperature trends, instantaneous information to trigger key alarms and long-term trend analysis is available in real-time.

NIR-b delivers access to data that in the past was too time consuming or even impossible to collect. Now the operator has the tools to increase furnace efficiency and product quality, and also reduce process costs.



Figure 4. The NIR-b detects an air leak while this end fired furnace is firing from the right port. Cold air is pulled in through a crack and indicates a minimum temperature of 1336 Celsius. That same area was over 100 Celsius hotter when the firing was reversed.

With the NIR-b, the operator can set points and areas of interest, measure live data points, and store and trend the data for future analysis. By monitoring live video the operator can configure the most efficient firing pattern and achieve optimum performance from the burners. This saves significant costs by reducing fuel usage and providing improved performance and life of the furnace or melt tank.

Any air or glass leaks detrimental to the efficiency of the furnace are clearly visible and simple to detect. All positions are monitored from the safety of a control room, where an operator can respond in real-time before catastrophic events can occur.



Figure 5. NIR-b on auto retraction mechanism – shown retracted

## Summary

Adding thermal-imaging capabilities that enable operators to maintain an accurate visual of the entire glass-melt tank, as well as take temperature measurements at any point in the process and in any location within the tank, is invaluable.

The addition of thermal imaging improves the quality of the yield, ensures damage within the tank can be discovered rapidly—before it becomes a major repair, adds an unprecedented level of data analysis, and reduces the total cost of operations.

This imaging capability is especially important within the settings of emission legislation and emission control requirements affecting furnace structure.

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### ABOUT AMETEK LAND

AMETEK Land is a global supplier of non-contact temperature measurement instrumentation, process imaging solutions and combustion and environmental analyzers. Founded in 1947, LAND has been the premium supplier of temperature measurement solutions and combustion emissions monitoring.

AMETEK Land has facilities in the United Kingdom, China, France, Germany, India, Italy, Japan, Singapore, Spain and the United States.

The full range of non-contact temperature products includes high accuracy hand-held portables, fixed system spot temperature sensors, thermal line scanners, process thermal imagers and calibration sources. Many application specific systems solutions are available