AMETEK® PROCESS INSTRUMENTS

APPLICATION NOTE

# MONITORING AIR/FUEL MIXTURES IN GLASS AND GLASS FIBER MANUFACTURING

## Controlling Product Quality Through Oxygen Measurement

### MEASUREMENT OF PREMIX GAS

To produce the desired flame in a glass forehearth, or when making fiberglass (glass fiber) insulation, an air/fuel pre-mixer is used. The pre-mixer combines compressed natural gas or propane with air and this mixture is then piped to the process burners. At the burner, a fuel-rich or fuel-lean flame is produced depending on the air/fuel ratio selected. In many combustion applications, an oxygen ($O_2$) analyzer measures the excess fuel (fuel-rich) or excess $O_2$ (fuel-lean) directly in the flue gas. In this application, however, the flue gas cannot easily be reached or may not provide an accurate measurement due to air leakage. Therefore, a premix gas analyzer must be used.

**Overview:**

- Control of air/fuel ratio is critical to the quality of glass or glass fiber products.
- Processes using open flame burners cannot use traditional flue gas analysis.
- The PreMix 2000 and CMFA-P2000 operate in fuel-rich or fuel-lean conditions.
- The analyzer responds quickly to changes in the pre-mix gas by analyzing a small sample, paralleling actual burner conditions.

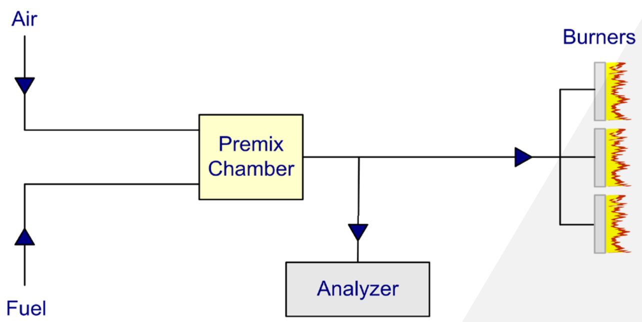


**Figure 1.** Analysis of premix gas

### GLASS FIBER MANUFACTURING

Precise combustion control is needed to manufacture quality glass fiber insulation products. The final stage of the glass fiber process uses a high velocity flame to melt coarse glass strands and draw them out into extremely fine fibers. By regulating the air/fuel mixture, the tensile strength, density, weight, and "R" factor of the insulation can be controlled.

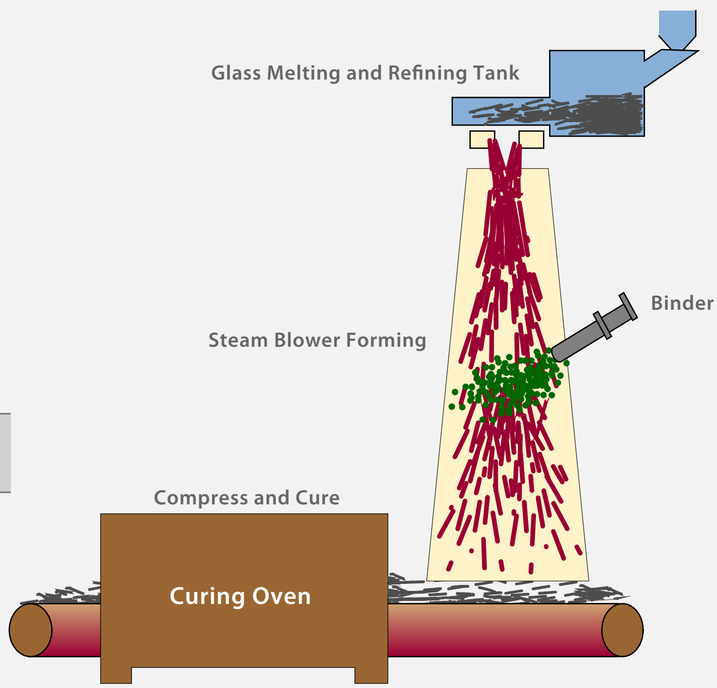


**Figure 2.** Glass fiber manufacture

## CONTAINER GLASS FOREHEARTHS

In the manufacture of bottles and other glass containers, open-flame burners are used to control the atmosphere of the molten glass in the forehearth. Depending on the product and desired process conditions, a slightly rich or a slightly lean combustion fuel mixture is needed in the different zones in the forehearth. Maintaining the correct air/fuel mixture ensures the quality of the end product and also protects manufacturing equipment.

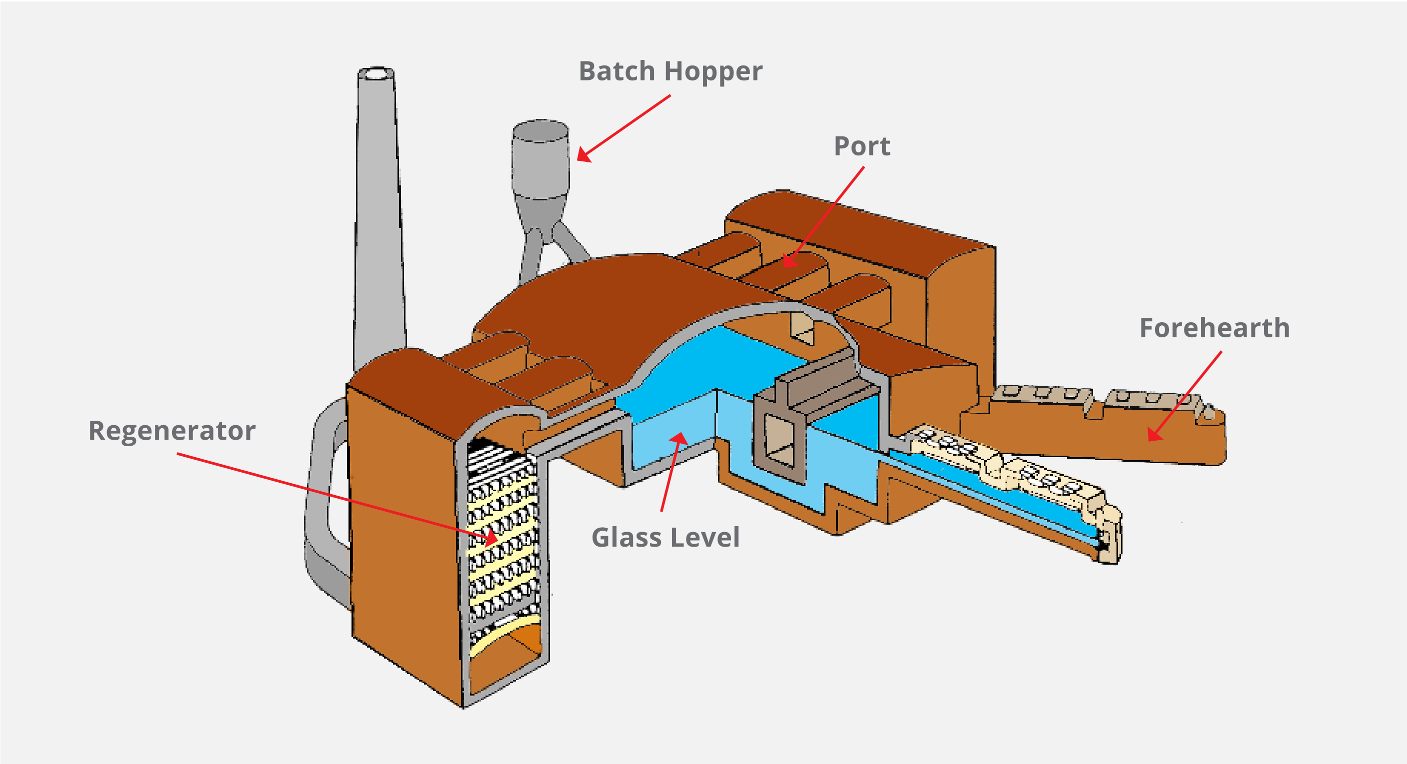


**Figure 3.** Glass melt tank and forehearth

## CHALLENGES TO MAINTAINING PRODUCT QUALITY

Electrochemical, paramagnetic or laser $O_2$ analyzers can be used to monitor and control the air/fuel ratio in glass or glass fiber production. However, product defects still occur, and for no apparent reason. The problem lies with the measurement principle – electrochemical, paramagnetic or laser $O_2$ analyzers measure the concentration by volume of the $O_2$ molecules in the unburned air/fuel mixture.

For example, assume a bank of burners operate on natural gas with a 9.6:1 air/fuel ratio. The analyzer will display a value around 19% $O_2$, a normal and expected value. What happens if there is a change in heat content of the gas? Consider these scenarios:

1. In place of natural gas, mix and burn 1 cubic foot (cu. ft.) of hydrogen ($H_2$) with 9.6 cu. ft. of air. According to the $O_2$ analyzer the air/fuel mixture is correct, yet the product quality has suddenly dropped off

2. Mix and burn 1 cu. ft. of nitrogen with 9.6 cu. ft. of air. Even though the burners would now be trying to run with rarefied air, the analyzer still reads 19% $O_2$

Although these examples are deliberately extreme, they show that this also applies to small variations in the calorific value of the fuel or humidity of the mixture. Hence product defects occur when using these types of analyzers.

The measuring principle used by electrochemical, paramagnetic or laser $O_2$ analyzers cannot recognize variations in the heat value or in the humidity of the mixture. They are therefore unsuitable for controlling the air/fuel ratio of these processes. This is particularly noticeable in sub-stoichiometric applications where even under steady conditions, a three-decimal-place resolution would be needed to maintain a specific air/fuel ratio.

Every change in the heat content or humidity of the air/fuel mixture directly corresponds to a change in the flue gas atmosphere and affects the quality of the product.

## PRINCIPLE OF OPERATION FOR THERMOX PREMIX ANALYZERS

The stationary PreMix 2000 and the portable CMFA-P2000 are $O_2$ analyzers designed specifically for analysis of premix gas.

A small sample of the air/fuel mixture passes through the analyzer where it is ignited and completely burned. The newly created flue gas is immediately analyzed on a zirconium oxide ($ZrO_2$) cell. The analyzer can handle oxidizing as well as sub-stoichiometric (reducing) premix gases, and provides a continuous measurement of the excess $O_2$ or excess fuel in the process flue gas.

This approach ensures the optimum air/fuel ratio before the premix gas reaches the burner. The unique concept of these analyzers simulates the combustion process in advance of the burners and thereby monitors the flue gas atmosphere, which directly affects product quality.

Both analyzers register every variation in the heat content of the fuel, in humidity and, naturally, any changes in the air/fuel ratio control system.

## CMFA-P2000 PORTABLE ANALYZER

MEASURES: **Excess $O_2$ or Excess Fuel**

The portable CMFA-P2000 houses both the sensor and the Series 2000 Control Unit in a luggage-style carrying case. It can be used as a premix analyzer or a flue gas $O_2$ analyzer. For details and specifications, refer to the CMFA-P2000 product data sheet (Bulletin 0158). For further information on the use of $ZrO_2$ in furnace atmosphere control, see the Application Note, “The Other Side of Zirconium Oxide”.

**CMFA-P2000 ANALYZER**

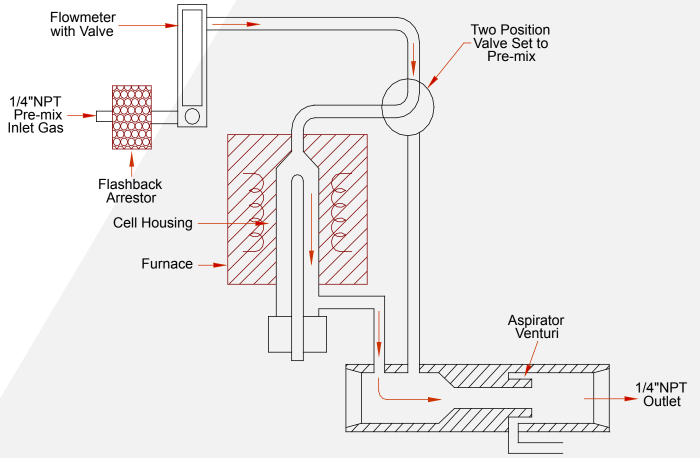


**Figure 4.** CMFA-P2000 flow diagram

## PREMIX 2000 STATIONARY ANALYZER

MEASURES: **Excess $O_2$ or Excess Fuel**

The PreMix 2000 analyzer uses the Series 2000 Control Unit. It enables the user to select the measurement to be displayed, as well as analog output ranges and alarm limits.

This allows for easy system integration into the overall combustion control process. For details and specifications, refer to the PreMix 2000 product data sheet (Bulletin F-0160).


**PREMIX 2000 ANALYZER**

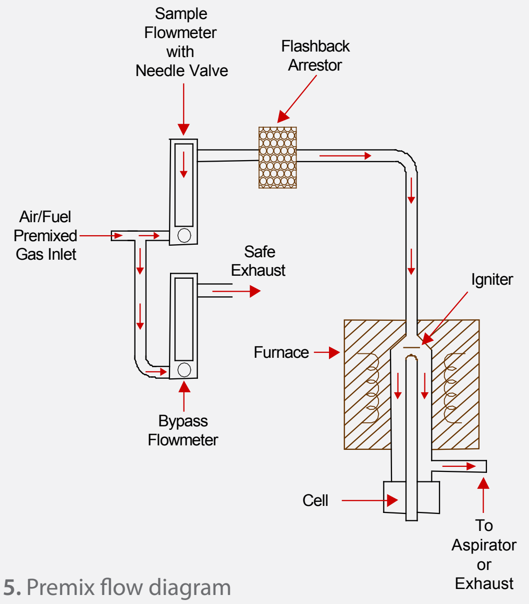


**Figure 5.** Premix flow diagram

## COMPARISON WITH OTHER MEASUREMENT TYPES

### 1. Flame temperature

Unlike measurements of flame temperature, the PreMix 2000 determines exactly how lean or rich the air/fuel mixtures are. The analyzer provides an immediate response to changes in the air/fuel mixture versus the slow response of a temperature measurement. And the sample stream products of combustion measured by the analyzer match the actual process conditions, whereas a temperature measurement in a controlled atmosphere cannot duplicate process conditions.

### 2. BTU analyzer

Unlike BTU analyzers, the PreMix 2000 automatically corrects for air that may be trapped in the fuel. In this situation, a BTU analyzer will overestimate the amount of air required for desired combustion.

### 3. Air/gas meter (oxygen displacement)

In theory, it is possible to measure and control the air/fuel ratio by directly measuring the $O_2$ concentration of the premixed gas with a paramagnetic or fuel cell type of $O_2$ sensor. However, these types of sensors will not respond to changes in $H_2$ to carbon ratio, or to density changes, and are not sensitive enough to maintain specific excess fuel conditions. The graph shows that a resolution of 0.001% $O_2$ in an 18% $O_2$ mixture would be required to maintain accurate control. Such a resolution is just not possible with any of these analyzers.

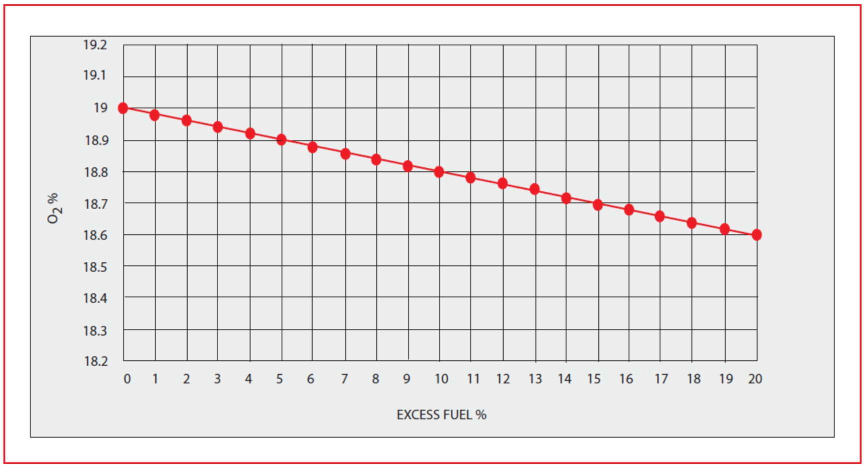


**Figure 6.** Oxygen in premix vs. excess fuel


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