# Energy Assessment Protocol for Oxy-Fuel Fired Glass Furnaces

## Summary

The glass industry is a major energy consumer. Depending on the market sector, a glass furnace heated by oxy-fuel burners may use from 3.5 to 6 million Btu to melt and refine a ton of glass. The glass industry has generally aimed at achieving energy efficiency through furnace design (e.g., inclusion of heat recovery). However, little attention has been paid to improving the efficiency of a furnace once it is up and running. The Department of Energy, recognizing this deficiency, commissioned a team to develop a methodology that could be used by glass producers to increase furnace efficiency, and that could serve as a model for other energy-intensive industries.

Accordingly, a team comprising PPG Industries, Eclipse/Combustion Tec and the Diagnostic Instrumentation and Analysis Laboratory at Mississippi State University (DIAL) developed and demonstrated the use of an energy assessment protocol for oxy-fuel fired glass furnaces. The protocol is intended to identify potential opportunities for energy savings, based on a structured evaluation of the operating furnace, and then to confirm the effectiveness of any changes made. Development of energy and mass balances for the furnace is a key feature of the protocol, as is identification of localized areas of the furnace where large heat losses occur. The initial application of the protocol was at the PPG Industries fiber glass plant in Shelby, NC. Application of the protocol indicated that a change in burners would be beneficial. As reported by PPG, the partial burner changeout resulted in a 10% improvement

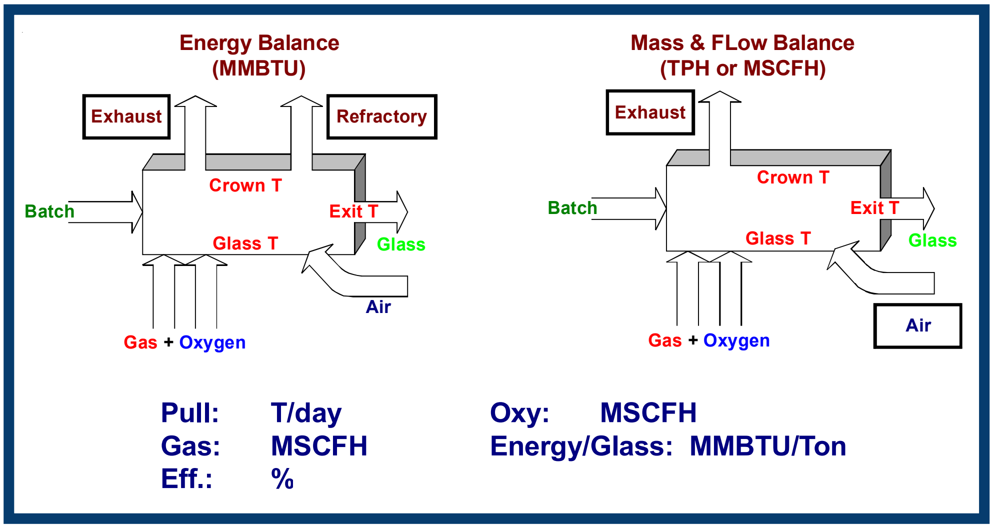


*Figure 1: Mass and Energy Balance Diagrams*

## Benefits for Our Industry and Our Nation

- Reduced energy consumption for glass melting
- Reduced NOx emissions

## Applications in Our Nation's Industry

The energy assessment protocol developed is specific to the glass industry. However, the principals employed are general and can be easily adapted to other energy-intensive industries.

## Project Partners

DIAL at Mississippi State University
Starkville, MS

PPG Industries, Inc.
Pittsburgh, PA and Shelby, NC

Eclipse/Combustion Tec
Rockford, IL

in energy transfer into the glass or a 2.6% energy improvement in overall furnace efficiency, as well as a 21% reduction in $NO_X$ emissions. It is estimated that energy savings of at least 6% could result if all of the recommendations arising from use of the protocol are implemented.

## Project Overview

The DOE Industrial Technologies Program funded development and demonstration of a protocol that a glass producer could use to assess the energy performance of an operating furnace. Thus, a producer using the protocol would be able to locate excessive energy losses, and use this information to identify opportunities for energy savings. Once actions were taken to capture these savings, the producer could then use the protocol to evaluate how effective the actions were.

The project team consisted of PPG Industries, Eclipse/Combustion Tec and the Diagnostic Instrumentation and Analysis Laboratory at Mississippi State University (DIAL), all members or associate members of the Glass Manufacturing Industry Council (GMIC). PPG brought to the team a desire to improve the energy efficiency of its operations. It proposed using one of its fiberglass furnaces to demonstrate the use of the protocol. DIAL had characterized the environment within several working glass furnaces, and had developed specialized instrumentation and methods needed for the project. Eclipse, the manufacturer of the burners used in the PPG furnace, brought extensive field experience to the team, as well as in-depth knowledge of burner performance.

## Energy Assessment Protocol

The project team developed the protocol based on DIAL, Eclipse and PPG experience in field measurement and support, and on similar efforts from other industries. The protocol defines a three-phase process for identifying improvements and verifying the effectiveness of any changes made.

- Preparation. The assessment team examines the furnace and the surrounding facility to develop a detailed plan for the assessment. Energy-related measurements made by the glass producer are identified. Additional parameters that must be measured by the assessment team are agreed upon. This results in a detailed plan for the initial measurement campaign that includes services needed (e.g., electricity, cooling water), support equipment and probes, skeletal energy and mass balances, exact measurement points, possible interferences, and a target date for the initial measurement campaign. The assessment team then gathers the necessary equipment and supplies, calibrates instrumentation as needed, collects necessary facility data (e.g., typical fuel and oxygen flow rates), and prepares to carry out the plan during the initial measurement campaign. Even at this preliminary phase, important qualitative observations about furnace operations can be made.

- Initial measurements. The purpose of this phase is to identify opportunities for improved energy performance. Energy and mass balances for the operating furnace are developed, and augmented by measurements and observations of localized phenomena specific to the furnace (e.g., mapping external surface temperatures of the furnace). The mass balance includes such parameters as the gas and oxygen flow into the furnace, the batch feed rate, the air infiltration rate, the exhaust gas flow rate and composition, the glass pull rate, and gas exfiltration rate. The energy balance includes the heat of combustion of natural gas, the gas and oxygen flow rates, temperatures of the exiting gases and the glass, and the furnace's external temperatures. The energy and mass balances need to be as accurate as possible in order to uncover opportunities for improvement, since in general these may be relatively small (< 5% of energy usage). The localized measurements and observations help to pinpoint specific areas of the furnace where action can be taken (e.g., adding extra insulation or plugging a port). The team completes this phase by communicating the opportunities found to the glass producer.

- Verification measurements. The purpose of this phase is to verify the effectiveness of any changes made as a result of the initial measurements, and to quantify their impact. The same measurements are made as for the previous phase. These are then compared to those from the previous phase to draw quantitative conclusions. For both of these phases, the measurement campaigns may extend over several days. Again, the energy and mass balances need to be as accurate as possible in order to be able to accurately detect relatively small differences.

## Demonstration

The protocol was first used on one of the fiber glass furnaces at PPG's plant in Shelby, NC, which is the largest single continuous strand fiber glass manufacturing plant in the world. Based on this initial experience, the protocol was further refined. The latest version is available on DIAL's website (www.dial.msstate.edu). The data used for the energy and mass balances were obtained in various ways: PPG provided glass and superstructure temperatures, melter pressure, gas and oxygen usage, flow rates and purities, melter pull rate, bubbler flow rates and batch charging rates from its process control system. DIAL measured gas temperatures (using suction pyrometry), interior wall temperatures (using a ratio pyrometer), major vapor space species concentrations (using extractive gas analysis), gas velocities within the furnace (using a high-temperature multi-directional pitot tube), and exterior wall and ambient temperatures (using bare and contact thermocouples). For most of the measurements, traverses of special probes across the furnace were made to obtain detailed profiles, e.g., of velocities at the exhaust. PPG also performed extractive gas analysis using a mass spectrometer in order to obtain data for comparison with DIAL's. Combustion Tec examined the burners and their controls. These data were used to provide energy and mass balances for the furnace, and to develop local temperature maps of the furnace pinpointing areas of energy loss.

As a result of the initial measurements phase, the team found good agreement for $CO_2$ and $O_2$ measurements made using DIAL's gas analyzers and PPG's mass spectrometer. In addition, the assessment determined that the fuel gas and oxygen flow meters used required recalibration and identified possible error in the oxygen-to-gas ratio. The agreement achieved between mass and energy inputs and outputs was excellent. The mass balance closure agreement was approximately 1%, and the energy balance closure was approximately 5%. Other important observations involved heat losses around open ports and refractory joints.

Application of the protocol indicated burner replacement could improve furnace efficiency. In order to demonstrate this improvement, Combustion Tec installed two of its new Primefire® 400 low-$NO_X$ burners, replacing two of the existing seven burners. It was expected that the improved controls associated with these burners would enhance the efficiency of combustion, and hence the energy efficiency of the furnace.

The verification phase confirmed these expectations. A 10% improvement in energy transfer into the glass was reported by PPG, substantiated by improved batch blanket movement toward the back of the melter as a result of a greater return flow. Overall, this represented a 2.6% improvement in energy efficiency for burners that account for just 30% of the energy input. In addition, researchers recognized a 21% reduction in the $NO_x$ emission rate for the subject furnace. This was accomplished by replacing only two burners, and without optimization of the burner profile. By replacing the remaining burners, in conjunction with other process changes, it is estimated that the total improvement in energy efficiency will exceed 6%.

The energy assessment protocol developed was successful in evaluating glass furnace performance. It helped both to identify aspects of furnace operation that could be improved and to verify improved heat transfer efficiency and reduced $NO_x$ emissions after installing the new burners. These results also validated the measurement tools and methodology employed as appropriate for use in oxy-fuel furnaces. A schematic of the boundaries for the mass and energy balances is provided in Figure 1.

## Lessons Learned

Periodic evaluation of a furnace's energy efficiency can potentially pay big dividends through reduced energy usage. With significantly higher prices for natural gas, the primary fuel of choice in the glass industry, reducing energy use will become increasingly important. The protocol developed through this project can be extremely beneficial by providing a structured approach for assessment of the furnace's energy efficiency, and the identification of potential system improvements.

In this case, the return on using the protocol to carry out the assessment was significant — reduction in energy consumption of 2.6% by installing more efficient burners, which would save the glass producer more than $100,000 per year if the entire furnace were converted to the more efficient burners. Additionally, reduced emissions would also result. Implementation of other specific improvements in furnace operations identified by the protocol would likely further increase the value of the assessment.

The energy assessment protocol developed under this project is specific to the glass industry. However, the principles employed – particularly the use of heat and mass balances, and the development of temperature maps around the furnace – are general and can be easily adapted to other energy-intensive industries. In fact, both DIAL and Combustion Tec have used parts of the methodology developed here in other industries. The unique features of this approach, however, are that it is comprehensive – all areas of the furnace and its operations are considered; it is structured – hence, more rigorous than "ad hoc" methods; but it is also flexible enough to accommodate different sources of data depending on the sophistication of the glass producer and the measurement tools available and still be able to produce valuable results.

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September 2004