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Quarterly Report

Demonstration of Oxygen-Enriched Air Staging at Owens-Brockway Glass Containers

Feb. 1, 1996 - Apr. 30, 1996

The objective of the program is to demonstrate the use of a previously developed combustion modification technology to reduce NO_x emissions from sideport regenerative container glass melters. A 17-month development program has been established with specific objectives to: 1) acquire baseline operating data on the host sideport furnace in Vernon, California, 2) evaluate secondary oxidant injection strategies based on earlier endport furnace results and through modeling of a single port pair, 3) retrofit and test one port pair (the test furnace has six port pairs) with a flexible OEAS system, and select the optimal system configuration, 4) use the results from tests with one port pair to design, retrofit, and test OEAS on the entire furnace (six port pairs), and 5) analyze test results, prepare report, and finalize the business plan to commercialize OEAS for sideport furnaces. The host furnace for testing in this program is an Owens-Brockway 6-port pair sideport furnace in Vernon, California producing 325-ton/d of amber container glass. The baseline NO_x level of this optimized furnace is about 4.0 lb/ton of glass. An anticipated NO_x reduction of 50% will lower the NO_x production level to below 2 lb/ton. Secondary oxidant staging techniques being considered include oxygen-enriched ambient air staging (OEAS) and oxygen staging (OS).

The OEAS technology utilizes a unique method of combustion air staging to control NO_x formation by reducing the oxygen available in the flame's high temperature zone and improving flame temperature uniformity and combustion efficiency. The amount of primary combustion air entering through the ports is reduced to decrease NO_x formation in the flame, and oxygen-enriched air is injected into the furnace near the exit port to complete combustion in a second stage within the furnace. The OEAS technology has been successfully retrofitted to three endport container glass melting furnaces; a 150 ton/d endport glass tank producing flint glass in Huntington Park, California, a 200 ton/d endport glass tank producing amber glass in Houston, Texas, and a 320 ton/day endport glass tank producing flint glass in Huntington Park, California. With endport furnace NO_x reduction levels of 50-70%, the OEAS technology shows an excellent potential for similar performance on sideport furnaces. Sideport furnaces are used for nearly 65% of U.S. glass production. Although the potential successful application of OEAS to sideport furnaces is high, considerable design effort and development testing are required. Endport and sideport furnaces are similar in concept, but these furnaces are significantly different in physical design and flame characteristics.

The project team consists of IGT, which originated the concept and is the prime contractor, and the following subcontractors: Combustion Tec, Inc. (CTI), combustion equipment manufacturer and commercialization partner; Air Products and Chemicals, Inc. (APCI), O_2 supplier and commercialization partner; and Owens-Brockway Glass Containers, glass producer, and owner of the host site.

Summary of Accomplishments

Lilja completed the majority of the OEAS system installation at the Owens-Brockway furnace in February. The CTI skids were finished and tested in February. They were sent by truck to Vernon, California in preparation for final installation. The test instrumentation, probes, tubing, gas sampling trains, chart recorders, data acquisition system, racks, and ancillary equipment were assembled by IGT. All of the test equipment will be shipped in early March.

Air Products completed the modeling work at the end of January, and the results indicated that the side-of-port injection through the burner blocks would not affect furnace thermal efficiency, would not cause any adverse heating effects, and would result in burnout of both NO_x and CO. Results also showed that the jets would not penetrate into the furnace, and all burnout would occur in the ports. To recover the heat from CO burnout, the OEAS strategy relies on burnout in the furnace. Based on these results, the project team explored other staging locations. Based on furnace physical characteristics and desired staging locations the team selected underport lancing at 25° to 30° from the horizontal and crown injection at 30° from the vertical as preferred staging locations.

A project meeting was held on Feb. 22 at the Owens-Brockway Technical Center in Toledo, OH. At that meeting, the project team discussed the modeling results, the new staging locations, and the schedule timeline. Owens-Brockway expressed concerns about both the under-port and crown locations with regards to the condition of the brick. It was agreed that Owens-Brockway would evaluate the furnace condition and Air Products would model the other staging locations before a decision was made regarding drilling holes and choosing other staging locations. Owens-Brockway requested that, even if another staging location is selected for testing, that single-port pair OEAS testing still be conducted at the side-of-port location. The project team agreed with this request.

A schedule was set for baseline testing in the middle of March to be followed by single-port pair testing in late March or early April.

Work in March included finishing the modeling work, completing the air and oxygen skid installation and conducting baseline testing.

Air Products completed modeling of OEAS using underport and crown injection locations. Results of this work showed the majority of CO can be burned out in the furnace while achieving the same high burnout level as using side-of-port injection and without causing any adverse effects on the furnace. The modeling study conclusions were reviewed by IGT, CTI, and Owens-Brockway.

A decision was reached to evaluate all three staging locations during the single-port pair trial. Injectors were installed in the burner blocks of the fifth port pair to evaluate staging using side-of-port injection. On one side of the furnace a single, centered hole was drilled below the port to allow underport injection. On the other side of the furnace, two holes were drilled below the port for underport injection and one, centered hole was drilled in the crown. This provided OEAS testing using underport injection providing good coverage of the entire port and crown injection from a single location.

Baseline testing was conducted in March. Measurements were made of NO_x , CO, CO_2 , and O_2 concentrations at the back of the regenerator for each port. The same measurements were also made in the flue tunnels and the stack. Temperatures were measured at the back of the port at port number 5. Data was collected over a five day campaign. During this time the furnace production rate was set at 297 to 308 ton/d of glass. Different air/fuel ratios were used, and the furnace was found to be producing just under 4 lb NO_x /ton of glass. Complete data analysis will be performed during the next two months.

The air and oxygen skid installation was completed in March, and the piping for the fifth port pair testing was finished. The system was pressure checked, and the reversal switching was confirmed. A large oxygen valve needed to be opened to supply oxygen to the skid, but this valve could not be opened. Owens-Brockway repaired this valve before the OEAS testing began in April. Other work finished before staging was begun included sealing the burner blocks on ports 4, 5, and 6; drilling the holes for the staging injectors; and moving some lines to allow access of the driller to the underport location.

Work in April included final preparation for the single port pair testing, injector installation, and single port pair testing of port number 5.

A decision was reached in March to evaluate three staging locations during the single-port pair trial. The selected positions were side-of-port through unused oil burner blocks, underport (directly into the furnace) using both one hole (centered) and two holes, and furnace crown using one centered hole. Modeling work suggested underport holes be drilled at an angle of 30° to the horizontal and the crown hole be drilled 30° to the vertical. Optimum staging velocity was determined to be approximately 300 ft/s.

These furnace holes were drilled in April along with a hole at the charging end of the furnace to allow a camera system to be installed. CTI had only manufactured four injectors, so these were installed first in the side-of-port burner blocks.

Before OEAS testing was conducted, the fuel to port 5 was increased to several, successively higher levels to determine the optimum air/fuel ratio for low NO_x production. A preferred stoichiometry of between 0.90 and 0.95 was selected, and this ratio was used for all OEAS testing. This preferred air/fuel ratio significantly reduced NO_x , but CO was over 3000 ppm in the exit port.

OEAS testing was conducted first using the side-of-port staging positions. Tests were conducted with enriched air (35% O₂) and oxygen. The injection angle and orifice size could not be changed. Therefore, velocity was changed by manipulating the total flow to the injector. These tests showed NO_x reductions of up to 35% with complete CO burnout. Preferred staging conditions were selected using both enriched air and oxygen, and an extended, 8-hour test was conducted at the preferred enriched air staging conditions.

After side-of-port testing was complete, the injectors were moved to the underport staging locations. Similar tests were conducted using enriched air and oxygen. Flows, velocities, and O₂ enrichment level were varied in these tests. Results were similar to the side-of-port tests. The total oxygen needed for CO burnout was slightly higher than for side-of-port injection, but this may be because the furnace gas flow pattern causes some of the injected oxygen to be spread to neighboring ports. All staging and oxidant conditions were not the same. Two important qualitative conclusions were reached during testing. First, oxygen injection with only one hole is not desirable because the exit port is overheated. Second, two hole underport injection is much more effective for CO burnout. The single hole injection configuration apparently does not do an effective job of covering the port.

Following the underport staging tests, the test procedure was repeated for the furnace crown injection location. This position also provides effective CO burnout. Concerns, however, were expressed regarding jet impingement on the glass surface. The camera showed that the jet does penetrate to the surface of the glass. Owens-Brockway also showed great reluctance toward installing OEAS through the furnace crown.

The final test was an extended test of 4 hours using underport enriched air staging at the preferred condition to achieve low NO_x and effective CO burnout. During this test, samples were taken in the back of the regenerator and in the stack from the full furnace. Results from stack sampling showed an overall NO_x reduction of 8 to 10 percent. Since OEAS was only operating on one of the six ports, the numbers suggest an overall furnace NO_x reduction of approximately 50 percent can be achieved. This reduction would decrease the furnace NO_x production from 3.8 lb/ton of glass to approximately 2.0 lb/ton of glass.

Testing data will be reviewed and summarized early next month. A meeting will be held with IGT, CTI, Air Products, and Owens-Brockway to review the testing data and determine the preferred conditions and positions for OEAS on the full furnace. This meeting will be held next month to allow CTI as much time as possible to manufacture the remaining hardware for the full furnace.

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A, B	1. System Definition																											
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