Cupola Oxy-fuel System Reduces Emissions While Cutting Fuel and Alloy Costs

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Since the 1960s, many improvements in cupola technology have enabled the cupola to remain competitive with alternative technologies (Boehm, 2002). However, with the ever increasing challenges of regulation, energy costs, and charge material availability, the importance of continuing to develop and implement new technologies has never been greater.

Five years ago, Air Products renewed efforts on a cupola technology to address rising costs, declining scrap quality, and limited availability of foundry coke. The technology, APCOS™ (Air Products Cupola Oxy-fuel System), which was originally developed in the early 1990s, is a flexible tool that allows cupola operators to control energy distribution and melt temperature while reducing coke consumption. Experience has shown that the positive impact of APCOS technology improves over time as operators understand its capabilities and can optimally integrate it into their cupola's operation. This article provides an update on how the technology is able to reduce costs and emissions regulated by the EPA and also reports on enhancements that improve the efficiency of the technology.

Figure 1: APCOS™ (Air Products Cupola Oxy-fuel System) Configuration

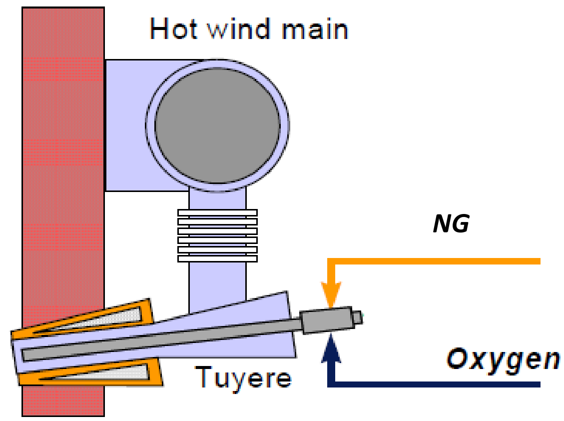


Figure 2: Total Fuel Reductions

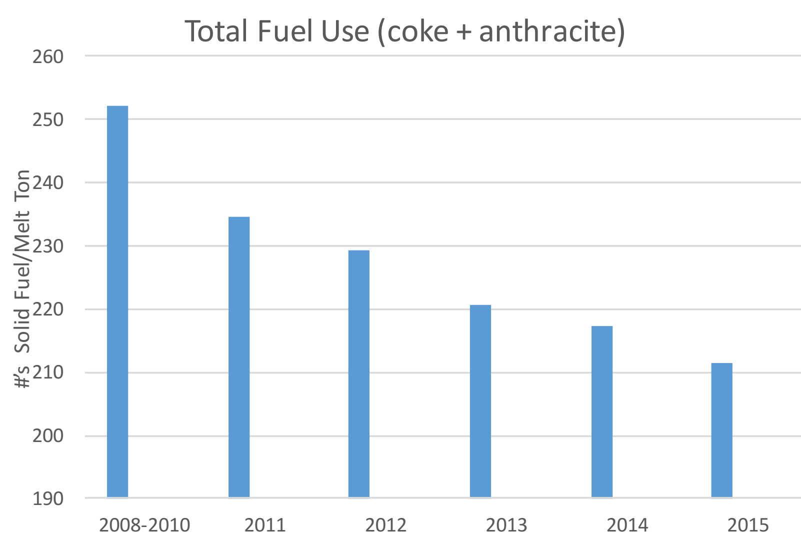
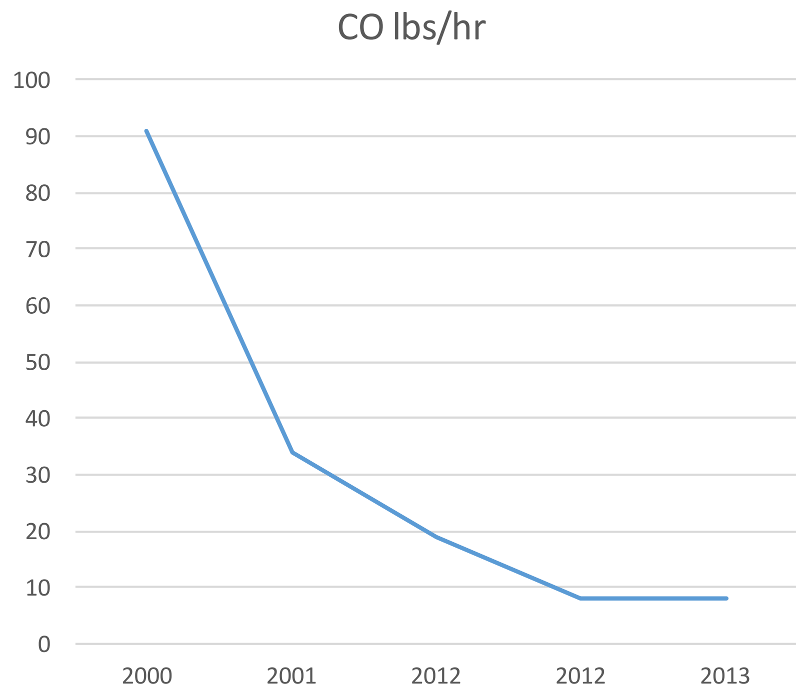


Figure 3: CO Reduction from APCOS Technology



APCOS technology is a tuyere-based system that operates in conjunction with a cupola's current oxygen injection system. The technology uses a proprietary burner design that injects supersonic oxygen and natural gas to release energy in the melt zone to replace coke and/or increase production. Experience has shown that there is an ~10% gain in efficiency when adding energy directly to the melt zone. Consequently, 1 BTU added via APCOS technology reduces coke requirement by ~1.1 BTU. Furthermore, the ability to add heat directly to the melt zone facilitates the substitution of coal for a portion of the remaining coke charge.

The impact of APCOS technology on total fuel use at a foundry producing ductile iron is highlighted in Figure 2. The figure shows a total carbon-based fuel reduction of 17%. However, since the use of anthracite to replace coke has increased each year, and anthracite is significantly less expensive than coke, the cost benefit achieved was far greater than 17%.

Using anthracite adds some complexity to the operation as it becomes another charge material to handle, and size is a challenge. According to Katz, the density of anthracite is 50% higher than coke, which permits a greater mass of charges in the preheat zone. This increases the residence time in the preheat zone, as well as the efficiency of heat transfer. One of the primary obstacles to using anthracite is lower iron temperatures (Katz, 1999). APCOS technology, however, is able to adjust temperature to the melt zone to alleviate this obstacle.

The ability to provide heat into the melt zone enables optimal control of cupola temperatures, which has led to increased alloy recovery and reduced flue gas pollutant emissions. Some of the most dramatic improvements to the operation using APCOS technology have, in fact, been in the reduction of CO, CO_2, SO_2 and NO_X. This is particularly crucial as the U.S. has pledged a 26% reduction in greenhouse gases by 2025 from our 2005 levels (Hoover, 2015), and regulatory pressure is expected to increase. Figures 3 and 4 highlight a 90% reduction in CO and SO_2 due to the combined effect of integrating APCOS technology into cupola operation, thereby optimizing cupola energy release and temperature distribution while reducing coke consumption and increasing the amount of anthracite used.

While injecting oxygen and natural gas into a cupola to reduce fuel costs has proven to be successful, the degree of benefit is inherently limited by the water vapor produced via combustion of methane. Specifically, the water vapor produced from the oxygen-natural gas reaction gasifies a portion of the coke via endothermic (i.e. energy-consuming) reactions. To mitigate this effect, Air Products has recently developed the next generation of the APCOS offering, APCOS II technology, which operates primarily with high carbon, low hydrogen solid fuel instead of natural gas, thereby substantially reducing water vapor production in the cupola.

The APCOS II system further increases the potential for coke savings by eliminating a source of coke loss via gasification. Moreover, since the amount of endothermic gasification is reduced, more energy is available for melting iron. As summarized in Figure 5, the potential for increased available energy and reduced coke consumption improves with the amount of solid fuel delivered from the APCOS II burners relative to oxy-gas firing. The economic benefit of these savings can be substantial. For example, assuming 10 MMBtu/hr of APCOS II energy delivery, coke consumption would decrease by as much as 500 lb/hr over and above savings already delivered by APCOS technology (see Figure 2). For coke priced at $500/ton, this correlates to an additional savings of approximately $1MM per year of operation.

Figure 4: SO_2 Reduction from APCOS Technology

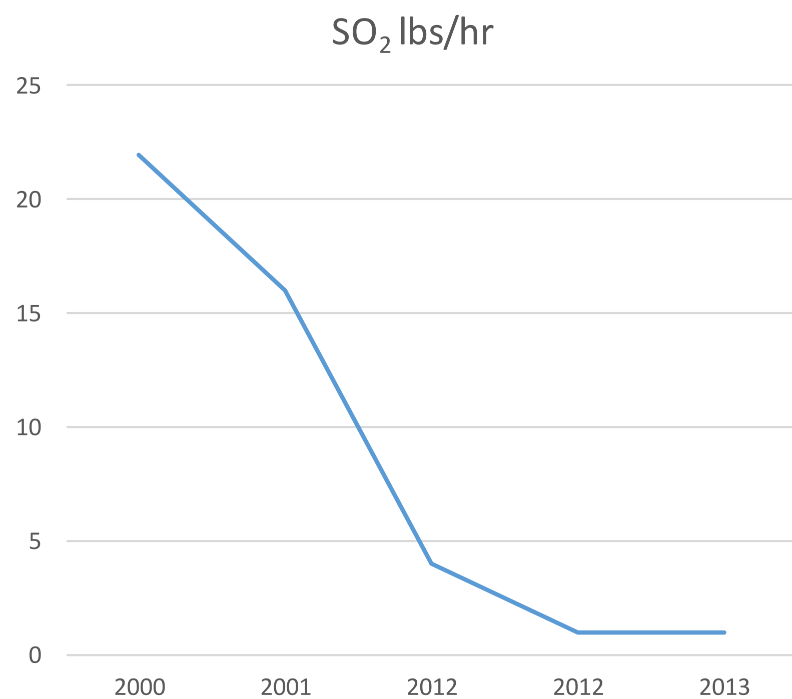
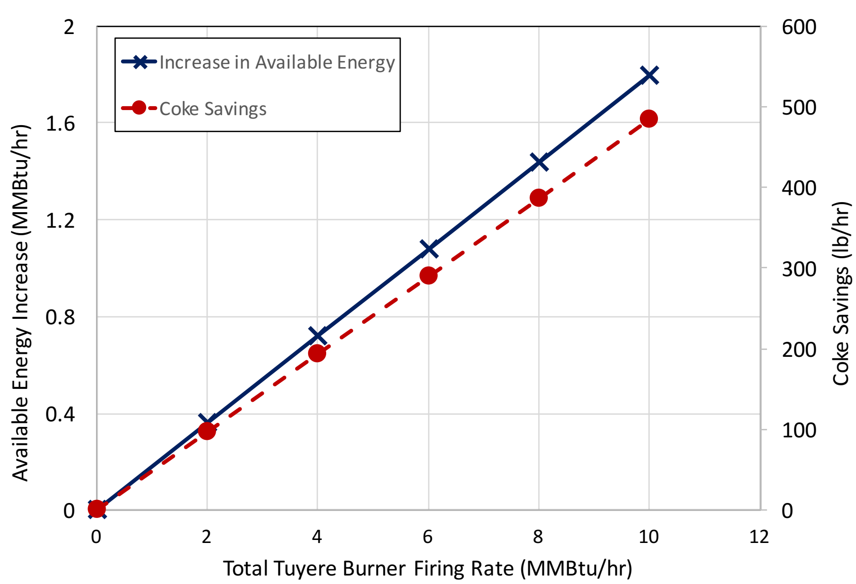


Figure 5: Increase in Available Energy and Reduction in Coke Gasification Enabled by APCOS II Technology vs Gas Firing



Due to the high velocity operating conditions of the APCOS II burner, the solid fuel must be heated, ignited, and combusted within milliseconds of leaving the burner. To guarantee stability and efficiency of this process, a natural gas pilot is part of the patented APCOS II design. Robustness of the new technology was validated during development via testing of a variety of solid fuels, including coke breeze, petroleum coke, and waste anthracite. A convenient feature of the burner design is that it is capable of operating at its design firing rate with either natural gas or solid fuel. Consequently, if some disruption occurs in the supply of solid fuel, the burners can be switched over to operate with natural gas with the push of a button. Photos of the APCOS II burner operating in both the solid fuel and gaseous fuel modes are presented in Figures 6 and 7, respectively.

In summary, the APCOS technology has proven to be an effective tool in reducing fuel cost, alloy cost, and harmful emissions. The development of the new APCOS II technology uses solid fuel to reduce charge coke usage and increase the energy delivered to the melt zone by reducing the water vapor and hydrogen created in the combustion process. This patented design provides the operator with the flexibility to choose the fuel type, as well as the firing rates and stoichiometry, thereby enabling cupola operators to meet the ever increasing challenges of regulation, energy cost, and charge material availability.

Figure 6: APCOS II Burner Operating in Solid Fuel Mode

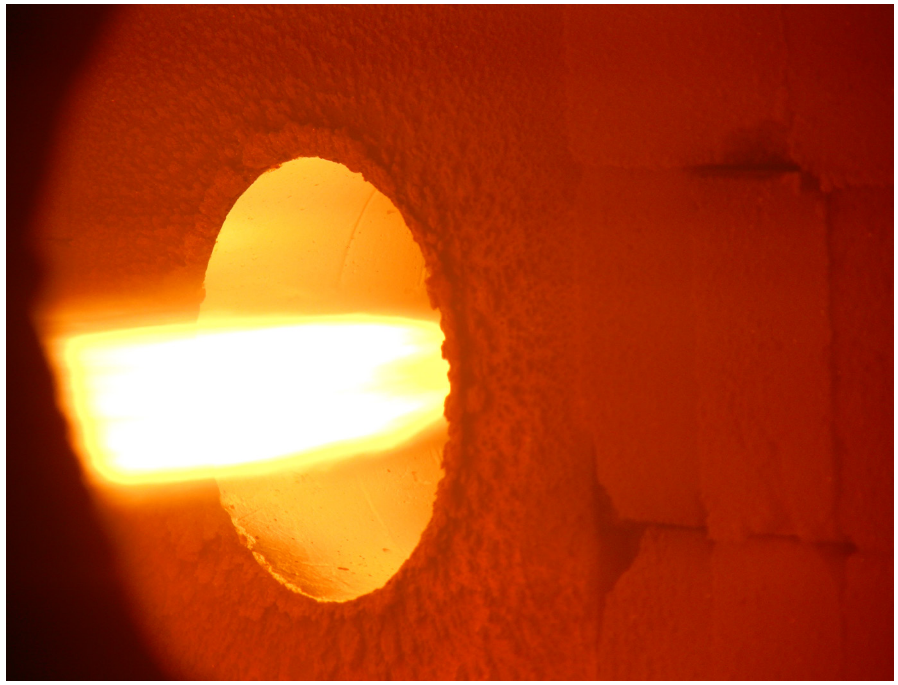
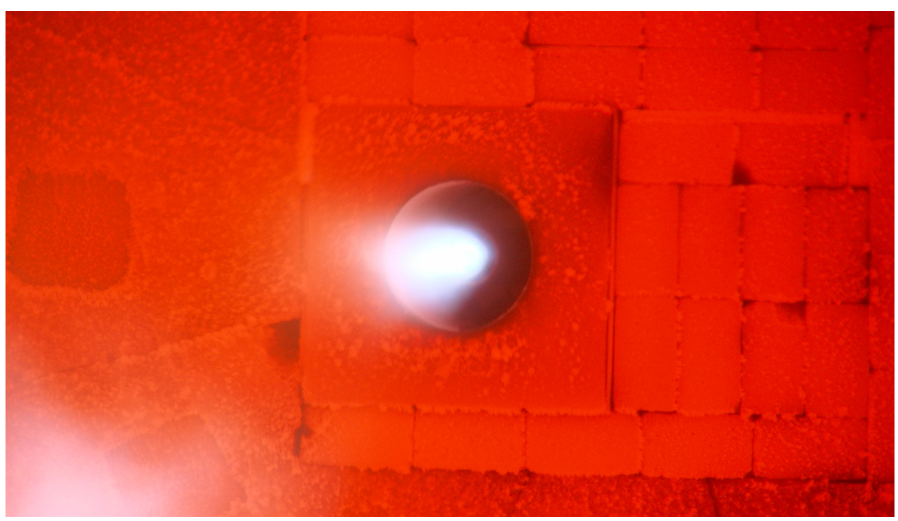


Figure 7: APCOS II Burner Operating in Gaseous Fuel Mode



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