First Co-Firing Gas Burner, Optimized on Computer, Reduces Particulate Emissions 24%, Saves $0.13/MMBtu

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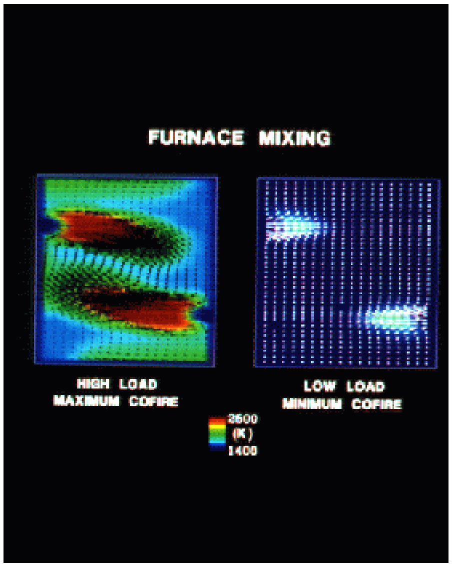


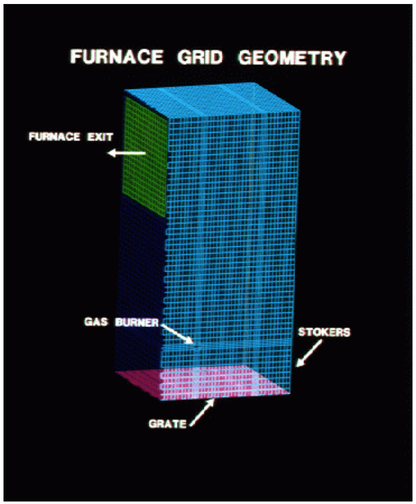
Furnace mixing simulation.

Installation of natural gas cofiring on a coal-fired spreader stoker at Dover Power & Light cut particulate emissions by 24% and saved $0.13/MMBtu, primarily because of the ability to fire at loads above 150,000 lb/hr. This level of performance had previously been precluded by opacity emissions or fan limitations. This installation, located in Dover, Ohio, is believed to be the first in the United States in which a gas burner was designed and installed specifically for gas co-firing. A key to the success of the retrofit project was the use of computational fluid dynamics (CFD) to optimize the placement of the burners in order to maximum cofiring performance.

Over 1,500 coal-fired stoker boilers are operated in the United States. They use a broad spectrum of coal feed and grate systems, including spreaders, mass feed chain grates and under feed stokers. Most of the stokers are over 30 years old and are becoming more difficult to maintain in compliance with environmental emissions regulations. The majority of emissions of unburned carbon and CO from a spreader stoker boiler are the result of poor mixing within the furnace, called channeling. Many units have been derated and have experienced reduced availability and efficiency due to opacity problems, decreasing quality of stoker coal supplies, and limitations in fuel/air handling system.

One of the options that a coal-fired boiler owner has to reduce emissions is to convert completely to natural gas firing. However, the cost associated with complete conversion to natural gas is high. Furthermore, normally only a marginal improvement is needed to bring these boilers into compliance with Title V of the Clean Air Act. For these reasons, natural gas cofiring is receiving renewed attention as a resource to enable stoker boilers to meet emissions standards, recover lost performance and continue reliable service.

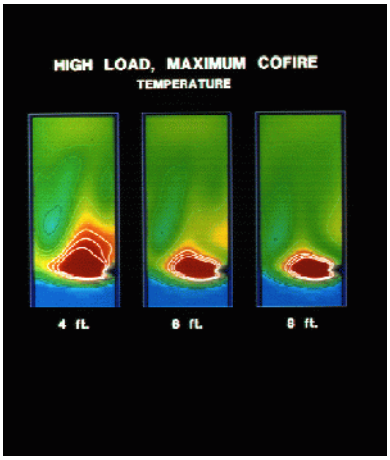
The term cofire in industrial coal-fired boilers has long been used for the installation of one sidewall burner sized for full boiler capacity. These burners were installed on both new units and, more commonly, on a retrofit basis for warm-up, coal light off and to serve as a standby for coal interruptions. The burners were not intended for sustained gas firing simultaneously with coal. Around 1990, the gas industry began evaluating whether auxiliary gas burners could offer compelling benefits to boiler operators when used for sustained gas cofiring. These evaluations showed cofiring improved operational flexibility, increased efficiency, reduced opacity and NOx emissions. In fact, the initial evaluations showed that overall boiler performance improvements of 5% to 20% gas would in many cases justify the additional fuel cost.



Simulation showing high load, maximum cofire temperature.

However, little effort was made in early installations to optimize gas cofiring performance. The burners used in most installations were designed to fire full burner load and had a relatively large throat diameter. The gas burners were limited to a load turndown of about 10:1. However, the high cost of natural gas limited the gas cofiring rate to about 10% over the operating range of the boiler. This results in the gas burner operating from 5% to 10% of its capacity where the flame had insufficient momentum to penetrate the combustion gases over the bed. Also, the burner position was usually dictated by access rather than by performance enhancement considerations. As a result, early installations were not able to take full advantage of the benefits of cofiring.

In an effort to overcome these difficulties, the Gas Research Institute (GRI) initiated a project in September, 1994 with the team of Acurex Environmental, The Coen Company, East Ohio Gas, and Dover Light & Power to further develop the potential of gas cofiring. The goal of the project was to optimize gas burner design and location on an existing coal fired boiler to optimize gas cofiring performance. The targeted boiler was a coal fired stoker unit where coal is fired on a spreader stoker at the bottom of a furnace. Undergrate air flows through the grate with the use of both forced draft and induced draft fans resulting in a slight negative static boiler pressure. Pulverized coal, nut and pea size, is fed into the spreader stoker boiler by way of a spreader, which throws the coal across the grate from the front of the boiler to the back. The motion of the grate brings the coal to the front of the boiler with a residence time of approximately six hours. During that time, the majority of the coal is reacted and bottom ash is dropped off the front of the grate into hoppers. As with most stoker boilers, this one experienced challenging emissions control and opacity problems. The problems arose because the distribution of coal onto the stoker grate usually resulted in uneven piles of coal where complete combustion is hindered. Smoke, CO and fly ash are generated, increasing the fines content of the coal. These products of incomplete combustion rose in the furnace and failed to mix with the rest of the furnace flue gases. The plant fires a local nominally 2.5 percent sulfur Ohio coal, which is highly variable in sizing and ash content. The boiler was originally designed to produce 165,000 lb/hr of steam, however, this peak output could be sustained only when firing exemplary coal. For example, attempts to operate near peak capacity with low quality coal were frequently limited by opacity excursions because the electrostatic precipitator could not remove enough of the particulates. Attempts to alleviate opacity excursions with higher excess air ran up against the limits on the induced draft fan. As a result of these limitations, the boiler load was derated to 145,000

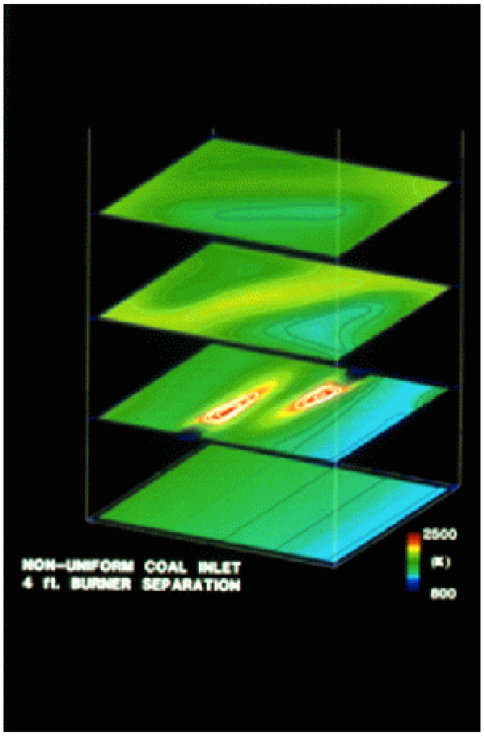


The furnace grid geometry.

lb/hr, a loss of more than 10% in boiler capacity. This forced the plant to increase purchased power at a net higher operating cost.

The first step in the project was to evaluate different cofiring options using computational fluid dynamics (CFD). Coen engineers have used FLUENT CFD software from Fluent, Inc., Lebanon, NH, since 1986 to analyze and optimize burner designs. We selected this software package because it has a wide range of robust physical models for combustion processes. A body fitted coordinate scheme saves time in setting up the geometry of the furnace and a provision for local coordinate systems makes it easy to set up the velocity at each burner face as a boundary condition. Initial geometry and grid generation for the boiler modeled the entire furnace, the pendant superheater, and the first pass of the convection section of the boiler. However, the results of an initial study revealed that a nearly constant pressure boundary existed at the exit of the furnace, after the superheater. Taking advantage of this fact, two smaller models were developed for the regions of the furnace before and after the superheater. This allowed more accurate models to be developed for each section and faster solutions to be obtained.

FLUENT solves the governing equations of continuity, momentum and energy over each of the control volumes formed by the computational grid. After integrating these equations over the control volumes, velocity and pressure coupling are resolved via the Semi-Implicit-Pressure -Linked-Equation (SIMPLE) algorithm. Turbulence closure was provided by the k-e turbulence model with standard coefficients, although other turbulence models are also available. The turbulent boundary conditions for momentum and heat transfer in the near wall region followed the logarithmic law of the wall. Conduction in the furnace wall was accounted for using a conjugate heat transfer model. Gas phase combustion was modeled as a one step global reaction with fuel and oxidant components reacting to form combustion products. Transport and chemical reaction rates were governed by either kinetic (Arrhenius) rate equations or mixing of eddies (Magnussen model). Coal combustion was not modeled and the grate flow was simulated by flue gases at the proper stoichiometry and temperature obtained by field measurements.



Non-uniform coal inlet.

Three different gas cofiring burner configurations, with burner offset distances of four, six and eight feet, were examined. The first simulation performed was a cold flow case without gas cofiring burners. The results of this baseline model allowed the definition of a proper pressure drop across the pendant superheater in the furnace. Once the general flow patterns and superheater pressure loss characteristics were determined, the CFD investigation continued with two boiler and two cofiring loads for each of the three burner offset distances considered.

The project specified opposed and offset dual gas burners to give better gas flame penetration through the combustion gases. The offset configuration also induces a vortex motion which helps to break up channeling above the grate that can be a mechanism for increasing unburned carbon and CO emissions. The burner swirl was counterclockwise for both front and rear burners. For the burner at the front wall, this effectively sweeps fines from the spreaders back toward the grate and primary flame rather than short circuiting up the front wall and out the boiler. Near the rear of the boiler, where the majority of the stoker heat release occurs, the swirl entrains the combustion gases off the grate and directs the flame towards the center of the boiler away from the back wall. The predicted furnace temperatures for a vertical slice through the center line of boiler revealed significant differences between the various burner offset distances considered. The four-foot offset resulted in flames from each of the two gas burners being deflected towards each other, creating a localized region of high temperature in the center of the furnace. As a result, a large volume of the furnace near the front and back walls was not affected by the flames of the gas burners. These regions would increase the likelihood of incomplete coal combustion. It was also evident that fly ash caught in the regions surrounding this condensed flame region would not be affected by the gas cofiring burners. The six-foot burner separation case indicated improved furnace coverage by the gas flames, but cooler regions still persisted near the front and back walls of the boiler. When the burner separation was increased to eight feet, a significant increase in the flow near the boiler front and rear walls was observed. This caused cooler flue gases to be convected into the tails of the cofiring flame and reduced the penetration of the flame to the opposite wall of the furnace. Based on these findings, the eight-foot separation scheme was used in the installation.

The Dover Power & Light plant was retrofitted with Coen cofire burners during an outage in May-June 1995. The boiler was brought back on line July 6, 1995 using gas for warmup. After a period of validation of the new coal automatic control system installed during the retrofit, the unit was cofired with gas for the first time on August 4 and has been cofired for the majority of time since. The boiler was tested with and without cofiring gas to determine performance effects benefits. The fluctuations in coal sizing and quality experienced during one 3-week test period in August 1995 would normally have limited the boiler load to 145,000 lb/hr. With approximately 12% cofire, the boiler was operated for 2 weeks of an August peak generation period with daily loads in the 150,000 to 160,000lb/hr range with no significant increase in opacity level relative to what would have been produced at the derated performance level. Long term testing of the unit will continue to obtain data on emissions and efficiency benefits resulting from sustained gas cofiring.

Results of the study showed that cofiring burners improve mixing within the furnace and create a swirling flow pattern that promotes more completecombustion of coal fines and reactions of product gases. This improves efficiency and also reduces exhaust gas opacity. The effectiveness of gas cofiring in controlling opacity at high loads is attributable to dual effects of carbon burnout by the gas flames and displaced coal firing (by the cofired gas). In addition, excess air reductions during the high load operation with gas cofiring yielded more draft fan reserve than with just coal firing, where fan limits would frequently limit load. This is because overall excess air is lower with gas firing due to the improved thermal distribution and enhanced mixing.

The derate recovery provided a savings of $0.17/MMBtu, which accrues from both avoided demand charges and avoided cost of purchasing power, particularly at peak load periods. This benefit alone is sufficient to compensate for the higher fuel cost associated with gas cofiring. When other benefits, such as improved efficiency through excess air reduction and carbon utilization, reduced opacity and enhanced operability, are balanced against the capital and operating costs of the retrofit, the result is a net savings of $0.13/MMBtu.