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IN-DEPTH FOCUS

Refueling Oil-Fired Boilers With Petroleum Coke

The following article was prepared by Craig J. Cain-Borgman, Senior Business Development Manager, EPI Structured Business Dept. of Air Products and Chemicals, Inc. It is presented herein as an information piece and is not meant to be an endorsement or advertisement of any sort for the process by Jacobs Consultancy. Our sole objective is to provide our clients with cutting edge, timely information about areas of interest. To that end, we welcome submittals from our clients of papers, articles, or presentations to be included in this publication as space and content allow. Submissions may be sent to david.gipson@jacobs.com

About Air Products

Air Products is one of the world 's largest industrial gas producers, supplying a broad range of industrial gases—chiefly oxygen, nitrogen, argon, hydrogen and helium and related equipment for their production, distribution and use—to hundreds of thousands of customers throughout the world. These gases are used in most industries, including food and metal processing, semiconductor manufacturing, healthcare, aerospace and chemical production.

Air Products' chemicals business includes polymers, polyurethane intermediates and additives, amines, and specialty and epoxy additives used in applications such as adhesives, coatings, polyurethane foams, textiles, herbicides, pesticides, water treatment chemicals, reinforced composites and inks.

In addition to a broad product line and invested presence in more than 30 countries, the company has world-class production and applications technology and a long-standing commitment to safety, efficiency, and cost-effectiveness in every facet of its operations. U.S. corporate headquarters are located in eastern Pennsylvania 's Lehigh Valley, near Allentown. European headquarters are at Hersham, near London; and Asian headquarters are in Singapore, with offices in Tokyo and Hong Kong.

Alternatives to High Natural Gas and Oil Prices

The relatively recent increase in natural gas and oil prices has given rise to renewed interest in a number of uses for lower cost fuels, including petroleum coke and in the application of technologies to exploit the lower price of petroleum coke. Interest in gasification of petroleum coke for syngas and/or power generation has noticeably increased, as has recent interest in development of circulating fluidized bed boilers to utilize petroleum coke. Air Products and Chemicals, Inc. and Foster Wheeler Corporation have been developing a new technology to burn petroleum coke in existing oil-fired generating units, exploiting the potential of these currently noncompetitive assets to produce low-cost electricity. The following is a general discussion of that technology and the status of its commercialization.

Refueling Oil-Fired Boilers—Petcoke vs. Orimulsion Blend

Air Products has previous experience in reviewing potential refueling of the existing oil-fired boiler fleet in the United States with Orimulsion® as a supplier of flue gas desulfurization equipment and operation and maintenance services through its Pure Air joint venture with Mitsubishi Heavy Industries. Although the Pure Air joint venture has been dissolved, Air Products' interest in the conversion of these low-value, high-cost generating facilities to lower cost fuels continued. The concept of blending petroleum coke with Orimulsion®* to further

reduce fuel costs was reviewed and found to offer incremental improvements to the economics of conversion to Orimulsion®. By increasing the percentage of petroleum coke in the blended fuel, average fuel cost is further reduced.

One of the biggest problems with trying to burn solid fuel in a boiler originally designed for oil-firing is fouling (i.e. plugging) of the boiler convection pass. Tube spacing in the convection pass of the boiler is too close to accommodate the much higher ash content of coal compared to oil (e.g. 10% versus 0.5%). However, petcoke's very low ash content (typically 0.5%) addresses this ash loading issue. Moreover, the ash chemistry of petcoke is very similar to residual fuel oil ash, whereas ash chemistry of coal creates corrosion and slagging issues on the boiler tubes that makes conversion of an oil-fired design to coal firing impractical.

Oxygen Enriched Combustion

Air Products was concerned with high percentages of petcoke creating combustion problems due to the low volatility of petroleum coke. Experience in Japan had shown that high percentages, approximately 75%, of petroleum coke could be combusted utilizing specialized burners, but the amount of air flow into the boiler had to be increased with a resulting derate of the boiler's design capacity. Generically, a boiler designed for production of 100MWe becomes a 40 to 50MWe boiler following this conversion. In addition, the flame was not as stable as a typical solid fuel flame and NOx production increased due to high excess combustion airflow.

Air Products has a long history of oxygen enhanced combustion research and applied some of that experience to the problem of efficiently combusting petroleum coke with shorter combustion residence time than normally required. In oxygen enriched combustion, pure oxygen is substituted for a portion of the air to enhance the combustion process. Following presentation of Air Products' concept to Foster Wheeler, an agreement was reached between the two companies to jointly develop and commercialize the technology to refuel existing oil-fired boilers.

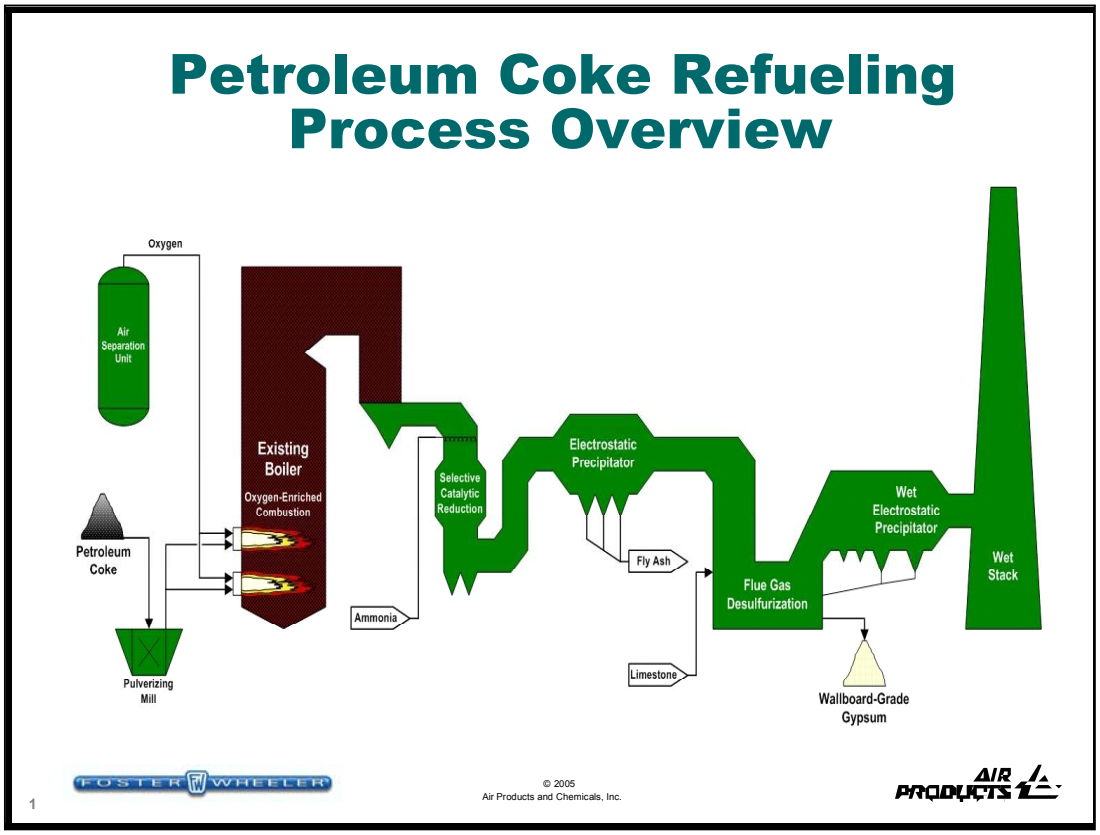
Initial testing of petroleum coke combustion utilizing a Foster Wheeler burner of proprietary design commenced in December of 2000 at Foster Wheeler's Combustion and Environmental Test Facility (CETF) located in Dansville, NY. The CETF is a flexibly designed facility built to allow simulation and data capture for both wall-fired and down-fired configurations. The facility is thermally equivalent to 6 MWe generating unit, utilizing two 30 MMBtu/hr burners. It is well instrumented to provide data for burner scaling and emissions prediction for full-scale units. Initial testing was focused on air-only combustion of petcoke to predict the potential derate and to compare the relative benefit to oxygen enriched combustion of coke.

Compelling Results Economics Increase; NO_x Decrease

Results of these tests were compelling: they showed that the refueling concept only worked with oxygen enrichment from an economic standpoint. A second phase of testing commenced in December 2001 to confirm results of the initial phase and to provide further data for design optimization and scaling. A major concern was the potential formation of large amounts of thermal NO_x due to the higher flame temperatures resulting from oxygen enrichment. Air Products was able to utilize its experience to inject oxygen in such a manner as to not only maintain NO_x, but to achieve a significant decrease in NO_x formation. Based on economic modeling of the resulting design, Air Products and Foster Wheeler filed a joint patent application to protect their joint intellectual property.

Design Phase and Commercialization

The overall design concept is illustrated below:



Petroleum coke is pulverized, then injected into the boiler furnace where it is burned using a combination of combustion air and oxygen produced by an on-site air separation unit (ASU). Selective catalytic reduction (SCR) NO_X control equipment reduces NO_X emissions by 75+%. An electrostatic precipitator is used for particulate emission control. A wet limestone SO_2 scrubber is used to reduce SO_2 emissions by 95+%. Finally, a wet electrostatic precipitator is installed to control acid plume issues. While this equipment represents a substantial capital investment of $300-450/kw (e.g. $90 – $135 million for a 300 MW unit), capital cost for this refueling concept is 30-50% of the cost for repowering an oil-fired unit with a new circulating fluidized bed (CFB) boiler.

The next phase of commercialization began with location of a site for a temporary demonstration of the oxygen enhanced combustion technology in an operating utility boiler. A host facility has been located and engineering completed for necessary facility modifications required to complete such a demonstration. Although proof of technology has been achieved, additional heat flux data and more robust emissions data from a commercial scale facility is required in order to allow Air Products and Foster Wheeler to intelligently provide permit and operating guarantees required for successful permitting and financing of a refueling. At present, the host site is planning a facility outage during March 2006 at which time the site modifications will be made. Following facility startup, a 30-day, 24-hour continuous demonstration will be conducted firing 100% petroleum coke utilizing the oxygen enhanced combustion process with the use of liquid oxygen. Data provided will then be utilized to engineer the refueling of the first commercial unit and for the filing of the air permit for that unit.

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