Program status: Ongoing

PROGRAM FACT SHEET

Fuel Flexibility for Industrial Boilers

Goal

The goal is to develop technologies to retrofit boilers, gain expertise to integrate hardware to achieve fuel flexibility in industrial boilers, and operate the boilers in an environmentally-friendly manner.

Team

A partial list of companies that have worked with The Energy Institute to develop and implement the multifuel concept are: Commonwealth of Pennsylvania, U.S. Departments of Energy and Defense, ABB Combustion Engineering, Foster Wheeler Energy and Development Corporation, CDA International, Raytheon Engineers & Constructors, Tampella Power Corporation, Faber Burner, Energy and Environmental Research Corporation, MicroEnergy Systems, Inc., Allis Minerals Systems, Corning Inc., Ceramem Separations, Inc., Clean Air Engineering, Bradford Coal Company, AMAX Research and Development, Hatfield Quality Meats, and Cargill Taylor Meats, and National Cattlemen's Beef Association.

Program Discussion

For nearly two decades, The Energy Institute at Penn State has been actively involved in industrial boiler research and development with an emphasis on multifuel capabilities, hardware development and testing, fuels evaluation, and emissions characterization and reduction. Historically, the emphasis has been on 'multi-fossil fuel' capabilities, which has evolved into the utilization of alternative fuels, such as agricultural by-products, in industrial boilers designed for fossil fuels. Fuel flexibility allows the industrial boiler operator to reduce energy (fuel) costs, utilize a waste product, obtain fuel flexibility, and use indigenous resources (i.e., home-grown fuels). The fuels of interest include coal, coal-water slurry fuel (CWSF), coal wastes, fuel oils, natural gas, Synthetic fuels, orimulsions, petroleum coke, tire-derived fuels, refuse-derived fuels, animal fats/ vegetable oils, animal proteins and tissue, manure/ litter, grasses/ crop residues, waste wood products, food processing wastes, waste seeds, and sewage sludge.

There are several technical considerations, which have been addressed during the development of the mulifuel boiler concept. These include modifying control systems, installing material handling, introducing the fuel into the boiler, removing ash (when applicable) from the system, integrating the fuel deliver system, burner, and boiler for proper combustion performance and, in the case of low-NO_x burners, low emissions production, managing ash deposition and erosion for proper heat transfer and metal wastage, and controlling emissions. To address these issues, hardware has been developed, optimized, and evaluated, which includes burners, atomizers, combustion systems, control systems, a heat-pipe heat exchanger, fuel (both solid and liquid) delivery systems, an industrial-sale pulverizer, a hybrid CWSF preparation facility, combustion enhancers, ash removal devices, particulate (ceramic and fabric filters) control devices, selective and nonselective catalytic reduction systems, and a sorbent injection system.

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Background

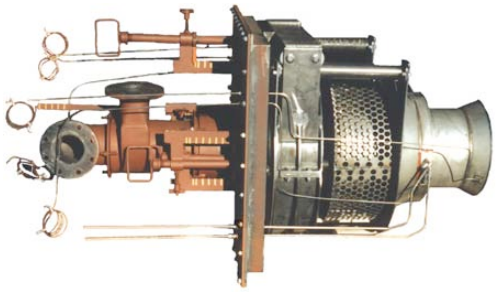
The U.S. Departments of Energy (DOE) and Defense (DOD) have recognized, since the late 1980's, the importance of positioning the U.S. for the use of coal and alternative fuels in industrial boilers designed for natural gas and fuel oil. Penn State has been working at developing and integrating technologies to fire coal-based fuels as well as alternative fuels in industrial boilers for DOE since 1989. Initial activities focused on retrofitting industrial boilers to fire CWSFs. This effort was later intensified in 1992 when DOD established a National Center of Excellence for Coal Utilization at Penn State. The charge to the Center was to develop clean coal-based technologies to: decrease DOD's dependence on foreign oil and increase its use of coal; promote public and private sector deployment of technologies for utilizing coal-based fuels in oil-designed combustion equipment; and provide a continuing environment for research and development of coal-based technologies for small-scale applications at a time when market conditions in the U.S. were not favorable. Combined with significant industry sponsorship, the program has been ongoing for more than a decade, and has emphasized the development of near-zero emissions technologies for coal-fired boilers.

Demonstration Boiler

Results

The initial focus in this topic area was on developing clean, coal-based, retrofit combustion technologies for burning CWSF and dry, micronized coal in oil-designed combustion equipment. Initial developments using these technologies were first identified by DOE and later confirmed by the U.S. Corps of Engineers as being of highest priority to DOD. To evaluate the technical and economic viability of firing coal-based fuels in oil-designed boilers, fundamental research, pilot-scale testing, proof-of-concept demonstrations, and two fully-engineered retrofit designs for a boiler located at the Naval Warfare Center in Crane, Indiana were performed. The technical aspects of the demonstrations involved component evaluation, modification, and integration into a boiler system.

Subsequent focus was on emissions control strategies to achieve ultra-low emissions when firing coal-based fuels in industrial-scale boilers. Although industrial-scale boilers were specifically targeted, the technologies developed are applicable to any coal-fired boiler facility because the scale at Penn State was sufficient to represent utility boilers. The emissions addressed included SO_2, NO_x, fine particulate matter ($PM_{2.5}$), and air toxics (trace elements and volatile organic compounds). In addition to achieving ultra-low targets of SO_2, NO_x and particulate matter, a detailed characterization of air toxics, specifically mercury, from coal-fired industrial boilers was conducted to assist DOE in identifying control strategies.



Foster Wheeler Low NO_x Burner

Work then expanded upon emissions reduction strategies through the use of deeply-cleaned coals as a means for reducing air toxics, lowering fine particulate matter and mercury emissions even further by using ceramic filters, in lieu of fabric filters, and performing a preliminary CO_2 removal/ sequestration study through bench-scale investigations and pilot-scale verifications.

Likewise, DOE funded a joint ABB Combustion Engineering/ Penn State project to develop and test a multifuel burner (natural gas, fuel oil and micronized coal) for retrofitting gas and oil-fired industrial boilers. This was done in recognition of the future possibility that economics and/ or political intervention may one day dictate the conversion from oil or natural gas to coal in boilers that were originally designed to burn oil or gas.

The outcome of these efforts was the development of technologies to retrofit boilers and the gaining of expertise to integrate existing hardware to achieve fuel flexibility in industrial boilers. Concurrent with the development of the retrofit technology, Penn State is working with industry evaluating nontraditional fuels – e.g., animal wastes, rendered products, emulsions, RDF pellets – fuels that are being considered to replace natural gas and fuel oils in industrial boilers due to the high energy costs associated with the gas and oils and their demonstrated price volatility. While the initial development focused on watertube boilers, this activity has expanded into firetube boilers and fluidized-bed systems.

Key Contact

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Key Publications

Miller, B.G. and S. Falcone Miller, “Utilizing Biomass in Industrial Boilers: The Role of Biomass and Industrial Boilers in Providing Energy/National Security,” *The First CIBO Industrial Renewable Energy & Biomass Conference,* Minneapolis, Minnesota, April 7-9, 2003.

Miller, B. G., A. W. Scaroni, S. A. Britton, D. A. Clark, J. L. Morrison, S. V. Pisupati, R. L. Poe, P. M. Walsh, R. T. Wincek, J. Xie, R. L. Patel, D. E. Thornock, and R. W. Borio, "Coal-Water Slurry Fuel Combustion Testing in an Oil-Fired Industrial Boiler Final Report," Prepared for the U.S. Department of Energy Pittsburgh Energy Technology Center, Pittsburgh, Pennsylvania, March 10, 1997, DE-FC22-89PC88697, 800 pages.

Patel, R., D. E. Thornock, R. W. Borio, B. G. Miller, and A. W. Scaroni, "Demonstration of Microfine Coal Firing with the RSFC Burner in a Gas/Oil Designed Industrial Boiler," *21st International Conference on Coal Utilization and Fuel Systems*, Coal and Slurry Technology, Assoc., March 18-21, 1996.

Miller, B.G., S. Falcone Miller, S.V. Pisupati, C. Song, R.S. Wasco, R.T. Wincek, X. Xu, A.W. Scaroni, R. Hogg, S. Chander, M.T. Ityokumbul, M.S. Klima, P.T. Luckie, A. Rose, R.L. Gordon, J. Lazo, and A.M. Schaal, “The Development of Coal-Based Technologies for Department of Defense Facilities; Phase III Final Report, Prepared for the U.S. Department of Energy Federal Energy Technology Center, Pittsburgh, Pennsylvania, Phase III Final Report, January 30, 2004, 665 pages; Phase II Final Report, July 31, 2000, 784 pages; Phase I Final Report, January 31, 1997, 590 pages; DE-FC22-92PC92162.