the ENERGY lab

PROJECT FACTS

Existing Plants, Emissions & Capture

Oxy-combustion Technology Development for Industrial Scale Boiler Applications

Background

The mission of the U.S. Department of Energy's (DOE) Existing Plants, Emissions & Capture (EPEC) Research & Development (R&D) Program is to develop innovative environmental control technologies to enable full use of the nation's vast coal reserves, while at the same time allowing the current fleet of coal-fired power plants to comply with existing and emerging environmental regulations. The EPEC R&D Program portfolio of post- and oxy-combustion carbon dioxide (CO_2) emissions control technologies and CO_2 compression is focused on advancing technological options for the existing fleet of coal-fired power plants in the event of carbon constraints. This project is one of six R&D carbon capture projects that were selected from the EPEC program by DOE to receive funding from the American Recovery and Reinvestment Act of 2009 (ARRA). These projects will accelerate carbon capture research and development for industrial sources toward the goal of cost-effective carbon capture and storage within 10 years. With the addition of ARRA funding, this project was extended to test additional fuels and concepts as well as to prepare design packages for reference commercial-scale oxy-combustion boiler systems.

Oxy-combustion is a promising near-term technology for carbon capture from pulverized coal (PC)-fired power plants. Oxy-combustion replaces combustion air with a mixture of oxygen and recycled flue gas, creating a high CO_2 content flue gas stream that can be more easily processed for sequestration or as a high purity product. For more than a decade, Alstom Power, Inc. and other researchers have been actively working on various oxy-combustion-based CO_2 control technologies. In these projects, a large body of scientific information and knowledge has been accumulated, but product development and technology gaps exist. In particular, oxy-combustion characteristics in a tangentially-fired (T-fired) boiler are not well understood. Furnace aerodynamics and fuel-air mixing with T-firing technology is vastly different from swirl-stabilized, wall-fired burners that require different design considerations to optimize oxy-combustion. Since T-fired boilers make up 44 percent of the world's installed base and 41 percent of that of the United States, a technology solution for T-fired boilers is important to address both existing and new units.

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PERFORMANCE PERIOD

Start Date	End Date
10/01/2008	09/30/2013

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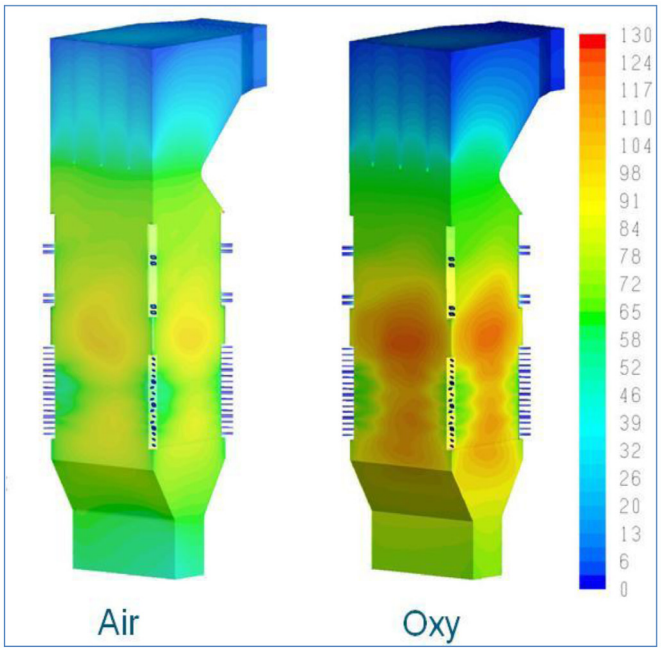
U.S. DEPARTMENT OF ENERGY

Project Description

Alstom will perform a focused R&D program to develop an oxy-combustion firing system designed for retrofit to T-fired boilers and to produce optimized demonstration (100 to 200 MW) and reference commercial (500 to 600 MW) boiler design packages. The evaluation will use an array of tools, including Alstom's proprietary models and design codes, along with three-dimensional computational fluid dynamics (CFD) modeling. A techno-economic analysis will be performed to assess the overall viability of concepts. The effects of design parameters that influence combustion and furnace heat absorption will be examined; these range from oxygen to recycled flue gas ratio, injection of pure oxygen in various configurations, injection direction and interaction of the various streams, overfire oxidizer quantities and locations, and firing system design. A range of tests with different emissions profiles will be performed, as different potential flue gas cleanup schemes have different optimum flue gas constituents from the boiler.

Pilot-scale tests will be conducted at Alstom's 15 megawatt-thermal (MWth) T-Fired Boiler Simulation Facility (BSF)—which has been used for previous programs involving low NO_x firing system development and in-furnace limestone injection—to develop and test oxy-combustion T-fired technology. Several oxy-combustion system designs, including internal flue gas recirculation (FGR) and various oxygen injection schemes, will be evaluated for cost-effective, furnace design conditions in a T-fired boiler. Promising advanced design concepts to improve second generation boiler and overall plant performance and costs will also be evaluated. Testing will be performed with various types of coal to evaluate the effect of coal components on the oxy-combustion system performance. Additionally, both high temperature and low temperature corrosion issues under oxy-combustion will be investigated.

Results from the BSF testing and the refined simulation tools will be applied to develop a basic design for a demonstration-scale oxy-combustion boiler. Reference oxy-combustion boiler designs will be developed for a commercial-scale oxy-combustion boiler system for both industrial and utility applications that will be integrated and optimized for overall oxy-plant performance and costs.



Heat flux profiles

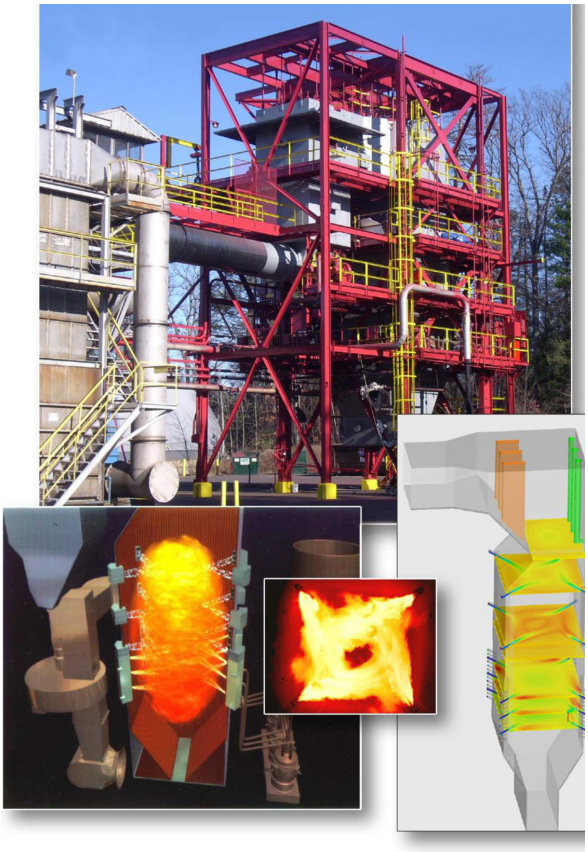
Primary Project Goal

The overall project goal is to develop and test oxy-combustion tangentially-fired technology for PC-fired power plants, providing commercially attractive CO_2 capture solutions for the retrofit of existing boilers and the installation of new boilers, in support of the target of capturing greater than 90 percent CO_2 with less than a 35 percent increase in the cost of electricity.

Objectives

The project objectives are to:

- Design and develop an innovative oxy-combustion system for existing T-fired boiler units that minimizes overall capital investment and operating costs.
- Evaluate the performance of oxy-combustion T-fired boiler systems in pilot-scale tests at the BSF.
- Address technical gaps in design of oxy-combustion commercial utility boilers through focused testing in the BSF and by improving engineering and CFD tools.
- Develop a design package, optimized for performance and cost, for a demonstration-scale oxy-combustion boiler and auxiliary systems.
- Develop a design package, optimized for performance and cost, for both industrial and utility commercial-scale reference oxy-combustion boilers and auxiliary systems.



T-fired boiler design and boiler simulation

Planned Activities

- Develop and refine design and simulation tools for oxy-combustion application, and perform techno-economic analyses to identify optimal oxy-combustion designs for pilot-scale testing.
- Conduct at least one additional large T-fired, pilot-scale test series on the BSF over a range of combustion conditions, including the oxygen to re-circulated flue gas ratio, effect of injecting pure oxygen in various configurations, injection direction and interaction of the oxygen and re-circulated flue gas streams, total excess oxygen, furnace staging, various air in-leakage rates, reduced loads, and comparison tests with air firing.
- Test a range of coal types including subbituminous, low-sulfur bituminous, high-sulfur bituminous, and lignite coal.
- Test promising second generation oxy-combustion boiler design concepts. The test matrix for these designs will address internal (close-coupled) FGR, reduced FGR rates for new applications, and increased boiler capacity for existing applications.

COST

Total Project Value
$18,012,786

DOE/Non-DOE Share
$15,000,000 / $3,012,786

DOE Base/ARRA
$5,000,000/$10,000,000

Government funding for this project is provided in whole or in part through the American Recovery and Reinvestment Act.

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- Develop general oxy-combustion guidelines for broader application of the test results to different types of industrial boiler and furnaces. General guidelines for design and operation of tangential-fired boilers will be reviewed and modified as appropriate for oxy-combustion.
- Utilize project series test results and validated simulation tools to prepare oxy-combustion demonstration- and commercial-scale design packages.

Accomplishments

- Several oxy-combustion design concepts were evaluated through techno-economic analysis for different oxy-combustion firing options, and mass and energy balances performed for the different alternatives, as well as with CFD simulations using FLUENT software, to identify the most cost-effective options for testing at 15 MWth in the BSF, and the established testing requirements.
- The T-fired BSF was modified to operate under oxy-combustion and provide the flexibility to test under a broad range of conditions.
- Five large pilot scale runs were completed on the 15 MWth BSF to document performance over a range of oxy-combustion conditions. Test series were successfully completed on subbituminous, high- and low-sulfur bituminous, and lignite coals.
- Detailed test data were compared with BSF model predictions, and CFD and engineering models were refined and calibrated with updated boundary conditions and measured input test data on deposition, furnace heat flux, etc. Boiler design and performance models were also evaluated and refined for oxy-combustion based on test results.
- The existing BSF was modified for oxy-combustion system testing, including facility modifications, coal procurement and preparation, oxygen supply, and test planning.
- A test series was completed on the dried lignite coal recently utilized at the world's first full pilot-scale (30 MWth) oxy-combustion facility in order to establish a performance correlation between these two large pilot facilities.

Benefits

This project will develop a better understanding of the characteristics of oxy-combustion as compared to air-fired combustion under various T-fired boiler conditions, and develop, test, and design an oxy-combustion T-fired boiler concept that can be retrofitted to existing PC-fired power plants or installed in new boilers, while minimizing incremental capital and operating costs. The project will include evaluation of a novel concept that could reduce FGR system costs and significantly reduce the total volume of the flue gas stream to be treated by the air pollution control devices (APCD). For new units, this will result in significant savings in incremental capital and operating costs for APCDs. This project will provide sufficient technical and economic information for time-effective demonstration design, construction, and validation of oxy-combustion firing in commercial T-fired boilers to enable acceleration of the commercialization of oxy-combustion technology.