Project Title:

Oxy-Combustion Boiler Material Development

Technology Area:	**Technology Maturity:**
Oxy-Combustion	Laboratory evaluation using synthetic gases

Primary Project Goal:

Foster Wheeler is conducting a laboratory test program to determine the effect of oxy-combustion on the corrosion and tube life of pulverized coal (PC)-fired boilers.

Technical Goals:

- Conduct computational fluid dynamic (CFD) modeling of air- and oxy-fired PC boilers to determine the flue gas compositions that will exist throughout these units and especially along the furnace waterwalls where highly corrosive micro-climates can exist.
- Use laboratory electric tube furnaces operating at boiler tube temperatures to expose coupons of conventional and advanced boiler tube materials to the CFD flue gas compositions synthesized from gas cylinders for 1,000 hours.
- Conduct post-test macroscopic and microscopic analyses of the material coupons to identify corrosion mechanisms; evaluate the corrosiveness of oxy-fired flue gas relative to air-fired flue gas and identify materials suitable for oxy-combustion.

Technical Content:

An oxy-combustion boiler retrofit will utilize flue gas recycle to maintain the heat absorption of the original air-fired boiler and limit the combustion temperature. Since air nitrogen (N_2) is eliminated, the recycle stream will contain increased levels of the products of combustion including carbon dioxide (CO_2), water vapor (H_2O), and corrosive contaminants (i.e., carbon monoxide [CO], sulfur dioxide [SO_2], hydrogen sulfide [H_2S], and hydrogen chloride [HCl]). As a result, corrosion conditions are expected to increase throughout the boiler. To assess the corrosiveness of oxy-combustion flue gas, coupons of conventional and advanced waterwall and superheater/reheater materials will be exposed to oxy- and air-fired flue gases in electric tube furnaces. Rectangular shaped coupons, typically 19 mm (3/4 inch) wide by 25 mm (1 inch) high by 3 mm (1/8 inch) thick, will be used to investigate tube materials, tube welds, and tube weld overlays; bullet shaped coupons,

Table 1: Waterwall Materials

	Material	Description	Boiler Use	Nominal Composition
1	Tube	SA210-A1	Conventional	0.27%Carbon
2	Tube	SA213-T2	Conventional	1/2 Cr-1/2Mo
3	Tube	SA213-T11	Conventional	1-1/4Cr-1/2Mo
4	Weld	T11 to T11	Conventional	1-1/4Cr-1/2Mo
5	Weld Overlay	309L StnStl	Conventional	24Cr
6	Weld Overlay	Inconel 622	Conventional	21Cr-55Ni
7	Weld Overlay	VDM Alloy 33	Conventional	33Cr-31Ni
8	Thermal Spray	IGS UTEx 5-450	Relatively New	40Cr-55Ni
9	Thermal Spray	IGS UTEx 5-480	Relatively New	25Cr-60Ni
10	Thermal Spray	IGS UTEx 5-500	Relatively New	15Cr-80Fe

Table 2: Superheater/Reheater Materials

	Material	Description	Boiler Use	Nominal Composition
1	Tube	T22	Conventional	2-1/4Cr-1Mo
2	Tube	304H StnStl	Conventional	18Cr-8Ni
3	Tube	347H StnStl	Conventional	18Cr-9Ni
4	Tube	T91/T92	Newer Boilers	9Cr
5	Tube	NF709	Newer Boilers	20Cr-25Ni
6	Tube	HR3C	Newer Boilers	25Cr-20Ni
7	Weld Overlay	Inconel 622	Conventional	21Cr-55Ni
8	Weld Overlay	VDM Alloy 33	Conventional	33Cr-31Ni
9	Weld Overlay	Inconel 72	Conventional	44Cr-55Ni
10	Welded Coupon	T22 to 304H	Conventional	1-1/4 Cr to 18 Cr

typically 19 mm (3/4 inch) in diameter by 38 mm (1-1/2 inch) high, will investigate thermal spray coatings. The conventional and advanced materials to be tested are listed in Table 1 and Table 2.

The coupons, mounted in racks and inserted in electric tube test furnaces (see Figure 1), will be exposed for 1,000 hours to synthesized air- and oxy-fired flue gases. Foster Wheeler will conduct CFD analyses of nominal 500-MWe air- and oxy-fired boilers to determine flue gas recycle rates, bulk flue gas compositions, corrosive wall micro-climates, and gas compositions for the furnace tests. The test gases will be synthesized/blended from gas cylinders and consist of varying concentrations of CO_2, H_2O, N_2, CO, SO_2, H_2S, and HCl.

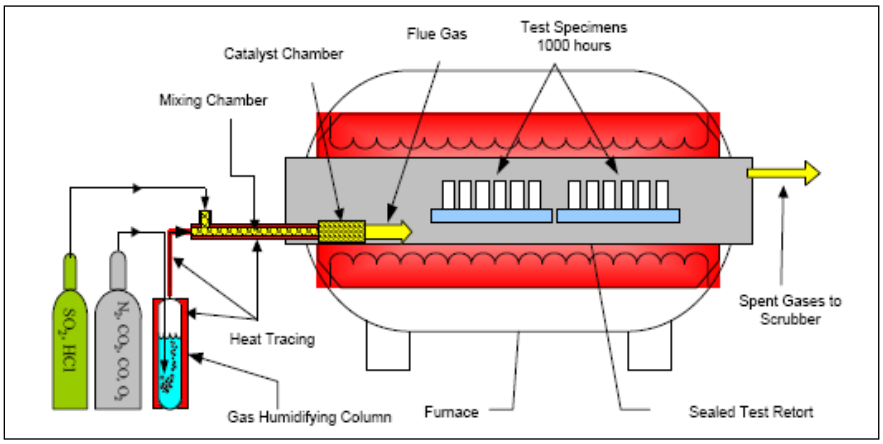

Figure 1: Coupons Mounted in Racks and Inserted in Electric Tube Test Furnaces

The material coupons will be coated with three types of synthetic ash deposits representative of high, medium, and low sulfur coals. The deposits will be produced from reagent grade powders that are mixed and applied to the coupons as a paste. The waterwall materials will be tested at three temperatures: 399°C, 468°C, and 538°C (750°F, 875°F, and 1,000°F); the superheater/reheater materials will be tested at: 538°C, 593°C, and 649°C (1,000°F, 1,100°F, and 1,200°F) – temperatures that span the range of boilers operating at subcritical and supercritical pressure. Upon completion of exposure testing, the condition of the coupons will be evaluated macroscopically and microscopically and the materials will be assessed for their suitability for oxy-combustion.

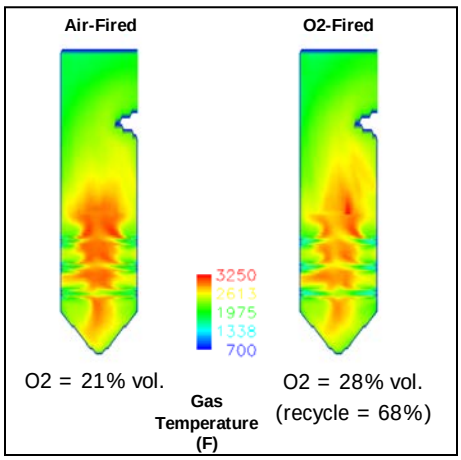

Figure 2: Example of Foster Wheeler CFD Analyses

Technology Advantages:

This project will identify the corrosion mechanisms that occur under oxy-combustion and assess the suitability of conventional and advanced boiler materials for this new combustion environment.

R&D Challenges:

Flue gas recycle used for the oxy-combustion process could increase corrosion of boiler materials.

Results To Date/Accomplishments:

CFD analyses of nominal 500-MWe PC boilers (wall- and tangential-fired) have identified the bulk flue gas compositions and waterwall micro climates that will exist in these units under air- and oxy-firing. The most corrosive gas compositions together with intermediate levels of corrosiveness for each combustion mode have been selected for use in laboratory electric furnace corrosion studies. Coupons of boiler materials, coated with deposits representative of high to low sulfur coals, have been placed in the furnaces operating at boiler tube temperatures, and exposure to the gases for 1,000 hours has begun.

Next Steps:

- Complete the planned test matrix and conduct macroscopic and microscopic examination of the material coupons to identify corrosion mechanisms and material suitability for oxy-combustion.

Final test results will not be available until the September 2011 project completion date.

Available Reports/Technical Papers/Presentations:

"Oxy-Combustion Boiler Material Development," Annual NETL CO_2 Capture Technology for Existing Plants R&D Meeting, March 2009, Pittsburgh, Pennsylvania.

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