Quarterly Progress Report
Covering Period April 1, 2010 to June 30, 2010
Date of Report – July 21, 2010

Award Number: DE-FC36-04GO17884

Project Title: Improving Heat Recovery in Biomass-Fired Boilers

Project Period: October 1, 2009 to September 30, 2012

Recipient Organization: Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, TN

Partners:
Alstom Power, cost sharing partner
Andritz Oy, cost sharing partner
Babcock & Wilcox, cost sharing partner – not in original group
Domtar Corporation, cost sharing partner
FM Global, cost sharing partner
FPInnovations-Paprican, participant and cost sharing partner
Foster Wheeler, cost sharing partner – not in original group
Georgia Institute of Technology, participant and cost sharing partner
Haynes International, cost sharing partner
International Paper, cost sharing partner
MeadWestvaco, cost sharing partner
Metso Power, cost sharing partner – not in original group
OutoKumpu, cost sharing partner
Rolled Alloys, cost sharing partner
Sandvik Materials Technology, cost sharing partner – not in original gp
SharpConsultant, participant
Special Metals, cost sharing partner
ThyssenKrupp VDM, cost sharing partner
Weyerhaeuser Company, cost sharing partner

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DOE Contract Specialist:

1. **Project Objective:** The goal of this project is to improve heat recovery in biomass-fired boilers by enabling these boilers to operate with higher superheater tube temperatures thus improving the energy efficiency in the many industries that use biomass as fuel including the chemical, petrochemical, steel, and forest products industries. The challenge to obtaining increased energy efficiency is to clearly identify all operative corrosion mechanisms in the superheaters when operating at temperatures above the first melting point of the deposits, and then address solutions to each of these mechanisms in turn. This will be achieved by a program that combines theoretical thermodynamic analyses, laboratory studies and in situ probes to explore and expand the operating envelope of future biomass-fueled steam generating systems.

2. **Background:** High energy prices are an increasingly critical component of manufacturing costs in North American process industries and are likely to become even more significant as traditional fossil fuels become more scarce and more contaminated. The effect of these increased costs, combined with the new emphasis on greenhouse gas reduction, is presenting a challenge to energy intensive industries that currently consume large amounts of fossil fuels. In response, companies are looking to non-traditional fuels based on biomass to help address these critical issues and allow them to remain competitive in a global marketplace.

Relative to most fossil fuels, biomass-based fuels are extremely inhomogeneous and contain significant impurities, such as chlorides, alkali metals and heavy metals that deposit on heat transfer surfaces. While these deposits may reduce the overall energy efficiency of the boiler, their principal effect is to cause rapid corrosion of heat transfer surfaces that approach, or exceed, the first melting point of the deposits. As a consequence, boilers burning biomass have largely been limited to operating with superheater steam temperatures of less than 510°C (950°F) and steam pressures of less than 11 MPa (1600 psi). Most existing biomass boilers in North America operate at substantially lower steam temperatures and pressures, particularly those utilized as waste utility boilers.

While small, incremental gains in energy efficiency can be met by improving operation of existing biomass-fired boilers, much larger gains could be obtained by designing and building biomass boilers that operate with substantially higher pressures and superheater steam temperatures than is the current practice. To gain this enhanced energy efficiency and retain operational reliability, challenging materials problems in the areas of high temperature strength and environmental degradation must be overcome, particularly at temperatures near or above the first melting point of the superheater tube deposits.

3. **Accomplishments:** A visit was made to Georgia Institute of Technology to discuss the possibility of a graduate student conducting studies of metal oxide solubility in molten salts that have the composition of deposits that collect on superheater tubes in biomass-fired boilers. Three members of the research team visited Foster Wheeler offices in Livingston, NJ to discuss this project and the possibility of Foster Wheeler becoming a particiant in the project. In mid-June, three team members traveled to Finland and Sweden where they met with a number of people from industrial and research organizations interested in this research. Discussions addressed the research project as well as specifics on the conditions and materials to be used in the laboratory and field tests.

4. **Progress and Status:**

Task 1. Conduct critical review of technology status

The participants in the project continue to collect reprints of papers and reports of relevance to the project.

During the third quarter, the project's co-investigators met with Prof. Preet Singh of Georgia Institute of Technology to discuss the possibility of having a graduate student conduct corrosion studies that would be of relevance to the project. In particular, studies would likely address the solubilities of chromia, alumina and silica in selected molten salts. These arrangements have not been formalized, but discussions are continuing.

The investigators also traveled to Livingston, New Jersey to meet with four Foster Wheeler research staff members. Foster Wheeler is the world's leading supplier of circulating fluidized bed power boilers, and they have supplied more than 50 boilers designed to burn biomass or mixtures that include biomass as one component of the fuel. They expect that use of biomass fuels in the US will initially be dominated by co-firing with coal. The best performing materials in testing conducted by Foster Wheeler have been 622 weld overlay and NF709. The Foster Wheeler staff members also discussed several approaches to controlling superheater corrosion – operating above the dew point of corrosive deposits, moving the superheater out of the flue gas stream to a less corrosive location, and removing chlorides from biofuels.

Foster Wheeler's R & D director, Horst Hack, said they would like to be a participant in our project, and they would provide suggestions of sites that we might want to consider for insertion and exposure of corrosion probes.

During the latter part of June, the investigators traveled to Finland and Sweden where they met with staff of two boiler manufacturers, several government and university research facilities, a power company and a tube manufacturer. Discussions at all these facilities concentrated on the performance of superheater materials exposed to deposits in biomass-fired boilers. Andritz Oy and Foster Wheeler Energia Oy are the boiler manufacturers who were visited at their facilities in Varkaus, Finland. Andritz staff described their experience with recovery boiler superheaters while the Foster Wheeler Energia staff provided information on their experience with the large number of biomass-fired boilers they have supplied. They offered some advice on selection of superheater tube materials and on the laboratory and field testing we have planned.

Meetings held at Åbo Akademi in Turku, Finland were particularly worthwhile because of the current research activities being conducted there as well as the opportunity to discuss some aspects of the Finnish government funded project on recovery boiler superheater materials (SKYREC). Of particular interest are studies on reaction of metal oxides with potassium chloride and development of thermochemical models to predict the likelihood of corrosion in combustion environments. We agreed with Prof. Mikko Hupa, chair of the university's Process Chemistry Centre, to collaborate on the metal oxide solubility studies. Discussions with Prof. Hupa brought up some important issues with the laboratory corrosion studies, and these will be considered as the conditions of the laboratory studies are defined. We also intend to coordinate our project studies with those being conducted in the SKYREC project. This should help with our understanding of the degradation of chromia forming alloys by molten salts.

A meeting at Vattenfall Power Consultant in Racksta, Sweden, provided an opportunity to learn more about the company and their patented Chlorout technology to convert alkali chlorides to high melting point alkali sulfates thus avoiding the problem with superheater tube degradation by potassium chloride. We also learned they have a very favorable experience on use of the Foster Wheeler design of moving the final superheater stage into the fluidized bed. They indicated an interest in becoming an industrial partner in our project.

The final stop was in Sandviken, Sweden, at Sandvik Materials Technology, an industrial partner in our project, where we learned about their experiences with superheaters and biomass boilers. They have considerable experience with both chromia and alumina forming alloys and are developing a new alumina forming nickel based alloy. Consequently, the Sandvik researchers have an interest in the Alumina-Forming Austenitic alloys being developed at ORNL. They do not have samples of their new alloy available for inclusion in our tests, but they are planning to provide tubes of several different alloys for our laboratory and field studies.

Task 2. Quantify financial benefits of increased superheater tube temperatures
Suitable software appears to be available through a consultant, and efforts are underway to determine the best arrangement for getting access to this software.

Task 3. Conduct laboratory corrosion in environments simulating superheater conditions in biomass fired boilers
While the three lead investigators were together in Finland and Sweden, discussions were held to address the issues of experiment design, selection of sample material, selection of salt environment and test temperature. Significant progress was made in resolving these questions.

Task 4. Measure corrosion rates of alternate materials in superheater environments below, at, and above the deposit melting point temperature
While the three lead investigators were together in Finland and Sweden, discussions were held to address the issues of corrosion probe design, selection of sample material, selection of boiler environments and exposure temperature. Significant progress was made in resolving these questions.

Task 5. Report on project activities and prepare final report summarizing project results
During the visit to Foster Wheeler in the US and the various sites in Finland and Sweden, a presentation describing this project was made in order to inform them about the project objectives and testing plans.

5. Scope Issues:
None

6. Patents:
None

7. Publications/Presentations:
As described in Task 5, presentations describing the project were made at all the sites visited.

8. Plans for Next Quarter:
- Complete plans for laboratory corrosion studies
- Identify sources of tube materials for fabrication of corrosion samples and corrosion probes
- Identify sites for exposure of corrosion probes
- Continue evaluation of existing software for calculation of energy benefits

9. Commercialization Status:
Commercialization efforts will be conducted in collaboration with boiler manufacturers and boiler operators. Those discussions will be initiated after results of laboratory and field testing are available and initial energy benefits calculations have been made.

Task/ Milestone Number	Title or Brief Description	Task/Milestone Completion Date				Progress Notes
		Original Planned	Revised Planned	Actual	Percent Complete	
1	Initiate critical review of technology status	11/1/09		10/1/09	100%	Collecting reports and papers, met with European researchers
2	Complete determination of laboratory test plan	9/30/10			25%	Work delayed by problems setting up FPInnovations subcontract
3	Complete determination of corrosion probe test plan	9/30/10			25%	
4	Initiate laboratory corrosion testing	10/31/10			5%	
5	Initiate corrosion probe testing	12/31/10			5%	
7	Complete oxide solubility tests in molten salt solutions	1/31/11				
8	Initiate energy benefits calculations	6/30/11				
9	Complete at least 4 meetings with participants including kick-off meeting and annual meeting	9/30/12			25%	Kick-off meeting conducted December 10th and 11th, 2009
10	Complete final report	9/30/12				

Project Spend Plan

Quarter	From	To	Estimated Federal Share of Outlays	Actual Federal Share of Outlays	Estimated Recipient Share (Cost Share) of Outlays	Actual Recipient Share (Cost Share) of Outlays	Cumulative Actual Outlays (Federal + Recipient)
	Start	12/31/09		42.3K		36.0K	78.3K
2Q10	1/1/10	3/31/10		63.3K		1.5K	64.8K
3Q10	4/1/10	6/30/10		136.9K		13.7K*	150.6K
4Q10	7/1/10	9/30/10	139.5K		45.0K		
1Q11	10/1/10	12/31/10	153.5K		95.0K		
2Q11	1/1/11	3/31/11	153.5K		100.0K		
3Q11	4/1/11	6/30/11	153.5K		100.0K		
4Q11	7/1/11	9/30/11	153.5K		100.0K		
1Q12	10/1/11	12/31/11	143.5K		100.0K		
2Q12	1/1/12	3/31/12	143.5K		85.0K		
3Q12	4/1/12	6/30/12	143.5K		65.0K		
4Q12	7/1/12	9/30/12	143.5K		65.0K		
Totals			**1,327.5K**	**242.5K**	**755.0K**	**51.2K**	**293.7K**

* Estimate based on attendance at meetings during this quarter