ADMINISTRATIVE INFORMATION

1. **Project Name:** Materials for Industrial Heat Recovery Systems

2. **Lead Organization:** Weyerhaeuser Company
2901 Weyerhaeuser Way South
PO Box 9777
Federal Way, WA 98063-9777

3. **Principal Investigator:** Peter Gorog, Weyerhaeuser Company,
Email: peter.gorog@weyerhaeuser.com, ph: 253-924-6514
fax: 253-924-5920

4. **Project partners:** Jim Keiser, Oak Ridge National Laboratory,
Email: keiserjr@ornl.gov, ph: 865-574-4453 fax: 865-241-0215
Preet Singh, Institute of Paper Science and Technology @ Georgia Tech,
Email: preet.singh@ispt.gatech.edu, ph: 404-894-6641 fax: 404-894-4778
Doug Singbeil, Pulp and Paper Research Institute of Canada,
Email: dsingbeil@paprican.ca, ph: 604-222-3264 fax: 604-222-3207
Todd Boggess, Secat Inc.,
Email: tboggess@secat.net, ph: 859-514-4989 ext: 103 fax: 859-514-4988
Jerry Yuan, Process Simulations Ltd.,
Email: jwyuan@psl.bc.ca, ph: 604-822-1245 fax: 604-822-1934

5. **Date Project Initiated:** 04/01/2004

6. **Expected Completion Date:** 03/31/2008

PROJECT RATIONALE AND STRATEGY

7. **Project Objective:** The goal of this project is to utilize improvements in materials to increase energy efficiency and process reliability in the Aluminum and Forest Products industries. More specifically, the project focus on issues with the tube materials used in recuperators on aluminum melting furnaces and in the upper walls and superheaters of kraft black liquor recovery boilers.

8. **Technical Barrier(s) Being Addressed:** The Technology Roadmaps for both the Aluminum and Forest Products Industries specifically identify the need for improved energy efficiency and cost effectiveness in their manufacturing operations. Current designs and materials used in recuperators on melting furnaces in the Aluminum industry do not permit operation for the required period of time. As a result, the industry has largely abandoned the use of this technology. Currently, to reduce energy consumption the Aluminum industry would like to improve the performance of recuperators on their melting furnaces. To boost pulp production and improve energy efficiency, the Forest Products industry would like increase the capacities and operating pressures of their recovery boilers. To meet these objectives, the materials used for tubes in recuperators and in the upper walls and superheaters of Kraft black liquor recovery boilers need to be improved. In discussions with industrial leaders, it became apparent that the solutions to these matters have a number of common elements. In both cases the industries are dealing with problems associated with severe tube distortions, material overheating and localized corrosion. In recognition these shared issues in an effort to develop synergy and improve the chances of success the industries decided to work together on these matters. As a result, in addition to the technical hurdles being addressed around materials, the cross-cutting nature of this project begins to remove the traditional barriers in communication between these important industries in the U.S. economy.

9. **Project Pathway:** The pathway being used in this R&D project is based on one successfully employed by the Forest Products industry and ONRL in an earlier IMF-AIM effort. ("Alternate Materials for Recovery Boiler Floor Tubes"). The key elements of this approach include: industrial involvement in defining the problem and developing the proposal for the cost shared research program; use of an industrial advisory team to oversee the project; global participation of materials suppliers, engineering companies, recovery boiler system designers and end-user companies; industry providing access to their equipment and data needed by researchers; development of laboratory simulation test systems; industry supporting materials testing in the actual industrial environments under investigation; utilizing special facilities and expertise at ORNL and other industrial sponsored research institutes; holding periodic review meetings with all of the participants. This approach assures that industry is a full partner in the project and quickly becomes aware of the results and recommendations made by the researchers working on the project.

10. **Critical Metrics:** The improvements in materials and changes in operations from this study when fully implemented could yield a savings in excess of 10 trillion Btu per year. The specific metrics for this project are:
    - Identify alternate materials to achieve a six-fold extension in the working life of recuperator tubes in aluminum melting furnaces. By eliminating the energy losses and unplanned outages associated with this issue the Aluminum industry would save ~ 0.6 trillion Btu's per year.
    - Help to improve the overall design of recuperators such that they are sufficiently economical and reliable so that they will be installed on new aluminum melting furnaces built over the next decade. This would save the Aluminum industry ~ 3 trillion Btu's per year.
    - Improve the overall recovery boiler efficiency of new boilers by 1.5% and increase by 20% the total amount of black liquor being burned in retrofitted boilers in the next decade. This would save the Forest Products industry ~ 7 trillion Btu's per year.

PROJECT PLANS AND PROGRESS

11. **Past Accomplishments:** The major progress on this project is as follows:
    - For the aluminum recuperator task, members of the ORNL staff visited the Logan Aluminum mill in Russellville, Kentucky. During this visit, a severely damaged tube was given to ORNL for analysis. The plant also provided the furnace drawings and other data needed for gas flow and heat transfer modeling. The mill has also agreed to provide access to the specialized cameras available at ORNL for determining the tube temperatures and other information about the chemical environments in the recuperators. Work is underway to install windows needed for these measurements.
    - For the mid-furnace corrosion task, the project has visited and selected the recovery boiler at the Weyerhaeuser mill Flint River, Georgia. As part of a separate project this boiler is instrumented with eight ports for gas sampling at various locations on the furnace wall. Previous measurements have shown the highest corrosion rates occur in the areas that see the maximum variation in gas composition and had high level of sulfur bearing gases. More measurements are being made. CFD modeling has been started to help explain the measurements.
    - Progress on the superheater work is now underway. Plans are being developed to install test coupons in recovery boilers. Funding in this area has been significantly reduced.
    - The task on primary air port corrosion and cracking is now essentially complete. A final report is being prepared. This work is being carried over from an earlier IMF-AIM funded project.
    - A project review meeting was held at ORNL on February 2-3, 2005 with an attendance of about 55 including representatives of suppliers, users and other research organizations.

12. **Future Plans:** The effort planned for the various tasks during the remainder of the project is being extended over an additional year because the funding for the first two years was reduced to significantly less than originally planned in the project proposal. The revised work plan for the remaining years is as follows:

Task 1 Aluminum melting furnace recuperators – The effort to characterize the type and extent of tube degradation was partially completed as was the effort to characterize the tube environment. During FY06 Hyperspectral Imaging will be used to better characterize the temperature profile across the bank of recuperator tubes as a function of position, as a function of time in a specific melting cycle and as a function of total operating time. In addition, studies will be initiated to characterize the chemical environment of the recuperator tubes as a function of the same three parameters. One of the subcontractors will work with recuperator manufacturers to address the issues with alternative tube materials and alternate designs. Computational fluid dynamic (CFD) modeling studies will be used to characterize the gas flowing from the furnace through the bank of recuperator tubes. The effects of the water spray and the diluent air that is added will be considered. Based on the temperatures and gas compositions that are measured and calculated, alternative alloys will be identified, and, if possible, tubes of these material(s) will be installed.
Task 2 Recovery boiler primary air port tubes – Effort on this task is essentially completed.
Task 3 Corrosion of tubes in the mid-furnace area – Researchers with the Institute of Paper Science and Technology at Georgia Tech and Process Simulations Limited are building on a separate project in which they, respectively, have measured the gas composition and modeled gas flow in the mid-furnace area. The FY06 effort on this project will provide for expansion of this work to additional boilers and to the operation of laboratory corrosion studies under conditions simulating those identified through the measuring and modeling effort. Based on the results of the field measurements, the CFD modeling and the laboratory corrosion studies, alternate materials or surface treatments will be recommended.
Task 4 Superheater tube corrosion and cracking – During FY05, an effort was initiated by the Pulp and Paper Research Institute of Canada to contact recovery boiler manufacturers with the objective of collecting information about superheater tube materials and tube performance. This surveying will be completed during FY06, while the CFD modeling will be expanded to put more emphasis on the conditions in the superheater area. The feasibility of building a corrosion probe will be investigated, and collection of strain data from the Ashdown superheater tubes will be continued. Discussions will also be continued to promote collaboration and data exchanges with researchers in the Finnish program studying superheater tube issues. Based on the information gathered from measurements, modeling and, possibly the probe studies, alternate superheater tube materials will be recommended.
Task 5 Reporting and organization – Review meetings were planned for several times per year, but the reduction in funding during the initial portions of this project slowed the rate of accomplishments and lessened the need for such frequent meetings. For FY06 and subsequent years, review meetings will be held more frequently and the submission of quarterly reports will continue.

Date	Milestone/Deliverable	Partner Activities
Dec. 2005	Initiate measurements on recuperator tubes with hyperspectral camera	Partners – Provide access to furnaces and install appropriate window material
May 2006	Recommend alternate materials for recuperator tubes	E3M - History of material performance and Secat - Examination of degraded samples
Jan 2006	Begin measurements and modeling of mid-furnace area of alternate boiler	Partners – Identify alternate test site PSL & IPST – Begin studies
March 2007	Recommend alternate materials or surface treatments	IPST at GaTech – Contribute information Partners – evaluate recommendations
Jan 2006	Determine feasibility of building a probe for superheater tube studies	Paprican – Help define tube conditions Partners – Provide sites for testing
July 2007	Recommend alternate superheater tube materials for various conditions	Paprican – History of material performance PSL – CFD modeling of gas flow
Feb 2006	Conduct project review meetings	All subcontractors contribute information; all partners participate in meetings
March 2008	Submit final report	Will include contributions from all subcontractors

13. **Project Changes:** Funding for FY05 has been significantly reduced. The DOE is expected to extend this project by at least one year thus carrying the work into FY2008.

14. **Commercialization Potential, Plans, and Activities:** This technology will be implemented by tube suppliers, equipment designers and end-users. Throughout this project the researchers will develop engineering specification and standard operation procedures. The combination of these documents and the close working relationship between the researchers and various industrial partners should encourage rapid and extensive utilization of the knowledge developed in this project.

15. **Patents, Publications, Presentations:**

Publications

- "Current Understanding Of Cracking Of Recovery Boiler Primary Air Port Composite Tubes", James R. Keiser, Douglas L. Singbeil, Gorti B. Sarma, Joseph R. Kish, Kimberly A. Choudhury, Laurie A. Frederick, Jerry Yuan, Camden R. Hubbard, Robert W. Swindeman, Preet M. Singh,, TAPPI Paper Summit, May 3-5, 2004, Atlanta, Georgia.
- "Cracking And Corrosion Of Composite Tubes In Black Liquor Recovery Boilers", James R. Keiser, Douglas L. Singbeil, Gorti B. Sarma, Joseph R. Kish, Kimberly A. Choudhury, Laurie A. Frederick, J. Peter Gorog, François R. Jetté, Camden R. Hubbard, Robert W. Swindeman, Preet M. Singh, Jerry Yuan, Philip J. Maziasz, Chapter in *40 Years Recovery Boiler Co-Operation in Finland*, Proceedings of the International Recovery Boiler Conference, Haikko Manor, Porvoo, Finland, May 12-14, 2004.
- "Causes And Solutions For Recovery Boiler Primary Air Port Composite Tube Cracking", James R. Keiser, Douglas L. Singbeil, Gorti B. Sarma, Joseph R. Kish, Kimberly A. Choudhury, Camden R. Hubbard, Laurie A. Frederick, Jerry Yuan, Preet M. Singh, Proceedings of the 11th International Symposium on Corrosion in the Pulp and Paper Industry, Charleston, SC, June 7-11, 2004. **Winner of I. H. Welden Best Paper Award**
- "Cracking And Performance Of Composite Tubes And Air Port Designs In A Kraft Recovery Boiler", Joseph R. Kish, Douglas L. Singbeil, James R. Keiser, Angela Wensley and François R. Jetté, Proceedings of the 11th International Symposium on Corrosion in the Pulp and Paper Industry, Charleston, SC, June 7-11, 2004. **Winner of Conference Best Paper Award**

Presentations

- "Current Understanding Of Cracking Of Recovery Boiler Primary Air Port Composite Tubes", James R. Keiser, TAPPI Paper Summit, Atlanta, Georgia, May 3-5, 2004.
- "Cracking And Corrosion Of Composite Tubes In Black Liquor Recovery Boilers", James R. Keiser, International Recovery Boiler Conference, Haikko Manor, Porvoo, Finland, May 12-14, 2004.
- "Causes And Solutions For Recovery Boiler Primary Air Port Composite Tube Cracking", James R. Keiser, 11th International Symposium on Corrosion in the Pulp and Paper Industry, Charleston, SC, June 7-11, 2004.
- "Cracking And Performance Of Composite Tubes And Air Port Designs In A Kraft Recovery Boiler", Joseph R. Kish, 11th International Symposium on Corrosion in the Pulp and Paper Industry, Charleston, SC, June 7-11, 2004.
- "Materials For Industrial Heat Recovery Systems", François Jetté, University of Toronto, Toronto, Ontario, November 9, 2004.
- "Materials For Industrial Heat Recovery Systems", James R. Keiser, AF&PA Recovery Boiler Committee Meeting, Atlanta, Georgia, February 9, 2005.
- Team members made about 25 presentations at the "Materials for Industrial Heat Recovery Systems" project review meeting held February 2-3, 2005 at Oak Ridge National Laboratory.