REPORT TITLE: BOILER MATERIALS FOR

ULTRASUPERCRITICAL COAL POWER PLANTS

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1.0 Executive Summary

A. Project Objective

The principal objective of this project is to develop materials technology for use in ultrasupercritical (USC) plant boilers capable of operating with 760°C (1400°F), 35 MPa (5000 psi) steam.

B. Background and Relevance

In the 21st century, the world faces the critical challenge of providing abundant, cheap electricity to meet the needs of a growing global population while at the same time preserving environmental values. Most studies of this issue conclude that a robust portfolio of generation technologies and fuels should be developed to assure that the United States will have adequate electricity supplies in a variety of possible future scenarios.

The use of coal for electricity generation poses a unique set of challenges. On the one hand, coal is plentiful and available at low cost in much of the world, notably in the U.S., China, and India. Countries with large coal reserves will want to develop them to foster economic growth and energy security. On the other hand, traditional methods of coal combustion emit pollutants and CO₂ at high levels relative to other generation options. Maintaining coal as a generation option in the 21st century will require methods for addressing these environmental issues.

This project has established a government/industry consortium to undertake a five-year effort to evaluate and develop of advanced materials that allow the use of advanced steam cycles in coal-based power plants. These advanced cycles, with steam temperatures up to 760°C, will increase the efficiency of coal-fired boilers from an average of 35% efficiency (current domestic fleet) to 47% (HHV). This efficiency increase will enable coal-fired power plants to generate electricity at competitive rates (irrespective of fuel costs) while reducing CO₂ and other fuel-related emissions by as much as 29%.

Success in achieving these objectives will support a number of broader goals. First, from a national prospective, the program will identify advanced materials that will make it possible to maintain a cost-competitive, environmentally acceptable coal-based electric generation option. High sulfur coals will specifically benefit in this respect by having these advanced materials evaluated in high-sulfur coal firing conditions and from the significant reductions in waste generation inherent in the increased operational efficiency. Second, from a national prospective, the results of this program will enable domestic boiler manufacturers to successfully compete in world markets for building high-efficiency coal-fired power plants.

The project is based on an R&D plan developed by the Electric Power Research Institute (EPRI) that supplements the recommendations of several DOE workshops on

the subject of advanced materials, and DOE's Vision 21. In view of the variety of skills and expertise required for the successful completion of the proposed work, a consortium that includes EPRI and the major domestic boiler manufacturers (Alstom Power, Babcock and Wilcox (a division of McDermott Technologies Inc.), Foster Wheeler and Babcock Borsig Power) has been developed.

C. Project Tasks

The project objective is expected to be achieved through 9 tasks as listed below:

- Task 1. Conceptual Design and Economic Analysis
 Task 2. Mechanical Properties of Advanced Alloys
 Task 3. Oxidation Resistance
- Task 4. Fireside Corrosion Resistance Task 5. Welding Review
- Task 6. Fabricability
- Task 7: Coatings
- Task 8: Design Data and Rules
- Task 9: Project Integration and Management

D. Major Accomplishments During the Quarter

- A large amount of work was performed on design of the boiler for the Ultra Supercritical Cycle. Conceptual design for steam conditions of 5500 psi /1350F/1400F is 95% complete. Efficiencies of various cycles were finalized. Evalations of the impact of various cycle parameters (condenser pressure, HHV/LHV etc.)on net plant efficiency were evaluated to show both U.S. and European assumptions. These include taking the U.S. efficiency based on HHV and converting to LHV which results in a rise in efficiency due to the moisture in the coal. Backpressure used in the European projects are about .62"Hg which is much lower than the 2"Hg used in U.S. calculations.
- A breakeven analysis was performed to determine how much could be spent in the construction of a USC plant for it to breakeven with a conventional plant during a 20 or 30 year life. Several cost savings will offset the higher initial cost over the life of the plant. The primarily saving is in the area of fuel consumption but reduced fuel handling, ash handling, and other maintenance issues were also considered. The result of this analysis demonstrated that if the USC plant heat rate is 7,538 Btu/kWh, then the USC Total Plant Cost can be 11.6% higher at the same cost of electricity as a conventional subcritical PC Plant.
- The impact of several different coals were evaluated including PRB(Powder River Basin), Ohio Pitt 8 and a South African coal. Task 1 is essentially finished. Reports for Task 1 are not yet complete.

- Typical boiler designs were completed. The designs were performed to allow for selection of alloys that will be used in different areas of the boiler. Thickness requirements for tubes and headers manufactured from different alloys were analyzed. Materials that required thick sections were ruled out due to thermal fatigue concerns.
- A materials procurement database has been created to coordinate materials procurement needs. The Marcko alloy originally thought to be unavailable now appears to be available. HR6W is available but quotes indicate long lead-time. Quotes for materials have been received for most of the alloys and procurement is underway. Much work was performed contacting material suppliers, checking availability, and obtaining pricing information. Due to availability of tube products, much of the development will be performed on plate with verification on tube products at a later date.
- Literature review of steam oxidation tests is nearly complete. Work has started on reconfiguring test facility and ordering new equipment for steam oxidation testing.
- Preliminary design of the test loops for fireside corrosion testing using the existing system in the Niles plant is complete. Niles plant has given the goahead for installation of the test loops.
- The equipment upgrade for the assessment of Creep-Fatigue properties was completed and calibration is underway.

E. Plans for the Next Quarter

It is anticipated that the following work will be completed during the next quarter:

- Issue draft report for Task 1 from each organization participating in task.
- Continued procurement of test materials
- Attempt to resolve dumping charge issues on materials
- Source and procure filler materials
- Finish draft state of the art report on coatings
- Start testing of coatings

F. Issues

- Some materials have six to nine month lead time for delivery. Other product forms are being evaluated to see if this can expedite receipt.
- The unexpected high cost of nickel base alloys will cause the material budgets to be exceeded.

2.0 Taskwise Status

Task 1: Conceptual Design and Economic Analysis (Task lead EPRI)

• The objective of Task 1 is to specify the temperature/pressure distribution for 760°C/35 MPa (1400°F/5000 psi) steam inlet conditions so that the data needs and the range of test parameters can be identified and the economics of material selection established.

Task 1A: Alstom Approach (Alstom Power Co.)

- Objectives: The primary objectives of this subtask are:
 - Develop a conceptual boiler design for a high efficiency ultra supercritical cycle designed for 1400F steam temperature.
 - Identify tubing and piping materials needed for high temperature surface construction.
 - Estimate gas and steam temperature profiles so that appropriate mechanical, corrosion and manufacturing tests of materials could be designed and conducted to prove suitability of the selected alloys.
- Progress for the Quarter:

Design was centered on a boiler operating at 5500 psi with 1350 psi superheat and 1400 psi reheat. Temperatures and pressures were estimated throughout the boiler and materials for each section were selected. The pressure and temperature dictated using a spiral wall design.

The waterwalls used T92 tubing, $1 \frac{1}{2}$ " OD with 0.250 wall thickness. The top of the waterwalls in the lower heat flux section reverted back to the typical vertical tube design and used 1.25" OD tubing with 0.220 minimum wall thickness. Chromizing or overlays will be need in some areas due to corrosion concerns.

Superheat tubes transitioned from Super 304H to In 617 and finally to In 740. Diameter used for superheat tubing was 2" OD. The lower pressure in the reheat section allowed for use of more materials.

The conceptual design is complete. Assumptions used included that this unit will be used for base load service due to its high efficiency. This allowed for slightly thicker headers than would be allowed for a cycling unit based on thermal fatigue quidelines.

- Concerns:
- Plans for the Next Quarter: Final report should be completed by the end of September.

Task 1B: Babcock Approach

- Objective: The objectives of this subtask are the same as in Subtask 1A.
- Progress for the Quarter:

Preliminary designs were completed. The boiler utilized T23 for most of the waterwalls. The boiler design was close to requiring a spiral type firebox. Extensive work was performed in the feedwater and economizer to allow for vertical tubing.

Efficiency was calculated for the plant using 6% auxiliary power and boiler efficiency of 90.4%. After adjusting for LHV of the coal, using imported coal, and .62 "Hg backpressure instead of the US standard of 2 "Hg, the efficiency of the cycle is within 1 to 2% of what is claimed in Thermie.

The boiler design was based on a 2 pass (Carolina boiler) designed with Ohio coal. Higher than normal RH surface and economizer surface was requires. The boiler utilizes 2 separate SH outlet headers to balance temperature and one RH outlet header.

- Concerns: No concerns at this time.
 - Plans for the Next guarter:

Issue final report.

Task 1C: Economic Analysis

• Objective: The objective of this task is to determine relative economics of the USC plant.

• Progress for the Quarter:

Economic analysis was performed using EPRI PC Plant Cost & Performance Model. The model compared net plant heat rate against plant cost for a 2400 psi subcritical boiler, a standard 3600 psi supercritical boiler, and a 5000 psi ultrasupercritical boiler. Overall plant efficiency for the supercritical boiler was varied between 45 and 46%. Twenty and thirty year design lives of the plant were analyzed.

The primary question that was to be answered was how much more could be spent on equipment during initial construction that the resulting fuel savings would result in the same life cost as a subcritical or conventional supercritical plant. Analysis indicated that if the USC plant heat tare was 7538 BTU/Kwh, then the USC Total Plant Cost could be 11.6% higher at the same cost of electricity as a conventional subcritical PC plant. Improved efficiency would also lead to a 13.4% lower USC balance of plant cost through smaller coal handling, pollution control and other balance of plant costs for the same net plant size.

- Concerns: None
 - Plans for the Next Quarter: The subtask will be completed and a report issued before September 30, 2002.

<u>Task 2: Mechanical Properties of Advanced Alloys</u> (Task lead ORNL)

The objective of Task 2 is to produce the database needed to design a boiler to operate at the steam conditions within the scope of the project. In the near term, the target steam conditions are 760C (1400F) and 35 MPa (5000 psig). To attain this objective, eight subtasks have been identified that relate to material selection, test plan development, and data collection to meet the needs of a state-of-the-art design methodology consistent with internationally accepted power boiler construction codes.

Subtask 2A: Assessment of the Alloy Performance Requirements:

This assessment will focus on performance needed for boiler service in the temperature range of 1200F (649C) to 1600F (871C) and will provide justification for the materials selected for the pressure retention components of the boiler.

The report that provides background and details of the assessment is still being written. For this reason, it was decided to issue the report in several parts. The draft of first part, dealing with 9-12% chromium steels, is finished but is being revised. The second part, dealing with austenitic stainless steels remains in an "outline" form. The third part, on high alloys and nickel base alloys is 35% completed, while the fourth part, dealing with advanced alloys requiring significant developmental work, remains in an outline form.

Task 2B: Detailed Test Plan:

The mechanical properties test plan is being reviewed in light of the materials selected for the initial thrust of the project, and data are being collected for each of the eight alloys identified by the USC Project Team.

No additional effort has been made to revise the test plan. We are waiting for the final listing of materials and product form that will be included.

Task 2C: Long Term Creep Strength:

The objective of the long-term creep testing is to identify the general characteristics of the creep and damage accumulation in the candidate alloys.

Work is continuing to upgrade 20 creep machines for long-time creep testing to 871C (1600F). An additional 20 machines are considered to be "ready for service." A creep testing laboratory in Ohio will provide another 20 machines.

Some operating creep machines are being used to assist in the evaluation of the optimum thermal-mechanical condition for Inconel 740. Tests performed at 815C (1500F) and 138MPa (20 ksi) show that the alloy should be solution treated at 1175C or higher.

A few exploratory creep tests were started on 12Cr2WV steel specimens available from previous research at ORNL. Three stresses at 649C (1200F) were selected to examine creep behavior in the temperature region where the strength of the 12Cr-W-V steels falls rapidly with test time and temperature.

About 200 pounds (92 kg) of HCM12A steel were procured. The material is from a thick-section component. The intent is to use this material for equipment checkout and for comparison with behavior of higher performance martensitic steels.

Task 2D: Microstructural Analysis:

The objective of the microstructural analysis is to identify the microstructural changes that significantly lead to strengthening, weakening, and internal damage characteristic of each material and to explore how these characteristics relate to the exposure conditions of the testing.

A subcontract with the University of Cincinnati is in the final approval stages. It is expected that the subcontract will be in place in July. The first effort will be the metallurgical characterization of the "starting" materials.

Task 2E: Assessment of Creep-Fatigue Properties:

The objective of the creep-fatigue studies is to develop a database that will lead to practical yet conservative method to address the issue of creep-fatigue damage in the boiler materials.

Work to upgrade four electro-mechanical (EM) fatigue machines was completed and calibration of the machines is underway. Electrical resistance furnaces have been installed on two EM machines for testing the martensitic steels. Temperatures calibrations have been completed and current efforts involve the elimination of noise from the sensor signals. This reduction is necessary for computer-based data acquisition. Two EM machines are equipped with induction heaters. Samples of HR120 have been machined for checkout testing in these machines.

Task 2F: Modeling of Weld Joints:

The objective of Task 2F is to produce the experimental data needed model dissimilar metal and thick section weld joints.

There was no action on Task 2F this month.

Task 2G: Study of Accelerated Testing Methods:

The objective of the accelerated testing is to provide a method to rapidly characterize changes in the strength of the candidate materials.

There was no action on Task 2G this month

Task 2H: Model Validation:

The objective of the model validation testing is to produce a database that can be used to confirm or validate the design rules that are developed in Task 8.

Efforts to develop the model validation subtask have not progressed beyond the preliminary test matrix identified in the test plan. Some effort has been made to collect design rules prepared for the high temperature gas cooled reactors program. These include Japanese work on modified Hastelloy X, German work on Alloy 800H and 617, and U. S. work on alloy 617.

Task B: Steamside Corrosion Resistance

Some improvements steam exposure facilities at ORNL were made. Now, the facility may computer controlled to ramp temperature upward in an argon environment, switch to steam at a designated temperature, hold for a pre-selected time, cool in steam to a selected temperature, and switch back to argon. Preparation of samples for testing should be finished in July.

Boiler Materials for Ultrasupercritical Coal Power Plants

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Task 3 Steamside Oxidation Resistance

Quarterly Report April - June 2002

Prepared by:

J. M. Sarver McDermott Technology, Inc.

July 2, 2002

Task 3A Autoclave Testing

Background

Steamside oxidation tests will be performed on commercially available and developmental materials at temperatures between 650°C and 900°C (1202°F - 1652°F).

Experimental

Great progress was made in construction of the steam oxidation test facility during the quarter ended June, 2002. A 60 gallon stainless steel feedtank was installed near the furnace. High purity water was plumbed to this feedtank and the feedtank was equipped with the required recirculating system, pressure gauge, water trap fittings, etc. A centrifugal pump was purchased and installed to provide water from the feedtank to the test rig. These components are shown in Figure 3-1.



Figure 3-1 Feedtank and Centrifugal Pump

The test solution will be pumped through $\frac{1}{2}$ " Alloy 600 tubing that will pass through an opening in the back of the furnace. This tubing will run along side of the retort and will be connected to the front of the retort. It is in this tubing that the test solution will flash to steam. After the steam passes through the retort containing the test specimens, it will exit the back of the retort through $\frac{1}{2}$ " Alloy 600 tubing that passes through an opening at the back of the furnace. Once outside of the furnace, the tubing passes through a cooling coil where the steam will be condensed. The condensate can flow to drain or can be sampled. The components described above are shown in Figures 3-2 and 3-3.

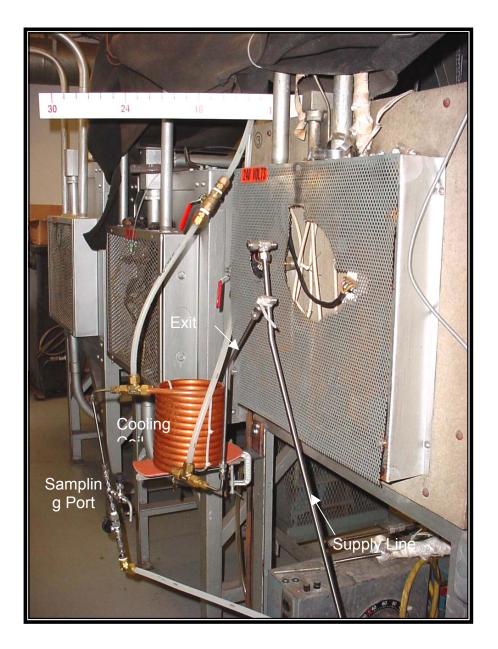


Figure 3-2 Back of Furnace and Cooling Coil

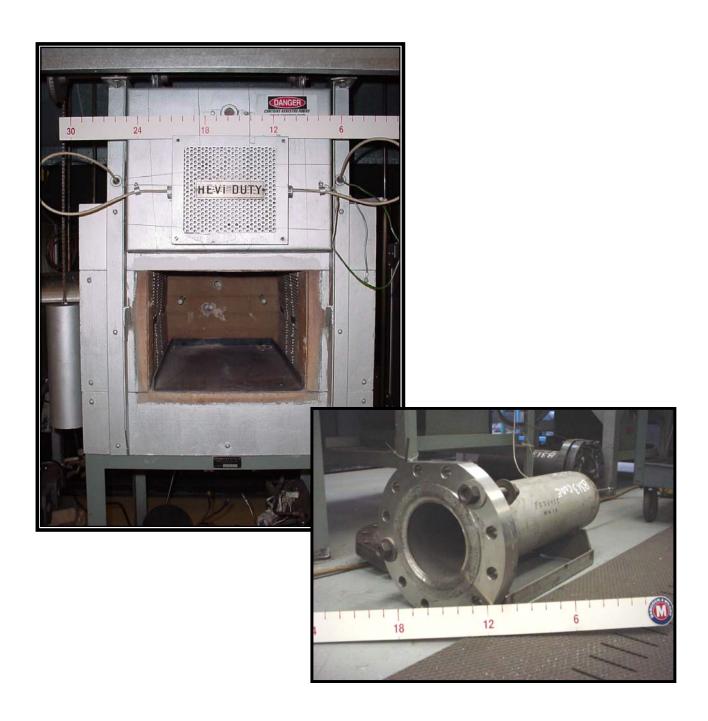


Figure 3-3 Front of Furnace and Retort

All components of the test facility appear to be working properly. The feedtank has been filled and drained with high purity water several times with an argon cover gas to insure that oxygen has been removed from the test solution. The argon gas supply has also been plumbed into the supply line to allow cooling of the retort following a test run without condensation of steam. A trial run at 900°C in deaerated high purity water and without specimens is planned for July or August, 2002. This trial run is designed to insure that the test facility operates properly, and should form an oxide on the 310SS retort.

The anticipated testing methodology remains unchanged from that previously reported. During the quarter ended June, 2002, changes were made to the list of anticipated materials that will be evaluated. The latest list of anticipated test materials is shown in Table 3-1.

Table 3-1

ANTICIPATED USC TASK 3 TEST MATERIALS				
Slot	650°C (1202°F)	800°C (1472°F)	900°C (1652°F)	
1	P92 (F)	P92 (F)	P92 (F)	
2	SAVE 12 (F)	SAVE 12 (F)	SAVE 12 (F)	
3	230 (A)	230 (A)	230 (A)	
4	HR-120 (A)	HR-120 (A)	HR-120 (A)	
5	SAVE 25 (A)	SAVE 25 (A)	SAVE 25 (A)	
6	Marko 617 (A)	Marko 617 (A)	Marko 617 (A)	
7	Super 304H (A)	Super 304H (A)	Super 304H (A)	
8	Alloy 740 (A)	Alloy 740 (A)	Alloy 740 (A)	
9	HR6W (A)	HR6W (A)	HR6W (A)	
10	304H (A)	304H (A)	304H (A)	
11	T23 (F)	T23 (F)	310HCbN (A)	
12	"Abe Alloy" (F)	310HCbN (A)	214 (A)	
13	VS2161A (F)	347HFG (A)	RA333 (A)	
14	VS2129 (F)	214 (A)	RA602CA (A)	
15	Coated 1	Coated 1	Coated 1	
16	Coated 2	Coated 2	Coated 2	
17	Coated 3	Coated 3	Coated 3	
18	Coated 4	Coated 4	Coated 4	
19	Coated 5	Coated 5	Coated 5	
20	Coated 6	Coated 6	Coated 6	
Possible	347 HFG (A)		RA353	
Substitutions	188 (A)			

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Presently, MTI is in possession of Haynes alloys 230, HR-120 and 188, and Rolled Alloys RA333, RA602CA and RA353. Through discussions with V&M Tubes, a small quantity of P92 tubing has been promised to MTI. Sources for the remaining materials must be identified in the near future.

MTI created a sketch of a test rack for holding the specimens during the steam oxidation tests, as shown in Figure 3-4.

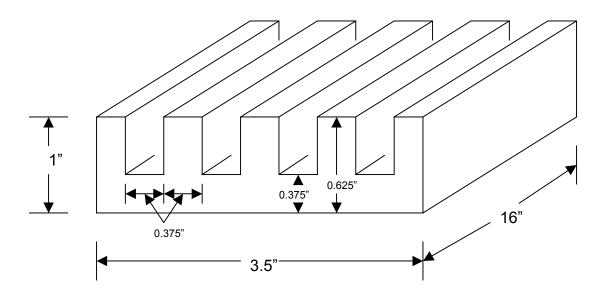


Figure 3-4 Test Rack for Holding Steam Oxidation Specimens

MTI received a quotation of ~\$700 per rack for 10 racks from Vesuvius McDanel (high purity alumina). MTI is continuing to seek other potential sources for the test racks.

Activities Next Quarter

Between July and September, 2002, MTI will complete construction of the test facility and will perform at least one high temperature trial in it. Test materials will continue to be collected. Materials that will not be available for testing will be substituted with available materials. Specimen fixturing for inside of the retort will be ordered/constructed. MTI will continue to work with ORNL on plans for a high pressure test run, possibly at CC Technologies.

Task 3B Coating Tests

Background

Coated specimens for steamside oxidation testing will be prepared in conjunction with Task 7 and evaluated after testing.

Experimental

Dialogue continued with Task 7 personnel regarding test materials, specimen size and available test slots.

Activities Next Quarter

Communications will be maintained with Task 7 personnel to coordinate delivery of coated materials for the first steam oxidation test run.

Task 3C Assessment of Temperature

Background

Based on the steamside oxidation test results, the practical temperature limits for the materials tested will be determined.

Experimental

No progress will be possible until results from the steamside oxidation tests are available (GFY2003).

Activities Next Quarter

None

Task 3D Review of Available Information & Reporting

Background

Available steamside oxidation literature pertaining to materials and environmental conditions of interest will be reviewed. Project status updates will be prepared and status meetings will be attended as required.

Experimental

The literature review was expanded during the quarter ended June, 2002 to include ferritic steels, stainless steels and nickel-based alloys. The topics contained in the literature review include a discussion on oxidation kinetics, a discussion on the oxidation rate exhibited by various classes of materials, a discussion of oxidation mechanism, a discussion of oxide scale morphology and a discussion on exfoliation.

The literature review is complete except for minor additions designed to tie the review specifically to the USC project. The literature review has been reviewed at MTI and will be ready for review by other consortium members in July, 2002.

Monthly status reports were prepared for April and May, 2001, and a Quarterly Report was prepared for the January – March, 2002 time period.

Activities Next Quarter

The literature review will be completed and issued. Monthly status reports will be written for July and August, 2002. A Quarterly report will be written for the April – June, 2002 time period. The contents of the Quarterly report will be disseminated at a consortium Project Review Meeting in Columbus, Ohio on July 10-11, 2002.

Task 3E Conduct Experimental Exposures

Background

The steam oxidation behavior of model Fe-Cr alloys will be evaluated.

Experimental

Since ORNL has some model Fe-Cr and Fe-Ni-Cr alloys available, there appears to be no need for MTI to fabricate any additional model alloys. Current plans are for ORNL to perform the testing of these model alloys. MTI will remain cognizant of the ORNL test results on these model alloys.

Activities Next Quarter

MTI will maintain cognizance of ORNL activities pertaining to model alloy test results.

Task 3F Characterization

Background

Samples of the model Fe-Cr alloys fabricated in Task 3E will be characterized before and after steamside oxidation testing using metallographic and electron optic techniques.

Experimental

None.

Activities Next Quarter

MTI will maintain cognizance of ORNL activities pertaining to model alloy characterization.

Task 3G Data Analysis and Coordination

Background

The steamside oxidation results will be evaluated to determine the effects of material properties and environmental factors on oxidation behavior.

Experimental

No progress will be possible until the steamside oxidation tests have been completed (GFY2006).

Activities Next Quarter

None.

Task 4: Fireside Corrosion (Task lead Foster Wheeler)

The objective of the task is to evaluate the relative resistance of various advanced alloys to fireside corrosion over the full temperature range expected for the USC plant.

Task 4A Laboratory Testing

- Objective: To perform laboratory tests on candidate alloys exposed to various deposits representative of the three coals at the range of temperatures expected for the USC plant.
- Results: The materials to test are being finalized and test sample procurement has begun.
- Task Schedule and Concerns: Candidate materials need to be identified and procured.
- Plans for Next Quarter: Finalize materials and procure test materials.

Task 4B Corrosion Probe Testing in Utility Boilers

- Objective: To install corrosion probes of various alloys at three coal fired power plants and control them at the temperature ranges expected for the USC plant.
- Results: Previous corrosion probe designs are being reviewed in light of the higher test temperatures to determine the required probe dimensions. This information will be utilized for probe material procurement.
- Task Schedule and concerns: Identification of correct tubing diameters is crucial before procurement can be specified.
- Plan for Next Quarter: Foster Wheeler will define tube dimensions for probes and begin locating Host Power Plants.

Task 4C Steam Loop Testing

- Objective: To install steam loops at two power stations and evaluate candidate alloys in boilers for fireside corrosion.
- Results: Babcock & Wilcox has ordered the materials for their steam loop. (see Task 6). The preliminary design for the test loops using the existing system in the Niles plant was completed. To meet the desired surface metal temperature conditions, the steam temperature within the new sections must be increased. Due to temperature limits (materials) in the outlet tubing of the existing system and the nozzle at the

customer's reheat outlet pipe, this steam must be attemperated immediately after leaving the section.

- * A water attemperation system was designed to provide the cooling needed to put the steam back into the customer's piping.
- * A basic system design to provide higher steam temperature was completed and presented it to Niles plant personnel for approval.
- * On June 25 the plant informed us that Reliant's head office is getting up to speed on this project and the current testing and evaluating their position as host for this testing. A favorable response is expected by mid-July.
- * Due to the plant's concern with using water for attemperation (out of service leakage into the reheater), steam attemperation using the same source used for the sections was developed.

Concerns:

Activities Planned for Next Quarter:

- * Obtain approval from Reliant to proceed
- * Complete equipment sizing.
- * Begin graphics work.
- * Generate specifications for valves etc.

Babcock-Borsig is reviewing the preliminary concept of the B&W steam test loop and combining that with their previous experience in Europe and beginning discussions to locate a Host plant.

Boiler Materials for Ultrasupercritical Coal Power Plants Quarterly Report (April – June 2002) Task 5: Welding Development

The major objectives for Task 5 are:

- To define weld metal choices for candidate materials.
- To evaluate weldability issues.
- To establish acceptable welding procedures and practices.
- To evaluate the effects of manufacturing heat treatments and preheat and post weld heat treatments on weldment integrity and properties.
- To produce samples needed to determine the properties of candidate ultrasupercritical alloy welds and weldments, including the dissimilar metal weld joint between the various types of material (actual mechanical and property testing will be performed under Task 2).

Progress for the Quarter

The Task 5 efforts were directed towards planning and procurement of the materials that will be used in the program. These were more preliminary activities rather than being associated with any specific subtask item and included:

- Organizing and assigning personnel.
- Developing detailed welding plans.
- Reviewing literature on weldability of alloys selected for study.
- Identifying sources and obtaining procurement information for base materials and filler metals.

Material procurement is proving to be significantly more difficult than expected in that not all product forms available, the nickel base alloys are very expensive, some materials have long lead times, and some have the possibility of being assessed "dumping charges." With regard to each specific material involved in the welding studies:

- Super 304H.
 - Currently only available in tubing from Sumitomo but attempts are being made to determine if plate can be obtained on special order.
 - Price is significantly lower than that for the nickel base alloys.

- Long lead time for delivery.
- Dumping charges might be assessed.
- Purchase order has been placed to supply tubing requirements for all tasks.
- CCA 617 (known in Europe as Marcko).
- Determined to be available in tubing and plate through Krupp VDM.
- Price is very high for tubing but more modest for 2-inch thick plate.
 - Long lead time for delivery.
- Dumping charges might be assessed.
 - Purchase order for tubing and plate to supply requirements for all tasks is being prepared.

Haynes 230

- Available in tubing and plate from Haynes.
- Price is very high for tubing but more modest for 3-inch thick plate.
 - Lead times for delivery shorter than for CCA 617 and Inconel 740.
- Domestic supply so dumping charges will not be assessed.
- Purchase order has been placed for thin and thick plate and for a small quantity of tubing.

Inconel 740

- Available in tubing and plate from Special Metals.
- Price is very high for tubing but more modest for 3-inch thick plate.
- Long lead times for delivery.
- Domestic supply so dumping charges will not be assessed.
- Purchase order information is being developed.

HR6W

- Available only in tubing from Sumitomo.
- Price is high.
- Dumping charges might be assessed.
- Purchase order information is being developed.

SAVE 12

- Available only in pipe from Sumitomo.
- Price is very high.
- Dumping charges might be assessed.
- Purchase order information is being developed.

Concerns

- Base material sourcing difficulties and long delivery times have, in some cases, delayed the start of welding activities by 6 to 9 months.
- The unexpectedly high cost of the nickel base alloys will cause the material budgets to be exceeded and might result in program cost overruns and/or reductions in program scope.
- That certain alloys are not available in all desired product forms will necessitate changes to the program scope.
- If dumping charges are assessed, the impact of the high material costs could be much greater (these charges have been rumored to be as high as 160% of the base price).

Activities Planned for Next Quarter

Plans for next quarter include:

- Attempt to resolve dumping charge issue.
- Continue base material procurement.
- Source and procure filler metals.
- Continue review of welding literature regarding alloys to be studied.

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TASK 6: FABRICABILITY

Task 6 Objective

The objectives of the task are to establish fabrication guidelines for the candidate alloys for boiler components of the ultrasupercritical plant. To establish the affect fabrication operations have on the properties of these materials of construction, and to determine the remedial actions needed to return the material to their original condition and properties. This will be achieved via prototypic manufacturing operations of both thick and thin components.

The Task is subdivided into three subtasks. Subtask 6A involves manufacturing trials of thin walled components typical of boiler superheaters. Subtask 6B involves fabrication trials of typical thick walled components. Subtask 6C is intended to allow for manufacturing trials of new materials that are introduced late during the span of the contract.

This task has been delayed in starting due to the funding shortfall for this year. Activity was limited to detailed planning, material selection, and material procurement activities. The following summarizes activity taken this last quarter dealing with all three subtasks.

In Task 1, the best candidate materials for the highest temperature, and most severe duty areas of the USC boiler were identified. The six (6) best candidates were then divided up amongst the four consortium member participants in the task as follows;

- Alstom Power Super 304H (thick walled) and CCA 617 (thin)
- B&W Alloy 230 (thick and thin walled)
- Babcock Borsig Save 12 (thick walled); HR6W (thin)
- Foster Wheeler Inconel 740 (thick and thin walled)

These materials were also assigned to these same participants for procurement for the amount of material needed for the whole program, including this task.

Material quantities for all the tasks were defined and supplied to EPRI.

Material inquiries were generated by each member and vendor quotes were solicited, and vendors selected. A number of important and consequential issues were quickly uncovered. For one, it was generally discovered that the raw material costs were much higher than originally envisioned due to the fact that the alloys are highly alloyed, not always readily available in all product forms, and we were procuring in relatively small quantities which resulted in pricing premiums due to lack of economy of scale. There was also the complication that the alloys procured from foreign material manufacturers would probably be subject to the anti-dumping tariffs that had recently been put in place by the United States government. Some of these issues were still being resolved at the close of this quarter.

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One of the biggest findings with impact on Task 6 during this stage was the fact that for most of the materials, we would not be able to obtain the grades in a thick walled pipe product form. This required that the preliminary manufacturing trials for thick walled components would have to be modified to adopt a thick, flat plate form rather than a pipe product. It was also necessary to reduce some of the quantities we bought in order to stay within cost limitations. This has forced each consortium task member to re-evaluate the detailed manufacturing plans accordingly. It is an objective of the task to duplicate as much as possible the same manufacturing operations on all the materials of like thickness to allow for direct comparison of material performance. It will be a major objective of next quarter activity to settle on a revised manufacturing plan that can be accomplished by all participants.

Based on responses from material vendors, we have been able to obtain quotes or promises for all of the materials listed above with these exceptions. Sumitomo, the supplier of Super 304H can only supply this material in tubular form, so we will only have thin walled material available to the program. On the plus side it appears we will be able to obtain the CCA 617 material in both thin and thick sections. As of the end of this quarter the only material that had actually been placed on order was the alloy 230 material from Haynes International. However, all other material orders were getting close to being placed. Lead times vary, but it is apparent that most of the alloys will not be available in much quantity until late in the 2002 calendar year.

Concerns

- Raw material costs were higher than originally estimated, and the significant cost adder of anti-dumping tariffs has put a strain on already reduced funding resources. This will need to be worked out and orders placed within acceptable risk to the purchasing agencies, and taking into account leaving available funding for program activities for the complete year.
- The long lead times for some of the materials will potentially delay start of manufacturing trials. The earliest fabricated materials will be needed to develop test samples for Task 2 mechanical property testing to assess the effect of these operations on long term creep properties. We will be working closely with Task 2 leadership to determine the necessary timeframe for sample delivery.

Activities Planned for Next Quarter

- Completion of raw material procurement activity will be accomplished.
- Receipt and inspection of materials, and dispersing the materials needed by other tasks.
- Development of a revised manufacturing trial plan agreeable to all four parties, consistent with their fabrication capabilities.

Boiler Materials for Ultrasupercritical Coal Power Plants Quarterly Report (April – June, 2002) Task 7 Coatings

The major objectives for Task 7 Coatings are:

- Review state-of-the-art of coating technology and identify development needs.
- Develop coating manufacturing techniques, which can provide corrosion/erosion protection for components in USC boilers, cost effectively.
- Establish manufacturing techniques for application of internal coatings for oxidation protection, cost effectively.
- Provide coated samples for corrosion and oxidation testing in the laboratory and "in the field".

These objectives will be accomplished through execution of eight sub-tasks. Progress on these sub-tasks during the reporting period is described below.

Progress for the Quarter

Task 7A: Detailed Study of Current State of the Art

- Efforts continued on examining the state of the art.
- The 16th Annual Conference on Fossil Energy Materials was attended. Several relevant presentations were made on diffusion coatings and thermal spray methods. Technical papers are available from DOE at www.netl.doe.gov, navigate to publications, conference proceedings and select the indicated conference.
- Progress was made on the draft report but it was not finished as planned.

Task 7B: Coating Feasibility (Internal Coating)

 Bench-laboratory scale experiments were conducted to assess the feasibility of diffusion coatings on samples of NF616, HCM12A, and T-91 with control samples of T-22. Variants of the chemical vapor deposition (CVD) process including pack cementation and the blanket approach have been used to generate Cr-rich, Cr-Alrich and Cr-Si-rich diffused layers utilizing proprietary and other patented formulations. Seven tests were conducted during the period May-June 2002 and the metallographic sections have been prepared. The coating characteristics of selected samples including composition profiles will be evaluated during the month of July.

Task 7E: Process Scale Up - Preliminary Trials

- Procured sample quantities of Haynes 230, 617, and HR-120 alloys (1/4" plate) for initial coating trials
- Continued assessment of potential coatings for compatibility with 6 selected alloys
- Revised test plan to utilize plate materials (rather than tubes) for laser cladding and coating trials
- Initiated investigation of Cold Spray Technology for application of coatings
 - Continued assessment of potential coatings for compatibility with 6 selected alloys
- Reviewed properties and characteristics of plated nanocoatings for oxidation resistance
- Acquired and reviewed additional information on Cold Spray Technology for application of coatings to candidate alloys
- Continued assessment of potential coatings for compatibility with 6 selected alloys, as well as other potential candidate alloys
- Prepared retort and support equipment for diffusion coating sample alloys at MTI

Concerns

None

Activities Planned for Next Quarter

Task 7A:

Finish draft state of the art report and circulate for comments.

Task 7B:

- During the period July September 2002, tests will be conducted to evaluate the
 feasibility of similar diffusion coatings in Ni-base and Fe-base high-temperature
 alloys. Preliminary evaluation of aluminide-type coatings using Al-base paints
 followed by high temperature treatments has been conducted on Fe-base alloys.
 The objective of this approach is to generate a BCC ordered subsurface phase that
 would ease subsequent diffusion coating treatments with the retention of carbon in
 the base alloys. The metallographic evaluation will be completed in the month of
 July.
- Searches in the open literature continue for techniques to apply surface modifications in the ID of tubular components.
- Additional samples for testing in superheated steam will be procured.
- Electroless Ni-plating and other novel approaches considered as a promising and economical alternatives to diffusion coatings will be evaluated.

Task 7E:

- Select candidate coatings to be applied using Cold Spray Technology for evaluation
- Conduct a chromizing run to diffusion coat samples of Haynes 230, HR-120, 617, as well as samples of Rolled Alloys 333, 602CA, 353, and 253
- Procure samples of other candidate alloys for diffusion coating trials
- Prepare samples of 6 selected alloys for laser coating trials

Task 8: Design Data and Rules (Task lead Alstom Power Co.)

The objective of the task is to explore application of advanced mathematical models for pressure-parts to boiler and pressure parts industry for reducing product costs in new designs. There is an opportunity to reduce pressure part costs through:

- Standardized design rules and restricted component configurations based on more sophisticated analyses that will provide consistent safety margins and reliability.
- Advanded design life tools to reduce ignorance factors in safety margins based on the levels and details of analysis and available material behavior information.
- ASME Code approval of these tools.
- Progress for the Quarter: Collection and consolidation of material property data for use in preliminary design has been started.
- Concerns: None
- Plans for the Next Quarter: Define subtasks and get project activities underway, especially analytical information. A review of task plan prepared by M. Gold will be performed. ASME Section VIII is currently reviewing methods to include fatigue requirements in the Code. This will be followed closely. Task 8 personnel will meet at the September ASME Code Meeting. Ways to include composite tubing into the ASME Code need to be evaluated.

Task 9: Program Management and Integration (Task lead EIO, EPRI)

- Objective: The objective of the task is to provide technical and administrative management support.
- Progress for the Quarter:
 - Materials selection, request for quotes, and ordering material for tasks was coordinated. This was of prime importance because the same materials will be used for several different tasks.
 - Minutes were prepared and submitted for the March Steering Committee Meeting.
 - Monthly reports were submitted for April and May 2002.
 - Second Quarter Report was completed and submitted.
 - A meeting of the Steering committee and the Task Leaders was held on March 7 and 8 in Pittsburgh. All logistical arrangements were made. In addition, conference calls between all the members were held on February 18 and April 3, 2002. All meetings and conferences were minuted and the minutes were distributed.
 - Task 1 work was managed and coordinated as part of this task.
 - Communication and the coordination with the team members were continuously maintained via phone calls and e-mail.
 - A conference call was held on May 2, 2002 to discuss materials procurement issues and project status.

Concerns:

- Timely follow-up on action items agreed upon by consortium members continues to be a challenge.
- Plans for the Next Quarter:
 - Project management and integration activities will continue.
 - Conference calls will be held monthly to coordinate project.
 - Project Steering Committee Meetings will be held every four months. The next meeting is scheduled for November 20 and 21 in Columbus, Oh.