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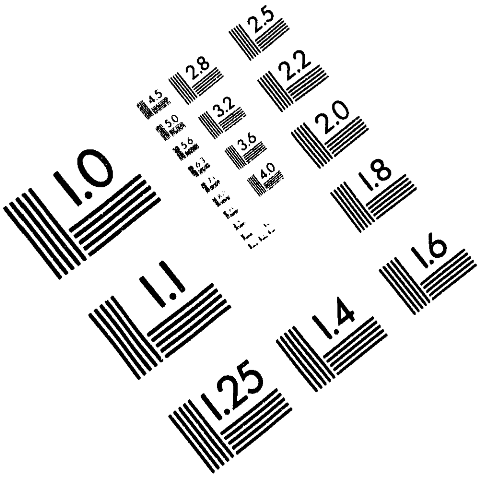

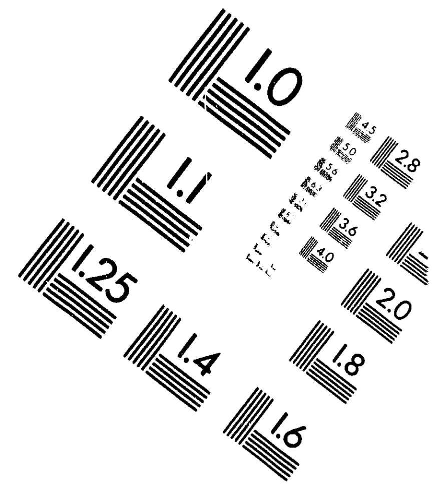

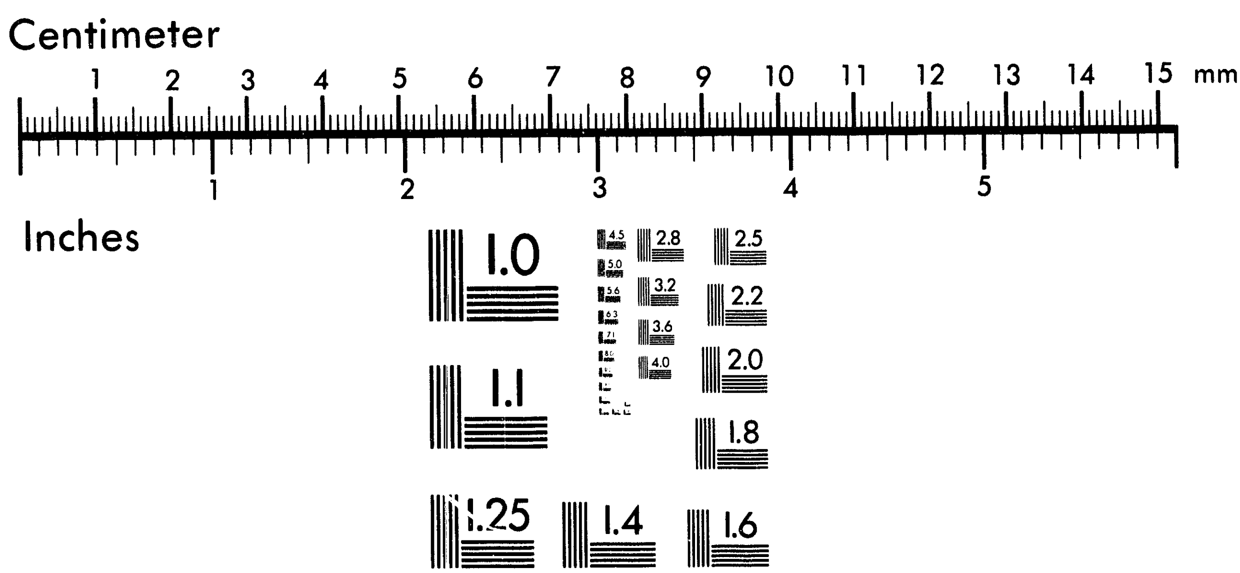

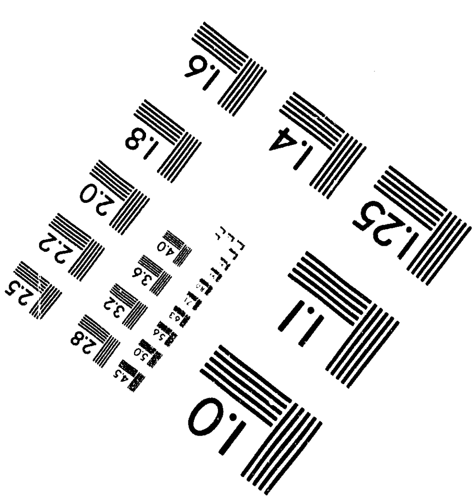

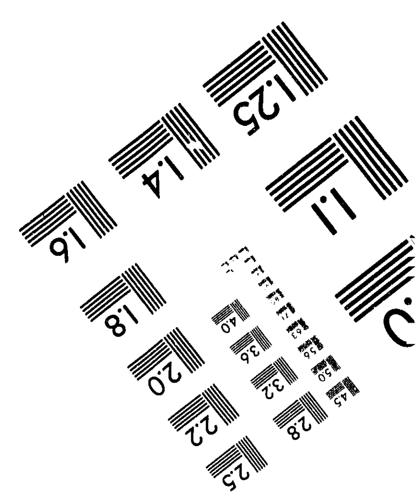

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TECHNICAL PROGRESS REPORT NO. 6 JANUARY - MARCH, 1994

U.S. DEPARTMENT OF ENERGY

PITTSBURGH ENERGY TECHNOLOGY CENTER

CONTRACT DE-AC22-92PC92159

FOR

ENGINEERING DEVELOPMENT OF ADVANCED COAL-FIRED

LOW-EMISSION BOILER SYSTEMS

SUBMITTED BY:

COMBUSTION ENGINEERING, INC.

1000 PROSPECT HILL ROAD

P.O. BOX 500

WINDSOR, CONNECTICUT 06095-0500

MAY 17, 1994

DISCLAIMER

PATENT STATUS

Cleared by Chicago OIPC May 3, 1994

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EXECUTIVE SUMMARY

INTRODUCTION

The Pittsburgh Energy Technology Center of the U.S. Department of Energy (DOE) has contracted with Combustion Engineering, Inc. (ABB CE) to perform work on the "Engineering Development of Advanced Coal-Fired Low-Emission Boiler Systems" Project and has authorized ABB CE to complete Phase I on a cost-reimbursable basis.

The overall objective of the Project is the expedited commercialization of advanced coal-fired low-emission boiler systems. The specified primary objectives are:

- NOx emissions not greater than one-third NSPS.
- SOx emissions not greater than one-third NSPS.
- Particulate emissions not greater than one-half NSPS.

The specific secondary objectives are:

- Improved ash disposability and reduced waste generation.
- Reduced air toxics emissions.
- Increased generating efficiency.

The final deliverables are a design data base that will allow future coal-fired power plants to meet the stated objectives and a preliminary design of a commercial generation unit.

The deliverables for Phase I are a Project Work Plan covering all four phases, concept and component evaluation and selection, an R, D & T Plan, a preliminary Commercial Generating Unit design, and a Phase I Report. The work in Phase I which will cover a 24-month period, is organized in the following six Tasks:

Task 1 - Prepare, and obtain DOE approval of, a comprehensive Management Plan and manage the Project as described therein. Prepare a detailed Project Work Plan, Milestone Schedule/Plan, Cost Plan, Notice of Energy R&D Project, QA/QC Plan, and Hazardous Substance Plan.

Task 2 - A comprehensive assessment and system analysis of candidate technologies which have the potential to achieve the primary objectives and one or more of the secondary objectives. This work includes coal selection, subsystem technical assessment, concept development and evaluation, a Concept Selection Report, and preliminary engineering design of subsystems to demonstrate uncertain technologies.

Task 3 - Produce the Research, Development and Test (R, D & T) Plan. The process will involve preparation of a draft R, D & T Plan; preparation of a Design Deficiency Analysis which identifies information and data required, recommended approach to generating it, and estimated resources and time required; preparation of a detailed R, D & T Plan to include engineering analysis, component development via generating design data and experimental work, and finally subsystem testing.

Task 4 - Implement component definition with engineering analysis, modeling, and experimental R&D and testing to support preliminary design of a low-emission boiler system, design of the POC Test Facility, and the Subsystem Test Design. An additional objective is to identify the POC Test Facility site.

Task 5 - Using the results of the preceding activities, select one low-emission boiler system concept from the Concept Selection Report and develop a Preliminary Engineering Design for a 350 MWe coal-fired unit. With this design in view, the Design Deficiency analysis and the R, D & T Plan will be reviewed to ensure that Phase II R&D and testing satisfy system development needs.

Task 6 - Issue a Phase I Report which will include a summary and description of the results of the work performed in Phase I, through documentation of the Commercial Generating Unit Design, a detailed documentation of all R&D and testing conducted in Phase I, and a thorough description of the updated Project Work Plan for Phases II and III.

The Project will be managed by ABB CE as the contractor and the work will be accomplished and/or guided by this contractor and the following team members:

- DOE Contracting Officer's Representative (COR)
- ABB Environmental Systems, Inc. (ABBES)
- Energy and Environmental Research Corporation (EER)
- Raytheon Engineers and Constructors, Inc. (RE & C)
- Dr. Janos Beér, MIT and Dr. Jon McGowan, U. of Mass.
- Association of Edison Illuminating Companies - Power Generation Committee (AEIC)
- Advanced Energy Systems Corporation (AES)
- Electric Power Research Institute (EPRI)
- Illinois Clean Coal Institute (ICCI)
- Peridot Chemicals, Inc.
- Richmond Power & Light
- Southern Company Services, Inc. (SCS)

SUMMARY

Work continued as planned and scheduled. Total expenditures are below budget. Tasks 2 and 3 are complete. Task 4 is currently slightly behind schedule but is projected to finish on or ahead of schedule. Task 5 was started early. Task 6 will start in April.

The following major deliverables were issued:

- Slides and narrative for PETC Audio/Visual Combustion 2000 Exhibit.
- Technical Paper for the 19th International Technical Conference on Coal Utilization & Fuel Systems.
- Draft of Technical Paper (for internal review) for the 1994 International Joint Power Generation Conference.

Two advisors were added to the Team - Richmond Power & Light and Peridot Chemicals, Inc. RP&L is an excellent candidate for the POC host. Peridot has expertise in the production and marketing of sulfuric acid.

A regular Quarterly Review Meeting was held with DOE-PETC.

No changes to the Work Plan are anticipated for the next quarter.

TASK 1 - PROJECT PLANNING AND MANAGEMENT

All work in Task 1 and all Task 1 deliverables for the reporting period were completed on schedule. All monthly Status, Summary, Milestone Schedule, and Cost Reports were submitted on schedule. Expenditures to date are below budget. See Appendix A.

A meeting of DOE-PETC and the ABB LEBS Team was held in RE&C's Philadelphia offices on February 8, 1994. The primary objectives of the meeting were:

- Assess project status - schedule/budget/manpower/deliverables.
- Provide a status report of, and discuss, Task 4 and Task 5 activities.

These objectives were attained and several other topics were covered. See meeting agenda in Appendix C.

Technology transfer activities included:

- Prepared slides with narrative for PETC Combustion 2000 Exhibit.
- Organized a Technical Session titled "Technical Status of DOE's Combustion 2000 Program" for the '94 International Joint Power Generation Conference. The five Combustion 2000 contractors and DOE-PETC each agreed to write and deliver paper.
- Drafted ABB's paper for this conference.
- Wrote and presented a paper for the 19th International Conference on COAL UTILIZATION & FUEL SYSTEMS. (See Apprndix B.)

Two advisors were added to the Team:

Peridot Chamicals, Inc.
1680 Route 23 North
Wayne, New Jersey 07470
(Mr. Irwin Zonis)

Richmond Power & Light
2000 U.S. 27 South
P. O. Box 908
Richmond, Indiana 47375
(Mr. Dale Norris)

Peridot Chemicals, Inc. expertise is in the area of sulfuric acid production and marketing. They are involved in by-product chemicals from utility FGD systems. They will provide guidance on the SNOx sulfuric acid marketing.

Richmond (Indiana) Power & Light is an excellent candidate for the POC host. A meeting was held at their Whitewater Valley Plant on March 15. The meeting was attended by personnel from RP&L, DOE, RE&C and ABB. A follow-up meeting is schedule for April 27.

Preliminary work on updating Phase II and III cost estimates was completed and the approximate total cost was given to DOE-PETC. ABB conditionally agreed to 25% cost share in these Phases.

Task 5 working meetings of the LEBS Team were held January 6 and March 3. Meeting agendas are included in Appendix C and are discussed under Task 5 below.

TASK 2 - CONCEPT DEVELOPMENT

No further activity is anticipated.

TASK 3 - RESEARCH, DEVELOPMENT, AND TEST PLANS

No further activity is anticipated.

TASK 4 - COMPONENT DEFINITION

Two Subtasks were focused on during this quarter: 4.2 - Experimental Research and 4.3 - Combustion Modeling. Results are summarized below.

Experimental Research

Preparation for the high temperature selective non-catalytic reduction (SNCR) of NOx was started. It was decided that ammonia will be used as the reducing agent and that Illinois #6 coal firing will be the source of the NOx. The effectiveness of this particular SNCR will be tested in the Multi-State Drop Tube-2 (MSDT-2) which is shown in Figure 1. Testing will be conducted with air so as to best replicate actual flue gas compositions. The preliminary test matrix is shown in Table 1. The goal of the experimental research is to quantify the conditions (temperature, fuel/oxygen and NH3/NOx ratios) that result in the optimum reduction of NOx with the least amount of ammonia slip.

The Fourier Transform Infra-Red (FTIR) spectrometer was used last quarter to measure the concentrations of hydrocarbons and nitrogenous species released from Illinois #6 coal. The analysis of these measurements has been completed and the results can be found in Table 2.

Modeling

Case and grid files for the conceptual furnace design have been generated for the Fluent computational code (the computational grid has approximately 220,000 nodes). The code is currently up and running; however limitations in computer hardware had been slowing the work but this difficulty has been resolved.

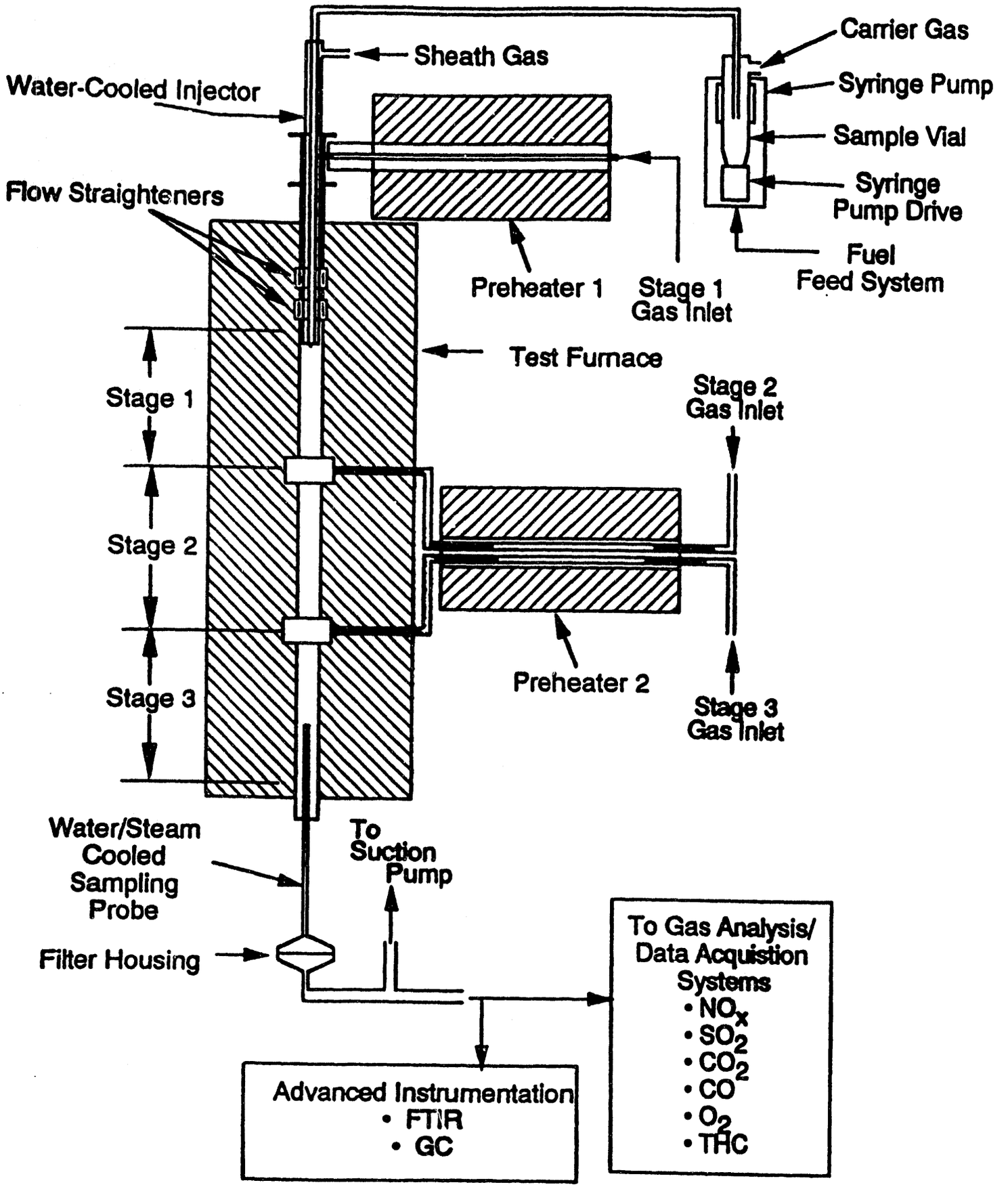
In order to better plan the experimental research, CHEMKIN and Jasper computer models have been utilized to help identify the most advantageous temperature and stoichiometry regions for ammonia induced NO_x reduction. Preliminary results indicate that regions with very low O_2 concentrations and high temperatures (>2450 °F) are most advantageous.

The pyrolysis/tar yield data and spectrometer results from the coal characterization performed on Illinois #6 coal are used as inputs into the Fluent, Jasper and CHEMKIN computer codes.

Work Next Quarter

The high temperature SNCR experiments are scheduled to take place in May. Work on the improvement of the conceptual furnace design and the validation of the combustion modeling will continue.

Figure 1 Schematic of ABB Combustion Engineering's Multi-Stage Drop Tube-2 (MSDT-2)



ABB's Multi-Stage Drop Tube-2 (MSDT-2)

Table 1 Preliminary Test Matrix for the Study of High Temperature Selective Non-Catalytic Reduction (SNCR)

Test Number	Temperature °F	Stoichiometry	NH3/NO Ratio
1	2650	0.6	1.0
2	2450	0.6	1.0
3	2150	0.6	1.0
4	2650	0.8	1.0
5	2450	0.8	1.0
6	2150	0.8	1.0
7	2650	1.0	1.0
8	2450	1.0	1.0
9	2150	1.0	1.0
10	2650	1.2	1.0
11	2450	1.2	1.0
12	2150	1.2	1.0
13	*	**	1.0
14	*	**	1.5
15	*	**	2.0

* Optimum Temperature based upon Maximum NOx Reduction

** Optimum Stoichiometry based upon Maximum NOx Reduction

Table 2 Selected Fourier Transform Infra-Red (FTIR) Spectrometer Results from the Analysis of Illinois #6 Coal

	ILCC-1	ILCC-2	ILCC-3	ILCC-4	ILCC-5	ILCC-6	ILCC-6A	ILCC-7	ILCC-8	ILCC-9	ILCC-10
	2650 °F	2650 °F	2650 °F	2650 °F	2650 °F	2400 °F	2400 °F	2400 °F	2150 °F	2150 °F	2150 °F
	2" RX ZONE	4" RX ZONE	8" RX ZONE	10" RX ZONE	16" RX ZONE	2" RX ZONE	10" RX ZONE	16" RX ZONE	2" RX ZONE	10" RX ZONE	16" RX ZONE
H4	177	114	8	4	1	60	54	14	22	206	121
O	602	438	691	756	922	96	584	621	44	385	444
CN	100	136	129	131	75	5	155	152	0	100	143
OS	0	0	0	1	1	0	0	0	0	0	0
O2	7	10	7	3	4	4	9	8	5	9	6
20	1	0	0	0	1	1	1	0	0	0	0
O	12	46	21	14	30	24	46	22	8	10	2
H3	0	0	0	0	0	0	0	0	0	0	0
THYLENE	43	16	0	0	1	35	2	0	17	37	1
O2	82	73	73	117	95	43	87	87	43	63	62
TYRENE	26	14	4	7	5	34	4	4	17	21	6
THANE	1190	1292	1157	974	873	311	1502	1279	386	1026	896
APHTHALENE	0	0	0	0	0	0	0	0	0	0	0
ROPYLENE	17	0	0	35	6	68	0	0	87	0	0
OLUENE	20	26	26	4	40	4	29	27	9	20	21
S2	9	7	30	45	19	0	15	34	0	7	34
H-ACETYLENE	13	18	18	7	7	1	12	10	1	11	9
CETYLENE	120	195	186	200	98	8	280	224	0	103	239
O2	23	12	5	3	0	24	11	5	19	29	22
ENZENE	20	10	0	3	2	5	0	0	0	20	6

TASK 5 COMMERCIAL GENERATING UNIT DESIGN

Boiler and SNOx Design:

The preliminary boiler and SNOx™ design were finalized and integrated. This included design and selection of the following components and systems:

1. circulation system
2. start-up system
3. superheaters and high and low pressure reheaters
4. economizer and associated piping
5. low NO_x firing system including pulverizers with classifiers
6. air and gas ductwork
7. air preheater
8. forced draft and primary air fans
9. CeraMem™ filter
10. SO_2 reactor
11. WSA condenser
12. induced draft fan
13. air/condensate heat exchanger

Performance at 100% and part loads was estimated. Specification sheets for major components were developed for pricing. The general arrangement drawings and flow schematics were made and were transmitted to other members of the Team. Work on modularization is in progress.

Plant Design:

Work on the Commercial Generating Unit accelerated during the quarter. The preliminary plant layout from Task 2 was revised and finalized. Process and equipment conceptual design proceeded for the balance of plant systems.

Reliability analysis was finalized and draft report prepared and reviewed. Final comments will be incorporated as part of the Task 5 Report.

A modularization meeting was held in January. Results were factored into the plant arrangement.

Equipment sizing and vendor inquiries were included to obtain dimensional, performance and cost information on the pieces of equipment. Alternate condenser arrangements were examined to assess the impact on plant modularization.

Construction cost information for labor and materials in the Kenosha area was accumulated. Cost estimating methodology based on modification of the EEDB models was begun. Preparation of the LEBS cost estimating structure was begun. Work began on a mock-up of the draft report for Task 5.

PLANS FOR NEXT QUARTER

TASK 1 - Project Planning and Management

Continue to execute the Management Plan, the Project Work Plan and the QA/QC Plan as written. Continue to issue all reports as scheduled. Conduct a Project Review with DOE-PETC. Closely monitor funds and manpower expenditures. Continue video teleconferences between ABB CE and R,E&C.

Finalize technical papers for the Eleventh Annual International Pittsburgh Coal Conference, the 1994 International Joint Power Generation Conference, and the Tenth Annual Coal Preparation, Utilization and Environmental Control Contractors Conference.

TASK 2 - Concept Development

No work planned.

TASK 3 - Research, Development, and Test Plans

No work planned.

TASK 4 - Component Definition

Complete the engineering analysis, experimental work and modeling and issue a report.

TASK 5 - Commercial Generating Unit Design

Complete the design effort and prepare a draft report.

TASK 6 - Phase I Report

Commence work on the Phase I Report.

APPENDIX C

MEETING - DOE LEBS PROJECT

Date: January 6, 1994, 8:30 a.m.

Place: Raytheon Philadelphia Offices

Attendees: Raytheon - East
ABB ES
ABB CE

Agenda:

1. Open ACTION Items

2. ABB ES RAM Analysis

3. Task 5
   - Status Review
   - Cost Targets
   - Equipment Layout
   - Winslow 12/27/93 letter
   - EPP Update

4. Task 6
   - CGU Rendering

5. Quarterly Project Review Meeting 1/27/94
   - Agenda
   - Arrangements

6. Miscellaneous Topics
   - Minutes from December 2 and 16, 1993 meetings
   - Approve Boiler RAM Analysis
   - Sulfur Institute's "Sulfur Outlook"

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MEETING AGENDA
DOE LEBS PROJECT

Time: 8:30 AM to approximately 3:30 PM, February 8, 1994.

Place: Raytheon Engineers & Constructors - 30 South 17th Street, Philadelphia

Attendees: DOE PETC - John Winslow, Michael Izsak
ABB Team - Richard Borio, Robert Kaminski (and others from RE & C),
Mark Palkes, John Regan, James Wesnor

Schedule * :

1. -	Introductions and Agenda Review (Regan)	8:30
2. -	Project Status and Management Activities (Regan)	8:40 - 9:30

- Schedule/Cost/Manpower
- Team Meetings
- Project Advisors
- POC Host
- QA/QC
- Technology Transfer

3. -	Task 4 Report (Borio)	9:30 - 10:15

- Work Plan
- Experimental Research
- Modeling
- Remaining Work

	Break	10:15 - 10:30
4. -	Task 5 Report	10:30 - 12:00

- Boiler, SNOX Integration (Palkes)
- SNOX, Acid (Wesnor)
- CGU Design Basis, Layout (Kaminski, et al)
- RAM (Kaminski, et al)
- Cost Estimating (Kaminski, et al)

	Lunch	12:00 - 1:00
5. -	General Discussion and Planned Activities (All)	1:00 - 2:00
6. -	Review, Action Items, Wrap-up (Regan)	2:00 - Conclusion

* Timing is flexible.

January 28, 1994

MEETING - DOE LEBS PROJECT

Date: March 15, 1994 8:00 am

Place: Richmond, Indiana Power & Light

Attendees: Richmond P&L - (*)
DOE-PETC - John C. Winslow, Project Manager
ABB CE - John W. Regan, Project Manager
RE&C - Robert S. Kaminski, Project Manager
William Swegler, Chief Engineer - Fossil Projects

Agenda:

1. Project summary. (Regan, Winslow)
2. Richmond P&L objectives. (*)
3. Desired site characteristics. (Kaminski, Regan)
4. Review existing installation - fuel, steam requirements, load characteristics, etc. Preliminary discussion only.(all)
5. Tour of facilities. (all)
6. The next step. (all)

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