DOE/PC/79796--T7

DOE/PC/79796--T7

DE90 002869

ENHANCING THE USE OF COALS BY GAS REBURNING–SORBENT INJECTION

Quarterly Report No. 7

For the Period

December 1, 1988 to February 28, 1989

CONTRACT NUMBER: DE-FC 22-87PC 79796

Prepared for:

U.S. Department of Energy

Gas Research Institute

State of Illinois Department of Energy and Natural Resources

Prepared by:

Energy and Environmental Research Corporation

18 Mason

Irvine, California 92718

March 23, 1989

U.S. DOE PATENT CLEARANCE IS NOT REQUIRED PRIOR TO THE PUBLICATION OF THIS DOCUMENT

TABLE OF CONTENTS

LEGAL NOTICE

This report was prepared by Energy and Environmental Research Corporation (EER) as an account of work sponsored by the Gas Research Institute (GRI), the United States Department of Energy (DOE), and the State of Illinois Department of Energy and Natural Resources (ENR). Neither GRI, DOE, ENR, nor members of GRI, DOE, ENR, nor any person acting on their behalf;

a. Makes any warranty or representation, express or implied with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately-owned rights, or

b. Assumes any liability with respect to the use of, or for damages resulting from the use of, any information, apparatus, method, or process disclosed in this report.

1.0 SUMMARY

The objective of this project is to evaluate and demonstrate a cost effective emission control technology for acid rain precursors, oxides of nitrogen (NO_x) and sulfur (SO_x), on three coal fired utility boilers in Illinois. The units selected are representative of pre-NSPS design practices: tangential, wall, and cyclone fired. The specific objectives are to demonstrate reductions of 60 percent in NO_x and 50 percent in SO_x emissions, by a combination of two developed technologies, gas reburning (GR) and sorbent injection (SI).

With GR, about 80-85 percent of the coal fuel is fired in the primary combustion zone. The balance of the fuel is added downstream as natural gas to create a slightly fuel rich environment in which NO_x is converted to N_2. The combustion process is completed by overfire air addition. SO_x emissions are reduced by injecting dry sorbents (usually calcium based) into the upper furnace, at the superheater exit or into the ducting following the air heater. The sorbents trap SO_x as solid sulfates and sulfites, which are collected in the particulate control device.

This project will be conducted in three phases at each site: (1) Design and Permitting, (2) Construction and Startup, and (3) Operation, Data Collection, Reporting and Disposition. Technology transfer to industry will be accomplished through the formation of an industry panel. Phase 1 of the project commenced on June 5, 1987 and includes five tasks as follows:

- Task 1 - Project Management
- Task 2 - Process Design
  - Subtask 2.1 - Host Site Characterization
  - Subtask 2.2 - Process Specification
- Task 3 - Project Engineering
- Task 4 - Environmental Reports, Permitting, Plans and Design
- Task 5 - Technology Transfer

During this quarter, work continued on all Phase 1 tasks.

In Task 1, Project Management, close coordination of all project activities continued. Various alternatives for resolving the Professional Liability Insurance issue have been assessed and presented to the funders. Completion of Phase 1 is projected as March 15 for the wall fired unit, and May 15 for the tangentially and cyclone fired units. Costs of the Phase 2 work (and consequently of the entire project) have been reevaluated based on further input from bids on general construction and ESP upgrading, as well as comparison to independent cost estimates made by Black & Veatch, EER's Architect/Engineer subcontractors. Based on the discussion of cost and schedule projections with the Participants Committee and Senior Review Committee on January 19 in Chicago, it became evident that the full scope of the three-site GR-SI project cannot be accomplished within existing budget constraints. EER was requested to present its recommendations to the funders on the most favorable options to accomplish project objectives. A meeting was scheduled for this purpose to be held on March 8 in Pittsburgh.

In Task 2, Process Design, work continued on both subtasks. In subtask 2.1, Host Site Characterization, work continued on the baseline test reports and Phase 3 test plans, which will be finalized and submitted to the funders and hosts during the coming quarter. In subtask 2.2, drafting of the final process design report for Edwards has been completed, the other two tasks are in preparation. Work was completed on the Lakeside thermal performance, boiler performance and boiler efficiency evaluations; the same evaluations will be completed next quarter for Hennepin. In addition, the Lakeside ESP evaluation still needs to be completed next quarter (the last quarterly report summary stated incorrectly that all Phase 1 technical work on Task 2.2 has been completed).

In Task 3, Project Engineering, work progressed near completion during this quarter. For Edwards, firm bids have been received on general construction and electrical work, ESP field addition, SO_3 system upgrade and on dry fly ash handling and storage. The final engineering design report for Edwards has also been drafted. For the other two sites these reports are in preparation. Bid packages have also been sent out for Hennepin, with bids due to EER in March. Project engineering work has been completed for Lakeside, and bid packages are in preparation for release in March.

In Task 4, Environmental Reports, Permitting Plans and Design, a statement of finding has been received by CILCO from the archaeologist on his survey of the proposed pipeline route. This completes the requirements for obtaining NEPA approval, based on the Environmental Assessment submitted to DOE headquarters. Draft copies of the Environmental Monitoring Reports have been submitted for review and comments to DOE. All three hosts approved EER's recommendations on ash management based on detailed GR-SI ash characterization--dry and remote site disposal for Edwards and Lakeside, wet disposal into a new pond at Hennepin. Permitting assistance to the host utilities continued through contacts with IEPA, who in turn provide liaison with EPA Region 5. Information obtained from DOE was passed along to the host utilities on EPA's position on NSPS and PSD reviews at the conclusion of Clean Coal projects--in the interest of fostering novel, improved technology, EPA has taken a "no action" position vis-a-vis a request by Ohio Edison for a reburning demonstration project.

In Task 5, Technology Transfer, the second meeting of the Industry Panel was held in Chicago on January 18, 1989. Altogether, 53 individuals attended, consisting of 21 representatives of project participants and hosts, and 32 representatives of industry, research organizations, consultants, etc. This well-attended meeting focused on the details of GR-SI designs and Phase 3 test plans. A number of valuable comments have been reviewed from the panel, which EER is evaluating. Responses will be distributed to the membership.

Key Words

SO_x	Ash	Emission
SO_2	Coal	Control
NO_x	Gas	Boiler
NO	Sorbent	Precipitator
		Flue Gas

2.0 INTRODUCTION

Clean Coal Technology implies the use of coal in an environmentally acceptable manner. Coal combustion results in the emission of two acid rain precursors: oxides of sulfur (SO_x) and oxides of nitrogen (NO_x). This clean coal technology project will demonstrate a combination of two developed technologies to reduce both NO_x and SO_x emissions: gas reburning and calcium based dry sorbent injection. The demonstrations will be conducted on three pre-NSPS utility boilers representative of the U.S. boilers which contribute significantly to the inventory of acid rain precursor emissions: tangentially fired, wall fired, and cyclone fired units.

Gas reburning is a combustion modification technique that consists of firing 80-85 percent of the fuel corresponding to the total heat release in the lower furnace. Reduction of NO_x to molecular nitrogen (N_2) is accomplished via the downstream injection of the remaining fuel requirement in the form of natural gas (which also reduces the total SO_x emissions). In a third stage, burnout air is injected at lower temperatures in the upper furnace to complete the combustion process without generating significant additional NO_x.

Dry sorbent injection consists of injecting calcium based sorbents (such as limestone, dolomite, or hydrated lime) into the combustion products. For sulfation of the sorbent to $CaSO_4$, an injection temperature of about 1230°C is optimum, but calcium-sulfur reactions can also take place at lower temperatures. Thus, the sorbent may be injected at different locations, such as with the burnout air, at the exit from the superheater, or into the ducting downstream of the boiler with H_2O added for humidification. The calcium sulfate or sulfite products are collected together with unreacted sorbent by the particulate collection device, usually an electrostatic precipitator or bag filter.

The specific goal of this project is to demonstrate NO_x and SO_x emission reductions of 60 percent and 50 percent, respectively, on three coal fired utility boilers having the design characteristics mentioned above. Host Site Agreements have been signed by EER and three utility companies in the State of

Illinois: Illinois Power Company (Test Site A, Hennepin Unit 1, 80 MW tangentially fired boiler in Hennepin), Central Illinois Light Company (Test Site B, Edwards Unit 1, 117 MW front wall fired boiler in Bartonville), and City Water Light and Power (Test Site C, Lakeside Unit 7, 40 MW cyclone fired boiler in Springfield). Alternate host sites would be utilized in the event that unforeseen problems develop with any of the above tests.

Co-funding for this project is provided by the Gas Research Institute (GRI) and the State of Illinois Department of Energy and Natural Resources (ENR)--the other Funding Participants. GRI and ENR are responsible for funding approximately one-third and one-sixth, respectively, of the total project costs.

To achieve the objectives of the project, it will be conducted in the following three phases at each host site.

Phase 1: Design and Permitting

Phase 2: Construction and Startup

Phase 3: Operation, Data Collection, Reporting and Disposition

Phase 1 of the project is being conducted in parallel for test sites A, B, and C over a period of 15 months. For this reason, quarterly reports will be issued during Phase 1, combining the work done related to all three sites. Starting with Phase 2, which will consist of a staggered schedule of eight months duration for each Test Site, separate reporting will be instituted to cover the work done at each site. This practice will be continued for the remainder of the total project schedule of 54 months, which includes the Phase 3 work at each site.

During the last quarter of Phase 1, Design and Permitting, work continued on each task of the project. The principal objectives of the work performed during this quarter were as follows:

- Manage and coordinate all project tasks.

- Meet with funders to discuss costs, schedules, cost management options and transition into Phase 2.
- Hold Participants Committee--Senior Review Committee meeting in Chicago on January 19.
- Resolve Professional Liability insurance issue through presentation of alternatives to funders.
- Meet with host utilities to review budget outlook and discuss technology demonstration options.
- Bring to completion Phase 1 work on Edwards, near completion on Hennepin and Lakeside.
- Complete drafts of baseline test reports.
- Complete drafts of Phase 1 test plans, taking into account the input received from the Industry Panel.
- Complete process specification work, including thermal performance, boiler performance and efficiency calculations, and evaluating of ESP enhancement options.
- Issue bid packages, receive and evaluate bid for Edwards general construction and electrical work, ESP extension, SO_3 injection system enhancement, instrumentation and controls.
- Release bid packages for Hennepin.
- Coordinate monthly engineering review meetings with hosts and Black & Veatch, EER's A/E subcontractor.
- Assess reports received from subcontractors and consultants.
- Submit all Environmental Information Volume material to DOE.
- Submit drafts of the Environmental Monitoring Plans for each site to DOE.
- Evaluate and select ash management options, obtain host utility approval of recommendations.
- Organize and conduct Industry Panel meeting in Chicago on January 18, focused on designs and Phase 3 test plans.

3.0 PROJECT DESCRIPTION

Within the three phases of the project, the following tasks will be performed to demonstrate the cost effective control of NO_x and SO_x emissions from pre-NSPS coal fired utility boilers:

PHASE 1: DESIGN AND PERMITTING

Task 1 - Project Management

- Coordination of all Participant and subcontractor efforts
- Coordination with the three host site and alternate host sites
- Planning and scheduling all tasks
- Monitoring all technical efforts
- Keeping DOE, GRI, and ENR fully informed of project status
- Continual review of relevant ongoing technical developments

Task 2 - Process Design

Subtask 2.1 - Host Site Characterization

- Establishment of the condition of each host site, including field evaluations.

Subtask 2.2 - Process Specification

- Preparation of GR-SI process designs, aiming at 60% and 50% reduction in NO_x and SO_x, respectively.
- Continuing bench scale tests to define key process parameters.

Task 3 - Project Engineering

- Preparation of site specific detailed engineering designs, construction plans and schedules, cost estimates, startup plans and Phase 3 test plans.

Task 4 - Environmental Reportings, Permitting, Plans and Design

- Preparation of relevant environmental data for obtaining NEPA approval.

- Preparation of Environmental Monitoring Plan.
- Assistance to host sites in obtaining environmental permits.

Task 5 - Technology Transfer

- Formation of an Industry Panel for technology transfer.
- Arrangement of Panel meetings on (1) process design and (2) detailed engineering design and plans for Phases 2 and 3.

PHASE 2: CONSTRUCTION AND STARTUP

Task 1 - Project Management

- Continuation of Phase 1 project management activities.
- Arrangement of project review meetings at approximately the 20 and 100 percent completion points for each site.

Task 2 - Installation and Checkout

- Installation of the emission control and auxiliary equipment.
- Checkout of functional operation of all components.

Task 3 - Technology Transfer

- Continuation of technology transfer activities initiated in Phase 1.
- Meetings with Industry Panel to review installations and plans.

Task 4 - Restoration

- Decision on disposition of test equipment if project is discontinued: to be retained by host sites or removal and restoration work.

PHASE 3: OPERATION, DATA COLLECTION, REPORTING AND DISPOSITION

Task 1 - Project Management

- Continuation of Phases 1 and 2 project management activities.
- Conducting final project review at conclusion of project.

Task 2 - Technology Demonstration

Subtask 2.1 - Optimization Testing

- Evaluation of effects of process variables on emission control performance.
- Determination of operating conditions for optimum overall performance.

Subtask 2.2 - Evaluation of Alternative Coals and Sorbents

- Evaluation of performance of alternative coals and sorbents:
  - High and medium sulfur coals, with consideration of cleaned and run-of-mine coals.
  - Selection of sorbents from high calcium and dolomite limestones, hydrated limestones and limes.

Subtask 2.3 - Long-Term Testing

- Operation of GR-SI equipment under optimized conditions for approximately one-year duration at each host site.
- Measurement of emission control system performance.
- Determination of boiler impacts.

Task 3 - Evaluation of Demonstration Results

- Analysis of test data.
- Preparation of guideline manuals for application of GR-SI technology, including design recommendations, cost projection and comparisons with competing technologies.

Task 4 - Restoration

- Disposition of GR-SI equipment installation:
  - To be retained by host site or removal and restoration work.

Task 5 - Technology Transfer

- Continuation of technology transfer activities from Phases 1 and 2.
- Meeting with Industry Panel at one host site to review results obtained there and plans for other two host sites.
- Meeting with Industry Panel at completion of project.

4.0 PROJECT STATUS

Work has continued on all tasks of Phase 1 of this project. This section of the report provides details of the work performed during the quarter December 1988 through February 1989.

4.1 Task 1 - Project Management

Monthly and special reports were submitted as stipulated by the reporting requirements of the Cooperative Agreement. Coordination of all tasks of Phase 1 continued, with target dates to complete the work for the Edwards host site by March 15, and for the Hennepin and Lakeside project sites by May 15, 1989.

Cost projections have been made at different levels:

(i) In the absence of firm bids for Phase 2 construction and other costs, best estimates were prepared, which included reviews of Phase 1 and Phase 3 costs. The total costs projected for Phases 1 and 3 remained unchanged. These estimates and schedule projections were discussed at a meeting with DOE and GRI in Irvine, California on December 15, 1988 and subsequently with ENR in Springfield, Illinois on January 11, 1989.

(ii) The Phase 2 cost projections that indicated significant growth for construction relative to the original estimates were revised and presented along with total costs and schedule projections to the Participants Committee meeting in Chicago on January 19. (This meeting was also attended by Senior Review Committee representatives.) This presentation included a discussion of technology demonstration options available based on budget constraints. EER was requested to further consider these options and present its best recommendations to the funders at a meeting scheduled for Pittsburgh on March 8.

(iii) With the bids in hand on the Edwards project site construction, precipitator extension and other items required for the GR-SI demonstration, firm cost estimates were made for the Phase 2 effort at that site. Also, EER's cost estimating procedures were further "calibrated" by independent estimates made by Black & Veatch, EER's Architect/Engineer subcontractor, for the Edwards and Hennepin project sites, with generally good agreement. These estimates indicated that the original scope of the project could not be completed with the available budget of $30 million. Thus, the objective became to re-scope the project in a manner such that the goal of achieving commercial readiness through field evaluations of both Gas Reburning and Sorbent Injection at a sufficient number of sites.

At all of the meetings with the funding organizations, the issue of Professional Liability insurance related to boiler modification activities were discussed. The options available for this purpose include costly insurance or a fronted policy, establishing an escrow account for Errors/ Omission coverage or other budgetary changes. Final decision on this issue will be made after the March 8 meeting in Pittsburgh.

In addition to the above activities, project management has been involved in the coordination of preparation of final reports on the Phase 1 activities. These reports, including Phase 1 baseline test reports, design reports, various environmental reports and permitting documents, Phase 3 test plans have been targeted to be completed in March for Edwards, and in May for Hennepin and Lakeside.

4.2 Task 2 - Process Design

4.2.1 Subtask 2.1 - Host Site Characterization

Draft Phase 1 test reports were completed for all three sites. A detailed preliminary test plan for all three sites was presented to the Industry Panel. Suggestions received from panel members at that meeting, as well as suggestions received from Riley Stoker concerning Edwards Unit 1, are being considered in writing the draft test-plan reports. Key issues in the test plans include provisions not only for measuring the reductions in SO_x and

NO_x emissions, but quantifying the capital, operating, maintenance, and availability costs of the GR-SI process--particularly as these costs might apply to future installations. Different lengths of operating time are needed for reasonable evaluations of various aspects of the process. Fifty days each of baseline and GR-SI operation appear to be adequate for quantifying emissions reductions, but longer periods may be needed for evaluating other impacts.

A Phase 1 baseline test report draft for Hennepin Unit 1 was finalized after internal review, and was forwarded to Illinois Power for approval.

A test plan draft report for Edwards Unit 1 was revised based on comments received in internal review and the other comments mentioned above. The report is now in typing.

Plans for the coming quarter include finalization of the Hennepin and Edwards test plan drafts for utility review, finalization of the Edwards and Lakeside Phase 1 test reports, and issuing of the Hennepin Phase 1 test report following Illinois Power approval.

4.2.2 Subtask 2.2 - Process Specification

4.2.2.1 Introduction

The overall objective of the Process Specification subtask of the project is to develop detailed conceptual design specifications for the application of gas reburning and sorbent injection to each of the host utility boilers. The activities necessary to develop the process specification include the identification of operational and performance characteristics for each boiler, and a series of design studies to identify the optimum conditions for the application of gas reburning and sorbent injection, and to develop specific design criteria. The activities are divided into a number of sub-elements which include:

- Boiler Characterization - Compilation of all available structural, operational, and performance data to permit evaluation of each boiler for reburning and sorbent injection application. Additional current data are obtained in a baseline field test program as part of subtask 2.1.

- Isothermal Modeling - Construction of isothermal physical flow models and validation of bulk and detailed flow field structure against available full scale information. The flow field data are used as inputs into the furnace heat transfer model. The isothermal models are used to develop the characteristics of the reburn gas, burnout air, and sorbent injectors necessary to produce adequate mixing of the reactant streams. Injector designs are optimized via detailed measurements to define mixing characteristics for the full operating range.

- Thermal Performance Analysis - Application of 2D and/or 3D furnace heat transfer and boiler performance codes for analysis of thermal performance characteristics of each unit over the nominal operating range. A range of possible reburning and sorbent injection applications are identified based on boiler thermal characteristics, process requirements and available access. The thermal effects of reburning and sorbent injection are analyzed to select arrangements which have minimal effects on boiler performance. Then the detailed process design is specified and detailed thermal analyses will be conducted for the full retrofit situation.

- Process Specification - Coupling of heat transfer and flow analyses with process models to develop predictions of NO_x and SO_2 reductions for a range of process variable parameters. This includes further optimization of process and design parameters. Detailed design specifications will be developed for process application, including injector characteristics, injector locations, reactant flow rates, stoichiometries, etc.

- Electrostatic Precipitator (ESP) Performance Enhancement - The injection of sorbent into the upper furnace (or flue gas duct) will increase the inlet particulate loading for the existing ESP. Further, currently available laboratory and field data indicate that sorbent injection processes can result in fly ash with high electrical resistivity, making it difficult or impossible to collect in an ESP. Some form of ESP performance enhancement is therefore needed for at least two of the three demonstration sites. Potential enhancement technologies are identified, and systematic, site-specific studies are conducted to evaluate the various technologies in terms of their predicted performance, impacts on plant performance and operation, and cost. Through discussions with the utilities, enhancement technologies for each site are selected, and detailed designs are developed in Task 3.

4.2.2.2 Wall Fired Boiler

Process design work on the Edwards Unit 1 boiler was essentially completed during the period with the preparation of a draft of the final report for the Process Specification task. The report summarizes the GR-SI system design specifications for Edwards, along with EER's predictions of unit performance and operability. The Edwards final report will be issued in March, 1989.

4.2.2.3 Tangentially Fired Boiler

Thermal performance computer model runs utilizing EER's 2-dimensional furnace heat transfer and combustion model in conjunction with a boiler performance model of the Hennepin Unit 1 boiler were completed during the quarter. These computer model simulations provide the basis for EER's assessment of the impacts of GR-SI application on the thermal performance of the Hennepin boiler. Thermal performance predictions for baseline and nominal GR-SI operation were forwarded to RAMCO--EER's boiler design subcontractor for the Hennepin unit--for review and comment.

Results and conclusions of the thermal performance assessment work on the Hennepin unit will be presented in the final process design report.

Work on the final process design report for the Hennepin system also continued. Sections of the report detailing the results of the isothermal modeling work and ESP performance enhancement evaluation were completed. A report section describing the results of the boiler thermal performance assessment was also begun.

4.2.2.4 Cyclone Fired Boiler

Thermal performance analysis work on the Lakeside Unit 7 boiler was completed during the period. A brief summary of the performance predictions for full load operation with and without GR-SI follows.

The main tool for analysis of thermal performance in the furnace is a two-dimensional furnace heat transfer and combustion zone model (referred to hereafter as the "2D code"). The 2D code has been coupled with a sorbent injection and sulfation model. The 2D furnace model is basically a zone model. That is the furnace volume is divided into a certain number of volume zones (often referred to as gas zones) and into a corresponding number of surface or boundary zones. An axisymmetric cylindric grid is used to represent the furnace. The furnace is divided axially and radially into zones, providing for spatial resolution of heat transfer quantities. Figure 4.2-1 is a schematic of Lakeside Station Unit No. 7 Boiler. Figure 4.2-2a shows a pretreatment schematic of the region to be modeled, including key features such as heat exchanger banks and mass inlets. This schematic has been divided into 21 layers (referred to as "3D layers" in Figure 4.2-2a), roughly following the direction of flow from bottom to top. These layers correspond to the 21 axial layers in Figure 4.2-2b, which shows a cross-section of the axisymmetric cylindric grid used in the 2D code. This grid is also divided into 5 or fewer radial zones.

In converting from the 3D layers in Figure 4.2-2a to the 2D grid in Figure 4.2-2b, it is important to preserve the furnace volume and total wall

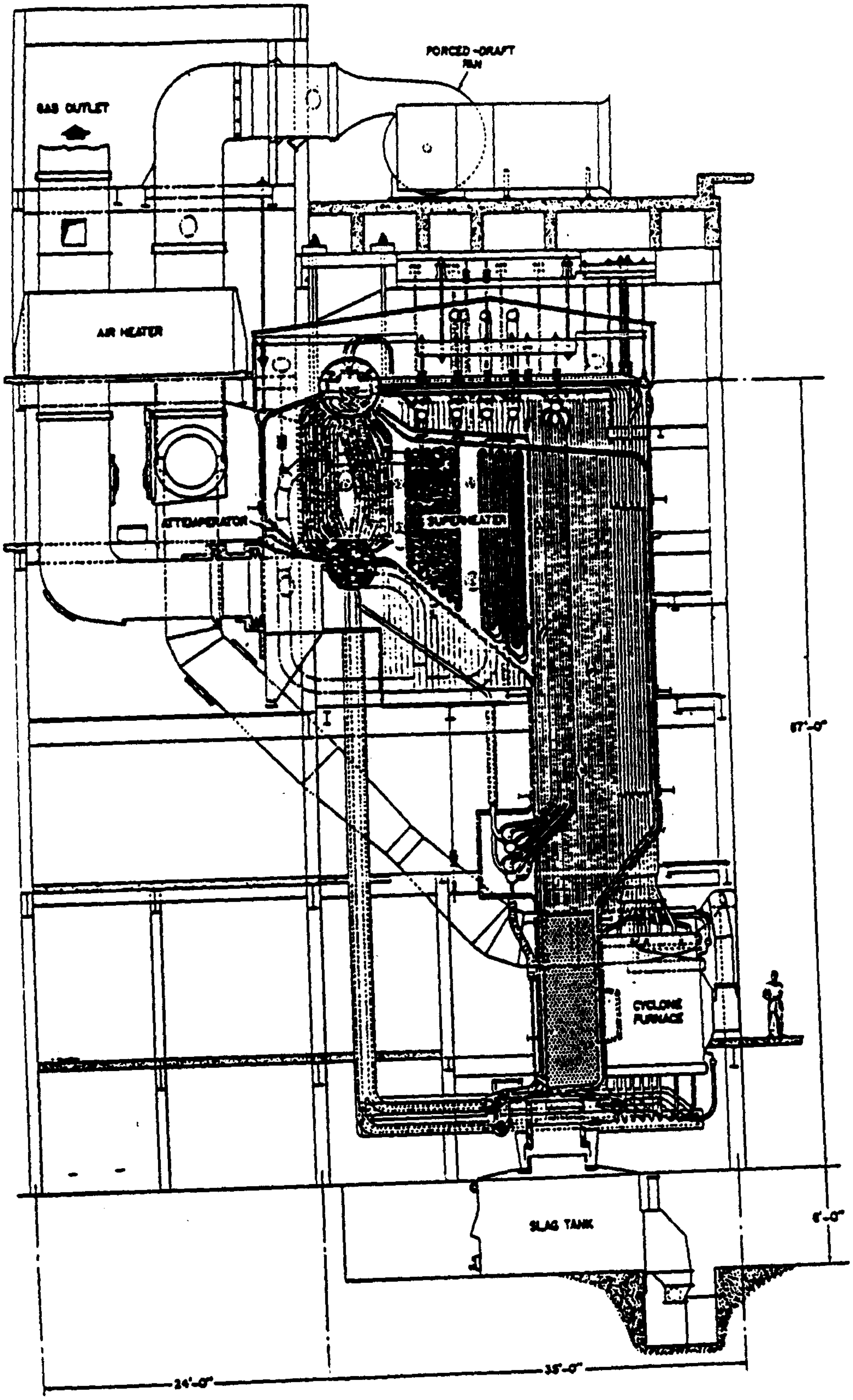


Figure 4.2-1 Schematic of Lakeside Station Unit No. 7 boiler.

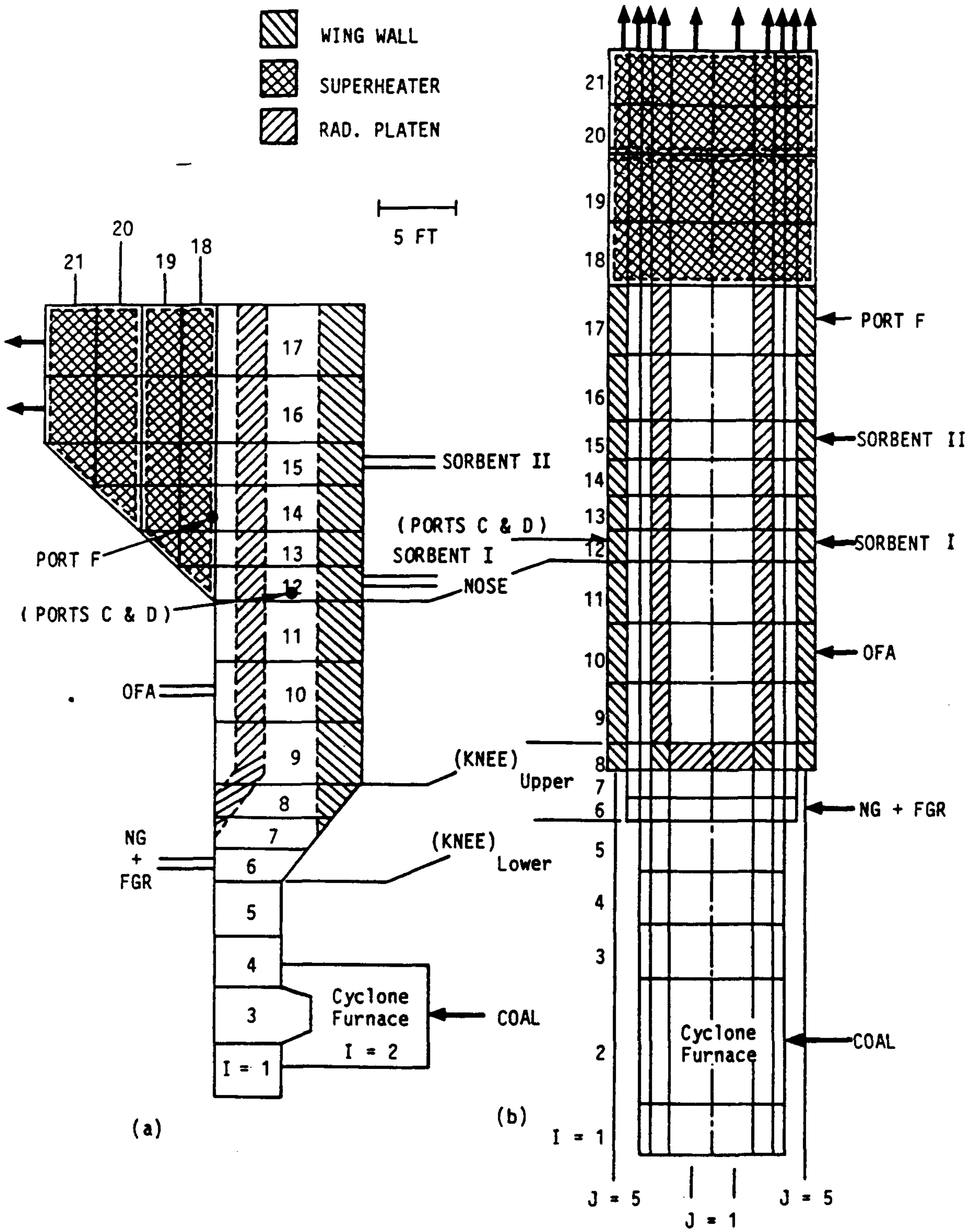


Figure 4.2-2 Lakeside boiler geometry (a) 3D layer division; (b) Cylindric grid for 2D model.

surface area. Furnace surface area controls the heat transfer from gas zones to wall surfaces, and the furnace volume controls the coal and NG residence time.

A key part of the furnace heat transfer model is the sub-model for calculating the multi-directional radiative exchange between all volume and surface zones. This sub-model is derived from Monte-Carlo techniques. The model uses a semi-stochastic approach to track radiative beams proceeding through processes of emission, gas-phase attenuation, surface absorption and reflection, until all energy in each beam is absorbed within a prescribed numerical tolerance.

The total energy conservation calculations are carried out for volume zones and surface zones separately in order to obtain gas temperatures in gas zones and deposit temperatures on wall surfaces. In volume zone balances, the sensible heat, the net convective heat fluxes to adjacent zones and the net radiative fluxes from a volume zone are equated to the release of chemically bound heat in that zone. The heat balance for wall surface zones is formulated by analogy to the volume zone heat balances such that the heat conducted through the layer covering the wall surface zone is equal to the sum of the convective heat fluxes and the net radiative fluxes from adjacent gas zones.

The combustion model has the following sub-models:

- Devolatilization;
- Burn-out of char particles; and
- Burn-out of volatile matter.

Coal particles are devolatilized according to an Arrhenius rate law. The combustion rate of devolatilized char particles is a function of diffusion rate, chemical reaction rate and local oxygen concentration. Volatile lumps are assigned statistically distributed lifetimes, and each lump reacts completely at the end of its assigned lifetime.

The flow field is not calculated but is prescribed as an input for 2D code. The prescription allows for specification of velocity profiles, recirculation patterns, and turbulent exchange between zones. In practice, specified flow fields are generally based on isothermal flow model observations, and on experience in modeling similar boilers.

Ash deposit thickness plays a very important role in the 2D heat transfer model. It affects how much heat can be absorbed from the water/steam cycle. However, due to the constraints of measurement, only rough relative estimates can be obtained from field observations. Values for deposit-related parameters were set on the basis of EER's experience with modeling other boilers in conjunction with visual observations of the deposits in the field. The values were then refined by using baseline field test results to calibrate the 2D model. The sensitivity of model predictions to deposit-related input parameters was fully investigated during the studies.

- <u>Comparison to Experimental Data for 100% and 68% Loads</u>

Figures 4.2-3 through 4.2-6 show the comparison of predicted gas temperatures with measured ones for 100% and 68% loads. Figures 4.2-3 and 4.2-5 are plotted against vertical height, while Figures 4.2-4 and 4.2-6 are plotted against radial distance at ports C & D. The measurements were taken during December 1987 site characterization tests. Data were taken from ports C and D, which are just above the nose point in zone layer 12 in Figure 4.2-2b and from port F, which is just before the entrance of the secondary superheaters and mapped onto zone layer 17 in Figure 4.2-2b.

The solid-line curves in Figures 4.2-3 through 4.2-6 are the predicted mean gas temperatures for each layer, with the temperatures of individual zones weighted by the flow profile. The Standard Deviation (STD) is shown in each graph for statistical comparison purposes. In Figures 4.2-3 and 4.2-5, the predicted gas temperatures fall well between the measured data band and some of them, are within the STD range. However, Figures 4.2-4 and 4.2-6 show some discrepancies between prediction and measurement because the 2D flow field can not fully represent a 3D furnace flow field. Overall, the

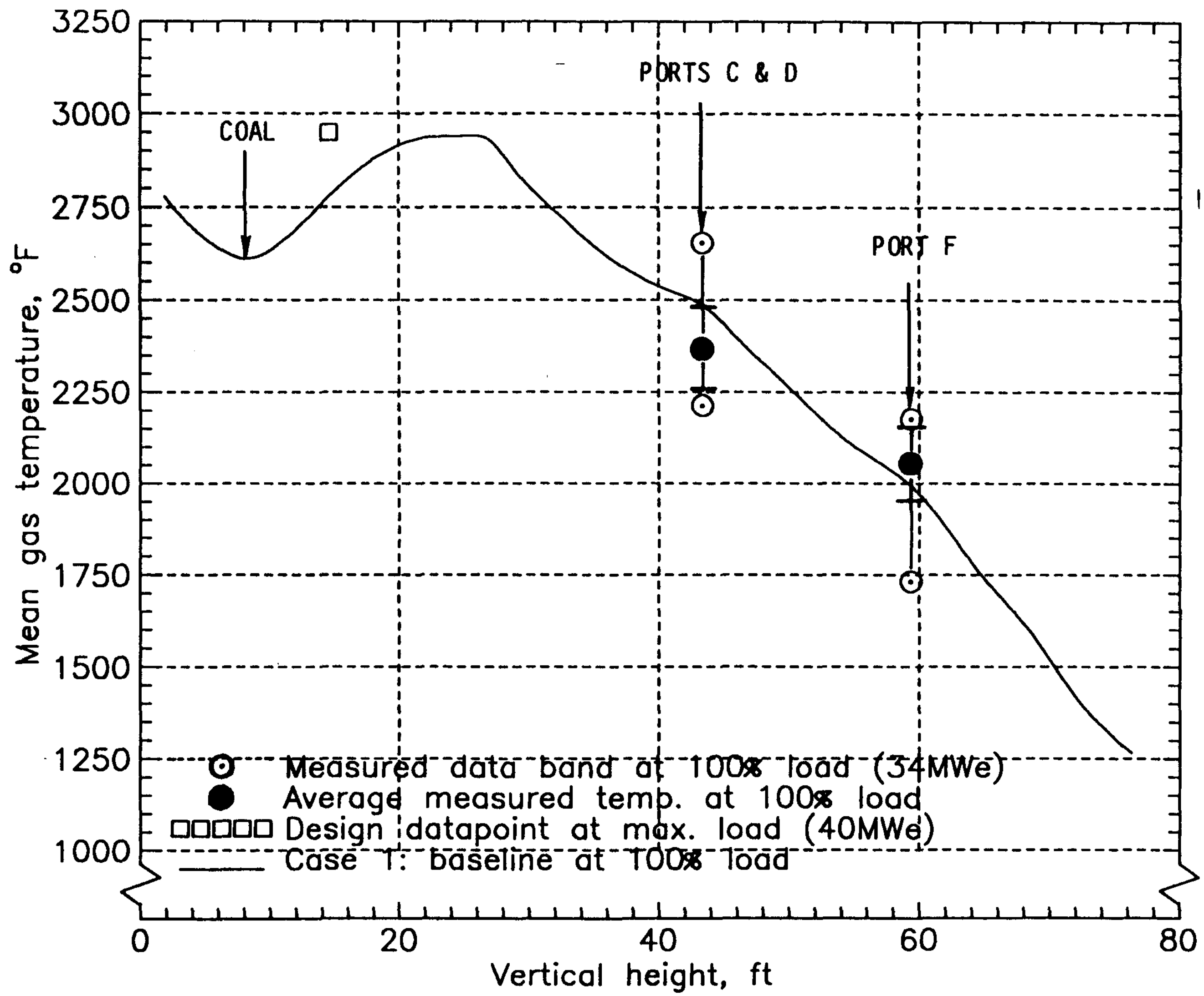


Figure 4.2-3 Compare the mean gas temperature distribution predicted for baseline case with measured data points at 100% load (34MWe).

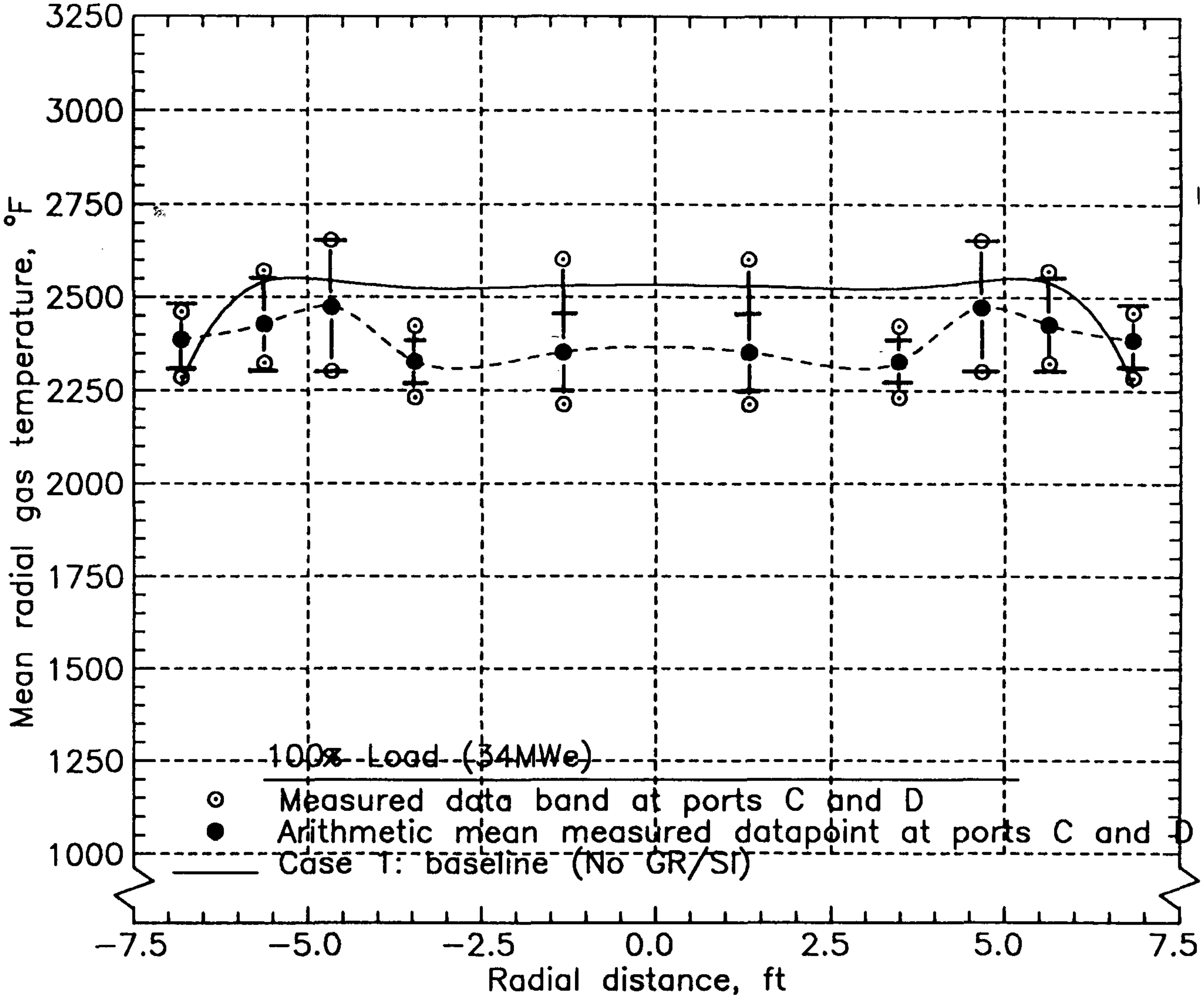


Figure 4.2-4 Compare the mean gas temperature distribution along radial direction predicted for baseline case with measured datapoints of 100% load (34MWe) at ports C & D.

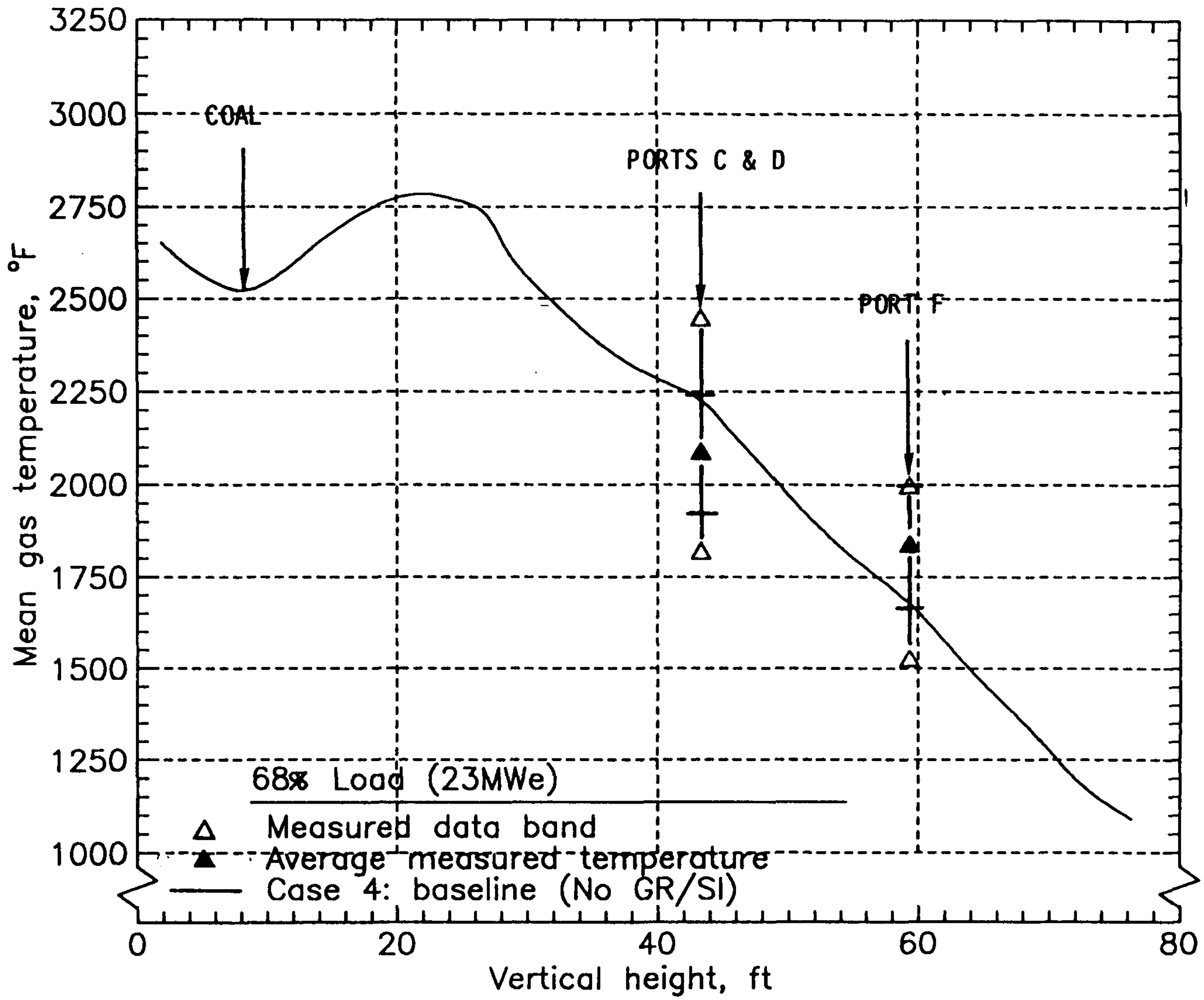


Figure 4.2-5 Compare the mean gas temperature distribution predicted for baseline case with measured data points at 68% load (23MWe).

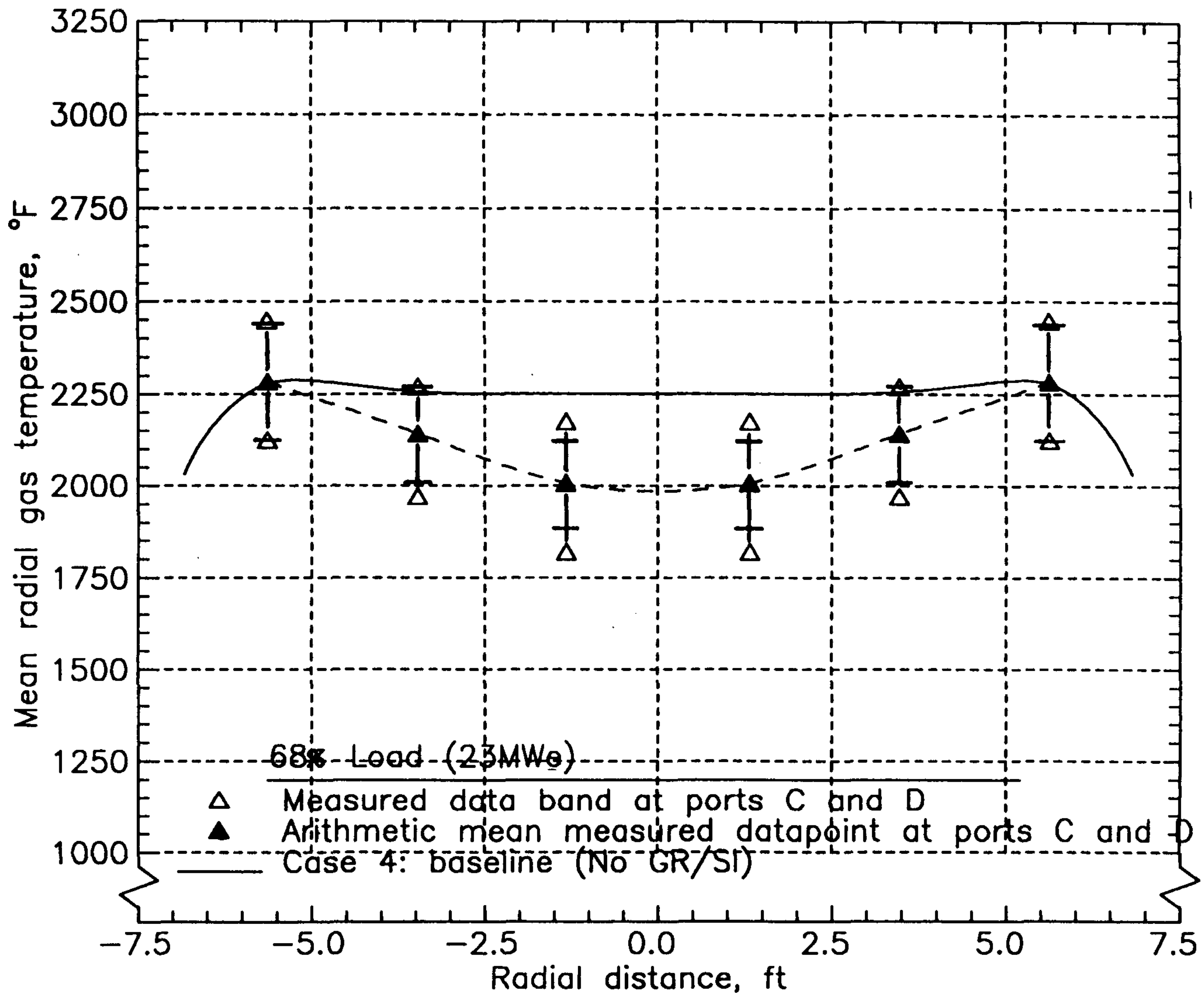


Figure 4.2-6 Compare the mean gas temperature distribution along radial direction predicted for baseline case with measured datapoints of 68% load (23MWe) at ports C and D.

comparison is quite satisfactory. The baseline cases for 100% and 68% loads are established and considered as calibration cases for the GR and GR-SI studies. Further comparison to experimental data will be made in the section on Boiler Code Results.

- Impacts of GR and GR-SI at 100% Load

Figures 4.2-7 and 4.2-8 show the impacts of GR and GR-SI on furnace mean gas temperature distribution and net total heat flux densities. Each quantity is plotted against 2D grid axial height, for Cases 1, 2 and 3. Cases 1, 2 and 3 represent baseline (coal only), gas reburning, and gas reburning with sorbent injection, respectively.

Note that curves for Cases 2 and 3 almost coincide with each other over most of the plot range. This is not surprising, as the relative impact of introducing sorbent injection is small compared to that for the introduction of gas reburning. Most of the profile variations between Cases 2 and 3 are in the region of the over-fire air and sorbent injection ports, due to the mass flow differences at these locations.

Figure 4.2-7 shows the impact of GR and GR-SI on mean gas temperature distribution against grid vertical height. Preserving the same stoichiometry in cyclone furnaces as for the baseline case, and maintaining the reburning zone stoichiometry at approximately 0.9, there is 22.4% less heat input in cyclone furnaces for Cases 2 and 3 than in Case 1. The lower heat input results in lower gas temperatures up to natural gas + flue gas recirculation (NG + FGR) ports. From the (NG + FGR) ports upward, the temperature drops for the GR and GR-SI cases, primarily due to the impact of FGR. There is also a dip in temperature at the introduction of OFA for Cases 2 and 3, and at the introduction of sorbent CA for Case 3. Due to the diversion of 5% of the total combustion air flow from the OFA ports to the sorbent injection nozzles for use as sorbent CA, the dip for Case 2 is deeper than for Case 3. The introduction of OFA for Case 2 changes the temperature trend from lower to higher than baseline case at the turning location of Sorbent I. However the

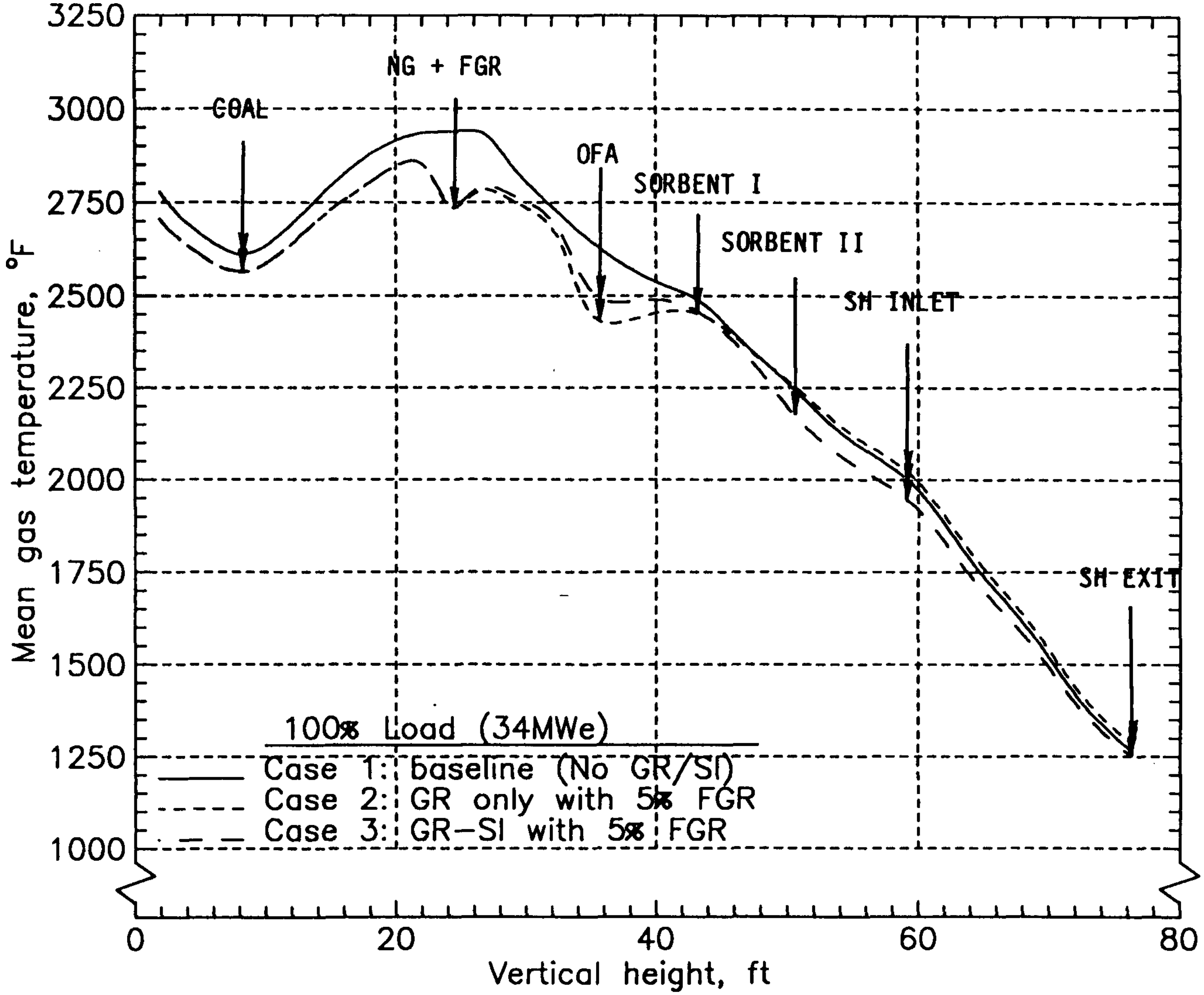


Figure 4.2-7 Compare the mean gas temperature distribution along axial distance predicted for Cases 1, 2 and 3.

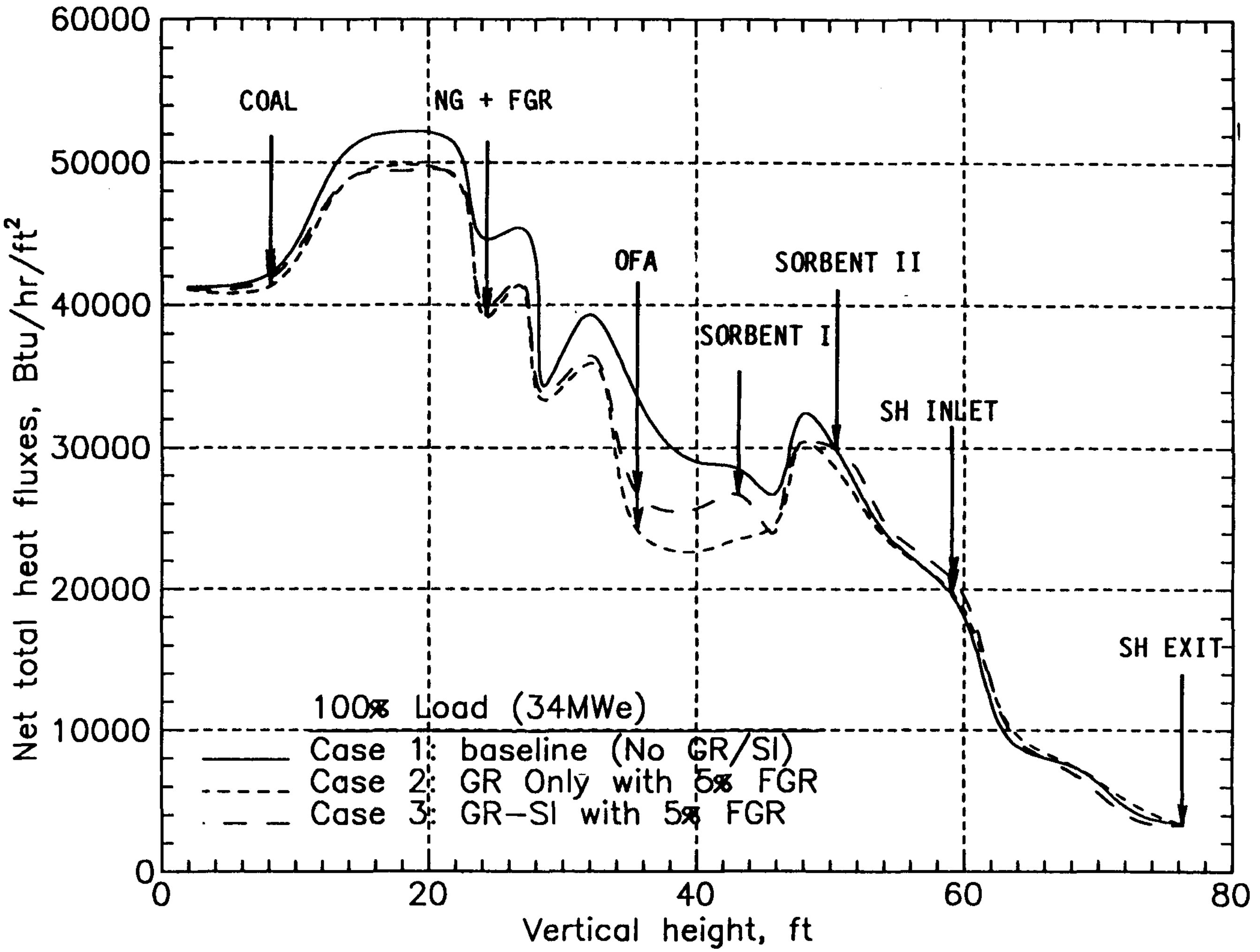


Figure 4.2-8 Compare the net total heat flux densities along axial distance predicted for Cases 1, 2 and 3.

introduction of sorbent injection quenches the flue gas temperature so that the profile for Case 3 becomes lower than that of baseline after the OFA port.

Figure 4.2-8 shows the net total heat flux densities to the wall as a function of vertical height for Cases 1, 2 and 3. Lower heat fluxes below the (NG + FGR) ports for Cases 2 and 3 than those of Case 1 is due to 22.4% less heat input in cyclone furnaces. Sharp reductions in heat fluxes around 24 ft and 36 ft result from introduction of (NG + FGR) and OFA correspondingly. Five percent OFA diversion causes a less sharp reduction for Case 3 than for Case 2.

- Background and Application of Boiler Performance Model

The 2D heat transfer code calculates heat fluxes to furnace walls and heat exchangers in the domain shown in Figure 4.2-2a, but does not calculate the heat balance for the steam side. A separate program, referred to here as the Boiler Performance Model or the Boiler Code, is run following the 2D code, to calculate the steam side heat balance for all heat exchange surfaces of the flue gas path in the boiler.

For boiler sections which are not included in the domain of the 2D code, such as the drum section and air preheater section in Figure 4.2-1, the Boiler Code calculates a heat balance for both the gas and steam sides. For these sections, the gas side heat balance accounts for convection only; radiation is neglected. Heat transfer coefficients for tube banks are calculated based on geometry and flue gas properties; heat transfer coefficients for walls are user-specified. The user must also specify the thickness of ash deposits; ash conductivity is calculated by the program as a function of temperature. For the current application which includes a drum section, it is assumed that pressures of drum, primary superheater inlet and waterwall inlet are the same for each load.

It should be noted that the Boiler Code includes a simplistic model for the air heater. The model simulates the heat exchange between flue gas and air by specifying air heater surface area and overall heat transfer coefficient. The enthalpy increase of air side is equal to the enthalpy decrease of gas side. The leakage effects can be modeled by adjusting exchange surface and/or heat transfer coefficient to match the design or experimental exit temperature of flue gas where the latter is applied in current modeling work.

For boiler sections which are included in the domain of the 2D code, such as primary and secondary superheaters, it is not necessary to recalculate the gas side heat balance as this has been done in the 2D code. For these sections, the heat flux to the wall is set by 2D code results. Other information such as flue gas composition is also passed from the 2D code.

- Comparison to Experimental Data for 100% and 68% Loads

Tables 4.2-1 and 4.2-2 compare the results of baseline Cases 1 and 4 with the corresponding field test measurements, taken during the December 1987 site characterization tests. This is the same testing period during which the in-furnace temperature measurements shown in Figures 4.2-3 through 4.2-6 were taken.

For 100% load, note that the predicted steam flow matches the measured average value to within 5 percent. There are insignificant temperature differences between field test data and the predictions except for the gas temperature into secondary superheater. The discrepancy at this position is attributed to the fact that the experimental data do not necessarily represent true mean gas temperature as detailed temperature profiles were not measured. However the predicted gas temperature, into the secondary superheater does fall within 3 percent of the measured mean value.

For 68% load, the steam flow is predicted within 3 percent of the mean measured value. Again there is a discrepancy in the gas temperature into the secondary superheater.

TABLE 4.2-1 MODEL VERIFICATION FOR LAKESIDE UNIT NO. 7 BOILER AT 100% LOAD (34MWe)

ITEM	Field Test* Dec. 1987	Prediction Case 1
Steam/Water Mass Flows (Klb/hr)		
Into Drum	-	308.6
Exit Superheater	324.2 ± 11.3	308.6
Steam Side Temperatures (°F)		
Into Primary Superheater	-	536.
Exit Primary Superheater	-	737.
Into Secondary Superheater	-	624.
Exit Secondary Superheater**	890. ± 8.	890.
Heat Transfer to Steam (MBtu/hr)		
Drum(Including Heat Flux from Drum Attemperator)	-	79.0
Waterwall(Including Heat Fluxes to Wing Walls and Rad. Platen)***	-	178.9
Primary Superheater***	-	51.9
Secondary Superheater***	-	50.1
Gas Side Temperatures (°F)		
Into Secondary Superheater***	2055. ± 101.	1995.
Into Primary Superheater***	-	1589.
Into Drum Section***	-	1265.
Into Air Heater	760. ± 7.	761.
Exit Air Heater	320. ± 10.	319.

* The Standard Deviation (STD) is presented in the column of field test.
** The value is set in Table 4, Part I.
*** The value is an output of 2D code computation.

TABLE 4.2-2 MODEL VERIFICATION FOR LAKESIDE UNIT NO. 7 BOILER AT 68% LOAD (23MWe)

ITEM	Field Test* Dec. 1987	Prediction Case 1
Steam/Water Mass Flows (Klb/hr)		
Into Drum	-	204.2
Exit Superheater	208.9 ± 6.6	204.2
Steam Side Temperatures (^{o}F)		
Into Primary Superheater	-	532.
Exit Primary Superheater	740. ± 5.	735.
Into Secondary Superheater	-	636.
Exit Secondary Superheater**	875. ± 18.	890.
Heat Transfer to Steam (MBtu/hr)		
Drum(Including Heat Flux from Drum Attemperator)	-	45.6
Waterwall(Including Heat Fluxes to Wing Walls and Rad. Platen)***	-	133.9
Primary Superheater***	-	33.5
Secondary Superheater***	-	31.3
Gas Side Temperatures (^{o}F)		
Into Secondary Superheater***	1827. ± 168.	1679.
Into Primary Superheater***	-	1331.
Into Drum Section***	-	1090.
Into Air Heater	641. ± 10.	655.
Exit Air Heater	275. ± 5.	277.

* The Standard Deviation (STD) is presented in the column of field test.
** The value is set in Table 4, Part I.
*** The value is an output of 2D code computation.

- Impacts of GR and GR-SI at 100% Load

As shown in Table 4.2-3, the gas reburning cases show higher intermediate steam temperatures, lower steam flow rates and higher gas temperatures than for the baseline case. The lower steam flow rates for reburning cases are due to the fact that less heat is transferred to the waterwall and steam drum sections. The higher intermediate steam temperatures are partially due to heat flux increase in the primary superheater section. Note that when GR or GR-SI is introduced, heat fluxes to drum section increase primarily due to higher primary superheater steam exit temperature than for the baseline case.

- Boiler Efficiency

Table 4.2-4 lists boiler efficiency calculations for all cases, based on the ASME heat loss method, as described in "ASME Test Form for Abbreviated Test" (PTC 4.1-a and 4.1-b). Heat exchange through the air heater is considered. For this calculation, heat losses are calculated based on 2D and Boiler Code input data and output results. The exceptions are radiation losses and unmeasured losses, which are taken or interpolated from the B & W design report. Table 4.2-4 compares the effect of introducing gas reburning and sorbent injection at 100% load. The results show that the major change in efficiency occurs between Cases 1 and 2, with a smaller change between Cases 2 and 3. The largest heat loss change is in the loss due to moisture from the combustion of hydrogen. This change is due to the large hydrogen content of the natural gas compared to the coal. The heat loss due to moisture from fuel for baseline case is 0.45% higher than for GR and GR-SI cases. This is due to the higher moisture content of the coal fuel compared to the fuel mixture of coal and natural gas. The heat loss due to combustible in refuse for Case 1 is higher than for Case 3, due to the higher fraction of unburnt carbon.

4.2.2.5 Other

A draft report detailing the results of the Southern Research Institute's (SoRI's) evaluation of the effects of GR-SI on the performance of the Edwards ESP was received. This report is currently under review by EER. SoRI's work

TABLE 4.2-3 LAKESIDE BOILER PERFORMANCE AT 100% LOAD(34MWe): EFFECT OF GAS REBURNING AND SORBENT INJECTION FOR DESIGN CONDITIONS

ITEM	Case 1 Baseline	Case 2 GR only	Case 3 GR/SI
Steam/Water Mass Flows (Klb/hr)			
Into Drum	308.6	306.9	304.8
Exit Superheater	308.6	306.9	304.8
Steam Side Temperatures (^{O}F)			
Into Primary Superheater	536.	536.	536.
Exit Primary Superheater	737.	757.	743.
Into Secondary Superheater	624.	614.	623.
Exit Secondary Superheater*	890.	890.	890.
Heat Transfer to Steam (MBtu/hr)			
Drum(Including Heat Flux from Drum Attemperator)	79.0	89.4	82.3
Waterwall(Including Heat Fluxes to Wing Walls and Rad. Platen)**	178.9	168.4	173.1
Primary Superheater**	51.9	54.8	51.8
Secondary Superheater**	50.1	52.5	49.9
Gas Side Temperatures (^{O}F)			
Into Secondary Superheater**	1995.	2016.	1940.
Into Primary Superheater**	1589.	1612.	1558.
Into Drum Section**	1265.	1285.	1251.
Into Air Heater	761.	769.	759.
Exit Air Heater	319.	322.	322.

* The value is set in Table 4, Part I.
** The value is an output of 2D code computation.

TABLE 4.2-4 GROSS BOILER EFFICIENCY USING THE ASME ABBREVIATED HEAT LOSS METHOD

A. Impacts of GR and GR-SI at 100% Load

	Case 1 Baseline	Case 2 GR Only	Case 3 GR-SI
Heat Loss (%)			
Dry Gas	4.93	4.82	4.82
Moisture from Fuel	1.91	1.46	1.46
Moisture from Combustion	4.04	5.61	5.61
Combustible in Refuse	0.57	0.58	0.69
Radiation*	0.50	0.50	0.50
Unmeasured*	1.50	1.50	1.50
Total Losses	13.45	14.47	14.58
Gross Efficiency (%)	86.55	85.53	85.42

* The value is taken from B & W design report.

on the Lakeside (cyclone-fired boiler) ESP also continued during the period. Some difficulties were encountered in matching performance predictions of the SoRI ESP model with performance data collected in the field during the Baseline Tests. These difficulties are under investigation at SoRI, and it is expected that SoRI's final report on the Lakeside unit will be forwarded to EER in March.

A meeting was held with the Hartford Steam Boiler Insurance Company (HSB) to discuss potential impacts of the application of GR-SI on a utility's existing insurance coverage. The purpose of the meeting was to acquaint HSB personnel with GR-SI technology, and to identify any additional information needed by HSB for their evaluation of the technology and its application. The discussions centered mainly on the flame safety aspects of the gas reburning system, but also touched upon fireside corrosion, fly ash erosion, and sorbent storage and handling.

The meeting seemed to go well, and HSB personnel stated that they were now "comfortable" with the GR-SI technology. To make a final decision to underwrite any particular installation, however, they will need site-specific design information. EER agreed to provide such information on the Edwards and Lakeside sites as it becomes available. (The Edwards and Lakeside sites are each insured by HSB). CILCO and CWLP were represented at the meeting. A similar meeting with the insurance broker/carrier for the Hennepin unit is planned for early March.

4.3 Task 3 - Project Engineering

Phase 1 engineering progress neared completion during this quarter. The General Construction Bid Package for CILCO Edwards Station was completed and released for bid. A total of nine contractors submitted bids. Firm bids have also been received for the ESP field addition, SO_3 injection system upgrade, dry fly ash handling and storage system modifications, the 16.8 kV to 4160 V transformer and the Leeds & Northrup controller. Engineering has completed and submitted to project management for review its portion of the CILCO Edwards Station Final Report. The report contains an executive summary of the engineering effort, a process design overview, detailed descriptions of GR-SI equipment and balance-of-plant modifications, and a detailed discussion of the Phase 2 construction and start-up plans.

The General Construction Bid Package for IP Hennepin Station has also been completed and released for bid. Bids will be received by March 14, 1989. Bids are also being received for modifications to the existing ash system, including the addition of new sluice piping, and for the construction of a SI fly ash pond. Work has been initiated on the engineering final design report.

Engineering was completed this quarter for CWLP Lakeside Station, and we are proceeding to finalize the General Construction specifications and drawings for a bid release in March. Meetings have been held with CWLP and CILCO to discuss the natural gas supply for the project. Bid preparations have begun for a new fly ash dry handling and storage system and the GR-SI microprocessor-based control system.

4.3.1 CILCO Edwards Station

Engineering completed its Phase 1 effort for CILCO Edwards Station. A general work package was prepared for installation of all GR-SI equipment to be purchased by EER. This general package also includes all work necessary to supply power to the GR-SI equipment from a single metered feed.

In addition to the general construction work package, we have solicited bids for several balance-of-plant modifications necessary to support the GR-SI process. These balance-of-plant work packages were written as turnkey jobs. This approach was taken to utilize the engineering expertise of the original equipment supplier.

As a result of Southern Research's report discussing the predicted performance of the existing ESP under sorbent injection conditions, EER developed costs for the addition of two fields to the ESP. Cost proposals for this work were received from Joy Technologies and Environmental Elements.

Leeds and Northrup have provided a firm cost for the supply and installation of a microprocessor controller with a interfacing CRT console to interface with the existing L&N distributed control system.

United Conveyor quoted the necessary work to rebuild the mothballed dry handling and storage system for use with the SI fly ash and additional pickup points (ESP, econ/air heater hoppers and FGR multiclone).

Wahlco quoted an additional SO_3 converter skid and the necessary modifications to increase the injection capacity to 100 ppm for sorbent injection.

Riley Stoker completed their work scope with the exception of a formal review of EER's Phase 3 test plan. Riley's review of the Edwards physical and operating performance, in addition to EER planned modifications, identified no problems with the GR-SI retrofit.

The engineering volume of the Final Design Report has been completed. The outline used is as follows:

4.0 CONSTRUCTION PLAN

4.1 Overview

4.2 Schedule

4.3 Management & Engineering Support

5.0 START-UP PLAN

5.1 Overview

5.2 Schedule

The completion of the engineering final design report marks the end of Phase 1 for CILCO Edwards Station.

4.3.2 IP Hennepin Station

Significant progress was made on the IP Hennepin Station engineering after previous delays regarding ash disposal and ESP enhancement. The necessary duct modifications for humidification were identified and given to Black & Veatch to perform detailed design. The existing flue gas duct from the air heater hoppers to the ESP inlet will be raised and new ducting fabricated. The duct modification also requires the relocation of the ID fans and replacing the ductwork from the ESP outlet to the ID fan inlet.

Black & Veatch prepared a draft of the General Construction specification. A meeting was held with IP to review the specification and our detailed equipment arrangements. EER and Black & Veatch then finalized the General Construction specification, bid documents, and contract drawings. The bid package was released on February 10, 1989. A review meeting was held with IP to review the final bid package prior to the contractor pre-bid meeting. Bids were due March 13, 1989, but an extension to March 24 was granted.

Due to the delay in arriving at a decision for SI fly ash disposal, it was not possible to complete the final design for the new SI fly ash pond. EER selected Hammontree Associates to prepare a preliminary design and construction cost estimate. IP supplied a list of qualified bidders for the ash pond. Several of them were contacted to obtain budgetary estimates. Upon

Phase 2 overlap approval, the detailed design of the ash pond will be undertaken and binding bids solicited.

To convey the sluiced SI fly ash to the new pond location addition, sluice piping is required. Furthermore, with the addition of the FGR multiclone and the flue gas duct modifications for humidification, several new ash pick-up points are needed. A work scope was prepared and United Conveyor was contacted. As a safeguard to the possible scaling resulting from the sluiced SI fly ash, a Teflon boot and ram will be installed in the existing Hydrovac to prevent deposits from plugging the device. A new electronic control panel for the ash system on the air heater hoppers will also be supplied to accommodate the modifications.

Work has been started on the IP Hennepin engineering design final report. The report will be formatted in a similar basis as shown for the CILCO Edwards' report.

4.3.3 CWLP Lakeside Station

Process engineering effort was completed this quarter. The selection of major equipment has been finalized and detailed arrangement drawings have been prepared. Once this information was reviewed with CWLP, it was forwarded to Black & Veatch for design of the foundations and power/control wiring. During the host site review, the operation of the sootblower system was questioned. The operation of the GR-SI process could require frequent cleaning of the furnace and convective surfaces. After reviewing the condition of the existing sootblowers, the replacement of all the original sootblowers was added to the General Construction work scope.

Black & Veatch prepared a draft of the General Construction specification for review by EER and CWLP. EER provided CWLP with the bidding and contract documents for the General Construction specification. Black & Veatch is currently finalizing the specification. The bid package will be released on March 16 with the bids due on April 17, 1989.

Specifications are also being prepared for a new SI fly ash dry handling an storage system. This bid package will also be released during mid-March for United Conveyor and Allen-Sherman-Hoff to bid.

Discussions continue with CWLP and CILCO on the supply of natural gas to the Lakeside Station. We will contract with CILCO to install approximately 2000 foot supply line. CILCO will in turn own and operate the line. CWLP presently buys gas from Panhandle Eastern. The gas is transmitted to the plant by CILCO for a fee. Different options for buying the gas and the associated costs have been reviewed with CWLP and CILCO. This information has been forwarded to GRI and they have expressed an interest to be active in negotiating the gas supply.

4.4 Task 4 Environmental Reports, Permitting Plans and Design

4.4.1 Environmental Information Volumes

CILCO received a Statement of Findings from the archaeologist that conducted the archaeological, cultural, historical (ACH) field survey of the proposed natural gas pipeline route. The survey revealed the presence of three prehistoric sites and one cluster of buildings. It is expected that one of the sites, from which dozens of "flakes and stone tools fragments" were recovered, will require additional archaeological survey. This will include additional surface collection and either the excavation of ten 1 meter by 1 meter units or the grading of a strip across the site. The cluster of buildings is apparently 20th century vintage and of no historic or architectural significance. The two other prehistoric sites are small and dispersed and at least one is peripheral to the pipeline route. A complete report is being prepared by the archaeologist. When received, the report will be forwarded to the State Historic Preservation Officer (SHPO) along with a request for a ruling of the activities that must be undertaken to satisfy ACH requirements during pipeline installation.

The Edwards Station Environmental Assessment (EA) was submitted the first week in January to DOE's Office of Fossil Energy and Assistant Secretary for

Environment, Safety, and Health for review. Based on DOE estimates of two months for headquarters review and approval, NEPA approval for Edwards Station should be received at the beginning of March.

The Lakeside Station EA, submitted in early December, is also still in headquarters review. Approval of this document was expected in early February.

As discussed in previous quarterly reports, NEPA approval for the GR-SI project at Hennepin Station has already been obtained.

EER received copies of the planned Federal Register Floodplain/Wetland Involvement Notices for Edwards and Lakeside Stations in mid-February. These notices were forwarded to the respective host utilities for review and comments are expected at the beginning of March. EER's internal review revealed no significant concerns; however, some minor corrections are needed in discussions of the GR-SI by-product management plans for both sites. All EER and host utility review comments will be documented and submitted to DOE.

4.4.2 Environmental Monitoring Plan

Site-specific draft Environmental Monitoring Plans (EMPs) for the three project sites were submitted to the host utilities in November and December for review. Comments from all three hosts were received by EER at the end of January, and revised draft EMPs were submitted to DOE at the beginning of February.

4.4.3 Permitting Plans and Design

All three hosts have reviewed the Waste Disposal Alternatives reports discussed in the last quarterly report and have agreed with EER's ash management recommendations (off-site dry disposal at Edwards and Lakeside Stations and on-site wet disposal to a new pond at Hennepin Station). Engineering design of the ash management systems has commenced for all three sites.

Results of baseline and GR-SI ash characterization tests conducted on samples generated in EER's pilot-scale Fuels Evaluation Facility (FEF) were submitted to each host in December. Coals obtained directly from the three host sites were fired in the FEF under both baseline and GR-SI conditions. Host boiler conditions were simulated by adjusting temperature and fuel/air stoichiometry histories to match measured or predicted values. GR-SI simulation was accomplished by injecting natural gas, overfire air, and sorbent at the furnace locations where temperatures corresponded to those calculated for the host boiler. Ash samples collected during the baseline and GR-SI tests were subjected to the chemical, physical and leaching tests listed in Table 4.4-1. Ash samples were analyzed by EER's in-house laboratory and by an outside laboratory, Commercial Testing and Engineering (CT&E).

Results of the mineral analyses of the baseline and GR-SI ash samples are summarized in Table 4.4-2. Note that the GR-SI ash has a high lime content due to the presence of unreacted sorbent, as well as the lime content of the coal ash. This value exceeds the CaO content of fly ashes produced from the combustion of western U.S. coals, which have typical lime contents of 15 to 25 percent. The sulfur trioxide content of the GR-SI ash is high since $CaSO_4$ produced in the SO_2 capture process shows up as SO_3 in this analysis. When CaO and SO_3 are ignored, the other major components of the GR-SI ash are present in approximately the same proportions as for the baseline ash, as expected. These results indicate that approximately 50 percent of the Edwards and Hennepin GR-SI ash and 67 percent of the Lakeside GR-SI ash comprises spent and unreacted sorbent.

The sulfate, phenols, sulfide (total and reactive), chloride, cyanide, and total organic carbon content and the chemical oxygen demand, alkalinity, and pH of the GR-SI ashes are summarized in Table 4.4-3. Measurement of these parameters was conducted to address the Illinois Special Waste Stream Application requirements. The Special Waste Stream Application requires specific actions if the reactive cyanide or reactive sulfide exceed 10 ppm. IEPA allows measurement of total cyanide and sulfide to suffice if the total level of each is below 10 ppm. Note that the total cyanide is well below this limit; however, total sulfides for all three GR-SI ash samples are more than

Table 4.4-1. Parameters Evaluated

PARAMETER	METHOD	SAMPLES ANALYZED	
		BASELINE	GR-SI
Mineral Analysis	ASTM D4326	X	X
Sulfate	ASTM D1757		X
Phenols	Std Methods for Water and Wastewater (SWW) Method 510		X
Sulfide	SMWW 427		X
Chloride	SMWW 407C		X
Cyanide	SMWW 412		X
Total Organic Carbon	ASTM D429		X
Chemical Oxygen Demand	ASTM D1252		X
EP Tox - Metals, pH	Ref: EPA SW-846	X	X
Paint Filter Test	Ref: EPA SW-846		X
Specific Gravity	ASTM C188, C618		X
Apparent Loose Density	ASTM C110-85, Section 15	X	X
Apparent Packed Density	ASTM C110-85, Section 16	X	X
Fineness	ASTM C430, C618		X
Heat Rise on Addition of Water	ASTM C110-85, Section 10	X	X
Pozzolanic Activity	ASTM C311, C618		X
Increase of Drying Shrinkage	ASTM C311, C618		X
Autoclave Expansion	ASTM C151, C618		X
Water Requirement	ASTM C311, C618		X
Settling Rate in Water	ASTM C110-85, Section 9	X	X

Table 4.4-2. Mineral Analysis

	EDWARDS		HENNEPIN		LAKESIDE	
	BASELINE	GR-SI	BASELINE	GR-SI	BASELINE	GR-SI
Silica, SiO_2	50.42	25.83	54.99	28.16	56.15	17.55
Alumina, Al_2O_3	25.35	9.55	20.91	10.72	16.64	5.36
Titania, TiO_2	1.55	0.52	1.00	0.50	0.92	0.28
Ferric oxide, Fe_2O_3	9.36	4.58	12.19	6.21	11.21	4.02
Calcium oxide, CaO	7.09	44.41	5.13	42.27	8.28	51.57
Magnesia, MgO	1.12	2.21	1.26	2.33	1.03	2.49
Potassium oxide, K_2O	1.90	0.67	2.41	0.91	2.03	0.31
Sodium oxide, Na_2O	0.63	0.39	1.30	0.69	1.42	0.40
Sulfur trioxide, SO_3	1.59	10.61	0.34	6.21	1.52	16.16
Phosphorus pentoxide, P_2O_5	0.36	0.35	0.27	0.35	0.30	0.33
Strontium oxide, SrO	0.18	0.04	0.02	0.02	0.03	0.02
Barium oxide, BaO	0.10	0.02	0.05	0.01	0.01	0.00
Manganese oxide, Mn_3O_4	0.01	0.01	0.00	0.00	0.05	0.00
Total	99.66	99.19	99.87	98.38	99.59	98.49

Table 4.4-3. Chemical Characteristics

CONSTITUENT	UNITS	EDWARDS	HENNEPIN	LAKESIDE
Sulfate	wt percent	13.12	11.34	15.45
Phenols	ppm_w	<10	<10	<10
Sulfide, total	ppm_w	4700	3770	3890
Sulfide, reactive	ppm_w	<1	<1	<1
Chloride	ppm_w	<400	1200	2600
Cyanide, total	ppm_w	0.02	0.03	0.03
Total organic carbon	wt percent	0.79	0.72	0.26
Chemical oxygen demand	ppm_w	19870	19330	7220
Alkalinity, as $CaCO_3$	mg/1	2540	2630	2580
pH		12.0	12.3	12.2

two orders of magnitude above the limit. It is currently unclear whether the high sulfides content is attributable to an analytical interference or to the fact that the samples were generated in pilot-scale tests. High total sulfides levels are not anticipated in GR-SI ash. Analysis for reactive sulfide was conducted to satisfy IEPA requirements; reactive sulfide was below 1 ppm for all samples. The application also requires that wastes be drummed and labeled if the total phenol concentration exceeds 1000 ppmv. Note that the total phenol content of all three GR-SI ashes is substantially below this limit.

Another requirement of the Special Waste Stream Application is generation of leachate from the ash by the EP Toxicity procedure and subsequent analysis of the leachate for the eight EP metals as well as hexavalent chromium and pH. Results of the EP Toxicity characterization of the baseline and GR-SI ash samples are summarized in Table 4.4-4. The table also details the leaching process and lists the levels for the eight EP metals at which a waste is classified hazardous due to the toxicity characteristic. Also, although the EPA hazardous waste regulations only address pH of liquid wastes (not of EP leachates), the upper pH level beyond which an aqueous solution is classified hazardous due to the corrosivity characteristic is also listed. Both the metals concentrations and the pH of the baseline and GR-SI ash leachates are below the limits at which the ash would be classified as hazardous.

The paint filter test is a semi-quantitative analysis of the amount of free liquid in a solid sample. All three GR-SI ash samples passed the paint filter test. The Illinois Special Waste Stream Application accepts this as an indication that the sample does not have a liquid phase. Samples that pass the paint filter test are exempted from the requirement for total organic halogen analysis. In addition, analysis for percent solids indicated that all three GR-SI ash samples contain 100 percent solids.

The baseline and GR-SI ash gravity, density, and fineness results are summarized in Table 4.4-5. The packed density of ash determines the amount of landfill space required for dry disposal. Note that the GR-SI ash packed density (approximately 50 lb/ft^3) is somewhat lower than the value (65 lb/ft^3)

Table 4.4-4. EP Toxicity

	EDWARDS		HENNEPIN		LAKESIDE		EPA HAZARD LEVEL
	BASELINE	GR-SI	BASELINE	GR-SI	BASELINE	GR-SI	
Arsenic, As	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	5.0
Barium, Ba	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	100.0
Cadmium, Cd	0.11	<0.01	0.08	<0.01	0.15	<0.01	1.0
Chromium, Cr	0.48	0.15	1.26	0.14	1.15	<0.05	5.0
Hexavalent Chromium, Cr^{+6}	<0.04	<0.04	<0.2	<0.04	<0.2	<0.04	--
Lead, Pb	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	5.0
Mercury, Hg	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.2
Selenium, Se	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.0
Silver, Ag	0.03	0.09	0.02	0.08	0.04	0.09	5.0
Sample Weight	100.04	100.03	100.02	100.04	100.01	100.01	
Volume of 0.5N acetic acid required for pH adjustment	300	400	200	400	400	400	
Volume of deionized water added to the extract	1700	1600	1800	1600	1600	1600	
Final volume of the extract	2000	2000	2000	2000	2000	2000	
Initial pH	10.41	12.12	10.44	12.22	11.48	12.20	12.5
Final pH	4.84	12.09	4.86	12.14	4.86	12.15	

Table 4.4-5. Physical Characteristics

	EDWARDS		HENNEPIN		LAKESIDE	
	BASELINE	GR-SI	BASELINE	GR-SI	BASELINE	GR-SI
Specific Gravity		2.66		2.62		2.75
Apparent Loose Density (lb/ft^3)	45.5	28.7	48.0	28.7	44.9	24.9
Apparent Packed Density (lb/ft^3)	67.9	50.5	63.5	51.7	64.8	47.3
Fineness--Amount Retained on No. 325 Sieve (wt percent)		9.20		9.01		9.49

used in estimating land disposal requirements for the EIV and Waste Disposal Alternatives report. While this may increase disposal volume requirements, the ash generation rate used in determining disposal volume was very conservative. Thus, it is neither necessary nor useful to revise the estimated disposal costs on the basis of this data.

Temperature rise on addition of water, or slaking rate, is summarized in Figures 4.4-1 through 4.4-3 for all six ash samples. The significant temperature rise observed upon addition of water to the GR-SI ash sample is attributable to hydration of the free lime. This temperature rise and the attendant problem of ash pile steaming may complicate dry disposal of GR-SI ash generated at Edwards and Lakeside Stations. Temperatures sufficiently high to represent a safety problem have been observed in previous full-scale demonstrations of sorbent injection for SO_2 control. Also, if the ash temperature remains high after delivery to the disposal location, heavy equipment operators may need to exercise caution to prevent tire damage. The observed temperature rise occurred at a water to ash mass ratio of 4:1. During wet disposal of GR-SI ash, as recommended for Hennepin Station, this ratio is expected to be about 17.6:1. The additional water will significantly reduce the final temperature.

Additional tests were conducted to evaluate the engineering characteristics of the GR-SI ashes. Results of these tests are summarized in Table 4.4-6. Settling rate data for the baseline ashes are also included for comparison. ASTM Method C618 establishes standard specifications for fly ash and raw or calcined natural pozzolan for use as a mineral admixture in portland cement concrete. The first value listed in Table 4.4-6, the 7-day pozzolanic activity, indicates the compressive strength of a test bar made from GR-SI ash, lime, and sand in precise ratios determined by a formula in ASTM Method C311. Method C618 does not specify a minimum compressive strength for ash from lignite or subbituminous coals; however, the minimum strength for ash from anthracite and bituminous coals and for raw pozzolans is 800 psi. The 28-day pozzolanic activity compares the compressive strength of portland cement test bars to bars made from a mixture of 65 percent (by volume) portland cement with 35 percent GR-SI ash. The GR-SI ash 28-day pozzolanic

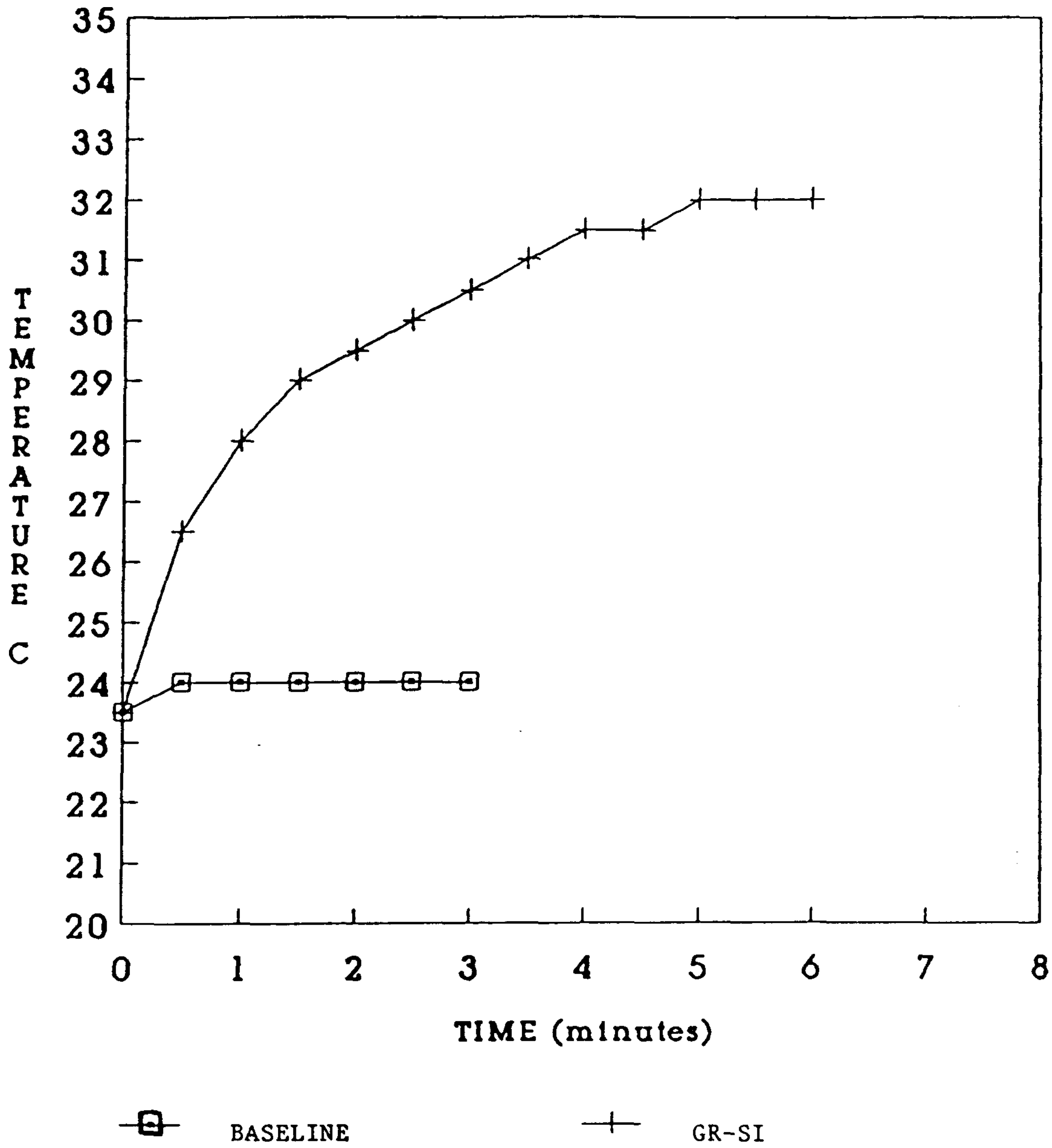


Figure 4.4-1. Slaking Rate of Edwards Coal Fly Ash
by ASTM C110-85 Section 10.

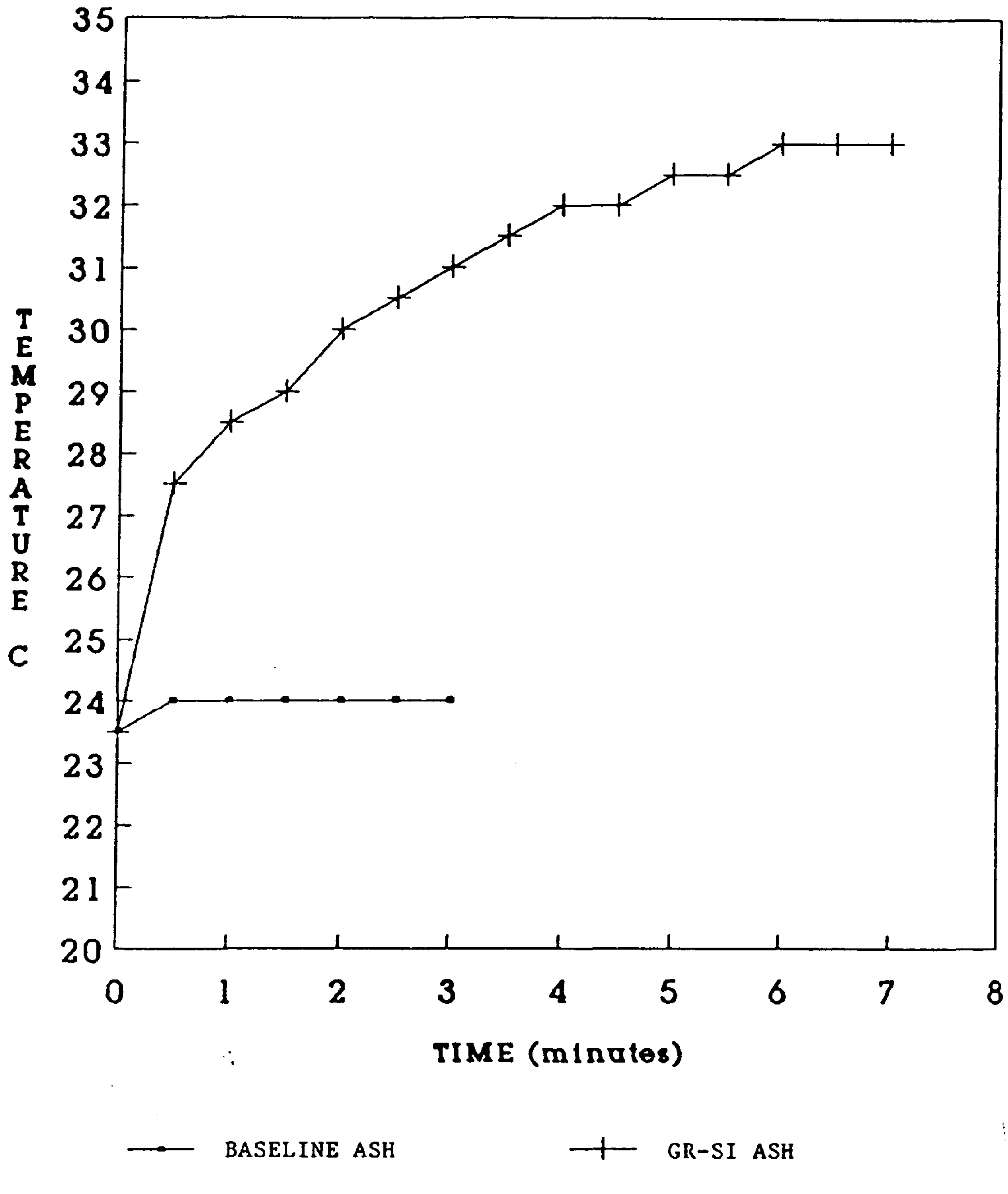
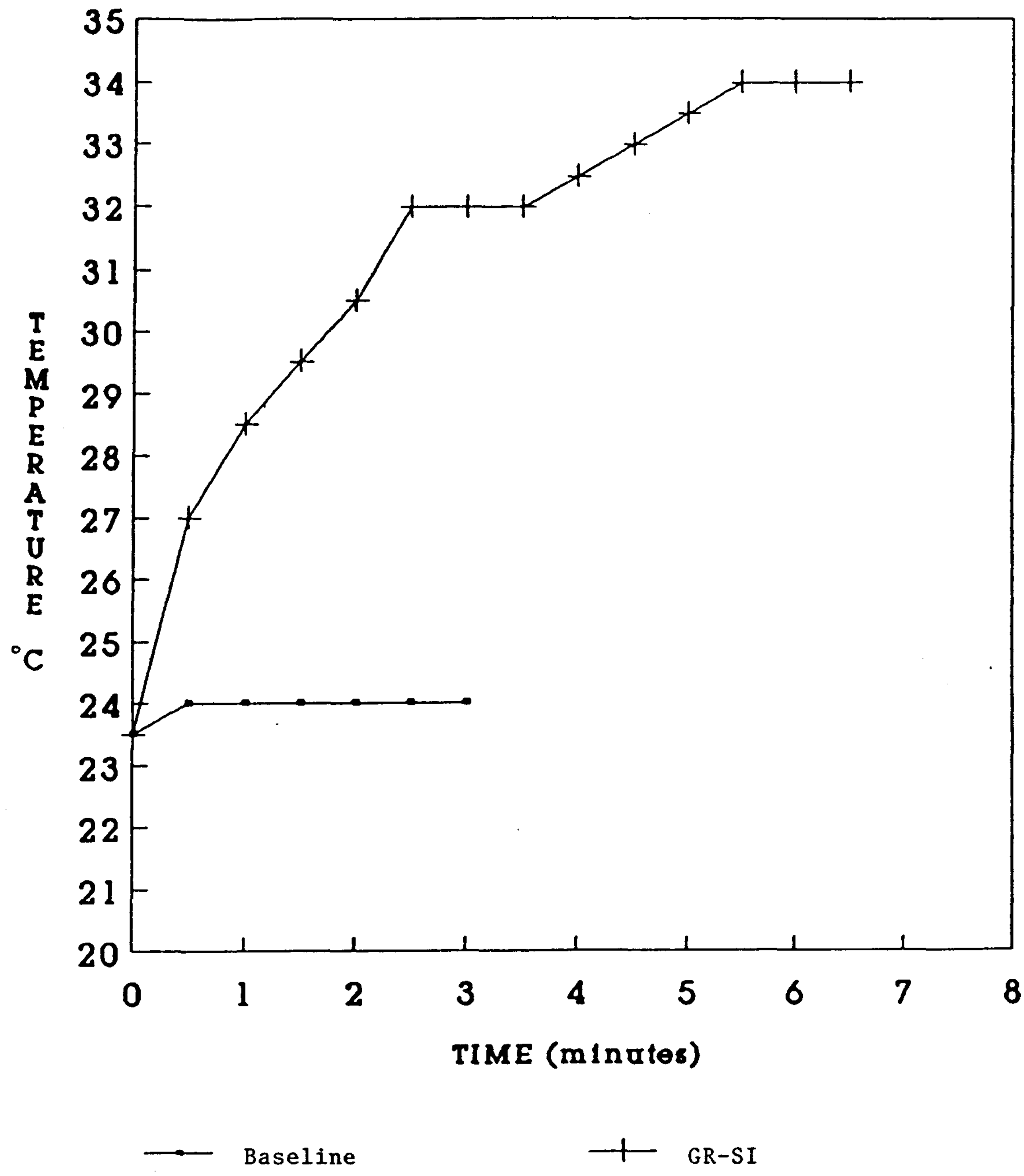


Figure 4.4-2. Slaking Rate of Hennepin Coal Fly Ash
by ASTM C110-85 Section 10.



Sample size was 100g. in 400ml of water.

Figure 4.4-3. Slaking Rate of Lakeside Coal Fly Ash by ASTM C110-85 Section 10.

Table 4.4-6. Engineering Properties

	EDWARDS		HENNEPIN		LAKESIDE	
	BASELINE	GR-SI	BASELINE	GR-SI	BASELINE	GR-SI
7-Day Pozzolanic Activity (psi)		785		505		330
28-Day Pozzolanic Activity (percent of control)		133.6		127.4		122.4
Increase of Drying Shrinkage of Mortar Bars		0.007		0.024		0.051
Autoclave Expansion (percent)		-0.0005		-0.022		-0.029
Water Requirement (percent)		103.2		108.9		113.7
Settling Rate Sedimentation ht (ml)						
15 min	17.0	37.5	14.5	36.5	17.0	46.25
30 min	15.5	27.75	14.0	29.5	16.25	33.0
45 min	15.25	26.75	14.0	29.5	16.25	33.0
1 hour	15.25	26.75	14.0	29.5	16.25	32.75
2 hours	15.25	26.75	14.0	29.5	16.25	32.75
4 hours	15.25	26.75	14.0	29.5	16.25	32.75
24 hours	15.25	26.75	14.0	29.5	16.25	32.75

activity (approximately 120 to 135 percent) far exceeds the minimum required specification (75 percent) established by ASTM Method C618. The increase of drying shrinkage of mortar bars compares the shrinkage of test bars formed from GR-SI ash and portland cement with bars of portland cement alone. To meet the specification of ASTM Method C618, the shrinkage increase must be less than 0.03. Autoclave expansion is an indication of the impact of steam and pressure on a test sample of GR-SI ash and portland cement. The maximum expansion or contraction allowable under ASTM Method C618 is 0.8 percent. The water requirement compares the amounts of water needed to attain standard flow qualities when preparing the samples used to evaluate the 28-day pozzolanic activity. A water requirement in excess of 105 percent fails to comply with the ASTM C618 specification. Settling rate measures the time required for sedimentation of baseline and GR-SI ash samples, which is especially important for wet disposal considerations. The data in Table 4.4-6 indicate that both Hennepin ash samples reach their final settling states within 30 minutes of agitation. This is an indication that additional residence time in a settling pond may not be required for wet disposal of GR-SI ash.

The results summarized above indicate that the recommended disposal alternatives should pose no serious problems. Leachable concentrations of all eight metals specified under the RCRA EP Toxicity method were well below values that would classify the ashes as hazardous. The temperature rise observed when water was added to the GR-SI ashes indicates that caution will be required to ensure that the temperature remains within acceptable limits during dry disposal; however, the additional dilution associated with wet disposal should eliminate this concern. Finally, the tests provide inconclusive results regarding the ability of the GR-SI ash to satisfy the standard specification for use as a concrete admixture. Further evaluation of this and other beneficial uses of GR-SI ash will be undertaken during Phase 3 of this project.

Project permitting issues are being addressed from two perspectives: programmatic and project-specific. From the programmatic perspective, DOE's Office of Clean Coal Technology has initiated discussions with U.S. EPA headquarters to investigate permitting considerations for DOE CCT projects.

In early February, EER and the three host utilities were requested to provide recommended programmatic exemption provisions and language. Responses from the host utilities were:

CILCO

In the interest of promoting the timely development of innovative clean coal technologies,

and

in the interest of promoting the voluntary use of such technologies by interested industries...

legislative and/or regulatory provisions are needed which:

- expedite and streamline permitting requirements
- exempt new source review requirements associated with both the initial permitting and for post demonstration phase voluntary operation of the technology (i.e., NSPS, PSD)
- allow restoration to pre-CCT operation and conditions without new regulatory requirements or permit requirements
- place sole permitting authority on one regulatory agency, preferably the state (so as to avoid differing regulatory approaches and views)
- allow the use of a full spectrum of CCT irrespective of emission reduction targets (i.e., don't target specific technologies with mandated emission reduction targets)

IP

Utilities cannot commit to the installation of pollution control equipment under the Clean Coal Technology program unless they receive assurance up front that they can return to their pre-demonstration operating conditions, permit conditions and allowable emission rates without triggering either the Prevention of Significant Deterioration (PSD) rules or any New Source Performance Standards (NSPS). Since participation in the CCT program is voluntary and usually for a limited time period, the participating utilities should not be penalized with requirements to continue using the CCT demonstration technology or installing and operating control technology to meet the NSPS or PSD.

CCT projects with a demonstration period of two years or less should be automatically exempted (a "blanket exemption") from triggering any Clean Air Act requirements when their demonstration period has ended and source reverts to its former allowable emission rates (i.e., the actual emissions during the demonstration must not be considered representative of the source's actual emissions). A joint memo of agreement between EPA and DOE stating this position for the CCT projects is desired. This exemption should be available to any project as long as it was complying with its applicable allowable emission rates immediately prior to participating in the CCT project.

In lieu of a blanket exemption for all CCT projects, the participating utilities must be able to request a site-specific exemption for PSD and NSPS for their project. The utilities need to receive a document from EPA so they know exactly which rules and regulations would or would not apply to their CCT projects after the demonstration is completed and those pollution control devices are no longer used.

CWLP

- keep the existing permits--the project period would be covered by a completely independent exemption or "add-on" permit
- have DOE acknowledge ownership of CCT by-products
- clearly state that any modifications made in conjunction with the CCT project do not constitute "modifications" or "major modifications" in accordance with 40 CFR 52.21(b)(2) and 40 CFR 60.14
- leave existing permits in force during the project without any requirement for change, i.e. make the CCT projects exempt from any permitting requirements--address any potential environmental impacts through the NEPA process
- ensure that, if removal of equipment at project end entails an expenditure of more than 50 percent of the original facility cost, an exemption from New Source Review requirements is included.

EER and the three host utilities are coordinating with Illinois EPA (IEPA) to develop and implement project-specific permitting approaches. IEPA is acting as liaison with U.S. EPA Region 5 and EPA headquarters to ensure that the specific permitting approaches developed for this project are considered with all EPA requirements. Permitting concerns can be grouped into start-up considerations and end-of-project concerns. The start-up considerations are relatively routine matters, addressing issues such as permitting requirements, exceedance provisions, and emission compliance determination mechanisms. Site-specific approaches for these issues are being worked out directly with IEPA, with input from EPA Region 5. End-of-project concerns involve questions about the applicability of EPA Prevention of Significant Deterioration (PSD) and New Source Review (NSR) provisions when GR-SI is discontinued and, as a result, emissions increase to pre-project levels. U.S. EPA is currently developing an approach to address these concerns; some type of precedent in this area is expected within the next month. As soon as such precedent is available, EER and the host utilities will examine its implications and proceed accordingly.

4.5 Task 5 - Technology Transfer

The second meeting of the Industry Panel was held at the Gas Research Institute in Chicago, Illinois on January 18, 1989. The Industry Panel is a group of technical experts from industries that will have a direct role in the commercial implementation of the Gas Reburning-Sorbent Injection technology. The Industry Panel meets periodically throughout the project for technology transfer. This includes opportunities for industry to provide technical input and to obtain information which will enhance their ability to apply the technology at the completion of the project. The first Industry Panel meeting was held in March 1988 and focused on the overall project plan. The second meeting focused on the Gas Reburning-Sorbent Injection system designs for the three specific host sites and the field evaluation plans for Phase 3.

The following organizations were represented:

ORGANIZATION	PERSONS
Project Participants and Hosts	
EER	7
DOE	4
GRI	5
Host Utilities	5
Sub-total	21
Industry	
Electric Utilities	7
Gas Utilities	5
Coal Suppliers	3
Sorbent Suppliers	1
Architect/Engineers	3
Boiler Manufacturers	3
Precipitator Manufacturers	1
Research Organizations	5
Consultants	4
Subtotal	32
TOTAL	53

The meeting agenda is attached (Attachment 4-1). The morning and early afternoon included presentations by EER personnel on various aspects of the project with the major emphasis on the gas reburning-sorbent injection system designs and the Phase 3 field evaluation plans. Following these presentations, the Industry Panel was divided into six groups. Each group was a representative cross-section of industry and included an EER project team member to coordinate the discussions. Each group selected a spokesman to report the results of their discussion to a plenary session which followed. The key comments of these groups are summarized below:

1. There were several comments on tube wastage measurements. Generally, the consensus was that evaluation of normal tube wastage rates with any reasonable accuracy was impossible even in a fairly long test program. EER should use state of the art instrumentation to establish if rapid tube wastage occurs during the Phase 3 tests.

2. Heat rate impacts should be added to the economic analysis. EER should provide cost guidelines to industry as soon as possible.
3. The field test program should be restructured to evaluate and optimize gas reburning and sorbent injection separately. Overfire air port operation should also be evaluated as a separate alternative.
4. The initial tests should focus on demonstrating Gas Reburning-Sorbent Injection system performance at the design point. If additional resources are available, alternate coals, sorbents, etc. should be evaluated at the end of the test program.
5. Additional measurements should be added to the test matrix, including: time-lapse video of ash deposition, tube metal temperature measurements, corrosion coupons, suction pyrometer temperature measurements, etc.
6. The gas reburning controls should meet NEPA requirements.
7. The Richmond sorbent injection project results should be incorporated into the design of the tangentially fired sorbent injection system.

Most of these questions and comments addressed items which EER had already considered but did not present at the Industry Panel meeting due to the limited time available for the presentations. EER agreed to distribute responses to these questions and comments to the panel members.

5.0 PLANNED ACTIVITIES

During the next quarter (March through May, 1989) the following work is planned:

5.1 Task 1 - Project Management

- Meet with DOE, GRI, and ENR on March 8 to present EER's recommendations on viable options that will accomplish objectives of the field evaluation project leading to commercialization.
- Develop detailed plans in cooperation with funders and host utilities for transition into Phase 2.
- Develop finalized revised costs and schedules for re-scoped project, submit for approval to funders.
- Manage and coordinate remaining Phase 1 project tasks.
- Continue established communications with funders, host utilities, subcontractors and consultants.
- Submit deliverables to funders and host utilities, request agreement for their participation in Phase 2.
- Draft Project Evaluation Plan and submit with Continuation Application for Phase 2.
- Draft business plan for GR-SI commercialization.
- Draft report on insurance issues.

5.2 Task 2 - Process Design

5.2.1 Task 2.1 - Host Site Characterization

- Finalize baseline test reports for all three host sites.
- Finalize Phase 3 test plans for all three host sites taking into account comments received from Industry Panel at the January 18 meeting in Chicago.

5.2.2 Task 2.2 - Process Specification

- Complete Lakeside ESP evaluation.
- Complete Hennepin thermal performance evaluation.
- Finalize all Process Design Reports.

5.3 Task 3 - Project Engineering

- Complete Hennepin and Lakeside Phase 1 final design reports.
- Evaluate Hennepin general construction bids.
- Release Lakeside general construction bid package.
- Release and receive Lakeside SI fly ash dry handling and storage bids.

5.4 Task 4 - Environmental Reports, Permitting Plans and Design

- Finalize Edwards, Hennepin and Lakeside draft EMPs based on DOE review and comments.
- Submit delayed Archaeological, Cultural, Historical survey report and Illinois Historic Preservation Agency pipeline authorization letter as Appendix C to Edwards EIV.
- Assist host utilities on preparation of requisite permit and permit modification applications to be approved by IEPA and U.S. EPA Region 5.

5.5 Task 5 - Technology Transfer

- Summarize responses to Industry Panel comments received at the January 18 meeting in Chicago and distribute to membership.

6.0 REPORT DISTRIBUTION LIST

The number in parentheses () indicates the total number of copies submitted.

6.1 Funding Organization Distribution

6.1.1 DOE

Mr. Harry J. Ritz (2)
PETC Technical Project Manager
Mail Stop 920-L
U.S. Department of Energy/PETC
P.O. Box 10940
Pittsburgh, PA 15236

Mr. Richard D. Rogus (1)
Contracting Specialist
AD-21, Mail Stop 921-165
U.S. Department of Energy/PETC
P.O. Box 10940
Pittsburgh, PA 15236

Mr. Douglas Uthus (1)
HQ Program Manager
FE-22, 3E-042, Forrestal
U.S. Department of Energy
Washington, DC 20585

Office of Patent Counsel (1)
U.S. Department of Energy
9800 South Cass Avenue
Argonne, IL 60439

Department of Energy (3)
Office of Technology Transfer
Mail Stop 58-105
U.S. Department of Energy/PETC
P.O. Box 10940
Pittsburgh, PA 15236

Dr. S.N. Roger Rao (1)
Burns and Roe Technical Group Manager
P.O. Box 18288
Pittsburgh, PA 15236

Mr. Charles Drummond (1)
Mail Stop 920-L
U.S. Department of Energy/PETC
P.O. Box 10940
Pittsburgh, PA 15236

Mr. George G. Weth (1)
Senior Program Manager
Office of Clean Coal Technology
FE-24, C-177
U.S. Department of Energy
Washington, DC 20545

Dr. C. Lowell Miller (1)
Associate Deputy for Clean Coal
Office of Clean Coal Technology
FE-24, C-178
U.S. Department of Energy
Washington, DC 20545

6.1.2 Gas Research Institute

Dr. F. Richard Kurzynske (10)
Gas Research Institute
8600 West Bryn Mawr Avenue
Chicago, IL 60631

6.1.3 ENR

Mr. M. Elbl (10)
Illinois Department of Energy and Natural Resources
325 West Adams Street
Springfield, IL 62706

6.2 Host Utility Distribution

6.2.1 CWLP

Mr. James Rechner (6)
Electric Division Manager
City Water Light and Power
Municipal Building
Springfield, IL 62757

6.2.2 IP

Mr. T. J. May (6)
Illinois Power Company
500 South 27th Street
Decatur, IL 62521

6.2.3 CILCO

Mr. James F. Wittmer (6)
CILCO
300 Liberty Street
Peoria, IL 61602

ATTACHMENT 4-1

INDUSTRY PANEL MEETING AGENDA

9:00	Introductions		
9:15	Project Overview		
9:45	GR-SI Design for Three Units		
		9:45	Process and Engineering Designs
		10:45	Break
		11:00	Environmental Considerations
11:30	Phase 3 Test Plan		
12:00	Lunch		
1:00	Test Plan Continued		
2:00	Industry Discussion		
		2:00	Group Discussions
		3:00	Break
		3:15	General Discussions
3:50	Conclusions		
4:00	Adjourn		