DOE/MC/25140-3159

DOE/MC/25140--3159

DE93 004820

HOT GAS CLEANUP TEST FACILITY FOR GASIFICATION AND PRESSURIZED COMBUSTION

QUARTERLY TECHNICAL PROGRESS REPORT
JANUARY 1 - MARCH 31,1992

Prepared by

SOUTHERN COMPANY SERVICES, INC.
800 Shades Creek Parkway
P.O. Box 2625
Birmingham, Alabama 35202

Work Performed Under DOE Cooperative Agreement No. DE-FC21-90MC25140

THE UNITED STATES DEPARTMENT OF ENERGY
Morgantown Energy Technology Center
3610 Collins Ferry Road
P.O. Box 880
Morgantown, West Virginia 26507-0880

DISCLAIMER

HOT GAS CLEANUP TEST FACILITY FOR GASIFICATION AND PRESSURIZED COMBUSTION
QUARTERLY TECHNICAL PROGRESS REPORT
JANUARY 1 - MARCH 31, 1992

TABLE OF CONTENTS

Section		Page No.
1.0	**INTRODUCTION AND SUMMARY**	1
2.0	**REVIEW OF TECHNICAL PROGRESS**	2
2.1	Project Management	2
2.2	Task 1.4 Transport Reactor Development Unit	2
2.3	Task 1.5 Facility Expansion Estimate	7
2.3.1	Environmental Permit Information	7
2.3.2	Design Basis	7
2.3.3	Advanced Gasifier Module Modifications	12
2.3.4	Advamced PFBC/Topping Combustor/Gas Turbine System	13
2.3.5	Fuel Cell Module	14
2.3.6	Particulate Control Devices	14
2.3.7	Balance of Plant	17
3.0	**PLANS FOR FUTURE WORK**	18
4.0	**REFERENCES**	19
APPENDIX A	Hot Gas Cleanup Test Facility Expansion Summary	
APPENDIX B	Preliminary Intergrated TRDU Project Schedule	
APPENDIX C	Power Systems Development Facility Design Basis	
APPENDIX D	Request For Conceptual Design Information From Fuel Cell Vendors	
APPENDIX E	SRI White Paper on Alkali Sampling	
APPENDIX F	Request For Conceptual Design Information From PCD Vendors	
APPENDIX G	SRI Summary of PCD Vendors Meetings	

1.0 INTRODUCTION AND SUMMARY

This quarterly technical progress report summarizes work completed during the Sixth Quarter of the First Budget Period, January 1 through March 31, 1992, under the Department of Energy (DOE) Cooperative Agreement No. DE-FC21-90MC25140 entitled "Hot Gas Cleanup Test Facility for Gasification and Pressurized Combustion." The objective of this project is to evaluate hot gas particle control technologies using coal-derived gas streams. This will entail the design, construction, installation, and use of a flexible test facility which can operate under realistic gasification and combustion conditions. The major particulate control device issues to be addressed include the integration of the particulate control devices into coal utilization systems, on-line cleaning techniques, chemical and thermal degradation of components, fatigue or structural failures, blinding, collection efficiency as a function of particle size, and scale-up of particulate control systems to commercial size.

The major emphasis during this reporting period was expanding the test facility to address system integration issues of hot particulate removal in advanced power generation systems. The conceptual design of the facility was extended to include additional modules for the expansion of the test facility, which is referred to as the Power Systems Development Facility (PSDF). A letter agreement was negotiated between Southern Company Services (SCS) and Foster Wheeler (FW) for the conceptual design of the Advanced Pressurized Fluid-Bed Combustion (APFBC)/Topping Combustor/Gas Turbine System to be added to the facility. The expanded conceptual design also included modifications to the existing conceptual design for the Hot Gas Cleanup Test Facility (HGCTF), facility layout and balance of plant design for the PSDF. Southern Research Institute (SRI) began investigating the sampling requirements for the expanded facility and assisted SCS in contacting Particulate Control Device (PCD) vendors for additional information. SCS also contacted the Electric Power Research Institute (EPRI) and two molten carbonate fuel cell vendors for input on the fuel cell module for the PSDF. M. W. Kellogg prepared a draft of the TRTU test results. The Transport Reactor Development Unit (TRDU) work was initiated with a kickoff meeting at the Energy & Environmental Research Center (EERC) in Grand Forks, ND attended by MWK and SCS.

It should be noted that this report includes accounts of progress made by MWK, FW and SRI.

2.0 REVIEW OF TECHNICAL PROGRESS

2.1 PROJECT MANAGEMENT

Project activities during this time period focused primarily on expanding the test facility and initiating the TRDU work. The conceptual design of the facility was extended to include a within scope, phased expansion of the existing Hot Gas Cleanup Test Facility Cooperative Agreement to also address systems integration issues of hot particulate removal in advanced coal-based power generation systems. This expansion will include the consideration of the following modules at the test facility in addition to the existing Transport Reactor gas source and Hot Gas Cleanup Units:

1. Carbonizer/Pressurized Circulating Fluidized Bed Gas Source.
2. Hot Gas Cleanup Units to mate to all gas streams.
3. Combustion Gas Turbine.
4. Fuel Cell and associated gas treatment.
5. Externally Fired Gas Turbine/Water Augmented Gas Turbine.

A description of the facility expansion is in Appendix A. A proposal to increase the level of effort to extend the conceptual design of the test facility under the cooperative agreement was submitted to DOE/METC in March. A letter agreement was negotiated with FW to allow them to proceed with the conceptual design of the Advanced Pressurized Fluid-Bed Combustion (APFBC) system integrated with the Topping Combustor and Gas Turbine module. FW will be responsible for the Westinghouse and Allison portion of the work.

The cooperative agreement was modified to include the addition of the TRDU work at EERC. A letter agreement was negotiated between SCS and EERC for their portion of the work. A modification to the MWK subcontract for the design portion of the work was sent to MWK by SCS for review.

2.2 TASK 1.4 TRANSPORT REACTOR DEVELOPMENT UNIT (TRDU)

2.2.1 TRDU Kickoff Meeting

A kickoff meeting was held at the (EERC) to formally begin the TRDU project. Representatives from SCS, EERC, and M.W. Kellogg were in attendance. A number of factors which will influence the TRDU design were discussed, the most important ones being:

1) Excessive heat loss could result in the reactor taking a long time to reach steady state conditions,
2) The TRDU design should be such that maintenance of the reactor can be done easily from existing platforms and floors,
3) Gasifier location in the EERC Gasification Tower,
4) The flange size should not exceed 300 psi. This would facilitate maintenance of the TRDU,

5) The TRDU should be supported at two levels to facilitate section removal for inspection, redesign, or maintenance. The bottom section should be easily removable for inspection, and
6) Water may condense in the cyclone system during heat up.

There were several discussions which centered around the heat balance for the TRDU and the location of the TRDU in the EERC's Gasification Tower. The TRDU will have to be designed to compensate for some heat losses through its surface area. Therefore, to keep the heat loss within reasonable limits the following options were considered:

1) No more than 30% of the feed should be consumed for heat generation,
2) Large amounts of insulating refractory could be used to prevent heat loss but it may be difficult to fit the reactor into the space at EERC due to existing structural beams. Alternatively, one could have smaller amounts of insulating refractory with electrical heat tracing to compensate for the heat loss.
3) The coal feed rate could be increased from a nominal 140 lb/hr to 200 lb/hr to compensate for the heat loss.
4) The air feed to the gasifier could be preheated to reduce heat losses.

After touring the gasifier tower and discussing the options, the following choices were made to resolve these issues.

1) Increase coal feed rate to 200 lb/hr,
2) Preheat air to a minimum of Wilsonville design specification,
3) Investigate the effect on reactor size, code requirements, and heat loss of raising the reactor skin temperature to 450°F,
4) Heat trace reactor only in areas that may need to have reduced diameters for beam clearances,
5) Reduce inner diameter of mixing section as per M.W. Kelloggs final design determination,
6) Pneumatic coal transport system may be added depending on final location of gasifier. The placement of the reactor may not allow easy access of the crane to the coal feed hopper and a pneumatic transport system may be required, and
7) The existing EERC mild gasification carbonizer primary and secondary cyclones will be relocated to make more room for the TRDU.

The heat loss from the reactor was estimated to be 265,000 Btu/hr. Preheating the air will decrease the sensible heat requirements of the reactants. Final heat balance calculations will be made to determine the design criteria for the air preheater and the TRDU.

One of the major concerns was the increased diameter of the reactor to address the conductive heat loss. The original design called for a 16" o.d. riser, 18" o.d. standpipe, and a 22" o.d. mixing section. A revised design indicated a 26" o.d. riser, 28" o.d. standpipe, and a 36" o.d. mixing section. The increase in size caused extreme difficulty in placing the reactor in the EERC gasification tower due to the locations of existing structural beams. In order to decrease the reactor o.d. as much as possible, the skin temperature of the vessel could be raised to 450°F and insulation could be added outside the vessel. External heat tracing could also be added if the heat losses become too large.

2.2.2 TRDU Design Basis

The process design basis document for the TRDU was finalized. Material balances for the reactor operating in gasification and combustion modes were prepared. The coal feed rate in the gasification mode is 198 lb/hr. The coal chosen for the EERC work is an Illinois #6 bituminous coal which was chosen because of its use in the Wilsonville design basis. The sorbent chosen for the TRDU has been Longview limestone. The analysis of the coal (corrected to 5% moisture content) and limestone is shown in Table 2-1.

It should be noted that although the primary focus of the TRDU is operating in the gasification mode, some preliminary engineering for the combustion mode was done to identify interface points and estimate the size for the boiler in the event it becomes desirable to operate in this mode in the future.

Table 2-1
Coal and limestone feed requirements

Coal		**Limestone**	
Proximate Analysis		$CaCO_3$	97.45 wt%
Moisture	5.0 wt%	$MgCO_3$	1.58 wt%
Volatile matter	42.25 wt%	Inerts	0.97
Ash	9.41 wt%		
Fixed carbon	43.34 wt%		
Ultimate Analysis			
Carbon	67.54 wt%		
Hydrogen	4.75 wt%		
Nitrogen	1.33 wt%		
Sulfur	2.85 wt%		
Ash	9.41 wt%		
Oxygen	9.12 wt%		
Coal HHV (as fed)	12,859 Btu/lb		
Size distribution			
Maximum size	840 μm		500 μm
90%	<500 μm		<420 μm
50%	<200 μm		<100 μm
10%	<10 μm		<5 μm

The feed grind specifications are being provided as a guideline only and EERC will review these limits with regard to the capability of their existing equipment and advise M.W. Kellogg of any incompatibility.

The transport reactor is being designed to operate under the conditions listed in Table 2-2 in the gasification and combustion mode.

Table 2-2
TRDU Design Basis

	Gasification mode	**Combustion mode**
Reactor inlet pressure	120 psig	120 psig
Steam/coal flowrate	0.34	
Air/coal flowrate	4.0	
Excess air		10.0%
Ca/S (mole/mole)	1.5	1.5
Air inlet temperature	800°F	75°F
Steam preheat temperature	1000°F	
Coal feed rate	198 lb/hr	149.4 lb/hr
Percent carbon conversion expected	>80%	100%
HHV of fuel gas expected	>100 Btu/scf	
Percent desulfurization expected		>90%
Maximum heat loss as % of coal feed	19.5%	
Disengager and cyclone efficiency	99.99%	99.99%
Dust concentration in outlet stream	2050 ppmw	1762 ppmw

The sizing of the transport reactor was completed. The sizes of the various component parts are summarized below. The overall reactor height including cyclones is approximately 75 feet.

Mixing zone ID, in 5.0
Mixing zone height, ft 10.0
Riser, ID, in. 3.5
Riser height, ft. 50.0
Standpipe ID, in. 4.5

Preliminary sizing of the boiler, based on an estimated heat duty of 1 MBtu/hr and a steam pressure of 150 psig shows that a 1.5 ft ID boiler tube is adequate for the service. However, the design will be reviewed after the heat loss calculations are completed. It has been recommended that the pressure of the steam be raised to approximately 300 psig for a more practical design.

Minimum aeration requirements for the standpipe and J-valve are as follows:

Steam (gasification)	52 lb/hr
Nitrogen (gasification)	82 lb/hr
Air (combustion)	46 lb/hr

Process loadsheets were prepared for the reactor system, and process flow diagrams for the reactor operating in gasification as well as combustion modes were also prepared. P&IDs will not be produced for the TRDU project, instead, MWK will prepare Process Control Diagrams.

EERC indicated that they were considering electrical air preheating as opposed to other types discussed previously. Nitrogen is to be used for instrument purging, and differential pressure transmitters will use separate purge systems on the high and low pressure legs. All instrumentation is indoors and heat tracing or winterization is not required. EERC does not use load cells on lockhoppers to measure feed flowrates. Instead, they prefer to calibrate the star feeders to determine flowrates. It was noted that if an on-line gas chromatograph was required on the product gas streams, it should not be installed downstream of the existing Water Scrubber since the circulating water would absorb some of the sulfur compounds. A recommended installation would be downstream of the particulate control device with indirect cooling.

A preliminary layout of the transport reactor system based on 12'-6" center to center between the riser and standpipe was presented and discussed at a review meeting. The handout also included a summary of refractory thickness calculations for two different skin temperatures, 350° and 450°F. It was decided that a narrower riser to downcomer spacing of about 8' would be preferred. M.W. Kellogg will prepare a new layout based on this spacing and verify its acceptability within other constraints, namely existing structural steel and system stresses. At both skin temperatures 150 psi flanges with flexitallic gaskets are acceptable according to code.

MWK provided a preliminary integrated schedule for the TRDU project, a copy of which is attached in Appendix B.

2.2.3 TRDU Environmental Activities

An updated Environmental Assessment (EA) has been prepared by the EERC for the TRDU project in compliance with the requirements of the National Environmental Policy Act (NEPA). The findings of this EA are that the design, construction and operation of the TRDU should be insignificant. There are three existing systems currently in operation: circulating fluid-bed combustor, carbonizer, and gasifier. Each of these units rotates operation so only one unit is on-line at any given time. Inclusion of the TRDU would only affect the rotation of the units, not the amount of emissions. This project would have little or no impact on air quality, water quality, solid waste management, noise levels, floodplains, wetlands, historic areas, or the ecology.

2.3 TASK 1.5 FACILITY EXPANSION ESTIMATE

The conceptual design of the facility was expanded to include the additional modules listed in Section 2.1. This expanded facility is referred to as the Power Systems Development Facility (PSDF). The objective of this task is to develop a conceptual design of the expanded facility and estimate the cost to design, construct and operate. The work breakdown structure for this task in shown in Table 2-3.

The deliverables to DOE for the facility expansion estimate include the following:

1. A conceptual design of the Power Systems Development Facility.

2. A cost estimate to design, construct and operate the Power Systems Developement Facility.

3. Recommendations to DOE/METC on how to proceed with the expanded project.

A scope of work was developed for each participant in the facility expansion estimate. An overall schedule for the expansion was developed and presented at the kickoff meeting held in Birmingham on February 20. The schedule for the facility expansion estimate is shown in Figure 2-1.

2.3.1 Environmental Permit Information

The environmental information collected during this quarter primarily supports the NEPA requirements for government contracts. Focus has remained on the collection of appropriate information for NEPA documentation including existing facilities emissions (air and water) and proposed remediation work at the Clean Coal Research Center.

During this period, information was gathered to begin the statistical air modeling needed to support the NEPA documentation. Preliminary ASPEN modeling was received from DOE that predicted emissions for both the APFBC and the transport reactor. NO_x emissions predicted by the ASPEN modeling were discussed with Kellogg. Annual emissions rate for the expanded facility were developed.

On February 4th, SCS and SEI met with the Alabama Department of Environmental Management (ADEM) to discuss the expanded project in Wilsonville and permitting requirements. Representatives were present from all branches of ADEM and permit application requirements were discussed with all three branches. All areas expressed support for the research project.

2.3.2 Design Basis

The design effort for the PSDF was organized as shown in the following Block Flow Diagram illustrated in Figure 2-2. The Areas designated with an "A" and "B" are associated with the MWK Transport Reactor Module and the Foster Wheeler Advanced

TABLE 2-3

WORK BREAKDOWN STRUCTURE FOR EXTENDED CONCEPTUAL DESIGN

Task 1.5 Facility Expansion Estimate

Subtask 1.5.1 Environmental Information (SCS)

1.5.1.1 Additional NEPA Information
1.5.1.2 Air Quality Modeling

Subtask 1.5.2 Facility Design Basis (SCS)

1.5.2.1 Modification of Design Basis
1.5.2.2 Particulate Control Device Vendor Input

Subtask 1.5.3 Advanced Gasifier Module Modifications (MWK)

1.5.3.1 Alternate Oxygen Case
1.5.3.2 Design Revisions
1.5.3.3 Facility Flare and Thermal Oxidizer Design
1.5.3.4 Layout Revisions
1.5.3.5 Kellogg Project Management and Support

Subtask 1.5.4 Advanced PFBC Module (Foster Wheeler)

1.5.4.1 Module Process Design Data
1.5.4.2 Information for Balance-of-Plant Conceptual Design
1.5.4.3 Cost and Schedule Information
1.5.4.4 Foster Wheeler Project Management

Subtask 1.5.5 Topping Combustor (Westinghouse)

1.5.5.1 Material and Energy Balance
1.5.5.2 Preliminary Combustor Design
1.5.5.3 Spool Piece Conceptual Design
1.5.5.4 Westinghouse Project Management

Subtask 1.5.6 Gas Turbine (Allison)

1.5.6.1 Advanced PFBC System Design
1.5.6.2 Externally Fired Gas Turbine Design

TABLE 2-3 (con't)

WORK BREAKDOWN STRUCTURE FOR EXTENDED CONCEPTUAL DESIGN

Subtask 1.5.7 Externally Fired Gas Turbine Module (SCS)

1.5.7.1 Review of Existing Indirect Cycle Work
1.5.7.2 Feasibility of Integration into the PSDF
1.5.7.3 Potential Performance and Requirements Estimate
1.5.7.4 Module Layout
1.5.7.5 Module Cost Estimate

Subtask 1.5.8 Fuel Cell Module (SCS)

Subtask 1.5.9 Particulate Control (SRI)

1.5.9.1 Particulate Sampling Requirements
1.5.9.2 Particulate Control Device Specifications
1.5.9.3 Project Management

Subtask 1.5.10 Balance of Plant (SCS)

1.5.10.1 Coal and Limestone Storage and Preparation
1.5.10.2 Ash Handling
1.5.10.3 Final Gas Stream Pollution Control System
1.5.10.4 Instrumentation & Data Acquisition
1.5.10.5 Utility Systems
1.5.10.6 Electrical
1.5.10.7 Site Preparation and Structural
1.5.10.8 Administration/Service Buildings
1.5.10.9 Cost Estimation

Subtask 1.5.11 Facility Design Document/Operations Estimate (SCS)

1.5.11.1 Facility Process Engineering
1.5.11.2 Facility Design Document Preparation
1.5.11.3 Operations Estimate

Subtask 1.5.12 Overall Project Management (SCS)

1.5.12.1 SCS R&EA Activities
1.5.12.2 SCS Engineering Activities
1.5.12.3 Cost and Scheduling

FIGURE 2-1 TASK 1.5 FACILITY EXPANSION ESTIMATE SCHEDULE

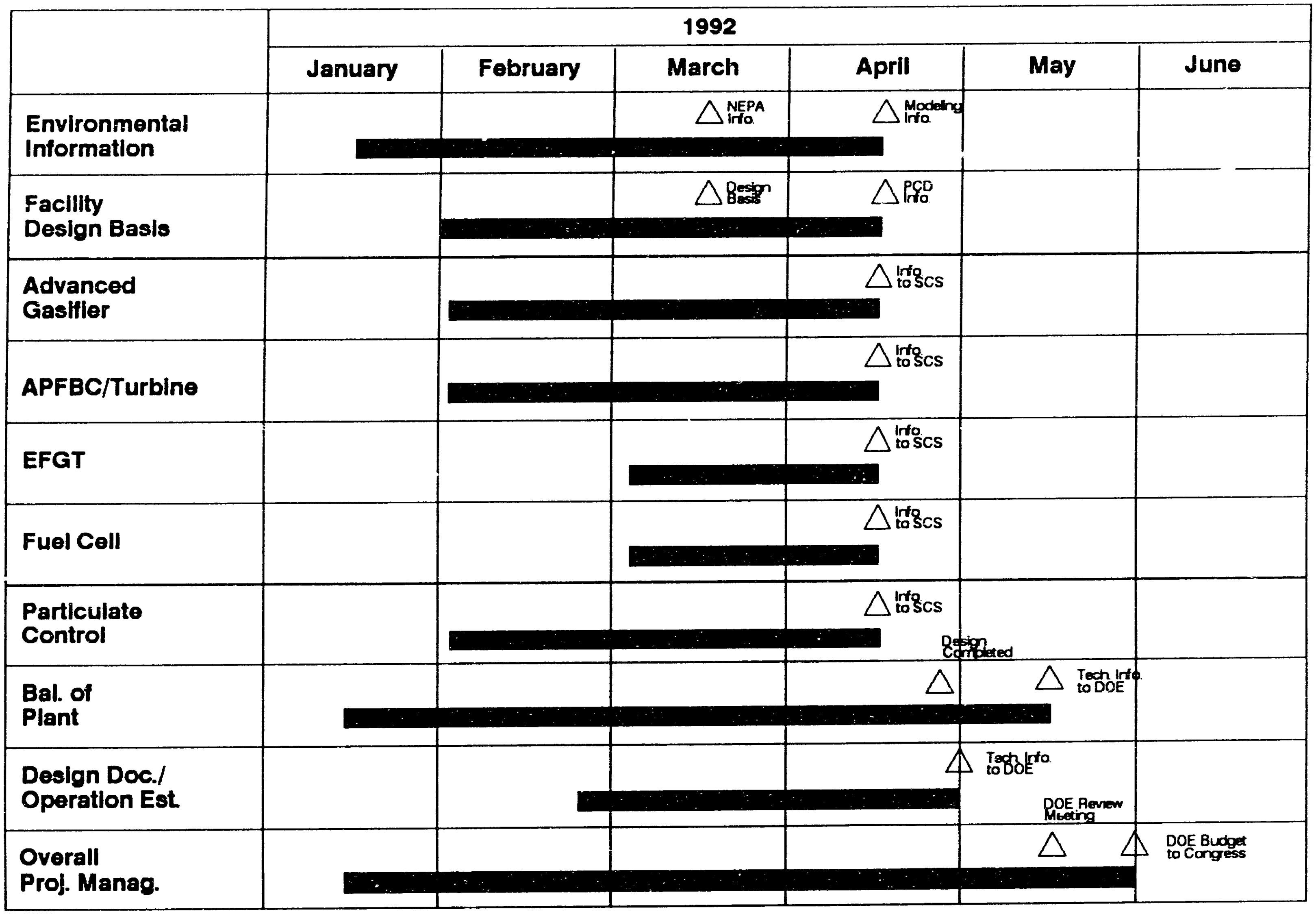
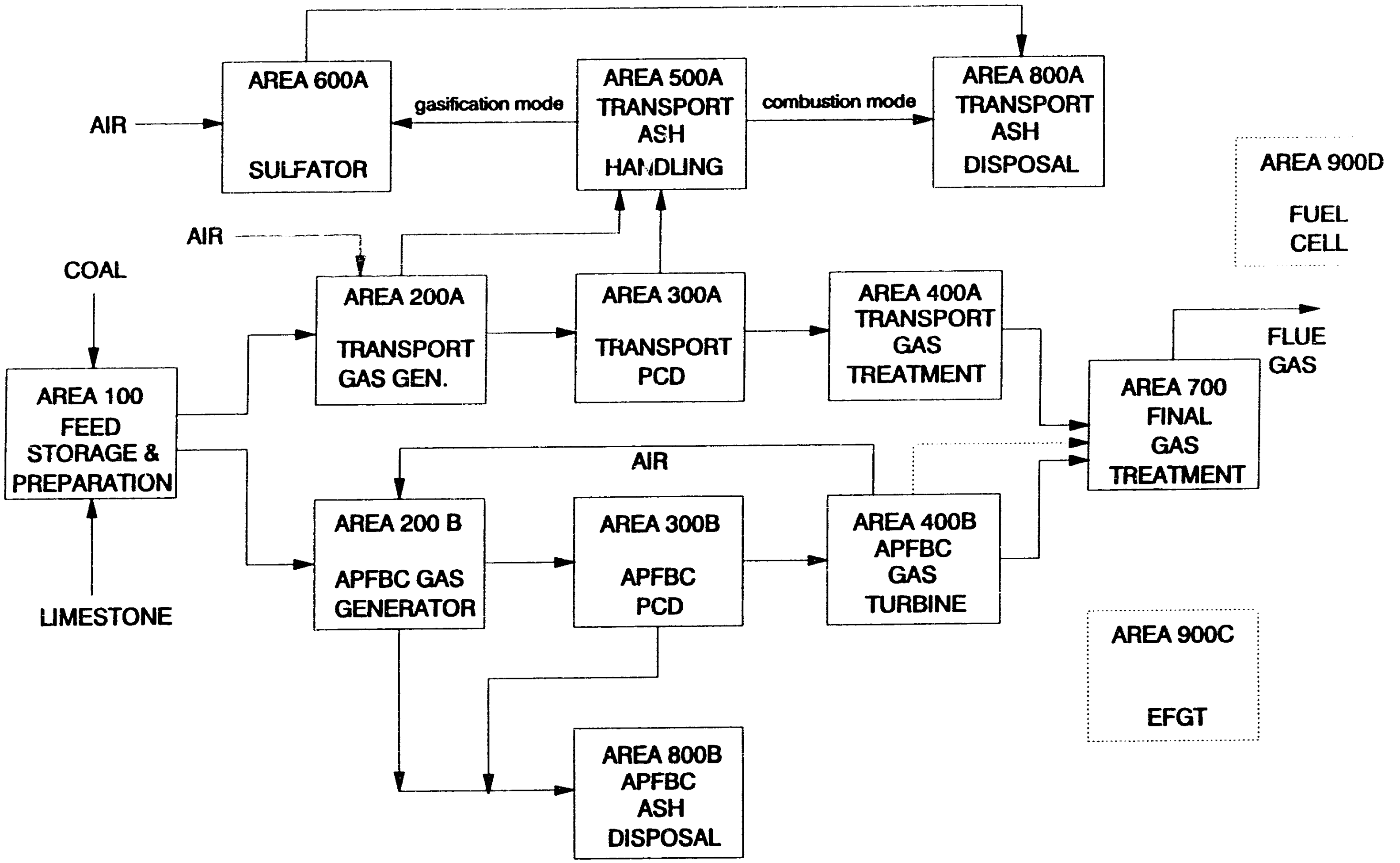


FIGURE 2-2

POWER SYSTEMS DEVELOPMENT FACILITY BLOCK FLOW DIAGRAM



Southern Company Services, Inc.

Revision A
April 27, 1992

PFBC Module, respectively. Areas without an alphabetic designation are associated with the balance of plant with many components in these areas shared by both the MWK and FW trains.

The overall design basis document for the Power Systems Development Facility is in APPENDIX C.

2.3.3 Advanced Gasifier Module Modifications

The work by MWK during this quarter involved final revisions for completion of the conceptual design for the stand-alone facility as well as design modifications required for incorporation of the additional modules into the facility design.

A more economic and versatile cyclone design was evaluated. Calculations have confirmed that cyclones can be close coupled to the reactor, thereby reducing the quantity of refractory lined pipe required. This modification is reflected in the estimate for the stand-alone HGCUTF. However, vendor confirmation is required to ascertain whether particulate loadings exiting the cyclones can be varied within the desired range if the third stage cyclone is deleted.

The steam injection system, for temperature excursion control, upstream of the PCD has been eliminated because of its high cost and complexity. A nitrogen system will be used instead to control any temperature excursions.

Due to the potential difficultly in operating an atmospheric bubbling bed sulfator with the small size spent solids from the transport gasifies, the economics of a pressurized transport sulfator versus the current atmospheric bubbling bed design is being evaluated. Calculations have been made to size the equipment associated with the a transport sulfator in support of a cost estimate.

Process calculations were started to develop four additional heat and material balances (Illinois # 6 and Eagle Butte coals at 1600 and 1000°F gas to the PCD) for combustion cases at a nominal 1600°F combustor operating temperature; these balances will reflect more closely the expected normal operating conditions. The combustor computer model has been run for all cases and heat and material balances have been completed for the two Illinois # 6 cases.

For increased flexibility of the Transport gasifier, particularly for integration with a Fuel Cell, calculations were performed to predict the gas composition with Illinois # 6 coal from an oxygen blown transport gasifier. The calculated gas composition are shown in Table 2-4.

Table 2-4
Gas Composition for Oxygen-Blown Transport Gasifier with Illinois No. 6 Bituminous Coal

Component	Volume %
CO	35.36
H_2	30.43
CO_2	10.93
CH_4	0.21
N_2	8.44
NH_3	0.01
H_2O	14.58
HCN	0.04
H_2S	0.02

Further modifications to the flare, thermal oxidizer, structural design and layout will be evaluated based on the design of the additional modules and incorporated into the design as necessary.

In addition to the above design modifications, the capital cost estimate for the stand-alone facility was issued to SCS for review.

2.3.4 Advanced PFBC/Topping Combustor/Gas Turbine System

During this quarter work was initiated on the conceptual design for the FW APFBC and Combustion Turbine Modules. This area is the responsibility of FW with Westinghouse and Allison under subcontract to FW for the design of the topping combustor and gas turbine, respectively. FW developed a schedule, based on the overall schedule presented at the February 20 kickoff meeting, for their portion of the conceptual design and cost estimate.

The following items were initiated and completed during the quarter by FW:

- Footprint and envelope definition
- Block Flow Diagram
- Heat and Material Balances
- Feedstock requirements
- Process Flow Diagrams
- Flare philosophy
- P&IDs
- Equipment data sheets
- Utility definition and requirements
- Process description
- Fluid Bed Heat Exchanger drafting and estimating
- Fluid Bed Heat Exchanger equipment specifications and materials of construction
- plot plan
- equipment list
- general control philosophy
- preliminary motor list

In addition to the work described above, a Gas Turbine Coordination meeting was held at FWUSA on March 19 to define the requirements for integration of the gas turbine and combustor into the overall system. In conjunction with this meeting, tours of the FW APFBC Pilot Plant were conducted.

Discussions at the meeting included:

- the footprint of the combustor and trubine
- requirements for turbine isolation and fuel gas diversion during turbine upsets
- instrumentation requirements and control of combustor and turbine
- requirements for particulate and alkali sampling and monitoring
- maximum allowable concentration and duration for excursions in alkali to turbine
- maximum allowable concentration and duration for excursions in particulates to turbine

During the quarter Allison and Westinghouse completed data sheets, cost, fabrication, and delivery data for the combustor/turbine.

The conceptual cost estimate has been initiated and should be completed on schedule during the next quarter. Milestones for the project have been defined and a schedule is being developed for EPC and operations phases. All work associated with the conceptual design should be completed on schedule during the next quarter.

Detailed design will begin in the next quarter pending resolution of contractual issues.

2.3.5 Fuel Cell Module

SCS contacted EPRI and two molten carbonate fuel cell vendors to obtain additional information for the Fuel Cell Module °F expanded facility. SCS is investigating the use of EPRI's nominal 100 KW test skid, that is currently under fabrication, to determine the effects of contaminants from hot gas cleanup systems. Input is also being solicited by SCS from EPRI and the fuel cell vendors on the appropriate size beyond the nominal 100 KW testing or full stack height testing, working towards fully integrating the transport gasifier with the fuel cell module.

Meetings were held with Energy Research Corp. and M-C Power to gain their input for the fuel cell module. A packet of information with a list of requested information located in Appendix D were given to each vendor to respond by to SCS.

2.3.6 Particulate Control

2.3.6.1 Particulate Apparatus and Instrumentation

SRI completed the conceptual design of the particulate sampling system required under the original scope of work. Under the expanded scope of work, this conceptual design is being reviewed to ensure that it is compatible with the new APFBC and other systems. The preliminary drawings of the particulate sampling systems and port arrangements and the preliminary list of equipment needed for the particulate sampling will be modified as needed. The new equipment requirements and specifications will be used as a basis for developing a cost estimate for the particulate sampling system. The new cost estimate will be part of the revised manpower and cost estimates to be submitted to SCS in April.

In view of the new emphasis on turbine operation and alkali control, SRI examined the needs for alkali sampling and monitoring at the Wilsonville facility. Continuous monitoring of alkali is needed at the inlet of the turbine, because of the stringent limitation on alkali entering the turbine and the potential for turbine damage. Alkali sampling is needed at the outlet of the alkali getter beds to assess the performance of the getter and to detect any channeling, deterioration of the getter, or breakthrough of alkali. The alkali sampling at the getter bed outlet can be done with a separate alkali sampling probe, since combined particulate and alkali sampling will be done at the PCD inlet and the PCD outlet (getter bed inlet). The alkali samples obtained at the inlet and outlet of the PCD will serve to indicate any uptake of alkali on the ceramic filter elements in the PCD. The loss of alkali vapor across the PCD is of interest because long-term capture of alkali vapor by filter materials alters the structure of the ceramic (Alvin, et al, 1991).

The combined particulate and alkali sampling mentioned above can be accomplished using a modified particulate sampling probe in which an alkali sorbent trap or an alkali condenser is connected to the back end of the particulate sampler. The sampling of alkali alone can be accomplished using a separate probe based on the use of either the sorption technique or the condensation technique. For both the combined particulate and alkali sampling and the alkali sampling alone, there is a need to determine which of the two alkali collection methods (sorption or condensation) is best in terms of collection efficiency and ease of use. In the sorption method, alkali vapor is adsorbed on activated bauxite or other suitable sorbent. The adsorbed alkali is then extracted from the sorbent, and the extract is analyzed by atomic emission spectroscopy (AES) or by ion-specific electrodes. In the condensation technique, the alkali vapor is condensed on inert beads. The condensed alkali is then recovered by rinsing the beads with deionized water, and the rinse water is analyzed by AES or ion-specific electrode. As with the two alkali collection methods, there is a need to determine which of the two analytical procedures (AES or ion-specific electrode) is best in terms of accuracy and ease of use.

The alkali concentration in the gas stream entering the turbine may be continuously monitored by on-line AES. This is the basic principle of operation that is employed in both the Ames alkali analyzer and the fiber optic alkali monitor (FOAM). The FOAM is basically a subsequent implementation of the Ames analyzer, in which the stepper motor-driven spectrometer and photomultiplier detector are replaced by fiber optics, a narrow bandpass optical filter, and a photodiode detector. Both the Ames analyzer and the FOAM require a so-called "double" sampling arrangement because the monitor's burner module will accept only a small portion of the total sample flow. The double arrangement involves sampling from the process stream isokinetically at a high flow rate, discharging the primary flow into an expansion chamber where most of the primary flow is drawn off, and then sampling isokinetically from the expansion chamber to obtain the secondary sample flow that is monitored. Experience with the Ames analyzer and the FOAM suggests that these monitors tend to read an alkali concentration that is low by a factor of two to three, but the monitors are sensitive to changes in the alkali concentration (Haas, et al, 1991).

A white paper that discusses the issues related to alkali sampling and monitoring in more detail is included as Appendix E.

2.3.6.2 Particulate Control Devices

To inform the PCD vendors of the new scope of the Wilsonville facility, letters were sent to each vendor along with a list of questions and information needed for the extended conceptual design and is included in Appendix F. In March, meetings were held with Industrial Filter & Pump in Cicero, Illinois; Babcock & Wilcox in Barberton, Ohio; and Westinghouse in Pittsburgh. Arrangements were made for Combustion Power Company to visit the SCS offices in Birmingham in April and for Calvert to discuss the PCD issues with SCS and SRI by conference call.

In general, the visits were worthwhile, and the vendors openly discussed their particulate control technologies. All of the vendors agreed that it was feasible to design a PCD that would be interchangeable between the Foster Wheeler carbonizer and the Kellogg transport reactor. The PCD would be designed for the maximum flow rate generated by the carbonizer (about 2000 acfm), and about half of the filter elements would be blanked off when the PCD was used on the transport reactor, where the flow rate is about 1000 acfm. The vendors generally preferred to have a cyclone ahead of the PCD to reduce the frequency of pulse cleaning cycles. One possible exception was the supplier of the granular bed filter, Combustion Power, who expressed a desire to test the granular bed filter with the full dust loading. The vendors cautioned that any cyclone installed ahead of the PCD should not be too efficient, since very small particles tend to produce an impermeable dust cake. All of the vendors agreed that they could supply a cyclone with their PCD system.

All of the vendors supplied estimates of the physical dimensions for their PCDs, along with projections of service life and heat loss. A candle filter for the transport reactor/carbonizer was estimated to be about 4 to 6 ft in diameter and about 15 to 30 ft in height. The Babcock & Wilcox tube filter would have about the same diameter, but it would be considerably taller, with a height of about 60 ft. The Combustion Power granular bed filter would also be about the same diameter, but the entire system would be even taller, with a height of over 90 ft. A candle filter or tube filter for the PFBC was estimated to be about 7 to 8 ft in diameter. Projected service life ranged from one to three years, and projected heat loss ranged from 10 to 60°F.

SRI submitted a letter to SCS summarizing the findings from the first three vendor meetings. A copy of the letter is included as Appendix G.

Under the expanded scope of work, SRI anticipated receiving samples from the Foster Wheeler pilot plant in Livingston, New Jersey, but no samples have been available to date. When the Foster Wheeler samples are received, they will be characterized by the same procedures used on the TRTU samples (i.e., Coulter

Counter for volumetric particle sizing, Shimadzu centrifuge for aerodynamic particle sizing, BET method for specific surface area analysis, helium pycnometry for particle density measurement, electrostatic tensiometer for tensile strength measurement, and scanning electron microscopy for examination of particle morphology). The characteristics of the Foster Wheeler particles will be included in the Request for Proposal (RFP) for the PCDs, along with the characteristics of the Kellogg transport reactor particles.

2.3.7 Balance of Plant

During this quarter the balance of plant design for the stand-alone HGCTF was completed and the Facility Design Document for the stand-alone facility was prepared. Most of the work during this time period concentrated on the facility expansion estimate.

Preliminary balance of plant design was started as information became available from FW and MWK. A meeting was held in Wilsonville to discuss plans and site requirements with Alabama Power Company and SEI. A plot plan was then developed for the expanded facility after considering layouts on greenfield sites, the liquefaction site and the agglomeration site. A site walkdown was performed for the selected site.

The structures for the MWK Transport Reactor module and the FW APFBC module were combined into a single structure. The revised structural layout was reviewed with FW and MWK. The combined structure should result in a cost savings compared to separate structures for each module. The increased footprint size of the combined structure reduces the requirements for the foundation compared to the tall and narrow stand-alone structures. A revised process structure material takeoff had been initiated.

Work also began on the design of the utility section of the plant as some information was became available near the end of March. Equipment lists and utilities from the liquefaction and agglomeration facilities were reviewed for possible use in the expanded facility.

Other activities included:

- initiation of a cost estimate for the extended design
- development of a preliminary design and construction schedule.

3.0 PLANS FOR FUTURE WORK

1. Complete the conceptual design of the expanded test facility.

2. Submit to DOE/METC a report on the conceptual design of the Power Systems Development Facility and the estimated cost to design, construct and operate.

3. Finalize the design for the TRDU and estimate the additional cost to fabricate and install to minimize the heat loss from the system.

4. Establish the Foster Wheeler and EERC subcontracts.

5. Propose a modification to the Cooperative Agreement for the increase in the level of effort for the detailed design, construction and operation of the expanded test facility.

6. Begin detailed design for the Power Systems Development Facility in order to maintain schedule for the facility.

7. Develop Request for Proposals (RFP) for the particulate control devices for the Power Systems Development Facility.

4.0 REFERENCES

Alvin, M. A., T. E. Lippert, D. M. Bachovchin, J. E. Lane, and R. E. Tressler. *Thermal/ Chemical Stability of Ceramic Cross-Flow Filter Materials.* In: Proceedings of the Eleventh Annual Gasification and Gas Stream Cleanup Systems Contractors Review Meeting. U.S. Department of Energy, Morgantown Energy Technology Center, Morgantown, WV. August 1991.

Haas, W. J., D. E. Eckels, S. H. D. Lee, and W. M. Swift. *Alkali Monitoring for Direct Coal-Fired Turbine Combustors.* In: Proceedings of the Eighth Annual Coal-Fueled Heat Engines and Gas Stream Cleanup Systems Contractors Review Meeting. U.S. Department of Energy, Morgantown Energy Technology Center, Morgantown, WV. 1991.

Appendix A

Hot Gas Cleanup Facility Expansion Summary

HOT GAS CLEANUP TEST FACILITY FOR GASIFICATION AND PRESSURIZED COMBUSTION DOE COOPERATIVE AGREEMENT DE-FC21-90MC25140

EXTENDED CONCEPTUAL DESIGN TASK 1.5 FACILITY EXPANSION ESTIMATE

INTRODUCTION

Southern Company Services (SCS) has been investigating the feasibility of constructing a Power Systems Development Facility (PSDF) at Southern Clean Fuels in Wilsonville, AL. The proposed Power Systems Development Facility (PSDF) is a within scope, phased expansion of the existing Hot Gas Cleanup Test Facility Cooperative Agreement between DOE/METC and SCS. The PSDF would combine a number of pilot-scale test facilities at a single site to reduce overall capital and operating cost compared to individual stand-alone facilities, while continuing DOE/METC's objective of carrying out meaningful systems and component testing for advanced coal-based power generation development.

The intent of the PSDF is to provide a flexible test facility that can be used to develop advanced power system components, evaluate advanced turbine system configurations, and assess the integration and control issues of these advanced power systems.

The near-term research and development needs for advanced coal-based power generation identified by DOE/METC and industry are the need for a dedicated test facility for testing hot particulate removal devices and the continued development of a higher efficiency advanced pressurized fluid-bed combustion (APFBC) system. Mid-term research and development needs are for externally-fired gas turbine (EFGT) and water injected gas turbine systems. The longer-term research needs include the integration of coal gasification with fuel cells to develop a high efficiency, low emissions system for future base load power generation at a reasonable cost.

FACILITY DESCRIPTION

The PSDF will consist of five modules for systems and component testing. These modules include a APFBC Module, an Advance Gasifier Module, Compressor/Turbine Module, Water Augmented Gas Turbine Module and a Fuel Cell Module. Each of these modules can be combined as shown in Figure 1 to provide a flexible test facility. However, due to budgetary constraints and contractual issues associated with the Department of Energy's Acquisition Regulation and efforts to provide better cost justification to Congress, the construction of the modules needs to be phased into the facility over a period of time. A schedule of the phasing of the test facility is illustrated in Figure 2. The numbers for the cash flow requirements of the facility over the next five years are based on DOE/METC's

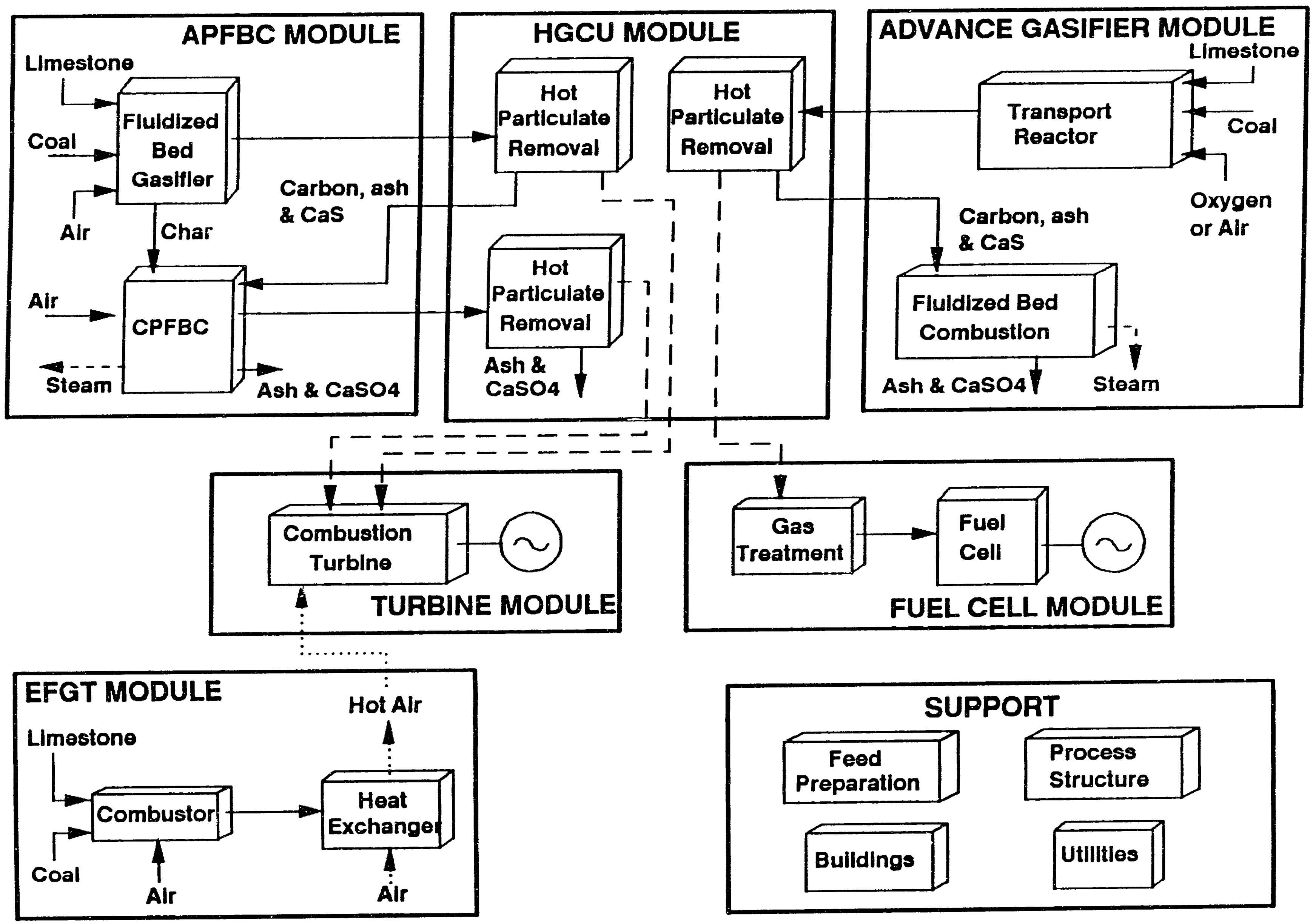
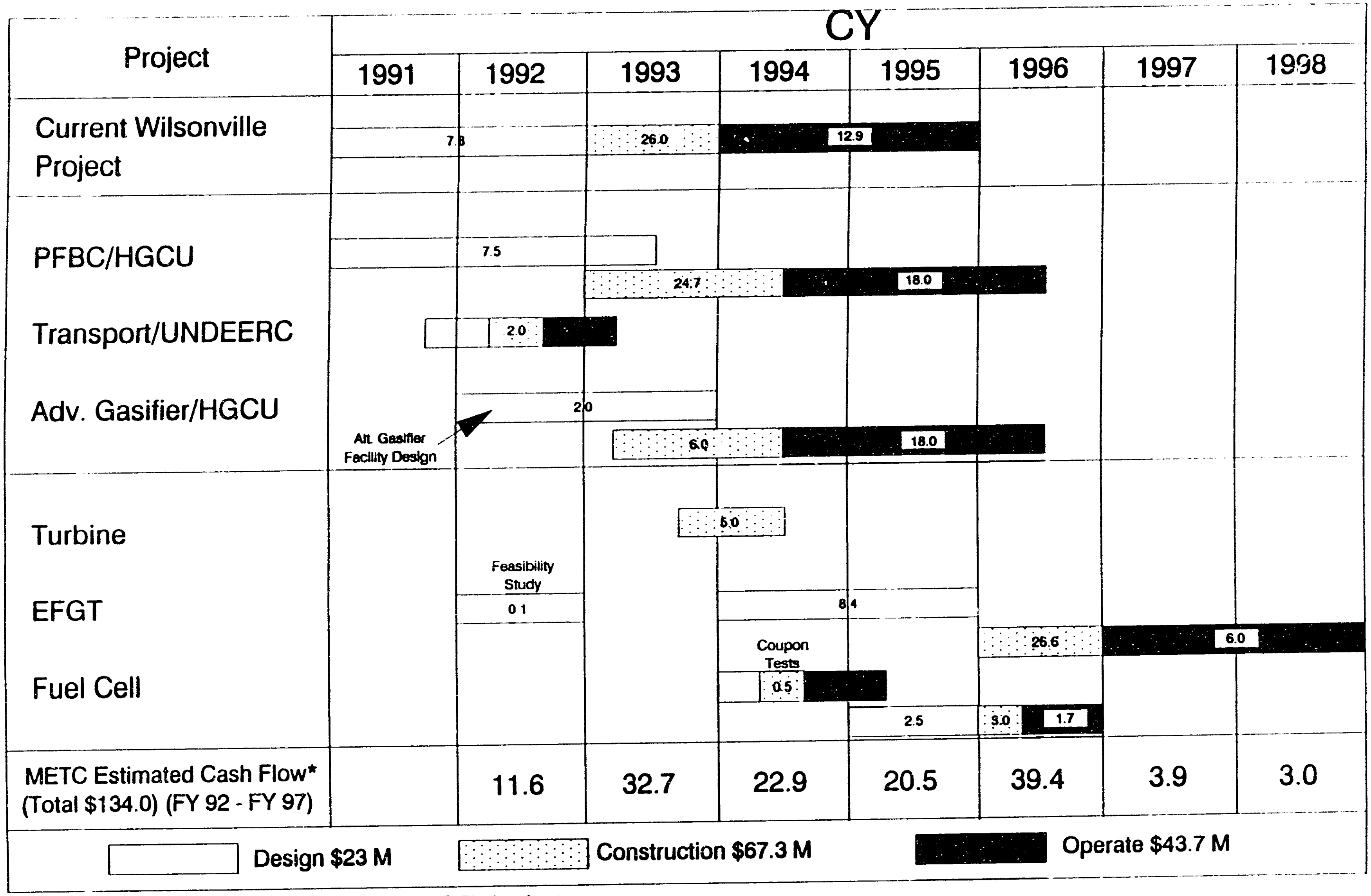


FIGURE 1 POWER SYSTEMS DEVELOPMENT FACILITY PROCESS DIAGRAM

FIGURE 2
DOE/SCS Compromise Proposed Schedule/Total Cost ($Million)



* Subject to Congressional approval and DOE's budget

estimates. A key aspect of the cash flow estimate is that the combined industry participants will be able to share at least 20 percent of the total cost. One of the first tasks that must be accomplished to implement this "Strawman" recommendation is for SCS and it's subcontractors to conduct an expanded conceptual design effort to validate the cost estimates shown in Figure 2.

The first modules to be designed and installed at the PSDF would be the APFBC, Compressor/Turbine, and Advance Gasifier Modules. The APFBC module consists of Foster Wheeler's technology for second generation PFBC. This module relies on the partial conversion of the coal to a fuel gas with the remaining char converted in a PFBC. Both the fuel gas and PFBC exhaust gas streams are filtered to remove particulates, then combined to fire a combustion turbine. The advance gasifier module involves M. W. Kellogg's transport technology for pressurized combustion and gasification to provide either an oxidizing or reducing gas for parametric testing of hot particulate control devices. The compressor/turbine module currently consists of a GM-Allison 501 gas turbine, nominally producing 4 MW of electric power, which will provide a more cost effective compressed gas source than an electric driven compressor train. The final selection of the gas turbine would depend upon a number of factors, including the ability of the turbine supplier to provide cost share. The gas turbine would be modified to accommodate a gas combustion system supplied by either Westinghouse or Allison, depending upon the results of topping combustor test being conducted by Foster Wheeler.

Installing and operating these three modules at the same time will allow the facility to provide the capability for both parametric and long-term testing of particulate control devices (PCDs) to support the DOE Clean Coal Program. Three separate PCD technologies can be tested at the facility under both parametric and long-term testing by rearranging the PCDs between the Advance Gasifier and APFBC Modules. This requires that the facility be carefully laid out to accommodate the physical movement of the PCDs from one module to another, or alter the routing of hot piping to PCDs from the different modules, while still accounting for downstream systems and the addition of future modules. SCS recognizes that additional development of the transport reactor in a gasification mode is required (at the University of North Dakota Energy and Environmental Research Center (UNDEERC)) prior to operating the transport module in this mode at the PSDF. However, SCS feels confident that the transport reactor has a sufficient design base to provide assurance that the unit can be operated in a pressurized combustion mode initially to support the operation of the PCDs.

The provision to water inject the gas turbine, install an EFGT module, and install a Fuel Cell Module could be phased into the PSDF in the future. The EFGT module will be designed for the potential scaleup of indirect-fired cycles currently being sponsored by DOE/METC and DOE/PETC. The externally-fired combined cycle (EFCC) is being sponsored under DOE/METC consists of a system including combustion/heat exchanger/HRSG/cleanup to heat air to 2,300°F to produce power in a gas turbine. The DOE/PETC sponsored program includes high performance power systems (HIPPS) and integrate combustion/heating/cleanup to heat air to 1,800°F that fired with natural gas in a topping combustor prior to producing power in a gas turbine. The fuel cell module integrated with the transport gasifier and can be used to test advanced fuel cells such as molten carbonate and solid oxide fuel cells. A preliminary conceptual layout of the proposed PSDF is shown in Figure 3 to illustrate how the facility may be arranged to accommodate the components needed for the overall PSDF program. Future modules are shown in dotted lines. Both the APFBC and Advance Gasifier Modules would share a common support structure with the PCDs located at end bays of the structure for easier access. Coal and limestone storage with crushing, control room and support buildings can be shared. Currently the preferred location for the PSDF is the confines of the site being used for the coal liquefaction facility at Southern Clean Fuels in Wilsonville, AL. The ability to remediate this site within the schedule shown in Figure 2 will determine whether this location is actually used. The alternative location is immediately next to the coal liquefaction facility on an unused piece of property. Social, economic, and environmental issues associated with using either site are being addressed under the NEPA process.

The phasing of the installation of the modules as proposed has several advantages. The construction activities can be combined to maximize the utilization of construction equipment and labor while minimizing the overlap of construction with the operation of the facility. Capital cost savings can be achieved due to the fact that most of the central support infrastructure (buildings, fire protection, backup electric generators, coal and limestone storage areas, etc) already exists if the Direct Coal Liquefaction Project site can be used. Only incremental increases to support both the APFBC and Advance Gasifier Modules would be required compared to the duplication of all of the infrastructure at individual stand-alone pilot-plants. The operating costs for on-site O&M, engineering, and administration would also increase incrementally by operating multi-modules at a central site. In addition, the possibility of sharing common utilities also exists with a combined facility.

PROJECT ORGANIZATION

The project organization for the proposed PSDF is shown in Figure 4. An advisory committee composed of representatives from DOE, EPRI and the utility industry will provide guidance in the overall technical direction for the facility.

SCS Research and Environmental Affairs would be responsible for overall project management and procurement of the PCDs. SCS Engineering would be responsible for coordinating the design of the facility as well as plant layout and balance-of-plant design. The process engineering for the APFBC module would be done by Foster Wheeler. Foster Wheeler will also take the lead in integrating the APFBC module with the combustion gas turbine, working with Westinghouse for the topping combustor design and Allison for the design of the gas turbine and air compressor. M. W. Kellogg will provide the process engineering for the transport reactor unit. Southern Research Institute will develop the

FIGURE 3

POWER SYSTEMS DEVELOPMENT FACILITY PRELIMINARY CONCEPTUAL LAYOUT

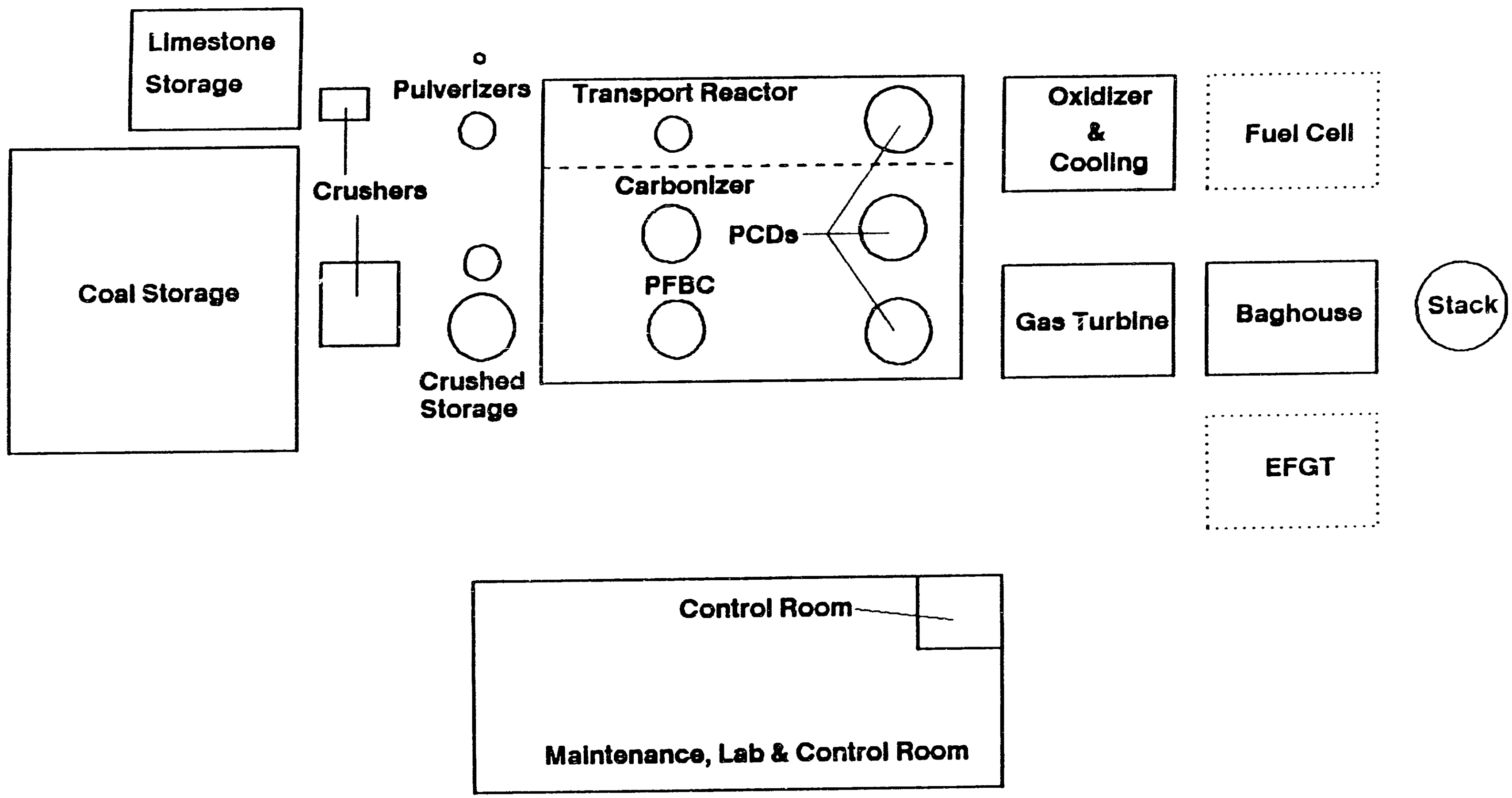
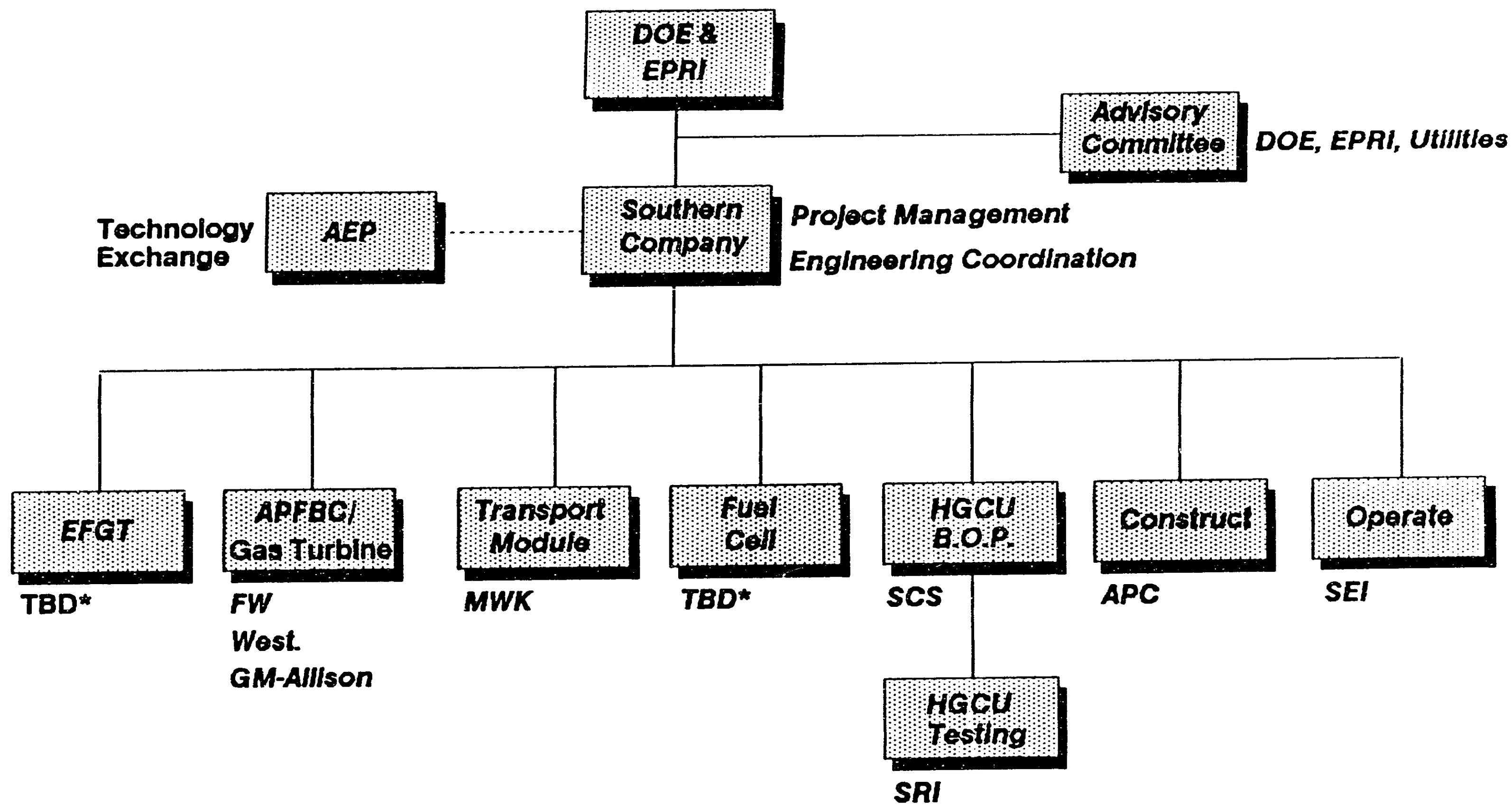


FIGURE 4
JOINT DOE/EPRI/INDUSTRY POWER SYSTEMS DEVELOPMENT FACILITY

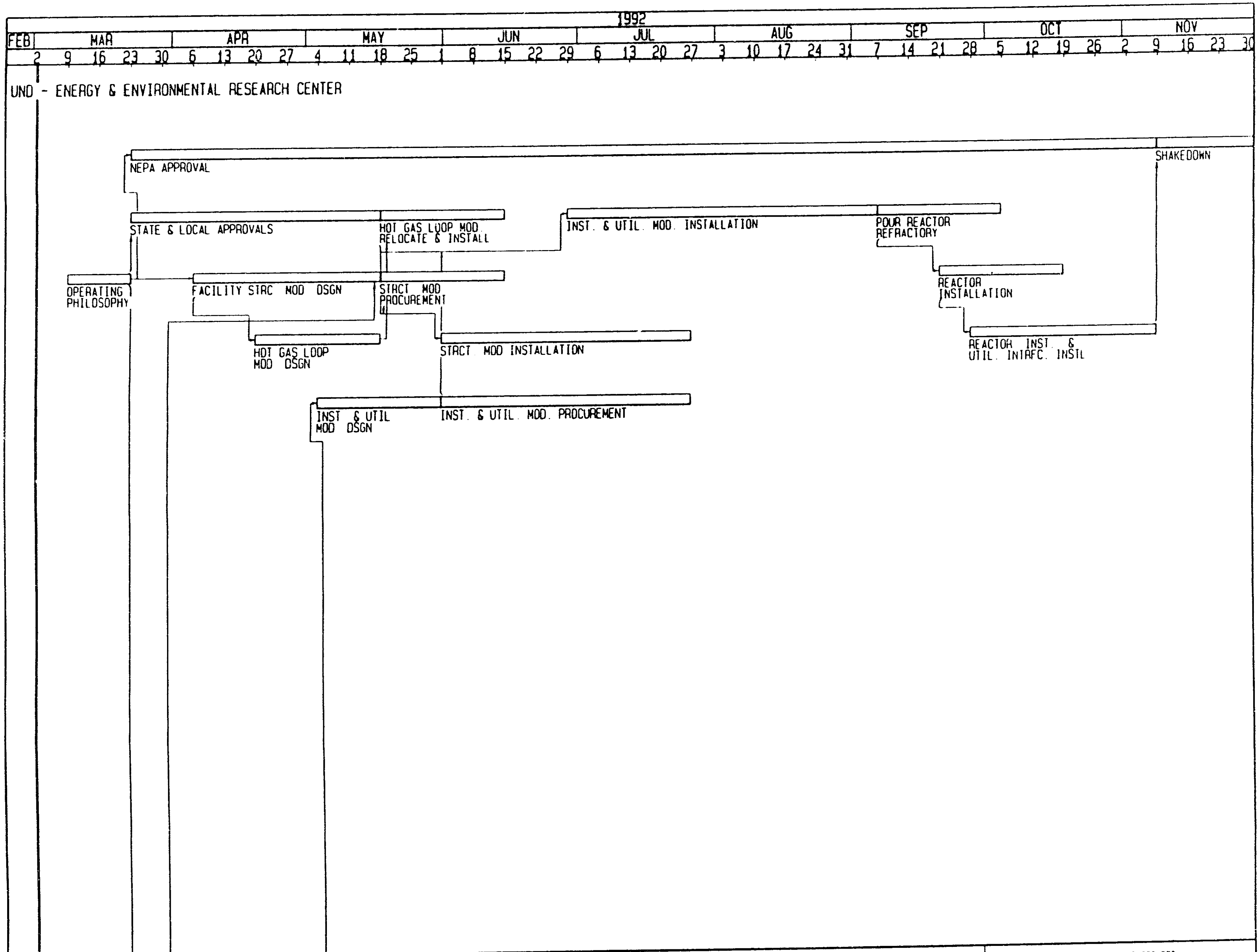


* *To be determined*

testing plan for the PCDs and evaluate the PCDs performance. Southern Electric International will be the facility operator. SCS will be responsible for coordinating the design for the water augmented gas turbine (EFGT) module.

Appendix B

Preliminary Intergrated TRDU Project Schedule



Activity Bar/Early Dates (description)
Critical Activity
Progress Bar

Primavera Systems, Inc 1984-1991

Planning Unit : Week

Project Start : 2MAR92
Project Finish: 3JAN93

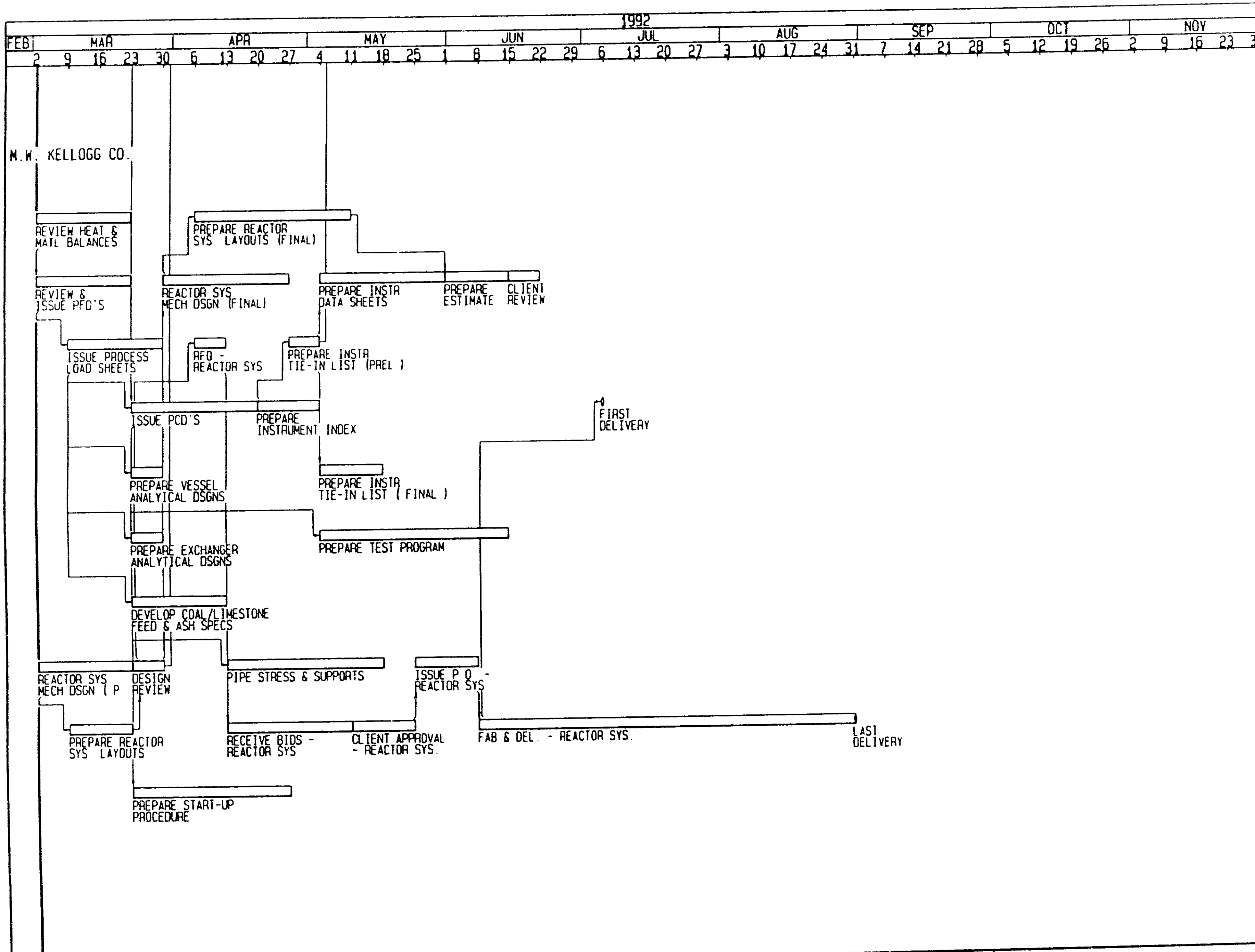
SOUTHERN COMPANIES SERVICES
TRANSPORT REACTOR DEVELOPMENT UNIT
TIME SCALED LOGIC DIAGRAM

Sheet 1 of 2

Data Date 2MAR92
Plot Date 30MAR92

M.W. KELLOGG PROJECT 6704

Date	Revision	Checked	Approved



Activity Bar/Early Dates	description
Critical Activity	
Progress Bar	

Primavera Systems, Inc. 1984-1991

Planning Unit : Week

Project Start : 2MAR92
Project Finish: 3JAN93

SOUTHERN COMPANIES SERVICES
TRANSPORT REACTOR DEVELOPMENT UNIT
TIME SCALED LOGIC DIAGRAM

Sheet 2 of 2

Data Date: 2MAR92
Plot Date: 30MAR92

M.W. KELLOGG PROJECT 6704

Date	Revision	Checked	Approved

Appendix C

Power Systems Development Facility Design Basis

POWER SYSTEMS DEVELOPMENT FACILITY

DESIGN BASIS DOCUMENT

Revision A

Southern Company Services, Inc.

DESIGN BASIS DOCUMENT REVISION LOG

Revision Number	Issue Date	Sections Revised

AREA LISTING

AREA	DESCRIPTION	CURRENT REVISION
100	FEED STORAGE AND PREPARATION	
200A	TRANSPORT GAS GENERATOR	
200B	ADVANCED PFBC GAS GENERATORS	
300A	PARTICULATE CONTROL DEVICES FOR TRANSPORT GAS GENERATOR	
300B	PARTICULATE CONTROL DEVICES FOR ADVANCED PFBC	
400A	GAS COOLING AND TREATMENT FOR TRANSPORT GAS GENERATOR	
400B	GAS TURBINE	
500A	ASH HANDLING FOR TRANSPORT	
600A	SULFATOR	
700	FINAL GAS TREATMENT	
800A	ASH DISPOSAL FOR TRANSPORT	
800B	ASH DISPOSAL FOR ADVANCED PFBC	
900C	INDIRECT GAS TURBINE	
900D	FUEL CELL	
1000	INSTRUMENTATION AND DATA ACQUISITION	

AREA 2000 IS NOT REVISED

2000	UTILITIES: 2000 BOILER FEEDWATER AND STEAM SYSTEM	
	2100 SERVICE WATER (COOLING WATER)	
	2200 SERVICE/INSTRUMENT AIR SYSTEM	
	2300 AUXILIARY FUEL SYSTEM	
	2400 FIRE PROTECTION SYSTEM	
	2500 WASTEWATER TREATMENT SYSTEM	
	2600A NITROGEN SYSTEM	
	2600B OXYGEN SYSTEM	
	2700 WATER TREATMENT/CHEMICAL FEED SYSTEMS	
	2800 SAFETY/SECURITY SYSTEMS	

AREA 3000 IS NOT REVISED

3000 ELECTRICAL: 3000 POWER DISTRIBUTION

3100 CONTROL & DATA ACQUISITION CIRCUITRY

3002 LIGHTING

3003 COMMUNICATIONS

3004 HEAT TRACING / FREEZE PROTECTION

4000 BUILDINGS

AREA 100 FEED PREPARATION

1. **Description:** This area includes all components required for receiving, storing, and processing coal and limestone. Included are the coal and limestone storage area, truck unloading facilities, scales, covered storage provisions, run-off provisions, reclaim hoppers, conveyors, magnetic separators, crushers, sampling provisions, feeders, pulverizers, air heaters, cyclones, dust collection systems, storage silos, blowers, fans, coal and limestone piping, chutes, supports, foundations, electrical equipment, controls, raceways, and grounding.

Area Interface Points:

- Storage silo discharge to lock hopper and/or surge bin (AREA 200A)
- Storage silo discharge to lock hopper and/or surge bin (AREA 200B)
- Limestone make-up to Sulfator (AREA 600A)
- Utilities (AREA 2000)
- Instrumentation and Data Acquisition (AREA 1000) (Alarms and Emer. stop only)
- Electrical Distribution and Utilities (AREA 3000)

Design Interface:

Lead: SCS
Interface: SCS will provide properly sized coal and limestone feed up to a location identified by MWK in AREA 200A and by FW in AREA 200B at or near the physical boundary of the process structure. Feed within each area will be the responsibility of Lead design organization for that area.

Coal:

	Design Coal Illinois No. 6 Bituminous	Alternate Coal Eagle Butte Sub-bituminous
Proximate Analysis, wt.% (AR)		
Moisture	12.9	20.5
Volatile Matter	36.8	34.7
Fixed Carbon	41.7	38.0
Ash	8.6	6.8
Ultimate Analysis, wt.% (MF)		
Carbon	71.1	68.7
Hydrogen	5.0	5.1
Nitrogen	1.4	0.9
Chlorine	0.3	0.0
Sulfur	3.0	1.1
Ash	9.9	8.5
Oxygen (by diff.)	9.3	15.7
HHV, Btu/lb, AR	11,200	9,800

Ash Analysis, wt.% of ash

SiO_2	50.2
Al_2O_3	18.8
TiO_2	1.0
Fe_2O_3	16.1
CaO	5.4
MgO	1.1
K_2O	1.96
Na_2O	0.92
SO_3	4.2
P_2O_5	0.2
SrO	0.02
BaO	0.06
Mn_3O_4	0.04

AR - As received   MF - Moisture Free

Coal Moisture:

	Ill. No. 6	Eagle Butte
Design (AR), wt.%	12.9	20.5
Maximum (AR), wt.%	15.0	25.0
After Grinding, wt.%	5.0	12.0

Coal Grinding:

As-received: Size = 2.5" x 0", Bulk Density = 50 lb/ft3

As-ground:
- For AREA 200A:
  - Gasification Mode: Average Particle Diameter = 100 microns
  - Combustion Mode: Average Particle Diameter = 200 microns; 80% < 420 microns (35 mesh)
- For AREA 200B:
  - 1/8"
- For AREA 900C:
  - To be specified

Losses during grinding: no more than 15%

Output:
- For AREA 200A:
  - Continuous feed = 3 tons/hr at 5% moisture
- For AREA 200B:
  - Continuous feed = 3 tons/hr
- For AREA 900C:
  - To be specified

Limestone: Longview
Analysis, wt.%, dry

$CaCO_3$	97.45
$MgCO_3$	1.58
SiO_2	0.20
R_2O_3	0.74

Limestone Moisture:

As-received, wt.%	10.0
After Grinding, wt.%	2.0

Limestone Grinding:

As-received: Size = 2.5" x 0", Bulk Density = 100 lb/ft3
As-ground:
For AREA 200A:
As-ground: Average Particle Diameter = 100 microns
80% < 250 microns
Bulk Density = 95 lb/ft3

For AREA 200B:
1/8"
For AREA 900C:
To be specified

Losses during grinding: no more than 15%

Output:
For AREA 200A:
Output:10 tons in 8 hours. Continuous feed to Gasifier = 838 lb/hr
(Based on maximum design Ca/S = 1.5)

For AREA 200B:
To be specified by FW
For AREA 900C:
To be specified

Storage Capacities:

- As-received Coal = 21 day capacity (for each coal), pile
- Crushed Coal = 24 hours capacity(is this OK as feed to Carbonizer)
- Pulverized Coal = 24 hours capacity, silo
- As-received Limestone = 21 day capacity, pile
- Crushed Limestone = 24 hours capacity(is this OK as feed to Carbonizer)

- Pulverized Limestone = 24 hours capacity, silo

Waste Stream:

- Coal pile run-off
- Limestone pile run-off
- Fine particulates from grinding Pyrites

Control and Data Acquisition Requirements:

- Control systems for coal and limestone will be independent and automatic and located near the equipment. Alarms will be sent back to the DCS in the main control. The main control room will also have an Emergency Stop function.

- Sized feed from storage silos determined by demand signals from AREA 200A, 200B and 900C.

- System will include no provisions for automatic start of the processing equipment (ie, crusher, pulverizer, etc.)from control room. All starting will be from local control station.

- Automatic stop for each system will occur under the following "normal" conditions:
  - Storage bin high level.
  - "Normal" shutdown signal from control room or local control station.

- "Normal" stop will include provisions for clearing pulverizers and piping.

- Alarm and Trip Conditions:
  - In event of process system trip - Stop transport to lock hoppers and initiate normal shutdown sequence.
  - In event of coal handing system trip - Alarm in control room and initiate N_2 purge.
  - In event of limestone handling system trip - Alarm in control room.
  - Provide emergency trip capability in control room. E-trip shall include N_2 purge (coal handling only).
  - Provide pulverized coal and limestone storage silo low and high level alarms in control room.
  - Provide pulverized coal storage silo O_2 alarm in control room.

- Control room continuous monitoring requirements:
  - Storage silo levels
  - O_2 level in coal storage silo
  - Operating status (ON/OFF) of equipment

Utilities: Nitrogen for purge, grinding, and silo blanket (coal)

Service water
Plant air
Fire protection
Auxiliary fuel for drying

Electrical:

Voltages: 480/3/60
120/1/60
240/1/60

Suggested Vendors:

Pulverizer & associated equip.:	Williams Patent Crusher Bradly Pulverizers
Pulverized coal handling:	Howden Environmental Systems 5155 East River Road Minneapolis, MN 55421 612-571-0560 FAX: 612-571-0426
Solid flow shut-off valves:	Everlasting Valves Hile Controls of Alabama, Inc. 205-995-0030 FAX: 205-995-1243

Comments:

- o Provide paved covered storage area to reduce drying requirements and minimize pile run-off treatment provisions.
- o Consider possibility for using same crushing and grinding equipment for both coal and limestone.

Conceptual Design Requirements:

- o Description of process
- o Size equipment
- o List of equipment/materials
- o Estimated cost
- o Delivery dates
- o Preliminary P&ID's

AREA 200A TRANSPORT GAS GENERATOR

1. **Description:** The process system necessary for producing the hot gas streams to Area 300A. This includes the transport reactor (gasifier/combustor), coal and limestone lock hopper system, start-up burners, necessary compressed gas and air systems, cyclones, fluid bed boiler, fluid bed cooler, high temperature gas cooler, piping, supports, controls, electrical power equipment, raceways, and grounding. Equipment layout drawings. Include provisions to operate with oxygen-blown gasification.

2. **Area Interface Points:**

   - Coal silo discharge (AREA 100) to coal lock hopper.
   - Limestone silo discharge (AREA 100) to limestone lock hopper.
   - High pressure hot gas to PCD (AREA 300A)
   - Recycle gas from recycle gas compressor (Area 400A).
   - Steam for gasification from high pressure/temperature steam drum (AREA 400A)
   - Start-up steam from steam drum (AREA 400A)
   - Steam for high temperature gas cooler from steam drum (AREA 400A)
   - Feedwater from drum (AREA 400A) for fluid bed boiler.
   - Utilities (AREA 2000)
   - Instrumentation and Data Acquisition (AREA 1000)
   - Electrical (AREA 3000)
   - Ash Handling (AREA 500A)

3. **Design Interface:**

Lead: MWK
Interface: MWK will design the complete gas generator process and will provide all layout and detail drawings for 200A regardless of system within the physical boundary of the process structure. Piping interfaces for coal, limestone, and utilities will be identified on drawings at structure boundaries. Electrical interfaces will also be identified at structure boundaries.

SCS is responsible for design of structure and foundations based on MWK layouts. Control and data acquisition (AREA 1000) is the responsibility of SCS, but required equipment and instrumentation within the structure boundaries is the responsibility of MWK.

4. **Gas Generator Output:**

BASIS: 1000 ACFM to PCD inlet, all conditions, both modes. PCD inlet pressure variable (gasification only).

ASSUMPTIONS: PCD inlet temperature = 1000 to 1800°F

Appendix D

Fuel Cell Vendor Information and Requested Information

Request for
Conceptual Design Information

Fuel Cell Module

Wilsonville Power Systems Development Facility

Southern Company Services, Inc.

INTRODUCTION

Southern Company Services (SCS) is investigating the feasibility of expanding the Hot Gas Cleanup Test Facility for gasification and pressurized combustion (HGCUTF) into a Power Systems Development Facility (PSDF). The PSDF would be located at Southern Company's Clean Coal Research Center in Wilsonville, AL and would be operated under a cooperative agreement between the Morgantown Energy Technology Center (METC) and SCS. The PSDF would combine a number of pilot-scale test facilities at a single site to reduce overall capital and operating costs compared to individual stand-alone facilities.

The objective of the PSDF is to provide a flexible test facility that can be used to develop advanced power system components, evaluate advanced turbine system configurations, and assess the integration and control issues of these advanced power systems.

The near-term research and development needs for advanced coal-based power generation identified by DOE/METC and industry are a dedicated test facility for testing hot particulate removal devices and the continued development of a higher efficiency advanced pressurized fluid-bed combustion (APFBC) system. The longer-term research needs include the integration of coal gasification with fuel cells to develop a high efficiency, low emissions system for future base load power generation at a reasonable cost.

FACILITY DESCRIPTION

The PSDF will consist of five modules for systems and component testing. These modules include an APFBC Module, an Advanced Gasifier Module, Compressor/Turbine Module, Water Augmented Gas Turbine Module and a Fuel Cell Module. Each of these modules can be combined as shown in Figure 1 to provide a flexible test facility.

One of the first modules to be designed and installed at the PSDF will be the Advanced Gasifier Module which will use M.W. Kellogg's Transport Reactor. Initially, the Advanced Gasifier Module will be used for parametric testing of hot particulate control devices. Later, either a molten carbonate or solid oxide fuel cell module will be installed and integrated with the Transport Reactor. The schedule for the installation and testing of the fuel cell module is shown in Figure 2.

INFORMATION REQUESTED

SCS is requesting the information necessary to complete a conceptual design and cost estimate for testing a fuel cell skid at Wilsonville to demonstrate the integrated gasification fuel cell concept.

A simplified process flow diagram for the transport reactor module is shown in Figure 3. The fuel gas to be used in the fuel cell is specified in Table 1. In addition to these components, the fuel gas will contain some particulates, which will consist of coal mineral matter, unreacted limestone, and Ca/Mg salts. Please indicate whether testing with the air-blown, oxygen-blown or both cases is recommended. The cost estimate for the fuel cell skid should include the cost of any gas cleanup required prior to feeding the fuel cell. The fuel gas flow listed in the table should be regarded as the maximum amount of fuel gas available and the fuel cell need not be sized for this flow. The optimum size for testing should be determined based on cost and technical information obtained from the testing.

Conceptual Design Information

The following information is needed by SCS for completion of the conceptual design:

- footprint of fuel cell skid
- skid loads for foundation requirements
- utility requirements
- electrical requirements
- I/O count for instruments
- Process and Instrumentation Drawings if available
- gas composition and conditions leaving the fuel cell
- electrical power produced
- fuel gas flow rates required and the maximum fluctuation that can be tolerated
- required temperature and pressure of the fuel gas

The foundation for the skid would be provided by SCS and the interface for all piping, electrical wiring and instrumentation cables would be at the boundary of the fuel cell skid. The electrical power generated should be at 4160V AC at the interface. A DCS will be provided by SCS with the control strategy/philosophy and all instrumentation provided by the fuel cell vendor. Any necessary exhaust gas conditioning will be provided by SCS.

Cost and Schedule Information

The project is cost shared 20% by industry and 80% by the Department of Energy. Please indicate the amount of cost sharing you would provide and the following information.

- design cost and schedule
- construction cost and schedule
- operating and maintenance cost per month
  (for operating and maintenance personnel please provide manhours instead of cost)

Table 1 Fuel Gas Data

Component	Air Blown Volume %	Air Blown Lb/hr		Oxygen Blown Volume %	Oxygen Blown Lb/hr
CO	18.37	3164			
H_2	13.65	169			
CO_2	8.07	2184			
CH_4	0.36	35			
N_2	51.09	8799			
Ar	0.00	0			
O_2	0.00	0			
NH_3	0.0068	1			
H_2S	0.0246	5			
COS	0.00???	0			
SO_2	0.00	0			
H_2O	8.40	931			
HCl	0.00???	0			
C_{2+}	0.00	0			
NO_x	0.00	0			
HCN	0.0222	4			
Total Flow					
Lb/hr	15291				
Lb Moles/hr	614.8				
SCFM	3,888				
Molecular Weight	24.873				
Temperature, °F					
Minimum	600				
Maximum					
Pressure, psig					
Minimum	???				
Maximum	300				

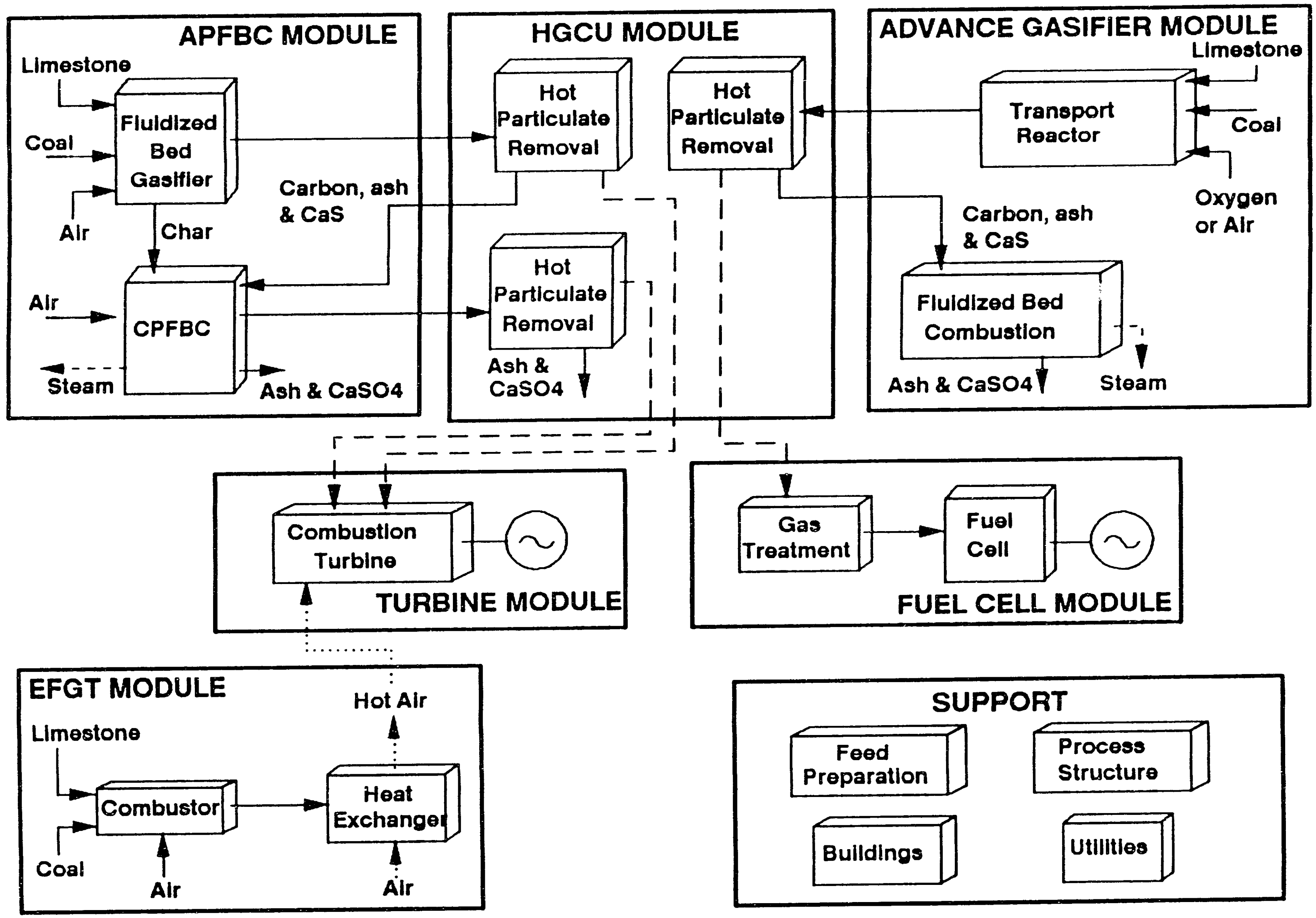
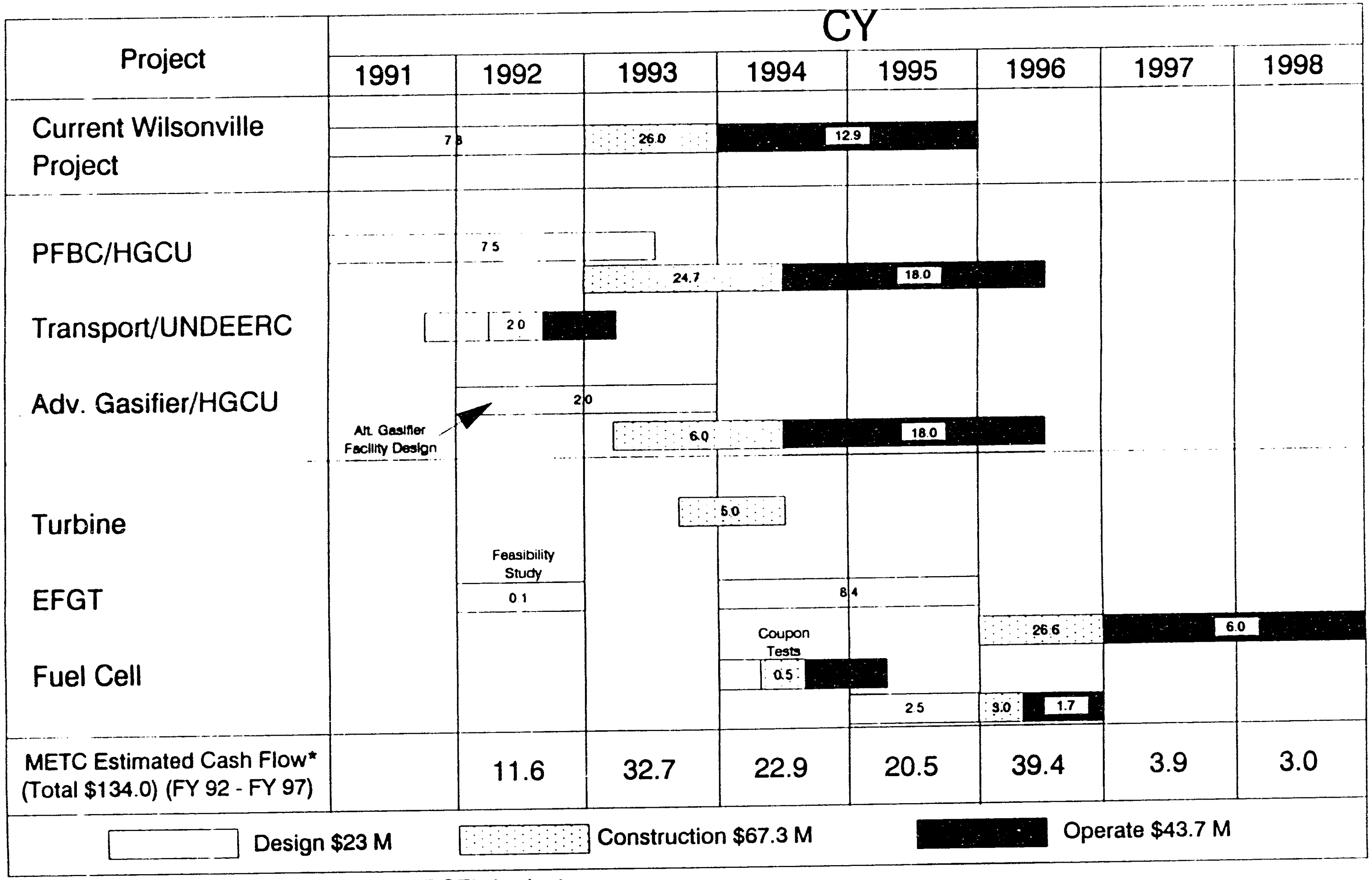


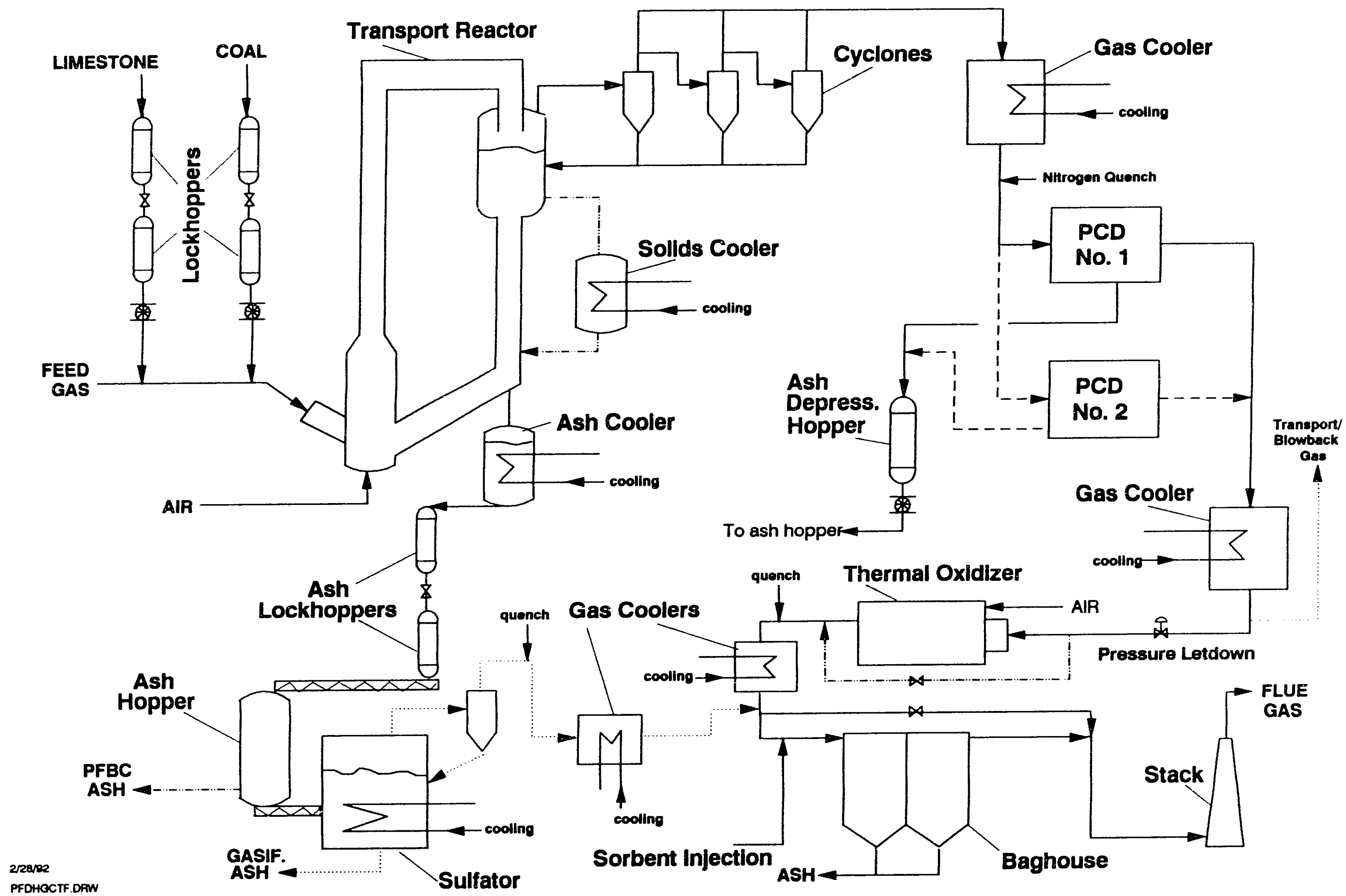
FIGURE 1 POWER SYSTEMS DEVELOPMENT FACILITY PROCESS DIAGRAM

FIGURE 2
DOE/SCS Compromise Proposed Schedule/Total Cost ($Million)



* Subject to Congressional approval and DOE's budget

WILSONVILLE HOT GAS CLEANUP TEST FACILITY



Appendix E

SRI White Paper on Alkali Sampling

Alkali Sampling and Monitoring at the Wilsonville Power Systems Development Facility

Prepared by

Southern Research Institute
P. O. Box 55305
Birmingham, AL 35255-5305

for

Southern Company Services
P. O. Box 2625
Birmingham, AL 35202

To Be Included in the Expanded Scope of Work for the Wilsonville Power Systems Development Facility (Formerly the Wilsonville Hot Gas Cleanup Test Facility)

DOE Cooperative Agreement No. DE-FC21-90MC25140

April 20, 1992

Alkali Sampling and Monitoring at the Wilsonville Power Systems Development Facility

CONTENTS

INTRODUCTION AND BACKGROUND	1
Need for Alkali Sampling and Monitoring	1
Overview of Alkali Sampling Techniques	3
Overview of Alkali Monitoring Techniques	5
ALKALI SAMPLING AT WILSONVILLE	9
Sampling Locations and Objectives	10
Sampling Alkali Alone	12
Sampling Alkali in Conjunction with Particulate Matter	13
ALKALI MONITORING AT WILSONVILLE	14
Monitoring Locations and Objectives	15
Potential Approaches to Monitoring	16
Recommendations	17
REQUIRED MANPOWER AND ESTIMATED COSTS	17
Detailed Design (Phase II), June 1992 to December 1993	17
Installation (Phase III), January1993 to June 1994	18
Operations and Testing (Phase IV), June 1994 to June 1996	19
REFERENCES	20

Alkali Sampling and Monitoring at the Wilsonville Power Systems Development Facility

INTRODUCTION AND BACKGROUND

This document discusses the requirements for alkali sampling and monitoring at the Wilsonville Power Systems Development Facility (PSDF). The need for alkali sampling and monitoring at the PSDF is explained, and available sampling and monitoring techniques are briefly reviewed. Potential sampling and monitoring locations and objectives are summarized, and sampling and monitoring approaches are suggested. Estimated manpower requirements and costs associated with alkali sampling and monitoring are included.

The original purpose of the Wilsonville facility was to test high-temperature particulate control devices (PCDs) under conditions expected in gasification and pressurized fluidized-bed combustion (PFBC) processes. The original facility was based upon the Kellogg transport reactor, a flexible gas generator capable of simulating both gasification and PFBC processes. The original facility included two PCDs, with one PCD being operated and evaluated while the other PCD was serviced or modified. Since the original facility design included neither a gas turbine nor any form of alkali control, alkali sampling and monitoring were considered to be unnecessary. In view of the expansion of the facility to include the Foster Wheeler advanced PFBC (APFBC) system and the Allison gas turbine, the need for alkali sampling and monitoring must be reconsidered.

Need for Alkali Sampling and Monitoring

To minimize the potential for high-temperature corrosion of the gas turbine, Allison has recommended a limit of 20 ppb on the alkali concentration in the flue gas entering the turbine (Davis, 1992). Equilibrium calculations suggest that the fuel gas generated by the Foster Wheeler carbonizer may contain as much as 40,000 ppb of alkali, and the flue gas generated by the PFBC may contain as much as 240 ppb of alkali (Robertson, 1990). Based on these predicted concentrations, compliance with the Allison specification will require removal of 99.95% of the alkali in the carbonizer gas and removal of 92% of the alkali in the PFBC gas. Foster Wheeler plans to incorporate packed beds of alkali "getter" in both the carbonizer and the PFBC gas streams to effect the required alkali removal. Alkali sampling will be required to verify that the getter is providing adequate alkali control.

The alkali sampling techniques that are currently available involve either the adsorption of alkali vapor on an appropriate sorbent or the condensation of alkali vapor on inert beads. The alkali is then extracted from the sorbent or rinsed off the beads, and the extract or rinse is analyzed for sodium and potassium. For the most accurate results, the analysis should be done by atomic emission spectroscopy (AES), which would require transporting the samples to the Southern Research Institute (SRI) laboratories in Birmingham, about 35 miles from the Wilsonville facility. Using this procedure, the results would probably not be available until several days, or possibly several weeks, after the sampling is done. The results could be obtained faster using on-site analysis with specific-ion electrodes (Newby, 1992). It would still be necessary to use AES to check the specific-ion analyses, at least until the on-site procedures are proven to be reliable. If the on-site procedures using the specific-ion electrodes prove satisfactory, the turnaround time could be reduced to several hours.

According to Allison (Davis, 1992), "Any excursion of particulate and alkali above the limits will accelerate the reduction of turbine life. Excursions of more than a few minutes should be avoided." Excursions in alkali concentration could result from preferential channeling of the gas through a portion of the getter bed, from premature deactivation of some of the getter, or from an increase in the alkali content of the coal. In view of the potential for these alkali excursions and the stringent alkali limit set by the turbine manufacturer, alkali levels should be continuously monitored. Even with the fastest possible turnaround, batch sampling alone is not adequate to protect against excursions that last only several minutes. Even if a batch sampling run coincided with a sudden increase in alkali level, the turbine could be damaged before the analytical results were available. Continuous monitoring is essential to ensure compliance with the turbine manufacturer's guidelines.

Based on the foregoing discussion, we believe that both batch sampling and monitoring of alkali levels are needed at the Wilsonville facility. The remainder of this document describes the available sampling and monitoring techniques, the objectives of the sampling and monitoring activities, the potential sampling and monitoring locations, suggested approaches, and estimated manpower requirements and costs.

Overview of Alkali Sampling Techniques

The techniques that are available for the batch sampling of alkali vapor are based on either adsorption of the vapor on a sorbent or condensation of the vapor on inert beads. With both of these techniques, heated filters precede the sorbent trap and condenser in the sampling trains. Solid-phase alkali is determined by analyzing the particulate matter collected on the heated filter. The pipe that connects the filter to the sorbent trap or condenser is heated to prevent the loss of alkali vapor on the pipe wall. Vapor-phase alkali is determined by extracting the adsorbed vapor from the sorbent and analyzing the extract for sodium and potassium, or by rinsing the condensed alkali off the inert beads and analyzing the rinse.

Argonne National Laboratory (ANL) has pioneered the development of batch alkali sampling using sorbent traps. The work at ANL has shown that the loss of alkali vapor on metal sampling lines is the major source of error in batch alkali measurements. A research project that has just started at ANL will focus on identifying sampling line materials that have reduced affinity for alkali vapor. Various alloys, refractory metals, and ceramics will be tested for alkali uptake under PFBC conditions (Lee, 1992). To avoid the problem with alkali loss on metal sampling lines, ANL has developed an alkali sorbent trap that mounts directly into the tube sheet of the candle filter on their PFBC test unit as shown in Figure 1. Lee and Carls (1989) compared the alkali measurements made with this configuration to extractive measurements made at the same location through a heated, stainless steel sampling line. The results suggested that roughly half of the alkali vapor was lost in the sampling line, which was 3.6 ft in length.

For large-scale systems, it is obviously impractical to use an alkali sorbent trap that is mounted directly into the filter tube sheet as done at ANL, since this approach would require frequent shutdown of the filter to retrieve the sorbent trap for analysis. However, the work at ANL points out the need to minimize the length of metal sampling lines. In an in situ sampling train, the sorbent trap could be mounted directly behind the particulate sampler, and both the particulate sampler and the sorbent trap could be inserted into the process ducting. This configuration would maintain all of the metal surfaces at the process

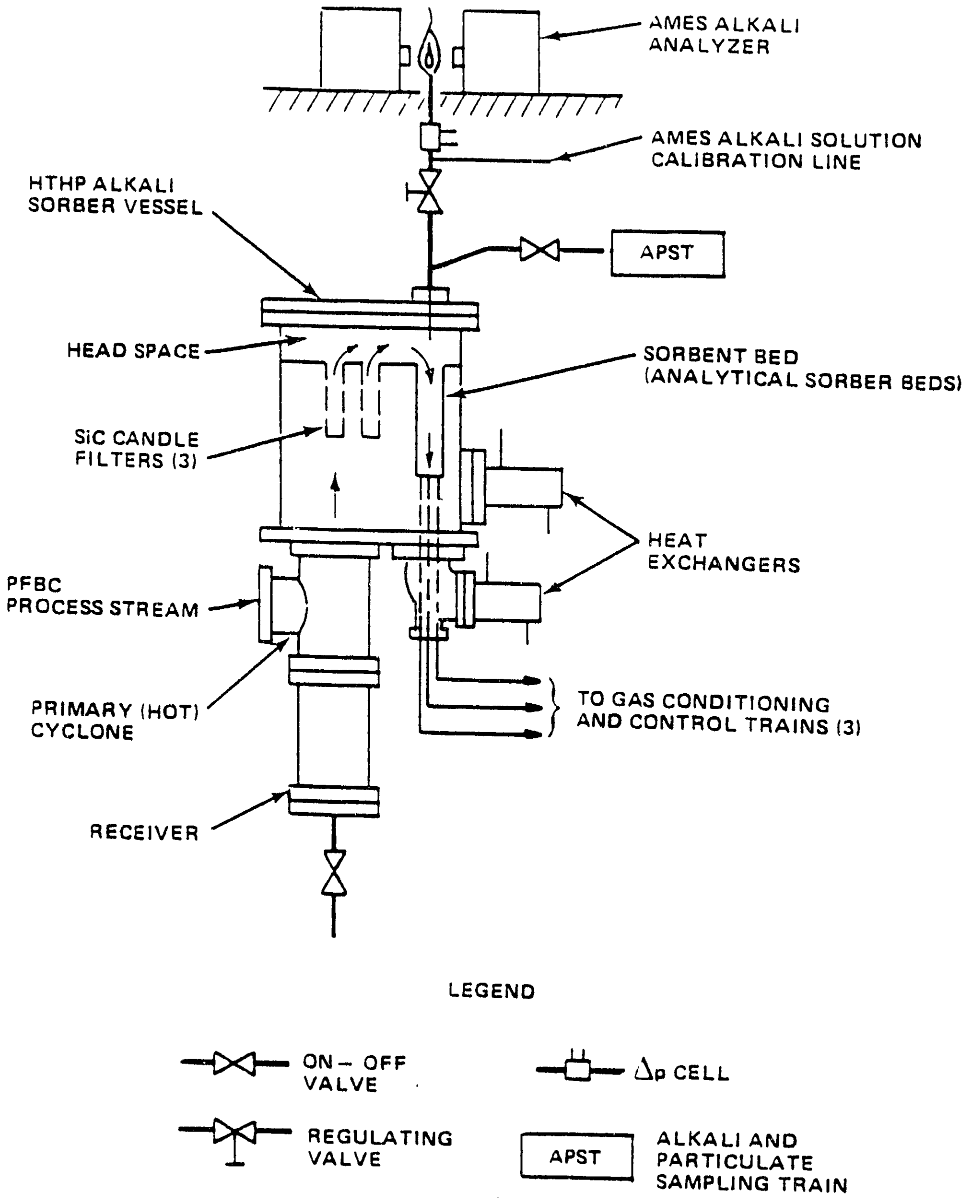


Figure 1. In Situ Sorbent Trap Used for Alkali Vapor Measurements at Argonne National Laboratory (after Lee and Carls, 1989).

temperature, while minimizing the length of sampling line. In an extractive sampling train, the sorbent trap could be mounted directly behind a heated filter that is located as close as possible to the process ducting. In this configuration, the filter, sorbent trap, and connecting pipe must be maintained at the process temperature by an external heat source. Of course, the connecting pipe should be as short as possible.

As an alternative to the sorbent trap, a condenser can be used to collect the alkali vapor. Westinghouse has developed a batch alkali sampling train that uses a condenser packed with inert beads (Newby, 1992). In the Westinghouse condenser design, the incoming gas is cooled by air that is circulated through a concentric tube assembly in the center of the packed bed of inert beads, as shown in Figure 2. The beads, which may be either glass or stainless steel, serve as sites for condensation of the alkali vapor. The used beads and their container are rinsed with deionized water to recover the collected alkali. The rinse water is then analyzed for sodium and potassium. The analysis can be done by AES or by specific-ion electrodes. The choice of analytical procedure to be used at the Wilsonville facility will depend upon the equipment that is available on site. The support laboratories at the Wilsonville coal liquefaction facility contain all of the equipment needed for AES, but this equipment is on loan from Southern Company Service's central laboratory and may not be available for use at the PSDF.

If the needed equipment is available for use at the PSDF, then the alkali analyses should be done by AES. If the AES equipment is not available, then the alkali analyses should be done by specific-ion electrode, with frequent checks by AES. If the on-site procedures using the specific-ion electrodes prove to be reliable, it may be possible to reduce or eventually eliminate the checks by AES.

Overview of Alkali Monitoring Techniques

The concentration of alkali in a gas stream may be continuously monitored by introducing a portion of the gas stream into a premixed propane-oxygen flame and measuring the intensities of the characteristic atomic emission lines of the excited sodium and potassium atoms, which emit at wavelengths of 589 nm and 766.5 nm, respectively. This is the basic principle of operation that is employed in both the Ames alkali analyzer and the fiber optic alkali monitor (FOAM). The FOAM is basically a subseqent implementation of the Ames analyzer, in which the stepper motor-driven spectrometer and photomultiplier detector are

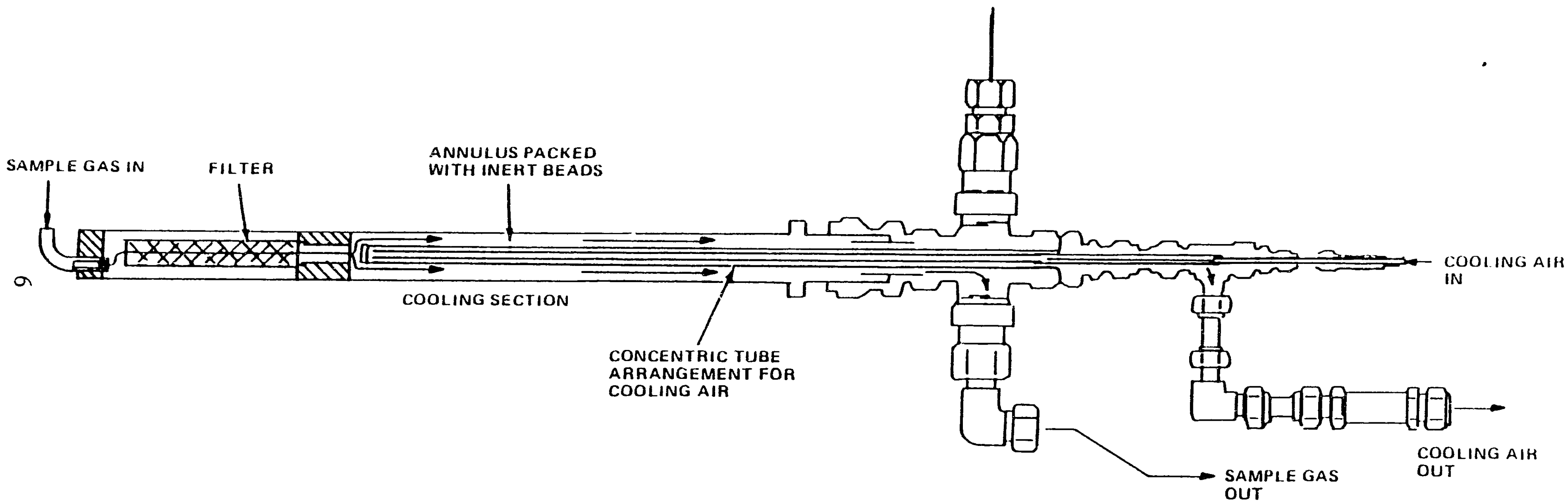


Figure 2. Alkali Sampling Probe Developed by Westinghouse (after Newby, 1992).

replaced by fiber optics, a narrow bandpass optical filter, and a photodiode detector. Both the original Ames analyzer and the FOAM require a so-called "double" sampling arrangement, as illustrated in Figure 3. This double sample arrangement is needed because the alkali monitor burner module will accept only a small portion of the total gas flow entering the sampling system. The sampling rate cannot be reduced to match the requirements of the burner module because that would make it impossiible to maintain isokinetic sampling through an appropriate sampling nozzle. The required nozzle diameter would be so small that the nozzle would be easily plugged by particulate matter.

To maintain isokinetic sampling and provide the needed flow to the burner module, the main sample stream is expanded, and a portion of the main sample stream is exhausted, as shown in the schematic drawing. The gas flow needed for the burner module is withdrawn from the expansion chamber isokinetically via a secondary sampling orifice. The secondary sample stream must be withdrawn isokinetically, since the sample is split ahead of the filter section. The filter is a porous metal thimble. The primary and secondary sampling rates are determined using calibrated orifices. The entire system is heat traced and insulated to maintain all components at the process temperature.

Ames Laboratory and ANL recently completed a comparison of alkali measurements made with the Ames alkali analyzer and with the ANL sorbent trap described earlier (Haas, et al, 1990). The sorbent trap was mounted in the tube sheet of the ANL candle filter as described earlier, and the Ames analyzer sampled from the head space above the sorbent trap. Comparative measurements were made with the ANL PFBC burning Illinois No. 6 coals from three different mines: Old Ben, Burningstar, and Wabash. At the sampling point, the gas temperature was 1560°F and the gas pressure was 135 psi. The results are summarized below.

	Measured Sodium Level, ppbw		Measured Potassium Level, ppbw	
Coal Mine	Sorbent Trap	Ames Analyzer	Sorbent Trap	Ames Analyzer
Old Ben	92	30 to 40	32	10 to 30
Burningstar	58	20 to 30	5	5 to 10
Wabash	66	30 to 60	11	15 to 40

These results suggest that the Ames analyzer tends to measure a lower level of alkali than does the sorbent trap method. Loss of alkali in the sampling line, which was about 3.3 ft

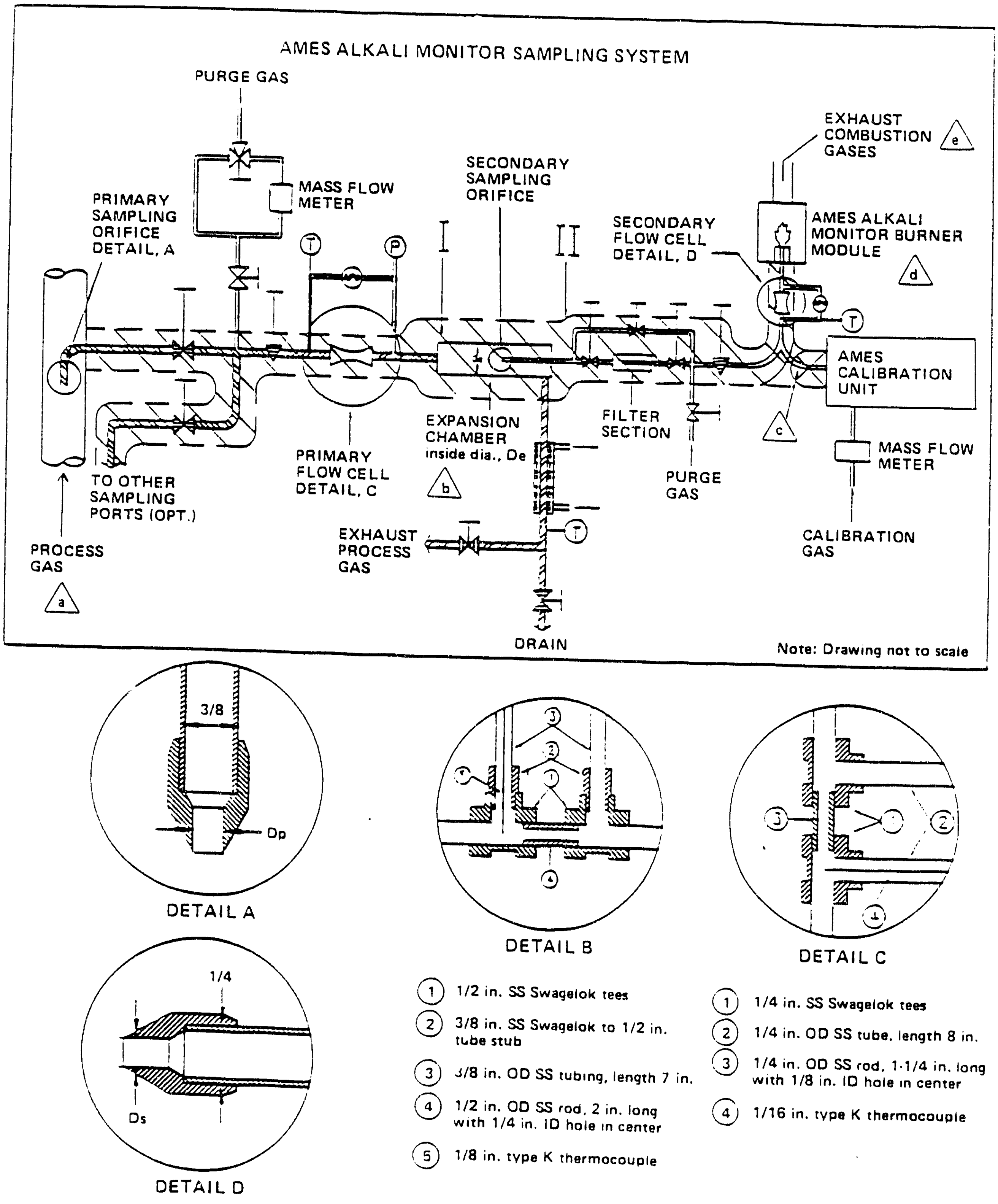


Figure 3. Double Sampling Arrangement Used with Ames Alkali Monitor (after Haas, et al, 1991).

long, is the most likely explanation. As in batch alkali sampling systems, the sampling lines for alkali monitoring systems should be as short as possible.

ALKALI SAMPLING AT WILSONVILLE

In this section, we discuss the approach to batch alkali sampling that is currently envisioned for use in the PSDF. We describe the recommended sampling locations, explain the rationale for their selection, and discuss the objectives of the sampling at each location. We have not yet selected the type of alkali vapor collector to be used, since we do not have the information needed to compare the performance of the sorbent trap to that of the condenser. To make this selection, it will be necessary to perform laboratory comparisons of the two methods during the detailed design phase of the project. The laboratory comparisons would be designed to assess the alkali capture efficiencies of the two methods under identical operating conditions. The assessment would be based upon the injection of a known amount of alkali at the probe inlet while high-temperature gas is drawn through the probe. The sorbent extract and the condenser rinse would then be analyzed by the same procedures. The amount of alkali recovered from the extract and from the rinse will then be compared to the amount of alkali injected into the probe to determine the collection efficiency of the two methods.

Similarly, it will be necessary to compare the two methods of analyzing the extract and rinse: AES and specific-ion electrode. This comparison will be based on analyses of solutions containing known amounts of sodium and potassium. The sodium and potassium concentrations measured by the two analytical procedures will be compared to the known concentration determined by the solution formulation. Based on an assumed range of alkali vapor concentrations, volume of extract or rinse, and volume of gas sampled, we will estimate the range of sodium and potassium concentrations in the extract or rinse. This range of concentrations will be duplicated in the solution formulations used to test the analytical procedures. For example, if the sodium vapor concentration ranges from 20 ppb to 20,000 ppb, the extract (or rinse) volume is 1 L, and the volume of gas sampled is 3400 L (at standard conditions), then the sodium concentration in solution would range from about 70 to 70,000 μg/mL (70 to 70,000 ppmw). Even the lowest of these concentrations is well above the sensitivity limits of both analytical methods. (The gas volume of 3400 L at standard conditions is equivalent to sampling at a rate of 1 scfm for 2 hrs.)

The evaluations of the two alkali collection techniques and the two analytical methods will be performed during the detailed design phase of the project. The manpower requirements and costs of these evaluations are included in the estimates given later in this document. Equipment costs will depend upon which collection technique and which analytical method are ultimately selected. Estimated equipment costs for the various alternatives are included later in this document.

Sampling Locations and Objectives

The recommended locations for alkali sampling are shown on the simplified process flow diagram in Figure 4. We recommend that alkali sampling be performed in conjunction with the particulate sampling that will be done at the inlet and outlet of the PCDs. At these sampling locations, the alkali sampling will be done using a sorbent trap, or condenser, that is connected to the back end of the in situ particulate sampling probe. This configuration will allow the alkali collector to be inserted into the process gas stream along with the particulate collector. A sketch of this configuration is included in the document dealing with particulate sampling. Alkali sampling at the PCD inlets is intended to quantify the alkali levels generated by the carbonizer and the PFBC. Alkali sampling at the PCD outlet will provide an indication of the amount of alkali that is lost on the ceramic filter elements in the PCDs. The loss of alkali vapor across the PCD is of interest because long-term capture of alkali vapor by filter materials alters the structure of the ceramic (Alvin, et al, 1991).

Alkali should be sampled downstream from the getter beds to assess the performance of the getter. The sample obtained at the PCD outlet will serve as an inlet sample for this assessment of the getter. If the PCD is operating properly, the particulate loading at the PCD outlet (getter inlet) should be very low ($\leq$ 20 ppmw) and there should be no need for particulate sampling at the getter outlet. Therefore, the sampling at the getter outlet will be done with a probe designed specifically for alkali sampling alone (i.e., not in conjunction with particulate sampling). The alkali sampling at the getter outlet will serve to monitor the gradual depletion of the getter and the gradual breakthrough of alkali vapor. Because of the turnaround time involved, this sampling will probably not detect a sudden breakthrough of alkali until hours after the breakthrough first occurs. Therefore, we recommend

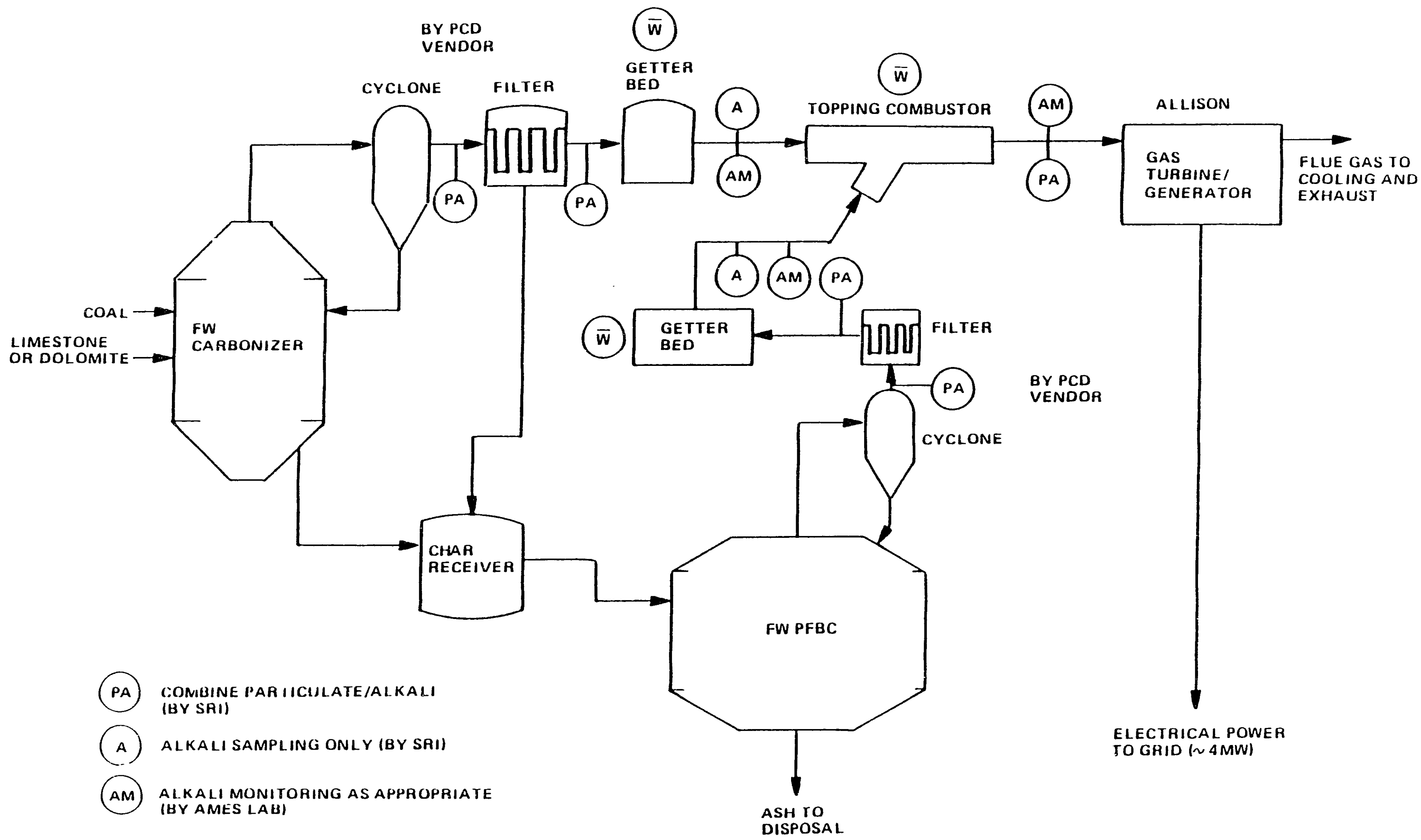


Figure 4. Simplified Process Flow Diagram of APFBC System Showing Particulate and Alkali Sampling Points.

continuous monitoring of alkali to supplement the batch sampling at the getter outlet. The continuous monitoring is discussed later in this document.

At the turbine inlet (outlet of the topping combustor), we recommend monitoring and sampling of alkali in conjunction with particulate sampling. Monitoring is necessary because even short-term excursions in alkali concentration can lead to turbine damage (Davis, 1992). Batch sampling is needed to verify long-term compliance with the particulate and alkali limits set by the turbine manufacturer.

Sampling Alkali Alone

At the locations where only alkali will be sampled (i.e., no particulate sampling will be done), we will use a sampling probe designed specifically for alkali sampling. The design of the probe will probably be similar to that of the Westinghouse probe discussed earlier, except that the condenser may be replaced with a sorbent trap. The final design will depend upon the outcome of the laboratory evaluations of the sorbent trap and the condenser. The cost of the alkali sampling probe has been estimated based on information supplied by Westinghouse. To allow simultaneous evaluation of both getters or simultaneous sampling upstream and downstream of the turbine, it will be necessary to have two of these probes. Therefore, the cost estimate assumes that two probes will be procured.

The sampling runs that are done exclusively for alkali measurement (i.e., not in conjunction with particulate measurement) will be primarily intended to evaluate the performance of the alkali getter beds. If the getter beds are performing properly (i.e., there are no channeling problems), one alkali measurement per week may be adequate to characterize getter performance and detect any gradual deterioration of the getter. As the getter is exhausted and outlet alkali levels begin to increase, it will probably be necessary to measure alkali levels more frequently. Westinghouse has indicated that the getter beds will be designed for a getter life of about six months (Newby, 1992). Since there is some uncertainty in the predicted getter life, it is reasonable to assume that the alkali levels are measured infrequently for the first five months of getter use, and then more frequently during the last month of getter use. To estimate manpower requirements, we have assumed that weekly alkali measurements are made during the first five months of getter use and that daily measurements are made during the last month of getter use. This corresponds to a total of 52 measurements over a period of six months or 208 measurements over the entire test program (mid-1994 to mid-1996).

Each alkali measurement will require about 30 minutes for probe insertion, one hour for probe heat up, two hours for the sampling run, 30 minutes for probe removal, 30 minutes for probe cool down, two hours for extraction (or rinsing) and analysis, and 30 minutes for data reduction and recording. Thus, the total time required for each measurement is about seven hours, resulting in a requirement of 1456 manhours for the 208 measurements. To allow time to become familiarized with the sampling and analytical techniques and to allow for some duplicate runs, the manhour requirement should probably be increased to about 1600 manhours.

Sampling Alkali in Conjunction with Particulate Matter

At locations where both alkali and particulate measurements are needed, we will use a sorbent trap or condenser that is incorporated into the particulate sampling probe. The backup filter on the cascade impactor or cascade cyclone assembly will serve as the particulate filter for the alkali collector. Both the particulate sampler and the alkali collector will be inserted into the process gas stream and allowed to reach process temperature before sampling is begun. The alkali collector will be an integral part of the particulate sampling probe, and it will have no effect on the probe operation. Therefore, the manpower required to operate the probe should be the same as that required to operate a probe that samples only particulate matter. The manpower required for the probe operation is described in a separate document dealing with particulate sampling and is included in the manpower requirements for particulate sampling. Therefore, these manpower requirements are not included in the estimates for alkali sampling. The manhours that need to be included here are only those required for extraction (or rinsing) of the alkali collector, analysis of the extract (or rinse), and data reduction and recording. As stated earlier, these activities should require about 2.5 hours per run.

During periods of detailed PCD evaluation, we plan to perform one particulate sampling run per shift (three runs per day). Each detailed PCD evaluation will involve at least 1000 hrs of PCD operation, and four such evaluations may be performed over the course of the project. Based on these assumptions, a total of 504 particulate sampling runs would be performed over the entire test program (mid-1994 to mid-1996). Because a trained analyst will be available only on the day shift, only one of the three daily particulate sampling runs will include alkali measurement. Therefore, we estimate that there will be 168 alkali analyses (one third of the 504 particulate samples) associated with the combined alkali and particulate sampling. At 2.5 hours per sample, these analyses should require about 420 manhours. These manhours are in addition to those required for the getter evaluations discussed earlier.

ALKALI MONITORING AT WILSONVILLE

As mentioned earlier, batch alkali sampling cannot provide the quick turnaround of results needed to protect the turbine against damage by alkali attack. Since alkali excursions of several minutes may cause turbine damage, we require continuous monitoring of the concentration of alkali entering the turbine. The monitoring may be done using the Ames alkali analyzer or the FOAM. Both of these instruments were described earlier. One criticism of these instruments is that they tend to measure low levels of alkali, primarily as a result of the loss of alkali on metal sampling lines. Typically, the concentrations measured by the Ames analyzer and the FOAM are lower by a factor of two or three than those measured using sorbent traps. While this discrepancy shows that there is a problem with accuracy, it does not suggest that the Ames analyzer or the FOAM is useless as a monitor. Extensive testing at Ames Laboratory has shown that these instruments are responsive to changes in the alkali levels in process gas streams (Eckels, 1992). Therefore, it is our opinion that alkali monitoring using the Ames analyzer or the FOAM should be included in the plans for the PSDF.

Through discussions with Ames Laboratory and with the Department of Energy (DOE), we have identified two potential approaches to alkali monitoring at the PSDF. We could procure the instruments and allow our on-site staff to operate and maintain them (after appropriate training by personnel from Ames Laboratory), or we could allow Ames Laboratory to periodically travel to the site, set up the equipment, and perform alkali monitoring on a periodic basis. The latter approach has been used on several other DOE-sponsored projects involving pilot-scale gasifiers and combustors. It is our understanding that the cost of the periodic trips by Ames Laboratory would be covered under a separate agreement between Ames and DOE. It should also be noted that the alkali monitors are quite expensive (about $250,000 each). Therefore, it is obvious that the latter option, involving the periodic monitoring trips by Ames Laboratory, would be far less expensive to the project. However, this option would not provide continuous protection of the turbine. If an alkali excursion causes damage that requires the complete replacement of the turbine blades, the cost would easily exceed the cost of an alkali monitor. Therefore, it may be short-sighted to rule out the purchase of a monitor on the basis of cost alone.

In selecting an approach to alkali monitoring, we believe that these factors should be considered:

- The carbonizer will generate alkali levels that are several orders of magnitude greater than the turbine specification.

- There is a possibility of channeling of gas through the getter bed, resulting in breakthrough of alkali to the turbine.

- The turbine supplier for the project, and several other turbine suppliers, have confirmed that the turbine's tolerance for alkali is quite low.

- The cost of the turbine is roughly 17 times the cost of an alkali monitor; the cost of complete blade replacement probably exceeds the cost of an alkali monitor.

- Commercial integrated gasification combined cycle (IGCC) and PFBC plants will probably require alkali monitoring, so there is a need to demonstrate that long-term monitoring is feasible.

- The cost of an alkali monitor is about 0.2% of the cost of the entire PSDF project.

In view of these facts, we recommend that at least one alkali monitor be included in the plans for the PSDF.

Monitoring Locations and Objectives

Potential alkali monitoring locations were shown on the simplified process flow diagram given earlier. The turbine inlet is the primary location. A dedicated monitor should be provided for that location to ensure continuous protection of the turbine. As indicated on the process flow diagram, some monitoring should also be done at the outlets of the getter beds to monitor getter deterioration with time and rapidly detect any alkali breakthrough.

Potential Approaches to Alkali Monitoring

To avoid purchasing more than one alkali monitor, the alkali monitoring that is done on the getter beds should be provided by Ames Laboratory through the direct arrangement with DOE mentioned earlier. This monitoring would be required only during the last month of getter life, when the getter is deteriorating and alkali breakthrough is most likely. Based on a getter life of six months, this approach would require the Ames personnel to be on site four times, for a month each time. At the beginning of the test program, one additional visit would be required to allow the Ames personnel to train the on-site staff in the operation and maintenance of the on-site monitor. Ames Laboratory has indicated that the costs of their trips and their monitoring would be covered under a separate arrangement between Ames and DOE. The only requirement for manpower to be provided by SRI would be for two technicians to be on site for the training by the Ames personnel. We estimate that the training would take about two weeks, corresponding to a requirement of 160 manhours for the two technicians.

Since even short-term alkali excursions may damage the turbine, interruptions of the monitoring at this location must be kept to an absolute minimum. This requirement for uninterrupted service leads us to the conclusion that on-site personnel must be responsible for the regular operation, maintenance, and calibration of the alkali monitor at the turbine inlet. To maximize the accuracy of the monitoring, a single point calibration check should be done daily, and a thorough instrument checkout and calibration should be done during each system shutdown or outage. We estimate that it takes about 30 minutes to perform a single-point calibration check, and it takes about four hours for a thorough instrument checkout and calibration. Assuming that a system shutdown or outage occurs every two months, the total time required for spot checks and detailed instrument checks would be 413 manhours.

Recommendations

Based on the foregoing discussion, we recommend the purchase of one alkali monitor to be installed at the turbine inlet. We further recommend that two technicians be trained in the operation and maintenance of the monitor, and that one technician be given responsibility for maintaining proper operation of the monitor throughout the project. To avoid the purchase of an additional monitor, we recommend that the monitoring at the outlets of the getter beds be done by Ames Laboratory. Our understanding is that this monitoring can be funded under a separate agreement between Ames and DOE.

REQUIRED MANPOWER AND ESTIMATED COSTS

This section details the manhours and costs associated with the alkali sampling and monitoring described above. The manhours and costs associated with the evaluations of the alkali collection methods and the analytical methods will be incurred during the detailed design phase of the project (Phase II). The manhours and costs associated with procurement and installation of the alkali sampling probes and installation of the alkali monitor and training in its use will be incurred during the installation phase (Phase III). The manhours and costs associated with the alkali sampling and monitoring will be incurred during the operations and testing phase (Phase IV). So that the cost breakdown will correspond to the existing project structure, the manhours and costs are broken down by phase. These manhours and costs could be placed in new subtasks that are set aside specifically for alkali sampling and monitoring, or they could be added to the manhours and budgets for the existing sampling and monitoring subtasks.

Detailed Design (Phase II), June 1992 to December 1993

During the detailed design phase, it will be necessary to select the method of alkali collection to be used (sorbent trap or condenser) and to select the analytical procedure to be used (AES or specific-ion electrode). As discussed previously, laboratory evaluations of the two alkali collection methods and the two analytical procedures will be required to make an intelligent selection. To minimize the equipment costs associated with this effort, we will attempt to borrow a sorbent trap from ANL and a sampling probe with built-in condenser from Westinghouse. It will still be necessary to fabricate a makeshift probe to be used with the sorbent trap for this testing. We estimate that 80 manhours of machine shop labor will be required for the probe fabrication. For the evaluation of the alkali collection methods, we estimate a labor requirement of 160 manhours provided by technicians and chemists. For the evaluation of the analytical methods, we estimate a labor requirement of 80 manhours provided by chemists.

During the detailed design phase, SRI will need to coordinate with SCS on the design of the ports and accesses for the alkali sampling probes and monitors. We have allowed 80 manhours of senior engineering time for this coordination. Another 80 manhours of senior engineering time should be set aside to cover the additional reporting and management associated with the new laboratory evaluations and the design coordination described above. A summary of the manhour requirements for the detailed design phase is given below.

	Manhours by Labor Classification			
Description of Work To Be Done	Engineer	Chemist	Technician	Shop
Fabricate probe				80
Evaluate alkali collection methods		80	80	
Evaluate analytical procedures		80		
Port and access design coordination	80			
Management and reporting	80			

The cost of the above work, including a nominal allowance of $2500 for materials and supplies, is estimated to be about $38,100.

Installation (Phase III), January 1993 to June 1994

During the installation phase, SRI will procure and install two batch alkali sampling probes and an alkali monitor. The final design of the alkali sampling probes will depend upon the outcome of the comparative evaluations of the sorbent trap and condenser, which were discussed earlier. Although the choice of alkali collector will have some effect on the cost of the probe, this effect should be rather small. Therefore, for cost estimating, we have used the cost that Westinghouse reported for the production of their condenser-type probes (about $50,000 per probe). For two probes, the cost would be about $100,000. For installation and initial checkout of the probes, we have assumed that two technicians would be on site for three days, resulting in a labor requirement of 48 manhours.

Based on information supplied by Ames Laboratory, the cost of an alkali monitor would be about $250,000. The installation of the monitor and the training of our on-site staff in its use would be done by Ames personnel at no cost to the project, since this would be funded under a separate agreement between Ames and DOE. However, two SRI technicians must be on site for two weeks to receive the training, resulting in a labor requirement of 160 manhours. For additional reporting and management work related to the procurement and installation of the probe and monitor, and supervision of the training, we have allocated 80 manhours of senior engineering time. A breakdown of the manhours for the installation phase (Phase III) is given below.

	Manhours by Labor Classification			
Description of Work To Be Done	Engineer	Chemist	Technician	Shop
Select and procure probes	80			
Install and check out probes			48	
Procure monitor	40			
Receive training on monitor			160	
Management and reporting	80			

The cost of the above work, exclusive of equipment costs, is estimated to be $33,000. This cost is small in comparison to the cost of the probes ($100,000) and the monitor ($250,000). The total cost of all alkali-related work and equipment purchases during this phase of the project is estimated to be $498,600.

Operations and Testing (Phase IV), June 1994 to June 1996

During the operations and testing phase, SRI will provide all batch alkali measurements as described previously. Based on weekly measurements during the first five months of getter life and daily measurements during the last month of getter life, we estimate that the sampling downstream from the getter beds will require a total of 1600 manhours, as detailed previously. This includes all of the time required for probe preparation and operation and sample recovery and analysis as previously described. For the additional alkali analyses that are required for the combined alkali/particulate sampling runs, a total of 420 manhours is estimated, as detailed previously. We estimate that 400 manhours of senior engineering time will be required to analyze the data and provide the additional project management and reporting associated with the alkali sampling.

As detailed previously, we estimate that 413 manhours will be required for spot checks and detailed checks of the alkali monitor to be performed by on-site SRI technicians. To analyze, interpret, and report the monitoring data, we have allocated 200 manhours of senior engineering time. A breakdown of manhours required for all alkali sampling and monitoring during the operations and testing phase is given below.

	Manhours by Labor Classification			
Description of Work To Be Done	Engineer	Chemist	Technician	Shop
Batch sampling & analysis of alkali alone			1600	
Alkali analysis for combined runs			420	
Spot and detailed checks on monitor			413	
Monitoring data analysis & interpretation	200			
Management and reporting	400			

The cost of the above work, including a nominal allocation of $20,000 for materials and supplies, is estimated to be $237,450.

REFERENCES

Alvin, M. A., T. E. Lippert, D. M. Bachovchin, J. E. Lane, and R. E. Tressler. *Thermal/ Chemical Stability of Ceramic Cross-Flow Filter Materials.* In Proceedings of the Eleventh Annual Gasification and Gas Stream Cleanup Systems Contractors Review Meeting, Morgantown, WV. August 1991.

Davis, H. Personal Communication to C. Kastner, Foster Wheeler Corporation (FAX dated March 13, 1992).

Eckels, D. Personal Communication to R. Dahlin, Southern Research Institute (Phone conversations on March 11 and March 16, 1992).

Haas, W. J., D. E. Eckels, S. H. D. Lee, and W. M. Swift. *Alkali Monitoring for Direct Coal-Fired Turbine Combustors.* In Proceedings of the Eighth Annual Coal-Fueled Heat Engines and Gas Stream Cleanup Systems Contractors Review Meeting, Morgantown, WV. 1991.

Lee, S. H. D. Personal Communication to R. Dahlin, Southern Research Institute (Phone conversation on March 11, 1992).

Lee, S. H. D. and E. L. Carls. *Measurement of Alkali Vapor Concentration in PFBC Flue Gas.* In Proceedings of the International Conference on Fluidized Bed Combustion, San Francisco, CA. April 1989.

Newby, R. A. Personal Communication to R. Dahlin, Southern Research Institute (Meeting at Westinghouse Science and Technology Center, Pittsburgh, March 31, 1992).

Robertson, A. Personal Communication to W. Farthing, Southern Research Institute (Letter dated September 27, 1990).

Appendix F

PCD Vendor Information and Requested Information

SOUTHERN COMPANY SERVICES, INC.
SOUTHERN RESEARCH INSTITUTE

Wilsonville Power Systems Development Facility

Particulate Control Devices

Information Needed for Extended Conceptual Design

---

1. Technical Feasibility

- Can the particulate control device (PCD) be designed so that it can be used with either the Kellogg transport reactor or the Foster Wheeler carbonizer? (The transport reactor generates 1000 acfm of flue gas or fuel gas at 1800°F and 300 psia. The carbonizer generates 1100 - 1900 acfm of fuel gas at 1800°F and 158 psia.)

- Is it just a matter of adding more candles to increase the capacity from 1000 acfm to 1900 acfm? How difficult is it to plug and unplug some of the candles to allow testing at the same face velocity with either gas flow rate?

- Is a cyclone required for good PCD performance? (The transport reactor requires one or two cyclones for recycle, but the carbonizer may not require a cyclone.) Should the cyclone be spoiled to reduce its collection efficiency or increase the size of the particles entering the PCD? (PCD vendor should include a cyclone with the carbonizer PCD, if needed.)

- What are physical dimensions and weight of the PCD that can be used with eitherthe transport reactor or the carbonizer? (Diameter and height of pressure vessel, overall height and working diameter, total weight, hopper capacity, supports)

- What are physical dimensions and weight of the PCD for the PFBC? (The PFBC will generate 7000 - 8000 acfm of flue gas at 1600°F and 138 psia.)

- How is the pressure drop projected to increase over time?

- What is the projected service life of the PCD?

- What is the projected heat loss (temperature drop)?

- How reliable are the seals between the candles and the tube sheet? What pressure differential would be required to unseat the seal?

2. Cost Information

   - Transport reactor/carbonizer PCD: capable of handling up to 1100 - 1900 acfm of fuel gas at 1800°F and 158 psia AND 1000 acfm of fuel gas or flue gas at 1800°F and 300 psia

   - PFBC PCD: capable of handling 7000 - 8000 acfm of flue gas at 1600°F and 138 psia

   - PCD vendor should also quote on a cyclone if needed for good PCD performance.

   - PCD vendor should indicate the level of proposed cost sharing.

3. Utility Information

   - Transport reactor/carbonizer PCD:

     Pulse gas (type, pressure, temperature, flow rate)
     Cooling requirements
     Electrical requirements
     Instrumentation and data acquisition requirements

   - PFBC PCD:

     Pulse gas (type, pressure, temperature, flow rate)
     Cooling requirements
     Electrical requirements
     Instrumentation and data acquisition requirements

Appendix G

SRI Summary of PCD Vendor Meetings

Southern Research Institute

April 2, 1992

GBN	JPG
DHP	RSD
WEF	RLJ
7252	FILE

Mr. Rodney E. Sears
Project Manager
Southern Company Services
P. O. Box 2625
Birmingham, Alabama 35202

Dear Rod:

I thought our recent visits to Industrial Filter and Pump (IF&P), Babcock and Wilcox (B&W), and Westinghouse were definitely worthwhile. The visits allowed us to more thoroughly explain the change in scope of the hot gas cleanup project. They also allowed us to gain a better understanding of the various particulate control devices (PCDs) being developed and to discuss certain critical issues related to PCD design, operation, and reliability.

I was encouraged by the vendors' responses to our questions concerning the PCDs for the carbonizer and transport reactor. All of the vendors agreed that it was feasible to design a PCD that would be interchangeable between the carbonizer and the transport reactor. They also agreed that it was a relatively simple matter to blank off filter elements, so that tests could be run at the same face velocity with different gas flow rates. Tom Lippert suggested the possibility of designing a PCD vessel that would accept the different types of filter elements and internals offered by the various vendors. Such a design could probably accomodate any of the candle-type elements offered by IF&P, Westinghouse, or Calvert, as well as the cross-flow elements offered by Westinghouse. The Asahi/Babcock tube-type elements would require a fundamentally different vessel design to accomodate the different internal arrangement of tubes, tube sheets, and blowback piping. Of course, the granular bed filters would also require a fundamentally different vessel design.

All of the vendors were interested in continued development and testing of advanced materials of construction. There seemed to be general agreement that the silicon carbide candles with clay binders were too susceptible to thermal shock. However, there was not a concensus on the best materials of construction for the filter elements and tube sheets. The soft ceramics being developed by IF&P appeared to offer some advantages over the conventional hard ceramic materials (mullite, cordierite, or silicon carbide). The

P.O. Box 55305 • Birmingham, Alabama 35255-5305 • (205) 581-2000 • FAX (205) 581-2726
2000 Ninth Avenue South • 35205

advantages claimed by IF&P included: lower density, better tolerance of thermal shocks, and lower cost. Westinghouse appears to have settled on mullite as the material of choice for both their candles and their cross-flow filter elements. Tom Lippert said that their testing has not shown any significant differences between mullite and cordierite. (I thought I remembered Ceramem claiming that cordierite was superior because of its lower coefficient of thermal expansion.) Tom also indicated that Westinghouse was working with 3-M and DuPont on developing other advanced materials by vapor deposition of silica into Nextel fibers or sintered fibers.

None of the vendors refused to supply a cyclone with their PCD systems, although it was apparent that none of the vendors had a good handle on the desired cyclone performance. In general, some reduction of the inlet dust loading was said to be desirable to reduce the frequency of pulse cleaning cycles. However, it was also recognized that a high-efficiency cyclone may have an adverse effect on the PCD by allowing only the very fine particles to enter the PCD. A very fine size distribution could result in excessive plugging of the pores in the ceramic filter elements. From the discussions, I inferred that the ability to vary cyclone collection efficiency, or even bypass the cyclone altogether, may be desirable.

Our discussions with Paul Eggerstedt and Tom Lippert revealed what I thought was a significant difference of opinion concerning pulse cleaning of the filter elements. Paul expressed a perference for a relatively long pulse ($\approx$ 1 sec, compared to $\approx$ 0.2 sec used by Schumacher) that was relatively low in pressure (100 to 200 psi over line pressure, compared to $\geq$ 300 psi over line pressure used by Schumacher). He said that this long, low-pressure pulse was better than a short, high-pressure pulse, because the shorter pulses did not allow enough time for the ash to clear the filter element, so that the ash that was cleaned from the top of a candle was redeposited on the bottom of the candle. Tom Lippert seemed to disagree with this argument, pointing out that the longer pulses must be heated to avoid thermal shock of the ceramic elements. He also noted that the cleaning pulses used in the Tidd candle filter are typically at 600 to 700 psi, and the pulse cleaning system is designed to go as high as 1500 psi. Paul Weitzel indicated that B&W planned to use a pulse pressure of 550 to 600 psi with the Asahi/Babcock tube filter.

There were also different points of view concerning the need for a membrane coating on the filter elements. Paul Eggerstedt noted that layered candles condition faster. He showed us graphs of pressure drop versus time that confirmed that the layered candles had lower pressure drops than the monolithic candles. Paul Weitzel implied that Asahi had shown that the submicron ceramic membrane coating that they use on their filter tubes greatly reduced or eliminated the conditioning period. Tom Lippert implied that a membrane coating was an unnecessary expense. He suggested that an uncoated candle would become conditioned with ash, and the conditioned layer would act as a membrane.

Other issues that were discussed during our visits included: the need to address scale-up issues (e.g., the number of elements that can be cleaned with a single pulse); the need to address interfaces between the PCDs and other systems so as to minimize "finger-pointing;" the need for baffles in the PCD vessel to improve flow distribution; the need for "post-mortem" analysis of filter elements to assess structural changes and failure modes; the need to minimize the temperature drop across the PCD; the possibility of sorbent injection ahead of the PCDs to adsorb alkali vapor; and the possibility of using the Tidd candle filter on the pressurized fluidized-bed combustor (PFBC) at Wilsonville. Tom Lippert said that the Tidd candle filter would be available by the first quarter of 1994, and it would be the right size for the Foster Wheeler PFBC. The Tidd filter vessel contains 400 candles. Modeling done by Westinghouse suggested that the complete breakage of two of the Tidd candles would result in particulate emissions that exceeded New Source Performance Standards. We agreed that Southern Company should talk to DOE about the possibility of using the Tidd filter on the PFBC at Wilsonville.

The vendors requested information on the dust loadings and particle sizes emitted by the Foster Wheeler carbonizer and PFBC. We informed the vendors that Foster Wheeler had no information on dust loadings or particles sizes, because they have not yet made any such measurements in their pilot plant. We told the vendors to base their budgetary cost estimates on reasonable assumptions concerning the dust loadings and the particle sizes. We noted that the data on dust loadings and particle sizes would be included in the formal request for proposals (RFP) to be issued this summer. None of the vendors objected to that approach.

I believe I have covered all of the significant issues that we addressed with the PCD vendors. I hope these observations prove helpful.

Thank you for the opportunity to accompany you on the vendor visits, and I look forward to our discussions with Calvert and Combustion Power.

Sincerely,

Bob

Robert S. Dahlin, Ph.D., P.E.
Manager, Advanced Particulate Control Program

Project 7252

Reactor ID = 10"
Reactor exit temperature = 1800°F
Reactor pressure = 325 PSIA

	Coal Flow (#/HR)	Gas Flow (Moles/HR)	Reactor Gas Velocity (FPS)	PCD Inlet P (PSIA)
GASIFICATION				
PCD T				
1000°F	3876	742	28.2	194
1800°F	3876	742	28.2	300
COMBUSTION				
PCD T				
1000°F	2920	1149	43.7	300
1800°F	1886	742	28.2	300

NOTE: FLOWS ARE APPROXIMATE, BASED ON REACTOR SIMULATION CALCULATIONS AS OF 8/7/91

Gas Stream Composition:

Component, vol.%	Gasification	Combustion
H2	12.75	0.00
CO	16.77	0.07
CO2	8.89	15.99
CH4	0.48	0.00
O2	0.00	1.95
N2	51.30	74.88
C2-compounds	0.00	0.00
C3-compounds	0.00	0.00
C4-compounds	0.03	0.00
H2O	9.74	6.95
SO2	0.00	33 ppm
H2S	0.02	0.00
COS	0.00	0.00
NOx	0.00	0.16
NH3	0.01	0.00
HCN	0.02	0.00

Particulate Loadings, ppm by wt.
Minimum
Maximum

4. Steam to Gas Generator:

Pressure = 400 psig
Temperature = (saturated)

5. Air to Gas Generator:

Ambient Air Properties (Design Values)

	Summer	Winter
Temperature	95°F	10°F
Elev. (ft. msl)	475	
Relative Humidity	48%	
Humidity Ratio (lb/lb)	0.017	
Mol. Wt. (wet)	28.80	
Mol. Wt. (dry)	28.98	

Feed Properties
Pressure =
Temperature =
Moisture Content =

6. Transport Gas to Gas Generator:

Pressure = 350 psig
Temperature = Maximum (Compressor Discharge w/ No Aftercooler)
Moisture Content = 5.61 vol %
Dew Point = 230°F

7. Cyclones:

- o Number of Cyclones
  Two low-efficiency cyclones
  One high-efficiency cyclone

- o Ash Removal

8. Gas Generator Startup:

The gas generator will utilize a startup burner to heat the reactor to certain temperature prior to feeding coal. The fuel for the startup burner will be natural gas or LPG. Approximate duty: $1x10^6$ BTU/HR

9. Flare:

A flare will be required for startup of the system and during process upset. The fuel for the flare will be LPG or natural gas. Investigate the feasibility of sizing the flare for use by AREA 200A and 200B.

10. High Temperature Gas Cooler:

- Cooling Duty
  Highest inlet temperature = 1900°F
  Lowest inlet temperature = 1000°F

  Highest outlet temperature = 1800°F
  Lowest outlet temperature = 1000°F

- Special Requirements

Need to be able to control for any temperature spikes in the gas particularly during combustion. May need to partially quench the gas to protect the particulate control devices from temperature surges. Evaluate N2 and steam.

11. Control and Data Acquisition Requirements: All control will be by the DCS. All monitored points will be recorded by the DAS.

12. Utilities:

- Electrical
- Nitrogen (purge)
- LPG or natural gas fuel for gas generator startup burner and flare ($1x10^6$ BTU/HR required for startup)
- Plant air and control air
- Service water for equipment cooling
- Fire protection

13. Electrical:

Voltages: 4160/3/60
480/3/60
240/1/60
120/1/60

Motor Loads:

DESCRIPTION	HP
Air Compressor	3000
Booster Compressor	15
Coal Feeder	1
Limestone Feeder	1/2

14. Comments:

- o Pressure relief at gas generator outlet.
- o Dry solids feed vs slurry solid feed needs to be addressed.
- o Cyclones need to be connected in a variety of configurations to produce a wide range of particulate loadings.
- o Method of ash draw down from gas generator needs to be addressed.
- o Design and operation of the flare system.

15. Conceptual Design Requirements:

- o Description of process
- o Process flow diagrams
- o Size equipment
- o List of equipment/materials
- o Preliminary P&IDs
- o List of instrumentation
- o Estimated cost
- o Delivery dates

AREA 200B ADVANCED PFBC

1. **Description:** The process system necessary for producing the hot gas streams to 400B. This includes the carbonizer, CPFBC, char transfer system, fluid bed heat exchanger, coal and limestone lock hopper system or slurry feed system for the coal, start-up burners, cyclones, piping, supports, controls, electrical power equipment, raceways, and grounding. All lined pipe up stream of the topping combustor. Also, included in this area is all equipment required to cool, depressurize and transport the ash from Area 200B and 300B to the designated interface point with AREA 800B. Equipment layout drawings.

2. **Area Interface Points:**

   o Coal and limestone (AREA 100) to feed lock hopper or surge bin.
   o High pressure hot gas to PCD (AREA 300B)
   o Ash from Area 300B
   o Air from Area 400B
   o Ash to Area 800B
   o Utilities (AREA 2000)
   o Instrumentation and Data Acquisition (AREA 1000)
   o Electrical (AREA 3000)

3. **Design Interface:**

Lead: FW
Interface: FW will design the complete gas generator process and will provide all layout and detail drawings regardless of system within the physical boundary of the process structure. Piping interfaces for coal, limestone, ash and utilities will be identified on drawings at structure boundaries. Electrical interfaces will also be identified at structure boundaries.

SCS is responsible for design of structure and foundations based on FW layouts. Control and data acquisition (AREA 1000) is the responsibility of SCS, but required equipment and instrumentation within the structure boundaries is the responsibility of FW.

4. Gas Generator Output:

BASIS: Supply Gas to fully load Allison 501 Gas Turbine

Gas Stream Composition:

Source	Carbonizer	PFBC
Component, vol.%		
H_2		
CO		
CO_2		
CH_4		
O_2		
N_2		
C2-compounds		
C3-compounds		
C4-compounds		
H_2O		
SO_2		
H_2S		
COS		
NOx		
NH_3		
HCN		

Particulate Loadings, ppm by wt.

	Minimum	Maximum
To Cyclones:		
Carbonizer		
CPFBC		
To PCDs		
Carbonizer		
CPFBC		
To Topping Combustor		

5. Ash Production:

- Operating basis: maximum continuous ash production rate and conditions;

Production Rate	Density	Temperature
1,766 lb/hr		300°F

6. **Air from Area 400B**

Specify conditions for all air streams entering area 200B

Pressure =
Temperature =

7. **Gas Generator Startup:**

8. **Flare:** See Gas Generator section for gas composition to the flare. The gas to the flare would be from the carbonizer.
Also specify conditions here.

9. **Control and Data Acquisition Requirements:** All control will be by the DCS. All monitored points will be recorded by the DAS.

10. **Utilities:**
    - o Electrical
    - o Nitrogen (purge)
    - o Natural Gas or LPG fuel for gas generator startup burner and flare ($1x10^6$ BTU/HR required for startup)
    - o Plant air and control air
    - o Service water for equipment cooling
    - o Fire protection

11. **Electrical:**

Voltages: 4160/3/60
480/3/60
240/1/60
120/1/60

Motor Loads:

DESCRIPTION	HP

12. **Comments:**

- o Design and operation of the flare system.

13. **Conceptual Design Requirements:**

- o Description of process
- o Process flow diagrams
- o Size equipment
- o List of equipment/materials
- o Preliminary P&IDs
- o List of instrumentation

- o Estimated cost
- o Delivery dates

AREA 300A PARTICULATE CONTROL DEVICES FOR TRANSPORT

1. **Description:** This area includes the particulate control devices (PCD) to be tested with the Transport Reactor. the feasibility to change PCDs between AREA 300A and 300B should be evaluated. The PCDs will be procured and installed as a complete system.

2. **Interface Points:**
   - o Gas stream from Gas Generator (AREA 200A)
   - o Gas stream to Gas Cooling & Treatment (AREA 400A)
   - o PCD Pressure vessel bottom flange to Ash Handling (AREA 500A)
   - o Blowback gas from Area 400A to PCD
   - o Cooling water/steam from Area 400A.
   - o Instrumentation and Data Acquisition (AREA 1000)
   - o Utilities (AREA 2000)
   - o Electrical (AREA 3000)

3. **Design Interface:**

Lead: SCS (R&EA)
Interface: Procurement and/or contractual agreements with PCD vendors is the responsibility of SCS Research and Environmental Affairs (R&EA). Vendor documentation is received by SCS Engineering and transmitted to MWK and other team members in accordance with established correspondence procedures.

Detail and layout drawings required for the installation of the PCD devices will be the responsibility of MWK. Piping, electrical, and I&C interfaces will be identified at structure boundaries. Structural support detail drawings are the responsibility of SCS based on layouts provided by MWK.

4. **P^D Characteristics:**

   See attached summary.

5. **Control and Data Acquisition Requirements:**
   - o Inlet and outlet temperature to data acquisition system (DAS).
   - o Inlet and outlet pressure to (DAS).
   - o Control will be by Distributed Control System (DCS).

6. **Utilities:**

   Electrical
   - Nitrogen for blowback gas and purging
   - Air for blow back gas
   - Service water
   - Fire protection
   - Plant air

7. Electrical:

Voltages: 480/3/60
240/1/60
120/1/60

Loads:

8. Comments:

- o Need to provide continuous ash draw down from bottom of PCD.
- o Need to provide separate area for working on PCD internals outside of the pressure vessel.
- o Need to provide lifting mechanism for maintenance of PCD or access by crane.

9. Conceptual Design Requirements:

- o Description of process
- o Process flow diagrams
- o Size equipment
- o List of equipment/materials
- o Preliminary P&IDs
- o List of instrumentation
- o Estimated cost
- o Delivery dates

AREA 300B PARTICULATE CONTROL DEVICES FOR ADVANCED PFBC

1. **Description:** This area includes the particulate control devices (PCD) to be tested with the advanced PFBC. Separate PCDs will be used for the carbonizer and the combustor. The feasibility to change PCDs between AREA 300A and 300B should be evaluated. The PCDs will be procured and installed as a complete system. Unlike Area 300A, the cyclones may be procured as part of the PCD package. However, FW will estimate the cyclone cost for the conceptual design.

2. **Interface Points:**

   - o Gas stream from Gas Generators (AREA 200B)
   - o Gas stream to Turbine (AREA 400B)
   - o Ash to AREA 200B
   - o Instrumentation and Data Acquisition (AREA 1000)
   - o Utilities (AREA 2000)
     Assumed that blowback gas will be nitrogen from AREA 2600A
     Also assumed that any quench up stream of PCDs would use nitrogen
   - o Electrical (AREA 3000)

3. **Design Interface:**

Lead: SCS (R&EA)
Interface: Procurement and/or contractual agreements with PCD vendors is the responsibility of SCS Research and Environmental Affairs (R&EA). Vendor documentation is received by SCS Engineering and transmitted to other team members in accordance with established correspondence procedures.

Detail and layout drawings required for the installation of the PCD devices will be the responsibility of FW. Piping, electrical, and I&C interfaces will be identified at structure boundaries. Structural support detail drawings are the responsibility of SCS based on layouts provided by FW.

4. **PCD Characteristics:**

   See attached summary.

5. **Control and Data Acquisition Requirements:**

   - o Inlet and outlet temperature to data acquisition system (DAS).
   - o Inlet and outlet pressure to (DAS).
   - o Control will be by Distributed Control System (DCS).

6. **Utilities:**

Electrical
Nitrogen for blowback gas and purging
Air for blow back gas
Service water
Fire protection
Plant air

7. **Electrical:**

Voltages: 480/3/60
240/1/60
120/1/60

Loads:

8. **Comments:**

- o Need to provide continuous ash draw down from bottom of PCD.
- o Need to provide separate area for working on PCD internals outside of the pressure vessel.
- o Need to provide lifting mechanism for maintenance of PCD or access by crane.

9. **Conceptual Design Requirements:**

- o Description of process
- o Process flow diagrams
- o Size equipment
- o List of equipment/materials
- o Preliminary P&IDs
- o List of instrumentation
- o Estimated cost
- o Delivery dates

AREA 400A GAS COOLING AND TREATMENT

1. **Description:** Includes all gas stream components from the outlet of the PCD's in Area 300A to inlet of the thermal oxidizer in Area 700. This includes gas coolers, blowback compressor and surge drum, pressure letdown valve, gas stream piping, ductwork, supports, controls, electrical power equipment, raceways, and grounding. This area also includes the process steam system which is comprised of the steam drum and piping system required for the fluid bed cooler, fluid bed boiler, and all gas coolers.

2. **Area Interface Points:**

   - o Gas from PCD's (AREA 300A)
   - o Blowback gas to PCD (AREA 300A)
   - o Transport gas to AREA 200A
   - o Saturated liquid from steam drum to primary gas cooler, fluid bed cooler, and fluid bed boiler at AREA 200A
   - o Steam from drum to gasifier (AREA 200A)
   - o Utilities (AREA 2000)
   - o Instrumentation and Data Acquisition (AREA 1000)
   - o Electrical (AREA 3000)

3. **Design Interface:**

Lead: MWK
Interface: The process steam system which includes the steam drum and all steam piping within the confines of the process structure is the responsibility of MWK. The utility system (AREA 2000) is the responsibility of SCS and includes the condensate and makeup for the drum. Piping for Area 400A within the confines of the structure is the responsibility of MWK regardless of system. Interface connections will be identified at structure boundaries. Similarly, physical electrical and I&C interfaces will also be identified at structure boundaries.

4. **Gas Stream Conditions:**

Operating Mode	Gasification	Combustion
Gas Temp. out of PCD		
Minimum, °F	1000	1000
Maximum, °F	1750	1600
Gas Composition, vol%		
H_2	________	________
CO	________	________
CO_2	________	________
CH_4	________	________

	Gasification	Combustion
O_2	________	________
N_2	________	________
C_2-compounds	________	________
C_3-compounds	________	________
C_4-compounds	________	________
H_2O	________	________
SO_2	________	________
H_2S	________	________
COS	________	________
NOx	________	________
NH_3	________	________
HCL	________	________
MW	________	________
Specific Heat	________	________

Operating Mode	Gasification	Combustion
Particulate Loadings, ppm by wt.		
Minimum	________	________
Maximum	________	________

Gas Pressure out of PCD, psig
Letdown Pressure, psig

5. **High Pressure Gas Cooler:**

o Cooling Duty

Maximum outlet temperature equal to maximum temperature for pressure letdown valve =

Minimum outlet temperature = 500°F

6. **Recycle Gas to Gas Generator:**

Pressure = 350 psig (transport); 600 psig (blowback)

Temperature =

7. **Utilities**

o Condensate and Feedwater System to receive medium pressure steam from the steam drum, condense it, and resupply the condensate as boiler feedwater.
Quantity: 60,000 lbm/hr @ 450 psig (saturated) from drum to Utility System. Return to drum as condensate at approximately 150°F. Drum pressure: 450 psig

- o Makeup to steam drum.
  Quantity: 3000 lbm/hr (Controlling case: Gasification = 2400 pph + 1% Blowdown)
- o Wastewater treatment for receiving blowdown from drum.
  Quantity: 600 lbm/hr
- o Plant air
- o Service water
- o Fire protection
- o Electrical
- o Nitrogen for purge
- o Quench water for cooling gas stream

8. Electrical

Voltages: 480/3/60
240/1/60
120/1/60

Loads:

9. Comments

- o Pressure letdown valve for high temperature, particulate laden gas stream needs to be addressed.
- o Provide a maintenance vent header.
- o Design system to avoid release of CO and VOC.

- o CEM standard for power plants will apply.

10. Conceptual Design Requirements:

- o Description of process
- o Process flow diagrams
- o Size equipment
- o List of equipment/materials
- o Preliminary P&IDs
- o List of instrumentation
- o Estimated cost
- o Delivery dates

AREA 400B GAS TURBINE

1. **Description:** Includes the combustor, turbine, compressor, generator and all associated equipment. Interface points include the inlet of the topping combustor (Area 300B) and the exhaust gas to area 700. The interface point to Area 700 is the inlet of the gas cooler. This includes controls, electrical power equipment, raceways, and grounding. A steam turbine will not be included in the facility; therefore, any steam generated due to cooling requirements will be sent to AREA 2000, if it is not needed for the process.

2. **Area Interface Points:**

   - Gas from PCD's (AREA 300B)
   - Air to Area 200B
   - Turbine Exhaust to Area 700
   - Utilities (AREA 2000)
   - Instrumentation and Data Acquisition (AREA 1000)
   - Electrical (AREA 3000)

3. **Design Interface:**

Lead: FW/Westinghouse/Allison
Interface: Any heat exchangers within the combustor/turbine/compressor and the associated piping within the structure is the responsibility of FW. The utility system (AREA 2000) is the responsibility of SCS and includes any condensate and makeup required for a steam system and steam for startup of the combustor on natural gas or LPG. Piping within the confines of the combustor/turbine/compressor area is the responsibility of the FW design team regardless of system. Interface connections will be identified at structure boundaries. Similarly, physical electrical and I&C interfaces will also be identified at structure boundaries.

4. **Gas to Combustor**

Source	Carbonizer	Combustor
Gas Temp. out of PCD		
Minimum, °F		
Maximum, °F		
Gas Pressure, psig		
Gas Composition, vol%		
H_2		
CO		
CO_2		
CH_4		
O_2		

N_2	______	______
C_2-compounds	______	______
C_3-compounds	______	______
C_4-compounds	______	______
H_2O	______	______
SO_2	______	______
H_2S	______	______
COS	______	______
NOx	______	______
NH_3	______	______
HCL	______	______
MW	______	______
Specific Heat	______	______

Source	Carbonizer	Combustor
Particulate Loadings, ppm by wt.		
Minimum	______	______
Maximum	______	______

Air to Compressor

Ambient Air Properties (Design Values)

	Summer	Winter
Temperature	95°F	10°F
Elev. (ft. msl)	475	
Relative Humidity	48%	
Humidity Ratio (lb/lb)	0.017	
Mol. Wt. (wet)	28.80	
Mol. Wt. (dry)	28.98	

Required air Streams:

	Carbonizer	CFBC	Transport AIR	Topping Combustor
Pressure				
Temperature				
Moisture Content				

5. Utilities

- o Condensate and Feedwater System
- o Makeup water
- o Wastewater treatment for receiving blowdown.
- o Plant air

- Service water
- Fire protection
- Electrical
- Nitrogen for purge
- Quench water for cooling gas stream

6. Electrical

Voltages: 480/3/60
240/1/60
120/1/60

Loads:

7. Comments

- CEM standard for power plants will apply.

8. Conceptual Design Requirements:

Description of process
- Process flow diagrams
- Size equipment
- List of equipment/materials
- Preliminary P&IDs
- List of instrumentation
- Estimated cost
- Delivery dates

AREA 500A ASH HANDLING

1. **Description:** Includes all equipment required to cool, depressurize and transport the ash form AREAS 200A, 300A, and 600A to the designated interface point with AREA 800A. This includes all electrical power equipment, controls, raceways, and grounding.

2. **Area Interface Points:**

    - o Gas generator (AREA 200A) spent solids
    - o PCD hopper (AREA 300A)
    - o Cyclone bottoms (AREA 200A)
    - o Ash to/from Sulfator (AREA 600)
    - o Utilities (AREA 2000)
    - o Instrumentation and Data Acquisition (AREA 1000) (Alarms only)
    - o Electrical (AREA 3000)

3. **Design Interface:**

Lead: MWK
Interface: MWK will be responsible for ash depressurization and transport to sulfator and spent solids collection hoppers.

4. **Ash Production:**

    - o Operating basis: maximum continuous ash production rate and conditions;

	Production Rate	Density	Temperature
Gasification	757 lb/hr	54 lb/ft3	150°F
Combustion	590 lb/hr	54 lb/ft3	600°F

5. **Control and Data Acquisition Requirements:** Control will be local and independent. Alarms will be sent to the DCS in the main control room. The DCS will also have an Emergency Stop function.

6. **Utilities:**
    - o Electrical
    - o Nitrogen (purge)
    - o Service/Instrument Air
    - o Service water

7. **Electrical:**

Voltages: 480/3/60
240/1/60
120/1/60

Loads:

Description	Load (HP)

8. **Comments:**

9. **Conceptual Design Requirements:**

- o Description of process
- o Size equipment
- o List of equipment/materials
- o Estimated cost
- o Delivery dates
- o Preliminary P&ID

AREA 600A SULFATOR

1. **Description:** This area contains a sulfator in the event that the limestone and ash mixture (LASH) from the gas generator during gasification operation needs to be treated to reduce the quantity of sulfides prior to disposal. Included are all the necessary equipment required to properly oxidize the sulfides to sulfate in the limestone and ash mixture, and heat exchangers to cool the gas to the temperature required in Area 700.

2. **Area Interface Points:**

   - o Limestone and ash from gas generator (AREA 200A)
   - o PCD ash from AREA 300A (gasification mode only)
   - o Flue gas from sulfator to Area 700
   - o Limestone and ash from/to ash handling system (AREA 500A).
   - o Makeup limestone from AREA 100
   - o Instrumentation and Data Acquisition (AREA 1000)
   - o Utilities (AREA 2000)
   - o Electrical (AREA 3000)

3. **Design Interface:**

Lead: MWK
Interface: MWK will design the complete sulfator process and will provide all layout and detail drawings regardless of system within the physical boundary of the process structure. Piping interfaces for limestone and utilities will be identified on drawings at structure boundaries. Electrical interfaces will also be identified at structure boundaries.

SCS is responsible for design of structure and foundations based on MWK layouts. Control and data acquisition (AREA 1000) is the responsibility of SCS, but required equipment and instrumentation within the structure boundaries is the responsibility of MWK.

4. **Gas Generator Spent Limestone and Ash Characteristics:**

Mode	Gasif.
Lash temp., °F	
______	
Lash Composition (wt%)	
carbon	______
flyash	______
calcium sulfate	______
calcium oxide	______

calcium sulfide ______

Particle size distribution ______

Bulk density lb/ft3 ______

5. **Control and Data Acquisition Requirements:** Control will be by the DCS in the main control room.

6. **Utilities:**
Electrical
   - Service Water
   - Auxiliary Fuel for startup
   - Plant/control air
   - Fire protection

7. **Electrical:**

Voltages: 480/3/60
240/1/60
120/1/60

Loads:

8. **Comments:**

9. **Conceptual Design Requirements:**

- o Description of process
- o Size equipment
- o List of equipment/materials
- o Preliminary P&ID
- o Estimated cost
- o Delivery dates

AREA 700 GAS COOLING AND TREATMENT

1. **Description:** Includes all equipment for final processing of the gas from areas 400A, 400B and 600A. The gas from Area 400A will be at conditions suitable for feed to a thermal oxidizer. The gas from Area 600A will be at conditions suitable for feed to the baghouse and discharge from the stack. The gas from Area 400B will require cooling prior to discharge at the stack. Equipment in this area will include: thermal oxidizer, final gas cleanup devices (sorbent injection system and baghouse), stack, gas stream piping, ductwork, supports, environmental air quality compliance monitoring equipment, controls, electrical power equipment, raceways, and grounding.

2. **Area Interface Points:**

   - o Gas from AREAS 400A and 400B
   - o Ash from final gas cleanup device to AREA 800A
   - o Flue gas from sulfator (AREA 600A)
   - o Instrumentation and Data Acquisition (AREA 1000)
   - o Electrical (AREA 3000)

3. **Design Interface:**

Lead: MWK for thermal oxidizer and SCS for balance of area
Interface: MWK is responsible for design up to and including the thermal oxidizer.

Interface connections will be identified at structure boundaries. Similarly, physical electrical and I&C interfaces will also be identified at structure boundaries.

4. **Gas Stream Conditions to Area 700:**

Source	Gasification from Transport	Combustion from Transport	PFBC from AREA 400B
Gas Temp. to Area 700			
Minimum, °F	1000	1000	
Maximum, oF	1750	1600	
Gas Composition, vol%			
H2			
CO_2			
CH_4			
O_2			
N_2			
C_2-compounds			
C_3-compounds			
C_4-compounds			

H_2O
SO_2
H_2S
COS
NOx
NH_3
HCL
MW
Specific Heat

Particulate Loadings,
ppm by wt.
Minimum
Maximum

Gas Pressure, psig

5. Thermal Oxidizer:

- o Fuel - LPG or natural gas
- o Ambient Air Properties (Design Values)

<u>Summer</u>	<u>Winter</u>
Temperature	95°F 10°F
Elev. (ft. msl)	475
Relative Humidity	48%
Humidity Ratio (lb/lb)	0.017
Mol. Wt. (wet)	28.80
Mol. Wt. (dry)	28.98

- o Gas Stream Heating Value =
- o Thermal Oxidizer Heat Exchanger Duty

Maximum Inlet Temperature =

Minimum Outlet Temperature = 300°F

6. Baghouse Ash Production:

Transport Reactor:
PCD

Operations Mode	Normal Gasif.	Normal Comb.	Out-of-service Gasif.	Out-of-service Comb.
Part. loading in gas stream, ppmw	____	____	2000	2000
Ash Prod., lb/hr	____	____	____	____

Advanced PFBC:

Part. loading in gas stream, ppmw

Ash Prod., lb/hr

7. Baghouse Ash Characteristics:

Mode	Gasif.	Comb.
Ash temp., oF	____	____
Ash Composition (wt%)		
carbon	____	____
flyash	____	____
calcium sulfate	____	____
calcium oxide	____	____
calcium sulfide	____	____
Particle size distribution	____	____
Bulk density lb/ft3	____	____

8. **Duct Sorbent Injection:**

	Transport Gasification	Transport Combustion	Advanced PFBC
Gas Composition, vol.%			
H_2			
CO			
CO_2			
CH_4			
O_2			
N_2			
C_2-compounds			
C_3-compounds			
C_4-compounds			
H_2O			
SO_2			
H_2S			
COS			
NO_x			
MW			
Specific Heat			

9. **Control and Data Acquisition Requirements:** Control will be by DCS. All monitored points will be recorded by the DAS.

10. **Utilities**

- Auxiliary fuel (LPG or natural gas) for thermal oxidizer.
- Plant air
- Service water
- Fire protection
- Electrical
- Nitrogen for purge
- Blowback air for baghouse
- Quench water for cooling gas stream
- Sorbent injection air

11. **Electrical**

Voltages: 480/3/60
240/1/60
120/1/60

Loads:

12. Comments

- Provide a maintenance vent header.
- Design system to avoid release of CO and VOC.
- All bins should be mass flow bins with flow inducers, such as live bottoms or vibrators. Design for minimum stoppage.
- Design of duct injection sorbent feed system needs to be addressed.
- CEM standard for power plants will apply.
- Potential for baghouse fire should be addressed.

13. Conceptual Design Requirements:

- Description of process
- Process flow diagrams
- Size equipment
- List of equipment/materials
- Preliminary P&IDs
- List of instrumentation
- Estimated cost
- Delivery dates

AREA 800A ASH HANDLING

1. **Description:** Includes equipment required for transport of the ash from interface points with AREAS 500A and 700 to the final disposal location. The ash product will be conveyed from the pick-up points to a storage silo where it will be loaded out to dump trucks for off-site disposal. This includes all piping and valves, ash silo, solids transfer blower, feeders, dust control, load out facilities, pipe supports, support steel, foundations, electrical power equipment, controls,raceways, and grounding.

2. **Area Interface Points:**

   - Spent solids receiver from AREA 500A
   - Baghouse bottoms (AREA 700)
   - Utilities (AREA 2000)
   - Instrumentation and Data Acquisition (AREA 1000) (Alarms only)
   - Electrical (AREA 3000)

3. **Design Interface:**

Lead: SCS
Interface: SCS will be responsible for transport from baghouse hoppers, spent solids receiver outlet flanges to final disposal site.

4. **Ash Production:**

   - Operating basis: maximum continuous ash production rate and conditions;

	Production Rate	Density	Temperature
Gasification	757 lb/hr	54 lb/ft3	150°F
Combustion	590 lb/hr	54 lb/ft3	600°F

5. **Ash Storage:**

   - Provide for 88 hours storage at a design ash production rate of 757 lb/hr.

   - Truck loading station under the storage silo with provisions for dust control during truck loading operations.

   - Provide for inert blanket for storage silo to prevent caking of ash from atmospheric moisture.

6. **Control and Data Acquisition Requirements:** Control will be local and independent. Alarms will be sent to the DCS in the main control room. The DCS will also have an Emergency Stop function.

7. Utilities:

- o Electrical
- o Nitrogen (purge)
- o Service/Instrument Air
- o Service water

8. Electrical:

Voltages: 480/3/60
240/1/60
120/1/60

Loads:

Description	Load (HP)	
Vacuum pump	20	
Aeration Blower	5	Ash
Conditioner	10	Dry
Unloader Vent Fan	2	Dry
Unloader Hoist	2	

9. Comments:

- o All bins should be mass flow bins with flow inducers, such as live bottoms, vibrators, and/or aeration. Design for minimum stoppage.

10. Conceptual Design Requirements:

- o Description of process (include pug mill for ash conditioning)
- o Size equipment
- o List of equipment/materials
- o Estimated cost
- o Delivery dates
- o Preliminary P&ID

AREA 800B ASH HANDLING

1. **Description:** Ir..des equipment required for transport of the ash from interface points with AREA 200B to the final disposal location. The ash product will be conveyed from the pick-up points to a storage silo where it will be loaded out to dump trucks for off-site disposal. This includes all piping and valves, ash silo, solids transfer blower, feeders, dust control, load out facilities, pipe supports, support steel, foundations, electrical power equipment, controls,raceways, and grounding.

2. **Area Interface Points:**

   - Spent solids receiver in AREA 200B
   - Utilities (AREA 2000)
   - Instrumentation and Data Acquisition (AREA 1000) (Alarms only)
   - Electrical (AREA 3000)

3. **Design Interface:**

Lead: SCS
Interface: SCS will be responsible for transport from spent solids receiver outlet flanges to final disposal site.

4. **Ash Production:**

   - Operating basis: maximum continuous ash production rate and conditions;

Production Rate	Density	Temperature
3,766 lb/hr		300°F

5. **Ash Storage:**

   - Provide for 88 hours storage
   - Truck loading station under the storage silo with provisions for dust control during truck loading operations.
   - Provide for inert blanket for storage silo to prevent caking of ash from atmospheric moisture.

6. **Control and Data Acquisition Requirements:** Control will be local and independent. Alarms will be sent to the DCS in the main control room. The DCS will also have an Emergency Stop function.

7. **Utilities:**
   Electrical
   Nitrogen (purge)

Service/Instrument Air
Service water

8. Electrical:

Voltages: 480/3/60
240/1/60
120/1/60

Loads:

9. Comments:

- All bins should be mass flow bins with flow inducers, such as live bottoms, vibrators, and/or aeration. Design for minimum stoppage.

10. Conceptual Design Requirements:

- Description of process (include pug mill for ash conditioning)
- Size equipment
- List of equipment/materials
- Estimated cost
- Delivery dates
- Preliminary P&ID

AREA 900D FUEL CELL

The fuel cell will be procured as package. Interfaces will include AREA 200A for the syngas and area 700 for gas to the stack.

AREA 1000 INSTRUMENTATION AND DATA ACQUISITION

1. **Description:** Plant Control System: Consists of all components for automatic and manual control and monitoring of the process except that FW will use the 6000 series of numbers for their instrument index. Included are instrumentation, pneumatic controls, electronic conditioning, microprocessors, cabinets, power supplies, uninterruptible power supply system, prefabricated cables, control board and inserts, operator interface devices (indicators, manual/auto stations, CRT'S, etc.), system configuration, circuits, and raceways.

   Data Analysis System: Consists of all components of a digital data analysis system including processing computer required to receive, condition, store, transfer, and display data from selected process and equipment sensors. Included are the computer central processing unit, power supplies, input/output cabinets, prefabricated cables, software, digital memory devices, associated input/output peripherals (e.g., keyboards, printers, modems, CRT's, trend strip recorders), operator and programmer interface equipment, circuits,and raceways. This does not include process and equipment sensors, HVAC, fire protection, or architectural provisions or enclosures. The data analysis system may be separate or an integral part of the plant control system.

2. **Area Interface Points:** ALL

3. **Design Interface:**

Lead: SCS
Interface: SCS is responsible for designing, furnishing, and configuring the plant digital control and data acquisition systems. MWK and the FW/Westinghouse/Allison design team are responsible for determining the process control definition for all areas within their scope of work. MWK and the FW/Westinghouse/Allison design team are also responsible for all control valves, controllers, transmitters, transducers, thermocouples, etc., for all systems for which they have design responsibility. Similarly, SCS is responsible for instrumentation for systems or sub-systems within their scope of work.

4. **Comments:**

5. **Conceptual Design Requirements:**

   - Plant Control System/Data Acquisition System
   - Assessment of alternatives
   - Functional description of system
   - Equipment list
   - Estimated cost
   - Delivery

- I/O list
- Control Room Design
- Preliminary general arrangement drawings

AREA 2000 BOILER FEEDWATER/STEAM SYSTEM

1. **Description:** Consists of all components required to receive saturated medium pressure steam from the steam drum, condense the steam, and resupply the condensate as boiler feedwater. Make-up to the drum is also included. Components include steam piping from the drum, condenser, condensate pump(s) and piping, cooling tower(s), circulating water pump(s) and piping, deaerator if required, make-up pump(s) and piping, controls, foundations, supports, electrical power equipment, controls, raceways, and grounding. Raw water supply and cooling tower make-up is not included in this system.

2. **Area Interface Points:**

   - o Steam from drum (AREA 400)
   - o Makeup to drum (AREA 400)
   - o Condensate return to drum (AREA 400)

3. **Design Interface:**

Lead: SCS
Interface: SCS is responsible for design of the system. Piping and equipment within the confines of the Gasifier/PCD structure is the responsibility of MWK. Interface points will be identified at structure boundaries.

4. **Design Conditions:**

   - o Flow: 60000 lbm/hr
   - o Drum Pressure: 450 psig
   - o Condensate Return Temp : 150$_o$F
   - o Steam for Gasification: 2400 lbm/hr
   - o Blowdown: 600 lbm/hr (1%)

5. **Comments:**

6. **Control and Data Acquisition Requirements:** Control will be by the DCS in the main control room.

7. **Conceptual Design Requirements:**

   - o Description of process
   - o Size equipment
   - o List of equipment/materials
   - o Estimated cost
   - o Delivery dates
   - o Preliminary P&ID
   - o Valve schedule (control valves)

- Instrument list

AREA 2100 SERVICE WATER SYSTEM

1. **Description:** Consists of all components required to provide raw water to the boiler feedwater treatment system, to provide cooling tower make-up, to provide quench water as needed, to satisfy miscellaneous cooling water requirements, and for hose connections. Included are all pumps, piping, storage tanks, controls, structures, foundations, supports, electrical power equipment, controls, raceways, and grounding.

2. **Area Interface Points:**

   - Service water to Areas 100, 200, 300, 400, 500, and 600.
   - Instrumentation and Data Acquisition (AREA 1000)
   - Electrical (AREA 3000)

3. **Design Interface:**

Lead: SCS
Interface: SCS is responsible for the design of the system. Piping within the boundary of the Gasifier/PCD structure is the responsibility of MWK. Interface points will be identified on MWK design documents.

4. **Design Conditions:**

5. **Comments:**

   - Consider obtaining water from City of Wilsonville, E.C Gaston Steam Plant, river, and drilling well.

6. **Control and Data Acquisition Requirements:** Control will be from the DCS in the main control room with local auto/manual stations for the pumps and automatic valves.

7. **Conceptual Design Requirements:**

   - Study of alternatives (Wilsonville, Gaston, river)
   - Description of process
   - Size equipment
   - List of equipment/materials
   - Preliminary P&ID
   - Valve schedule (control valves)
   - Instrument List
   - Estimated cost
   - Delivery dates

AREA 2200 SERVICE/INSTRUMENT AIR SYSTEM

1. **Description:** Includes all compressors, receiver tanks, dryers, piping, electrical power equipment, controls, raceways, and grounding required to provide service air and instrument air.

2. **Area Interface Points:**

3. **Design Interface:**

Lead: SCS
Interface: SCS is responsible for the design of the system. Piping within the boundary of the Gasifier/PCD structure is the responsibility of MWK. Interface points will be identified on MWK design documents.

4. **Design Conditions:**

5. **Comments:**

6. **Control and Data Acquisition Requirements:** Control will be local and furnished with the compressors.

7. **Conceptual Design Requirements:**

   - o Description
   - o List of equipment/materials
   - o Preliminary P&ID
   - o Cost Estimate

AREA 2300 AUXILIARY FUEL SYSTEM

1. **Description:** All components for receiving, unloading, storing, and distributing fuel to the startup burner(s), pulverizer air heater(s), and other devices as required. This includes truck unloading station, unloading piping, storage tank, containment facilities, distribution pumps and piping, foundations, supports, electrical power equipment, controls, raceways, and grounding.

2. **Area Interface Points:**

   - Fuel for coal/limestone drying (AREA 100)
   - Gas Generator startup fuel (AREA 200)
   - Flare pilot (AREA 200)
   - Sulfator startup fuel (AREA 600)

3. **Design Interface:**

Lead: SCS
Interface: The complete unloading, storage and distribution system is the responsibility of SCS. Auxiliary fuel requirements for gas generator, flare, and sulfator will be determined by MWK. In addition, MWK is responsible for all piping within the gasifier/PCD structural boundaries. Physical interface points will be identified on MWK/SCS design documents.

4. **Comments:**

5. **Control and Data Acquisition Requirements:** Control will be by the DCS in the main control room.

6. **Conceptual Design Requirements:**

   - Study of alternatives, including integration with Agglomeration
   - Project unloading facilities and possible use of natural gas or LPG
   - Description of system
   - Preliminary P&ID
   - Size equipment
   - List of equipment/materials
   - Estimated cost
   - Delivery dates

AREA 2400 FIRE PROTECTION SYSTEM

1. **Description:** Includes all fire protection systems required to meet federal, state, and local requirements. As applicable this may include fire pumps, fire protection storage tanks, yard main system, standpipe and hose systems, and special protection systems required for specific hazards.

2. **Area Interface Points:**

3. **Design Interface:**

Lead: SCS
Interface: SCS is responsible for design of the fire protection systems. Piping and equipment within the Gasifier/PCD structure is the responsibility of MWK.

4. **Comments:**

5. **Control and Data Acquisition Requirements:** None

6. **Conceptual Design Requirements:**

   - o System integration study
   - o Description of system
   - o Preliminary P&ID
   - o List of equipment/materials
   - o Estimated cost
   - o Delivery dates

AREA 2500 WASTEWATER TREATMENT SYSTEM

1. **Description:** Includes collection and treatment of all wastewater streams as required. As applicable this includes coal pile run-off, boiler blowdown, cooling tower blowdown, floor drains, yard drains, and sewage. The scope includes routing waste streams to appropriate collection points; installation of treatment equipment as required; appropriate supports, foundations, electrical power equipment, controls, raceways, and grounding; and discharge piping or drains.

2. **Area Interface Points:**

3. **Design Interface:**
Lead: SCS
Interface:

4. **Comments:**

5. **Control and Data Acquisition requirements:** Control will be local. Alarms will be sent back to the DCS in the main control room.

6. **Conceptual Design Requirements:**

   o System integration study
   o Description of systems
   o Preliminary P&ID
   o Equipment/material list
   o Estimated cost
   o Delivery Date

AREA 2600 NITROGEN SYSTEM

1. **Description:** All equipment, piping, and controls required for inerting and purging. This includes nitrogen storage, valves and piping, analysis and control system, nozzles, and other devices as required.

2. **Area Interface Points:**

3. **Design Interface:**

Lead: SCS
Interface: SCS is responsible for design of the nitrogen system. Piping within the Gasifier/PCD structure is the responsibility of MWK.

4. **Comments:**

5. **Control and Data Acquisition Requirements:** Control will be by the DCS in the main control room where there is a need for automatic control in the Gasifier/PCD structure.

6. **Conceptual Design Requirements:**

   - o Description of system
   - o Preliminary P&ID
   - o Equipment/material list
   - o Estimated cost
   - o Delivery Date

AREA 2700 WATER TREATMENT/CHEMICAL FEED

1. **Description:** Includes all facilities for treating boiler feedwater and condensate. As required such facilities may include equipment and systems for clarification, filtration, and demineralization of raw water as well as introduction of chemicals into the process streams. Also included are filtered/treated water storage tanks, chemical storage, all contiguous water and chemical pumps and piping, water analysis and control system, regenerative waste treatment, electrical power equipment, controls, raceways, and grounding, and water treatment building.

2. **Area Interface Points:**

3. **Design Interface:**

Lead: SCS
Interface: SCS is responsible for design of the water treatment/chemical feed system. Piping within the Gasifier/PCD structure is the responsibility of MWK.

4. **Comments:**

5. **Control and Data Acquisition Requirements:** Control will be by the DCS in the main control room where there is a need for automatic control in the Gasifier/PCD structure.

6. **Conceptual Design Requirements:**

   - o Description of the system
   - o List of equipment/materials
   - o Preliminary P&ID
   - o Estimated cost
   - o Delivery date

AREA 2800 SAFETY/SECURITY

1. **Description:** Includes all systems and equipment required for personnel protection and site security. This includes safety showers, alarm systems, surveillance equipment, respirators, signs, and other equipment as required.

2. **Area Interface Points:**

3. **Design Interface:**

Lead: SCS
Interface:

4. **Comments:**

5. **Conceptual Design Requirements:**

   o Estimated cost (include security fencing)

AREA 3000 POWER DISTRIBUTION

1. **Description:** This area includes all components required to receive power from the substation provided by Alabama Power Company and distribute the power at appropriate power levels to the various systems within the plant. This includes switchgear, transformers, power circuit breakers, disconnects, cable, protective relays, meters, raceways and grounding.

2. **Area Interface Points:** All

3. **Design Interface:**

Lead: SCS
Interface: SCS is responsible or design of the system except for raceways within the confines of the process structure which is the responsibility of MWK. MWK will also be responsible for all lighting, receptacles, and misc. power circuits within the structure. Interface points will be at pull boxes and distribution panels located at the structure boundaries.

4. **Conceptual Design Requirements:**

   - o Description
   - o Assessment of Alternatives
   - o Single Line Diagram
   - o List of equipment/materials
   - o Estimated Cost
   - o Delivery Time

AREA 3001 CONTROL & DATA ACQUISITION CIRCUITRY

1. **Description:** This Area includes all equipment, cables, and raceways required to transmit field inputs to the DCS and to take the outputs of the DCS to the controlled devices.

2. **Area Interface Points:** All

3. **Design Interface:**

Lead: SCS
Interface:SCS is responsible for the entire system except for circuits and raceways within the battery limits of the process structure which are the responsibility of MWK. The interface point will be at an I/O junction box provided at the boundary of the process structure.

4. **Conceptual Design Requirements:**

- o Description
- o List of equipment/material
- o Estimated Cost
- o Delivery Time

AREA 3002 LIGHTING

1. **Description:** This area includes all fixtures, receptacles, circuits, and raceways required to provide lighting in buildings and outdoor areas.

2. **Area Interface Points:**

3. **Design Interface:**

Lead: SCS
Interface: SCS is responsible for the entire system except for the process structure which is the responsibility of MWK.

4. **Conceptual Design Requirements:**

   - o Description
   - o List of equipment/materials
   - o Estimated Cost
   - o Delivery Time

AREA 3003 COMMUNICATIONS

1. **Description:** This area includes all equipment, raceways, and circuits required to provide public address and telephone systems for the plant.

2. **Area Interface Points:**

3. **Design Interface:** None - SCS is responsible for the entire system, including that for the process structure.

4. **Conceptual Design Requirements:**

   - o Description
   - o List of equipment/materials
   - o Estimated Cost
   - o Delivery Time

AREA 3004 HEAT TRACING/FREEZE PROTECTION

1. **Description:** This area includes all equipment, raceways, and circuits required to provide freeze protection to piping and instrument lines.

2. **Area interface Points:**

3. **Design Interface:**

Lead: SCS
Interface: SCS is responsible for the entire system, except for the process structure which is the responsibility of MWK.

4. **Conceptual Design Requirements:**

   - o Description
   - o List of equipment/materials
   - o Estimated Cost
   - o Delivery Time

END

DATE FILMED

2/2/93