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HOT GAS CLEANUP TEST FACILITY FOR GASIFICATION AND PRESSURIZED COMBUSTION

QUARTERLY TECHNICAL PROGRESS REPORT
APRIL 1 - JUNE 30, 1992

Prepared by

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

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HOT GAS CLEANUP TEST FACILITY FOR GASIFICATION AND PRESSURIZED COMBUSTION QUARTERLY TECHNICAL PROGRESS REPORT APRIL 1 - JUNE 30, 1992

1.0 INTRODUCTION AND SUMMARY

This quarterly technical progress report summarizes work completed during the Seventh Quarter of the First Budget Period, April 1 through June 30, 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 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.

This expansion to the Hot Gas Cleanup Test Facility is herein referred to as the Power Systems Development Facility (PSDF).

The major emphasis during this reporting period was completing the conceptual design for the PSDF. A subcontract 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 for the PSDF. Modification to the existing conceptual design for the Hot Gas Cleanup Test Facility (HGCTF) layout and balance of plant design for the PSDF were completed. Southern Research Institute (SRI) completed their investigation of the sampling requirements for the PSDF and assisted SCS in compiling the information received from the Particulate Control Device (PCD) vendors. SCS also received technical and cost information from the Electric Power Research Institute (EPRI) and two molten carbonate fuel cell vendors for the PSDF. The design of the Transport Reactor Development Unit (TRDU) by M. W. Kellogg (MWK) continued during this time period. The University of North Dakota Energy &

Environmental Research Center (UNDEERC) reviewed the TRDU design modifications to determine impacts on installation and operation.

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

2.0 REVIEW OF TECHNICAL PROGRESS

2.1 Project Management

Project activities during this time period focused on completing the conceptual design for the PSDF and continuing the design of the TRDU. A subcontract was established with FW for 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 UNDEERC subcontract for the TRDU work was also established during this time period.

Additional information was supplied to DOE/METC to address questions generated from the technical and cost review of the proposal to increase the level of effort for the conceptual design of PSDF under the cooperative agreement. The modification for the PSDF conceptual design was negotiated and the cooperative agreement was modified during this time period.

A review meeting was held at DOE/METC on June 3 to review the 100 percent completion mark of the conceptual design for the PSDF. Prior to the meeting a draft overview of the facility was submitted to DOE for review. After DOE submits comments back to SCS the overview will be finalized.

The cost estimate for the Power Systems Development Facility was developed as Volume III: Cost Estimate. The cost estimate is based on the conceptual design outlined in Volume I: General Overview and in the details described in Volume II: Design Document.

For the cost estimate each member of the design team developed a capital cost and engineering cost to design and construct the PSDF pertaining to their envelope of the design. In addition to developing capital cost, each member of the design team also included estimated manhours to erect the major pieces of equipment. SCS also obtained cost information for the Particulate Control Devices (PCD) and fuel cell information by contacting various vendors. SCS assembled the capital costs and an erection cost for the PSDF. The operations estimate, conducted with the assistance of Southern Electric International (SEI), was based on the conceptual design of the facility and experience at SCS' Clean Coal Research Center in Wilsonville, Alabama.

The capital cost and construction estimate for the PSDF was determined by dividing the facility into various envelopes with each member of the design team responsible for an envelop based on the scope of their design. M. W. Kellogg was responsible for the transport train; the Foster Wheeler team was responsible the APFBC system; and SCS was responsible for the particulate control devices (PCDs) and the balance-of-plant for the facility.

The cost for equipment and bulks were estimated for each envelop along with construction manhours for erection of the material. The capital cost and construction labor manhours were based on either vendor quotes or on historical information within each company. A review meeting was held to clarify interface points between envelopes in an attempt to avoid double accounting of equipment and bulks. SCS complied all the capital cost and construction cost information. Alabama labor rates were applied to the construction manhours and construction overheads, based on similar projects in the past, were also applied to determine the cost for installing the equipment and bulk materials.

SCS assembled all the cost information from the team members to develop a cost estimate to design, install and operate the PSDF.

2.2 Transport Reactor Development Unit

DOE, EPRI, SCS, M. W. Kellogg Co., and the Energy and Environmental Research Center (EERC), held a meeting on June 5, 1992 to review the design of the Transport Reactor Development Unit (TRDU). Items discussed at this meeting included: the objective of the TRDU work, the Transport Reactor Test Unit (TRTU) results and their impact on the TRDU design, the TRDU design and key issues (e.g. design basis, design modifications, schedules), and TRDU installation/operation plans (e.g. layout, impact of design modifications, environmental activities). The objective of the TRDU program is to verify the hydrodynamics and achieve accurate steady state material balances around the transport reactor at various operating conditions. The TRTU operated at a nominal 2-10 lb/hr coal feed rate, and the TRDU would operate at a nominal 200 lb/hr of coal feed rate providing scaleup information which can be used to better design the Wilsonville transport reactor unit. The TRDU is also expected to reduce shakedown time at Wilsonville by providing experience with solids circulation behavior and control techniques in the transport flow regime. EERC was chosen as the site for the TRDU tests due to its existing coal/sorbent feed infrastructure, existing gas cleanup system, and experienced personnel. The Houston TRTU results indicate that in the gasification mode high carbon conversions can be achieved with the transport reactor at a small scale. However, there were some physical differences between the TRTU and the Wilsonville transport reactor that warranted the testing of an intermediate size unit.

The design basis for the TRDU was presented at this meeting including coal feed rate, limestone feed rate, reactor temperature and pressure, and percent gasification and desulfurization expected. The major design modification has been due to an anticipated increase in the heat loss from the TRDU. To compensate for this heat loss the coal feed rate has been increased to 200 lb/hr, and more efficient insulation has been specified for the transport reactor spool pieces. In order to accommodate the larger coal flow rate and a larger reactor (due to the presence of more refractory insulation), several modifications have to be made to the EERC gasification tower. The modifications include removing some beams, gratings, and moving existing carbonizer equipment to alternate locations. The height of the riser section was also decreased to 40' to accommodate the entire transport reactor, disengager, and primary cyclone within the gasification tower at EERC.

2.2.1 M. W. Kellogg Activities

Nozzles have been designed for the TRDU and these have been incorporated into the reactor layout. The required inside diameters of the major nozzles are listed in Table 2-1.

Table 2-1 TRDU Nozzle Descriptions

Description	Nozzle ID, in.
J-leg aeration nozzles	0.25
Steam injection nozzles	0.302
Standpipe aeration nozzles	0.094
Thermowells	0.546
Pressure taps	0.215
Boiler take off	4.0
Boiler solids return	3.0
Fill nozzle	3.0
Coal injection nozzles	0.302
Air injection nozzles	0.466
Secondary air injection nozzle	0.466
Solid drain	3.0
Start-up burner nozzle	3.0

A preliminary rating of the combustion boiler has been completed. The size of the boiler is estimated to be 18" wide and 27' tall. This preliminary sizing was used to develop the overall layout and to ensure that if the boiler is added there would be adequate space at the EERC.

The ash withdrawal system has been designed utilizing a holo-flite screw cooler and specifications have been issued for the coal/limestone feed and ash withdrawal systems.

The duty required for the start-up burner has been calculated to be approximately 1.5 MMBtu/hr and loadsheets have been prepared accordingly. The design of the start-up burner duct system has been completed. Development of a data sheet and requisition for the start-up burner has begun.

Due to height limitations in the EERC structure, the TRDU riser height was reduced from 50 ft to 40 ft. This reduction is expected to impact the performance of the gasifier in the following manner: gasification carbon conversion rate is expected to drop by 3% and the HHV of the fuel gas is expected to be lower by about 6%.

The cyclone performance data was received from General Electric and analyzed, and the results are presented in Table 2-2. The overall particle collection efficiency of this cyclone system is expected to be 99.99% with a dust loss rate of nominally 1.95 lb/hr in the gasification mode.

Table 2-2 TRDU Cyclone Design Data

	Disengager cyclone	**Primary cyclone**	**Secondary cyclone**
Inlet velocity, ft/s	30.4	48.3	48.6
Collection efficiency, %	99.974	43.96	37.02
Inlet solid flow rate, lb/hr	21,287	5.527	3.097
Solid collection rate, lb/hr	21,281.5	2.429	1.147
Solid loss rate, lb/hr	5.527	3.097	1.95

Skin temperature profiles for the TRDU reactor system under normal and startup conditions have been calculated. These will serve as the basis for the stress calculations. Pipe stress calculations for the TRDU have begun and these will establish the basis for support locations and expected support loads.

2.2.2 EERC Activities

Installation of the beams for the crane well floor area has been completed for all the floors. Because the final floor plan for the TRDU has not been completed, work on the support structure for the reactor has not been started. The floor grating for the crane well floor has been installed. The handrail design is being completed and installation should start the week of July 6, 1992. Modifications to the non-load-bearing floors is in the design phase because design drawings of the reactor have not been finalized.

Two pieces of existing EERC equipment, carbonizer primary cyclone and carbonizer secondary cyclone, had to be moved in order to make room for the TRDU. The cyclones have been placed in storage. The inlet spool piece and top cross had to be modified to allow for rotation and to position the solids drain from the cyclone. These modifications are in the final review stages.

Several items are in the process of being procured including one of the nuclear-level detectors for the water scrubbing system, a partial order for the additional safety lighting, structural beams, floor grating, handrail modifications, and minor instrumentation items. The bulk of the procurement will not proceed until the final determination of the reactor design.

Documents were submitted to the North Dakota State Health Department for a permit to construct and install the TRDU in the EERC gasification tower. There was approval from the standpoint of air emissions and treated wastewater discharge; however, there were some problems with permits for the disposal of the char material coming out the TRDU. Because this ash like material may contain limited amounts of CaS it may not pass the sulfide leachability standards. A meeting has been held with the State Health Department to discuss the solid waste disposal issue. The two options for disposing the solid wastes are to dispose of the ash as a hazardous waste, or to oxidize the material in a combustor to provide data for the sulfator at Wilsonville.

2.3 Facility Expansion Estimate

The conceptual design of the expanded facility, herein referred to as the Power Systems Development Facility, was completed during the quarter and the design document was issued to all members of the project team.

2.3.1 Environmental Information

The environmental information collected during this quarter primarily supports the National Environmental Policy Act (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.

Southern Company Services' Environmental Information Volume was submitted to DOE on May 15, 1992. The report included site layout maps, material balances from the conceptual design of the facility, calculations concerning raw material consumption and emissions, expected ash analysis, ten year emissions from existing facilities, and the one hundred year floodplain Map for the site. Additionally, several recent environmental reports conducted for projects near the site were included. On May 26, the statistical air modeling report was completed and submitted to DOE and TVA for review.

On June 23rd, Southern Company Services and the Department of Energy met in Wilsonville, Alabama with Tennessee Valley Authority, the subcontractor chosen by the DOE to draft the Environmental Assessment. Additional information compiled for TVA concerning the NEPA Environmental Assessment include: a water balance around the facility, noise level estimates three feet from various PSDF Process Equipment, and supplemental information to support the modelling report.

2.3.2 Overall Process Engineering

Overall process engineering activities during this quarter consist of development of optimum general arrangement diagrams incorporating the proposed PSDF modules, design data for balance-of-plant conceptual design, development of overall block flow diagrams and heat and material balances, and initiation of an ASPEN simulation for the PSDF.

2.3.2.1 General Arrangement Diagrams

Existing property maps, topographic maps and aerial photographs of the land adjacent to the existing project sites at Wilsonville were reviewed once again for proposed siting. Based on field walkdowns, preliminary mapping, constraints associated with existing facilities, plant access and site preparation costs, the site shown in Figure 2-1 was chosen as the location for PSDF.

Figure 2-2 also shows a layout of the integrated facility. Coal and limestone storage pads will be located in the existing Selective Agglomeration facility (a DOE/PETC project which is scheduled to end by September 1992) at the Wilsonville. Coal and sorbent will be conveyed to the crusher and grinder pad located at a slightly higher elevation from the storage pads. The main process pad is located next to the crusher and grinder pad. Both the transport reactor and the APFBC system's carbonizer and CPFBC are located in the main process pad. A common bay for access separates the transport train from the APFBC train. The PCD bay is located on the western end of the pad. Topping combustor and gas turbine follows the PCD bay in the APFBC train. Exhaust gases from the gas turbine are discharged through a stack attached to the northwest corner of the process structure.

Following the PCD, the gases from the transport train goes to the thermal oxidizer (in gasification mode) and the combusted gases are discharged through a stack attached to the southwest corner of the process structure. Fuel cell test skid will be located close to the transport PCD, and enough space is provided for future expansion to a multi-MW fuel cell. Also, space in the site layout is provided for location of WAGT near the PCDs in the APFBC train. The main utilities and cooling towers are located to the south of the process structure. A pipe trench will connect the process structure with the utility area.

The conceptual layout of the administrative and service building is to the north of the main process structure. The building will have offices for engineering, administrative and supervisory personnel. Also, located in this building are the following: Control room fronting the process structure, data acquisition room, locker and change rooms, small conference room, and analytical laboratory. Total footage for this building is estimated at 11,200 sq. ft. Existing building at the site will also be used for storage and as a large conference room.

To the east of the main process structure lies the warehouse and maintenance buildings. The maintenance shop will have an instrument air clean room. An interior firewall will separate warehouse area from maintenance shop area. Total square footage for this building is estimated at 4,500 sq. ft. During the early stage of construction, the shell of this structure will be erected and the building will be used as a construction warehouse. The interior will be finished during the final stages of construction.

The facility has been designed with sufficient room for possible future modifications and additions, especially in the PCD area. Provision has been made in the site layout for future phased integrations of multi-MW fuel cell and

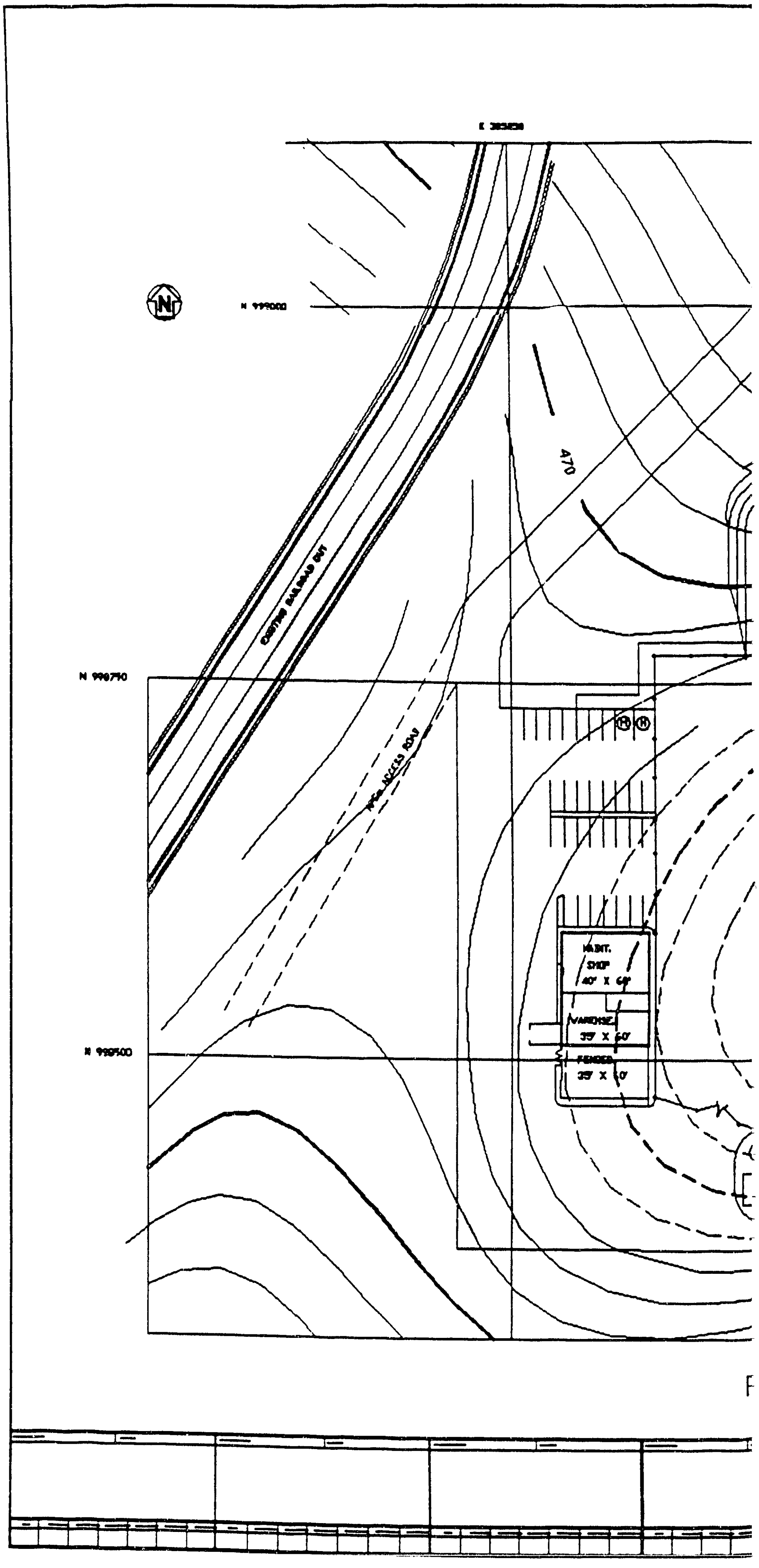
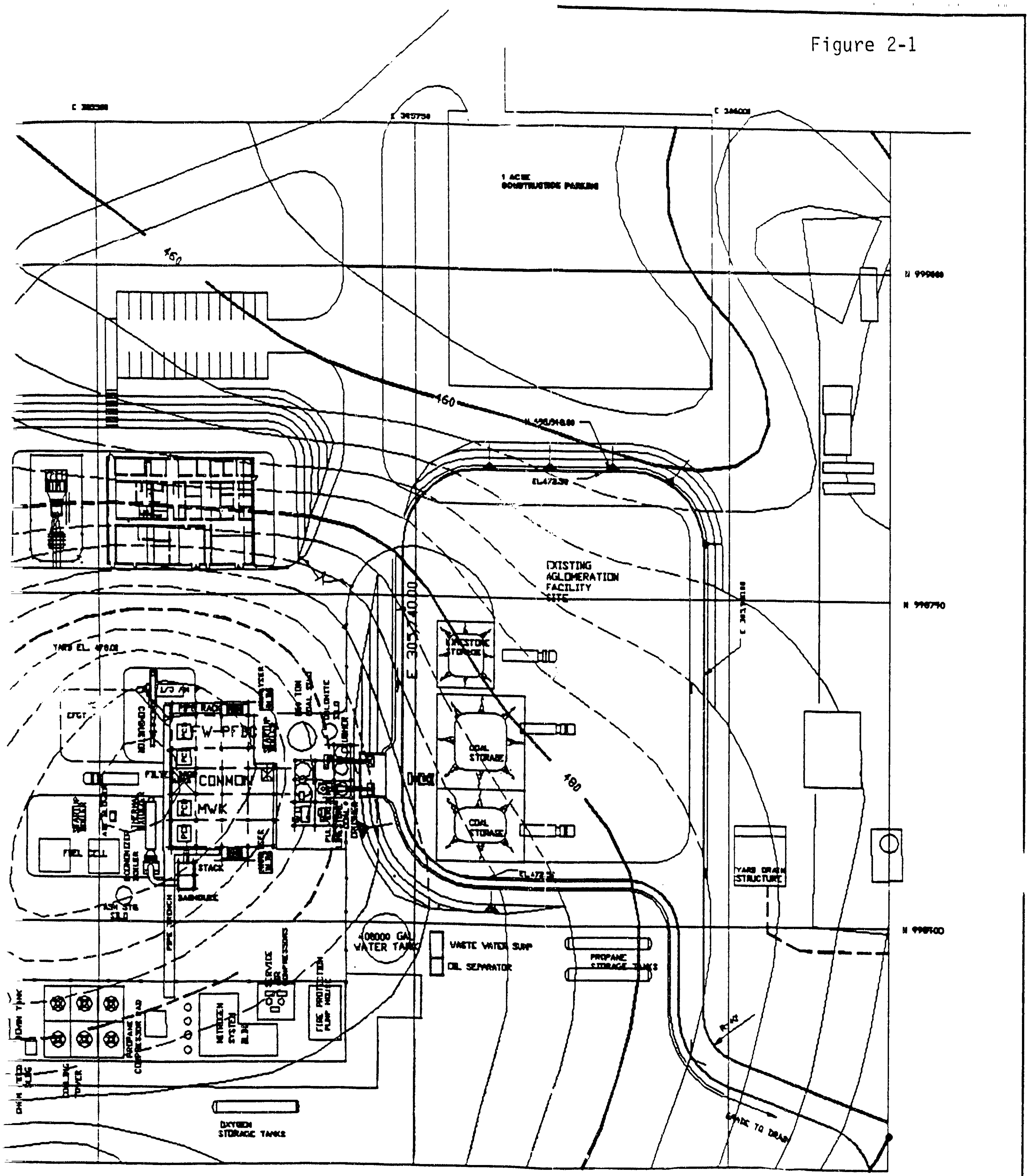

470
MAINT.
SHOP
WAREHSE.
35' X 60'

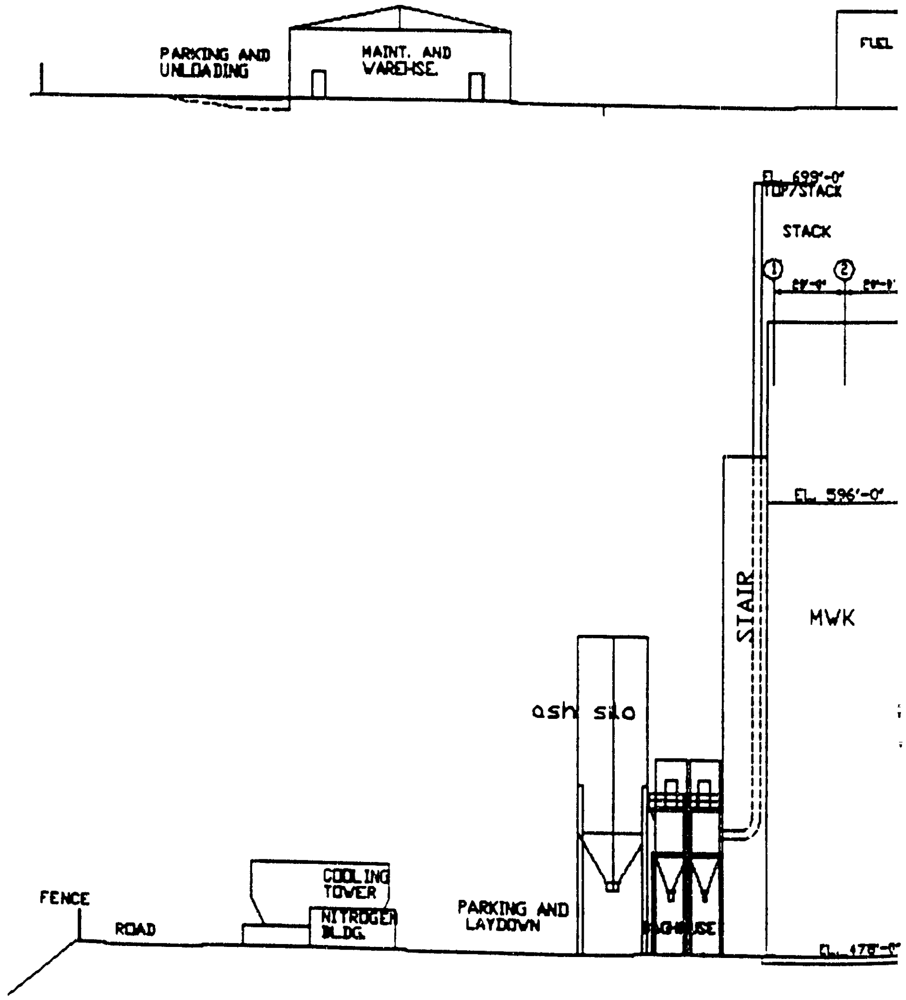
Figure 2-1



SDF SITE AND GENERAL ARRANGEMENT DIAGRAM

AUTOCAD
SOUTHERN COMPANY SERVICES, INC.
DEPARTMENT OF ENERGY
WILSONVILLE GASIFICATION HOT GAS CLEANUP PROJECT PLANT ARRANGEMENT PLAN
CDI VBF
R406 E-C-P013 A

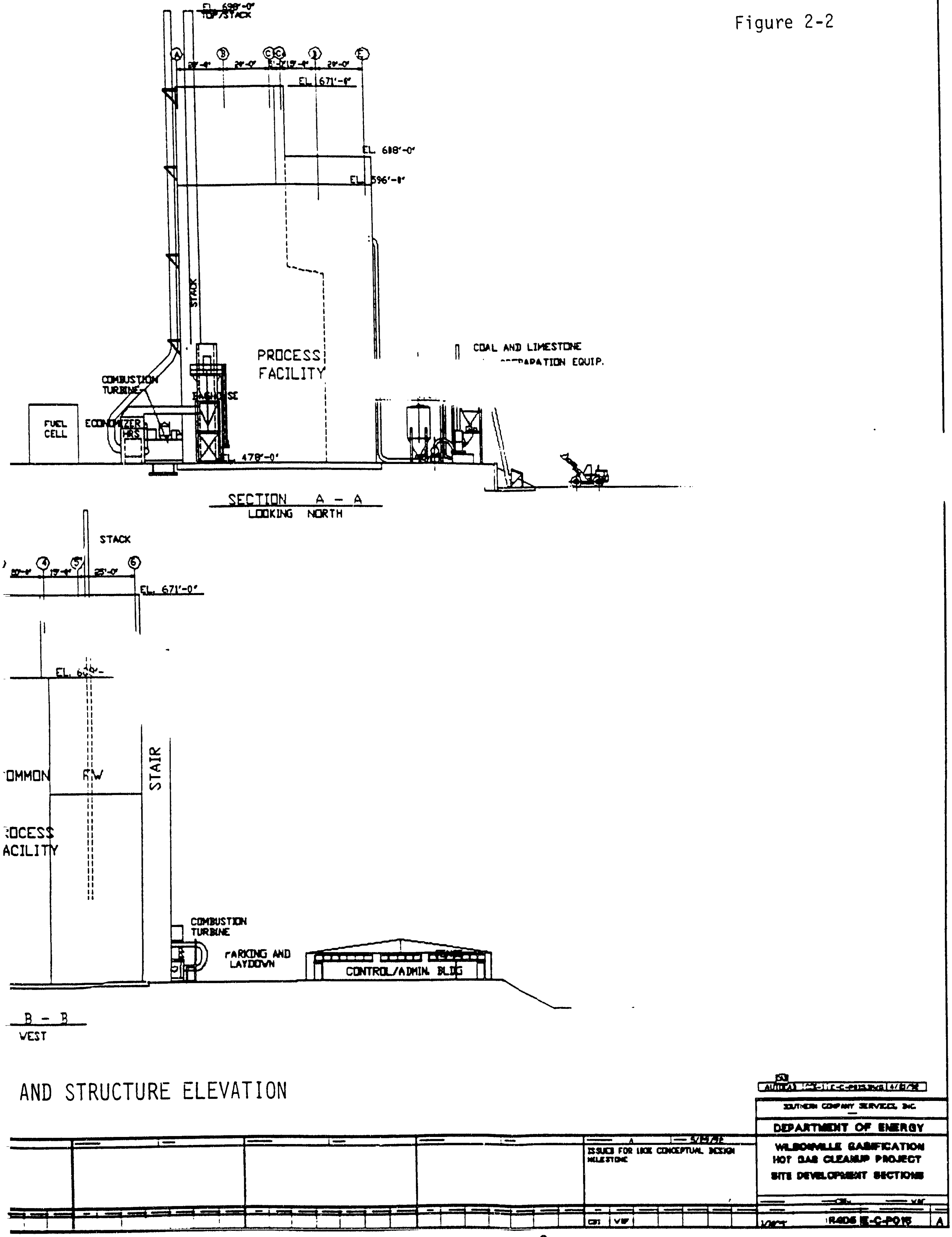
A 5/29/92 ISSUED FOR 100% CONCEPTUAL DESIGN MILESTONE



SECTION
LOOKI

PLAN

Figure 2-2



EL. 698'-0" TOP/STACK
EL. 671'-0"
EL. 608'-0"
EL. 596'-0"
STACK
PROCESS FACILITY
COMBUSTION TURBINE
BAGHOUSE
FUEL CELL
ECONOMIZER
HRS
EL. 478'-0"
COAL AND LIMESTONE
PREPARATION EQUIP.
SECTION A – A
LOOKING NORTH
STACK
EL. 671'-0"
STAIR
COMMON
RW
PROCESS FACILITY
COMBUSTION TURBINE
PARKING AND LAYDOWN
CONTROL/ADMIN. BLDG
B – B
WEST
AND STRUCTURE ELEVATION
ISSUED FOR 10% CONCEPTUAL DESIGN MILESTONE
SOUTHERN COMPANY SERVICES, INC.
DEPARTMENT OF ENERGY
WILSONVILLE GASIFICATION
HOT GAS CLEANUP PROJECT
SITE DEVELOPMENT SECTIONS

water-augmented gas turbine. Careful consideration for additional space is given to any areas with design uncertainties. For flexibility in maintenance and equipment change out, the overall site layout will allow access by crane on at least two sides of the process structure. Additional access is provided with a common dropout area between the transport reactor and APFBC process structures. Hoists are installed in the process structure in the PCD bay where routine lifting of equipment for maintenance or inspection will be required as part of the test program.

2.3.2.2 Block Flow and Plot Diagrams

An overall process block flow diagram was prepared to combine the transport reactor train, APFBC train, fuel cell, and balance-of-plant process designs. Major pieces of equipment and their equipment number can be reviewed along with a general process flow. Figure 2-3 shows the flow diagram with boundaries marked by respective process areas, and Figure 2-4 shows the flow diagram with boundaries marked by respective project participants who were involved in the design process.

Isometric views of the process structure housing the Kellogg's transport reactor are shown in Figures 2-5 and 2-6. A list of major equipment and its numbers is given in Figure 2-5. A footprint of the Foster Wheeler's APFBC train including the Westinghouse's topping combustor and Allison's gas turbine generating set is shown in Figure 2-7.

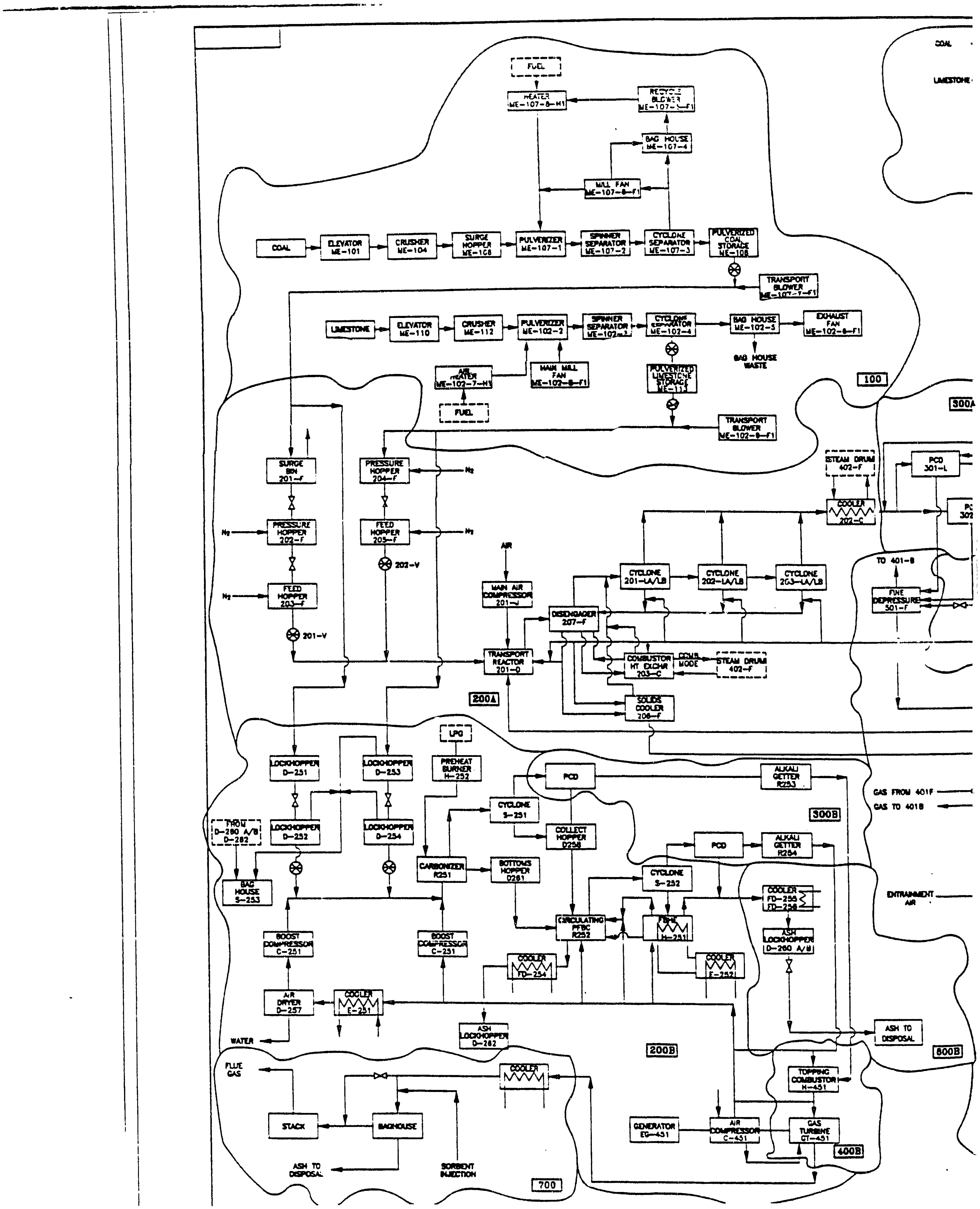
2.3.2.3 Benefits of Integrated Facility

The consolidation and integration of the facilities at the PSDF will result in significant cost savings. Also, the integration will provide more flexibility within each module of the overall facility and allow implementation of a broad range of test programs. Provision has been made in the conceptual design of the integrated facility to maximize the use of equipment and technology for testing. For example, the PCDs used with the transport reactor and with the carbonizer can be interchanged for additional testing.

Cost savings are expected in all phases (design, construction and operation) of the project. The savings result from the economies of scale associated with sharing process utilities, equipment, support functions and personnel between the modules to be located at the site. Most of the design and capital related costs savings are expected to be associated with the balance-of-plant. The design of the balance of plant is shared among the various modules. Location at the single site, eliminates duplication of design efforts for the balance of plant and results in only incremental increases or in some cases no increase in the design cost. Due to integration, insignificant increase in effort is needed during the detailed design of balance-of-plant.

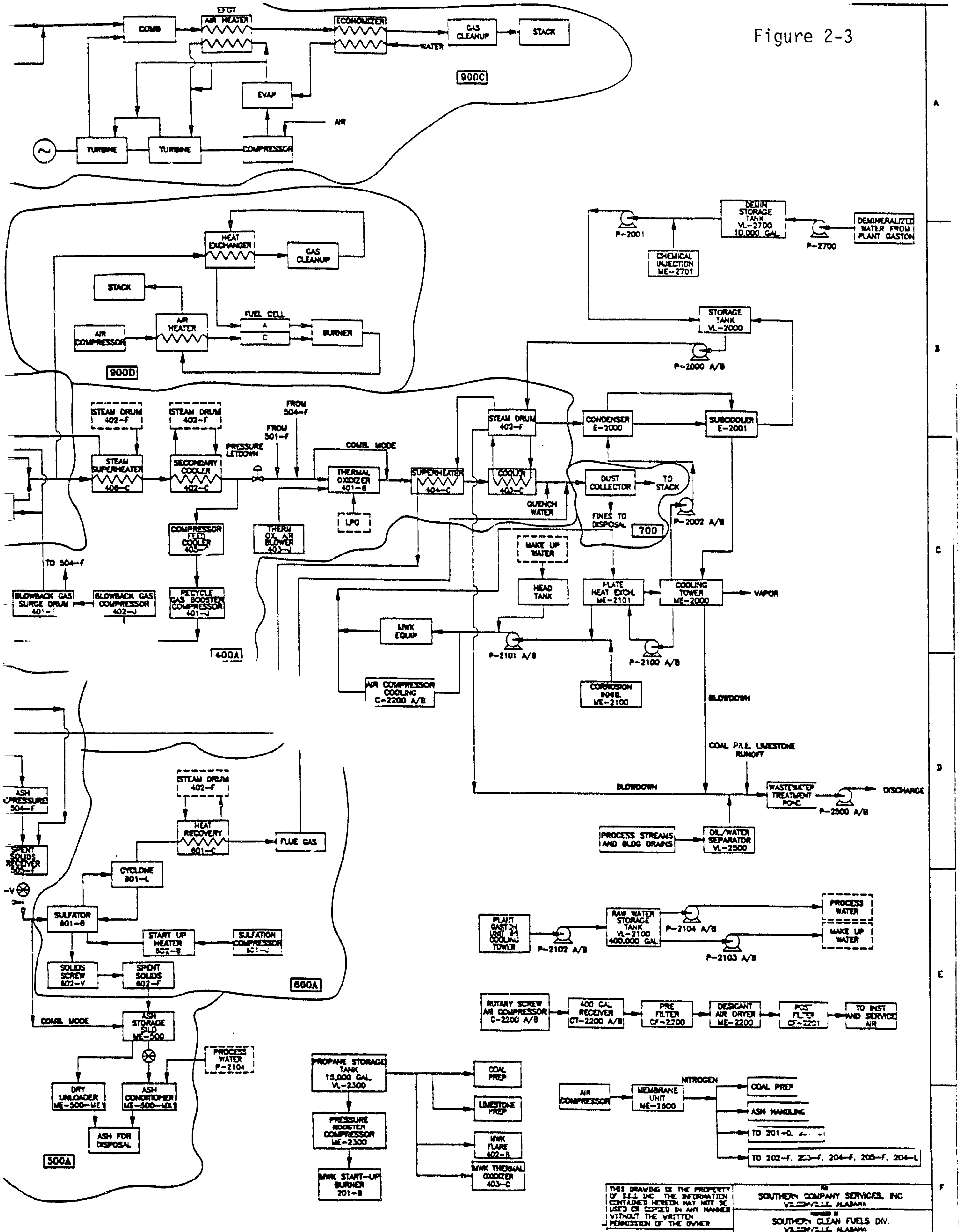
The cost savings for capital expenditures for equipment for balance-of-plant are expected to parallel those savings associated with the design. The following areas and equipment will be shared among all the various modules:

The coal storage area will be common for all the modules and only incremental capacity will be required. The front end loader required for loading coal into



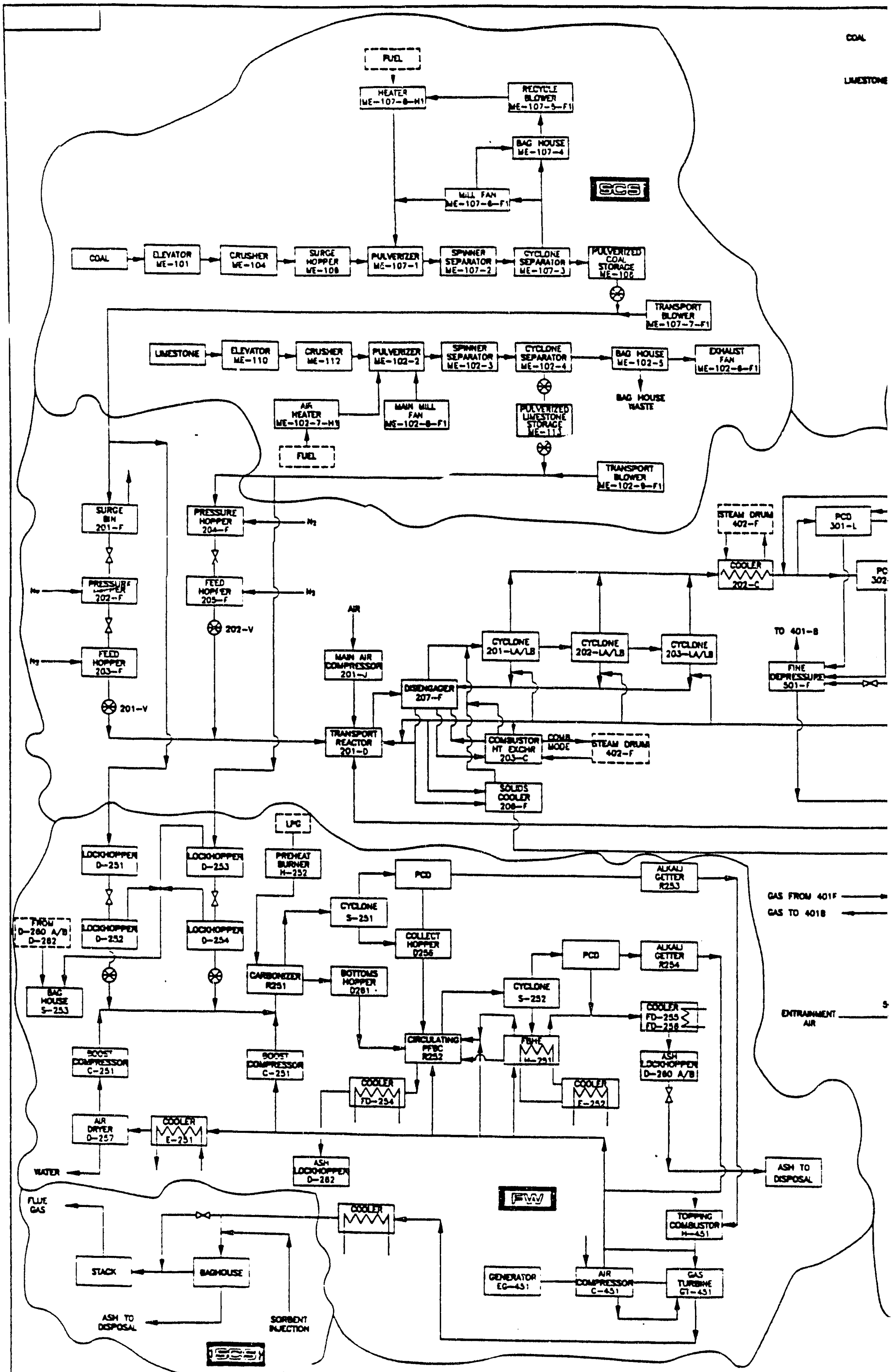
AN OVERALL BL

Figure 2-3



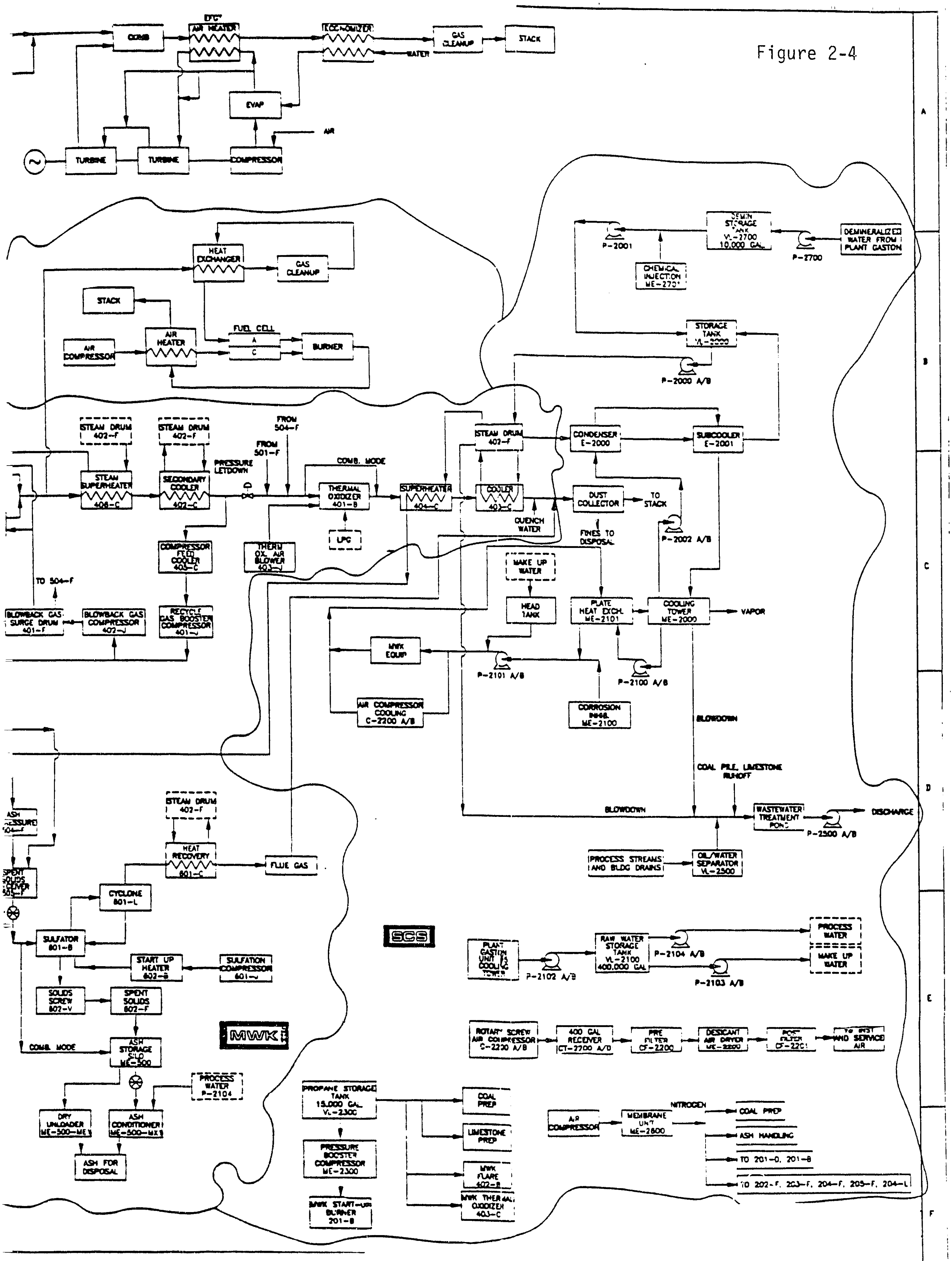
:K FLOW DIAGRAM MARKED BY PROCESS AREAS

HGCUBFD-03


COAL
LIMESTONE
FUEL
HEATER ME-107-8-H1
RECYCLE BLOWER ME-107-5-F1
BAG HOUSE ME-107-4
MILL FAN ME-107-6-F1
SCS
COAL
ELEVATOR ME-101
CRUSHER ME-104
SURGE HOPPER ME-108
PULVERIZER ME-107-1
SPINNER SEPARATOR ME-107-2
CYCLONE SEPARATOR ME-107-3
PULVERIZED COAL STORAGE ME-106
TRANSPORT BLOWER ME-107-7-F1
LIMESTONE
ELEVATOR ME-110
CRUSHER ME-112
PULVERIZER ME-102-2
SPINNER SEPARATOR ME-102-3
CYCLONE SEPARATOR ME-102-4
BAG HOUSE ME-102-5
EXHAUST FAN ME-102-6-F1
BAG HOUSE WASTE
AIR HEATER ME-102-7-H1
MAIN MILL FAN ME-102-8-F1
PULVERIZED LIMESTONE STORAGE ME-113
FUEL
TRANSPORT BLOWER ME-102-9-F1
SURGE BIN 201-F
PRESSURE HOPPER 204-F
STEAM DRUM 402-F
PCD 301-L
COOLER 202-C
PCD 302
PRESSURE HOPPER 202-F
FEED HOPPER 205-F
202-V
TO 401-B
AIR
FEED HOPPER 203-F
MAIN AIR COMPRESSOR 201-J
CYCLONE 201-LA/LB
CYCLONE 202-LA/LB
CYCLONE 203-LA/LB
FINE DEPRESSURE 501-F
DISENGAGER 207-F
201-V
TRANSPORT REACTOR 201-D
COMBUSTOR HT EXCHR 203-C
COMB MODE
STEAM DRUM 402-F
SOLIDS COOLER 208-F
LPG
LOCKHOPPER D-251
LOCKHOPPER D-253
PREHEAT BURNER H-252
PCD
ALKALI GETTER R253
GAS FROM 401F
GAS TO 401B
CYCLONE S-251
FROM D-260 A/B D-262
LOCKHOPPER D-252
LOCKHOPPER D-254
COLLECT HOPPER D256
BAG HOUSE S-253
CARBONIZER R251
BOTTOMS HOPPER D281
PCD
ALKALI GETTER R254
CYCLONE S-252
COOLER FD-255 FD-256
ENTRAINMENT AIR
BOOST COMPRESSOR C-251
BOOST COMPRESSOR C-251
CIRCULATING PFBC R252
FBHE H-251
ASH LOCKHOPPER D-260 A/B
COOLER FD-254
COOLER F-252
AIR DRYER D-257
COOLER E-251
ASH LOCKHOPPER D-262
ASH TO DISPOSAL
WATER
FWV
FLUE GAS
COOLER
TOPPING COMBUSTOR H-451
STACK
BAGHOUSE
GENERATOR EG-451
AIR COMPRESSOR C-451
GAS TURBINE GT-451
ASH TO DISPOSAL
SORBENT INJECTION
SCS

AN OVERA

Figure 2-4



BLOCK FLOW DIAGRAM MARKED BY COMPANIES

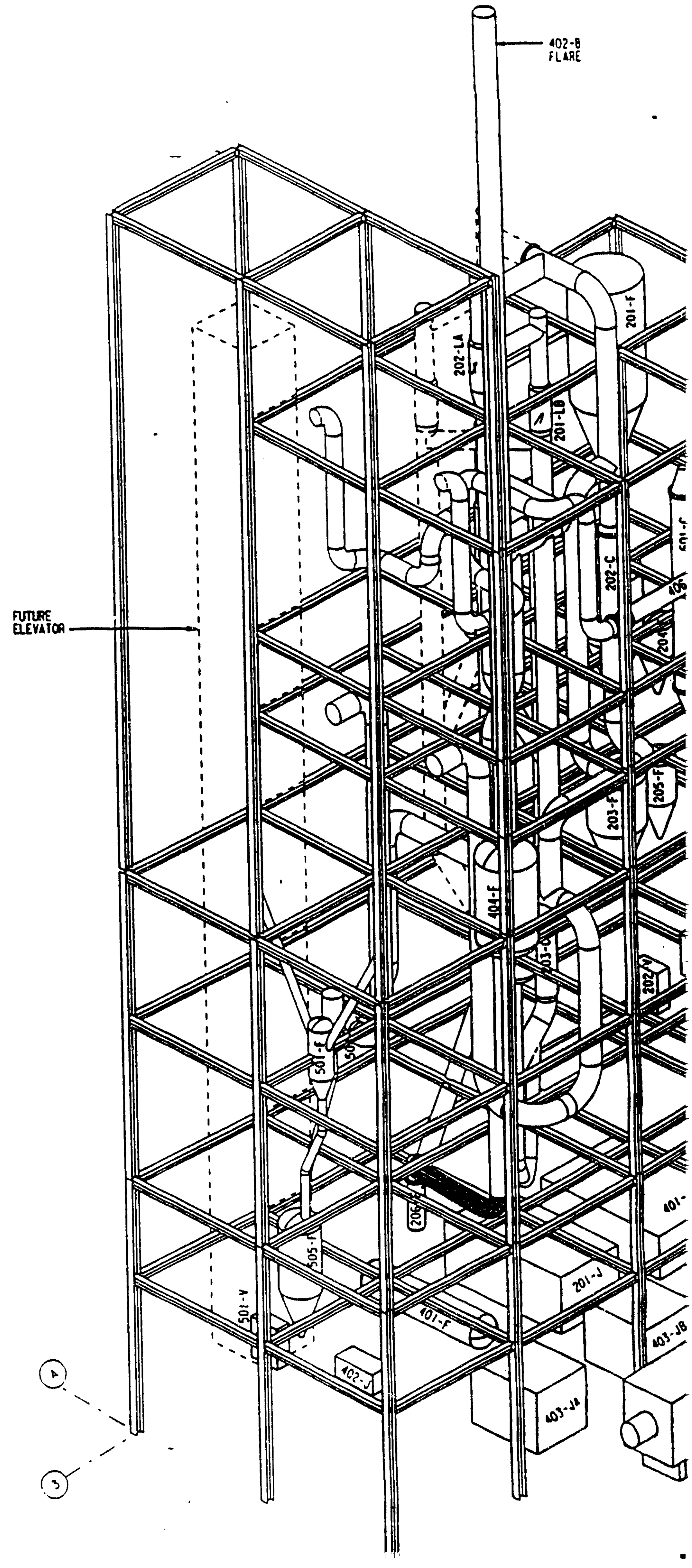


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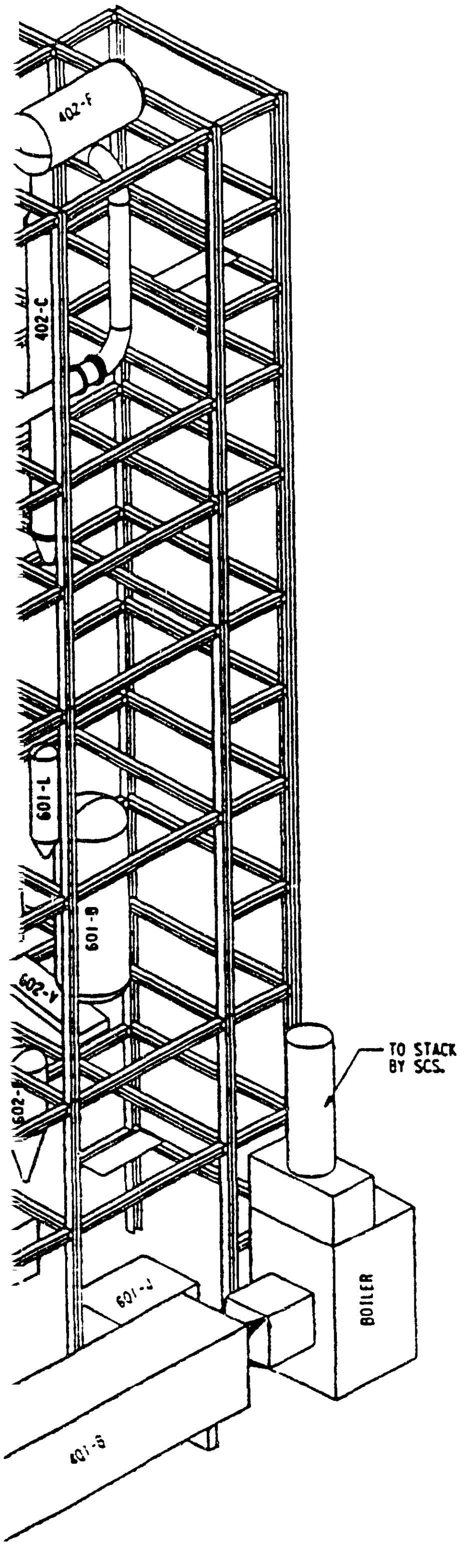
Figure 2-5

EQUIPMENT LIST

ITEMS	DESCRIPTION	NO REQ.
CLASS B:		
201-B	START UP BURNER	1
401-B	THERMAL OXIDIZER	1
402-B	FLARE	1
601-B	SULFATOR	1
602-B	SULFATOR START-UP HEATER	1
CLASS C:		
202-C	PRIMARY GAS COOLER	1
203-C	COMBUSTOR HEAT EXCHANGER	1
402-C	SECONDARY GAS COOLER	1
403-C	FLUE GAS COOLER	1
404-C	STEAM SUPERHEATER	1
405-C	COMPRESSOR FEED COOLER	1
406-C	TRIM STEAM SUPERHEATER	1
601-C	SULFATOR HEAT RECOVERY EXCHANGER	1
CLASS D:		
201-D	TRANSPORT GASIFIER / COMBUSTOR	1
CLASS F:		
201-F	COAL SURGE BIN	1
202-F	COAL PRESSURIZATION HOPPER	1
203-F	COAL FEED HOPPER	1
204-F	LIMESTONE PRESSURIZATION HOPPER	1
205-F	LIMESTONE FEED HOPPER	1
206-F	SOLIDS COOLER	1
207-F	GASIFIER/COMBUSTOR DISENGAGER	1
401-F	BLOWBACK GAS SURGE DRUM	1
402-F	STEAM DRUM	1
404-F	FLARE SEAL DRUM (NOT ON PFD)	1
501-F	FINES DEPRESSURIZATION HOPPER	1
504-F	ASH DEPRESSURIZATION HOPPER	1
505-F	SPENT SOLIDS RECEIVER	1
602-F	SPENT SOLIDS SILO	1
CLASS J:		
201-J	MAIN AIR COMPRESSOR	1
401-J	RECYCLE GAS BOOSTER COMPRESSOR	1
402-J	BLOWBACK GAS COMPRESSOR	1
403-JA/JB	THERMAL OXIDIZER AIR BLOWER	2
601-J	SULFATION AIR COMPRESSOR	1
CLASS L:		
201-LA/LB	GASIFIER/COMBUSTOR CYCLONE	2
202-LA/LB	GASIFIER/COMBUSTOR CYCLONE	2
203-LA/LB	GASIFIER/COMBUSTOR CYCLONE (DELETED)	2
204-L	COAL DEPRESSURIZATION FILTER	1
205-L	LIMESTONE DEPRESSURIZATION FILTER	1
301-L*	PARTICULATE CONTROL DEVICE #1	1
302-L*	PARTICULATE CONTROL DEVICE #2	1
601-L	SULFATOR CYCLONE	1
CLASS V:		
201-V	COAL FEEDER	1
202-V	LIMESTONE FEEDER	1
501-V	SPENT SOLIDS FEEDER	1
602-V	SULFATOR SOLIDS SCREW COOLER	1

* - NOT IN MWK SCOPE



1	PRELIMINARY CLOSE COUPLED DESIGN				2/13/92
NO	REVISION DESCRIPTION	BY	CHK.	APPR.	DATE

ENGINEERED — DRAWN SELCER/GOOD — SCALE NONE
CHECK — ISSUED FOR BID
DESIGNED — APPR. — ISSUED FOR CONST.
DATE

The M. W. Kellogg Company

DOE/SOUTHERN COMPANY SERVICES
WILSONVILLE, ALABAMA
HOT GAS CLEANUP TEST FACILITY
PLOT MODEL
ISOMETRIC VIEW

CLASS	AREA	JOB NO.	DRAWING NO.	REV
M		6704-	10-D12	1

ISOMETRIC VIEW OF MWK STRUCTURE
(From Southwest Corner of the Process Structure)

FILE ...ZIO:C104.111110D11.DWG;1
DATE 13-FEB-92 TIME 12:42:41
ISSUE BY BRILLHARTKU BOX J19A

22x34

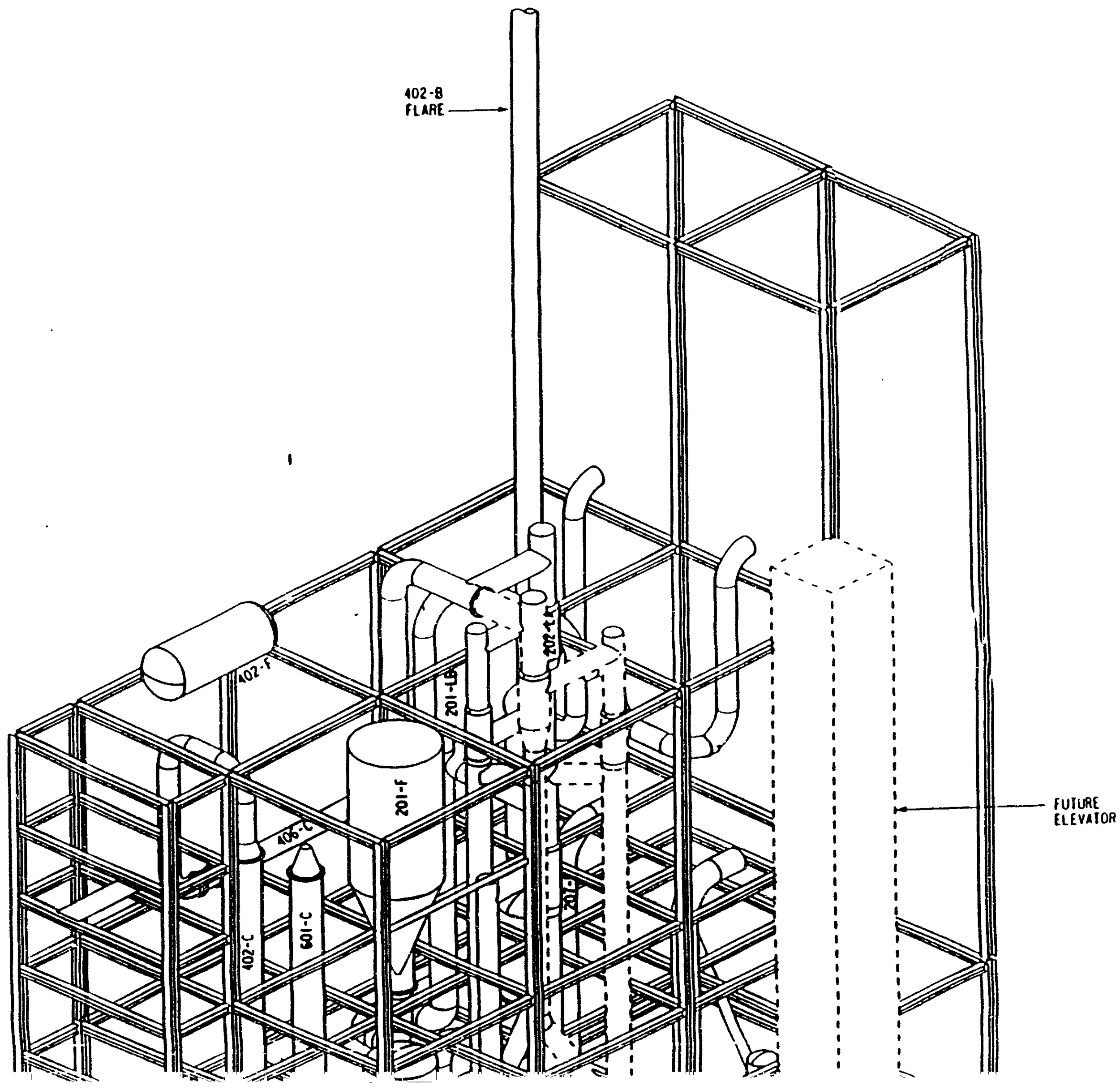
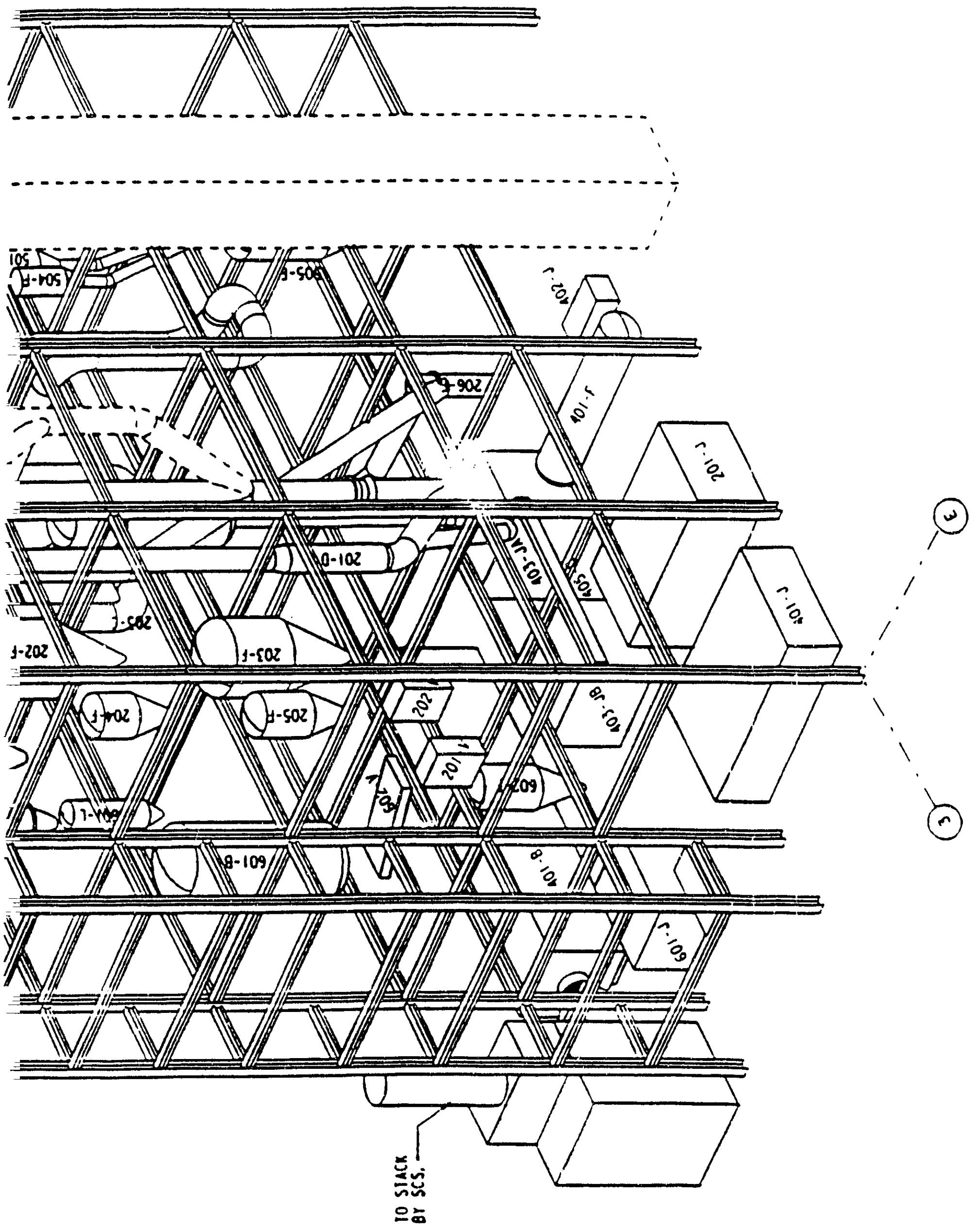


Figure 2-6

ISOMETRIC VIEW OF MWK STRUCTURE
(From Northeast Corner of the Process Sturcture)



1 PRELIMINARY CLOSE COUPLED DESIGN

The M. W. Kellogg Company

DOE/SOUTHERN COMPANY SERVICES

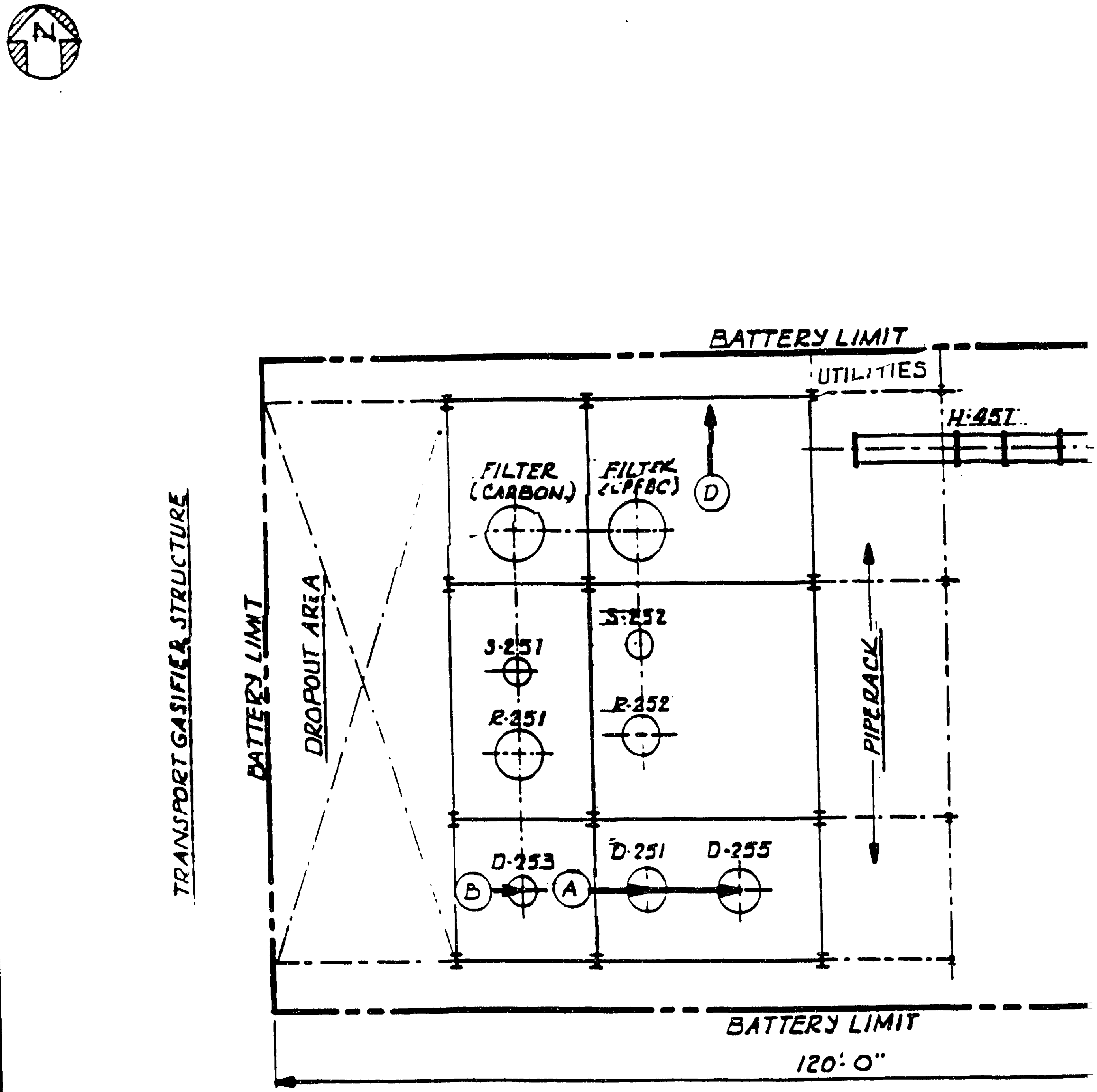
WILSONVILLE, ALABAMA

HOT GAS CLEANUP TEST FACILITY

PLOT MODEL

ISOMETRIC VIEW

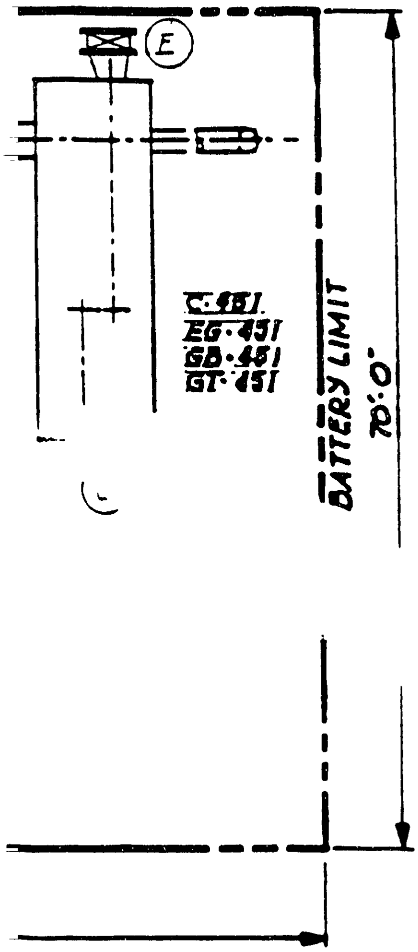
M 1 | 6704- | 10-D11 11



REVISION

FOOTPRINT

Figure 2-7



REFERENCE DRAWINGS

E-C-PC02-E : WILSONVILLE HOT GAS CLEAN-UP TEST FACILITY SITE DEVELOPMENT PLAN

E-C-P006-A : WILSONVILLE HOT GAS CLEAN-UP TEST FACILITY SITE DEVELOPMENT SECTIONS

LEGEND

- (A) COAL SUPPLY
- (B) SORBENT SUPPLY
- (C) POWER GENERATED
- (D) ASH DISCHARGE
- (E) TURBINE EXHAUST

INTERFACE DRAWING
APFBC SYSTEM
[illegible] STEMS DEVELOPMENT FACILITY
FOR
SOL[illegible] COMPANY SERVICES
WILSONVIL[illegible] ALABAMA

This Drawing is the Property of the
FOSTER WHEELER USA CORPORATION
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AND IS LENT WITHOUT CONSIDERATION OTHER THAN THE BORROWER'S AGREEMENT THAT IT SHALL NOT BE REPRODUCED, COPIED, LENT, OR DISPOSED OF DIRECTLY OR INDIRECTLY NOR USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT IS SPECIFICALLY FURNISHED. THE APPARATUS SHOWN IN THE DRAWING IS COVERED BY PATENTS.

DRAWN BY:	TWK	4/04/92	SCALE: 1/16" = 1'-0"	
CHECKED BY:			DWG. No.	REV
APPROVED BY:			37141-4-01-13	A

CHARGE No. 11-37141

- OF APFBC TRAIN

the hoppers will be shared. Although different coal size requirements for the FW and MWK modules does not permit the sharing of coal crushing and grinding equipment, the structure for housing this equipment will be common.

All of the process equipment in both transport reactor and APFBC train will be located in a common structure. The large common structure is expected to result in significant savings compared to the relatively tall and narrow structures required for either the MWK or FW process in a stand alone facility. Integration of the modules into a single structure increases the footprint and thus simplifies the foundation and structural requirements.

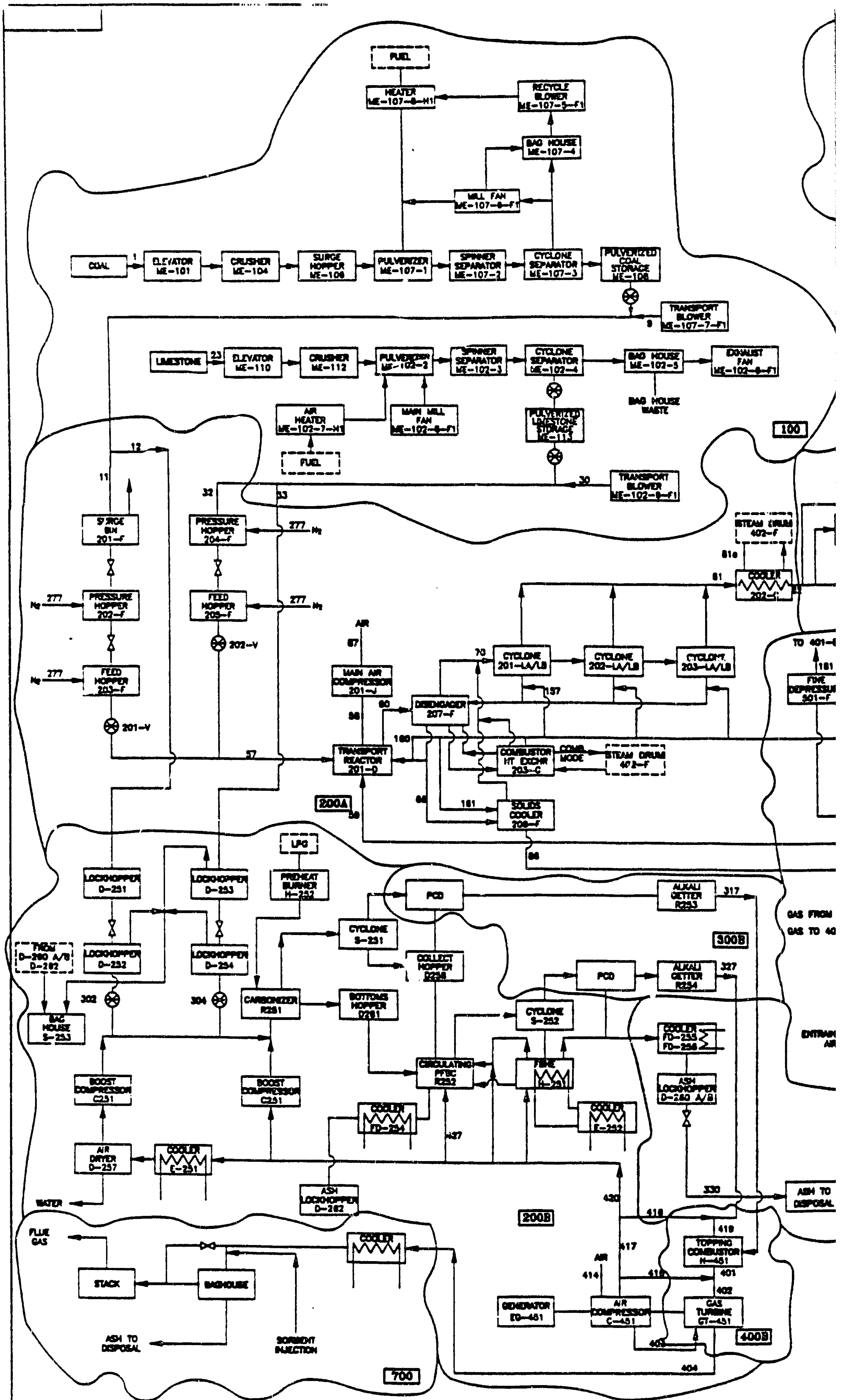
The ash disposal system will also have common equipment. An additional dump truck will not be required for transport of the ash to the Plant Gaston Landfill for disposal. Large costs savings will result in the utilities and support sections of the plant since many of the utilities required for the two processes are the same. In some cases no additional capacity is required and in other cases the capacity increase will be incremental. Savings will be realized in the following areas due to shared resources:

- water pipe lines from Plant Gaston
- boiler feed water treatment
- cooling water treatment
- building for motor control center, locker rooms, control room
- laboratory
- warehouse
- maintenance shop
- tools and maintenance equipment
- initial warehouse inventory
- control and data acquisition system
- sanitary waste water treatment system
- laboratory analytical equipment
- fire protection system
- controls for all shared utility equipment
- Continuous Emissions Monitoring Analytical equipment (only one device is required for use on both stacks)
- coal storage
- site preparation
- incoming electrical lines
- access roads.

Construction cost will also be significantly reduced since the amount of equipment to be installed is reduced by sharing. Significant saving will also result from the coordinated construction of the various modules which will reduce the mobilization cost compared to a stand alone facility. Integration also results in only an incremental increase in the number of people required to operate the facility.

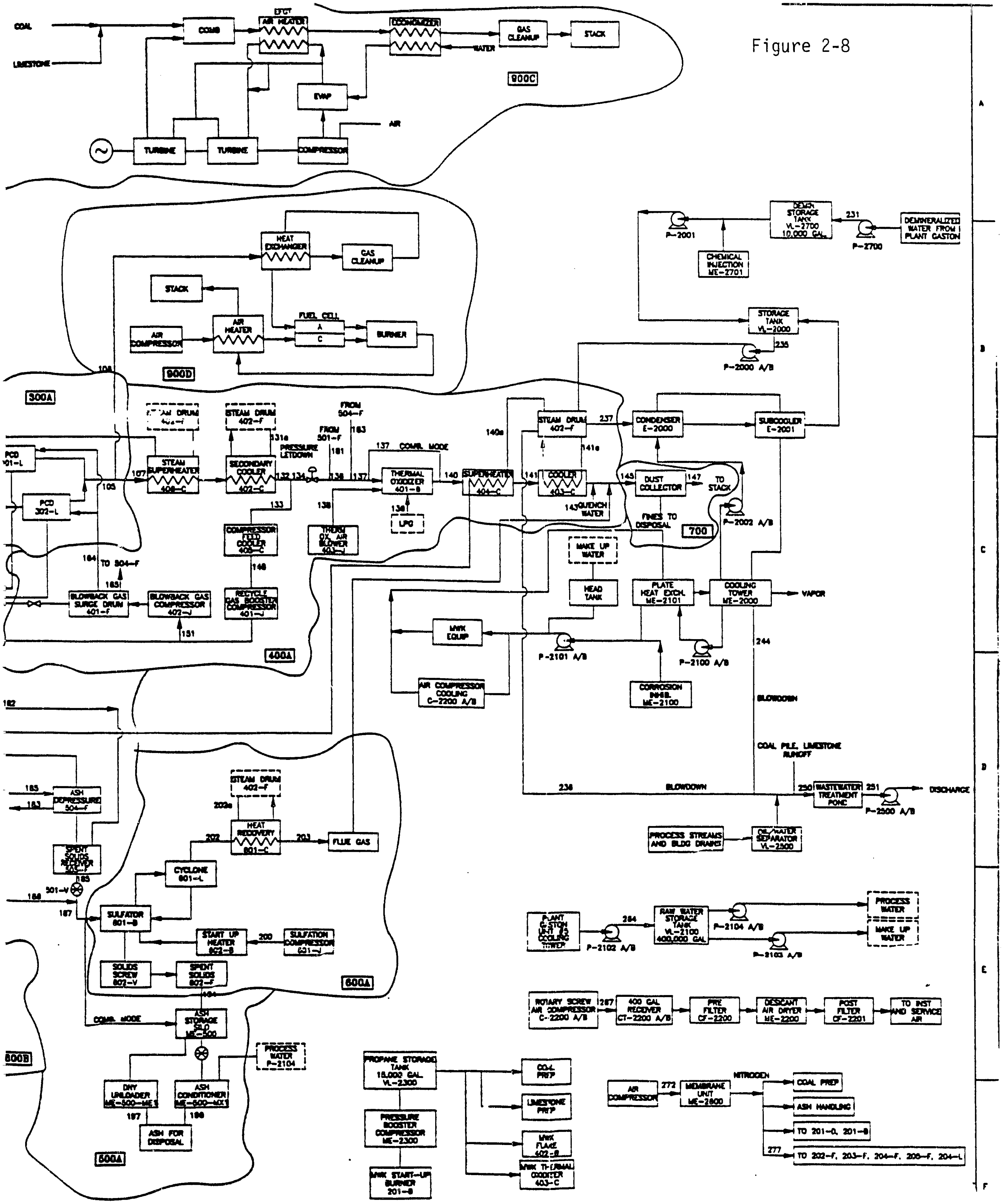
2.3.2.4 Overall Heat and Material Balance

Figure 2-8 is a overall block flow diagram of the integrated Power Systems Development Facility. Figure 2-8 and the Table 2-3 give the stream numbers by Area designations.). Table 2-4 gives a preliminary heat and material balance as


FUEL
HEATER ME-107-8-H1
RECYCLE BLOWER ME-107-5-F1
BAG HOUSE ME-107-4
MILL FAN ME-107-6-F1
COAL
ELEVATOR ME-101
CRUSHER ME-104
SURGE HOPPER ME-106
PULVERIZER ME-107-1
SPINNER SEPARATOR ME-107-2
CYCLONE SEPARATOR ME-107-3
PULVERIZED COAL STORAGE ME-108
TRANSPORT BLOWER ME-107-7-F1
LIMESTONE
ELEVATOR ME-110
CRUSHER ME-112
PULVERIZER ME-102-2
SPINNER SEPARATOR ME-102-3
CYCLONE SEPARATOR ME-102-4
BAG HOUSE ME-102-5
EXHAUST FAN ME-102-6-F1
BAG HOUSE WASTE
AIR HEATER ME-102-7-H1
MAIN MILL FAN ME-102-8-F1
PULVERIZED LIMESTONE STORAGE ME-113
FUEL
100
TRANSPORT BLOWER ME-102-9-F1
SURGE BIN 201-F
PRESSURE HOPPER 204-F
PRESSURE HOPPER 202-F
FEED HOPPER 205-F
FEED HOPPER 203-F
202-V
201-V
STEAM DRUM 402-F
COOLER 202-C
AIR
MAIN AIR COMPRESSOR 201-J
CYCLONE 201-LA/LB
CYCLONE 202-LA/LB
CYCLONE 203-LA/LB
DISENGAGER 207-F
TRANSPORT REACTOR 201-D
COMBUSTOR HT EXCHR 203-C
COMB MODE
STEAM DRUM 402-F
SOLIDS COOLER 208-F
200A
TO 401-
FINE DEPRESSU 501-F
LPG
LOCKHOPPER D-251
LOCKHOPPER D-253
PREHEAT BURNER H-252
PCD
ALKALI GETTER R253
CYCLONE S-231
COLLECT HOPPER D258
300B
GAS FROM
GAS TO 40
FROM D-280 A/B D-282
LOCKHOPPER D-252
LOCKHOPPER D-254
BAG HOUSE S-253
CARBONIZER R251
BOTTOMS HOPPER D261
PCD
ALKALI GETTER R254
CYCLONE S-252
COOLER FD-255 FD-256
ENTRAIN AIR
CIRCULATING PFBC R252
FINE H-251
ASH LOCKHOPPER D-280 A/B
BOOST COMPRESSOR C251
BOOST COMPRESSOR C251
COOLER FD-254
COOLER E-252
AIR DRYER D-257
COOLER E-251
WATER
ASH LOCKHOPPER D-262
ASH TO DISPOSAL
200B
TOPPING COMBUSTOR H-451
FLUE GAS
COOLER
STACK
BAGHOUSE
AIR
GENERATOR EG-451
AIR COMPRESSOR C-451
GAS TURBINE GT-451
400B
ASH TO DISPOSAL
SORBENT INJECTION
700

OVERALL B

Figure 2-8



ɔCK FLOW DIAGRAM WITH HEAT & MATERIAL BALANCE STREAM NUMBERS

TABLE 2-3

AREA DESIGNATION TABLE - PSDF

Area	Participant	SCS stream no.
100	MWK, SCS	1-50
200A	MWK, SCS	51-100
300A	MWK, SCS	101-130
400A	MWK, SCS	131-180
500A,600A,800A	MWK, SCS	181-210
700	MWK, SCS	211-230
2000	MWK, SCS	231-280
200B	FW	301-370
300B	FW	371-400
400B	FW	401-440
800B	FW	441-480
900D	Fuel cell	501-550
900C	EFGT	551-600

TABLE B-2

AREA

HEAT AND MATERIAL BALANCE PSDF SUMMARY SHEET 12 1892

IDENTIFICATION	Mol Weight	1 Coal to elevator ME 101 Wt%	lb/hr	9 Entrainment air to surge bin & lockh Vol%	lb/hr	11 Coal to surge bin 201-F Wt%	lb/hr	12 Coal to FW lockhoppers Wt%	lb/hr	23 Limestone to elevator ME-110 Wt%	lb/hr	30 Entrainment air to press hop & lockh Vol%	lb/hr	32 Limestone to press hopp 204 F Wt%	lb/hr	33 Limestone to FW lockhopper Wt%	lb/hr
TEMPERATURE F			80		80		80		80		80		80		80		80
PRESSURE, PSIA			15		15		15		15		15		15		15		15
GASES CO	28.011																
H2	2.016																
CO2	44.010																
CH4	16.043																
N2	28.013			79.00	700							79.00	611				
O2	31.999			21.00	212							21.00	185				
NH3	17.030																
H2S	34.080																
COS	60.075																
SO2	64.063																
H2O	18.015																
HCl	36.461																
C2+	44.097																
NOx	30.006																
HCN	27.026																
Ar	39.948																
Total		0.00	0	100.00	812	0.00	0	0.00	0	0.00	0	100.00	786	0.00	0	0.00	0
Flow lbmoles/hr			0.0		31.6		0.0		0.0		0.0		27.6				
Avg mol wt					28.847								28.847				
Gas vol ACFM																	
Gas vol SCFM																	
LIQUID H2O	18.015									100.00	175			100.00	9	100.00	18
SOLIDS C	12.011	61.83	6,289			67.54	2,138	69.67	3,817								
H	1.008	4.36	443			4.75	150	4.91	269								
O	15.999	8.10	824			9.12	289	9.13	500								
N	14.007	1.22	124			1.33	42	1.37	75								
S	32.064	2.61	265			2.85	90	2.94	161								
Cl	35.453	0.26	26			0.00	0	0.29	16								
Ash		8.62	877			9.41	298	9.69	531								
H2O	18.015	12.90	1,312			5.00	158	2.00	110								
TOTAL SOLIDS		100.00	10,171	0.00	0	100.00	3,166	100.00	5,479	0.00	0	0.00	0	0.00	0	0.00	0
SORBENT CaO	56.079									0.00	0			0.00	0	0.00	0
CaCO3	100.089									97.45	1,533			97.45	422	97.45	881
CaS	72.144									0.00	0			0.00	0	0.00	0
CaSO4	136.142									0.00	0			0.00	0	0.00	0
MgO	40.311									0.00	0			0.00	0	0.00	0
MgCO3	84.321									1.58	25			1.58	7	1.55	14
Inerts										0.97	15			0.97	4	1.00	9
TOTAL SORBENT		0.00	0	0.00	0	0.00	0	0.00	0	100.00	1,573	0.00	0	100.00	433	100.00	904
TOT FL, lb/hr			10,171		812		3,168		5,479		1,748		786		442		822
Btu/SCF LHV Gas							0										
Btu/lb LHV Sol			11,200				11,737		11,000								
Tot heat val MMBtu/hr			114		0		37		60		0		0		0		0

TABLE 2-4

AREA 200A HEAT AND MATERIAL BALANCE PSDF SUMMARY SHEET 12 MAY 1992

IDENTIFICATION	Mol Weight	57 Coal and limestone to tran reac 201 D Wt%	lb/hr	58 Air to transp reactor 201-D Wt%	lb/hr	59 Steam to transp reactor 201-D Wt%	lb/hr	60 Fuel gas/LASH to disengager 207-F Vol%	lb/hr	68 Recirc solid to solid cooler 206 F Wt%	lb/hr	70 Gases to cyclones 201/202/203 LA/LB Wt%	lb/hr	81 Fuel gas to primar gas cooler 202 C Vol%	lb/hr	81a BFW to primary gas cooler 202 C Wt%	lb/hr
TEMPERATURE F			80		400		650		1,768		1,768		1,768		1,788		
PRESSURE, PSIA			15		350		450		325		300		325		315		
GASES CO	28.011							18.37	3,564			18.37	3,564	18.37	3,878		
H2	2.016							13.65	191			13.65	191	13.65	207		
CO2	44.010							8.07	2,480			8.07	2,480	8.07	2,875		
CH4	16.043							0.38	40			0.38	40	0.36	43		
N2	28.013			79.00	8,761			51.09	8,914			51.09	8,914	51.09	10,781		
O2	31.999			21.00	2,660			0.00	0			0.00	0	0.00	0		
NH3	17.030							0.01	1			0.01	1	0.01	1		
H2S	34.080							0.02	6			0.02	6	0.02	6		
COS	60.075							0.00	0			0.00	0	0.00	0		
SO2	64.063							0.00	0			0.00	0	0.00	0		
H2O	18.015					100.00	1,076	8.40	1,049			8.40	1,048	8.40	1,140		
HCl	36.461							0.00	0			0.00	0	0.00	0		
C2+	44.097							0.00	0			0.00	0	0.00	0		
NOx	30.006							0.00	0			0.00	0	0.00	0		
HCN	27.026							0.02	4			0.02	4	0.02	4		
Ar	39.948							0.00	0			0.00	0				
Total		0.00	0	100.00	11,421	100.00	1,076	99.99	17,229	0.00	0	99.99	17,229	99.99	18,733	0.00	0
Gas flow lbmole/hr			0.0		395.9		59.7		692.9		0.0		692.9		753.0		0.0
Avg mol wt					28.850		18.015		24.866				24.866		24.877		
Gas vol ACFM					174		26		849				849		952		
Gas vol SCFM					2,503		378		4,380				4,380		4,763		
LIQUID H2O	18.015	100.00	9														
SOLIDS C	12.011	67.54	2,138					40.09	39,797	40.09	184	40.09	7,859	40.09	25		
H	1.008	4.75	150					1.11	1,103	1.11	5	1.11	221	1.11	1		
O	15.999	9.12	289					0.07	71	0.07	0	0.07	14	0.07	0		
N	14.007	1.33	42					0.35	346	0.35	2	0.35	69	0.35	0		
S	32.064	2.85	90					1.38	1,345	1.36	6	1.38	269	1.36	1		
Cl	35.453	0.00	0					0.00	0	0.00	0	0.00	0	0.00	0		
Ash		9.41	298					57.02	56,608	57.02	262	57.02	11,322	57.02	36		
H2O	18.015	5.00	158					0.00	0	0.00	0	0.00	0	0.00	0		
TOTAL SOLIDS		100.00	3,166	0.00	0	0.00	0	100.00	99,270	100.00	459	100.00	19,854	100.00	63	0.00	0
SORBENT CaO	56.079	0.00	0					35.88	21,114	35.88	98	35.88	4,223	35.88	4		
CaCO3	100.089	97.45	422					0.00	0	0.00	0	0.00	0	0.00	0		
CaS	72.144	0.00	0					61.49	36,184	61.49	167	61.49	7,237	61.49	7		
CaSO4	136.142	0.00	0					0.00	0	0.00	0	0.00	0	0.00	0		
MgO	40.311	0.00	0					1.15	679	1.15	3	1.15	136	1.15	0		
MgCO3	84.321	1.58	7					0.00	0	0.00	0	0.00	0	0.00	0		
Inerts		0.97	4					1.48	872	1.48	4	1.48	174	1.48	0		
TOTAL SORBENT		100.00	433	0.00	0	0.00	0	100.00	58,849	100.00	272	100.00	11,770	100.00	11	0.00	0
TOT FL, lb/hr			3,608		11,421		1,076		175,348		731		48,853		18,807		0
Btu/SCF LHV Gas			0						100		0		100		100		
Btu/lb LHV Sol			11,737						6,468		6,468		6,466		6,486		
Tot heat val MMBtu/hr			37		0		0		668		3		155		29		0

AREA 200A AREA 200A

IDENTIFICATION	Mol Weight	82 Fuel gas to PCDs 301 L/302 L Vol%	lb/hr	88 LASH to ash depres 504 F Wt%	lb/hr	87 Air to main compre 201-J Vol%	lb/hr
TEMPERATURE, F			1,788		600		60
PRESSURE, PSIA			315		290		15
GASES CO	28 011	18 37	3,878				
H2	2 016	13 65	207				
CO2	44 010	8 07	2,875				
CH4	16 043	0 38	43				
N2	28 013	51 08	10,781			79 00	8,901
O2	31 999	0 00	0			21 00	2,703
NH3	17 030	0 01	1				
H2S	34 080	0 02	6				
COS	60 075	0 00	0				
SO2	64 063	0 00	0				
H2O	18 015	8 40	1,140				
HCl	36 461	0 00	0				
C2+	44 097	0 00	0				
NOx	30 006	0 00	0				
HCN	27 026	0 02	4				
Ar	39 948						
Total		99 99	18,733	0 00	0	100 00	11,604
Gas flow lbmole/hr			753 0		0 0		402 2
Avg mol wt			24 677				28 850
Gas vol ACFM			852				2,490
Gas vol SCFM			4,783				2,543
LIQUID H2O	18 015						
SOLIDS C	12 011	40 09	25	40 09	184		
H	1 008	1 11	1	1 11	5		
O	15 999	0 07	0	0 07	0		
N	14 007	0 35	0	0 35	2		
S	32 064	1 38	1	1 38	6		
Cl	35 453	0 00	0	0 00	0		
Ash		57 02	36	57 02	262		
H2O	18 015	0 00	0	0 00	0		
TOTAL SOLIDS		100 00	63	100 00	459	0 00	0
SORBENT CaO	56 079	35 88	4	35 88	98		
CaCO3	100 089	0 00	0	0 00	0		
CaS	72 144	61 49	7	61 49	167		
CaSO4	136 142	0 00	0	0 00	0		
MgO	40 311	1 15	0	1 15	3		
MgCO3	84 321	0 00	0	0 00	0		
Inerts		1 48	0	1 48	4		
TOTAL SORBENT		100 00	11	100 00	272	0 00	0
TOT FL lb/hr			18,807		731		11,604
Btu/SCF LHV Gas			100		0		
Btu/lb LHV Sol			6,466		6,466		
Tot heat val MMBtu/hr			29		3		0

IDENTIFICATION	Mol Weight	105 Fuel gas to steam superheater 406-C Vol%	lb/hr	106 Fuel gas to fuel cell area 900D Vol%	lb/hr	107 Fuel gas to steam superheater 406-C Vol%	lb/hr
TEMPERATURE, F			1,768		1,768		1,768
PRESSURE, PSIA			305		305		305
GASES CO	28 011	18 37	3,882	18 37	144	18 37	3,738
H2	2 016	13 65	208	13 65	8	13 65	200
CO2	44 010	8 07	2 679	8 07	100	8 07	2,579
CH4	16 043	0 36	43	0 36	2	0 36	41
N2	28 013	51 09	10,787	51 09	402	51 09	10,385
O2	31 999	0 00	0	0 00	0	0 00	0
NH3	17 030	0 01	1	0 01	0	0 01	1
H2S	34 080	0 02	6	0 02	0	0 02	6
COS	60 075	0 00	0	0 00	0	0 00	0
SO2	64 063	0 00	0	0 00	0	0 00	0
H2O	18 015	6 40	1,142	6 40	42	6 40	1,100
HCl	36 461	0 00	0	0 00	0	0 00	0
C2+	44 097	0 00	0	0 00	0	0 00	0
NOx	30 006	0 00	0	0 00	0	0 00	0
HCN	27 026	0 02	4	0 02	0	0 02	4
Ar	39 948	0 00	0	0 00	0	0 00	0
Total		99 99	18,762	99 99	698	99 99	18,064
Gas flow lbmole/hr			754 5		28 2		726 3
Avg mol wt			24 866		24 762		24.870
Gas vol ACFM			985		37		948
Gas vol SCFM			4,770		177		4,593
LIQUID H2O	18 015						
SOLIDS C	12 011						
H	1 008						
O	15 999						
N	14 007						
S	32 064						
Cl	35 453						
Ash							
H2O	18 015						
TOTAL SOLIDS		0 00	0	0 00	0	0.00	0
SORBENT CaO	56 079						
CaCO3	100 089						
CaS	72 144						
CaSO4	136 142						
MgO	40 311						
MgCO3	84 321						
Inerts							
TOTAL SORBENT		0 00	0	0 00	0	0 00	0
TOT FL. lb/hr			18,762		698		18,064
Btu/SCF LHV Gas			100		100		100
Btu/lb LHV Sol			6,466		6,466		6,466
Tot heating val MMBtu/hr			29		1		28

IDENTIFICATION	Mol Weight	131a BFW to secondary gas cooler 402 C Vol%	lb/hr	132 Fuel gas to press letdown Vol%	lb/hr	133 Recyc gas to compr feed cooler 405 C Vol%	lb/hr	134 Fuel gas to press letdown Wt%	lb/hr	136 Fuel gas to therm oxidizer 401-B Vol%	lb/hr	137 Fuel gas to therm oxidizer 401-B Vol%	lb/hr	138 Air to thermal oxidizer 401 B Vol%	lb/hr	139 LPG to thermal oxidizer 401 B Vol%	lb/hr
TEMPERATURE, F			458		600		600		600		600		600		100		100
PRESSURE, PSIA			450		295		295		295		295		25		25		100
GASES CO	28.011			18.37	3,882	18.37	722	18.37	3,180	18.37	3,181	18.37	3,184				
H2	2.016			13.65	208	13.65	39	13.65	169	13.65	169	13.65	169				
CO2	44.010			8.07	2,679	8.07	498	8.07	2,181	8.07	2,182	8.07	2,184				
CH4	16.043			0.36	43	0.36	8	0.36	35	0.36	35	0.36	35				
N2	28.013			51.09	10,787	51.09	2,007	51.09	8,780	51.09	8,783	51.09	8,799	79.00	14,890		
O2	31.999			0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	21.00	4,521		
NH3	17.030			0.01	1	0.01	0	0.01	1	0.01	1	0.01	1				
H2S	34.080			0.02	6	0.02	1	0.02	5	0.02	5	0.02	5				
COS	60.075			0.00	0	0.00	0	0.00	0	0.00	0	0.00	0				
SO2	64.063			0.00	0	0.00	0	0.00	0	0.00	0	0.00	0				
H2O	18.015			8.40	1,142	8.40	212	8.40	930	8.40	930	8.40	931				
HCl	36.461			0.00	0	0.00	0	0.00	0	0.00	0	0.00	0				
C2+	44.097			0.00	0	0.00	0	0.00	0	0.00	0	0.00	0			100.00	175
NOx	30.006			0.00	0	0.00	0	0.00	0	0.00	0	0.00	0				
HCN	27.026			0.02	4	0.02	1	0.02	4	0.02	4	0.02	4				
Ar	39.948																
Total		0.00	0	99.99	18,762	99.99	3,488	99.99	15,275	99.99	15,280	99.99	15,292	100.00	19,411	100.00	175
Gas flow lbmole/hr			0.0		754.5		140.4		614.1		614.3		614.7		672.8		4.0
Avg mol wt					24.866		24.841		24.872		24.874		24.876		28.850		44.097
Gas vol ACFM					484		90		394		394		4,657		2,692		4
Gas vol SCFM					4,770		887		3,884		3,885		3,888		4,255		25
LIQUID H2O	18.015	100.00	9,325														
SOLIDS C	12.011			40.09	0	40.09	0	40.09	0	40.09	0	40.09	0				
H	1.008			1.11	0	1.11	0	1.11	0	1.11	0	1.11	0				
O	15.999			0.07	0	0.07	0	0.07	0	0.07	0	0.07	0				
N	14.007			0.35	0	0.35	0	0.35	0	0.35	0	0.35	0				
S	32.064			1.36	0	1.36	0	1.36	0	1.36	0	1.36	0				
Cl	35.453			0.00	0	0.00	0	0.00	0	0.00	0	0.00	0				
Ash				57.02	0	57.02	0	57.02	0	57.02	0	57.02	0				
H2O	18.015			0.00	0	0.00	0	0.00	0	0.00	0	0.00	0				
TOTAL SOLIDS		0.00	0	100.00	0	100.00	0	100.00	0	100.00	0	100.00	0	0.00	0	0.00	0
SORBENT CaO	56.079			35.88	0	35.88	0	35.88	0	35.88	0	35.88	0				
CaCO3	100.089			0.00	0	0.00	0	0.00	0	0.00	0	0.00	0				
CaS	72.144			61.49	0	61.49	0	61.49	0	61.49	0	61.49	0				
CaSO4	136.142			0.00	0	0.00	0	0.00	0	0.00	0	0.00	0				
MgO	40.311			1.15	0	1.15	0	1.15	0	1.15	0	1.15	0				
MgCO3	84.321			0.00	0	0.00	0	0.00	0	0.00	0	0.00	0				
Inerts				1.48	0	1.48	0	1.48	0	1.48	0	1.48	0				
TOTAL SORBENT		0.00	0	100.00	0	100.00	0	100.00	0	100.00	0	100.00	0	0.00	0	0.00	0
TOT FL, lb/hr			9,325		18,762		3,488		15,275		15,280		15,292		19,411		175
Btu/SCF LHV Gas			0		100		100		100		100		100		0		2,316
Btu/lb LHV Sol			0		6,466		6,466		6,466		6,466		6,466		0		0
Tot heating val MMBtu/hr			0		29		5		23		23		23		0		3

AREA 400A

IDENTIFICATION	Mol Weight	140 Gas to super heater 404-C Vol%	140 lb/hr	140a BFW to super heater 404-C Vol%	140a lb/hr	141 Gas to cooler 403-C Wt%	141 lb/hr	141a BFW to cooler 403-C Vol%	141a lb/hr	143 Quench water to gas Vol%	143 lb/hr	145 Gas to baghouse Vol%	145 lb/hr	147 Gas to stack Vol%	147 lb/hr	148 Recycle gas to boost compr 401 J Wt%	148 lb/hr
TEMPERATURE, F			800		456		800		456		100		350		330		270
PRESSURE, PSIA			20		450		20		450		300		20		15		285
GASES CO	28 011	0 00	0			0 00	0					0 00	0	0 00	0	18 37	722
H2	2 016	0 00	0			0 00	0					0 00	0	0 00	0	13 65	39
CO2	44 010	14 78	7,774			14 78	7,774					12 54	8,533	12 54	8,533	8 07	498
CH4	16 043	0 00	0			0 00	0					0 00	0	0 00	0	0 38	8
N2	28 013	70 65	23,690			70 65	23,690					61 87	26,704	61 87	26,704	51 09	2,007
O2	31 999	1 54	590			1 54	590					1 50	742	1 50	742	0 00	0
NH3	17 030	0 00	1			0 00	1					0 00	1	0 00	1	0 01	0
H2S	34 080	0 00	0			0 00	0					0 00	0	0 00	0	0 02	1
COS	60 075	0 00	0			0 00	0					0 00	0	0 00	0	0 00	0
SO2	64 063	0 01	10			0 01	10					0 01	10	0 01	10	0 00	0
H2O	18 015	13 03	2,810	100 00	1,076	13 03	2,810	100 00	29,870			24 28	6,755	24 28	6,755	8 40	212
HCl	36 461	0 00	0			0 00	0					0 00	0	0 00	0	0 00	0
C2+	44 097	0 00	0			0 00	0					0 00	0	0 00	0	0 00	0
NOx	30 006	0 00	0			0 00	0					0 00	0	0 00	0	0 00	0
HCN	27 026	0 01	4			0 01	4					0 01	4	0 01	4	0 02	1
Ar	39 948																
Total		100 00	34,879	100 00	1,076	100 00	34,879	100 00	29,870	0 00	0	99 99	42,749	99 99	42,749	99 89	3,488
Gas flow lbmole/hr			1197 1		59 7		1197 1		1683 6		0 0		1545 7		1545 7		140 4
Avg mol wt			29 138		18 015		29 138		18 015				27 657		27 657		24 841
Gas vol ACFM			13,475		22		13,475		605				11,184				62
Gas vol SCFM			7,570		378		7,570		10,520				8,775				887
LIQUID H2O	18 015									100 00	3,894						
SOLIDS C	12 011											0 63	0			40 09	0
H	1 008											0 02	0			1 11	0
O	15 999											0 12	0			0 07	0
N	14 007											0 60	0			0 35	0
S	32 064											0 02	0			1 38	0
Cl	35 453											0 00	0			0 00	0
Ash												88 60	3			57 02	0
H2O	18 015											0 00	0			0 00	0
TOTAL SOLIDS		0 00	0	0 00	0	0 00	0	0 00	0	0 00	0	99 99	3	0 00	0	100 00	0
SORBENT CaO	56 079											19 75	1			35 88	0
CaCO3	100 089											0 00	0			0 00	0
CaS	72 144											0 00	0			61 49	0
CaSO4	136 142											78 61	4			0 00	0
MgO	40 311											0 72	0			1 15	0
MgCO3	84 321											0 00	0			0 00	0
Inerts												0 92	0			1 48	0
TOTAL SORBENT		0 00	0	0.00	0	0.00	0	0.00	0	0.00	0	100 00	5	0 00	0	100 00	0
TOT FL. lb/hr			34,879		1,076		34,879		29,870		3,894		42,757		42,749		3,488
Btu/SCF LHV Gas			0		0				0		0		0				100
Btu/lb LHV Sol					0				0		0		92				6,488
Tot heating val MMBtu/hr			0		0		0		0		0		0		0		5

IDENTIFICATION	Mol Weight	151 Recycle gas to blbk compr 402 J Vol%	151 lb/hr	157 Recycle gas to cyclone 201 LA/LB Vol%	157 lb/hr	160 Recycle gas to transp reac 201 D Vol%	160 lb/hr	181 Recycle gas to solid cool 208-F Vol%	181 lb/hr	164 Recycle gas to PCDs 301-L/302 L Wt%	164 lb/hr	165 Vent gas to ash depress 504-F Vol%	165 lb/hr
TEMPERATURE, F			450		450		450		450		550		550
PRESSURE, PSIA			400		400		400		400		600		600
GASES CO	28 011	18 37	9	18 37	312	18 37	401	18 37	106	18 37	6	18 37	2
H2	2 016	13 65	0	13 65	17	13 65	21	13 65	6	13 65	0	13 65	0
CO2	44 010	8 07	6	8 07	215	8 07	277	8 07	73	8 07	4	8 07	2
CH4	16 043	0 36	0	0 36	3	0 36	4	0 36	1	0 36	0	0 36	0
N2	28 013	51 09	25	51 09	867	51 09	1,115	51 09	295	51 09	16	51 09	7
O2	31 999	0 00	0	0 00	0	0 00	0	0 00	0	0 00	0	0 00	0
NH3	17 030	0 01	0	0 01	0	0 01	0	0 01	0	0 01	0	0 01	0
H2S	34 080	0 02	0	0 02	1	0 02	1	0 02	0	0 02	0	0 02	0
COS	60 075	0 00	0	0 00	0	0 00	0	0 00	0	0 00	0	0 00	0
SO2	64 063	0 00	0	0 00	0	0 00	0	0 00	0	0 00	0	0 00	0
H2O	18 015	8 40	3	8 40	92	8 40	118	8 40	31	8 40	2	8 40	1
HCl	36 461	0 00	0	0 00	0	0 00	0	0 00	0	0 00	0	0 00	0
C2+	44 097	0 00	0	0 00	0	0 00	0	0 00	0	0 00	0	0 00	0
NOx	30 006	0 00	0	0 00	0	0 00	0	0 00	0	0 00	0	0 00	0
HCN	27 026	0 02	0	0 02	0	0 02	0	0 02	0	0 02	0	0 02	0
Ar	39 948												
Total		99 99	43	99 99	1,507	99 99	1,937	99 99	512	99 99	28	99 99	12
Gas flow lbmole/hr			1 5		80 7		77 7		20 7		1 0		0 4
Avg mol wt			28 353		24.815		24 843		24.695		28 361		28 420
Gas vol ACFM			1		25		32		8		0		0
Gas vol SCFM			11		383		493		130		7		3
LIQUID H2O	18 015												
SOLIDS C	12 011	40 09	0	40 09	0	40 09	0	40 09	0	40 09	0	40 09	0
H	1 008	1 11	0	1 11	0	1 11	0	1 11	0	1 11	0	1 11	0
O	15 999	0 07	0	0 07	0	0 07	0	0 07	0	0 07	0	0 07	0
N	14 007	0 35	0	0 35	0	0 35	0	0 35	0	0 35	0	0 35	0
S	32 064	1 38	0	1 38	0	1 38	0	1 38	0	1 38	0	1 38	0
Cl	35 453	0 00	0	0 00	0	0 00	0	0 00	0	0 00	0	0 00	0
Ash		57 02	0	57 02	0	57 02	0	57 02	0	57 02	0	57 02	0
H2O	18 015	0 00	0	0 00	0	0 00	0	0 00	0	0 00	0	0.00	0
TOTAL SOLIDS		100 00	0	100 00	0	100 00	0	100 00	0	100 00	0	100 00	0
SORBENT CaO	56 079	35 88	0	35 88	0	35 88	0	35 88	0	35 88	0	35 88	0
CaCO3	100 089	0 00	0	0 00	0	0 00	0	0 00	0	0 00	0	0 00	0
CaS	72 144	61 49	0	61 49	0	61 49	0	61 49	0	61 49	0	61 49	0
CaSO4	136 142	0 00	0	0 00	0	0 00	0	0 00	0	0 00	0	0 00	0
MgO	40 311	1 15	0	1 15	0	1 15	0	1 15	0	1 15	0	1 15	0
MgCO3	84 321	0 00	0	0 00	0	0 00	0	0 00	0	0 00	0	0 00	0
Inerts		1 48	0	1 48	0	1 48	0	1 48	0	1 48	0	1 48	0
TOTAL SORBENT		100 00	0	100 00	0	100 00	0	100 00	0	100 00	0	100 00	0
TOT FL, lb/hr			43		1,507		1,937		512		28		12
Btu/SCF LHV Gas			100		100		100		100		100		100
Btu/lb LHV Sol			6,488		6,485		6,485				6,465		6,485
Tot heating val MMBtu/hr			0		2		3		1		0		0

A\ JUA 600A, 700, 800A HEAT AND MATERIAL BALANCE : PSDF SUMMARY SHEET .2-MAY-1992

IDENTIFICATION	Mol Weight	181 Vent to thermal oxidizer 401-B Vol%	181 lb/hr	182 LASH to solids receiver 505-F Wt%	182 lb/hr	183 Vent to thermal oxidizer 401-B Vol%	183 lb/hr	185 LASH to sulfator 601-B Wt%	185 lb/hr	186 Air to sulfator 601-B Wt%	186 lb/hr	187 LASH to sulfator 601-B Vol%	187 lb/hr	184 Ash to storage silo ME-500 Wt%	184 lb/hr	197 Ash to disposal Vol%	197 lb/hr
TEMPERATURE, F			1,788		1,788		600		600		425		600		150		140
PRESSURE, PSIA			305		305		25		15		50		15		15		15
GASES CO	28 011	18 37	1			18 37	2										
H2	2 016	13 65	0			13 65	0										
CO2	44 010	8 07	1			8 07	2										
CH4	16 043	0 38	0			0 38	0										
N2	28 013	51 09	3			51 09	7			79 00	140	79 00	140				
O2	31 999	0 00	0			0 00	0			21 00	42	21 00	42				
NH3	17 030	0 01	0			0 01	0										
H2S	34 080	0 02	0			0 02	0										
COS	60 075	0 00	0			0 00	0										
SO2	64 063	0 00	0			0 00	0										
H2O	18 015	8 40	0			8 40	1										
HCl	36 461	0 00	0			0 00	0										
C2+	44 097	0 00	0			0 00	0										
NOx	30 006	0 00	0			0 00	0										
HCN	27 028	0 02	0			0 02	0										
Total		99 99	5	0 00	0	99 99	12	0.00	0	100 00	182	100 00	182	0 00	0	0 00	0
Gas flow lbmole/hr			0		0		0		0		6		6		0		0
Avg mol wt			30 209				28 420				28 842		28 842				
Gas vol ACFM			0		0		3		0		20		80				
Gas vol SCFM			1		0		3		0		40		40				
LIQUID H2O	18 015																
SOLIDS C	12 011	40 08	0	40 09	25	40 08	0	40 09	209			40 09	209	0 69	2	0 69	2
H	1 008	1 11	0	1 11	1	1 11	0	1 11	6			1 11	6	0 02	0	0 02	0
O	15 999	0 07	0	0 07	0	0 07	0	0 07	0			0 07	0	0 12	0	0 12	0
N	14 007	0 35	0	0 35	0	0 35	0	0 35	2			0 35	2	0 60	2	0 60	2
S	32 064	1 38	0	1 38	1	1 36	0	1 38	7			1 38	7	0 02	0	0 02	0
Cl	35 453	0 00	0	0 00	0	0 00	0	0 00	0			0 00	0	0 00	0	0 00	0
Ash		57 03	0	57 02	36	57 03	0	57 02	298			57 02	298	98 54	295	98 54	266
H2O	18 015	0 00	0	0 00	0	0 00	0	0.00	0			0 00	0	0 00	0	0 00	0
TOTAL SOLIDS		100 00	0	100 00	63	100 00	0	100 00	522	0 00	0	100 00	522	99 99	299	99 99	269
SORBENT CaO	56 079	35 88	0	35 88	4	35 88	0	35 88	102			35 88	102	19 64	69	19 64	80
CaCO3	100 089	0 00	0	0 00	0	0 00	0	0.00	0			0 00	0	0 00	0	0 00	0
CaS	72 144	61 49	0	61 49	7	61 49	0	61.49	175			61 49	175	0 00	0	0 00	0
CaSO4	136 142	0 00	0	0.00	0	0 00	0	0.00	0			0 00	0	78 72	355	78 72	320
MgO	40 311	1 15	0	1 15	0	1 15	0	1.15	3			1.15	3	0 72	3	0 72	3
MgCO3	84 321	0 00	0	0 00	0	0 00	0	0.00	0			0 00	0	0 00	0	0 00	0
Inerts		1 48	0	1.48	0	1 48	0	1.48	4			1 48	4	0 92	4	0 92	4
TOTAL SORBENT		100 00	0	100 00	11	100 00	0	100.00	284	0 00	0	100 00	284	100 00	451	100 00	408
TOT FL, lb/hr			5		74		12		808		182		988		750		675
Btu/SCF LHV Gas			100		0		100		0		0		0		0		0
Btu/lb LHV Sol			6,485		6,486		6,486		6,486		0		6,486		102		102
Tot heating val MMBtu/hr			0		0		0		3		0		3		0		0

IDENTIFICATION	Mol Weight	198 Ash to disposal Wt%	lb/hr	200 Air to start up heater 602-B Wt%	lb/hr	202 Flue gas to heat rec 601-C Vol%	lb/hr	202a BFW to heat rec 601-C Vol%	lb/hr	203 Flue gas to baghouse Vol%	lb/hr
TEMPERATURE, F			140		425		1,650		250		490
PRESSURE, PSIA			15		50		20		500		15
GASES CO	28.011					0.00	0			0.00	0
H2	2.016					0.00	0			0.00	0
CO2	44.010					13.02	759			13.02	759
CH4	16.043					0.00	0			0.00	0
N2	28.013			79.00	2,875	81.23	3,014			81.23	3,014
O2	31.999			21.00	873	3.60	153			3.60	153
NH3	17.030					0.00	0			0.00	0
H2S	34.080					0.00	0			0.00	0
COS	60.075					0.00	0			0.00	0
SO2	64.063					0.00	0			0.00	0
H2O	18.015					2.15	51			2.15	51
HCl	36.461					0.00	0			0.00	0
C2+	44.097					0.00	0			0.00	0
NOx	30.006					0.00	0			0.00	0
HCN	27.026					0.00	0			0.00	0
Total		0.00	0	100.00	3,748	100.00	3,977	0.00	0	100.00	3,977
Gas flow lbmole/hr			0		130		132		0.0		132.5
Avg mol wt					28.850		30.026				30.026
Gas vol ACFM					411		2,497				1,499
Gas vol SCFM					821		838				838
LIQUID H2O	18.015							100.00	4,062		
SOLIDS C	12.011	0.69	0			0.69	0			0.69	0
H	1.008	0.02	0			0.02	0			0.02	0
O	15.999	0.12	0			0.12	0			0.12	0
N	14.007	0.60	0			0.60	0			0.60	0
S	32.064	0.02	0			0.02	0			0.02	0
Cl	35.453	0.00	0			0.00	0			0.00	0
Ash		98.54	30			98.54	3			98.54	3
H2O	18.015	0.00	0			0.00	0			0.00	0
TOTAL SOLIDS		99.99	30	0.00	0	99.99	3	0.00	0	99.99	3
SORBENT CaO	56.079	19.64	9			19.64	1			19.64	1
CaCO3	100.089	0.00	0			0.00	0			0.00	0
CaS	72.144	0.00	0			0.00	0			0.00	0
CaSO4	136.142	78.72	36			78.72	4			78.72	4
MgO	40.311	0.72	0			0.72	0			0.72	0
MgCO3	84.321	0.00	0			0.00	0			0.00	0
Inerts		0.92	0			0.92	0			0.92	0
TOTAL SORBENT		100.00	45	0.00	0	100.00	5	0.00	0	100.00	5
TOT FL, lb/hr			75		3,748		3,985		4,062		3,985
Btu/SCF LHV Gas			0		0		0		0		0
Btu/lb LHV Sol			102		0		102		0		102
Tot heating val MMBtu/hr			0		0		0		0		0

AREA 200B — HEAT AND MATERIAL BALANCE - PSDF SUMMARY SH. — 12-MAY-1992

IDENTIFICATION	Mol Weight	302 Coal to carbonizer Wt%	302 lb/hr	304 Limestone to carbonizer Wt%	304 lb/hr	317 Fuel gas to topping combustor Vol%	317 lb/hr	327 Flue gas to topping comb Vol%	327 lb/hr	330 Ash to disposal Wt%	330 lb/hr
TEMPERATURE, F			80		80		1,600		1,600		300
PRESSURE, PSIA			15		15		170		148		15
GASES CO	28 011						1,667				
H2	2 016						48				
CO2	44 010						1,731		7,174		
CH4	16 043						318				
N2	28 013						8,457		48,687		
O2	31 999								9,539		
NH3	17 030						27				
H2S	34 080						17				
COS	60 075										
SO2	64 063										
H2O	18 015						383		533		
HCl	36 461										
C2+	44 097						231				
NOx	30 006										
HCN	27 026										
Ar	39 948						159		845		
Total		0 00	0	0.00	0	0 00	11,048	0 00	66,778	0 00	0
Flow lbmoles/hr			0		0		406		2,250		0
Avg mol wt.							27 206		29 681		
Gas vol ACFM											
Gas vol SCFM											
LIQUID H2O	18 015			100.00	18						
SOLIDS C	12 011	69 67	3,817								365
H	1 008	4 91	269								
O	15 999	9 13	500								
N	14 007	1 37	75								
S	32 064	2 94	161								
Cl	35 453	0 29	16								
Ash		9 69	531								540
H2O	18 015	2 00	110								
TOTAL SOLIDS		100 00	5,479	0.00	0	0.00	0	0 00	0	0 00	905
SORBENT CaO	56 079				0						240
CaCO3	100 089				881						
CaS	72 144				0						1
CaSO4	136 142				0						613
MgO	40 311				0						7
MgCO3	84 321				14						
Inerts					9						
TOTAL SORBENT		0 00	0	0 00	904	0.00	0	0.00	0	0.00	881
TOT FL, lb/hr			5,479		922		11,048		66,778		1,766
Btu/SCF LHV Gas											
Btu/lb LHV Sol			11,000								
Tot heat val MMBtu/hr			60		0		0		0		0

AREA 400B

HEAT AND MATERIAL BALANCE - PSDF SUMMARY SHEET

14-MAY-1992

IDENTIFICATION	Mol Weight	401 Flue gas to gas turbine Vol%	lb/hr	402 Flue gas to gas turbine Vol%	lb/hr	403 Air to gas turbine Vol%	lb/hr	404 Flue gas to gas cooler Vol%	lb/hr	414 Air to air compressor Vol%	lb/hr	416 Air to topping combustor Vol%	lb/hr	417 Air to solids cooler, compr, etc Vol%	lb/hr	418 Air to topping combustor Vol%	lb/hr
TEMPERATURE, F			2,350		1,877		693		980		59		693		693		693
PRESSURE, PSIA			147		145				15		15		165		165		165
GASES CO	28 011																
H2	2 016																
CO2	44 010		13,078		13,092				13,098		60						
CH4	16 043																
N2	28 013		81,723		83,324		8,840		91,888		91,795		22,347		63,008		6,784
O2	31 999		8,018		14,638		2,670		17,257		28,322		6,751		19,034		2,050
NH3	17 030																
H2S	34 080																
COS	60 075																
SO2	64 063		32		32				32								
H2O	18 015		2,690		3,185				3,381		847						
HCl	36 461																
C2+	44 097																
NOx	30 006		6		6				6								
HCN	27 026																
Ar	39 948		1,115		1,481				1,626		1,626						
Total		0.00	86,660	0.00	115,758	0.00	11,510	0.00	127,268	0.00	122,650	0.00	29,098	0.00	82,042	0.00	8,834
Flow lbmoles/hr			2,929		3,944		399		4,345		4,251		1,009		2,844		306
Avg mol wt			29 587		29 351		28 847		29 268		28 852		28 847		28 847		28 847
Gas vol ACFM																	
Gas vol SCFM																	
LIQUID H2O	18 015																
SOLIDS C	12 011																
H	1 008																
O	15 999																
N	14 007																
S	32 064																
Cl	35 453																
Ash																	
H2O	18 015																
TOTAL SOLIDS		0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
SORBENT CaO	56 079																
CaCO3	100 089																
CaS	72 144																
CaSO4	136 142																
MgO	40 311																
MgCO3	84 321																
Inerts																	
TOTAL SORBENT		0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
TOT FL, lb/hr			86,660		115,758		11,510		127,268		122,650		29,098		82,042		8,834
Btu/SCF LHV Gas											0		0		0		0
Btu/lb LHV Sol											0		0		0		0
Tot heat val MMBtu/hr			0		0		0		0		0		0		0		0

AREA 400B

IDENTIFICATION	Mol Weight	419 Air to topping combustor Vol%	419 lb/hr	420 Air to solid cool PFBC, etc Vol%	420 lb/hr	427 Air to PFBC Vol%	427 lb/hr
TEMPERATURE, F			1,500		693		693
PRESSURE, PSIA			150		165		165
GASES CO	28 0:1						
H2	2 0'3						
CO2	44 010		7,178				
CH4	16 043						
N2	28 013		55,248		56,224		49,768
O2	31 999		11,549		16,984		15,034
NH3	17 030						
H2S	34 080						
COS	60 075						
SO2	64 063						
H2O	18 015		883				
HCl	36 461						
C2+	44 097						
NOx	30 006						
HCN	27 026						
Ar	39 948		956				
Total		0 00	75,812	0 00	73,208	0 00	64,802
Flow lbmoles/hr			2,558		2,538		2,246
Avg mol wt			29 559		28 847		28 847
Gas vol ACFM							
Gas vol SCFM							
LIQUID H2O	18 015						
SOLIDS C	12 011						
H	1 008						
O	15 999						
N	14 007						
S	32 064						
Cl	35 453						
Ash							
H2O	18 015						
TOTAL SOLIDS		0 00	0	0 00	0	0.00	0
SORBENT CaO	56 079						
CaCO3	100 089						
CaS	72 144						
CaSO4	136 142						
MgO	40 311						
MgCO3	84 321						
Inerts							
TOTAL SORBENT		0 00	0	0 00	0	0 00	0
TOT FL, lb/hr			75,812		73,208		64,802
Btu/SCF LHV Gas			0		0		0
Btu/lb LHV Sol			0		0		0
Tot heat val MMBtu/hr			0		0		0

AREA 2000 HEAT AND MATERIAL BALANCE PSDF SUMMARY SHEET 12-MAY-1992

IDENTIFICATION	Mol Weight	231 Water to storage tank VL-2700 Vol%	231 lb/hr	235 Water to steam drum 402-F Wt%	235 lb/hr	238 Water blowdown to waste water tr Vol%	238 lb/hr	237 Water to condenser E-2000 Vol%	237 lb/hr	244 Water to waste wat tr pond Vol%	244 lb/hr	250 Water to waste wat tr pond Wt%	250 lb/hr	251 Water to discharge Wt%	251 lb/hr	264 Water to sturgage tank VL-2100 Wt%	264 lb/hr
TEMPERATURE, F					250		456		456		80		80		80		80
PRESSURE, PSIA					500		450		450		14 5		14 5		14 5		65 0
GASES CO	28 011																
H2	2 016																
CO2	44 010																
CH4	18 043																
N2	28 013																
O2	31 999																
NH3	17 030																
H2S	34 080																
COS	60 075																
SO2	64 063																
H2O	18 015							100 00	33,711								
HCl	36 461																
C2+	44 097																
NOx	30 006																
HCN	27 026																
Total		0 00	0	0 00	0	0 00	0	100 00	33,711	0 00	0	0 00	0	0 00	0	0 00	0
Gas flow lbmole/hr			0		0		0		1,871		0		0		0		0
Avg mol wt									18 015								
Gas vol ACFM									681								
Gas vol SCFM									11,833								
LIQUID H2O	18 015			100.00	35,497	100 00	710			100 00	12,857	100.00	18,732	100.00	18,732	100 00	84,811
SOLIDS C	12 011																
H	1 008																
O	15 999																
N	14 007																
S	32 064																
Cl	35 453																
Ash																	
H2O	18 015																
TOTAL SOLIDS		0 00	0	0 00	0	0 00	0	0.00	0	0 00	0	0 00	0	0 00	0	0 00	0
SORBENT CaO	56 079																
CaCO3	100 089																
CaS	72 144																
CaSO4	136 142																
MgO	40 311																
MgCO3	84 321																
Inerts																	
TOTAL SORBENT		0 00	0	0 00	0	0 00	0	0.00	0	0 00	0	0 00	0	0 00	0	0 00	0
TOT FL, lb/hr			0		35,497		710		33,711		12,857		18,732		18,732		84,811
Btu/SCF LHV Gas					0		0		0								
Btu/lb LHV Sol					0		0		0								
Tot heating val MMBtu/hr			0		0		0		0		0		0		0		0

AREA 2000

IDENTIFICATION	Mol Weight	287 Air to receiver CT 2200 A/B Wt%	lb/hr	272 Air to membrane unit ME-2800 Wt%	lb/hr	277 Nitrogen to 202-F 203-F, 205 F, etc Vol%	lb/hr
TEMPERATURE, F			100				120
PRESSURE, PSIA			139				500
GASES CO	28 011						
H2	2 016						
CO2	44 010						
CH4	16 043						
N2	28 013		701			100 00	102
O2	31 999		212				
NH3	17 030						
H2S	34 080						
COS	60 075						
SO2	64 063						
H2O	18 015						
HCl	36 461						
C2+	44 097						
NOx	30 006						
HCN	27 026						
Total		0 00	913	0 00	0	100 00	102
Gas flow lbmole/hr			31 7		0		4
Avg mol wt			28 847				28 013
Gas vol ACFM			23				1
Gas vol SCFM			200				23
LIQUID H2O	18 015						
SOLIDS C	12 011						
H	1 008						
O	15 999						
N	14 007						
S	32 064						
Cl	35 453						
Ash							
H2O	18 015						
TOTAL SOLIDS		0 00	0	0 00	0	0 00	0
SORBENT CaO	56 079						
CaCO3	100 089						
CaS	72 144						
CaSO4	136 142						
MgO	40 311						
MgCO3	84 321						
Inerts							
TOTAL SORBENT		0.00	0	0 00	0	0.00	0
TOT FL, lb/hr			913		0		102
Btu/SCF LHV Gas							0
Btu/lb LHV Sol							0
Tot heating val MMBtu/hr			0		0		0

well as stream compositions for the entire facility. The material balance is based on the use of Illinois No. 6 coal and Longview Limestone.

The overall heat and material balance uses MWK's Case 2 study in which the transport reactor is operated in gasification mode and high temperature gas is fed to the PCD). Coal and limestone are ground to an average particle diameter of 100 microns. Coal and limestone from a pressurization/feed hopper system is fed continuously at a controlled rate by feeders to a transfer line where it is picked up by recycle carrier gas and fed to the transport reactor. Air from the main air compressor and superheated steam (gasification mode) from Area 400 are also fed to the transport reactor. Other heat and material balance case studies with bituminous and subbituminous coal feeds to the transport reactor are presented in Design Documents submitted to DOE.

The overall heat and material balance also uses the balances developed by FW for the advanced Circulating Pressurized Fluidized Bed Combustion module. All streams identified in the APFBC module are 100 percent load and are based on the use of Illinois No. 6 coal and longview limestone. Coal delivered to the unit will be crushed to 1/8 inch x 0 and dried to less than 2 percent surface moisture. Longview limestone will be delivered in a crushed (1/8 inch x 0) and dried condition. A bypass stream of 12% of the air flow to the carbonizer and CPFBC results in a lower vitiated air temperature (1500°F) entering the topping combustor. At this inlet temperature level the topping combustor metal temperatures should be easily kept at "safe levels". Unit operation will start at this level of bypass and as confidence is gained gradually move toward 0% by pass.

Although provision has also been made for the feeding of a coal water mixture (CWM), this was not considered as a basis for designing the APFBC module. Allowance has also been made in the specification of the FBHE equipment for simulation of the commercial plant maximum power output case, viz., maximum steam generation (heat removal) by the FBHE.

2.3.2.5 ASPEN Process Simulation Package Development

SCS has begun work on developing a process simulation package for the Power Systems Development Facility. A personal computer based ASPEN package with model manager has been chosen as the simulator primarily because of its broad applicability and its ability to handle solids components. This type of system has allowed SCS engineers who are unfamiliar with ASPEN programming language to quickly develop models and to review results within minutes of completing code changes. The objective of the simulation is to create a package that will reliably provide material and heat balances around the entire test facility under a variety of operating conditions. Scenarios that could be tested out using this simulation include the use of different particulate control devices, running the gasifier/combustor at different pressures, temperatures, recycle rates, and obtaining environmental emission information under these scenarios. The philosophy in this effort is that a detailed equipment simulation of a gasifier, a particulate control device or any other piece of equipment is not required. From a process perspective it is considered more important to be able to simulate bulk thermodynamic changes as they take place at equipment exits given inlet streams and operating conditions for each unit operation. Thus the internal details of a reactor or combustor are not of concern to SCS. However it is necessary to understand the basic reactions and their temperature dependencies that are taking place in the reactor since they impact outlet gas concentrations and flows.

A first draft simulation of the M. W. Kellogg transport train in the air blown, high temperature, gasification mode has been completed. The simulation includes unit operations from coal/limestone/steam/air input to the gasifier to flue gas vent, and solids disposal. The simulation assumes ideal gas behavior throughout the entire flowsheet. In general, there appears to be reasonable agreement between the ASPEN predictions and M. W. Kellogg's material balance data at these conditions for this particular mode of operation. Some significant refinements and improvements need to be incorporated into the model before it can be used as a reliable tool for prediction of stream properties.

A first version simulation of the Foster Wheeler PFBC train is also being developed at this time. The simulation is being refined and updated as more information becomes available from literature searches. As with the M. W. Kellogg train the Foster Wheeler train simulation is not a detailed equipment model but rather a representation of the overall thermodynamic changes occurring in the process with each unit operation.

2.3.3 Advanced Gasifier Module Modifications

Heat and material balances were completed for an oxygen blown gasification case as part of the facility expansion. The equipment capacities needed for this case were checked against those specified in the stand-alone facility design. All equipment capacities for the oxygen blown case are the same as in the stand-alone facility design except that a larger capacity sulfator is required for the oxygen blown case.

A preliminary design of the flare system to be utilized by both the transport reactor and the FW carbonizer was completed. The system includes an oil quench system to cool the 1800°F gas from the carbonizer. This design was used to estimate the cost of the flare system. However, in the detailed design, separate flare systems will likely be designed, since the flare system will be a integral part of the control philosophy for each process.

In addition to the facility expansion estimate, four heat and material balances for the various combustion cases were completed at a temperature of 1600°F.

2.3.4 Advanced PFBC/Topping Combustor/Gas Turbine System

As part of the extended conceptual design, Foster Wheeler completed the design of their second generation PFBC technology for Wilsonville PSDF. In addition to testing the PCDs, the APFBC train will allow system integration studies as it includes a gas combustion system and a gas turbine generating set. The topping combustor was designed by Westinghouse using a multi-annular swirl burner (MASB).

The compressor/turbine/generating set currently consists of a GM-Allison 501 gas turbine, nominally producing 4 MW of electric power. This will provide a more cost effective compressed gas source than an electric driven compressor train. The gas turbine design was modified by Allison to accommodate the gas combustion system supplied by Westinghouse.

Foster Wheeler along with Westinghouse and GM-Allison completed the conceptual design of APFBC train and submitted the design information to SCS on April 15. Based on this information, SCS engineering proceeded to complete the balance-of-plant design.

2.3.5 Fuel Cell Module

Energy Research Corporation and M-C Power each responded to SCS's request for information needed to complete the conceptual design and cost estimate for the fuel cell module. The information provided by the vendors included process information and the cost for providing a new fuel cell stack. EPRI provided information on the 100 kW skid mounted fuel cell test facility that is being fabricated for testing at Destec's coal gasification plant in Plaquemine, LA. EPRI has indicated that the test facility will be available for testing at the PSDF in the 1995 time frame.

The information was incorporated into the conceptual design and can be found in volume II.1 of the design document.

2.3.6 Particulate Control

2.3.6.1 Particulate Sampling Apparatus and Instrumentation

The conceptual design of the particulate and alkali sampling system was completed. A document summarizing the key features of the conceptual design is included as Appendix A. The particulate sampling and monitoring systems are designed to function at pressures up to 300 psig and at temperatures up to 1800°F. The sampling system is designed to provide representative, size-fractionated samples of the particulate matter entering and leaving the PCDs. These samples will be used to determine the overall collection efficiency of the PCD and the collection efficiency as a function of particle size. Plans call for SRI to provide four inlet sampling systems and four outlet sampling systems. All eight systems will be designed to allow in-situ sampling of both particles and alkali vapor. Each of the eight systems will include a sampling probe, a nozzle, a sample collector, a mechanism for inserting and removing the probe, and means for metering and controlling the sample flow. A cascade cyclone assembly will be used as the sample collector in the inlet sampling system, while a cascade impactor will be used as the sample collector in the outlet sampling system.

The conceptual design also provides for real-time particulate monitors to detect fluctuations in the particulate mass concentrations in the gas streams entering and leaving the PCDs. We tentatively plan to provide one opacity monitor, eight sniffers (small, active filters inserted into the gas stream), and nine microphonics monitors (devices that sense individual particle collisions on thin metal reeds inserted into the gas stream). These plans may be changed as warranted by developments in monitoring technology. Regardless of which technologies are ultimately selected, the goal will be to ensure rapid and reliable detection of any significant failure of the PCD.

In addition to the particulate sampling and monitoring discussed above, alkali sampling and monitoring is needed to protect the gas turbine against alkali corrosion and monitor the performance of the alkali getter beds on the APFBC system. Real-time alkali monitoring will be provided under a separate arrangement between DOE and Ames Laboratory. Alkali sampling at the inlet and outlet of the getter beds will be done using probes to be supplied by Foster Wheeler. Alkali sampling at the inlet and outlet of the PCD will be done using an alkali sample collector connected to the back end of the particulate sample collector (cyclone or impactor). 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 will 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 will be accomplished using the Foster Wheeler probe, possibly with modifications to use the sorption technique in lieu of 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. During the detailed design phase, laboratory testing will be done to determine the best methods for alkali sample collection and analysis.

2.3.6.2 Particulate Control Devices

SRI completed the development of a new PCD data base using the latest information received from the PCD vendors during the meetings held in March and April. The new data base contains information from five vendors: Babcock & Wilcox, Calvert Environmental, Combustion Power, Industrial Filter and Pump, and Westinghouse. The data base is implemented in dBASE IV, Version 1.5. A new format has been used that produces five types of reports: technology status and issues, performance data, size and structural data, utility requirements, and instrumentation and data acquisition requirements. The data base may be readily updated with new information from additional vendors.

2.3.6.3 Particulate Analysis

All work on the characterization of particulate samples from Kellogg's transport reactor test unit (TRTU) was completed last quarter. A summary of the TRTU particle characteristics will be included in the PCD request for proposals (RFP). On June 30, SRI received four sets of particulate samples from the carbonizer test unit operated by Foster Wheeler in Livingston, NJ. Each set comprised a sample from the cross-flow filter drain and a sample from the primary cyclone drain. Two sets were collected while the carbonizer was fed with an Illinois No. 6 coal, and two sets were collected while the carbonizer was fed with an Eagle Butte Powder River Basin coal. One set from the Illinois No. 6 tests and one set from the Eagle Butte tests was for characterization. These two sets of samples (four samples in all) will be characterized by the same procedures used on the samples from the Kellogg transport reactor test unit (TRTU), except that the Coulter Counter will not be used. (SRI determined that the Coulter Counter results are not reliable for this type of sample. The sorbent in the samples tends to dissolve in the liquid that is normally used in the Coulter Counter, and, the char particles, which are predominantly carbon, may not be detected by the Coulter Counter.) The characteristics of the carbonizer particles will also be included in the request for proposals (RFP) to be submitted to the PCD vendors. The results of the characterization tests will be discussed in the next quarterly report.

2.3.7 Balance of Plant Design and Engineering Coordination

The conceptual design and cost estimate for the balance of plant for the expanded facility was completed. This included equipment specifications and layout, design of the process structure, and layout of the overall facility.

Based on the conceptual design of the facility, schedules for detailed design, construction and startup were developed. Staffing plans for design and construction management were developed for both a July and October 1994 startup of the plant.

Cash flows for both a July and October 1994 startup were also developed. The evaluation of various cash flow scenarios is continuing. The total project cost will be re-estimated by December 31, 1992. The detailed design will be well under way by this time and more accurate information will be available.

Planning for the detailed design, scheduled to begin in July, was initiated. A Project Procedures Manual was developed for coordination of the overall design effort. For the SCS engineering effort a design tasks numbering system for identification with the work breakdown scheme was completed.

A "letter of intent" to establish electrical service was issued to Alabama Power Company. This letter allowed Alabama Power to site the 115 kV line for the facility. The line siting was needed for evaluation in the NEPA process.

2.3.8 Facility Design Document

To facilitate the design of the facility by the project team, the overall process flow sheet has been broken down into several design areas. Figure 2-9 is a block flow diagram showing the main process design areas (Areas 100-800). Area designations for the entire facility and descriptions are shown in Table 2-5. The conceptual design documents (Volume II) are arranged by area for ease of reference.

The design of the integrated facility was carried out by various team members. The design of core process areas 200A (transport reactor) and 200B (carbonizer and a PFB combustor) were carried out by M.W. Kellogg (MWK) and Foster Wheeler (FW), respectively. The design of transport reactor and APFBC system is based on the technologies that are being developed by Kellogg and Foster Wheeler at present. Kellogg's design also covers areas 400A (cooling and treatment of gas from transport reactor), 500A (transport reactor ash handling system), and 600A (a sulfator to treat ash from the transport reactor in gasification mode). Topping combustor and gas turbine along with a air compressor and generator in area 400B are designed by Westinghouse and GM-Allison, respectively.

Area 300 (particulate control devices) and 900D (fuel cell) will be designed by vendors once they are selected for participation in the project. Various developers were contacted and conceptual design packages were obtained for area 300 in order to estimate costs. Provision has been made in the site layout to locate a WAGT system. However, at present, design, procurement and construction costs are not estimated for the WAGT system.

The balance of the plant conceptual design has been carried out Southern Company Services (SCS). This includes areas 100 (coal and limestone feed preparation), 700 (final gas treatment), 800A/B (ash disposal), 1000 (instrumentation and data acquisition), 2000 (utilities), 3000 (electrical), and 4000 (buildings and process structure). MWK and FW along with Westinghouse and Allison carried out designs for areas 1000-4000 which were within their process areas. Interface points between areas and battery limits and interface points between design team members were clearly defined to delineate design effort and facilitate estimation of costs with reasonable accuracy.

The design efforts to date are presented in three detailed design documents which were submitted to DOE in June 1992. The first (Volume II.1) of these three design documents deals with the transport reactor train and fuel cell. Detailed conceptual design of APFBC train including the topping combustor and gas turbine is given in Volume II.2. Volume II.3 deals with the design of balance-of-plant, particular control devices, and specialized sampling probes and techniques. Design information in the three design documents are organized by design areas for ease of reference during detailed engineering design. The design documents will be updated periodically during Phase 2 of the project.

FIGURE 2-9

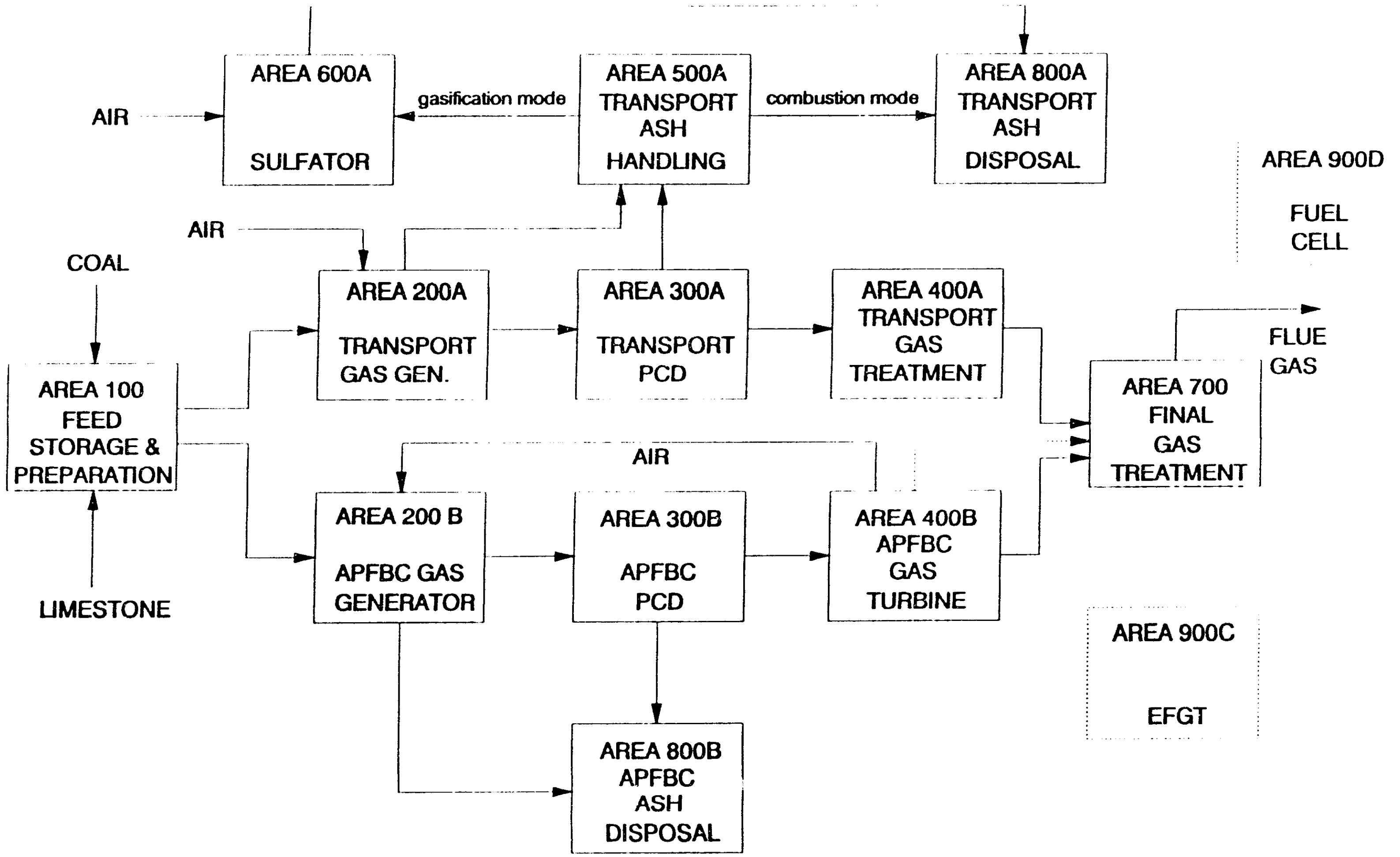


FIGURE 3-1. POWER SYSTEMS DEVELOPMENT FACILITY BLOCK FLOW DIAGRAM

Southern Company Services, Inc.

Revision A
February 20, 1992

TABLE 2-5

HOT GAS CLEANUP TEST FACILITY AREA DESIGNATION

AREA	DESCRIPTION
100	FEED PREPARATION
200A	GAS GENERATOR USING MWK'S TRANSPORT REACTOR
200B	GAS GENERATOR USING FW'S APFBC SYSTEM
300A/B	PARTICULATE CONTROL DEVICES
400A	COOLING AND TREATMENT OF GAS FROM TRANSPORT REACTOR
400B	TOPPING COMBUSTOR AND GAS TURBINE
500A	TRANSPORT REACTOR ASH HANDLING
600A	SULFATOR (TRANSPORT REACTOR GASIFICATION MODE)
700	FINAL GAS TREATMENT
800A	TRANSPORT REACTOR ASH DISPOSAL
800B	APFBC ASH DISPOSAL
900C	EXTERNALLY FIRED GAS TURBINE
900D	FUEL CELL
1000	INSTRUMENTATION AND DATA ACQUISITION
2000	UTILITIES: 2000 Boiler feedwater and steam systems 2100 Service Area (Cooling Water) 2200 Service/instrument air system 2300 Auxiliary fuel system 2400 Fire protection system 2500 Wastewater treatment system 2600 Nitrogen system 2700 Water treatment/chemical feed systems 2800 Safety/security systems
3000	ELECTRICAL: 3000 Power Distribution 3001 Control & data acquisition circuitry 3002 Lighting 3003 Communications 3004 Heat tracing/freeze protection
4000	BUILDINGS AND STRUCTURE/PLOT DIAGRAMS

3.0 PLANS FOR FUTURE WORK

1. Complete the conceptual design cost estimate for the PSDF.

2. Submit to DOE/METC a report on the conceptual design of the 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. Propose a modification to the Cooperative Agreement for the increase in the level of effort for the detailed design, construction and operation of the PSDF.

5. Begin detailed design for the expanded facility in order to maintain schedule for the facility.

6. Finalize and issue a 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.

APPENDIX A - Conceptual Design for Particulate and Alkali Sampling

MAY 18, 1992

CONCEPTUAL DESIGN FOR PARTICULATE AND ALKALI SAMPLING AT THE HOT GAS CLEANUP TEST FACILITY

DOE Cooperative Agreement No. DE-FC21-90MC25140

Comprehensive knowledge of particulate characteristics is required to analyze the performance of the particulate control devices (PCDs) to be evaluated at the Wilsonville Power Systems Development Facility. The equipment and procedures for sampling the particulate matter generated by these advanced pressurized combustion and gasification processes have been developed to accommodate ranges of particle characteristics relevant to the formation and transport of these particles. Analyses of particle samples have been critical in the development of these sampling procedures and equipment. In particulate control device (PCD) and turbine operations somewhat different sets of parameters are important than in conventional systems. Furthermore, in these advanced systems, sensitivity to small changes in particle characteristics is expected to be greater, and procedural options are fewer or less well developed in responding to problems which may result from varying or unexpected process conditions. Particulate size distribution and morphology determine particle penetration and energy loss (pressure drop), and play an important role in the durability of filtration devices. Particle mass loading, size distribution, morphology, and levels of alkali metals, both particulate and vapor, play distinct roles in subjecting turbine components to erosion and corrosion. Characterization of alkali vapor will also be needed to quantify turbine exposure and to assess the performance of the getter beds installed to protect the turbine.

In addition to analyses of hopper samples and mass balance calculations, which have been critical tools in previous research of advanced coal conversion processes, size-fractionated particulate samples obtained directly from the process gas are needed. While analysis of hopper samples is known to reveal gross variations in size and morphology of individual particles, in-situ, size-separated samples provide size of particle agglomerates suspended in the gas stream approaching the PCD or turbine. Agglomerate size is determined by process transport parameters and the particle morphology as well as by the sizes of the individual particles. It is the aerodynamic size distribution of these agglomerates which determines the particulate mass loading that actually reaches the filter elements, penetrates into the element matrix, and passes through the PCD. The morphology of the respective size fractions affects such other factors as energy loss resulting from pressure drop in the filter and durability of the filter elements. Sampling directly from the process gas is the only option downstream of the PCDs and the turbine to measure PCD performance or to determine turbine exposure. Knowledge of the aerodynamic size distribution of the particles at these locations is useful in understanding PCD operation. This particle size distribution is also useful in determining the collection efficiency as a function of particle size that occurs on turbine surfaces, since specified exposure criteria are size dependent. Comprehensive data regarding particulate characteristics and alkali concentration are needed to relate hardware performance, including likely variation thereof, to specific parameters of process operations. Frequent measurements increase the ability to identify events that are a result of specific, intentional changes in operating parameters, as distinct from those which are either a result of unintended changes or are random in nature.

Batch Sampling Devices

The quality of data from inertial sizing devices such as cascade impactors and small cascade cyclone samplers has been thoroughly validated by extensive use in conventional combustion gas streams. Several types of cascade impactors and one type of cascade (series) cyclone sampler have been developed for sampling typical flue gases upstream and downstream of PCDs. A comprehensive theory of operation of these devices has been verified over a wide range of conditions. The conditions of advanced coal-based energy production processes are somewhat beyond those used in verification measurements, but are well within the applicable range of the relevant theories of particulate dynamics. In cascade impactors, particulate matter is deposited onto inert substrates by high velocity jets in a series of stages, each of which provides a size fraction of the total particulate sample. Separation is accomplished in cascade cyclones by accelerating the gas through several complete turns in each collection stage. Cyclones can collect much larger samples than is possible with cascade impactors because cyclones have, in general, lower gas velocities and larger area of deposition. Cascade cyclones are appropriate for size-segregated samples at the inlets of PCDs while cascade impactors are most appropriate at the outlets of PCDs and at the turbine, where stage catches will normally be small for sample times measured in hours.

Impactors and cyclones may be used either by extracting process gas through transport lines to the device outside the gas stream (*extractive* sampling), or by inserting the entire device directly into the process gas stream (*in situ* sampling). When extractive sampling is employed, specific design criteria for the transport line and duct orientation are important to avoid deposition of the sample material on walls. Furthermore, the sample gas in the collection device must be maintained at the process temperature to ensure that a representative sample is obtained. These constraints tend to favor the use of in situ sampling. In either case, significant design and fabrication efforts are required for these advanced applications. The conceptual design of the probe system for operation of the cascade cyclone and cascade impactor trains is illustrated in figure 1. Access to the process duct is by way of double-valved sampling ports. The probes are identical for cyclones or impactors. The probe consists of a hollow shaft [13], ground to provide a good running seal against the packing [10]. (The numbers in brackets refer to the probe components identified in Figure 1.) The shaft terminates in the sample collector (cyclone or impactor) [e.g.14], whose outside diameter (O.D.) will not exceed 3.75 in., so as to pass easily through the 4 in. sampling port. A sorbent cartridge or condenser may be attached to the back end of the particulate sampler to collect samples of alkali vapor. Tubing and cabling are routed through the shaft for transport of the sample gas flow to the external flow control valves and flow measurement orifices and for temperature readout or other requirements. Standard methods are adequate for conditioning, controlling and measuring sample flow.

Specification of the O.D. of the shaft is based on considerations of probe rigidity, space for routing internal lines, leakage across the packing, and required insertion force. It appears that an O.D. of 2 in. will be a reasonable compromise among these constraints. In the figure, the probe shaft is illustrated at its maximum size (approximately 3.75 in.), and the dotted region indicates the range of probable diameters. Nitrogen purge will prevent leakage of process gas around the seal. Power assisted manual operation is planned with safeguards to prevent removal without sealing of the double-block-and-bleed valve [7-8].

Two batch sampling procedures are being considered for sampling alkali vapor at process temperature: One is based on the sorption of alkali vapor on bauxite sorbent and the other is a method that uses controlled condensation of alkali vapor on glass beads. The choice of alkali sampling procedure will be based upon comparative evaluations to be done during the detailed design phase.

Continuous Monitoring

Continuous particulate monitors are generally less accurate than cascade impactors and cyclones, and continuous monitors do not retain representative, size-fractionated samples for further characterization. However, continuous particulate monitoring is much less labor-intensive than is batch sampling. Nearly continuous sampling, important to reduce statistical uncertainties or improve reproducibility in results with variable process conditions, is impractical with these methods. During the past two decades, several detection processes have been exploited for the development of continuous, real-time particulate monitors. Some of these devices have been adapted for operation on process streams with conditions comparable to those of the Wilsonville operations. In one study involving transmissometers (opacity meters), meaningful responses to variations of process operation have been documented (Woodruff, et al, 1986). However, reliable performance for stand-alone measurement has not been demonstrated for any of the available instruments. There have been no significant demonstrations of the level of accuracy by comparison with reference data.

Continuous, real-time monitors of particles and alkali are needed for the Wilsonville demonstration project; however, the need for monitors may be much greater at full-scale facilities, which would not have the extensive and intensive batch sampling proposed for this project. In full-scale plants, real-time data on particulate loading and size distribution is important to support operational decisions related to filter leakage, system upsets, and long-term exposure estimation. Devices that appear promising for continuous monitoring at the Wilsonville Facility have been provisionally selected, although further consideration will be given to the selection in the detailed design phase. Criteria involved in the selection include the results of previous testing, the simplicity of mechanical operation, the expected sensitivity to extraneous conditions, and initial and long-term cost. In addition, the design of process ducting and access will include features needed to readily allow testing of other devices. This consideration applies specifically to access for optical devices which require viewing a volume of process gas at multiple angles and to comparison between results of different measurement methods. A continuous fiber optic alkali monitor (FOAM), developed under DOE funding, is expected to be available under a separate DOE project.

Measurement Frequency and Location

Table 1 presents the planned locations and frequencies of particulate and alkali measurements, the planned locations for monitors, and other parameters related to PCD and turbine operation. Although modifications may be introduced during the detailed design phase, the transmissometer is a high priority. Evaluation of the Ames alkali monitor and possibly other devices for particulate monitoring is expected with separate funding. Two of the three other monitors listed will be selected for evaluation. We will continue to maintain our contacts with the vendors of particulate monitoring equipment and to keep abreast of new developments in monitoring hardware. We will take advantage of any opportunities to test new monitors under existing projects or on a trial basis in cooperation with the vendors.

Measurements at the inlet and outlet of the PCD installed on the transport reactor will include intense periods of parametric testing in which process set points will last 24 to 48 hours. To ensure adequate data collection in this time, two batch sampling probe systems will be installed at these locations allowing two sets of sampling runs per shift or six sets per day. During the long-term testing, the level of effort devoted to this sampling will be reduced to two sets of runs per week on the transport reactor system, one set per week on the carbonizer, one set per week on the PFBC, and one set per week on the turbine outlet. This number of samples may be collected by devoting one day per week to measurements on the carbonizer system, one day per week to measurements on the PFBC system, one day per week to measurements on the turbine outlet, and two days per week to measurements on the transport reactor system.

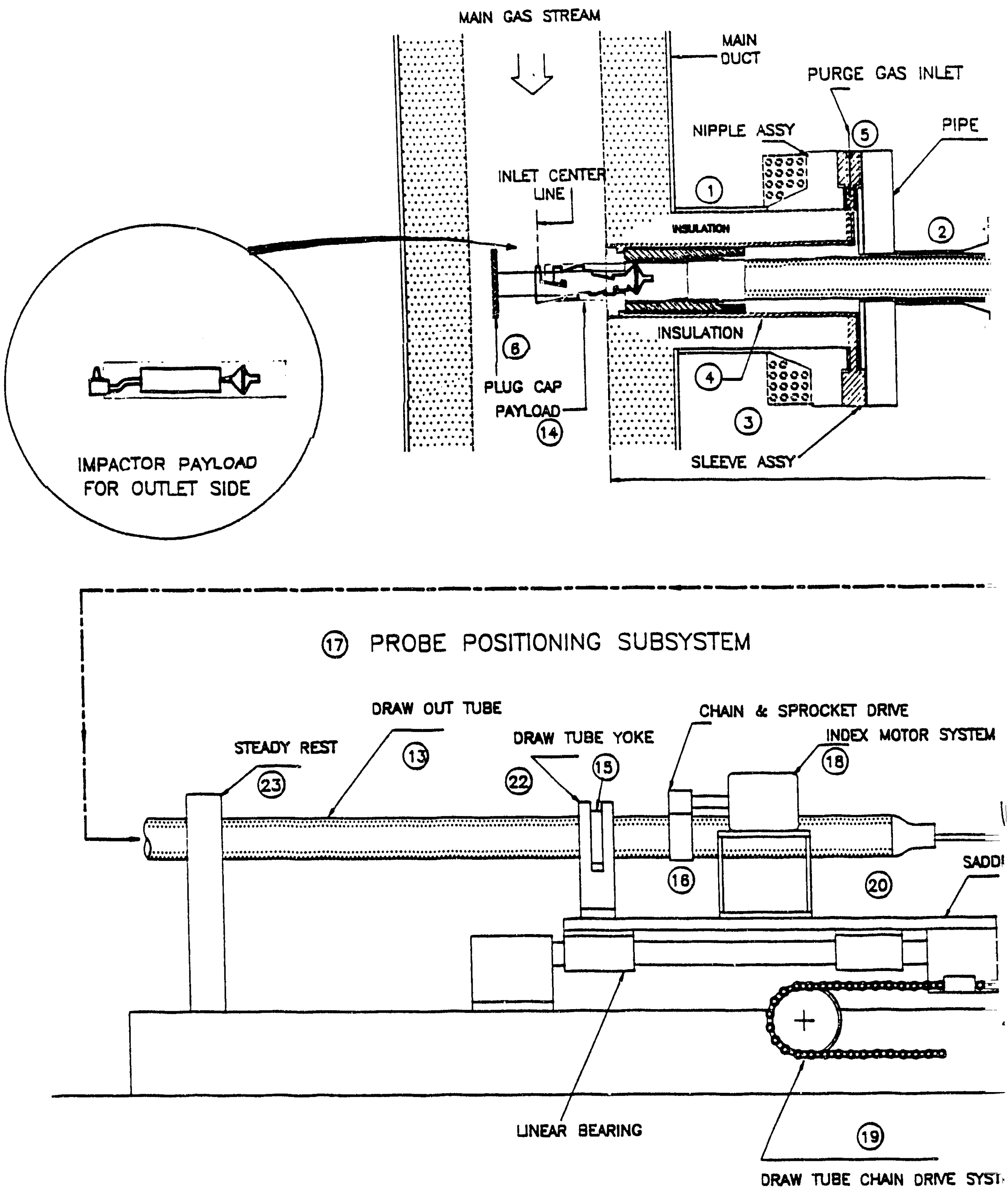
Reference:

Woodruff, S. D., et. al. "On-Line Measurement of the Alkali and Particulate Loading of the Process Stream of a Fixed-Bed Gasifier" U. S. Department of Energy DOE/METC-86/2019 (DE86001041), October 1986.

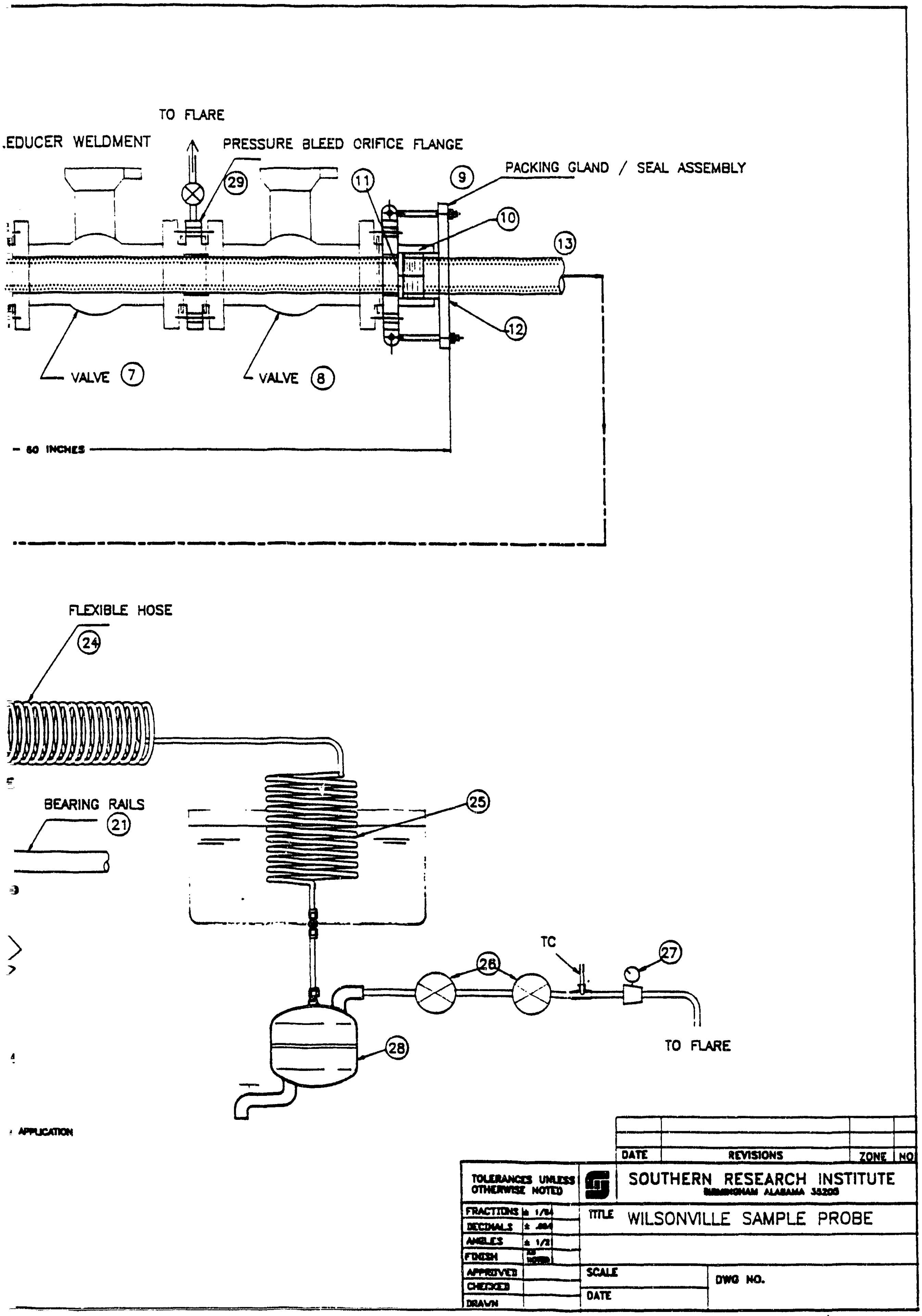
Table 1. Frequency & Location of Measurements Related To PCD and Turbine Operation (long-term operation & parametric testing of PCD's)

Measurement/observation	Transport Reactor PCD		Carbonizer PCD		PFBC PCD		TURBINE
	inlet	outlet	inlet	outlet	inlet	outlet	outlet
Continous particulate monitoring (3 installed)							
Filter dP/dt (SNIFFER, surface area)	X	X	X	X	X	X	X
Microphonic detector (>3 micron)	X	X	X	X	X	X	X
Trieboelectric (> 3 micron)	X	X	X	X	X	X	X
Transmissometer (surface area)		X		*		*	
Other optical		other project		other project		other project	other project
Continuous Alkali Monitoring (Ames)	other project	other project	other project	other project	other project	other project	
Batch							
In-situ mass concentration (includes alkali)	2/week or 6/day	2/week or 6/day	1/week	1/week	1/week	1/week	1/week
In-situ particle concentration & size (includes alkali)	2/week or 6/day	2/week or 6/day	1/week	1/week	1/week	1/week	1/week
SEI Supplied							
System pressure drop	continuous		continuous		continuous		continuous
System cleaning parameters	continuous		continuous		continuous		continuous
Gas flow rate	continuous		continuous		continuous		continuous
Temperature	continuous		continuous		continuous		continuous

* Included in process cost (Foster Wheeler)



NOTE- THIS DEVICE HAS BEEN DISCLOSED FOR PATE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