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Technical Notes for the Conceptual Design for an Atmospheric Fluidized-Bed Direct Combustion Power Generating Plant

Volume 3

April 1978

Prepared For
U.S. Department of Energy
Assistant Secretary for Energy Technology
Division of Power Systems

Under Contract No. EF-77-C-01-2583

MASTER

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Technical Notes for the Conceptual Design for an Atmospheric Fluidized-Bed Direct Combustion Power Generating Plant

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April 1978

Prepared By
Stone & Webster Engineering Corporation

For
U.S. Department of Energy
Assistant Secretary for Energy Technology
Division of Power Systems
Washington, DC 20545

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TECHNICAL NOTES FOR THE
CONCEPTUAL DESIGN FOR AN ATMOSPHERIC FLUIDIZED-BED
DIRECT COMBUSTION POWER GENERATING PLANT

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PART IIIB

**570 Mwe FOSTER WHEELER AFB PLANT DEFINITION
AND
DESIGN CRITERIA**

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1.0 OBJECTIVE

The objective of this part (Part IIIB) of the Report is to describe the design, arrangement, thermodynamics, and economics of a 578 Mwe (nominal gross) electric power generating plant equipped with a Foster Wheeler Energy Corporation (FWEC) Atmospheric Fluidized Bed (AFB) boiler.

This document represents a portion of an overall report describing the conceptual designs of two atmospheric fluidized bed boilers and balance of plants for the generation of electric power and the analysis and comparison of these conceptual designs to a conventional pulverized coal-fired electric power generation plant equipped with a wet limestone flue gas desulfurization system. The reader is cautioned from drawing conclusions from this portion without reviewing the full report. Conclusions regarding the various aspects of this effort are presented in Parts IV and V of this report.

2.0 INTRODUCTION

The FWEC plant duplicates the base plant described in Part I of this Report except where a change has been required due to an AFB unique feature. These changes, as would be expected, are primarily in the boiler area, i.e., from the turbine room side of the silo bay through the stack. Changes required in the turbine-related equipment include the following:

- 13.8 kv electrical system
- Larger boiler feed pump and drive
- Larger cooling tower
- Larger turbine generator
- Larger circulating water pump
- New start-up boiler feed pump
- Larger condenser
- Extraction system modifications
- Turbine Bypass and Reheater Cooling System

3.0 GENERAL

The FWEC AFB plant is a 578 Mwe (nominal gross) fourth extension to an existing site. Because the plant is an even-numbered extension, auxiliary systems and services are either used or extended rather than installed. The capital cost estimate noted in Table IIIB-1 includes services and/or systems as detailed in Appendix IIIB-A, FWEC AFB Plant Description of Work.

The plant is designed to standard utility central station codes and standards as indicated in the following representative list:

Federal EPA Standards/Regulations
OSHA Regulations

ASME Codes
ANSI Standards
NFPA Codes
National Electrical Code
Uniform Building Code
Local Codes and Standards

The plant is equipped with the AFB Boiler, mechanical dust collectors, and fabric filters to meet the 1.2 lb-per-million-Btu EPA SO₂ emission limit and a 0.06 lb-per-million-Btu particulate emission limit.

Like current facilities, the plant has an economic life of 30 yr, starting in 1982, with a planned loading cycle as noted in Table IIIB-2.

4.0 THERMODYNAMIC CYCLE

Heat Balance Diagrams 12919.02B-HBSK-1, 2, 3, and 4 describe the thermodynamic characteristics of the plant at maximum (VWO), 75 percent, 50 percent, and 25 percent load, respectively.

The balanced draft, once-through type boiler has a heat input of 5,417,500,000 Btu/hr at VWO with a mixed gas outlet temperature of 283 F.

The turbine is a 2,520 psig/1,000 F/1,000 F four-flow tandem compound machine with 30 in. last stage blades. It is rated at approximately 578 Mwe when supplying seven stages of feedwater heating, the boiler feed pump drive, and exhausting into a multipressure condenser with approximately 1/2 percent makeup.

Using the fuel and the economic evaluation factors noted in Table I-2, in Part I of this Report, the following plant design features were optimized as part of the base plant effort and have not been optimized as part of the AFB effort.

- Main turbine end size
- Boiler feed pump drive
- Feedwater heater number, terminal difference, and drain cooler approach
- Condenser tube size and length, surface per zone, temperature rise and flow
- Cooling tower range approach and flow

TABLE IIIB-1
CAPITAL COST ESTIMATE
FOR A
570 MWE FOSTER WHEELER AFB

<u>Block</u>	<u>Description</u>	<u>Material (000)</u>	<u>Labor (000)</u>	<u>Total (000)</u>	<u>Man-Hours (000)</u>	<u>\$/Kw (Net)</u>
1	Land and Land Rights		Not Included			-
2	Yardwork	104	158	262	9	0
3	Main Powerhouse	7,180	7,032	14,212	377	26
4	Administration Building		Not Included			-
5	Miscellaneous Buildings		Not Included			-
*6	Boiler Equipment by Vendor	24,044	12,447	36,491	629	67
*7A	Balance of Boiler Plant Equipment	10,657	7,902	18,559	398	34
*7B	Ash Handling Equipment	7,363	4,095	11,458	202	21
*8	Fuel Handling and Storage Equipment	4,908	3,596	8,504	188	16
9	Stack	794	1,300	2,094	46	4
*10	Fabric Filter (Baghouse)	4,736	4,551	9,287	233	17
*11	Flue Gas Desulfurization	0	0	0	0	0
*12	Turbine Generator Equipment by Vendor	18,939	868	19,807	44	37
13	Balance of Turbine Plant Equipment (Excluding Condensing System)	927	2,186	3,113	118	6
*14	Condenser/Circulating Water System	5,515	2,500	8,015	137	15
15	Water Treatment	412	58	470	3	1
16	Waste Treatment	0	0	0	0	0
*17	Accessory Electrical Equipment	7,424	6,267	13,691	327	25
18	Miscellaneous Power Plant Equipment	106	276	382	15	1

TABLE IIIB-1 (Cont'd)

<u>Block</u>	<u>Description</u>	<u>Material (000)</u>	<u>Labor (000)</u>	<u>Total (000)</u>	<u>Man-Hours (000)</u>	<u>\$/Kw (Net)</u>
19	Main Transformers	1,230	107	1,337	6	3
20	Transmission Lines		Not Included			-
	TOTAL DIRECT COST	94,339	53,343	147,682	2,728	273
	Engineering, General, and Administrative	11,294	7,460	18,754	-	35
	Field Distributable Cost	<u>4,557</u>	<u>3,143</u>	<u>7,700</u>	<u>40</u>	<u>14</u>
	DIRECT, INDIRECT, AND DISTRIBUTABLE COST SUBTOTAL	110,190	63,946	4,136	2,768	322
	Allowance for Indeterminates	<u>11,019</u>	<u>6,395</u>	<u>17,414</u>	<u>277</u>	<u>32</u>
	TOTAL 1976 COST	121,209	70,341	1,550	3,045	354
	Escalation to July 1980	<u>18,787</u>	<u>26,026</u>	<u>44,813</u>	<u>-</u>	<u>83</u>
	TOTAL ESCALATED PLANT COST	139,996	6,367	36,363	3,045	437
	Allowance for Fund Used During Construction	<u>19,599</u>	<u>13,491</u>	<u>33,090</u>	<u>-</u>	<u>61</u>
	TOTAL PLANT CAPITAL COST, APRIL 1982	159,595	109,858	269,453	3,045	498

*Major change from base plant

TABLE IIIB-2

ECONOMIC PARAMETERS

Unit life, yr	30	
Plant size, kw (Nominal Gross)	578,000	
Net Unit Output, kw	541,161	
Potential Station Output, kw-hr	1.42×10^{11}	
Planned Station Output, kw-hr	7.61×10^{10}	
Levelized Annual, Station Output, kw-hr	3.02×10^9	
Expenditure midpoint	July 1980	
Commercial operation	April 1982	
Annual fixed charge rate, %	15.35	
Present worth discount rate, %	10.5	
Allowance for funds used during construction, %	8.0	
Composite labor escalation, %/yr	7.25	
Composite material escalation, %/yr	3.25	
Fuel escalation, %/yr	7.0	
Limestone escalation, %/yr	5.5	
1982 limestone cost, \$/ton	12.75	
1982 fuel cost, \$/ton ($\text{¢}/10^6$ Btu)	21.25 (96.0)	
Replacement capacity cost, \$/kw	399	
Replacement fuel cost, \$/kw (mills/kwhr)	9 (29.05)	
<u>Capitalized Fuel Cost</u>	<u>\$/Kw</u>	<u>\$/Btu/Kw-hr</u>
Constant overload range	719*	33,598*
Directly proportional to load	591*	
Proportional to square of load	505*	
Not proportional to load		
at 94% load	427*	22,527*
at 75% load	176*	7,437*
at 50% load	116*	3,631*

Year	<u>Planned Unit Operation, Percent of Year</u>				
	<u>UNIT LOAD</u>				
	<u>VWO</u>	<u>94</u>	<u>75</u>	<u>50</u>	<u>0</u>
1-5	0.6	50.2	21.3	12.5	15.4
6-10	0.6	45.7	19.0	18.6	16.1
11-15	0.5	43.4	18.7	15.5	21.9
16-20	0.5	40.0	18.9	9.5	31.1
21-25	0.2	28.9	10.0	8.2	52.7
26-30	0.1	20.5	5.0	3.7	70.7

Average Capacity Factor, %	53.53
Capacity Factor Corrected for Present Worth, %	63.74

*Changed from base plant

BOILER OUTPUT 4,371,000 Btu PER HOUR
 CROSS SECTION HEAT RATE 8250 BTU PER SQ-FT
 NET STATION HEAT RATE 8001 Btu PER KW-HR

LEAKAGES

	FLOW	ENTHALPY
A	4150	1450.33
B	372	1450.33
C	35477	1432.17
D	8292	1305.43
E	7184	1305.43
F	4110	1300.37
G	7773	1347.64
H	2800	1347.64
I	1200	1347.64

LEGEND

- STEAM
- WATER
- POWER
- LB FLOW, POUNDS PER HOUR
- H ENTHALPY, BTU PER POUND
- TEMPERATURE, DEGREES F
- TO F TERMINAL DIFFERENCE, DEGREES F
- OC DRAIN COOLER APPROACH, DEGREES F
- KW POWER, KILOWATTS
- IN HG PRESSURE, IN OF MERCURY, ABS.
- PSIA PRESSURE, LB PER SQUARE IN., ABS.
- THROTTLE OR INTERCEPT VALVE
- CONTROL VALVE

THIS HEAT BALANCE DIAGRAM WAS PRODUCED FROM BALANCE NUMBER 100 WHICH WAS GENERATED ON 25 NOV 1977

HEAT BALANCE DIAGRAM
 100% WMO, O.P., 79 F WET BULB
 TC4F 3C" L5B
 FOSTER WHEELER ENERGY CORPORATION
 AFB PLANT
 DOE AFB STUDY

STONE & WEBSTER ENGINEERING CORPORATION
 BOSTON, MASSACHUSETTS

REVISED ISSUE 1
 201, POWER
 28 NOV 1977
 DRAWING NO. 12919.028-HBSK-B1-1

REVISED ISSUE 1	2000	2000	2000
ADD. PAGES	2000	2000	2000

5.0 PLANT ECONOMICS

5.1 Capital Costs

The present-day (1976) cost to build the plant as noted in Table IIIB-1 is \$191,550,000 (\$354/kw). This cost, when including escalation and 8 percent interest during construction, is equivalent to a total capital investment at the time of commercial operation (1984) of \$269,453,000 (\$498/kw).

A detailed description of the equipment and services included in this cost estimate is presented in Appendix IIIB-A.

The capital cost changes from the base plant are identified in Table IIIB-3.

5.2 Operating Costs

The operating costs for the FWEC AFB plant are shown in Table IIIB-4 and are based on an annual fixed charge rate of 15.35 percent and a levelized annual generation of 3.02×10^9 kw-hr.

The planned generation for this plant is 7.61×10^{10} kw-hr. The capital recovery on the \$269,453.00 is equivalent to a 13.69 mil/kw-hr annual operating cost on the levelized annual generation.

The fuel cost was computed using a 1982 cost of \$21.25/ton (\$0.96/10⁶ Btu) with 7.0 percent/year for escalation.

The limestone cost was computed using a 1982 cost of \$12.75/ton with 5.5 percent/year for escalation.

ASH disposal costs were computed using base plant information and the FWEC AFB solid waste flow rate.

Operation and maintenance costs were computed using information from the base plant less the FGD O&M costs noted in Appendix I-D.

5.3 Economic Evaluation Factors

Table IIIB-2 describes the economic evaluation factors used to develop the FWEC plant design. These factors have been used to evaluate annual operating costs for the FWEC AFB plant design as shown on Table IIIB-4.

6.0 FWEC AFB PLANT PROJECT SCHEDULE

No schedule information has been made available by Foster Wheeler Energy Corporation.

7.0 PLANT ARRANGEMENT

7.1 Site

Drawing 12919.02B-EY-602A depicts the FWEC AFB plant site. Those features included in the construction of the plant are highlighted with heavier lines.

A new coal/limestone crusher house will be located in the yard. An independent dual set of belt conveyors will tie into the existing conveying system in the yard and run to the boiler building.

This unit utilizes a twelve-cell mechanically induced draft cooling tower for heat rejection.

7.2 Turbine Room

The turbine room is essentially identical to the base plant except for the ground floor (Drawing 12919.02B-EM-203A) which has been revised to include a start-up feed pump.

7.3 Boiler Room

As noted on Drawings 12919.02B-EM-202A and 202B, the boiler room dimensions are approximately 151 ft wide by 96 ft deep by 216 ft high, with the ground operating and mezzanine floors matching those of the turbine room.

The coal/limestone bunker bay between the boiler room and the auxiliary bay dimensions are approximately 162 ft long by 35 ft deep by 301 ft high, with the coal tripper conveyor floor at El. 279 ft.

The forced draft and bed letdown cooler booster fans are located in a closed room for sound attenuation. Because this room will experience subatmospheric pressure, double door air locks are supplied.

Boiler area composites are shown on Drawings 12919.02B-EP-202A through 202H. Column locations and bracing are as noted on Drawings 12919.02B-ES-601A, 606A, 609A, and 609B.

TABLE IIIB-3

CAPITAL COST CHANGES FOR A FWEC AFB PLANT

<u>Block No.</u>	<u>Account</u>	<u>Description</u>
1	All	No Change
2	All	No Change
3	1101.10	Decrease Substructure Cost
3	1101.20	Decrease Superstructure Cost
4	All	No Change
6	1200.00	Increase Boiler Cost
6	1200.1131	Decrease Boiler Steel
6	1200.15	Increase Cost of Coal and Limestone Delivery and Injection Systems
6	1200.261	Add Carbon Reinjection System
6	1200.261	Add Bed Letdown System
6	1200.261	Add Main Bed Dust Collector
7A	1200.221	Delete Scrubber Duct Work and Dampers
7A	1200.221	Increase Air and Gas Duct Cost
7A	1200.2291	Increase Duct Insulation Cost
7A	1200.231	Increase FD Fan and Drive Cost
7A	1200.232	Increase ID Fan and Drive Cost
7A	1200.32	Increase BFP and Drive Cost
7A	1200.321	Add Startup Boiler Feed Pump
7A	1200.60	Add Steam to Reheat Bypass System
7B	1200.50	Delete Existing Bottom and Fly Ash Systems
7B	1200.51	Add New Bed Material Collection and Disposal System
7B	1200.54	Add New Fly Ash Collection and Disposal System

TABLE IIIB-3 (Cont'd)

<u>Block No.</u>	<u>Account</u>	<u>Description</u>
8A	1241.20	Add New Coal and Limestone Crushing and Conveying Equipment
8A	1241.20	Add New Tripper Equipment
8A	1241.41	Increase Inplant Coal and Limestone Storage
8A		Delete Limestone Preparation Equipment
8A	1241.49	Increase Coal and Limestone Chutes, Gates, etc.
8B	1242.00	(Ignition)
8C	All	No Change
8D	All	Add New Crusher House
9	1200.81	Change Stack Liner to Steel
10	1200.252	Eliminate Precipitator Cost
10	1200.252	Add New Fabric Filter (Baghouse)
11	1200.27	Delete all Scrubber Costs
12	1400.10	Increase Turbine-Generator Cost
14A	All	Change included in Block 14E
14B	1400.21	Increase Condenser Cost
14B	1400.281	Increase Circulating Water Pump and Drive Cost
14C	1400.30	No Change
14D	All	No Change
14E	1400.34	Increase Cooling Tower Cost
14E	1400.348	No Change
15	1200.34	No Change
16		Eliminate Ash and Scrubber Waste System Cost

TABLE IIIB-3 (Cont'd)

<u>Block No.</u>	<u>Account</u>	<u>Description</u>
17	1500.123	Increase Power Cable Cost
17	1500.211	Increase Unit Station Service Transformer Cost
17	1500.211	Increase Reserve Station Service Transformer Cost
17	1500.252	Increase Station Service Switchgear Cost
17	1500.253	Increase 480 V Substation Cost
17		Add Nonsegregated Bus Duct
17	1500.71	Increase Main Control Board Cost
17	1500.72	Increase Control Systems' Cost
18	1600.47	No Change
19		No Change
20		No Change

TABLE IIIB-4

FWEC AFB PLANT ANNUAL OPERATING COSTS (MILLS/KW-HR) NET

Capital Recovery	13.69
Fuel Cost	18.07
Limestone Cost	1.84
Operating and Maintenance	
Power Plant	3.36
FGD Plant	0
Sludge Stabilization Plant	0
Ash and Sorbent Disposal	0.10
Particle Emission Control Equipment	<u>0.33</u>
	37.39

THIS DRAWING BASED ON
FOSTER WHEELER ENERGY
CORPORATION AFB DESIGN

NOT TO BE USED FOR CONSTRUCTION

NO.	DATE	REVISION	MADE	APPROVED
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
MAJOR FACILITIES PROJECT MANAGEMENT DIVISION

CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT
ERDA CONTRACT NO. ER-77-C-84-8888

DRAWN BY: STONE & WEBSTER ENGINEERING CORP.
BOSTON, MASS. 02107
DESIGNED: DATE: 10-3-77
CHECKED: J. D. VITO DATE: 10-3-77
APPROVED: DATE: 10-3-77

TITLE: SITE PLAN

12919028-EM-2034-1

NOTE:
1. SCALE $\frac{1}{4} = 1'-0"$
2. FOR GENERAL NOTES & REFERENCE DWG. EM-202A

THIS DRAWING BASED ON FOSTER WHEELER
ENERGY CORPORATION AFB DESIGN

NOT TO BE USED FOR CONSTRUCTION

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UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
MAJOR FACILITIES PROJECT MANAGEMENT DIVISION
CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT
EPDA CONTRACT NO. EF-77-G-91-882

DESIGNED BY: STONE & WEBSTER ENGINEERING CORP.
BOSTON, MASS. 02107
DESIGNED: FW SCHREIBER DATE 11-5-77
CHECKED: T. SIBBALD DATE 11-5-77
APPROVED: P.F. LIPMAN DATE

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
MAJOR FACILITIES PROJECT MANAGEMENT DIVISION
CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT
EPDA CONTRACT NO. EF-77-G-91-882

THIS GENERAL APP
PLAN-GROUP
S&W DWG
LINE BUILDING
EL. 0'-0"
9028-EM-2034-1

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NOTES:
1. SCALE: $\frac{1}{16}'' = 1'-0''$

THIS DRAWING BASED ON FOSTER
WHEELER ENERGY CORPORATION AFB DESIGN

NOT TO BE USED FOR CONSTRUCTION

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REV	DATE	REVISION	BY	APP

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
MAJOR FACILITIES PROJECT MANAGEMENT DIVISION

CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT
ERDA CONTRACT NO. EF-77-C-01-2583

DRAWING BY:
STONE & WEBSTER ENGINEERING CORP.
BOSTON, MASS. 02107

DESIGNED: _____ DATE: _____
DRAWN: M. JOHNSON DATE: 11-4-77
CHECKED: T. S. BALD DATE: 11-18-77
APPROVED: P. LIPARI DATE: _____

UNITED STATES
ENERGY RESEARCH AND
DEVELOPMENT ADMINISTRATION

TITLE
GENERAL ARRANGEMENT
BOILER AREA - PLAN SHEET 1
S&W DWG. NO. 12919028-EM-202A-1

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NOTES
1. SCALE: 1" = 1'-0"

2-2
(EM-202A J-3)

NOT TO BE USED FOR CONSTRUCTION

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UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
MAJOR FACILITIES PROJECT MANAGEMENT DIVISION
CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT
ERDA CONTRACT NO. EF-77-G-01-2583

DRAWING BY:
STONE & WEBSTER ENGINEERING CORP.
BOSTON, MASS. 02107

UNITED STATES
ENERGY RESEARCH
AND
DEVELOPMENT ADMINISTRATION

DESIGNED: M. JOHNSON DATE: 11-4-77
CHECKED: T. SIBBALD DATE: 11-15-77
APPROVED: P. LIPARI DATE: 11-15-77

TITLE:
GENER
BOILER AF
S&W DWG

MANAGEMENT
ION SHEET 2
102B-EM-202B-1

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GENERAL NOTES
 1. SCALE - 1/4" = 1'-0"
 2. [Symbol] DENOTES LIMESTONE HOPPER SOURCE

REFERENCE DRAWINGS
 COMPOSITE-BOILER AREA-PLAN-EL 3'-0" SHEET 2 EP-202B
 COMPOSITE-BOILER AREA-PLAN-EL 6'-0" SHEET 3 EP-202C
 COMPOSITE-BOILER AREA-PLAN-EL 9'-0" SHEET 4 EP-202D
 COMPOSITE-BOILER AREA-PLAN-EL 12'-0" SHEET 5 EP-202E
 COMPOSITE-BOILER AREA-SECTION 1-1 SHEET 6 EP-202F
 COMPOSITE-BOILER AREA-SECTION 2-2 SHEET 7 EP-202G
 COMPOSITE-BOILER AREA-SECTION 3-3 SHEET 8 EP-202H

THIS DRAWING BASED ON FOSTER WHEELER
 ENERGY CORPORATION AFB DESIGN

NOT TO BE USED FOR CONSTRUCTION

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NO. DATE REVISION MADE APPROVED

UNITED STATES
 ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
 MAJOR FACILITIES PROJECT MANAGEMENT DIVISION

CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT
 ERDA CONTRACT NO. EF-77-C-01-2563

DRAWING BY: STONE & WEBSTER ENGINEERING CORP.
 BOSTON, MASS. 02107

DESIGNED BY: R. LANGLEY DATE: 10-7-77
 DRAWN BY: R. LANGLEY DATE: 10-21-77

CHECKED BY: J. S. BARNARD DATE: 11-4-77
 APPROVED BY: J. L. PARR DATE: 11-4-77

TITLE: COMPOSITE-BOILER AREA
 PLAN-EL 0'-0" SHEET 1

S&W DWG. NO. 1291902B-EP-202A1

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ORIGINAL ISSUE

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NOTES
SCALE = 1:100

2. GENERAL NC

2. GENERAL NOTES & REFERENCE DWGS

EP-202A

THIS DRAWING BASED ON FOSTER WHEELER
ENERGY CORPORATION AFB DESIGN

NOT TO BE USED FOR CONSTRUCTION

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UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
MAJOR FACILITIES PROJECT MANAGEMENT DIVISION

CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT
ERDA CONTRACT NO. EF-77-C-01-2583

DRAWING BY: STONE & WEBSTER ENGINEERING CORP. BOSTON, MASS. 02107	UNITED STATES ENERGY RESEARCH AND
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DRAWING BY: STONE & WEBSTER ENGINEERING CORP. BOSTON, MASS. 02107	UNITED STATES ENERGY RESEARCH AND
---	---

DESIGNED	R. LANGLEY	DATE	10-7-77
DRAWN	R. LANGLEY	DATE	10-21-77

CHECKED <u>T. SIBBALD</u>	DATE <u>11-4-77</u>	DATE <u>11-4-77</u>	DATE <u>11-4-77</u>
APPROVED <u>P. F. LIPARI</u>	DATE <u>11-4-77</u>	DATE <u>11-4-77</u>	DATE <u>11-4-77</u>

TITLE:	COMPOSITE-B PLAN-EL31'0"	REA 2
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DATE S&W DWG. NO. 12 P202B-1

REA
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NOTES
1. SCALE - $\frac{1}{8}'' = 1'-0''$

2. GENERAL NOTES & REFERENCE DWGS

2. GENERAL NOTES & REFERENCE DWGS EP-202A

EP-202A

THIS DRAWING BASED ON FOSTER WHEELER
ENERGY CORPORATION AFB DESIGN

NOT TO BE USED FOR CONSTRUCTION

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UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
MAJOR FACILITIES PROJECT MANAGEMENT DIVISION

CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT
ERDA CONTRACT NO. EF-77-C-01-2583

DRAWING BY: STONE & WEBSTER ENGINEERING CORP. BOSTON, MASS. 02107	UNITED STATES ENERGY RESEARCH AND
---	---

DESIGNED R. L. ANGLE DATE 10-7-77
DRAWN R. L. ANGLE DATE 10-21-77

CHECKED	T. SIBBALD	DATE	11-4-77	DATE	DISCUSSING NO.	DATE	DISCUSSING NO.
APPROVED	P. E. LIPARI	DATE					
TITLE: COMPOSITE POWER AREA							

COMPOSITE-BOILER AREA
PLAN-EL610-SHEET 3

DATE: S&W DWG. NO. 12919.02B-EP-202C

Age Group	Percentage of Respondents
18-29	85%
30-49	80%
50-69	75%
 

NOTES
 1. SCALE: 1/8" = 1'-0"
 2. GENERAL NOTES & REFERENCE DWGS EP-202A

THIS DRAWING BASED ON FOSTER WHEELER
 ENERGY CORPORATION A-B DESIGN

NOT TO BE USED FOR CONSTRUCTION

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NO.	DATE	REVISION	MADE	APPROVED	
UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION MAJOR FACILITIES PROJECT MANAGEMENT DIVISION CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT ERDA CONTRACT NO. EF-77-C-01-2583					
DRAWING BY: STONE & WEBSTER ENGINEERING CORP. BOSTON, MASS. 02107			UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION		
DESIGNED: R. LANGLEY DATE: 10-7-77			APPROVED:		
DRAWN: R. LANGLEY DATE: 10-21-77			CHECKED: I. SIBBALD DATE: 11-4-77		
APPROVED: P. LIPARI DATE:			DATE:		
TITLE: COMPOSITE-BOILER AREA PLAN-EL-91'-0" SHEET 4					
S&W DWG.			028-EP-2020-1		

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NOTES

1. SCALE - $\frac{1}{8}'' = 1'-0''$
2. GENERAL NOTES & REFERENCE DWGS EP-202A

THIS DRAWING BASED ON FOSTER WHEELER
ENERGY CORPORATION AFB DESIGN

NOT TO BE USED FOR CONSTRUCTION

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UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
MAJOR FACILITIES PROJECT MANAGEMENT DIVISION

CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT
ERDA CONTRACT NO. EF-77-C-01-2583

DRAWING BY: STONE & WEBSTER ENGINEERING CORP. BOSTON, MA 02107	UNITED STATES ENERGY RESEARCH CORPORATION
--	---

DESIGNED R.L. WIGLEY	DATE 10-7-77	DEVELOPMENT ADMINISTRATOR
DRAWN R. LANGFAY	DATE 10-21-77	REVIEWED

CHECKED	T. SIBBALD	DATE	11-4-77
APPROVED	P. F. LIPARI	DATE	

TITLE: COMPOSITE-BOILER AREA
PLAN-FL 121'-0" SHEET 5

DATE S&W DWG. NO. 1291902B-EP-202

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NOTES
1. SCALE - $\frac{1}{8}'' = 1'-0''$

2. GENERAL NOTES & REFERENCE DWGS EP-202A

THIS DRAWING BASED ON FOSTER WHEELER
ENERGY CORPORATION AFB DESIGN

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UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
MAJOR FACILITIES PROJECT MANAGEMENT DIVISION

CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT
ERDA CONTRACT NO. EF-77-C-01-2583

DRAWING BY: STONE & WEBSTER ENGINEERING CORP. BOSTON 14, MASS. 02107	UNITED STATES ENERGY RESEARCH
--	----------------------------------

DESIGNED R. LANGLEY DATE 10-7-77
DRAWN R. LANGLEY DATE 10-21-77

DRAWN	DATE	APPROVED	
CHECKED T. SIBBALD	DATE 11-4-77	DATE	BRIDGE NO.
APPROVED P. F. LIPARI	DATE		

TITLE: COMPOSITE-BOILER AREA-
SECTION 1-SHEET 6

DATE	S&W	1291902B-EP-202F
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(EP-202A E-B)
(EP-202B E-B)
(EP-202C E-B)
(EP-202D E-B)
(EP-202E E-B)

NOTES
1. SCALE $\frac{1}{8}''=1'-0''$

2. GENERAL NOTES & REFERENCE DWGS

EP-202A

THIS DRAWING BASED ON FOSTER WHEELER
ENERGY CORPORATION AFB DESIGN

NOT TO BE USED FOR CONSTRUCTION

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UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION MAJOR FACILITIES PROJECT MANAGEMENT DIVISION			
CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT ERDA CONTRACT NO. EF-77-C-01-2583			
DRAWING BY: STONE & WEBSTER ENGINEERING CORP. BOSTON, MASS. 02107		UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION	
DESIGNED R. L. LANGLEY DATE 10-7-77		REVIEWED	
DRAWN R. L. LANGLEY DATE 10-21-77		APPROVED	
CHECKED T. S. BEALD DATE 11-4-77		SUBMITTED	
APPROVED P. F. LIPARI DATE		DATE	
TITLE: COMPOSITE-BOILER AREA- SECTION 2-2-SHEET 7			
S&W DWG. NO. 12919028-EP-202G1			

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1291902B-202H-1

NOTES
1. SCALE: 1/8"=1'-0"
2. GENERAL NOTES & REFERENCE DWGS EP-202A

THIS DRAWING BASED ON FOSTER WHEELER
ENERGY CORPORATION AFB DESIGN

NOT TO BE USED FOR CONSTRUCTION

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UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION MAJOR FACILITIES PROJECT MANAGEMENT DIVISION CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT ERDA CONTRACT NO. EP-77-C-01-2593			
DRAWING BY: STONE & WEBSTER ENGINEERING CORP. BOSTON, MASS. 02107		UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION	
DESIGNED: R. J. RANGLEY DATE: 10-7-77		APPROVED:	
DRAWN: R. J. RANGLEY DATE: 10-21-77		DATE: 11-4-77	
CHECKED: T. S. BILDAL DATE: 11-4-77		DATE: 11-4-77	
APPROVED: P. F. LIPART DATE:		DATE:	
TITLE: COMPOSITE-BOILER AREA SECTION 2.2 SHEET 8			
S&W DW 1902B-EP-202H-1			

NO.	DATE	REVISION	MADE
1	10-7-77	ORIGINAL ISSUE	
2	10-21-77		
3	11-4-77		
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NOTES
SCALE: 1/8"=1'-0"

REFERENCE DWGS
PLANS-DRAFT LEVELS
ELEVATIONS-VERTICAL BRACING
GENERAL ARRANGEMENT BOILER AREA

ES-60A
ES-60SA & B
EMDSE SERIES

THIS DRAWING BASED ON FOSTER WHEELER
ENERGY CORPORATION AFB DESIGN

NOT TO BE USED FOR CONSTRUCTION

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UNITED STATES			
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION			
MAJOR FACILITIES PROJECT MANAGEMENT DIVISION			
CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT			
ERDA CONTRACT NO. EF-77-C-01-2583			
DRAWN BY: STONE & WEBSTER ENGINEERING CORP. BOSTON, MASS 02107		UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION	
DESIGNED BY: J. HARRIS	DATE: 10-26-77	APPROVED BY:	DATE: 10-26-77
DRAWN BY: J. HARRIS	DATE: 10-26-77	APPROVED BY:	DATE: 10-26-77
CHECKED BY: J. HARRIS	DATE: 10-26-77	APPROVED BY:	DATE: 10-26-77
APPROVED BY: P. T. LEMBI	DATE:	APPROVED BY:	DATE:
TITLE: COLUMN LOCATION PLAN			
S&W DWG. NO. 129102B-ES-60A-1			

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NOTES
1. SCALE: 1/4" = 1'-0"
2. REFERENCE DWGS: ES-606A

THIS DRAWING BASED ON FOSTER WHEELER
ENERGY CORPORATION AFB DESIGN

NOT TO BE USED FOR CONSTRUCTION

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DESIGNED BY: STONE & WEBSTER ENGINEERING CORP. BOSTON, MASS. 02107
DATE: 12-24-77
CHECKED BY: J. HARRIS
DATE: 12-23-77
APPROVED BY: J. HARRIS
DATE: 12-23-77

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
MAJOR FACILITIES PROJECT MANAGEMENT DIVISION
CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT
ERDA CONTRACT NO. EP-TI-G-01-250

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
CONSTRUCTION DIVISION

TITLE: PLANS - BRACED LEVELS
S&W DWG. NO. 1
ES-606A-1

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NOTES
 1. SCALE: 1/8" = 1'-0"
 2. REFERENCE DWGS ES-604

THIS DRAWING BASED ON FOSTER WHEELER
 ENERGY CORPORATION AFB DESIGN

NOT TO BE USED FOR CONSTRUCTION

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UNITED STATES
 ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
 MAJOR FACILITIES PROJECT MANAGEMENT DIVISION
 CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT
 ERDA CONTRACT NO. EF-77-C-01-250

DRAWING BY:
 STONE & WEBSTER ENGINEERING CORP.
 BOSTON, MASS. 02107

DESIGNED BY:
 J. HARRIS
 DATE 10-26-77

CHECKED BY:
 J. HARRIS
 DATE 10-31-77

APPROVED BY:
 P. F. LEBEL
 DATE

UNITED STATES
 ENERGY RESEARCH
 AND
 DEVELOPMENT ADMINISTRATION

TITLE:
 ELEVATIONS-VERTIC

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S&W DWG. N

B-ES-609B-1

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8.0 PROCESS SYSTEMS

8.1 General

The flow diagrams indicated hereinafter utilize the notation "Pipe C1 YYYYX," "Insul C1 X" and "VXX-YYYYX," where X denotes an alpha character and Y denotes a numeric character.

"Pipe C1 YYYYX" is a denoter of pipe material, pressure rating, schedule, etc., as described in Appendix I-2.

"Insul C1 X" is a denoter of pipe insulation material and thickness as described in Appendix I-3.

"VXX-YYYYX" is a denoter of valve type, pressure rating, construction, and preparation, etc. These details are identified in the "Pipe C1" indicated on the flow diagram. A general explanation of the notation system is shown on Drawing STD-MM-1002-1-2. (See Part I of this Report.)

8.2 Steam Systems

8.2.1 Main Steam, Hot and Cold Reheat

Refer to Flow Diagram 12919.02B-EM-102A.

Main Steam

The main steam system is identical to the base plant described in Section 8.2.1 except that a high pressure and low pressure turbine bypass system is supplied to assure minimum flow through the superheater and reheater. Also the pressures, temperatures, and flows vary slightly as noted on Heat balances 12919.02B-HBSK-1, 2, 3, and 4 as a result of permitting the base plant stack gas reheating steam to expand through the turbine.

Cold Reheat

The cold reheat system is identical to the base plant described in Section 8.2.1 except that a high pressure and low pressure turbine bypass system is supplied to assure minimum flow through the superheater and reheater and also two electromatic relief valves were installed on the hot reheat line. Also the pressures, temperatures, and flows vary slightly as noted on Heat balances 12919.02B-HBSK-1, 2, 3, and 4 as a result of permitting the base plant stack gas reheating steam to expand through the turbine.

Hot Reheat

The hot reheat system is identical to the base plant described in Section 8.2.1 except that a high pressure and low pressure turbine bypass system is supplied to assure minimum flow through the superheater and reheater. Also the pressures, temperatures, and flows vary slightly as noted on Heat Balances 12919.02B-HBSK-1, 2, 3, and 4 as a result of permitting the base plant stack gas reheating steam to expand through the turbine and due to the FWEC reheater pressure drop.

8.2.2 Extraction

Refer to Flow Diagram 12919.02B-EM-103A.

The extraction steam system is identical to the base plant system described in Section 8.2.2 of Part I of this Report except that the extraction pressures, temperatures, and flows vary slightly as noted on heat balances 12919.02B-HBSK-1, 2, 3, and 4 as a result of permitting the base plant stack gas reheating steam to expand through the turbine. In addition, due to the FWEC once-through boiler design an integral separator drain system as described below has been superimposed on the extraction system to recover energy during start-ups. This necessitates the addition of a second nonreturn valve in the first point extraction for turbine entrained energy protection.

Boiler Integral Separator Drain System

The boiler integral separator drain system's main function is to allow flushing of the once-through boiler and to recover some of the energy that would normally be wasted by being bypassed to the condenser during start-up. The drain system drains in order to the deaerator, first point heater, or condenser depending on the temperature of the drain water.

8.2.3 Auxiliary Steam

The auxiliary steam system is identical to the base plant Part I of this Report except that there is no requirement for stack gas reheating.

8.3 Water Systems

8.3.1 Circulating and Makeup Water and Condenser Air Removal

Refer to Flow Diagram 12919.01-EM-110A.

The circulating and makeup water and condenser air removal systems are identical to the base plant system described in Section 8.3.1 of Part I of this Report except that the condenser duty is approximately 5 percent greater as a result of the

- LEGEND
- CONTROL VALVE - AIR TO CLOSE
 - NON RETURN VALVE - NRV
 - CONTROL VALVE - AIR TO OPEN
 - MOTOR OPERATED VALVE - MOV
 - SAFETY VALVE - SV
 - GLOBE VALVE - VO
 - NORMALLY CLOSED VALVE
 - GATE VALVE - VO
 - FLANGE CONN.
 - FLOW ORIFICE - RO
 - BY EQUIP. MFR
- TT THERMOCOUPLE
 TT TEMP. TRANSMITTER
 TV TEST WELL
 TIR TEMP. INDICATING RECEIVER
 SP SAMPLE POINT
 M MANUAL SAMPLE CONDS.
 RTD RESISTANCE TEMP. DETECTOR
 D DRAIN
 DV DOWN VALVE
 VV VENTILATOR VALVE
 PI PRESSURE INDICATOR
 PC POWER CONTROLLER
 PSW PRESSURE CONTROL RELIEF VALVE
 R RECORDER
 PL POINT ON LONGER
 V VENT
 T TEST
 F FURNACE
 PIT PRESSURE INDICATING TRANS

- NOTES:
1. ALL PRESSURE CONN'S 3/8" SW UNLESS OTHERWISE NOTED
 2. ALL TEMPERATURE CONN'S ARE 1/2" UNLESS OTHERWISE NOTED PER DNG STD-MP-005-1
 3. MAIN STEAM VALVES 2" AND SMALLER ARE MARK NO VOS-250FY
 4. HOT REHEAT VALVES 2" AND SMALLER ARE MARK NO VOS-150R UNLESS OTHERWISE NOTED
 5. COLD REHEAT VALVES 2" AND SMALLER ARE MARK NO VOS-60C EXCEPT AS NOTED

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UNITED STATES	
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION	
MAJOR FACILITIES PROJECT MANAGEMENT DIVISION	
CONCEPTUAL DESIGN ATMOSPHERIC FLAMING BED POWER PLANT	
ERDA CONTRACT NO. 57-77-01-0003	
DESIGNED BY STONE & WEBSTER ENGINEERING CORP. BOSTON, MASS. 02107	APPROVED BY J. L. GORDON DATE 10-11-77
CHECKED BY J. L. GORDON DATE 10-11-77	APPROVED BY J. L. GORDON DATE 10-11-77
TITLE FLOW DIAGRAM MAIN STEAM & REHEAT	
S&W DNG NO. 129902B-EM02A1

LEGEND

- GLOVE VALVE - VS
- GLOVE VALVE - VS
- CONTROL VALVE, AIR TO OPEN
- NORMALLY CLOSED VALVE
- PISTON OPERATED SHUTTER VALVE - MSV
- AIR/SHAMOUNT
- SAFETY VALVE - SV
- REFRIGER
- GAGE OPERATING
- GAGE GLASS
- PI PRESSURE INDICATING TRANSMITTER
- PRESSURE INDICATOR
- TEST AND COMPLE
- TEST WELL
- RTD RESISTANCE TEMP. DETECTOR
- TEST LONGER
- P/EN PRESSURE REDUCING VALVE
- V
- VENT
- VENT
- CONTROL VALVE - AIR TO CLOSE
- CRACK VALVE - VC
- V - TYPE STRAINER
- SOLINOID OPERATED (3-WAY)
- DEMISTS CONDENSER AIR FLOW, MINIMIZE
- FLOW ORIFICE - R
- FLOW REVERSE TR
- BY ELECTRIC MFR
- BY TURBINE MFR.
- BY SEN FLOW

NOTES

- 1-ALL PRESSURES CONSIDERED 2 GPM
2-ALL TEMPERATURES CONSIDERED 1:5 W
3-ALL GLOBE VALVES 1" AND SMALLER TO BE VOR-BOC
4-PIPING AND FITTINGS IN CONDENSER WORK FURNISHED
BY (LAT-4) AND INSTALLED BY MECHANICAL
SECTOR
5-CONDENSER WORK PIPING TO BE FIELD LAGED
WITH 7/8" 304 SS

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ENERGY CORPORATION AFB DESIGN

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UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
MAJOR FACILITIES PROJECT MANAGEMENT DIVISION
CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT
ERDA CONTRACT NO. EF-77-C-01-2883

DRAWING BY: STONE & WEBSTER ENGINEERING CORP. BOSTON, MASS. 02107		UNITED STATES NAVY ENGINEERING AND DEVELOPMENT ADMINISTRATION
DESIGNED	DATE	
DRAWN <u>W.A. LEBRETON</u>	DATE <u>1-1-77</u>	
<u>W.A. LEBRETON</u>	<u>1-1-77</u>	

CHECKED: 1-31-BALD DATE: 1-7-97
 APPROVED: P.F. LIPARI DATE: _____
 TITLE: FLOW DIAGRAM
 EXTRACTION LINES
 S&W DWG N 28EM103A

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expansion of the stack gas reheating steam through the turbine. Table IIIB-5 identified the system changes from base plant.

8.3.2 Condensate

Refer to Flow Diagram 12919.01-EM-104A.

The condensate system is identical to the base plant system described in Section 8.3.2 of Part I of this Report.

8.3.3 Feedwater and Desuperheating Water

Refer to Flow Diagram 12919.02B-EM-105A.

8.3.3 Feedwater

The feedwater system is identical to the base plant system described in Section 8.3.3 of Part I of this Report except that at low boiler pressures during start-up, the 5,110 gpm, 8,689 ft TDH (53 percent load) start-up feed pump will be used to supply boiler feedwater.

Main Steam Desuperheating Water

Water from the feedwater system just upstream of the economizer is injected into the primary superheater outlet to maintain a secondary superheater outlet temperature of 1,000 F.

Reheat-Desuperheater

Water from an intermediate stage of the boiler feed pump is supplied to the reheater inlet to maintain a hot reheat steam temperature of 1,000 F. Water is also supplied to the high and low pressure turbine bypass lines for steam desuperheating during start-up/shutdown or a turbine trip.

8.3.4 Heater Drains

Refer to 12919.01-EM-106A.

The heater drain system is identical to the base plant system described in Section 8.3.4 of Part I of this Report except that the pressures, temperatures, and flows vary slightly as noted on heat balances 12919.02B-HBSK-1, 2, 3, and 4.

8.3.5 Cooling Water Systems

8.3.5.1 Component Cooling Water

The component cooling water system is identical to the base plant system described in Section 8.3.5.1 of Part I of this Report.

8.3.5.2 Bearing Cooling Water

The bearing cooling water system is identical to the base plant system described in Section 8.3.5.2 of Part I of this Report.

8.3.6 Other Water Systems

8.3.6.1 Condensate Polishing

Refer to Flow Diagram 12919.01-EM-128A.

The demineralizer system is identical to the base plant system described in Section 8.3.6.1 of Part I of this Report.

8.3.6.2 Chemical Feed

Refer to Flow Diagram 12919.02B-EM-119A.

8.3.6.2.1 Chemical Feed - Condensate

The condensate chemical feed system is identical to the base plant system described in Section 8.3.6.2.1 of Part I of this Report.

8.3.6.2.2 Chemical Feed - Boiler

As the FWEC boiler is of the once-through design, there is no requirement for chemical feed above and beyond the condensate chemical feed system.

8.4 Material Handling Systems

8.4.1 Coal and Limestone Handling System

Refer to Flow Diagrams 12919.02B-EM-170A, EM-170B, 170C, and General Arrangement Drawings 12919.02B-EM-211A through 211E.

The coal and limestone parameters for this study are as shown in Tables I-6 and I-7 in Part I of this Report.

The coal/limestone handling system consists of the yard and station subsystem and the distribution and injection subsystem.

8.4.1.1 Delivery Subsystem

Sections 8.4.1.1.1, Delivery to Site, 8.4.1.1.2, Transfer to Storage, and 8.4.1.1.3, Transfer to Station remain as described in the base plant report for the existing Units 1-3.

The transfer of coal and limestone to the station for use in the AFB unit can be accomplished by using two paths from either source, i.e., As Delivered or Storage.

TABLE IIIB-5

HEAT REJECTION SYSTEM PARAMETERS

Design wet bulb, F	79
Design dry bulb, F	96
Dry air density, lb/cu ft	0.0705 @ 96 F
Heat rejected by cooling tower, Btu/hr	2.814×10^6
Heat rejected by condenser, Btu/hr	2.627×10^6

<u>Parameter</u>	<u>Tower</u>	<u>Condenser</u>
Flow, gpm	198,400*	185,500*
Range, F	27.7	28.66*
Cells/zones	12	2
Type	Wood fill wet mechanical	Multipressure
Surface, ft ²	-	309,625*
Approach, F	12.71*	5.3
Tube diameter, in.	-	7/8
Tube length, ft	-	48
Tube gage, BWG	-	22
Tube material	-	304 SS

*Change from base plant

- NOTES
- 1 ALL PRESSURE CONNECTIONS ARE 3" RW
 - 2 PROVIDE 0' TO 6" OF LOW VOLT CLAMP OR BUSHING FOR PERMANENT INSTALLATION. SEE N.E.C. 7-10-1 FOR TEMPORARY CLAMPING METHODS AND CYCLES OF TIGHTENING.
 - 3 THERMALLY PROTECTED POWER ON ALL DRUM VEIN AND TEST CABLES.
 - 4 ALL PIPING ON VESSEL UNLESS NOTED OTHERWISE:
 - 5 A) ALL GOOD. B) SMALLER THAN SHOWN IN E.T.S.O.N. 1148-B
 - 6 DRAIN HOOD VESSEL 150'-250'
 - 7 TEMPERATURE CONNECTIONS 1/2" UNLESS OTHERWISE NOTED
- 7 ALL GEAR OPERATING VALVES TO BE OPERABLE BY PORTABLE AIR WRENCH
- 8 14" ID 2.147" MIN WALL FOR STRAIGHT PIPE
 - 9 12" ID 1.845" MIN WALL FOR STRAIGHT PIPE
 - 10 10" ID .931" MIN WALL FOR STRAIGHT PIPE
- THIS DRAWING BASED ON FOSTER WHEELER
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- LEGEND
- GATE VALVE - VG
 - GLOBE VALVE - VO
 - NORMALLY CLOSED VALVE
 - CHECK VALVE - VC
 - STRAINER
 - BALL VALVE
 - REDUCER
 - PI PRESSURE INDICATOR
 - LC LEVEL CONTROL
 - LS LEVEL SWITCH
 - LG GAGE GLASS
 - D DRAIN
 - V VENT
 - BY CHEMICAL FEED EQUIP MFR
 - RELIEF VALVE - SV
 - BY TANK MANUFACTURER
 - SCREWED CAP
 - PRESSURE REDUCING VALVE - PRV
 - ⊕ DENOTES CONDENSER MFR. CONN. NUMBER

- NOTES:
1. ALL PRESSURE CONNS $\frac{3}{4}$ " UNLESS NOTED
 2. DAY TANKS ARE MANUALLY FILLED

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UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION MAJOR FACILITIES PROJECT MANAGEMENT DIVISION	
CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT ERDA CONTRACT NO. EF-77-C-01-2583	
DRAWING BY: STONE & WEBSTER ENGINEERING CORP. BOSTON, MASS. 02107	UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
DESIGNED BY: W. L. LEMAN	DATE: 11-1-77
CHECKED BY: R. E. LIPARI	DATE: 11-1-77
TITLE: FLOW DIAGRAM CHEMICAL FEED	
S&W DWG. NO. 12919.028-EM-119A-1	

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12919028-B-EM-1700

NOTE:
L CRUSHERS HAVE INTERNAL BY PASS.

REFERENCE DWG
FLOW DIAGRAM SH-1-COAL & SORBENT HANDLING EM-170A

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DESIGNED: _____ DATE: _____		DEVELOPMENT: _____	
CHECKED: T. S. BALDWIN DATE: 11-7-77		APPROVED: _____	
APPROVED: P. L. PARI DATE: _____		TITLE: FLOW DIA COAL & SORBENT S&W DWG. NO. _____	
PROJECT NO. 12919028-B-EM-1700		SHEET NO. 13	

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NOTES
 1. SCALE: 1/8"=1'-0"
 2. GENERAL NOTES AND REFERENCE DWGS: EM-211A

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UNITED STATES
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 MAJOR FACILITIES PROJECT MANAGEMENT DIVISION
 CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT
 ERDA CONTRACT NO. EF-77-C-01-2883

DRAWN BY: STONE & WEBSTER ENGINEERING CORP.
 BOSTON, MASS. 02107
 DESIGNED BY: R. LANGLEY DATE: 10-7-77
 DRAWN BY: R. LANGLEY DATE: 10-21-77
 CHECKED BY: T. SIBBALD DATE: 11-4-77
 APPROVED BY: P. F. LIPARI

UNITED STATES
 ENERGY RESEARCH
 AND
 DEVELOPMENT ADMINISTRATION
 APPROVED: _____
 DATE: _____

TITLE: GEN ARRG
 HANDLING IN P
 S&W DWG

1299028-EM-211B-1

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NOTES
1. SCALE: 1"=1'-0"
2. GENERAL NOTES & REFERENCE DWGS EM-211A

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ENERGY CORPORATION AFB DESIGN

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UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION MAJOR FACILITIES PROJECT MANAGEMENT DIVISION					
CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT ERDA CONTRACT NO. EF-77-C-01-2883					
DRAWING BY: STONE & WEBSTER ENGINEERING CORP. BOSTON, MASS. 02107			UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION		
DESIGNED R. LANGLEY DATE 10-7-77			REVIEWED		
DRAWN R. LANGLEY DATE 10-21-77			APPROVED		
CHECKED T. S. B. B. DATE 11-4-77			DATE		
APPROVED P. F. L. PARI DATE			DATE		
TITLE: GEN. ARR'GT COAL/LIMESTONE HANDLING IN PLANT SECTIONS 2-2&3-35H3					
S&W DWG. NO. 12919028-EM-21C1

ORIGINAL ISSUE												
CROSSER HOUSE SHEET 1/3												
S&W DWG. NO. 129028-EM-211E												
CROSSER HOUSE SHEET 1/3												
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As Delivered

The coal and limestone is delivered from the railroad unloading hoppers onto existing conveyors C-2B and C-3B, bypassing the existing crushers 1B and 2B onto conveyor C-5B which is used normally as the stockout conveyor to yard storage location 1. A new fixed tripper will transfer coal or limestone from the existing C-5B onto new conveyors C-15 to C-16 to the surge hopper through the new coal or limestone crushers via flop gate. From the crushers, the coal/limestone is transferred via new conveyors C-20 and C-21 onto new tripper C-22 or via new conveyors C-23 and C-24 onto new tripper C-25 and into the coal/limestone bunkers.

From Yard Storage Location 2

Coal or limestone from coal pile 2 is reclaimed using the existing stacker reclaimer conveyor C-7B. A new fixed tripper will transfer coal or limestone from the existing conveyor C-7B onto conveyors C-17 to C-18 into the crusher house and then to the coal/limestone bunkers as described above.

8.4.1.1.4 Tramp Iron Protection

The inlet chute of both the new coal and limestone crushers will be equipped with magnets to remove tramp iron; otherwise, the section remains as described in the base plant report.

8.4.1.1.5 Mass Transfer Measurement

Mass Transfer Measurement remains as described in the base plant report for all units.

8.4.1.1.6 Crushers

Crushers remain as in the base plant report for Units 1-3. The new coal crushers discharge -1 in. coal with -2 1/2 in. ROM input. The new limestone crushers discharge -3/16 in. limestone with -3/4 in. input. Each crusher is rated at 900 TPH.

8.4.1.1.7 Sampling

Sampling, an "as received" sample is included in the discharge chute of each set of new crushers for the AFB unit; otherwise, the section remains as described in the base plant report.

8.4.1.1.8 System Included With This Unit

The coal/limestone handling system included in the scope of this unit is as follows:

1. The installation of fixed trippers on existing conveyors C-5B and C-7B.

2. The installation of a new crusher house which includes two limestone crushers and two coal crushers and associated equipment such as ductwork, samplers, grizzlies, etc.
3. The installation of eleven complete new conveyors, including two tripper conveyors.
4. The installation of four main beds, one CBC and two limestone bunkers, including vibrators, discharge piping, and discharge chutes.

8.4.1.2 Distribution and Injection Subsystem

Refer to Flow Diagrams 12919.02B-EM-115B and 115C.

Coal supplied to the four main bed and one CBC coal bunker is discharged by gravity through piping and into a series of chutes at each boiler level that feed sixty overfeed spreader stokers (twelve stokers per level) which feed the main bed and another twelve overfeed spreader stokers which feed the CBC. Due to access problems, four new belt conveyors are required to feed the CBC coal chutes.

Limestone supplied to the two limestone bunkers is discharged by gravity to twenty penetrations at the side of the boiler just above the main beds (four penetrations, two used normally, per level) and four penetrations at the side of the CBC just above the CBC.

8.4.2 Ash Handling System

Refer to Flow Diagram 12919.02B-EM-120A, B, and C, and General Arrangements 12919.02B-EM-212A and 212B.

The coal ash analysis for this plant is shown on Table I-8 in Part I of this Report.

The ash handling system consists of the bed material letdown and disposal subsystem, the carbon collection and reinjection subsystem, and the fly ash collection and disposal subsystem.

8.4.2.1 Fly Ash Collection and Disposal Subsystem

Refer to Flow Diagram 12919.02B-EM-120C.

Fly ash collected in the CBC dust collector, fabric filter, air regenerative preheater, and stack fly ash hoppers is transported, using a vacuum-pressure pneumatic system, to the fly ash silos in the ash waste treatment area. Periodically, the ash is discharged to trucks and hauled to the on-site disposal area.

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ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
MAJOR FACILITIES PROJECT MANAGEMENT DIVISION

CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT
ENRDA CONTRACT NO. EF-77-2-01-2583

DRAWING BY:
STONE & WEBSTER ENGINEERING CORP.
BOSTON, MASS. 02107

DESIGNED: _____ DATE: _____
CHECKED: J. A. SCHREIBER DATE: 11-1-77
APPROVED: _____ DATE: _____

TITLE: FLOW DIAGRAM
LIMESTONE DISTRIBUTION & INJECTION

S&W DWG. NO. 12919.02B-EM-115B1

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UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION MAJOR FACILITIES PROJECT MANAGEMENT DIVISION CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT ERDA CONTRACT NO. EF-77-C-01-2583	
DRAWING BY: STONE & WEBSTER ENGINEERING CORP. NORTON, MASS. 01907	UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
DESIGNED: F.W. SCHWEIPEL CHECKED: T.A. SUBBALU APPROVED: P. LUDWIG	DATE: 11-16-77 DATE: 11-16-77 DATE: 11-16-77
TITLE: CCAAL DISTRIB AND INJECTION	
S&W DW	

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- LEGEND:
- 1. ● SUPPLIED BY ASH HANDLING MFG
 - 2. ○ CYLINDER OPERATED VALVE
 - 3. ◇ GATE VALVE
 - 4. ◻ CHECK VALVE
 - 5. ◇ PRESSURE REGULATING VALVE
 - 6. ○ OFFICE
 - 7. ◇ RELIEF VALVE
 - 8. ◇ VACUUM BREAKER
 - 9. ◇ GLOBE VALVE
 - 10. ◇ CONTROL VALVE
 - 11. ◇ BUTTERFLY VALVE

REFERENCE DWGS:
 FLOW DIAGRAM - CARBON COLLECTION & REDUCTION EM-200
 FLOW DIAGRAM - FLY ASH COLLECTION & DISPOSAL EM-202

THIS DWG BASED ON FOSTER WHEELER
 ENERGY CORPORATION AFB DESIGN

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UNITED STATES
 ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
 MAJOR FACILITIES PROJECT MANAGEMENT DIVISION

CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT
 EXDA CONTRACT NO. EP-77-C-01-0503

DRAWN BY: STONE & WEBSTER ENGINEERING CORP. BOSTON, MASS. 02107
 DESIGNED: DATE: 11-7-72
 CHECKED: F.W. SCHUBERT DATE: 11-7-72
 APPROVED: R.F. LIPSKI DATE: 11-7-72

THIS DWG. NO. 12919028 EM-20A-1

NOTE:
1. GENERAL NOTES, REFERENCE DRAWINGS &
LEGEND EM-1208A

THIS DRAWING BASED ON FOSTER WHEELER
ENERGY CORPORATION AFB DESIGN

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
<p>UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION MAJOR FACILITIES PROJECT MANAGEMENT DIVISION</p> <p>CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT ERDA CONTRACT NO. EF-77-C-01-2583</p> <p>DRAWN BY: STONE & WEBSTER ENGINEERING CORP. UNITED STATES BOSTON, MASS. 02107 ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION</p> <p>DESIGNED: DATE: 11-7-77 DRAWN: F.W. S. HREIBER DATE: 11-7-77 CHECKED: J. L. B. B. B. DATE: 11-7-77 APPROVED: P. L. L. L. L. DATE: 11-7-77</p> <p>FLOW DIAGRAM CARBON COLLECTION & REINJECTION S&W DWG. 028EM-1208-1</p>

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ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
MAJOR FACILITIES PROJECT MANAGEMENT DIVISION
CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT
ERDA CONTRACT NO. EF-77-C-01-2983

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DESIGNED _____ DATE _____
DRAWN P. PERROTTA DATE 10-15-77
CHECKED A. J. BRECHUE DATE 11-7-77
APPROVED R. LIPARI DATE _____

TITLE: FLOW DIAGRAM
FLY ASH COLLECTION & DISPOSAL

FLY ASH COLLECTION & DISPOSAL
S&W DWG. NO. 12919.02B-EM-20C

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NOTES:
1. SCALE: $\frac{1}{8}'' = 1'-0''$
2. GENERAL ARRANGEMENT, ASH HANDLING SHI 12 9182 B; EM-2124

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ENERGY CORPORATION AFB DESIGN

NOT TO BE USED FOR CONSTRUCTION

[illegible]

8.4.2.2 Bed Material Letdown and Disposal Subsystem

Refer to Flow Diagram 12919.02B-EM-120A.

Bed letdown material is transported to silos in the ash waste treatment area by a pressurized pneumatic system. Periodically the ash is discharged to a truck and hauled to the on-site disposal area. Bed material when required, will be used as a supplement to maintain bed level in the carbon burnup cell.

8.4.2.3 Carbon Collection and Reinjection Subsystem

Refer to Flow Diagram 12919.02B-EM-120B.

Fly ash collected by the main bed mechanical dust collectors and economizer hoppers is pneumatically transported to the carbon burnup cell. Three blowers, two running and one standby, convey the ash collected in the hopper air lock devices through a double supply header extending from the blowers to the CBC. Each header ties into a first level distributor box with seven outlets. Each of these lines feeds a second level distributor box with eight outlets. This results in a total of 112 lines feeding the CBC.

8.4.2.4 Bed Letdown Cooling

Bed letdown material is cooled by the use of air from a booster fan located off the discharge of the forced draft fans. Letdown material is drawn off from each of the twenty (20) compartments of the main beds and is cooled by twenty (20) air coolers. Main bed material will be cooled from 1550 F to 250 F.

Similarly bed material from the CBC is drawn off from each of the four (4) compartments and is cooled by four (4) air coolers. CBC letdown materials will be cooled from 2000 F to 250 F.

Cooling air supplied by the booster fan is introduced into the top of the air cooler and terminates just above the beds in the free board area.

8.5 Wet Limestone Flue Gas Desulfurization System (FGD)

There is no requirement for a FGD System on the FWEC AFB boiler.

8.6 Air and Gas Systems

Refer to Flow Diagram 12919.02B-EM-115A.

The air and gas systems consist of the following subsystems:

- Combustion air
- Bed letdown cooling air

Flue gas

8.6.1 Combustion Air

Each of two half-capacity, forced draft (F.D.) fans take suction from the fan room and discharges air to the boiler undergrid plenum via a half size steam/air heater and one part of a two section, half size, regenerative air heater (APH).

Air pressure is regulated by adjusting the inlet (suction) vanes on the F.D. fans.

The steam/air heater is used to maintain the average cold end temperature of the APH to minimize corrosion. F.D. fans also supply air to the suction of the bed letdown cooler booster fans.

8.6.2 Bed Letdown Cooler Booster Fans

The main function of the bed letdown cooler booster fans is to supply cooling air to cool bed letdown material.

The booster fans take suction from the F.D. fan discharge and flow is held constant by varying the position of the inlet (suction) vanes on the fans.

8.6.3 Flue Gas

Flue gas (combustion products) is drawn from the furnace through the convection pass (heat recovery area), through the mechanical dust collectors (cyclones), through one section of the two section APHs, and through the fabric filter (baghouse) by two half-capacity induced draft (I.D.) fans. The I.D. fans discharge directly to the stack.

Freeboard pressure is maintained at approximately 0 in. H₂O by varying the opening on the I.D. fan suction dampers.

8.7 Other Systems

8.7.1 Ignition Oil and Air

Refer to Flow Diagram 12919.02B-EM-116A.

The ignition oil and air system consists of ignition oil and ignition air subsystems.

8.7.1.1 Ignition Oil

Two ignition oil pumps take suction from the existing light oil storage tank through an extension to the existing suction header. The ignition oil pumps discharge to a total of twelve burners.

LOCATION	MARK NUMBERS	
F5H 2	765A TO 765D	771A TO 771D
F5H 1	766A TO 766D	772A TO 772D
RH 2	767A TO 767D	773A TO 773D
BH 2	768A TO 768D	774A TO 774D
BH 1	769A TO 769D	775A TO 775D
C B C	770A TO 770D	776A TO 776D

BED LETDOWN COOLER INSTRUMENT NUMBERS

- NOTES:
1. FLOW VENTURI
 2. DAMPER
 3. GLOBE VALVE
 4. FLOW INDICATOR

THIS DWG. BASED ON FOSTER WHEELER
ENERGY CORPORATION AFB DESIGN

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UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
MAJOR FACILITIES PROJECT MANAGEMENT DIVISION
CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER
ERDA CONTRACT NO. EF-77-C-01-2550

DRAWING BY:
STONE & WEBSTER ENGINEERING CORP.
BOSTON, MASS. 02107

UNITED STATES
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AND

DESIGNED _____	DATE _____	DEVELOPMENT ADMINISTRATOR _____
DRAWN <u>FW. SCHNEIDER</u>	DATE <u>10-14-77</u>	REVIEWER _____
CHECKED <u>AN. LABRECQUE</u>	DATE <u>11-7-77</u>	APPROVER _____
APPROVED <u>P.F. LIPARI</u>	DATE _____	DATE _____

FLOW DIAGRAM
COMBUSTION AIR & FLUE GAS
SAW DWG. NO. J291902B-FM-115A

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WHEELER ENERGY CORPORATION
AFB DESIGN.

[illegible]

Two burners are located at each bed level. Two burners are also located at the CBC.

8.7.1.2 Ignition Air

Ignition air is supplied to each ignition burner for combustion. In addition, atomizing and operation (retract) air is supplied from the existing compressed air system.

8.7.2 Combustion Air Heating and Air Preheater Wash

Refer to Flow Diagram 12919.01-EM-117A.

The Combustion Air Heating and Air Preheat Wash Systems are identical to the base plant system described in Section 8.7.2 of Part I of this report.

9.0 ELECTRICAL SYSTEMS

The FWEC AFB plant electrical system is shown on Drawing 12919.02B-EW-1A. Refer to Table IIIB-6, Large Motor Loads. The bases for the plant auxiliary requirement as shown on the heat balances are defined on Table IIIB-7, Running Auxiliary Power.

The electrical system for the FWEC AFB is considerably different from that of the base plant. Due to the large draft fan loads and the addition of a start-up boiler feed pump, it necessitated the use of 13.8 kv switchgear to avoid exceeding the short circuit rating of the 4 kv bus and ensure sufficiently high starting voltages.

In the base plant, the 4 kv station service loads were divided among six buses primarily because of short circuit considerations. This is not practical in the AFB because the six largest motors account for approximately 70 percent of the station auxiliary load. To ensure satisfactory operation of the system, all large motors 4,500 hp and larger are supplied from two 13.8 kv buses. Voltages for smaller motors follow the same criteria as in the base plant. The number of 4 kv buses has been reduced to two in the AFB, with consequent simplification of the system and elimination of some tie breakers no longer required. However, it is necessary to use 350 mva class breakers for the incoming line and bus tie positions in the 4.16 kv switch gear, since a 3,000 amp rating is not available in the 250 mva class. All feeder breakers are 250 mva class, with high momentary rating, as in the base plant.

One full-size unit station service transformer is provided rather than the two half-size transformers used in the base plant. However, two auxiliary station service transformers are required to supply the 4 kv system from the 13.8 kv switchgear.

The rest of the auxiliary station service system for the AFB is designed to the same criteria as the base plant. Electrical arrangements are as noted on Drawings 12919.02B-EE-612A, 612B, 612C, 251A, and 251B.

9.1 Lighting Design Criteria

The lighting system criteria for the FWEC AFB plant are identical to the base plant criteria noted in Section 9.1 of Part I of this Report.

9.2 Raceways Design Criteria

The Raceway Design Criteria for the FWEC AFB Plant are identical to the base plant criteria noted in Section 9.2 of Part I of this Report.

9.3 Wire and Cable Design Criteria

The wire and cable design criteria for the FWEC AFB plant are identical to the base plant criteria noted in Section 9.3 of Part I of this report except that 15 kv shielded cable will be required, in addition to the types listed in Section 9.3.1.

9.4 Grounding System Design Criteria

The grounding design criteria for the FWEC AFB plant are identical to the base plant criteria noted in Section 9.4 of Part I of this report.

National Electrical Code, 1975,
Article 250

Grounding

ANSI C5.1, NFPA No. 78

Lightning Protection Code

IEEE 80-1971

Safety in A-C Substation
Grounding

9.4.2.3 Component Design

Ground cable will be soft drawn, Class A, stranded, bare copper, of a size listed in Table I-9. Ground rods will be copper-clad steel 3/4 in. in diam and 10 ft long. All taps or splices between cables or ground rods shall be made by the Cadweld or Thermoweld process.

TABLE IIIB-6

LARGE MOTOR LOADS - FOSTER WHEELER AFB

<u>Service</u>	<u>No. Conn.</u>	<u>Voltage</u>	<u>HP</u>	<u>RPM</u>
Forced Draft Fan	2	13,200	12,000	1,200
Induced Draft Fan	2	13,200	8,000	1,200
Air Compressor	1	13,200	4,500	1,800
Start-up Boiler Feed Pump	1	13,200	10,000	3,600
Circulating Water Pump	2	4,000	3,000	400
Condensate Pump	2	4,000	1,500	1,200
Limestone Crusher	2	4,000	1,000	1,200
Coal Crusher	2	4,000	450	1,200
Cooling Tower Makeup Pump	1	4,000	350	900
Booster Fan	2	4,000	500	1,200
Conveyor No. 20	1	4,000	300	1,800
Conveyor No. 23	1	4,000	300	1,800
Bed Letdown Blower	3	460	250	1,800
Fly Ash Press Blower	2	460	250	1,800
Cooling Tower Fan	12	460	50/200	1,800
Dust Collector Press Blower	2	460	250	1,800
Carbon Reinjection Blower	3	460	120	1,800

TABLE IIIB-7

Running Auxiliary Power - Foster Wheeler AFB Plant

(All Figures in Kilowatts)

	<u>Plant Load</u>		
	<u>VWO</u>	<u>75%</u>	<u>50%</u>
Forced Draft Fans	12204	5148	1528
Induced Draft Fans	9340	3941	1167
Bed Letdown Cooling Fans	445	334	222
Carbon ReInjection Blowers	189	80	24
Fly Ash Transport Blowers	378	159	47
Bed Material Transport Blowers	378	159	47
Coal and Limestone Conveyors	(		)
Coal and Limestone Crushers	(Included in Margin		)
Material Stockout and Reclaim Equipment	(Below		)
Circulating Water Pump	3109	3109	3109
Condensate Pumps	1641	692	205
Startup Boiler Feed Pump	-	-	-
Cooling Tower Makeup Pumps	202	151	101
Cooling Tower Fans	1432	1074	716
Air Compressors	3357	2518	1679
Baghouse Cleaning Fans	(Included in Margin		)
	Below		
Margin for Intermittent Load and Undefined Loads	<u>3495</u>	<u>2974</u>	<u>2444</u>
Total Running Auxiliary Power	37,159	20,339	11,289

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(1-5)
SCALE: $\frac{1}{8}'' = 1'-0''$

SCALE: $\frac{1}{8}'' = 1' - 0''$

NOTES:
SCALE: $\frac{3"}{32'} = 1" = 0'$ UNLESS NOTED

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ENERGY CORPORATION AFB DESIGN

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UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
MAJOR FACILITIES PROJECT MANAGEMENT DIVISION
CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT
ERDA CONTRACT NO. EF-77-C-01-2893

DRAWING BY: STONE & WEBSTER ENGINEERING CORP. BOSTON, MASS. 02107		UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION	
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CHECKED <u>O. F. RODO</u>	DATE <u>10-21-77</u>	NOT RECORDED BY _____	DATE _____
APPROVED <u>P. FILIPARI</u>	DATE _____		

TITLE: CABLE TRAY ARRANGEMENT
BOILER AREA-SH. I-F.W. AFB PLANT
S&W DWG. NO. 12919.02B-EE-612A

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NOTES: 1. SCALE: 1/4" = 1'-0" UNLESS NOTED

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ENERGY CORPORATION AFB DESIGN

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UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION MAJOR FACILITIES PROJECT MANAGEMENT DIVISION	
CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT ERDA CONTRACT NO. EF-77-C-1-2583	
DRAWN BY: STONE & WEBSTER ENGINEERING CORP. BOSTON, MASS. 02107	UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
DESIGNED BY: K.WIECIECEN DATE: 3-21-77	APPROVED: [Signature] DATE: 3-21-77
CHECKED BY: F. HODG DATE: 3-21-77	APPROVED: [Signature] DATE: 3-21-77
TITLE: CABLE TRAY ARRANGEMENT BOILER AREA-SH. B PLANT S&W DWG. N B-EE-612B-1	

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(EE-612B, E-2) 4-4
(EE-612B, E-4) 5-5
(EE-612B, H-4) 7-7
(EE-612A, F-5) 8-8
(EE-612A, G-5) 11-11
(EE-612B, E-4)

NOTES:
1. SCALE: $\frac{1}{8}'' = 1'-0''$

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CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT ERDA CONTRACT NO. EF-77-G-01-253	
DESIGNED BY: STONE & WEBSTER ENGINEERING CORP. BOSTON, MASS. 02107	UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
DESIGNED BY: H. KWIECEN DATE: 2-21-77	DATE: 2-21-77
CHECKED BY: D. F. ROOD DATE: 10-21-77	DATE: 10-21-77
APPROVED BY: J. LIPARI DATE: _____	
TITLE: CABLE TRAY ARRANGEMENT BOILER AREA - SH 3 - FW AFB PLANT	
S&W DWG. NO. 12919.02B-EE-612C	

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PLAN-EL40'-0"
CONTROL & COMPUTER RMS

- EQUIPMENT IDENTIFICATION**
- 1 - MAIN CONTROL ROOM
 - 2 - OPERATOR'S CONSOLE
 - 3 - HVAC CONTROL PANEL
 - 4 - FIRE PROTECTION PANEL
 - 5 - STEAM TURBINE SUPERVISORY CAB.
 - 6 - MISC CONTROL BOARD
 - 7 - SEQUENCE OF EVENTS RECORDER
 - 8 - LOGGING & ALARM TYPES
 - 9 - TABLE
 - 10 - CENTRAL PROCESSOR UNIT
 - 11 - COMPUTER I/O CABINETS
 - 12 - PROGRAMMER'S CONSOLE

NOTE:
1. SCALE: $\frac{1}{4}'' = 1'-0''$

PLAN-EL19-0"
RELAY & BATTERY RMS

- EQUIPMENT IDENTIFICATION
- 15 - 125V DC DIST PNL A
 - 16 - 125V DC BATTERY CHARGER
 - 17 - 125V DC DIST PNL B
 - 18 - COMPUTER TERMINAL CAB.
 - 19 - CABLE HANDLING, PREP & INJECTION RL" CAB.
 - 20 - DOLMITE MOLT, PREP & INJECTION RL" CAB.
 - 21 - FLUIDIZED BED CONTROL & LOGIC CAB.
 - 22 - STEAM TURBINE CONTROL CABINET
 - 23 - ANKUSATOR LOGIC CABINET
 - 24 - SIGNAL CONDITIONING CABINET
 - 25 - MOTOR POWER SUPPLY CAB.
 - 26 - GENERATOR & TRANSFORMER RFLAY CAB.A
 - 27 - GENERATOR & TRANSFORMER RFLAY CAB.B
 - 28 - STEAM INVERTER CAB.
 - 29 - 120V AC DIST PANELS

THIS DRAWING BASED ON FOSTER WHEELER
ENERGY CORPORATION AFB DESIGN

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10	CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT			
11	EDRA CONTRACT NO. EF-77-C-01-2259			
12	DRAWING BY: STONE, WEBSTER ENGINEERING CORP. BOSTON, MASS. 02107		UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION	
13	DESIGNED R.B. PITTMAN		DATE 2-15-72	
14	DRAWN R.B. PITTMAN		DATE 2-15-72	
15	CHECKED G.F. ROSE		DATE 10-15-72	
16	BY G.F. ROSE		DATE 10-15-72	

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ma: ARRANGEMENT-FW AFB PLANT
CONTROL, RELAY & BATTERY ROOMS
S&W DWG. N 28-EE-251A

- 4.15KV SWGR BUS P
P1- MAKE-UP WATER PUMP 4-1
P2- CIRCULATING WATER PUMP 4-2
P3- CONDENSATE PUMP 4-2
P4- COAL CRUSHER 4-2
P5- BED LET-DOWN COOLING BOOSTER FAN 4-2
P6- LIMESTONE CRUSHER 4-2
P7- BUS P METERING & INSTRUMENTATION
P8- AUX STEADDOWN XFMR B
P9- TO 480V SUBS-2000KVA
P10- TO 480V SUBS-3000KVA
P11- TO 480V SUBS-3000KVA
P12- CONVEYOR MD.23

NOTES:
1. SCALE: 1"=4'-0"

THIS DRAWING BASED ON FOSTER WHEELER
ENERGY CORPORATION AFB DESIGN

NOT TO BE USED FOR CONSTRUCTION

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UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
MAJOR FACILITIES PROJECT MANAGEMENT DIVISION
CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT
ERDA CONTRACT NO. EF-77-C-01-2383

DRAWING BY: STONE & WEBSTER ENGINEERING CORP. BOSTON, MASS. 02107		UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
DESIGNED: J.F. WALSH	DATE 9-18-77	REVISIONS 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379 380 381 382 383 384 385 386 387 388 389 390 391 392 393 394 395 396 397 398 399 400 401 402 403 404 405 406 407 408 409 410 411 412 413 414 415 416 417 418 419 420 421 422 423 424 425 426 427 428 429 430 431 432 433 434 435 436 437 438 439 440 441 442 443 444 445 446 447 448 449 450 451 452 453 454 455 456 457 458 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474 475 476 477 478 479 480 481 482 483 484 485 486 487 488 489 490 491 492 493 494 495 496 497 498 499 500 501 502 503 504 505 506 507

APPROVED P. F. LIPARI DATE

TITLE: ARRANGEMENT-SWITCHGEAR AREA
FW AFB PLANT

[illegible]

10.0 CONTROL SYSTEMS AND INSTRUMENTATION

10.1 General

The general design criteria for control systems and instrumentation for FWEC AFB plant will be identical to those of the base plant as detailed under Section 10 of Part 1. The AFB plant employs similar conventional techniques for load control, start-up, shutdown, and emergency shutdown and trips. This section presents a brief description of the control system, highlights of the protective system, and a summary of the start-up and loading procedure for the fluidized bed boiler equipment. Operation and controls of other major systems are described in the appropriate system descriptions in Appendix IIIB-B.

An instrument list has been compiled to identify the quantity of instrumentation required and to supplement the information contained in the system flow diagrams. The instrument list is made up in two parts and is included under Appendix IIIB-E. Part C of the instrument list shows all the instruments common to both boiler designs - B&W and FWEC - whereas Part B shows the instrumentation for the particular boiler design included in this report.

Equipment technical data sheets have been prepared for all significant control components which are not a part of any vendor-engineered and supplied subsystem. The data sheets are in two parts and are included under Appendix IIIB-D. Part C combines data sheets common for both boiler manufacturers, and Part B combines data sheets for the Foster Wheeler design.

Wherever appropriate, this description shall be supplemented by the details contained in the report supplied by the boiler manufacturer (Appendix IIIB-C).

The presentation is conceptual in nature, and it will be apparent that there are many interface areas that must be defined completely before a plant can be instrumented. It should be recognized that the development of the control systems design is based on incomplete test data from smaller units and their similarity with the conventional pulverized coal power plant systems. It will be improper to use these controls on any large unit until the performance of these large utility sized units are simulated using mathematical modeling techniques and the interrelationships of the various parameters are well established.

10.2 Control System

10.2.1 General

The control systems objective for the AFB steam generator power plant was to provide controls to operate the plant efficiently, safely, and with the maximum amount of plant availability. To accomplish this, the following features are provided:

1. The automation required to start up and shut down the various plant components required for load changes
2. A loading scheme that will produce the best heat rate at all times
3. An emergency or safety system to handle contingency conditions
4. A coordinated control system to operate all of the plant components properly

A total analog control system, with a digital information system of the type currently used on conventional power plant, is applied to the AFB plant. To some extent, digital equipment will be used for plant automation, sequential loading, and safe shutdown.

The digital portion includes a Bed Segment Control System, which incorporates the necessary controls for purging, ignition, and sequential loading. A safety system to monitor the critical boiler parameters and, if necessary, to shut down the AFB boiler in a safe and orderly fashion is a part of the segment control.

The analog control system is designed to operate the boiler and turbine in parallel as a coordinated unit, so as to produce the required generator output in a fast, stable, and efficient manner over the entire operating range. The analog control develops necessary control signals corresponding to unit load demand, monitors fuel flow, airflow, feedwater flow, etc., and control these parameters to achieve the required steam flow, pressure, and temperature. Included in the analog control systems are all the sensors, controllers, hand/auto stations, and final drive units. The analog system will provide suitable buffered outputs to indicators and/or recorders in the main control room. The hand/auto stations will be mounted in the control room. The following is a brief description of the major analog control systems of Foster Wheeler-designed AFB once-through subcritical steam generator.

10.2.2 Unit Load Control

The Unit Load Control system regulates process mass and energy balance. The unit load control system will contain feed-forward elements and establish demands for boiler and turbine subsystems. The control system permits the unit to operate in the boiler follow, turbine follow, or coordinated mode while responding to a load demand signal.

The unit load demand as generated from the load dispatch system or as manually set by the operators is used to develop feed-forward control signal for the boiler and the turbine. The system recognizes various equipment and operational limits and runbacks so as not to exceed unit capability at any time. The unit load demand is also suitably modified by throttle pressure error and generator megawatt error to develop proper boiler load demand signal.

The boiler load demand, suitably characterized, is used as feed-forward demand signal for feedwater flow, fuel flow, and airflow.

10.2.3 Combustion Control in Main Beds

Refer to Logic Diagrams 12919.02B-LSK-18.5A, 18.5C, and 18.5D for schematic logics.

The combustion control is designed to satisfy the energy input demand from the fuel-air demand. At the outset, it should be recognized that the AFB boiler design requires that bed expansions be maintained at a relatively constant value by maintaining a constant air velocity through the bed. This restricts variation of air mass to a very narrow band throughout the entire load range. Thus, the combustion control of the AFB boiler is really restricted to control of the fuel only.

The basic fuel demand for each cell is developed by suitably modifying the boiler load demand with the steam temperature error. The adjusted signal is then compared with the actual measured total fuel flow to derive the master fuel demand for all operating bed segments in the boiling, superheater, or reheater beds.

For the boiling beds (12919.02B-LSK-18.5A), the master fuel demand is further corrected for the feedwater inlet temperatures. For the superheater beds (12919.02B-LSK-18.5C), the master fuel demand is adjusted for the superheat temperature error; whereas, for the reheater beds (12919.02B-LSK-18.5D), reheat temperature error modifies the master fuel demand signal to establish the fuel demand for the reheater bed segments.

Mean bed temperature is monitored for all beds and imposes a trimming signal on the individual bed segment fuel demand signal. Normally, the bed temperature is regulated around 1,550 F (adjustable) set point. If the bed temperature increases, the fuel feed will be proportionately reduced and vice versa. A limited amount of load turndown capability will be achieved by varying the bed temperature between 1,450 F and 1,650 F to change the heat flux.

Airflow is measured on each bed segment and controlled to maintain a constant air velocity. The airflow measurement is adjusted for undergrid air temperature and mean bed temperature to compute the air velocity. The calculated velocity is compared with the set point to derive the modified air demand signal.

To prevent fuel from exceeding available air, the fuel demand signal is always limited by the measured airflow.

Individual bed segment Hand/Auto stations in the control room will allow the operator to interrupt or bias the fuel-air demand.

Final control of combustion is achieved by positioning the individual segment combustion air control damper and by varying the coal feeder speed corresponding to air and fuel demand, respectively.

10.2.4 Bed Material Control in Main Bed

Refer to Logic Diagrams 12919.02B-LSK-18.5B, 18.5C, and 18.5D.

The inventory of bed material is regulated by control of the limestone feed rate and the bed letdown rate.

Limestone feed rate is maintained as a ratio of coal flow demand. This ratio is based on the recent as-fired coal sampling and is adjustable by the operator. The limestone demand is adjusted to compensate for the effect of temperature on CaO sulfur capture efficiency. Normally, when the beds are operated around 1,550 F, this compensation will not be operative. However, when bed temperature is modulated to achieve a load turndown, the limestone feed rate will be changed based on Calcium Oxide/Sulfur Utilization Temperature Curve.

Limestone feed rate is also increased manually by the operator if an average "SO₂" value of greater than set point is detected in the "SO₂" monitors.

Bed material letdown rate is matched with limestone feed rate to provide the necessary bed material inventory at any time. Although it will not be possible to measure the bed height accurately, a bed level measurement using differential pressure transmitters (PDTs) will be employed to determine approximate bed

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level errors from the set point. This deviation will be used to bias the bed letdown control to restore bed level error to zero and to maintain proper mass of bed material.

10.2.5 Combustion Control in Carbon Burnup Beds

Refer to Logic Diagram 12919.02B-LSK-18.5E for schematic logic.

CBC beds burn high carbon content fly ash elutriated from the other beds. To accomplish the carbon burnup, the bed temperature in CBC must be maintained at a constant higher value (1,850 F + 50 F) compared to the main beds.

The temperature error is used as a primary demand signal for fuel. Since the fly ash returns to CBC are not controlled, the temperature is controlled by modulating the flow of the supplementary coal feed.

bed segment excess oxygen is measured in the freeboard area and airflow is controlled as necessary to maintain oxygen within limits or a minimum fluidizing velocity, whichever requires greater fluidizing velocity.

bed fluidizing velocity is computed from the airflow measurement modified by undergrid air temperature and the mean bed temperature.

10.2.6 Bed Material Control in Carbon Burnup Beds

Refer to Logic Diagram 12919.02B-LSK-18.5F.

The fluidized mass of bed material in the CBC normally does not need any regulation. The lost bed material inventory (approximately 3 percent per hour), due to attrition and elutriation, will be made up by extraction from the main bed letdown at a point after the tap cooler. Whenever supplemental coal burning is required to maintain the CBC bed operating temperature, fresh limestone feed and associated bed letdown control will be activated.

Limestone feed rate is determined as a ratio of the coal flow demand. The ratio adjustment incorporates correction for lower sulfur capture efficiency at higher (1,850 F) CBC operating temperature. SO₂ indication will be provided for manual adjustment of the limestone demand by the operator, whenever required.

bed level is measured by using differential pressure transmitters and is used to control the bed material replenishment from the main beds into the CBC for lower than normal (set point) CBC bed level.

bed material withdrawal rate from the CBC is matched with limestone feed rate to provide a constant bed material inventory at any time.

For a bed level higher than normal, the bed letdown control device demand signal is biased by the level error so as to keep the bed level within limits.

10.2.7 Feedwater Control

Refer to Logic Diagram 12919.02B-LSK-18.5G for schematic logic.

The feedwater control system is designed to provide a demand for feedwater flow to the boiler. The boiler demand is used to establish a demand for feedwater flow. This feedwater flow demand is compared with measured flow to develop a feedback error signal which modifies the original feed-forward demand signal. A minimum feedwater flow demand of 35 percent of full load assures that an adequate flow is maintained at low loads to protect the bed tubes from overheating.

Whenever the firing rate in any beds (boiling, superheater, or reheater) is unable to satisfy demand, a firing rate error will modify the demand for feedwater flow for loads above 35 percent. This assists in maintaining the feedwater flow/firing rate ratio within predetermined limits, thus minimizing the steam temperature upsets.

10.2.8 Forced Draft Fan

Refer to Logic Diagram 12919.02B-LSK-18.5G.

The forced draft fan supplies air to all six beds for fluidizing the coal and limestone bed material and to maintain adequate air for proper combustion. The combustion air plenum pressure at the F.D. fan discharge is maintained at a constant pressure by regulating the F.D. fan inlet vanes. Airflow to the bed segments is regulated by the individual segment undergrid dampers.

10.2.9 Induced Draft Fan

Refer to Logic Diagram 12919.02B-LSK-18.5G.

The draft control system maintains the combustion cells at a constant (slightly negative) pressure in the freeboard area directly above the bed at steady state conditions and will minimize deviations during transient disturbances. The draft control system provides a demand for the I.D. fan inlet vanes. The control system uses the total airflow signal modified by the average cell draft error (based on cell draft set point) as the feed-forward demand signal. The total airflow will be determined as the sum of all flows through the main beds and the CBC beds.

NOTES

1. CONTROL FOR ONE CBC BED SEGMENT SHOWN, CONTROL FOR OTHER CBC BED SEGMENTS SIMILAR.

THIS DIAGRAM IS BASED ON FOSTER WHEELER DESIGN

COMBUSTION CONTROL	
COAL FEED AND AIR DAMPER CONTROLS	
CARBON BURN-UP CELL	
ERDA AFB STUDY	
STONE & WEBSTER ENGINEERING CORPORATION	
12919.02B-LSK-18.5E	

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1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16

NOTES:
1. CONTROL FOR ONE CBC BED SEGMENT SHOWN
CONTROL FOR OTHER CBC BED SEGMENTS SIMILAR

THIS DIAGRAM IS BASED ON FOSTER WHEELER DESIGN

BED MATERIAL CONTROL									
BED LETDOWN AND LIMESTONE FEED CONTROLS									
CARBON BURN-UP CELL									
ERDA AFB STUDY									
STONE & WEBSTER ENGINEERING CORPORATION									
12919.02B-LSK-18.5F

THIS DIAGRAM IS BASED ON FOSTER WHEELER DESIGN

**FEEDWATER, FORCED DRAFT FAN
AND INDUCED DRAFT FAN CONTROLS**

ERDA AFB STUDY

STONE & WEBSTER ENGINEERING CORPORATION

12919.02B-L SK-18.5G

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This demand is then compared to actual I.D. fan suction pressure, and the resultant error signal then controls I.D. fan inlet vane drive.

10.2.10 Superheat Steam Temperature Control

Refer to Logic Diagram 12919.02B-LSK-18.5H.

Final steam temperature is controlled by adjusting the bed firing rate demand. However, rapid corrections are not possible by changing the firing rate due to the time lag before a change in the firing rate affects the final steam temperature. Spray attenuation is used to achieve a rapid, temporary correction of the steam temperature while the firing rate is being modified to produce a slower, permanent correction. The steam temperature set point (derived from the final superheater outlet temperature error adjusted by the load index signal) is compared with the actual measured superheater inlet steam temperature to develop a steam temperature error. The resulting error is used by superheat steam temperature control to operate a base-loaded spray between the two fluidized beds of finishing superheater surfaces. This location provides quick response time to changes in final steam temperature.

10.2.11 Reheat Steam Temperature Control

Refer to Logic Diagram 12919.02B-LSK-18.5H.

Final reheat steam temperature is controlled by adjusting the reheater bed firing rate. However, the heat recovery area dampers located in the gas pass provide the primary control for the reheat steam temperature. These dampers are operated between minimum and maximum limits with additional control provided through the use of spray systems. The spray system controls transient temperature excursions on a rapid, temporary basis. If the spray flow demand is continuous, the firing rate will be adjusted by removing reheat bed segments. For low reheat temperature, when the reheat pass damper is at its extreme open position, the firing rate will be adjusted by igniting additional segments. The reheater outlet temperature error, trimmed by the load index signal, is used sequentially to position the reheat and superheat pass dampers.

10.2.12 Steam to Reheat System

Refer to Logic Diagram 12919.02B-LSK-18.5J.

A turbine bypass system sized to pass 35 percent of VWO main steam is required as a prerequisite to maintain flow and temperature conditions through the fired bed segments during start-up and shutdown.

The bypass control valves operate to maintain the minimum 35 percent MCR flow through the AFB boiler during start-up and shutdown. As turbine load is ramped from 18 percent to 35 percent, the HP turbine bypass valves, responding to throttle pressure error corrected unit load demand signal, gradually close as the HP turbine control valves open. At 35 percent MCR flow through the turbine, the HP bypass valves are fully closed.

The LP bypass valves operate to maintain a constant hot reheat pressure until the minimum flow requirement for the boiler can be satisfied by the steam flow through the turbine. After that, the LP bypass valves will remain closed.

The turbine bypass control system will include spray attenuation for temperature matching of the bypass steam with the steam temperature at the HP turbine exhaust and at LP turbine exhaust.

10.3 Plant Protection and Safety

10.3.1 General

The AFB plant is designed with a reliable protective system to maintain plant safety. This system overrides all other plant controls to return the plant to a safe condition, either operational or shutdown. The protection system consists of the two basic modes of operation:

1. Emergency Shutdown and Trips
2. Runbacks and Limits

10.3.2 Emergency Shutdown and Trips

Refer to Logic Diagrams 12919.02B-LSK-1-3A and 1-3B.

The plant will usually be shut down using the normal shutdown procedures. Emergency conditions can occur, however, which will require emergency shutdown procedures. The emergency shutdown can result from several types of failures. Major categories which have been evaluated are as follows:

1. Loss of Feedwater - The loss of feedwater will result in loss of bed cooling and a rapid increase in bed temperature. This will create a boiler/turbine trip condition. Fuel feed will be tripped to keep the bed from overheating. The unit will then be safely shut down with an airflow runback to the minimum fluidizing velocity with the HP and LP turbine bypass system in operation.

BED SEGMENT TRIP (TYPICAL)

NOTES:
1. REFER LSK-1-3A.

THIS DIAGRAM IS BASED ON FOSTER WHEELER DESIGN

BOILER TRIP & RUNBACK - SHEET 2 OF 2

ERDA AFB STUDY
STONE & WEBSTER ENGINEERING CORPORATION
12919.02B-LSK-1-3B

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2. Failure of Boiler Tubes - Tube leaks would be determined by measuring the total difference between the feedwater flow and final steam flow. In case of a major leak, the AFB boiler-turbine unit should be shut down immediately.
3. Total Loss of Air - Total loss of combustion air would trip the boiler.
4. Loss of Airflow to the Bed - The fuel and limestone feed to that bed will be stopped and the boiler will continue to operate at reduced load.
5. Loss of Coal Feeding Equipment - Loss of coal feed to a bed will automatically shut down that bed. The remainder of the system would continue to operate safely but at a reduced load.
6. High Bed Temperature - This condition would initiate an alarm for operator attention/correction. An excessively high temperature will trip the bed.
7. Turbine Trip - On a turbine trip, the boiler would be run back to 35 percent MCR load. This trip signal would open the bypass lines around the turbine to provide cooling of the reheater beds, and the boiler, at this point, could remain in operation with fires cut in the reheater beds. This operational requirement provides the AFB boiler with the advantage of remaining in a hot standby mode on a turbine trip. However, if it was determined that a restart of the turbine could not be initiated, the boiler would be tripped.

10.3.3 Runback and Limits

A system of runbacks and limits will form part of the control system and maintain the plant at a safe load during abnormal conditions. This system will override the load demand to adjust the operating level as required. The runbacks and limits will be operational only when the plant is in automatic control. When operating in a manual mode, the alarm system will warn the operators of the abnormal condition and, if necessary, the trip system will shut down part or all of the plant to prevent damage.

The control items that will be included in the runback scheme are:

High Bed Temperature
Insufficient feedwater flow
Insufficient sorbent flow
Turbine Trip

The plant operating limits are determined by the availability of critical equipment in service, such as

F.D. Fans

I.D. Fans

Fuel/Sorbent Feeding Equipment, etc.

10.4 Start-Up and Loading Procedure

10.4.1 General

The normal start-up of the AFB unit is sequential. The procedure is similar to other FWEC once-through subcritical pulverized coal-fired steam generators except for the firing and sequencing of various beds. The normal start-up procedure requires purging of the air side and flushing of the water side before firing the beds.

10.4.1.1 Purging Cycle

Bed purging is performed at each level individually, starting with the lower beds and working upward. Each bed is purged with 25 percent MCR airflow for approximately 5 min which is similar to NFPA requirement for PC boilers.

10.4.1.2 Flushing Cycle

The purpose of the flushing mode is to remove feedwater impurities from the boiler circuits, feedwater heater, and deaerator. Flushing is performed at 15 percent boiler flow.

10.4.1.3 Light Off and Warm Unit

When satisfactory water conditions have been obtained, the carbon burnup cell (CBC) is ignited, using raw coal as fuel, to raise the fluid temperature. At about 450 F fluid temperature, a minimum feedwater flow of 35 percent is established. Subsequently, the firing rate is increased by starting sections of the boiling beds (BB1 and BB2) to continue raising fluid temperature and pressure.

During this phase of operation, steam generation starts. Steam is separated from the water in the separators and a separator level is established. At this time, the superheater and the reheater beds are not fired. Turbine above seat drain valves is opened at about 200 psi steam pressure to warm the main steam lines.

10.4.1.4 Roll and Apply Initial Turbine Load

Firing rate in BB1 and BB2 is increased further by adding more segments into operation thereby raising the throttle pressure to 850 psi. High pressure and low pressure turbine bypass control system will hold the throttle pressure at 850 psi and hot reheat pressure at the operator adjusted set point. At this stage, all the steam is flowing to the condenser via the reheater and the turbine valves are opened for warming and rolling.

When 35 percent steam is flowing through HP/LP bypass, sections of superheater and reheater beds are lighted off to bring the superheat (main steam) and the reheat (reheat steam) temperatures to desired value. At this time, the separator drain valve closes and the boiler is operating in the once-through mode.

When the turbine is up to speed, the unit is synchronized and initial loading applied. At 850 psi throttle pressure, the load is raised to 18 percent by transferring the boiler steam flow from the HP/LP bypass to the turbine. At this stage, the turbine throttle control valves will be set at the 50 percent open position.

10.4.1.5 Loading 18 Percent to 100 Percent

Throttle pressure is then ramped to its design value with the throttle valve in the fixed 50 percent position. Between 18 percent and 35 percent load, the load increase is obtained by firing additional bed segments to raise the throttle pressure and transferring the steam flow from the bypass to the turbine. The boiler feedwater flow rate remains constant at 35 percent. Above 35 percent load, the HP/LP bypass is completely closed and feedwater flow is increased in direct proportion to the unit load.

Above 50 percent load, the turbine is loaded at constant throttle pressure by varying the throttle valve opening. Pumping rate and firing rate are modulated to maintain constant throttle pressure and temperature.

10.4.2 On-Line Loading

The plant load can be varied by adjusting the firing of the bed segments simultaneously or sequentially. Sequential operation of the segments requires starting and stopping equipment. The fastest load changes are accomplished by adjusting the segments already in service. Since time is required to ignite the additional segments, load increases beyond the operating range of the equipment already in service will be slower. Load decreases can be accomplished rapidly by tripping portions of the operating beds.

The sequential segment loading scheme is used for normal demands for increase or decrease of the load. As part of the Bed Segment Control, a computer program determines the most desirable starting and loading sequence.

11.0 ENVIRONMENTAL SYSTEMS

The base plant is designed to comply with all existing federal, state, and local environmental regulations.

11.1 Air Quality

Operation of the plant will result in emissions of particulate matter, sulfur dioxide, and nitrogen oxides to the atmosphere. These emissions will be controlled to comply with EPA New Source Performance Standards. Particulate matter will be controlled by use of a fabric filter. Sulfur dioxide emissions will be controlled by use of a sulfur sorbent bed of limestone. Nitrogen oxides will be maintained well below conventional boiler emissions due to the low combustion temperature in the fluidized bed. Emissions of these contaminants and applicable regulations are summarized below.

	<u>Plant Emission</u>	<u>New Source Performance Standards</u>
Particulate matter	0.06 lb/10 ⁶ Btu	0.1 lb/10 ⁶ Btu
Sulfur Dioxide	1.2 lb/10 ⁶ Btu	1.2 lb/10 ⁶ Btu
Nitrogen Oxides	0.3 lb/10 ⁶ Btu	0.7 lb/10 ⁶ Btu

Emissions of particulate matter, sulfur dioxide, and nitrogen oxides are approximately 345 lb/hr, 6,504 lb/hr, and 1,626 lb/hr, respectively.

11.2 Noise

The FWEC plant is designed to comply with OSHA in-plant noise levels to ensure worker safety. There will be a fan room, inlet silencers, and acoustical lagging to control the noise from the forced draft fans.

Additional equipment which contributes to high noise levels will be silenced by enclosures, acoustical lagging, and/or silencers. Examples of this equipment include boiler feed pumps, power control valve, and HVAC equipment.

11.3 Waste Treatment

Liquid wastes resulting from operation of the FWEC plant will be conveyed to an existing liquid waste treatment system. Typical wastes which will be conveyed include boiler blowdown, equipment

drains, floor drains, and coal pile runoff. Sanitary waste will be treated in an existing system.

Solid wastes from plant operation include fly ash and bed letdown. These wastes, which consist primarily of fly ash, calcium sulfate, and calcium oxide, will be collected and pneumatically conveyed to silos located at the landfill area. Trucks will then transport the material to the area of the landfill which is being worked.

The solid waste represents approximately 128,000 lb/hr and 171 acre-ft/yr based on the performance coal and a unit capacity of 53.53 percent.

11.4 Environmental Monitoring

An environmental monitoring system is provided for continuously monitoring opacity, sulfur dioxide, nitrogen dioxide, and carbon dioxide. These instruments are installed to ensure compliance with New Source Performance Standards and will signal an alarm if levels of these contaminants in the flue gas exceed the standards.

J.O.No. 12919.02B

APPENDIX IIIB-A
DESCRIPTION OF WORK
FOR A
FOSTER WHEELER ENERGY CORPORATION
570 MW ATMOSPHERIC FLUIDIZED BED BOILER
ELECTRIC GENERATING PLANT

STONE & WEBSTER ENGINEERING CORPORATION
Boston, Massachusetts

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*Change from Base Plant

BLOCK NO. 1 - LAND AND LAND RIGHTS

As this unit is the fourth extension to an existing site already owned by the Client, no land or land rights are included.

In addition, transmission line rights-of-way or ownership is presumed to exist.

FWEC AFB plant total area is 1.910 acres.

BLOCK NO. 2 - YARD WORK1100.00000 YARD WORK1100.10000 Clearing, Grading, and Surfacing1100.11000 Clearing

No clearing is included in this scope.

1100.12000 Grading - Yard

Preliminary site grading is assumed to be complete. Minor regrading for the construction of the new structure will be performed.

Final site grading will be done immediately before commercial operation of the plant.

1100.13000 Surfacing - Yard

No surfacing is included in this scope.

1100.14000 Landscaping

No landscaping is included in this scope.

1100.20000 Roads, Parking Areas, and Fences1100.21000 Roads and Parking Areas

No parking areas are included in this scope. Station access road will be 24 ft-0 in. wide asphalt paved using one course 3 in. thick for a total of 1,200 L.F. The 8 in. crushed stone base and 4 in. stabilized topping for the station access road will be provided. Finish grading will be provided before applying the asphalt paving. Station service roads will be 24 ft-0 in. wide using an 8 in. crushed stone base and 4 in. stabilized topping for a total of 4,300 L.F. being provided. No asphalt paving is provided on station service roads. All railroad grade crossings will be provided. Any subgrade work required to establish the specified grades before applying the base material will be provided.

1100.23000 Fences

No fencing is included in this scope.

1100.30000 Water and Sewer Systems and Other Service Lines**1100.31000 Water Systems****Domestic Water**

Domestic water for the plant will be supplied from the previous unit.

Service Water

Service water for the station will be taken from the existing well water system. Service water will be used for the makeup water demineralizers and hose stations.

River Water

River water for the station will be taken from the existing makeup water pump house. River water will be used for cooling tower makeup. Air preheater washing will be from an existing ash sluice system.

Water Piping

Piping, valves, and fittings will be provided.

1100.33000 Storm Sewer System

The storm sewer system will receive surface runoff, roof drainage, and the effluent from oil separators which serve plant floor drains, equipment drains, and station transformers. The storm sewer will terminate at a connection furnished with the previous unit.

1100.34000 Fire Protection System

The yard fire system will consist of a buried pipe distribution system serving fire hydrants with connections to the plant to serve interior hose stations and special fire protection systems.

All yard hydrants will be provided with fully equipped hose houses. Yard fire piping shall be buried and shall be 150 lb seamless carbon steel pipe, with welded fittings, protected with X-TRV-Coat coating, or equivalent. Piping for interior hose stations, and stand-pipe systems shall be seamless carbon steel with welded fittings. Post indicator isolation valves will be 175 lb type.

1100.36000 Yard Steam Lines

Piping, valves, and fittings will be provided.

1100.60000 Trackwork

An existing railroad spur from the main line will provide access to the main powerhouse. Removal of the existing trackwork in the boiler and turbine areas will be performed as required.

1100.70000 Yard Lighting

The yard lighting will serve the additional roadway requirements of the site. Lighting will be provided at corners, curves, and gate entrances and the lighting level will be no greater than 1/2 ft candle in these areas.

BLOCK NO. 3 - MAIN POWERHOUSE**1101.00000 MAIN POWERHOUSE**

The main powerhouse consists of the boiler area, turbine area, silo bay, auxiliary bay, and the control room area.

The main powerhouse consists of the following:

Boiler Related Equipment

Boiler Room	89.5 ft x 146 ft x 205.6 ft =	2,686,575 ft ³
Bunker Bay	43.5 ft x 193.5 ft x 301 ft =	2,533,592 ft ³
FD Fan Room	70 ft x 151 ft x 31 ft =	327,670 ft ³
ID Fan Room	53 ft x 151 ft x 46 ft =	368,138 ft ³
Total Boiler Area Volume =		5,915,975 ft ³
Total Boiler Room Floor Space =		40,057 ft ²

Turbine Related Equipment

Turbine Room	98 ft x 185 ft x 101 ft =	1,831,130 ft ³
Auxiliary Bay	39 ft x 185 ft x 101 ft =	728,715 ft ³
Deaerator Enclosure	39 ft x 92 ft x 29.5 ft =	105,846 ft ³
Control Room	35 ft x 167 ft x 101 ft =	590,345 ft ³
Total Turbine Area Volume =		3,256,036 ft ³
Total Plant Volume =		9,172,011 ft ³

1101.10000 Substructure

The building foundation will consist of reinforced concrete footings supported on piles. Grade beams will be provided around the perimeter of the building extending below the frost line. Pile cap and grade beam type foundation will be used except in cases where subslab proves more economical. The ground floor slabs and equipment foundations will be reinforced concrete supported on piles. Flood protection and/or design will be provided to El. (-) 1 ft-0 in.

1101.20000 Superstructure

The superstructure will be steel frame construction braced against wind and impact loads. Connections will utilize high strength bolts.

The exterior building walls will be uninsulated metal siding supported by steel channel girts. The 12 in. thick reinforced concrete fire wall along the B column line will be extended approximately 80 ft from the previous unit. Fixed and operating aluminum louvers as required for ventilation will be provided. Translucent wall panels will be provided on the east wall to match the panels of the existing unit. The building roofs will consist of a steel supported painted metal roof deck with

insulation and built-up roofing. Interior partitions will be concrete block.

Boiler steel consisting of columns, girders, beams, and supplementary steel to support the boiler, retractable soot blowers, and temperature probe will be furnished.

Hollow steel doors will be provided for both exterior and interior application for the main powerhouse. Industrial rolling steel doors will be located at the railroad access to the turbine building and other areas of the main powerhouse to provide equipment and truck access. Where possible, doors will be relocated from the previous unit north wall to the north wall of this unit.

Superstructure floors and walkways will generally be of grating or concrete floors.

There will be a control room at the operating floor next to the turbine area. The control room will be an extension of the previous unit control room and will contain a main control board for operating all prime-order equipment. There will also be a number of auxiliary control boards for supervising equipment having a secondary order of operations. Interior walls of the control room and associated rooms will be concrete block. Doors will be of hollow steel construction with pressed steel frames. Floors will be vinyl asbestos tile. A hung luminous ceiling will be provided for the entire area. Special care will be taken to ensure maximum sound attenuation in the control room.

Two stairwells will be located in the boiler area for access and egress and additional stairs, as required, for access to equipment. Stairs will generally have grating treads with abrasive nosings. Two enclosed crossover walkways will be provided above the conveyor house level extending between this and the previous unit.

Grating and treads are to be welded steel painted black for interior use and galvanized for exterior use. Grating will be a minimum of 1 1/4 in. by 3/16 in. except stair landing will be 1 in. by 3/16 in. bars.

All handrails will be double rail pipe handrails with a smooth continuous top rail. Exterior platforms and caged ladders will be provided for emergency access from boiler room roof to ground using intermediate roof levels at platforms where possible.

1101.40000 Service Equipment

1101.41000 Plumbing System

Floor and equipment drains will be collected in pipes and trenches and empty into an in-plant sump. From here the drains will be pumped to an existing valved connection which leads to

the above ground oil separator system for subsequent disposal to the ash pond.

Roof drainage system consisting of roof boxes, horizontal piping, and downspouts will be provided. Water will discharge directly into the storm sewer system.

Potable water will be provided by the previous unit. Water will be distributed to drinking water coolers within the powerhouse. Emergency shower and eyewash stations will be provided in acid areas. Hot water and sanitary facilities are not being provided for this unit.

1101.42000 Heating System

Steam unit heaters will be provided.

1101.43000 Ventilation System (air density equals 0.0754 lb/cu ft at 60 F)

Boiler room ventilation will require approximately 1,200,000 cfm of air to be supplied to and exhausted from the boiler room to limit the indoor temperature to 120 F during maximum summer ambient temperature of 96 F. Air will be brought in through fan rooms in the upper levels of the boiler room and distributed through ductwork to the hot region of the room. Air will also enter the plant by natural ventilation through motor-operated hooded louvers and doors. Air will exhaust through gravity roof ventilators.

Turbine room ventilation will require approximately 500,000 cfm to limit the indoor temperature to 110 F during maximum summer temperatures. Air will be brought in by fan and duct systems and by natural means. Air forced into the turbine room will be filtered with 85 percent ASHRAE weight arrestance, roll type filters. Fans will exhaust the air through the roofs and walls.

Other areas within the powerhouse will be ventilated by conventional means. These include the conveyor gallery, auxiliary bay, deaerator area, switchgear area, battery room, cable room, clean and dirty oil tanks room, limestone preparation area, and the laboratory and sample area of the turbine room.

New yard structures will also be ventilated. These include the cooling tower pump house, the new conveyor galleries and the crusher house.

The control and relay rooms will each be air conditioned by separate, independent systems. Heating will be provided by means of duct mounted electric air heaters.

1101.46000 Fire Protection System

To bring fire protection water into the plant, connections will be made to the existing below ground fire protection loop which surrounds this unit.

Halon fire protection systems will be provided for the computer room, selected areas of the control room, the electrical equipment room, and miscellaneous electrical areas.

Water spray systems will be provided to protect the turbine lubrication oil tank, oil pumps and coolers, oil conditioning equipment, oil storage rooms, hydrogen seal oil unit, and the outdoor transformers.

Water hose stations will be strategically located throughout the entire powerhouse.

1101.47000 Elevator

Electric freight and passenger elevators will not be provided. Elevator access will be from the previous unit.

1101.5000 Lighting System

The main powerhouse lighting system will be a combination of vapor lighting fixtures, fluorescent fixtures, and incandescent fixtures, as required, to give a level of 100 ft candles in the main control board areas; 30 ft candles on the operating floor, in the relay equipment rooms, and in the switchgear areas; and 20 ft candles in other areas. Fixtures will be suitable for each area as classified. Emergency d-c lighting will be provided for safe egress from all areas.

1101.90000 Painting

Structural steel will be sandblasted and painted with one coat of an inorganic zinc primer and a top coat of an acrylic latex in the shop. It will be touched up as required. At selected areas, concrete block will be given one coat of filler and one finish coat of paint.

BLOCK NO. 4 - ADMINISTRATION BUILDING

As the existing facility includes an administration building/office, no provision is included for an administration building.

BLOCK NO. 5 - MISCELLANEOUS BUILDINGS

The existing facility includes a number of miscellaneous buildings for construction and/or operation which will be utilized for this unit.

BLOCK NO. 6 - BOILER EQUIPMENT BY VENDOR**1200.10000 Boiler Equipment**

The boiler will be a once through type, with a balanced draft furnace, producing 3,972,963 lb/hr of steam at 2,620 psig/1,000 F, with single reheat to 1,000 F. The boiler will be designed to burn Midwest bituminous coal with No. 2 fuel oil provided for ignition. The coal will have a heat value of 11,081 Btu per lb, an ash content of 10 percent, a moisture content of 13.52 percent, and a sulfur content of approximately 3 percent. Final feedwater temperature will be 485 F.

1200.11100 Boiler Pressure Parts

Pressure parts include boiler tubing, headers, safety valves, power relief valves, and boiler trim. The furnace will be designed for ± 16 in. H2O (± 26 in. H2O yield).

1200.11310 Support Steel With Boiler

The boiler package includes hangers for top supporting unit and auxiliary equipment from the main girders, columns, beams, and supplementary steel, which are not included in the boiler package but are included as part of the building frame.

1200.11400 Boiler Casing

Outer casing for boiler, furnace, reheater, superheater and economizer, and air heater will be of 18 gage galvanized steel, except for the top of the boiler, and will be furnished on a delivered basis with the boiler.

1200.12100 Boiler Superheater and Reheater

The superheater and reheater will maintain steam temperatures at 1,000 F with a tolerance of 10 F over the range of 60 percent to full load. Included with the boiler are the necessary controls, valves, piping, and nozzles for attemperator water flow.

The reheater is designed for reheating to 1,000 F.

1200.13000 Boiler Economizer

The economizer, installed within the boiler setting, will be of the spiral fin type and have sufficient capacity to pass the entire quantity of feedwater required when operating at full load.

1200.14000 Boiler Setting and Insulation

Boiler setting, insulation, casing, and lagging are included with the boiler package. Insulation for flues, ducts, mechanical collectors, and air heaters will be covered with 18 gage ribbed

aluminum. Piping insulation will be covered with 0.020 in. thick aluminum.

1200.15000 Coal Feed and Ignition

Sixty 9,500 lb/hr spreader stokers operating in groups of three are supplied (12 per level) to feed coal to the main boiler beds.

Each stoker is equipped with a 1 hp, 1,800 rpm, 460 v, 3 phase, 60 Hz motor.

In addition, twelve 9,500 lb/hr spreader stokers operating in groups of threes are supplied to feed coal to the CBC when required. Each stoker is equipped with a 1 hp, 1,800 rpm, 460 v, 3 phase, 60 Hz motor.

Seal and cooling air for the stokers is supplied from the bed letdown cooler booster fans.

1200.16000 Limestone Feed Equipment

Twenty 7.75 tph rotary feeders are supplied (three per level) to feed limestone to the main boiler beds. Each feeder is equipped with a 1/2 hp, variable speed, 480 v, 3 phase, 60 Hz motor.

In addition, four 7.75 tph rotary feeders are supplied to deliver limestone to the CBC. Each feeder is equipped with a 1/2 hp variable speed, 480 v, 3 phase, 60 Hz motor.

1200.17100 Boiler Soot Blowers

The boiler will not be furnished with air soot blowers. Provision for the future addition of soot blowers is included.

1200.22200 Draft Ducts with Boiler

- a. Forced draft air ducts between air heaters and the boiler.
- b. Flue gas ducts between economizer outlet and air heaters.

1200.22920 Boiler Duct Insulation with Boiler

Insulation for ducts will be mineral fiber covered with 18 gage ribbed aluminum.

1200.26100 Air Heaters

Two bisector regenerative type air heaters will be included with the boiler. Included will be oil coolers, oil piping, main and auxiliary electric motor drives, air soot blowers, and water wash devices.

1200.26200 OTHER BOILER EQUIPMENT

Main Bed Mechanical Collectors

Six cyclone type dust collectors will be supplied in the ductwork between the economizer outlet and the regenerative air heater to collect the unburned fuel entrained in the air stream. The collectors are located outdoors and are designed for a collection efficiency of 95.5 percent at a cut size of 10 microns with a pressure drop of 3.3 in. H₂O.

CBC Mechanical Collectors

A cyclone type dust collector will be supplied in the ductwork between the CBC gas outlet and the regenerative air heater to reduce the dust loading on the air heater. The collector is located outdoors and is designed for a collection efficiency of 90 percent at a cut size of 10 microns with a pressure loss of 2.6 in. H₂O.

Bed Material Letdown Cooler System

Two half-capacity centrifugal type booster air fans, each with a rated capacity of 42,600 cfm at 126 F, will be furnished. The fans will be located in an enclosed fan room. Each fan will be driven by a 500 hp, 1,200 rpm, 4,160 v, 3 phase, 60 Hz motor.

All interconnecting ducts between the fans and the 24 letdown coolers (four per main bed level and four on the CBC) will be furnished. Twenty-four letdown coolers with associated control bypass dampers will be supplied.

Flow control from each cooler will be controlled by a 4.2 tph rotary feeder. Each rotary feeder, 24 total, will be powered by a 1/2 hp, variable speed, 460 v, 3 phase, 60 Hz motor.

Carbon Re-injection System

A pneumatic system including air lock devices, controls, blowers, piping, valves, etc., will be supplied to transport the high-carbon ash from the main bed mechanical dust collector and economizer hoppers to the carbon burn-up cell. Pneumatic air will be provided by three full-size blowers, each driven by a 120 hp, 1,800 rpm, 460 v, 3 phase, 60 Hz motor.

BLOCK NO. 7A - BALANCE OF BOILER PLANT EQUIPMENT**1200.22100 Draft Ducts Not With Boiler**

Air ductwork from the F.D. fans to the air heaters and gas ductwork from the air heaters to the fabric filter, from the fabric filter to the I.D. fans, from the I.D. fans to 18 in. outside of the stack will be supplied. Ductwork from 18 in. outside of the concrete stack to the liner will be furnished with the stack.

1200.22400 Air Preheaters

Combustion air is preheated after the forced draft fans by steam-air heating coils designed to maintain the minimum average cold end temperature at the regenerative air heaters.

1200.22910 Duct Insulation Not With Boiler

Gas ducts not supplied with the boiler will be insulated with prefabricated, factory assembled, mineral fiber, panels with 18 gage ribbed aluminum lagging. (This insulation will include the baghouse and hoppers.)

1200.23000 DRAFT FANS**1200.23100 Forced Draft Fans**

Two half-capacity centrifugal type forced draft fans, each with a rated capacity of 750,000 cfm at 96 F (0.0681 lb/cu ft), will be furnished. The fans will be located indoors in enclosed fan rooms. Each fan will be driven by a 12,000 hp, 1,200 rpm, 13,200 v motor.

The forced draft fans will be arranged to take outside air.

1200.23200 Induced Draft Fans

Two half-capacity centrifugal type induced draft fans, each with a rated capacity of 1,159,000 cfm at 288 F, will be furnished. The fans will be located outdoors. Each fan will be driven by a 8,000 hp, 1,200 rpm, 13,200 v motor.

1200.30000 FEEDWATER EQUIPMENT**1200.31000 Feedwater Heaters**

Seven stages of extraction feedwater heating will be furnished consisting of three low pressure stages, a deaerator, and three high pressure stages. All closed heaters are the horizontal shell and tube type. The feedwater heater insulation will be mineral fiber with aluminum lagging.

High Pressure Heaters

The 1st, 2nd, and 3rd point heaters will be located on the operating floor level and will have carbon steel tubes. High pressure heater drains will cascade in sequence to the deaerator under normal level conditions and to the condenser under extreme high level conditions. Tube side design pressure will be 4,500 psig. Feedwater bypasses will be provided for the high pressure heaters.

Deaerator (4th Point Heater)

The deaerator will be a tray type equipped with internal sprays and a vent condenser. The deaerator storage tank will have a 5 min capacity at full load. Design pressure will be 75 psig.

Low Pressure Heaters and Drain Coolers

The 5th point, 6th point, and split 7th point heaters will have stainless steel tubes and will be located in the condenser necks. Heater drains from the 5th point and from the 6th point heaters cascade to their respective separated drain coolers and then directly to the condenser. The 7th point heater drains flow through loop seals to the condenser. Tube side design pressure will be 600 psig.

The 5th, 6th, and 7th point heaters will be provided with a common bypass with motor-operated valves.

1200.32000 BOILER FEED PUMP

1200.32100 Boiler Feed Pump, Turbine Driven

One full-capacity, centrifugal barrel type boiler feed pump with shaft driven matched booster pump will be furnished. The booster pump will take suction from the deaerator and supply the boiler feed pump which, in turn, discharges to the high pressure heaters. The boiler feed pump with its matched booster pump will be driven by a steam turbine. The pump will have an approximate capacity of 9,550 gpm.

Start-up Boiler Feed Pump, Motor-Driven

One 53 percent start-up boiler feed pump will be furnished. The motor-driven start-up pump will take suction from the deaerator and supply water to the boiler through the high pressure heaters. The start-up pump will have an approximate capacity of 5,110 gpm.

1200.33000 BOILER CHEMICAL TREATMENT EQUIPMENT

1200.34000 Condensate Chemical Treatment Equipment

Facilities will be provided for feeding hydrazine to the condensate system. Each system will consist of a covered steel measuring tank and chemical feed pump. The chemical feed pumps

will have a nominal capacity of 10-30 gal per hr and discharge pressures suitable for the service. The tanks will be equipped with a level indicator and a low level switch.

1200.34900 SAMPLING SYSTEM

Sampling Panel

Sampling and analysis for chemical control in condensate, boiler feed, boiler water, and steam systems will be provided by a central sampling system which includes two freestanding central sampling panels located in the laboratory and sample area in the previous unit boiler room.

The sampling panel provided for terminal points of sampling lines will include two sections. It will provide for sample conditioning, pressure and flow control, and sample analysis, including continuous automatic analyzers for conductivity, hydrazine, pH, silica, phosphate, and dissolved oxygen. Sinks for collection of samples and necessary piping for returning samples to the system or dumping to waste will be installed.

Sampling System

Samples to be piped to the central sampling panel shall include the following:

- Condensate pump discharge
- Condensate at deaerator inlet
- Boiler feed pump suction
- Economizer inlet
- Superheater outlet
- Reheater inlet
- Reheater outlet
- Heater drains

Conductivity cells, recorders, and controllers will be provided, as required, for the condensate pump discharge, feedwater entering and leaving the deaerator, economizer inlet steam, and heater drains.

Cells for pH measurement, recorders, and controllers will be provided on the panel, as necessary, for the condensate pump discharge and economizer inlet.

One oxygen analyzer will be provided to monitor the condensate pump discharge and the deaerator outlet. A silica analyzer will be provided to monitor the economizer inlet, if required, and the boiler water. These analyzers will be located at the sample panel.

1200.38000 Blowdown and Blowoff Equipment

A blowoff tank, ASME Code Section VIII, A285C will be provided.

1200.60000 Piping and Covering

Piping, valves, fittings, and hangers will be provided for the following systems:

- Main Steam
- HP Turbine Bypass
- IP/LP Turbine Bypass
- Auxiliary Steam
- Hot Reheat
- Cold Reheat
- Extraction
- Condensate
- Boiler Feed Discharge
- Boiler Feed Suction
- Steam Line Blowout
- LP Feedwater Heater Drains
- Condensate Makeup and Draw-off
- Ignition Oil
- Service Water
- River Water
- Potable Water
- Makeup Water
- Drains to Condenser
- Drains to Boiler Blowoff Tank
- Boiler Safety Valves,
Vents, and Drains Beyond the First Valve
- Feedwater Heater Relief, Vents, and Drips
- Chemical Feed
- Nitrogen Blanketing
- Service Air
- Instrument Air
- CO2
- Halon
- Hydrogen
- Scanner Cooling Air
- Boiler Chemical Cleaning and Acid Wash
- Preboiler and Heater Shell Chemical
Cleaning and Flush

1200.65200 Nitrogen System

A nitrogen system will be provided for blanketing the carbon steel tube feedwater heaters and deaerator. The nitrogen source will be extended from the previous unit.

1200.67200 Piping - Electric Heat Tracing

Electric heat tracing will be provided on water lines and horizontal air lines subject to freezing.

The system will be complete with heating cable, contactor, thermostats, transformers, monitoring ammeters, and circuit breakers. Primary instrument tubing out of doors will be heat traced bundles.

1200.69000 Pipe Covering

All lines requiring insulation will be insulated with mineral fiber and aluminum jacketing.

1200.84000 Miscellaneous Equipment Foundations

The forced draft and induced draft fan foundations will be reinforced concrete mats supported on piles.

1200.85000 Miscellaneous Pumps and Tanks

One full-capacity bearing cooling water pump and heat exchanger will be furnished. The bearing cooling water pump will be motor-driven. The bearing cooling water system will be cross-tied to the previous unit.

The bearing cooling water system will serve the fan bearings and oil coolers, condensate pump bearings, boiler feed pump and turbine oil coolers, furnace doors, air heater oil coolers, and other miscellaneous coolers.

Existing tanks for fire protection water, service water, condensate, acid, caustic, and ignition oil are adequate to serve this unit.

1200.86000 Hoist and Monorails

Facilities will be provided to handle the forced and primary air fan rotors and electric motors, removable sections of the combustion air preheaters, boiler room hoist, ash sluice pumps, service water pumps, and similar pieces of equipment.

Air heater baskets and pulverizer dismantling will have motorized hoists and trolley beams.

A trolley beam and hoist system will be provided by the precipitator manufacturer to remove T-R sets from their roof-mounted locations and lower the T-R sets to grade elevation.

A trolley beam and hoist system will be provided for the SO₂ removal system.

1200.89000 Painting Equipment and Piping

Steel surfaces will be shop cleaned and shop painted with a prime and finish coat. No finish coat will be provided unless required by safety code. Touch-up painting will be done in the field. Items not suitable for shop cleaning and shop painting will be cleaned and painted in the field.

1200.90000 PRELIMINARY OPERATIONS AND TESTS**1200.91000 Preliminary Operations**

Provisions for preliminary operation and start-up, including blowing of the steam leads, will be included.

1200.92000 Preboiler Cycle and Boiler Chemical Cleaning

Temporary provisions will be made to alkaline clean the feedwater and condensate system.

Provisions for preoperational chemical cleaning of the boiler tubes and economizer, including the alkaline boil-out, acid cleaning, acid neutralization, all flushes, and surface passivation, will be included.

BLOCK NO. 7B - ASH HANDLING EQUIPMENT1200.50000 Ash Handling Equipment

The design of the ash systems will be based upon a 15 percent ash coal with 60 percent of the ash to the mechanical dust collector inlets and 60 percent of the ash to the bottom of the boiler.

1200.51000 Spent Bed Letdown Holding Tanks

A 60 ft long by 16 ft wide by 8 ft high (straight side) dry holding tank with six hoppers each 6 ft high will be provided for collection of the main bed letdown. A 60 ft long by 10 ft wide by 3 ft high dry holding tank with three hoppers each 6 ft high will be provided for collection of the carbon burn-up cell bed letdown. The tanks will be made of steel and be provided with observation windows, internal illumination, and two air-operated air lock devices on each hopper.

1200.52000 Spent Bed Material Disposal System

A dry bed letdown material removal system will be provided complete with abrasion-resistant piping, fittings, and controls for transporting bed material from the holding tanks to two storage silos located in the ash waste treatment area. The bed material is then removed from the silo by trucks and transported to the on-site solid waste disposal area.

Three half-size bed letdown blowers will be provided to supply pressurized conveyor air to transport the bed material to the silos. Each blower will be driven by a 250 hp, 1,800 rpm, 460 v, 3 phase, 60 Hz motor.

The bed letdown removal system will be controlled from a common board located near the bed letdown holding tanks. Control may be either automatic or manual. Local manual control panels will be located at the equipment. Alarms will be provided to indicate malfunctions and/or local problems.

1200.54000 Fly Ash Handling System

The fly ash handling system will be designed to remove ash from the carbon burn-up cell mechanical dust collector hoppers fabric filter hoppers, regenerative air preheater (APH) hoppers, and stack hoppers, and convey the ash by air using two vacuum-pressure systems to a pair of silos located in the ash waste treatment area. One full-size vacuum-pressure system will serve the mechanical dust collector, AHP, and stack hoppers while the other full-size system will serve the fabric filter hoppers. Each vacuum-pressure system will have the capability to convey the entire fly ash flow, should one be inoperable.

Two full-size vacuum-producers, each driven by a 60 hp, 1,800 rpm, 460 v, 3 phase, 60 Hz motor and two full-size pressure-producers, each driven by a 250 hp, 1,800 rpm, 460 v,

3 phase, 60 Hz motor will provide the conveying air for the fabric filter fly ash removal system.

Two full-size vacuum producers, each driven by a 60 hp, 1,800 rpm, 460 v, 3 phase, 60 Hz motor and two full-size pressure-producers, each driven by a 250 hp, 1,800 rpm, 460 v, 3 phase, 60 Hz motor will provide the conveying air for the mechanical dust collector, preheater, and stack fly ash removal system.

Each pair of bed letdown storage silos and fly ash storage silos will use air assist fluidizing air when unloading. Fluidizing air will be provided to each pair of silos by two full-size blowers, each driven by a 30 hp, 1,800 rpm, 460 v, 3 phase, 60 Hz motor.

Air-operated slide gates will control the discharge of individual collection hoppers.

Pipe, valves, fittings, primary and secondary collectors, and control gates will be furnished to make a complete system.

A fly ash panel located near the bed letdown panel with a graphic display of the fly ash handling system will be provided for each system. Each panel will include pushbuttons with indicating lights required to operate and monitor the fly ash handling system. Each panel will include a pressure and vacuum recorder.

Control room annunciators and monitoring will be provided.

Spent main bed material will be used to maintain bed level in the carbon burn-up cell. Material will be conveyed pneumatically via a pair of main bed holding tank air-lock devices to the CBC by a blower driven by a 40 hp, 1,800 rpm, 460 v, 3 phase, 60 Hz motor.

BLOCK NO. 8 - FUEL AND LIMESTONE HANDLING AND STORAGE EQUIPMENTBLOCK NO. 8A - COAL AND LIMESTONE HANDLING1241.20000 Conveying Equipment - Coal and Limestone

A fixed tripper will be installed on the existing 54 in. conveyors to and from the existing stacker reclaimer.

Four (two in series) new 54 in., 1,800 tph conveyors will be installed between the fixed tripper and the new 32-50 ton crusher house surge hopper.

Two new 900 tph 100 percent-1 in. coal crushers and associated screens, ductwork, chutes, magnets, grizzlies, etc., will be supplied. Each crusher is equipped with a 450 hp, 4,000 v 3 phase, 60 Hz drive motor.

Two new 900 tph 100 percent- 3/16 in. limestone crushers and associated screens, ductwork, chutes, magnets, grizzlies, etc., will be supplied. Each crusher is equipped with a 1,000 hp 4,000 v, 3 phase, 60 Hz drive motor.

Four (two in series) new 48 in., 1,200 tph conveyors will be supplied to transport the coal from any crusher to the in-plant tripper conveyors.

Two new 48 in., 1,200 tph tripper conveyors will be installed to fill the in-plant coal and limestone bunkers.

1241.41000 Coal and Limestone BunkersCoal Bunkers

Ten hours of in-plant coal storage (full load on performance coal) will be supplied as follows:

One - 30 ft deep by 60 ft wide by 55 ft straight side four-hopper coal bunkers.

Two - 30 ft deep by 15 ft wide by 17 ft straight side single-hopper coal bunkers.

Limestone Bunkers

Ten hours of in-plant limestone storage will be supplied as follows:

Two - 30 ft deep x 22.5 ft wide by 32 ft straight side twelve-hopper limestone bunkers.

Bunkers and hoppers will be made of A-242 steel with stainless steel at the bottom portion of the hoppers.

1241.49000 Bunker Gates and Accessories

1. Twenty-four vibrators located at each bunker hopper outlet
2. Twenty-four vibrators located at each downspout
3. Twenty-four chain operated slide gate at the outlet of each hopper.
4. Ninety-six chain operated slide gate at the inlet to each coal spreader stoker and limestone rotary feeder.
5. Forty-six flow detectors, one in each limestone line and one in the coal feed to each chute.
6. Twenty spreader stoker coal feed chutes for the main bed (one chute for every three stokers).
7. Two spreader stoker feed chutes for the CBC (one chute for every six stokers).
8. Three 36 in., 50 tph belt conveyors to transport coal from a single hopper coal bunker to a CBC coal feed chute.
9. All coal and limestone piping between the bunker hoppers and the stoker feeder, and rotary feeder, respectively.

1241.51000 Coal Handling Service Facilities Building Service**Dust Collection**

The dust collection system of the previous unit will be extended to serve this unit.

Ventilation

In-plant bunkers will be provided with ventilation.

Fire Protection

The gallery above the coal bunkers will be protected by water hose stations. Heat sensors, to detect abnormally high temperature, will also be installed in the gallery to provide alarm both locally and in the control room.

1241.52000 Coal Handling Service Facilities - Electrical

Lighting will be provided in galleries across the front of the boiler and above the in-plant silos.

1241.72000 Coal Storage and Reclaiming Equipment - R.R. Track

The stacker-reclaimer track will be extended for this unit.

1241.95800 Conveyor Gallery

A conveyor gallery will be furnished across the front of the boiler to join the previous unit, including superstructure, siding, roofing, and floor.

BLOCK NO. 8B - FUEL OIL EQUIPMENT (INCLUDED IN BLOCK 7A COSTS)1242.00000 FUEL OIL EQUIPMENT AND STRUCTURES1242.20000 Fuel Oil - PumpsIgnition Oil Pumps

Two half-capacity ignition oil pumps will be furnished to supply light oil to the boiler ignitors. The pumps will be located in the boiler area. The pumps will be arranged to take suction from the existing system.

BLOCK NO. 8C - FUEL GAS EQUIPMENT

There is no plan to use gas for main or ignition fuel. There is, therefore, no provision included for the combustion of fuel.

BLOCK NO. 8D - AUXILIARY FUEL STRUCTURES

In addition, a new 64 ft-6 in. long x 39 ft-6 in. wide x 93 ft high crusher house is included, as well as a new 24 ft wide x 8 ft high x 1,200 ft long conveyor gallery.

BLOCK NO. 9 - STACK**1200.81000 Stack**

One 616 ft high reinforced concrete shell designed to be freestanding against wind loads will be provided. Seismic design will be incorporated.

A carbon steel liner will be provided.

Test connections will be provided as required for monitoring the stack gases.

A ladder located in the annular space between the concrete shell and liner will be provided from the ground to the top of the stack. Galvanized steel grating platforms will be provided as required.

1200.81400 Stack Lighting

High intensity strobe lights will be provided on the outside of the concrete shell.

Internal lighting will be provided for the ladder and for the platforms within the concrete shell.

1200.82000 Stack Foundation

The stack will have a reinforced concrete foundation supported on piles.

BLOCK NO. 10 - FABRIC FILTER (BAGHOUSE)1200.25200 Fabric Filter (Baghouse)

One fabric filter will be furnished in the flue gas path between the flue gas outlet of the regenerative air heater and the I.D. fans inlet. The fabric filter will be located outdoors in four main box sections, two upper and two lower. The fabric filter will be designed to handle 2,318,000 cfm of gas at 288 F with a gross air-to-cloth ratio of 2.73 and meet the particulate emission limit of 0.1 lb/million Btu.

Insulation

The precipitator insulation will be prefabricated mineral fiber panel with aluminum lagging.

Foundations and Superstructure

The foundations and superstructure for the precipitator will be constructed similar to the foundations and superstructure of the main powerhouse.

BLOCK NO. 11 - FLUE GAS DESULFURIZATION

No flue gas desulfurization is required for this plant. There is no provision included for this equipment.

BLOCK NO. 12 - TURBINE GENERATOR EQUIPMENT BY VENDOR1400.10000 Turbine Generator Unit1400.11000 Turbine Generator

The turbine will be a tandem compound, single reheat unit, with one single flow HP-IP element and two double flow LP elements with 30 in. last stage blades operating at 3,600 rpm. Generation is 578,320 kw at out steam conditions of 2,520 psig and 1,000 F at the throttle, 1,000 F single reheat exhausting at 3.9 in. Hg abs average, with full extraction for all seven stages of feedwater heating with 0.04 percent makeup and extraction steam for a full capacity turbine-driven boiler feed pump. Nameplate rating of the turbine generator will be 539,515 kw.

The turbine generator will be supplied with electrohydraulic control system and lube oil system.

The generator will be a hydrogen-cooled, 3,600 rpm, 22 kv, 3 phase, 60 Hz unit rated at 647,325 kva at 60 psig hydrogen pressure, 0.9 PF, 0.58 short circuit ratio. An Alterrex type excitation system will be furnished.

Also included with the turbine generator equipment will be a gland steam sealing system and shell and tube gland exhaust condenser with two motor-driven gland steam exhausters, supervisory instrumentation, hydrogen coolers, and other accessories necessary for a complete installation.

1400.13000 Turbine Generator - Cooling System

Hydrogen circulated through generator coolers will be used to cool the generator rotor. Hydrogen seal oil coolers will be included with the turbine generator.

1400.14000 Turbine Generator - Oil Coolers

The turbine lube oil system consists primarily of a main oil reservoir on which will be mounted two a-c auxiliary oil pumps and a d-c emergency oil pump. Also in the main oil reservoir are two full-capacity tube type oil coolers. A shaft driven main oil pump is furnished as part of the front standard. Interconnecting piping, fittings, and valves are included with the turbine.

An initial oil charge will not be furnished with the turbine.

BLOCK NO. 13 - BALANCE OF TURBINE PLANT EQUIPMENT
(EXCLUDING CONDENSING AND CIRCULATING WATER EQUIPMENT)

1400.15000 Turbine Generator - Lubricating Oil Conditioning Equipment

A filter type lube oil conditioner will be furnished including a recirculating pump and motor to continuously circulate a portion of the oil from the main oil reservoir through the filter and back to the reservoir. Also a transfer pump will be furnished to transfer oil to and from "Dirty" and "Clean" oil tanks.

1400.16000 Turbine Generator - Purge System

CO2 for generator purging will be supplied from the previous unit which is equipped with an adequate high pressure system.

1400.61000 Turbine Piping and Valves

The turbine manufacturer will furnish all pipe and fittings and all necessary valves and accessories, as required, for all integral lines involved in the operation, cooling, purging, draining, venting, sampling, sealing, and lubrication of the turbine generator and auxiliary equipment furnished. All piping, fittings, and valves are to be furnished in accordance with the requirements of ANSI code for pressure piping B31.1.0.

In addition, pipes, valves, fittings, and hangers for the following systems will be provided:

- Turbine Generator Lubricating Oil
- Component Cooling Water
- Condenser Air Removal
- Gland Sealing Steam
- Miscellaneous Drains

1400.61900 Hydrogen System

Hydrogen for generator cooling shall be extended from Unit No. 3.

1400.67000 Heat Tracing

Heat tracing will be provided for certain piping and exposed parts and will be electric.

1400.69000 Pipe Insulation

The turbine manufacturer will furnish all thermal insulation and appearance lagging required to completely insulate and finish all equipment and piping provided.

Insulation will be applied where necessary for personnel protection such that the surface temperature at any point at any time does not exceed 140 F when the ambient is 100 F.

Preformed segmented pipe insulation, mineral fiber, will be provided for all steam jacketing.

Flat, brushed aluminum jacketing will be used for all hot piping, valves, and fittings, and will be sealed to prevent the absorption of oil into the insulation.

1400.81000 Turbine Generator Foundation

The turbine generator will be supported on a reinforced concrete rigid frame pedestal resting on a reinforced concrete mat supported on piles.

1400.82000 Turbine Generator Vibration Joint

A vibration joint will be laid around the periphery of the pedestal at the operating floor.

1400.84000 Miscellaneous Equipment Foundations

Reinforced concrete foundations supported on piles will be provided for the miscellaneous equipment.

All support steel and framing, platforms, walkways, and stairs will be furnished as necessary to permit access to equipment.

1400.85000 Miscellaneous Pumps and Tanks

Two full-capacity equipment cooling water pumps will be furnished. The equipment cooling water pumps will be motor-driven. The equipment cooling water system will be cross-tied to the previous unit.

The equipment cooling water system will serve the turbine generator hydrogen, lube oil, electrohydraulic fluid, stator cooling, Alterrex, generator leads, vacuum pump seal water, and bearing cooling water heat exchangers.

One carbon steel "Clean" oil tank and one carbon steel "Dirty" oil tank will be furnished.

1400.86000 Monorails

Monorails will be provided for equipment such as pumps and motors.

1400.89000 Painting Equipment and Piping

Steel surfaces will be shop cleaned and shop painted with a prime and finish coat. Touch-up painting will be done in the field. Items not suitable for shop cleaning and shop painting will be cleaned and painted in the field. Insulated and jacketed equipment and piping will not be painted.

1400.90000 Preliminary Operation and Test

The turbine manufacturer will provide technical direction to the Purchaser and Engineers regarding methods and procedures for the installation and start-up of this specified equipment.

BLOCK NO. 14A - SCREENWELL STRUCTURE

As the cooling tower basin will be extended to permit the circulating water pumps to return water through the circulating water system, no provision is included for a screenwell structure.

BLOCK NO. 14B - CONDENSING SYSTEM1400.20000 CONDENSING SYSTEM1400.21000 Condenser

The turbine exhaust condenser will be a transverse, dual pressure, twin shell, single pass unit with 309,625 sq ft of 7/8 in. diam, 22 gage, 48 ft, 304 stainless steel tubes. Provisions will be made for mounting four low pressure heater shells in the condenser necks. The water box design pressure will be 75 psig,

1400.22000 Condenser-Air Removal System

Noncondensibles will be extracted from the condenser by two full capacity mechanical air removal pumps.

1400.28100 Circulating Water Pumps

Circulating water will be pumped from the cooling tower basin to the condenser by two, half-capacity, vertical, circulating water pumps each rated at 99,200 gpm and driven by a 3,000 hp, 400 rpm, 4,000 v motor.

1400.28200 Condensate Pumps

Two, five-eighths capacity vertical condensate pumps with motors will be furnished. Each pump will have a capacity of approximately 4,700 gpm with a total head of 1,040 ft and be driven by a 1,500 hp, 1,200 rpm, 4,000 v motor. There will be no provision for a third condensate pump.

BLOCK NO. 14C - INTAKE/DISCHARGE SYSTEM**1400.30000 Intake and Discharge System**

Cooling water will be pumped from the cooling tower basin through the condenser and then to the discharge line with approximately 1,500 linear ft of 7 ft diam pipe. Double fixed screens will be provided instead of traveling screens.

1400.37000 Chlorination and Inhibitor Feed Systems

The liquid chlorine evaporator, chlorine solution feed equipment, and necessary controls provided with the previous unit will be used to treat the circulating water. An inhibitor feed system consisting of a 12,500 gal sulfuric acid storage tank, a 100 gal sulfuric acid feed tank, and two 1 gpm acid metering pumps will be provided to treat the circulating water in the cooling tower.

BLOCK NO. 14D - COOLING PONDS/RESERVOIRS

Since the heat rejection system utilizes cooling towers, no provision is included for heat rejection system cooling ponds or reservoirs.

BLOCK NO. 14E - COOLING TOWER1400.34000 Cooling Tower Equipment

A mechanical draft cooling tower will be provided to reject the heat from the condenser and component cooling water systems. Twelve cells, each with motor-driven fan, rated at 50/200 hp, reversible, will be designed to cool 198,400 gpm of water from 119.5 F to 91.8 F with a wet bulb temperature of 79 F (air density equal to .0705 lb/cu ft).

A reinforced concrete foundation supported on soil will be provided.

1400.34800 Makeup Water Pump

A vertical, 9,000 gpm makeup pump will be installed in the existing pump house. The pump will be driven by a 350 hp, 900 rpm, 4,000 v motor. The existing makeup line from the pump house to the existing unit cooling tower will be extended to serve the tower of this unit.

BLOCK NO. 15 - WATER TREATMENT SYSTEM**1200.34000 WATER TREATING EQUIPMENT**

Makeup water treatment will be extended from the previous unit to serve this unit.

1200.34320 Condensate Polisher

A full flow, Powdex condensate polishing system will be provided. The polisher will consist of two half-capacity vessels complete with holding and precoat pumps, slurry mixing tank with agitator, freestanding control panel with instrumentation, control valves, and piping.

BLOCK NO. 16 - WASTE TREATMENT SYSTEMEquipment Washing and Cleaning Treatment System

Washing and cleaning wastes will be collected and pumped to existing facilities.

Sewage Treatment System

Sewage will be pumped to existing facilities.

Oil/Water Separation System

Only wastes will be connected to existing oil/water separator facilities.

BLOCK NO. 17 ACCESSORY ELECTRICAL EQUIPMENT**1500.00000 ACCESSORY ELECTRICAL EQUIPMENT****1500.11100 Electrical Equipment Footings**

Reinforced concrete foundations supported on piles will be provided for the main step-up, and unit, reserve and auxiliary service transformers, with facilities to collect spilled oil.

Concrete block partitions will be provided between the transformers.

1500.11400 Miscellaneous Supports

Miscellaneous supports will be required for the outdoor portion of the isolated phase bus duct generator leads and the 13.8 kv and 4.16 kv station service leads.

1500.11500 Electrical Structures

Duct lines will consist of 4 in. plastic conduit encased in reinforced concrete ducts and will extend underground to site locations as required. Where roadways are crossed, or where encased in concrete slabs, steel conduits will be used in duct lines. Manholes will be provided as required.

1500.12220 Generator Leads

Isolated phase bus ducts will be provided for carrying the output of the generator to the main transformer. The buses will be of the continuous, all welded type, forced cooled for use at 22 kv. The unit station service transformer will be fed from these buses by self-cooled isolated phase bus taps. The bus assemblies will include potential transformers and forced cooling units.

1500.12300 Power Cable and Accessories

Cables for 4,160 v and 13.8 kv service will be aluminum or copper, nonshielded or shielded, as required, with an overall jacket. Constructions will be single, triplexed, or three-conductor flame-retardant, as required.

Nonsegregated phase bus duct rated 15 kv, 2,000 amp will be used between the unit and reserve station service transformers and the 13.8 kv switchgear.

Nonsegregated phase bus duct rated 5 kv, 3,000 amp will be used between the auxiliary station service transformers and the 4,160 v switchgear.

Cables for 480 v service will be flame retardant triplexed or three-conductor copper or aluminum, as required.

1500.12400 Control Wiring

Cable for control wiring will be single and multi-conductor copper stranded with fire-resistant 90 C thermosetting insulation over each conductor and with an overall thermosetting jacket on multi-conductor cables.

Instrument cables will be twisted pair and multi-conductor copper with fire resistant thermosetting insulation, shielded, with thermosetting jacket overall.

Thermocouple extension wire will be twisted pair or multi-conductor of the chromel constantan type with fire-resistant thermosetting insulation, shielded or unshielded as required, with thermosetting jacket overall.

1500.12500 Grounding System

The grounding system will consist of 500 mcm and No. 4/0 bare copper cable with 3/4 in. by 10 ft long ground rods and will be connected to the previous unit grid.

All equipment and/or structural steel will be connected to the main ground grid as required so that the steel will essentially extend the ground system.

All equipment will be connected to the grid or building steel as required, using 4/0 AWG or 2 AWG bare copper cables.

1500.12600 Cathodic Protection

An induced current cathodic protection system will be designed and installed for protection of pilings, buried pipelines, condensing facilities, and other buried and submerged structures as deemed necessary.

1500.13200 Conduit - Steel

Steel rigid conduits will be used in general for all conduits imbedded in concrete, including duct lines under heavily trafficked areas. Conduit in concrete will be used only when a cable-in-tray installation is impractical or more expensive.

1500.13300 Conduit-Aluminum

Rigid aluminum conduit will be used in all exposed areas both indoor and outdoor.

1500.13800 Cable Trays

Cable trays will be ladder type, aluminum for all applications. Fire stops will be provided where cable trays penetrate walls or floors.

1500.21100 Transformers - Station Service

One three winding unit station service transformer will be provided. The transformer will be rated 70 MVA, FOA, 22-13.8/13.8 kv, 65 C rise, 3 phase, oil immersed, with no load taps. Each secondary will be rated 35 MVA, FOA.

One three winding reserve station service transformer rated 42/70 MVA, OA/FOA, 13.8-13.8/13.8 kv, 65 C rise, 3 phase, oil immersed, with no load taps, will be provided. Each secondary winding will be rated 21/35 MVA, OA/FOA.

Two auxiliary station service transformers will be provided, each rated 16 MVA, OA, 13.8-4.16 kv, 65 C rise, 3 phase, oil immersed. The auxiliary station service transformers will be equipped with load tap changers.

Transformer impedances shall be as required for short circuit and motor starting considerations.

1500.21300 Lighting and Secondary Power Transformers

Lighting and secondary power transformers, as required, will be of the single phase or 3 phase, dry type, with taps, ranging in capacity from 1 kva to 30 kva.

1500.23000 Surge and Protection Equipment

The generator neutral will be connected through neutral grounding equipment consisting of a dry type distribution transformer and secondary loaded resistor. These will be metal-enclosed and located near the generator leads bus ducts.

1500.25220 Station Service Switchgear

The 13.8 kv switchgear will consist of two buses, with a total of four, 2,000 amp, and eight, 1,200 amp, 750 MVA, metal clad air circuit breakers. Each bus will be fed from a separate secondary winding of the unit station service transformer. Each bus will also have the capability of being fed from the reserve station service transformer for start-up, or in the event that the normal source is out of service for any reason. The 4,160 v switchgear will consist of two buses, with a total of three, 3,000 amp, 350 MVA Class, nineteen, 1,200 amp, 250 MVA Class metal-clad air circuit breakers. Each bus will be fed from the 13.8 kv switchgear through an auxiliary station service transformer. A bus tie breaker will allow both buses to be fed through one transformer for emergency operation at reduced load.

1500.25300 Unit Substations - 480 V

Eight double ended 480 v unit substations with drawout type thermal-magnetic trip air circuit breakers will be provided. These substations will have various combinations of 1,600 amp and 600 amp breakers as required. Each substation includes two

4,160-480 v, 1,000/1,333 kva, AA/FA dry type transformers, close coupled to the switchgear. These substations are for unit auxiliaries in the turbine, fluidized bed, baghouse, and cooling tower areas. One vertical section of spare compartments for future breakers will be provided per transformer. Additional 480 v unit substations will be provided as a part of the SO₂ removal system.

1500.25600 Motor Control Centers

Motor control centers will be furnished and located throughout the plant and auxiliary buildings. Approximately 35 will be required.

Each motor control center will include molded case air circuit breakers and draw-out type molded case circuit breaker combination starters. The main bus will be rated 600 or 800 amp, 600 v, and the vertical buses will be rated 300 amp, 600 v. The buses will be braced to withstand a short circuit current of 22,000 amp symmetrical.

1500.45200 Batteries and Battery Chargers

A 125 v d-c, 59 cell lead-calcium battery, rated approximately 1,800 amp/hr at the 8 hr discharge rate, will be provided to supply power to UPS inverter, emergency bearing oil pumps, emergency seal oil pumps, emergency d-c and lighting loads, controls, indicating lights, etc. A battery output voltmeter, ammeter, shunt, and ground detector will be provided.

A regulated solid state battery charger will be furnished to recharge the battery within 12 hr while supplying the normal d-c station load. Cross-connections will be provided to enable the spare battery charger for the previous unit to also be used as a spare for this unit.

The battery and battery charger will be connected to the 125 v d-c distribution bus. The d-c system will be ungrounded.

The battery system will have sufficient capacity to permit orderly shutdown of the unit with no other power available.

One 20 kva single phase uninterruptible power supply will be provided for continuous power requirements to vital a-c systems such as data logger, recorders, boiler controls, and burner controls.

1500.48000 Power Transformer Fire Protection

The unit, reserve, and auxiliary station service transformers will be protected by automatic deluge water spray systems. Electric dual sensor detection will be provided with local alarms and alarm annunciation in the control room. Remote-manual operation of deluge valves will be from the control room.

1500.70000 INSTRUMENTS AND CONTROLS

All principal controls for the station that are essential for the operation of the unit and require manipulation, adjustment, or monitoring during normal operation will be located in the main control room.

The main control room will be located on the operating floor.

The control room will contain the main control board, the fire and ventilation control panel, coal handling system panel, and auxiliary control panel. In addition, it will contain the logging typewriter, alarm typewriter, utility typewriter, events recorder printer, and the operator's console for the unit data logger operation.

Adjoining the control room will be an electronic equipment room. This room will contain all the electronic equipment which requires air conditioning or calibration in conjunction with the various monitoring devices located in the control room. This includes the data logger cabinets, turbine electrohydraulic control cubicles, analog control cabinets, burner control cabinets, events recorder and annunciator cabinets, uninterruptible power supply, control power panel boards, and relay panels.

1500.71000 Main Control Board

The system shall include combination bench and vertical type control board in a central control room for this and the previous units. The main control board arrangement of this unit will be similar to that of the previous unit. The board shall contain instruments and controls for the major control systems, together with generator and station service power metering and miscellaneous controls.

Included in the front vertical section shall be the turbine supervisory instrumentation, monitoring instrumentation for the fluidized bed steam generator, illuminated annunciator units mounted near the top of the panel, and turbine water induction protection controls.

The rear vertical section shall include protective relays for the generator and transformers, metering and totalizing equipment, and a d-c distribution panel.

The benchboard section shall include the turbine electrohydraulic controls and controls for major auxiliary equipment, including the bed segment management system and coordinated boiler, and turbine control system.

Miniaturized control recording/indicating devices will be used, wherever possible, to assure maximum reliability, and the location of the devices on the boards shall allow the operator to view the alarms and major variables. The boards shall be

designed for operation by a standing operator. Voltages over 125 v and high pressure steam, water, air, or gas will not be used in the control room.

Auxiliary Control Panels

Located in the main control room there will also be auxiliary control panels which shall include instruments and controls and comprise various sections of the miscellaneous control board. These panels shall include:

1. Fly Ash and Bed Letdown Handling System Monitoring Panel
2. Cooling Tower Control Panel
3. Fire Protection System Panel
4. HVAC Control Panel

An auxiliary system electrical board will be adjacent to the miscellaneous control board and shall be complete with mimic bus and bench controls.

Miscellaneous Panels

Transmitter and instrument racks shall be located about the plant for mounting of instrumentation for associated equipment not located in the main control room. In addition, there will be located in the plant the following control panels and cabinets:

- a. Generator Hydrogen and Seal Oil Panel
- b. Bed Letdown and Fly Ash Handling Control Panels
- c. Chemical Feed Control Panel
- d. Water and Steam Sample Panel
- e. HVAC Panel

1500.72000 Instrumentation and Controls

Major control systems shall be electronic and part of the centralized controls in the main control room. Local control systems will be pneumatic and rack mounted where possible. Electric drives will be used where suitable, taking economics into consideration.

A plant manual containing loop, logic, and elementary electrical diagrams, instrument list and data sheets, flow diagrams, heat balances, and computer information will be provided for personnel training.

INSTRUMENTS AND CONTROLS - MAJOR SYSTEMS

Coordinated Boiler Turbine Control System

A coordinated control system utilizing solid state electronic control components will be provided for boiler-turbine control and miscellaneous systems. Transfers to and from the automatic and manual control modes will be bumpless. The boiler-turbine

control system will place demands on turbine and boiler simultaneously from either a load dispatch system or operator setting.

The coordinated boiler-turbine controls will be designed to maintain automatically a constant load on the unit by varying the boiler controls in parallel with the turbine controls. The system will also be capable of operating in the boiler following control mode by means of a panel mounted selector switch. Runbacks will be provided to limit the boiler and turbine load in the event of unbalance in the various systems, such as loss of one F.D. fan, loss of one I.D. fan, etc.

Steam Temperature Control

The system will provide full automatic or manual control of superheat and reheat temperature. Reheat temperature will be primarily controlled by bypass dampers, spray attemperation, and/or adjusting firing rate in the reheater bed. Superheat temperature will be maintained by spray attemperation and/or adjusting superheater bed firing rate.

Deaerator Level Control

A three-element level control system will be provided. The control system will operate two control valves sequentially. One valve will modulate to control the deaerator level up to approximately 50 percent load. The second valve will modulate to control deaerator level from approximately 50 percent load to maximum load.

Solid state electronic controls will be provided with remote manual stations located on the main control board. Final operators will be pneumatic with electropneumatic converters.

Feedwater Control

A feedwater control system will be provided to maintain a nearly constant storage of fluid in the boiler. The boiler demand modified by feedwater flow error is used to establish a demand for feedwater flow. A minimum feedwater flow of 35 percent is maintained at all times to protect the tubes in the bed from overheating. Beyond 35 percent load the feedwater flow is established directly from the boiler demand.

Combustion Control

Combustion controls will be provided to maintain proper fuel and combustion air flow to generate the steam required while maintaining safe conditions. Coal feed and airflow will be regulated in response to Mw load change. The bed temperature will be used to trim fuel flow demand so that the bed temperature can be maintained within designed limits. Airflow is controlled to provide constant bed expansion. Airflow will be trimmed to

maintain proper excess oxygen. Oxygen will be measured for each of the five beds.

Solid state electronic controls will be provided with remote manual stations located on the main control board.

Bed Segment Control

A solid state bed segment control system will be provided to safely light-off the steam generator and to provide sequential operation of bed segments as a function of load. Purging will be incorporated as a precautionary measure. A preprogrammed logic for determining the optimum number of bed segments required and their sequence of firing will be included as a part of the control scheme to achieve the most efficient boiler operation.

The controls for operating the system will be mounted on the main control board. The control subpanel indicators and indicating lights will track the steps during sequential bed segment loading.

Carbon Burnup Cell Controls

CBC will be controlled to maintain a constant bed temperature. The fly ash (char) feed to CBC as available from the main beds is continuous but not controlled. The temperature in CBC will be controlled by modulating the bed level and/or coal feed. Bed level will be measured by means of differential pressure transmitter. Cell excess oxygen is monitored to maintain oxygen within limits.

Solid state electronic controls will be provided with remote manual stations located on the main control board.

Bed Material Letdown Control

A control system will be provided to regulate bed material inventory by control of limestone feed rate and material dump feeder speed. Limestone feed rate will be primarily adjusted from the coal feed via a ratio controller based on coal sample analysis.

Solid state electronic controls will be provided with remote manual stations located on the main control board.

Combustion Air Preheater Control System

Steam to the combustion air preheaters will be supplied from a turbine extraction stage with automatic backup of steam at reduced pressure from the auxiliary steam system. Average cold-end air preheater temperature will be used as an index of steam flow requirements. Condensed steam from the coil heaters will pass to the main condenser via two drain receivers and receiver level control valves.

Solid state electronic controls will be provided with remote manual stations located on the main control board. Final operators will be pneumatic with electropneumatic converters.

Air Heater Cold-End Temperature Control

Two automatic control systems will be provided, one for each air heater. The cold-end temperature for each system will be obtained from six chromel constantan thermocouples located in the air duct to the air heater and in the flue gas duct from the air heater. The temperature will be averaged and compared to a set point.

Solid state electronic controls will be provided with remote manual stations located on the main control board.

Final operators will be pneumatic with electropneumatic converters.

Furnace Draft Control

A complete draft control system will be provided to maintain a constant pressure in the freeboard area directly above the bed at steady state conditions and to minimize deviations during transient disturbances. The system will maintain furnace draft consistent with the steam generator design by modulating the inlet louvers of the induced draft fans as required.

Draft will be measured at the tap in each cell as recommended by the steam generator manufacturer.

Solid state electronic controls will be provided with remote manual stations located on the main control board.

Final drive units will be pneumatic with electropneumatic converters.

Main Boiler Feed Pump Recirculation Control

A recirculation control system will be provided to maintain minimum flow through the main boiler feed pumps whenever the feedwater flow to the boiler is below that required by the boiler feed pumps for protection of the pump internals.

A primary flow metering device (orifice plate) at the suction side of the pumps will provide for a measurement of flow. The flow measurement will be utilized to operate a modulating recirculation control system.

The control system will operate the recirculation control valve.

An override OPEN-AUTO switch will be provided on the main control board for remote operation of this system.

All controls will be mounted locally and will be pneumatically operated.

The final operator will be pneumatically actuated and open on air failure or power failure.

Condensate Recirculation Control

A recirculation control system will be provided to maintain a specified minimum flow through the condensate pumps and the gland steam condenser. The condensate recirculation will be based on the minimum flow requirement of the condensate pumps or the gland steam condenser, whichever is higher.

A primary flow metering device (orifice plate) at the inlet of the gland steam condenser will provide for a measurement of flow. The flow measurement will be utilized to modulate the recirculation valve as required to maintain the flow requirements.

The controls for this system will be mounted locally and will be pneumatically operated.

The condensate recirculation valve will be pneumatically actuated and will open on air failure.

Turbine Lube Oil Temperature Control

A control system will be provided to maintain the temperature of the lube oil leaving the lube oil coolers at a preselected value recommended by the turbine manufacturer. Two completely separate control systems will be furnished, one for the main turbine and one for the boiler feed pump turbine.

The systems will control the lube oil temperature leaving the respective coolers by modulating pneumatically operated control valves in each common cooling water discharge line from the coolers. The temperature control will be based on the temperatures of the lube oil in each common header downstream of the coolers.

All controls will be mounted locally and be pneumatically operated.

Generator Hydrogen Temperature Control

A control system will be provided to maintain the temperature of the hydrogen leaving the coolers at a preselected value recommended by the turbine generator manufacturer.

The system will control the hydrogen temperature leaving the coolers by modulating a pneumatically actuated control valve in the common cooling water discharge line from the coolers. The temperature control will be based on the temperature of the hydrogen in the common cold hydrogen stream leaving the coolers.

All controls will be mounted locally and be pneumatically operated.

Heater Drains Control

A control system will be provided for each heater in the condensate and feedwater system to maintain the level in the heater at a preselected value.

The systems will control the level in the heaters external to the condenser neck by modulating the drain valve for that heater. An alarm will be provided for high level plus contacts which will initiate the closing of the upstream drain valve.

On extreme high level, the control systems will initiate the following actions:

- a. Close extraction line nonreturn valve.
- b. Close extraction line motor-operated block valve.
- c. Open extraction line drain valve.

For the highest point condenser neck heaters, the systems will control the level in the drain coolers by modulating the control valve and alarm on high level. On extreme high level, the control systems will initiate the opening of the condensate line motor-operated bypass valve.

For the lowest point condenser neck heaters, the system will alarm at high level and on extreme high level will initiate the opening of the condensate line motor-operated bypass valve.

All controls will be mounted locally and will be pneumatically operated.

Final operators will be pneumatically actuated.

Turbine Control

The turbine-generator will be equipped with an electrohydraulic control system that will provide load, speed, or acceleration control, and emergency functions which trip the unit on overspeed, low vacuum, thrust bearing wear, and low bearing oil pressure. An operator's subpanel, mounted on the main control

board, will be included as part of the system and will contain the operating, monitoring, and testing controls. A control cabinet containing the solid state integrated circuits will be located in a room directly adjacent to the unit control room. An hydraulic power supply unit will be located on the ground floor elevation.

A turbine supervisory system will be located in the unit control room which will provide the following monitoring and alarming functions: vibration, eccentricity, spindle position, control valve position, speed, and rotor position. A turbine metal temperature recorder will be provided to guide turbine metal and main steam temperature matching.

The following auxiliary systems will be provided with remote panels: hydrogen seal oil system and emergency seal oil pumps, hydrogen pressure and purity, and hydrogen dryers.

Turbine generator bearing and oil temperatures will be monitored by the plant data logger.

Annunciator and Sequence-of-Events Printer

A coordinated control room annunciator and events printer will be provided consisting of all solid state equipment.

The alarms will be coordinated by means of logical groupings in respect to location of corresponding controls, importance, and required response time to the alarm. Additionally, alarms will be grouped under a common window with the particular alarm identified by the events printer.

Steam to Reheat Steam Bypass Control

A 35 percent duty turbine HP and IP/LP bypass control system is required as a prerequisite to maintain flow and temperature through the fired bed segments.

The HP bypass control valve will operate to maintain the minimum 35 percent MCR flow through the boiler during start-up and shutdown. As turbine load is ramped from 18 percent to 35 percent, the HP turbine bypass valve, responding to signals from the coordinated control system, will gradually close as the HP turbine control valves open. At 35 percent MCR flow through the turbine, the HP bypass valve will be fully closed.

The LP bypass valve will operate in parallel with HP bypass valve to maintain a balance between the two bypass steam flows from 0-35 percent load. After that, LP bypass valve will be kept shut.

Both HP and IP/LP turbine bypass control system will include spray attenuation for temperature matching of the bypass steam flow with the flow at the HP turbine outlet and at the condenser.

Solid state electronic controls will be provided with remote manual stations located on the main control board. Final operators will be pneumatic with electropneumatic converters.

Instruments

Sufficient instrumentation will be provided to permit safe operation of the unit when the central information system is out of service. The monitoring devices for these instruments will be located on the main control board or at local stations, depending upon their degree of importance.

A maximum of local instrumentation will be provided for local monitoring and equipment calibration. These devices will be primarily thermometers and pressure gages.

Environmental Source Monitoring System

Environmental source monitoring will be in accordance with current Environmental Protection Agency requirements.

The SO₂, NO₂, oxygen, and opacity taken from the downstream side of the fabric filter will be monitored and recorded by the data logging system. Sampling connections for SO₂, NO₂, oxygen, and particulate will be provided. A strip chart recorder for oxygen and opacity meter for smoke density will also be provided.

1500.73000 Computer System

A data logger monitoring system will be provided to monitor and log the various plant parameters. The system will contain the following monitoring devices: an operator's console, a logging typewriter, an alarm typewriter, a utility typewriter, and two CRTs.

The system will be capable of performing the following functions: scan-alarm of analog and digital inputs, periodic log, demand log, group review, postmortem review, analog trend recording (4 points), and digital trend plus performance calculation and turbine monitoring. Application software is not included.

The system will be used for analog and digital inputs and those contact closures used for initiating the postmortem review. The system may also be used for operating guides.

1500.76000 Instruments, Tubing, and Wiring

Tubing, piping, fittings, valves, and instrument support materials will be provided. As many as possible or all transmitters, switches, and associated equipment will be located on local racks or panels. Level controls for the condensate receiver, deaerator storage tank, and feedwater heaters will be installed on standpipes.

In general, primary sensing lines and sampling lines will be fabricated from stainless steel tubing; whereas air supply and control signal tubing will be of copper. Since most instrumentation is electronic, copper tubing will be used only for local control loops, such as heater level controls and simple pressure and temperature controls.

Heat tracing will be provided for all outdoor primary sensing lines.

BLOCK NO. 18 - MISCELLANEOUS POWER PLANT EQUIPMENT1600.00000 - MISCELLANEOUS POWER PLANT EQUIPMENT1600.100000 Turbine Room Traveling Crane

The existing crane furnished for the previous unit will be extended to serve this unit.

1600.20000 COMPRESSED AIR SYSTEM1600.21000 Compressors and Auxiliaries

The compressed air systems, including instrument, service, and soot-blowing air will be extended from existing facilities to serve this unit. No new air compressors will be furnished but a 4,160 v feeder will be furnished to supply one of the existing 4,500 hp air compressors from the auxiliary system of this unit.

1600.26000 Air Piping Valves and Fittings

All air system piping, valves, and fittings will be provided.

1600.41000 Shop Equipment

Existing site shop equipment will serve this unit.

1600.47000 Auxiliary Steam

Auxiliary steam will be supplied from existing facilities.

1600.70000 - Plant Communication and Signal System

Conduit and junction boxes will be provided for the plant communication system. Wiring and equipment will be furnished by others.

1600.89000 - Painting

Steel surfaces will be shop cleaned and shop painted with a primer and finish coat. Touch-up painting will be done in the field. Items not suitable for shop cleaning and shop painting will be cleaned and painted in the field. Insulated and jacketed equipment and piping will not be painted.

BLOCK NO. 19 - SUBSTATIONS5300 SUBSTATION AND SWITCHING STATION EQUIPMENT5300.10000 Connections, Supports, and Structures

Reinforced concrete foundations supported on piles will be provided for the main transformer with facilities to collect spilled oil.

Structures will be provided to facilitate takeoff of the high voltage lines from the main transformer.

All 345 kv lines, equipment, and associated relays will be by others. Controls and instruments located on boards in the main control room and wiring terminated on these boards will be provided.

One breaker position will be added by others to the existing 138 kv switchyard for the tie to the reserve station service transformer. This addition will include a disconnecting switch, a circuit breaker, pot heads, and solid dielectric power cable, relays, controls, and accessories required to provide a complete termination for this unit's reserve station service transformer leads consisting of three single conductors and one spare.

Relay panels will be added to the existing control house for the control of the above switchyard breakers.

5300.21000 Transformers

The main generator step-up transformer will be 3 phase, 580 mva FOA, 65 C temperature rise, 22-345 kv with no-load taps. Lightning arresters and auxiliary equipment will be provided.

5300.48000 Fire Protection

The main transformers will be protected by an automatic deluge water spray system. Electric dual sensor detectors will be provided with local alarms and alarm annunciation in the control room. Operation of the deluge valve will be accomplished by remote-manual means from the control room.

BLOCK NO. 20 - TRANSMISSION LINES

No provision is included for the installation, relocation, or removal of transmission lines.

APPENDIX IIIB-B
SYSTEM DESCRIPTIONS

J.O. No. 12919.02B

SYSTEM DESCRIPTION 2-1
CIRCULATING WATER - FWEC

1.0 System Requirements

1.1 Function

The circulating water system removes heat from the condenser and releases it to the atmosphere through the cooling tower. In addition, the tower is utilized to release the heat collected by the component cooling water system.

1.2 Design Requirements

1.2.1 General

The circulating water system will be designed for reliable power generation.

The type and number of pumps, towers, condensers and tubes will be consistent with high reliability, operating flexibility and combined minimum investment, performance penalty and environmental impact.

1.2.2 Codes and Standards

The circulating water pumps will be designed to the Hydraulic Institute Standard and all other codes and standards referenced in specification P121N.

The condensers will be designed to the Heat Exchange Institute Standards for Surface Condensers and all other codes and standards referenced in specification P111V.

The cooling tower will be designed to the Cooling Tower Manufacturers Association Standards for cooling towers and all other codes and standards referenced in specification S106B.

The circulating water piping and valves will be designed to the codes and standards referenced in specifications S107A/S107F and P302Q.

All other system components will be designed to all codes and standards referenced in the specification(s) in Section 7.02.

1.2.3 Specific Requirements

The circulating water system will be designed to 105 ft H₂O at 92 F and full vacuum.

The circulating water system is designed to permit continued unit operation without exceeding 5.0 in. HgA back pressure or requiring load reduction on the design day with a wet bulb temperature of 79/82 F.

The cooling tower is designed to reject 2.728×10^9 Btu/hr at a flow rate of 198,400 gpm on the design day while maintaining a cold water basin temperature of 92 F.

The pump discharge valve will be interlocked with the pump motor to prevent backflow through the pump on start-up, shutdown or trip.

The inlet water box butterfly valves are interlocked with the outlet water box valves to minimize hydraulic shocks to the condenser and expansion joints.

Spare pumping or cooling tower capacity is not required.

2.0 System Design

2.1 Detailed System Description

Refer to Flow Diagram 12919.01-EM-110A.

Two 99,200 gpm, 105 ft TDH, vertical centrifugal pumps take water from the cooling tower basin and discharge into one line. The line passes into the water boxes of the low pressure condenser; the water then passes to the inlet of the high pressure condenser. The condenser is a transverse, dual pressure, twin shell, single pass unit with 309,625 sq ft of 7/8 in. diam, 22 gage, 48 ft, 304 stainless steel tubes.

The water then flows to the mechanical draft cooling tower to cool the circulating water. The cooling tower is provided with 12 cells, each with a motor-driven fan rated at 50/200 hp, reversible and is designed to cool 198,400 gpm of water from 125 F to 92 F with a wet bulb temperature of 79 F.

Motor-operated valves are supplied at the discharge of the pumps.

The discharge of each pump and the inlet and outlet water boxes are equipped with an expansion joint.

Removable screens and stop logs are supplied for each pump to permit isolation for maintenance and protection against large materials entering the pumps.

2.2 Performance Characteristics

The performance characteristics of the system components will be as included in the specifications, manufacturers' drawings, instructions and/or operation books referenced in Section 7.02.

The predicted tower plume, drift and freezing data are included in the study report PS-6.

2.3 Arrangement

The schematic piping, wiring and tubing arrangement shall be as noted on the flow diagrams, elementary diagrams and loop diagrams referenced in Sections 7.03, 7.08, and 7.05, respectively.

The physical arrangement of the system, machinery and other equipment will be as noted on the piping, machine location and manufacturers' drawings referenced in Sections 7.07, 7.06, and 7.02, respectively.

2.4 Component Design

The bases of design of each component shall be as included in the specification(s) and the manufacturers' drawings, specifications and/or information referenced in Section 7.02.

2.5 Instrumentation and Controls

2.5.1 General

The specific design of the instrument and control components shall be as described in the specification and shown on the drawings referenced in the Instrument Schedule for that component.

The description of the system control and monitoring functions will be as shown and described in the logic diagrams and control descriptions referenced in Section 7.04.

2.5.2 Testability

All circulating water system components are normally in service.

2.5.3 Specific Regulatory Requirements

There are no regulatory requirements specifically applicable to the circulating water system.

2.6 System Interfaces

The system interfaces with the following other plant systems:

<u>Title</u>	<u>Number</u>
Condenser Air Removal	5-1

3.0 System Limitations, Set Points, and Precautions

Failure of one circulating water pump at full load operation will require load reduction.

The circulating water pumps will have to be tripped manually when the basin level falls 2 ft below normal water level.

4.0 System Operation

4.1 Filling

The basin is filled using the normal tower basin makeup valve (4LCV18) in approximately 6 hr using two makeup water pumps.

4.2 Start-up

Circulating water pump should be started one at a time in any order. The pump discharge valve will automatically open on a start signal to the pump.

The condenser inlet and outlet water box and cooling tower return valves should be opened.

4.3 Shutdown

The system is shut down in the reverse order described in 4.2 above.

Any side of the condenser may be isolated by closing the inlet water box isolation valve and then the corresponding outlet water box isolation valve.

5.0 Safety Features for Potential Emergencies

Not applicable

6.0 System Maintenance

The system components should be maintained in accordance with the manufacturers' operating, instruction and/or maintenance books.

7.0 Appendix

7.01 General

7.01.1 Summary of Design Conditions

7.01.2 Line Designation Table No.

7.01.3 Instrument Schedule

7.02 Specification(s)/Purchase Orders/Manufacturers' Print Prefix

E015E	4,160 V Switchgear
E041A	4 Kv Motors
P111V	Condenser
P121N	Circulating Water Pump
P302Q	Motor Operated Flanged Butterfly Valves
P305P	Rubber Expansion Joints
S106B	Mechanical Draft Cooling Tower
S106U	Stop Logs
S107A	Circulating Water Pipe
S107F	Circulating Water Pipe

7.03 Flow Diagrams

<u>Number</u>	<u>Title</u>
12919.01-EM-110A	Circulating & Makeup Water & Condenser Air Removal

7.04 Logic Diagrams

<u>Number</u>	<u>Title</u>
Later	Later

7.05 Loop Diagrams

<u>Number</u>	<u>Title</u>
Later	Later

7.06 Machine Location Drawings

<u>Number</u>	<u>Title</u>
12919.02B-EM-202	Boiler Area Machine Location
12919.02B-EM-203	Turbine Area Machine Location

7.07 Piping Drawings

<u>Number</u>	<u>Title</u>
12919.02B-EP-202	Boiler Area Piping Composites

7.08 Electrical Drawings

<u>Number</u>	<u>Title</u>
12919.02B-EE-612A,B,C	Cable Tray Arrangements, Boiler Area

7.09 Engineering Sketches and Other Engineering Information

7.09.3 Other

SYSTEM DESCRIPTION 3-1
MAIN STEAM - FWEC
ERDA - AFB STUDY

1.0 System Requirements

1.1 Function

The main steam system transports steam from the boiler, superheat-outlet to the turbine.

1.2 Design Requirements

1.2.1 General

The main steam system is designed for reliable power generation.

1.2.2 Codes and Standards

The main steam system downstream of the main steam stop valve inlet up to but not including the turbine stop valves will be designed in accordance with ANSI B.31.1.0 and all codes and standards referenced in specification P301B.

All piping downstream of and including the turbine stop valves will be designed to the turbine manufacturer's standards.

All other system components will be designed to the codes and standards referenced in the specification(s) in Section 7.02.

1.2.3 Specific Requirements

The main steam system will be designed to set safety valve (2,620 psig) at (1,005 F).

The main steam system pressure drop from the outboard isolation valve to the turbine stop valve shall not exceed 100 psi at rated flow conditions.

2.0 System Design

2.1 Detailed System Description

Refer to Flow Diagram 12919.02A-EM-102A.

The main steam system consists of a single header extending from the superheater outlet to the two turbine stop valves.

A motor-operated, main steam stop valve is installed in main steam line to isolate the boiler from the environs.

One spring loaded safety and two electromatic relief valves are installed on the main steam lines between the boiler and the turbine stop valve to prevent boiler main steam line overpressure. (System Description 32-8.) The electromatic valve will provide overpressure relief whenever required and thereby forego the operation of the safety valves on the drum and main steam leads.

The single header splits into two lines to the two turbinestop valves.

The two main steam lines are then joined in a manifold to permit pressure equalization and flow disribution to the turbine.

The stop valves are piped to the high pressure turbine through four turbine control valves. The turbine stop and control valves will close on any turbine trip. The control valves modulate the flow to the turbine to maintain the turbine speed, load, and boiler pressure.

A line is piped to the HP turbine drive for the boiler feed pump.

The main steam system is drained at several points (System Description 32-5) to prevent line quenching and turbine water induction and to permit line preheating.

HP/LP Bypass

During startup it is necessary to assure a minimum flow of 35 percent MCR flow through the superheater and reheater. This is accomplished as follows:

1. The HP bypass is modulated to pass the difference between 35 percent MCR flow and HP turbine flow. This flow is desuperheated and introduced into the cold reheat line upsteam of the reheat desuperheater.
2. The combined reheat valve modulates to hold a reheat bowl pressure compatible with the HP turbine flow at the existing pressure and temperature, until the boiler minimum flow requirement is established through the turbine, at which time the CRV is fully open.

3. The LP bypass valve by holding a hot reheat system pressure bypasses the hot reheat system flow in excess of the IP turbine flow to the condenser.

On a boiler or turbine trip, the HP and LP bypasses open to assure superheater and reheater cooling as the residual carbon in the bed is burned out.

2.2 Performance Characteristics

The performance characteristics of the system components are as included in the ammended specifications, manufacturers' drawings, instructions, and/or operation books referenced in Section 7.02.

2.3 Arrangement

The schematic piping arrangement and instrumentation is as noted on the flow diagrams and loop diagrams referenced in Sections 7.03 and 7.05, respectively.

The physical arrangement of the system, machinery, and other equipment is as noted on the Piping, Machine Location, and manufacturers' drawings referenced in Sections 7.07, 7.06, and 7.02, respectively.

2.4 Component Design

The bases of design of each component are as included in the specification(s) and the manufacturer's drawings, specifications, and/or information referenced in Section 7.02.

2.5 Instrumentation and Controls

2.5.1 General

The specific design of the instrument and control components are as described in the specification and shown on the drawings referenced in the Instrument Schedule for that component.

The description of the system control and monitoring functions shall be as shown and described in the logic diagrams and control descriptions referenced in Section 7.04.

2.5.1.2 Design Information

2.5.2 Testability

Each main steam stop valve, turbine stop valve, and turbine control valve is equipped with test circuits which permit closure to prove operability.

2.5.3 Specific Regulatory Requirements

None

2.6 System Interfaces

The system interfaces with the following other plant systems:

<u>System Title</u>	<u>System Number</u>
Cold Reheat	3-2
Hot Reheat	3-3
Extraction Steam	3-4
Miscellaneous Turbine Building Drains	11-1
Main Steam Safety Valve Vents & Drains	11-4

3.0 System Limitations, Set Points, and Precautions

Refer to the loop and logic diagrams for the set point of specific instruments.

4.0 System Operation

Refer to turbine manufacturer's operating instruction for operation of the main steam system.

5.0 Safety Features for Potential Emergencies

Not Applicable

6.0 System Maintenance

All system components should be maintained in accordance with the manufacturer's operating instruction and/or maintenance books.

7.0 Appendix

7.01 General

7.01.1 Summary of Design Conditions

7.01.2 Line Designation Table No. 4MSS

7.01.3 Instrument Schedule

**7.02 Specification(s)/Purchase Orders/Manufacturer's
Drawing Prefix**

<u>Number</u>	<u>Title</u>
P301B	Shop Fabricated Piping
P301C	Field Erection of Piping
P301H	Materials for Main Steam Pipe
P301N	Design & Fabrication of Piping Supports
P301P	Main Steam, Feedwater Sliding Restraints

7.03 Flow Diagrams

<u>Number</u>	<u>Title</u>
12919.02B-EM-102A	Main Steam and Reheat

7.04 Logic Diagrams

<u>Number</u>	<u>Title</u>
12919.02B-LSK-18.5J	Steam to Reheat System - HP and LP Bypass & Spray Control

7.05 Loop Diagrams

<u>Number</u>	<u>Title</u>
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7.06 Machine Location Drawings

<u>Number</u>	<u>Title</u>
12919.02B-EM-202	Boiler Area Machine Location
12919.02B-EM-203	Turbine Area Machine Location

7.07 Piping Drawings

<u>Number</u>	<u>Title</u>
12919.02B-EP-202	Boiler Area Piping Composites

7.08 Electrical Drawings

<u>Number</u>	<u>Title</u>
12919.02B-EE-612A,B,C	Cable Tray Arrangements, Boiler Area

7.09 Engineering Sketches and Other Information

7.09.1 Heat Balances

<u>Number</u>	<u>Title</u>
12919.02B-HBSK-1	Turbine VWO
12919.02B-HBSK-2	75% Turbine VWO
12919.02B-HBSK-3	50% Turbine VWO
12919.02B-HBSK-4	25% Turbine VWO

7.09.2 Stress Analysis

7.09.3 Other

J.O. No. 12919.02B

October 1977

SYSTEM DESCRIPTION 3-2
COLD REHEAT - FWEC
ERDA AFB STUDY

1.0 System Requirements

1.1 Function

The cold reheat system transports steam from the high pressure turbine exhaust to the boiler reheater and maintains the hot reheat steam temperature.

1.2 Design Requirements

1.2.1 General

The cold reheat system is designed for reliable power generation.

1.2.2 Codes and Standards

All piping will be designed to ANSI B31.1.0 and all codes and standards referenced in Specification P301B.

1.2.3 Specific Requirements

The system will be designed to 600 psia at 625 F and full vacuum.

The system pressure drop will not exceed 8 psi at rated boiler conditions.

2.0 System Design

2.1 Detailed System Description

Refer to Flow Diagram 12919.02B-EM-102A.

A single cold reheat line is piped from the high pressure turbine to the reheaters. The turbine has double leads.

Auxiliary steam is taken off of the cold reheat line.

Six safety valves are installed on the cold reheat line.

Extraction steam for the first point extraction is taken off of the cold reheat line and piped to the heater (System Description 3-4).

HP/LP Bypass

During start-up, it is necessary to assure a minimum flow of 35 percent MCR flow through the superheater and reheater. This is accomplished as follows:

1. The HP bypass is modulated to pass the difference between 35 percent MCR flow and HP turbine flow. This flow is desuperheated and introduced into the cold reheat line upstream of the reheat desuperheater.
2. The combined reheat valve modulates to hold a reheat bowl pressure compatible with the HP turbine flow at the existing pressure and temperature until the boiler minimum flow is established through the turbine, at which time the CRV is fully open.
3. The LP bypass valve, by holding a hot reheat system pressure, passes the hot reheat system flow in excess of the IP turbine flow to the condenser.

On a boiler or turbine trip, the HP and LP bypasses open to assure superheater and reheater cooling as the residual carbon in the bed is burned out.

2.2 Performance Characteristics

The performance characteristics of the system components are as included in the specifications, manufacturer's drawings, instructions, and/or operation books referenced in Section 7.02.

2.3 Arrangement

The schematic piping and wiring arrangement is as noted on the flow diagrams and elementary diagrams referenced in Sections 7.03 and 7.08.1, respectively.

The physical arrangement of the system, machinery, and other equipment is as noted on the piping, machine location, and manufacturer's drawings referenced in Sections 7.07, 7.06, and 7.02, respectively.

2.4 Component Design

The bases of design of each component are as included in the specification(s) and the manufacturer's drawings, specifications, and/or information referenced in Section 7.02.

2.5 Instrumentation and Controls

2.5.1 General

The specific design of the instrument and control components is as described in the specification and shown on the drawings referenced in the Instrument Schedule for that component.

The description of the system control and monitoring functions shall be as shown and described in the logic diagrams and control descriptions referenced in Section 7.04.

2.5.2 Testability

(Later)

2.5.3 Specific Regulatory Requirements

There are no regulatory requirements specifically applicable to the cold reheat system.

2.6 System Interfaces

The cold reheat system interfaces with the following other plant systems:

<u>System Title</u>	<u>System Number</u>
Main Steam	3-1
Hot Reheat System	3-3
Extraction Steam	3-4
Auxiliary Steam System	3-7
Drains to the Condenser	11-1
Boiler Safety Valve Vents	11-4

3.0 System Limitations, Set Points, and Precautions

Refer to the loop and logic diagrams for the set points of specific instruments.

4.0 System Operation

Refer to the turbine manufacturer's operating instruction for operation of the cold reheat system.

5.0 Safety Features for Potential Emergencies

Not applicable

6.0 System Maintenance

The system and its components should be maintained in accordance with the manufacturer's operating and/or maintenance instructions.

7.0 Appendix

7.01 General

7.01.1 Summary of Design Conditions

7.01.2 Line Designation Table No. 4 CRS

7.01.3 Instrument Schedule

7.02 Specification(s)/Purchase Orders/Manufacturer's Drawing Prefix

P103D	Turbine Generator
P301N	Design and Fabrication of Piping Supports

7.03 Flow Diagrams

<u>Number</u>	<u>Title</u>
12919.02B-EM-102A	Main Steam and Reheat

7.04 Logic Diagrams

<u>Number</u>	<u>Title</u>
12919.02B-LSK-18.5J	Steam to Reheat System HP and LP Bypass and Spray Control

7.05 Loop Diagrams

Later

7.06 Machine Location Drawings

<u>Number</u>	<u>Title</u>
12919.02B-EM-203	Turbine Room Machine Locations
12919.02B-EM-202	Boiler Area Machine Locations

7.07 Piping Drawings

Number

12919.02B-EP-202

Title

Boiler Area Piping
Composites

7.08 Electrical Drawings

Number

12919.02B-EE-612A,B,C

Title

Cable Tray Ar-
rangements,
Boiler Area

7.09 Engineering Sketches and Other Information

7.09.1 Heat Balances

Number

12919.02B-HBSK-1

12919.02B-HBSK-2

12919.02B-HBSK-3

12919.02B-HBSK-4

Title

Turbine VWO

75% Turbine VWO

50% Turbine VWO

25% Turbine VWO

7.09.2 Stress Analysis

7.09.3 Other

J.O. No. 12919.02B

October 1977

SYSTEM DESCRIPTION 3-3
HOT REHEAT - FWEC
ERDA AFB STUDY

1.0 System Requirements

1.1 Function

The function of the hot reheat system is to transport steam from the boiler reheater to the IP turbine stop/intercept valves.

1.2 Design Requirements

1.2.1 General

The hot reheat system is designed for reliable power generation.

1.2.2 Codes and Standards

All piping from the reheater outlet connection up to the stop/intercept valves will be designed to ANSI B31.1.0 and all codes and standards noted in Specification P301B.

All piping and components downstream and including the stop/intercept valves are designed to General Electric Company, Large Steam Turbine Division Standards.

1.2.3 Specific Requirements

The system will be designed to 560 psia at 1005 F.

The hot reheat system pressure drop will not exceed 40 psi at rated boiler conditions.

2.0 System Design

2.1 Detailed System Description

Refer to flow diagram 12919.02B-EM-102A.

The reheater section of the boiler receives steam from the high pressure turbine via the cold reheat system (System Description 3-2).

A single hot reheat line transports the steam to the intermediate pressure turbines through a combined stop-control valve called the combined reheat valve (CRV). The turbine header has double leads.

The two CRVs modulate on turbine overspeed and close on turbine trip.

Two electromatic relief and two safety relief valves are installed on the discharge line of the reheater to prevent system overpressure (System Description 32-8).

HP/LP Bypass

During start-up, it is necessary to assure a minimum flow of 35 percent MCR flow through the superheater and reheater. This is accomplished as follows:

- 1) The HP bypass is modulated to pass the difference between 35 percent MCR flow and HP turbine flow. This flow is desuperheated and introduced into the cold reheat line upstream of the reheat desuperheater.
- 2) The combined reheat valve modulates to hold a reheat bowl pressure compatible with the HP turbine flow at the existing pressure and temperature until the boiler minimum flow requirement is established through the turbine, at which time the CRV is fully open.
- 3) The LP bypass valve by holding a hot reheat system pressure passes the hot reheat system flow in excess of the IP turbine flow to the condenser.

On a boiler or turbine trip, the HP and LP bypasses open to assure superheater and reheater cooling as the residual carbon in the bed is burned out.

2.2 Performance Characteristics

The performance characteristics of the system components are as included in the turbine manufacturer's heat balance, manufacturers' drawings, instructions and operation books, and the Engineers' heat balances referenced in Section 7.09.1.

2.3 Arrangement

The schematic piping instrumentation arrangement is as noted on the flow diagrams referenced in Section 7.03.

The physical arrangement of the system, machinery, and other equipment is as noted on the Piping, Machine Location, and manufacturers' drawings referenced in Section 7.07, 7.06 and 7.02, respectively.

2.4 Component Design

The bases of design of each component are as included in the specification(s) and the manufacturers' drawings, specifications, and/or information referenced in Section 7.02.

2.5 Instrumentation and Controls

2.5.1 General

The specific design of the instrument and control components are as described in the specification and shown on the drawings referenced in the Instrument Schedule for that component.

The description of the system control and monitoring functions will be as shown and described in the logic diagrams and control descriptions referenced in Section 7.

2.5.2 Testability

The CRVs can be tested to prove operability.

2.5.3 Specific Regulatory Requirements

There are no regulatory requirements specifically applicable to the hot reheat system.

2.6 System Interfaces

The hot reheat system interfaces with the following other plant systems:

<u>System Title</u>	<u>System Number</u>
Main Steam	3-1
Cold Reheat System	3-2
Drains to the Condenser	11-1
Boiler Safety Valve Vents	11-4

3.0 System Limitations, Set Points, and Precautions

Refer to the loop and logic diagrams for the set point of specific instruments.

4.0 System Operation

Refer to the turbine manufacturer's operating instruction for operating of the hot reheat system.

5.0 Safety Features for Potential Emergencies

Not applicable

6.0 System Maintenance

The system and its components should be maintained in accordance with the manufacturer's operating, instruction, and/or maintenance books.

7.0 Appendix

7.01 General

7.01.1 Summary of Design Conditions

7.01.2 Line Designation Table No. 4 HRS

7.01.3 Instrument Schedule

7.02 Specification(s)/Purchase Orders/Manufacturers' Drawing Prefix

<u>Number</u>	<u>Title</u>
P103D	Turbine Generator
P301N	Design and Fabrication of Piping Supports
P301B	Piping Fabrication

7.03 Flow Diagrams

<u>Number</u>	<u>Title</u>
12919.102B-EM-102A	Main Steam and Reheat

7.04 Logic Diagrams

<u>Number</u>	<u>Title</u>
12919-02B-LSK-18.5J	Steam to Reheat System HP and LP Bypass and Spray Control

7.05 Loop Diagrams

<u>Number</u>	<u>Title</u>
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7.06 Machine Location Drawings

<u>Number</u>	<u>Title</u>
12919.02B-EM-203	Turbine Room Machine Locations
12919.02B-EM-202	Boiler Area Machine Locations

7.07 Piping Drawings

<u>Number</u>	<u>Title</u>
12919.02B-EP-202	Boiler Area Piping Composites

7.08 Electrical Drawings

<u>Number</u>	<u>Title</u>
12919.02B-EE-612A,B&C	Cable Tray Arrangements, Boiler Area

7.09 Engineering Sketches and Other Information

7.09.1 Heat Balances

<u>Number</u>	<u>Title</u>
12919.02B-HBSK-1	Turbine VWO
12919.02B-HBSK-2	75 Percent Turbine VWO
12919.02B-HBSK-3	50 Percent Turbine VWO
12919.02B-HBSK-4	25 Percent Turbine VWO

7.09.2 Stress Analysis

7.09.3 Other

J.O. No. 12919.02B

October, 1977

SYSTEM DESCRIPTION 3-4
EXTRACTION STEAM - FWEC
ERDA AFB STUDY

1.0 System Requirements

1.1 Function

The function of the extraction steam system is to transport steam from seven levels of turbine extraction to the respective feedwater heaters, the auxiliary steam system, and to the boiler feed pump turbine (System 7-4).

1.2 Design Requirements

1.2.1 General

The extraction steam system will be designed for reliable power generation.

1.2.2 Codes and Standards

All piping will be designed to ANSI B.31.1.0 and all codes and standards referenced in specification P301B.

All other system components will be designed to the codes and standards referenced in the specification(s) in Section 7.02.

1.2.3 Specific Requirements

The systems will be designed to attain the heater shell pressures noted on the VWO heat balance noted in Appendix 7.09.01.

In addition, the extraction steam system will be designed to limit the total entrained energy to a level equal to or less than the turbine manufacturer's requirements and to prevent turbine water induction in accordance with the recommendation contained in ASME Standard TWDPS, Part 1.

All extraction lines inside the condenser neck will be standard weight stainless steel.

All valves 2 1/2 in. and larger operating below atmospheric pressure are water sealed.

2.0 System Design

2.1 Detailed System Description

Each of the seven extraction systems except the fifth, sixth, and seventh extraction is equipped with a motor-operated gate valve and at least one air-assisted nonreturn valve between the turbine and each heater.

The gate valve is used for heater isolation during maintenance and on high heater level as additional protection against turbine water induction.

The air assist "to open" on the nonreturn valves will be released on turbine trip or high heater level to protect against turbine overspeed and water induction, respectively.

Each extraction steam system line is equipped with drains to permit preheating and minimize turbine water induction.

The extraction steam system shown on flow diagram 12919.02B-EM-103 consists of seven subsystems as described below.

2.1.1 First Point Extraction

Two lines from the high pressure turbine are piped to a manifold; one line extends from the manifold to the first point feedwater heater through a motor-operated gate valve and two extraction nonreturn valves.

An additional line extends from the first point extraction through a motor-operated gate valve and one nonreturn valve to feed the auxiliary steam system.

2.1.2 Second Point Extraction

One line transports steam from the IP turbine to the second point heater via a motor-operated gate valve and a nonreturn valve.

2.1.3 Third Point Extraction

The third point extraction nozzle on the IP turbine is piped to the third point heater through a motor-operated gate valve and a nonreturn valve. One line is piped to the auxiliary steam system. An additional line is piped to the LP turbine drive on the boiler feed pump.

2.1.4 Fourth Point Extraction

The two fourth point extraction nozzles on each low pressure turbine are joined and piped to the deaerator heater

through a motor-operated gate valve and three nonreturn valves. An additional line is piped to the auxiliary steam system.

2.1.5 Fifth Point Extraction

The two fifth point extraction nozzles on the low pressure turbine are piped directly to the fifth point heater in that condenser neck.

2.1.6 Sixth Point Extraction

The two sixth point extraction nozzles on the low pressure turbine are piped directly to the sixth point heater in the condenser neck of that turbine.

2.1.7 Seventh Point Extraction

The seventh point extraction nozzles on each low pressure turbine are piped directly to the seventh point heater in the condenser neck, one per each LP turbine.

2.2 Performance Characteristics

Each extraction system is designed to maintain the heater shell pressure noted on the Engineers' heat balances noted in Section 7.09.01.

2.3 Arrangement

The schematic piping and wiring arrangement is as noted on the flow diagrams and elementary diagrams referenced in Sections 7.03 and 7.08.1, respectively.

The physical arrangement of the system, machinery, and other equipment is as noted on the piping, machine location, and manufacturer's drawings referenced in Sections 7.07, 7.06, and 7.02, respectively.

2.4 Component Design

The bases of design of each component are as included in the specification(s) and the manufacturer's drawings, specifications, and/or information referenced in Section 7.02.

2.5 Instrumentation and Controls

2.5.1 General

The specific design of the instrument and control components is as described in the specification and shown on the drawings referenced in the Instrument Schedule.

The description of the system control and monitoring functions shall be as shown and described in the logic diagrams and control descriptions referenced in Section 7.04.

2.5.2 Testability

Each nonreturn valve can be tested periodically by manually unloading the air cylinder and observing the motion of the counterweight arm to verify that the disc shaft is not bound.

2.5.3 Specific Regulatory Requirements

There are no regulatory requirements specifically applicable to the extraction steam systems.

2.6 System Interfaces

The extraction steam system interfaces with the following other plant systems.

<u>System Title</u>	<u>System Number</u>
Main Steam	3-1
Cold Reheat	3-2
Auxiliary Steam System	3-5
Condensate System	4-1
Low Pressure Heater Drains	4-2
Feedwater System	6-1
High Pressure Heater Drains	6-6
Feedwater Pump Turbine Steam and Exhaust	7-4
Drains to Condenser	11-1

3.0 System Limitations, Set Points, and Precautions

Refer to the loop and logic diagrams for the set point of specific instrumentation.

4.0 System Operation

(later)

5.0 Safety Features for Potential Emergencies

Not applicable

6.0 System Maintenance

The system components should be maintained in accordance with the manufacturer's operating, instruction, and/or maintenance books.

7.0 Appendix

7.01 General

7.01.1 Summary of Design Conditions

7.01.2 Line Designation Table No. ESS

7.01.3 Instrument Schedule

**7.02 Specification(s)/Purchase Orders/Manufacturer's
Drawing Prefix**

12919.02B-P301B	Shop Fabricated Piping
12919.02B-P301H	Field Erection of Piping
12919.02B-P301N	Design and Fabrication of Piping Supports
12919.02B-P302R	Motor-operated Carbon Steel and Alloy Valves, 2 1/2 In. and Larger
12919.02B-P303P	Turbine Extraction Steam Nonreturn Valves
12919.02B-P305Q	Stainless Steel Expansion Joints

7.03 Flow Diagrams

Number

Title

12919.02B-EM-103A

Extraction Steam

7.04 Logic Diagrams

Title

Later

Extraction Control

7.05 Loop Diagrams

Later

Extraction Steam

7.06 Machine Location Drawings

Number

Title

12919.02B-EM-203

Turbine Area Machine
Locations

7.07 Piping Drawings

Later

7.08 Electrical Drawings

7.08.1 Elementary Diagrams

Number

Title

Later

7.08.2 Wiring Diagrams

Number

Title

12919.02B-EW-1C

FWEC-AFB Plant
One-Line Diagram

7.08.3 Wiring Diagrams

Number

Title

Later

7.08.4 Conduit Drawings

Number

Title

Later

7.09 Engineering Sketches and Other Information

7.09.01 Heat Balances

Number

Title

12919.02B-HBSK-B1

Turbine VWO

12919.02B-HBSK-B2

75% Turbine VWO

12919.02B-HBSK-B3

50% Turbine VWO

12919.02B-HBSK-B4

25% Turbine VWO

7.09.02 Stress Analysis

Later

J.O. No. 12919.02B

October , 1977

SYSTEM DESCRIPTION 4-1
CONDENSATE - FWEC
ERDA AFB STUDY

1.0 System Requirements

1.1 Function

The functions of the condensate system are to deliver preheated, demineralized water to the deaerator, to supply packing seal water, and exhaust hood sprays.

1.2 Design Requirements

1.2.1 General

The condensate system will be designed for reliable power generation.

1.2.2 Codes and Standards

All piping will be designed to ANSI B.31.1.0 and all codes and standards referenced in Specification P301B.

All heat exchangers will be designed to ASME VIII. The feedwater heaters and gland steam condenser will also conform to all codes and standards referenced in Specifications P221B, P111V, and P103D, respectively.

All pumps will be designed to the Hydraulic Institute standards and all codes and standards referenced in Specification P222V.

All other system components will be designed to the codes and standards referenced in the specification(s) in Section 7.02.

1.2.3 Specific Requirements

The condensate system will be capable of delivering 62.5 percent rated feedwater flow on the loss of one condensate pump to assure continued safe VWO load operation.

The condensate system will be designed to permit the loss of at least one single component without requiring unit shutdown.

2.0 System Design

2.1 Detailed System Description

Refer to flow diagram 12919.01-EM-104A.

Two five-eighths capacity condensate pumps take suction from the condenser hotwell and deliver the condensate to the deaerator via the full flow condensate polishing demineralizer (System Description 4-6), the full flow integral bypass gland steam condenser, two drain coolers, two half-capacity seventh point heaters and the full capacity sixth and fifth point extraction feedwater heaters.

A permanent basket type strainer is installed at the suction of each condensate pump. In addition, each condensate pump is equipped with a normally open pump suction vent, an orificed normally closed pump start-up vent, and shaft packing seal water.

The condensate system also supplies water to the exhaust hood sprays, boiler fill, and the valve and pump packing seals subsystems.

The exhaust hood sprays are fed downstream of the polishing demineralizer through an isolation valve and a modulating control valve.

Valve and Pump Stem Seal Subsystem

The valve stem and pump shaft packing seal water is supplied through a pressure reducing valve. Loss of seal water pressure will be annunciated in the main control room.

Excessive condensate is drawn off to the condensate storage tank (System Description 4-3).

Minimum condensate system flow is assured by recirculating a portion of the flow back to the condenser to maintain the flow at the gland steam condenser outlet equal to or greater than the minimum flow set point.

Hotwell condensate purity is normally monitored at the condensate pump discharge header. (See System Description 21-1.) On high readings, however, provision is made to monitor the condensate purity in each half of each condenser shell and at each tube sheet to permit locating any tube leak.

Condenser pressure and hotwell level are indicated in the control room.

Low pressure heaters are equipped with isolation and bypass valves.

In addition to remote manual heater isolation, automatic heater isolation will occur on high heater level as part of turbine water induction prevention (System Description 3-4).

2.2 Performance Characteristics

The performance characteristics of the system components are as included in the specifications, manufacturer's drawings, instructions, and/or operation books referenced in Section 7.02.

2.3 Arrangement

The schematic piping, electrical, and instrumentation arrangement is as noted on the flow diagrams, elementary diagrams, and loop diagrams referenced in Sections 7.03, 7.08, and 7.05, respectively.

The physical arrangement of the system, machinery, and other equipment is as noted on the piping, machine location, and manufacturer's drawings referenced in Sections 7.07, 7.06, and 7.02, respectively.

2.4 Component Design

The bases of design of each component are as included in the specification(s) and the manufacturer's drawings, specifications, and/or information referenced in Section 7.02.

2.5 Instrumentation and Controls

2.5.1 General

The specific design of the instrument and control components is as described in the specification and shown on the drawings referenced in the Instrument Schedule for that component.

The description of the system control and monitoring functions shall be as shown and described in the logic diagrams and control descriptions referenced in Section 7.04.

2.5.2 Testability

Later

2.5.3 Specific Regulatory Requirements

None

2.6 System Interfaces

The system interfaces with the following other plant systems:

<u>System Title</u>	<u>System Number</u>
Extraction Steam	3-4
Auxiliary Steam	3-9
LP Heater Drains	4-2
Condensate Makeup and Drawoff	4-3
Condensate Polishing Demineralizer	4-7
Condenser Air Removal	5-1
Feedwater	6-1
Turbine Gland Steam	16-1
Turbine Plant Sampling	21-1
Turbine Building Floor Drains	23-7

3.0 System Limitations, Set Points, and Precautions

Refer to the loop and logic diagrams for the set point of any specific instrument.

4.0 System Operation

Later

5.0 Safety Features for Potential Emergencies

Later

6.0 System Maintenance

The system components should be maintained in accordance with the manufacturer's operating, instruction, and/or maintenance books.

7.0 Appendix

7.01 General

7.01.1 Summary of Design Conditions

7.01.2 Line Designation Table

7.01.3 Instrument Schedule

7.02 Specification(s)/Purchase Orders/Manufacturer's Drawing Prefix

P103D	Turbine Generator (Gland Steam Condenser)
P111V	Condenser
P221B	Closed Feedwater Heaters
P222V	Condensate and Boiler Feedwater Pumps
P301B	Shop Fabricated Piping
P301N	Design and Fabrication of Piping Supports
P302E	Carbon Steel Valves 2 1/2" and Larger
P302H	Forged Steel Valves 2" and Smaller

P302P	Motor-Operated Carbon Steel Valves 2 1/2"
	and Larger
P305D	Permanent Strainers
P305P	Rubber Expansion Joints
P306A	Thermal Insulation
E015E	4,160 V Switchgear

7.03 Flow Diagrams

<u>Number</u>	<u>Title</u>
12919.01-EM-104A	Condensate

7.04 Logic Diagrams

<u>Number</u>	<u>Title</u>
Later	

7.05 Loop Diagrams

<u>Number</u>	<u>Title</u>
Later	

7.06 Machine Location Drawings

<u>Number</u>	<u>Title</u>
12919.0ZB-EM-202	Boiler Area Machine Locations
12919.0ZB-EM-203	Turbine Area Machine Locations

7.07 Piping Drawings

<u>Number</u>	<u>Title</u>
12919.0ZB-EP-202	Boiler Area Piping Composites

7.08 Electrical Drawings

7.08.1 Elementary Diagram

<u>Number</u>	<u>Title</u>
Later	

7.08.2 Wiring Drawings

<u>Number</u>	<u>Title</u>
Later	

7.08.3 Cable Tray Drawings

Number

Title

Later

7.08.4 Conduit Drawings

Number

Title

Later

7.09 Engineering Sketches and Other Information

7.09.01 Heat Balances

Title

12919.02B-HBSK-B1

Turbine VWO

12919.02B-HBSK-B2

75% Turbine VWO

12919.02B-HBSK-B3

50% Turbine VWO

12919.02B-HBSK-B4

25% Turbine VWO

7.09.02 Stress Analysis

Later

7.09.3 Other

J.O. No. 12919.02B

October 1977

SYSTEM DESCRIPTION 4-2
L.P. FEEDWATER HEATER DRAINS - FWEC
ERDA AFB STUDY

1.0 System Requirements

1.1 Function

The function of the Low Pressure Heater Drains System is to transfer the condensed steam drains from the shell side of the low pressure heaters to the drain coolers or condenser during normal operation and to the condenser during abnormal operation.

1.2 Design Requirements

1.2.1 General

The L.P. Feedwater Heater Drains System will be designed for reliable power generation.

The system will be designed for flashing fluids and to prevent turbine water induction in accordance with ASME Standard TWDPs, Part 1.

1.2.2 Codes and Standards

All piping will be designed to ANSI B31.1.0 and all codes and standards referenced in Specification P301B.

The feedwater heaters will be designed to ASME VIII and all codes and standards referenced in Specification P22IV.

All other system components will be designed to all codes and standards referenced in the Specification(s) in Section 7.02.

1.2.3 Specific Requirements

All control valves in the drain lines will be placed as close to the receiving vessel as possible.

Piping between the control valve and the receiving vessel shall be one schedule heavier than required before the control valve.

2.0 System Design

2.1 Detailed System Description

The low pressure feedwater heater drain system includes the following subsystems:

- a. Four LP feedwater heaters, two seventh, a sixth, and a fifth point heater located in the condenser neck along with individual level control systems for the drains
- b. LP feedwater heaters bypass and isolation system to preclude turbine water induction
- c. The deaerator level control system

Seventh Point Heater Drains

The seventh point heater is drained directly to the condenser through a loop seal drain line. No drains are cascaded to this heater. Each heater and loop seal is equipped with local gage glasses and each heater is equipped with drain temperature indication for performance testing. Each of the seventh point heaters is equipped with high level alarm. On an extreme high seventh point heater level, the whole LP heater string will be isolated and bypassed as a part of turbine water induction protection.

Sixth and Fifth Point Heater Drains

The sixth and fifth point heaters are installed in the condenser neck, and will have no drains cascaded to them. Each heater will be provided with an external drain receiver tank which will eliminate water level from the heater and keep the water further from the turbine. Also, a drain cooler will be provided between the receiver tank and the condenser. The flow of drains (from the heater drain receiver) through the cooler and to the condenser will be controlled by individual modulating "normal" water level drain control valves. In the event that normal water level cannot be maintained, a second, completely separate, modulating "emergency" water level drain control valve will drain excess level to the condenser directly from the receiver tank bypassing the drain cooler.

On an extreme high heater water level the whole LP heater string will be isolated and bypassed as a part of turbine water induction protection. High drain receiver level and extreme high heater level will also be annunciated in the control room.

Each drain receiver will be equipped with local gage glasses. Each control valve station consists of an inlet and

outlet isolation valve, an upstream and downstream pressure test connection, and an upstream drain.

Deaerator Level Control

A horizontal tray type deaerator heater with internal vent condenser will be provided. The heater is mounted on a horizontal storage tank with a capacity of about 5 min of operation at full load.

The level in the storage tank is maintained by regulating the amount of condensate entering the deaerator. A three element control system is utilized which compares the actual condensate flow to a demand (feedwater flow) and is corrected by the storage tank level.

The control system will be equipped with two level control valves, one block valve, one bypass valve, one drain valve, a narrow range, and a wide range level transmitter.

The level control valves are arranged in parallel and are sized so that only one of two valves will operate under cavitating conditions. The level control valves will close on an extreme high water level in the deaerator storage tank. The block valve is provided to facilitate isolation of the two control valves and to shut off the condensate flow when control valves fail to close. A motor-operated bypass valve is provided to enable remote-manual throttling of condensate flow when level controllers are out of service. The drain valve is provided to drain condensate from the deaerator storage tank to the condenser on high tank level and is sized to handle expected leakage through the closed control valve.

2.2 Performance Characteristics

The performance characteristics of the system components are as included in the specifications, Manufacturer's drawings, instructions and/or operation books referenced in Section 7.02.

2.3 Arrangement

The piping schematic, electrical schematic, and instrumentation arrangement are as noted on the flow diagrams, elementary diagrams and loop diagrams referenced in Sections 7.03, 7.08, and 7.05, respectively.

The physical arrangement of the system, machinery and other equipment is as noted on the Piping, Machine Location, and Manufacturer's drawings referenced in Sections 7.07, 7.06, and 7.02, respectively.

2.4 Component Design

The bases of design of each component are as included in the specification(s) and the manufacturer's drawings, specifications and/or information referenced in Section 7.02.

2.5 Instrumentation and Controls

2.5.1 General

The specific design of the instrument and control components are as described in the specification and shown on the drawings referenced in the Instrument Schedule.

The description of the system control and monitoring functions shall be as shown and described in the logic diagrams and control descriptions referenced in Section 7.04.

2.5.2 Testability

Later

2.5.3 Specific Regulatory Requirements

None

2.6 System Interfaces

The low pressure heater drain system interfaces with the following systems:

<u>System Title</u>	<u>System Number</u>
Extraction Steam	3-4
Condensate	4-1
Feedwater	6-1
High Pressure Heater Drains	6-6

3.0 System Limitations, Set Points, and Precautions

Refer to the loop and logic diagrams for the set point of specific instrumentation.

4.0 System Operation

Later

5.0 Safety Features for Potential Emergencies

Not applicable

6.0 System Maintenance

All system mechanical components are to be maintained in accordance with the operation and maintenance instructions submitted in accordance with the component specification listed in Section 7.02.

7.0 Appendix

7.0.1 General

7.01.1 Summary of Design Conditions

7.01.2 Line of Designation Table No. HDL

7.01.3 Instrument Schedule

7.02 Specification(s)/Purchase Orders

12919.02B-P221V	Closed Feedwater Heaters
12919.02B-P222V	Condensate and Boiler Feedwater Pumps
12919.02B-P301N	Design & Fabrication of Piping Supports
12919.02B-P302E	Carbon Steel Valves 2 1/2" & Larger
12919.02B-P302H	Forged Steel Valves 2" & Smaller

7.03 Flow Diagrams

Number

Title

12919.02B-EM-106A

Heater Drains

7.04 Logic Diagrams

Title

Later

L.P. Feedwater Heater Drains
L.P. Feedwater Heater Isolation and
and Bypass
Deaerator Level Control

7.05 Loop Diagrams

Title

Later

L.P. Heater Drain

7.06 Machine Location Drawings

Number

Title

12919.02B-EM-203A

Turbine Room Machine Location

7.07 Piping Drawings

Later

Title

LP Heater Drain Piping
Feedwater Piping

7.08 Electrical Drawings

Later

7.09 Engineering Sketches

None

J.O. No. 12919.02B

October 1977

SYSTEM DESCRIPTION 4-3
CONDENSATE MAKEUP AND DRAWOFF - FWEC
ERDA AFB STUDY

1.0 System Requirements

1.1 Function

The function of the condensate makeup and drawoff system is to maintain the condenser hotwell level at a predetermined level and supply a source of water for various other systems.

1.2 Design Requirements

1.2.1 General

The condensate makeup and drawoff system will be designed for reliable power generation.

1.2.2 Codes and Standards

All piping will be designed to ANSI B31.1.0 or as applicable and codes and standards referenced in specification P301B.

All other system components will be designed to the codes and standards referenced in the specifications in Section 7.02.

1.2.3 Specific Requirements

The normal condenser makeup and drawoff shall be sized for five percent of rated feedwater flow. The emergency condenser makeup shall be sized for (later) lb/hr.

The demineralized water storage tank overflow will be sized for the largest single flow into the tank.

2.0 System Design

2.1 Detailed System Description

Refer to Flow Diagram 12919.01-EM-104A.

2.1.1 General

A split condenser is provided with a high pressure shell and a low pressure shell. The hotwell makeup line from the demineralizer water storage tank is connected to the LP shell side. Condensate pump suction is taken from the hotwell on the HP shell side.

2.1.2 Makeup System

Makeup water is added to the condenser from the existing unit demineralized water storage tank through two control valves, the normal makeup control valve and the emergency makeup control valve. The hotwell level control valve set points are established such that during normal operating conditions the normal makeup valve is modulating and the emergency makeup valve and drawoff valves are closed. On an extreme low level, the emergency makeup valve will open to supply additional makeup to the system.

2.1.3 Drawoff System

On a high condenser hotwell level, the condensate is drawn off from the system at a point downstream of gland steam condenser and returned to the demineralized storage tank through a modulating control valve. During periods of high conductivity, the condensate drawoff will be dumped to the waste sump through a blowdown valve.

2.2 Performance Characteristics

The performance characteristics of the existing system components are as included in the specifications, manufacturer's drawings, instructions, and/or operation books referenced in Section 7.02.

2.3 Arrangement

The schematic piping and wiring arrangement is as noted on the flow diagrams and elementary diagrams referenced in Sections 7.03 and 7.08, respectively.

The physical arrangement of the system, machinery, and other equipment is as noted on the piping, machine location, and manufacturer's drawings referenced in Sections 7.07, 7.06, and 7.02, respectively.

2.4 Component Design

The basis of design of each component is as included in the specification(s) and the manufacturer's drawings, specifications, and/or information referenced in Section 7.02.

2.5 Instrumentation and Controls

2.5.1 General

The specific design of the instrument and control components is as described in the specification and shown on the drawings referenced in the Instrument Schedule for that component.

The description of the system control and monitoring functions shall be as shown and described in the logic diagrams and control descriptions referenced in Section 7.04.

2.5.2 Testability

No specific requirements.

2.5.3 Specific Regulatory Requirements

None

2.6 System Interfaces

The condensate makeup and drawoff system interfaces with the following systems:

<u>System Title</u>	<u>System Number</u>
Chemical Feed	-
Condensate	4-1
Condensate Demineralizer	-
Boiler Feed	6-1

3.0 System Limitations, Set Points, and Precautions

Refer to the instrument schedule for the set point of any instrument.

The normal condenser makeup valve maintains hotwell normal water level (NWL) at El. (later). The emergency condenser makeup valve will start opening (later) in. below NWL and will be fully open (later) in. below NWL.

4.0 System Operation

4.1 Normal Operation

As noted in Section 2.1, system operation is basically automatic with several manual intermittent demands.

4.2 System Shutdown and Draining

Any demand or return may be shut down using the manual isolation valves supplied. After isolation these lines can be drained.

5.0 Safety Features for Potential Emergencies

Not applicable

6.0 System Maintenance

All system components should be maintained in accordance with the manufacturer's operating, instruction, and/or maintenance books.

7.0 Appendix

7.01 General

7.01.1 Summary of Design Conditions

7.01.2 Line Designation Table

7.01.3 Instrument Schedule

7.02 Specification(s)/Purchase Orders/Manufacturer's Print Prefix

<u>Number</u>	<u>Title</u>
P301B	Shop Fabricated Piping
P301N	Design and Fabrication of
	Piping and Supports
P302E	Carbon Steel Valves 2 1/2 In.
	and Larger
P302H	Forged Steel Valves 2 In. and
	Smaller

7.03 Flow Diagrams

<u>Number</u>	<u>Title</u>
12919.01-EM-104A	Condensate

7.04 Logic Diagrams

<u>Number</u>	<u>Title</u>
Later	

7.05 Loop Diagrams

<u>Number</u>	<u>Title</u>
Later	

7.06 Machine Location Drawings

<u>Number</u>	<u>Title</u>
12919.02B-EM-203	Turbine Area Machine Locations
12919.02B-EM-202	Boiler Area Machine Locations

7.07 Piping Drawings

<u>Number</u>	<u>Title</u>
12919.02B-EP-202	Boiler Area Piping Composites

7.08 Electrical Drawings

<u>Number</u>	<u>Title</u>
Later	

7.09 Engineering Sketches and Other Engineering Information

7.09.1 Heat Balances

<u>Number</u>	<u>Title</u>
12919.02B-HBSK-B1	Turbine VWO
12919.02B-HBSK-B2	75% Turbine VWO
12919.02B-HBSK-B3	50% Turbine VWO
12919.02B-HBSK-B4	25% Turbine VWO

7.09.2 Stress Analysis

7.09.3 Other

J.O. No. 12919.02B

October 1977

SYSTEM DESCRIPTION 5-1
CONDENSER AIR REMOVAL - FWEC
ERDA AFB STUDY

1.0 System Requirements

1.1 Function

The function of the condenser air removal system is to provide the required start-up vacuum for turbine generator operation and to remove noncondensable gases from the condenser shells during plant operation.

1.2 Design Requirements

1.2.1 General

The air removal system will be designed for reliable power generation.

The system shall have sufficient duplication to assure continued operation.

The capacity of the air removal pumps shall be determined in accordance with potential air inleakage, and the water vapor contained in the air-gas mixture.

1.2.2 Codes and Standards

All piping will be designed to ANSI B.31.1 and all codes and standards referenced in specifications P111V and P112E.

Motor driven air removal pumps will be sized in accordance with the recommendations of the Heat Exchange Institute Standards for Condensers.

1.2.3 Specific Requirements

None

2.0 System Design

2.1 Detailed System Description

2.1.1 General

Refer to flow diagram 12919.01-EM-110A

Two perforated pipes run the length of each of the two condenser shells to evacuate the noncondensables. These four pipes combine to form the main air removal suction header.

The system consists of two full-capacity water seal vacuum pumps which take suction through a common line from the main air removal suction header.

Each system consists of an air removal pump, inlet separator, outlet reservoir separator and associated controls.

During start-up both air removal pumps are manually started to evacuate the condenser as quickly as possible. Once normal volume is obtained, one pump can be shut down and placed in the standby mode.

Each pump discharges through a discharge moisture separator/silencer.

Seal water carried over with the air is collected in each discharge moisture separator/silencer. Seal water is supplied from the condensate system and the level is automatically controlled.

2.2 Performance Characteristics

The performance characteristics of the system components are as included in the specifications, manufacturers' drawings, instructions, and/or operation books referenced in Section 7.02.

2.3 Arrangement

The schematic piping, wiring and tubing arrangement is as noted on the flow diagrams, elementary diagrams and loop diagrams referenced in Sections 7.03, 7.08, and 7.05, respectively.

The physical arrangement of the system, machinery and of the equipment is as noted on the Piping, Machine Location and manufacturers' drawings referenced in Sections 7.07, 7.06, and 7.02, respectively.

2.4 Component Design

The bases of design of each component are as included in the specification(s) and the manufacturers' drawings, specifications, and/or information referenced in Section 7.02.

2.5 Instrumentation and Controls

2.5.1 General

The specific design of the instrument and control components are as described in the specification and shown on the drawings referenced in the Instrument Schedule for that component.

A description of the system control and monitoring functions shall be as shown and described in the logic diagrams and control descriptions referenced in Section 7.04.

2.5.2 Testability

All standby equipment is periodically tested.

2.5.3 Specific Regulatory Requirements

There are no regulatory requirements directly applicable to the condenser air removal system.

2.6 System Interfaces

The condenser air removal system interfaces with the following other plant systems:

<u>System Title</u>	<u>System Number</u>
Condensate	4-1
Condensate Makeup and Drawoff	4-3

3.0 System Limitations, Set Points, and Precautions

Refer to instrument schedule for the set point of specific instrumentation.

4.0 System Operation

4.1 Start-up

Start-up vacuum, i.e., less than or equal to 5 in. HgA, is established by opening vacuum pump inlet valves and starting both air removal pumps. The start-up vacuum will be attained in approximately 1 hour.

After attaining 5 in. HgA, the vacuum pumps will automatically transfer to their holding mode.

4.2 Normal Operation

During normal operation, the air removal system requires little attention. Periodically, the standby vacuum pump should be cycled and/or placed in service.

5.0 Safety Features for Potential Emergencies

Not applicable

6.0 System Maintenance

The system components should be maintained in accordance with the manufacturers' operating instruction and/or maintenance book.

7.0 Appendix

7.01 General

7.01.1 Summary of Design Conditions

7.01.2 Line Designation Table 4ARC

7.01.3 Instrument Schedule

7.02 Specification(s)/Purchase Orders

P111V	Condenser
P112E	Condenser Air Removal Pumps
P301B	Shop Fabricated Piping
P301N	Design and Fabrication of Piping Supports
P302E	Carbon Steel Valves 2 1/2" & Smaller - Category II

7.03 Flow Diagrams

<u>Number</u>	<u>Title</u>
12919.01-EM-110A	Circ. & Makeup Water & Condenser Air Removal

7.04 Logic Diagrams

<u>Number</u>	<u>Title</u>
Later	

7.05 Loop Diagrams

<u>Number</u>	<u>Title</u>
Later	

7.06 Machine Location Drawings

<u>Number</u>	<u>Title</u>
12919.02B-EM-202	Boiler Room Machine Locations
12919.02B-EM-203	Turbine Room Machine Locations

7.07 Piping Drawings

<u>Number</u>	<u>Title</u>
12919.02B-EP-202	Boiler Area Piping Drawings

7.08 Electrical Drawings

<u>Number</u>	<u>Title</u>
(later)	

7.09 Engineering Sketches

None

J.O. No. 12919.02B

October 1977

SYSTEM DESCRIPTION 6-1
BOILER FEEDWATER - FWEC
ERDA AFB STUDY

1.0 System Requirements

1.1 Function

The function of the feedwater system is to deliver feedwater from the condensate system to the boiler at the required pressure and temperature.

1.2 Design Requirements

1.2.1 General

The feedwater system up to, but not including, the outboard boiler isolation valve will be designed for reliable power generation.

1.2.2 Codes and Standards

Piping from the boiler feed pump discharge up to, but not including, the outermost boiler isolation valve will be furnished in accordance with the latest ANSI B31.1.0 and all codes and standards referenced in Specification P301B.

Piping from the boiler to the outermost isolation valve will be furnished in accordance with the latest ASME I and all codes and standards referenced in Specification P301B.

All heat exchangers will be designed to ASME VIII and all codes and standards referenced in Specification P221B.

The feedwater pumps will be designed to the Hydraulic Institute Standards and all codes and standards referenced in Specification P222V.

All other system components will be designed to the codes and standards referenced in the specifications in Section 7.02.

1.2.3 Specific Requirements

The feedwater system shall be capable of delivering 3,813,688 lb of water per hour at 484.03 F and 2,920 psia to the boiler at turbine valve wide open condition.

2.0 System Design

2.1 Detailed System Description

Refer to flow diagram 12919.02B-EM-105A.

One full-capacity, centrifugal barrel type, steam-turbine driven boiler feed pump with shaft driven matched booster pump is provided. The booster pump will take suction from the deaerator and supply the suction of the boiler feed pump which, in turn, discharges to the economizer section of the boiler via, in series, the three high pressure heaters. Boiler feedwater is also used for desuperheating the superheater and the reheater.

Feedwater to the superheater desuperheaters is provided from a tap off the economizer feedwater line upstream of the boiler isolation valve. Feedwater is taken from one tap and then divides into two lines, each with a flowmeter, a feedwater control valve which closes on a turbine trip, and a temperature control valve before entering the superheater desuperheater section of the boiler.

Feedwater to the reheat desuperheaters is provided directly from an interstage portion of the feedwater pump. Feedwater flows through a flowmeter, through a feedwater control valve which shuts off on a turbine trip, and a temperature control valve before entering the reheat desuperheater section of the boiler.

Feedwater is also provided by the interstage takeoff to the high pressure and low pressure turbine bypass systems for desuperheating. A single line is provided for the HP bypass system desuperheater. Feedwater flows through a flowmeter, through a feedwater control valve which shuts off on a turbine trip, and a temperature control valve before entering the HP bypass system desuperheater.

A single line which divides into two separate lines is provided for the LP bypass system desuperheater. In each line, feedwater flows through a flowmeter, through a feedwater control valve which shuts off on a turbine trip, and a temperature control valve before entering the LP bypass system desuperheater.

A heater bypass line with manually operated isolation valves is provided for use during the isolation of any heater.

A boiler fill line from the condensate system, bypassing the feedwater pumps and the flow control valves, is connected to the economizer inlet piping.

A new start-up boiler feedwater pump, check valve, and motor-operated isolation valve are provided to bypass the feedwater pump isolation valve and check valve when feedwater demands are low during start-up. The start-up pump will also permit main pump warm-up.

The start-up pump is able to supply 35 percent MCR minimum flow to the boiler and spray water for the HP and LP turbine bypass systems in the event of a boiler feedpump turbine trip.

Both the start-up and feedwater pumps are equipped with a pump recirculation back to the deaerator storage tank to prevent pump damage at low loads.

The feedwater pumps are provided with a seal injection system to minimize outleakage of heated feedwater through the seals. Condensate from the condensate pump discharge is injected into the inboard and outboard seals of each pump. Seal injection water pressure is automatically controlled by a modulating pressure control valve.

2.2 Performance Characteristics

The performance characteristics of the system components are as included in the specifications, manufacturer's drawings, instructions and/or operation books referenced in Section 7.02.

2.3 Arrangement

The piping schematic, electrical schematic, and instrumentation arrangement is as noted on the flow diagrams, elementary diagrams, and loop diagrams referenced in Sections 7.03, 7.08.1, and 7.05, respectively.

The physical arrangement of the system machinery and other equipment is as noted on the piping, machine location, and manufacturer's drawings referenced in Sections 7.07, 7.06, and 7.02, respectively.

2.4 Component Design

The bases of design of each component are as included in the specification(s) and manufacturer's drawings, specifications and/or information referenced in Section 7.02.

2.5 Instrumentation and Controls

2.5.1 General

The specific design of the instrument and control components are as described in the specification and shown on the drawings referenced in the Instrument Schedule for that component.

The description of the system control and monitoring functions shall be as shown and described in the logic diagrams and control descriptions referenced in Section 7.

2.5.2 Testability

Later

2.5.3 Specific Regulatory Requirements

None

2.6 System Interfaces

The system interfaces with the following other plant systems:

<u>System Title</u>	<u>System Number</u>
Extraction Steam	3-4
Condensate	4-1
HP Heater Drains	6-6
Turbine Plant Sampling	22-1

3.0 System Limitations, Set Points, and Precautions

Refer to the loop and logic diagrams for any specific instrument.

4.0 System Operation

A tap from the condensate system downstream of the demineralizer permits initial boiler fill prior to starting of the feed pumps.

The start-up feed pump will be utilized for start-up and low load operation and will also permit pump warm-up. During start-up, the feedwater flow will be manually controlled. The feedwater flow demand and measured flow are compared and any error is used to modify the feed pump output by adjusting the feed pump turbine speed.

5.0 Safety Features for Potential Emergencies

Not applicable.

6.0 System Maintenance

All system mechanical components are to be maintained in accordance with the operation and maintenance instructions submitted in accordance with the component specification listed in Section 7.02.

7.0 Appendix

7.01 General

7.01.1 Summary of Design Conditions

7.01.2 Line Designation Table

(Later)

7.01.3 Instrument Schedule

7.02 Specification(s)/Purchase Order(s)/ Manufacturer's Print Prefix

12919.02B-P222V	Condensate, Heater Drain, and Boiler Feedwater Pumps
12919.02B-P221V	Closed Feedwater Heaters
12919.02B-P301B	Shop-Fabricated Piping
12919.02B-P301N	Design and Fabrication of Piping Supports
12919.02B-P302E	Carbon Steel Valves 2 1/2 In. and Larger - Category II

12919.02B-P302H

Forged Steel Valves 2 In. and
Smaller - Category II

12919.02B-P302P

Motor-Operated Carbon Steel
Valves 2 1/2 In. and Larger -
Category II

7.03 Flow Diagrams

Title

12919.02B-EM-105A

Boiler Feed

7.04 Logic Diagrams

Title

(Later)

Boiler Feedwater

7.05 Loop Diagrams

(Later)

Boiler Feedwater

7.06 Machine Location Drawings

Title

12919.02B-EM-203A

Turbine Room Machine Location

12919.02B-EM-202A,B

Boiler Area

7.07 Piping Drawings

Title

12919.02B-EP-202A-H

Boiler Feedwater Piping

7.08 Electrical Drawings

(Later)

7.09 Engineering Sketches

(None)

October 1977

SYSTEM DESCRIPTION 6-6
H.P. FEEDWATER HEATER DRAINS - FWEC
ERDA AFB STUDY

1.0 System Requirements

1.1 Function

The function of the H.P. Feedwater Heater Drains System is to transfer condensed steam drains from the shell side of the high pressure heaters to the next lower pressure heater or, during abnormal operation, the condenser.

1.2 Design Requirements

1.2.1 General

The high pressure feedwater heater drain system will be designed for reliable power generation.

1.2.2 Codes and Standards

All piping will be designed to ANSI B.31.1.0 and all codes and standards referenced in Specification P301B.

The feedwater heaters will be designed to ASME VIII and all codes and standards referenced in Specification P221B.

All other components will be designed to the codes and standards referenced in the specifications in Section 7.02.

1.2.3 Specific Requirements

The H.P. feedwater heater drain system will be designed to minimize turbine water induction in accordance with ASME Standard TWDPs, Part 1.

All control valves in the drain lines will be placed as close to the receiving vessel as possible.

Piping between the control valve and the receiving vessel shall be one schedule heavier than that required before the control valve.

2.0 System Design

2.1 Detailed System Description

Refer to flow diagram 12919.02B-EM-106A.

The H.P. heater drain system consists of three subsystems, one for each extraction heater stage.

On extreme high level trip of any heater, operator response is required to reset the system to return to a normal mode.

The temperature of each normal heater drain line is monitored for performance testing.

Each heater is equipped with a local level indicator and a level switch which will alarm if a high level occurs in the heater, close the normal drain valve of the next higher heater, and fully open the "emergency" drain to the condenser.

In addition, each heater is equipped with a level switch with independent connections to the heater which will alarm if high-high level occurs, trip the extraction NRV to vent, and close the extraction steam isolation valve.

First Point Heater Drain

The first point heater will normally drain to the second point heater through a modulating fail-close level control valve. The normal drain will close on high water level in the second point heater.

On higher than normal level in the first point heater shell, the heater will be drained to the condenser through a modulating fail-open "emergency" level control valve.

Second Point Heater Drain

The second point heater will normally drain to the third point heater through a modulating fail-close level control valve. The normal drain will close on high water level in the third point heater.

On higher than normal level in the second point heater shell, the heater will be drained to the condenser through a modulating fail-open "emergency" level control valve.

Third Point Heater Drain

The third point heater will normally drain to the deaerator through a modulating fail-close level control valve. The normal drain will close on high water level in the deaerator.

On higher than normal level in the third point heater shell, the heater will be drained to the condenser through a modulating fail-open "emergency" level control valve.

2.2 Performance Characteristics

The performance characteristics of the system components are as included in the specifications, manufacturer's drawings, instructions, and/or operation books referenced in Section 7.02.

2.3 Arrangement

The piping schematic, electrical schematic, and instrumentation arrangement are as noted on the flow diagrams, elementary diagrams, and loop diagrams referenced in Sections 7.03, 7.08, and 7.05, respectively.

The physical arrangement of the system, machinery, and other equipment is as noted on the piping, machine location, and manufacturer's drawings referenced in Sections 7.07, 7.06, and 7.02, respectively.

2.4 Component Design

The bases of design of each component are as included in the specification(s) and the manufacturer's drawings, specifications, and/or information referenced in Section 7.02.

2.5 Instrumentation and Controls

2.5.1 General

The specific design of the instrument and control components are as described in the specification and shown on the drawings referenced in the Instrument Schedule for that component.

The description of the system control and monitoring functions will be as shown and described in the logic diagrams and control descriptions referenced in Section 7.04.

2.5.2 Testability

Later

2.5.3 Specific Regulatory Requirements

None

2.6 System Interfaces

The H.P. heater drain system interfaces with the following systems:

<u>System Title</u>	<u>System Number</u>
Extraction Steam	3-4
Condensate	4-1
Low Pressure Heater Drains	4-2
Feedwater	6-1

3.0 System Limitations, Set Points, and Precautions

Refer to the loop and logic diagrams for the set point of specific instrumentation.

4.0 System Operation

Later

5.0 Safety Features for Potential Emergencies

Not applicable

6.0 System Maintenance

All system components are to be maintained in accordance with the operation and maintenance instructions submitted in accordance with the component specification listed in Section 7.02.

7.0 Appendix

7.01 General

7.01.1 Summary of Design Conditions

7.01.2 Line Designation Table No. HDH

7.01.3 Instrument Schedule HDH

7.02 Specification(s)/Purchase Orders/Manufacturers' Print Prefix

12919.02B-P221B	Closed Feedwater Heaters
12919.02B-P301B	Shop Fabricated Piping
12919.02B-P301N	Design and Fabrication of Piping Supports
12919.02B-P302E	Carbon Steel Valves 2 1/2 In. and Larger
12919.02B-P302H	Forged Steel Valves 2 In. and Smaller

7.03 Flow Diagrams

<u>S&W Number</u>	<u>Title</u>
12919.02B-EM-106	Heater Drains

7.04 Logic Diagrams

<u>Number</u>	<u>Title</u>
Later	H.P. Heater Drains

7.05 Loop Diagrams

Later	H.P. Heater Drains
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7.06 Machine Location Drawings

<u>Number</u>	<u>Title</u>
12919.02B-EM-203A	Turbine Room Machine Location

7.07 Piping Drawings

Title

Later

HP Heater Drain Piping
Feedwater Piping

7.08 Electrical Drawings

Later

7.09 Engineering Sketches

None

J.O. No. 12919.02B

November, 1977

SYSTEM DESCRIPTION 8-1
COAL AND LIMESTONE HANDLING - FWEC
ERDA - AFB STUDY

1.0 SYSTEM REQUIREMENTS

1.1 Function

The coal and limestone system prepares and transports coal and limestone from the yard to the boiler.

1.2 Design Requirements

1.2.1 General

The coal and limestone handling system is designed for reliable power generation.

1.2.2 Codes And Standards

The coal and limestone handling system components will be designed to the codes and standards referenced in the specifications in Section 7.02.

1.2.3 Specific Requirements

The coal and limestone handling system will be designed to deliver 547,200 lb/hr of coal and 307,800 lb/hr of limestone to the main boiler beds.

2.0 SYSTEM DESIGN

2.1 Detailed System Description
Refer to Flow Diagrams

The coal and limestone handling system consists of a yard handling system and an in-plant distribution and injection system.

The yard coal/limestone handling system consists of an independent dual series of belt conveyors tied into the existing conveyor system which serves Units 1-3.

The conveyors transport the coal/limestone to a new crusher house. The crusher house contains two new coal crushers and two new limestone crushers each rated at a gross capacity of 900 tph.

A dual series of new conveyors transports the crushed coal/limestone from the yard onto new tripper conveyors which fill the coal and limestone bunkers.

There are four coal bunkers that supply the main beds. A main chute at each bunker discharges coal into a series of distribution of chutes that feed the coal stokers. Sixty coal spreader stokers feed the main beds of the boiler. Two coal bunkers supply the CBC. Three belt conveyors in series feed two coal distributor chutes. Each distributor chute feeds six stokers. The 12 spreader stokers feed the CBC of the boiler.

2.2 Performance Characteristics

The performance characteristics of the system components are as included in the specifications, manufacturer's drawings, instruction and/or operation books referenced in Section 7.02.

2.3 Arrangement

The schematic piping arrangement and instrumentation is as noted on the flow diagrams and loop diagrams referenced in Sections 7.03 and 7.05, respectively.

The physical arrangement of the system machinery and other equipment is as noted on the piping, machine location, and manufacturer's drawings referenced in Sections 7.07, 7.06, 7.02, respectively.

2.4 Component Design

The bases of design of each component are included in the specifications and the manufacturer's drawings, specifications, and/or information referenced in Section 7.02.

2.5 Instrumentation And Controls

2.5.1 General

The specific design of the instrument and control components are as described in the specification and shown on the drawings referenced in the instrument schedule for that component.

The description of the system control and monitoring functions shall be as shown and described in the logic diagrams and control descriptions referenced in Section 7.07.

2.5.2 Testability

The coal and limestone handling system in the yard operates intermittently when loading the bunkers.

The distribution and injection system is normally in service.

2.5.3 Specific Regulatory Requirements

There are no regulatory requirements specifically applicable to the coal and limestone handling system.

2.6 System Interfaces

The system interfaces with the following other plant system:

None

3.0 SYSTEM LIMITATIONS, SET POINTS, AND PRECAUTIONS

Later

4.0 SYSTEM OPERATION

Later

5.0 SAFETY FEATURES FOR POTENTIAL ENERGENCIES

Fire protection will be provided for the crusher house.

6.0 SYSTEM MAINTENANCE

All system components should be maintained in accordance with the manufacturer's operating, instruction, and/or maintenance books.

7.0 APPENDIX

7.0.1 General

7.01.1 Summary of Design Conditions

7.01.2 Line Designation Table No. Later

7.01.3 Specifications Purchase Orders/Manufacturers' Drawing Prefix

<u>Number</u>	<u>Title</u>
P 301B	Shop-fabricated piping
P 301C	Field-fabricated piping
P301N	Design and fabrication of piping supports
	Coal and limestone handling equipment

7.03 Flow Diagrams

<u>Number</u>	<u>Title</u>
12919.02B-EM-170A	Coal and sorbent handling Sh. 1
12919.02B-EM-170B	Coal and sorbent handling Sh. 2
12919.02B-EM-170C	Coal and sorbent handling Sh. 3
12919.02B-EM-115B	Limestone distribution and injection
12919.02B-EM-115C	Coal distribution and injection

7.04 Logic Diagrams

<u>Number</u>	<u>Title</u>
Later	

7.05 Loop Diagrams

<u>Number</u>	<u>Title</u>
Later	

7.06 Machine Location Drawings

<u>Number</u>	<u>Title</u>
12919.02B-EM-211A	Gen arrg't coal/limestone handling in plant Sheet 1
12919.02-EM-211B	Gen arrg't coal/limestone handling in plant Section 1-1 Sheet 2
12919.02-EM-211C	Gen arrg't coal/limestone handling in plant Sections 2-2 and 3-3 Sheet 3
12919.02R-EM-211D	Gen arrg't coal/limestone handling - yard Sheet 4
12919.02B-EM-211E	Gen arrg't crusher house Sheet 5

7.07 Piping Drawings

<u>Number</u>	<u>Title</u>
12919.02B-EP-202A	Composite Boiler Area Plan El. 0'-0" Sheet 1

12919.02B-EP-202B	Composite Boiler Area Plan El. 31'-0"
	Sheet 2
12919.02B-EP-202C	Composite Boiler Area Plan El. 6'-0"
	Sheet 3
12919.02B-EP-202D	Composite Boiler Area Plan El. 91'-0"
	Sheet 4
12919.02B-EP-202E	Composite Boiler Area Plan El. 121'-0"
	Sheet 5
12919.02B-EP-202F	Composite Boiler Area Section 1-1
	Sheet 6
12919.02B-EP-202G	Composite Boiler Area Section 2-2
	Sheet 7
12919.02B-EP-202H	Composite Boiler Area Section 3-3
	Sheet 8

7.08 Electrical Drawings

Number

Title

Later

7.09 Engineering Sketches and Other Information

Later

7.09.1 Heat Balances

Not Applicable

7.09.2 Stress Analysis

Later

7.09.3 Other

J.O. No. 12919.02B

October , 1975

SYSTEM DESCRIPTION 9-15
MAKEUP WATER - FWEC
ERDA - AFB STUDY

1.0 SYSTEM REQUIREMENTS

1.1 Function

The functions of the makeup water system are:

1. To deliver river water to the plant site for use as makeup for cooling tower losses, i.e., evaporation, blowdown, and drift.
2. To supply water for other plant uses.

1.2 Design Requirements

1.2.1 General

The makeup water system will be designed for reliable power generation.

1.2.2 Codes and Standards

All pumps will be designed to the Hydraulic Institute Standards and all codes and standards referenced in specification P222G or P222W.

All tanks will be designed to ASME VIII, API, or AWWA and all codes and standards referenced in specification P223A or P223F.

All piping will be designed to ANSI B.31.1.0 or ASME III, as applicable, and all codes and standards referenced in specification P301B.

All other system components will be designed to all codes and standards referenced in the specification(s) in Section 7.02.

1.2.3 Specific Requirements

The river water subsystem shall be designed to permit the removal of any one of the mechanical components without requiring the shutdown of the power generating unit.

2.0 SYSTEM DESIGN

2.1 Detailed System Description

Refer to Flow Diagram 12919.01-EM-110A.

A full capacity, vertical, 9,000 gpm makeup pump is provided. The pump delivers river water from the makeup pump house to the cooling tower. Three pumps are located in the pump house, two existing and one new. The existing makeup line from the pump house to the existing unit cooling tower will be extended to serve the tower of this unit.

A motor-operated discharge valve is provided to open automatically when the makeup pump is started.

The pump will be tied into the existing unit makeup line and will supply makeup water to the cooling tower basin through the level control valve.

A motor-operated strainer is provided at the discharge of the makeup pump. The strainer is supplied with automatic backwash control to permit intermittent backflushing. The control consists of a pneumatic cylinder-operated ball valve which is actuated by a pressure differential.

2.2 Performance Characteristics

The performance characteristics of the system components are as included in the amended specifications, manufacturers' drawings, instructions and/or operation books referenced in Section 7.02.

2.3 Arrangement

The schematic piping and wiring arrangement is as noted on the flow diagrams and elementary diagrams referenced in Sections 7.03 and 7.08, respectively.

The physical arrangement of the system, machinery, and other equipment is as noted on the piping, machine location, and manufacturers' drawings referenced in Sections 7.07, 7.06, and 7.02, respectively.

2.4 Component Design

The bases of design of each component are as included in the specification(s) and the manufacturer's drawings, specifications, and/or information referenced in Section 7.02.

2.5 Instrumentation and Controls

2.5.1 General

The specific design of the instrument and control components are as described in the specification and shown on the drawings referenced in the instrument schedule for that component.

A description of the system control and monitoring functions shall be as shown and described in the logic diagrams and control descriptions referenced in Section 7.04.

2.5.2 Testability

All standby components can be tested to prove operability.

Standby and operating equipment are alternated periodically.

2.5.3 Specific Regulatory Requirements

There are no regulatory requirements specifically applicable to the makeup water system.

2.6 System Interfaces

The makeup water system interfaces with the following other plant systems:

<u>System Title</u>	<u>System Number</u>
Circulating Water	2-1

3.0 SYSTEM LIMITATIONS, SET POINTS, AND PRECAUTIONS

Refer to the loop and logic diagrams for the set point of any specific instrument.

4.0 SYSTEM OPERATION

4.1.1 Fill and Start-up

During initial fill and after a system shutdown, one of the makeup pumps should be started with its discharge valve closed. The motor-operated discharge valve should be jogged opened to fill the piping system and prevent system water hammer. When the system is filled, the discharge valve control switch on all pumps should be placed in the AUTO position.

4.1.1 Normal Operation

One manually started makeup pump is normally running. When the common pump discharge header pressure drops below the set point, it is annunciated in the control room, and the second automatic standby pump starts a second pump. The discharge valve of the second pump will automatically open in response to the pump starting.

When pump flow decreases below the low flow set point, it is annunciated and the operator should secure one of the operating pumps. The discharge valve of that pump will automatically close.

SHOULD THE SECOND PUMP BE REQUIRED TO START MORE THAN (LATER) TIMES PER (LATER), IT SHOULD BE LEFT IN THE RUNNING MODE FOR (LATER), OR UNTIL ATMOSPHERIC CONDITIONS CHANGE TO PRECLUDE THE RESTART OF THE SECOND FOR (LATER).

4.1.3 Shutdown

The makeup pumps may be shut down only if both units are shut down and some other unit in the plant is in operation. If all units are shut down, one of the makeup pumps must be left in service to assure that river water is available to the site.

5.0 SAFETY FEATURES FOR POTENTIAL EMERGENCIES

Not applicable

6.0 SYSTEM MAINTENANCE

All system components should be maintained in accordance with the manufacturers' operating, instruction, and/or maintenance books.

7.0 APPENDIX

7.01 General

7.01.1 Summary of Design Conditions

7.01.2 Line Designation Table

7.01.3 Instrument Schedule

7.02 Specification(s) /Purchase Order (s) /Manufacturers' Print Prefix

P121D	Water Screens
P222G	Miscellaneous Vertical Centrifugal Pumps
P301B	Shop-Fabricated Piping
P301N	Design and Fabrication of Piping Supports
P302E	Carbon Steel Valves 2 1/2 In. and Larger
P302H	Forged Steel Valves 2 In. and Smaller
P302P	Motor-Operated Carbon Steel Valves 2 1/2 In. and Larger

7.03 Flow Diagrams

<u>Number</u>	<u>Title</u>
12919.01-EM-110A	Circ. Water and Cond. Air Removal

7.04 Logic Diagrams

<u>Number</u>	<u>Title</u>
Later	Later

7.05 Loop Diagrams

<u>Number</u>	<u>Title</u>
Later	Later

7.06 Machine Location Drawings

<u>Number</u>	<u>Title</u>
12919.02B-EM-203	Turbine Area Machine Locations
12919.02B-EM-202	Boiler Area Machine Locations

7.07 Piping Drawings

<u>Number</u>	<u>Title</u>
12919.02B-EP-202	Boiler Area Piping Composites

7.08 Electrical Diagrams

<u>Number</u>	<u>Title</u>
Later	Later

7.09 Engineering Sketches and Other Information

7.09.1 Heat Balances

<u>Number</u>	<u>Title</u>
12919.02B-HBSK-1	Turbine VWO
12919.02B-HBSK-2	75% Turbine VWO
12919.02B-HBSK-3	50% Turbine VWO
12919.02B-HBSK-4	25% Turbine VWO

8.09.2 Stress Analysis

S7.09.3 Other

J.O. No. 12919.02B

October, 1977

SYSTEM DESCRIPTION 17-1
BED LETDOWN AND DISPOSAL - FWEC
ERDA-AFB STUDY

1.0 SYSTEM REQUIREMENTS

1.1 Function

The bed letdown system transports cooled spent bed material collected from the main cells, either to the silos or to carbon burnup cell makeup. Bed material collected from the carbon burnup cell is transported directly to waste (silos).

1.2 Design Requirements

1.2.1 General

The bed letdown system is designed for reliable power generation.

1.2.2 Codes and Standards

The bed letdown system piping will be designed to the ash handling manufacturer's standard.

All other system components will be designed to the codes and standards referenced in the specification(s) in Section 7.02.

1.2.3 Specific Requirements

The bed letdown system will be designed to remove bed letdown material at the rate of 150 tons per hour.

2.0 SYSTEM DESIGN

2.1 Detailed System Description

Refer to Flow Diagram 12919.02B-EM-120A.

The bed letdown system consists of a double header extending from the blowers to the silos.

Three blowers, two running and one standby, convey the ash from bed letdown holding tanks via air lock devices to two silos. Ash flow is controlled by rotary feeders located under each bed material cooler.

A single carbon burnup cell makeup blower is used to supplement the carbon burnup cell.

Each header has the capability to supply ash to either silo.

Fluidizing blowers are supplied with the silos to provide air when removing ash from the silos.

2.2 Performance Characteristics

The performance characteristics of the system components are as included in the amended specifications, manufacturers' drawings, instructions, and/or operation books referenced in Section 7.02.

2.3 Arrangement

The schematic piping arrangement and instrumentation are as noted on the flow diagrams and loop diagrams referenced in Sections 7.03 and 7.05, respectively.

The physical arrangement of the system, machinery, and other equipment is as noted on the piping, machine location, and manufacturers' drawings referenced in Sections 7.07, 7.06, and 7.02, respectively.

2.4 Component Design

The bases of design of each component are as included in the specification(s) and the manufacturers' drawings, specifications, and/or information referenced in Section 7.02.

2.5 Instrumentation and Controls

2.5.1 General

The specific design of the instrument and control components is as described in the specification and shown on the drawings referenced in the instrument schedule for that component.

The description of the system control and monitoring functions shall be as shown and described in the logic diagrams and control descriptions referenced in Section 7.04.

2.5.2 Testability

All bed letdown system components are normally in service.

2.5.3 Specific Regulatory Requirements

There are no regulatory requirements specifically applicable to the bed letdown system.

2.6 System Interfaces

The system interfaces with the following other plant systems:

<u>Title</u>	<u>Number</u>
Fly Ash Collection and Disposal	17-2
Carbon Collection and Reinjection	17-3

3.0 SYSTEM LIMITATIONS, SET POINTS, AND PRECAUTIONS

Refer to the loop and logic diagrams for the set point of specific instruments.

4.0 SYSTEM OPERATION

Refer to ash handling manufacturers' operating instructions for operation of the bed letdown system.

5.0 SAFETY FEATURES FOR POTENTIAL EMERGENCIES

Not applicable.

6.0 SYSTEM MAINTENANCE

All system components should be maintained in accordance with the manufacturers' operating instruction and/or maintenance books.

7.0 APPENDIX

7.01 General

7.01.1 Summary of Design Conditions

7.01.2 Line Designation Table No. later

7.01.3 Instrument Schedule

7.02 Specification(s) Purchase Orders/Manufacturers'
Drawing Prefix

<u>Number</u>	<u>Title</u>
P301B	Shop Fabricated Piping
P301C	Field Erection of Piping
P301N	Design and Fabrication of Piping Supports
-	Ash Handling Equipment

7.03 Flow Diagram

<u>Number</u>	<u>Title</u>
12919.02B-EM-120A	Bed Letdown and Disposal System

7.04 Logic Diagrams

<u>Number</u>	<u>Title</u>
Later	

7.05 Loop Diagrams

<u>Number</u>	<u>Title</u>
Later	

7.06 Machine Location Drawings

<u>Number</u>	<u>Title</u>
12919.02B-EM-202	Boiler Area Machine Locations
12919.02B-EM-203	Turbine Area Machine Locations

7.07 Piping Drawings

<u>Number</u>	<u>Title</u>
12919.02B-EP-202	Boiler Area Piping Composites

7.08 Electrical Drawings

<u>Number</u>	<u>Title</u>
12919.02B-EE-612A,B,C	Cable Tray Arrangements Boiler Area

7.09 Engineering Sketches and Other Information

7.09.1 Heat Balances

<u>Number</u>	<u>Title</u>
12919.02B-HBSK-1	Turbine VWO
12919.02B-HBSK-2	75% Turbine VWO
12919.02B-HBSK-3	50% Turbine VWO
12919.02B-HBSK-4	25% Turbine VWO

7.09.2 Stress Analysis

7.09.3 Other

SYSTEM DESCRIPTION 17-2
FLY ASH COLLECTION AND DISPOSAL - FWEC
ERDA-AFB STUDY

1.0 SYSTEM REQUIREMENTS

1.1 Function

The Fly Ash Collection System collects ash from the carbon burnup cell dust collectors, fabric filters, air preheater, and stack hoppers and pneumatically transports it to a pair of silos.

1.2 Design Requirements

1.2.1 General

The Fly Ash Collection System is designed for reliable power generation.

1.2.2 Codes and Standards

The Fly Ash Collection System piping will be designed to the ash handling manufacturer's standard.

All other system components will be designed to the codes and standards referenced in the specification(s) in Section 7.02.

1.2.3 Specific Requirements

The Fly Ash Collection System will be designed to remove fly ash material at the rate of 76 tons per hour.

2.0 SYSTEM DESIGN

2.1 Detailed System Description

Refer to flow diagram 12919.02B-EM-120C.

The Fly Ash Collection System consists of two full-size vacuum-pressure systems each consisting of two pressure blowers, primary and secondary collectors, two vacuum producers, and a silo. One system will serve the CBC dust collectors, while the other serves the fabric filters, stack, and air preheater. Each system has the capability to convey the entire ash flow should one become inoperable.

Two separate disposal lines lead out to the silos. Each disposal line has the capability to supply either silo.

Fluidizing blowers are supplied with the silos to provide air assist removing ash from the silos.

2.2 Performance Characteristics

The performance characteristics of the system components are as included in the amended specifications, manufacturer's drawings, instructions, and/or operation books referenced in Section 7.02.

2.3 Arrangement

The schematic piping arrangement and instrumentation is as noted on the flow diagrams and loop diagrams referenced in Sections 7.03 and 7.05, respectively.

The physical arrangement of the system, machinery, and other equipment is as noted on the piping, machine location, and manufacturer's drawings referenced in Section 7.07, 7.06, 7.02, respectively.

2.4 Component Design

The bases of design of each component are as included in the specification(s), the manufacturer's drawings specifications, and/or information referenced in Section 7.02.

2.5 Instrumentation and Controls

2.5.1 General

The specific design of the instrument and control components are as described in the specification and shown on the drawings referenced in the instrument schedule for the component.

The description of the system control and monitoring functions shall be as shown and described in the logic diagrams and control descriptions referenced in Section 7.04.

2.5.2 Testability

All Fly Ash Collection System components are normally in service.

2.5.3 Specific Regulatory Requirements

There are no regulatory requirements specifically applicable to the Fly Ash Collection System.

2.6 System Interfaces

The system interfaces with the following other plant systems:

<u>Title</u>	<u>Number</u>
Bed Letdown and Disposal	17-1
Carbon Collection and Reinjection	17-3

3.0 SYSTEM LIMITATIONS, SET POINTS, AND PRECAUTIONS

Refer to the loop and logic diagrams for the set point of specific instruments.

4.0 SYSTEM OPERATION

Refer to ash handling manufacturer's operating instructions for operation of the Fly Ash Collection System.

5.0 SAFETY FEATURES FOR POTENTIAL EMERGENCIES

Not applicable.

6.0 SYSTEM MAINTENANCE

All system components should be maintained in accordance with the manufacturer's operating instruction and/or maintenance books.

7.0 APPENDIX

7.01 General

7.01.1 Summary of Design Conditions

7.01.2 Line Designation Table No. (Later)

7.01.3 Instrument Schedule

7.02 Specification(s) Purchase Orders/Manufacturer's
Drawing Prefix

<u>Number</u>	<u>Title</u>
P301B	Shop-Fabricated Piping
P301C	Field Erection of Piping
P301N	Design and Fabrication Of Piping Supports
-	Ash Handling Equipment

7.03 Flow Diagrams

<u>Number</u>	<u>Title</u>
12919.02B-EM-120C	Fly Ash Collection and Disposal

7.04 Logic Diagrams

<u>Number</u>	<u>Title</u>
Later	

7.05 Loop Diagrams

<u>Number</u>	<u>Title</u>
Later	

7.06 Machine Location Drawings

<u>Number</u>	<u>Title</u>
12919.02B-EM-202	Boiler Area Machine Locations
12919.02B-EM-203	Turbine Area Machine Locations

7.07 Piping Drawings

<u>Number</u>	<u>Title</u>
12919.02B-EP-202	Boiler Area Piping Composites

7.08 Electrical Drawings

<u>Number</u>	<u>Title</u>
12919.02B-EE-612A,B,C	Cable Tray Arrangements, Boiler Area

7.09 Engineering Sketches and Other Information

7.09.1 Heat Balances

<u>Number</u>	<u>Title</u>
12919.02B-HBSK-1	Turbine VWO
12919.02B-HBSK-2	75% Turbine VWO
12919.02B-HBSK-3	50% Turbine VWO
12919.02B-HBSK-4	25% Turbine VWO

7.09.2 Stress Analysis

7.09.3 Other

J.O. No. 12919.02B

October, 1977

SYSTEM DESCRIPTION 17-3
CARBON COLLECTION AND REINJECTION - FWEC
ERDA-AFB STUDY

1.0 SYSTEM REQUIREMENTS

1.1 Function

The carbon collection and reinjection system transports fly ash of high carbon content collected in the main bed dust collectors and economizer hoppers and pneumatically conveys it to the carbon burnup cell for carbon utilization.

1.2 Design Requirements

1.2.1 General

The carbon collection and reinjection system is designed for reliable power generation.

1.2.2 Codes and Standards

The carbon collection and reinjection system is designed to the ash handling manufacturer's standard.

All other system components will be designed to the codes and standards referenced in the specification(s) in Section 7.02.

1.2.3 Specific Requirements

The carbon collection and reinjection system will be designed to convey high carbon fly ash at the rate of 77 tons per hour to the CBC.

2.0 SYSTEM DESIGN

2.1 Detailed System Description

Refer to flow diagram 12919.02B-EM-120B.

The carbon collection and reinjection system consists of a double supply header extending from the blowers to the CBC.

Three blowers, two running and one standby, convey the ash collected in the main bed dust collector and economize hoppers to the CBC.

Each header ties into a first level distributor box with seven outlets. Each of these lines feeds a second level distributor box with eight outlets. This results in a total of 112 lines feeding the CBC.

2.2 Performance Characteristics

The performance characteristics of the system components are as included in the amended specifications, manufacturers' drawings, instructions, and/or operation books referenced in Section 7.02.

2.3 Arrangement

The schematic piping arrangement and instrumentation is as noted on the flow diagrams and loop diagrams referenced in Sections 7.03 and 7.05, respectively.

The physical arrangement of the system, machinery, and other equipment is as noted on the piping, machine location, and manufacturers' drawings referenced in Sections 7.07, 7.06, and 7.02, respectively.

2.4 Component Design

The bases of design of each component are as included in the specification(s) and the manufacturer's drawings, specifications, and/or information referenced in Section 7.02.

2.5 Instrumentation and Controls

2.5.1 General

The specific design of the instrument and control components are as described in the specification and shown on the drawings referenced in the instrument schedule for that component.

The description of the system control and monitoring functions shall be as shown and described in the logic diagrams and control descriptions referenced in Section 7.04.

2.5.2 TESTABILITY

All carbon collection and reinjection system components are normally in service.

2.5.3 Specific Regulatory Requirements

There are no regulatory requirements specifically applicable to the carbon collection and reinjection system.

2.6 System Interfaces

The system interfaces with the following other plant systems:

<u>TITLE</u>	<u>NUMBER</u>
Fly Ash Collection and Disposal	17-2
Bed Letdown and Disposal	17-1

3.0 SYSTEM LIMITATIONS, SET POINTS, AND PRECAUTIONS

Refer to the loop and logic diagrams for the set point of specific instruments.

4.0 SYSTEM OPERATION

Refer to ash handling manufacturer's operating instructions for operation of the carbon reinjection system.

5.0 SAFETY FEATURES FOR POTENTIAL EMERGENCIES

Not Applicable

6.0 SYSTEM MAINTENANCE

All system components should be maintained in accordance with the manufacturer's operating instruction and/or maintenance books.

7.0 APPENDIX

7.01 General

7.01.1 Summary of Design Conditions

7.01.2 Line Designation Table No. (Later)

7.01.3 Instrument Schedule

7.02 Specification(s) Purchase Order/Manufacturer's
Drawing Prefix

NUMBER

TITLE

P301B

Shop-Fabricated Piping

P301C

Field Erection of Piping

P301N

Design and Fabrication of

Piping Supports

-

Ash Handling Equipment

7.03 Flow Diagrams

Number

Title

12919.02B-EM-120B

Carbon Collection and
Reinjection

7.04 Logic Diagrams

Number

Title

Later

7.05 Loop Diagrams

Number

Title

Later

7.06 Machine Location Drawings

Number

Title

12919.02B-EM-202

Boiler Area Machine
Locations

12919.02B-EM-203

Turbine Area Machine
Locations

7.07 Piping Drawings

Number

Title

Later

7.08 Electrical Drawings

Number

Title

12919.02B-EE-612A,B,C

Cable Tray Arrangements
Boiler Area

7.09 Engineering Sketches and Other Information

7.09.1 Heat Balances

Number

Title

12919.02B-HBSK-1

Turbine VWO

12919.02B-HBSK-2

75% Turbine VWO

12919.02B-HBSK-3

50% Turbine VWO

12919.02B-HBSK-4

25% Turbine VWO

7.09.2 Stress Analysis

7.09.3 Other

J.O.No. 12919.02B

October 1977

SYSTEM DESCRIPTION 19-3
SECONDARY AIR AND FLUE GAS - FWEC
ERDA AFB STUDY

1.0 SYSTEM REQUIREMENTS

1.1 Function

The function of the Secondary Air and Flue Gas System is twofold:

1. Supply heated air to the boiler for combustion.
2. Remove the flue gas from the boiler and particulate from the flue gas before being discharged to the stack.

1.2 Design Requirements

1.2.1 General

The Secondary Air and Flue Gas System will be designed for reliable power generation.

1.2.2 Codes and Standards

All system components will be designed to all codes and standards referenced in the Specification(s) in Section 7.02.

1.2.3 Specific Requirements

The forced draft (F.D.) fans shall be capable of supplying 4,656,000 lb of air per hour at 600 F to the boiler at turbine valves wide open (VWO) conditions.

The mechanical collectors and fabric filters shall be capable of meeting the current Federal Standard for particulate emission of 0.1 lb/10⁶ Btu of heat input.

The induced draft (I.D.) fans shall be capable of supplying 5,953,000 lb of flue gas per hour at 300 F to the stack at turbine VWO conditions.

2.0 SYSTEM DESIGN

2.1 Detailed System Description

Refer to Flow Diagram 12919.02B-EM-115A.

The Secondary Air portion of the system has two half-capacity F.D. fans to take outside air from a fan room and discharge the air into a regenerative air heater (APH). The APH heats the combustion air before discharging it through ductwork to the undergrid plenums of the main beds and CBC.

Two steam/air heaters are provided upstream of the APH to maintain the average cold end temperature of the APH and minimize corrosion. Air flow is regulated by adjusting the inlet (suction) vanes on the F.D. fans. The F.D. fans also supply air to the bed letdown cooler booster fans which are used to supply cooling air to remove heat from the spent bed material.

The Flue Gas portion of the system has a mechanical collector in the ductwork from the main beds and the CBC. The mechanical collector in the gas stream from the main beds is used to reduce particulate emissions and to recapture any unburned carbon that may have become entrained in the flue gas. The recaptured carbon is reinjected into the CBC portion of the boiler to increase boiler efficiency and reduce fuel costs.

The mechanical collector in the gas stream from the CBC is used to reduce particulate emissions.

The flue gas enters the APH and transfers heat to the secondary air before entering the fabric filter.

The fabric filter is used to further reduce the emissions that may reach the stack.

Two half-capacity centrifugal type I.D. fans pull the flue gas from the boiler through the preceding equipment and discharge to atmosphere via the stack. Flue gas flow is regulated by adjusting the inlet vanes on the I.D. fans.

2.2 Performance Characteristics

The performance characteristics of the system components are as included in the specifications, manufacturer's drawings, instructions, and/or operation books referenced in Section 7.02.

2.3 Arrangement

The piping schematic, electrical schematic, and instrumentation arrangement are as noted on the flow diagrams, elementary diagrams, and loop diagrams referenced in Sections 7.03, 7.08, and 7.05, respectively.

The physical arrangement of the system, machinery, and other equipment is as noted on the piping, machine location, and manufacturer's drawings referenced in Sections 7.07, 7.06, and 7.02, respectively.

2.4 Component Design

The bases of design of each component are as included in the specification(s) and the manufacturer's drawings, specifications, and/or information referenced in Section 7.02.

2.5 Instrumentation and Controls

2.5.1 General

The specific designs of the instrument and control components are as described in the specification and shown on the drawings referenced in the Instrument Schedule.

The description of the system control and monitoring functions shall be as shown and described in the logic diagrams and control descriptions referenced in Section 7.04.

2.5.2 Testability

Later

2.5.3 Specific Regulatory Requirements

None

2.6 System Interfaces

The Secondary Air and Flue Gas System interfaces with the following systems:

<u>System Title</u>	<u>System Number</u>
Bed Letdown and Disposal	17-1
Fly Ash Collection and Disposal	17-2
Carbon Collection and Reinjection	17-3

3.0 SYSTEM LIMITATIONS, SET POINTS, AND PRECAUTIONS

Refer to the loop and logic diagrams for the set point of specific instrumentation.

4.0 SYSTEM OPERATION

Later

5.0 SAFETY FEATURES FOR POTENTIAL EMERGENCIES

Not applicable

6.0 SYSTEM MAINTENANCE

All system mechanical components are to be maintained in accordance with the operation and maintenance instructions submitted in accordance with the component specification listed in Section 7.02.

7.0 APPENDIX

7.0.1 General

7.01.1 Summary of Design Conditions

7.01.2 Line Designation Table

Later

7.01.3 Instrument Schedule

7.02 Specification(s)/Purchase Orders

12919.02B-P212C Forced Draft and Induced Draft Fans -
Centrifugal

12919.02B-P212D Drives for Forced Draft and Induced
Draft Fans

7.03 Flow Diagrams

<u>Number</u>	<u>Title</u>
12919.02B-EM-115A	Combustion Air and Flue Gas

7.04 Logic Diagrams

<u>Number</u>	<u>Title</u>
Later	

7.05 Loop Diagrams

<u>Number</u>	<u>Title</u>
Later	

7.06 Machine Location Drawings

<u>Number</u>	<u>Title</u>
12919.02B-EM-202A,B	General Arrangement Boiler Area

7.07 Piping Drawings

<u>Number</u>	<u>Title</u>
12919.02B-EP-202A-H	Composite Boiler Area

7.08 Electrical Drawings

12919.02B-EW-1A

Main One Line Diagram

7.09 Engineering Sketches

None

APPENDIX IIIB-C

FOSTER WHEELER ENERGY CORPORATION FINAL REPORT

CONCEPTUAL DESIGN for an ATMOSPHERIC FLUIDIZED BED STEAM GENERATOR

PREPARED FOR

STONE & WEBSTER ENGINEERING CORPORATION

PRIME CONTRACTOR FOR

UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

UNDER

CONTRACT NO. EF-77-C-01-2583

PREPARED BY

FOSTER WHEELER ENERGY CORPORATION

PROJECT MANAGER: K. A. REED

STONE & WEBSTER ENGINEERING CORPORATION CONTRACT # E.C.C.3
FOSTER WHEELER ENERGY CORPORATION CONTRACT # 2-43-3075

NOVEMBER 1977

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Section 1

EXECUTIVE SUMMARY

Foster Wheeler Energy Corporation (FWEC) is pleased to submit the results of this conceptual study to Stone & Webster Engineering Corporation for the design and budget estimate for a 570 MW atmospheric fluidized bed steam generator. The results of this study indicate that a large central station steam generator utilizing the fluid bed combustion process can be designed, constructed and operated in a fashion similar to an equivalent pulverized coal unit. Foster Wheeler has selected the Once-Through-cycle stacked bed arrangement with the overbed feed system as the optimum design for simplicity of operation, minimum cost and maximum unit availability. With the inherent advantages of the fluidized bed steam generator, as listed below, it will be the replacement of the pulverized coal/scrubber system in the future:

- Reduced capital and annual operating costs.
- Reduced emissions of sulfur dioxide (SO_2) with the combustion of coal in the bed of limestone.
- Reduced emissions of nitrogen dioxide (NO_x) due to the low combustion temperatures.
- Reduced heat transfer surface with the tubing immersed into the fluidized bed zone.

Foster Wheeler Energy Corporation, as a leader in the technology of fluidized bed combustion, and based on its present design and operating experience from existing fluidized bed facilities, offers the results of this report as a viable design for generating steam using high sulfur coal.

570 MW AFB
STEAM GENERATOR
FIGURE 1-1

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1.1 CORPORATE EXPERIENCE

Foster Wheeler has been supplying design services and equipment to the steam power industry since the turn of the century. In the interest of strengthening its contribution to the efficient use of energy resources, Foster Wheeler organized the Foster Wheeler Energy Corporation (FWEC), effective October 1, 1974. FWEC, through its Equipment, Process Plants, and Fired Heater Divisions, provides design, manufacturing and construction capability for steam generators for the production of electric power, industrial processes and ship propulsion; for process plants to produce fuels and chemicals; and for specialized allied equipment, such as fired heaters and nuclear power components.

To strengthen its efforts in energy research and development, Foster Wheeler further reorganized the FWEC Research Division into a separate corporation, effective January 1, 1977. Foster Wheeler Development Corporation (FWDC) is now FW's worldwide research and development center. In addition to a continuation of present services covering a wide spectrum of mechanical, chemical and materials engineering, FWDC will concentrate its efforts on various energy applications.

Foster Wheeler Energy Corporation has been concerned with fluidized bed technology for many years, first as part of a pure research program, literature surveys of the technical press, both national and international, then by making bench top and pilot plant investigations and by the critical

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examination of overseas and domestic experiences. The Corporation has designed and built more than thirty (30) fluidized bed furnaces for process or chemical use and has also conducted flow model tests, heat transfer studies and other similar endeavors that provided the Corporation with an extended matrix of design parameters used for units being engineered, fabricated, constructed or operated. We have been intimately involved with demonstration size fluidized bed units made for various branches of the United States government research facilities and have been successful in obtaining a contract for a demonstration size fluidized bed steam generator designed for 300,000 lb/hr of steam at 1350 psi and 925F that has been built at Rivesville, West Virginia. Most recently we have been awarded a contract for design, engineering, fabrication, erection and testing of a 100,000 lb/hr saturated steam, 625 psig industrial size boiler for Georgetown University. This contract is presently in the fabrication phase with initial operation expected in March 1979.

1.2 OBJECTIVE

The objective of this program was to develop a preliminary design for a 570 MW atmospheric fluidized bed (AFB) steam generator with its ancillary equipment which will be capable of combusting high sulfur coal in an environmentally acceptable manner without recourse to flue gas desulfurization. This preliminary design will be of sufficient detail to describe the technical feasibility and costs associated with the AFB steam generator and equipment.

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1.3 SCOPE OF SUPPLY

The conceptual design study includes the preliminary design of the atmospheric fluidized bed steam generator including the following ancilliary systems:

Combustion air and flue gas system from the forced draft fan inlet to the induced draft fan outlet including:

- Fans, silencers and drives
- Air duct, gas flues with insulation and lagging as required
- Supports and hangers
- Regenerative air heaters with drives
- Steam coil air heaters

Materials handling systems including:

- Coal feed system from the coal feeder inlet
- Limestone feed system from the feed pipe inlet flange
- Bed letdown/cooler system terminating at the cooler outlet flange
- Bed material recycle system to the carbon burnup cell
- Mechanical and electrostatic or baghouse fly ash collectors with insulation and lagging.

Steam generator systems including:

- Steam generating surface
- Safety and relief valves
- Start-up system including piping and valves
- Miscellaneous drain and vent valves with piping
- Insulation and lagging
- Ignition system
- Steam temperature controls
- Combustion controls
- Furnace safety and fuel automation system
- Steel limited to buckstay and stiffening and top support steel
- Sootblower system as required.

The following equipment is beyond the scope of this study:

Foundations and supporting structural steel
Steam generator building
Coal and limestone crushing, drying, conveying systems
and silos
Platforms, walkways and stairs
Utilities
Bed letdown disposal system after coolers
Chimney
Electrical systems and devices
Civil work
Utility and control piping
Feedwater treatment systems
Feedwater heaters and main feed pumps
Main steam, reheat, feedwater piping and supports
Ash handling systems

1.4 FUEL AND SORBENT ANALYSIS

AFB Steam Generator design is based on the performance fuel. All equipment has been designed to operate at the 100% load condition using the worst case coal.

1.4.1 Coal Analysis

<u>Ultimate Analysis (%)</u>	<u>Performance Coal</u>	<u>Worst Coal</u>
Total Moisture	13.55*	13.55*
Ash	10	15
Carbon	61.15	55.4
Hydrogen	4.27	3.87
Nitrogen	1.21	1.10
Oxygen	7.27	6.58
Chlorine	0	0
Sulfur	2.55	4.5
	<u>100.00</u>	<u>100.00</u>
Higher Heating Value BTU/lb (as received)	11,081	10,160
Grindability, Hardgrove Size, Inch	55 -1½	66 -1½

*Includes 11% surface moisture

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Sieve Analysis

100%	-1 $\frac{1}{2}$ inch
45%	- $\frac{1}{4}$
35%	-1/8
25%	-1/16

Ash Analysis

<u>Basis</u>	<u>Wt. Percent Range - Dry</u>
P ₂ O ₅	0.15 - 0.18
S ₂ O ₃	35.32 - 44.12
Fe ₂ O ₃	23.80 - 25.20
Al ₂ O ₃	18.57 - 23.85
TiO ₂	0.69 - 0.93
CaO	2.25 - 8.75
NaO	0.58 - 0.8
K ₂ O	1.55 - 2.93
MgO	0.7 - 1.04
SO ₃	0.6 - 9.26
R ₂ O	0.0 - .05
Initial Deformation	1900 - 2240F
Softening	1980 - 2240F
Liquid	2280 - 2750F

1.4.2 The system design and performance has been based on the following limestone sample:

Sorbent Analysis (% by weight)

CaCO ₃	86.6
MgCO ₃	3.0
R ₂ O ₃	0.6
Moisture	9.8*

*Includes 8% surface moisture

Sieve Analysis

100%	-3/4 inch
60-90%	-1/2 inch
35-60%	-4 mesh
10-30%	-30 mesh
1-10%	-200 mesh

1.5 PERFORMANCE

The performance of the proposed 570 MW AFB steam generator is as follows:

● Steam capacity (M lb/hr)	3977
● Pressure, superheater outlet (lb/in ² g)	2620
● Temperature, superheater/reheater outlet (F)	1005/1005
● Temperature, feed entering unit (F)	481
● Coal feed rate (M lb/hr)	488.9
● Limestone feed rate (M lb/hr)	94.4
● Particulate emissions (MM Btu)	0.0242
● SO ₂ emissions (MM Btu)	1.1562
● NO _x emissions (MM Btu)	0.3069
● CO emission (MM Btu)	0.04
● HC emission (MM Btu)	0.01

1.6 COSTS

The costs (based on mid 1977 dollars) of design, procurement, fabrication and delivery of a 570 MW AFB steam generator including all equipment as outlined under the scope of equipment, Section 1.3, is estimated at \$33,670,000. Erection of this equipment at an undetermined site is estimated at 650,000 manhours exclusive of the erection of the baghouse dust collector for which the erection costs are included in the equipment price.

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The above equipment cost estimate results in a cost of \$59.00 per kilowatt and if construction costs are assumed at \$20.00 per man-hour, the construction cost will be \$23.00 per kilowatt. This results in an overall delivered and erected cost of the AFB system of \$82.00 per kilowatt. A present day natural circulation pulverized coal system with similar scope of supply will result in an equipment cost of \$67.00 per kilowatt and a construction cost of approximately \$34.00 per kilowatt for a total of \$101.00 per kilowatt. This represents approximately a 19% cost reduction for the AFB system when compared to a pulverized coal unit without the application of scrubber systems for emission control. The primary reason for the significant cost savings indicated above are the reduction in cost due to the use of a once-through steam cycle and simplification of the fuel feeding system.

Section 2

OVERALL PLANT DESIGN BASIS

(TASK 4210)

2.1 EQUIPMENT ARRANGEMENT AND SELECTION2.1.1 Physical Arrangement and Selection2.1.1.1 Steam Generator ArrangementA. Description

The AFB steam generator is comprised of five (5) main bed cells (MBC) and a single carbon burn-up cell (CBC). The MBCs are nominally 22 ft. in depth by 60 ft. in width, and are arranged in a vertical stack. Figure 2.1 depicts the arrangement of a typical MBC. Heat transfer surface is provided in each cell and is arranged for boiling, superheat and reheat duty. The MBCs operate at a bed temperature of 1550F. The CBC is located to the rear of the MBC stack and is sized nominally 60 ft. in width by 20 ft. in depth. The CBC is fitted with heat transfer surface within the bed to limit bed temperature to 1900F. Sectional side elevations and plan views of the MBCs and CBC are depicted in Figures 4.8, 4.9, 4.10 and 4.11.

Combustion air is introduced along each sidewall of the unit to the MBCs and the CBC into compartmented plenums beneath each cell and flows upward through the air distributors. The plenum chambers in the MBCs are conveniently formed by water-cooled surface which also serves to form adjacent cell roofs and air distributor sections.

FIGURE 2.1
TYPICAL MBC ARRANGEMENT

Fuel is fed along the front wall of the MBCs and limestone is fed at each rear corner of the MBCs.

Gases generated in the MBCs pass through the open freeboard above each bed and exit through a water-cooled screen along the upper rear wall of each cell. The gas from each cell rises through a common water-cooled gas column and is directed downward over convection reheater and superheater surface arranged in a parallel-pass heat recovery area (HRA). Reheater and superheater convection duty is adjusted by means of gas biasing dampers located in each pass of the HRA beneath the convection reheater and superheater. Gas exiting the biasing dampers passes over extended surface economizer whereupon it is reduced in temperature to 720F prior to entering the flue gas system. A hopper is provided beneath the economizer to drop out larger size particulate.

All sections of the steam generator, with the exception of the CBC air distributor, which come in contact with flue gas or active bed are water- or steam-cooled. The CBC grid is designed to be air-cooled due to mechanical considerations. Details of the CBC grid plate design are shown in Figure 4.14, while the MBC grid details are indicated in Figure 4.13.

B. Main Bed Cell (MBC) Arrangement

The MBCs are arranged in a vertical stack five (5) beds high. The exterior walls are of MonowallTM construction and are arranged to channel the steam generator loads to the supporting penthouse grid steel.

The unit is top supported in a conventional manner.

The vertical stack arrangement was selected for the AFB design for the following reasons:

- Minimum Plan Area Requirements
- Balanced Heat Flow to Boiler Circuit
- Simplified Circuitry and Mechanical Design

C. Main Bed Cell (MBC) Heating Surface

MBC heating surface is arranged in each cell in horizontal coils which traverse the cells across the 60 ft. dimension. Individual coils are balanced to maintain uniform heating across the bank. The compartmented plenums permit each cell to be fired in increments of one-quarter for turn-down purposes. The plenum compartments are positioned perpendicularly to the front wall of the unit and the horizontal coils, and as such, are 22 ft. in depth by 15 ft. in width. As a result of this arrangement, heat pick-up in a given circuit is always in a state of balance. Moreover, the balanced condition is insensitive to firing rate across the unit. Tube coils are supported above the grid by air-cooled stainless steel piers which run from front to rear across the air distributor. Tube bundles are strapped and caned in position using conventional techniques. These methods of tube support permit spanning the 60 ft. dimension without difficulty and provide for accurate placement of each tube, maintenance of required spacing and resistance to bed-induced vibration. The bed surface

is drainable as is the entire boiler circuit. Arrangement of surface can be seen in Figures 8.1 and 8.3.

D. Heat Recovery Area (HRA) Arrangement

The HRA utilized in the AFB design is conventional. The reheater is placed forward in the pass while the superheater is placed toward the rear. Convection duty is lower than in a comparably sized pulverized-coal (P-C) unit due to the dramatically lowered combustion exit temperature. As a result, the HRA is substantially smaller in size. Each pass of the HRA is no greater than 17 ft. in depth which permits tube coils to be supported without intermediate hangers. The cross-section, therefore, is varied by changing the width of the HRA in order to provide for proper gas velocities. It is important to note, however, that depth of the HRA could be increased by providing intermediate stringer supports. As such, the HRA could be adjusted in order to be compatible with other design constraints, as the case may be. HRA arrangement is depicted in Figure 8.1.

The flue gas velocity through the HRA is nominally 55 ft/sec in accordance with standard boiler design practice. This provides for optimum use of convection surface. This is contrasted with earlier tower designs in which convection surface placed above each cell was subject to rather low gas velocities, resulting in ineffective use of convection surface.

The HRA utilized in the present AFB design coupled with the arrangement of the MBCs results in optimum usage of heating surface and the

minimization of circuit headers and transfer lines.

Gas flow through the HRA is biased by means of automatic reheat temperature control dampers placed beneath the reheat and superheat convection surface. Gases leaving the dampers pass over an extended surface economizer and are cooled to 720F prior to entering the dust collection trains.

E. Combustion Air Inlets

Combustion air is fed to the unit along either side of the MBCs and the CBC. Four (4) inlets are provided for each cell to supply air individually to each of the segments. Control/shut-off dampers are provided in each of the supply ducts to individually regulate combustion air. Venturi measuring devices are provided in each duct to accurately measure the flow to each segment.

Air supply ducts are placed on either side of the unit in order to leave free and total access to the front wall for purposes of coal feed. The dual-inlet combustion air system also decreases the height required for the air plenum to limit air velocities to proper levels.

Combustor sidewall panels have been arranged to form the plenum floors and the air distributors at each level. This method of construction also provides for open access to the plenum chambers in each cell and permits the introduction of combustion air without the requirement of

bumping side wall tubes to provide for air inlets. Hot hangers are provided in the plane of the side wall at each penetration, however, the bulk of the dead loads are channeled to the front and rear walls bordering the combustors.

Arrangement of combustion air inlets and plenums are depicted in Figures 8.1, 8.2 and 8.3.

F. Carbon Burn-Up Cell (CBC) Arrangement

Combustion air is admitted to the CBC through a plenum chamber having four (4) compartments and flows upward through a refractory covered grid. CBC temperature is controlled at 1900F through means of water-cooled heating surface placed in the bed.

Carbonaceous flyash catch from the MBC dust collection train is the primary feedstock to the CBC. Flyash is injected pneumatically under the bed and is combusted in one pass through the bed. The operating temperature of 1900F provides for adequate carbon combustion while avoiding potential clinkering problems within the bed.

Supplemental coal firing to the CBC is provided for start-up purposes and to maintain temperature if conditions warrant.

Gases generated in the CBC flow upward through the freeboard and pass into convection surface placed in a cross-sectional constriction.

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which induces reasonably higher gas velocities than those present immediately above the bed. Gases exit the convection area and pass through mechanical dust collectors prior to entering the vertical shaft Ljungstrom airheaters. The flyash captured at the CBC exit is of no further value and is sent to waste.

Several CBC gas exit schemes were investigated prior to selection of the final design. The first arrangement routed CBC exhaust gases directly to the MBC gas pass and the HRA. This arrangement, however, led to extremely high recirculating dust loads in the HRA. A second arrangement was developed using high temperature mechanical collectors to remove flyash from the CBC exhaust gases prior to routing to the MBC gas pass. This arrangement, however, required the use of mechanical collectors designed for 2000F service. The final arrangement, described above, was selected since it eliminated the recirculating dust loading in the HRA and the need for high temperature mechanical separators. Details of the CBC are shown in Figure 8.1.

G. Feed System Arrangement - MBCs

Coal feed is provided along the front wall of the unit from a multiple outlet bunker through downspouts routed to conical coal distributors located along each level. Each conical distributor feeds a group of chain-type spreader feeders along the front wall of the unit. The coal feed system is indicated schematically in Figure 5.7. The spreader

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rotor is located 2ft.-9in. above the top of the expanded bed when measured at the rotor centerline. The spreaders are arranged to be operated independently in order to selectively fire bed segments at a given level. The throw pattern of the spreaders is such that large pieces of coal are thrown toward the rear wall of the combustors. Progressively smaller particles of coal concentrate toward the front wall of the unit.

Limestone feed is provided at the rear corners of each cell immediately above the expanded bed. Feed is metered gravimetrically and is introduced through pipes in free-fall, as shown schematically in Figure 5.8. The concentrated feed was selected to take advantage of the effect of the high CO_2 partial pressure in the region of the feed point and its effect on reducing explosion losses due to slower calcination rates. In addition, concentrated feed of limestone permits the control of the path of limestone from feed to drain, as shown in Figure 4.8, and promotes maximum utilization as a result of controlled residence within the bed. Bed material drains are provided along the front wall of the unit at four (4) locations at each level. The drains are designed in such a way as to burn-out residual carbon in the first stage and to cool the spent bed material to 250F in the second stage prior to disposal. The cooling medium utilized in the cooler/combustors is ambient temperature air, boosted in pressure from the forced draft (FD) fans. Since the outlet of the coolers is within the bed, the cooling air becomes one and the same as the combustion air and

all heat generated in the combustion and cooling of the spent bed is thereby returned to the system. Bed cooler details are shown in Figure 5.9.

The placement of the coal feeders, limestone injection ports and spent bed drains discussed above results in the following conditions being realized:

- Large coal particles are provided with maximum residence time in which to burn.
- Limestone explosion losses are minimized.
- Limestone residence time is maximized.
- Spent bed carbon loss is minimized.
- Spent bed sensible heat is returned to the system.
- Feed systems are drastically simplified while maintaining proper combustion considerations.

H. Feed System Arrangement - CBC

Primary feed to the CBC is provided from the catch of the mechanical dust collectors and economizer hoppers in the system. Flyash is transported pneumatically and injected under the CBC grid at multiple points, as described in Figure 5.4. The system is designed to fire one-quarter segments of the CBC independently and to maintain the dust hoppers in an empty condition.

Raw coal can be fed to the CBC by means of twelve (12) spreader stokers located along the rear wall of the CBC. Coal feed can be used

for start-up or supplementing flyash feed to the CBC, as required. Coal feed system schematic arrangement is described in Figure 5.7.

Fresh limestone feed is provided toward the front corners of the CBC, as shown in Figure 5.8, and may be used for maintaining bed level as well as initially charging the bed.

Provisions are included to inject spent bed material to the CBC toward the front corners of the cell for purposes of offsetting bed material attrition in the cell.

CBC drains, which essentially are duplicates of the MBC drains described previously, are provided along the rear wall of the unit to cool the CBC bed extraction prior to disposal. Under normal conditions, extraction of CBC bed material is not required.

The CBC feed system arrangement described provides for the following:

- Maximum system flexibility.
- Acceptable burn-up of carbon.
- Maximum utilization of bed material.
- Ease of start-up.

2.1.1.2 Air and Gas Side Equipment Arrangement

A. Description

Combustion air requirements of the AFB are furnished by two (2) centrifugal forced draft (FD) fans operating in parallel. The fans discharge through evase sections and thence through steam coil air heaters, which are used for start-up and to maintain airheater cold-end temperatures, as required. Combustion air is pre-heated on passing through two (2) vertical shaft Ljungstrom airheaters and passes through total combustion air measuring venturis prior to entering the MBC and CBC plenum chamber. Combustion air is admitted to the combustion zone through air distributors.

Product gases of combustion from the MBCs pass through the cell freeboard, the common gas column, the heat recovery area, and exit the boiler at the economizer outlet. Gases are directed through parallel trains of mechanical dust collectors for primary clean-up. Carbonaceous flyash captured in the collectors is injected pneumatically to the CBC. Gases exit the dust collectors and pass through the regenerative airheaters prior to entering the baghouse collectors for final clean-up. Gases leaving the baghouse collectors pass through two (2) induced-draft (ID) fans operating in parallel and exit through breeching to the stack.

Overall air and gas flow paths are indicated schematically in Figure 4.5. Physical equipment arrangement is show in Figures 8.4 and 8.5.

B. Forced Draft and Induced Draft Fans

The forced draft (FD) and induced draft (ID) fans selected for the AFB design are of the centrifugal type and operate in parallel. The fans are provided with system cross-overs to allow for operation of a given FD fan with either ID fan. The FD fans regulate total combustion air flow to the AFB while the ID fans hold draft above the beds at $-.1$ in. WG.

C. Air Preheaters

The two (2) air preheaters are of the Ljungstrom regenerative type and are arranged for vertical flow of air and gas. Steam coil airheaters are provided upstream of the regenerative airheaters to maintain cold-end average temperature, as required. Hoppers are provided under the airheaters on both the air and gas sides to catch and dispose of flyash or deluge water, as the case may be.

D. Mechanical Dust Collectors

Combustion gases exiting the HRA pass through flues which direct the flow through parallel trains of mechanical dust collectors. Based on expected dust particle size distribution leaving the AFB, manufacturers of such equipment have indicated that efficiencies better than 95% are attainable. The performance predicted for the AFB is based on 92% collection efficiency which is felt to be more realistic for this equipment.

The mechanical dust collectors serve to provide the source of carbon reinjection to the carbon burn-up cell (CBC) and thereby permit

achieving commercially acceptable carbon loss in the system.

The mechanical dust collectors are placed upstream of the regenerative airheaters and serve to minimize dust loading to the airheaters. This is an important consideration due to the extremely high dust loading which is experienced in the AFB and the associated potential for airheater pluggage.

E. Baghouse Dust Collectors

Baghouse dust collection is provided as the final gas clean-up element in the system. The baghouse modules are placed downstream of the airheaters and are arranged in two stacks which are two modules high.

Baghouse collection was selected due to the extremely high collection efficiencies which are possible and the insensitivity of baghouse collection to particle chemical composition. Investigations into the suitability of hot and cold precipitation for the AFB indicated that little data is available to support the use of precipitation for the AFB and as a result we cannot recommend the use of precipitators at this time. A detailed evaluation of dust collection systems is presented in Section 6 of this report.

2.1.1.3 Coal and Limestone System Arrangement

A. Description

Coal feed is introduced along the front wall of the MBCs and along the rear wall of the CBC by means of spreader feeders placed 2ft.-9in. above the top of the expanded bed. Coal is distributed to the twelve (12) feeders at each level by means of conical distributors arranged along each level, as described in Figure 5.7.

Limestone feed is arranged for introduction at three (3) points in each MBC level and two (2) points for the CBC, as show in Figure 5.8. Under normal conditions, limestone is fed along the side walls of the unit toward the rear of the MBCs and the front of the CBC.

B. Coal Feed System Arrangement

Coal feeders are located along the front wall of the unit and are fed by conical distributors.

Other than the bed material combustor/coolers which are arranged at each level along the front wall, steam/water headers, air supply ducts and transfer piping have been kept clear in order to provide ample clearance along the front wall for coal feed.

Coal feed is introduced to the unit in a direction perpendicular to that of the horizontal tubes located within the cells. In this manner heat input to a cell may be varied by regulating individual segments of a

cell or removing selected segments of a cell entirely. This technique of load control is termed SEGMENTAL FLUIDIZATION and as utilized in the AFB design provides for rapid load changes while maintaining uniform heat input across each tube bank in the system.

C. Limestone Feed System Arrangement

Limestone injection ports are located at positions along the sidewalls at each level away from the coal firing walls. The placement of the limestone injectors provides for maximum residence time of the sorbent since bed material extraction is accomplished along the front wall. Operation of the cells is such that, in conditions of start-up or turn-down, limestone feed to a given bed can be introduced from the outboard segments. In abnormal circumstances, limestone can be fed to a selected level at the centerline of the unit along the front wall. Limestone feed at the points discussed provides for operation of the unit under all possible conditions while maintaining a functionally reliable and uncomplicated feed system.

2.1.2 Once-Through Cycle Selection

An inherent advantage of fluidized bed combustion is the ability to obtain greatly increased heat transfer rates for convection surface located within the bed zone. Based on tests at the Rivesville, West Virginia, 30 MW Fluidized Bed demonstration facility and the Alexandria pilot unit of Pope, Evans and Robbins Inc., the convection heat transfer coefficient for tubes in a fluidized bed averages about 40 Btu per hour per sq. foot per degree Fahrenheit. With this high heat transfer rate there is an economic advantage in designing the fluid bed boiler with maximum surface in the fluid beds. The large furnace volume inherent in the design of conventional pulverized coal fired boilers is replaced by a plurality of fluid beds with heat transfer surface installed in these beds. However a minimum amount of convection superheat surface and reheat surface is needed outside of the fluid beds to permit rolling, bringing up to speed, and initial loading of the turbine. This convection surface is best placed in a separate cavity where flue gas velocities across the surface may be designed to be close to conventional velocities of from 50 to 65 ft. per second.

In the design of surface in the fluidized bed, sufficient tube to tube spacing must be allowed to provide for mixing in the bed for the one inch feed size used and the accumulation of over sized particles in the bed during operation. For the arrangement of surface in the bed, a horizontal run of tubes is the most practical. However because of this horizontal run of tubing in the bed, the circuitry must utilize high mass flows, especially in subcritical designs where a two phase mixture of steam

and water will route through these tubes in the bed. Because of these high mass flow requirements and the need to handle two phase mixtures, the boiler type to use should be either assisted circulation or once-through design.

Foster Wheeler has selected the once-through design as optimum for use with AFB Steam Generator for the following reasons:

2.1.2.1 Availability: Conventional Foster Wheeler pulverized coal fired steam generators utilizing the once-through cycle have had a history of excellent availability. Figure 2.2 attached illustrates recent availability data of the Pennsylvania Power, Mansfield Station, Public Service Indiana, Gibson Station, and the Monongahela Power, Harrison Station. These once-through units, all greater than 600 MW in capacity have exhibited availability substantially greater than industry averages, which include both drum and once-through designs of similar size.

2.1.2.2 Economical Considerations: Based on the increasing trend of fuel cost, higher efficiency cycles will be sought for the use of fossil fuel steam generators. The supercritical once-through cycle has been used for central stations both in the U.S. and abroad. The use of the supercritical Rankine cycle gives the highest efficiency without resorting to a combined cycle or a topping cycle. Its application is proven and reliable operation has been achieved as referenced in Figure 2.2.

However, in this study a subcritical cycle has been used by direction. Foster Wheeler has chosen the subcritical once-through unit, in lieu of an assisted circulation unit utilizing a steam drum, so that the resulting design would have an arrangement which would provide for easy extrapolation to a supercritical cycle for future application.

Another item considered in the selection of the subcritical once-through unit as opposed to an assisted circulation unit, is the lower first

RECENT BOILER OPERATING AVAILABILITY ONCE-THRU UNITS

FIGURE 2.2 BOILER OPERATING AVAILABILITY

cost of the once-through unit due to the elimination of pumps, manifolding for pumps, steam drum, etc. Please refer to Table 2.1 for a further comparison of the three unit types discussed.

2.1.2.3 Integral Separator Start-Up System. Once-through steam generators require start-up systems which in the past have added to the complexity of starting a once-through unit and in some cases have resulted in extra maintenance and loss of availability. To simplify the start-up system for the once-through unit, Foster Wheeler has developed the Integral Separator Start-Up System (ISSS), shown in Figure 2.3. This system incorporates separators in the high pressure circuitry, avoiding the need for transfer of flow to a bypass circuit from the main flow path during start-up. As a result, start-up with the integral separator system is similar to start-up of a natural circulation unit. Pressure increase is accomplished through an increased firing rate, with steam temperature control through use of the spray attemperator system. While on the start-up system, multiple separators, located in the main flow path and designed for full pressure and temperature, perform the function of a steam drum. Steam is separated from the steam/water mixture entering the separators and routed to the superheater circuits. The separated water is routed through a drain circuit to the deaerator or high pressure heaters for recovery of heat, then recycled to the unit through use of the feed pump.

2.1.2.4 Boiler Circuit Design. The pressure part weight of the subcritical once-through steam generator proposed is less than the assisted circulation unit design because of the use of small diameter tubes and the avoidance of the use of a thick steam drum. Because of this smaller pressure part weight, a reduction of start-up time should be experienced and the unit should be more responsive to load changing.

<u>Item</u>	<u>3500/1000/1000</u> <u>Once-Through Unit</u> <u>Supercritical</u>	<u>2400/1000/1000</u> <u>Once-Through Unit</u> <u>Subcritical</u>	<u>2400/1000/1000</u> <u>Drum with Assisted</u> <u>Circulation</u>
cycle efficiency	highest	lower	lower
First cost (D&S)	10% higher than base	base	3% higher than base (pumps, pump manifolding risers, downcomers, drum)
boiler arrangement	maximum flexibility	maximum flexibility	downcomers, pump manifold, risers, drum, etc. - limit arrangement flexibility
flexibility of circuitry	excellent	excellent	excellent
Turndown	excellent	excellent	excellent
ease of start-up	Solids handling & light-off limit start-up rate. No effect due to circuit design	Solids handling & light off limit start-up rate. No effect due to circuit design.	Solids handling & light-off limit start-up rate. No effect due to circuit design.
start-up time (w/o consideration of bed light-off time)			
cold	9 hrs	9 hrs	9 hrs
warm (weekend shutdown)	3½ hrs	3½ hrs	3 hrs
hot (overnight shutdown)	1½ hrs	1½ hrs	1 hrs
Heat lost during start-up	min., drain flow from separators reclaimed by high pressure heaters & deaerator.	min., drain flow from separators reclaimed by high pressure heaters & deaerator.	max., unless superheater bypass flow is routed to feedwater heaters
Pump installation	feed pump	feed pump	recirculation pump required in addition to feed pump

TABLE 2.1
STEAM GENERATOR CYCLE PERFORMANCE ANALYSIS

FIGURE 2.3 START-UP SYSTEM
ATMOSPHERIC FLUIDIZED BED STEAM GENERATOR

Figure 2.4 compares in schematic form the assisted circulation boiler with the subcritical Benson design once-through unit.

As shown in Figure 2.4 the Benson type circuitry consists basically of heated risers coupled to unheated downcomers, and utilizes a number of heated passes in series. This type of circuit arrangement lends itself well to the fluidized bed unit in that a plurality of fluid beds must be used for this type of unit design. Inlet orificing of circuits is not required in this Benson type of design but is customarily required in the assisted circulation design.

The Benson type design will also utilize different circuits for the boiling bank tubes in the fluid beds and the enclosure waterwalls. In the assisted circulation design these two very different types of circuits must be incorporated in a parallel arrangement. These circuits are highly different in their absorption characteristics and are much better designed as separate circuits.

2.1.2.5 Steam to Reheat Bypass System: To enhance operating capability during start-up, cycling, and emergency shut-down, a steam to reheat bypass system has been included. With this system, throttle steam conditions to the turbine can be regulated to match turbine metal temperatures by lighting off additional superheat and reheater surface in the beds as required. During emergency shut-down, the steam to reheat system is also a benefit in that steam flow is assured through superheater and reheat banks in the bed after a turbine trip. In addition the lifting of safety valves during a trip would be avoided because of the ability of the system to bypass steam to the reheater and condenser when the turbine intercept and control valves are closed.

ASSISTED CIRCULATION
WITH DRUM

BENSON DESIGN

FIGURE 2.4 DESIGN CONCEPTS FOR THE SUBCRITICAL
ONCE-THROUGH STEAM GENERATOR

Another advantage of the steam to reheat system is the minimizing of turbine erosion due to exfoliated particles in the steam because of the ability during start-up to flush the high pressure circuits and reheat circuits through the low pressure bypass to the condenser. In this manner these exfoliated particles are purged before steam is admitted to the turbine.

2.1.2.6 Load Control: Operational capability of the unit is increased by the use of segmental fluidization which enables the unit to achieve uniform load increase and decrease by bringing into service more or less fluid bed segments. Each segment of a bed will produce approximately a 5% load change. Finer adjustment of load can also be achieved by controlling bed temperature. Again the use of the subcritical once-through concept allows the arrangement of the tubes in the bed to be such as to permit the concept of segmental fluidization without resulting fluid temperature upsets in the bank.

2.1.2.7 Design Flexibility: The once-through circuit concept is inherently better suited to the fluid bed boiler. In the fluid bed boiler a plurality of fluid bed circuits are used and with the once-through concept the routing of these circuits can be accomplished without jeopardizing an efficient arrangement of the components. Since there is not a fixed arrangement of a drum, with attendant downcomers from the drum and circuit risers to the drum, more freedom in unit arrangement is permitted.

In addition the once-through concept makes possible the design of highest mass flow rates in the boiling circuits within the beds and should provide for a superior functional design. In addition, as pointed out earlier the boiling bank circuits within the beds can be made separate from the enclosing waterwall circuits. In the assisted circulation design

these circuits would be arranged in parallel with the boiling bank circuits and the waterwall enclosure circuits having widely different circuit characteristics.

The once-through circuit utilizes integral separators (for the 570 MW unit proposed—eight 30 inch OD integral separators are used) with these separators having minimal space requirements. In addition the integral separator does not need to be at the highest point in the circuitry and this gives additional flexibility in their location. A usual location is adjacent to the primary superheater inlet elevation.

With the once-through circuitry concept utilizing the integral separator start-up system, start-up of the unit will be much like that used for a natural circulation unit. A steam to reheat system is also utilized to protect superheat and reheat surface in the beds during emergency trips and to permit better turbine matching capability during start-up. An assisted circulation unit would also have to perform the same functions and require a steam to reheat system, or its equivalent, to do so.

2.1.2.8 Summary: A summary of our reasons for using the once through cycle is as follows:

- The once-through cycle has a good record of availability, and an impressive experience record in both United States and abroad.
- Increasing fuel cost trends will justify the use of the supercritical cycle for fossil fuel fired steam generators, and the subcritical once-through unit arrangement lends itself to extrapolation to a supercritical unit design.
- The Integral Separator Start-Up System, a Foster Wheeler development, has made start-up and cycling operation of the once-through steam generator a simple and reliable procedure.
- The operating capability of the once-through unit concept, utilizing the integral separator start-up system and a steam to reheater bypass system, is such that start-up, cycling, and

emergency shutdown can all be accommodated with ease and reliability.

- The once-through concept gives design flexibility for the circuits and results in optimum arrangement for the steam generator.
- The once-through concept results in smaller diameter tubes and headers plus elimination of the drum and associated risers resulting in considerable weight savings and resulting lower cost than assisted circulation units.

2.2 DESIGN PARAMETER SELECTION

The following parameters have been selected as the basis for the AFB Steam Generator Design. For further data or background covering the design parameter selections, refer to the listing of publications on fluidized bed combustion included in the Bibliography under Section 13.

2.2.1 Sulfur Capture in Fluidized Bed Combustion Processes

2.2.1.1 Introduction.

Considerations in General. Factors affecting sulfur dioxide emissions from fluid bed combustion units are summarized in Figure 2.5. This listing is not intended to be all inclusive but to represent some of the many conditions that must be considered in configuring a fluid bed combustion system. As more experience is gained in larger operating beds the complexity of the problem presented might be reduced considerably. In practice, when certain factors or parameters are adjusted to minimize sulfur emissions, - dust emissions, unburned carbon, unburned sulfur, hydrocarbons and carbon monoxide emissions may tend to increase.

Fuels fired and Firing Variations. Complete data concerning chemical constituents in the fuel should be evaluated, including a definitive review of the pyritic, ash sulfate and organic sulfur content. A good understanding of the ash constituents is also required and special tests in real fluidized bed combustion test facilities are indicated where large size coal is to be fired.

Ash tests are required to determine the percent cinder or clinker produced from the burning coal, the percent of inert oversized material that

FIGURE 2.5 FACTORS AFFECTING SO_x EMISSIONS

<u>Factor (increasing)</u>	<u>SO_x Emission</u>	<u>Practical Range of Factor</u>
1. Fuel sulfur fired	increases	.2 to 7 wt. %
2. Unburned sulfur elutriated from main beds	increases	1/3 to 2/3 S/C Ratio in fuel for elutriated carbon
3. Excess air fired	decreases	18 to 30% XSA
4. Lime/Fuel sulfur ratio (CaO/S)	decreases	.3/1 to 4/1
5. Bed Temperature	increases	1500F to 2000F
6. Superficial velocity	increases	2 to 12 ft/sec
7. Expanded bed height, lime inventory	decreases	2 to 10 ft
8. Bed mean particle size	increases	.01 in. to .10 in.
9. Grogging agents	decreases	.05 to .20 lb/lb bed
10. Catalysts added (Na and K donors)	decreases	.01 to .03 lb/lb fuel
11. Tube rows deep in bed	decreases	0 to 36 rows
12. Fuel particle size	decreases	.01 in. to 2 in.
13. CBC cell at 2000F	increases	0 - 7% variation
14. Main cell fines reinjection	decreases	.2 to 2 lb dust/lb fuel
15. Bed pressure	decreases (dolomite) increases (limestone)	1 ATA to 30 ATA 1 ATA to 30 ATA
16. Water vapor pressure in gases	decreases	.05 to 1 ATA
17. Acceptor internal Na, K concentration	decreases	0 to 3 wt. %
18. Bed inert (Dead ash, carbon, grogs, etc.) content	increases	2 to 25% maximum
19. Reactive coal ash content	decreases	10 to 20% fired ash
20. Limestone attrition rate	decreases	2 to 6%/hr
	increases	6%/hr +
21. Fines agglomeration with crushed spent bed	decreases	20 to 40% of feed limestone
22. After bed dust holdup	decreases	.05 to 1.0 lb dust/lb fuel
23. After bed gas residence time	decreases	.5 to 2 seconds

is non-reactive in the system, and the percentage of ash constituents transferred to limestone bed material in the process. Where overbed spreader feeder feeding of coarser fuels is selected as a firing variation, the understanding of the ashing characteristics of the fuel is considered extremely important. In order to achieve the best performance with this firing variation, the fines content of the fuel feed under 1/8 in. size should be minimized.

Acceptors Used - Catalysts, Groggs. Figure 2.6 indicates, in outline form, some of the characteristics of limestone which should be understood before their selection for use in fluid bed combustion systems. Considerable attention should be paid to inherent grain size of the limestone and the inherent sodium, potassium, iron and silicon oxides. The geologic or age classification, area source and photo-micrographic data on the limestone should be available. As with coal, it is important that the specific limestone selected for use in a process be tested in real burning fluidized bed tests of credible size. Where tests cannot be conducted, it is important that certain laboratory determinations be made on the limestone to correlate its performance with other known limestones.

Figures 2.7-10 characterize limestones with respect to utilization, attrition, attrition loss, physical data and chemical composition as a function of inherent clay content.

The general trend that is indicated among certain limestones used is that the higher the impurity or clay level, the slower the attrition rate of

FIGURE 2.6 ACCEPTORS

Data required for the proper design of fluidized bed combustion units.

Intended Applications

Range

T _b	Temperature	1500 - 1600F
P _b	Pressure	1 ATA
U _g	Fluid velocity	8 - 10 ft/sec
H _e	Bed height	4 ft - 5 ft
F _g	Gas Analysis	CO ₂
		H ₂ O
		SO ₂
		CO

Ø max x Ø min. size distrib.	1/8 in. x 0 in., 3/16 in. x 0
Ø average size	.034 in. - .044 in.
CaO/S Ratio	1.5 - 4.0

CHEMICAL - CaO

PHYSICAL DATA (raw, calcined, sulfated)

CaCO ₃	ρ _B (g/cc)	bulk density
Ca(OH) ₂	ρ _P (g/cc)	particulate density
MgO	σ _c (Kg/Cm)	- crushing strength-
MgCO ₃ *	Pore Vol. (cc/g)-	-
Na ₂ O	Pore dia. (μm) -	-
K ₂ O	BET surface (Cm ² /g)	-
Al ₂ O ₃	Grain size (μm)-	-
Fe ₂ O ₃	Grain shapes -	-
SiO ₂	(Photo micrograms)	-
CO ₂	Hardness (BHN) -	-
CL		

SO₃

SULFATION TEST**

% STOICHIOMETRIC

H ₂ O	150 (100-200 μ)	-
Other	450 (400-500 μ)	-
100	1100 (1000-1200 μ)	-
- LOI	1800 (1600-2000 μ)	-
- Surface H ₂ O	3700 (3400-4000 μ)	-

* Identify other carbonates
> 2% weight

GEOLOGIC - Origin + Age

- Classification
- Source Area
- Photo micrographic

ATTRITION TEST % wt/hr as sulfated/as calcined

**as sulfated in lab. FBC conditions
or pilot plant run - (preferred) with
intended fuel and limestone.

FIGURE 2.7 LIMESTONE ATTRITION vs INHERENT CLAY CONTENT

A speculative interpretation
Re: Westinghouse for EPRI - RP-721-1 June 77
Ulerich, et al

FIGURE 2.8 LIMESTONE UTILIZATION vs INHERENT CLAY CONTENT

FIGURE 2.9 LIMESTONE CHEMICAL COMPOSITION vs INHERENT CLAY CONTENT

A Speculative Interpretation

Re: Westinghouse for EPRI - RP-721-1 June 77
Ulerich, et al

FIGURE 2.10 LIMESTONE PHYSICAL DATA vs INHERENT CLAY CONTENT

the limestone. Similarly, finer grained limestones are in evidence with increasing inert or clay content. The harder, slower attriting limestone in this class suggests that it should be more difficult to realize optimum performance in the fluid bed combustion process. Conversely, the higher purity limestones with less clay or inert content and coarser grains will attrite at a high rate. These limestones suggest that they should be more coarsely ground and react in larger fluidized bed volumes which encourage attrition.

Attrition of limestone acceptors before the basic particle is elutriated, continuously exposes unreacted fresh lime surface. If a minimum number of limestone feed points is to be used, or if overbed feeding of limestone is to be considered, the fines content in the limestone should be similarly limited as with the overbed feeding of coarser coals. These two factors seem to explain much of the difference experienced in the operation of the fluid bed test facilities and indicate that the basic process should be optimized around the characteristics of the specific limestones available or intended to be used in the process. That is to say that there are a set of bed operating parameters and particle sizes that will achieve acceptable combustion efficiency, but realize better sulfur removal efficiencies. With the effect of attrition considered in a fluidized bed over long residence time periods, higher lime utilization may be experienced.

The results from the Alexandria, Virginia pilot plant operated by Pope, Evans and Robbins, when testing Greer limestone, comprise a major input to the National Fluidized Bed Combustion Data Bank, at present. The re-

FIGURE 2.11 - FLUID BED COMBUSTION REACTIONS

Coal Ashes

CaO, Na₂O, K₂O also participate in capture... for bituminuous coals with typical ash chemistry 15 to 25% of stoichiometric loading can be experienced.

EQUILIBRIUM DECOMPOSITION OF CaCO_3 IN FLUIDIZED BEDS

THIS THEORETICAL CURVE IS INCLUDED TO SHOW THAT FOR A GIVEN PARTIAL PRESSURE OF CO_2 IN THE GAS PHASE OVER A $\text{CaO} + \text{CaCO}_3$ SOLID PHASE THAT A CERTAIN MINIMUM CALCINATION TEMPERATURE MUST BE EXCEEDED TO CAUSE DECOMPOSITION OF CaCO_3 AND AVOID ITS RECOMBINATION, THUS ACTIVATING THE MATERIAL FOR SULFUR CAPTURE.

NOTE: $P_{\text{CO}_2} = (\text{Vol. \% CO}_2 \text{ IN GAS}/100) (\text{BED PRESSURE ATA})$

For AFB $P_{\text{CO}_2} = (14/100) (1.05) = .15 \text{ ATA}$, $T_{\text{MIN}} = 1420^\circ\text{F}$, 20% XSA

For PFB $P_{\text{CO}_2} = (15/100) (10.) = 1.5 \text{ ATA}$, $T_{\text{MIN}} = 1700^\circ\text{F}$, 20% XSA

IN REAL FLUID BEDS THE CO_2 PARTIAL PRESSURE AT THE BASE OF THE BED IS CONSIDERABLY LOWER THAN AT THE TOP AND THE CALCINATION COULD BE AFFECTED AT TEMPERATURES OF APPROXIMATELY 1350°F (AFB) AND 1600°F (PFB) FOR 20% EXCESS AIR COMBUSTION.

Figure 2.12

sponse of the unit and the behavior of this limestone in the test facility must be carefully judged when comparing its performance to the likely performance of other limestones.

2.2.1.2 Theory.

Basic Chemistry of Reactants. Figure 2.11 shows some of the simple reactions occurring in the fluid bed combustion process involving the calcination of limestone and the capture of sulfur dioxide and trioxide by lime. Depending upon the type of fuel, coal ash may participate to a greater or lesser degree in the sulfur capture mechanism. Failure to account for this fact has produced some misunderstanding of the data published for fluidized bed combustion facilities. In addition to capture by the fuel's own ash, a certain percentage of the sulfur fired into a system leaves as unburned sulfur. Certain indications from tests conducted in the British program and others give evidence that from five percent to sixty percent or better of the coal sulfur may be retained by the coals own ash under favorable combustion conditions, with around five percent for anthracite, from fifteen to twenty-five percent bituminous coals, and from forty to sixty percent for certain lignite and sub-bituminous coals.

Reaction Equilibrium Limits. Figure 2.12 represents an equilibrium partial pressure/temperature diagram for the decomposition of calcium carbonate. Temperatures for operation of the fluidized bed must be selected high enough to cause the calcination or decomposition of calcium carbonate. Although the reaction of sulfur dioxide, oxygen and lime is favored kinetically

with increasing temperature, there is a reverse tendency for calcium sulfate to decompose with increasing temperature. An appreciable sulfur capture or retention cannot be expected near or above the 2000F temperature level. This decomposition effect is considered a major explanation of why an apparant optimum sulfur capture exists for most limestones in the 1500-1560F temperature band.

Where carbon burnup cells, operating at higher temperatures, are used to burn incompletely combusted carbon with certain amounts of residual sulfur from the main cells of the boiler, operating temperatures may have to be compromised with those required to achieve high combustion efficiencies to limit the equilibrium release of sulfur dioxide from spent bed material, and allowing some capture of sulfur released by the recycle carbon char.

2.2.1.3 Heat Release and Material Balances.

Estimated Heat Release and Material Balances. Figure 2.13 indicates a ten zone combustion or sulfur reaction model for a fluid bed combustion system. A slightly different mechanism might tend to govern in each one of these different zones of the model, however, present data does not permit detailed consideration of each of these zones on an individual basis and overall empirical data is used to estimate the performance. There is reason to expect that in the larger bed or system applications, where larger volumes and contact times may be provided, that performance may exceed expectations when based on limited pilot plant tests. Figure 2.14 indicates the sulfur distribution estimated from typical criteria throughout the system.

FIGURE 2.13 - SULFUR REACTION MODEL

A - 10 Zone Combustion (Sulfur Reaction) Model

1. Coal Injection Zone	5. Main Fluid Bed - Freeboard	8. CBC Bed - Tap Cooler
2. Main Fluid Bed - Hothead	6. Gas Column + HRA	9. CBC Bed - Freeboard
3. Main Fluidized Bed	7. CBC Fluidized Bed	10. Baghouse - Filter Cake
4. Main Fluid Bed - Tap Cooler		
- (xx) Numbers in parenthesis - released, or burned to gas

FIGURE 2.14 - SULFUR DISTRIBUTION AND CAPTURE

Approximate Sulfur Combustion, Capture and Losses (% of Feed Sulfur)
 (xx) % of Sulfur burned to gas (based on 2.55% S in Fuel)
 <xx> % of Sulfur captured by lime
 [xx] % of Sulfur captured by coal ash

Based on pilot plant experience, approximate rules have been used to distribute the materials throughout the system. In this analysis, approximately one-third of the limestone product formed on capturing of sulfur is elutriated overhead, while two-thirds of these products are retained, tapped from the bed. The main bed also includes two unburned sulfur escape routes in the elutriated dust and in the tap stream leaving the bed. The sulfur to carbon ratio in these streams is adjusted to be about one-half of the sulfur to carbon ratio in the basic fuel fed to the system and sulfur is considered to be mainly of the organic variety, as found in the carbon char in the escaping streams. Pyritic sulfur (FeS), tends to burn more readily than organic sulfur, with low content found in elutriated and tap streams. Sulfur in residual char may be estimated as about 80% of the organic sulfur to carbon ratio in the feed fuel, when known.

2.2.1.4 Experimental Data.

Small Scale Tests. Data from small scale test facilities was reviewed and selected for conditions representative of those required for the design study. The cases considered are summarized in Figure 2.15.

An attempt was made to deduce empirical limited range proration functions from modelling studies conducted by the NCB (United Kingdom), and others. This procedure, as modified by engineering judgement has been used to establish design estimating curves shown in Figures 2.17-19.

With the potential to conduct combustion of fuel fines in the freeboard, with large volume freeboards, gas collection column and heat recovery

Curves	Facility Bed Size	Bed Parameters Height	Temp.	Superficial Velocity	Excess Air	Fines Recycle	Tubes in Bed	Limestone Type	Size	Coal Type	Size	Sulfur
Case	(ft.)	(ft.)	(F)	(ft./sec.)	(%)				(in.)		(in.)	(wt.%)
1.	Large Boiler Estimate (large)	4.0	1550	10	20	Inherent	Yes	Grove	3/16" x 0	Eastern Bituminous	1" x 0	4.5
2.	NCB (UK) (1.5 x 3.0)	3.5	1550	8	18	-	Yes	Limestone	1/8 x 0	Pitt. #8	1/8 x 0	2.75
3.	PER - FEM (1.5 x 6.0)	4.0	1550	14	20	-	Yes	Greer	1/8 x 16m	Sewickly	1/4 x 0	4.1
4.	PER - FEM (1.5 x 6.0)	4.0	1550	14	20	-	Yes	Ger. Valley	1/8 x 16m	Sewickly	1/4 x 0	4.1
5.	B & W (3' x 3')	1.5	1550	10	20	-	Yes	Lowell	1/4 x 16m	Pitts. 8	1/4 x 0	2.75
6.	NCB (UK) (1.5 x 3.0)	2.1	1550	8	24	-	Yes	Limestone 18	1/8 x 0	Pitts. #8	1/8 x 0	2.75
7.	NCB (UK) (1.5 x 3.0)	2.1	1550	8	18	-	Yes	Limestone 18	1/8 x 0	Welbeck	1/8 x 0	1.25
8.	CRE (UK) (2.25 Ø)	2.1	1550	8	18	Yes	Yes	Limestone 18	1/8 x 0	Pitts. #8	1/8 x 0	2.75
9.	USEM (PERC) (3' Ø)	2.0	1550	6	20	Inherent	Yes	Grove	1/4 x 3/16	Bit. Avg.	1/4 x 0	2.9
9A.	USEM (PERC) (3' Ø)	2.0	1550	6	20	Yes	Yes	Grove	1/4 x 3/16	Bit. Avg.	1/4 x 0	2.9
10.	NCB (1.5 x 3)	2.1	1550	11	18	-	Yes	Limestone 18	1/8 x 0	Pitts. #8	1/8 x 0	2.75
11.	CPC (3' Ø)	4	1850	10	140	Inherent	No	Pfizer	3/15 x 0	Ill. #6	1/4 x 0	3.95
12.	PER (1.5 x 3)	2.0	1850	9	30	Yes	No	Greer	1/8 x 16m	Sewickly Char	.04	1.4

Figure 2.15 - Test Unit Information

FIGURE 2.16 - COMPOSITE PLOT - SULFUR RETENTION VERSUS
CaO/S MOLAR RATIO

FIGURE 2.17 - COMPOSITE PLOT - SULFUR RETENTION
VERSUS BED TEMPERATURE

FIGURE 2.18 - SO_x RETENTION FOR TYPICAL ATMOSPHERIC FLUIDIZED BEDS

FIGURE 2.19 - SO_x RETENTION FOR TYPICAL ATMOSPHERIC FLUIDIZED BEDS

area in the proposed design, indicating a high dust holdup and gas residence time at temperature, there is a tendency to believe that the results from test facilities with high inherent after bed dust recirculation would represent the proposed large scale design better. These conditions are simulated in test cases 8, 9 and 11 with fines recycle in Figure 2.15.

Figure 2.16 represents a composite plot of data from the facilities reviewed.

No curves are given for cases 11 and 12, representing high temperature CBC cell operation, as points are prorated.

Figure 2.17 represents a composite plot of test curves on a field of proposed design curves, showing the variation of sulfur retention with bed operating temperatures. Figures 2.17-19 represent the basis upon which this study was conducted.

Figure 2.16 presents selected results from a number of small test facilities. These results vary widely between facilities operating with similar conditions and feedstocks, giving evidence of sensitivity to configuration variations and method (or quality) of fuel feeding.

In individual facilities, results for different acceptors and fuels fired under similar conditions also vary widely. The variability in certain cases is not obvious and is difficult to explain theoretically.

The following conclusions are suggested:

- Until widespread experience is gained, each new fuel and acceptor should be tested to finalize design data, and attempt optimization of feed size distribution and fluidized bed parameters.
- Larger scale beds are expected to perform more predictably and better than evidenced in small facilities.
- Poor feed distribution of fines with channeling increases free-board burning, reducing in bed performance.
- Fines recirculation improves performance of these facilities markedly.
- Initial feed size, attrition rate, and bed residence time have a major impact on performance.

In the absence of detailed information or test experience with the given fuel and limestone combination, a performance basis had to be selected for this study based on these curves, as modified for the intended conditions of service.

Figures 2.18 and 2.19 indicate approximate performance curves prepared for a Grove (BCR1359) limestone and a typical eastern bituminous coal. These curves were prepared after inspection of data for Illinois #6, and Pittsburgh seam #8 coal when fired with BCR1359 (Grove) limestone and limestone 18; from the NCB (UK) test program, the US Bureau of Mines (Pittsburgh) facilities; the Fluidized Bed Module (Pope, Evans & Robbins) at Alexandria, Virginia; and the Combustion Power Company (Menlo Park, Cal.) units.

With the larger potential for dust holdup and internal recirculation before cooling, in larger scale beds, improved performance with well designed

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tube bundles, deeper beds, etc., this data was prorated from experimental operating points using adjusted correlations indicated in Reference 1 following. Improved performance correlations from the ERDA modelling program at The Massachusetts Institute of Technology are anticipated at the completion of that program.

In estimating performance of the CBC cell operating at 1850F and 30% excess air, recent test data from the PER Fluidized Bed Module facility at Alexandria, Virginia (Reference 3) and the earlier CPC unit at Menlo Park, California (Reference 4) was inspected and prorated similarly.

2.2.1.5 References

1. "National Coal Board - Final Report, June 70-71, Reduction of Atmospheric Pollution" Ref: -DHB-060971 for EPA.
2. Appendix 6 - Task VI - Mathematical Modelling of Sulfur Retention
3. "System Model and Data Base System for Fluidized Bed Combustion at M.I.T." under ERDA contract - various progress reports.
4. "ERDA/PER Fluidized Bed Combustion program Interim Report 90 and Monthly Progress Reports".
5. "Energy Conversion from Coal Utilizing CPU - 4000 Technology" - Report March 1977, under ERDA contract - Ex-76-C-01-1536.

2.2.2 Heat Transfer

The following describes the heat transfer coefficients used throughout the Fluidized Bed Steam Generator:

2.2.2.1 Bed Heat Transfer Coefficients. The design coefficients represented in Table 2.2 are based primarily upon averaged rates experienced in the 11' 3" x 12' 2" and 1' 2" x 5' 6" beds at the Rivesville 30 MW MFB and Alexandria, FEM pilot plants of Pope, Evans and Robbins. These rates were experienced under comparable operating conditions as to those expected on larger utility boiler applications, and have basically been repeated by others experimenting in well designed test facilities.

The in-bed tube bundle rates represented are averaged for the bundle from side to side and from top to bottom. In formal engineering design of tube bundles, and surface setting - the actual bed to tube transfer coefficients are known to vary with bed particle size distribution, bed temperature, tube outside metal temperature, inter-particle/intra-tube/bubble-gas velocities, and position in the bed. Local coefficients will vary with time and around the circumference of the tubes. Final design coefficients, surface setting, arrangement and metals selections will reflect these variations.

For a given tube bundle configuration and the resulting quality of fluidization at the side waterwalls a surface effectiveness factor will be applied from experience. Recent test experience with the Rivesville 30 MW superheat bundle indicates stable heat addition to the coils

TABLE 2.2

A COMPARISON OF OVERALL HEAT TRANSFER COEFFICIENTS
(APPROXIMATE)

	<u>DESIGN</u> (U_d)		<u>UPSET</u> (U_u)		<u>SPOT</u> (U_s)	
Heat Transfer Coefficients based on wetted or rinsed surface to be modified by surface effectiveness factors at water-walls.	for surface setting, normal absorption expected (BTU/hr - ft ² - °F)		for maximum fluid temperatures with minimum imbalanced fluid flow (BTU/hr - ft ² - °F)		local maximum rate for metals selection, when used with upset fluid temperatures (BTU/hr - ft ² - °F)	
<u>Fluidized Bed</u>	<u>Main</u>	<u>CBC</u>	<u>Main</u>	<u>CBC</u>	<u>Main</u>	<u>CBC</u>
Tube bundles	40	45	55	61.9	70	78.3
Walls	50	55	60	66	70	77.3
Fluidization Grid (Plate)	20	-	24	-	28	-
Fluidization Grid (Tube)	-	15	-	18	-	21
<u>Freeboard Enclosure</u>						
Walls, Roof, -average	11.8	17.5	14.2	21	16.5	24.5
Tube bundle	-	8.3	-	10.0	-	11.6
<u>Gas Collection Column</u>						
Walls, roof, -average	12.2		14.6		17.1	
<u>HRA</u>						
HRA Enclosure						
Roof, walls, -average	8.1		9.7		11.3	
Tube bundles	13.2		15.8		18.5	
<u>Lower Economizer</u>						
Tube bundles	8.5		10.2		11.9	
Note: With upset rates maximum average gas/bed temperatures are used. With spot - maximum local temperatures used			1.2 U_d or 1.375 U_d (bed) (tubes) = U_u		1.4 U_d or 1.75 U_d (bed) (tubes) = U_s	

in parallel in the bundle with heat pickup per coil not varying more than $\pm 4\%$ from the average.

Recent test data from the Alexandria test facility of PER indicates that mean bed particle size in the CBC cell will equilibrate smaller than the main cells which operate at lower temperatures, resulting in an improved quality of fluidization and heat transfer coefficient.

The attached list of references indicates literature relevant to fluidized bed heat transfer. A major reliance will be placed upon empirical correlations based upon experience in operating units under comparable or directly relateable conditions.

ERDA has sponsored a number of research contracts to develop models for the fluidized bed combustion and heat transfer process. Certain of these programs were reviewed at a recent Fluidized Bed Combustion Technology Exchange Workshop in Reston, Virginia in April 1977, and generally reflect increased understanding of the process in the Academic Community.

The basic problem of heat transfer in real coal burning, non-ideal fluidized beds of large particles such as those required for utility service is one that does not lend itself readily to solution by precise engineering theory and modeling, and major emphasis is placed upon test results from pilot plants of credible size when operating under comparable conditions. Engineering theory is presently useful for

limited range extrapolations where differences in coefficients of not more than 10% are involved. If differences of more than 10% are indicated it is adviseable to consider additional testing to cover the extended range of conditions required.

2.2.2.2 Freeboard Heat Transfer Coefficients. In the freeboard zone extending 6 feet above the bed, waterwall heat transfer coefficients are similarly treated empirically, with conventional engineering theory modified to agree with apparent test observations. The problem of heat transfer modelling in a zone of high recirculating dust loadings, containing luminous burning particles, with bubbles bursting off the top of the bed is a complex one.

Where heat transfer surface is installed directly above an operating bed, velocities are kept up to avoid dust accumulation in or above the bundle. Coefficients are estimated conventionally and modified for the effects of high dust loadings to agree with apparent test observations.

2.2.2.3 Gas Collection Column Heat Transfer Coefficients. The upflow gas collection pass with multiple inlets and high dust holdup is treated similarly. In formal engineering design this pass is analyzed for expected dust holdup and flow patterns to estimate adjustments to conventional predictions indicated.

2.2.2.4 Heat Recovery Area Heat Transfer Coefficients. Coefficients similarly are estimated by conventional theory and adjusted for the effects of high dust loadings expected.

2.2.2.5 Selected Publications on Fluidized Bed Combustion

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- D. L. Keairns, "Heat Transfer from a Horizontal Tube in a Fluidized Bed at 1600°F," Westinghouse Research Laboratories, Research Report 68-9D3-273-R13, October 25, 1968.
- D. L. Keairns, "Heat Transfer from Horizontal Tubes in a Rectangular Fluidized Bed," Westinghouse Research Laboratories, Research Report 68-9D3-273-R3, May 29, 1968.
- W. R. Hager and S. D. Schrag, "Particle Circulation Downstream from a Tube Immersed in a Fluidized Bed," Chemical Engineering Science, 1967, Vol. 31, pp. 657-659.
- D. R. McGaw, "The Development of a Mechanism for Gas - Particle Heat Transfer in Shallow-Fluidized Beds of Large Particles," Chemical Engineering Science, 1977, Vol. 32, pp. 11-18.
- R. L. Rice and Neil H. Coates, "Combustion of Coals in Fluidized Beds of Limestone," Morgantown Energy Research Center.
- J. C. Chen, "Heat Transfer to Tubes in Fluidized Beds," The American Society of Mechanical Engineers for presentation at the ASME-AIChE Heat Transfer Conference, St. Louis, Missouri, August 9-11, 1976.
- B. R. Andeen and L. R. Glicksman, "Heat Transfer to Horizontal Tubes in Shallow Fluidized Beds," The American Society of Mechanical Engineers for presentation at the ASME-AIChE Heat Transfer Conference, St. Louis, Missouri, August 9-11, 1976.
- J. Kubie, "Bubble Induced Heat Transfer in Gas Fluidized Beds," Int. J. Heat Mass Transfer, Vol 19, pp. 1441-1453.
- D. E. Elliott and M. J. Virrr, "Small-Scale Applications of Fluidized-Bed Combustion and Heat Transfer".
- A. P. Fraas, "Heat Exchange for High Temperature Thermodynamic Cycles," Heat Transfer Division of the American Society of Mechanical Engineers for Presentation at the Winter Annual Meeting, Houston, Texas, November 30 - December 4, 1975.

- W. J. Bartel and W. E. Genetti, "Heat Transfer from a Horizontal Bundle of Bare and Finned Tubes in an Air Fluidized Bed," AICHE Symposium Series.
- N. I. Suromyatnikov, L. K. Vasanova and A. I. Karpenko, "Heat Transfer in a Liquid Fluidized Bed," Heat Transfer - Soviet Research, Vol. 6, Nov. 4, July - August 1974.
- V. N. Vedamurthy and V. M. K. Sastri, "An Analysis of the Conductive and Radiative Heat Transfer to the Walls of Fluidized Bed Combustor," Int. J. Heat Mass Transfer, Vol. 17, pp 1 - 9.
- H. K. Lese and R. I. Kermodé, "Heat Transfer from a Horizontal Tube to a Fluidized Bed in the Presence of Unheated Tubes," The Canadian Journal of Chemical Engineering, Vol. 50, February 1972.
- A. Watson, "The Influence of Axial Wall Conduction in Variable Property Convection - with Particular Reference to Supercritical Pressure Fluids," Int. J. of Heat Mass Transfer, Vol. 20, pp 65 - 71.
- J. L. Hodges, R. C. Hoke, R. Bertrand, "Prediction of Temperature Profiles in Fluid Bed Boilers," Heat Transfer Division of the American Society of Mechanical Engineers for presentation at the ASME-AICHE Heat Transfer Conference, St. Louis, Missouri, August 9-11, 1976.
- A. O. O. Denloye and J. S. M. Botterill, "Heat Transfer in Flowing Packed Beds", Chemical Engineering Science, 1977, Vol. 32, pp. 461-465.
- W. C. Howe and C. Aulisio, "Control Variables In Fluidized Bed Steam Generation," Chemical Engineering Progress, July 1977, pp. 69-73.
- S. J. Wright, R. Hickman and H. C. Ketley, "Heat Transfer in Fluidized Beds of Wide Size Spectrum at Elevated Temperatures," British Chemical Engineering, December, 1970, Vol. 15, No. 12, pp. 1-4.

2.2.3 Fuel and Sorbent Feed Size

2.2.3.1 Fuel Size. Fines are limited to control heat release in the injection zone and avoid reducing conditions, unburned fines loss from the system and heat release above or after the main combustion beds.

Oversize must be limited to control combustible and non-reactive inert content in the bed, avoid raising minimum fluidizing velocity and permit free intra-tube fluidization between tubes in practical tube bundles placed in beds.

With the overbed fuel feed system, the fraction of feed with settling velocities less than twice the fluidizing velocity should be minimized, typically to less than $5\% < 1/8$ in. If fines cannot be practically limited, special design provisions should be made to accommodate high fines content.

Maximum coal feed size, must be controlled to ensure adequate performance. Economically, the incentive would appear to be to maximize coal top size to minimize crushing, fines generation, and drying requirements, however, certain practical constraints must be respected limiting the size distribution:

A. Top Size Constraints to:

- Control bed combustible content below 5 to 10%.
- Control bed inert content buildup from coal ashes to less than 20 to 30% (without forcing higher tap rates than required for good limestone utilization).

- Control bed inert size distribution to avoid poorer quality of fluidization and loss in reaction efficiency.
- Provide practical clearances between heat transfer surface tubes which must be installed in the bed, say of 2 in., without forcing larger volume (height x area) than required for economic performance. With an L/d ratio of particles of about 1.5 this implies a $1\frac{1}{4}$ in. top size.

B. Fines Constraints - Fines content should be minimized to control freeboard heat release and combustibles loss to less than about 15% and 10% respectively, of fuel input heating value. Economically, it is desirable that all combustion occur within the bed where the most economic heat transfer surface can be installed and reaction efficiencies are maximum, i.e. to ensure good carbon burnout and limestone utilization.

C. Mean Size Control - Depending upon the coals reactivity (burning rate) and its ashing characteristics, the coal feed size (surface average) should be optimized to control equilibrium combustible content in the bed and therefore the tap losses. Practically, it is difficult to meet all objectives at the same time and a compromise must be sought.

2.2.3.2 Limestone Size. Similar to fuel sizing, limestone size distribution must be controlled to ensure adequate performance.

From a given feed size distribution, feed rate, and tap rate (which may be forced up by high inert build-up from coal ashes) it is difficult to predict the equilibrium particle size that will occur in the bed. The hard inert content (in the coal as well as the limestone feed), attrition rates (influenced by coal ash fluxing) and the active lime surface actually available

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for capture will all influence the best size distribution selected. Actual testing is the most economic and reliable way to determine the optimum limestone feed sizing.

Fines must be controlled to avoid loss of fine particles to the less reactive freeboard.

The mean particle size resulting in the bed tends to determine or govern the efficiency of the bed as a chemical reactor (striving for complete combustion and sulfur capture with minimum limestone consumption) and as a heat transfer device (striving to remove required heat to maintain bed temperatures with maximized heat transfer coefficients).

Between the top feed size and the bottom cut, determined by bed fluidizing and stripping velocities, a mean will establish. With weaker or softer limestone the characteristics of the bed as an effective pulverizer (or crusher) must be respected and taken advantage of. A bed mean size between .03 in. and .05 in. is considered a practical range for commercial units resulting in a minimum fluidizing velocity of from 3 ft./sec. to about 5 ft./sec. and operating velocities of from 6 to 12 ft./sec.

With the overbed feed of coarser coal, an extra incentive exists to operate towards the higher fluidizing velocities to ensure good mixing, avoid clinkering, and to promote elutriation to extinction of coal ashes as well as sulfated limestone shells on the bed material.

2.2.3.3 Feed Size and Fluidizing Velocity Compatibility. Figure 2.20 shows the terminal velocities for various sized particles for different materials used in the fluidized bed combustion process. Entering with the bed superficial fluidizing velocity and interparticle stripping velocities, the particles which will have difficulty penetrating the bed and reacting there can be estimated.

When considering overbed feed, coal particles less than 1/8" will have difficulty penetrating the bed and burning there; particles less than 1/16 in. will react towards the top of the bed less effectively.

Fresh limestone particles less than 18 mesh (.0394 in.) will have difficulty penetrating the bed, as calcined, and reacting there; particles less than 25 mesh (.028 in.) will react towards the top of the bed, less effectively, when considering overbed feed.

These finer particles are highly reactive, with a high surface to volume ratio. The coal particles in the .042 in. to .074 in. band, and the limestone particles in the .025 in. to .065 in. band, along with coal char (.054 in. - .105 in.) and bed material (.031 in. - .055 in.) residues elutriated and stripped from the bed, will contribute to a theoretical dense elutriated phase at the upper bed. This material can be churned back into the bed as bubbles burst and collapse and will contribute heavily to the heat released and capture occurring towards the upper bed.

FIGURE 2.20 TERMINAL VELOCITIES FOR BED PARTICLES

Particles with sizes smaller than listed above will elutriate from the cells and have reduced residence time in the freeboard zone.

Figure 2.21 represents feed and product size distributions considered in this study. In this study, the basic feed size of coal and limestone were given. Every attempt was made to limit the creation of additional fines in preparation for firing. Although the distribution resulting is not the optimum, respecting the foregoing considerations, design can be accomplished to achieve acceptable performance.

FIGURE 2.21 APPROXIMATE PARTICLE SIZE DISTRIBUTION

2.2.4 Combustion Efficiency

There are many parameters in the design of a fluidized bed steam generator that have significant effects on combustion efficiency. At the present state of the art of fluidized bed systems design, characterization of the effects of each of the design parameters is incomplete. In addition to the design parameters of the steam generator, combustion efficiency is also affected by characteristics of the fuel and limestone used in the process. The following is a summary of some of the major parameters affecting combustion efficiency and a brief description of their effects:

- Fuel size - Fuel sizing should be selected to minimize fine particles below $1/8$ in. High concentrations of fine particles will result in carryover of unburned combustibles detrimentally affecting the overall combustion efficiency. Coal particles in excess of 1 in. should also be minimized to maintain the carbon content of the bed at a reasonable level. Significant percentages of oversized coal particles will result in combustible particles being withdrawn in the bed material drain, thereby reducing combustion efficiency.
- Fluidizing velocity - Wide ranges of fluidizing velocities have been used in fluidized bed pilot units. Increasing fluidizing velocity will have a result of increasing combustible losses if no other parameters are changed. As the size of the fluidized bed is directly proportional to the selected fluidizing velocity, an economic optimum must be selected in a tradeoff between combustion efficiency and boiler size. FWEC has selected a fluidizing velocity of 10 ft/sec which should be near this optimum.
- Bed depth - Increasing bed depth will result in improved combustion efficiency when no other parameters are changed. Very high combustion efficiencies have been shown with bed depths in the area of 8 ft. or more. This is not considered a practical selection due to high combustion air pressures required with increased bed depths. The bed depth selected for this study is considered near the optimum for the overall unit efficiency.

- Freeboard height - A high freeboard above the fluidized bed will result in maintaining the gas temperature for longer durations. The freeboard height used in this study is in excess of most pilot units and should result in improved combustion efficiency. Also the large common gas pass prior to the HRA section will result in maintaining combustion gases above 1400F for a considerable time. These design decisions are all in the right direction for maximizing combustion efficiency.
- Bed temperature - As discussed in Section 2.2.8, bed temperature was selected to obtain maximum sulfur capture. Increasing bed temperature will result in improved combustion efficiency up to the point of the coal ash softening temperature at which point the bed will tend to agglomerate and be fluidized. In practical operating situations the bed temperature can be varied approximately 200F and should be maintained above 1500F for reasonable combustion efficiencies.
- Excess air - Since complete combustion does not take place in the main fluidized bed cells, the term excess air can be misleading. In this case, it is preferred to use excess oxygen which should be in 3-4% range for maximum combustion efficiency. Excess oxygen from the main cells below 3% will result in increasing the unburned combustible carryover. Excess oxygen in excess of 4% in the main cells will result in little improvement in unburned combustible carryover however this will result in additional efficiency loss due to increased gas losses at the stack.

Estimates for combustion efficiency used in this study are conservative based on data obtained from pilot unit operations to date. The unit surfacing has been based on 89% combustion taking place in the main cells with the majority of the heat losses carrying through as unburned combustibles and being reinjected into the carbon burn-up cell. With proper operating conditions combustion efficiency is expected to be better than indicated by these design decisions, however, design in this conservative manner allows for maximum operating flexibility. If combustion efficiency is indeed better than 89%

in the main cells it can be allowed for by varying the operating conditions of the unit. That is to say, reduce the fuel input to the primary cells and fire supplementary coal in the carbon burn-up cell. It would be considerably more difficult to make operating adjustments if the design was based on a higher combustion efficiency in the main cells than actually achieved.

A bibliography is included under Section 13 of this report, giving a partial selective listing of references considered in establishing the estimated performance used in this study.

Presently fluidized bed test data for overbed feeding of the larger fuel sizes used in this study is not available. To estimate performance for this study, certain prorations of data and assumptions were required. Test data were reviewed and speculative screening curves plotted to help define factors required to project performance. Where relatable experience was not available, certain theoretical estimates were made to define limits of performance. An attempt was made to place maximum reliance on relatable test experience and to minimize assumptions.

For combustion within a fluidized bed, carbon burn-out efficiency and loss to elutriation and tap streams is a complex problem as indicated in the references provided in the appendix. An understanding of coal burning rates, attrition rates and ashing characteristics is required. Prior to formal design of a fluidized bed unit it is strongly recommended that actual

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testing of the intended fuels and bed material be performed on a credible pilot unit to characterize the performance of both feed stocks.

Figure 2.22 indicates an approximate heat release and combustible loss associated with the unit developed in this study. The heat release rates indicated are shown as percent of the fuel higher heating value. Relatively high heat release in the freeboard zones associated with overbed feeding have been accounted for in this heat release distribution. Figure 2.23 shows a similar distribution of the fuel carbon combustion throughout the unit.

Based on the design parameters selected an overall boiler efficiency of 86.38% is predicted. This is based on an overall unburned combustible loss of 2.10%. More details on the performance of this unit are shown in Section 3.

FIGURE 2.23 CARBON DISTRIBUTION

Approximate Carbon Combustion and Loss (% of feed Carbon)

(xx) combustion, burned to gas 61.15% carbon in fuel

Note: A study case with high freeboard release

2.2.5 Fluidizing Velocity

The selection of bed fluidizing velocity impacts practically all aspects of design, performance and cost. The smaller the mean acceptor particle size that is permitted in the bed by elutriation and attrition limits, the more favorable is the effect on quality of fluidization, and gas solids mixing and contacting. Bed reaction efficiency is proportional to gas and solids residence times. Gas residence time in the bed is proportional to bed height and inversely proportional to fluidizing velocity or as velocity increases static bed height should also increase to maintain efficiency. Economics imply high velocities to minimize size or plan areas and bed weights, however, the requirement to install heat transfer surface in the bed on spacings which permit fluidization dictates that the bed be of a certain minimum volume. Economics indicate that static bed heights or pressure drops should be minimized, to limit fan power consumption. An economically compromised solution is then indicated which favors higher fluidizing velocities, at average bed depths, which accomodate acceptable circuitry and installation of heat transfer surface.

Coarser limestone grinds tend to minimize grinding and drying requirements, however they increase minimum fluidizing velocities, and lower lime utilization. Ironically, as lower fluidizing velocities are used, bed expansion factors also decrease for the same particle sizes, requiring deeper beds for comparable gas residence times. With overbed feeding of coarse fuel, it becomes important to design with higher fluidizing velocities for the

following reasons:

- Ensure suspension and mixing of fuel into the bed avoiding maldistribution and sticking of burning fuel to bed material.
- Higher velocities promote wearing off of coal ash as fuel burns and attrition of sulfated acceptor shells.
- Higher bed turbulence favors combustion and lime sulfation reactions kinetically, improving the availability of oxygen.

In this study, the following fluidizing velocities were considered:

	<u>Superficial Fluidizing Velocities (ft/sec)</u>	
	<u>MBC</u>	<u>CBC</u>
Design	10	8
Peak	12	12
Control	5+	6
Minimum	4.2	4.0-

With practical bed particle sizes considered, it is important to maintain operating velocities at least about 20% above minimum fluidizing to ensure uniformity.

Normal CBC operation should be maintained at a velocity about 20% below MBC operation, considering increased MBC elutriate char residence time to promote burnup in the CBC.

With incomplete data and understanding of how the given fuels and acceptors will respond in real burning fluidized beds, design parameters under engineering control could not be optimized, realistically, with respect to fluidizing velocity. Although base parameter selection is not expected to change significantly, certain parameters may be subject to some modification before committing final design.

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The choice of fluidizing velocity and other parameters in this study are not represented as being the optimum, but within the economic, practical and process constraints as considered in this study, are judged to be a good selection representing the better performance attainable.

2.2.6 Bed Height and Pressure Drop

The selection of bed height, with bed fluidizing velocity, temperature and bed particle sizes determined by other considerations, must be made to provide acceptable reactor efficiency and heat transfer considering:

- Loss of efficiency as a result of coarser overbed feed coal and limestone sizes selected to minimize grinding and drying requirements.
- Compensate for lower bed gas residence times indicated by higher fluidizing velocities.
- The bed must be of a certain minimum volume, or height, to accommodate required heat transfer surface which must be installed to maintain bed temperatures. With practical tube sizes and clearances established to permit larger maximum fuel feed sizes and ensure good fluidization about tubes, heat transfer requirements can dictate beds at a certain minimum volume. As working fluid temperatures increase, log mean temperatures decrease driving volume requirements up.

In this study the following bed height parameters and resulting pressure drops were selected:

	Approximate Height (ft.)	
	<u>Main Cells</u>	<u>CBC Cell</u>
Design Static	2.0	2.3
Design Expanded	4.0+	4.0
Maximum Expanded	5.0	5.0
Control Expanded (min.)	1.5	2.5
Top of Bed to Top Tube	1.5	.5
Bottom of Bed to Bottom Tube	1.5	2.5

	Approximate Pressure Drop (inches H ₂ O)	
	<u>Main Cells</u>	<u>CBC Cell</u>
Design Bed	34	36
Design Grid	22	16
Regulating Damper	2	6
	<u>58</u>	<u>58</u>

Experience has indicated that expanded bed heights should not be run less than about 1.5 ft. under conditions of high turn down, as fuel mixing and distribution, and maintaining fluidization can become problematic with the coarser fuels fed.

2.2.7 Bed Surfacing

The presence of tubes within the fluidizing bed limits bubble sizes, improves the quality of fluidization and removes the heat required to maintain bed temperature. Tube spacings are maintained at least 10 times the larger acceptor particle size in the bed at the 95% weight passing sieve point to ensure effective fluidization around tubing.

Tube spacings must also be set greater than the largest possible fuel feed size, which must respect the maximum L/D ratio of the fuel particles to be fed. Convenient surfacing with series steam circulating requires tubed bed depths of from 1.5 ft. to 3.5 ft. depending upon service temperatures.

2.2.8 Bed Operating Temperatures

In general the fluidized bed combustion process must operate over a temperature range of from 900F to 2000F (900F minimum light-off; 1400F minimum control; 1550F normal operation to optimize sulfur capture in the main cells or 1850 to 2000F in the carbon burnup cell where sulfur capture is of less importance) .

Although main bed operating temperatures are set at 1550F for efficient limestone utilization (refer to Section 2.2.1) additional heat may be released in the freeboard raising temperatures there to the 1650F to 1850F range locally. Maximum combustion zone temperatures, with gas chemistry controlled to be net oxidizing, are controlled by design with operation not to exceed 2000F for the following reasons:

- Avoid ash softening or fusion conditions.
- Avoid appreciable thermal decomposition of CaSO_4 formed in the process.

In this study main bed temperatures were selected to correspond with the temperature at which sulfur retention maximizes for minimum limestone consumption for typical bituminous coals. When actual tests are performed on the intended coals and acceptors, this temperature may shift $\pm 30\text{F}$.

Where sulfur capture and limestone utilization are not overriding considerations, bed operating temperatures may be compromised for the following reasons:

- a. Lower temperatures.
 - Maximize heat absorbed by in bed surfaces (most efficient).
 - Lower heat input to steam circuits located in the beds for fast responding load control.
 - Lower NO_x formation for high nitrogen content fuels.

b. Higher temperatures.

- Increase combustion efficiency for low reactivity fuels and where fines recycle directly to main beds is considered.
- Reduce the duty and amount of heat transfer surface which must be installed, where driving temperatures are reduced by high steam temperatures or outside metal temperatures occurring at low load.

In this study carbon burn-up cell temperatures were selected to provide a high carbon burn-up efficiency, as limited by maximum temperature limits and practical considerations.

CBC cell operating temperatures, when burning main cell elutriated chars, are limited by the following:

a. Upper limit.

- Avoid thermal decomposition of calcium sulfate, where spent bed material is used for the CBC bed.
- Avoid ash softening temperatures.
- To provide margin against difficult to predict changes in combustible content or heating values of chars.
- To provide design margin against higher combustible carry-off than normally planned for from main beds at maximum loading.

b. Lower limit.

- Ensure ignition, stable combustion and acceptable burn-out of chars.

These considerations are discussed in more detail under Sections 2.2.1 and 2.2.4.

In this study the following bed temperatures were considered:

	Bed Temperatures (F)	
	<u>Main Cells</u>	<u>CBC Cell</u>
Design	1550	1900
Peak	1650	2000
Control	1400	1800, 1550 (coal)
Minimum Stable	1300	1600, 1300 (coal)
Light Off	1000	1000 (coal)

2.2.9 Excess Air

Sulfur capture is enhanced by increasing mean oxygen partial pressure in the bed, however, excess oxygen much above 3 to 4% has marginal effect and tend to raise the small thermal NO_x levels somewhat. Economics suggest minimizing excess air to lower dry gas losses which impact thermal efficiency.

In this study excess air was selected to provide acceptable combustion and reaction efficiencies, and provide sufficient margin for combustion controls to respond and avoid allowing the operating beds to fall below critical oxygen contents locally.

The minimum recommended excess oxygen contents for acceptable performance are 3 and 4% when measured above operating beds, for main cells and CBC cells respectively. At no time should oxygen partial pressure be allowed to fall below .5% where reducing/regenerating conditions may develop in the bed. At this point considerable SO_2 may be driven from sulfated beds and a sticky eutectic of $\text{CaS} \cdot \text{CaSO}_4$ may form tending to defluidize and fuse the bed.

In this study the following excess oxygen contents were considered:

	Oxygen Contents (Volume %)		
	<u>Main Cells</u>	<u>CBC Cells</u>	<u>Combination</u>
Design	3.2	4.7	3.3+
(Equivalent excess air)	(20)	(30)	(22)
Minimum Recommended	3.0	4.0	3.2-
Absolute Minimum	.5	1.0	---

Although operating experience in larger beds may allow operation with lower excess air than indicated, the design values are increased for the following reasons:

- Marginal improvement of in-bed combustion and sulfur removal efficiency.
- Assure net oxidizing conditions in upper tubed beds, where coal enters the bed from the top. Oxygen activity is considered important to the avoidance of sulfiding conditions in fluid beds.
- Provide increased margin against the development of reducing conditions, considering variables in fuel feed rate and combustable content, and variable losses induced by changes in feed moisture and limestone calcining duty.

During initial operation it is considered important to maintain high excess air to promote development of stable oxide coatings on high temperature bed tubing.

2.2.10 Freeboard Height

The height allowed above the bed for the disengaging of larger sized particles elutriated and thrown into the freeboard as bubbles burst through the top of the beds is normally termed freeboard.

With the overbed-feeding of coal and limestone finer than indicated by optimum process conditions, the importance of the zone above the bed takes on increased significance when considered as a secondary reactor to promote sulfur capture, provide control of peak freeboard temperatures and combustion of finer materials. In this case, solids holdup, residence time, mixing and recirculation in the zone of the bed are important. The heat absorption capability of this zone is similarly important. In this study a freeboard height of almost 12 feet has been allowed as compared to 6 feet minimum considered for in-bed feed systems, to provide increased gas and solids residence times, heat absorbing surface and to provide for the distribution of feeds in a lower velocity zone before accelerating gases to the offtake.

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Future designs contemplating higher fines content in the feed stocks, with over bed feed, must receive increased attention to optimize the volume and configuration of this zone and the downstream gas collection column to optimize their performance.

Freeboard height and configuration must be designed to avoid temperatures exceeding 2000 to 2200 F locally where oxidizing conditions prevail, to avoid ash fusion and calcium sulfate decomposition temperatures. If with high finer fuel loading, local oxygen content can become depressed and approach .5% by volume, tending towards reducing--special design provisions will have to be incorporated to avoid this condition.

2.3 AFB EMISSIONS

The air pollutants that are of primary concern in a utility coal fired steam generator include particulate matter, sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), and hydrocarbons (HC). In particular, the Environmental Protection Agency (EPA) has put limits on particulate matter, SO_2 and NO_x emissions. The fluid bed steam generator has the capability of limiting the gaseous emissions to acceptable levels without use of external equipment. Details of the fluid bed mechanisms accomplishing these are outlined below. In addition, a brief description of the particulate removal system is presented. This system will be discussed in further detail under Section 6 "Particulate Removal Equipment." Emission data for the performance fuel is provided in Figure 2.24.

Thermal and noise emissions associated with the AFB steam generator will be no more severe than with a similar size pulverized coal unit and will comply with all existing federal standards.

2.3.1 SO_2 Emission

Combustion in the fluidized bed is obtained by fluidizing with air at a the bed at a specified rate to obtain suspension and combustion of the coal particles. The mechanism for limiting SO_2 emissions from the combustion process consists of injecting limestone into the bed to form a homogenous mixture with the coal particles. The injected limestone in the bed calcines to form calcium oxide (CaO) from the combustion heat. This CaO reacts

Figure 2.24 EMISSION DIAGRAM FOR PERFORMANCE COAL

chemically with the SO_2 released from the combustion of sulfur compounds in the coal, forming calcium sulfate (CaSO_4). The CaSO_4 which is an inert solid is continuously removed from the bed through the bed material removal tap. The combustion temperature of 1550F in the main beds, where most of the coal is burned, optimizes the sulfur capture by the limestone. Typical SO_2 reduction vs. temperature curves for atmospheric fluidized bed are given in Figure 2.25. Flyash leaving the main cells is captured in the cyclone dust collectors and reinjected into the carbon burnup cell (CBC). The CBC cell operates at a temperature of 1900F to maximize carbon burnout. Temperature is not optimum for sulfur capture, however. The relatively small amount of sulfur compounds do not adversely affect the total SO_2 emission. The chemical reactions leading to sulfur capture are:

Although most of the sulfur capture occurs in the fluidized beds, some additional capture can occur after the bed in the freeboard zone, gas pass, heat recovery area (HRA), cyclones, flues and baghouse. A small part of the fuel sulfur will be removed through the bed tap as unburned sulfur or captured by the coal ash.

The maximum quantity of SO_2 emitted to the atmosphere for performance and worst coals is estimated to be no more than 1.16 lb per million Btu.

Figure 2.25 Typical SO_x Reduction

2.3.2 NO_x Emission

Oxidation of nitrogen in fuel and combustion air produces nitrogen oxide (NO), a part of which further oxidizes to form nitrogen dioxide (NO₂) in the furnace with the remaining nitrogen oxide (NO) converting to NO₂ after being emitted from the stack. The NO and NO₂ combination is termed NO_x for the oxides of nitrogen and there are several factors which influence the amount of NO_x formed. The major factors are combustion temperature, amount of nitrogen in fuel, amount of excess air, and amount of oxygen in the flue gases. As discussed earlier, a combustion temperature of 1550F is used for the main beds to optimize sulfur capture. At this temperature, only limited NO_x is produced from the nitrogen present in the combustion air and the formation of NO_x from the fuel nitrogen is also not excessive. There is approximately 3.2% oxygen in the flue gases thus further minimizing the NO_x formation. Results from a fluidized bed test unit in Alexandria, Virginia have shown that in the 1500F to 1650F temperature range, the NO_x formation from fuel nitrogen is very small and well within the EPA limits to a temperature of 2000F. Typical NO₂ formation vs. temperature curves for atmospheric fluidized bed combustion are given in Figure 2.26. With the CBC temperature of 1900F, the small amount of fuel nitrogen available at this point contributes very little to the total NO_x formation. Tests have further indicated a reduction in the amount of NO_x from the point of formation (fluid bed) to the point of emission (stack). This is attributed to the interaction of NO with carbon monoxide which results in

Figure 2.26 Typical NO_x Generation

formation of carbon dioxide and nitrogen. The natural characteristics of the fluid bed combustion process reduce the NO_x formation to approximately 50% of that produced with the ordinary pulverized coal combustion processes in service today.

The NO_x formation for the performance and worst case fuels are estimated to be 0.31 and 0.29 lbs per million Btu input, respectively, which are well within the EPA limit of 0.7 lb per million Btu input.

2.3.3 CO Emission

The maximum quantity of carbon monoxide emitted to the atmosphere is estimated at $0.04 \text{ lb}/10^6 \text{ Btu}$.

2.3.4 HC Emission

The maximum quantity of hydrocarbons, expressed as C_6H_6 , emitted to the atmosphere is estimated at $0.01 \text{ lb}/10^6 \text{ Btu}$.

2.3.5 Particulate Emission

The particulate emission criteria for the fluidized bed steam generator has been specified at 0.06 lb per million Btu input. This limit, which is more stringent than the present EPA limit of 0.1 lb per million Btu input, requires very high particulate removal efficiencies and limits consideration to only electrostatic precipitators or baghouses as the primary dust collection equipment. The electrostatic precipitator arrangement downstream of the air preheater ("cold" precipitator) was discarded due to the inherent

low sulfur content of the flue gases with the fluidized bed combustion process. This "cold" precipitator location is recommended only for conventional boilers using high sulfur coal where the sulfur lowers the ash resistivity to the desirable range. The precipitator location upstream of the air preheater ("hot" precipitator) is more desirable from the resistivity viewpoint, however, with dust resistivity being a critical factor in precipitator performance and scarcity of this data from a fluid bed steam generator, the reliability of the precipitator performance must be considered questionable. Despite the limited baghouse experience with large scale utility boilers, its consistent high efficiency performance independent of the dust chemistry and loading, suggest the baghouse to be the preferred particulate removal system at this time. The temperature limitation on available bag fabrics (550F) requires the baghouse to be located at a point downstream of the air preheater ("cold" baghouse).

A mechanical precollector system for the main beds and carbon burn-up cell, upstream of the air preheaters is required to reduce dust loading on the air preheaters to an acceptable level and limit dust accumulation in the flues. This system also reduces the dust loading to the baghouse, which reduces the efficiency requirements and improves bag filter life. In addition, this system is used to collect the elutriated material from the main beds, which contain unburned combustible material representing up to approximately 11% of the fuel heating value, for reinjection into the carbon burnup cell. This further combustion under more favorable conditions

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improves the steam generator overall thermal efficiency. Details of the particulate collection system are further expanded under Section 6.0 of the report.

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SECTION 3

AFB STEAM GENERATOR MATERIAL AND ENERGY BALANCES (TASK 4231)

3.1 SUMMARY PERFORMANCE SHEETS

Table 3.1 lists performance information for the 570 MW subcritical, once-through AFB steam generator. The information listed is based on unit operation when firing the performance coal. Steam side conditions were set by the turbine cycle specified for the study.

Items of special note include the following:

- The unit efficiency includes a fan credit for the purpose of comparison to a pulverized coal (PC) steam generator. The fan credit was based on the static head developed by the forced draft (FD) fans minus 20 in. WG, which is a typical FD fan static head for a PC steam generator.
- The air flow leaving the regenerative air heaters listed in Table 3.1 is 95.5% of the total combustion air required. The remaining combustion air is supplied through the bed letdown coolers and the CBC pneumatic underfeed system.
- The pressure drop through the main steam circuitry including both heated and unheated pressure parts is 600 psi. The re-heat pressure drop is 40 psi.
- Air heater leakage is 621,000 lbm/hr.
- Bed letdown material is cooled to 250F.

TABLE 3.1 570 MW AFB STEAM GENERATOR SUMMARY PERFORMANCE

Load (% MCR)	100
Steam (M lbm/hr).....	3977.0
Grade Elevation (ft).....	400
Pressure, superheater outlet (psig).....	2620
Temperature, steam superheater outlet (F).....	1005
Pressure, economizer inlet (psig).....	3220
Reheat steam (M lbm/hr).....	3558.9
Temperature, steam entering reheater (F).....	628
Temperature, steam leaving reheater (F).....	1005
Pressure, steam entering reheater (psig).....	576
Pressure, steam leaving reheater (psig).....	536
Temperature (F):	
Feed entering unit.....	484
Air entering unit.....	96
Air leaving air heater.....	639
Gas leaving MBC fluidized bed.....	1550
Gas leaving economizer.....	720
Gas entering air heater.....	720
Gas leaving air heater.....	300
Gas leaving air heater corrected for leakage.....	283
Bed letdown material.....	250
Excess air leaving MBC/CBC (%).....	20/30
Wet gas entering air heater (M lbm/hr).....	5332
Wet gas leaving air heater (M lbm/hr).....	5953
Air entering air heater (M lbm/hr).....	5276
Air leaving air heater (M lbm/hr).....	4656
Gas-side loss (in. WG):	
HRA.....	3.5
Mechanical collectors.....	3.0
Air heater.....	5.1
Flues.....	2.0
Bag house.....	6.0
Total Gas Side Loss.....	19.6
Air-side loss (in. WG)	
Air heater.....	3.7
Ducts.....	2.5
Grid.....	22.0
Bed.....	36.0
Measuring Device.....	1.4
Steam coil.....	1.0
Total Air-Side Loss.....	66.6

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Steam-side pressure loss (psi)*:

Economizers	53
Waterwall enclosures	388
Superheaters	159
Total main steam loss	600
Reheaters	40
Total reheat steam loss	40

*Heated and unheated pressure part losses.

Heat loss (%)

Dry gas.....	4.54
Hydrogen and moisture in fuel.....	5.42
Moisture in air.....	0.11
Unburned combustible.....	2.10
Radiation.....	0.17
Calcination and other.....	0.23
Fan credit.....	-0.45
Unaccounted.....	0.50
Manufacturer's margin.....	1.00
Total heat loss.....	13.62
Steam generator efficiency (%).....	86.38

Performance Based on Fuel Specified Below:

Grindability (Hardgrove).....	55.0
Maximum moisture (%).....	13.55
Surface moisture (%).....	11.05

Ultimate Analysis (% by weight):

	<u>As Received</u>
Ash.....	10.00
Sulfur.....	2.55
Hydrogen.....	4.27
Carbon.....	61.15
Moisture.....	13.55
Nitrogen.....	1.21
Oxygen.....	7.27
	100.00

Higher Heating Value (Btu/lb)..... 11,081

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Limestone Analysis (% by weight):

CaCO ₃	86.6
MgCO ₃	3.0
H ₂ O*.....	9.8
Other.....	<u>0.6</u>
	100.0

*Includes surface moisture

3.2 MATERIAL BALANCE FLOW DIAGRAMS

Figures 3.1, 3.2, and 3.3 are the material balance flow diagrams for the performance coal, worst coal with 50% flyash elutriated, and worst coal with 100% flyash elutriated, respectively. The steam generator was sized for the performance coal, while the steam generator auxiliary equipment was sized for the worst coal. Bed letdown equipment was sized from the material balance for the worst coal with 50% flyash elutriated. The mechanical dust collectors and the baghouse were sized from the material balance for the worst coal with 100% flyash elutriated.

Each flow diagram was based on the following:

- 89% burn-up in the MBC's
- Bed letdown material leaving coolers with 1.25% carbon.
- 10% of the limestone fed into the MBC's is blown out of the MBC's without contributing to bed sulfur capture.
- Air to fines ratio of 1.0 for pneumatic underfeed of recycled fines into CBC.
- Overall collection efficiency of 92% for HRA hopper and mechanical dust collectors. The diagrams indicate the HRA hopper capturing 10% of the solids leaving the HRA.
- CBC mechanical dust collector efficiency equal to 90%.
- Baghouse efficiency equal to 99%.
- A fraction of the bed letdown material leaving the letdown coolers supplements the CBC bed with 3% of the CBC bed weight.
- Under normal operating conditions CBC bed letdown coolers are not in operation.

MATERIAL FLOW DIAGRAM 570 MW FLUIDIZED BED STEAM GENERATOR (PERFORMANCE COAL)

FIGURE 3.1 MATERIAL FLOW DIAGRAM - PERFORMANCE COAL

MATERIAL FLOW DIAGRAM 570 MW FLUIDIZED BED STEAM GENERATOR (WORST COAL - 50% FLYASH ELUTRIATED)

FIGURE 3.2 MATERIAL FLOW DIAGRAM - WORST COAL (50% ASH ELUTRIATED)

MATERIAL FLOW DIAGRAM 570 MW FLUIDIZED BED STEAM GENERATOR (WORST COAL-100% FLYASH ELUTRIATED)

FIGURE 3.3 MATERIAL FLOW DIAGRAM - WORST COAL (100% ASH ELUTRIATED)

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- A fixed quantity of air is passed through the bed letdown taps to maintain a 10 ft/sec superficial fluidizing velocity while the remainder of cooling air is bypassed around the bed.
- Bed letdown cooling air is taken from the FD fan discharge and passed through booster fans.
- Air for pneumatic underfeed of recycled fines to the CBC is obtained from independent blowers.
- Coal flows indicated are based on a unit efficiency that includes the manufacturer's margin and a fan credit as described in Section 3.1.

Section 4

AFB STEAM GENERATOR DESIGN
(Task 4232)4.1 STEAM GENERATOR ARRANGEMENT

Drawings covering the physical arrangement of the steam generator and its associated equipment are included under Section 8 of this report. These drawings include the arrangement of the water/steam and air/flue gas systems.

4.1.1 Steam/Water Circuitry

4.1.1.1 General. Figure 4.1 schematically illustrates the steam and water circuitry. Feedwater enters the steam generator through the Heat Recovery Area (HRA) extended surface economizer (ECON1). From ECON1 sub-cooled water passes through the convection economizer located above the Carbon Burnup Cell (CBC) bed (ECON2) and then through the horizontal CBC bed heating surface (ECON3). After passing through ECON3, the sub-cooled water is directed through the two CBC sidewall enclosures (CBCSW). From CBCSW, the fluid passes through the horizontal Main Bed Cell (MBC) bed steam generating surfaces (BB1 and BB2). Figure 4.2 denotes the temperature-enthalpy diagram for the subcritical cycle specified. As noted on this diagram, the transition from subcooled water to a steam/water mixture occurs within BB1.

BOILER STEAM AND WATER CIRCUITRY DIAGRAM

NOMENCLATURE:

MBC - MAIN BED CELL
 CBC - CARBON BURNUP CELL
 HRA - HEAT RECOVERY AREA
 ECON - ECONOMIZER
 BB - BOILING BED
 FW - FRONT WALL
 SW - SIDE WALL

RW - REAR WALL
 GP - GAS PASS
 I.S. - INTEGRAL SEPARATORS
 PRI - PRIMARY SUPERHEATER
 FSH - FINISHING SUPERHEATER
 RHT - REHEATER

FIGURE 4.1 STEAM AND WATER CIRCUITRY DIAGRAM

FIGURE 4.2 STEAM AND WATER TEMPERATURE - ENTHALPY DIAGRAM

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The steam/water mixture leaving BB2 then passes through the boiler enclosure surfaces in the following order: front wall (FW), sidewalls (SW), rear wall (RW), gas pass (GP), heat recovery area (HRA) and roof (ROOF). Figure 4.3 schematically illustrates the relative location of the vertical boiler enclosure passes. As noted in Figure 4.2 the transition from a two-phase mixture to superheated steam occurs in the RW pass at full load conditions.

From the ROOF outlet, superheated steam passes through seven (7) integral separators. The integral separators (see Figure 4.4) are required during start-up and low load operation to separate the entering steam/water mixture, allowing only steam to pass on to the superheating circuits. A detailed description of the once-through integral separation start-up system is described in Section 11 of this report.

After passing through the integral separators, the superheated steam passes through the convention superheater (PRI) located in the outboard pass of the HRA. The superheated steam then passes through the horizontal MBC bed superheating surfaces (FSH1 and FSH2). Base spray stations each having a continuous 3% MCR flow are located upstream of FSH1 and FSH2. The sprays provide control of final steam temperature by reacting to short term final steam temperature transients.

- NOTES:
1. Bed enclosure sidewalls form grid and bed roof.
 2. Gas pass rear wall forms CBC roof and rear wall.
 3. Gas pass sidewalls form sidewalls for ECON2 in CBC; CBC sidewalls are a separate pass.

FIGURE 4.3 ENCLOSURE CIRCUITRY ARRANGEMENT

INTEGRAL SEPARATOR

Figure 4.4
4-6

The reheat circuitry consists of convection surface located in the inboard pass of the HRA (RHT1) and horizontal MBC bed reheat surface (RHT2). The reheat steam first passes through RHT1 and then through RHT2.

The all-series arrangement for the steam/water circuitry eliminates the need for valving in the main steam lines, thus simplifying unit operation and the control system. However, as described in Section 11 of this report, a minimum of 35% full load flow is required during start-up and low load operation with this arrangement.

Table 4.1 lists the steam/water circuitry material requirements. All pressure part materials indicated are similar to those utilized in a conventional pulverized coal steam generator.

4.1.1.2 Economizers. Economizer surface is concentrated in three areas of the unit, i.e., the HRA outlet (ECON1), the CBC outlet (ECON2) and the CBC bed (ECON3).

ECON 1 is a counterflow heat exchanger consisting of Kentube extended surface elements running in-line, parallel to the unit sidewalls in a multi-loop horizontal tube arrangement with water passing in up-flow so the static head aids in insuring stable flow distribution through the tubes during low load operation. Flue gas from the HRA inboard and outboard passes is directed over the economizer elements by means of control dampers located directly above the economizer. With the economizer elements running parallel to the unit sidewalls, each element is heated uniformly, even when gas temperature varia-

<u>Pass</u>	<u>O. D. (in.)</u>	<u>N. W. (in.)</u>	<u>Material</u>	<u>Side Spacing (in.)</u>	<u>Back Spacing (in.)</u>	<u>No. Tubes</u>	<u>Sections Wide</u>	<u>Loop-in-Loop</u>	<u>Loops</u>	<u>Heating Surface (ft²)</u>	<u>Notes</u>
HRA Economizer (ECON1)	2	0.200	SA-210C	5	5	238	144	2	3	107,900	Kantube elements with 3/4" fins, 0.075" thick on 2" O.D. tubes, 24 fins/foot.
CBC Conv. Economizer (ECON2)	2 1/4	0.207	SA-210C	4	3	360	180	2	8	47,100	
CBC Bed Economizer (ECON3)	2 1/4	0.217	SA-210C	10	7 1/2	96	24	4	1/2	3,400	
CBC Sidewall Encl. (CBCSW)	1-3/4	0.163	SA-210C	2	-	238	-	-	-	720	
MBC Steam Gen. Bed (BB1)	1-7/8	0.195	SA-213 T22	7	5	146	73	2	1 1/2	12,800	
MBC Steam Gen. Bed (BB2)	1-7/8	0.197	SA-213 T22	7	5	146	73	2	1 1/2	12,800	
MBC Front Wall Encl. (FW)	1-3/4	0.200	SA-210C	2	-	361	-	-	-	9,700	
MBC Sidewall Encl. (SW)	2-3/4	0.263	SA-210C	3 1/2	-	150	-	-	-	23,900	MBC sidewall and roof tubes. MBC grid tubes.
	2-1/2	0.257	SA-210C	3 1/2	-	150	-	-	-		
MBC Rear Wall Encl. (RW)	1-3/4	0.200	SA-210C	2	-	361	-	-	-	23,100	
Gas Pass Encl. (GP)	1-3/4	0.200	SA-213 T2	2	-	361	-	-	-	25,100	Gas pass rear wall tubes. Gas pass sidewall tubes.
	1-5/8	0.200	SA-213 T2	2	-	154	-	-	-		
ERA Encl. (HRA)	1 1/4	0.157	SA-210C	2	-	1077	-	-	-	11,000	
Roof Encl. (ROOF)	1-3/4	0.200	SA-213 T2	2	-	361	-	-	-	5,800	
HRA Conv. Superheater (PRI)	2-1/4	0.238	SA-213 T11	6	3	360	120	3	9 1/2	71,700	Horizontal elements. Vertical elements.
	2-1/4	0.238	SA-213 T11	6	3	360	120	3	1/2		
MBC Superheater Bed (FSH1)	2-1/8	0.223	SA-213 TP 304H	7	5	219	73	3	1	14,800	
MBC Superheater Bed (FSH2)	2 1/2	0.333	SA-213 TP 304H	7	5	219	73	3	1	17,700	
HRA Conv. Reheater (RET1)	2-1/4	0.180	SA-210C	4	3	900	180	5	1-3/4	40,000	Horizontal elements. Vertical elements.
	2-1/4	0.180	SA-213 T2	8	3	900	90	10	1/2		
MBC Reheater Bed (RET2)	2-3/8	0.180	SA-213 TP 304H	7	5	438	73	6	1/2	16,600	

TABLE 4.1 MATERIALS OF CONSTRUCTION

tions occur leaving the HRA inboard and outboard passes. ECON1 surface was selected to lower the flue gas temperature from approximately 920F to 720F at full load conditions. The entering gas temperature was selected to avoid exceeding the maximum allowable fin tip temperature. Sufficient space at the center of the tube bundle was provided for future installation of stationary rotary sootblowers.

ECON2 is a parallel upflow heat exchanger consisting of bare-tube elements running in-line, parallel to the unit sidewalls in a multi-loop horizontal tube arrangement. By means of ECON2, the flue gas leaving the CBC freeboard is cooled from approximately 1630F to 720F, eliminating the need for a refractory lined duct and high temperature cyclone to handle the CBC exhaust gases. Clearance between adjacent economizer elements was set based on the flue gas temperature and ash analysis to avoid ash bridging between elements while at the same time providing a sufficient gas-side film conductance. With the elements running parallel to the unit sidewalls, each ECON2 element can be supported from the RW and GP enclosure elements without the need for a complex stringer support arrangement. Sufficient space was provided at the center of the tube bundle for future installation of retractable rotary sootblowers.

ECON3 is a single pass heat exchanger consisting of bare-tube elements running in-line, perpendicular to the unit sidewalls. The ECON3 heating surface was selected to maintain the CBC bed temperature at 190CF at full load operating conditions. Since the CBC consists of four (4)

independently operated segments located across the unit width, the bed tubes were extended perpendicular to the unit sidewalls to avoid heat distribution variations from element to element when less than all four segments are in operation.

4.1.1.3 Waterwalls. Waterwalls enclosing the steam generator are of MonowallTM construction. The waterwall enclosures include the following passes - CBCSW, FW, SW, RW, GP, HRA, and ROOF. Each pass is a vertical up-flow circuit except for the ROOF which is essentially horizontal (-1 deg. slope). Figure 4.3 schematically illustrates the relative location of the vertical enclosure passes in plan view.

Except for the CBCSW headers, all waterwall headers are connected by a combination of risers, downcomers, and feeders, designed to minimize longitudinal flow in the headers. Longitudinal flow of a two-phase mixture through inlet headers can cause separation of phases, resulting in flow variations from element to element. All risers from each individual pass are fan mixed to their corresponding downcomers to provide thorough mixing of the steam/water mixture between passes. Single phase, sub-cooled water passes through the CBCSW pass. Consequently, transfer piping connected to the inlet and outlet header ends, transports the sub-cooled water to and from the CBCSW pass.

The FW pass, which forms the MBC front wall, is comprised of 1-3/4 in. OD tubes on 2 in. centers. The tubes extend vertically upward in straight

lengths except for some tubes which must bend to form openings for the coal feeders, bed letdown/coolers, emergency limestone feed pipes, and access doors.

The RW pass, which forms the MBC rear wall, gas pass front wall, and CBC front wall, is also comprised of 1-3/4 in. OD tubes on 2 in. centers. The tubes extend vertically upward in straight lengths except for some tubes which must bend to form the screen through which the MBC flue gases must pass to enter the gas pass. Except for the section that forms the CBC front wall, the RW tubes are heated from both sides.

The SW pass is comprised of the tubing that forms the MBC sidewalls, MBC roofs (except for the top bed), and MBC water-cooled grids (Section 4.4 describes the water-cooled grid design in detail). The tubes forming the grid are 2 1/2 in. OD on 3 1/2 in. centers, while the sidewall and roof tubes are 2-3/4 in. OD on 3 1/2 in. centers. Formation of the MBC roof and grid with the sidewall tubes provides a convenient means for introducing air into the air plenum beneath the grid since sidewall tubes do not have to be bumped to provide a screen opening.

The GP pass is comprised of 1-5/8 in. OD tubes that form the side walls of the gas pass and also extend downward to form the side walls of the CBC upper economizer (ECON2), and 1-3/4 in. OD tubes that form the gas pass rear wall, HRA front wall, and CBC roof and rear wall. All tubes are on 2 in. centers.

The HRA and ROOF passes are of conventional design. The HRA pass

includes the HRA sidewalls, rear wall, and partition wall. The pass is formed by $1\frac{1}{4}$ in. OD tubes on 2 in. centers. The ROOF pass forms the roof for the top MBC, the gas pass, and the HRA. The pass is formed by $1\text{-}\frac{3}{4}$ in. OD tubes on 2 in. centers.

Because of the variation in depth between the gas pass and CBC, the CBC sidewalls form a separate pass (CBCSW). The elements are $1\text{-}\frac{3}{4}$ in. OD on 2 in. centers. At the top of the CBC freeboard zone where the CBCSW tubes meet the GP sidewall tubes a scissors connection forms a seal between the two enclosure passes. The CBCSW pass has two (2) inlet and outlet headers with single end connections. Unlike the MBC sidewall tubes, the CBCSW tubes do not form a water cooled grid. As discussed, a Section 4.4 the CBC grid is formed with a refractory covered plate.

4.1.1.4 MBC Surface Arrangement. Each MBC bed is equipped with horizontal, upflow heating surface designed to maintain the bed temperature at 1550F. Since each MBC consists of four (4) independently operated segments located across the unit width, the bed tubes extend perpendicular to the unit sidewalls to avoid heat distribution variations from element to element when less than four segments are in operation. The tubes are arranged in a staggered array with 7 in. side spacing and 5 in. back spacing which is compatible with the sidewall tube spacing required for penetration and support purposes. The uniform spacing across the MBC depth provides uniform heat distribution throughout the bed volume while promoting uniform air distribution and bed mixing.

The centerline of the uppermost tube is $2\frac{1}{2}$ in. from the top of the bed, while the centerline of the lowest tube is 18 in. from the centerline of the water-cooled grid tubes. The clearance between the grid tubes and the lowest bed tubes provides space for access and maintenance purposes.

The MBC bed heating surface includes the following steam/water circuitry passes, all arranged on a staggered pitch: steam generating surfaces (BB1 and BB2), reheater (RHT2), and superheating surfaces (FSH1 and FSH2).

Steam generating beds, BB1 and BB2, are the first and second MBC's from the bottom of the unit, respectively. As noted in Section 11.1 of this report, segments of BB1 and BB2 are the first MBC segments brought into service since a minimum flow of 35% MCR is maintained through the circuitry during start-up. Locating BB1 and BB2 in the lower half of the unit aids in the waterwall water circulation during start-up and low load operation since the tubing is heated strongest at the bottom, which assists the forced circulation with some natural circulation. In addition, since BB1 is in operation at all times, it acts as a hopper for the gas pass by removing de-entrained flyash that falls down through the gas pass into the bottom bed. If the bottom bed were not in operation under all main cell operating conditions, this flyash could accumulate in the bottom bed.

BB1 and BB2 tubes are 1-7/8 in. OD. A high mass flow is provided through the tubes to avoid undesirable flow regimes (stratified, wavy, slug, plug) created by the two phase mixture passing through the tubes. Since

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subcooled water enters BB1, the BB1 inlet header has double end connections, whereas the BB1 outlet header and the BB2 inlet and outlet headers are equipped with fan mixed feeders and risers required to avoid separation of the phases within the headers and also to insure uniform fluid temperature entering the downstream pass.

RHT2 is the center MBC bed. Since the reheat flow can tolerate only a small pressure drop through the reheat circuitry, 2-3/8 in. OD tubes span from one MBC side wall to the other in a single run of tubing. Inlet and outlet headers are single end connected to transfer piping. The outlet header is the steam generator termination for 1005F, 536 psig steam to the low pressure turbine.

FSH1 and FSH2 are the upper MBC bed levels. FSH1 and FSH2 are comprised of 2-1/8 in. OD and 2 1/2 in. OD tubes, respectively. All inlet and outlet headers have single end connections connected to single transfer lines which ensures uniform conditions entering and leaving each pass. The circuitry was designed with mass flow rates high enough to sufficiently cool the tubes over the load range without creating an excessive pressure loss. The FSH2 outlet header is the steam generator termination for 1005F, 2620 psig steam to the high pressure turbine.

All once-through steam generators control final steam temperature by adjustment of the firing rate. In addition, all FWEC coal-fired once-through units are designed with a base-loaded spray system to handle small excursions

in final steam temperature resulting from load changes, variations in coal quality, and transient conditions. For the same reason base-loaded sprays are located upstream of FSH1 and FSH2. These are optimum spray locations because the large quantity of heat absorbed in the superheater banks guarantees dry steam at the finishing superheater outlet and because these locations provide quick response time to changes in final steam temperature.

4.1.1.5 Convection Superheater and Reheater. The steam generator is equipped with a Heat Recovery Area similar to that used on most conventional pulverized coal utility boilers designed and built by Foster Wheeler Energy Corporation. The inboard pass of the HRA has convection reheater (RHT1), while primary superheater (PRI) is located in the outboard pass.

PRI is the first superheating pass downstream of the integral separators. It is a counterflow heat exchanger consisting of bare-tube elements running in-line, parallel to the unit sidewalls in a multi-loop horizontal upflow tube arrangement with a vertical outlet leg. The tubes are $2\frac{1}{4}$ in. OD with 6 in. side spacing and 3 in. back spacing. Flow enters PRI through a single header fed by feeders leaving the integral separators. The outlet header has a single end connection from which a single transfer pipe directs flow to the finishing superheater bed circuits. During start-up, before the MBC superheating beds are ignited, PRI provides superheated steam to warm the steam lines and roll the turbine.

RHT1 is the first pass in the reheat circuitry. It is a counter-

flow heat exchanger consisting of bare-tube elements running in-line, parallel to the unit sidewalls in a multi-loop horizontal upflow tube arrangement with a vertical outlet leg. The tubes are $2\frac{1}{4}$ in. OD with 3 in. back spacing, and 4 in. and 8 in. side spacing for the horizontal and vertical runs, respectively. Both inlet and outlet headers have single end connections. Gas temperatures at the RHT1 inlet permit placement of the inlet header within the gas stream, minimizing the number of enclosure penetrations required. Adjustment of the parallel pass dampers provides control of the final reheat temperature.

4.1.2 Air Systems

4.1.2.1 General. The Air Flow system including damper locations is schematically illustrated on Figure 4.5. Two (2) forced draft (FD) fans supply air that is utilized for the following:

- Combustion of coal in the MBC's at 20% excess air.
- Combustion of recycled fines in the CBC at 30% excess air.
- Fluidization of coal and limestone in the MBC's.
- Fluidization of recycled fines in the CBC.
- Cooling of the MBC bed letdown material.

Approximately 86% of the air discharged from the FD fans passes through two (2) Ljungstrom regenerative air heaters, raising the air temperature to 639F. This quantity of air represents 95.5% of the combustion air required. Steam coil air heaters are located upstream of each air heater in order to prevent cold end acid corrosion during low load operating conditions. The preheated air leaving the air heaters is passed through

NOTES:

1. AIR FLOW TO MBC'S IS CONTROLLED BY A TOTAL OF 20 AUTOMATIC REGULATING DAMPERS.
2. AIR FLOW TO CBC IS CONTROLLED BY A TOTAL OF 4 AUTOMATIC REGULATING DAMPERS.
3. HRA INBOARD AND OUTBOARD PASS DAMPERS.
4. AIR FLOW TO THE 24 SOLIDS COOLERS IS CONTROLLED BY 24 AUTOMATIC REGULATING DAMPERS.
5. AIR FLOW THROUGH THE 24 SOLIDS COOLER BYPASS DUCTS IS CONTROLLED BY 24 AUTOMATIC REGULATING DAMPERS.
6. A TOTAL OF 4 ACTUATED SHUTOFF DAMPERS ARE REQUIRED, ONE FOR EACH CBC SEGMENT.

FIGURE 4.5 AIR AND GAS FLOW DIAGRAM

a system of ductwork which directs the air to each MBC and CBC segment. A horizontal duct equipped with a one-sided venturi measuring device (see Section 4.1.2.2) and an automatic control damper feed each MBC and CBC segment air plenum. Each duct is designed for an air velocity of 50 ft/sec at full load operating conditions. This velocity is felt to be an optimum compromise based on economic, erosion, and ash fallout factors.

From each MDC air plenum the preheated air passes through a water cooled grid arrangement (see Section 4.4) that provides a uniform distribution of air to the bed area for fluidization and combustion of the bed material. Because of the number of grid penetrations required for the CBC pneumatic underfeed system, the CBC grid is formed with a refractory covered plate, as described in Section 4.4.

The outer segments of each bed are divided into two (2) sections, one of which is used for ignition. Consequently the air duct supplying the outer segments is equipped with two (2) independently controlled dampers. A bypass duct equipped with a control damper is also required to supply combustion air to the light-off oil burners. Details of the ignition system are described in Section 4.3.

A fraction of the air (2.5%) discharged from the FD fans is directed through two (2) booster fans which increase the air pressure to a level that will allow it to pass through the bed letdown coolers (Section 5.3 describes the bed letdown coolers). In addition to the booster fans, two (2) blowers are required to provide approximately 17% of the CBC combustion air requirement, in order to pneumatically underfeed the recycled fines.

Table 10.1 lists the air system auxiliary equipment requirements. Air flow quantities are indicated in Figure 3.1, 3.2, and 3.3 under Section 3 of this report.

4.1.2.2 Air Flow Metering Devices. Flow to each MBC and CBC segment is measured by a one-sided venturi meter located in the horizontal air duct feeding each segment air plenum. One-sided venturi meters were selected because of their moderate permanent pressure loss and moderate cost, as compared to airfoil and orifice plate meters. Airfoil meters create the least permanent pressure loss but are expensive. Orifice plates are least expensive but create the highest permanent pressure loss. For the meter design selected the permanent air pressure loss is 1.4 in. W.G.

In addition to the one-sided venturi meters the air flow to each bed letdown cooler must be measured as well as the air flow discharged from the CBC pneumatic underfeed system. The quantity of air required for these devices is relatively small; 2.7% of the total unit combustion air for the bed letdown coolers and 1.8% of the total unit combustion air for the CBC pneumatic underfeed system. Orifice plate meters can be used for these air flow measurements.

4.1.3 Flue Gas System

4.1.3.1 General. The flue gas flow system including damper location is schematically illustrated on Figure 4.5. Flue gas exits each MBC at a temperature of 1640F and enters the adjacent gas pass which directs the flue gas

to the HRA. In rising through the gas pass the flue gas temperature drops to 1446F before entering the HRA. In the HRA 33% of the flue gas is directed over the inboard pass (RHT1) while the remainder is directed over the outboard pass (PRI). Dampers at the outlet of each pass control the gas flow through the respective passes. Since the flue gas temperature leaving each pass is less than 1000F, both RHT1 and PRI inlet headers are placed in the gas stream, minimizing enclosure wall penetrations and insulation requirements. The inboard and outboard flue gas streams recombine after the control dampers and then pass over the HRA economizer (ECON1), leaving at a temperature of 720F. Flue gas velocities throughout the unit are indicated in Figure 4.6. As can be seen, tubing arrangements and pass dimensions were selected to provide suitable flue gas velocities, i.e., high gas side film conductances without excessive flyash erosion.

Flue gas generated in the CBC leaves the CBC freeboard at a temperature of 1630F. From the CBC freeboard the gases pass over a convection economizer (ECON2) which cools the flue gas to a temperature of 720F. Figure 4.7 indicates the flue gas velocities through the CBC.

The flue gas leaving the HRA economizer passes through six (6) mechanical dust collectors arranged in parallel, while the flue gas leaving the CBC convection economizer passes through a single mechanical dust collector. Flyash captured from the MBC flue gas stream is pneumatically injected into the CBC bed. Flyash captured by the CBC mechanical dust collector is discarded. Downstream of the mechanical dust collectors the two flue gas

FIGURE 4.6 MBC FLUE GAS VELOCITIES

FIGURE 4.7 CBC FLUE GAS VELOCITIES

streams combine before entering two (2) Ljungstrom regenerative air heaters arranged in parallel. The flue gas leaves the air heaters at 283F. From the air heaters the gas stream passes through a baghouse, after which it passes through two induced draft (ID) fans before going to the stack.

Crossover flues are provided upstream and downstream of the regenerative air heaters, baghouse, and ID fans. The crossover flues permit part load unit operation when a single piece of auxiliary equipment is out of service.

4.1.3.2 Soot Blowing System. As indicated on the steam generator arrangement (Figure 8.1) the AFB unit includes only provisions for a future soot blower system. In general the fluidized bed combustion process operates over a temperature range between 1300F (lower stable operating temperature) to 1900F (CBC operating temperature). Although main bed operating temperature is set at 1550F for maximum limestone utilization, higher temperatures will occur in the freeboard zone. Based on the design conditions, however, temperatures throughout the steam generator will not exceed the ash softening temperature for the fuel ash. With this combustion process, operating at temperatures much lower than conventional pulverized coal fired furnaces, molten ash species will not be produced. The ash produced does not have a tendency to fuse or pack on the transfer surface. Within the fluidized beds, the scrubbing action of the mildly abrasive limestone particles tends to remove any larger deposits formed on the bed tube bundles.

Provisions for a future soot blowing system are being included in the steam generator convection passes for the following reasons:

- During prolonged periods of low load operation with colder steam generator metal there is a tendency to produce hydrocarbons or esters in the combustion zone which do not burn to completion. Present evidence is that these compounds would tend to adhere to elutriated dust, thereby limiting their adhesion to heat absorbing surface.
- During peak load operation with a high fines content in the feed or high excess air, burning fines could be swept through the convection passes and form a lightly fused crown on the tubing. As the unit is cycled, these deposits could fall off and lodge in a tube bundle reducing free flow area. This occurrence is not probable based on the liberal tube spacing and gas flow arrangement.
- As with bed material, if dust deposits on tubes or in hoppers are allowed to become moist or wet, they may experience a mild hydrolic set. With normal efforts to control unit internal air humidity during periods of prolonged shutdown, this should not pose a serious problem requiring soot blowers.

Based on actual operating experience at fluidized bed pilot plants and the 30MW Rivesville, West Virginia multi-cell unit, there is no apparent need to install sootblowers on a fluidized bed steam generator. Future requirement for this system is a function of operating experience and the demonstrated ability to avoid improper operation.

Based on the flyash chemistry, the sootblower system, if required, would include only high pressure air for cleaning of the air heaters and heat transfer surfaces. A steam or water activated blowing system would tend to react with the ash and CaO to form agglomerated solids, causing difficulties with dust collecting equipment.

4.2 MAIN BED CELL

4.2.1 General

The AFB steam generator has a total of five (5) main bed cells (MBCs) stacked vertically adjacent to a gas pass which directs the flue gas leaving each MBC to a conventional heat recovery area (HRA). The MBCs are the primary combustion zones for the fuel fired. Figures 8.1, 8.2, and 8.3 which are included in Section 8, illustrate the stacked MBC arrangement.

4.2.2 MBC Design

Figures 4.8 and 4.9 schematically illustrate a typical MBC plan view and sectional side view, respectively.

Each MBC is 60 ft. wide, 22 ft. deep, and 30 ft. high. The plan area dimensions selected were based on the following design criteria:

- Superficial fluidizing velocity - 10 ft/sec
- Bed operating temperature - 1550F
- Overbed feeder range - 22 ft.
- Number of beds high - 5
- Total fuel fired - 488.9 M lb/hr
- Combustion efficiency - 89%
- Excess Air - 20%

The overall cell height was selected to provide the following dimensions for optimum combustion and equipment arrangement:

FIGURE 4.8 MBC PLAN VIEW

FIGURE 4.9 MBC SECTIONAL SIDE VIEW

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- Air plenum height - 8 ft.
- Bed height - 4 ft.
- Freeboard zone height - 12 ft.
- Exit screen height - 6 ft.

Each MBC is divided into four (4) independently controlled segments in order to facilitate steam generator turndown. Fuel is fed into the MBC by twelve (12) overbed coal feeders positioned along the MBC front wall. The feeder rotor centerline is positioned approximately 2 ft.-9 in. above the top of the bed. The feeders are operated in groups of three (3) to provide independent fuel flow control to each MBC segment. Section 5.1 describes the coal feed system in detail.

Limestone is gravity fed into each MBC through the MBC sidewalls near the MBC rear wall by two (2) 6 in. nominal feed pipes. The feed pipes penetrate the sidewall enclosure directly above the top of the bed. Each feed pipe supplies the limestone requirements for 50% of the bed plan area. An emergency limestone feed pipe (6 in. nominal) is provided at the center of the MBC front wall as illustrated in Figure 4.8. Details of the limestone feed system are included in Section 5.2.

Bed material letdown coolers are provided for each MBC segment to control bed inventory as well as recapture the sensible heat in the letdown material. The bed material letdown coolers are discussed in Section 5.3.

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Air flow to each segment is independently controlled by means of dampers located in each of the four (4) horizontal air ducts feeding the MBC segments. The two (2) air ducts positioned near the MBC rear wall feed the central MBC segments while the two (2) ducts positioned near the MBC front wall feed the outer MBC segments. Each outer segment is equipped with a start-up/ignition system as described in Section 4.4.

Each MBC is enclosed by water-cooled circuitry as described in Section 4.1.1.3. Heat transfer surface is also located within the bed to maintain the bed temperature at 1550F for optimum sulfur capture (see Section 4.1.1.4 for circuitry details).

Air is distributed throughout the bed by means of inclined tee nozzles mounted on a water-cooled grid, details of which are included in Section 4.5.2.

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4.3 CARBON BURN-UP CELL

4.3.1 General

The carbon burn-up cell (CBC) is included on the AFB Steam Generator to provide a second pass carbon burn-up cycle under more optimized firing conditions. Figure 8.1 depicts the arrangement of the CBC. Solids which elutriate from the main bed cells are collected in the heat recovery area (HRA) hoppers and main cyclone hoppers. The collection efficiency of these combined hoppers (see material flow diagram figure 3.1) will result in approximately 92% recycle of main bed solids to the CBC. These solids will be pneumatically transported to the CBC and injected under the bed through an array of nozzles. Refer to Section 5.4 for details of the fly ash reinjection system. Solids elutriated with the gas stream from the CBC will be routed to a separate CBC cyclone where collected material will be discarded, thereby eliminating potential build up of solids in the gas stream.

The CBC also includes the capability of firing supplemental coal through use of the overbed feed system. The spreader feeders are arranged along the CBC rear wall similar to the MBCs. Operation of the CBC is also similar to the MBC in that air, fuel, flyash, limestone flow and bed letdown can be operated independently for each of the four (4) CBC segments. Refer to Figures 4.10 and 4.11 for a sectional side view and plan arrangement of the CBC. During periods of coal firing in the CBC, limestone will be injected to effect the SO_2 capture. It should be noted,

FIGURE 4.10 CBC PLAN VIEW

FIGURE 4.11 CBC SECTIONAL SIDE VIEW

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however, that no credit is taken for sulfur capture in the CBC for calculation of emission levels from the steam generator for both performance and worst case fuels.

A system is also included to provide supplemental bed material to the CBC. The supplemental bed material is required due to an estimated 3% bed material loss per hour due to attrition of material within the bed and eventual elutriation of particles with the exiting gas stream. Since the reinjected fly ash does not contribute to formation of the bed, this would represent a permanent loss and therefore, supplemental bed material is required to maintain the necessary bed depth for proper combustion. Refer to Section 5.5 for further details of the bed material recycle system.

Coal burn-up in the MBC's has been set at 89%. Of the solids recycled to the carbon burn-up cell, it is anticipated that 90% will be combusted which results in an overall steam generator carbon loss of approximately 2.10% for the performance coal. This carbon loss represents a realistic loss to efficiency while still providing for an overall steam generator efficiency of an acceptable level for a utility unit.

4.3.2 CBC Design

The design of the CBC has been based on available test data and operating experience at the Rivesville, West Virginia test facility. The following design parameters have been selected and result in a carbon burn-up cell with a plan area of 1200 square feet (20 ft. deep

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by 60 ft. wide).

- * Bed operating temperature - 1900F
- * Bed fluidizing velocity - 8 ft/sec
- * Bed height (expanded) - 4 ft
- * Design excess air - 30%

The above criteria provides a conservative design while maintaining optimum combustion conditions, and holding bed operating temperature below that found to produce slagging conditions within the cell.

The CBC cell has been designed to be enclosed totally with water cooled surface. The rear wall, front wall and roof are composed of main and gas pass enclosure circuitry. The sidewalls are composed of cono-mizer circuitry denoted CBCSW. In addition, the cell will contain one pass of economizer bed circuitry denoted ECON3 distributed uniformly throughout the bed in order to maintain a bed temperature of 1900F while firing reinjected flyash from the main cells. The CBC will also include economizer convection surface denoted ECON2 located approximately 12 ft. above the expanded bed surface. This surface will effectively reduce the gas temperature leaving the cell to approximately 720F, thereby eliminating the need for a refractory lined exit duct. Sidewalls enclosing ECON2 are formed from the gas pass sidewall circuits.

4.3.3 Operating Flexibility

The carbon burn-up cell has been designed to operate effectively under various modes of operation. Sizing of the cell has been based on

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an assumed maximum carry over from the main cells of approximately 11% of the higher heating value of the coal. This is considered to be conservative design in that, based on available data, the actual heating value content to the CBC may be somewhat less. In order to maintain stable firing conditions in the CBC sufficient to combust the recycled flyash, a back up overbed feed system has been included which is activated to supplement firing when bed temperatures are reduced below a set limit. When conditions require supplemental coal firing, limestone will also be injected into the bed in an attempt to capture SO_2 . During start-up, the coal and limestone feed will be used exclusively to ignite the bed prior to stabilization of fires and an established flow of fly ash in the main cells.

In summary, the following modes of operation can be utilized in the CBC in order to tailor operation of the steam generator to the system requirements:

- Start-up - Raw coal and limestone exclusively.
- Stable operation - Reinjecting fly ash alone in any number of segments.
- Load ramping - Reinjecting fly ash with supplemental coal and limestone to maintain required bed temperatures.
- Other - Reinjecting fly ash firing with or without supplemental coal and limestone in selected segments and/or coal and limestone exclusively in other segments.

4.4 STARTUP/IGNITION SYSTEM

4.4.1 General

The primary function of the ignition system is to raise the bed material temperature to a level that will promote ignition and stable combustion. For this objective each MBC and CBC outer segment is equipped with a below grid hot gas ignition section. The ignition section forms 50% of the outer segment, i.e., 12.5% of the bed plan area. Although each cell has two (2) ignition sections, only one is used for bed light-off. The other ignition section in each level is provided as a back-up should the preferred ignition section fail. The preferred startup/shutdown sequence is discussed under Section 11 of this report.

4.4.2 MBC Ignition System

Figure 4.12 illustrates the typical ignition system arrangement for the Main Bed Cells. The horizontal air duct feeding the outer segment is divided into two sections, each of which has independently controlled air flow dampers. The upper duct section is refractory lined and feeds the ignition section of the bed which is also refractory lined. The grid is water-cooled (see Section 4.2.2) and does not require refractory material. A single low velocity burner is mounted to the side of the upper duct section. Air is supplied to the ignition burner through a duct which branches from the horizontal air duct between the one-sided venturi measuring device and the air flow control dampers. The air supply line is equipped with an independently controlled damper.

FIGURE 4.12
IGNITION SYSTEM

Prior to light-off, each MBC is purged using the forced draft (FD) and induced draft (ID) fans. Refer to Section 11 for purge cycle details. When purging is complete, the ignition burner for the segment to be lit is fired. Air flow to the burner is controlled by the damper in the ignition burner air supply line. To maintain a gas temperature of approximately 1500F entering the ignition section plenum, dilution air is introduced through the upper duct air flow control damper. The dilution air cools the damper while the ignition burner is in operation. The hot air/gas mixture generated passes through the bed, without fluidizing it, raising the bed temperature. When the bed temperature reaches approximately 1000F to 1200F, coal is fed into the bed. Simultaneously, the bed is fluidized by increasing the air flow. Once stable combustion is established, the ignition burner is shut down. In preparation for light-off of the remainder of the segment, the bed temperature may be increased to approximately 1700F. In order to light-off the remainder of the segment, two methods are utilized:

- Cold light-off: Coal is fed into the unfluidized area. Air is then slowly introduced causing the area to fluidize and mix from the interface of the hot and cold bed material. The flame front propagates across the segment with the fluidizing front. When the complete segment is fluidized, fuel and air are adjusted to the required load.
- Hot start: Since the unfluidized area is maintained at approximately 400 to 500F, coal and air are simultaneously fed to the slumped area causing it to fluidize and mix with the hot material. The flame front propagates across the area quickly. Once the complete segment is ignited, fuel and air are adjusted to the required load.

In order to ignite the remaining segments within the bed, the same procedure is followed except that an entire segment is ignited.

Each burner is sized for approximately 30×10^6 Btu/hr. This is sufficient for a cold unit light-off in approximately 45 minutes.

4.4.3 CBC Ignition System

The CBC outer segments are equipped with an ignition system that is identical to the MBC ignition system except for the following:

- The horizontal air inlet ducts are proportionally smaller (4 ft x $4\frac{1}{2}$ ft as compared to 4 ft x 7 ft).
- The ignition section is proportionally smaller ($7\frac{1}{2}$ ft x 20 ft as compared to $7\frac{1}{2}$ ft x 22 ft).
- The ignition section requires a refractory grid.

As discussed in Section 4.5.3 the CBC does not have a water cooled grid. The grid is formed from a refractory covered plate. Because of the high gas temperatures required for ignition, the metal plate must be eliminated from the ignition section portion of the grid. Consequently, the ignition section grid is formed with refractory tiles cast with openings.

Ignition burners identical to the MBC ignition burners can be utilized for the CBC ignition system.

Although the CBC is equipped with a pneumatic underfeed system for firing recycled fines under normal operating conditions, fresh coal and

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limestone are initially fired in the CBC for light-off. Therefore the CBC light-off procedure is identical to the MBC light-off procedure as discussed in Section 4.4.2.

4.5 GRID DESIGN

4.5.1 General

Fluidized bed systems require an air distribution system that provides a uniform distribution of air throughout the entire bed in order to promote uniform bed mixing and a high quality of fluidization over the load range. The distribution system must also prevent bed material from falling into the air plenum when not in operation and also withstand the operating temperatures that occur within the bed over the load range. A nozzle type grid design having these qualities is described in the subsequent subsections.

4.5.2 MBC Grid Design

In order to provide a water-cooled roof over each MBC (except for the top bed), the sidewall tubes must traverse half the bed length twice; once to form the roof enclosure and once across the grid elevation to bring the tubes into position to form the sidewalls (see Figure 8.3 in Section 8). In doing so, a convenient means is provided to construct a water-cooled air distribution system. Figure 4.13 illustrates the arrangement.

Finned $2\frac{1}{2}$ in. O.D. tubes on $3\frac{1}{2}$ in. centers span across the MBC width at the grid elevation. Mounted on each fin are inclined $\frac{1}{4}$ in. nominal stainless steel TP 310, schedule 10 tee nozzles spaced approximately $2\frac{1}{2}$ in. apart. Each nozzle is mechanically fastened or welded to the fin.

FIGURE 4.13 MBC GRID ARRANGEMENT

The tee type nozzle provides a durable design that will provide a uniform distribution of air throughout the bed for extended periods of operation.

As illustrated in Figure 4.13 the nozzles are set in a staggered array and directed approximately 20° from the grid tube centerline so as to avoid direct jet impingement on adjacent nozzles. To avoid direct jet impingement on the grid tubes the top of the nozzle is approximately 5 in. from the grid tube centerline elevation. The nozzle portion of the tee is angled 15° down from horizontal to prevent bed material from falling into the air plenum through the nozzle when the segment is not in operation.

The number of nozzles (approximately 22,000 per MBC) was selected to provide the capability for 50% bed turndown, i.e., 50% of full load air flow, bed inventory, and bed height. The design criteria were based on having a grid pressure drop of 30% of bed pressure drop at the minimum turndown condition. The resultant full load grid pressure drop is 22 in. WG.

A minimum flow of 35% MCR is maintained through the grid tubes under all operating conditions. This water-cooled feature permits use of the below grid hot gas ignition system as discussed in Section 4.3 without the need for a refractory type grid in the ignition section.

4.5.3 CBC Grid Design

The CBC grid is formed with inclined tee nozzles, the same as used for the MBC grids except for the following:

- The CBC nozzles are mounted on a refractory covered plate. A water-cooled grid using the CBC sidewall tubes was not used because the CBC sidewall tubes must have side spacing compatible with the gas pass sidewall tubes in order to form a seal at the point where the two passes intersect. The gas pass sidewall tubes are small O.D. (1-5/8 in.) with a tight side spacing (2 in.). Consequently, sufficient space is not available between tubes to locate the grid nozzles as well as the pneumatic underfeed nozzles.
- The CBC nozzles are arranged in-line on approximately 3.6 in. centers.
- The number of nozzles (approximately 13,000) was selected to provide a pressure drop of 16 in. WG at full load operating conditions when burning the performance coal with 89% burn-up in the MBCs.
- Approximately 17% of the CBC combustion air enters the CBC through the underfeed nozzles and not through the grid nozzles.

Figure 4.14 illustrates the CBC grid nozzle arrangement.

Since the CBC grid is not water-cooled, the ignition section portion of the CBC grid must be formed with refractory tiles cast with openings that will provide the desired air distribution pattern as well as prevent bed material from falling into the air plenum. A typical method for forming the openings is to cast the tiles with semi-circular notches on the tile edges so that when the tiles are pieced together circular openings result. Refractory grids of this type are commercially available.

FIGURE 4.14 CBC GRID ARRANGEMENT

Section 5

COAL, SORBENT AND ASH SYSTEMS

(TASK 4233)

5.1 FUEL FEED SYSTEM5.1.1 General

Coal feed systems used to date for AFB demonstration applications have been subject to numerous operational problems which have limited the operation and subsequent testing of fluidized bed combustion systems. These previous systems were designed based on existing data from pilot plant applications and subsequently led to complex multiple needle or under feed pipe systems. These systems have been plagued with problems such as maldistribution, plugging, coking and erosion which are inherent to their design. Foster Wheeler, in an effort to formulate a viable system which will alleviate the problems of past systems, has proposed the overbed spreader feeder system to distribute fuel to the AFB. The advantages of this system are as follows:

- Reduction in fuel feed points from one (1) per 9 ft.² to one (1) per 110 ft.².
- Greatly reduced potential for fuel line pluggage and erosion problems. The overbed feed system will route the fuel directly from the silo to the spreader feeder inlet in plug flow.
- Greatly simplified fuel distribution system with the reduction in number of feed points. Each coal downspout can also be grouped to feed six (6) spreader feeders which results in ten (10) feed pipes for the MBCs on the 570 MW unit.
- Elimination of the fuel dryers. Fuel moisture content in the area of 5 to 10 percent has no detrimental effect on the overbed spreader feeder system.

- ° Elimination of pneumatic transport system including pumps, piping and controls.
- ° Minimized feed system monitoring with reduced feed points.
- ° Reduced potential for maldistribution which will occur with plugged under feed nozzles or faulty distributors. Results of present tests indicate that the spreader feeder will provide uniform distribution of a typical coal.

5.1.2 Overbed Spreader Feed Considerations

To date, only limited data is available regarding the effects of overbed fuel feed on the fluid bed combustion process. The following listing presents considerations which, when further testing occurs, may vary results slightly from the data presently available.

5.1.2.1 Fines. The nominal 1 in. by 0 fuel feed size with high moisture content (5 to 10 percent) may result in fines adhering to larger particles, resulting in retarded freeboard ignition and improving probability of fines penetrating the bed. The agglomerated particles will, however, be structurally weak and may attrite and elutriate at a higher rate, tending to release heat toward the upper bed.

5.1.2.2 Ash. Larger size residual ash from the coarse grind coal (1 in. x 0) will tend to increase inert content of the bed. With this ash build-up, tap rate will be higher with a lower active sorbent bed residence time, than with the needle feed system used in small scale units to date. The increased ash residence, with higher grinding

attrition will result in increased sulfur capture by the fuel's ash.

5.1.2.3 Freeboard Burning. With overbed feed, an increase in fine fuel burn in the freeboard and upper bed will occur. In addition, the fuel may thermally fracture on injection into the bed producing fine fragments which elutriate from the bed prior to complete combustion. It is presumed that the percent of heat release above the bed and carbon carryover will be slightly greater than with the needle feed system.

5.1.2.4 NO_x Emissions. With approximately $\frac{1}{2}$ to $\frac{2}{3}$ of the fuel nitrogen contained in volatile matter and the expected higher burning rates in the upper bed and freeboard zones, NO_x emissions are expected to be slightly higher with the overbed feed system.

5.1.2.5 Moisture. With higher fuel moisture content and lower initial heating with freeboard heat transfer, actual fines production due to thermal shock fracture should be reduced.

5.1.3 Review of Alternate Fuel Feed Systems

There are several fundamental ways to inject the fuel into the furnace of a fluidized bed steam generator. Laboratory or pilot efforts are principally interested in the feasibility of the process and therefore the type of system is of minor import. The needle type feed is simply a tube through which coal travels downward to reach the burning area from a vibrating type distributor. The pneumatic under feed system conveys

fuel pneumatically through conduits to the fluidized bed terminating in a nozzle immediately above the grid. Both of these systems require dry $\frac{1}{4}$ in. x 0 coal to prevent blockages in the transport conduits. After examining various alternatives, Foster Wheeler Energy Corporation recommends the use of the overbed spreader feeder system to inject coal into the furnace. With this device neither coal sizing or moisture content is critical. Refer to Table 5.1 for a comparison of coal feed methods. A review of the alternative follows:

5.1.3.1 Needle Feeding. The first laboratory units designed for the fluidized burning of coal in a limestone bed were built to establish the feasibility of the technology. The earliest models included equipment with typical grid plate dimensions from twelve (12) in. by twelve (12) in. to the largest unit, eighteen (18) in. by seventy two (72) in., then in extended use in Alexandria, Virginia. In most cases a single feed point was used to direct the coal and limestone mix to the bed.

The ERDA demonstration unit now in operation at the Monongahela Power Company at Rivesville, West Virginia quite logically, therefore, was designed to continue with this feed criterion of one (1) feed pipe, generally known as a needle, for every nine (9) ft.² of grid surface. Figure 5.1 depicts a typical needle feed arrangement. The unit was designed for 300,000 lb/hr of steam at 1350 psi, 925F at the superheater outlet with 385F feedwater and under these conditions 28,000 lb/hr of coal and 7,800 lb/hr

<div> <div>FEED POINTS REQ'D</div> <div> <div>FOR 228 MW UNIT</div> <div>FOR 570 MW UNIT</div> </div> </div>	COAL SIZE	COAL MOISTURE	GRID AREA PER FEED POINT			
	NEEDLES	UNDERFEED	SPREADER FEEDER			
	THRU PIPE SLOPED 16°/45° DOWN TO FURNACE	THRU 3" PIPE HORZ RUN BENEATH GRID VERTICAL DISCHARGE	FROM HOPPER THRU VOLUMETRIC FEEDER, TO ROTOR			
	1/4" x 0	1/4" x 0	1-1/4" x 0			
	2% SURFACE (MAX.)	2% SURFACE (MAX.)	NOT CRITICAL			
	9 SQ. FT/NEEDLE	9 SQ. FT/PIPE	110 SQ. FT/FEEDER			
	218	218	30			
	854	854	72			

TABLE 5.1 COMPARISON OF COAL FEED METHODS

FIGURE 5.1 NEEDLE FEED

of limestone were conveyed into the furnace through a total of fifty two (52) needles. Thus, a total of 36,600 lb/hr of material was fed through 52 needles resulting in 705 lbs through each needle per hour.

The needles were $1\frac{1}{2}$ in. diameter pipes sloped between 16 and 45 degrees from the horizontal and extending into the furnace. Vibrating feeders, located above the entrance point to the furnace, fed the material to each needle. There has been occasional clogging of needles by oversized lumps or by wet coal. At times, the discharge needles have become coked, further preventing uniform coal flow. To alleviate some of these conditions, the size of the needles was increased to 2 in. I D and the discharge point raised from the grid plate by shortening the needles inside the bed. Also, the coal purchased has been specified for uniform sizing and with a maximum moisture content. These modifications to the equipment and coal specifications allow more reliable operation of the steam generator.

Operating difficulties experienced, starting late 1976, together with the inherent design limitations, requiring that the needles be placed near the outside walls, have resulted in Foster Wheeler Energy Corporation considering other fuel feed systems for commercial size applications.

5.1.3.2 Pneumatic Under Feed Nozzles. It is possible to pneumatically feed sized coal through a pipe running horizontally beneath the grid plate, then turning upward through the bed, to be discharged through a tee in a horizontal direction immediately above the grid plate. To accomplish the conveying of fuel in this manner requires the use of

approximately 1.4 lb. of air per pound of material transported and a pressure of 3 to 4 psi. The actual quantity transported depends upon the size distribution and moisture in the coal. The conveying pipe would be 3 in. OD with a minimum thickness of 3/8 in. for wear protection and provided with clean out plugs with quick disconnect joints to clear any plugged pipes.

The discharge point immediately above the grid plate is at a static pressure of 36 to 48 in. WG depending upon the fluidized operating bed height. This static pressure must be added to the piping losses incurred in the transportation of the material from the first distributing point. At shut-down it would be necessary to blow all of the transport pipes clear to prevent internal corrosion and to remove resident coal that could cake and reduce flow areas. The air required for transport should be dried before it is compressed to avoid the introduction of moisture to the coal being transported.

There is also an inherent limitation of the maximum size of coal ($\frac{1}{4}$ in. x 0) that can be injected pneumatically in a $2\frac{1}{2}$ in. ID conveying pipe that might include four (4) 90 degree bends and 70 ft. of horizontal run from the second splitter. This system requires dry coal in order to function properly over a long period of time, therefore, it is mandatory that a coal dryer be available to reduce the surface moisture of the coal constantly while the unit is in operation. A blockage in a conveying pipe located in the plenum chamber requires that the steam generator be shut down to dismantle and clear it before resuming operation.

In the 570 MW unit installation, there are five (5) main cells, each 22 ft. deep and 60 ft. wide. Using nine (9) ft.² of grid area per nozzle there would be 144 nozzles per cell or approximately 720 nozzles for the five (5) main cells. Additionally, the carbon burnup cell, 20 ft. deep and 60 ft. wide, requires another 134 nozzles, making the total requirement of 854 under feed coal nozzles for the steam generator. In addition, each of the four (4) segments of the five (5) main cells would require independent fuel feed and controls to attain partial load operation. Refer to figures 5.2 and 5.3 for a typical MBC pneumatic under feed system. There is also a separate system required for the carbon burnup cell that would be similar to that of the MBC fuel feed system.

5.1.3.3 Spreader Feeder (Chain Feeder Type). The spreader feeder has been used in coal firing for many years. This feeder, located on the front wall of a fluidized bed boiler, can throw coal onto the fluidized bed. This device is denoted on Figure 5.4. It consists of a small hopper which directs coal onto a plate. The plate has a series of 1 in. bars spaced at 2 in. centers, which are attached to a chain on each side. The bars move the coal horizontally and it falls onto a rotor. The rotor has several paddles attached to a 4 in. diameter shaft which rotates and propels the coal into the furnace. The coal dropping onto the rotor slides along the blades outward to provide a varying trajectory of the coal into the furnace. The rotor speed can be varied to suit the coal moisture and size distribution with regard to distance thrown. There are also

FIGURE 5.2 SCHEMATIC OF UNDERFEED SYSTEM (MBC)

TYPICAL MAIN BED CELL UNDERFEED COAL SYSTEM

FIGURE 5.3. TYPICAL MAIN BED CELL UNDERFEED COAL SYSTEM

SPREADER
FENDER
FIGURE 5.4

adjustments available to the feed rate by changing the speed of the chain feeder. Cooling and sealing air is forced through the unit to keep coal fines from the operating mechanisms. The principal bearings are water-cooled. A variable speed electric motor powers the spreader feeder. Coal can be thrown from the feeder to a distance in excess of 20 feet, depending upon the size and moisture consist. A uniform side to side distribution pattern can be achieved.

For the unit there will be twelve (12) spreader feeders, as described herein, located along the front wall of each of the five (5) main cells. These spreaders will be capable of operation in groups of three (3) in order to provide segmental fluidization for each of the four (4) segments composing each MBC. The CBC will also include twelve (12) feeders located along the rear wall. Refer to Figures 8.1 and 8.3 for the arrangement of the fuel feeders. This arrangement provides ample access in the front of the burning levels for maintenance of the feeders, operating dampers linkages, control actuators, and general observation of the unit.

One of the principal advantages of spreader feeder units is the lack of sensitivity to moisture in the fuel. Wet coal can be handled readily and the moisture aids the agglomeration of coal fines to larger particles for injection into the furnace. Since there are no small diameter conveying pipes, coal sized at nominal 1 in. x 0 is suitable for this type of feed. The system has been designed for uniform flow (no constrictions) to eliminate pluggage and segregation.

The proven reliability of the large number of spreader feeder feeders now in use around the world attest to their ability to convey coal into a furnace effectively. The general simplicity of the coal handling equipment with gravity feed from the coal silo through feed pipes and conical distributors located directly above the spreader hoppers assures continuous uniform coal supply to each feed point. This system is inherently more reliable and less costly than either the needle feed or under bed feed systems described in the previous sections.

To determine the performance of a spreader unit used to feed a fluid bed, Foster Wheeler Energy Corporation has embarked upon a program to install such a unit in one of the cells of the pilot plant at Monongahela Power and Light Company facility at Rivesville, West Virginia.

5.1.4 Selected Distribution and Feed System

5.1.4.1 System Requirements. Refer to Figure 5.5 for a schematic arrangement of the coal feed system. The coal distribution system must be capable of providing uniform, uninterrupted coal flow to the five (5) main bed cells (MBCs) and the carbon burn-up cell (CBC). Fuel metering and final distribution to the cells is provided by the twelve (12) spreader feeders located along the firing walls of each of the cells. The distribution system must provide for the feeding of a uniform mixture of fuel from bed to bed and from side to side of a given bed in order to maintain acceptable firing conditions. These requirements must be met during start-up and turn-down conditions, as well as at maximum continuous rating (MCR).

FIGURE 5.5 570 MW AFB COAL DISTRIBUTION SYSTEM

In view of these requirements, it is important that the entire feed system be designed to optimize the conditions experienced at the cells.

5.1.4.2 Crusher Facilities. A crusher system for the AFB is required to reduce the run-of-mine fuel to nominal 1 in. size prior to introduction to the unit. Control of fines in the crusher facility is important for safety considerations. Minimization of fines production is important since fines in general present difficulties in handling and can cause problems in the combustion zone.

Capacity requirements for the crushers are established on the basis of total fuel feed rate at MCR, bunker storage capacity, system redundancy and operational requirements.

Conveying of crushed fuel from the crusher facility may be provided by inclined belt-conveyors in accordance with standard utility practice.

5.1.4.3 Bunker Arrangement. Coal bunkers with multiple outlets, or individual coal silos are required to feed the five (5) MBCs and the CBC. The tripper system should be arranged to fill the system uniformly while avoiding particle size segregation of material within the system.

The bunkers should be provided with sufficiently large outlets to assure flow of material under all conditions. Since the fuel is undried in the processing system, it is important to avoid potential hang-ups in the

bunkers by careful design. Limitation of fines generated in the system, inherent as a result of the large feed size (-1 in.) enhances the flow of coal through the bunkers.

Bunkers designed for mass flow are recommended in order to minimize operational difficulties associated with ratholing, bridging and segregation of material.

5.1.4.4 Coal Downspouts and Distributors. Coal downspouts at the bunker outlets transport material downward to the various firing levels. Distributors are provided at the termination of each downspout to split the flow to multiple spreader feeders. In this case, each distributor feeds six (6) spreader feeders, and thereby, a total of ten (10) distributors and downspouts are required for the MBCs, while two (2) are required for the CEC.

Material in this system is carried in plug flow through the bunker outlets, the downspouts and into the distributors. Since rate control is provided by the spreader feeders, metering is not required in the individual downspouts, thus eliminating the requirement for additional hardware in the system. Two (2) mechanical interruptions are recommended in the system. The first is a manually operated slide gate at the discharge of each bunker. The second is a manually operated ram gate at the entrance to each spreader feeder. The isolation gates provide for the capability of servicing feed system equipment while maintaining unit operation (possibly at reduced level).

5.1.4.5 Coal Feeders. A total of seventy two (72) spreader feeders are required for the AFB steam generator. Each MBC will include twelve (12) feeders located along the front wall, with each feeder distributing coal to an area of 110 ft.² of bed surface (5 ft. wide by 22 ft. deep). The CBC includes feeders similar to the MBCs.

The spreader feeder will provide a uniform distribution of coal particles across the bed area, however, large particles are more likely to be thrown further into the furnace and, conversely, those smaller particles that do not agglomerate or are torn from larger lumps will remain in an area nearer the feed point. Many of the small particles of coal that burn above the bed have a high probability of desulfurization by reacting with calcined lime suspended in the freeboard zone (refer to section 5.2). These smaller particles must traverse the furnace to the exit and thus have ample opportunity to react with the calcined lime. In operation, the continuous movement of the fluidized bed constantly abrades the coal providing new surfaces for burning and for exposure to calcium oxide.

Spreader feeder components are designed with ample clearances for the path of coal and to operate at low stress values to assure long overall life. Each spreader is powered by a 1½ HP motor and therefore can be shut down without affecting the other units. Over a period of 55 years, the spreader feeders have been proven to be a relatively simple, reliable, low cost

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device to distribute coal uniformly over a given area, and it is Foster Wheeler Energy Corporation's recommendation that the overbed feed system be used to deliver coal to each cell of the fluidized bed utility sized steam generator.

5.2 LIMESTONE FEED SYSTEM

5.2.1 General

The requirement for a simple, reliable and responsive limestone feed system for the AFB steam generator is of paramount importance as this system is the prime motive force in the reduction of sulfur emissions to the atmosphere. The selected system must have the capability of handling varying samples of limestone as well as moisture levels up to approximately 10 percent (includes 8 percent surface moisture). For the study case, the system must be capable of supplying a total of 307,800 lb/hr of limestone to the five main bed cells (MBC) in order to limit the SO₂ emission from the 4.5 percent sulfur coal (worst case coal) to meet existing Federal standards. Refer to the material flow diagrams under Section 3 for further limestone requirements for the performance and worst case coals.

5.2.2 Limestone Feed System Considerations

5.2.2.1 Size Distribution Considerations. Based on available data an effective limestone size for sulfur capture is in the range of 3/16 in. to 20 mesh. Particles of stone larger than 3/16 in. form a finite layer of CaSO₄ on their surface (approximately 4 mills) which then retards further reaction of the interior or the major bulk of the stone. These particles will tend, to a certain extent, to attrite within the bed and scale off pieces of their surface to expose fresh CaO, however, unless a separate system for

classification, crushing and recycling of the bed material is included, the actual utilization of these large particles will be low. Conversely, the small particles less than 16 mesh will tend to be carried off with the flue gas as their terminal velocity will be less than the velocity of the gas stream. These small particles will tend to form a calcium rich atmosphere in the freeboard area or effectively produce a low density fluidized phase above the actual bed. This atmosphere will tend to reduce the sulfur dioxide to a further degree as it passes through the 12 ft. of freeboard zone provided, however, capture will be at a reduced efficiency from that within the actual fluidized bed.

A viable alternative to the problem of limestone fines could be their use in the scrubber system at a nearby or adjacent pulverized coal boiler. After crushing to the minus 3/16 in. size, the fines would be screened off below 20 mesh and a separate conveying system would transport them to the scrubber limestone storage bin. For the purpose of this study, however, this system was not considered.

5.2.2.2 Bed Injection Considerations. Injection of limestone at or near the fluidized bed surface will enhance utilization for the following reasons:

- Allowing the limestone fines to be released just above the bed will produce a lime rich atmosphere in the freeboard area and enhance the sulfur capture in that zone. In addition, these fines, upon heating and calcining in the freeboard, will act as a heat sink to snub peak temperatures around the zone where fine coal is injected, improving sulfur capture.

- Laboratory tests indicate that limestones, when more gradually heated in zone temperatures that are higher than the bed operating temperature and where carbon dioxide partial pressure is maximum, will experience less thermal shock and explosion loss, and calcine at a slower rate to produce a more active lime acceptor.

From this standpoint, it is desirable for the limestone fines to be injected into the bed with the fuel feed through use of the overbed feed system. This, however, creates feed system control problems and cannot be justified economically with the costs of the additional screening and handling systems.

In addition to elutriation of feed material, the following bed reactions will result in enhancing the lime rich zone above the fluidized bed:

- Thermal shock - breakage of the larger particles due to release of H_2O and CO_2 upon limestone entering the high temperature bed area.
- Grinding attrition in the bed.
- Chemical ash fluxing with the bed.

With the provision to control bed inventory during both start-up or during normal operation through the use of limestone feed, the least complicated limestone system with a minimum number of feed points is desirable. Mixing of limestone with coal feed and injection through a multi-point arrangement would overload the coal feed system and create segregation, maldistribution

and control problems. Inclusion of a separate limestone feed system for bed inventory control could not be economically justified.

Location of the limestone feed injection point at a distance from the bed removal tap will promote the longest residence time for the lime particles within the bed and, therefore, promote the greatest utilization. Injection of limestone with the fuel, based on uniform fuel distribution, will incur a degree of short circuiting of limestone to the bed removal tap without sufficient reaction time.

Based on the moisture content of the study sorbent sample (see Section 1.4.2) of up to 9.8 percent by weight, use of a pneumatic underfeed system would require limestone dryers and crushers to reduce the moisture content and size to a level suitable for pneumatic transport. In addition, a complex monitoring system would be required for each feed point for an indication of particle dropout and pluggage within the pipes. Use of the overbed feed system (gravity drop) through a minimum number of feed points eliminates the requirement for dryers and greatly reduces the potential of pluggage problems.

As fine coal and limestone does continue to react in the above bed zones (freeboard, gas pass, heat recovery area, cyclones, baghouse, etc.), secondary capture will be significant because of the high dust holdup (residence time), high temperature and high turbulence zones created by the large unit

configurations.

5.2.2.3 Basic Considerations. Based on sorbent data, the following determinations have been made relating to limestone utilization:

- Minimum bed temperature required to calcine limestone is approximately 1300F to 1400F.
- Maximum bed temperature allowable is limited by high equilibrium decomposition pressures of SO_2 over acceptor alkali-sulfates (1900F to 2100F for CaSO_4).
- Maximum bed temperatures, is limited by the presence of lower melting point alkali-sulfates (1650F to 1750F for NaSO_4 and K_2SO_4).
- Presence of inherent clay influences the behavior of the acceptor in the bed and impacts the selected size distribution.

5.2.3 Limestone Feed System Selection

Based on operating experience and the above considerations, Foster Wheeler Energy Corporation has selected the overbed, gravity drop limestone feed system as the one offering the greatest simplicity, reliability and responsiveness. In addition, the overbed feed will be most compatible with the fuel feed system as presented under Section 5.1.

Limestone feed size to the AFB steam generator has been set at minus 3/16 in, plus 0 size. This size range will limit the unreacted lime due to oversize, however, fines loss will still require consideration. Since it would be both uneconomical and impractical to purchase sized limestone (minus 3/16 in., plus 20 mesh) for a commercial size steam generator and based on the

high fines content of the sample limestone (see Section 1.4.2), we have included a reduction in limestone utilization or sulfur capture. This reduction in efficiency equates to a loss of approximately 10 percent of the required limestone and is an adjusted factor based on the fines present and the anticipated utilization above the bed.

To limit the generation of limestone fines, it is recommended that the mechanisms for crushing and conveying of limestone be selected based on their capability to minimize fines generation.

The limestone system requires sizing based on the worst case coal sample (see Section 1.4), however, it will operate effectively over the entire range of fuels prescribed. Limestone flows for the performance and worst case fuels will be in accordance with the following table:

<u>Fuel</u>	<u>Fuel Sulfur % by Wt</u>	<u>CaO/S Molar Ratio</u>	<u>Total Limestone Flow (M lb/hr)</u>	<u>Limestone Flow to Each MBC (M lb/hr)</u>
Performance	2.55	2.1	94.4	18.9
Worst Case	4.5	3.47	307.8	61.6

5.2.3.1 Feedpoint Location. The limestone feed point for the MBCs are indicated in Figures 4.8 and 4.9. The limestone feed points for the CBC are indicated on Figure 4.10 and 4.11. As indicated on these drawings, the limestone will be gravity dropped from the feedpipe terminating just above the expanded bed surface with its flow rate controlled by a belt type feeder. The actual flow rate to each bed is determined by the demand signal from the

control system (based on coal flow) and trimmed by the SO_2 level in the flue gas. As indicated on Figure 4.8, the primary limestone feed points for the MBCs are located at the rear of each of the main cell sidewalls. Under normal operating conditions, limestone is injected at these points to supply the requirements of 50% of each bed level (two segments). With the bed extraction points (letdown coolers) located at the front wall of each segment, a circulation pattern from the rear to front wall is formed which eliminates any potential stagnant bed areas. In addition, this arrangement provides maximum residence time in the bed, thereby attaining a high degree of calcium utilization. The arrangement is designed to operate satisfactorily based on the preferred sequence of bed segment light-off and shut-down (see Figure 11.2) which requires operation of the outer segments prior to lighting of an inner segment. In the event an equipment failure prevents the operation of the outer segment, a secondary (emergency) feed point has been provided at the center of the front wall of each bed level as indicated on Figure 4.8. This emergency feed point provides the limestone requirements of the center two bed segments of each bed level. However, a percentage of the limestone feed from this emergency tap will be short circuited directly to the letdown cooler taps due to the feed point location on the front wall. Based on this, it is stressed that this feed point is strictly for emergency use to be utilized only when the outer segments are non-operational. This limestone feed only when the outer segments are non-operational. This limestone feed

system is similar for each of the five (5) MBCs. Nominal 6 in. OD pipes will be furnished for each of the MBC feed points. Furnace pressure at this pipe termination above the bed will be -0.1 in. WG under normal operating conditions, therefore, requiring only a minimal seal across the limestone feeder.

Limestone feed to the CBC is required during the following situations:

- Initial light-off to establish a bed level.
- To facilitate sulfur capture during coal firing or when coal is used to supplement the fly ash to increase bed temperature.

Refer to Section 4.3 for further details regarding limestone requirements in the CBC. Similar to the MBCs, the outer limestone feed points (refer to Figure 4.10) will supply the limestone requirements of 50 percent of the bed area (two segments). The emergency center feed point is not included on the CBC. Limestone to the CBC will be through nominal 4 in. OD pipes.

5.2.3.2 Limestone Distribution System Refer to Figure 5.6.

for the schematic arrangement of the limestone distribution system.

Limestone bunkers with multiple outlets or individual storage silos are required to feed the five (5) MBCs and the CBC. A total of twelve (12) primary feed lines are required to supply limestone to the AFB steam generator. Since limestone feed to the MBCs and CBC is to the sidewalls, the bunkers could be located on both sides of the unit. One (1) additional feed line is required at the center of the front wall for the MBC emergency limestone feed point. As in the design of all bunkers, the limestone bunkers

FIGURE 5.6 570 MW AFB LIMESTONE DISTRIBUTION SYSTEM

should be designed for mass flow with ample outlets in order to avoid rat-holing, bridging and segregation of material.

Downspouts at the bunker outlets transport limestone in plug flow to belt-type feeders which are used to meter limestone feed as required by the combustion control system. Feeders of the volumetric or gravimetric type may be used compatibly with the AFB system. The feeder outlets are arranged to discharge in free-fall into sloping downspouts connected to injection points immediately above the bed level. The system described provides for proper process control while maintaining maximum system reliability.

In order to provide additional redundancy, limestone injection points have been provided at the centerline of each cell along the front wall. These points are intended for use during abnormal operating conditions when limestone is unable to be introduced through the outboard points. As such, it is recommended that a single belt-feeder be provided at the discharge of a separate limestone bin (suitably located), to feed a downtake system located along the front wall. Suitable manually operated diverter valves should be provided to direct the feed stream to a given level. A system such as that described provides for continued operation under emergency conditions.

5.3 BED LETDOWN COOLER

5.3.1 General

The primary functions of the bed letdown coolers are as follows:

- Maintain a fixed bed inventory by controlling the bed material removal rate. Bed material removal rate is controlled as a function of limestone feed rate and trimmed by bed level. Refer to Section 11 for control philosophy details on the bed letdown coolers.
- Cool bed material from the bed operating temperature of approximately 1550F to 250F. With the bed coolers located within the air plenums, the material leaving the coolers at 250F will not require high temperature material handling equipment.
- Minimize unburned carbon loss in the letdown material by acting as an after-burner. The cooler is designed to reduce the unburned carbon content of the letdown material from approximately 6% in the active bed to approximately 1.25% at the outlet of the cooler.

5.3.2 MBC/CBC Letdown Cooler Design

Each MBC and CBC segment is equipped with a bed letdown cooler located along the same wall as the coal feeders. The MBC's require a total of twenty (20) coolers, while the CBC requires only four (4) coolers. The CBC coolers are designed for approximately 50% of the MBC cooler capacity. Figure 5.7 illustrates the bed letdown cooler design.

Two rectangular openings, 9 in. by 4 ft.- 4 in. are provided in the water-cooled grid near the MBC front wall. The openings are formed by offsetting the water-cooled grid tubes horizontally, allowing the grid tubes, which are part of the SW pass, to remain fully drainable. From the grid elevation

the refractory lined slots extend one foot into the cooler's largest cross section which is $3\frac{1}{4}$ ft. by 15 ft. (the cooler spans the entire segment 15 ft. width). Three of the four cooler sidewalls are sloped at a 60 degree angle, while the fourth side is formed by the vertical front wall enclosure tubes. Alternate front wall tubes are bumped to provide openings $2\frac{1}{4}$ in by $1\frac{1}{2}$ ft which allow the letdown material to fall into a hopper located outside of the boiler enclosure.

Cooling air is introduced at the top of the external hopper. The air passes through the screen formed by the front wall tubes and then through the packed bed material. The cross section at the top of the cooler is large enough to prevent fluidization of the letdown material based on the cooling air requirements for both the performance and worst fuels.

A bypass duct equipped with a control damper is provided to maintain a 10 ft/sec superficial velocity through the refractory lined slots. The remaining air passes through the bypass and enters the MBC above the MBC bed level. The bypass is equipped with a hopper that drains into the external cooler hopper. Some of the cooling air introduced into the external hopper will leak through the letdown material in the external hopper and pass up into the bypass duct. This leakage air should aid in moving and cooling the letdown material in the external hopper, as well as

provide some cooling of any hot entrained material that passes through the bypass hopper.

The flow of bed letdown material is controlled by a rotary valve located below the external hopper. Since the letdown material flow is a function of the limestone feed rate, the rotary valve is controlled as a function of the feed rate signal. Air flow into the cooler is controlled by measurement of the letdown material temperature entering the rotary valve. A fixed quantity of air is required through the letdown slots in order to maintain a fluidizing velocity of 10 ft/sec. Consequently, the bypass damper is programmed to remain closed until the air flow requirement through the slots is obtained, after which it opens as a function of the total inlet air flow.

Figure 5.7 Bed Letdown Cooler

5.4 FLYASH COLLECTION/REINJECTION SYSTEM

5.4.1 General

The flyash collection/reinjection system is provided to collect, transport, and feed the unburned combustible material elutriated from the main bed cells (MBCs) into the carbon burn-up cell (CBC) in order to improve the overall steam generator combustion efficiency. The flyash is collected by the heat recovery area (HRA) ash hoppers and a system of six (6) mechanical dust collectors, details of which are discussed in Section 6.

The flyash collected is dry, devolatilized, small in size, and free flowing. It is pneumatically transported from the flyash collection devices and injected into the CBC by a number of feed pipes that pass through the CBC air plenum, through the refractory covered grid (see Section 4.5.3), and into the CBC bed. The portion of the feed pipe extending into the CBC bed connects to a "T" type nozzle. From experience gained at existing fluidized bed pilot plants and in particular, the Rivesville unit in West Virginia, an individual nozzle has been shown to feed 9 ft^2 of bed plan area satisfactorily. Based on the CBC plan area dimensions (60 ft. by 20 ft.) and the particulate collection system arrangement, systems having approximately 110 feed pipes were investigated with each pipe feeding approximately 11 ft^2 of bed area. This is slightly greater than the 9 ft^2 previously mentioned, however, it should provide satisfactory results.

Two (2) systems for pneumatically transporting and injecting the collected flyash into the CBC were considered and are discussed in the subsequent subsections.

5.4.2 Air Locks/Distributor Box System

The air lock/distributor box system consists of air locks under each of the twenty (20) particulate removal equipment hoppers. Each air lock feeds flyash into two parallel pneumatic transport lines. Each line consists of one (1) first level distributor box with eight (8) outlets. Each of these lines feeds a second level distribution box with seven (7) outlets. This results in a total of 112 lines entering the CBC.

One primary disadvantage of this system is that pluggage of one line upstream of the second level distributor boxes causes a major portion of the feed system to become inoperable. Another disadvantage of this system is the lack of experience with a large number of feed lines as required for this application.

5.4.3 Eductor System

An eductor is a device that takes in flyash by the effects of gravity and aspiration, and feeds it into a pneumatic transport line. As illustrated in Figure 5.8, the aspiration effect is created by the nozzle located at the flyash inlet. The eductor is a static device and is suitable for continuous operation. All parts that are subject to abrasion are made of

DETAIL OF EDUCTOR

FIGURE 5.8 DETAILS OF EDUCTOR SYSTEM

Ni-Hard and are easily replaced.

The eductor system requires 108 parallel pneumatic transport lines from the flyash collection device hoppers to the feed points in the CBC. Sixteen (16) lines extend from each of the six (6) main mechanical dust collectors, while twelve (12) lines extend from the HRA hoppers. Figure 5.9 schematically illustrates the arrangement.

In order to facilitate eductor connections to the flyash hoppers, the HRA and dust collector hoppers are the trough type with sloping sides and vertical ends. Between each eductor connection, a ridge is provided in the hopper bottom to prevent accumulation of flyash. This assures continuous supply of flyash to the eductor system and minimizes any potential for fire which could be caused by accumulated flyash.

The pipes conveying the flyash are 3 in. ID and 0.5 in. thick, made of alloy cast iron. At 90° turns, a "T" connection is used which results in a pocket accumulation of flyash providing abrading surface for the flowing flyash thus reducing abrasion problems at bends. The "T" junction provides the additional advantage of a port for maintenance. Manual isolation valves are provided in the flyash and air lines feeding and leaving the eductor for maintenance purposes. An additional manual isolation valve is provided in each transport line directly below the grid elevation. Typical eductor connections to the hoppers, blowers, and supply header are illustrated in Figure 5.8.

- * REPRESENTS 24 LINES
- ** REPRESENTS 6 LINES
- M MANUAL VALVE
- E EDUCTOR SYSTEM (SEE FIGURE 5.10 FOR DETAILS)

FIGURE 5.9 FLY ASH RE-INJECTION SYSTEM SCHEMATIC

Three (3) 50% capacity positive displacement blowers (6000 CFM, 750 HP motor per blower) supply 110 CFM of air at 18 psig to each of the 108 eductor nozzles through two (2) supply headers. The conveying pipes are insulated to minimize heat losses. The pipe arrays from the dust collectors and economizer hoppers are distributed to the CBC in such a manner that a uniform ejection of flyash is obtained even in the case of off-set steam generator firing resulting in biased flyash collection in the dust collectors. The use of 108 parallel lines from hoppers to the CBC is desirable since if one line should require maintenance, flyash can be transported by the remaining lines, thus minimizing the possibility of steam generator outage. Significant experience with this kind of system by major flyash handling equipment manufacturers gives further confidence for the application under consideration.

5.5 BED MATERIAL RECYCLE TO CBC

5.5.1 General

A system will be provided to recycle used bed material from the main cells to the carbon burn-up cell (CBC). This supplemental bed material is required in the CBC due to the attrition of the material within the bed and the elutriation of smaller particles to the gas stream. It is anticipated that approximately 3% of the bed material weight will be lost per hour at the maximum steam generator load. Since the reinjected flyash which is combusted in the CBC merely passes through the bed to the gas stream and does not contribute to the bed weight, the supplemental bed material is required in order to maintain the pre-set bed depth for maximum combustion efficiency. Although this requirement could be fulfilled through the addition of fresh limestone, the use of bed material from the MBCs will not incur a calcining loss and is more economical.

Bed material injected into the CBC will be extracted at a point after the main bed letdown/coolers and pneumatically transported at an anticipated rate of 11,400 lb/hr for the performance coal at the MCR load to the four (4) CBC segments. This material being transported will be relatively inert, composed primarily of CaSO_4 , ash and CaO at a temperature of approximately 250F. Carbon content of this material will be approximately 1.25% for the performance coal, however, no credit was taken for the potential heat release of this material as it resides in the CBC bed. In addition, the calcium oxide exposed due to the breakage of the CaSO_4 off the

surface of the lime particles will serve to enhance sulfur capture in the CBC. However, due to the higher operating temperature of 1900F, no credit was taken for this potential reduction in sulfur emissions.

5.5.2 Design

Injection of the bed material will be through two (2) pipes located next to the limestone feed pipes on the outer segment sidewalls of the CBC. Refer to the sectional side view of the CBC, Figure 4.11 for the location of these feed pipes. The bed material will be pneumatically injected into the CBC at a point just above the expanded bed surface.

Section 6

PARTICULATE REMOVAL EQUIPMENT
(Task 4234)6.1 GENERAL

The 570 MW fluidized bed steam generator presented includes a solids collection system to limit the stack particulate emissions to less than 0.06 lb/million BTU fired. Another feature required of the particulate collection system is to conveniently reinject a large percentage of the unburned carbon elutriates from the main beds into the carbon burn-up cell (CBC) for further combustion. Of the range of coals under consideration, the worst case fuel (see Section 1.4.1) governed equipment sizing due to the greater dust content of the combusted gases exiting the main beds and CBC. For worst case coal, 167,282 lb/hr of elutriated solids containing approximately 25% unburned carbon exit the main beds. With injection of approximately 92% of these elutriates into the CBC, 130,260 lb/hr of solids exit the CBC with the gas stream. This number includes the bed make-up material that attrites and leaves the CBC. The gas temperature leaving the main beds and the CBC is 720F at the maximum continuous rated (MCR) steam generator load. For the worst case coal, the 0.06 lb/million BTU fired emission criterion limits the particulates emitted from the stack to a maximum of 333 lb/hr.

There are two (2) major particulate removal systems that have the potential of satisfying the emission limits. One system uses the principle of electrostatic precipitation to collect the dust particles and can be located before or after the air preheater. The second system, using fabric

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bags in a large baghouse, passes dirty gas through cloth with the particulate collected on the surface of the bag filters. Due to temperature limitations on the available fabric material, the baghouse can only be located after the air preheater. A third system, cyclones, using centrifugal action separates the particulates from the gas. Due to the relatively low efficiency available for the cyclone equipment, it cannot be used independently to meet the emission requirements. It, however, offers a relatively inexpensive method to supplement and improve the performance of the two (2) major systems mentioned. An evaluation of electrostatic precipitators and baghouses along with cyclones as applicable to the 570 MW steam generator is presented below:

6.1.1 Electrostatic Precipitator

6.1.1.1 General Description. The electrostatic precipitator electrically charges the particles suspended in the gas stream by a series of wire or frame type discharge electrodes and attracts them toward plate type collecting electrodes. The collecting electrodes are periodically rapped to release the particles to free fall into the hopper below. A number of plates in series, called the "fields", are used; the number depending on the efficiency required. Very high efficiencies (99.8+) can be achieved with proper particle resistivity characteristics.

6.1.1.2 Precipitator Location. The most significant parameter controlling the performance of a precipitator is the resistivity of the

particulate. Depending upon the resistivity, a "hot" or a "cold" precipitator is preferred. The hot precipitator cleans the gases coming directly from the boiler, upstream of the air preheater whereas the cold precipitator treats the gases coming out of the air preheater. For this unit, gas temperatures for the hot and cold precipitators are 720F and 288F, respectively. Figures 6.1 and 6.2 show the backend arrangement using "cold" and "hot" precipitator locations, respectively. It should be noted that the "cold" precipitator arrangement requires a mechanical dust collector upstream of the air heater to avoid potential plugging in the air heater.

In general, the particulate resistivity is strongly dependent on the sulfur content of the flyash. Flyash with low sulfur content has high resistivity at the air preheater outlet gas temperature (288F) and is difficult to charge. On the other hand, high sulfur content assures lower resistivity in the lower temperature range resulting in efficient collection. Even though the Stone & Webster boiler uses high sulfur coal, fluid bed combustion reduces the sulfur content in the flyash and the resulting particulate matter in the gas stream behaves like a Western low sulfur coal. In most cases, a gas temperature above 600F assures improved resistivity even for low sulfur flyash and efficient particulate collection is obtained. This suggests that between the cold and hot precipitators, the hot precipitator is more desirable based on the low sulfur content of the flyash. An additional advantage of the hot precipitator over the cold is that the flyash resistivity and therefore the collection efficiency in the 600F to 800F gas temperature range is not influenced by small variations in gas temperature.

FIGURE 6.1 BACKEND ARRANGEMENT WITH "COLD" PRECIPITATOR

FIGURE 6.2 BACKEND ARRANGEMENT WITH "HOT" PRECIPITATOR

6.1.1.3 Hot Precipitator Performance. Having chosen the hot precipitator over the cold precipitator, based on flyash sulfur content and its influence on the resistivity, the evaluation effort concentrated on the specific application to the Stone & Webster fluid bed boiler. There are several problems associated with a hot precipitator for any application, e.g. thermal expansion, non-uniform gas flow, inaccurate electrode spacing, back corona, overloading, etc. These are normal problems and have been demonstrated to be relatively easy to solve with proper design in conventional pulverized coal boiler applications.

There is an additional problem unique to the fluidized bed boiler in that little operating data is available to verify the chemistry and resistivity of the dust elutriated from the unit and carried in the flue gas. In addition to the ash, calcium compounds (CaSO_4 , CaO and CaCO_3) and higher percentages of carbon (about 25%) than are generally found in pulverized coal gas streams, are present in the flue gas. The little resistivity data for calcium compounds that is available indicates that the resistivity could be unacceptably high in the temperature range of interest (720F). A review of data on precipitators now in operation on boilers using Western coal indicates the insensitivity of the efficient collection to the fuel ash composition, but also cautions those specifying the equipment to be aware of the trace elements with principal concern to sodium oxide. A review of Na_2O content in the coal and limestone applicable to the Stone & Webster steam generator

indicates that less than 0.8% of Na_2O could be expected, whereas published data on hot precipitators using Western coal correlates better performance with greater than 1.0% concentration of Na_2O in the ash.

6.1.1.4 Unburned Carbon Collection. Several papers on the subject of electrostatic precipitation point to the difficulty in efficient collection of carbon (due to its very low resistivity) from high carbon dust. A mechanical collector upstream of the precipitator can be used to collect a large percentage of the carbon for reinjection into the carbon burnup cell with additional advantages of reduced dust loading on the precipitator. However, recent tests performed on a steam generator using a hot precipitator in which Western pulverized coal was burned, found that well over 95% of the carbon was caught in the first field. A spreader stoker installation built by Foster Wheeler firing Montana coal uses a hot precipitator in which the carbon caught in the first field is reinjected to the furnace and the unit operates well. This experience suggests that with proper precipitator design, the mechanical collector upstream to catch the unburned carbon may be unnecessary.

6.1.2 Baghouse

6.1.2.1 General Description. The baghouses use the straight forward principle of passing dirty gas through a fabric filter; the dust is captured by the filter and the clean gas passes through. Initial buildup of the captured dust on a clean fabric improves the filtration performance at the expense of a small increase in pressure drop. The filter is in the form

of fabric bags which are typically 12 in. diameter and 30 ft. long for utility boiler applications. Several compartments of bags with individual hoppers and inlet outlet dampers are used. The dirty gas can be inside or outside the bags. The dust build-up is cleaned periodically by taking one compartment out of service at a time. Two basic cleaning mechanisms are available. Generally, a reverse gas system is used with baghouses using dirty gas inside the bags. Clean gas from the outlet plenum is gently blown through the bags being cleaned in direction opposite to normal flow. The reverse flow and resulting collapse of the bags loosens the accumulated dust which falls in the hopper below. A pulse flow cleaning system is used with baghouses using dirty gas outside. A pressurized pulse of clean air is injected into the bags which expands the bags resulting in loosening of the dust cakes. A shaker mechanism independently or in combination with any of the two systems described above is also sometimes used.

Several fabrics are available, the choice depending on the temperature and the chemical composition of the gases. No fabric is available to stand temperatures above the 500F - 550F level which limits the location of the baghouse to after the air preheater. In addition to fabric damage due to excessive gas temperature, the bags can be damaged due to acid corrosion and abrasion. The abrasion could be due to large particles or by bags creasing during the cleaning cycle. Fiberglass bags appear to be the most suitable for the Stone & Webster fluidized bed boiler application. A teflon or silicon coating on

fiberglass provides resistance to acid attack and lubrication to reduce abrasion. The temperature limitation for fiberglass fabric is 500F. In order to reduce the number of damaging cleaning cycles and reduce abrasion of the bags from large particles, a mechanical collector upstream of the baghouse is desirable. This precollector will capture most of the unburned carbon since these particles are invariably a relatively large size which can be injected into the CBC. The particulate collected in the baghouse can be sent to waste. This mechanical collector baghouse arrangement is shown in the schematic of Figure 6.3.

6.1.2.2 Selection Criteria. The most important criterion in selecting a baghouse is the air to cloth ratio. This ratio is simply the ratio of the volume of the dirty gas to square feet of cloth area required. The lower the air to cloth ratio, the larger the baghouse and longer the bag life. Of the two major manufacturers of baghouses, one using shaker assisted reverse flow cleaning generally recommends air to cloth ratios of 2.5 to 3.0. The other using reverse air cleaning recommends air to cloth ratio of about 2.0. The major maintenance cost associated with a baghouse is the periodic replacement of the damaged bags with bag life somewhere between 1 and 4 years.

6.1.2.3 Performance. The baghouse performance is relatively independent of the variation in gas flow rate. The particulate chemical composition is important only to the extent that if the gas temperature is less than the acid dewpoint, corrosion could damage the bags. In addition, too much

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moisture in the gas can result in blinding of the bags due to the formation of thick mud cakes. These cakes sometimes cannot be removed by the cleaning mechanism and increase the pressure drop. (A typical baghouse results in 3 to 6 in. WG pressure drop.) The acid corrosion and caking problems can be alleviated by preheating and insulation so that the acid dewpoint is not reached and the moisture does not condense. A by-pass system around the bags is desirable to avoid hot (720F) gases contacting the bags and can also be used during start-up when the gas temperature is near the dewpoint.

One principal advantage of the baghouse system is the very high efficiency that it offers (99.9%+) whereby even submicron particles are collected at very high efficiency. This is desirable should EPA regulations be changed to further limit particulate emission rate, especially in the sub-micron range.

There is, however, not very much experience data available on the baghouses as applicable to large size utility boilers. A review of the existing baghouse installations for industrial and utility boilers indicates that most of the installations use fiberglass bags with air to cloth ratio between 2 and 3. The baghouse experience at the Pennsylvania Power & Light, Sunbury Station with 800,000 cfm and air to cloth ratio of 1.9 has been very good. Only a very small percentage of bags needed replacement due to damage with a large number still performing satisfactorily after four years of service.

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6.1.3 Economic Considerations

A leading manufacturer of electrostatic precipitators and baghouses recently conducted an economic evaluation of the cold and hot precipitators and baghouses for a typical power plant burning low sulfur coal. This evaluation indicates that the baghouses are economically more attractive than the hot precipitator from both initial investment and annual cost viewpoints. This is especially true in view of the very large precipitator required to improve reliability in case of an unknown dust.

6.1.4 Conclusion

The discussion presented above leads to the conclusion that at this time the baghouse is the preferable particulate collection equipment primarily due to the reliability that it offers for a relatively unknown application such as the fluidized bed steam generator. The primary objective of the Stone & Webster study is to demonstrate the feasibility of a large scale fluidized bed steam generator and, in order to maximize effort in that area, any potential problems associated with the peripheral equipment should be minimized.

6.1.5 Mechanical Dust Collector

As mentioned earlier, the baghouse can be located only downstream of the air heater due to bag fabric temperature limitations. There are several advantages to supplementing the baghouse with a mechanical collector upstream. The mechanical collector reduces the dust loading on the baghouse

thus reducing its size and improving bag life and additionally facilitates the reinjection of the collection from a relatively few hoppers. The mechanical collector can be located before or after the air heater. The location upstream of the air heater is preferable since this results in relatively clean gas going through the air heater. This leads to the conclusion that a mechanical collector upstream of the air heater is needed to supplement the baghouse.

A mechanical collection system for the dust exiting the CBC cell is also necessary to avoid high dust loading entering the air heater and to provide a means of collecting dust for removal to waste. The 720F gas stream exiting this mechanical collector can be mixed with the 720F main bed gas stream before or after the main mechanical collector system discussed above. Since the CBC cell collector removes a large percentage ($>90\%$) of the dust, little advantage is gained by passing these gases through the main mechanical collector at the expense of increasing its size due to additional gas volume. The CBC cell gas stream after passing through its own mechanical collector joins the main gas stream upstream of the air heaters. The physical location of the two mechanical collectors along with other back end equipment is shown in the schematic of Figure 6.3.

Having concluded the baghouse - mechanical precollector to be the optimum particulate collection system, the effort concentrated on selection of the specific equipment based on system performance requirements and cost. The following describes the selection process for the mechanical collector and the baghouse systems.

FIGURE 6.3 BACKEND ARRANGEMENT WITH BAGHOUSE

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6.2 EQUIPMENT SELECTION

6.2.1 Mechanical Dust Collector

As mentioned earlier, two mechanical collector systems are required. One for the main beds and the other for the CBC. In making the selection for the main mechanical collector, high collection efficiency was desired to reinject a large percentage of the unburned carbon exiting the main beds to the CBC thus improving overall boiler efficiency. The criterion for the CBC collector was only to have a reasonable collection efficiency so that the downstream equipment is spared the large dust loading. A review of various mechanical collection systems indicated that cyclone collectors would perform the desired function at reasonable cost for both main and CBC gas streams. Particular attention was given to the multiclones offered by Western Precipitation Division of the Joy Manufacturing Co. These multiclones comprise several individual tubes (cyclones) which separate the dust from the gas by whirling the gases at high velocity resulting in dust particles collection at the tube surface by inertial and centrifugal action. The smaller the tube diameter, the higher the gas velocity, pressure drop, collection efficiency, and initial cost. The particle size distribution is an important variable in determining collection efficiency and in order to predict the particle size distribution for the 570 MW fluidized bed steam generator under consideration, test data

available for fluid bed pilot plants in Alexandria and England were reviewed. Taking into account the coal and limestone feed size and the method of firing, it was judged that for the main beds, no more than 8 percent of the dust by weight will be less than 10 micron in size. No test data is available for the dust elutriated from the CBC cell and it was assumed that no more than 20 percent of the dust by weight will be less than 10 micron in size.

Having established the particle size distribution, the multiclone sizing was done using gas flow and dust loading data based on performance fuel. It was found that six modules of Western Precipitation multiclone model 12VM35 220-11 would give 95% collection efficiency with 3.0 in. WG pressure drop. This selection would provide 95.5% collection with 3.3 in. WG pressure drop for design (worst) fuel. For the CBC cell, one module of 12VM35 154-11 was chosen with about 2.6 inch pressure drop and 90% collection efficiency for both design and performance fuels. Pertinent design data for performance and design fuels for main and CBC multiclones is presented in Table 6.1. It should be noted that despite the 95 and 95.5% collection efficiencies stated by Joy Manufacturing Company for the performance and design coals, respectively, a conservative approach is taken in steam generator design by limiting the combined hopper drop and multiclone collection efficiency to 92%. The material flow diagrams for performance and design coals reflect this lower 92% efficiency. Approximately 10% of the MBC elutriates are assumed to be collected in the flue gas hoppers and the remainder in the multiclones, giving a net collection of 92% for reinjection into the CBC.

		Collector Designation ⁴	Gas Flow (M ACFM ³)	Dust Loading (Grains/Ft ³)	Collection Efficiency (%)	Pressure Drop (in. WG)
Performance Fuel	Main Beds ¹	Six (6) 12 VM35 220-11	2361	4.2	95.0	3.0
	CBC ²	One (1) 12 VM35 154-11	264	28.1	90.0	2.6
Worst Fuel	Main Beds ¹	Six (6) 12 VM35 220-11	2475	7.1	95.5	3.3
	CBC ²	One (1) 12 VM35 154-11	267	57.0	90.0	2.6

NOTES:

1. Particle size distribution for MBC collectors - 8% less than 10 microns.
2. Particle size distribution for CBC collectors - 20% less than 10 microns.
3. Gas temperature = 720F.
4. Western Precipitation model designation.

A = 25'-6"
 B = 14'-3"
 C = 25'-7"
 D = 7'-10"
 E = 13'-6"

Model: 12 VM35 220-11

A = 17'-11"
 B = 14'-3"
 C = 25'-7"
 D = 7'-10"
 E = 13'-6"

Model: 12 VM35 154-11

TABLE 6.1 MECHANICAL DUST COLLECTOR DATA

6.2.2 Baghouse

The technical data necessary to design a baghouse system for the 570 MW unit is presented in Table 6.2. The gas flow and solids data is somewhat different from that presented in the materials balance diagram but is sufficiently close to permit a baghouse sizing. The inlet grain loading was approximated using a high (92%) collection efficiency of the main multiclones and 90% collection efficiency of the CBC multiclone. The outlet grain loading corresponds to the 0.06 lbs/million BTU fired limit on particulate emission. Three leading manufacturers of baghouses were approached to give their quotes for the 570 MW steam generator. These were:

- Western Precipitation Division of Joy Manufacturing Co.
- Wheelabrator - Frye Inc.
- Carborundum Company

It became apparent that due to the large plan area required for a baghouse, a preferable system would comprise four (4) independent baghouses with two on ground level and the other two on a second level. This also alleviates the limited space available in the length direction due to the presence of a river. The "double decking" arrangement has been used in the past for electrostatic precipitators which weigh significantly more than a comparable baghouse. The four (4) baghouse system offers the additional advantage of redundancy. The three baghouse manufacturers were asked to quote on the four (4) baghouse double deck arrangement.

TABLE 6.2 BAGHOUSE DESIGN DATA

Fuel Firing Rate	=	535,577	lb/hr
Limestone Feed Rate	=	273,653	lb/hr
Fuel HHV	=	10,160	Btu/lb

<u>Fuel Composition (%)</u>		<u>Limestone Composition (%)</u>	
C	55.40	CaCO ₃	86.6
H ₂	3.87	MgCO ₃	3.0
N ₂	1.10	R ₂ O ₃	0.6
O ₂	6.58	H ₂ O	9.8
S	4.50		
Ash	15.00		
H ₂ O	13.55		

Flue Gas Entering (lb/hr)

SO ₂	6,431
O ₂	197,773
NO ₂	1,564
CO	218
CO ₂	1,173,940
N ₂	3,773,591
C ₆ H ₆	54
H ₂ O	344,153
Leakage Air	<u>835,000</u>
Total Gas Flow	6,335,000

Volumetric Gas Flow Rate	=	1,915,000	ACFM @ 288F
Solids Entering Baghouse	=	19,200	lb/hr
Baghouse Inlet Grain Loading	=	1 to 2	grains/ft ³
Allowable Outlet Grain Loading	=	0.0197	grains/ft ³

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An evaluation of the three quotes based on technical and cost viewpoints was performed. The Wheelabrator-Frye offering was judged to be the best compromise of the reliability of performance and cost. This offer consists of four (4) double decked baghouses with the following design features:

Bag Size:	11.5 in. diameter x 31 ft. long
Cloth Air per Bag:	91.5 ft. ²
Bag Fabric:	Fiberglass with Silicon coating
Bag per Compartment:	12 x 17 = 204
Compartments per Baghouse:	10
Total Number of Bags:	2040/per baghouse
Bag Reach:	2
Maximum Gas Temperature:	550F
Gross Air-to-Cloth Ratio:	2.57
Net Air-to-Cloth Ratio:	2.85
(Four (4) Compartments cleaning)	
Net Air-to-Cloth Ratio:	3.02
(Four (4) Compartments cleaning, Two (2) Maintenance)	
Cleaning Method:	Shaker Assisted Reverse Air
Pressure Drop:	6.0 in. WG
Bag Life:	1 to 2 years (1 year guarantee)
Reverse Air-to-Cloth Ratio:	1.0

An internal bypass uses a damper between the inlet and outlet plenums of the baghouse and the inlet gas is short circuited by opening the damper whenever a bypass of the bags is desired. Each of the four (4) baghouses measure approximately 56 ft. in width and 108 ft. in depth (length) with an extra 5 ft. all around for walkways and stairways. The height of each baghouse is approximately 60 ft.

Section 7

AFB MECHANICAL CONSIDERATIONS

(Task 4235)

7.1 OVERVIEW

The structural integrity of the large-scale AFB is a function of conservative design practices applied to the boiler pressure parts, including air distributors, the buckstay systems, penthouse support structures and the structural suspension system.

Certain of these considerations present unique problems, while others represent state of the art boiler design techniques.

The considerations presented herein apply specifically to the stacked bed AFB, and indeed, certain of these paved the way to the present AFB design.

7.2 BOILER MECHANICAL DESIGN

The stacked bed AFB makes use of continuous monolithic water- and/or steam-cooled welded-membrane walls to form the enclosure and partition walls. These monowallsTM serve to channel the bulk of the AFB loads to the penthouse superstructure.

The heat recovery area (HRA) of the AFB makes use of standard design practices which have proven to be conservative over years of operation in conventional Foster Wheeler pulverized coal units.

Air distributors are designed to provide for acceptable operating considerations from a process standpoint while observing rather complicated demands from a structural viewpoint. Some of these considerations are directly a function of service temperatures, cyclical thermal gradients, and static and dynamic loadings. Ample consideration must be afforded dimensional stability, freedom of movement and seal design.

The bed surface in the Foster Wheeler AFB design is placed parallel to the firing wall of the unit in order to provide for balanced firing across any given bank under all firing conditions. In the 570 MW AFB this results in tube runs 60 ft in length as measured from the centerline of each side wall. Intermediate tubing supports are mandatory in such an arrangement, and are provided quite simply by air-cooled piers tied to the grid, and spanning front to rear. Maintenance of tube-to-tube clearances in the vicinity of a support pier is accomplished through the use of tie-lugs and canes, as required. Variations of these support techniques can be seen in typical Foster Wheeler designs. Adequate provision for expansion of submerged bed surface relative to the sidewalls is important and is recognized as is proper seal design.

7.3 BUCKSTAY SYSTEMS

The Foster Wheeler AFB configuration very nearly duplicates a pulverized-coal unit in the extent of the boiler enclosure periphery. As a result, standard stiffening systems can be utilized, to a great

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extent, without modification. Buckstay tiers typically surround the unit on 6-10 ft centers. Details of the buckstay corner ties can be seen in figure 7.1. Vertical buckstays are placed, where required, to complete the system.

In addition to containing the boiler enclosure, the buckstay system is provided with guides and bumpers to transfer wind and/or seismic loads to the boiler structural steel at designated key levels.

7.4 PENTHOUSE

The penthouse serves as a transition level between the boiler enclosure and the structural suspension system. It is at this point that pressure part loads are channeled by way of hot hangers and spring hangers to the upper grid steel of the penthouse. Cold straps support the grid stringers to the boiler suspension steel.

The penthouse casing is fabricated of tee-stiffened 11-gauge plate and an S-seal is provided around the periphery at the bottom of the casing to seal the casing and the boiler enclosure boundary. The S-seal provides for relative movement of the systems.

The casing is fabricated to be essentially air-tight and is provided with a pressurization fan set to operate slightly above atmospheric pressure. The pressurization system effectively provides for zero-leakage of furnace gases into the penthouse even in the case of damaged internal seals.

TYPICAL BUCKSTAY SYSTEM

FIGURE 7.1
TYPICAL BUCKSTAY SYSTEM

7.5 STRUCTURAL STEEL

The structural steel system for the 570 MW AFB is designed to support the seismic, dead, live and wind loads imposed by the steam generator, associated piping, platforms, walkways and stairs, and feed systems including coal and limestone storage bunkers.

The Foster Wheeler AFB design is unique in that the placement of main storage bunkers may be in direct line with the distributing down-takes to the spreader feeders and limestone feed points. Economic considerations indicate that 10-16 hour storage bunkers located in this fashion are cost effective when compared with alternate means of conveying, shuttling and storing of coal and limestone.

The placement of the steam generator in close proximity to multiple coal and limestone bunkers is not without problems and demands that careful attention be paid to the selection of proper column locations and major bents in order to provide for structural requirements and process clearance requirements.

Section 8

AFB STEAM GENERATOR AND AUXILIARY EQUIPMENT DRAWINGS
(Task 4236)8.1 AFB STEAM GENERATOR DRAWINGS

AFB steam generator drawings include the following:

- Figure 8.1 General Arrangement - 570 MW Fluidized Bed Steam Generator
- Figure 8.2 Plan Sections - 570 MW Fluidized Bed Steam Generator
- Figure 8.3 Front Elevation - 570 MW Fluidized Bed Steam Generator

For clarity, the coal and limestone feed system, bed letdown cooler arrangement, and ignition system details are not shown. Detailed descriptions and illustrations of these systems are included in their respective section of the report. Pressure part inlet and outlet connections are referenced to the steam and water circuitry diagram indicated on Figure 4.1.

8.2 AUXILIARY EQUIPMENT DRAWINGS

Auxiliary equipment drawings include the following:

- Figure 8.4 Auxiliary Equipment Arrangement (Elevation) - 570 MW Fluidized Bed Steam Generator
- Figure 8.5 Auxiliary Equipment Arrangement (Plan) - 570 MW Fluidized Bed Steam Generator

Relative location of the mechanical fly ash collectors, air heaters, forced and induced draft fans, baghouse and steam generator are illustrated.

REVISIONS			
NO.	DESCRIPTION	DATE	APPROVED
A	FIRST SUBMITTAL	10-3-77	
B	ADDED COLUMN LINES	10-2-77	

UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION MAJOR FACILITIES PROJECT MANAGEMENT DIVISION			
CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT ERDA CONTRACT NO. 17-77-C-01-2563			
DESIGNED BY FOSTER WHEELER ENERGY CORP. LIVINGSTON, N.J. 07033		UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION	
DESIGNED	DATE	BY	DATE
DRAWN	DATE	CHECKED	DATE
APPROVED	DATE	BY	DATE
GENERAL ARRANGEMENT - BOILER 570 MW FLUIDIZED BED STEAM GENERATOR			
FWEC DWG. NO. 43-3075-5-10		B	

FIGURE 8.1 GENERAL ARRANGEMENT - 570 MW FLUIDIZED BED STEAM GENERATOR

NO.	DESCRIPTION	DATE	APPROVED
A	FIRST SUBMITTAL	10-5-77

SECTION D-D

SECTION B-B

SECTION A-A

UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION MAJOR FACILITIES PROJECT MANAGEMENT DIVISION	
CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT ERDA CONTRACT NO. EF-77-C-01-2583	
DESIGNED BY FOSTER WHEELER ENERGY CORP. LIVINGSTON, N.J. 07033	UNITED STATES ENERGY RESEARCH DEVELOPMENT ADMINISTRATION
DRAWN BY AL. D. CHISO DATE 8-25-77	CHECKED BY DATE 8-25-77
APPROVED BY DATE	TITLE BOILER PLAN SECTIONS - 570 MW FLUIDIZED BED STEAM GENERATOR
FWEC DWG. NO. 43-3075-5-11	

FIGURE 8.2 PLAN SECTIONS - 570 MW FLUIDIZED BED STEAM GENERATOR

FIGURE 8.3 FRONT ELEVATION - 570 MW FLUIDIZED BED STEAM GENERATOR

REVISIONS			
NO	DESCRIPTION	DATE	APPROVED
A	FIRST SUBMITTAL	0-5-77	
B	ADDED COLUMN LINES	0-5-77

UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION MAJOR FACILITIES PROJECT MANAGEMENT DIVISION	
CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT ERDA CONTRACT NO. EF-77-C-01-2583	
DESIGNED BY FOSTER WHEELER ENERGY CORP. LIVINGSTON, N.J. 07039	UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
DESIGNED: _____ DATE: _____	AS NOTED: _____
DRAWN: E. LEEF DATE: 0-25-77	APPROVED: _____
CHECKED: _____ DATE: _____	DATE: 0-25-77
APPROVED: _____ DATE: _____	DATE: 0-25-77
EQUIPMENT ARRANGEMENT - ELEVATION 570 MW FLUIDIZED BED STEAM GENERATOR	
FWEC DWG. NO. 43-3075-5-12 B	

FIGURE 8.4 AUXILIARY EQUIPMENT ARRANGEMENT (ELEVATION) - 570 MW FLUIDIZED BED STEAM GENERATOR

REVISIONS			
NO	DESCRIPTION	DATE	APPROVED
A	FIRST SUBMITTAL	10-3-77	
B	ADDED COLUMNS	10-6-77

UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION MAJOR FACILITIES PROJECT MANAGEMENT DIVISION	
CONCEPTUAL DESIGN ATMOSPHERIC FLUIDIZED BED POWER PLANT ERDA CONTRACT NO. EF-77-C-01-2583	
DESIGNED BY FOSTER WHEELER ENERGY CORP. LIVINGSTON, N. J. 07032	UNITED STATES ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
DESIGNED: _____ DATE: _____	_____
DRAWN: AL. DIPIONZO DATE: 10-26-77	_____
CHECKED: _____ DATE: _____	SCALE: 1/4" = 1'-0"
APPROVED: _____ DATE: _____	DATE: _____
TITLE EQUIPMENT ARRANGEMENT - PLAN 570 MW FLUIDIZED BED STEAM GENERATOR	
FWEC DWG. NO. 43-3075-5-13	

FIGURE 8.5 AUXILIARY EQUIPMENT ARRANGEMENT (PLAN) - 570 MW FLUIDIZED BED STEAM GENERATOR

Section 9

AFB STEAM GENERATOR MATERIAL AND LABOR ESTIMATE
(Task 4237)

The total cost for the 570 MW Atmospheric Fluidized Bed Steam Generator in accordance with the scope of supply as outlined under Section 1.3 is estimated at \$33,671,000. This price is based on mid 1977 dollars with no freight costs to the job site included. This price includes all engineering, project management, estimating, purchasing and contract administration services similar to that included on an equivalent size commercial pulverized coal unit.

Erection cost for the steam generator has been estimated at 650,000 man-hours for a U.S. average productivity area.

Pricing for the major vendor equipment is listed under Table 9.1. All prices indicated are budget values. The double level baghouse, indicated under Item 12 of Figure 9.1 has been priced by the vendor with equipment, support steel and erection. The baghouse erection price of \$3,930,000 would represent approximately 196,000 man-hours of erection at a rate of \$20.00 per hour. For pricing purposes, however, total baghouse pricing, including erection, has been included under the AFB steam generator price.

Substantial cost savings are realized with the Foster Wheeler AFB Steam Generator due to the following:

- Location of heat transfer surface in high absorption zones.
- Use of the once-through cycle eliminates costly drum, pumps, etc.
- Inherent emission control of the AFB combustion process with elimination of flue gas scrubbing systems.

TABLE 9.1 MAJOR VENDOR EQUIPMENT LIST

ITEM NO.	DESCRIPTION	CAPACITY, SIZE, AND/OR FEATURES	NO. REQD.	TOTAL* PRICE
1	FD Fans with Inlet Vanes and Silencers. Centrifugal Fans with Air Foil Blades. DWDI.	750,000 CFM, Static Head 95 in. H ₂ O, 120,000 lb/unit.	2	\$ 640,000
2	FD Fan Motors. Squirrel Cage Induction, Open Drip Proof.	12,000 hp, 1200 rpm, 4160 volts	2	\$ 320,000
3	Booster Fans. Single Inlet	42,600 CFM, Static Head 45.5 in. H ₂ O	2	\$ 104,000
4	Booster Fan Motors. Squirrel Cage Induction, Open Drip Proof	500 hp, 1200 rpm, 4160 volts	2	\$ 27,000
5	Air Preheaters, Inverted Vertical Shaft.	25 hp motor, 1,039,500 lb shipping wt/unit	2	\$1,640,000
6	Steam Coil Air Heaters		2	\$ 23,000
7	CBC Flyash Reinjection System including 108 eductors, piping, valves and three (3) Blowers.	Three (3) 750 hp motors for the three (3) Blowers delivering 6000 CFM of air, each, at 18 psig.	1	\$ 650,000
8	ID Fans with Inlet Dampers Centrifugal Fan, Modified Radial Tip Blades, DWDI.	1,159,000 CFM, Static Head 32.3 in. H ₂ O 158,000 lb shipping wt/fan.	2	\$ 570,000
9	ID Fan Motors. Squirrel Cage Induction, WP II	8000 hp, 720 rpm, 4160 volts 3 Phase, 60 Hz.	2	\$ 315,000
10	Main Multi-tube Dust Collectors with 12 in. Diameter Tubes	393,500 CFM at 720F, Pressure Drop 2.6 in. H ₂ O, 44,560 lb shipping wt	6	\$ 371,000
11	CBC Multi-tube Dust Collector with 12 in. Diameter Tubes	264,000 CFM at 720F, Pressure Drop 2.6 in. H ₂ O, 44,560 lb shipping wt	1	\$ 113,000

TABLE 9.1 MAJOR VENDOR EQUIPMENT LIST (Continued)

ITEM NO.	DESCRIPTION	CAPACITY, SIZE, AND/OR FEATURES	NO. REQD.	TOTAL* PRICE
12	Four Double Decked Baghouses, including support steel	1,915,000 Total CFM with 1 to 2 Grains per ft ³ , 6 in. H ₂ O Pressure Drop	1	Equipment: \$4,570,000 Erection: \$3,930,000
13	Coal Feeders	9500 lb/hr fuel capacity Includes Coal Feed and Throw Control	72	\$ 754,000
14	Ignition System	30 million Btu/hr capacity	12	\$ 220,000
15	Start-up Valves			\$ 300,000
16	Turbine By-Pass Valves			\$ 162,000
17	Combustion and Steam Temperature Controls		1	\$ 600,000
18	Furnace Safety System		1	\$ 250,000
19	Instrumentation			\$ 250,000
20	Miscellaneous Vent and Drain Valves			\$ 83,000
21	Penthouse Pressurization Fan		1	\$ 4,000
22	Safety & Electromatic Relief Valves			\$ 155,000

Section 10

AFB STEAM GENERATOR POWER REQUIREMENTS

(Task 4238)

10.1 OVERVIEW

In order to estimate power requirements for the 570 MW atmospheric fluidized bed steam generator, requirements for all the major auxiliary equipment were defined. Estimates of auxiliary power requirements were made for small sub-systems and are considered realistic. The forced draft fan, the induced draft fan, solids cooler booster fan, the baghouse reverse air fans and the ash reinjection blowers represent approximately 98 percent of the total power requirements. The following is an itemized description of the installed and MCR condition power requirements for the AFB steam generator. These requirements are summarized in Table 10.1 for quick reference.

10.2 Forced Draft Fans

Two forced draft fans, each with 50 percent air capacity, are selected to provide combustion air to the carbon burnup cell and five main beds. The test block conditions were derived both using Foster Wheeler standards and procedures suggested by Stone & Webster. The more conservative test block condition was used to size the fans. Each of the two fans requires a 12,000 horsepower motor for the test block condition. At MCR condition, the fan operates at 83.2 percent efficiency requiring 8184 brake

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Table 10.1 Power Requirements For 570 MW AFB Steam Generator

Equipment	Installed Power Horse Power	MCR Condition Horse Power
FD Fans (2) **	24,015	17,116
ID Fans (2)	16,015	12,516
Solids Cooler Booster Fans (2)	1,004	309
Baghouse (4)	248	176
Air Preheater (2)	50	45*
Stokers (72)	72	54*
Penthouse Pressurization (1)	40	37*
Ash Reinjection Blowers (3)	2,250	1,500
Miscellaneous Sealing & Cooling	506*	447*
TOTAL	44,200	32,200

* Estimated

** Number Required

horsepower. Accounting for motor efficiency at this condition, input power equivalent to 8552 horsepower is required. The oil recirculating system requires a 7.5 horsepower motor with 6 horsepower estimated requirement at MCR load.

10.3 Induced Draft Fans

Two induced draft fans, each with 50 percent capacity, are selected to provide for the flow of flue gas from the furnace to the stack. Similar to the FD fan, the test block conditions were derived using both Foster Wheeler standards and Stone & Webster recommendations with the worst case being used to size the fan. Each induced draft fan requires an 8000 horsepower motor for the test block condition. At MCR load, the fan operates at 50 percent efficiency requiring 5970 brake horsepower which results in 6252 horsepower requirement accounting for motor efficiency. The oil circulating system requirements are the same as the forced draft fan, i.e., 7.5 horsepower motor with 6 horsepower at MCR for each fan.

10.4 Solids Cooler Booster Fans

A booster fan system to provide air to cool the solids extracted from the beds is required. The booster fan system takes suction from the forced draft fans and provides additional head to supplement the solids cooling air requirement. Two booster fans with 55 percent capacity each for the worst case fuel are utilized for this purpose. The test block conditions, calculated on the basis of Foster Wheeler standards, result

in 500 horsepower motor requirement for each fan with 307 total horsepower required at MCR condition using performance coal. Only one fan is required at MCR condition with performance coal. The oil circulating system requires a 2 horsepower motor for each fan.

10.5 Baghouse

The fan power required to overcome the 5 to 6 inches of water pressure in the flue gas system during normal cleaning mode is included in the induced draft fan capacity. The selected baghouse system utilizes shaker-assisted reverse air cleaning. Four baghouse modules are utilized in the AFB system for the particulate removal and each baghouse is equipped with a reverse air fan. Each baghouse consists of ten (10) compartments and during normal operation one compartment is in the cleaning mode at any given time. The reverse air flow requirements are met by intaking clean gas from the baghouse outlet plenum and flowing it through the bags in the compartment being cleaned in the direction opposite to normal gas flow. Each of the four baghouse system reverse air fans requires a 60 horsepower motor with 42 horsepower requirement for the MCR condition. Each of the four shaker mechanisms requires a 2 horsepower motor.

10.6 Air Preheater

There are two (2) air preheaters for the AFB steam generator to provide combustion air at required temperature to the fluid beds. Each preheater is equipped with a 25 horsepower motor with 22.5 horsepower estimated requirement at MCR condition.

10.7 Spreader Feeders

A total of 72 spreader feeders are required to provide coal to the fluid beds. Each stoker requires one (1) horsepower motor with estimated 0.75 horsepower requirement at MCR condition.

10.8 Penthouse Pressurization Fan

A 40 horsepower motor fan is selected for penthouse pressurization. The MCR condition power requirement is estimated to be 37 horsepower.

10.9 Ash Reinjection Blowers

A blower system is needed to provide pneumatic conveying air for the transport of ash collected in the main mechanical dust collectors to the carbon burn-up cell. Three blowers, each with 50 percent capacity, are provided. Each blower requires a 750 horsepower motor.

10.10 Sealing and Cooling

An estimate was made for the total sealing and cooling requirements for the AFB steam generator plant. An installed power requirement approximately 500 to 600 horsepower is estimated with about 90 percent of it required at MCR condition.

Section 11

AFB STEAM GENERATOR CONTROL SYSTEM DESCRIPTION
(Task 4239)11.1 START-UP, LOADING SEQUENCE AND EMERGENCY SHUT-DOWN

The subsequent sub-sections describe the start-up and loading sequence for the AFB steam generator during cold and hot starts. Equipment terminology is referenced to Figure 11.1 which schematically illustrates the fluid flow diagram for a once-through steam generator equipped with integral separators, and to Figure 11.2 which illustrates the control functions of the start-up valves.

11.1.1 Cold Start11.1.1.1 Flushing Cycle

- The PPR valves are opened.
- Stop valve Y and control valve W are closed.
- Control valves F and E are closed.
- Main steam line drain and turbine stop valves are closed. High and low pressure by-pass valves are also closed.
- Feed pump is started and flow established at 15%.
- Control valve P and PB are on automatic and control separator water level. Water flow should initially be routed to the condenser via the D valve until water quality leaving the steam generator is of start-up quality and then routed through the E valve to the feedwater heater.
- Circulate water through the unit until the cation conductivity of the water leaving the separators is below 1.0 micromho.

FIGURE 11.1 START-UP SYSTEM
ATMOSPHERIC FLUIDIZED BED STEAM GENERATOR

FIGURE 11.2 START-UP VALVE CONTROL FUNCTION

11.1.1.2 Light-Off and Warm Unit

- When satisfactory water conditions are obtained, light-off the carbon burn-up cell using raw coal as fuel. Refer to Figure 11.3 for the preferred sequence of bed segment light-off and shutdown.
- To obtain maximum reclamation of start-up heat input, place control valves E and F in automatic so that the separator drain water flows to the deaerator and feed-water heater.
- When the temperature of the water at the inlet to the W and Y valves reaches 450F slowly raise the feedwater flow to 35%.
- Light-off segments in BB1 and BB2 as required to continue raising fluid temperature and pressure.
- When steam pressure is greater than 200 psi, open turbine overseat drain valves to warm main steam lines.

11.1.1.3 Roll and Apply Initial Turbine Load

- Continue operation as in light-off and warm cycle.
- Increase firing in BB1 and BB2 to raise turbine throttle pressure to 850 psi.
- Place high and low pressure by-pass systems in automatic. HP bypass will hold throttle pressure at 850 psi. LP bypass will hold reheat pressure at the prescribed minimum value.
- Warm and roll the turbine.
- When 35% steam is flowing through the HP/LP by-pass, light-off sections of beds F3H2 and RHT2 and bring superheat and reheat temperatures to desired value.
- The P valve will gradually close as the HP/LP steam flow increases. The P valve will be completely closed when the HP/LP flow is 35%.
- When the turbine is up to speed, synchronize and apply initial load.
- At 850 psi throttle pressure, raise load to 18%.

FIGURE 11.3 START-UP SEQUENCE

11.1.1.4 Raise Turbine Load to 50%

- With throttle pressure of 850 psi and turbine load of 18%, the turbine throttle valves will be at the 50% position. At a fixed valve position, the turbine load is directly proportional to throttle pressure, with 50% load reached at full throttle pressure. The actual valve position is varied from 50% during transient load changes. But when the load reaches the desired value, the pressure continues to change until the valves return to the 50% position.
- Light-off additional cell segments to raise throttle pressure to the value required to obtain the desired turbine load when the throttle valves are at 50% position.
- Between 18% and 35% load, as load demand increases, boiler steam flow is transferred from the HP/LP by-pass to the turbine. The boiler feedwater flow rate remains constant at 35%.
- Above 35% load, the HP/LP by-pass is out of service and feedwater flow is increased in direct proportion to the unit load.

11.1.2 Hot Start

Follow the cold start-up and loading sequence. The flushing, warming and initial loading cycles will be considerably shorter because the feedwater and pressure parts are at or near operating temperature.

11.1.3 Emergency Shutdown

- Fuel feed trips.
- HP and LP by-pass open on automatic.
- Feedwater flow runs back to 35%.
- Air flow runs back. Maintains minimum fluidizing velocity.
- When bed temperature is 1000F - air flow trips.
- When bed temperature is 700F - feedwater flow trips.
- As pressure decays in the superheaters and the reheater, HPC and LPC close.

11.2 ANALOG CONTROL - SYSTEM DESCRIPTION AND LOGIC DIAGRAMS

11.2.1 Coordinated Boiler-Turbine Control

The analog control system is designed to operate the boiler and turbine in parallel as a coordinated unit so as to produce the required generator output in a fast, stable and efficient manner over the entire operating range. This control range includes low load operation where the by-pass system is in service. Figure 11.4 schematically illustrates the coordinated AFB steam generator-turbine control system.

The unit load demand as developed from the automatic dispatch system or as manually set by the operator is used as the proportional feedforward control index to the boiler and turbine. The control system responds by varying the throttle pressure during sliding pressure operation, and otherwise adjusting the turbine valves and the boiler input variables to match megawatt generation to demand for constant pressure operation.

Final superheat and reheat steam temperature controls are closely coordinated so as to minimize any interaction between them while maintaining temperatures within narrow limits. Close temperature regulation is further achieved by utilizing feedback from actual measured steam temperature errors for final corrective trimming and calibrating the basic feedforward control.

The control system recognizes any limitation in the boiler or turbine as may be caused by the loss of some auxiliary equipment. In this way, the load on the boiler-turbine unit cannot be more than the capability

FIGURE 11.4
COORDINATED AFB STEAM
GENERATOR-TURBINE CONTROL SYSTEM

of the in-service equipment. Furthermore, the system will automatically transfer from the base coordinated control mode to either "boiler following" or "turbine following" in accordance with the respective operational limitation.

In summary, the system operates as follows:

By-Pass System in Service

- Turbine following in sliding pressure mode.
- Throttle pressure varied by firing rate.
- Superheat steam temperature by spray.
- Reheat steam temperature by damper regulation.

Once-Through Operation

- Coordinated control of boiler and turbine.
- Load and throttle pressure by varying turbine control valves, feedwater and firing rate.
- Superheat steam temperature by feedwater/firing rate ratio with transients by spray.
- Reheat steam temperature by damper regulation.

11.2.2 Unit Master

The Unit Master control logic is schematically represented in Figure 11.5. The Unit Master portion of the control system develops a load demand signal which is sent in parallel to the turbine and boiler, characterized where necessary, and used to position flow control devices

on fans, pumps, valves, etc. The control permits the turbine/boiler set to operate in the boiler follow, turbine follow, or coordinated (boiler and turbine together) modes while responding to an area load demand signal or a manual signal selected by the operator.

The system contains manually adjustable maximum and minimum load levels, and rate of change. It automatically limits and runs back the load if any of the auxiliary equipment is lost, or when the ratios of turbine load, fuel flow, air flow, or water flow exceed pre-established limits. The system also automatically transfers from the coordinated mode to boiler or turbine follow on loss of the area demand signal or auxiliary that prevents either the boiler or turbine from safely responding to a change in demand.

The boiler load demand controls feedwater flow, fuel flow and air flow in parallel to maintain the turbine throttle conditions at set point values. Throttle pressure error modifies the above demand. Steam temperature and feedwater temperature errors are corrected by modifying the water to firing rate ratio.

11.2.3 Feedwater Flow

The feedwater flow control logic is schematically represented in Figure 11.6. The boiler load signal from the Unit Master is the demand for the feedwater and fuel flow. At loads less than 35%, the set point for water flow is 35% except when the water temperature is less than 450F (232.2C). At this lower temperature the flow is maintained at 15%. During

DEMAND FROM
BOILER MASTER

FEEDWATER

ECONOMIZER INLET
TEMPERATURE
(FROM SEPARATOR SYSTEM)

FIGURE 11.6 FEEDWATER LOGIC DIAGRAM

this period, the fuel rate is increased 5% to prevent a decrease in water temperature because of the increase in flow. The feedwater flow demand and measured flow are compared, and any error used to modify the feed pump output. Because the relationship between demand for pump output (flow) and speed are non-linear and a function of pressure, the demand signal to the pump is characterized and compensated accordingly. This compensation is downstream of the operator control station to facilitate better manual operation.

To prevent physical damage to the tubes, two alarm contacts are provided. The first is at 25% flow with no delay; the second is at 30% flow with a 5-minute time delay. Both trips are deactivated during the cold start-up when the water flow is 15%.

11.2.4 Fuel Master

Figure 11.7 schematically illustrates the fuel master control logic. The boiler load demand signal from the Unit Master is characterized and modified by the difference between the measured fluid temperature and the predicted temperature entering the economizer and adjusted for steam temperature error. This signal is then compared to total measured fuel flow as determined from the sum of coal feeder speeds. Any difference between the demand and actual flow signals readjusts the master demand.

DEMAND FROM
BOILER MASTER

ECON. INLET
TEMPERATURE
(FROM SEPARATOR SYSTEM)

FUEL FLOW
(EACH CELL)

FIGURE 11.7
FUEL MASTER LOGIC DIAGRAM

11.2.5 Combustion Air Pressure

The boiler load demand signal from the Unit Master is characterized and added to the signal derived from the difference between the operator adjusted set point and measured pressure at the FD fan discharge.

11.2.6 Furnace Draft

The furnace draft control loop, which is schematically illustrated in Figure 11.8, is a two-element type using a feed-forward signal of air flow plus correction by redundant furnace draft measurements to establish the demand for induced draft fan damper position. Downstream of the operator control station, the fan damper position is limited in the opening direction by a characterized air flow signal derived from redundant air flow transmitters.

As additional protection, controls are included for the induced draft (ID) fan discharge damper. This loop becomes active when conditions indicate that the principal loop controlling the ID fan inlet damper malfunctions. The redundant air flow is characterized to establish a signal indicating the maximum expected ID fan suction. The normal position for the discharge damper is its almost open (90%) position. As long as the measured ID suction is less than the maximum expected, the damper remains in its almost open position. When the measured suction exceeds the maximum expected, the damper moves in the closed direction through a proportional controller. A minimum automatic damper position limit, manual means to close the damper, and a test loop to exercise the damper between almost open and 100% open are also included in this protective loop.

FURNACE DRAFT
(5.0)

AIR FLOW
FROM FLUID
BED

FURNACE
DRAFT

AIR FLOW
(REDUNDANT)

GAS
TEMP

ID FAN
SUCTION

FIGURE 11.8
FURNACE DRAFT
LOGIC DIAGRAM

11.2.7 Steam Temperature

The steam temperature control logic is schematically represented in Figure 11.9. The philosophy of this control loop is to position the spray valves as a function of load and modify this position during transient temperature changes while making long-term changes in the feedwater-to-firing rate ratio.

The set point for final steam temperature is set by the operator through a rate of change limiter to avoid upsets caused by too rapid a change. The set point is limited to a minimum of 750F and maximum of 1000F. This set point is compared to the measured set point and any difference is used to modify the feedwater-to-firing rate ratio in the Unit Master.

The spray valve program keeps the valves closed until the unit is operating in the once-through mode (greater than 35%) when the valves are ramped to their 50% position between 35% and 38% load. With no transients the valves remain at the 50% position throughout the remainder of the steam generator load range. The spray valve position is automatically increased or decreased from mid-position on a derivative basis based on steam temperatures measured at the inlet to each spray. An error in final steam temperature will also cause a transient change in the position of the spray valves.

A superheat by-pass spray is supplied to control the steam temperature before and during the throttle pressure ramp. The throttle pressure

FIGURE 11.9 STEAM TEMPERATURE CONTROL LOGIC DIAGRAM

program positions the by-pass spray valve as a function of the program and establishes a program for steam temperature set point at loads less than 20%. Because of the time lag in the temperature feedback, the valve position correction by temperature is limited to $\pm 10\%$. Above this load, the limit is removed.

11.2.8 Reheat Steam Temperature

Figure 11.10 schematically illustrates the reheat steam temperature control logic. Reheat steam temperature is controlled primarily by sequentially manipulating the superheater and reheater pass dampers and by changing the firing rate in cell RHT2. Spray water injection is utilized for emergency conditions only. The set point for reheat temperature is measured superheat temperature with a manually adjustable minimum.

A load demand signal modified by reheat steam temperature error is used to sequentially position the reheat and superheat pass dampers, then modifies the fuel demand signal to RHT2.

High measured reheat temperature will open the superheat pass dampers before closing the reheat pass dampers. Emergency correction by spray water is included only in case the set point is exceeded beyond the capability of pass damper and bed control to maintain the required temperature. Reheat spray flow is limited to 5% of the feedwater flow.

FIGURE 11.10 REHEAT STEAM TEMPERATURE CONTROL LOGIC DIAGRAM

11.2.9 Air Heater Cold End

The temperature of the air entering the air heater is modulated to maintain the average air/flue gas temperature above a manually adjusted set point. Several measurements of air temperature entering the air heater and a similar quantity of measurements of the flue gas temperature leaving the air heater are averaged and compared to the set point. Any error is used to modify the flow of steam through the steam coil air heater.

11.2.10 Turbine By-Pass Systems

11.2.10.1 High Pressure By-Pass. Figure 11.11 includes the high pressure by-pass logic diagram. The valve opening demand is the pressure limited algebraic sum of the characterized boiler demand signal and a fixed signal. The demand is also pressure and temperature compensated.

The boiler demand signal is characterized to represent the expected turbine steam flow as a function of load. This is subtracted from a fixed value representing the minimum feedwater flow required for tube protection. This difference signal passes through a limiter which keeps the valve demand signal at zero until the separator pressure is 850 psi.

The final control function compensates the valve position demand for the pressure and temperature of the steam at the superheater outlet.

On a turbine trip, the valve opens a preset amount to assure 35% flow through the bed tubes.

11.2.10.2 Low Pressure By-Pass. Figure 11.11 includes the low pressure by-pass logic diagram. The valve opening demand is the deviation of reheat pressure from set point or valve position. Turbine load transfers the demand signal from one source to the other. This demand is also pressure and temperature compensated.

Prior to the turbine stop valve by-pass opening, the valve is controlled by reheat pressure. As the stop valve by-pass opens, the LP valve position is controlled by either reheat pressure (which is a function of load) or the ratio of the LP valve position to the HP valve position. The ratio control will maintain the LP flow equal to the HP flow as the load is changed.

11.2.10.3 High Pressure and Low Pressure By-Pass Temperature.

Figure 11.12 denotes the logic for the high pressure and low pressure by-pass temperature control. Steam temperature downstream of the high and low pressure by-pass valves is maintained below a maximum value for protection of the reheater and the condenser respectively. Each loop uses the same control philosophy.

Steam temperature is measured and compared to a setpoint. Deviation from set point modifies the spray valve position to change the quantity of spray water as required to reduce the error. To reduce the temperature excursion when the high or low pressure by-pass valve is opened, rate action based on the respective valve position is added to the temperature error.

FIGURE 11.11 HIGH AND LOW PRESSURE
BY-PASS CONTROL LOGIC
DIAGRAM

HIGH (OR LOW) PRESSURE
BY-PASS SYSTEM TEMP.

FIGURE 11.12

HIGH AND LOW PRESSURE BY-PASS
TEMPERATURE CONTROL LOGIC DIAGRAM

11.2.11 Separator Start-Up System

Refer to Figure 11.1 for the schematic of the integral separator start-up system (ISSS).

11.2.11.1 Furnace Fluid Pressure. Refer to Figure 11.13 for the furnace fluid pressure logic. The fluid pressure at the furnace outlet is controlled by a set of three valves, PPR, W and Y.

The PPR is a set of valves which operate in the open or closed mode. A boiler trip closes all PPR valves. Selection of the flushing mode opens all the valves. The valves remain open as long as the boiler is in operation.

The W valve controls the pressure of the fluid flowing through the boiling circuits of the boiler. Measured pressure is compared to set point and deviations between the two modulates the position of the "W" valves to maintain required back pressure on the furnace.

The Y valve is pulsed opened in steps when the W valve is almost completely open. As the Y valve opens the pressure will sag causing the W valve to partially close, this action will cause the Y valve action to stop. This series of actions take place until the Y valve reaches 15% open. At this time, the Y valve runs to 100% open. The control action is such that all valves ultimately operate in the wide open position when the by-pass system is out of service.

FURNACE FLUID PRESSURE

FIGURE 11.13 FURNACE FLUID PRESSURE LOGIC DIAGRAM

11.2.11.2 Separator Level. Refer to Figure 11.14 for separator level logic. The control of the P/Pb valves is a combination of water level in the separators and minimum feedwater flow. During start-up, with the required minimum feedwater flow and no steam flow, the valves are controlled by the separator level signal only. As steam generation increases, the level will become less than set point value. At this time, the steam flow signal (valve position) from the high pressure by-pass control will hold the P/Pb valves open as a function of the high pressure by-pass valve position so that the sum of the steam and water flows is equal to the minimum feedwater flow.

The Pb and P valves open in sequence with the Pb first and fully open at 10% signal. The level is measured in two locations, one at each end of the separator groups. The highest level is used for control.

During normal operation, the Pb and P valves will open to relieve an overpressure condition (> 2850 psi). Opening is limited to a 30% signal.

11.2.11.3 Water Distribution Valves. Refer to Figure 11.15 for the water distribution valve logic. A series of valves is used to distribute the separator drain water for heat recovery purposes.

The "F" valve functions to maintain the economizer inlet water temperature at set point.

FIGURE 11.14 INTEGRAL SEPARATOR LEVEL
LOGIC DIAGRAM

FIGURE 11.15 WATER DISTRIBUTION VALVE LOGIC DIAGRAM

The "D" valve controls the amount of water being dumped to the condenser. High separator level and pressure downstream of the P valve causes the "D" valve to open.

11.2.12 Fluidized Bed (MBC)

11.2.12.1 Fuel

A. Steam Generating Beds - The steam generating beds (BB1 and BB2) include 2 beds with 4 segments per bed or a total of 8 segments. Refer to Figure 11.16 for the boiling bed fuel control logic.

The boiler load demand signal, combined with temperature errors of feedwater entering the economizer and leaving the carbon burn-up cell, and rate of water temperature change at the "W" valve inlet is the corrected fuel demand. This is limited by measured air flow to prevent fuel from exceeding available air and further limited by mean fluidized bed temperature compared to measured fuel flow. Any error between measured fuel flow and fuel demand changes the speed demand signal to the coal feeder.

B. Superheating Beds - The superheating beds (FSH1 and FSH2) include 2 beds with 4 segments per bed or a total of 8 segments. Refer to Figure 11.17 for the superheating bed fuel control logic.

The boiler load demand signal, combined with steam temperature error then limited by air flow and mean bed temperature, is compared to measured fuel flow. Any error between the demand and actual flow modifies the coal feeder speed demand signal.

FIGURE 11.16
BOILING BED FUEL CONTROL LOGIC
DIAGRAM

FIGURE 11.17 SUPERHEATING BED FUEL CONTROL LOGIC DIAGRAM

C. Reheat Bed - The reheat bed (RHT2) includes 1 bed with 4 segments or a total of 4 segments. Refer to Figure 11.18 for the reheat bed control logic.

The boiler load demand signal modified by reheat temperature error and limited by air flow and mean bed temperature is compared to measured fuel flow. Any error between the demand and actual flow modifies the coal feeder speed demand signal.

11.2.12.2 Air Flow. Air flow is measured on each bed segment or a total of 20 segments. Refer to Figure 11.19 for the air flow logic diagram.

Bed expansion is to be maintained at a relatively constant value by maintaining a constant air velocity through the bed. The differential across a flow element is measured, then corrected for measured air temperature at the flow element, then corrected a second time for mean bed temperature to obtain calculated bed velocity. This signal is compared to a set point and the difference used to adjust the position of the combustion air control damper.

11.2.12.3 Limestone Flow. Limestone flow is measured for the 2 feed points per bed or a total of 10 flow measurements. Refer to Figure 11.20 for the limestone feed logic diagram.

FIGURE 11.18 REHEAT BED FUEL CONTROL LOGIC DIAGRAM

FIGURE 11.19 AIR FLOW LOGIC DIAGRAM

FIGURE 11.20 LIMESTONE FEED LOGIC DIAGRAM

Limestone will be controlled by means of a three-element control system. Fuel flow signals from each half bed are used as a feed-forward signal for limestone. This demand is modified by a signal representing deviation of measured SO_2 from desired level. The combined signal is the set point for the limestone feeder speed. Deviation from set point will vary the limestone feeder speed.

11.2.12.4 Bed Material Letdown. Bed material letdown is measured at each removal cooler for a total of 20 flow measurements. Refer to Figure 11.21 for the bed material letdown control logic.

Bed removal rate is a three-element control system. Limestone flow is used as a feed-forward signal. This demand is modified by the deviation of a calculated bed level measurement from set point. This modified signal is the set point for rotary valve speed. The difference between the measured and desired valve speed is used to vary the speed.

The bed level is calculated by establishing a ratio of the pressure drops across a known bed depth and an unknown one then multiplying this ratio by the value of the known depth. The result is the unknown bed depth.

11.2.12.5 Bed Material Cooler. The bed material cooler is included with each letdown device for a total of 20 coolers. Refer to Figure 11.22 for the bed material cooler logic diagram.

ROTARY VALVE
SPEED
(FROM BED REMOVAL)

SPENT MATERIAL
TEMPERATURE

FIGURE 11.22 BED MATERIAL COOLER LOGIC
DIAGRAM

The speed of the bed material removal device is used as a feed-forward signal for the amount of coolant required. This signal is modified by a signal representing the error between measured spent material temperature and its setpoint. The adjusted signal positions the coolant damper and, through a characterizer, a by-pass damper.

11.2.13 Carbon Burn-Up Cell (CBC)

The carbon burnup cell includes 4 segments, each capable of independent operation.

11.2.13.1 Air Flow. Air flow is measured for each segment for a total of 4 flow measurements. Refer to Figure 4.23 for the air flow control logic.

Air flow is controlled to maintain a pre-selected oxygen content in the freeboard area or a minimum fluidizing velocity, whichever requires the greater air supply.

Bed fluidizing velocity is a calculated value determined by multiplying the differential across a flow element by the ratio of the mean bed temperature to the air temperatures. Signal scaling will be required to compensate for the difference in areas.

11.2.13.2 Coal Flow. Coal flow is measured for each segment for a total of 4 flow measurements. Refer to Figure 4.23 for the coal flow control logic.

FIGURE 11.23 CBC AIR AND FUEL CONTROL LOGIC DIAGRAM

Coal is added to the cell to maintain a constant bed temperature. The mean bed temperature is measured and compared to a set point and the error used to adjust the coal feeder speed.

11.2.13.3 Limestone Flow. Limestone flow is measured at each outer bed segment for a total of 2 measurements. Refer to Figure 11.24 for the limestone flow control logic.

Limestone is added to the cell to control SO₂ emission during coal firing only. A manually adjusted proportion of coal feeder speed signal is used as the demand for limestone feed rate. Any difference between this demand and measured speed of the limestone feeder is used to adjust the limestone feeder speed.

11.2.13.4 Bed Material Recycle (Make-Up). Bed material is injected at the outer bed segments. Refer to Figure 11.25 for the bed make-up control logic.

During normal operation the bed level is maintained by adding material withdrawn from the other beds. Bed level is measured as in Section 11.2.12.4. This measurement is compared to a set point and the difference used to increase or decrease the rate of the make-up feeder.

FIGURE 11.24 CBC LIMESTONE FEED AND BED MATERIAL LETDOWN CONTROL LOGIC DIAGRAM

FIGURE 11.25 CBC BED MAKE-UP CONTROL LOGIC DIAGRAM

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11.2.13.5 Bed Material Letdown. Bed letdown is included for each segment for a total of 4 measurements. Refer to Figure 11.24 for the bed material letdown control logic.

During start-up, bed material is removed at a rate that is proportional to the rate of adding limestone. A manually adjusted proportion of the limestone feeder signal is used as the demand for bed removal. Any difference between this demand and the measured valve speed is used to adjust the valve speed.

11.2.13.6 Bed Material Cooler. The bed material cooler is included for each segment. Refer to Section 11.2.11.5 for details of cooler control logic.

11.3 Purge, Prelight, and Safety System

The primary purpose of this system is to ensure that the unit is operated in a safe manner. If unsafe conditions are detected the unit is automatically shut-down. The secondary purpose is to aid the operator in starting up and shutting down equipment in an orderly fashion.

11.3.1 Purge

After each master fuel trip, a furnace purge is required to remove any combustible that may have accumulated. The purge sequence consists of establishing and maintaining the status of certain pieces of equipment for an uninterrupted period of time while fresh air is being passed through the air/flue gas passages of the steam generator and appurtenances. The items which are monitored during this period are:

- All ignitor fuel valves closed
- All coal feeder systems stopped
- ID fan running
- FD fan running
- Purge each bed independently with a minimum of 25% MCR air flow for a minimum of 5 minutes.

11.3.2 Prelight

When the purge cycle has been successfully completed, the unit is placed in a prelight state, indicating that the bed ignition systems can be

placed into service. The items which are monitored during this cycle are:

- Purge complete
- No trip conditions
- Ignitor oil pressure satisfactory
- Ignitor oil/air pressure differential satisfactory

11.3.3 Safety System

The safety system monitors preset conditions and generates a signal to shut down an individual cell segment, a complete cell, or the entire steam generator if any of the preset conditions are exceeded.

Signals that will cause an individual cell segment to shut down are:

- High bed temperature
- Low bed fluidizing velocity

Signals that will cause the entire steam generator to shut down are:

- Loss of FD fan
- Loss of ID fan
- Low feedwater flow
- High or low furnace flue gas pressure
- All cells shut down

Section 12

AFB STEAM GENERATOR DEVELOPMENT AREAS
(Task 4240)12.1 AGGLOMERATION TECHNIQUES12.1.1 Overview

The commercial AFB process is accomplished in large water- or steam-cooled beds in which superficial velocities typically range from 8-12 FPS. These moderately high velocities are dictated by economic considerations, primarily in minimizing unit bed cross sections.

Acceptable sulfur capture can be achieved under such conditions, however, in order to attain commercial boiler efficiency levels, a carbon burn-up cell (CBC) must be provided for recycling of the main bed cell (MBC) elutriated material.

The commercial AFB process makes use of overbed feeding techniques for coal and sorbent, in order to provide for maximum system reliability and simplicity.

Elutriated solids captured from the main bed cells (MBCs) are injected pneumatically into the carbon burn-up cell (CBC) for additional burnout prior to final discard.

As part of the ongoing development and improvement of the commercial AFB process the following are recognized as important objectives:

- Enhanced Combustion Efficiency
- Increased Sorbent Utilization
- Simplification of Sub-Systems

The following paragraphs will serve to identify the role of agglomeration techniques in furthering these objectives and to outline areas requiring further development.

12.1.2 Fuel Agglomeration

The presence of fuel fines in the AFB process presents certain unique problems which can be associated with any given feed system approach. Among these problem areas are fuel handling difficulties, rapid burning, the formation of localized reducing zones, and the potential for high carbon carryover from the primary combustors. The larger topsize permitted with and required by the overbed feed technique results in a significant reduction in fines content of the fuel and is expected to enhance overall conditions.

The handling and feeding of fuels having unusually high fines content (coal crushed for PC firing, direct strip mined coal, beneficiation plant end tailings, etc.) could present significant problems for the overbed feed system as related to the combustion process. Means of compacting, pelleting, extruding or agglomerating the fuel fines in such cases could serve to minimize such problems and enhance combustion efficiency, by promoting maximum combustion in the fluidized bed. This is important to the economics of this commercial

AFB steam generator design in that any heat released after the bed, must then be captured downstream by convection surface at 3 to 4 times the surface and cost of in bed surface. The fluid bed is also the most efficient reaction in the system in which to complete combustion and capture sulfur.

12.1.3 Sorbent Agglomeration

Operation of a large-scale AFB demands the use of run-of-mine limestone, crushed to the required size at the plant site. Crushed limestone topsize varies between 1/8 in. and 3/16 in. in most cases, depending on requirements related to bed design parameters (mostly fluidizing velocity) and limestone properties. Minimization of fines generation in processing the limestone is important and must be respected. Overall system calcium utilization is dependent upon the percentage of fines in the elutriatable range, as well as bed arrangement and feed system techniques.

Efforts which can be made to improve utilization include attrition promoting techniques, finer limestone grind and minimization of directly elutriatable particle size fractions.

Agglomeration of the limestone fines can serve to maintain the particles in the matrix of the bed until such time as they are ground to extinction and stripped from the bed. Assuming that fine particle residence

time is correspondingly increased, overall calcium utilization can be increased.

12.1.4 Flyash Agglomeration

In the process under discussion, carbonaceous flyash captured in the primary dust collectors is reinjected pneumatically to the carbon burn-up cell (CBC) through an array of tee-nozzles spaced on approximately 9 ft² injection centers. Spreader feeders are located along the rear wall of the CBC for supplemental firing of coal and for initial unit start-up.

The fine flyash must be distributed uniformly across the CBC to avoid the formation of localized reducing zones and overloading with fuel fines. The sub-system required to accomplish this task on a large AFB is complex and represents a sizable equipment investment.

The application of agglomeration techniques to the flyash captured in the primary dust collectors would permit the feed of flyash agglomerates to the CBC by way of the existing spreader feeders. Due to the increased size and mechanical strength of the agglomerates, a longer in-bed residence time can be achieved which effectively decreases the potential for formation of reducing zones and can increase overall combustion efficiency. Under such conditions it would be possible to operate the CBC at a lower temperature, thereby achieving additional sulfur capture in the system and reducing overall limestone feed requirements.

12.1.5 Agglomeration System Description

A schematic three-train agglomeration system is shown in Figure 12.1. Spent bed material removed from the process after cooling and elimination of oversize is pulverized and used as a binder in the limestone and coal agglomeration trains. The flyash train makes use of the inherent binding properties of the collected material. In each of the systems, water is provided at a rate of 10 percent by weight of the total feedstocks. The process is accomplished through the use of pan-type agglomerators. Flue gas dryers are utilized to cure the "green" agglomerates prior to conveying to storage bunkers.

12.1.6 Recommendations

In order to determine the overall feasibility and cost impact of such systems, the following are fitting subjects for investigation:

- Suitability of spent bed material as a binder.
- Required mix of materials required to produce acceptable agglomerates.
- Mechanical properties of agglomerates.
- Behavior of agglomerates in large-scale beds under firing conditions.

FIGURE 12.1

FLYASH, COAL AND LIMESTONE HANDLING SYSTEM

12.2 BED LETDOWN COOLER12.2.1 Description

In order to operate the AFB system in accordance with EPA emission limits for sulfur dioxide, the MBCs must continually be recharged with fresh sorbent. A portion of the injected sorbent is elutriated due to attrition and fluxing in the main beds and is carried through the gas side system where it is captured in the gas clean-up trains. The remaining spent sorbent must be removed through the bed drain system in order to maintain proper bed operating level in each cell. In removal of spent sorbent, residual coal ash and unburned carbon which exist in the matrix of the bed are also removed. Estimates of the carbon remaining in the bed material at the entrance to the taps varies and is a function of bed geometry, feed systems, the location of bed taps and fuel feed size. For purposes of fixing letdown system requirements, carbon content of 6% of the bed weight is used.

The purpose of the bed letdown system in the AFB design is three-fold, and the objectives are as follows:

- Recovery of Sensible Heat - The removal of spent bed material at 1550F represents a large thermal loss in light of the amount of material which must be withdrawn during normal operation. A commercial AFB cannot tolerate such thermal losses.
- Spent Solids Disposal - Ultimate disposal of spent solids in a landfill requires handling and transporting of the material. Reduction in temperature, therefore, of the spent solids must be accomplished prior to removal from the system.
- Carbon Burn-up Efficiency - Due to the high carbon content prevailing in the matrix of the bed, estimated at 6% of the bed by weight, it is mandatory that further carbon reduction be accomplished in the system prior to disposal.

The bed material letdown combustor/cooler described in Section 5.3 accomplishes the above objectives. It is recognized, however, that system operation is complicated and potential operational problems have been identified. As a result, efforts have been undertaken to develop a new generation bed letdown system which would meet the objectives identified for the present system while eliminating the potential operational problems associated with this design.

12.2.2 Proposed Design

Specific requirements of the proposed system are:

- Reduce carbon content of the spent bed material to 1.25% by weight.
- Reduce the temperature of the spent bed material to 250F while returning sensible heat to the process.

To achieve these objectives, a fluidized cooler is proposed. Bed material extraction points are required for each bed segment along the steam generator front wall. Metering of the bed extraction can be accomplished through use of high temperature rotary valves or low amplitude vibrating feeders located at each tap. Bed removal rate is controlled primarily by limestone feed rate while bed level serves as a trim. Material discharged from all operating rate control devices is transported to the CBC and injected at the front wall. As the spent bed material migrates toward the rear wall of the CBC, the carbon content is reduced to a level of 1.25% carbon by weight prior to removal at the four (4) bed taps located along the rear wall

of the CBC. The total spent bed material exiting the CBC is equal to the total bed material letdown from the main cells less the burned carbon and material elutriated. Withdrawal rate of the material from the CBC is regulated by rotary valves or vibrating feeders which are keyed to unit load and/or total solids feed rate. CBC bed depth serves as a trim on withdrawal rate. The spent solids which contain 1.25% carbon (by weight) exit the CBC at a temperature of 1900F and enter a two-stage fluidized cooler. Since carbon content has been reduced to an acceptable level within the CBC, the cooler duty is a function only of flow rate and temperature drop across the cooler. The proposed cooler consists of two sections separated by a partition; a high temperature zone with bed tubes and a low temperature air cooling zone. The high temperature zone, where the spent bed material enters, has water carrying tubes within the fluidized bed. In this zone the temperature of the spent bed material is reduced from approximately 1900F to 750F. The low temperature cooling zone cools the bed material from 750F to 250F by means of fluidizing air entering at approximately 150F. The total heat removed by air for both the high temperature and low temperature zones will be routed to the air preheater providing approximately 70% heat recovery. The significant advantages to the two part cooler is that in having bed cooling tubes recover most of the heat, the amount of air required can be kept to a minimum thus reducing the dust carryover and dry gas losses. Second, the air cooling section allows the temperature of the solids to be reduced to a point where low temperature materials may be used for handling and disposal. The basic schematic layout of the fluidized cooler is shown in Figure 12.2.

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12.2.3 Recommendations

In order to further the development and determine the overall feasibility of the proposed system, the following relationships need to be developed for large bed systems:

- Impact of minus 1 in. feed on bed carbon content.
- Impact of coal and limestone feed systems and bed geometry on bed carbon profile.

Determination of the above parameters would allow specific confirmation of the basis of the proposed design. Hardware and mechanical components associated with the proposed system are not considered to present developmental problems since such systems are commercially available and operation has successfully been demonstrated at the Rivesville MFBB unit.

FIGURE 12.2 FLUIDIZED SOLIDS COOLER

12.3 COMBUSTION EFFICIENCY12.3.1 Introduction

Traditionally, a fluidized-bed combustor has been fed by pneumatically injecting fuel into the bottom of the bed. Based on diffusion experiments conducted in the early 1960's, one feed point was required for every nine square feet of grid surface.

In scale-up of the AFB combustor from pilot plant to commercial size, the number of feed points becomes excessive and system reliability deteriorates. The requirements to process fuel to a relatively small topsize, dry the fuel prior to conveying and to provide for uniform distribution of the fuel to 800 or more feed points are difficult to meet and add cost to the system:

For these reasons, alternate feed systems have been pursued. The most attractive system, and the system chosen for the base AFB design, is that of the overbed spreader feeder.

12.3.2 Recommendations

The overbed feed system in the AFB process is basically untried at this point and areas requiring investigative work are identified:

- Feedboard burning - Devolatilization, thermal cracking, formation of tars and soot.
- Feed distribution - Maldistribution of feed above the bed and the effects of bed mixing has on compensating for these distributions.

- Oxides of sulfur - Increase due to excessive overbed combustion, if present.
- System heat release - Effect of overbed feed on carbon carry-over and combustion efficiency including CO levels.
- Oxides of nitrogen - Effect of feed size and overbed burning on NO_x formation.

Parametric analysis of overbed feed tests run at a facility of reasonable size, such as the Rivesville MFBB, would serve to provide means of removing such uncertainties.

In this light, it is important to emphasize the value of test firing candidate limestones as well as fuels in actual large-scale beds with geometric patterns similar to those of the proposed 570 MW AFB, in order to confirm and/or optimize feed system techniques and design parameters.

12.4 START-UP/IGNITION SYSTEM

12.4.1 Introduction

A typical AFB pilot facility makes use of an ignition system capable of producing heat input nearly equal to that of full. Generally, the entire bed has been ignited at once. A variation of this technique can be seen at the Rivesville MFBB, wherein the four bed cells are lit by first establishing a burning bed in the light-off cell and then transferring hot bed material consecutively to the remaining cells through slide gates.

These presently employed ignition techniques do not lend themselves to the commercial AFB process due to physical constraints of the system and the requirement for high heat input. As a result, the ignition technique which holds the greatest promise makes use of localized fluidization.

12.4.2 System Description

Through use of a compartmented plenum arrangement and in-bed or under-bed heaters, initiation is accomplished as follows:

- Ignition zone is heated to 1000 F.
- Ignition zone is fluidized.
- Fuel is fed to heated zone and temperature is raised to 1600F.
- Adjacent sections are fluidized and mixed with the primary zone material and fuel feed is adjusted to maintain bed temperature.

12.4.3 Recommendations

Investigations are required to determine the applicability of this system to the large-scale AFB process. A three-phase program is recommended.

First, it is necessary that the concept of localized fluidization be demonstrated in hot and cold tests. Determinations as follows are required:

- Can sufficient bed be maintained in the locally fluidized zone?
- What is the effective portion of the bed fluidized as a function of grid area?
- Will clinker formation be a result of interchange of bed containing fuel between fluidized and static zones?

Second, the ignition system needs to be investigated to determine the most applicable technique and tests need to be conducted to verify these conclusions.

Third, the ignition system should be tested in conjunction with local fluidization to assure compatability of the techniques and verify selected design parameters.

12.5 GRID DESIGN12.5.1 Introduction

The air distribution grids in the AFB serve to distribute combustion air throughout each of the beds. Grid design is varied and commercial grids may be water or air-cooled utilizing tee-nozzle or drilled distributor holes.

Provisions must be made for expansion of the grids as well as tight sealing at joints or the periphery, as the case may be.

12.5.2 Problem Areas. Quality Assurance

It is anticipated that sufficient testing will have developed confidence in the proposed designs, on a pilot-plant or industrial-sized plant, prior to committing to a full-scale demonstration plant design. If this is not the case, a prototype grid will have to be tested in an AFB unit of reasonable size.

Primary areas of concern in grid design/manufacture are the following:

- Dimensional control of orifice holes and/or nozzle passages during fabrication and heating to maintain uniform pressure drop.
- Dimensional control of sections during fabrication and heating to minimize leakage through joints and seals.
- Structure integrity to support loads at operating temperature.
- Ability to withstand warpage caused by thermal stresses.
- Ability to withstand thermal cycling.

Section 13

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S & W E.C.C.3

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PER, Alexandria, Virginia - 1.5' x 6' test unit

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DATE: NOVEMBER 1977
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APPENDIX IIIB-D
EQUIPMENT DATA SHEETS

NOTE

For Equipment Common to Foster Wheeler
and Babcock and Wilcox, refer to
Appendix IIIA-D (Babcock & Wilcox)
in Volume 2

COOLING TOWER DATA SHEET - AFB
J.O.No. 12919.02B-FWEC

Mark No. 4CTWR-1

Specification No.
Purchase Order No.

Service

Condenser Circulating Water and
Cooling Water Systems

No of Units
Operation

1
Continuous

Type
Fill

Mechanical Induced Draft
Wood

Number of Cells

12

Fans per Cell

1

Circulating Water Flow, gpm

198,400

Hot (inlet) Water Temp, F

120.37

Cold (outlet) Water Temp, F

91.71

Wet Bulb Temp, F

79

Approach

12.71

Air Density Corresponding
to 79 F, lb/ft

.0732

Motor Hp

50/200

Heat Rejected by Cooling
Tower, Btu/hr

2.814×10^9

Range, F

28.66

Maximum Drift, % of

Circulating Water Flow

.01

Codes:

ASTM

American Society for Testing and
Materials

ANSI

American National Standards
Institute

AISI

American Iron and Steel
Institute

ACI

American Concrete Institute

CTI Std

Cooling Tower Institute Standard
Specification

VERTICAL PUMP DATA SHEET - AFB
J.O.No. 12919.02B-FWEC

Mark No. 4CWP-1A,B

Specification No.
Purchase Order No.

Service
No. of Units
Indoors or Outdoors
Operation
Liquid Pumped
Pumping Temp
pH
Sp. Gr. at P.T.
Viscosity at P.T.
Capacity at P.T.
Pressure at suction nozzle
Differential Pressure or
Total Head
Shutoff TDH, Max
Hp
Pump Speed, rpm
Driver Type
Driver Furnished by
Type Lubrication
Discharge Size, in.

Circulating Water Pumps
2
Outdoors
Continuous
Cooling Tower Discharge
32 F - 95 F
6 - 7
1.0 - .994
1.79 - .70 cp
99,200 gpm each
Flooded
100 ft, 43 psig
160 ft, 68.8 psig
3,000
400
Motor
Purchaser
Water Pumped
60

Codes:

H.I.S.

Hydraulic Institute Standards

ANSI B31.1

American National Standards
Institute

B16.1

Cast Iron Pipe Flanges and Flanged
Fittings

B16.5

Steel Pipe Flanges, Flanged Valves,
and Fittings

B16.9

Factory Made Wrought Steel Butt-
Welding Fittings

B16.11

Forged Steel Fittings, Socket
Welding and Threaded

VERTICAL PUMP DATA SHEET - AFB
J.O.No. 12919.02B-FWEC

Mark No. 4 MUWP-1

Specification No.
Purchase Order No.

Service
No. of Units
Indoors or Outdoors
Operation
Liquid Pumped
Pumping Temp
pH
Sp. Gr. At P.T.
Viscosity at P.T.
Capacity at P.T.
Pressure at Discharge Nozzle
Pressure at Suction Nozzle

Cooling Tower Makeup
1
Outdoors
Continuous
River Water
32 F - 95 F
6.9 - 8.4
1.0 - .994
1.79 - .70 cp
9,000 gpm
115 ft, 50 psig
Flooded

Differential Pressure or
Total Head

115 ft, 50 psi

Hp

350

Pump Speed, rpm

900

Driver Type

Motor

Driver Furnished by

Purchaser

Type Lubrication

External Water Source

Discharge Size, Std

20 in., 150 lb

Codes:

ANSI

American National Standards
Institute

H.I.S.

Hydraulic Institute Standards

ASME

ASME Boiler and Pressure Vessel
Code

STEAM SURFACE CONDENSER DATA SHEET - AFB
J.O.No. 12919.02B-PWEC

Mark No. 4CND-2
(High Pressure)

Specification No.
Purchase Order No.

Service

Atmospheric Fluidized Bed Boiler
Steam Turbine

No. of Condenser Units

1

Active Tube Surface, %

100

Circulating Water, gpm

185,414

Total Steam Condensed,
Mlb/hr

1308.176

Heat Rejected By
Condenser, Btu/hr

1.2423×10^9

Ext Drips and Vapor
to Shell, Mlb/hr

397.992

Tube Water Velocity, ft/sec

7.41

Tube Cleanliness Factor, %

84

Circ. Water Temp, in, F
out, F

91.71

120.37

Range, F

28.66

Temp Condensate from Hot
Well, F

129.20

Abs. Press., Main Steam
Inlet, in. Hg

4.43

No. of Shells

1

Passes per Shell

1

Test Pressure, psig

85

Circulating Water Source:

Cooling Tower

Tube Material, gage, diam

304 SS, 22 BWG, 7/8 in.

Condenser Surface Area,
sq ft (High & Low)

309,625

Tube Length, ft

48

Codes:

ASME VIII

ASME Boiler and Pressure Vessel Code

ANSI

American National Standards Institute

H.E.I.

Heat Exchange Institute Standards
for Steam Surface Condensers,
6th Ed.

STEAM SURFACE CONDENSER DATA SHEET - AFB
J.O.No. 12919.02B-FWEC

Mark No. 4CND-1
(Low Pressure)

Specification No.
Purchase Order No.

Service

Atmospheric Fluidized Bed Boiler
Steam Turbine

No. of Condenser Units

1

Active Tube Surface, %

100

Circulating Water, gpm

185,414

Total Steam Condensed,

Mlb/hr

1470.415

Heat Rejected By

Condenser, Btu/hr

1.385×10^9

Ext Drips and Vapor to

Shell, Mlb/hr

0

Tube Water Velocity, ft/sec

8.70

Tube Cleanliness Factor, %

84

Circ. Water Temp, In, F

91.71

Out, F

120.37

Range, F

28.66

Temp Condensate From Hot

Well, F

129.20

Abs. Press., Main Steam

Inlet, in. Hg

3.35

No. of Shells

1

Passes per Shell

1

Test Pressure, psig

85

Circulating Water Source

Cooling Tower

Tube Length, ft

48

Hot Well Storage Capacity

22,000 Gal (High and Low Press.
Cond.)

Tube Material, Gage, Diam

304 SS, 22 BWG, 7/8 In.

Condenser Surface Area,

Sq ft (High & Low)

309,625

Codes:

ASME VIII

ASME Boiler and Pressure Vessel
Code

ANSI

American National Standards Insti-
tute

H.E.I.

Heat Exchange Institute Standards
for Steam Surface Condensers,
6th Ed.

CONDENSER AIR REMOVAL
EQUIPMENT DATA SHEET - AFB
J.O.No. 12919.02B-FWEC

Mark No. 4ARP-1A,B

Specification No.
Purchase Order No.

Service

Condenser Air Removal

No. of Units

2

Indoors or Outdoors

Indoors

Operation

Continuous (1 pump) see Note 1

Liquid Pumped

Air Vapor Mixture

Capacity

504 lb/hr (air vapor mixture) see
Note 2

Capacity, Dry Air

157.5 lb/hr (35 scfm) see Note 2

Seal Water Pressure (max)

125 psig

Seal Water Temp (max)

95 F

Driver Type

Motor

Driver Furnished by

Seller

Codes:

ANSI

American National Standards
Institute

ASME

The American Society of Mechanical
Engineers

ASTM

American Society for Testing and
Materials

NOTE 1 On initial start-up, condenser air removal equipment (two pumps operating) shall be capable of roughing or hogging operation that will reduce the condenser pressure from atmospheric pressure to 5 in. Hg abs within 60 min. The effective volume of the condenser is 65,000 ft³ and its temperature will be 50 F when hogging.

NOTE 2 Based at 1 in. Hg abs and 71.5 F.

VERTICAL PUMP DATA SHEET - AFB
J.O.No. 12919.02B-FWEC

Mark No. 4CP-1A,B

Specification No.
Purchase Order No.

Service

No. of Units

Indoors or Outdoors

Operation

Liquid Pumped

Pumping Temp/pH

Sp. Gr. at P.T.

Viscosity at P.T.

Capacity at P.T.

Condensate

2

Indoors

Continuous

Condensate

130.64 F/9.3 to 9.7

.987

.51 cp

3,750 gpm (2 pump operation)

4,700 gpm (1 pump operation)

Pressure at discharge

nozzle

1,040 ft, 444.8 psig

Pressure at suction

-30.40 ft, -13 psig

Differential Pressure or

Total Head

1070.4 ft, 457.8 psig

Available NPSH, ft

1.0

Hp

1,500

Pump Speed, rpm

1,200 rpm

Driver type

Motor

Driver Furnished by

Seller

Type Lubrication

Water pumped

Discharge Size, Std

14 in., 300 lb

Suction Size, Std

24 in., 150 lb

Codes:

ASME VIII

ASME Boiler and Pressure
Vessel Code

ANSI

American National Standards
Institute

NEMA MG1

National Electrical Manufacturers
Association: Motors and Standards

H.I.S.

Hydraulics Institute Standards

BOILER FEED BOOSTER PUMP DATA SHEET - AFB
J.O.No. 12919.02B-FWEC

Mark No. 4 BFP-1A

Specification No.
Purchase Order No.

Service
No. of Units
No. of Stages
Indoors or Outdoors
Operation
Liquid Pumped
Pumping Temp
pH
Sp. Gr. At P.T.
Viscosity at P.T.
Capacity at P.T.
Pressure at Discharge Nozzle
Pressure at Suction Nozzle

Boiler feed booster
1
1
Indoors
Continuous
Feed Water
296 F
9.2 - 9.6
.9203
.47 cp
9,550 gpm
450 ft
50.0 ft

Differential Pressure or
Total Head

450 ft

Hp

1,292

Pump Speed, rpm

6,300

Driver Type

Turbine

Driver Furnished by

Purchaser

Type Lubrication

Turbine oil

Discharge Size, Std

14 in., 300 lb

Codes:

ANSI

American National Standards
Institute

H.I.S.

Hydraulic Institute Standards

ASME

ASME Boiler and Pressure Vessel
Code

BOILER FEED PUMP DATA SHEET - AFB
J.O.No. 12919.02B-FWEC

Mark No. 4 BFP-1B

Specification No.
Purchase Order No.

Service
No. of Units
No. of Stages
Indoors or Outdoors
Operation
Liquid Pumped
Pumping Temp
pH
Sp. Gr. At P.T.
Viscosity at P.T.
Capacity at P.T.
Pressure at Discharge Nozzle
Pressure at Suction Nozzle

Boiler feed
1
3
Indoors
Continuous
Feed Water
296 F
9.2 - 9.6
.9203
.47
9,550 gpm
8,689 ft
430 ft

Differential Pressure or
Total Head

8,689 ft

Hp

22,830

Pump Speed, rpm

6,300

Driver Type

Turbine

Driver Furnished by

Purchaser

Type Lubrication

Turbine oil

Discharge Size, Std

18 in.

Codes:

ANSI

American National Standards
Institute

H.I.S.

Hydraulic Institute Standards

ASME

ASME Boiler and Pressure Vessel
Code

START-UP BOILER FEED PUMP DATA SHEET - AFB
J.O.No. 12919.02B-FWEC

Mark No. 4 SBFP-1

Specification No.
Purchase Order No.

Service
No. of Units
No. of Stages
Indoors or Outdoors
Operation
Liquid Pumped
Pumping Temp
pH
Sp. Gr. At P.T.
Viscosity at P.T.
Capacity at P.T.
Pressure at Discharge Nozzle
Pressure at Suction Nozzle

Start-up boiler feed
1
5
Indoors
Start-up
Feed Water
296 F
9.2-9.6
.9203
.47 cp
5,100 gpm
8,689 ft
97.2 ft

Differential Pressure or
Total Head

8,689 ft

Hp

10,000

Pump Speed, rpm

5,850

Driver Type

Motor

Driver Furnished by

Purchaser

Type Lubrication

Any oil greater than 150 SSU
at 100F

Discharge Size, Std

10 in., Schedule 160

Codes:

ANSI

American National Standards
Institute

H.I.S.

Hydraulic Institute Standards

ASME

ASME Boiler and Pressure Vessel
Code

DEAERATOR DATA SHEET
J.O. No. 12919.02B-FWEC

Mark No.: 4 CNM-EH4

Specification No.

Quantity: 1

Purchase Order

Location: Indoors

	<u>Flow</u>	<u>Enthalpy</u>
Condensate to Heater:	3,176,583 lb/hr	235.24 Btu/lb
Feedwater Heater Returns:	711,932 lb/hr	279.97 Btu/lb
Extraction Steam to Heater:	84,448 lb/hr	1289.89 Btu/lb
Total Water Delivered To Boiler Feed Pump:	3,972,963 lb/hr	266.03 Btu/lb

Operating Pressure: 49 psig

Pressure of Extraction Steam at Deaerator: 66.5 psia

Design Temperature, Shell: 320 deg F.

Design Temperature, Steam Inlet Nozzle: 570 deg F.

Design Pressure, psig: 70 psig

Required Storage Capacity Below Normal Level, Gal: 46,000 gal

Code Requirements: ASME Boiler and Pressure Vessel Code,
Section VIII, Div. 1
Standards of the Heat Exchange Institute

FEEDWATER HEATER
EQUIPMENT DATA SHEET - AFB
J.O. No. 12919.02B - FWEC

Mark No. 4FWS-EH7

Specification No.
Purchase Order No.

Service: First Point Extraction Heater
No. of Units: 1
Installation: Horizontal

Performance

Shell Side

Tube Side

Inlet:							
Feedwater						3,972,963 lb/hr	
						408.25 F	387.78 h
Steam	360,944	lb/hr	629.03	F	1309.43	h	
Drips	NA	lb/hr	NA	F	NA	h	
Inlet Pressure	594.61	psia					3401.7 psia
Steam Condensed	360,944	lb/hr					
Outlet							
Temperature/							
Enthalpy	416.25	F	392.79	h			485.23 F 471.05 h

Terminal Differences: Sat temp at steam inlet minus feedwater out,
0 F. Drips out minus feedwater in, 8 F.

Construction

Shell Side

Tube Side

Design Temperature:	650 F Barrel	550 F
	700 F Nozzle	
Design Pressure:	775 psig	4300 psig
Code Requirements:	ASME VIII, Div. 1	
	Heat Exchange Institute	
Materials:		
Tubes	ASME SA-556 GR2 or C2	

FEEDWATER HEATER
EQUIPMENT DATA SHEET - AFB
J.O. No. 12919.02B - FWEC

Mark No. 4FWS-EH6

Specification No.
Purchase Order No.

Service: Second Point Extraction Heater
No. of Units: 1
Installation: Horizontal

Performance

	<u>Shell Side</u>	<u>Tube Side</u>
Inlet:		
Feedwater		3,972,963 lb/hr 371.22 F 349.03 h
Steam	128,054 lb/hr 836.83 F 1441.88 h	
Drips	360,944 lb/hr 416.25 F 392.79 h	
Inlet Pressure	265.35 psia	3426.7 psia
Steam Condensed	128,054 lb/hr	
Outlet		
Temperature/		
Enthalpy	379.22 F 352.75 h	408.25 F 387.78 h

Terminal Differences: Sat temp at steam inlet minus feedwater out,
0 F. Drips out minus feedwater in, 8 F.

Construction

	<u>Shell Side</u>	<u>Tube Side</u>
Design Temperature:	650 F Barrel 700 F Nozzle	550 F
Design Pressure:	775 psig	4300 psig
Code Requirements:	ASME VIII, Div. 1 Heat Exchange Institute	
Materials:		
Tubes	ASME SA-556 GR2 or C2	

FEEDWATER HEATER
EQUIPMENT DATA SHEET - AFB
J.O. No. 12919.02 - FWEC

Mark No. 4FWS-EH5

Specification No.
Purchase Order No.

Service: Third Point Extraction Heater
No. of Units: 1
Installation: Horizontal

Performance

	<u>Shell Side</u>	<u>Tube Side</u>
Inlet:		
Feedwater		3,972,963 lb/hr 301.93 F 278.05 h
Steam	222,934 lb/hr 719.03 F 1385.43 h	
Drips	488,999 lb/hr 379.22 F 352.75 h	
Inlet Pressure	171.68 psia	3451.7 psia
Steam Condensed	222,934 lb/hr	
Outlet		
Temperature/		
Enthalpy	309.93 F 279.97 h	371.22 F 349.03 h

Terminal Differences: Sat temp at steam inlet minus feedwater out,
0 F. Drips out minus feedwater in, 8 F.

Construction

	<u>Shell Side</u>	<u>Tube Side</u>
Design Temperature:	650 F Barrel 700 F Nozzle	550 F
Design Pressure:	775 psig	4300 psig
Code Requirements:	ASME VIII, Div. 1 Heat Exchange Institute	
Materials:		
Tubes	ASME SA-556 GR2 or C2	

FEEDWATER HEATER
EQUIPMENT DATA SHEET - AFB
J.O. No. 12919.02B - FWEC

Mark No. 4CNM-EH3

Specification No.
Purchase Order No.

Service: Fifth Point Extraction Heater
No. of Units: 1
Installation: Horizontal

Performance

Shell Side

Tube Side

Inlet:

Feedwater

3,176,583 lb/hr
199.11 F 167.67 h

Steam 211,810 lb/hr 428.72 F 1250.35 h
Drips NA lb/hr NA F NA h

Inlet Pressure 40.53 psia

221.31 psia

Steam Condensed 211,810 lb/hr

Outlet

Temperature/

Enthalpy 268.04 F 236.96 h

266.04 F 235.34 h

Terminal Differences: Sat temp at steam inlet minus feedwater out,
2 F. Drips out minus feedwater in, 68.93 F.

Construction

Shell Side

Tube Side

Design Temperature:

450 F

300 F

Design Pressure:

50 psig

550 psig

Code Requirements:

ASME VIII, Div. 1
Heat Exchange Institute

Materials:

Tubes

ASME SA-688 TP304

FEEDWATER HEATER
EQUIPMENT DATA SHEET - AFB
J.O. No. 12919.02B - FWEC

Mark No. 4CNM-EH2

Specification No.
Purchase Order No.

Service: Sixth Point Extraction Heater
No. of Units: 1
Installation: Horizontal

Performance

	<u>Shell Side</u>	<u>Tube Side</u>
Inlet:		
Feedwater		3,176,583 lb/hr 162.9 F 131.43 h
Steam	116,560 lb/hr 222.99 F 1156.82 h	
Drips	NA lb/hr NA F NA h	
Inlet Pressure	11.79 psia	236.31 psia
Steam Condensed	116,560 lb/hr	
Outlet		
Temperature/ Enthalpy	201.11 F 169.21 h	199.11 F 167.67 h

Terminal Differences: Sat temp at steam inlet minus feedwater out,
2 F. Drips out minus feedwater in, 38.21 F.

Construction

	<u>Shell Side</u>	<u>Tube Side</u>
Design Temperature:	350 F	300 F
Design Pressure:	50 psig	550 psig
Code Requirements:	ASME VIII, Div. 1 Heat Exchange Institute	
Materials:		
Tubes	ASME SA-688 TP304	

**FEEDWATER HEATER
EQUIPMENT DATA SHEET - AFB
J.O. No. 12919.02B - FWEC**

Mark No. 4CNM-EH1A
4CNM-EH1B

Specification No.
Purchase Order No.

Service: Seventh Point Extraction Heater
No. of Units: 2
Installation: Horizontal

Performance

Shell Side

Tube Side

Inlet:
Feedwater

3,176,583 lb/hr
141.86 F 110.41 h

Steam 66,822 lb/hr 165.17 F 1132.27 h
Drips NA lb/hr NA F NA h

Inlet Pressure 5.32 psia
Steam Condensed 66,822 lb/hr

251.31 psia

Outlet

Temperature/
Enthalpy 164.9 F 132.87 h

162.9 F 131.43 h

Terminal Differences: Sat temp at steam inlet minus feedwater out,
2 F. Drips out minus feedwater in, 23.04 F.

Construction

Shell Side

Tube Side

Design Temperature:
Design Pressure:

300 F
50 psig

300 F
550 psig

Code Requirements:

ASME VIII, Div. 1
Heat Exchange Institute

Materials:
Tubes

ASME SA-688 TP304

DRAIN COOLER
EQUIPMENT DATA SHEET - AFB
J.O. No. 12919.02B - FWEC

Mark No. 4CNM-DC1

Specification No.
Purchase Order No.

Service: Fifth Point Extraction Heater Drain Cooler
No. of Units: 1
Installation: Horizontal

Performance

Shell Side

Tube Side

Inlet:

Feedwater

3,176,583 lb/hr
133.16 F 101.75 h

Drips 211,810 lb/hr 268.04 F 236.96 h

Inlet Pressure

261.31 psia

Outlet

Temperature/

Enthalpy

139.16 F 107.11 h

141.86 F 110.41 h

Terminal Differences: Drips out minus feedwater in, 6 F.

Construction

Shell Side

Tube Side

Design Temperature:

300 F

300 F

Design Pressure:

50 psig

550 psig

Code Requirements:

ASME VIII, Div. 1

Heat Exchange Institute

Materials:

Tubes

ASME SA-688 TP304

DRAIN COOLER
EQUIPMENT DATA SHEET - AFB
J.O. No. 12919.02B - FWEC

Mark No. 4CNM-DC2

Specification No.
Purchase Order No.

Service: Sixth Point Extraction Heater Drain Cooler
No. of Units: 1
Installation: Horizontal

Performance

Shell Side

Tube Side

Inlet:		
Feedwater		3,176,583 lb/hr
		130.79 F 99.38 h
Drips	116,560 lb/hr 201.11 F 169.21 h	
Inlet Pressure		271.31 psia
Outlet		
Temperature/		
Enthalpy	136.79 F 104.75 h	133.16 F 101.75 h

Terminal Differences: Drips out minus feedwater in, 6 F.

Construction

Shell Side

Tube Side

Design Temperature:	300 F	300 F
Design Pressure:	50 psig	550 psig
Code Requirements:	ASME VIII, Div. 1 Heat Exchange Institute	
Materials:		
Tubes	ASME SA-688 TP304	

**BED LETDOWN BLOWERS-AFB
12919.02B-PWEC**

Mark No.

**Specification No.
Purchase Order**

Service: Spent Bed Material Disposal

No. of Units	3
No. Running	2
Indoors or Outdoors	Indoors
Operation	Intermittent
Material Conveyed	Bed Letdown
Bed Material Temp	250 F
Bed Material Density, lb/ft³	80
Flow Rate, T/hr	150
Blower Capacity, cfm	3,800
Blower Static, psi	15
Driver Type	Motor
Driver Hp	250
Driver Furnished by	Seller
Discharge Size, in.	12
Blower Type	Positive Displacement

**FLY ASH BLOWERS-AFB
12919.02B-FWEC**

Mark No.

Specification No.
Purchase Order

Service: Fly Ash Disposal (CBC Dust Collector)

No. of Units	2
No. Running	1
Indoors or Outdoors	Indoors
Operation	Continuous
Material Conveyed	Fly Ash
Fly Ash Material Temp	750 F
Fly Ash Material Density, lb/ft ³	40
Flow Rate, T/hr	58.59
Blower Capacity, CFM	3,800
Blower Static, psi	15
Driver Hp	250
Driver Type	Motor
Driver Furnished By	Seller
Discharge Size, in.	12
Blower Type	Positive Displacement

FLY ASH BLOWERS-AFB
12919.02B-FWEC

Mark No.

Specification No.
Purchase Order

Service: Fly Ash Disposal (Fabric Filters)

No. of Units	2
No. Running	1
Indoors or Outdoors	Indoors
Material Conveyed	Fly Ash
Fly Ash Material Temp	750 F
Fly Ash Material Density lb/ft³	40
Flow Rate, T/hr	17.74
Blower Capacity, cfm	3,800
Blower Static, psi	15
Driver Hp	250
Driver Furnished By	Seller
Intake Size, in.	8
Blower Type	Positive Displacement

FLY ASH VACUUM PRODUCERS-AFB
12919.02B-FWEC

Mark No.

Specification No.
Purchase Order

Service: Fly Ash Disposal (CBC Dust Collector)

No. of Units	2
No. Running	1
Indoors or Outdoors	Indoors
Operation	Continuous
Material Conveyed	Fly Ash
Fly Ash Material Temp	750 F
Fly Ash Material Density, lb/ft ³	40
Flow Rate, T/hr	58.59
Blower Capacity, cfm	3,000
Blower Static, psi	13
Driver Hp	60
Driver Type	Motor
Driver Furnished By	Seller
Intake Size, in.	12
Blower Type	Centrifugal

FLY ASH VACUUM PRODUCERS-AFB
12919.02B FWEC

Mark No.

Specification No.
Purchase Order

Service: Fly Ash Disposal (Fabric Filters)

No. of Units	2
No. Running	1
Indoors or Outdoors	Indoors
Operation	Continuous
Material Conveyed	Fly Ash
Fly Ash Material Density, lb/ft ³	40
Flow Rate, T/hr	12.74
Blower Capacity, cfm	1,800
Blower Static, psi	13
Driver Hp	60
Driver Type	Motor
Driver Furnished By	Seller
Intake Size, in.	8
Blower Type	Centrifugal

SILO FLUIDIZING BLOWERS-AFB
12919.02B-FWEC

Mark No.

Specification No.
Purchase Order

Service: Silo Ash Removal

No. of Units	4
No. Running	2
Indoors or Outdoors	Indoors
Operation	Intermittent
Blower Capacity, cfm	1,200
Blower Static, psi	6
Driver Hp	30
Driver Type	Motor
Discharge Size, in.	6
Blower Type	Centrifugal

CBC BED MAKE-UP-BLOWER-AFB
12919.02B-FWEC

Mark No.

Specification No.
Purchase Order

Service: Carbon Burnup Cell Bed Makeup

No. of Units	1
No. Running	1
Indoors or Outdoors	Indoors
Operation	Intermittent
Material Conveyed	Bed Letdown
Bed Material Temp, F	250
Bed Material Density, lb/ft ³	80
Flow Rate, lb/hr	15,000
Blower Capacity, cfm	1,500
Blower Static, psi	10
Driver Type	Motor
Driver Hp	40
Driver Furnished By	Seller
Discharge Size, in.	6
Blower Type	Centrifugal

**CARBON REINJECTION BLOWERS-AFB
12919.02B-FWEC**

Mark No.

**Specification No.
Purchase Order**

Service: Carbon Reinjection to CBC

No. of Units	3
No. Running	2
Indoors or Outdoors	Indoors
Operation	Continuous
Material Conveyed	Fly Ash
Fly Ash Material Temp, F	750
Fly Ash Density, lb/ft³	40
Flow Rate, T/hr	77.3
Blower Capacity, cfm	2,000
Blower Static, psi	10
Driver Type	Motor
Driver Hp	120
Driver Furnished By	Seller
Discharge Size, in.	10
Blower Type	Positive Displacement

STONE & WEBSTER ENGINEERING CORPORATION
TECHNICAL DATA SHEET - PART B
CONTROL VALVE

CLIENT ERDA
PROJECT AFB STUDY

PREPARER
SPECIALIST

INITIAL DATE
11-15-77

T.D.S. NO. VI
PAGE
SPEC. NO.
J.O. NO. 12919.028

FOSTER WHEELER DESIGN

EQUIP. NO 4CV-751A, B, C, D		No. REQ'D 4		FSK-EM-102A	
SERVICE H.P. BYPASS CONTROL VALVE		ASME CODE		CLASS	
		S & W CATEGORY II			
SHUT-OFF PSIA			LOCATION:		
LINE SIZE/SCHED	17.5" ID 4" WALL	DESIGN PRESS.		TEMP.	
SIZING DATA	MINIMUM	NORMAL		MAXIMUM	
INLET PSIA	2520	850			
OUTLET PSIA	590	162			
SP. GR. OR (MW)	-	-			
FLOW RATE	350,000 #/HR	350,000 #/HR			
TEMP °F	1000 °F	1000 °F			
C _v REQUIRED	100	322			
C _v ACTUAL *		PLANT LINE NO.			
FLUID	STEAM				
S&W SEAT LEAK CLASS	CLASS 2				
BODY-FORM *		ACCESSORIES			
-SIZE (IN.) *		AIR SET (W/GAGE)		YES-2	
-ANSI RATING/CONN	2500 #/B.W.	LUBRICATOR (W/ISOL. VALVE)		NO	
MATERIAL (ASTM)-BODY	CR. MOLY	HANDWHEEL		YES	
-BONNET *		POSITIONER		YES	
TRIM CHARACTERISTIC	= %	MFG/MODEL *		/	
-NO. PORTS	ONE	INPUT/OUTPUT		3-15 / *	
-PORT SIZE (IN)	FULL PORT	TRANSDUCER		YES	
-MATERIAL-PLUG *		MFG/MODEL *		/	
-SEAT *		INPUT/OUTPUT		4-20mA / 3-15	
GUIDE *		CONNS-ELEC/PNEU.		1/2" NPT / 1/4" NPT	
BONNET	FLANGED/ W/FLANGE	SOLENOID VALVE TYPE		3-WAY	
PACKING	GRAFOIL 187/I	MFG./MODEL *			
BACK SEAT	NO	ENERGIZE TO		OPEN / VALVE	
LEAK-OFF CONN.	NO	SOL. COIL ENCL.		NEMA 4	
ACTION-AIR TO	CLOSE	ELECT. CONNS.		NEMA 1/2" NPT	
FLOW-TENDS TO	OPEN	BODY CONNS.		1/4" NPT	
ACTUATOR-TYPE *		LIMIT SWITCH		YES	
-SIZE *		MFG/MODEL *			
-STROKE IN. *		OPEN POSITION		2 SPDT	
AIR TO ACTUATOR *		CLOSE POSITION		2 SPDT	
CALC. NOISE (dBA) *		ENCLOSURE		NEMA 4	
VELOCITY (FPS) *		CONDUIT SIZE		1/2"	
MANUFACTURER *		SEISMIC DATA REQUIRED		NO	
MODEL NO. *		WEIGHT (NET) *			
NOTES: 1. * INDICATES INFORMATION TO BE SUPPLIED BY MFR. 2. VALVE BODY CR. MOLY AS PER ANSI B16.34, 1977 3. MAX AIR PRESSURE FOR VALVE OPERATION WILL BE 60 PSIG					
REV	1	2	3	4	

STONE & WEBSTER ENGINEERING CORPORATION
TECHNICAL DATA SHEET - PART B
CONTROL VALVE

CLIENT ERDA
PROJECT AFB STUDY

PREPARER
SPECIALIST

INITIAL DATE
GB7 11-15-77

T.D.S. NO. VI
PAGE
SPEC. NO.
J.O. NO. 12919.02B

FOSTER WHEELER DESIGN

EQUIP. NO 4CV-760		No. REQ'D 1		FSK- EM-105A	
SERVICE HP BYPASS SPRAY CONTROL		ASME CODE —		CLASS —	
S & W CATEGORY II					
SHUT-OFF PSIA 1200		LOCATION:			
LINE SIZE/SCHED		DESIGN PRESS. 1000		TEMP. 300	
SIZING DATA		MINIMUM		NORMAL	
				MAXIMUM	
INLET PSIA		1000		1200	
OUTLET PSIA		278		775	
SP. GR. OR (MW)		.918		.918	
FLOW RATE		488 GPM		488	
TEMP °F		302		302	
C _v REQUIRED		17		23	
C _v ACTUAL *				PLANT LINE NO.	
FLUID		WATER			
S & W SEAT LEAK CLASS		2			
BODY-FORM		GLOBE		ACCESSORIES	
-SIZE (IN.) *				AIR SET (W/GAGE) YES-2	
-ANSI RATING/CONN *		1		LUBRICATOR (W/ISOL. VALVE) NO	
MATERIAL (ASTM)-BODY *				HANDWHEEL YES	
-BONNET *				POSITIONER YES	
TRIM-CHARACTERISTIC		= 2%		MFG/MODEL * 1	
-NO. PORTS		ONE		INPUT/OUTPUT * 1	
-PORT SIZE (IN.)		FULL PORT		TRANSDUCER YES	
-MATERIAL-PLUG *				MFG/MODEL 3-15 1 *	
-SEAT *				INPUT/OUTPUT 4-20MA 13-15 PSIG	
GUIDE *				CONNS-ELEC/PNEU. 1/2" NPT 1/4" NPT	
BONNET		FLANGED/W		SOLENOID VALVE TYPE YES-3 WAY	
PACKING		TEFLON V RING		MFG./MODEL *	
BACK SEAT		NO		ENERGIZE TO OPEN 1 VALVE	
LEAK-OFF CONN.		NO		SOL. COIL ENCL. NEMA 4	
ACTION-AIR TO		OPEN		ELECT. CONNS. NEMA 1/2"	
FLOW-TENDS TO		CLOSE		BODY CONNS. 1/4" NPT	
ACTUATOR-TYPE		DIAPHRAGM		LIMIT SWITCH YES	
-SIZE *				MFG/MODEL *	
-STROKE IN. *				OPEN POSITION 2 SPDT	
AIR TO ACTUATOR *				CLOSE POSITION 2 SPDT	
CALC. NOISE (dBA) *				ENCLOSURE NEMA 4	
VELOCITY (FPS) *				CONDUIT SIZE 1/2"	
MANUFACTURER *				SEISMIC DATA REQUIRED NO	
MODEL NO. *				WEIGHT (NET) *	
NOTES: 1. * INDICATES INFORMATION SUPPLIED BY MFG 2. CAVITATION PROTECTION REQUIRED					
REV	1	2	3	4	

STONE & WEBSTER ENGINEERING CORPORATION
TECHNICAL DATA SHEET- PART B
CONTROL VALVE

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INITIAL DATE
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T.D.S. NO. VI
PAGE
SPEC. NO.
J.O. NO. 12919.02B

FOSTER WHEELER DESIGN

EQUIP. NO. 4CV-753A, B, C, D		No. REQ'D 4		FSK-EM-102A	
SERVICE LP BYPASS CONTROL VALVE		ASME CODE		CLASS	
S & W CATEGORY					
SHUT-OFF PSIA			LOCATION:		
LINE SIZE/SCHED		DESIGN PRESS.		TEMP.	
SIZING DATA		MINIMUM		NORMAL	
INLET PSIA		675		178	
OUTLET PSIA		150		89	
SP. GR. OR (MW)		-		-	
FLOW RATE		409,000		409,000 lbs/hr	
TEMP °F		1000		1000	
C _v REQUIRED		559		2150	
C _v ACTUAL *		PLANT LINE NO.			
FLUID		STEAM			
S & W SEAT LEAK CLASS		CLASS 2			
BODY-FORM		GLOBE		ACCESSORIES	
-SIZE (IN.)				AIR SET (W/GAGE)	
-ANSI RATING/CONN		1		LUBRICATOR (W/ISOL. VALVE)	
MATERIAL (ASTM)-BODY		CR. MOLY		HANDWHEEL	
-BONNET *				POSITIONER	
TRIM-CHARACTERISTIC		= 90		MFG/MODEL *	
-NO. PORTS		ONE		INPUT/OUTPUT	
-PORT SIZE (IN.)		FULL PORT		TRANSDUCER	
-MATERIAL-PLUG *				MFG/MODEL *	
-SEAT *				INPUT/OUTPUT	
GUIDE *				CONNS-ELEC/PNEU.	
BONNET		FLANGED/ W/FLANGE		SOLENOID VALVE TYPE	
PACKING		GRAFOIL 187/I		MFG./MODEL *	
BACK SEAT		NO		ENERGIZE TO	
LEAK-OFF CONN.		NO		SOL. COIL ENCL.	
ACTION-AIR TO		CLOSE		ELECT. CONNS.	
FLOW-TENDS TO		OPEN		BODY CONNS.	
ACTUATOR-TYPE		PISTON		LIMIT SWITCH	
-SIZE *				MFG/MODEL *	
-STROKE IN. *				OPEN POSITION	
AIR TO ACTUATOR				CLOSE POSITION	
CALC. NOISE (dBA) *				ENCLOSURE	
VELOCITY (FPS) *				CONDUIT SIZE	
MANUFACTURER *				SEISMIC DATA REQUIRED	
MODEL NO. *				WEIGHT (NET) *	

NOTES: * INDICATES INFORMATION SUPPLIED BY MFG

2. MAXIMUM AIR PRESSURE FOR VALVE OPERATION WILL BE 60 PSIG

REV	1		2		3		4	
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STONE & WEBSTER ENGINEERING CORPORATION
TECHNICAL DATA SHEET-PART B
CONTROL VALVE

CLIENT *ERDA*
PROJECT *AFB STUDY*

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INITIAL DATE
GBZ 11-15-77

T.D.S. NO. VI
PAGE
SPEC. NO.
J.O. NO. *12919.02B*

FOSTER WHEELER DESIGN

EQUIP. NO <i>4CV-762A,B</i>		No. REQ'D <i>2</i>		FSK- <i>EA-105A</i>	
SERVICE <i>LP BYPASS SPRAY CONTROL</i>		ASME CODE <i>—</i>		CLASS <i>—</i>	
		S & W CATEGORY <i>II</i>			
SHUT-OFF PSIA <i>1000</i>		LOCATION:			
LINE SIZE/SCHED		DESIGN PRESS. <i>1500</i>		TEMP. <i>300</i>	
SIZING DATA		MINIMUM		NORMAL	
				MAXIMUM	
INLET PSIA <i>1200</i>				<i>1000</i>	
OUTLET PSIA <i>395</i>				<i>189</i>	
SP. GR. OR (MW) <i>.918</i>				<i>.918</i>	
FLOW RATE <i>502</i>				<i>502 GPM</i>	
TEMP °F <i>302</i>				<i>302</i>	
C _v REQUIRED <i>16.9</i>				<i>16.9</i>	
C _v ACTUAL <i>*</i>		PLANT LINE NO.			
FLUID <i>WATER</i>					
S & W SEAT LEAK CLASS <i>CLASS 2</i>					
BODY-FORM <i>GLOBE</i>		ACCESSORIES			
-SIZE (IN.)		AIR SET (W/GAGE)		<i>YES - 2</i>	
-ANSI RATING/CONN <i>1</i>		LUBRICATOR (W/ISOL. VALVE)		<i>NO</i>	
MATERIAL (ASTM)-BODY <i>*</i>		HANDWHEEL		<i>YES</i>	
-BONNET <i>*</i>		POSITIONER		<i>YES</i>	
TRIM-CHARACTERISTIC <i>= 90</i>		MFG/MODEL <i>*</i>		<i>1</i>	
-NO. PORTS <i>ONE</i>		INPUT/OUTPUT		<i>3-15 1 *</i>	
-PORT SIZE (IN.) <i>FULL PORT</i>		TRANSDUCER		<i>YES</i>	
-MATERIAL-PLUG <i>*</i>		MFG/MODEL <i>*</i>		<i>1</i>	
-SEAT <i>*</i>		INPUT/OUTPUT		<i>4-20 MA 13-15</i>	
GUIDE <i>*</i>		CONNS-ELEC/PNEU.		<i>1/2" NPT 1/4" NPT</i>	
BONNET <i>FLANGED/11-11-11</i>		SOLENOID VALVE TYPE		<i>YES</i>	
PACKING <i>TEFLON V RING</i>		MFG./MODEL <i>*</i>			
BACK SEAT <i>NO</i>		ENERGIZE TO		<i>CLOSE 1/VALVE</i>	
LEAK-OFF CONN. <i>NO</i>		SOL. COIL ENCL.		<i>NEMA 4</i>	
ACTION-AIR TO <i>OPEN</i>		ELECT. CONNS.		<i>NEMA 1/2"</i>	
FLOW-TENDS TO <i>*</i>		BODY CONNS.		<i>1/4" NPT</i>	
ACTUATOR-TYPE <i>DIAPHRAGM</i>		LIMIT SWITCH		<i>YES</i>	
-SIZE <i>*</i>		MFG/MODEL <i>*</i>			
-STROKE IN. <i>*</i>		OPEN POSITION		<i>2 SPDT</i>	
AIR TO ACTUATOR		CLOSE POSITION		<i>2 SPDT</i>	
CALC. NOISE (dBA) <i>*</i>		ENCLOSURE		<i>NEMA 4</i>	
VELOCITY (FPS) <i>*</i>		CONDUIT SIZE		<i>1/2"</i>	
MANUFACTURER <i>*</i>		SEISMIC DATA REQUIRED		<i>NO</i>	
MODEL NO. <i>*</i>		WEIGHT (NET) <i>*</i>			

NOTES: 1. INDICATES INFORMATION SUPPLIED BY MFG.

2. CAVITATION PROTECTION REQUIRED

REV	1		2		3		4	
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STONE & WEBSTER ENGINEERING CORPORATION
TECHNICAL DATA SHEET - PART B
ELECTRONIC PRESSURE TRANSMITTERS

CLIENT ERDA
PROJECT AFB STUDY

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SPECIALIST

INITIAL DATE
GBF 11-15-77

T.D.S. NO. PIO
PAGE
SPEC. NO.
J.O. NO. 12919.02B

FOSTER WHEELER DESIGN

EQUIP. NO.	4PIT-751	4PIT-753	4PIT-755	4PIT-759
SERVICE	HP BYPASS STM PRESS	LP TURB BYPASS STM PRESS	SEPARATOR DRAIN PRESS	DEAERATOR SHELL PRESSURE
OPERATING CONDITIONS				
FLUID OR GAS	STEAM	STEAM	STEAM/WATER	STEAM/WATER
TEMPERATURE °F	1000°F	610°F		298
PRESSURE PSIG	577	135		50
ELEMENT TYPE	INDICATING	INDICATING	INDICATING	INDICATING
ELEMENT MATERIAL	316SS	316SS	316SS	316SS
ENCLOSURE (NEMA TYPE)	NEMA-4	NEMA-4	NEMA-4	NEMA-4
MOUNTING				
BODY MATERIAL				
RANGE				
OVERRANGE PROTECTION TO				
SPAN LIMITS				
OUTPUT SIGNAL	4-20MA DC	4-20MA DC	4-20MA DC	4-20MA DC
OUTPUT SIGNAL TO	4PCV-751	4PCV-753	4PCV-755	4PCV-759
PROCESS CONN. SIZE	1/2 NPT	1/2 NPT	1/2 NPT	1/2 NPT
CONDUIT CONN. SIZE	3/4 NPT	3/4 NPT	3/4 NPT	3/4 NPT
ACCURACY				
REPEATABILITY				
DEADBAND				
ACCESSORIES				
MANUFACTURER	*			
MODEL NO.	*			
WEIGHT	*			
CATEGORY				
NOTES:				
REV.	1	2	3	4

STONE & WEBSTER ENGINEERING CORPORATION
TECHNICAL DATA SHEET - PART B
ELECTRONIC PRESSURE TRANSMITTERS

CLIENT ERDA
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T.D.S. NO. P10
PAGE
SPEC. NO.
J.O. NO. 12919.02B

FOSTER WHEELER DESIGN

EQUIP. NO.	4PIT-833			
SERVICE	START UP SPRAY SUPPLY PRESS			
OPERATING CONDITIONS				
FLUID OR GAS	WATER			
TEMPERATURE °F				
PRESSURE PSIG				
ELEMENT TYPE	INDICATING			
ELEMENT MATERIAL	316SS			
ENCLOSURE (NEMA TYPE)	NEMA-4			
MOUNTING				
BODY MATERIAL				
RANGE				
OVERRANGE PROTECTION TO				
SPAN LIMITS				
OUTPUT SIGNAL	4-20MA DC			
OUTPUT SIGNAL TO	4PCV-833			
PROCESS CONN. SIZE	1/2 NPT			
CONDUIT CONN. SIZE	3/4 NPT			
ACCURACY				
REPEATIBILITY				
DEADBAND				
ACCESSORIES				
MANUFACTURER	*			
MODEL NO.	*			
WEIGHT	*			
CATEGORY				

NOTES:

REV.	1		2		3		4	
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STONE & WEBSTER ENGINEERING CORPORATION
TECHNICAL DATA SHEET - PART B
ELECTRONIC DIFFERENTIAL
PRESSURE / FLOW TRANSMITTERS

CLIENT **ERDA**
PROJECT **AFB STUDY**

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T.D.S. NO. P9
PAGE
SPEC. NO.
J.O. NO. **12919.02B**

FOSTER WHEELER DESIGN

EQUIP. NO.	4FIT-792	4FIT-793A	4FIT-793B	
SERVICE	DESUPERHEATER SPRAY FLOW	HP BYPASS SPRAY FLOW	LP BYPASS SPRAY FLOW	
OPERATING CONDITIONS				
FLUID	WATER	WATER	WATER	
TEMPERATURE °F				
PRESSURE PSIG				
TEMP. LIMITS				
PRESS. LIMITS				
TYPE	INDICATING	INDICATING	INDICATING	
CASE	NEMA-4	NEMA-4	NEMA-4	
MOUNTING				
ELEMENT MATERIAL	316SS	316SS	316SS	
BODY MATERIAL	304SS	304SS	304SS	
MAX. PRESSURE RATING				
CONNECTIONS	1/2 NPT	1/2 NPT	1/2 NPT	
DIFFERENTIAL RANGE				
OVERRANGE PROTECTION TO				
SPAN LIMITS				
CONDUIT CONN. SIZE	3/4 NPT	3/4 NPT	3/4 NPT	
OUTPUT SIGNAL	4-20MA DC	4-20MA DC	4-20MA DC	
OUTPUT SIGNAL TO				
ACCESSORIES				
MANUFACTURER	*			
MODEL NO.	*			
WEIGHT	*			
CATEGORY				
NOTES:				
REV.	1	2	3	4

STONE & WEBSTER ENGINEERING CORPORATION
TECHNICAL DATA SHEET-PART B
PRESSURE INDICATORS

CLIENT ERDA
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PAGE

SPEC. NO.

J. O. NO. 12919.02B

FOSTER WHEELER DESIGN

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STONE & WEBSTER ENGINEERING CORPORATION
TECHNICAL DATA SHEET - *PART B*
THERMOCOUPLES WITH THERMOWELLS

CLIENT ERDA
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PAGE
SPEC. NO.
J.O. NO. 12919.02B

FOSTER WHEELER DESIGN

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APPENDIX IIIB-E
INSTRUMENT SCHEDULE
FOSTER WHEELER

NOTE

For Equipment Common to Foster Wheeler and
Babcock and Wilcox, refer to Appendix IIIA-E
(Babcock and Wilcox) in Volume 2

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET I-1
PRESSURE INDICATORS - PI

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
4PI-797A	HP Bypass Spray Supply Press	Boiler Feed		EM-105	N/A	Later	N/A
4PI-797B	LP Bypass Spray Supply Press	Boiler Feed		EM-105	N/A	Later	N/A
4PI-798A	HP Bypass Spray Press	Boiler Feed		EM-105	N/A	Later	N/A
4PI-798B	LP Bypass Spray Press	Boiler Feed		EM-105	N/A	Later	N/A
4PI-869	FSH-2 Desuperhtr Spray Supply Pressure	Boiler Feed		EM-105	N/A	Later	N/A

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET I-2
PRESSURE INDICATING TRANSMITTERS - PIT

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
4PIT-751	HP Turb Bypass Stm Press	Main Steam	0-3000	EM-102A	Later	Later	4PCV-751, 4SOV-751
4PIT-753	LP Turb Bypass Stm Press	Main Steam	0-1000	EM-102A	Later	Later	4PCV-753 4SOV-753
*4PIT-755	Separator Drain Pressure	Extraction Steam		EM-103A	Later	Later	4PCV-755, 4SOV-755
*4PIT-759	Deaerator Shell Pressure	Extraction Steam		EM-103A	Later	Later	4PCV-759, 4SOV-759
4PIT-833	Start-up Spray Pressure	Boiler Feed	0-3500	EM-105A	Later	Later	4PCV-883, 4SOV-853
*4PIT-771A	Letdown Cooling Air	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-771A, 4U-771A
*4PIT-771B	Letdown Cooling Air	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-771B, 4U-771B
*4PIT-771C	Letdown Cooling Air	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-771C, 4U-771C
*4PIT-771D	Letdown Cooling Air	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-771D, 4U-771D
*4PIT-772A	Letdown Cooling Air	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-772A, 4U-772A
*4PIT-772B	Letdown Cooling Air	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-772B, 4U-772B
*4PIT-772C	Letdown Cooling Air	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-772C, 4U-772C
*4PIT-772D	Letdown Cooling Air	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-772D, 4U-772D
*4PIT-773A	Letdown Cooling Air	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-773A, 4U-773A
*4PIT-773B	Letdown Cooling Air	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-773B, 4U-773B

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STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET I-3
PRESSURE INDICATING TRANSMITTERS - PIT

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4PIT-773C	Letdown Cooling Air	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-773C, 4U-773C
*4PIT-773D	Letdown Cooling Air	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-773D, 4U-773D
*4PIT-774A	Letdown Cooling Air	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-774A, 4U-774A
*4PIT-774B	Letdown Cooling Air	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-774B, 4U-774B
*4PIT-774C	Letdown Cooling Air	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-774C, 4U-774C
*4PIT-774D	Letdown Cooling Air	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-774D, 4U-774D
*4PIT-775A	Letdown Cooling Air	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-775A, 4U-775A
*4PIT-775B	Letdown Cooling Air	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-775B, 4U-775B
*4PIT-775C	Letdown Cooling Air	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-775C, 4U-775C
*4PIT-775D	Letdown Cooling Air	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-775D, 4U-775D
*4PIT-776A	Letdown Cooling Air	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-776A, 4U-776A
*4PIT-776B	Letdown Cooling Air	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-776B, 4U-776B
*4PIT-776C	Letdown Cooling Air	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-776C, 4U-776C
*4PIT-776D	Letdown Cooling Air	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-776D, 4U-776D

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STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET I-4
PRESSURE DIFFERENTIAL TRANSMITTERS - PDT

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4PDT-765A	Bed Segment Bypass Damper	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-765A
*4PDT-765B	Bed Segment Bypass Damper	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-765B
*4PDT-765C	Bed Segment Bypass Damper	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-765C
*4PDT-765D	Bed Segment Bypass Damper	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-765D
*4PDT-766A	Bed Segment Bypass Damper	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-766A
*4PDT-766B	Bed Segment Bypass Damper	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-766B
*4PDT-766C	Bed Segment Bypass Damper	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-766C
*4PDT-766D	Bed Segment Bypass Damper	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-766D
**4PDT-767A	Bed Segment Bypass Damper	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-767A
*4PDT-767B	Bed Segment Bypass Damper	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-767B
*4PDT-767C	Bed Segment Bypass Damper	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-767C
*4PDT-767D	Bed Segment Bypass Damper	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-767D
*4PDT-768A	Bed Segment Bypass Damper	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-768A
*4PDT-768B	Bed Segment Bypass Damper	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-768B
*4PDT-768C	Bed Segment Bypass Damper	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-768C

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET I-5
PRESSURE DIFFERENTIAL TRANSMITTERS - PDT

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4PDT-768D	Bed Segment Bypass Damper	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-768D
*4PDT-769A	Bed Segment Bypass Damper	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-769A
*4PDT-769B	Bed Segment Bypass Damper	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-769B
*4PDT-769C	Bed Segment Bypass Damper	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-769C
*4PDT-769D	Bed Segment Bypass Damper	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-769D
*4PDT-770A	Bed Segment Bypass Damper	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-770A
*4PDT-770B	Bed Segment Bypass Damper	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-770B
*4PDT-770C	Bed Segment Bypass Damper	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-770C
*4PDT-770D	Bed Segment Bypass Damper	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-770D

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET I-6
PRESSURE SWITCHES - PS

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4PS-807A	Carb Collection Blower	Carb Collection & Reinjection		EM-120B	Later	Later	Later
*4PS-807B	Carb Collection Blower	Carb Collection & Reinjection		EM-120B	Later	Later	Later
*4PS-807C	Carb Collection Blower	Carb Collection		EM-120B	Later	Later	Later
*4PS-857A	Carb Collection Blower	Bed Material Letdown		EM-120A	Later	Later	Later
*4PS-857B	Carb Collection Blower	Bed Material Letdown		EM-120A	Later	Later	Later
*4PS-857C	Carb Collection Blower	Bed Material Letdown		EM-120A	Later	Later	Later
*4PS-870A	FAB Flt Fly Ash Blower Disch	Fly Ash Coll & Disposal		EM-120C	Later	Later	N/A
*4PS-870B	FAB Flt Fly Ash Blower Disch	Fly Ash Coll & Disposal		EM-120C	Later	Later	N/A
*4PS-871A	CBC Dust Coll/Prhtr,Stck Fly Ash Blower	Fly Ash Coll & Disposal		EM-120C	Later	Later	N/A
*4PS-871B	CBC Dust Coll/Prhtr,Stck Fly Ash Blower	Fly Ash Coll & Disposal		EM-120C	Later	Later	N/A

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDYINSTRUMENT LIST - PART B
FOSTER WHEELER DESIGNSHEET I-7
PRESSURE REGULATING VALVE - PRV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4PRV-818A	Vacuum Chamber	Fly Ash Coll & Disposal		EM-120C	N/A	Later	N/A
*4PRV-818B	Vacuum Chamber	Fly Ash Coll & Disposal		EM-120C	N/A	Later	N/A
*4PRV-865A	Equalizer Chamber	Fly Ash Coll & Disposal		EM-120C	N/A	Later	N/A
*4PRV-865B	Equalizer Chamber	Fly Ash Coll & Disposal		EM-120C	N/A	Later	N/A
*4PRV-866A	Secondary Collector	Fly Ash Coll & Disposal		EM-120C	N/A	Later	N/A
*4PRV-866B	Secondary Collector	Fly Ash Coll & Disposal		EM-120C	N/A	Later	N/A
*4PRV-867A	Secondary Collector	Fly Ash Coll & Disposal		EM-120C	N/A	Later	N/A
*4PRV-867B	Secondary Collector	Fly Ash Coll & Disposal		EM-120C	N/A	Later	N/A

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J.O.NO. 12919.02B
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET I-8
POWER CONTROL VALVES - PSV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
4PSV-865A	Hot Reheat Header	Main Steam		EM-102A	N/A	Later	4PC-865
4PSV-865B	Hot Reheat Header	Main Steam		EM-102A	N/A	Later	4PC-865

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDYINSTRUMENT LIST - PART B
FOSTER WHEELER DESIGNSHEET I-9
PRESSURE CONTROL VALVES - PCV,CV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
4PCV-751	HP Turb Bypass Control Valve	Main Steam		EM-102A	Later	Later	4PIT-751, EHC 4SOV-751
4PCV-753A	LP Turb Bypass Control Valve	Main Steam		EM-102A	Later	Later	4PIT-753, EHC 4SOV-753
*4PCV-755	Sep Drains to Condenser	Extraction Stm		EM-103A	Later	Later	4PIT-755, 4SOV-755
*4PCV-759	Sep Drains to Deaerator	Extraction Stm		EM-103A	Later	Later	4PIT-759, 4SOV-759
*4PCV-833	Desuperhtr Strtup Spray	Boiler Feed		EM-105A	Later	Later	4PIT-833, 4SOV-833

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STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFE STUDYINSTRUMENT LIST - PART B
FOSTER WHEELER DESIGNSHEET II-1
TEMPERATURE TRANSMITTERS - TT

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
4TT-3	Hot Reheat Outlet	Mn Stm & Reheat	0-1500 F	EM-102A	Later	Later	4TR-145, 4TIR-3, 4R-5-1, 4R-9-1
4TT-760	HP Turb Bypass Stm Temp	Mn Stm & Reheat	0-1500 F	EM-102A	Later	Later	4TR-760, 4TCV-760
4TT-762	LP Turb Bypass Stm Temp	Mn Stm & Reheat	0-1500 F	EM-102A	Later	Later	4TR-762, 4TCV-762

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET II-2
TEMPERATURE INDICATING RECEIVERS - TIR

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
4TIR-760	HP Bypass Desup Stm Temp	Main Steam		EM-102A	Later	Later	4TR-760, 4TT-760
4TIR-762A	LP Bypass Desup Stm Temp	Main Steam		EM-102A	Later	Later	4TR-762A 4TT-762A
4TIR-762B	LP Bypass Desup Stm Temp	Main Steam		EM-102A	Later	Later	4TR-762B 4TT-762B

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET II-3
THERMOCOUPLES - TR

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
4TR-760	HP Bypass Desup Stm Temp	Mn Stm & Reheat	0-1500 F	EM-102A	Later	Later	4TT-760, 4TCV-762
4TR-762A	LP Bypass Desup Stm Temp	Mn Stm & Reheat	0-1500 F	EM-102A	Later	Later	4TT-762A, 4CV-762A
4TR-762B	LP Bypass Desup Stm Temp	Mn Stm & Reheat	0-1500 F	EM-102A	Later	Later	4TT-762B, 4CV-762B
4TR-794	HP Bypass Spray Wtr Temp	Boiler Feed	0-1500 F	EM-105	Later	Later	4CV-762B

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET II-4
TEMPERATURE CONTROL VALVES - TCV,CV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4TCV-757	Sep Drns to Fdwtr Htr	Extraction Stn		EM-103A	Later	Later	4TT-5, 4SOV-757
*4CV-790	Desuperhtr Spray Temp Control Vlv	Boiler Feed		EM-105A	Later	Later	4SOV-790
4CV-760A	HP Bypass Spray Control	Boiler Feed		EM-105A	Later	Later	4TT-760, 4TR-760, 4SOV-760
4CV-760B	HP Bypass Spray Control	Boiler Feed		EM-105A	Later	Later	4TT-760, 4TR-760, 4SOV-760
4CV-760C	HP Bypass Spray Control	Boiler Feed		EM-105A	Later	Later	4TT-760, 4TR-760, 4SOV-760
4CV-760D	HP Bypass Spray Control	Boiler Feed		EM-105A	Later	Later	4TT-760, 4TR-760, 4SOV-760
4CV-762A	LP Bypass Spray Control	Boiler Feed		EM-105A	Later	Later	4TR-762, 4SOV-762, 4TT-762
4CV-762B	LP Bypass Spray Control	Boiler Feed		EM-105A	Later	Later	4TR-762, 4SOV-762, 4TT-762
4CV-762C	LP Bypass Spray Control	Boiler Feed		EM-105A	Later	Later	4TR-762, 4SOV-762, 4TT-762
4CV-762D	LP Bypass Spray Control	Boiler Feed		EM-105A	Later	Later	4TR-762, 4SOV-762, 4TT-762
4CV-762E	LP Bypass Spray Control	Boiler Feed		EM-105A	Later	Later	4TR-762, 4SOV-762, 4TT-762

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET II-5
TEMPERATURE CONTROL VALVES - TCV,CV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
4CV-762F	LP Bypass Spray Control	Boiler Feed		EM-105A	Later	Later	4TR-762, 4SOV-762, 4TT-762

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J.O.NO. 12919.02B
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET III-1
LEVEL TRANSMITTERS - LIT

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4LIT-754	Separator Level	Main Steam		EM-102A			4LCV-754, 4SOV-754

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET III-2
LEVEL CONTROL VALVES - LCV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4LCV-754	Separator Level Control Valve	Extraction Steam		EM-103A	Later	Later	4LIT-754, 4SOV-754

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STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDYINSTRUMENT LIST - PART B
FOSTER WHEELER DESIGNSHEET IV-1
FLOW TRANSMITTERS - FIT

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
4FIT-792	Desuperheater Spray Flow	Boiler Feed		EM-105A	Later	Later	4RO-792
4FIT-793A	HP Bypass Spray Flow	Boiler Feed		EM-105A	Later	Later	4RO-793A
4FIT-793B	LP Bypass Spray Flow	Boiler Feed		EM-105A	Later	Later	4RO-793B
*4FIT-777A	Bed Seg Comb Air Flow	Combustion Air & Flue Gas		EM-115A	Later	Later	4RO-777A
*4FIT-777B	Bed Seg Comb Air Flow	Combustion Air & Flue Gas		EM-115A	Later	Later	4RO-777B
*4FIT-777C	Bed Seg Comb Air Flow	Combustion Air & Flue Gas		EM-115A	Later	Later	4RO-777C
*4FIT-777D	Bed Seg Comb Air Flow	Combustion Air & Flue Gas		EM-115A	Later	Later	4RO-777D
*4FIT-778A	Bed Seg Comb Air Flow	Combustion Air & Flue Gas		EM-115A	Later	Later	4RO-778A
*4FIT-778B	Bed Seg Comb Air Flow	Combustion Air & Flue Gas		EM-115A	Later	Later	4RO-778B
*4FIT-778C	Bed Seg Comb Air Flow	Combustion Air & Flue Gas		EM-115A	Later	Later	4RO-778C
*4FIT-778D	Bed Seg Comb Air Flow	Combustion Air & Flue Gas		EM-115A	Later	Later	4RO-778D
*4FIT-779A	Bed Seg Comb Air Flow	Combustion Air & Flue Gas		EM-115A	Later	Later	4RO-779A
*4FIT-779B	Bed Seg Comb Air Flow	Combustion Air & Flue Gas		EM-115A	Later	Later	4RO-779B
*4FIT-779C	Bed Seg Comb Air Flow	Combustion Air & Flue Gas		EM-115A	Later	Later	4RO-779C
*4FIT-779D	Bed Seg Comb Air Flow	Combustion Air & Flue Gas		EM-115A	Later	Later	4RO-779D
*4FIT-780A	Bed Seg Comb Air Flow	Combustion Air & Flue Gas		EM-115A	Later	Later	4RO-780A

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STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET IV-2
FLOW TRANSMITTERS - FIT

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4FIT-780B	Bed Seg Comb Air Flow	Combustion Air & Flue Gas		EM-115A	Later	Later	4RO-780B
*4FIT-780C	Bed Seg Comb Air Flow	Combustion Air & Flue Gas		EM-115A	Later	Later	4RO-780C
*4FIT-780D	Bed Seg Comb Air Flow	Combustion Air & Flue Gas		EM-115A	Later	Later	4RO-780D
*4FIT-781A	Bed Seg Comb Air Flow	Combustion Air & Flue Gas		EM-115A	Later	Later	4RO-781A
*4FIT-781B	Bed Seg Comb Air Flow	Combustion Air & Flue Gas		EM-115A	Later	Later	4RO-781B
*4FIT-781C	Bed Seg Comb Air Flow	Combustion Air & Flue Gas		EM-115A	Later	Later	4RO-781C
*4FIT-781D	Bed Seg Comb Air Flow	Combustion Air & Flue Gas		EM-115A	Later	Later	4RO-781D
*4FIT-782A	Bed Seg Comb Air Flow	Combustion Air & Flue Gas		EM-115A	Later	Later	4RO-782A
*4FIT-782B	Bed Seg Comb Air Flow	Combustion Air & Flue Gas		EM-115A	Later	Later	4RO-782B
*4FIT-782C	Bed Seg Comb Air Flow	Combustion Air & Flue Gas		EM-115A	Later	Later	4RO-782C
*4FIT-782D	Bed Seg Comb Air Flow	Combustion Air & Flue Gas		EM-115A	Later	Later	4RO-782D

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STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDYINSTRUMENT LIST - PART B
FOSTER WHEELER DESIGNSHEET IV-3
RESTRICTION ORIFICE - RO

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
4RO-792	Desuperheater Spray Flow	Boiler Feed		EM-105	N/A	N/A	4FIT-792
4RO-793A	HP Bypass Spray Flow	Boiler Feed		EM-105	N/A	N/A	4FIT-793A
4RO-793B	LP Bypass Spray Flow	Boiler Feed		EM-105	N/A	N/A	4FIT-793B
*4RO-777A	Letdown Cooling Air Flow	Combustion Air & Flue Gas		EM-115A	N/A	N/A	4FIT-777A
*4RO-777B	Letdown Cooling Air Flow	Combustion Air & Flue Gas		EM-115A	N/A	N/A	4FIT-777B
*4RO-777C	Letdown Cooling Air Flow	Combustion Air & Flue Gas		EM-115A	N/A	N/A	4FIT-777C
*4RO-777D	Letdown Cooling Air Flow	Combustion Air & Flue Gas		EM-115A	N/A	N/A	4FIT-777D
*4RO-778A	Letdown Cooling Air Flow	Combustion Air & Flue Gas		EM-115A	N/A	N/A	4FIT-778A
*4RO-778B	Letdown Cooling Air Flow	Combustion Air & Flue Gas		EM-115A	N/A	N/A	4FIT-778B
*4RO-778C	Letdown Cooling Air Flow	Combustion Air & Flue Gas		EM-115A	N/A	N/A	4FIT-778C
*4RO-778D	Letdown Cooling Air Flow	Combustion Air & Flue Gas		EM-115A	N/A	N/A	4FIT-778D
*4RO-779A	Letdown Cooling Air Flow	Combustion Air & Flue Gas		EM-115A	N/A	N/A	4FIT-779A
*4RO-779B	Letdown Cooling Air Flow	Combustion Air & Flue Gas		EM-115A	N/A	N/A	4FIT-779B
*4RO-779C	Letdown Cooling Air Flow	Combustion Air & Flue Gas		EM-115A	N/A	N/A	4FIT-779C
*4RO-779D	Letdown Cooling Air Flow	Combustion Air & Flue Gas		EM-115A	N/A	N/A	4FIT-779D
*4RO-780A	Letdown Cooling Air Flow	Combustion Air & Flue Gas		EM-115A	N/A	N/A	4FIT-780A

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET IV-4
RESTRICTION ORIFICE - RO

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4RO-780B	Letdown Cooling Air Flow	Combustion Air & Flue Gas		EM-115A	N/A	N/A	4FIT-780B
*4RO-780C	Letdown Cooling Air Flow	Combustion Air & Flue Gas		EM-115A	N/A	N/A	4FIT-780C
*4RO-780D	Letdown Cooling Air Flow	Combustion Air & Flue Gas		EM-115A	N/A	N/A	4FIT-780D
*4RO-781A	Letdown Cooling Air Flow	Combustion Air & Flue Gas		EM-115A	N/A	N/A	4FIT-781A
*4RO-781B	Letdown Cooling Air Flow	Combustion Air & Flue Gas		EM-115A	N/A	N/A	4FIT-781B
*4RO-781C	Letdown Cooling Air Flow	Combustion Air & Flue Gas		EM-115A	N/A	N/A	4FIT-781C
*4RO-781D	Letdown Cooling Air Flow	Combustion Air & Flue Gas		EM-115A	N/A	N/A	4FIT-781D
*4RO-782A	Letdown Cooling Air Flow	Combustion Air & Flue Gas		EM-115A	N/A	N/A	4FIT-782A
*4RO-782B	Letdown Cooling Air Flow	Combustion Air & Flue Gas		EM-115A	N/A	N/A	4FIT-782B
*4RO-782C	Letdown Cooling Air Flow	Combustion Air & Flue Gas		EM-115A	N/A	N/A	4FIT-782C
*4RO-782D	Letdown Cooling Air Flow	Combustion Air & Flue Gas		EM-115A	N/A	N/A	4FIT-782D
*4RO-837A	Baghouse Fly Ash Blowers	Fly Ash Collection & Disposal		EM-120C	N/A	N/A	N/A
*4RO-837B	CBC Multi-clone Fly Ash Blowers	Fly Ash Collection & Disposal		EM-120C	N/A	N/A	N/A
*4RO-868A	Secondary Collector	Fly Ash Collection & Disposal		EM-120C	N/A	N/A	N/A
*4RO-868B	Secondary Collector	Fly Ash Collection & Disposal		EM-120C	N/A	N/A	N/A

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET IV-5
RESTRICTION ORIFICE - RO

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4RO-869A	Secondary Collector	Fly Ash Collec- tion & Disposal		EM-120C	N/A	N/A	N/A
*4RO-869B	Secondary Collector	Fly Ash Collec- tion & Disposal.		EM-120C	N/A	N/A	N/A

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STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET V-1
SOLENOID OPERATED VALVES - SOV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
4SOV-751	HP Bypass Control Valve	Mn Stm		EM-102A	Later	Later	4PCV-751 4PIT-751
4SOV-753	LP Bypass Control Valve	Mn Stm		EM-102A	Later	Later	4PCV-753 4PIT-753
*4SOV-754	Separator Level Control Valve	Extraction Stm		EM-103A	Later	Later	4LIT-754 4LCV-754
*4SOV-755	Separator Drains to Condenser	Extraction Stm		EM-103A	Later	Later	4PIT-755 4SOV-755
*4SOV-757	Separator Drains to Feedwater Heater	Extraction Stm		EM-103A	Later	Later	4TCV-757 4TT-5
4SOV-758	Extr Stm to 1st Pt Htr	Extraction Stm		EM-103A	Later	Later	4NRV-758
*4SOV-759	Separator Drains to Deaerator	Extraction Stm		EM-103A	Later	Later	4PIT-749 4PCV-759
4SOV-760	HP Bypass Spray Stop Valve	Boiler Feed		EM-105A	Later	Later	4TCV-760 4TR-760
4SOV-762	LP Bypass Spray Stop Valve	Boiler Feed		EM-105A	Later	Later	4TCV-762 4TR-762
4SOV-790	Superheater Desuper Spray Control Valve	Boiler Feed		EM-105A	Later	Later	4TCV-790
4SOV-791		Boiler Feed		EM-105A	Later	Later	4CU-791
4SOV-795	Suphtr Desup FSH-2 Stop Valve	Boiler Feed		EM-105A	Later	Later	4DOV-795
4SOV-796A	HP Bypass Spray Stop Valve	Boiler Feed		EM-105A	Later	Later	4DOV-796A
4SOV-796B	LP Bypass Spray Stop Valve	Boiler Feed		EM-105A	Later	Later	4DOV-796B
4SOV-833	Start-up Spray	Boiler Feed		EM-105A	Later	Later	4PCU-833 4PIT-833

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET V-2
SOLENOID OPERATED VALVES - SOV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4SOV-800A	Air Lock Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-800A
*4SOV-800B	Air Lock Valves	Bed Material		EM-120A	Later	Later	4COV-800B
*4SOV-800C	Air Lock Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-800C
*4SOV-800D	Air Lock valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-800D
*4SOV-800E	Air Lock Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-800E
*4SOV-800F	Air Lock Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-800F
*4SOV-800G	Air Lock Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-800G
*4SOV-800H	Air Lock Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-800H
*4SOV-800J	Air Lock Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-800J
*4SOV-800K	Air Lock Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-800K
*4SOV-800L	Air Lock Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-800L

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02
ERDA AFB STUDYINSTRUMENT LIST - PART B
FOSTER WHEELER DESIGNSHEET V-3
SOLENOID OPERATED VALVES - SOV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4SCV-800M	Air Lock Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-800M
*4SOV-801A	Air Lock Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-801A
*4SOV-801B	Air Lock Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-801B
*4SOV-801C	Air Lock Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-801C
*4SOV-801D	Air Lock Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-801D
*4SOV-801E	Air Lock Valves	Bed Material Letdown & Disposal		EM-120A	later	Later	4COV-801E
*4SOV-801F	Air Lock Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-801F
*4SOV-801G	Air Lock Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-801G
*4SOV-801H	Air Lock Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-801H
*4SOV-801J	Air Lock valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-801J
*4SOV-801K	Air Lock Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-801K

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STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET V-4
SOLENOID OPERATED VALVES - SOV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4SOV-801L	Air Lock Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-801L
*4SOV-801M	Air Lock Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-801M
*4SOV-802A	Bed Letdown Blowers	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-802A
*4SOV-802B	Bed Letdown Blowers	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-802B
*4SOV-802C	Bed Letdown Blowers	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-802C
*4SOV-802D	Bed Letdown Blowers	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-802D
*4SOV-803A	Bed Letdown Conveyor Pipe	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-803A
*4SOV-803B	Bed Letdown Conveyor Pipe	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-803B
*4SOV-804A	Fly Ash Blower Discharge	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-804A
*4SOV-804F	Fly Ash Blower Discharge	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-804F
*4SOV-805A	Air Lock Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-805A

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STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET V-5
SOLENOID OPERATED VALVES - SOV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4SOV-805B	Air Lock Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-805B
*4SOV-805C	Air Lock Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-805C
*4SOV-805D	Air Lock Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-805D
*4SOV-805E	Air Lock Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-805E
*4SOV-805F	Air Lock Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-805F
*4SOV-858A	Silo Crossover valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-858A
*4SOV-858B	Silo Crossover valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-805B
*4SOV-859A	Silo Crossover valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-859A
*4SOV-859B	Silo Crossover Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-859B
*4SOV-860A	Silo Crossover Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-860A
*4SOV-860B	Silo Crossover Valves	Bed Material Letdown & Disposal		EM-120A	Later	later	4COV-860B

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J.O.NO. 12919.02
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET V-6
SOLENOID OPERATED VALVES - SOV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4SOV-861A	Silo Crossover Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-861A
*4SOV-861B	Silo Crossover Valves	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-861B
*4SOV-862A	Silo Inlet Valve	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-862A
*4SOV-862B	Silo Inlet Valve	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-862B
*4SOV-863A	Silo Crossover Valve	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-863A
*4SOV-863B	Silo Crossover Valve	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-863B
*4SOV-864A	Silo Inlet Valve	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-864A
*4SOV-864B	Silo Inlet Valve	Bed Material Letdown & Disposal		EM-120A	Later	Later	4COV-864B
*4SOV-839A	Carbon Reinjection Blower	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-839A
*4SOV-839B	Carbon Reinjection Blower	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-839B
*4SOV-839C	Carbon Reinjection Blower	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-839C
*4SOV-839D	Carbon Reinjection Blower	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-839D

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STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02
ERDA AFB STUDYINSTRUMENT LIST - PART B
FOSTER WHEELER DESIGNSHEET V-7
SOLENOID OPERATED VALVES - SOV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4SOV-840A	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-840A
*4SOV-840B	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-840B
*4SOV-840C	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-840C
*4SOV-841A	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-841A
*4SOV-841B	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-841B
*4SOV-841C	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-841C
*4SOV-842A	Air Lock Valves	Carbon Collection		EM-120B	Later	Later	4COV-842A
*4SOV-842B	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-842B
*4SOV-842C	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-842C
*4SOV-843A	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-843A
*4SOV-843B	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-843B
*4SOV-843C	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-843C
*4SOV-844A	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-844A
*4SOV-844B	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-844B
*4SOV-844C	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-844C

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J.O.NO. 12919.02
ERDA AFB STUDYINSTRUMENT LIST - PART B
FOSTER WHEELER DESIGNSHEET V-8
SOLENOID OPERATED VALVES - SOV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4SOV-845A	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-845A
*4SOV-845B	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-845B
*4SOV-845C	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-845C
*4SOV-846A	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-846A
*4SOV-846B	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-846B
*4SOV-846C	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-846C
*4SOV-847A	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-844A
*4SOV-847B	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-847B
*4SOV-847C	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-847C
*4SOV-848A	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-848A
*4SOV-848B	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-848B
*4SOV-848C	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-848C
*4SOV-849A	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-849A
*4SOV-849B	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-849B
*4SOV-849C	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-849C

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J.O.NO. 12919.02
ERDA AFB STUDYINSTRUMENT LIST - PART B
FOSTER WHEELER DESIGNSHEET V-9
SOLENOID OPERATED VALVES - SOV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4SOV-850A	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-850A
*4SOV-850B	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-850B
*4SOV-850C	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-850C
*4SOV-851A	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-851A
*4SOV-851B	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-851B
*4SOV-851C	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-851C
*4SOV-852A	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-852A
*4SOV-852B	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-852B
*4SOV-853A	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-853A
*4SOV-853B	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-853B
*4SOV-854A	CBC Injection	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-854A
*4SOV-854B	CBC Injection	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-854B
*4SOV-854C	CBC Injection	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-854C
*4SOV-854D	CBC Injection	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-854D
*4SOV-854E	CBC Injection	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-854E

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STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET V-10
SOLENOID OPERATED VALVES - SOV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4SOV-854F	CBC Injection	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-854F
*4SOV-854G	CBC Injection	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-854G
*4SOV-854H	CBC Injection	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-854H
*4SOV-854J	CBC Injection	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-854J
*4SOV-854K	CBC Injection	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-854K
*4SOV-854L	CBC Injection	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-854L
*4SOV-854M	CBC Injection	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-854M
*4SOV-854N	CBC Injection	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-854N
*4SOV-854P	CBC Injection	Carbon Collection & Reinjection		EM-120B	Later	Later	4COV-854P
*4SOV-810A	Fly Ash Blower Disch Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-810A
*4SOV-810B	Fly Ash Blower Cross-Over Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-810B
*4SOV-811A	Fly Ash Blower Disch Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-811A
*4SOV-811B	Fly Ash Blower Cross-Over Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-811B
*4SOV-812A	CBC Multi-clone Hopper Outlet Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-812A
*4SOV-812B	CBC Multi-clone Hopper Outlet Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-812B

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STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET V-11
SOLENOID OPERATED VALVES - SOV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4SOV-812C	Air Preheater Hopper Outlet Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-812C
*4SOV-812D	Air Preheater Hopper Outlet Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-812D
*4SOV-812E	Stack Hopper Outlet Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-812E
*4SOV-813	Fly Ash Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-813
*4SOV-814A	Vacuum Chamber Inlet Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-814A
*4SOV-814B	Vacuum Chamber Inlet Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-814B
*4SOV-816A	Storage Silo Inlet	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-816A
*4SOV-816B	Storage Silo Inlet	Fly Ash Collection & Disposal		EM-120C	later	Later	4COV-816B
*4SOV-817A	Storage Silo Inlet	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-817A
*4SOV-817B	Storage Silo Inlet	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-817b
*4SOV-820	Baghouse Fly Ash Blower Disch Cross-Over Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-820
*4SOV-821A	Baghouse No. 1 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-821A
*4SOV-821B	Baghouse No. 1 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-821B
*4SOV-821C	Baghouse No. 1 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-821C
*4SOV-821D	Baghouse No. 1 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-821D

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STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02
ERDA AFB STUDYINSTRUMENT LIST - PART B
FOSTER WHEELER DESIGNSHEET V-12
SOLENOID OPERATED VALVES - SOV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>3len/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4SOV-821E	Baghouse No. 1 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	later	later	4COV-821E
*4SOV-821F	Baghouse No. 1 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-821F
*4SOV-821G	Baghouse No. 1 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-821G
*4SOV-821H	Baghouse No. 1 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-821H
*4SOV-821J	Baghouse No. 1 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-821H
*4SOV-821K	Baghouse No. 1 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-821K
*4SOV-822A	Baghouse No. 2 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-822A
*4SOV-822B	Baghouse No. 2 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-822B
*4SOV-822C	Baghouse No. 2 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-822C
*4SOV-822D	Baghouse No. 2 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	later	Later	4COV-822D
*4SOV-822E	Baghouse No. 2 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	later	Later	4COV-822E
*4SOV-822F	Baghouse No. 2 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	later	Later	4COV-822F
*4SOV-822G	Baghouse No. 2 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	later	Later	4COV-822G
*4SOV-822H	Baghouse No. 2 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	later	later	4COV-822H
*4SOV-822J	Baghouse No. 2 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	later	Later	4COV-822J

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STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02
ERDA AFB STUDYINSTRUMENT LIST - PART B
FOSTER WHEELER DESIGNSHEET V-13
SOLENOID OPERATED VALVES - SOV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4SOV-822K	Baghouse No. 2 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	later	Later	4COV-822K
*4SOV-823A	Baghouse No. 3 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-823A
*4SOV-823B	Baghouse No. 3 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	later	Later	4COV-823B
*4SOV-823C	Baghouse No. 3 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-823C
*4SOV-823D	Baghouse No. 3 Hopper Isolation Valve	Fly Ash collection & Disposal		EM-120C	later	Later	4COV-823D
*4SOV-823E	Baghouse No. 3 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-823E
*4SOV-823F	Baghouse No. 3 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	later	4COV-823F
*4SOV-823G	Baghouse No. 3 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-823G
*4SOV-823H	Baghouse No. 3 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-823H
*4SOV-823J	Baghouse No. 3 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-823J
*4SOV-823K	Baghouse No. 3 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-823K
*4SOV-824A	Baghouse No. 4 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-824A
*4SOV-824B	Baghouse No. 4 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	later	4COV-824B
*4SOV-824C	Baghouse No. 4 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-824C
*4SOV-824D	Baghouse No. 4 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-824D

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET V-14
SOLENOID OPERATED VALVES - SOV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4SOV-824E	Baghouse No. 4 Hopper Isolation Valve	Fly Ash collection & Disposal		EM-120C	later	later	4COV-824E
*4SOV-824F	Baghouse No. 4 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	later	Later	4COV-824F
*4SOV-824G	Baghouse No. 4 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	later	4COV-824G
*4SOV-824H	Baghouse No. 4 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	later	Later	4COV-824H
*4SOV-824J	Baghouse No. 4 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-824J
*4SOV-824K	Baghouse No. 4 Hopper Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-824K
*4SOV-825A	Common Hopper Drain Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-825A
*4SOV-825B	Common Hopper Drain Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-825B
*4SOV-826A	Common Hopper Drain Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-826A
*4SOV-826B	Common Hopper Drain Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-826B
*4SOV-827A	Common Hopper Drain Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-827A
*4SOV-827B	Common Hopper Drain Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-827B
*4SOV-828A	Common Hopper Drain Valve	Fly Ash Collection &		EM-120C	Later	Later	4COV-828A

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02
ERDA AFB STUDYINSTRUMENT LIST - PART B
FOSTER WHEELER DESIGNSHEET V-15
SOLENOID OPERATED VALVES - SOV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
		Disposal					
*4SOV-828B	Common Hopper Drain Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-828B
*4SOV-829	Baghouse Hopper Drain Isolation Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-829
*4SOV-831A	Bag Filter Outlet Valves	Fly Ash Collection &		EM-120C	Later	Later	4COV-831A
*4SOV-831B	Bag Filter Outlet Valves	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-831B
*4SOV-838	Vacuum Pump Suction Crossover Valve	Fly Ash Collection & Disposal		EM-120C	Later	Later	4COV-838

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET V-16
SAFETY VALVES - SV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
4SV-756A	Separator Drains	Extraction Steam		EM-103A	N/A	Later	N/A
4SV-756B	Separator Drains	Extraction Steam		EM-103A	N/A	Later	N/A

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET V-17
NON-RETURN VALVES - NRV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
4NRV-758	1st Pt Htr Extraction	Extraction Steam		EM-103A	Later	Later	4SOV-758
4NRV-761	HP Turb Exhaust	Main Steam		EM-102A	Later	Later	4SOV-761

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02
ERDA AFB STUDYINSTRUMENT LIST - PART B
FOSTER WHEELER DESIGNSHEET V-18
RELIEF VALVES - RV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4RV-806A	Carbon Collection Blower	Carbon Collection & Reinjection		EM-120B	N/A	Later	N/A
*4RV-806B	Carbon Collection Blower	Carbon Collection & Reinjection		EM-120B	N/A	Later	N/A
*4RV-806C	Carbon Collection Blower	Carbon Collection & Reinjection		EM-120B	N/A	Later	N/A
*4RV-815A	Bag Filter	Fly Ash Collection & Disposal		EM-120C	N/A	Later	N/A
*4RV-815B	Bag Filter	Fly Ash Collection & Disposal		EM-120C	N/A	Later	N/A
*4RV-819A	Silo Relief	Fly Ash Collection & Disposal		EM-120C	N/A	Later	N/A
*4RV-819B	Silo Relief	Fly Ash Collection & Disposal		EM-120C	N/A	Later	N/A
*4RV-835A	Baghouse Fly Ash Blower	Fly Ash Collection & Disposal		EM-120C	N/A	Later	N/A
*4RV-835B	Baghouse Fly Ash Blower	Fly Ash Collection & Disposal		EM-120C	N/A	Later	N/A
*4RV-836A	CBC Fly Ash Blower	Fly Ash Collection and Disposal		EM-120C	N/A	Later	N/A
*4RV-856A	Bed Letdown Blowers	Bed Material Letdown & Disposal		EM-120A	N/A	Later	N/A
*4RV-856B	Bed Letdown Blowers	Bed Material Letdown & Disposal		EM-120A	N/A	Later	N/A
*4RV-856C	Bed Letdown Blowers	Bed Material Letdown & Disposal		EM-120A	N/A	Later	N/A

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDYINSTRUMENT LIST - PART B
FOSTER WHEELER DESIGNSHEET VI-1
POWER OPERATED CONTROL DAMPERS - PCD

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4PCD-765A	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-765A
*4PCD-765B	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-765B
*4PCD-765C	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-765C
*4PCD-765D	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-765D
*4PCD-766A	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-766A
*4PCD-766B	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-766B
*4PCD-766C	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-766C
*4PCD-766D	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-766D
*4PCD-767A	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-767A
*4PCD-767B	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-767B
*4PCD-767C	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-767C
*4PCD-767D	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-767D
*4PCD-768A	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-768A
*4PCD-768B	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-768B
*4PCD-768C	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-768C
*4PCD-768D	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-768D
*4PCD-769A	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-769A
*4PCD-769B	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-769B
*4PCD-769C	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-769C
*4PCD-769D	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-769D
*4PCD-770A	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-770A
*4PCD-770B	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-770B

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET VI-2
POWER OPERATED CONTROL DAMPERS - PCD

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4PCD-770C	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-770C
*4PCD-770D	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-770D
*4PCD-771A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-771A
*4PCD-771B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-771B
*4PCD-771C	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-771C
*4PCD-771D	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-771D
*4PCD-772A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-772A
*4PCD-772B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-772B
*4PCD-772C	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-772C
*4PCD-772D	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-772D
*4PCD-773A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-773A
*4PCD-773B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-773B
*4PCD-773C	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-773C
*4PCD-773D	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-773D
*4PCD-774A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-774A
*4PCD-774B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-774B
*4PCD-774C	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-774C
*4PCD-774D	Letdown Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-774D
*4PCD-775A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-775A
*4PCD-775B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-775B
*4PCD-775C	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-775C
*4PCD-775D	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-775D

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDYINSTRUMENT LIST - PART B
FOSTER WHEELER DESIGNSHEET VI-3
POWER OPERATED CONTROL DAMPERS - PCD

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4PCD-776A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-776A
*4PCD-776B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-776B
*4PCD-776C	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-776C
*4PCD-776D	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-776D
*4PCD-777A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-777A
*4PCD-777B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-777B
*4PCD-777C	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-777C
*4PCD-777D	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-777D
*4PCD-778A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U0778A
*4PCD-778B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-778B
*4PCD-778C	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-778C
*4PCD-778D	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-778D
*4PCD-779A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-779A
*4PCD-779B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-779B
*4PCD-779C	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-779C
*4PCD-779D	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-779D
*4PCD-780A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-780A
*4PCD-780B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-780B
*4PCD-780C	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-780C
*4PCD-780D	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-780D
*4PCD-781A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-781A
*4PCD-781B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-781B

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET VI-4
POWER OPERATED CONTROL DAMPERS - PCD

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4PCD-781C	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-781C
*4PCD-781D	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-781D
*4PCD-782A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-782A
*4PCD-782B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-782B
*4PCD-782C	Letdwn Cool Air Sapp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-782C
*4PCD-782D	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4U-782D

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDYINSTRUMENT LIST - PART B
FOSTER WHEELER DESIGNSHEET VI-5
UNIT DRIVE - 4U

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4U-765A	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-765A
*4U-765B	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-765B
*4U-765C	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-765C
*4U-765D	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-765D
*4U-766A	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-766A
*4U-766B	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-766B
*4U-766C	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-766C
*4U-766D	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-766C
*4U-767A	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-767A
*4U-767B	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-767B
*4U-767C	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-767C
*4U-767D	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-767D
*4U-768A	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-768A
*4U-768B	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-768B
*4U-768C	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-768C
*4U-768D	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-768D
*4U-769A	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-769A
*4U-769B	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-769B
*4U-769C	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-769C
*4U-769D	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-769D
*4U-770A	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-770A
*4U-770B	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-770B

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDYINSTRUMENT LIST - PART B
FOSTER WHEELER DESIGNSHEET VI-6
UNIT DRIVE - 40

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4U-770C	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-770C
*4U-770D	Bed Seg Bypass Damp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-770D
*4U-771A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-771A
*4U-771B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-771B
*4U-771C	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-771C
*4U-771D	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-771D
*4U-772A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-772A
*4U-772B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-772B
*4U-772C	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-772C
*4U-772D	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-772D
*4U-773A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-773A
*4U-773B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-773B
*4U-773C	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-773C
*4U-773D	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-773D
*4U-774A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-774A
*4U-774B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-774B
*4U-774C	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-774C
*4U-774D	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-774D
*4U-775A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-775A
*4U-775B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-775B
*4U-775C	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-775C
*4U-775D	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-775D

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
3RDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET VI-7
UNIT DRIVE - 4U

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4U-776A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-776A
*4U-776B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-776B
*4U-776C	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-776C
*4U-776D	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-776D
*4U-777A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-777A
*4U-777B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-777B
*4U-777C	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-777C
*4U-777D	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-777D
*4U-778A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-778A
*4U-778B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-778B
*4U-778C	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-778C
*4U-778D	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-778D
*4U-779A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-779A
*4U-779B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-779B
*4U-779C	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-779C
*4U-779D	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-779D
*4U-780A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-780A
*4U-780B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-780B
*4U-780C	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-780C
*4U-780D	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-780D
*4U-781A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-781A
*4U-781B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-781B

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET VI-8
UNIT DRIVE - 4U

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4U-781C	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-781C
*4U-781D	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-781D
*4U-782A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-782A
*4U-782B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-782B
*4U-782C	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-782C
*4U-782D	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PCD-782D
*4U-783A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PSD-783A
*4U-783B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PSD-783B
*4U-784A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PSD-784A
*4U-784B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PSD-784B
*4U-785A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PSD-785A
*4U-785B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PSD-785B
*4U-786A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PSD-786A
*4U-786B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PSD-786B
*4U-786C	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PSD-786C
*4U-786D	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PSD-786D
*4U-787A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PSD-787A
*4U-787B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PSD-787B
*4U-787C	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PSD-787C
*4U-787D	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PSD-787D
*4U-788A	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PSD-788A
*4U-788B	Letdwn Cool Air Supp	Comb Air & Flue Gas		EM-115A	Later	Later	4PSD-788B

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDYINSTRUMENT LIST - PART B
FOSTER WHEELER DESIGNSHEET VI-9
POWER OPERATED DAMPERS - PSD

<u>Mark Number</u>	<u>Service</u>	<u>Svstem</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
4PSD-783A	Bed Letdwn Booster Fans	Comb Air & Flue Gas		EM-115A	Later	Later	4U-783A
4PSD-783B	Bed Letdwn Booster Fans	Comb Air & Flue Gas		EM-115A	Later	Later	4U-783B
4PSD-784A	Bed Letdwn Booster Fans	Comb Air & Flue Gas		EM-115A	Later	Later	4U-784A
4PSD-784B	Bed Letdwn Booster Fans	Comb Air & Flue Gas		EM-115A	Later	Later	4U-784B
4PSD-785A	FD Fans Disch to Air Prehtrs	Comb Air & Flue Gas		EM-115A	Later	Later	4U-785A
4PSD-785B	FD Fans Disch to Air Prehtrs	Comb Air & Flue Gas		EM-115A	Later	Later	4U-785B
4PSD-786A	Baghouse Inlet	Comb Air & Flue Gas		EM-115A	Later	Later	4U-786A
4PSD-786B	Baghouse Inlet	Comb Air & Flue Gas		EM-115A	Later	Later	4U-786B
4PSD-786C	Baghouse Inlet	Comb Air & Flue Gas		EM-115A	Later	Later	4U-786C
4PSD-786D	Baghouse Inlet	Comb Air & Flue Gas		EM-115A	Later	Later	4U-786D
4PSD-787A	Baghouse Outlet	Comb Air & Flue Gas		EM-115A	Later	Later	4U-787A
4PSD-787B	Baghouse Outlet	Comb Air & Flue Gas		EM-115A	Later	Later	4U-787B
4PSD-787C	Baghouse Outlet	Comb Air & Flue Gas		EM-115A	Later	Later	4U-787C
4PSD-787D	Baghouse Outlet	Comb Air & Flue Gas		EM-115A	Later	Later	4U-787D
4PSD-788A	ID Fans Inlt	Comb Air & Flue Gas		EM-115A	Later	Later	4U-788A
4PSD-788B	ID Fans Inlt	Comb Air & Flue Gas		EM-115A	Later	Later	4U-788B

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STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET VI-10
DIAPHRAGM OPERATED VALVE - CV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
4CV-795	Superhtr FSH-2 Stop Vlv	Boiler Feed		EM-105	Later	Later	4SOV-795
4CV-796A	HP Bypass Spray Stop Vlv	Boiler Feed		EM-105	Later	Later	4SOV-796A
4CV-796B	LP Bypass Spray Stop Vlv	Boiler Feed		EM-105	Later	Later	4SOV-796B

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STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDYINSTRUMENT LIST - PART B
FOSTER WHEELER DESIGNSHEET VI-11
CYLINDER OPERATED VALVES - COV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4COV-800A	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-800A
*4COV-800B	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-800B
*4COV-800C	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-800C
*4COV-800D	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-800D
*4COV-800E	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-800E
*4COV-800F	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-800F
*4COV-800G	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-800G
*4COV-800H	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-800H
*4COV-800J	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-800J
*4COV-800K	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-800K
*4COV-800L	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-800L
*4COV-800M	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-800M
*4COV-801A	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-801A
*4COV-801B	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-801B
*4COV-801C	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-801C

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET VI-12
CYLINDER OPERATED VALVES - COV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4COV-801D	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-801D
*4COV-801E	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-801E
*4COV-801F	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-801F
*4COV-801G	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-801G
*4COV-801H	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-801H
*4COV-801J	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-801J
*4COV-801K	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-801K	Later	Later	4SOV-801K
*4COV-801L	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-801L
*4COV-801M	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-801M
*4COV-802A	Bed Letdwn Blowers	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-802A
*4COV-802B	Bed Letdwn Blowers	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-802B
*4COV-802C	Bed Letdwn Blowers	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-802C
*4COV-802D	Bed Letdwn Blowers	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-802D
*4COV-803A	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-803A
*4COV-803B	Bed Letdwn Conveyor Pipe	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-803B

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDYINSTRUMENT LIST - PART B
FOSTER WHEELER DESIGNSHEET VI-13
CYLINDER OPERATED VALVES - COV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4COV-804A	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-804A
*4COV-804B	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-804B
*4COV-804C	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-804C
*4COV-804D	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-804D
*4COV-804E	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-804E
*4COV-804F	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-804F
*4COV-805A	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-805A
*4COV-805B	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-805B
*4COV-805C	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-805C
*4COV-805D	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-805D
*4COV-805E	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-805E
*4COV-805F	Air Lock Valves	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-805F
*4COV-858A	Silo Crossover Valve	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-858A
*4COV-858B	Silo Crossover Valve	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-858B
*4COV-859A	Silo Crossover Valve	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-859A

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET VI-14
CYLINDER OPERATED VALVES - COV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4COV-859B	Silo Crossover Valve	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-859B
*4COV-860A	Silo Crossover Valve	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-860A
*4COV-860B	Silo Crossover Valve	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-860B
*4COV-861A	Silo Crossover Valve	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-861A
*4COV-861B	Silo Crossover Valve	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-861B
*4COV-862A	Silo Inlet Valve	Bed Ltl Letdwn & Disp		EM-120A	Later	Later	4SOV-862A
*4COV-862B	Silo Inlet Valve	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-862B
*4COV-863A	Silo Crossover Valve	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-863A
*4COV-863B	Silo Crossover Valve	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-863B
*4COV-864A	Silo Inlet Valve	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-864A
*4COV-864B	Silo Inlet Valve	Bed Mtl Letdwn & Disp		EM-120A	Later	Later	4SOV-864B
*4COV-839A	Carbon Reinjection Blower	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-839A
*4COV-839B	Carbon Reinjection Blower	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-839B
*4COV-839C	Carbon Reinjection Blower	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-839C
*4COV-839D	Carbon Reinjection Blower	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-839D

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDYINSTRUMENT LIST - PART B
FOSTER WHEELER DESIGNSHEET VI-15
CYLINDER OPERATED VALVES - COV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4COV-840A	Air Lock Valves	Carbon Collection & Reinjection		EM-1203	Later	Later	4SOV-840A
*4COV-840B	Air Lock Valves	Carbon Collection & Reinjection		EM-1203	Later	Later	4SOV-840B
*4COV-840C	Air Lock Valves	Carbon Collection & Reinjection		EM-1203	Later	Later	4SOV-840C
*4COV-841A	Air Lock Valves	Carbon Collection & Reinjection		EM-1203	Later	Later	4SOV-841A
*4COV-841B	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-841B
*4COV-841C	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-841C
*4COV-842A	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-842A
*4COV-842B	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-842B
*4COV-842C	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-842C
*4COV-843A	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-843A
*4COV-843B	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-843B
*4COV-843C	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-843C
*4COV-844A	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-844A
*4COV-844B	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-844B
*4COV-844C	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-844C

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDYINSTRUMENT LIST - PART B
FOSTER WHEELER DESIGNSHEET VI-16
CYLINDER OPERATED VALVES - COV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4COV-845A	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-845A
*4COV-845B	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-845B
*4COV-845C	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-845C
*4COV-846A	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-846A
*4COV-846B	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-846B
*4COV-846C	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-846C
*4COV-847A	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-847A
*4COV-847B	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-847B
*4COV-847C	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-847C
*4COV-848A	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-848A
*4COV-848B	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-848B
*4COV-848C	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-848C
*4COV-849A	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-849A
*4COV-849B	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-849B
*4COV-849C	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-849C

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDYINSTRUMENT LIST - PART F
FOSTER WHEELER DESIGNSHEET VI-17
CYLINDER OPERATED VALVES - COV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4COV-850A	Air Lock Valves	Carbon Collection & Reinjection		EM-1203	Later	Later	4SOV-850A
*4COV-850B	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-850B
*4COV-850C	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-850C
*4COV-851A	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-851A
*4COV-851B	Air Lock Valves	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-851B
*4COV-851C	Air Lock Valves	Carbon Collection & Reinjection		EM-12CB	Later	Later	4SOV-851C
*4COV-852A	Air Lock Valves	Carbon Collection & Reinjection		EM-12CB	Later	Later	4SOV-852A
*4COV-852B	Air Lock Valves	Carbon Collection & Reinjection		EM-12CB	Later	Later	4SOV-852B
*4COV-853A	Air Lock Valves	Carbon Collection & Reinjection		EM-12CB	Later	Later	4SOV-853A
*4COV-853B	Air Lock Valves	Carbon Collection & Reinjection		EM-12CB	Later	Later	4SOV-853B
*4COV-854A	CBC Injection	Carbon Collection & Reinjection		EM-12CB	Later	Later	4SOV-854A
*4COV-854B	CBC Injection	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-854B
*4COV-854C	CBC Injection	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-854C
*4COV-854D	CBC Injection	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-854D
*4COV-854E	CBC Injection	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-854E

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDY

INSTRUMENT LIST - PART B
FOSTER WHEELER DESIGN

SHEET VI-18
CYLINDER OPERATED VALVES - COV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4COV-854F	CBC Injection	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-854F
*4COV-854G	CBC Injection	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-854G
*4COV-854H	CBC Injection	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-854H
*4COV-854J	CBC Injection	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-854J
*4COV-854K	CBC Injection	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-854K
*4COV-854L	CBC Injection	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-854L
*4COV-854M	CBC Injection	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-854M
*4COV-854N	CBC Injection	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-854N
*4COV-854P	CBC Injection	Carbon Collection & Reinjection		EM-120B	Later	Later	4SOV-854P
*4COV-810A	Fly Ash Blower Disch	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-810A
*4COV-810B	Fly Ash Blower Disch	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-810B
*4COV-811A	Pressure Chamber Inlet	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-811A
*4COV-811B	Pressure Chamber Inlet	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-811B
*4COV-812A	CBC Multi-clone Hoppers	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-812A
*4COV-812B	CBC Multi-clone Hoppers	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-812B

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDYINSTRUMENT LIST - PART B
FOSTER WHEELER DESIGNSHEET VI-19
CYLINDER OPERATED VALVES - COV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4COV-812C	Air Preheater Hoppers	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-812C
*4COV-812D	Air Preheater Hoppers	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-812D
*4COV-812E	Stack Hopper	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-812E
*4COV-813	Hopper Disch	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-813
*4COV-814A	Vacuum Chamber Inlet	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-814A
*4COV-814B	Vacuum Chamber Inlet	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-814B
*4COV-816A	Storage Silo Inlet	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-816A
*4COV-816B	Storage Silo Inlet	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-816B
*4COV-817A	Storage Silo Inlet	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-817A
*4COV-817B	Storage Silo Inlet	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-817B
*4COV-820	Fly Ash Blower Crossover Valves	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-820
*4COV-821A	Baghouse No. 1 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-821A
*4COV-821B	Baghouse No. 1 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-821B
*4COV-821C	Baghouse No. 1 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-821C
*4COV-821D	Baghouse No. 1 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-821D

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDYINSTRUMENT LIST - PART B
FOSTER WHEELER DESIGNSHEET VI-20
CYLINDER OPERATED VALVES - COV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4COV-821E	Baghouse No. 1 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-821E
*4COV-821F	Baghouse No. 1 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-821F
*4COV-821G	Baghouse No. 1 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-821G
*4COV-821H	Baghouse No. 1 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-821H
*4COV-821J	Baghouse No. 1 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-821J
*4COV-821K	Baghouse No. 1 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-821K
*4COV-822A	Baghouse No. 2 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-822A
*4COV-822B	Baghouse No. 2 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-822B
*4COV-822C	Baghouse No. 2 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-822C
*4COV-822D	Baghouse No. 2 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-822D
*4COV-822E	Baghouse No. 2 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-822E
*4COV-822F	Baghouse No. 2 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-822F
*4COV-822G	Baghouse No. 2 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-822G
*4COV-822H	Baghouse No. 2 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-822H
*4COV-822J	Baghouse No. 2 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-822J

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDYINSTRUMENT LIST - PART B
FOSTER WHEELER DESIGNSHEET VI-21
CYLINDER OPERATED VALVES - COV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4COV-822K	Baghouse No. 2 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-822K
*4COV-823A	Baghouse No. 3 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-823A
*4COV-823B	Baghouse No. 3 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-823B
*4COV-823C	Baghouse No. 3 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-823C
*4COV-823D	Baghouse No. 3 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-823D
*4COV-823E	Baghouse No. 3 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-823E
*4COV-823F	Baghouse No. 3 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-823F
*4COV-823G	Baghouse No. 3 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-823G
*4COV-823H	Baghouse No. 3 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-823H
*4COV-823J	Baghouse No. 3 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-823J
*4COV-823K	Baghouse No. 3 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-823K
*4COV-824A	Baghouse No. 4 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-824A
*4COV-824B	Baghouse No. 4 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-824B
*4COV-824C	Baghouse No. 4 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-824C
*4COV-824D	Baghouse No. 4 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-824D

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDYINSTRUMENT LIST - PART B
FOSTER WHEELER DESIGNSHEET VI-22
CYLINDER OPERATED VALVES - COV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4COV-824E	Baghouse No. 4 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-824E
*4COV-824F	Baghouse No. 4 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-824F
*4COV-824G	Baghouse No. 4 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-824G
*4COV-824H	Baghouse No. 4 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-824H
*4COV-824J	Baghouse No. 4 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-824J
*4COV-824K	Baghouse No. 4 Hopper Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-824K
*4COV-825A	Header Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-825A
*4COV-825B	Header Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-825B
*4COV-826A	Header Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-826A
*4COV-826B	Header Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-826B
*4COV-827A	Header Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-827A
*4COV-827B	Header Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-827B
*4COV-828A	Header Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-828A
*4COV-828B	Header Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-828B
*4COV-829	Header Isolation Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-829

*Supplied by Equipment Manufacturer

STONE & WEBSTER ENGINEERING CORP.

J.O.NO. 12919.02B
ERDA AFB STUDYINSTRUMENT LIST - PART B
FOSTER WHEELER DESIGNSHEET VI-23
CYLINDER OPERATED VALVES - COV

<u>Mark Number</u>	<u>Service</u>	<u>System</u>	<u>Range/Size</u>	<u>Flow Diagram</u>	<u>Elem/Logic Diagrams</u>	<u>Mfr Model & Order No.</u>	<u>Assoc Instr</u>
*4COV-831A	Vacuum Pump Suction Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-831A
*4COV-831B	Vacuum Pump Suction Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-831A
*4COV-838	Vacuum Pump Suction Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-838
*4COV-855	Silo Inlet Valve	Fly Ash Collec & Disp		EM-120C	Later	Later	4SOV-839

*Supplied by Equipment Manufacturer