WAESD-TR-85-0079

MHD Advanced Power Train

Phase I Final Report

Volume 7
Appendices

Prepared For

THE UNITED STATES DEPARTMENT OF ENERGY
PITTSBURGH ENERGY TECHNOLOGY CENTER

Contract DE-AC22-83PC60575

AUGUST 1985

Westinghouse
Advanced Energy Systems Division
Large, P.O. Box 10864, Pittsburgh, PA 15236

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Government Technical Project Officer:
Dr. Harold F. Chambers, Jr

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APPENDIX A

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A. PLANT STUDIES COMPUTER RESULTS

APPENDIX "A"

FOREWORD

This appendix provides additional data in support of the MHD/Steam Power Plant Analyses reported in report Volume 5. The data is in the form of SPA/SUMARY computer code printouts. Computer printouts are provided for:

Study Case No.	Title	Remarks
2A	1000 MWe, 36 Mol % O_2	Reference 1000 MWe
8	500 MWe, 36 Mol % O_2	Reference 500 MWe
9	200 MWe, 36 Mol % O_2	Reference 200 MWe
10	200 MWe, 36 Mol % O_2	Supersonic Channel Plasma Inlet M = 1.3

The order of presentation in all four cases is as follows:

(1) Overall Performance

(2) Component/Subsystem Information

(3) Plant Cost Accounts Summary

(4) Plant Costing Details and Cost of Electricity

A1 - REFERENCE 1000 MWe MHD/STEAM POWER PLANT

A1.1 Overall Performance

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE2A 36 PCT 7.5 ATM 01/31/83

OVERALL SYSTEM PERFORMANCE ....

REFERENCE COAL	MONTANA ROSEBUD
COAL THERMAL INPUT (MWT)	2278.0
PRIMARY CYCLE (MWT)	2246.6
SEED REGENERATION (MWT)	31.452
PLANT LIFE (YEARS)	
OPERATING MODE	
NET POWER OUTPUT (MWE)	989.09
PLANT EFFICIENCY (PCT)	43.419
THERMODYNAMIC EFFICIENCY (PCT)	31.385
MHD ENTHALPY EXTRACTION (PCT)	21.760
TOTAL HEAT INPUT TO STEAM (MWT)	1683.2
STEAM CYCLE EFFICIENCY (PCT)	42.101
AIR PREHEAT TEMPERATURE (DEG K)	922.22
REFERENCE ATMOSPHERE	
PRESSURE (ATM)	1.0002
DRY BULB TEMPERATURE (DEG K)	288.00
RELATIVE HUMIDITY (PCT)	60.000
STEAM CONDITIONS	
MAIN TURBINE THROTTLE PRESSURE (ATM)	164.30
MAIN TURBINE THROTTLE TEMPERATURE (DEG K)	811.10
REHEAT TEMPERATURE (DEG K)	811.10
STEAM TURBINE/GENERATOR TOTAL POWER (MWE)	547.92
STEAM TUR/GEN COST ($1000) (ACCT. 314.1)	41076.
HEAT/SEED RECOVERY COST ($1000)(ACCT.312.3,4)	90264.
POWER TRAIN COST ($1000)(ACCT.317.)	2.94773E+05
STEAM BOTTOM PLANT COST($1000)(ACCT.312,314)	1.71806E+05
PLANT CAPITAL COST ($1000)	7.60269E+05
COST OF ELECTRICITY (MILLS/KWH)	62.612

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE2A 36 PCT 7.5 ATM 01/31/83

POWER GENERATED AND CONSUMED ....

GROSS AC POWER (MWE)	
MHD POWER (AC)	476.64
STEAM TURBINE-GENERATOR POWER	547.92
TOTAL	1024.6
POWER CONSUMED (MWE)	
SEC. AIR BLOWER	2.80941E-02
DRAFT FAN POWER	.60695
CONDENSATE PUMP	.27404
COOLING TWR CIRC PUMP	6.6665
COAL HANDLING AND PROCESSING	13.255
ELECTROSTATIC PRECIP POWER	.44932
MHD MAGNET POWER	.67397
MISC. POWER	3.5254
TRANSFORMER LOSS	9.9908
TOTAL	35.470
NET POWER OUTPUT (MWE)	989.09

MECHANICAL DRIVE TURBINES (MW)

CYCLE AIR COMPRESSOR	101.16
OXYGEN PLANT POWER	62.846
BOILER FEED PUMPS	16.785

A1 - REFERENCE 1000 MWe MHD/STEAM POWER PLANT

A1.2 Component Subsystem Information

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE2A 36 PCT 7.5 ATM 01/31/83

COAL HANDLING AND PREPARATION ...

RAW COAL, AS RECEIVED	
SIZE (TOP SIZE AS DELIVERED, IN)	-I
MOISTURE CONTENT (PCT)	22.700
FLOW RATE (KG/S)	108.40
HIGH HEATING VALUE (J/KG)	2.57250E+07
COAL TO COMBUSTOR, AS FIRED	
SIZE (MESH, 70 PCT THRU)	0
MOISTURE CONTENT (PCT)	5.0000
FLOW RATE (KG/S)	88.200
FLOW CONTROL (PCT)	
TRANSPORT MEDIUM	COMB. GAS
MECHANISM	
RATIO	1.00000E-01
DRYING MEDIUM	
FLOW RATE (KG/S)	185.24
TEMPERATURE IN (DEG K)	644.40
TEMPERATURE OUT (DEG K)	377.70
HEAT REQUIRED FOR DRYING (MWT)	61.136
POWER REQUIREMENT (MWE)	13.255
KEY COMPONENT	
MINIMUM USEFUL LIFE (YEARS)	
REPLACEMENT TIME (HRS)	
COST($1000) (ACCT. 312.1)	53968.

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE2A 36 PCT 7.5 ATM 01/31/83

OXIDIZER SUPPLY ....

OXYGEN PLANT	
AMOUNT OF OXYGEN (PCT)	36.000
CONTAINED OXYGEN FLOW (TPD)	8729.9
EQUIVALENT PURE OXYGEN (TPD)	7734.8
O2 PREHEAT TEMP. (DEG K)	922.22
COST($1000) (ACCT. 317.7.2)	1.04722E+05
MAIN AIR COMPRESSOR	
TYPE OF COMPRESSOR	AXIAL FLOW
TYPE OF INTERCOOLING	NONE
AIR INLET CONDITIONS	
PRESSURE (ATM)	1.0002
TEMPERATURE (DEG K)	288.00
FLOW RATE (KG/S)	389.27
AIR OUTLET CONDITIONS	
PRESSURE (ATM)	7.7267
TEMPERATURE (DEG K)	545.92
ADIABATIC EFFICIENCY (PCT)	86.600
SHAFT POWER (MW)	101.16
LUBE SYSTEM POWER (MW)	0.
COST($1000) (ACCT. 317.5.7)	12908.
SECONDARY AIR INJECTION	
LOCATION	
PRESSURE (ATM)	1.0027
TEMPERATURE (DEG K)	288.25
FLOW RATE (KG/S)	110.32
FAN EFFICIENCY (PCT)	80.000
POWER REQUIREMENT (MWE)	2.80941E-02
KEY COMPONENT	
MINIMUM USEFUL LIFE (YEARS)	
COST($1000) (ACCT. 312.4.5)	4138.6

SEED FEED AND MANAGEMENT ....

TYPE	
SEED FLOW, TOTAL (KG/S)	9.8683
POTASSIUM CARBONATE, K2CO3 (KG/S)	3.1174
POTASSIUM SULFATE, K2SO4 (KG/S)	6.7509
POWER REQUIREMENT (MWE)	0.
TRANSPORT MECHANISM	
FLOW CONTROL (PCT)	
NUMBER OF MODULES	
KEY COMPONENT	
MINIMUM USEFUL LIFE (YEARS)	
REPLACEMENT TIME (HRS)	
COST ($1000) (ACCT.317.6.4)	3395.5

SEED RECOVERY/REGENERATION SYSTEM ...

TYPE	
RECOVERY (PCT)	95.000
REGENERATION (PCT)	33.300
TYPE OF REGENERATION PROCESS	FORMATE
POWER REQUIREMENTS (MWE)	0.
KEY COMPONENT	
MINIMUM USEFUL LIFE (YEARS)	
COST ($1000) (ACCT. 316.1-.3)	34359.

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE2A 36 PCT 7.5 ATM 01/31/83

MAIN COMBUSTOR ....

TYPE-NUMBER OF STAGES	2	
DIMENSIONS	1ST STAGE	2ND STAGE
LENGTH (M)	5.7278	6.5762
DIAMETER (M)	3.1129	1.6441
VOLUME (M**3)	43.528	17.775
WEIGHT (KG)	13461.	
COMBUSTOR EXIT CONDITIONS		
PRESSURE (ATM)	7.2766	
TEMPERATURE (DEG K)	2849.1	
FLOW RATE (KG/S)	490.03	
SLAG REMOVAL (PCT)	85.000	
RESIDENCE TIME (MICRO-SEC)		
1-ST STAGE		
2-ND STAGE		
COMBUSTOR HEAT LOSSES (MWT)	103.34	
COOLING WATER INLET		
PRESSURE (ATM)	190.50	
TEMPERATURE (DEG K)	588.90	
QUALITY	0.	
FLOW RATE (KG/S)	647.06	
COOLING WATER EXIT		
PRESSURE (ATM)	187.10	
TEMPERATURE (DEG K)	604.76	
QUALITY	0.	
NUMBER OF MODULES	1	
COST ($1000) (ACCT.317.1.6,312.4.6)	4100.5	

NOZZLE ....

LENGTH (M)	2.9098
WEIGHT (KG)	4205.9
NOZZLE EXIT MACH NUMBER	.87500
NOZZLE HEAT LOSS (MWT)	21.340
NUMBER OF MODULES	
MINIMUM USEFUL LIFE (YEARS)	
COST($1000) (ACCT.317.2.1)	166.11

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE2A 36 PCT 7.5 ATM 01/31/83

CHANNEL ....

TYPE	DIAGONAL		
DIMENSIONS			
INLET (MXM)	.96992	X	.96992
OUTLET (MXM)	2.5026	X	2.5026
LENGTH (M)	15.909		
WEIGHT (KG)	57377.		
NUMBER OF ELECTRODE PAIRS	1.06059E+03		
SLAG REMOVAL (PCT)			
ENTHALPY EXTRACTION (PCT)	21.760		
OVERALL (TURBINE) EFFICIENCY (PCT)	76.523		
INLET CONDITIONS			
PRESSURE (ATM)	4.7654		
TEMPERATURE (DEG K)	2717.3		
MACH NUMBER	.87500		
VELOCITY (M/S)	807.40		
FLOW RATE (KG/S)	490.03		
OUTLET CONDITIONS			
PRESSURE (ATM)	.74019		
TEMPERATURE (DEG K)	2244.4		
MACH NUMBER	.87569		
SURFACE TEMPERATURE (DEG K)	1800.0		
HEAT LOSS (MWT)	72.839		
PEAK ELECTRODE CURRENT DENSITY (A/CM**2)			
MAXIMUM HALL FIELD (KV/M)	2.5000		
COOLING WATER INLET			
PRESSURE (ATM)			
TEMPERATURE (DEG K)	357.97		
QUALITY	0.		
FLOW RATE (KG/S)	466.97		
COOLING WATER EXIT			
PRESSURE (ATM)	5.1024		
TEMPERATURE (DEG K)	400.00		
QUALITY	0.		
NUMBER OF CHANNELS	1		
MHD GROSS POWER BEFORE INVERSION (MWE)	488.56		
MHD GROSS POWER AFTER INVERSION (MWE)	476.64		
INVERTER EFFICIENCY (PCT)	97.500		
COST ($1000) (ACCT.317.2.2..3)	5977.7		

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE2A 36 PCT 7.5 ATM 01/31/83

DIFFUSER AND TRANSITION PIECE ....

TYPE			
DIMENSIONS			
INLET (MXM)	2.5026	X	2.5026
OUTLET (MXM)	8.0083	X	8.0083
LENGTH (M)	26.528		
WEIGHT (KG)	1.37360E+05		
PRESSURE RECOVERY COEFFICIENT	.60000		
INLET CONDITIONS			
PRESSURE (ATM)	.74019		
TEMPERATURE (DEG K)	2244.4		
MACH NUMBER	.87569		
FLOW RATE (KG/S)	490.03		
OUTLET CONDITIONS - DIFFUSER			
PRESSURE (ATM)	.98288		
TEMPERATURE (DEG K)	2283.6		
MACH NUMBER	.40000		
SURFACE TEMPERATURE (DEG K)			
HEAT LOSS (MWT)	100.00		
COOLING WATER INLET			
PRESSURE (ATM)	186.05		
TEMPERATURE (DEG K)	627.80		
FLOW RATE (KG/S)	219.27		
COOLING WATER EXIT			
PRESSURE (ATM)	183.67		
TEMPERATURE (DEG K)	633.10		
BOUNDARY LAYER CONTROLS			
MINIMUM USEFUL LIFE (YEARS)			
COST ($1000) (ACCT.317.2.4)	1000.1		

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE2A 36 PCT 7.5 ATM 01/31/83

MAGNET ....

TYPE	
DIMENSIONS	
LENGTH (M)	17.977
OVERALL DIAMETER (M)	8.9885
WARM BORE	
INLET DIAMETER (M)	1.9374
OUTLET DIAMETER (M)	3.6534
FIELD STRENGTH (TESLA)	
PEAK	6.0000
AVERAGE	
CURRENT DENSITY (A/CM**2)	
ENERGY STORAGE (MJ)	5915.4
WEIGHT (KG)	2.28333E+06
COST ($1000) (ACCT.317.3)	7[illegible]984.

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE 2A   36 PCT 7.5 ATM   01/31/83

RADIANT BOILER ....

TYPE			
DIMENSIONS			
INLET (MXM)	29.127	X	19.400
OUTLET (MXM)	29.127	X	19.400
LENGTH (M)	21.200		
WEIGHT (KG)	5.00000E+05		
EFFICIENCY (PCT)	0.		
COMBUSTION GAS INLET CONDITIONS			
PRESSURE (ATM)	.98288		
TEMPERATURE (DEG K)	2274.8		
FLOW RATE (KG/S)	490.03		
COMBUSTION GAS OUTLET CONDITIONS			
PRESSURE (ATM)	.95339		
TEMPERATURE (DEG K)	1867.0		
DWELL TIME (SEC)	2.5000		
HEAT TRANSFER AREA (M**2)			
SLAG REMOVAL (PCT)			
MAXIMUM TEMP GRADIENT (DEG K/SEC)			
WATER/STEAM INLET CONDITIONS			
PRESSURE (ATM)	183.70		
TEMPERATURE (DEG K)	604.76		
QUALITY	0.		
FLOW RATE (KG/S)	647.06		
WATER/STEAM EXIT CONDITIONS			
PRESSURE (ATM)	183.70		
TEMPERATURE (DEG K)	633.10		
QUALITY	1.0000		
THERMAL DUTY (MWT)	323.35		
MINIMUM USEFUL LIFE (YEARS)			
COST($1000) (ACCT.312.3.1)	7482.5		

CASE2A 36 PCT 7.5 ATM   01/31/83

```
HIGH TEMPERATURE AIR HEATER ****

TYPE
NUMBER OF MODULES                                 0
DIMENSIONS
  HEIGHT (M)                                             -I
  DIAMETER (M)                                           -I
  FLOW AREA (M**2)                                       -I
WEIGHT (KG)
SLAG REMOVAL (PCT)
COMBUSTION GAS INLET CONDITIONS
  PRESSURE (ATM)                                         -I
  TEMPERATURE (DEG K)                                    -I
  FLOW RATE (KG/S)                                       -I
COMBUSTION GAS OUTLET CONDITIONS
  PRESSURE (ATM)                                         -I
  TEMPERATURE (DEG K)                                    -I
AIR INLET CONDITIONS
  PRESSURE (ATM)                                         -I
  TEMPERATURE (DEG K)                                    -I
  FLOW RATE (KG/S)                                       -I
AIR OUTLET CONDITIONS
  PRESSURE (ATM)                                         -I
  TEMPERATURE (DEG K)                                    -I
  VELOCITY (M/S)
DWELL TIME (SEC)
LOSSES
  VALVE LEAKAGE (PCT)                                    -I
  VALVE COOLING (MWT)                                    -I
  CORE HEAD LOSS (MWT)                                   -I
THERMAL DUTY (MWT)                               0.
MINIMUM USEFUL LIFE (YEARS)
COST($1000) (ACCT.317.5.2--4)                    0.
```

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE2A 36 PCT 7.5 ATM 01/31/83

SUPERHEATER ....

TYPE		
DIMENSIONS		
LENGTH (M)		-I
WIDTH (M)		-I
HEIGHT (M)		-I
WEIGHT (KG)		
COMBUSTION GAS INLET CONDITIONS		
PRESSURE (ATM)	.95339	
TEMPERATURE (DEG K)	1977.7	
FLOW RATE (KG/S)	600.35	
COMBUSTION GAS OUTLET CONDITIONS		
PRESSURE (ATM)	.95339	
TEMPERATURE (DEG K)	644.40	
SLAG REMOVAL (PCT)		
WATER/STEAM INLET CONDITIONS		
PRESSURE (ATM)	183.70	
TEMPERATURE (DEG K)	633.10	
FLOW RATE (KG/S)	647.06	
WATER/STEAM OUTLET CONDITIONS		
PRESSURE (ATM)	164.30	
TEMPERATURE (DEG K)	811.10	
THERMAL DUTY (MWT)	729.59	
COST ($1000) (ACCT.312.4.3)	16678.	

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE2A 36 PCT 7.5 ATM 01/31/83

REHEATER ....

TYPE		
DIMENSIONS		
LENGTH (M)		-I
WIDTH (M)		-I
HEIGHT (M)		-I
WEIGHT (KG)		
COMBUSTION GAS INLET CONDITIONS		
PRESSURE (ATM)	.95339	
TEMPERATURE (DEG K)	1977.7	
FLOW RATE (KG/S)	600.35	
COMBUSTION GAS OUTLET CONDITIONS		
PRESSURE (ATM)	.95339	
TEMPERATURE (DEG K)	644.40	
SLAG REMOVAL (PCT)		
WATER/STEAM INLET CONDITIONS		
PRESSURE (ATM)	43.425	
TEMPERATURE (DEG K)	617.79	
FLOW RATE (KG/S)	520.82	
WATER/STEAM OUTLET CONDITIONS		
PRESSURE (ATM)	41.253	
TEMPERATURE (DEG K)	811.10	
THERMAL DUTY (MWT)	238.29	
COST ($1000) (ACCT.312.4.4)	21982.	

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE2A 36 PCT 7.5 ATM 01/31/83

OXIDANT PREHEATER ....

TYPE		
DIMENSIONS		
LENGTH (M)		-I
WIDTH (M)		-I
HEIGHT (M)		-I
WEIGHT (KG)		
COMBUSTION GAS INLET CONDITIONS		
PRESSURE (ATM)	.95339	
TEMPERATURE (DEG K)	1977.7	
FLOW RATE (KG/S)	600.35	
COMBUSTION GAS OUTLET CONDITIONS		
PRESSURE (ATM)	.95339	
TEMPERATURE (DEG K)	644.40	
AIR INLET CONDITIONS		
PRESSURE (ATM)	7.7267	
TEMPERATURE (DEG K)	545.92	
FLOW RATE (KG/S)	389.27	
AIR OUTLET CONDITIONS		
PRESSURE (ATM)	7.5017	
TEMPERATURE (DEG K)	922.22	
THERMAL DUTY (MWT)	157.94	
COST ($1000) (ACCT.317.5.5)	3629.3	

ECONOMIZER NO. 1....

DIMENSIONS	
LENGTH (M)	26.797
WIDTH (M)	13.005
HEIGHT (M)	13.005
WEIGHT (KG)	
COMBUSTION GAS INLET CONDITIONS	
PRESSURE (ATM)	.95339
TEMPERATURE (DEG K)	644.40
FLOW RATE (KG/S)	314.23
COMBUSTION GAS OUTLET CONDITIONS	
PRESSURE (ATM)	.95339
TEMPERATURE (DEG K)	425.00
WATER/STEAM INLET CONDITIONS	
PRESSURE (ATM)	205.42
TEMPERATURE (DEG K)	414.05
FLOW RATE (KG/S)	93.912
WATER/STEAM OUTLET CONDITIONS	
PRESSURE (ATM)	205.42
TEMPERATURE (DEG K)	588.90
THERMAL DUTY (MWT)	76.408
COST ($1000) (ACCT.312.4.1)	36355.

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE2A 36 PCT 7.5 ATM 01/31/83

GAS CLEAN UP ....

TYPES	
LOCATIONS	
LOSSES	
PRESSURE (PCT)	
THERMAL (MWT)	
REMOVAL EFFICIENCY (PCT)	
POWER REQUIRED (MWE)	.44932
MINIMUM USEFUL LIFE (YEARS)	
COST($1000) (ACCT.312.5.1)	17201.
STACK COST ($1000)(ACCT.312.5.3)	3801.6

EXHAUST EMISSIONS ....

PARTICULATE (G/J)	
NOX (G/J)	
SOX (G/J)	
TRACE ELEMENTS (G/J)	

PLANT COOLING ....

TYPE		
NUMBER OF MODULES		
DIMENSIONS		
HEIGHT (M)		
DIAMETER (M)		
CONDENSER PRESSURE (ATM)	6.70121E-02	
THERMAL DUTY (MWT)	952.36	
TEMPERATURE (DEG K)	311.61	
COOLING WATER		
FLOW RATE (KG/S)		-I
MAKE UP (PCT)		
POWER REQUIREMENTS (MWE)	6.6665	
MINIMUM USEFUL LIFE (YEARS)		
COST ($1000)		
HEAT REJECTION COST($1000)(ACCT. 314.3)	20318.	
CONDENSER COST($1000)(ACCT.314.2)	7411.5	

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE2A 35 PCT 7.5 ATM 01/31/83

OTHER PLANT COSTS ....

LAND AND LAND RIGHTS	
COST/ACRE ($1000)	5.0000
COST ($1000) (ACCT.310.)	3507.6
STRUCTURES AND IMPROVEMENTS	
IMPROVEMENTS TO SITE($1000)(ACT.311.12)	13516.
BUILDINGS & STRUCTURE COST ($1000)(ACCT.311.2)	77313.
BOILER PLANT EQUIPMENT	
COAL HAND. & PROCESS COST ($1000)(ACCT.312.1)	53968.
ASH AND SLUDGE COST ($1000) (ACCT. 312.2)	17911.
WATER TREATMENT COST($1000)	6099.2
DEAERATOR COST ($1000)	280.29
FEEDWATER SYSTEM COST($1000)	4694.2
DRAFT FAN AND DUCT COST ($1000)	3693.3
STEAM PIPE/VALVE COST($1000)(ACCT. 314.4)	17703.
ACC. ELECTRICAL EQUIP. COST ($1000)(ACT. 315.)	50000.
MISC. POWER PLANT EQUIP. COST ($1000)(ACCT.316)	5619.9
TRANSMISSION PLANT COST ($1000)(ACT. 350)	10706.
POWER CONSOLIDATION COST ($1000)(ACCT.317.4)	49225.

CASE2A 36 PCT 7.5 ATM 01/31/83

OTHER PLANT COSTS ....

AUXILIARY BOILER COST($1000)(ACT.312.6)	349.99
BOILER PLANT VALVE COST($1000)(ACT.312.71)	7290.5
MISC. BOILER PLANT COST($1000)(ACT.312.72)	2850.0
MISC. BOILER PLANT COST($1000)	17785.
FEEDWATER PUMP COSTS($1000)	3860.9
OTHER TURBINE EQUIP. COST($1000)(ACT.314.5)	2854.6
OXIDENT DUCT SYS. COST ($1000)(ACT.317.53)	5204.9
LAND FILL COST ($1000)(ACT. 311.11)	6835.9
ENGINEERING SERVICE COST ($1000)	52444.
ESCAL. & INT. DURING CONST. ($1000)	78288.
TOTAL PLANT COST ($1000)	9.04112E+05

FUEL COST (MILLS/KWH)	27.567
LIME COST ($/YEAR)	1526.4
OPER. & MAINT. COSTS (MIL/KWH)	6.1480
CAPITAL COSTS (MILLS/KWH)	28.896
SEED MAKEUP COST	1538.8
CREW COST	4603.9
O & M MATERIAL COST	4.53115E+06

A1 - REFERENCE 1000 MWe MHD/STEAM POWER PLANT

A1.3 Plant Cost Account Summary

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE2A 36 PCT 7.5 ATM 01/31/83

ACCOUNT NO.	DESCRIPTION	COST BASIS UNIT	TOTAL COST ($1000)
310.0	LAND COSTS	KG/S	3507.6
311.0	STRUCTURES AND IMPROVEMENTS	KG/S	90533.
311.1	IMPROVEMENTS TO SITE	KG/S	20351.
311.1.1	WASTE DISPOSAL LAND FILL AREA	KG/S	6835.9
311.1.2	OTHER YARD WORK	KG/S	13516.
311.2	MAIN BUILDING	KG/S	29902.
311.2.1	MHD BUILDING	KG/S	13375.
311.2.2	HRSR BUILDING	KG/S	16777.
311.2.3	POWER COND. SYSTEM BLDG.	KG/S	6107.7
311.2.4	MAGNET REFRIG. SYS. BLDG.	KG/S	773.13
311.3	STEAM TURBINE BLDG.	KG/S	15231.
311.3.1	STEAM TURBINE-GENERATOR BUILDING	KG/S)	15231.
311.3.2	STEAM TURBINE-COMPRESSOR BLDG.		(INCL. IN 317.7)
311.4	COAL BUNKER/PROCESSING AREA	KG/S	7963.2
311.5	SERVICE BUILDINGS	KG/S	8195.2
311.6	OTHER PROCESS BLDG. AND STRUCTURES	KG/S	8891.0
312.0	BOILER PLANT EQUIPMENT	KG/S	2.12264E+05
312.1	COAL HANDLING AND PROCESSING	KG/S	53968.
312.1.1	UNLOAD/STORE/RECLAIM SYSTEM	KG/S	19844.
312.1.2	PULVERIZING/DRYING SYSTEM	KG/S	23816.
312.1.3	FEED SYSTEM	KG/S	10308.
312.2	SLAG AND ASH HANDLING	KG/S	17911.
312.3	RADIANT BOILER	MWT	7482.5
312.4	STEAM GENERATOR SECTIONS	MWT	82782.
312.4.1	SUPERHEATR/REHEATER	MWT	38659.
312.4.2	OXIDANT PREHEATER	MWT	3629.3
312.4.3	ECONOMIZER/SECONDARY AIR HEATER	MWT,KG/S	40493.
312.5	EFFLUENT CONTROL		24696.
312.5.1	ELECTROSTATIC PRECIPITATOR	M3/S	17201.
312.5.2	FANS, DUCTING, STACK	MWE,M3/S	7494.9
312.6	AUXILIARY BOILER SYSTEMS	MWT	349.99
312.7	OTHER BOILER PLANT SYSTEMS		25075.
312.7.1	PIPING/VALVES/TANKS	KG/S	7290.5
312.7.2	MISCELLANEOUS BOILER PLANT	KG/S	17785.

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE2A 36 PCT 7.5 ATM 01/31/83

ACCOUNT NO.	DESCRIPTION	COST BASIS UNIT	TOTAL COST ($1000)
314.0	TURBOGENERATOR UNITS		89364.
314.1	STEAM TURBINE GN/ACCESSORIES	MWE	41076.
314.2	CONDENSERS/AUXILIARIES	MWT	7411.5
314.3	CIRCULATING WATER SYSTEM		20318.
314.3.1	COOLING TOWERS (INC.BASIN)	MWT	11723.
314.3.2	CIRC. WATER PUMPS/PIPING	MWT	8594.5
314.4	STEAM PIPING SYSTEMS	KG/S	17703.
314.4.1	FEEDWATER PIPING	KG/S	5195.9
314.4.2	STEAM PIPING	KG/S	6077.5
314.4.3	OTHER STEAM PLANT PIPING	KG/S	6429.8
314.5	OTHER TURBINE PLANT EQUIPMENT	KG/S	2854.6
315.0	ACCESSORY ELECTRIC SYSTEMS/EQUIP.	MWE	50000.
316.0	MISCELLANEOUS POWER PLANT EQUIP.	MWE	5619.9
317.0	MHD TOPPING CYCLE EQUIPMENT		2.91144E+05
317.1	COMBUSTION EQUIPMENT	MWE	4100.5
317.1.1	COMBUSTOR		4100.5
317.1.2	COAL INJECTION SYSTEM		(INCL. IN 312.1.3)
317.1.3	SLAG COLLECTION SYSTEM		(INCL. IN 312.2)
317.2	MHD GENERATOR SYSTEM		6244.0
317.2.1	NOZZLE	M	166.11
317.2.2	CHANNEL	MWE,M2	5077.7
317.2.3	DIFFUSER	MWE	1000.1
317.3	MAGNET SYSTEM	MJ	70984.
317.4	INVERTER/ELECTRODE CONTROL SYSTEM	M,KWE	49225.
317.5	OXIDIZER SYSTEM		18113.
317.5.1	OXIDANT COMPRESSORS	HP	12908.
317.5.2	OXIDANT HEATER		(INCL. IN 312.4.2)
317.5.3	AIR/OXYGEN/OXIDANT SYSTEM DUCTING	M3/S	5204.9
317.6	SEED SYSTEM		37754.
317.6.1	SEED REGENERATION SYSTEM	KG/S	34359.
317.6.2	SEED INJECTION SYSTEM	KG/S	3395.5
317.7	OXYGEN ENRIHMENT SYSTEM	TPD	1.04722E+05
317.8	MISC. MHD TOP. CYCLE SUP. EQUIP.		
350.0	TRANSMISSION PLANT	MWE	10706.

A1 - REFERENCE 1000 MWe MHD/STEAM POWER PLANT

A1.4 - Plant Costing Details and Cost of Electricity

MHD PROJECT COST ESTIMATE (DOLLARS X 10-3)

CASE 2A 35 PCT 7.5 ATM 01/31/83

ACCOUNT NUMBER	ACCOUNT DESCRIPTION	UNIT	QUANTITY	MATERIAL MAJOR COMPONENT	MATERIAL BAL OF PLT COST	INSTALLN COST	INDIRECT COST	CONTG	TOTAL COST
310.0	LAND AND LAND RIGHTS	KG/S	88.	0.	3189.	0.	0.	319.	3508.
311.0	STRUCTURES AND IMPROVEMENTS	KG/S	88.	0.	41646.	24810.	22331.	8878.	97664.
311.1	IMPROVEMENTS TO SITE	KG/S	88.	0.	6105.	6525.	5871.	1850.	20351.
311.1.1	WASTE DISP.LAND FILL AREA	KG/S	88.	0.	2051.	2192.	1972.	621.	6836.
311.1.2	OTHER YARD WORK	KG/S	88.	0.	4055.	4333.	3899.	1229.	13516.
311.2	MAIN BUILDING	KG/S	88.	0.	18516.	7973.	7177.	3366.	37033.
311.2.1	MHD BUILDING	KG/S	88.	0.	6688.	2880.	2592.	1216.	13375.
311.2.2	HRSR BUILDING	KG/S	88.	0.	8388.	3612.	3251.	1525.	16777.
311.2.3	POWER COND. SYSTEM BLDG.	KG/S	88.	0.	3054.	1315.	1184.	555.	6108.
311.2.4	MAGNET REFRIGN. SYS. BLDG.	KG/S	88.	0.	387.	166.	150.	70.	773.
311.3	STEAM TURBINE BUILDING	KG/S	88.	0.	6092.	4080.	3674.	1384.	15231.
311.3.1	STEAM TURB.-GEN. BUILDING	KG/S	88.	0.	6092.	4080.	3674.	1384.	15231.
311.3.2	STEAM TURB.-COMPR. BLDG.							(INCL.	IN 317.7)
311.4	COAL BUNKER/PROCESSING AREA	KG/S	88.	0.	2389.	2553.	2297.	724.	7963.
311.5	SERVICE BUILDINGS	KG/S	88.	0.	4098.	1764.	1588.	745.	8195.
311.6	OTHER PRCS. BLDG. AND STRUC.	KG/S	88.	0.	4445.	1914.	1723.	808.	8891.
312.0	BOILER PLANT EQUIPMENT	KG/S	88.	80852.	51894.	31701.	28523.	19295.	212264.
312.1	COAL HANDLING AND PROCSG.	KG/S	88.	22181.	11906.	7883.	7092.	4906.	53968.
312.1.1	UNLOAD/STORE/RECLAIM SYS.	KG/S	88.	0.	11906.	3229.	2905.	1804.	19844.
312.1.2	PULVERIZING/DRYING SYSTEM	KG/S	88.	15481.	0.	3249.	2922.	2165.	23816.
312.1.3	FEED SYSTEM	KG/S	88.	6700.	0.	1406.	1265.	937.	10308.
312.2	SLAG AND ASH HANDLING	KG/S	88.	0.	12538.	1970.	1775.	1628.	17911.
312.3	RADIANT BOILER	MWT	323.	4864.	0.	1021.	918.	680.	7483.

MHD PROJECT COST ESTIMATE (DOLLARS X 10-3)

CASE2A 36 PCT 7.5 ATM 01/31/83

ACCOUNT NUMBER	ACCOUNT DESCRIPTION	UNIT	QUANTITY	MATERIAL MAJOR COMPONENT	MATERIAL BAL OF PLT COST	INSTALLN COST	INDIRECT COST	CONTG	TOTAL COST
312.4	STEAM GENERATOR SECTIONS	MWT		53808.	0.	11291.	10157.	7525.	82782.
312.4.1	SUPERHEATER/REHEATER	MWT	968.	25128.	0.	5273.	4743.	3514.	38659.
312.4.2	OXIDANT PREHEATER	MWT	158.	2359.	0.	495.	445.	330.	3629.
312.4.3	ECONOMIZER/SECDARY AIR HTR	MWT	76.	26321.	0.	5523.	4969.	3681.	40493.
312.5	EFFLUENT CONTROL			0.	12194.	5399.	4858.	2245.	24696.
312.5.1	ELECTROSTATIC PRECIPITATOR	M3/S	1012.	0.	10320.	2799.	2518.	1564.	17201.
312.5.2	FANS/DUCTING/STACK	MWE	1000.	0.	1874.	2600.	2340.	681.	7495.
312.6	AUXILIARY BOILER SYSTEMS	MWT	1000.	0.	210.	57.	51.	32.	350.
312.7	OTHER BOILER PLANT SYSTEMS			0.	15045.	4080.	3671.	2279.	25075.
312.7.1	PIPING/VALVES/TANKS	KG/S	647.	0.	4374.	1186.	1067.	663.	7290.
312.7.2	MISC. BOILER PLANT	KG/S	647.	0.	10671.	2894.	2604.	1617.	17785.
314.0	TURBOGENERATOR UNITS			34056.	26771.	10743.	9670.	8123.	89364.
314.1	STEAM TURBINE GN/ACCES.	MWE	548.	34056.	0.	1729.	1557.	3734.	41076.
314.2	CONDENSERS/AUXILIARIES	MWT	952.	0.	4447.	1206.	1085.	674.	7412.
314.3	CIRCULATING WATER SYSTEM			0.	11331.	3758.	3382.	1847.	20318.
314.3.1	COOLING TOWERS (INC.BASIN)	MWT	952.	0.	7034.	1907.	1716.	1066.	11723.
314.3.2	CIRC. WATER PUMPS/PIPING	MWT	952.	0.	4297.	1850.	1666.	781.	8594.
314.4	STEAM PIPING SYSTEMS	KG/S	647.	0.	8852.	3811.	3431.	1609.	17703.
314.4.1	FEEDWATER PIPING	KG/S	647.	0.	2598.	1119.	1007.	472.	5196.
314.4.2	STEAM PIPING	KG/S	647.	0.	3039.	1308.	1178.	552.	6077.
314.4.3	OTER STEAM PLANT PIPING	KG/S	647.	0.	3215.	1384.	1246.	584.	6430.
314.5	OTHER TURBINE PLANT EQUIP.	KG/S	647.	0.	2141.	239.	215.	259.	2855.

MHD PROJECT COST ESTIMATE (DOLLARS X 10-3)

CASE2A 36 PCT 7.5 ATM 01/31/83

ACCOUNT NUMBER	ACCOUNT DESCRIPTION	UNIT	QUANTITY	MATERIAL MAJOR COMPONENT	MATERIAL BAL OF PLT COST	INSTALLN COST	INDIRECT COST	CONTG	TOTAL COST
315.0	ACC. ELECTRIC SYSTEMS/EQUIP.	MWE	1000.	0.	20000.	13395.	12060.	4545.	50000.
316.0	MISC. POWER PLANT EQUIP.	MWE	1000.	0.	3372.	914.	823.	511.	5620.
317.0	MHD TOPPING CYCLE EQUIP.			214283.	9133.	27965.	25168.	14598.	291144.
317.1	COMBUSTION EQUIPMENT	MWE	1000.	3485.	205.	216.	194.	0.	4101.
317.1.1	COMBUSTOR			3485.	205.	216.	194.	0.	4101.
317.1.2	COAL INJECTION SYSTEM							(INCL. IN	312.1.3)
317.1.3	SLAG COLLECTION SYSTEM							)INCL. IN	312.2)
317.2	MHD GENERATOR SYSTEM			5307.	312.	328.	296.	0.	6244.
317.2.1	NOZZLE	M	1.	141.	8.	9.	8.	0.	166.
317.2.2	CHANNEL	MWE	1000.	4316.	254.	267.	241.	0.	5078.
317.2.3	DIFFUSER	MWE	1000.	850.	50.	53.	47.	0.	1000.
317.3	MAGNET SYSTEM	MJ	5915.	60337.	3549.	3734.	3365.	0.	70984.
317.4	INVERTER/ELCTD.CTRL SYSTEM	M	16.	41841.	2461.	2589.	2333.	0.	49225.
317.5	OXIDIZER SYSTEM			10702.	2602.	1664.	1498.	1646.	18113.
317.5.1	OXIDANT COMPRESSORS	HP	135554.	10702.	0.	543.	489.	1173.	12908.
317.5.2	OXIDANT HEATER							(INCL. IN	312.4.2)
317.5.3	OXIDANT DUCT.SYSTEM	M3/S	133.	0.	2602.	1121.	1009.	473.	5205.
317.6	SEED SYSTEM			24540.	0.	5150.	4632.	3432.	37754.
317.6.1	SEED REGENERATION SYSTEM	KG/S	3.	22333.	0.	4687.	4216.	3123.	34359.
317.6.2	SEED INJECTION SYSTEM	KG/S	10.	2207.	0.	463.	417.	309.	3395.
317.7	OXYGEN ENRICHMENT SYSTEM	TPD	9730.	68069.	0.	14284.	12849.	9519.	104722.
317.8	MISC.MHD TOP.CYCLE SUP.EQUIP								
350.0	TRANSMISSION PLANT	MWE	999.	0.	7494.	1178.	1061.	973.	10706.

MHD PROJECT COST ESTIMATE (DOLLARS X 10-3)

CAS:24 36 PCT 7.5 ATM 01/31/83

ACCOUNT NUMBER	ACCOUNT DESCRIPTION	UNIT	QUANTITY	MATERIAL MAJOR COMPONENT	MATERIAL BAL OF PLT COST	INSTALLN COST	INDIRECT COST	CONTG	TOTAL COST
	SUBTOTALS			329192.	163496.	110706.	99635.	57241.	760269.
	ENGINEERING SERVICES								52444.
	OTHER COSTS								13111.
	TOTAL ESTIMATED OVERNIGHT CONSTRUCTION COSTS								825824.
	CONSTRUCTION PERIOD YEARS								5.5
	TOTAL ESTIMATED COST INCLUDING INTEREST AND ESCALATION DURING CONSTRUCTION								984112.

MHD PROJECT COST ESTIMATE (DOLLARS X 10-3)

CASE2A 36 PCT 7.5 ATM 01/31/83

OPERATING AND MAINT. COSTS ($1000/YR)

LABOR	4604.
SEED	1539.
LIME	1526.
MATERIAL	9609.

COST OF ELECTRICITY (MILLS/KWHR)

CAPITAL	28.9
FUEL	27.6
O&M	6.1
COE	62.6

A2 - REFERENCE 500 MWe MHD/STEAM POWER PLANT

A2.1 Overall Performance

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE8 36 PCT 6.0 ATM 01/31/83

OVERALL SYSTEM PERFORMANCE ....

REFERENCE COAL	MONTANA ROSEBUD
COAL THERMAL INPUT (MWT)	1162.8
PRIMARY CYCLE (MWT)	1146.7
SEED REGENERATION (MWT)	16.054
PLANT LIFE (YEARS)	
OPERATING MODE	
NET POWER OUTPUT (MWE)	494.81
PLANT EFFICIENCY (PCT)	42.555
THERMODYNAMIC EFFICIENCY (PCT)	29.471
MHD ENTHALPY EXTRACTION (PCT)	19.576
TOTAL HEAT INPUT TO STEAM (MWT)	877.01
STEAM CYCLE EFFICIENCY (PCT)	42.049
AIR PREHEAT TEMPERATURE (DEG K)	922.22
REFERENCE ATMOSPHERE	
PRESSURE (ATM)	1.0002
DRY BULB TEMPERATURE (DEG K)	288.00
RELATIVE HUMIDITY (PCT)	60.000
STEAM CONDITIONS	
MAIN TURBINE THROTTLE PRESSURE (ATM)	164.30
MAIN TURBINE THROTTLE TEMPERATURE (DEG K)	811.10
REHEAT TEMPERATURE (DEG K)	811.10
STEAM TURBINE/GENERATOR TOTAL POWER (MWE)	293.91
STEAM TUR/GEN COST ($1000) (ACCT. 314.1)	25254.
HEAT/SEED RECOVERY COST ($1000)(ACCT.312.3,4)	53198.
POWER TRAIN COST ($1000)(ACCT.317.)	1.57614E+05
STEAM BOTTOM PLANT COST($1000)(ACCT.312,314)	1.05070E+05
PLANT CAPITAL COST ($1000)	4.49102E+05
COST OF ELECTRICITY (MILLS/KWH)	70.508

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE8 36 PCT 6.0 ATM 01/31/83

POWER GENERATED AND CONSUMED ....

GROSS AC POWER (MWE)	
MHD POWER (AC)	218.87
STEAM TURBINE-GENERATOR POWER	293.91
TOTAL	512.78
POWER CONSUMED (MWE)	
SEC. AIR BLOWER	1.43401E-02
DRAFT FAN POWER	.30981
CONDENSATE PUMP	.14291
COOLING TWR CIRC PUMP	3.4766
COAL HANDLING AND PROCESSING	6.7657
ELECTROSTATIC PRECIP POWER	.22934
MHD MAGNET POWER	.34402
MISC. POWER	1.6898
TRANSFORMER LOSS	4.9981
TOTAL	17.971
NET POWER OUTPUT (MWE)	494.81

MECHANICAL DRIVE TURBINES (MW)

CYCLE AIR COMPRESSOR	44.305
OXYGEN PLANT POWER	32.078
BOILER FEED PUMPS	8.7581

A2 - REFERENCE 500 MWe MHD/STEAM POWER PLANT

A2.2 Component/Subsystem Information

CASE8 36 PCT 6.0 ATM 01/31/83

COAL HANDLING AND PREPARATION ...

RAW COAL, AS RECEIVED	
SIZE (TOP SIZE AS DELIVERED, IN)	-I
MOISTURE CONTENT (PCT)	22.700
FLOW RATE (KG/S)	55.330
HIGH HEATING VALUE (J/KG)	2.07250E+07
COAL TO COMBUSTOR, AS FIRED	
SIZE (MESH, 70 PCT THRU)	0
MOISTURE CONTENT (PCT)	5.0000
FLOW RATE (KG/S)	45.020
FLOW CONTROL (PCT)	
TRANSPORT MEDIUM	COMB. GAS
MECHANISM	
RATIO	1.00000E-01
DRYING MEDIUM	
FLOW RATE (KG/S)	94.554
TEMPERATURE IN (DEG K)	644.40
TEMPERATURE OUT (DEG K)	377.70
HEAT REQUIRED FOR DRYING (MWT)	31.206
POWER REQUIREMENT (MWE)	6.7657
KEY COMPONENT	
MINIMUM USEFUL LIFE (YEARS)	
REPLACEMENT TIME (HRS)	
COST($1000) (ACCT. 312.1)	36050.

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE8 36 PCT 6.0 ATM 01/31/83

OXIDIZER SUPPLY	
OXYGEN PLANT	
AMOUNT OF OXYGEN (PCT)	36.000
CONTAINED OXYGEN FLOW (TPD)	4456.0
EQUIVALENT PURE OXYGEN (TPD)	3948.1
O2 PREHEAT TEMP. (DEG K)	922.22
COST($1000) (ACCT. 317.7.2)	56386.
MAIN AIR COMPRESSOR	
TYPE OF COMPRESSOR	AXIAL FLOW
TYPE OF INTERCOOLING	NONE
AIR INLET CONDITIONS	
PRESSURE (ATM)	1.0002
TEMPERATURE (DEG K)	288.00
FLOW RATE (KG/S)	198.70
AIR OUTLET CONDITIONS	
PRESSURE (ATM)	6.1814
TEMPERATURE (DEG K)	510.05
ADIABATIC EFFICIENCY (PCT)	86.900
SHAFT POWER (MW)	44.305
LUBE SYSTEM POWER (MW)	0.
COST($1000) (ACCT. 317.5.7)	6668.4
SECONDARY AIR INJECTION	
LOCATION	
PRESSURE (ATM)	1.0027
TEMPERATURE (DEG K)	288.25
FLOW RATE (KG/S)	56.312
FAN EFFICIENCY (PCT)	80.000
POWER REQUIREMENT (MWE)	1.43401E-02
KEY COMPONENT	
MINIMUM USEFUL LIFE (YEARS)	
COST($1000) (ACCT. 312.4.5)	2244.3

CASE8 36 PCT 6.0 ATM 01/31/83

SEED FEED AND MANAGEMENT ....

TYPE	
SEED FLOW, TOTAL (KG/S)	5.0371
POTASSIUM CARBONATE, K2CO3 (KG/S)	1.5912
POTASSIUM SULFATE, K2SO4 (KG/S)	3.4459
POWER REQUIREMENT (MWE)	0.
TRANSPORT MECHANISM	
FLOW CONTROL (PCT)	
NUMBER OF MODULES	
KEY COMPONENT	
MINIMUM USEFUL LIFE (YEARS)	
REPLACEMENT TIME (HRS)	
COST ($1000) (ACCT.317.6.4)	2294.7

SEED RECOVERY/REGENERATION SYSTEM ...

TYPE	
RECOVERY (PCT)	95.000
REGENERATION (PCT)	33.300
TYPE OF REGENERATION PROCESS	FORMATE
POWER REQUIREMENTS (MWE)	0.
KEY COMPONENT	
MINIMUM USEFUL LIFE (YEARS)	
COST ($1000) (ACCT. 316.1-.3)	18758.

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE8 36 PCT 6.0 ATM 01/31/83

MAIN COMBUSTOR ....

TYPE-NUMBER OF STAGES	2	
DIMENSIONS	1ST STAGE	2ND STAGE
LENGTH (M)	4.7052	5.7136
DIAMETER (M)	2.5572	1.4284
VOLUME (M**3)	24.129	11.657
WEIGHT (KG)	7858.2	
COMBUSTOR EXIT CONDITIONS		
PRESSURE (ATM)	5.8213	
TEMPERATURE (DEG K)	2837.0	
FLOW RATE (KG/S)	250.13	
SLAG REMOVAL (PCT)	85.000	
RESIDENCE TIME (MICRO-SEC)		
1-ST STAGE		
2-ND STAGE		
COMBUSTOR HEAT LOSSES (MWT)	48.736	
COOLING WATER INLET		
PRESSURE (ATM)	190.50	
TEMPERATURE (DEG K)	588.90	
QUALITY	0.	
FLOW RATE (KG/S)	337.63	
COOLING WATER EXIT		
PRESSURE (ATM)	187.10	
TEMPERATURE (DEG K)	624.41	
QUALITY	0.	
NUMBER OF MODULES	1	
COST ($1000) (ACCT.317.1.6,312.4.6)	3569.7	

NOZZLE ....

LENGTH (M)	2.3231
WEIGHT (KG)	2580.8
NOZZLE EXIT MACH NUMBER	.87500
NOZZLE HEAT LOSS (MWT)	12.804
NUMBER OF MODULES	
MINIMUM USEFUL LIFE (YEARS)	
COST($1000) (ACCT.317.2.1)	115.86

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE8 36 PCT 6.0 ATM 01/31/83

CHANNEL ....

TYPE	DIAGONAL		
DIMENSIONS			
INLET (MXM)	.77435	X	.77435
OUTLET (MXM)	1.7944	X	1.7944
LENGTH (M)	11.736		
WEIGHT (KG)	31304.		
NUMBER OF ELECTRODE PAIRS	7.82396E+02		
SLAG REMOVAL (PCT)			
ENTHALPY EXTRACTION (PCT)	19.576		
OVERALL (TURBINE) EFFICIENCY (PCT)	77.311		
INLET CONDITIONS			
PRESSURE (ATM)	3.8143		
TEMPERATURE (DEG K)	2706.2		
MACH NUMBER	.87500		
VELOCITY (M/S)	8[illegible]5.75		
FLOW RATE (KG/S)	250.13		
OUTLET CONDITIONS			
PRESSURE (ATM)	.74019		
TEMPERATURE (DEG K)	2289.6		
MACH NUMBER	.87791		
SURFACE TEMPERATURE (DEG K)	1800.0		
HEAT LOSS (MWT)	38.325		
PEAK ELECTRODE CURRENT DENSITY (A/CM**2)			
MAXIMUM HALL FIELD (KV/M)	2.5000		
COOLING WATER INLET			
PRESSURE (ATM)			
TEMPERATURE (DEG K)	357.57		
QUALITY	0.		
FLOW RATE (KG/S)	243.37		
COOLING WATER EXIT			
PRESSURE (ATM)	5.1024		
TEMPERATURE (DEG K)	400.00		
QUALITY	0.		
NUMBER OF CHANNELS	1		
MHD GROSS POWER BEFORE INVERSION (MWE)	224.48		
MHD GROSS POWER AFTER INVERSION (MWE)	218.87		
INVERTER EFFICIENCY (PCT)	97.500		
COST ($1000) (ACCT.317.2.2,.3)	3530.1		

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE8 36 PCT 6.0 ATM 01/31/83

DIFFUSER AND TRANSITION PIECE ....

TYPE			
DIMENSIONS			
INLET (MXM)	1.7944	X	1.7944
OUTLET (MXM)	5.7420	X	5.7420
LENGTH (M)	19.020		
WEIGHT (KG)	70616.		
PRESSURE RECOVERY COEFFICIENT	.60000		
INLET CONDITIONS			
PRESSURE (ATM)	.74019		
TEMPERATURE (DEG K)	2289.6		
MACH NUMBER	.87791		
FLOW RATE (KG/S)	250.13		
OUTLET CONDITIONS - DIFFUSER			
PRESSURE (ATM)	.98220		
TEMPERATURE (DEG K)	2407.0		
MACH NUMBER	.40000		
SURFACE TEMPERATURE (DEG K)			
HEAT LOSS (MWT)	0.		
COOLING WATER INLET			
PRESSURE (ATM)	186.05		
TEMPERATURE (DEG K)	627.80		
FLOW RATE (KG/S)	111.92		
COOLING WATER EXIT			
PRESSURE (ATM)	183.67		
TEMPERATURE (DEG K)	633.10		
BOUNDARY LAYER CONTROLS			
MINIMUM USEFUL LIFE (YEARS)			
COST ($1000) (ACCT.317.2.4)	858.66		

CASE8 36 PCT 6.0 ATM 01/31/83

MAGNET ....

TYPE	
DIMENSIONS	
LENGTH (M)	13.262
OVERALL DIAMETER (M)	6.6308
WARM BORE	
INLET DIAMETER (M)	1.6608
OUTLET DIAMETER (M)	2.7619
FIELD STRENGTH (TESLA)	
PEAK	6.0000
AVERAGE	
CURRENT DENSITY (A/CM**2)	
ENERGY STORAGE (MJ)	2864.3
WEIGHT (KG)	1.10560E+06
COST ($1000) (ACCT.317.3)	34371.

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE8 36 PCT 6.0 ATM 01/31/83

RADIANT BOILER ....

TYPE			
DIMENSIONS			
INLET (MXM)	20.810	X	19.400
OUTLET (MXM)	20.810	X	19.400
LENGTH (M)	21.200		
WEIGHT (KG)	5.00000E+05		
EFFICIENCY (PCT)	0.		
COMBUSTION GAS INLET CONDITIONS			
PRESSURE (ATM)	.98220		
TEMPERATURE (DEG K)	2399.9		
FLOW RATE (KG/S)	250.13		
COMBUSTION GAS OUTLET CONDITIONS			
PRESSURE (ATM)	.95273		
TEMPERATURE (DEG K)	1867.0		
DWELL TIME (SEC)	2.5000		
HEAT TRANSFER AREA (M**2)			
SLAG REMOVAL (PCT)			
MAXIMUM TEMP GRADIENT (DEG K/SEC)			
WATER/STEAM INLET CONDITIONS			
PRESSURE (ATM)	183.70		
TEMPERATURE (DEG K)	604.41		
QUALITY	0.		
FLOW RATE (KG/S)	337.63		
WATER/STEAM EXIT CONDITIONS			
PRESSURE (ATM)	183.70		
TEMPERATURE (DEG K)	633.10		
QUALITY	1.0000		
THERMAL DUTY (MWT)	242.06		
MINIMUM USEFUL LIFE (YEARS)			
COST($1000) (ACCT.312.3.1)	5880.7		

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE8 36 PCT 6.0 ATM 01/31/83

HIGH TEMPERATURE AIR HEATER ....

TYPE		
NUMBER OF MODULES	0	
DIMENSIONS		
HEIGHT (M)		-I
DIAMETER (M)		-I
FLOW AREA (M**2)		-I
WEIGHT (KG)		
SLAG REMOVAL (PCT)		
COMBUSTION GAS INLET CONDITIONS		
PRESSURE (ATM)		-I
TEMPERATURE (DEG K)		-I
FLOW RATE (KG/S)		-I
COMBUSTION GAS OUTLET CONDITIONS		
PRESSURE (ATM)		-I
TEMPERATURE (DEG K)		-I
AIR INLET CONDITIONS		
PRESSURE (ATM)		-I
TEMPERATURE (DEG K)		-I
FLOW RATE (KG/S)		-I
AIR OUTLET CONDITIONS		
PRESSURE (ATM)		-I
TEMPERATURE (DEG K)		-I
VELOCITY (M/S)		
DWELL TIME (SEC)		
LOSSES		
VALVE LEAKAGE (PCT)		-I
VALVE COOLING (MWT)		-I
CORE HEAD LOSS (MWT)		-I
THERMAL DUTY (MWT)	0.	
MINIMUM USEFUL LIFE (YEARS)		
COST($1000) (ACCT.317.5.2--4)	0.	

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE8 36 PCT 6.0 ATM 01/31/83

SUPERHEATER ....

TYPE		
DIMENSIONS		
LENGTH (M)		-I
WIDTH (M)		-I
HEIGHT (M)		-I
WEIGHT (KG)		
COMBUSTION GAS INLET CONDITIONS		
PRESSURE (ATM)	.95273	
TEMPERATURE (DEG K)	1977.7	
FLOW RATE (KG/S)	306.44	
COMBUSTION GAS OUTLET CONDITIONS		
PRESSURE (ATM)	.95273	
TEMPERATURE (DEG K)	644.40	
SLAG REMOVAL (PCT)		
WATER/STEAM INLET CONDITIONS		
PRESSURE (ATM)	183.70	
TEMPERATURE (DEG K)	633.10	
FLOW RATE (KG/S)	337.63	
WATER/STEAM OUTLET CONDITIONS		
PRESSURE (ATM)	164.30	
TEMPERATURE (DEG K)	811.10	
THERMAL DUTY (MWT)	363.94	
COST ($1000) (ACCT.312.4.3)	9331.2	

CASE8 36 PCT 6.0 ATM 01/31/83

REHEATER ....

TYPE		
DIMENSIONS		
LENGTH (M)		-I
WIDTH (M)		-I
HEIGHT (M)		-I
WEIGHT (KG)		
COMBUSTION GAS INLET CONDITIONS		
PRESSURE (ATM)	.95273	
TEMPERATURE (DEG K)	1977.7	
FLOW RATE (KG/S)	306.44	
COMBUSTION GAS OUTLET CONDITIONS		
PRESSURE (ATM)	.95273	
TEMPERATURE (DEG K)	644.40	
SLAG REMOVAL (PCT)		
WATER/STEAM INLET CONDITIONS		
PRESSURE (ATM)	43.425	
TEMPERATURE (DEG K)	617.79	
FLOW RATE (KG/S)	270.28	
WATER/STEAM OUTLET CONDITIONS		
PRESSURE (ATM)	41.253	
TEMPERATURE (DEG K)	811.10	
THERMAL DUTY (MWT)	123.66	
COST ($1000) (ACCT.312.4.4)	12736.	

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE8 36 PCT 6.0 ATM 01/31/83

OXIDANT PREHEATER ....

TYPE		
DIMENSIONS		
LENGTH (M)		-I
WIDTH (M)		-I
HEIGHT (M)		-I
WEIGHT (KG)		
COMBUSTION GAS INLET CONDITIONS		
PRESSURE (ATM)	.95273	
TEMPERATURE (DEG K)	1977.7	
FLOW RATE (KG/S)	306.44	
COMBUSTION GAS OUTLET CONDITIONS		
PRESSURE (ATM)	.95273	
TEMPERATURE (DEG K)	644.40	
AIR INLET CONDITIONS		
PRESSURE (ATM)	6.1814	
TEMPERATURE (DEG K)	510.05	
FLOW RATE (KG/S)	198.70	
AIR OUTLET CONDITIONS		
PRESSURE (ATM)	6.0014	
TEMPERATURE (DEG K)	922.22	
THERMAL DUTY (MWT)	87.946	
COST ($1000) (ACCT.317.5.5)	2229.8	

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE8 36 PCT 6.0 ATM 01/31/83

ECONOMIZER NO. 1....

DIMENSIONS	
LENGTH (M)	26.797
WIDTH (M)	9.2911
HEIGHT (M)	9.2911
WEIGHT (KG)	
COMBUSTION GAS INLET CONDITIONS	
PRESSURE (ATM)	.95273
TEMPERATURE (DEG K)	644.40
FLOW RATE (KG/S)	160.39
COMBUSTION GAS OUTLET CONDITIONS	
PRESSURE (ATM)	.95273
TEMPERATURE (DEG K)	425.00
WATER/STEAM INLET CONDITIONS	
PRESSURE (ATM)	205.42
TEMPERATURE (DEG K)	414.85
FLOW RATE (KG/S)	47.935
WATER/STEAM OUTLET CONDITIONS	
PRESSURE (ATM)	205.42
TEMPERATURE (DEG K)	588.90
THERMAL DUTY (MWT)	39.001
COST ($1000) (ACCT.312.4.1)	20776.

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE8 36 PCT 6.0 ATM 01/31/83

GAS CLEAN UP ....

TYPES	
LOCATIONS	
LOSSES	
PRESSURE (PCT)	
THERMAL (MWT)	
REMOVAL EFFICIENCY (PCT)	
POWER REQUIRED (MWE)	.22934
MINIMUM USEFUL LIFE (YEARS)	
COST($1000) (ACCT.312.5.1)	9298.7
STACK COST ($1000)(ACCT.312.5.3)	2776.1

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE8 36 PCT 6.0 ATM 01/31/83

EXHAUST EMISSIONS ....

PARTICULATE (G/J)	
NOX (G/J)	
SOX (G/J)	
TRACE ELEMENTS (G/J)	

PLANT COOLING ....

TYPE	
NUMBER OF MODULES	
DIMENSIONS	
HEIGHT (M)	
DIAMETER (M)	
CONDENSER PRESSURE (ATM)	6.70121E-02
THERMAL DUTY (MWT)	496.65
TEMPERATURE (DEG K)	311.61
COOLING WATER	
FLOW RATE (KG/S)	-I
MAKE UP (PCT)	
POWER REQUIREMENTS (MWE)	3.4766
MINIMUM USEFUL LIFE (YEARS)	
COST ($1000)	
HEAT REJECTION COST($1000)(ACCT. 314.3)	12881.
CONDENSER COST($1000)(ACCT.314.2)	4398.8

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MHD FACILITY ... PERFORMANCE ANALYSIS DATA

                              CASE8  36 PCT 6.0 ATM    01/31/83

OTHER PLANT COSTS ....

LAND AND LAND RIGHTS
  COST/ACRE ($1000)                                  5.0000
  COST ($1000) (ACCT.310.)                           2445.8

STRUCTURES AND IMPROVEMENTS
  IMPROVEMENTS TO SITE($1000)(ACT.311.12)            10381.
  BUILDINGS & STRUCTURE COST ($1000)(ACCT.311.2)     51643.

BOILER PLANT EQUIPMENT
  COAL HAND. & PROCESS COST ($1000)(ACCT.312.1)      36050.
  ASH AND SLUDGE COST ($1000) (ACCT. 312.2)          11897.
  WATER TREATMENT COST($1000)                        4990.8
  DEAERATOR COST ($1000)                             189.44
  FEEDWATER SYSTEM COST($1000)                       2992.1
  DRAFT FAN AND DUCT COST ($1000)                    1885.2
  STEAM PIPE/VALVE COST($1000)(ACCT. 314.4)          11982.

ACC. ELECTRICAL EQUIP. COST ($1000)(ACT. 315.)       25000.

MISC. POWER PLANT EQUIP. COST ($1000)(ACCT.316)      3707.8

TRANSMISSION PLANT COST ($1000)(ACT. 350)            7065.7

POWER CONSOLIDATION COST ($1000)(ACCT.317.4)         24857.
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MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE8 36 PCT 6.0 ATM 01/31/83

OTHER PLANT COSTS ....

AUXILIARY BOILER COST($1000)(ACT.312.6)	230.91
BOILER PLANT VALVE COST($1000)(ACT.312.71)	4934.6
MISC. BOILER PLANT COST($1000)(ACT.312.72)	1880.3
MISC. BOILER PLANT COST($1000)	12470.
FEEDWATER PUMP COSTS($1000)	2417.0
OTHER TURBINE EQUIP. COST($1000)(ACT.314.5)	1932.1
OXIDENT DUCT SYS. COST ($1000)(ACT.317.53)	3974.8
LAND FILL COST ($1000)(ACT. 311.11)	4285.8
ENGINEERING SERVICE COST ($1000)	31417.
ESCAL. & INT. DURING CONST. ($1000)	46298.
TOTAL PLANT COST ($1000)	5.34671E+05

FUEL COST (MILLS/KWH)	28.127
LIME COST ($/YEAR)	779.14
OPER. & MAINT. COSTS (MIL/KWH)	8.2220
CAPITAL COSTS (MILLS/KWH)	34.159
SEED MAKEUP COST	785.46
CREW COST	3791.4
O & M MATERIAL COST	2.67343E+06

A2 - REFERENCE 500 MWe MHD/STEAM POWER PLANT

A2.3 Plant Cost Accounts Summary

CASE8 36 PCT 6.0 ATM 01/31/83

ACCOUNT NO.	DESCRIPTION	COST BASIS UNIT	TOTAL COST ($1000)
310.0	LAND COSTS	KG/S	2445.8
311.0	STRUCTURES AND IMPROVEMENTS	KG/S	61880.
311.1	IMPROVEMENTS TO SITE	KG/S	14667.
311.1.1	WASTE DISPOSAL LAND FILL AREA	KG/S	4285.8
311.1.2	OTHER YARD WORK	KG/S	10381.
311.2	MAIN BUILDING	KG/S	20307.
311.2.1	MHD BUILDING	KG/S	8934.3
311.2.2	HRSR BUILDING	KG/S	11207.
311.2.3	POWER COND. SYSTEM BLDG.	KG/S	4079.8
311.2.4	MAGNET REFRIG. SYS. BLDG.	KG/S	516.43
311.3	STEAM TURBINE BLDG.	KG/S	10174.
311.3.1	STEAM TURBINE-GENERATOR BUILDING	KG/S)	10174.
311.3.2	STEAM TURBINE-COMPRESSOR BLDG.		(INCL. IN 317.7)
311.4	COAL BUNKER/PROCESSING AREA	KG/S	5319.3
311.5	SERVICE BUILDINGS	KG/S	5474.2
311.6	OTHER PROCESS BLDG. AND STRUCTURES	KG/S	5939.0
312.0	BOILER PLANT EQUIPMENT	KG/S	1.32740E+05
312.1	COAL HANDLING AND PROCESSING	KG/S	36050.
312.1.1	UNLOAD/STORE/RECLAIM SYSTEM	KG/S	13255.
312.1.2	PULVERIZING/DRYING SYSTEM	KG/S	15909.
312.1.3	FEED SYSTEM	KG/S	6885.5
312.2	SLAG AND ASH HANDLING	KG/S	11897.
312.3	RADIANT BOILER	MWT	5880.7
312.4	STEAM GENERATOR SECTIONS	MWT	47318.
312.4.1	SUPERHEATR/REHEATER	MWT	22068.
312.4.2	OXIDANT PREHEATER	MWT	2229.8
312.4.3	ECONOMIZER/SECONDARY AIR HEATER	MWT,KG/S	23020.
312.5	EFFLUENT CONTROL		13960.
312.5.1	ELECTROSTATIC PRECIPITATOR	M3/S	9298.7
312.5.2	FANS, DUCTING, STACK	MWE,M3/S	4661.2
312.6	AUXILIARY BOILER SYSTEMS	MWT	230.91
312.7	OTHER BOILER PLANT SYSTEMS		17404.
312.7.1	PIPING/VALVES/TANKS	KG/S	4934.6
312.7.2	MISCELLANEOUS BOILER PLANT	KG/S	12470.

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE8 36 PCT 6.0 ATM 01/31/83

ACCOUNT NO.	DESCRIPTION	COST BASIS UNIT	TOTAL COST ($1000)
314.0	TURBOGENERATOR UNITS		56449.
314.1	STEAM TURBINE GN/ACCESSORIES	MWE	25254.
314.2	CONDENSERS/AUXILIARIES	MWT	4398.8
314.3	CIRCULATING WATER SYSTEM		12881.
314.3.1	COOLING TOWERS (INC.BASIN)	MWT	7432.4
314.3.2	CIRC. WATER PUMPS/PIPING	MWT	5448.7
314.4	STEAM PIPING SYSTEMS	KG/S	11982.
314.4.1	FEEDWATER PIPING	KG/S	3516.9
314.4.2	STEAM PIPING	KG/S	4113.6
314.4.3	OTHER STEAM PLANT PIPING	KG/S	4352.0
314.5	OTHER TURBINE PLANT EQUIPMENT	KG/S	1932.1
315.0	ACCESSORY ELECTRIC SYSTEMS/EQUIP.	MWE	25000.
316.0	MISCELLANEOUS POWER PLANT EQUIP.	MWE	3707.8
317.0	MHD TOPPING CYCLE EQUIPMENT		1.55384E+05
317.1	COMBUSTION EQUIPMENT	MWE	3569.7
317.1.1	COMBUSTOR		3569.7
317.1.2	COAL INJECTION SYSTEM		(INCL. IN 312.1.3)
317.1.3	SLAG COLLECTION SYSTEM		(INCL. IN 312.2)
317.2	MHD GENERATOR SYSTEM		4504.6
317.2.1	NOZZLE	M	115.86
317.2.2	CHANNEL	MWE,M2	3530.1
317.2.3	DIFFUSER	MWE	858.66
317.3	MAGNET SYSTEM	MJ	34371.
317.4	INVERTER/ELECTRODE CONTROL SYSTEM	M,KWE	24857.
317.5	OXIDIZER SYSTEM		10643.
317.5.1	OXIDANT COMPRESSORS	HP	6668.4
317.5.2	OXIDANT HEATER		(INCL. IN 312.4.2)
317.5.3	AIR/OXYGEN/OXIDANT SYSTEM DUCTING	M3/S	3974.8
317.6	SEED SYSTEM		21052.
317.6.1	SEED REGENERATION SYSTEM	KG/S	18758.
317.6.2	SEED INJECTION SYSTEM	KG/S	2294.7
317.7	OXYGEN ENRIHMENT SYSTEM	TPD	56386.
317.8	MISC. MHD TOP. CYCLE SUP. EQUIP.		
350.0	TRANSMISSION PLANT	MWE	7065.7

A2 - REFERENCE 500 MWe MHD/STEAM POWER PLANT

A2.4 Plant Costing Details and Cost of Electricity

MHD PROJECT COST ESTIMATE (DOLLARS X 10-3)

CASE 8 36 PCT 6.0 ATM 01/31/83

ACCOUNT NUMBER	ACCOUNT DESCRIPTION	UNIT	QUANTITY	MATERIAL MAJOR COMPONENT	MATERIAL BAL OF PLT COST	INSTALLN COST	INDIRECT COST	CONTG	TOTAL COST
310.0	LAND AND LAND RIGHTS	KG/S	45.	0.	2223.	0.	0.	222.	2446.
311.0	STRUCTURES AND IMPROVEMENTS	KG/S	45.	0.	28140.	16916.	15226.	6028.	66310.
311.1	IMPROVEMENTS TO SITE	KG/S	45.	0.	4400.	4702.	4231.	1333.	14667.
311.1.1	WASTE DISP.LAND FILL AREA	KG/S	45.	0.	1286.	1374.	1236.	390.	4286.
311.1.2	OTHER YARD WORK	KG/S	45.	0.	3114.	3328.	2995.	944.	10381.
311.2	MAIN BUILDING	KG/S	45.	0.	12369.	5326.	4794.	2249.	24737.
311.2.1	MHD BUILDING	KG/S	45.	0.	4467.	1924.	1731.	812.	8934.
311.2.2	HRSR BUILDING	KG/S	45.	0.	5603.	2413.	2172.	1019.	11207.
311.2.3	POWER COND. SYSTEM BLDG.	KG/S	45.	0.	2040.	878.	791.	371.	4080.
311.2.4	MAGNET REFRIGN. SYS. BLDG.	KG/S	45.	0.	258.	111.	100.	47.	516.
311.3	STEAM TURBINE BUILDING	KG/S	45.	0.	4069.	2726.	2454.	925.	10174.
311.3.1	STEAM TURB.-GEN. BUILDING	KG/S	45.	0.	4069.	2726.	2454.	925.	10174.
311.3.2	STEAM TURB.-COMPR. BLDG.							(INCL.	IN 317.7)
311.4	COAL BUNKER/PROCESSING AREA	KG/S	45.	0.	1596.	1705.	1535.	484.	5319.
311.5	SERVICE BUILDINGS	KG/S	45.	0.	2737.	1179.	1061.	498.	5474.
311.6	OTHER PRCS. BLDG. AND STRUC.	KG/S	45.	0.	2969.	1279.	1151.	540.	5939.
312.0	BOILER PLANT EQUIPMENT	KG/S	45.	49395.	33607.	19830.	17842.	12066.	132740.
312.1	COAL HANDLING AND PROCSG.	KG/S	45.	14816.	7953.	5266.	4737.	3277.	36050.
312.1.1	UNLOAD/STORE/RECLAIM SYS.	KG/S	45.	0.	7953.	2157.	1941.	1205.	13255.
312.1.2	PULVERIZING/DRYING SYSTEM	KG/S	45.	10341.	0.	2170.	1952.	1446.	15909.
312.1.3	FEED SYSTEM	KG/S	45.	4476.	0.	939.	845.	626.	6885.
312.2	SLAG AND ASH HANDLING	KG/S	45.	0.	8328.	1309.	1179.	1081.	11897.
312.3	RADIANT BOILER	MWT	242.	3822.	0.	802.	722.	535.	5881.

MHD PROJECT COST ESTIMATE (DOLLARS X 10-3)

CASE8 36 PCT 6.0 ATM 01/31/83

ACCOUNT NUMBER	ACCOUNT DESCRIPTION	UNIT	QUANTITY	MATERIAL MAJOR COMPONENT	MATERIAL BAL OF PLT COST	INSTALLN COST	INDIRECT COST	CONTG	TOTAL COST
312.4	STEAM GENERATOR SECTIONS	MWT		30757.	0.	6454.	5806.	4301.	47318.
312.4.1	SUPERHEATER/REHEATER	MWT	487.	14344.	0.	3010.	2708.	2006.	22068.
312.4.2	OXIDANT PREHEATER	MWT	88.	1449.	0.	304.	274.	203.	2230.
312.4.3	ECONOMIZER/SECDARY AIR HTR	MWT	39.	14963.	0.	3140.	2825.	2093.	23020.
312.5	EFFLUENT CONTROL			0.	6745.	3130.	2817.	1269.	13960.
312.5.1	ELECTROSTATIC PRECIPITATOR	M3/S	517.	0.	5579.	1513.	1361.	845.	9299.
312.5.2	FANS/DUCTING/STACK	MWE	500.	0.	1165.	1617.	1455.	424.	4661.
312.6	AUXILIARY BOILER SYSTEMS	MWT	500.	0.	139.	38.	34.	21.	231.
312.7	OTHER BOILER PLANT SYSTEMS			0.	10443.	2832.	2548.	1582.	17404.
312.7.1	PIPING/VALVES/TANKS	KG/S	338.	0.	2961.	803.	722.	449.	4935.
312.7.2	MISC. BOILER PLANT	KG/S	338.	0.	7482.	2029.	1826.	1134.	12470.
314.0	TURBOGENERATOR UNITS			20938.	17263.	6903.	6213.	5131.	56449.
314.1	STEAM TURBINE GN/ACCES.	MWE	294.	20938.	0.	1063.	957.	2296.	25254.
314.2	CONDENSERS/AUXILIARIES	MWT	497.	0.	2639.	716.	644.	400.	4399.
314.3	CIRCULATING WATER SYSTEM			0.	7184.	2382.	2144.	1171.	12881.
314.3.1	COOLING TOWERS (INC.BASIN)	MWT	497.	0.	4459.	1209.	1088.	676.	7432.
314.3.2	CIRC. WATER PUMPS/PIPING	MWT	497.	0.	2724.	1173.	1056.	495.	5449.
314.4	STEAM PIPING SYSTEMS	KG/S	338.	0.	5991.	2580.	2322.	1089.	11982.
314.4.1	FEEDWATER PIPING	KG/S	338.	0.	1758.	757.	682.	320.	3517.
314.4.2	STEAM PIPING	KG/S	338.	0.	2057.	886.	797.	374.	4114.
314.4.3	OTHER STEAM PLANT PIPING	KG/S	338.	0.	2176.	937.	843.	396.	4352.
314.5	OTHER TURBINE PLANT EQUIP.	KG/S	338.	0.	1449.	162.	146.	176.	1932.

MHD PROJECT COST ESTIMATE (DOLLARS X 10-3)

CASE 8 36 PCT 6.0 ATM   01/31/83

ACCOUNT NUMBER	ACCOUNT DESCRIPTION	UNIT	QUANTITY	MATERIAL MAJOR COMPONENT	MATERIAL BAL OF PLT COST	INSTALLN COST	INDIRECT COST	CONTG	TOTAL COST
315.0	ACC. ELECTRIC SYSTEMS/EQUIP.	MWE	500.	0.	10000.	6698.	6030.	2273.	25000.
316.0	MISC. POWER PLANT EQUIP.	MWE	500.	0.	2225.	603.	543.	337.	3708.
317.0	MHD TOPPING CYCLE EQUIP.			113071.	5353.	15239.	13715.	8007.	155384.
317.1	COMBUSTION EQUIPMENT	MWE	500.	3034.	178.	188.	169.	0.	3570.
317.1.1	COMBUSTOR			3034.	178.	188.	169.	0.	3570.
317.1.2	COAL INJECTION SYSTEM							(INCL. IN	312.1.3)
317.1.3	SLAG COLLECTION SYSTEM							)INCL. IN	312.2)
317.2	MHD GENERATOR SYSTEM			3829.	225.	237.	214.	0.	4585.
317.2.1	NOZZLE	M	1.	98.	6.	6.	5.	0.	116.
317.2.2	CHANNEL	MWE	500.	3001.	177.	186.	167.	0.	3530.
317.2.3	DIFFUSER	MWE	500.	730.	43.	45.	41.	0.	859.
317.3	MAGNET SYSTEM	MJ	2864.	29215.	1719.	1808.	1629.	0.	34371.
317.4	INVERTER/ELCTD.CTRL SYSTEM	M	12.	21128.	1243.	1307.	1178.	0.	24857.
317.5	OXIDIZER SYSTEM			5529.	1987.	1137.	1023.	967.	10643.
317.5.1	OXIDANT COMPRESSORS	HP	59368.	5529.	0.	281.	253.	606.	6668.
317.5.2	OXIDANT HEATER							(INCL. IN	312.4.2)
317.5.3	OXIDANT DUCT.SYSTEM	M3/S	85.	0.	1987.	856.	770.	361.	3975.
317.6	SEED SYSTEM			13684.	0.	2872.	2583.	1914.	21052.
317.6.1	SEED REGENERATION SYSTEM	KG/S	2.	12193.	0.	2559.	2302.	1705.	18758.
317.6.2	SEED INJECTION SYSTEM	KG/S	5.	1492.	0.	313.	282.	209.	2295.
317.7	OXYGEN ENRICHMENT SYSTEM	TPD	4456.	36651.	0.	7691.	6919.	5125.	56386.
317.8	MISC.MHD TOP.CYCLE SUP.EQUIP								
350.0	TRANSMISSION PLANT	MWE	495.	0.	4946.	777.	700.	642.	7066.

MHD PROJECT COST ESTIMATE (DOLLARS X 10-3)

CASE8 36 PCT 6.0 ATM 01/31/83

ACCOUNT NUMBER	ACCOUNT DESCRIPTION	UNIT	QUANTITY	MATERIAL MAJOR COMPONENT	MATERIAL BAL OF PLT COST	INSTALLN COST	INDIRECT COST	CONTG	TOTAL COST
	SUBTOTALS			183404.	103757.	66966.	60269.	34706.	449102.
	ENGINEERING SERVICES								31417.
	OTHER COSTS								7854.
	TOTAL ESTIMATED OVERNIGHT CONSTRUCTION COSTS								488373.
	CONSTRUCTION PERIOD YEARS								5.5
	TOTAL ESTIMATED COST INCLUDING INTEREST AND ESCALATION DURING CONSTRUCTION								534671.

MHD PROJECT COST ESTIMATE (DOLLARS X 10-3)

CASE8 75 PCT 6.0 ATM 01/31/83

OPERATING AND MAINT. COSTS ($1000/YR)

LABOR	3791.
SEED	785.
LIME	779.
MATERIAL	6204.

COST OF ELECTRICITY (MILLS/KWHR)

CAPITAL	34.2
FUEL	28.1
O&M	8.2
COE	70.5

A3 - REFERENCE 200 MWe MHD/STEAM POWER PLANT

A3.1 Overall Performance

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE9 36 PCT 5.0 ATM 01/31/83

OVERALL SYSTEM PERFORMANCE ....

REFERENCE COAL	MONTANA ROSEBUD
COAL THERMAL INPUT (MWT)	483.24
PRIMARY CYCLE (MWT)	476.57
SEED REGENERATION (MWT)	6.6720
PLANT LIFE (YEARS)	
OPERATING MODE	
NET POWER OUTPUT (MWE)	195.43
PLANT EFFICIENCY (PCT)	40.441
THERMODYNAMIC EFFICIENCY (PCT)	26.747
MHD ENTHALPY EXTRACTION (PCT)	16.766
TOTAL HEAT INPUT TO STEAM (MWT)	375.31
STEAM CYCLE EFFICIENCY (PCT)	40.955
AIR PREHEAT TEMPERATURE (DEG K)	922.22
REFERENCE ATMOSPHERE	
PRESSURE (ATM)	1.0002
DRY BULB TEMPERATURE (DEG K)	288.00
RELATIVE HUMIDITY (PCT)	60.000
STEAM CONDITIONS	
MAIN TURBINE THROTTLE PRESSURE (ATM)	164.30
MAIN TURBINE THROTTLE TEMPERATURE (DEG K)	811.10
REHEAT TEMPERATURE (DEG K)	811.10
STEAM TURBINE/GENERATOR TOTAL POWER (MWE)	124.90
STEAM TUR/GEN COST ($1000) (ACCT. 314.1)	12944.
HEAT/SEED RECOVERY COST ($1000)(ACCT.312.3,4)	25492.
POWER TRAIN COST ($1000)(ACCT.317.)	75926.
STEAM BOTTOM PLANT COST($1000)(ACCT.312,314)	53968.
PLANT CAPITAL COST ($1000)	2.35666E+05
COST OF ELECTRICITY (MILLS/KWH)	88.842

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE9 36 PCT 5.0 ATM 01/31/83

POWER GENERATED AND CONSUMED ....

GROSS AC POWER (MWE)	
MHD POWER (AC)	77.984
STEAM TURBINE-GENERATOR POWER	124.90
TOTAL	202.81
POWER CONSUMED (MWE)	
SEC. AIR BLOWER	5.95965E-03
DRAFT FAN POWER	.12875
CONDENSATE PUMP	6.18220E-02
COOLING TWR CIRC PUMP	1.5173
COAL HANDLING AND PROCESSING	2.8118
ELECTROSTATIC PRECIP POWER	9.53140E-02
MHD MAGNET POWER	.14297
MISC. POWER	.63735
TRANSFORMER LOSS	1.9740
TOTAL	7.3753
NET POWER OUTPUT (MWE)	195.43

MECHANICAL DRIVE TURBINES (MW)

CYCLE AIR COMPRESSOR	16.062
OXYGEN PLANT POWER	13.332
BOILER FEED PUMPS	3.7103

A3 - REFERENCE 200 MWe MHD/STEAM POWER PLANT

A3.2 Component/Subsystem Information

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE9 36 PCT 5.0 ATM 01/31/83

COAL HANDLING AND PREPARATION ...

RAW COAL, AS RECEIVED	
SIZE (TOP SIZE AS DELIVERED, IN)	-I
MOISTURE CONTENT (PCT)	22.700
FLOW RATE (KG/S)	22.995
HIGH HEATING VALUE (J/KG)	2.07250E+07
COAL TO COMBUSTOR, AS FIRED	
SIZE (MESH, 70 PCT THRU)	0
MOISTURE CONTENT (PCT)	5.0000
FLOW RATE (KG/S)	18.710
FLOW CONTROL (PCT)	
TRANSPORT MEDIUM	COMB. GAS
MECHANISM	
RATIO	1.00000E-01
DRYING MEDIUM	
FLOW RATE (KG/S)	39.296
TEMPERATURE IN (DEG K)	644.40
TEMPERATURE OUT (DEG K)	377.70
HEAT REGUIRED FOR DRYING (MWT)	12.969
POWER REQUIREMENT (MWE)	2.8118
KEY COMPONENT	
MINIMUM USEFUL LIFE (YEARS)	
REPLACEMENT TIME (HRS)	
COST($1000) (ACCT. 312.1)	21286.

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE9 36 PCT 5.0 ATM 01/31/83

OXIDIZER SUPPLY ....

OXYGEN PLANT	
AMOUNT OF OXYGEN (PCT)	36.000
CONTAINED OXYGEN FLOW (TPD)	1851.9
EQUIVALENT PURE OXYGEN (TPD)	1640.8
O2 PREHEAT TEMP. (DEG K)	922.22
COST($1000) (ACCT. 317.7.2)	24317.

MAIN AIR COMPRESSOR	
TYPE OF COMPRESSOR	AXIAL FLOW
TYPE OF INTERCOOLING	NONE
AIR INLET CONDITIONS	
PRESSURE (ATM)	1.0002
TEMPERATURE (DEG K)	288.00
FLOW RATE (KG/S)	82.578
AIR OUTLET CONDITIONS	
PRESSURE (ATM)	5.1512
TEMPERATURE (DEG K)	482.17
ADIABATIC EFFICIENCY (PCT)	87.200
SHAFT POWER (MW)	16.062
LUBE SYSTEM POWER (MW)	0.
COST($1000) (ACCT. 317.5.7)	2961.4

SECONDARY AIR INJECTION	
LOCATION	
PRESSURE (ATM)	1.0027
TEMPERATURE (DEG K)	288.25
FLOW RATE (KG/S)	23.403
FAN EFFICIENCY (PCT)	80.000
POWER REQUIREMENT (MWE)	5.95965E-03
KEY COMPONENT	
MINIMUM USEFUL LIFE (YEARS)	
COST($1000) (ACCT. 312.4.5)	1009.4

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE9 36 PCT 5.0 ATM 01/31/83

SEED FEED AND MANAGEMENT ....

TYPE	
SEED FLOW, TOTAL (KG/S)	2.0934
POTASSIUM CARBONATE, K2CO3 (KG/S)	.66130
POTASSIUM SULFATE, K2SO4 (KG/S)	1.4321
POWER REQUIREMENT (MWE)	0.
TRANSPORT MECHANISM	
FLOW CONTROL (PCT)	
NUMBER OF MODULES	
KEY COMPONENT	
MINIMUM USEFUL LIFE (YEARS)	
REPLACEMENT TIME (HRS)	
COST ($1000) (ACCT.317.6.4)	1515.2

SEED RECOVERY/REGENERATION SYSTEM ...

TYPE	
RECOVERY (PCT)	95.000
REGENERATION (PCT)	33.300
TYPE OF REGENERATION PROCESS	FORMATE
POWER REQUIREMENTS (MWE)	0.
KEY COMPONENT	
MINIMUM USEFUL LIFE (YEARS)	
COST ($1000) (ACCT. 316.1-.3)	8511.1

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE9 36 PCT 5.0 ATM 01/31/83

MAIN COMBUSTOR ....

TYPE-NUMBER OF STAGES	2	
DIMENSIONS	1ST STAGE	2ND STAGE
LENGTH (M)	3.4466	4.5030
DIAMETER (M)	1.8732	1.1257
VOLUME (M**3)	9.4840	5.7066
WEIGHT (KG)	3335.6	
COMBUSTOR EXIT CONDITIONS		
PRESSURE (ATM)	4.8511	
TEMPERATURE (DEG K)	2795.0	
FLOW RATE (KG/S)	103.95	
SLAG REMOVAL (PCT)	85.000	
RESIDENCE TIME (MICRO-SEC)		
1-ST STAGE		
2-ND STAGE		
COMBUSTOR HEAT LOSSES (MWT)	31.454	
COOLING WATER INLET		
PRESSURE (ATM)	190.50	
TEMPERATURE (DEG K)	588.90	
QUALITY	0.	
FLOW RATE (KG/S)	143.03	
COOLING WATER EXIT		
PRESSURE (ATM)	187.10	
TEMPERATURE (DEG K)	504.12	
QUALITY	0.	
NUMBER OF MODULES	1	
COST ($1000) (ACCT.317.1.6,312.4.6)	2972.0	

NOZZLE ....

LENGTH (M)	1.6328
WEIGHT (KG)	1324.4
NOZZLE EXIT MACH NUMBER	.87500
NOZZLE HEAT LOSS (MWT)	5.5500
NUMBER OF MODULES	
MINIMUM USEFUL LIFE (YEARS)	
COST($1000) (ACCT.317.2.1)	65.906

CASE9 36 PCT 5.0 ATM 01/31/83

CHANNEL ....

TYPE	DIAGONAL		
DIMENSIONS			
INLET (MXM)	.54427	X	.54427
OUTLET (MXM)	1.1766	X	1.1766
LENGTH (M)	10.646		
WEIGHT (KG)	19015.		
NUMBER OF ELECTRODE PAIRS	7.09750E+02		
SLAG REMOVAL (PCT)			
ENTHALPY EXTRACTION (PCT)	16.766		
OVERALL (TURBINE) EFFICIENCY (PCT)	75.204		
INLET CONDITIONS			
PRESSURE (ATM)	3.1793		
TEMPERATURE (DEG K)	2664.3		
MACH NUMBER	.87500		
VELOCITY (M/S)	798.76		
FLOW RATE (KG/S)	103.95		
OUTLET CONDITIONS			
PRESSURE (ATM)	.74019		
TEMPERATURE (DEG K)	2277.6		
MACH NUMBER	.87977		
SURFACE TEMPERATURE (DEG K)	1800.0		
HEAT LOSS (MWT)	20.522		
PEAK ELECTRODE CURRENT DENSITY (A/CM**2)			
MAXIMUM HALL FIELD (KV/M)	2.5000		
COOLING WATER INLET			
PRESSURE (ATM)			
TEMPERATURE (DEG K)	346.37		
QUALITY	0.		
FLOW RATE (KG/S)	103.12		
COOLING WATER EXIT			
PRESSURE (ATM)	5.1024		
TEMPERATURE (DEG K)	400.00		
QUALITY	0.		
NUMBER OF CHANNELS	1		
MHD GROSS POWER BEFORE INVERSION (MWE)	79.902		
MHD GROSS POWER AFTER INVERSION (MWE)	77.904		
INVERTER EFFICIENCY (PCT)	97.500		
COST ($1000) (ACCT.317.2.2..3)	2617.5		

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE9 36 PCT 5.0 ATM 01/31/83

DIFFUSER AND TRANSITION PIECE ....

TYPE			
DIMENSIONS			
INLET (MXM)	1.1766	X	1.1766
OUTLET (MXM)	3.7652	X	3.7652
LENGTH (M)	12.472		
WEIGHT (KG)	30364.		
PRESSURE RECOVERY COEFFICIENT	.60000		
INLET CONDITIONS			
PRESSURE (ATM)	.74019		
TEMPERATURE (DEG K)	2277.6		
MACH NUMBER	.87977		
FLOW RATE (KG/S)	103.95		
OUTLET CONDITIONS - DIFFUSER			
PRESSURE (ATM)	.98384		
TEMPERATURE (DEG K)	2397.2		
MACH NUMBER	.40000		
SURFACE TEMPERATURE (DEG K)			
HEAT LOSS (MWT)	0.		
COOLING WATER INLET			
PRESSURE (ATM)	186.05		
TEMPERATURE (DEG K)	627.80		
FLOW RATE (KG/S)	46.513		
COOLING WATER EXIT			
PRESSURE (ATM)	183.67		
TEMPERATURE (DEG K)	633.10		
BOUNDARY LAYER CONTROLS			
MINIMUM USEFUL LIFE (YEARS)			
COST ($1000) (ACCT.317.2.4)	701.90		

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE9 36 PCT 5.0 ATM 01/31/83

MAGNET ....

TYPE	
DIMENSIONS	
LENGTH (M)	12.030
OVERALL DIAMETER (M)	6.0151
WARM BORE	
INLET DIAMETER (M)	1.3354
OUTLET DIAMETER (M)	1.9844
FIELD STRENGTH (TESLA)	
PEAK	6.0000
AVERAGE	
CURRENT DENSITY (A/CM**2)	
ENERGY STORAGE (MJ)	1529.8
WEIGHT (KG)	5.90512E+05
COST ($1000) (ACCT.317.3)	18358.

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE9 36 PCT 5.0 ATM 01/31/83

RADIANT BOILER ....

TYPE			
DIMENSIONS			
INLET (MXM)	13.415	X	19.400
OUTLET (MXM)	13.415	X	19.400
LENGTH (M)	21.200		
WEIGHT (KG)	5.00000E+05		
EFFICIENCY (PCT)	0.		
COMBUSTION GAS INLET CONDITIONS			
PRESSURE (ATM)	.98384		
TEMPERATURE (DEG K)	2388.1		
FLOW RATE (KG/S)	103.95		
COMBUSTION GAS OUTLET CONDITIONS			
PRESSURE (ATM)	.95432		
TEMPERATURE (DEG K)	1867.0		
DWELL TIME (SEC)	2.5000		
HEAT TRANSFER AREA (M**2)			
SLAG REMOVAL (PCT)			
MAXIMUM TEMP GRADIENT (DEG K/SEC)			
WATER/STEAM INLET CONDITIONS			
PRESSURE (ATM)	183.70		
TEMPERATURE (DEG K)	604.12		
QUALITY	0.		
FLOW RATE (KG/S)	143.03		
WATER/STEAM EXIT CONDITIONS			
PRESSURE (ATM)	183.70		
TEMPERATURE (DEG K)	633.10		
QUALITY	1.0000		
THERMAL DUTY (MWT)	97.178		
MINIMUM USEFUL LIFE (YEARS)			
COST($1000) (ACCT.312.3.1)	2752.0		

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE9 36 PCT 5.0 ATM 01/31/83

HIGH TEMPERATURE AIR HEATER ....

TYPE		
NUMBER OF MODULES	0	
DIMENSIONS		
HEIGHT (M)		-I
DIAMETER (M)		-I
FLOW AREA (M**2)		-I
WEIGHT (KG)		
SLAG REMOVAL (PCT)		
COMBUSTION GAS INLET CONDITIONS		
PRESSURE (ATM)		-I
TEMPERATURE (DEG K)		-I
FLOW RATE (KG/S)		-I
COMBUSTION GAS OUTLET CONDITIONS		
PRESSURE (ATM)		-I
TEMPERATURE (DEG K)		-I
AIR INLET CONDITIONS		
PRESSURE (ATM)		-I
TEMPERATURE (DEG K)		-I
FLOW RATE (KG/S)		-I
AIR OUTLET CONDITIONS		
PRESSURE (ATM)		-I
TEMPERATURE (DEG K)		-I
VELOCITY (M/S)		
DWELL TIME (SEC)		
LOSSES		
VALVE LEAKAGE (PCT)		-I
VALVE COOLING (MWT)		-I
CORE HEAD LOSS (MWT)		-I
THERMAL DUTY (MWT)	0.	
MINIMUM USEFUL LIFE (YEARS)		
COST($1000) (ACCT.317.5.2--4)	0.	

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE9 36 PCT 5.0 ATM 01/31/83

SUPERHEATER ....

TYPE		
DIMENSIONS		
LENGTH (M)		-I
WIDTH (M)		-I
HEIGHT (M)		-I
WEIGHT (KG)		
COMBUSTION GAS INLET CONDITIONS		
PRESSURE (ATM)	.95432	
TEMPERATURE (DEG K)	1977.7	
FLOW RATE (KG/S)	127.35	
COMBUSTION GAS OUTLET CONDITIONS		
PRESSURE (ATM)	.95432	
TEMPERATURE (DEG K)	644.40	
SLAG REMOVAL (PCT)		
WATER/STEAM INLET CONDITIONS		
PRESSURE (ATM)	183.70	
TEMPERATURE (DEG K)	633.10	
FLOW RATE (KG/S)	143.03	
WATER/STEAM OUTLET CONDITIONS		
PRESSURE (ATM)	164.30	
TEMPERATURE (DEG K)	811.10	
THERMAL DUTY (MWT)	148.24	
COST ($1000) (ACCT.312.4.3)	4428.8	

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE9 36 PCT 5.0 ATM 01/31/83

REHEATER ....

TYPE	
DIMENSIONS	
LENGTH (M)	-I
WIDTH (M)	-I
HEIGHT (M)	-I
WEIGHT (KG)	
COMBUSTION GAS INLET CONDITIONS	
PRESSURE (ATM)	.95432
TEMPERATURE (DEG K)	1977.7
FLOW RATE (KG/S)	127.35
COMBUSTION GAS OUTLET CONDITIONS	
PRESSURE (ATM)	.95432
TEMPERATURE (DEG K)	644.40
SLAG REMOVAL (PCT)	
WATER/STEAM INLET CONDITIONS	
PRESSURE (ATM)	43.425
TEMPERATURE (DEG K)	620.55
FLOW RATE (KG/S)	114.75
WATER/STEAM OUTLET CONDITIONS	
PRESSURE (ATM)	41.253
TEMPERATURE (DEG K)	811.10
THERMAL DUTY (MWT)	51.682
COST ($1000) (ACCT.312.4.4)	6163.3

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE9 36 PCT 5.0 ATM 01/31/83

OXIDANT PREHEATER ....

TYPE		
DIMENSIONS		
LENGTH (M)		-I
WIDTH (M)		-I
HEIGHT (M)		-I
WEIGHT (KG)		
COMBUSTION GAS INLET CONDITIONS		
PRESSURE (ATM)	.95432	
TEMPERATURE (DEG K)	1977.7	
FLOW RATE (KG/S)	127.35	
COMBUSTION GAS OUTLET CONDITIONS		
PRESSURE (ATM)	.95432	
TEMPERATURE (DEG K)	644.40	
AIR INLET CONDITIONS		
PRESSURE (ATM)	5.1512	
TEMPERATURE (DEG K)	482.17	
FLOW RATE (KG/S)	82.578	
AIR OUTLET CONDITIONS		
PRESSURE (ATM)	5.0011	
TEMPERATURE (DEG K)	922.22	
THERMAL DUTY (MWT)	38.901	
COST ($1000) (ACCT.317.5.5)	1131.2	

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE9 36 PCT 5.0 ATM 01/31/83

ECONOMIZER NO. 1....

DIMENSIONS	
LENGTH (M)	26.797
WIDTH (M)	5.9897
HEIGHT (M)	5.9897
WEIGHT (KG)	
COMBUSTION GAS INLET CONDITIONS	
PRESSURE (ATM)	.95432
TEMPERATURE (DEG K)	644.40
FLOW RATE (KG/S)	66.659
COMBUSTION GAS OUTLET CONDITIONS	
PRESSURE (ATM)	.95432
TEMPERATURE (DEG K)	425.00
WATER/STEAM INLET CONDITIONS	
PRESSURE (ATM)	205.42
TEMPERATURE (DEG K)	414.05
FLOW RATE (KG/S)	19.922
WATER/STEAM OUTLET CONDITIONS	
PRESSURE (ATM)	205.42
TEMPERATURE (DEG K)	588.90
THERMAL DUTY (MWT)	16.209
COST ($1000) (ACCT.312.4.1)	10007.

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE9 36 PCT 5.0 ATM 01/31/83

GAS CLEAN UP ....

TYPES	
LOCATIONS	
LOSSES	
PRESSURE (PCT)	
THERMAL (MWT)	
REMOVAL EFFICIENCY (PCT)	
POWER REQUIRED (MWE)	9.53140E-02
MINIMUM USEFUL LIFE (YEARS)	
COST($1000) (ACCT.312.5.1)	4484.0
STACK COST ($1000)(ACCT.312.5.3)	1841.5

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE9 36 PCT 5.0 ATM 01/31/83

EXHAUST EMISSIONS ....

PARTICULATE (G/J)
NOX (G/J)
SOX (G/J)
TRACE ELEMENTS (G/J)

PLANT COOLING ....

TYPE	
NUMBER OF MODULES	
DIMENSIONS	
HEIGHT (M)	
DIAMETER (M)	
CONDENSER PRESSURE (ATM)	6.70121E-02
THERMAL DUTY (MWT)	216.76
TEMPERATURE (DEG K)	311.61
COOLING WATER	
FLOW RATE (KG/S)	-I
MAKE UP (PCT)	
POWER REQUIREMENTS (MWE)	1.5173
MINIMUM USEFUL LIFE (YEARS)	
COST ($1000)	
HEAT REJECTION COST($1000)(ACCT. 314.3)	7209.5
CONDENSER COST($1000)(ACCT.314.2)	2290.6

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE9 36 PCT 5.0 ATM 01/31/83

OTHER PLANT COSTS ....

LAND AND LAND RIGHTS	
COST/ACRE ($1000)	5.0000
COST ($1000) (ACCT.310.)	1576.4
STRUCTURES AND IMPROVEMENTS	
IMPROVEMENTS TO SITE($1000)(ACT.311.12)	7418.4
BUILDINGS & STRUCTURE COST ($1000)(ACCT.311.2)	30494.
BOILER PLANT EQUIPMENT	
COAL HAND. & PROCESS COST ($1000)(ACCT.312.1)	21286.
ASH AND SLUDGE COST ($1000) (ACCT. 312.2)	6986.4
WATER TREATMENT COST($1000)	3957.9
DEAERATOR COST ($1000)	112.96
FEEDWATER SYSTEM COST($1000)	1698.3
DRAFT FAN AND DUCT COST ($1000)	783.46
STEAM PIPE/VALVE COST($1000)(ACCT. 314.4)	7157.2
ACC. ELECTRICAL EQUIP. COST ($1000)(ACT. 315.)	10000.
MISC. POWER PLANT EQUIP. COST ($1000)(ACCT.316)	2139.7
TRANSMISSION PLANT COST ($1000)(ACT. 350)	4046.5
POWER CONSOLIDATION COST ($1000)(ACCT.317.4)	10157.

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE9 36 PCT 5.0 ATM 01/31/83

OTHER PLANT COSTS ....

AUXILIARY BOILER COST($1000)(ACT.312.6)	133.25
BOILER PLANT VALVE COST($1000)(ACT.312.71)	2947.5
MISC. BOILER PLANT COST($1000)(ACT.312.72)	1085.1
MISC. BOILER PLANT COST($1000)	8156.6
FEEDWATER PUMP COSTS($1000)	1302.3
OTHER TURBINE EQUIP. COST($1000)(ACT.314.5)	1154.1
OXIDENT DUCT SYS. COST ($1000)(ACT.317.53)	2618.4
LAND FILL COST ($1000)(ACT. 311.11)	2330.6
ENGINEERING SERVICE COST ($1000)	16908.
ESCAL. & INT. DURING CONST. ($1000)	24345.
TOTAL PLANT COST ($1000)	2.81146E+05

FUEL COST (MILLS/KWH)	29.597
LIME COST ($/YEAR)	323.81
OPER. & MAINT. COSTS (MIL/KWH)	13.768
CAPITAL COSTS (MILLS/KWH)	45.477
SEED MAKEUP COST	326.43
CREW COST	2979.0
O & M MATERIAL COST	1.39829E+06

A3 - REFERENCE 200 MWe MHD/STEAM POWER PLANT

A3.3 Plant Cost Accounts Summary

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE 9 36 PCT 5.0 ATM 01/31/83

ACCOUNT NO.	DESCRIPTION	COST BASIS UNIT	TOTAL COST ($1000)
310.0	LAND COSTS	KG/S	1576.4
311.0	STRUCTURES AND IMPROVEMENTS	KG/S	38353.
311.1	IMPROVEMENTS TO SITE	KG/S	9749.0
311.1.1	WASTE DISPOSAL LAND FILL AREA	KG/S	2330.6
311.1.2	OTHER YARD WORK	KG/S	7418.4
311.2	MAIN BUILDING	KG/S	12716.
311.2.1	MHD BUILDING	KG/S	5275.5
311.2.2	HRSR BUILDING	KG/S	6617.2
311.2.3	POWER COND. SYSTEM BLDG.	KG/S	2409.0
311.2.4	MAGNET REFRIG. SYS. BLDG.	KG/S	304.94
311.3	STEAM TURBINE BLDG.	KG/S	6007.3
311.3.1	STEAM TURBINE-GENERATOR BUILDING	KG/S)	6007.3
311.3.2	STEAM TURBINE-COMPRESSOR BLDG.		(INCL. IN 317.7)
311.4	COAL BUNKER/PROCESSING AREA	KG/S	3140.9
311.5	SERVICE BUILDINGS	KG/S	3232.4
311.6	OTHER PROCESS BLDG. AND STRUCTURES	KG/S	3506.8
312.0	BOILER PLANT EQUIPMENT	KG/S	72111.
312.1	COAL HANDLING AND PROCESSING	KG/S	21286.
312.1.1	UNLOAD/STORE/RECLAIM SYSTEM	KG/S	7827.0
312.1.2	PULVERIZING/DRYING SYSTEM	KG/S	9393.7
312.1.3	FEED SYSTEM	KG/S	4065.7
312.2	SLAG AND ASH HANDLING	KG/S	6986.4
312.3	RADIANT BOILER	MWT	2752.0
312.4	STEAM GENERATOR SECTIONS	MWT	22740.
312.4.1	SUPERHEATR/REHEATER	MWT	10592.
312.4.2	OXIDANT PREHEATER	MWT	1131.2
312.4.3	ECONOMIZER/SECONDARY AIR HEATER	MWT,KG/S	11016.
312.5	EFFLUENT CONTROL		7108.9
312.5.1	ELECTROSTATIC PRECIPITATOR	M3/S	4484.0
312.5.2	FANS, DUCTING, STACK	MWE,M3/S	2624.9
312.6	AUXILIARY BOILER SYSTEMS	MWT	133.25
312.7	OTHER BOILER PLANT SYSTEMS		11104.
312.7.1	PIPING/VALVES/TANKS	KG/S	2947.5
312.7.2	MISCELLANEOUS BOILER PLANT	KG/S	8156.6

CASE9 36 PCT 5.0 ATM 01/31/83

ACCOUNT NO.	DESCRIPTION	COST BASIS UNIT	TOTAL COST ($1000)
314.0	TURBOGENERATOR UNITS		30756.
314.1	STEAM TURBINE GN/ACCESSORIES	MWE	12944.
314.2	CONDENSERS/AUXILIARIES	MWT	2299.6
314.3	CIRCULATING WATER SYSTEM		7209.5
314.3.1	COOLING TOWERS (INC.BASIN)	MWT	4159.9
314.3.2	CIRC. WATER PUMPS/PIPING	MWT	3049.6
314.4	STEAM PIPING SYSTEMS	KG/S	7157.2
314.4.1	FEEDWATER PIPING	KG/S	2100.6
314.4.2	STEAM PIPING	KG/S	2457.1
314.4.3	OTHER STEAM PLANT PIPING	KG/S	2599.5
314.5	OTHER TURBINE PLANT EQUIPMENT	KG/S	1154.1
315.0	ACCESSORY ELECTRIC SYSTEMS/EQUIP.	MWE	10000.
316.0	MISCELLANEOUS POWER PLANT EQUIP.	MWE	2139.7
317.0	MHD TOPPING CYCLE EQUIPMENT		74795.
317.1	COMBUSTION EQUIPMENT	MWE	2972.0
317.1.1	COMBUSTOR		2972.0
317.1.2	COAL INJECTION SYSTEM		(INCL. IN 312.1.3)
317.1.3	SLAG COLLECTION SYSTEM		(INCL. IN 312.2)
317.2	MHD GENERATOR SYSTEM		3385.3
317.2.1	NOZZLE	M	65.906
317.2.2	CHANNEL	MWE,M2	2617.5
317.2.3	DIFFUSER	MWE	701.90
317.3	MAGNET SYSTEM	MJ	18358.
317.4	INVERTER/ELECTRODE CONTROL SYSTEM	M,KWE	10157.
317.5	OXIDIZER SYSTEM		5579.8
317.5.1	OXIDANT COMPRESSORS	HP	2961.4
317.5.2	OXIDANT HEATER		(INCL. IN 312.4.2)
317.5.3	AIR/OXYGEN/OXIDANT SYSTEM DUCTING	M3/S	2618.4
317.6	SEED SYSTEM		10026.
317.6.1	SEED REGENERATION SYSTEM	KG/S	8511.1
317.6.2	SEED INJECTION SYSTEM	KG/S	1515.2
317.7	OXYGEN ENRIHMENT SYSTEM	TPD	24317.
317.8	MISC. MHD TOP. CYCLE SUP. EQUIP.		
350.0	TRANSMISSION PLANT	MWE	4046.5

A3 - REFERENCE 200 MWe MHD/STEAM POWER PLANT

A3.4 Plant Costing Details and Cost of Electricity

MHD PROJECT COST ESTIMATE (DOLLARS X 10-3)

CASE9 75 PCT 5.0 ATM 01/31/83

ACCOUNT NUMBER	ACCOUNT DESCRIPTION	UNIT	QUANTITY	MATERIAL MAJOR COMPONENT	MATERIAL BAL OF PLT COST	INSTALLN COST	INDIRECT COST	CONTG	TOTAL COST
310.0	LAND AND LAND RIGHTS	KG/S	19.	0.	1433.	0.	0.	143.	1576.
311.0	STRUCTURES AND IMPROVEMENTS	KG/S	19.	0.	16943.	10338.	9305.	3658.	40243.
311.1	IMPROVEMENTS TO SITE	KG/S	19.	0.	2925.	3126.	2813.	886.	9749.
311.1.1	WASTE DISP.LAND FILL AREA	KG/S	19.	0.	699.	747.	672.	212.	2331.
311.1.2	OTHER YARD WORK	KG/S	19.	0.	2226.	2378.	2140.	674.	7418.
311.2	MAIN BUILDING	KG/S	19.	0.	7303.	3145.	2831.	1328.	14607.
311.2.1	MHD BUILDING	KG/S	19.	0.	2638.	1136.	1022.	480.	5275.
311.2.2	HRSR BUILDING	KG/S	19.	0.	3309.	1425.	1282.	602.	6617.
311.2.3	POWER COND. SYSTEM BLDG.	KG/S	19.	0.	1205.	519.	467.	219.	2409.
311.2.4	MAGNET REFRIGN. SYS. BLDG.	KG/S	19.	0.	152.	66.	59.	28.	305.
311.3	STEAM TURBINE BUILDING	KG/S	19.	0.	2403.	1609.	1449.	546.	6007.
311.3.1	STEAM TURB.-GEN. BUILDING	KG/S	19.	0.	2403.	1609.	1449.	546.	6007.
311.3.2	STEAM TURB.-COMPR. BLDG.							(INCL. IN 317.7)	
311.4	COAL BUNKER/PROCESSING AREA	KG/S	19.	0.	942.	1007.	906.	286.	3141.
311.5	SERVICE BUILDINGS	KG/S	19.	0.	1616.	696.	626.	294.	3232.
311.6	OTHER PRCS. BLDG. AND STRUC.	KG/S	19.	0.	1753.	755.	680.	319.	3507.
312.0	BOILER PLANT EQUIPMENT	KG/S	19.	25318.	19676.	10823.	9739.	6555.	72111.
312.1	COAL HANDLING AND PROCSG.	KG/S	19.	8749.	4696.	3109.	2797.	1935.	21286.
312.1.1	UNLOAD/STORE/RECLAIM SYS.	KG/S	19.	0.	4696.	1273.	1146.	711.	7827.
312.1.2	PULVERIZING/DRYING SYSTEM	KG/S	19.	6106.	0.	1281.	1153.	854.	9394.
312.1.3	FEED SYSTEM	KG/S	19.	2643.	0.	555.	499.	370.	4066.
312.2	SLAG AND ASH HANDLING	KG/S	19.	0.	4890.	768.	692.	635.	6986.
312.3	RADIANT BOILER	MWT	97.	1789.	0.	375.	338.	250.	2752.

MHD PROJECT COST ESTIMATE (DOLLARS X 10-3)

CASE9 36 PCT 5.0 ATM 01/31/83

ACCOUNT NUMBER	ACCOUNT DESCRIPTION	UNIT	QUANTITY	MATERIAL MAJOR COMPONENT	MATERIAL BAL OF PLT COST	INSTALLN COST	INDIRECT COST	CONTG	TOTAL COST
312.4	STEAM GENERATOR SECTIONS	MWT		14781.	0.	3102.	2790.	2067.	22740.
312.4.1	SUPERHEATER/REHEATER	MWT	200.	6885.	0.	1445.	1300.	963.	10592.
312.4.2	OXIDANT PREHEATER	MWT	39.	735.	0.	154.	139.	103.	1131.
312.4.3	ECONOMIZER/SECDARY AIR HTR	MWT	16.	7161.	0.	1503.	1352.	1001.	11016.
312.5	EFFLUENT CONTROL			0.	3347.	1640.	1476.	646.	7109.
312.5.1	ELECTROSTATIC PRECIPITATOR	M3/S	215.	0.	2690.	730.	656.	408.	4484.
312.5.2	FANS/DUCTING/STACK	MWE	200.	0.	656.	911.	819.	239.	2625.
312.6	AUXILIARY BOILER SYSTEMS	MWT	200.	0.	80.	22.	20.	12.	133.
312.7	OTHER BOILER PLANT SYSTEMS			0.	6662.	1807.	1626.	1009.	11104.
312.7.1	PIPING/VALVES/TANKS	KG/S	143.	0.	1768.	480.	432.	268.	2947.
312.7.2	MISC. BOILER PLANT	KG/S	143.	0.	4894.	1327.	1194.	741.	8157.
314.0	TURBOGENERATOR UNITS			10732.	9839.	3889.	3500.	2796.	30756.
314.1	STEAM TURBINE GN/ACCES.	MWE	125.	10732.	0.	545.	491.	1177.	12944.
314.2	CONDENSERS/AUXILIARIES	MWT	217.	0.	1374.	373.	335.	208.	2291.
314.3	CIRCULATING WATER SYSTEM			0.	4021.	1333.	1200.	655.	7210.
314.3.1	COOLING TOWERS (INC.BASIN)	MWT	217.	0.	2496.	677.	609.	378.	4160.
314.3.2	CIRC. WATER PUMPS/PIPING	MWT	217.	0.	1525.	657.	591.	277.	3050.
314.4	STEAM PIPING SYSTEMS	KG/S	143.	0.	3579.	1541.	1387.	651.	7157.
314.4.1	FEEDWATER PIPING	KG/S	143.	0.	1050.	452.	407.	191.	2101.
314.4.2	STEAM PIPING	KG/S	143.	0.	1229.	529.	476.	223.	2457.
314.4.3	OTER STEAM PLANT PIPING	KG/S	143.	0.	1300.	560.	504.	236.	2600.
314.5	OTHER TURBINE PLANT EQUIP.	KG/S	143.	0.	866.	97.	87.	105.	1154.

MHD PROJECT COST ESTIMATE (DOLLARS X 10-3)

CASE9 36 PCT 5.0 ATM 01/31/83

ACCOUNT NUMBER	ACCOUNT DESCRIPTION	UNIT	QUANTITY	MATERIAL MAJOR COMPONENT	MATERIAL BAL OF PLT COST	INSTALLN COST	INDIRECT COST	CONTG	TOTAL COST
315.0	ACC. ELECTRIC SYSTEMS/EQUIP.	MWE	200.	0.	4000.	2679.	2412.	909.	10000.
316.0	MISC. POWER PLANT EQUIP.	MWE	200.	0.	1284.	348.	313.	194.	2140.
317.0	MHD TOPPING CYCLE EQUIP.			54419.	3053.	7207.	6486.	3629.	74795.
317.1	COMBUSTION EQUIPMENT	MWE	200.	2526.	149.	156.	141.	0.	2972.
317.1.1	COMBUSTOR			2526.	149.	156.	141.	0.	2972.
317.1.2	COAL INJECTION SYSTEM							(INCL. IN 312.1.3)	
317.1.3	SLAG COLLECTION SYSTEM							)INCL. IN 312.2)	
317.2	MHD GENERATOR SYSTEM			2878.	169.	178.	160.	0.	3385.
317.2.1	NOZZLE	M	1.	56.	3.	3.	3.	0.	66.
317.2.2	CHANNEL	MWE	200.	2225.	131.	138.	124.	0.	2617.
317.2.3	DIFFUSER	MWE	200.	597.	35.	37.	33.	0.	702.
317.3	MAGNET SYSTEM	MJ	1530.	15604.	918.	966.	870.	0.	18358.
317.4	INVERTER/ELCTD.CTRL SYSTEM	M	11.	8633.	508.	534.	481.	0.	10157.
317.5	OXIDIZER SYSTEM			2455.	1309.	688.	620.	507.	5580.
317.5.1	OXIDANT COMPRESSORS	HP	21523.	2455.	0.	125.	112.	269.	2961.
317.5.2	OXIDANT HEATER							(INCL. IN 312.4.2)	
317.5.3	OXIDANT DUCT.SYSTEM	M3/S	42.	0.	1309.	564.	507.	238.	2618.
317.6	SEED SYSTEM			6517.	0.	1368.	1230.	911.	10026.
317.6.1	SEED REGENERATION SYSTEM	KG/S	1.	5532.	0.	1161.	1044.	774.	8511.
317.6.2	SEED INJECTION SYSTEM	KG/S	2.	985.	0.	207.	186.	138.	1515.
317.7	OXYGEN ENRICHMENT SYSTEM	TPD	1852.	15806.	0.	3317.	2984.	2210.	24317.
317.8	MISC.MHD TOP.CYCLE SUP.EQUIP								
350.0	TRANSMISSION PLANT	MWE	195.	0.	2833.	445.	401.	368.	4047.

MHD PROJECT COST ESTIMATE (DOLLARS X 10-3)

CASE9 36 PCT 5.0 ATM 01/31/83

ACCOUNT NUMBER	ACCOUNT DESCRIPTION	UNIT	QUANTITY	MATERIAL MAJOR COMPONENT	MATERIAL BAL OF PLT COST	INSTALLN COST	INDIRECT COST	CONTG	TOTAL COST
	SUBTOTALS			90469.	59060.	35729.	32156.	18252.	235666.
	ENGINEERING SERVICES								16908.
	OTHER COSTS								4227.
	TOTAL ESTIMATED OVERNIGHT CONSTRUCTION COSTS								256801.
	CONSTRUCTION PERIOD YEARS								5.5
	TOTAL ESTIMATED COST INCLUDING INTEREST AND ESCALATION DURING CONSTRUCTION								281146.

MHD PROJECT COST ESTIMATE (DOLLARS X 10-3)

CASE 9 36 PCT 5.0 ATM 01/31/83

OPERATING AND MAINT. COSTS ($1000/YR)

LABOR	2979.
SEED	326.
LIME	324.
MATERIAL	4016.

COST OF ELECTRICITY (MILLS/KWHR)

CAPITAL	45.5
FUEL	29.6
O&M	13.8
COE	88.8

A4 - SUPERSONIC CHANNEL 200 MWe MHD/STEAM POWER PLANT

A4.1 Overall Performance

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE 10 36 PCT 5.0 ATM 200 MW REF9008

OVERALL SYSTEM PERFORMANCE ....

REFERENCE COAL	MONTANA ROSEBUD
COAL THERMAL INPUT (MWT)	483.24
PRIMARY CYCLE (MWT)	476.57
SEED REGENERATION (MWT)	6.6720
PLANT LIFE (YEARS)	
OPERATING MODE	
NET POWER OUTPUT (MWE)	193.16
PLANT EFFICIENCY (PCT)	39.971
THERMODYNAMIC EFFICIENCY (PCT)	25.704
MHD ENTHALPY EXTRACTION (PCT)	15.521
TOTAL HEAT INPUT TO STEAM (MWT)	381.63
STEAM CYCLE EFFICIENCY (PCT)	41.383
AIR PREHEAT TEMPERATURE (DEG K)	922.22
REFERENCE ATMOSPHERE	
PRESSURE (ATM)	1.0002
DRY BULB TEMPERATURE (DEG K)	288.00
RELATIVE HUMIDITY (PCT)	60.000
STEAM CONDITIONS	
MAIN TURBINE THROTTLE PRESSURE (ATM)	164.30
MAIN TURBINE THROTTLE TEMPERATURE (DEG K)	811.10
REHEAT TEMPERATURE (DEG K)	811.10
STEAM TURBINE/GENERATOR TOTAL POWER (MWE)	129.10
STEAM TUR/GEN COST ($1000) (ACCT. 314.1)	13283.
HEAT/SEED RECOVERY COST ($1000)(ACCT.312.3,4)	25274.
POWER TRAIN COST ($1000)(ACCT.317.)	70580.
STEAM BOTTOM PLANT COST($1000)(ACCT.312,314)	54381.
PLANT CAPITAL COST ($1000)	2.31910E+05
COST OF ELECTRICITY (MILLS/KWH)	88.426

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE 10 36 PCT 5.0 ATM 200 MW REF9008

POWER GENERATED AND CONSUMED ....

GROSS AC POWER (MWE)	
MHD POWER (AC)	71.402
STEAM TURBINE-GENERATOR POWER	129.10
TOTAL	200.50
POWER CONSUMED (MWE)	
SEC. AIR BLOWER	5.95965E-03
DRAFT FAN POWER	.12888
CONDENSATE PUMP	6.23788E-02
COOLING TWR CIRC PUMP	1.5311
COAL HANDLING AND PROCESSING	2.8118
ELECTROSTATIC PRECIP POWER	9.53140E-02
MHD MAGNET POWER	.14297
MISC. POWER	.61250
TRANSFORMER LOSS	1.9511
TOTAL	7.3419
NET POWER OUTPUT (MWE)	193.16

MECHANICAL DRIVE TURBINES (MW)

CYCLE AIR COMPRESSOR	16.067
OXYGEN PLANT POWER	13.351
BOILER FEED PUMPS	3.8303

A4 - SUPERSONIC CHANNEL 200 MWe MHD/STEAM POWER PLANT

A4.2 Component/Subsystem Information

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE 10 36 PCT 5.0 ATM 200 MW REF9008

COAL HANDLING AND PREPARATION ...

RAW COAL, AS RECEIVED	
SIZE (TOP SIZE AS DELIVERED, IN)	-I
MOISTURE CONTENT (PCT)	22.700
FLOW RATE (KG/S)	22.995
HIGH HEATING VALUE (J/KG)	2.07250E+07
COAL TO COMBUSTOR, AS FIRED	
SIZE (MESH, 70 PCT THRU)	0
MOISTURE CONTENT (PCT)	5.0000
FLOW RATE (KG/S)	18.710
FLOW CONTROL (PCT)	
TRANSPORT MEDIUM	COMB. GAS
MECHANISM	
RATIO	1.00000E-01
DRYING MEDIUM	
FLOW RATE (KG/S)	39.296
TEMPERATURE IN (DEG K)	644.40
TEMPERATURE OUT (DEG K)	377.70
HEAT REQUIRED FOR DRYING (MWT)	12.969
POWER REQUIREMENT (MWE)	2.8118
KEY COMPONENT	
MINIMUM USEFUL LIFE (YEARS)	
REPLACEMENT TIME (HRS)	
COST($1000) (ACCT. 312.1)	21286.

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE 10 36 PCT 5.0 ATM 200 MW REF9008

OXIDIZER SUPPLY	
OXYGEN PLANT	
AMOUNT OF OXYGEN (PCT)	35.944
CONTAINED OXYGEN FLOW (TPD)	1854.6
EQUIVALENT PURE OXYGEN (TPD)	1643.2
O2 PREHEAT TEMP. (DEG K)	922.22
COST($1000) (ACCT. 317.7.2)	24345.
MAIN AIR COMPRESSOR	
TYPE OF COMPRESSOR	AXIAL FLOW
TYPE OF INTERCOOLING	NONE
AIR INLET CONDITIONS	
PRESSURE (ATM)	1.0002
TEMPERATURE (DEG K)	288.00
FLOW RATE (KG/S)	82.700
AIR OUTLET CONDITIONS	
PRESSURE (ATM)	5.1512
TEMPERATURE (DEG K)	481.95
ADIABATIC EFFICIENCY (PCT)	87.300
SHAFT POWER (MW)	16.067
LUBE SYSTEM POWER(MW)	(INC. IN MISC. POWER)
COST($1000) (ACCT. 317.5.7)	2962.2
SECONDARY AIR INJECTION	
LOCATION	
PRESSURE (ATM)	1.0027
TEMPERATURE (DEG K)	288.25
FLOW RATE (KG/S)	23.403
FAN EFFICIENCY (PCT)	80.000
POWER REQUIREMENT (MWE)	5.95965E-03
KEY COMPONENT	
MINIMUM USEFUL LIFE (YEARS)	
COST($1000) (ACCT. 312.4.5)	1009.4

CASE 10 36 PCT 5.0 ATM 200 MW REF9008

SEED FEED AND MANAGEMENT ....

TYPE	
SEED FLOW, TOTAL (KG/S)	2.0960
POTASSIUM CARBONATE, K2CO3 (KG/S)	.66211
POTASSIUM SULFATE, K2SO4 (KG/S)	1.4338
POWER REQUIREMENT(MWE)	(INC. IN MISC. POWER)
TRANSPORT MECHANISM	
FLOW CONTROL (PCT)	
NUMBER OF MODULES	
KEY COMPONENT	
MINIMUM USEFUL LIFE (YEARS)	
REPLACEMENT TIME (HRS)	
COST ($1000) (ACCT.317.6.4)	1516.0

SEED RECOVERY/REGENERATION SYSTEM ...

TYPE	
RECOVERY (PCT)	95.000
REGENERATION (PCT)	33.300
TYPE OF REGENERATION PROCESS	FORMATE
POWER REQUIREMENT(MWE)	(INC. IN MISC. POWER)
KEY COMPONENT	
MINIMUM USEFUL LIFE (YEARS)	
COST ($1000) (ACCT. 316.1-.3)	8520.4

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE 10 36 PCT 5.0 ATM 200 MW REF9008

MAIN COMBUSTOR ....

TYPE-NUMBER OF STAGES	2	
DIMENSIONS	1ST STAGE	2ND STAGE
LENGTH (M)	3.4466	4.5030
DIAMETER (M)	1.8732	1.1257
VOLUME (M**3)	9.4840	5.7066
WEIGHT (KG)	3335.6	
COMBUSTOR EXIT CONDITIONS		
PRESSURE (ATM)	4.8511	
TEMPERATURE (DEG K)	2794.1	
FLOW RATE (KG/S)	104.08	
SLAG REMOVAL (PCT)	85.000	
RESIDENCE TIME (MICRO-SEC)		
1-ST STAGE		
2-ND STAGE		
COMBUSTOR HEAT LOSSES (MWT)	31.930	
COOLING WATER INLET		
PRESSURE (ATM)	190.50	
TEMPERATURE (DEG K)	588.90	
QUALITY	0.	
FLOW RATE (KG/S)	147.66	
COOLING WATER EXIT		
PRESSURE (ATM)	187.10	
TEMPERATURE (DEG K)	603.64	
QUALITY	0.	
NUMBER OF MODULES	1	
COST ($1000) (ACCT.317.1.6,312.4.6)	2972.0	

NOZZLE ....

LENGTH (M)	1.6831
WEIGHT (KG)	1407.2
NOZZLE EXIT MACH NUMBER	1.3000
NOZZLE HEAT LOSS (MWT)	5.5500
NUMBER OF MODULES	
MINIMUM USEFUL LIFE (YEARS)	
COST($1000) (ACCT.317.2.1)	69.182

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE 10 36 PCT 5.0 ATM 200 MW REF9008

CHANNEL ....

TYPE	DIAGONAL		
DIMENSIONS			
INLET (MXM)	.56102	X	.56102
OUTLET (MXM)	1.1335	X	1.1335
LENGTH (M)	8.3502		
WEIGHT (KG)	14687.		
NUMBER OF ELECTRODE PAIRS	556.68		
SLAG REMOVAL (PCT)			
ENTHALPY EXTRACTION (PCT)	15.521		
OVERALL (TURBINE) EFFICIENCY (PCT)	74.281		
INLET CONDITIONS			
PRESSURE (ATM)	1.9522		
TEMPERATURE (DEG K)	2529.7		
MACH NUMBER	1.3000		
VELOCITY (M/S)	1154.3		
FLOW RATE (KG/S)	104.08		
OUTLET CONDITIONS			
PRESSURE (ATM)	.72341		
TEMPERATURE (DEG K)	2281.5		
MACH NUMBER	1.0001		
SURFACE TEMPERATURE (DEG K)	1800.0		
HEAT LOSS (MWT)	16.588		
PEAK ELECTRODE CURRENT DENSITY (A/CM**2)			
MAXIMUM HALL FIELD (KV/M)	2.5000		
COOLING WATER INLET			
PRESSURE (ATM)			
TEMPERATURE (DEG K)	357.94		
QUALITY	0.		
FLOW RATE (KG/S)	106.28		
COOLING WATER EXIT			
PRESSURE (ATM)	5.1024		
TEMPERATURE (DEG K)	400.00		
QUALITY	0.		
NUMBER OF CHANNELS	1		
MHD GROSS POWER BEFORE INVERSION (MWE)	73.969		
MHD GROSS POWER AFTER INVERSION (MWE)	71.402		
INVERTER EFFICIENCY (PCT)	96.530		
COST ($1000) (ACCT.317.2.2..3)	2241.8		

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE 10 36 PCT 5.0 ATM 200 MW REF9008

DIFFUSER AND TRANSITION PIECE ....

TYPE			
DIMENSIONS			
INLET (MXM)	1.1335	X	1.1335
OUTLET (MXM)	3.6271	X	3.6271
LENGTH (M)	12.015		
WEIGHT (KG)	28176.		
PRESSURE RECOVERY COEFFICIENT	.50000		
INLET CONDITIONS			
PRESSURE (ATM)	.72341		
TEMPERATURE (DEG K)	2281.5		
MACH NUMBER	1.0001		
FLOW RATE (KG/S)	104.08		
OUTLET CONDITIONS - DIFFUSER			
PRESSURE (ATM)	.99517		
TEMPERATURE (DEG K)	2341.0		
MACH NUMBER	.40000		
SURFACE TEMPERATURE (DEG K)			
HEAT LOSS (MWT)	25.000		
COOLING WATER INLET			
PRESSURE (ATM)	186.05		
TEMPERATURE (DEG K)	627.80		
FLOW RATE (KG/S)	46.513		
COOLING WATER EXIT			
PRESSURE (ATM)	183.67		
TEMPERATURE (DEG K)	633.10		
BOUNDARY LAYER CONTROLS			
MINIMUM USEFUL LIFE (YEARS)			
COST ($1000) (ACCT.317.2.4)	701.90		

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE 10 36 PCT 5.0 ATM 200 MW REF9008

MAGNET ....

TYPE	
DIMENSIONS	
LENGTH (M)	9.4357
OVERALL DIAMETER (M)	4.7179
WARM BORE	
INLET DIAMETER (M)	1.3591
OUTLET DIAMETER (M)	1.9301
FIELD STRENGTH (TESLA)	
PEAK	6.0000
AVERAGE	
CURRENT DENSITY (A/CM**2)	
ENERGY STORAGE (MJ)	1199.1
WEIGHT (KG)	4.62862E+05
COST ($1000) (ACCT.317.3)	14390.

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE 10 36 PCT 5.0 ATM 200 MW REF9008

RADIANT BOILER ....

TYPE			
DIMENSIONS			
INLET (MXM)	13.423	X	19.400
OUTLET (MXM)	13.423	X	19.400
LENGTH (M)	21.200		
WEIGHT (KG)	5.00000E+05		
EFFICIENCY (PCT)	0.		
COMBUSTION GAS INLET CONDITIONS			
PRESSURE (ATM)	.99517		
TEMPERATURE (DEG K)	2332.7		
FLOW RATE (KG/S)	104.08		
COMBUSTION GAS OUTLET CONDITIONS			
PRESSURE (ATM)	.96532		
TEMPERATURE (DEG K)	1867.0		
DWELL TIME (SEC)	2.5000		
HEAT TRANSFER AREA (M**2)			
SLAG REMOVAL (PCT)			
MAXIMUM TEMP GRADIENT (DEG K/SEC)			
WATER/STEAM INLET CONDITIONS			
PRESSURE (ATM)	183.70		
TEMPERATURE (DEG K)	603.64		
QUALITY	0.		
FLOW RATE (KG/S)	147.66		
WATER/STEAM EXIT CONDITIONS			
PRESSURE (ATM)	183.70		
TEMPERATURE (DEG K)	633.10		
QUALITY	1.0000		
THERMAL DUTY (MWT)	82.326		
MINIMUM USEFUL LIFE (YEARS)			
COST($1000) (ACCT.312.3.1)	2397.3		

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE 10 36 PCT 5.0 ATM 200 MW REF9008

HIGH TEMPERATURE AIR HEATER ....

TYPE		
NUMBER OF MODULES	0	
DIMENSIONS		
HEIGHT (M)		-I
DIAMETER (M)		-I
FLOW AREA (M**2)		-I
WEIGHT (KG)		
SLAG REMOVAL (PCT)		
COMBUSTION GAS INLET CONDITIONS		
PRESSURE (ATM)		-I
TEMPERATURE (DEG K)		-I
FLOW RATE (KG/S)		-I
COMBUSTION GAS OUTLET CONDITIONS		
PRESSURE (ATM)		-I
TEMPERATURE (DEG K)		-I
AIR INLET CONDITIONS		
PRESSURE (ATM)		-I
TEMPERATURE (DEG K)		-I
FLOW RATE (KG/S)		-I
AIR OUTLET CONDITIONS		
PRESSURE (ATM)		-I
TEMPERATURE (DEG K)		-I
VELOCITY (M/S)		
DWELL TIME (SEC)		
LOSSES		
VALVE LEAKAGE (PCT)		-I
VALVE COOLING (MWT)		-I
CORE HEAD LOSS (MWT)		-I
THERMAL DUTY (MWT)	0.	
MINIMUM USEFUL LIFE (YEARS)		
COST($1000) (ACCT.317.5.2--4)	0.	

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE 10 36 PCT 5.0 ATM 200 MW REF9008

SUPERHEATER ....

TYPE		
DIMENSIONS		
LENGTH (M)		-I
WIDTH (M)		-I
HEIGHT (M)		-I
WEIGHT (KG)		
COMBUSTION GAS INLET CONDITIONS		
PRESSURE (ATM)	.96532	
TEMPERATURE (DEG K)	1977.4	
FLOW RATE (KG/S)	127.48	
COMBUSTION GAS OUTLET CONDITIONS		
PRESSURE (ATM)	.96532	
TEMPERATURE (DEG K)	644.40	
SLAG REMOVAL (PCT)		
WATER/STEAM INLET CONDITIONS		
PRESSURE (ATM)	183.70	
TEMPERATURE (DEG K)	633.10	
FLOW RATE (KG/S)	147.66	
WATER/STEAM OUTLET CONDITIONS		
PRESSURE (ATM)	164.30	
TEMPERATURE (DEG K)	811.10	
THERMAL DUTY (MWT)	146.75	
COST ($1000) (ACCT.312.4.3)	4391.8	

CASE 10 36 PCT 5.0 ATM 200 MW REF9008

REHEATER ....

TYPE		
DIMENSIONS		
LENGTH (M)		-I
WIDTH (M)		-I
HEIGHT (M)		-I
WEIGHT (KG)		
COMBUSTION GAS INLET CONDITIONS		
PRESSURE (ATM)	.96532	
TEMPERATURE (DEG K)	1977.4	
FLOW RATE (KG/S)	127.48	
COMBUSTION GAS OUTLET CONDITIONS		
PRESSURE (ATM)	.96532	
TEMPERATURE (DEG K)	644.40	
SLAG REMOVAL (PCT)		
WATER/STEAM INLET CONDITIONS		
PRESSURE (ATM)	43.425	
TEMPERATURE (DEG K)	620.55	
FLOW RATE (KG/S)	118.26	
WATER/STEAM OUTLET CONDITIONS		
PRESSURE (ATM)	41.253	
TEMPERATURE (DEG K)	811.10	
THERMAL DUTY (MWT)	53.263	
COST ($1000) (ACCT.312.4.4)	6319.8	

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE 10 36 PCT 5.0 ATM 200 MW REF9008

OXIDANT PREHEATER ....

TYPE		
DIMENSIONS		
LENGTH (M)		-I
WIDTH (M)		-I
HEIGHT (M)		-I
WEIGHT (KG)		
COMBUSTION GAS INLET CONDITIONS		
PRESSURE (ATM)	.96532	
TEMPERATURE (DEG K)	1977.4	
FLOW RATE (KG/S)	127.48	
COMBUSTION GAS OUTLET CONDITIONS		
PRESSURE (ATM)	.96532	
TEMPERATURE (DEG K)	644.40	
AIR INLET CONDITIONS		
PRESSURE (ATM)	5.1512	
TEMPERATURE (DEG K)	481.95	
FLOW RATE (KG/S)	82.700	
AIR OUTLET CONDITIONS		
PRESSURE (ATM)	5.0011	
TEMPERATURE (DEG K)	922.22	
THERMAL DUTY (MWT)	38.977	
COST ($1000) (ACCT.317.5.5)	1133.0	

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE 10 36 PCT 5.0 ATM 200 MW REF9008

ECONOMIZER NO. 1....

DIMENSIONS	
LENGTH (M)	26.797
WIDTH (M)	5.9953
HEIGHT (M)	5.9953
WEIGHT (KG)	
COMBUSTION GAS INLET CONDITIONS	
PRESSURE (ATM)	.96532
TEMPERATURE (DEG K)	644.40
FLOW RATE (KG/S)	66.783
COMBUSTION GAS OUTLET CONDITIONS	
PRESSURE (ATM)	.96532
TEMPERATURE (DEG K)	425.00
WATER/STEAM INLET CONDITIONS	
PRESSURE (ATM)	205.42
TEMPERATURE (DEG K)	414.05
FLOW RATE (KG/S)	19.959
WATER/STEAM OUTLET CONDITIONS	
PRESSURE (ATM)	205.42
TEMPERATURE (DEG K)	588.90
THERMAL DUTY (MWT)	16.239
COST ($1000) (ACCT.312.4.1)	10022.

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE 10 36 PCT 5.0 ATM 200 MW REF9008

GAS CLEAN UP ....

TYPES	
LOCATIONS	
LOSSES	
PRESSURE (PCT)	
THERMAL (MWT)	
REMOVAL EFFICIENCY (PCT)	
POWER REQUIRED (MWE)	9.53140E-02
MINIMUM USEFUL LIFE (YEARS)	
COST($1000) (ACCT.312.5.1)	5609.1
STACK COST ($1000)(ACCT.312.5.3)	1842.3

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE 10 36 PCT 5.0 ATM 200 MW REF9008

EXHAUST EMISSIONS ....

PARTICULATE (G/J)	
NOX (G/J)	
SOX (G/J)	
TRACE ELEMENTS (G/J)	

PLANT COOLING ....

TYPE	
NUMBER OF MODULES	
DIMENSIONS	
HEIGHT (M)	
DIAMETER (M)	
CONDENSER PRESSURE (ATM)	6.70121E-02
THERMAL DUTY (MWT)	218.72
TEMPERATURE (DEG K)	311.61
COOLING WATER	-I
FLOW RATE (KG/S)	
MAKE UP (PCT)	
POWER REQUIREMENT (MWE)	1.5311
MINIMUM USEFUL LIFE (YEARS)	
COST ($1000)	
HEAT REJECTION COST($1000)(ACCT. 314.3)	7255.1
CONDENSER COST($1000)(ACCT.314.2)	2306.7

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE 10 36 PCT 5.0 ATM 200 MW REF9008

OTHER PLANT COSTS ....

LAND AND LAND RIGHTS	
COST/ACRE ($1000)	5.0000
COST ($1000) (ACCT.310.)	1576.4
STRUCTURES AND IMPROVEMENTS	
IMPROVEMENTS TO SITE($1000)(ACT.311.12)	7418.4
BUILDINGS & STRUCTURE COST ($1000)(ACCT.311.2)	30494.
BOILER PLANT EQUIPMENT	
COAL HAND. & PROCESS COST ($1000)(ACCT.312.1)	21286.
ASH AND SLUDGE COST ($1000) (ACCT. 312.2)	6986.4
WATER TREATMENT COST($1000)	3989.2
DEAERATOR COST ($1000)	115.15
FEEDWATER SYSTEM COST($1000)	1727.4
DRAFT FAN AND DUCT COST ($1000)	784.23
STEAM PIPE/VALVE COST($1000)(ACCT. 314.4)	7295.3
ACC. ELECTRICAL EQUIP. COST ($1000)(ACT. 315.)	10000.
MISC. POWER PLANT EQUIP. COST ($1000)(ACCT.316)	2139.7
TRANSMISSION PLANT COST ($1000)(ACT. 350)	4018.2
POWER CONSOLIDATION COST ($1000)(ACCT.317.4)	9108.4

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE 10 36 PCT 5.0 ATM 200 MW REF9008

OTHER PLANT COSTS ....

AUXILIARY BOILER COST($1000)(ACT.312.6)	133.25
BOILER PLANT VALVE COST($1000)(ACT.312.71)	3004.3
MISC. BOILER PLANT COST($1000)(ACT.312.72)	1085.1
MISC. BOILER PLANT COST($1000)	8249.4
FEEDWATER PUMP COSTS($1000)	1332.5
OTHER TURBINE EQUIP. COST($1000)(ACT.314.5)	1176.3
OXIDENT DUCT SYS. COST ($1000)(ACT.317.53)	2620.7
LAND FILL COST ($1000)(ACT. 311.11)	2330.6
ENGINEERING SERVICE COST ($1000)	16605.
ESCAL. & INT. DURING CONST. ($1000)	23953.
TOTAL PLANT COST ($1000)	2.76619E+05

FUEL COST (MILLS/KWH)	29.945
LIME COST ($/YEAR)	324.20
OPER. & MAINT. COSTS (MIL/KWH)	13.210
CAPITAL COSTS (MILLS/KWH)	45.271
SEED MAKEUP COST	326.83
CREW COST	2979.0
O & M MATERIAL COST	1.37801E+06

A4 - SUPERSONIC CHANNEL 200 MWe MHD/STEAM POWER PLANT

A4.3 Plant Cost Accounts Summary

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CASE 10 36 PCT 5.0 ATM 200 MW REF9008

ACCOUNT NO.	DESCRIPTION	COST BASIS UNIT	TOTAL COST ($1000)
310.0	LAND COSTS	KG/S	1576.4
311.0	STRUCTURES AND IMPROVEMENTS	KG/S	37980.
311.1	IMPROVEMENTS TO SITE	KG/S	9749.0
311.1.1	WASTE DISPOSAL LAND FILL AREA	KG/S	2330.6
311.1.2	OTHER YARD WORK	KG/S	7418.4
311.2	MAIN BUILDING	KG/S	12344.
311.2.1	MHD BUILDING	KG/S	5275.5
311.2.2	HRSR BUILDING	KG/S	6617.2
311.2.3	POWER COND. SYSTEM BLDG.	KG/S	2409.0
311.2.4	MAGNET REFRIG. SYS. BLDG.	KG/S	304.94
311.3	STEAM TURBINE BLDG.	KG/S	6007.3
311.3.1	STEAM TURBINE-GENERATOR BUILDING	KG/S)	6007.3
311.3.2	STEAM TURBINE-COMPRESSOR BLDG.		(INCL. IN 317.7)
311.4	COAL BUNKER/PROCESSING AREA	KG/S	3140.9
311.5	SERVICE BUILDINGS	KG/S	3232.4
311.6	OTHER PROCESS BLDG. AND STRUCTURES	KG/S	3506.8
312.0	BOILER PLANT EQUIPMENT	KG/S	73169.
312.1	COAL HANDLING AND PROCESSING	KG/S	21286.
312.1.1	UNLOAD/STORE/RECLAIM SYSTEM	KG/S	7827.0
312.1.2	PULVERIZING/DRYING SYSTEM	KG/S	9393.7
312.1.3	FEED SYSTEM	KG/S	4065.7
312.2	SLAG AND ASH HANDLING	KG/S	6986.4
312.3	RADIANT BOILER	MWT	2397.3
312.4	STEAM GENERATOR SECTIONS	MWT	22876.
312.4.1	SUPERHEATR/REHEATER	MWT	10712.
312.4.2	OXIDANT PREHEATER	MWT	1133.0
312.4.3	ECONOMIZER/SECONDARY AIR HEATER	MWT,KG/S	11032.
312.5	EFFLUENT CONTROL		8235.7
312.5.1	ELECTROSTATIC PRECIPITATOR	M3/S	5609.1
312.5.2	FANS, DUCTING, STACK	MWE,M3/S	2626.5
312.6	AUXILIARY BOILER SYSTEMS	MWT	133.25
312.7	OTHER BOILER PLANT SYSTEMS		11254.
312.7.1	PIPING/VALVES/TANKS	KG/S	3004.3
312.7.2	MISCELLANEOUS BOILER PLANT	KG/S	8249.4

CASE 10 36 PCT 5.0 ATM 200 MW REF9008

ACCOUNT NO.	DESCRIPTION	COST BASIS UNIT	TOTAL COST ($1000)
314.0	TURBOGENERATOR UNITS		31316.
314.1	STEAM TURBINE GN/ACCESSORIES	MWE	13283.
314.2	CONDENSERS/AUXILIARIES	MWT	2306.7
314.3	CIRCULATING WATER SYSTEM		7255.1
314.3.1	COOLING TOWERS (INC.BASIN)	MWT	4186.2
314.3.2	CIRC. WATER PUMPS/PIPING	MWT	3068.9
314.4	STEAM PIPING SYSTEMS	KG/S	7295.3
314.4.1	FEEDWATER PIPING	KG/S	2141.2
314.4.2	STEAM PIPING	KG/S	2504.5
314.4.3	OTHER STEAM PLANT PIPING	KG/S	2649.6
314.5	OTHER TURBINE PLANT EQUIPMENT	KG/S	1176.3
315.0	ACCESSORY ELECTRIC SYSTEMS/EQUIP.	MWE	10000.
316.0	MISCELLANEOUS POWER PLANT EQUIP.	MWE	2139.7
317.0	MHD TOPPING CYCLE EQUIPMENT		69447.
317.1	COMBUSTION EQUIPMENT	MWE	2972.0
317.1.1	COMBUSTOR		2972.0
317.1.2	COAL INJECTION SYSTEM		(INCL. IN 312.1.3)
317.1.3	SLAG COLLECTION SYSTEM		(INCL. IN 312.2)
317.2	MHD GENERATOR SYSTEM		3012.9
317.2.1	NOZZLE	M	69.182
317.2.2	CHANNEL	MWE,M2	2241.8
317.2.3	DIFFUSER	MWE	701.90
317.3	MAGNET SYSTEM	MJ	14390.
317.4	INVERTER/ELECTRODE CONTROL SYSTEM	M,KWE	9108.4
317.5	OXIDIZER SYSTEM		5582.9
317.5.1	OXIDANT COMPRESSORS	HP	2962.2
317.5.2	OXIDANT HEATER		(INCL. IN 312.4.2)
317.5.3	AIR/OXYGEN/OXIDANT SYSTEM DUCTING	M3/S	2620.7
317.6	SEED SYSTEM		10036.
317.6.1	SEED REGENERATION SYSTEM	KG/S	8520.4
317.6.2	SEED INJECTION SYSTEM	KG/S	1516.0
317.7	OXYGEN ENRICHMENT SYSTEM	TPD	24345.
317.8	MISC. MHD TOP. CYCLE SUP. EQUIP.		
350.0	TRANSMISSION PLANT	MWE	4018.2

A4 - SUPERSONIC CHANNEL 200 MWe MHD/STEAM POWER PLANT

A4.4 Plant Costing Details and Cost of Electricity

MHD PROJECT COST ESTIMATE (DOLLARS X 10-3)

CASE 10 36 PCT 5.0 ATM 200 MW REF9008

ACCOUNT NUMBER	ACCOUNT DESCRIPTION	UNIT	QUANTITY	MATERIAL MAJOR COMPONENT	MATERIAL BAL OF PLT COST	INSTALLN COST	INDIRECT COST	CONTG	TOTAL COST
310.0	LAND AND LAND RIGHTS	KG/S	19.	0.	1433.	0.	0.	143.	1576.
311.0	STRUCTURES AND IMPROVEMENTS	KG/S	19.	0.	16943.	10338.	9305.	3658.	40243.
311.1	IMPROVEMENTS TO SITE	KG/S	19.	0.	2925.	3126.	2813.	886.	9749.
311.1.1	WASTE DISP.LAND FILL AREA	KG/S	19.	0.	699.	747.	672.	212.	2331.
311.1.2	OTHER YARD WORK	KG/S	19.	0.	2226.	2378.	2140.	674.	7418.
311.2	MAIN BUILDING	KG/S	19.	0.	7303.	3145.	2831.	1328.	14607.
311.2.1	MHD BUILDING	KG/S	19.	0.	2638.	1136.	1022.	480.	5275.
311.2.2	HRSR BUILDING	KG/S	19.	0.	3309.	1425.	1282.	602.	6617.
311.2.3	POWER COND. SYSTEM BLDG.	KG/S	19.	0.	1205.	519.	467.	219.	2409.
311.2.4	MAGNET REFRIGN. SYS. BLDG.	KG/S	19.	0.	152.	66.	59.	28.	305.
311.3	STEAM TURBINE BUILDING	KG/S	19.	0.	2403.	1609.	1449.	546.	6007.
311.3.1	STEAM TURB.-GEN. BUILDING	KG/S	19.	0.	2403.	1609.	1449.	546.	6007.
311.3.2	STEAM TURB.-COMPR. BLDG.							(INCL.	IN 317.7)
311.4	COAL BUNKER/PROCESSING AREA	KG/S	19.	0.	942.	1007.	906.	286.	3141.
311.5	SERVICE BUILDINGS	KG/S	19.	0.	1616.	696.	626.	294.	3232.
311.6	OTHER PRCS. BLDG. AND STRUC.	KG/S	19.	0.	1753.	755.	680.	319.	3507.
312.0	BOILER PLANT EQUIPMENT	KG/S	19.	25177.	20441.	11002.	9899.	6651.	73169.
312.1	COAL HANDLING AND PROCSG.	KG/S	19.	8749.	4696.	3109.	2797.	1935.	21286.
312.1.1	UNLOAD/STORE/RECLAIM SYS.	KG/S	19.	0.	4696.	1273.	1146.	711.	7827.
312.1.2	PULVERIZING/DRYING SYSTEM	KG/S	19.	6106.	0.	1281.	1153.	854.	9394.
312.1.3	FEED SYSTEM	KG/S	19.	2643.	0.	555.	499.	370.	4066.
312.2	SLAG AND ASH HANDLING	KG/S	19.	0.	4890.	768.	692.	635.	6986.
312.3	RADIANT BOILER	MWT	82.	1558.	0.	327.	294.	218.	2397.

MHD PROJECT COST ESTIMATE (DOLLARS X 10-3)

CASE 10 36 PCT 5.0 ATM 200 MW REF9008

ACCOUNT NUMBER	ACCOUNT DESCRIPTION	UNIT	QUANTITY	MATERIAL MAJOR COMPONENT	MATERIAL BAL OF PLT COST	INSTALLN COST	INDIRECT COST	CONTG	TOTAL COST
312.4	STEAM GENERATOR SECTIONS	MWT		14870.	0.	3120.	2807.	2079.	22876.
312.4.1	SUPERHEATER/REHEATER	MWT	200.	6963.	0.	1461.	1314.	974.	10712.
312.4.2	OXIDANT PREHEATER	MWT	39.	736.	0.	155.	139.	103.	1133.
312.4.3	ECONOMIZER/SECDARY AIR HTR	MWT	16.	7171.	0.	1505.	1354.	1003.	11032.
312.5	EFFLUENT CONTROL			0.	4022.	1824.	1641.	749.	8236.
312.5.1	ELECTROSTATIC PRECIPITATOR	M3/S	215.	0.	3365.	913.	821.	510.	5609.
312.5.2	FANS/DUCTING/STACK	MWE	200.	0.	657.	911.	820.	239.	2627.
312.6	AUXILIARY BOILER SYSTEMS	MWT	200.	0.	80.	22.	20.	12.	133.
312.7	OTHER BOILER PLANT SYSTEMS			0.	6752.	1831.	1648.	1023.	11254.
312.7.1	PIPING/VALVES/TANKS	KG/S	148.	0.	1803.	489.	440.	273.	3004.
312.7.2	MISC. BOILER PLANT	KG/S	148.	0.	4950.	1342.	1208.	750.	8249.
314.0	TURBOGENERATOR UNITS			11013.	9960.	3945.	3551.	2847.	31316.
314.1	STEAM TURBINE GN/ACCES.	MWE	129.	11013.	0.	559.	503.	1207.	13283.
314.2	CONDENSERS/AUXILIARIES	MWT	219.	0.	1384.	375.	338.	210.	2307.
314.3	CIRCULATING WATER SYSTEM			0.	4046.	1342.	1208.	659.	7255.
314.3.1	COOLING TOWERS (INC.BASIN)	MWT	219.	0.	2512.	681.	613.	381.	4186.
314.3.2	CIRC. WATER PUMPS/PIPING	MWT	219.	0.	1534.	661.	595.	279.	3069.
314.4	STEAM PIPING SYSTEMS	KG/S	148.	0.	3648.	1571.	1414.	663.	7295.
314.4.1	FEEDWATER PIPING	KG/S	148.	0.	1071.	461.	415.	195.	2141.
314.4.2	STEAM PIPING	KG/S	148.	0.	1252.	539.	485.	228.	2504.
314.4.3	OTHER STEAM PLANT PIPING	KG/S	148.	0.	1325.	570.	514.	241.	2650.
314.5	OTHER TURBINE PLANT EQUIP.	KG/S	148.	0.	882.	98.	89.	107.	1176.

MHD PROJECT COST ESTIMATE (DOLLARS X 10-3)

CASE 10 36 PCT 5.0 ATM 200 MW REF9008

ACCOUNT NUMBER	ACCOUNT DESCRIPTION	UNIT	QUANTITY	MATERIAL MAJOR COMPONENT	MATERIAL BAL OF PLT COST	INSTALLN COST	INDIRECT COST	CONTG	TOTAL COST
315.0	ACC. ELECTRIC SYSTEMS/EQUIP.	MWE	200.	0.	4000.	2679.	2412.	909.	10000.
315.0	MISC. POWER PLANT EQUIP.	MWE	200.	0.	1284.	348.	313.	194.	2140.
317.0	MHD TOPPING CYCLE EQUIP.			49864.	2784.	6929.	6236.	3633.	69447.
317.1	COMBUSTION EQUIPMENT	MWE	200.	2526.	149.	156.	141.	0.	2972.
317.1.1	COMBUSTOR			2526.	149.	156.	141.	0.	2972.
317.1.2	COAL INJECTION SYSTEM							(INCL. IN 312.1.3)	
317.1.3	SLAG COLLECTION SYSTEM							(INCL. IN 312.2)	
317.2	MHD GENERATOR SYSTEM			2561.	151.	158.	143.	0.	3013.
317.2.1	NOZZLE	M	1.	59.	3.	4.	3.	0.	69.
317.2.2	CHANNEL	MWE	200.	1906.	112.	118.	106.	0.	2242.
317.2.3	DIFFUSER	MWE	200.	597.	35.	37.	33.	0.	702.
317.3	MAGNET SYSTEM	MJ	1199.	12231.	719.	757.	682.	0.	14390.
317.4	INVERTER/ELCTD.CTRL SYSTEM	M	8.	7742.	455.	479.	432.	0.	9108.
317.5	OXIDIZER SYSTEM			2456.	1310.	689.	620.	507.	5583.
317.5.1	OXIDANT COMPRESSORS	HP	21530.	2456.	0.	125.	112.	269.	2962.
317.5.2	OXIDANT HEATER							(INCL. IN 312.4.2)	
317.5.3	OXIDANT DUCT.SYSTEM	M3/S	42.	0.	1310.	564.	508.	238.	2621.
317.6	SEED SYSTEM			6524.	0.	1369.	1231.	912.	10036.
317.6.1	SEED REGENERATION SYSTEM	KG/S	1.	5538.	0.	1162.	1045.	775.	8520.
317.6.2	SEED INJECTION SYSTEM	KG/S	2.	985.	0.	207.	186.	138.	1516.
317.7	OXYGEN ENRICHMENT SYSTEM	TPD	1855.	15824.	0.	3321.	2987.	2213.	24345.
317.8	MISC.MHD TOP.CYCLE SUP.EQUIP								
350.0	TRANSMISSION PLANT	MWE	193.	0.	2813.	442.	398.	365.	4018.

MHD PROJECT COST ESTIMATE (DOLLARS X 10-3)

CASE 10 36 PCT 5.0 ATM 200 MW REF9008

ACCOUNT NUMBER	ACCOUNT DESCRIPTION	UNIT	QUANTITY	MATERIAL MAJOR COMPONENT	MATERIAL BAL OF PLT COST	INSTALLN COST	INDIRECT COST	CONTG	TOTAL COST
	SUBTOTALS			86053.	59658.	35683.	32114.	18401.	231910.
	ENGINEERING SERVICES								16605.
	OTHER COSTS								4151.
	TOTAL ESTIMATED OVERNIGHT CONSTRUCTION COSTS								252666.
	CONSTRUCTION PERIOD YEARS								5.5
	TOTAL ESTIMATED COST INCLUDING INTEREST AND ESCALATION DURING CONSTRUCTION								276619.

MHD PROJECT COST ESTIMATE (DOLLARS X 10-3)

CASE 10 36 PCT 5.0 ATM 200 MW REF9008

OPERATING AND MAINT. COSTS ($1000/YR)

LABOR	2979.
SEED	327.
LIME	324.
MATERIAL	3620.

COST OF ELECTRICITY (MILLS/KWHR)

CAPITAL	45.3
FUEL	29.9
O&M	13.2
COE	88.4

APPENDIX B

TABLE OF CONTENTS

B. SPECIAL STUDIES COMPUTER RESULTS

APPENDIX B

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

OVERALL SYSTEM PERFORMANCE ....

REFERENCE COAL	MONTANA ROSEBUD
COAL THERMAL INPUT (MWT)	80.000
PRIMARY CYCLE (MWT)	78.895
SEED REGENERATION (MWT)	1.1045
PLANT LIFE (YEARS)	
OPERATING MODE	
NET POWER OUTPUT (MWE)	22.042
PLANT EFFICIENCY (PCT)	27.553
THERMODYNAMIC EFFICIENCY (PCT)	18.969
MHD ENTHALPY EXTRACTION (PCT)	8.7225
TOTAL HEAT INPUT TO STEAM (MWT)	63.849
STEAM CYCLE EFFICIENCY (PCT)	32.914
AIR PREHEAT TEMPERATURE (DEG K)	922.22
REFERENCE ATMOSPHERE	
PRESSURE (ATM)	.83017
DRY BULB TEMPERATURE (DEG K)	288.00
RELATIVE HUMIDITY (PCT)	60.000
STEAM CONDITIONS	
MAIN TURBINE THROTTLE PRESSURE (ATM)	58.860
MAIN TURBINE THROTTLE TEMPERATURE (DEG K)	755.20

FORM 5432

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

POWER GENERATED AND CONSUMED ....

GROSS AC POWER (MWE)	
MHD POWER (AC)	6.6428
STEAM TURBINE-GENERATOR POWER	21.1044
TOTAL	27.7472
POWER CONSUMED (MWE)	
SEC. AIR BLOWER	7.79682E-02
DRAFT FAN POWER	1.75555E-02
CONDENSATE PUMP	1.28773E-02
COOLING TWR CIRC PUMP	.29133
COAL HANDLING AND PROCESSING	.46548
ELECTROSTATIC PRECIP POWER	1.57790E-02
MHD MAGNET POWER	2.36685E-02
MISC. POWER	7.48295E-02
TRANSFORMER LOSS	.22265
TOTAL	1.2021
NET POWER OUTPUT (MWE)	22.042

MECHANICAL DRIVE TURBINES (MW)

BOILER FEED PUMPS	.18843

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

COAL HANDLING AND PREPARATION ...

RAW COAL, AS RECEIVED

MOISTURE CONTENT (PCT)	22.700
FLOW RATE (KG/S)	3.8067
HIGH HEATING VALUE (J/KG)	2.07250E+07
COAL TO COMBUSTOR, AS FIRED	
MOISTURE CONTENT (PCT)	5.0000
FLOW RATE (KG/S)	3.0974
FLOW CONTROL (PCT)	
TRANSPORT MEDIUM	COMB. GAS
MECHANISM	
RATIO	1.00000E-01
DRYING MEDIUM	
FLOW RATE (KG/S)	6.5054
TEMPERATURE IN (DEG K)	644.40
TEMPERATURE OUT (DEG K)	377.70
HEAT REQUIRED FOR DRYING (MWT)	2.1470
POWER REQUIREMENT (MWE)	.46548

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

OXIDIZER SUPPLY ....

OXYGEN PLANT	
AMOUNT OF OXYGEN (PCT)	50.000
CONTAINED OXYGEN FLOW (TPD)	375.69
EQUIVALENT PURE OXYGEN (TPD)	375.69
O2 PREHEAT TEMP. (DEG K)	922.22

MAIN AIR COMPRESSOR	
TYPE OF COMPRESSOR	AXIAL FLOW
TYPE OF INTERCOOLING	NONE
AIR INLET CONDITIONS	
PRESSURE (ATM)	.83017
TEMPERATURE (DEG K)	288.00
FLOW RATE (KG/S)	10.028
AIR OUTLET CONDITIONS	
PRESSURE (ATM)	3.0909
TEMPERATURE (DEG K)	436.16
ADIABATIC EFFICIENCY (PCT)	87.300
SHAFT POWER (MW)	1.4599

SECONDARY AIR INJECTION	
LOCATION	
PRESSURE (ATM)	1.0027
TEMPERATURE (DEG K)	307.92
FLOW RATE (KG/S)	3.8743
FAN EFFICIENCY (PCT)	80.000
POWER REQUIREMENT (MWE)	7.79682E-02

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

SEED FEED AND MANAGEMENT ....

TYPE	
SEED FLOW, TOTAL (KG/S)	.27000
POTASSIUM CARBONATE, K_2CO_3 (KG/S)	8.52918E-02
POTASSIUM SULFATE, K_2SO_4 (KG/S)	.18470

SEED RECOVERY/REGENERATION SYSTEM ...

TYPE	
RECOVERY (PCT)	95.000
REGENERATION (PCT)	33.300

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

MAIN COMBUSTOR ....

TYPE-NUMBER OF STAGES	2	
DIMENSIONS	1ST STAGE	2ND STAGE
LENGTH (M)	1.9512	2.9614
DIAMETER (M)	1.0605	.74036
VOLUME (M**3)	1.7209	1.6233
WEIGHT (KG)	734.32	
COMBUSTOR EXIT CONDITIONS		
PRESSURE (ATM)	2.9109	
TEMPERATURE (DEG K)	2861.3	
FLOW RATE (KG/S)	13.490	
SLAG REMOVAL (PCT)	85.000	
RESIDENCE TIME (MICRO-SEC)		
1-ST STAGE		
2-ND STAGE		
COMBUSTOR HEAT LOSSES (MWT)	9.1518	
COOLING WATER INLET		
PRESSURE (ATM)	190.50	
TEMPERATURE (DEG K)	450.00	
QUALITY	0.	
FLOW RATE (KG/S)	24.176	
COOLING WATER EXIT		
PRESSURE (ATM)	187.10	
TEMPERATURE (DEG K)	464.91	
QUALITY	0.	

NOZZLE ....

LENGTH (M)	.77433
WEIGHT (KG)	297.85
NOZZLE EXIT MACH NUMBER	1.3000
NOZZLE HEAT LOSS (MWT)	5.5500

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CHANNEL ....

TYPE	DIAGONAL		
DIMENSIONS			
INLET (MXM)	.25811	X	.25811
OUTLET (MXM)	.45860	X	.45860
LENGTH (M)	3.7699		
WEIGHT (KG)	14987.		
NUMBER OF ELECTRODE PAIRS	251.33		
SLAG REMOVAL (PCT)			
ENTHALPY EXTRACTION (PCT)	8.7225		
OVERALL (TURBINE) EFFICIENCY (PCT)	68.188		
INLET CONDITIONS			
PRESSURE (ATM)	1.2047		
TEMPERATURE (DEG K)	2560.5		
MACH NUMBER	1.3000		
VELOCITY (M/S)	1145.5		
FLOW RATE (KG/S)	13.490		
OUTLET CONDITIONS			
PRESSURE (ATM)	.60572		
TEMPERATURE (DEG K)	2400.6		
MACH NUMBER	1.0050		
SURFACE TEMPERATURE (DEG K)	1800.0		
HEAT LOSS (MWT)	3.0087		
PEAK ELECTRODE CURRENT DENSITY (A/CM**2)			
MAXIMUM HALL FIELD (KV/M)	2.5000		

NUMBER OF CHANNELS	1
MHD GROSS POWER BEFORE INVERSION (MWE)	6.8816
MHD GROSS POWER AFTER INVERSION (MWE)	6.6428
INVERTER EFFICIENCY (PCT)	96.530

FORM F432

DIFFUSER AND TRANSITION PIECE ....

TYPE			
DIMENSIONS			
INLET (MXM)	.45860	X	.45860
OUTLET (MXM)	1.4675	X	1.4675
LENGTH (M)	4.8611		
WEIGHT (KG)	4612.6		
PRESSURE RECOVERY COEFFICIENT	.50000		
INLET CONDITIONS			
PRESSURE (ATM)	.60572		
TEMPERATURE (DEG K)	2400.6		
MACH NUMBER	1.0050		
FLOW RATE (KG/S)	13.490		
OUTLET CONDITIONS - DIFFUSER			
PRESSURE (ATM)	.82954		
TEMPERATURE (DEG K)	2518.7		
MACH NUMBER	.40000		

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

MAGNET ....

TYPE	
DIMENSIONS	
LENGTH (M)	4.2600
OVERALL DIAMETER (M)	2.1300
WARM BORE	
INLET DIAMETER (M)	.93071
OUTLET DIAMETER (M)	1.0807
FIELD STRENGTH (TESLA)	
PEAK	6.0000
ENERGY STORAGE (MJ)	226.75
WEIGHT (KG)	87526.

FORM F432

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

RADIANT BOILER ....

TYPE			
DIMENSIONS			
INLET (MXM)	4.8328	X	19.400
OUTLET (MXM)	4.8328	X	19.400
LENGTH (M)	21.200		
WEIGHT (KG)	5.00000E+05		
COMBUSTION GAS INLET CONDITIONS			
PRESSURE (ATM)	.82954		
TEMPERATURE (DEG K)	2511.4		
FLOW RATE (KG/S)	13.490		
COMBUSTION GAS OUTLET CONDITIONS			
PRESSURE (ATM)	.80465		
TEMPERATURE (DEG K)	1867.0		
DWELL TIME (SEC)	2.5000		
WATER/STEAM INLET CONDITIONS			
PRESSURE (ATM)	183.70		
TEMPERATURE (DEG K)	464.91		
QUALITY	0.		
FLOW RATE (KG/S)	24.176		
WATER/STEAM EXIT CONDITIONS			
PRESSURE (ATM)	183.70		
TEMPERATURE (DEG K)	633.10		
QUALITY	1.0000		
THERMAL DUTY (MWT)	18.903		

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

SUPERHEATER ....

COMBUSTION GAS INLET CONDITIONS	
PRESSURE (ATM)	.80465
TEMPERATURE (DEG K)	2008.1
FLOW RATE (KG/S)	17.364
COMBUSTION GAS OUTLET CONDITIONS	
PRESSURE (ATM)	.80465
TEMPERATURE (DEG K)	644.40
SLAG REMOVAL (PCT)	
WATER/STEAM INLET CONDITIONS	
PRESSURE (ATM)	183.70
TEMPERATURE (DEG K)	633.10
FLOW RATE (KG/S)	24.176
WATER/STEAM OUTLET CONDITIONS	
PRESSURE (ATM)	58.860
TEMPERATURE (DEG K)	755.20
THERMAL DUTY (MWT)	28.550

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

OXIDANT PREHEATER ....

COMBUSTION GAS INLET CONDITIONS	
PRESSURE (ATM)	.80465
TEMPERATURE (DEG K)	2008.1
FLOW RATE (KG/S)	17.364
COMBUSTION GAS OUTLET CONDITIONS	
PRESSURE (ATM)	.80465
TEMPERATURE (DEG K)	644.40
AIR INLET CONDITIONS	
PRESSURE (ATM)	3.0909
TEMPERATURE (DEG K)	436.16
FLOW RATE (KG/S)	10.028
AIR OUTLET CONDITIONS	
PRESSURE (ATM)	3.0009
TEMPERATURE (DEG K)	922.22
THERMAL DUTY (MWT)	5.1415

ECONOMIZER NO. 1....

DIMENSIONS	
LENGTH (M)	7.2390
WIDTH (M)	1.9844
HEIGHT (M)	1.9844
WEIGHT (KG)	
COMBUSTION GAS INLET CONDITIONS	
PRESSURE (ATM)	.80465
TEMPERATURE (DEG K)	644.40
FLOW RATE (KG/S)	7.3165
COMBUSTION GAS OUTLET CONDITIONS	
PRESSURE (ATM)	.80465
TEMPERATURE (DEG K)	477.00
WATER/STEAM INLET CONDITIONS	
PRESSURE (ATM)	65.814
TEMPERATURE (DEG K)	450.00
FLOW RATE (KG/S)	24.176
WATER/STEAM OUTLET CONDITIONS	
PRESSURE (ATM)	65.814
TEMPERATURE (DEG K)	463.03
THERMAL DUTY (MWT)	1.3836

FORM F432

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

OVERALL SYSTEM PERFORMANCE ....

REFERENCE COAL	MONTANA ROSEBUD
COAL THERMAL INPUT (MWT)	50.003
PRIMARY CYCLE (MWT)	49.313
SEED REGENERATION (MWT)	.69038
PLANT LIFE (YEARS)	
OPERATING MODE	
NET POWER OUTPUT (MWE)	12.840
PLANT EFFICIENCY (PCT)	25.678
THERMODYNAMIC EFFICIENCY (PCT)	16.461
MHD ENTHALPY EXTRACTION (PCT)	6.5833
TOTAL HEAT INPUT TO STEAM (MWT)	40.662
STEAM CYCLE EFFICIENCY (PCT)	32.191
AIR PREHEAT TEMPERATURE (DEG K)	922.22
REFERENCE ATMOSPHERE	
PRESSURE (ATM)	.83017
DRY BULB TEMPERATURE (DEG K)	288.00
RELATIVE HUMIDITY (PCT)	60.000
STEAM CONDITIONS	
MAIN TURBINE THROTTLE PRESSURE (ATM)	41.849
MAIN TURBINE THROTTLE TEMPERATURE (DEG K)	713.50

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

POWER GENERATED AND CONSUMED ....

GROSS AC POWER (MWE)	
MHD POWER (AC)	3.1338
STEAM TURBINE-GENERATOR POWER	13.433
TOTAL	16.2771
POWER CONSUMED (MWE)	
SEC. AIR BLOWER	4.87333E-02
DRAFT FAN POWER	1.09729E-02
CONDENSATE PUMP	5.60062E-03
COOLING TWR CIRC PUMP	.18746
COAL HANDLING AND PROCESSING	.29094
ELECTROSTATIC PRECIP POWER	9.86253E-03
MHD MAGNET POWER	1.47938E-02
MISC. POWER	4.05858E-02
TRANSFORMER LOSS	.12970
TOTAL	.73865
NET POWER OUTPUT (MWE)	12.840

MECHANICAL DRIVE TURBINES (MW)

BOILER FEED PUMPS	8.49155E-02

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

COAL HANDLING AND PREPARATION ...

RAW COAL, AS RECEIVED

MOISTURE CONTENT (PCT)	22.700
FLOW RATE (KG/S)	2.3793
HIGH HEATING VALUE (J/KG)	2.07250E+07
COAL TO COMBUSTOR, AS FIRED	
MOISTURE CONTENT (PCT)	5.0000
FLOW RATE (KG/S)	1.9360
FLOW CONTROL (PCT)	
TRANSPORT MEDIUM	COMB. GAS
MECHANISM	
RATIO	1.00000E-01
DRYING MEDIUM	
FLOW RATE (KG/S)	4.0661
TEMPERATURE IN (DEG K)	644.40
TEMPERATURE OUT (DEG K)	377.70
HEAT REQUIRED FOR DRYING (MWT)	1.3420
POWER REQUIREMENT (MWE)	.29094

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

OXIDIZER SUPPLY ....

OXYGEN PLANT	
AMOUNT OF OXYGEN (PCT)	50.000
CONTAINED OXYGEN FLOW (TPD)	234.82
EQUIVALENT PURE OXYGEN (TPD)	234.82
O2 PREHEAT TEMP. (DEG K)	922.22
COST($1000) (ACCT. 317.7.2)	5993.0

MAIN AIR COMPRESSOR	
TYPE OF COMPRESSOR	AXIAL FLOW
TYPE OF INTERCOOLING	NONE
AIR INLET CONDITIONS	
PRESSURE (ATM)	.83017
TEMPERATURE (DEG K)	288.00
FLOW RATE (KG/S)	6.2682
AIR OUTLET CONDITIONS	
PRESSURE (ATM)	2.6788
TEMPERATURE (DEG K)	417.45
ADIABATIC EFFICIENCY (PCT)	87.300
SHAFT POWER (MW)	.79598

SECONDARY AIR INJECTION	
LOCATION	
PRESSURE (ATM)	1.0027
TEMPERATURE (DEG K)	307.92
FLOW RATE (KG/S)	2.4216
FAN EFFICIENCY (PCT)	80.000
POWER REQUIREMENT (MWE)	4.87333E-02

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

SEED FEED AND MANAGEMENT ....

TYPE	
SEED FLOW, TOTAL (KG/S)	.16876
POTASSIUM CARBONATE, K2CO3 (KG/S)	5.33108E-02
POTASSIUM SULFATE, K2SO4 (KG/S)	.11545

SEED RECOVERY/REGENERATION SYSTEM ...

TYPE	
RECOVERY (PCT)	95.000
REGENERATION (PCT)	33.300

FORM F432

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

MAIN COMBUSTOR ....

TYPE-NUMBER OF STAGES	2	
DIMENSIONS	1ST STAGE	2ND STAGE
LENGTH (M)	1.6898	2.6671
DIAMETER (M)	.91839	.66679
VOLUME (M**3)	1.1178	1.1858
WEIGHT (KG)	505.83	
COMBUSTOR EXIT CONDITIONS		
PRESSURE (ATM)	2.5227	
TEMPERATURE (DEG K)	2848.9	
FLOW RATE (KG/S)	8.4319	
SLAG REMOVAL (PCT)	85.000	
RESIDENCE TIME (MICRO-SEC)		
1-ST STAGE		
2-ND STAGE		
COMBUSTOR HEAT LOSSES (MWT)	5.7203	
COOLING WATER INLET		
PRESSURE (ATM)	190.50	
TEMPERATURE (DEG K)	427.40	
QUALITY	O.	
FLOW RATE (KG/S)	15.255	
COOLING WATER EXIT		
PRESSURE (ATM)	187.10	
TEMPERATURE (DEG K)	442.17	
QUALITY	O.	

NOZZLE ....

LENGTH (M)	.64747
WEIGHT (KG)	208.25
NOZZLE EXIT MACH NUMBER	1.3000
NOZZLE HEAT LOSS (MWT)	5.5500

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CHANNEL ....

TYPE	DIAGONAL		
DIMENSIONS			
INLET (MXM)	.21582	X	.21582
OUTLET (MXM)	.36568	X	.36568
LENGTH (M)	3.6786		
WEIGHT (KG)	11864.		
NUMBER OF ELECTRODE PAIRS	245.24		
SLAG REMOVAL (PCT)			
ENTHALPY EXTRACTION (PCT)	6.5833		
OVERALL (TURBINE) EFFICIENCY (PCT)	60.452		
INLET CONDITIONS			
PRESSURE (ATM)	1.0567		
TEMPERATURE (DEG K)	2491.9		
MACH NUMBER	1.3000		
VELOCITY (M/S)	1128.4		
FLOW RATE (KG/S)	8.4319		
OUTLET CONDITIONS			
PRESSURE (ATM)	.60646		
TEMPERATURE (DEG K)	2357.7		
MACH NUMBER	1.0048		
SURFACE TEMPERATURE (DEG K)	1800.0		
HEAT LOSS (MWT)	2.0462		
PEAK ELECTRODE CURRENT DENSITY (A/CM**2)			
MAXIMUM HALL FIELD (KV/M)	2.5000		

NUMBER OF CHANNELS	1
MHD GROSS POWER BEFORE INVERSION (MWE)	3.2464
MHD GROSS POWER AFTER INVERSION (MWE)	3.1338
INVERTER EFFICIENCY (PCT)	96.530

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

DIFFUSER AND TRANSITION PIECE ....

TYPE			
DIMENSIONS			
INLET (MXM)	.36568	X	.36568
OUTLET (MXM)	1.1702	X	1.1702
LENGTH (M)	3.8762		
WEIGHT (KG)	2932.8		
PRESSURE RECOVERY COEFFICIENT	.50000		
INLET CONDITIONS			
PRESSURE (ATM)	.60646		
TEMPERATURE (DEG K)	2357.7		
MACH NUMBER	1.0048		
FLOW RATE (KG/S)	8.4319		
OUTLET CONDITIONS - DIFFUSER			
PRESSURE (ATM)	.83138		
TEMPERATURE (DEG K)	2481.6		
MACH NUMBER	.40000		

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

MAGNET ....

TYPE	
DIMENSIONS	
LENGTH (M)	4.1569
OVERALL DIAMETER (M)	2.0784
WARM BORE	
INLET DIAMETER (M)	.87091
OUTLET DIAMETER (M)	.96372
FIELD STRENGTH (TESLA)	
PEAK	6.0000
ENERGY STORAGE (MJ)	187.36
WEIGHT (KG)	72323.

FORM F432

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

RADIANT BOILER ....

TYPE			
DIMENSIONS			
INLET (MXM)	3.8208	X	19.400
OUTLET (MXM)	3.8208	X	19.400
LENGTH (M)	21.200		
WEIGHT (KG)	5.00000E+05		
COMBUSTION GAS INLET CONDITIONS			
PRESSURE (ATM)	.83138		
TEMPERATURE (DEG K)	2473.0		
FLOW RATE (KG/S)	8.4319		
COMBUSTION GAS OUTLET CONDITIONS			
PRESSURE (ATM)	.80644		
TEMPERATURE (DEG K)	1867.0		
DWELL TIME (SEC)	2.5000		
WATER/STEAM INLET CONDITIONS			
PRESSURE (ATM)	183.70		
TEMPERATURE (DEG K)	442.17		
QUALITY	0.		
FLOW RATE (KG/S)	15.255		
WATER/STEAM EXIT CONDITIONS			
PRESSURE (ATM)	183.70		
TEMPERATURE (DEG K)	633.10		
QUALITY	1.0000		
THERMAL DUTY (MWT)	10.604		

FORM F432

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

SUPERHEATER ....

COMBUSTION GAS INLET CONDITIONS	
PRESSURE (ATM)	.80644
TEMPERATURE (DEG K)	2008.1
FLOW RATE (KG/S)	10.853
COMBUSTION GAS OUTLET CONDITIONS	
PRESSURE (ATM)	.80644
TEMPERATURE (DEG K)	644.40
SLAG REMOVAL (PCT)	
WATER/STEAM INLET CONDITIONS	
PRESSURE (ATM)	183.70
TEMPERATURE (DEG K)	633.10
FLOW RATE (KG/S)	15.255
WATER/STEAM OUTLET CONDITIONS	
PRESSURE (ATM)	41.849
TEMPERATURE (DEG K)	713.50
THERMAL DUTY (MWT)	17.728

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

OXIDANT PREHEATER ....

COMBUSTION GAS INLET CONDITIONS	
PRESSURE (ATM)	.80644
TEMPERATURE (DEG K)	2008.1
FLOW RATE (KG/S)	10.853
COMBUSTION GAS OUTLET CONDITIONS	
PRESSURE (ATM)	.80644
TEMPERATURE (DEG K)	644.40
AIR INLET CONDITIONS	
PRESSURE (ATM)	2.6788
TEMPERATURE (DEG K)	417.45
FLOW RATE (KG/S)	6.2682
AIR OUTLET CONDITIONS	
PRESSURE (ATM)	2.6007
TEMPERATURE (DEG K)	922.22
THERMAL DUTY (MWT)	3.3301

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

ECONOMIZER NO. 1....

DIMENSIONS	
LENGTH (M)	5.3340
WIDTH (M)	1.5689
HEIGHT (M)	1.5689
WEIGHT (KG)	
COMBUSTION GAS INLET CONDITIONS	
PRESSURE (ATM)	.80644
TEMPERATURE (DEG K)	644.40
FLOW RATE (KG/S)	4.5731
COMBUSTION GAS OUTLET CONDITIONS	
PRESSURE (ATM)	.80644
TEMPERATURE (DEG K)	477.00
WATER/STEAM INLET CONDITIONS	
PRESSURE (ATM)	46.793
TEMPERATURE (DEG K)	427.40
FLOW RATE (KG/S)	15.255
WATER/STEAM OUTLET CONDITIONS	
PRESSURE (ATM)	46.793
TEMPERATURE (DEG K)	440.50
THERMAL DUTY (MWT)	.86483

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

OVERALL SYSTEM PERFORMANCE ....

REFERENCE COAL	MONTANA ROSEBUD
COAL THERMAL INPUT (MWT)	312.00
PRIMARY CYCLE (MWT)	307.69
SEED REGENERATION (MWT)	4.3077
PLANT LIFE (YEARS)	
OPERATING MODE	
NET POWER OUTPUT (MWE)	97.594
PLANT EFFICIENCY (PCT)	31.280
THERMODYNAMIC EFFICIENCY (PCT)	25.326
MHD ENTHALPY EXTRACTION (PCT)	16.285
TOTAL HEAT INPUT TO STEAM (MWT)	226.84
STEAM CYCLE EFFICIENCY (PCT)	32.898
AIR PREHEAT TEMPERATURE (DEG K)	922.22
REFERENCE ATMOSPHERE	
PRESSURE (ATM)	.83017
DRY BULB TEMPERATURE (DEG K)	300.00
RELATIVE HUMIDITY (PCT)	60.000
STEAM CONDITIONS	
MAIN TURBINE THROTTLE PRESSURE (ATM)	58.860
MAIN TURBINE THROTTLE TEMPERATURE (DEG K)	755.20

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

POWER GENERATED AND CONSUMED ....

GROSS AC POWER (MWE)	
MHD POWER (AC)	48.371
STEAM TURBINE-GENERATOR POWER	62.669
TOTAL	111.04
POWER CONSUMED (MWE)	
SEC. AIR BLOWER	.31675
DRAFT FAN POWER	8.32110E-02
CONDENSATE PUMP	4.57273E-02
COOLING TWR CIRC PUMP	1.0345
COAL HANDLING AND PROCESSING	1.8154
ELECTROSTATIC PRECIP POWER	6.15389E-02
MHD MAGNET POWER	9.23084E-02
MISC. POWER	.38963
TRANSFORMER LOSS	.98580
TOTAL	4.8249
NET POWER OUTPUT (MWE)	97.594

MECHANICAL DRIVE TURBINES (MW)

CYCLE AIR COMPRESSOR	12.374
BOILER FEED PUMPS	.66913

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

COAL HANDLING AND PREPARATION ...

RAW COAL, AS RECEIVED	
MOISTURE CONTENT (PCT)	22.700
FLOW RATE (KG/S)	14.846
HIGH HEATING VALUE (J/KG)	2.07250E+07
COAL TO COMBUSTOR, AS FIRED	
MOISTURE CONTENT (PCT)	5.0000
FLOW RATE (KG/S)	12.080
FLOW CONTROL (PCT)	
TRANSPORT MEDIUM	COMB. GAS
MECHANISM	
RATIO	1.00000E-01
DRYING MEDIUM	
FLOW RATE (KG/S)	25.371
TEMPERATURE IN (DEG K)	644.40
TEMPERATURE OUT (DEG K)	377.70
HEAT REQUIRED FOR DRYING (MWT)	8.3733
POWER REQUIREMENT (MWE)	1.8154

OXIDIZER SUPPLY ....

OXYGEN PLANT	
AMOUNT OF OXYGEN (PCT)	35.944
CONTAINED OXYGEN FLOW (TPD)	1197.4
EQUIVALENT PURE OXYGEN (TPD)	1060.9
O2 PREHEAT TEMP. (DEG K)	922.22
MAIN AIR COMPRESSOR	
TYPE OF COMPRESSOR	AXIAL FLOW
TYPE OF INTERCOOLING	NONE
AIR INLET CONDITIONS	
PRESSURE (ATM)	.83017
TEMPERATURE (DEG K)	300.00
FLOW RATE (KG/S)	53.395
AIR OUTLET CONDITIONS	
PRESSURE (ATM)	5.1512
TEMPERATURE (DEG K)	530.17
ADIABATIC EFFICIENCY (PCT)	87.300
SHAFT POWER (MW)	12.374
SECONDARY AIR INJECTION	
LOCATION	
PRESSURE (ATM)	1.0027
TEMPERATURE (DEG K)	320.74
FLOW RATE (KG/S)	15.110
FAN EFFICIENCY (PCT)	80.000
POWER REQUIREMENT (MWE)	.31675

SEED FEED AND MANAGEMENT ....

TYPE	
SEED FLOW, TOTAL (KG/S)	1.3532
POTASSIUM CARBONATE, K2CO3 (KG/S)	.42749
POTASSIUM SULFATE, K2SO4 (KG/S)	.92575

SEED RECOVERY/REGENERATION SYSTEM ...

TYPE	
RECOVERY (PCT)	95.000
REGENERATION (PCT)	33.300

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

MAIN COMBUSTOR ....

TYPE-NUMBER OF STAGES	2	
DIMENSIONS	1ST STAGE	2ND STAGE
LENGTH (M)	2.8204	3.8216
DIAMETER (M)	1.5328	.95540
VOLUME (M**3)	5.1968	3.4883
WEIGHT (KG)	1907.1	
COMBUSTOR EXIT CONDITIONS		
PRESSURE (ATM)	4.8511	
TEMPERATURE (DEG K)	2782.8	
FLOW RATE (KG/S)	67.196	
SLAG REMOVAL (PCT)	85.000	
RESIDENCE TIME (MICRO-SEC)		
1-ST STAGE		
2-ND STAGE		
COMBUSTOR HEAT LOSSES (MWT)	23.385	
COOLING WATER INLET		
PRESSURE (ATM)	190.50	
TEMPERATURE (DEG K)	450.00	
QUALITY	0.	
FLOW RATE (KG/S)	85.850	
COOLING WATER EXIT		
PRESSURE (ATM)	187.10	
TEMPERATURE (DEG K)	466.37	
QUALITY	0.	

NOZZLE ....

LENGTH (M)	1.3479
WEIGHT (KG)	902.54
NOZZLE EXIT MACH NUMBER	1.3000
NOZZLE HEAT LOSS (MWT)	5.5500

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CHANNEL ....

TYPE	DIAGONAL		
DIMENSIONS			
INLET (MXM)	.44930	X	.44930
OUTLET (MXM)	1.0400	X	1.0400
LENGTH (M)	11.650		
WEIGHT (KG)	96240.		
NUMBER OF ELECTRODE PAIRS	776.69		
SLAG REMOVAL (PCT)			
ENTHALPY EXTRACTION (PCT)	16.285		
OVERALL (TURBINE) EFFICIENCY (PCT)	70.396		
INLET CONDITIONS			
PRESSURE (ATM)	1.9527		
TEMPERATURE (DEG K)	2507.8		
MACH NUMBER	1.3000		
VELOCITY (M/S)	1149.5		
FLOW RATE (KG/S)	67.196		
OUTLET CONDITIONS			
PRESSURE (ATM)	.60696		
TEMPERATURE (DEG K)	2198.6		
MACH NUMBER	.99519		
SURFACE TEMPERATURE (DEG K)	1800.0		
HEAT LOSS (MWT)	15.416		
PEAK ELECTRODE CURRENT DENSITY (A/CM**2)			
MAXIMUM HALL FIELD (KV/M)	2.5000		

NUMBER OF CHANNELS	1
MHD GROSS POWER BEFORE INVERSION (MWE)	50.110
MHD GROSS POWER AFTER INVERSION (MWE)	48.371
INVERTER EFFICIENCY (PCT)	96.530

FORM F433

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

DIFFUSER AND TRANSITION PIECE ....

TYPE			
DIMENSIONS			
INLET (MXM)	1.0400	X	1.0400
OUTLET (MXM)	3.3280	X	3.3280
LENGTH (M)	11.024		
WEIGHT (KG)	23722.		
PRESSURE RECOVERY COEFFICIENT	.50000		
INLET CONDITIONS			
PRESSURE (ATM)	.60696		
TEMPERATURE (DEG K)	2198.6		
MACH NUMBER	.99519		
FLOW RATE (KG/S)	67.196		
OUTLET CONDITIONS - DIFFUSER			
PRESSURE (ATM)	.83600		
TEMPERATURE (DEG K)	2359.7		
MACH NUMBER	.40000		

FORM F432

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

MAGNET ....

TYPE	
DIMENSIONS	
LENGTH (M)	13.165
OVERALL DIAMETER (M)	6.5825
WARM BORE	
INLET DIAMETER (M)	1.2011
OUTLET DIAMETER (M)	1.8125
FIELD STRENGTH (TESLA)	
PEAK	6.0000
ENERGY STORAGE (MJ)	1383.9
WEIGHT (KG)	5.34204E+05

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

RADIANT BOILER ....

TYPE			
DIMENSIONS			
INLET (MXM)	10.786	X	19.400
OUTLET (MXM)	10.786	X	19.400
LENGTH (M)	21.200		
WEIGHT (KG)	5.00000E+05		
COMBUSTION GAS INLET CONDITIONS			
PRESSURE (ATM)	.83600		
TEMPERATURE (DEG K)	2348.6		
FLOW RATE (KG/S)	67.196		
COMBUSTION GAS OUTLET CONDITIONS			
PRESSURE (ATM)	.81092		
TEMPERATURE (DEG K)	1867.0		
DWELL TIME (SEC)	2.5000		
WATER/STEAM INLET CONDITIONS			
PRESSURE (ATM)	183.70		
TEMPERATURE (DEG K)	466.37		
QUALITY	0.		
FLOW RATE (KG/S)	85.850		
WATER/STEAM EXIT CONDITIONS			
PRESSURE (ATM)	183.70		
TEMPERATURE (DEG K)	633.10		
QUALITY	1.0000		
THERMAL DUTY (MWT)	56.818		

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

SUPERHEATER ....

COMBUSTION GAS INLET CONDITIONS	
PRESSURE (ATM)	.81092
TEMPERATURE (DEG K)	1977.6
FLOW RATE (KG/S)	82.306
COMBUSTION GAS OUTLET CONDITIONS	
PRESSURE (ATM)	.81092
TEMPERATURE (DEG K)	644.40
SLAG REMOVAL (PCT)	
WATER/STEAM INLET CONDITIONS	
PRESSURE (ATM)	183.70
TEMPERATURE (DEG K)	633.10
FLOW RATE (KG/S)	85.850
WATER/STEAM OUTLET CONDITIONS	
PRESSURE (ATM)	58.860
TEMPERATURE (DEG K)	755.20
THERMAL DUTY (MWT)	131.80

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

OXIDANT PREHEATER ....

COMBUSTION GAS INLET CONDITIONS	
PRESSURE (ATM)	.81092
TEMPERATURE (DEG K)	1977.6
FLOW RATE (KG/S)	82.306
COMBUSTION GAS OUTLET CONDITIONS	
PRESSURE (ATM)	.81092
TEMPERATURE (DEG K)	644.40
AIR INLET CONDITIONS	
PRESSURE (ATM)	5.1512
TEMPERATURE (DEG K)	530.17
FLOW RATE (KG/S)	53.395
AIR OUTLET CONDITIONS	
PRESSURE (ATM)	5.0011
TEMPERATURE (DEG K)	922.22
THERMAL DUTY (MWT)	22.530

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

ECONOMIZER NO. 1....

DIMENSIONS	
LENGTH (M)	7.3660
WIDTH (M)	4.8173
HEIGHT (M)	4.8173
WEIGHT (KG)	
COMBUSTION GAS INLET CONDITIONS	
PRESSURE (ATM)	.81092
TEMPERATURE (DEG K)	644.40
FLOW RATE (KG/S)	43.118
COMBUSTION GAS OUTLET CONDITIONS	
PRESSURE (ATM)	.81092
TEMPERATURE (DEG K)	477.00
WATER/STEAM INLET CONDITIONS	
PRESSURE (ATM)	65.814
TEMPERATURE (DEG K)	450.00
FLOW RATE (KG/S)	85.850
WATER/STEAM OUTLET CONDITIONS	
PRESSURE (ATM)	65.814
TEMPERATURE (DEG K)	471.30
THERMAL DUTY (MWT)	8.0738

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

OVERALL SYSTEM PERFORMANCE ....

REFERENCE COAL	MONTANA ROSEBUD
COAL THERMAL INPUT (MWT)	272.49
PRIMARY CYCLE (MWT)	268.72
SEED REGENERATION (MWT)	3.7621
PLANT LIFE (YEARS)	
OPERATING MODE	
NET POWER OUTPUT (MWE)	84.380
PLANT EFFICIENCY (PCT)	30.967
THERMODYNAMIC EFFICIENCY (PCT)	25.014
MHD ENTHALPY EXTRACTION (PCT)	15.970
TOTAL HEAT INPUT TO STEAM (MWT)	197.96
STEAM CYCLE EFFICIENCY (PCT)	32.898
AIR PREHEAT TEMPERATURE (DEG K)	922.22
REFERENCE ATMOSPHERE	
PRESSURE (ATM)	.83017
DRY BULB TEMPERATURE (DEG K)	300.00
RELATIVE HUMIDITY (PCT)	60.000
STEAM CONDITIONS	
MAIN TURBINE THROTTLE PRESSURE (ATM)	58.860
MAIN TURBINE THROTTLE TEMPERATURE (DEG K)	755.20

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

POWER GENERATED AND CONSUMED ....

GROSS AC POWER (MWE)	
MHD POWER (AC)	41.426
STEAM TURBINE-GENERATOR POWER	65.490
TOTAL	106.016
POWER CONSUMED (MWE)	
SEC. AIR BLOWER	.27663
DRAFT FAN POWER	7.26719E-02
CONDENSATE PUMP	3.99061E-02
COOLING TWR CIRC PUMP	.90283
COAL HANDLING AND PROCESSING	1.5855
ELECTROSTATIC PRECIP POWER	5.37447E-02
MHD MAGNET POWER	8.06170E-02
MISC. POWER	.33609
TRANSFORMER LOSS	.85233
TOTAL	4.2003
NET POWER OUTPUT (MWE)	84.380

MECHANICAL DRIVE TURBINES (MW)

BOILER FEED PUMPS	.58395

COAL HANDLING AND PREPARATION ...

RAW COAL, AS RECEIVED

MOISTURE CONTENT (PCT)	22.700
FLOW RATE (KG/S)	12.966
HIGH HEATING VALUE (J/KG)	2.07250E+07
COAL TO COMBUSTOR, AS FIRED	
SIZE (MESH, 70 PCT THRU)	0
MOISTURE CONTENT (PCT)	5.0000
FLOW RATE (KG/S)	10.550
FLOW CONTROL (PCT)	
TRANSPORT MEDIUM	COMB. GAS
MECHANISM	
RATIO	1.00000E-01
DRYING MEDIUM	
FLOW RATE (KG/S)	22.158
TEMPERATURE IN (DEG K)	644.40
TEMPERATURE OUT (DEG K)	377.70
HEAT REQUIRED FOR DRYING (MWT)	7.3128
POWER REQUIREMENT (MWE)	1.5855

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

OXIDIZER SUPPLY ....

OXYGEN PLANT	
AMOUNT OF OXYGEN (PCT)	35.944
CONTAINED OXYGEN FLOW (TPD)	1045.8
EQUIVALENT PURE OXYGEN (TPD)	926.57
O2 PREHEAT TEMP. (DEG K)	922.22
COST($1000) (ACCT. 317.7.2)	19797.

MAIN AIR COMPRESSOR	
TYPE OF COMPRESSOR	AXIAL FLOW
TYPE OF INTERCOOLING	NONE
AIR INLET CONDITIONS	
PRESSURE (ATM)	.83017
TEMPERATURE (DEG K)	300.00
FLOW RATE (KG/S)	46.632
AIR OUTLET CONDITIONS	
PRESSURE (ATM)	5.1512
TEMPERATURE (DEG K)	530.17
ADIABATIC EFFICIENCY (PCT)	87.300
SHAFT POWER (MW)	10.807

SECONDARY AIR INJECTION	
LOCATION	
PRESSURE (ATM)	1.0027
TEMPERATURE (DEG K)	320.74
FLOW RATE (KG/S)	13.196
FAN EFFICIENCY (PCT)	80.000
POWER REQUIREMENT (MWE)	.27663

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

SEED FEED AND MANAGEMENT ....

TYPE	
SEED FLOW, TOTAL (KG/S)	1.1818
POTASSIUM CARBONATE, K_2CO_3 (KG/S)	.37335
POTASSIUM SULFATE, K_2SO_4 (KG/S)	.80850

SEED RECOVERY/REGENERATION SYSTEM ...

TYPE	
RECOVERY (PCT)	95.000
REGENERATION (PCT)	33.300

MAIN COMBUSTOR ....

TYPE-NUMBER OF STAGES	2	
DIMENSIONS	1ST STAGE	2ND STAGE
LENGTH (M)	2.6506	3.6324
DIAMETER (M)	1.4406	.90809
VOLUME (M**3)	4.3138	2.9954
WEIGHT (KG)	1605.0	
COMBUSTOR EXIT CONDITIONS		
PRESSURE (ATM)	4.8511	
TEMPERATURE (DEG K)	2782.8	
FLOW RATE (KG/S)	58.685	
SLAG REMOVAL (PCT)	85.000	
RESIDENCE TIME (MICRO-SEC)		
1-ST STAGE		
2-ND STAGE		
COMBUSTOR HEAT LOSSES (MWT)	20.423	
COOLING WATER INLET		
PRESSURE (ATM)	190.50	
TEMPERATURE (DEG K)	450.00	
QUALITY	0.	
FLOW RATE (KG/S)	74.921	
COOLING WATER EXIT		
PRESSURE (ATM)	187.10	
TEMPERATURE (DEG K)	466.38	
QUALITY	0.	

NOZZLE ....

LENGTH (M)	1.2577
WEIGHT (KG)	785.83
NOZZLE EXIT MACH NUMBER	1.3000
NOZZLE HEAT LOSS (MWT)	5.5500

FORM 4432

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

CHANNEL ....

TYPE	DIAGONAL		
DIMENSIONS			
INLET (MXM)	.41925	X	.41925
OUTLET (MXM)	.98268	X	.98268
LENGTH (M)	11.754		
WEIGHT (KG)	91398.		
NUMBER OF ELECTRODE PAIRS	783.62		
SLAG REMOVAL (PCT)			
ENTHALPY EXTRACTION (PCT)	15.970		
OVERALL (TURBINE) EFFICIENCY (PCT)	69.053		
INLET CONDITIONS			
PRESSURE (ATM)	1.9568		
TEMPERATURE (DEG K)	2504.5		
MACH NUMBER	1.3000		
VELOCITY (M/S)	1148.8		
FLOW RATE (KG/S)	58.685		
OUTLET CONDITIONS			
PRESSURE (ATM)	.60696		
TEMPERATURE (DEG K)	2192.7		
MACH NUMBER	.99488		
SURFACE TEMPERATURE (DEG K)	1800.0		
HEAT LOSS (MWT)	14.404		
PEAK ELECTRODE CURRENT DENSITY (A/CM**2)			
MAXIMUM HALL FIELD (KV/M)	2.5000		

NUMBER OF CHANNELS	1
MHD GROSS POWER BEFORE INVERSION (MWE)	42.915
MHD GROSS POWER AFTER INVERSION (MWE)	41.426
INVERTER EFFICIENCY (PCT)	96.530

DIFFUSER AND TRANSITION PIECE ....

TYPE			
DIMENSIONS			
INLET (MXM)	.98268	X	.98268
OUTLET (MXM)	3.1446	X	3.1446
LENGTH (M)	10.416		
WEIGHT (KG)	21179.		
PRESSURE RECOVERY COEFFICIENT	.50000		
INLET CONDITIONS			
PRESSURE (ATM)	.60696		
TEMPERATURE (DEG K)	2192.7		
MACH NUMBER	.99488		
FLOW RATE (KG/S)	58.685		
OUTLET CONDITIONS - DIFFUSER			
PRESSURE (ATM)	.83611		
TEMPERATURE (DEG K)	2355.0		
MACH NUMBER	.40000		

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

MAGNET ....

TYPE	
DIMENSIONS	
LENGTH (M)	13.282
OVERALL DIAMETER (M)	6.6412
WARM BORE	
INLET DIAMETER (M)	1.1586
OUTLET DIAMETER (M)	1.7403
FIELD STRENGTH (TESLA)	
PEAK	6.0000
ENERGY STORAGE (MJ)	1297.0
WEIGHT (KG)	5.00642E+05

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

RADIANT BOILER ....

TYPE			
DIMENSIONS			
INLET (MXM)	10.080	X	19.400
OUTLET (MXM)	10.080	X	19.400
LENGTH (M)	21.200		
WEIGHT (KG)	5.00000E+05		
COMBUSTION GAS INLET CONDITIONS			
PRESSURE (ATM)	.83611		
TEMPERATURE (DEG K)	2343.0		
FLOW RATE (KG/S)	58.685		
COMBUSTION GAS OUTLET CONDITIONS			
PRESSURE (ATM)	.81103		
TEMPERATURE (DEG K)	1867.0		
DWELL TIME (SEC)	2.5000		
WATER/STEAM INLET CONDITIONS			
PRESSURE (ATM)	183.70		
TEMPERATURE (DEG K)	466.38		
QUALITY	0.		
FLOW RATE (KG/S)	74.921		
WATER/STEAM EXIT CONDITIONS			
PRESSURE (ATM)	183.70		
TEMPERATURE (DEG K)	633.10		
QUALITY	1.0000		
THERMAL DUTY (MWT)	48.773		

FORM F432

SUPERHEATER ....

COMBUSTION GAS INLET CONDITIONS	
PRESSURE (ATM)	.81103
TEMPERATURE (DEG K)	1977.6
FLOW RATE (KG/S)	71.881
COMBUSTION GAS OUTLET CONDITIONS	
PRESSURE (ATM)	.81103
TEMPERATURE (DEG K)	644.40
SLAG REMOVAL (PCT)	
WATER/STEAM INLET CONDITIONS	
PRESSURE (ATM)	183.70
TEMPERATURE (DEG K)	633.10
FLOW RATE (KG/S)	74.921
WATER/STEAM OUTLET CONDITIONS	
PRESSURE (ATM)	58.860
TEMPERATURE (DEG K)	755.20
THERMAL DUTY (MWT)	115.11

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

OXIDANT PREHEATER ....

COMBUSTION GAS INLET CONDITIONS	
PRESSURE (ATM)	.81103
TEMPERATURE (DEG K)	1977.6
FLOW RATE (KG/S)	71.881
COMBUSTION GAS OUTLET CONDITIONS	
PRESSURE (ATM)	.81103
TEMPERATURE (DEG K)	644.40
AIR INLET CONDITIONS	
PRESSURE (ATM)	5.1512
TEMPERATURE (DEG K)	530.17
FLOW RATE (KG/S)	46.632
AIR OUTLET CONDITIONS	
PRESSURE (ATM)	5.0011
TEMPERATURE (DEG K)	922.22
THERMAL DUTY (MWT)	19.677

MHD FACILITY ... PERFORMANCE ANALYSIS DATA

ECONOMIZER NO. 1....

DIMENSIONS	
LENGTH (M)	7.2390
WIDTH (M)	4.5019
HEIGHT (M)	4.5019
WEIGHT (KG)	
COMBUSTION GAS INLET CONDITIONS	
PRESSURE (ATM)	.81103
TEMPERATURE (DEG K)	644.40
FLOW RATE (KG/S)	37.657
COMBUSTION GAS OUTLET CONDITIONS	
PRESSURE (ATM)	.81103
TEMPERATURE (DEG K)	477.00
WATER/STEAM INLET CONDITIONS	
PRESSURE (ATM)	65.814
TEMPERATURE (DEG K)	450.00
FLOW RATE (KG/S)	74.921
WATER/STEAM OUTLET CONDITIONS	
PRESSURE (ATM)	65.814
TEMPERATURE (DEG K)	471.32
THERMAL DUTY (MWT)	7.0512

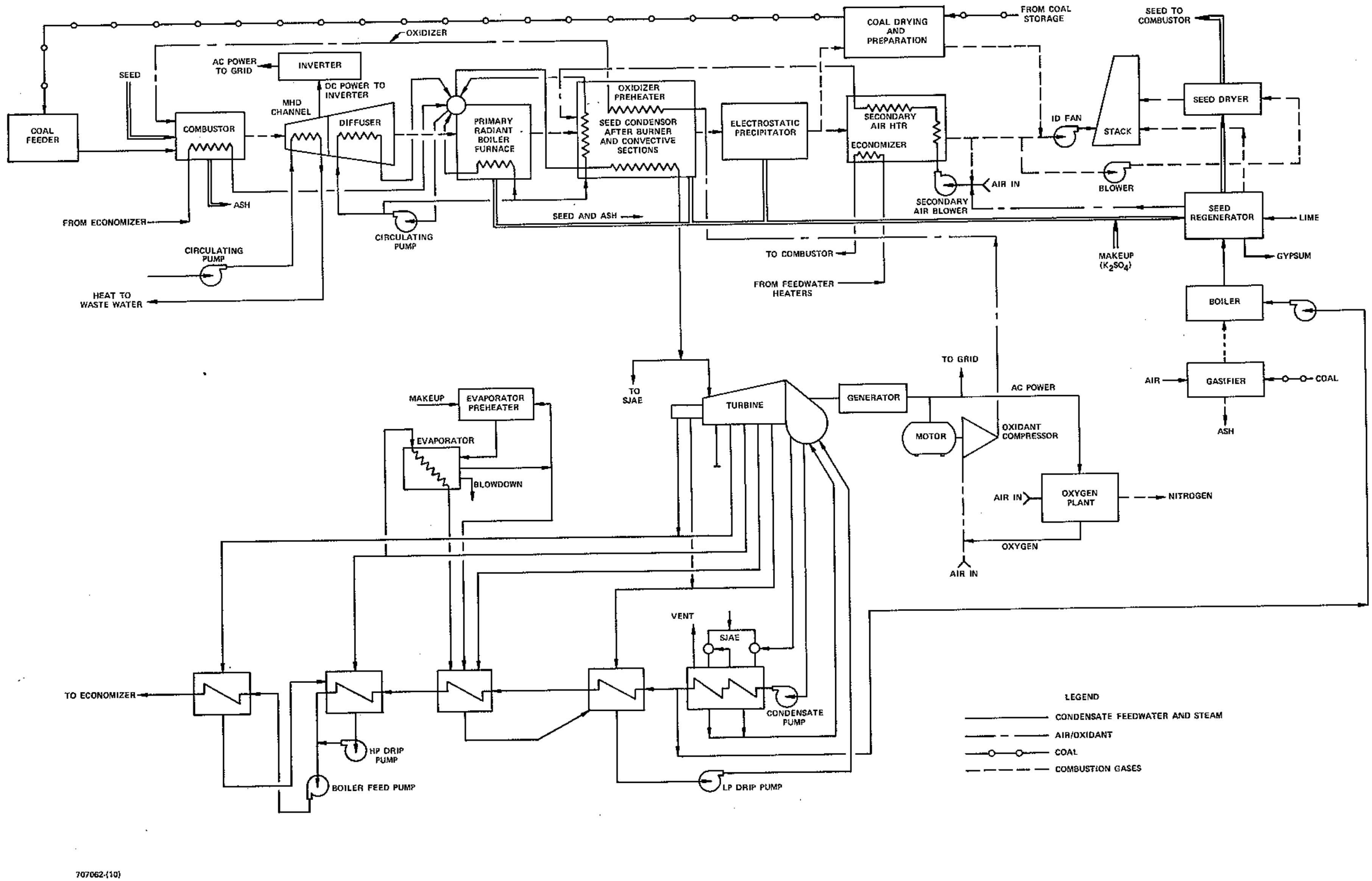

Figure B-1. CDIF 80 MW_t MHD/Steam Integrated Test System

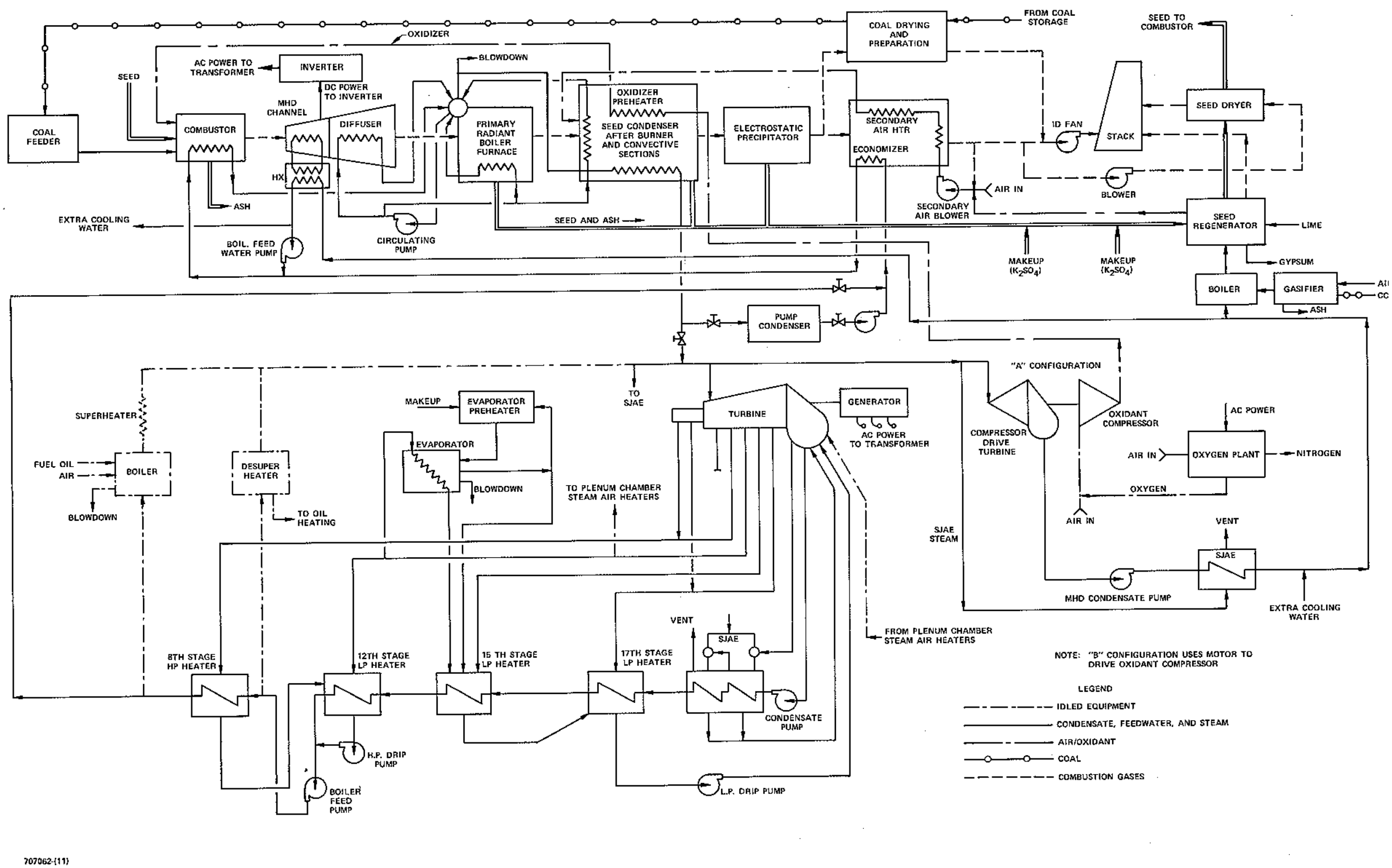

Figure B-2. Frank E. Bird Plant MHD Retrofit ("A" Configuration)

Part 2

WAESD-TR-85-0079

MHD Advanced Power Train

Phase I Final Report

Volume 7
Appendices

Prepared For

**THE UNITED STATES DEPARTMENT OF ENERGY
PITTSBURGH ENERGY TECHNOLOGY CENTER**

Contract DE-AC22-83PC60575

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Westinghouse
Advanced Energy Systems Division
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Part 2

C. MHD CHANNEL ELECTRODE VOLTAGE AND CURRENT

APPENDIX C - MHD GENERATOR ELECTRODE VOLTAGES AND CURRENTS

Table C-1 is a design preliminary calculation of the current and voltage on anode and cathode halfs of each split constant potential frame. Voltage reference for this calculation was arbitrarily delayed since diffuser will be grounded, the correct voltage of the frames is obtained by subtracting 22485 V.

Note first cathode is at frame 50 (labeled electrode number in listing); last anode is at frame 560.

These values calculated by STD Research Corp. are preliminary in that they did not include sidewall currents and did not include Faraday configuration inlet and exit regions (see Section 2.3.4).

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VAX/VMS   DWE         Q3DCC458 23-OCT-1984 16:40   LPA0: 23-OCT-1984 16:40   DISK$VAXVMSRL3:[JEH.APT.SPECIAL]
VAX/VMS   DWE         Q3DCC458 23-OCT-1984 16:40   LPA0: 23-OCT-1984 16:40   DISK$VAXVMSRL3:[JEH.APT.SPECIAL]
VAX/VMS   DWE         Q3DCC458 23-OCT-1984 16:40   LPA0: 23-OCT-1984 16:40   DISK$VAXVMSRL3:[JEH.APT.SPECIAL]
VAX/VMS   DWE         Q3DCC458 23-OCT-1984 16:40   LPA0: 23-OCT-1984 16:40   DISK$VAXVMSRL3:[JEH.APT.SPECIAL]

VAX/VMS   DWE         Q3DCC458 23-OCT-1984 16:40   LPA0: 23-OCT-1984 16:40   DISK$VAXVMSRL3:[JEH.APT.SPECIAL]
VAX/VMS   DWE         Q3DCC458 23-OCT-1984 16:40   LPA0: 23-OCT-1984 16:40   DISK$VAXVMSRL3:[JEH.APT.SPECIAL]
VAX/VMS   DWE         Q3DCC458 23-OCT-1984 16:40   LPA0: 23-OCT-1984 16:40   DISK$VAXVMSRL3:[JEH.APT.SPECIAL]

                   DDDD   W   W  EEEEE
                   D   D  W   W  E
                   D   D  W   W  E
                   D   D  W   W  EEEE
                   D   D  W W W  E
                   D   D  WW WW  E
                   DDDD   W   W  EEEEE

   QQQQQQ     333333    DDDDDDDD     CCCCCCCC    CCCCCCCC  44     44    5555555555   888888
   QQQQQQ     333333    DDDDDDDD     CCCCCCCC    CCCCCCCC  44     44    5555555555   888888
 QQ      QQ  33      33 DD      DD  CC          CC         44     44    55          88      88
 QQ      QQ  33      33 DD      DD  CC          CC         44     44    55          88      88
 QQ      QQ          33 DD      DD  CC          CC         44     44    555555      88      88
 QQ      QQ          33 DD      DD  CC          CC         44     44    555555      88      88
 QQ      QQ        33   DD      DD  CC          CC         4444444444         55     888888
 QQ      QQ        33   DD      DD  CC          CC         4444444444         55     888888
 QQ  QQ  QQ          33 DD      DD  CC          CC                44            55  88      88
 QQ  QQ  QQ          33 DD      DD  CC          CC                44            55  88      88
 QQ    QQ    33      33 DD      DD  CC          CC                44    55      55  88      88
 QQ    QQ    33      33 DD      DD  CC          CC                44    55      55  88      88
   QQQQ  QQ   333333    DDDDDDDD     CCCCCCCC    CCCCCCCC         44      555555     888888
   QQQQ  QQ   333333    DDDDDDDD     CCCCCCCC    CCCCCCCC         44      555555     888888

 DDDDDDDD     AAAAAA    TTTTTTTTTT     ;;;;     333333
 DDDDDDDD     AAAAAA    TTTTTTTTTT     ;;;;     333333
 DD      DD  AA      AA     TT         ;;;;   33      33
 DD      DD  AA      AA     TT         ;;;;   33      33
 DD      DD  AA      AA     TT                        33
 DD      DD  AA      AA     TT                        33
 DD      DD  AA      AA     TT         ;;;;         33
 DD      DD  AA      AA     TT         ;;;;         33
 DD      DD  AAAAAAAAAA     TT         ;;;;           33
 DD      DD  AAAAAAAAAA     TT         ;;;;           33
 DD      DD  AA      AA     TT           ;;   33      33
 DD      DD  AA      AA     TT           ;;   33      33
 DDDDDDDD    AA      AA     TT         ;;       333333
 DDDDDDDD    AA      AA     TT         ;;       333333

                   DDDD   W   W  EEEEE
                   D   D  W   W  E
                   D   D  W   W  E
                   D   D  W   W  EEEE
                   D   D  W W W  E
                   D   D  WW WW  E
                   DDDD   W   W  EEEEE

VAX/VMS   DWE         Q3DCC458 23-OCT-1984 16:40   LPA0: 23-OCT-1984 16:40   DISK$VAXVMSRL3:[JEH.APT.SPECIAL]
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ELECTRODE NUMBER	VOLTAGE INCREMENT (volts)	VOLTAGE TOTAL (volts)	CURRENT ANODE (amps)	CURRENT CATHODE (amps)	COORDINATE ANODE (m)	COORDINATE CATHODE (m)
1	0.00000	-71.99041	19.90294	0.00000	0.02221	-1.05400
2	-2.96621	-74.95662	21.75625	0.00000	0.04423	-1.03234
3	-4.04753	-79.00415	23.32035	0.00000	0.06628	-1.01069
4	-3.79245	-82.79660	24.74044	0.00000	0.08829	-0.98903
5	-2.51243	-85.30903	26.43979	0.00000	0.11020	-0.96738
6	-3.45092	-88.75995	28.01156	0.00000	0.13211	-0.94572
7	-3.72389	-92.48384	29.42095	0.00000	0.15410	-0.92407
8	-2.94836	-95.43220	30.81895	0.00000	0.17610	-0.90241
9	-2.77715	-98.20935	32.19605	0.00000	0.19806	-0.88076
10	-2.48384	-100.69319	33.71973	0.00000	0.22002	-0.85910
11	-2.27148	-102.96468	34.90956	0.00000	0.24206	-0.82745
12	-1.89326	-104.85794	36.26880	0.00000	0.26400	-0.81579
13	-1.65948	-106.51743	37.61326	0.00000	0.28597	-0.79413
14	-1.39655	-107.91397	38.89786	0.00000	0.30796	-0.77248
15	-1.08322	-108.99719	40.06844	0.00000	0.32996	-0.75082
16	-1.92342	-110.92062	41.71223	0.00000	0.35193	-0.72917
17	-4.98371	-115.90433	43.53030	0.00000	0.37395	-0.70751
18	-6.21757	-122.12189	45.38541	0.00000	0.39595	-0.68586
19	-5.15288	-127.27477	47.23660	0.00000	0.41796	-0.66420
20	-4.47622	-131.75099	49.19415	0.00000	0.43997	-0.64255
21	-5.68857	-137.43956	50.43484	0.00000	0.46206	-0.62089
22	-8.30621	-145.74577	51.70237	0.00000	0.48407	-0.59924
23	-7.90288	-153.64865	52.74081	0.00000	0.50614	-0.57758
24	-7.37572	-161.02437	53.80618	0.00000	0.52821	-0.55593
25	-6.82611	-167.85048	54.09025	0.00000	0.55031	-0.53427
26	-6.15419	-174.00467	55.09228	0.00000	0.57214	-0.51255
27	-5.57869	-179.58336	55.94925	0.00000	0.59403	-0.49052
28	-4.96024	-184.54359	56.85463	0.00000	0.61593	-0.46870
29	-4.39520	-188.93880	57.56517	0.00000	0.63786	-0.44689
30	-3.67120	-192.61000	58.54479	0.00000	0.65979	-0.42509
31	-2.98299	-195.59299	59.20019	0.00000	0.68180	-0.40340
32	-2.38878	-197.98177	59.68943	0.00000	0.70378	-0.38162
33	-1.56635	-199.54811	60.29971	0.00000	0.72573	-0.35983
34	-0.91689	-200.46500	61.16125	0.00000	0.74765	-0.33803
35	-0.20328	-200.66827	61.59521	0.00000	0.76968	-0.31630
36	0.56903	-200.09924	62.01281	0.00000	0.79165	-0.29455
37	1.24931	-198.84993	62.89261	0.00000	0.81358	-0.27274
38	2.06412	-196.78581	63.24203	0.00000	0.83563	-0.25105
39	2.79936	-193.98645	63.65005	0.00000	0.85762	-0.22929
40	3.60944	-190.37701	64.17710	0.00000	0.87959	-0.20754

ELECTRODE NUMBER	VOLTAGE INCREMENT (volts)	VOLTAGE TOTAL (volts)	CURRENT ANODE (amps)	CURRENT CATHODE (amps)	COORDINATE ANODE (m)	COORDINATE CATHODE (m)
41	4.27597	-186.10104	64.94598	0.00000	0.90158	-0.18579
42	5.19023	-180.91081	64.96131	0.00000	0.92368	-0.16409
43	6.01239	-174.89842	65.55446	0.00000	0.94564	-0.14232
44	6.77519	-168.12323	65.99359	0.00000	0.96767	-0.12060
45	7.55774	-160.56549	66.34079	0.00000	0.98972	-0.09888
46	8.42807	-152.13742	66.42567	0.00000	1.01176	-0.07715
47	9.22461	-142.91281	67.18969	0.00000	1.03371	-0.05536
48	9.99866	-132.91415	67.31113	0.00000	1.05580	-0.03370
49	10.88121	-122.03294	67.60518	0.00000	1.07784	-0.01194
50	11.67395	-110.35899	67.84785	13.12152	1.09986	0.00960
51	12.63115	-97.72784	68.13049	20.10539	1.12189	0.03082
52	13.26926	-84.45858	68.63791	21.62564	1.14390	0.05219
53	14.31798	-70.14060	68.63509	23.16131	1.16601	0.07354
54	15.18336	-54.95724	68.94856	24.73085	1.18804	0.09495
55	15.84173	-39.11551	69.16970	26.37320	1.21009	0.11644
56	16.77718	-22.33834	69.43764	27.53395	1.23216	0.13787
57	17.71339	-4.62495	69.47352	28.93500	1.25425	0.15924
58	18.50608	13.88114	69.65633	30.35648	1.27629	0.18063
59	19.31749	33.19863	70.15282	31.58711	1.29833	0.20206
60	20.29444	53.49307	69.87959	32.91628	1.32048	0.22343
61	21.21253	74.70560	70.20676	34.22782	1.34250	0.24481
62	22.01907	96.72466	70.46323	35.39060	1.36458	0.26623
63	22.91199	119.63666	70.44051	36.68515	1.38669	0.28759
64	23.78873	143.42538	70.58533	37.81809	1.40877	0.30898
65	32.16742	175.59280	70.74647	39.01292	1.43085	0.33034
66	46.28128	221.87408	70.76501	40.34809	1.45296	0.35171
67	50.42776	272.30185	70.62931	42.23721	1.47504	0.37303
68	50.28171	322.58356	70.68110	43.91048	1.49708	0 39441
69	50.30154	372 88510	70.71512	45.53777	1.51913	0.41576
70	49.77954	422 66464	70 34100	47.09710	1.54121	0.43707
71	49.32056	471.98520	69.71325	48.76138	1.56326	0.45832
72	50.67258	522.65778	69.68613	49.57190	1.58528	0.47969
73	49.62830	572.28607	69.41663	50.60612	1.60734	0.50094
74	49.63531	621.92139	69.23592	51 43242	1.62937	0.52220
75	49.65326	671.57465	68.81404	52.37098	1.65139	0.54344
76	49.48975	721.06439	68.91031	53.10303	1.67334	0 56469
77	49.72583	770.79022	68.50056	53.92084	1.69537	0.58589
78	49.55328	820.34351	68.28975	54.65781	1.71733	0.60712
79	49.56470	869.90820	67.94559	55.39312	1.73929	0.62832
80	49.48273	919.39093	67.90662	55.93309	1.76119	0.64953

ELECTRODE NUMBER	VOLTAGE INCREMENT (volts)	VOLTAGE TOTAL (volts)	CURRENT ANODE (amps)	CURRENT CATHODE (amps)	COORDINATE ANODE (m)	COORDINATE CATHODE (m)
81	49.60284	968.99377	67.53799	56.66017	1.78315	0.67069
82	49.51044	1018.50421	67.26635	57.18408	1.80505	0.69186
83	49.47699	1067.98120	67.03802	57.80280	1.82692	0.71300
84	49.46838	1117.44958	66.82167	58.23177	1.84879	0.73415
85	49.49451	1166.94409	66.53223	58.74931	1.87066	0.75525
86	49.47070	1216.41479	66.14008	59.41301	1.89251	0.77633
87	49.35474	1265.76953	66.03033	59.67115	1.91430	0.79747
88	49.46985	1315.23938	65.70079	60.12838	1.93612	0.81852
89	49.41309	1364.65247	65.43720	60.59162	1.95792	0.83957
90	49.42493	1414.07739	64.98186	61.11497	1.97970	0.86060
91	49.25879	1463.33618	64.96460	61.28575	2.00140	0.88168
92	49.46973	1512.80591	64.43121	61.59679	2.02319	0.90266
93	49.24780	1562.05371	64.27859	62.06966	2.04487	0.92362
94	49.36255	1611.41626	64.00601	62.27502	2.06658	0.94460
95	49.34497	1660.76123	63.66295	62.59803	2.08828	0.96553
96	49.30225	1710.06348	63.37496	62.79094	2.10995	0.98645
97	49.29590	1759.35938	63.08764	63.15745	2.13161	1.00733
98	49.29236	1808.65173	62.77475	63.36524	2.15326	1.02823
99	49.27319	1857.92493	62.44933	63.55686	2.17488	1.04909
100	49.22388	1907.14880	62.17812	63.73503	2.19648	1.06992
101	49.26587	1956.41467	61.87023	63.99841	2.21808	1.09072
102	49.23572	2005.65039	61.56749	64.16187	2.23966	1.11153
103	49.23804	2054.88843	61.26387	64.20364	2.26123	1.13230
104	49.22095	2104.10938	60.95784	64.38361	2.28279	1.15302
105	49.21509	2153.32446	60.66042	64.59215	2.30432	1.17373
106	49.21460	2202.53906	60.34993	64.66914	2.32585	1.19443
107	49.14624	2251.68530	59.92402	64.65634	2.34737	1.21510
108	48.65527	2300.34058	59.61628	64.83669	2.36884	1.23571
109	48.59668	2348.93726	59.36747	64.91437	2.39032	1.25633
110	48.68604	2397.62329	59.00936	65.00948	2.41180	1.27692
111	48.66211	2446.28540	58.95817	64.92790	2.43323	1.29749
112	48.88916	2495.17456	58.41073	65.12612	2.45470	1.31799
113	48.22339	2543.39795	58.48356	65.13789	2.47605	1.33852
114	49.09619	2592.49414	58.08348	65.20120	2.49748	1.35901
115	48.54492	2641.03906	57.99419	65.06690	2.51885	1.37948
116	48.95313	2689.99219	57.46817	65.26181	2.54025	1.39988
117	48.23315	2738.22534	57.54975	65.14809	2.56152	1.42031
118	49.09009	2787.31543	57.12575	65.20593	2.58289	1.44068
119	48.53198	2835.84741	56.97862	65.25233	2.60417	1.46104
120	48.85132	2884.69873	56.77937	65.17271	2.62547	1.48140

ELECTRODE NUMBER	VOLTAGE INCREMENT (volts)	VOLTAGE TOTAL (volts)	CURRENT ANODE (amps)	CURRENT CATHODE (amps)	COORDINATE ANODE (m)	COORDINATE CATHODE (m)
121	48.67578	2933.37451	56.37636	65.07198	2.64676	1.50173
122	48.45996	2981.83447	56.38234	64.95359	2.66797	1.52204
123	49.02295	3030.85742	56.07134	64.64922	2.68924	1.54233
124	48.72339	3079.58081	55.77153	64.08592	2.71047	1.56260
125	48.51172	3128.09253	55.61381	63.90224	2.73166	1.58284
126	48.81934	3176.91187	55.38960	63.71834	2.75285	1.60307
127	48.70142	3225.61328	55.10520	63.52760	2.77402	1.62326
128	48.75659	3274.36987	55.06308	63.33449	2.79515	1.64347
129	48.87256	3323.24243	54.55313	63.13607	2.81634	1.66365
130	48.29053	3371.53296	54.62719	62.93502	2.83740	1.68382
131	49.17188	3420.70483	54.23605	62.73449	2.85854	1.70396
132	48.52173	3469.22656	54.02316	62.53448	2.87961	1.72410
133	48.79883	3518.02539	54.04164	62.32000	2.90067	1.74422
134	48.97534	3567.00073	53.36994	62.11028	2.92179	1.76432
135	48.00049	3615.00122	53.61209	61.89427	2.94273	1.78441
136	49.37939	3664.38062	53.19616	61.66689	2.96381	1.80448
137	48.55786	3712.93848	53.16360	61.32475	2.98481	1.82454
138	48.89404	3761.83252	52.54606	61.39680	3.00586	1.84454
139	48.36670	3810.19922	52.75556	60.89786	3.02673	1.86462
140	49.03809	3859.23730	52.37975	60.70652	3.04775	1.88460
141	48.65088	3907.88818	52.07820	60.70250	3.06869	1.90457
142	48.78174	3956.66992	52.25658	59.95961	3.08957	1.92461
143	48.70776	4005.37769	51.51507	60.30403	3.11060	1.94446
144	48.57690	4053.95459	51.79448	59.66504	3.13138	1.96449
145	48.99658	4102.95117	51.22216	59.67506	3.15235	1.98437
146	48.30664	4151.25781	51.40897	59.06843	3.17316	2.00432
147	48.83936	4200.09717	50.80487	59.26521	3.19411	2.02413
148	48.50000	4248.59717	50.94436	58.68941	3.21487	2.04408
149	48.77002	4297.36719	50.66763	58.53801	3.23574	2.06390
150	48.67529	4346.04248	50.29144	58.48865	3.25656	2.08374
151	48.54248	4394.58496	50.63914	57.69964	3.27728	2.10363
152	48.94385	4443.52881	49.83671	58.08273	3.29820	2.12333
153	48.43164	4491.96045	50.06387	57.40960	3.31885	2.14323
154	48.76416	4540.72461	49.68830	57.36339	3.33965	2.16297
155	48.60547	4589.33008	49.77222	56.84267	3.36036	2.18277
156	48.82373	4638.15381	49.27420	56.91629	3.38115	2.20246
157	48.53125	4686.68506	49.36121	56.39632	3.40179	2.22225
158	48.76660	4735.45166	49.08647	56.24285	3.42252	2.24194
159	48.66016	4784.11182	48.83113	56.06675	3.44320	2.26160
160	48.60547	4832.71729	48.95866	55.51437	3.46382	2.28138

ELECTRODE NUMBER	VOLTAGE INCREMENT (volts)	VOLTAGE TOTAL (volts)	CURRENT ANODE (amps)	CURRENT CATHODE (amps)	COORDINATE ANODE (m)	COORDINATE CATHODE (m)
161	48.81396	4881.53125	48.42474	55.61650	3.48455	2.30099
162	48.53906	4930.07031	48.54218	55.07355	3.50511	2.32071
163	48.75586	4978.82617	48.25137	54.94453	3.52578	2.34032
164	48.67969	5027.50586	48.01046	54.79156	3.54637	2.35997
165	48.73877	5076.24463	48.20192	53.90180	3.56692	2.37968
166	48.87500	5125.11963	47.57280	54.34717	3.58760	2.39915
167	48.63184	5173.75146	47.72182	53.86237	3.60807	2.41884
168	48.80811	5222.55957	47.43486	53.59367	3.62866	2.43842
169	48.70459	5271.26416	47.45037	53.58057	3.64917	2.45795
170	48.93848	5320.20264	47.04438	53.35768	3.66975	2.47755
171	48.61670	5368.81934	47.11135	53.05899	3.69021	2.49710
172	48.86865	5417.68799	46.83306	52.90739	3.71074	2.51662
173	48.74170	5466.42969	46.62757	52.94544	3.73121	2.53613
174	48.78711	5515.21680	46.77133	52.31878	3.75165	2.55572
175	48.92090	5564.13770	46.20185	52.59881	3.77219	2.57513
176	48.65137	5612.78906	46.33728	52.16909	3.79255	2.59470
177	48.87549	5661.66455	46.12939	51.87653	3.81301	2.61418
178	48.76416	5710.42871	45.95767	51.95202	3.83343	2.63360
179	48.90332	5759.33203	45.81898	51.64176	3.85383	2.65310
180	48.77783	5808.10986	45.67239	51.43743	3.87423	2.67254
181	48.83447	5856.94434	45.52457	51.24392	3.89460	2.69197
182	48.78906	5905.73340	45.38612	51.14062	3.91497	2.71136
183	48.90234	5954.63574	45.23996	50.94362	3.93532	2.73081
184	48.81885	6003.45459	45.10119	50.71227	3.95566	2.75021
185	48.84570	6052.30029	44.95598	50.60054	3.97599	2.76959
186	48.84424	6101.14453	44.81853	50.34615	3.99631	2.78895
187	48.84521	6149.98975	44.67770	50.19033	4.01661	2.80834
188	48.86914	6198.85889	44.53765	50.10353	4.03691	2.82769
189	48.91797	6247.77686	44.39978	49.79323	4.05719	2.84706
190	48.78906	6296.56592	44.26109	49.71990	4.07746	2.86636
191	48.92822	6345.49414	44.12146	49.49243	4.09771	2.88570
192	48.81445	6394.30859	43.98846	49.23743	4.11795	2.90500
193	48.89844	6443.20703	43.84989	49.34483	4.13819	2.92427
194	48.98877	6492.19580	43.71711	48.87894	4.15840	2.94363
195	48.76709	6540.96289	43.58191	48.84438	4.17861	2.96285
196	48.92969	6589.89258	43.44806	48.57739	4.19881	2.98213
197	48.85303	6638.74561	43.31537	48.61883	4.21899	3.00136
198	48.99951	6687.74512	43.18285	48.22416	4.23916	3.02066
199	48.82080	6736.56592	43.04788	48.18587	4.25932	3.03985
200	48.91504	6785.48096	42.92125	48.02734	4.27947	3.05909

ELECTRODE NUMBER	VOLTAGE INCREMENT (volts)	VOLTAGE TOTAL (volts)	CURRENT ANODE (amps)	CURRENT CATHODE (amps)	COORDINATE ANODE (m)	COORDINATE CATHODE (m)
201	48.92969	6834.41064	42.78842	47.65887	4.29960	3.07832
202	48.81348	6883.22412	42.65850	47.82320	4.31973	3.09746
203	49.11914	6932.34326	42.52913	47.42497	4.33984	3.11673
204	48.76123	6981.10449	42.40350	47.29734	4.35994	3.13588
205	48.95996	7030.06445	42.27430	47.16051	4.38003	3.15504
206	48.99268	7079.05713	42.14680	47.00076	4.40010	3.17421
207	48.96680	7128.02393	42.01804	46.85531	4.42017	3.19336
208	48.92236	7176.94629	41.89130	46.70619	4.44022	3.21250
209	48.99268	7225.93896	41.76609	46.55989	4.46026	3.23164
210	48.92920	7274.86816	41.64249	46.41579	4.48029	3.25076
211	48.97949	7323.84766	41.51706	46.27753	4.50030	3.26987
212	48.93652	7372.78418	41.39685	46.13731	4.52031	3.28897
213	48.99414	7421.77832	41.26490	45.99588	4.54030	3.30806
214	48.91797	7470.69629	41.02888	45.86076	4.56027	3.32715
215	48.66455	7519.36084	41.18094	45.72195	4.58018	3.34622
216	49.42041	7568.78125	40.64476	45.58792	4.60020	3.36529
217	48.18555	7616.96680	40.87591	45.45052	4.62001	3.38434
218	49.43994	7666.40674	40.69915	45.31483	4.63995	3.40339
219	48.79688	7715.20361	40.45782	45.17882	4.65986	3.42243
220	48.88770	7764.09131	40.54496	45.04521	4.67969	3.44146
221	48.99512	7813.08643	40.32961	44.91400	4.69961	3.46047
222	48.96729	7862.05371	40.15366	44.77758	4.71946	3.47949
223	48.73535	7910.78906	40.26832	44.64882	4.73926	3.49848
224	49.31641	7960.10547	39.84074	44.51806	4.75916	3.51748
225	48.44287	8008.54834	40.07256	44.38988	4.77889	3.53646
226	49.41357	8057.96191	39.81601	44.25740	4.79877	3.55543
227	48.69824	8106.66016	39.65635	44.12706	4.81856	3.57440
228	49.03125	8155.69141	39.76619	43.99945	4.83831	3.59335
229	49.09668	8204.78809	39.36936	43.86917	4.85816	3.61229
230	48.65234	8253.44043	39.49459	43.74487	4.87785	3.63123
231	49.14063	8302.58105	39.38233	43.61841	4.89763	3.65016
232	49.09668	8351.67773	39.17546	43.49046	4.91739	3.66907
233	48.82520	8400.50293	39.22941	43.36407	4.93710	3.68796
234	49.19238	8449.69531	38.94737	43.24254	4.95687	3.70686
235	48.73535	8498.43066	39.02310	43.11654	4.97654	3.72577
236	49.24023	8547.67090	38.87691	42.99427	4.99628	3.74465
237	48.97949	8596.65039	38.68700	42.86683	5.01599	3.76352
238	48.95898	8645.60938	38.71490	42.74631	5.03565	3.78238
239	49.10156	8694.71094	38.57961	42.62711	5.05535	3.80124
240	49.06445	8743.77539	38.41118	42.49871	5.07503	3.82008

ELECTRODE NUMBER	VOLTAGE INCREMENT (volts)	VOLTAGE TOTAL (volts)	CURRENT ANODE (amps)	CURRENT CATHODE (amps)	COORDINATE ANODE (m)	COORDINATE CATHODE (m)
241	48.93750	8792.71289	38.47272	42.38337	5.09466	3.83892
242	49.27734	8841.99023	38.16859	42.25896	5.11436	3.85775
243	48.74707	8890.73730	38.24123	42.13880	5.13395	3.87656
244	49.25098	8939.98828	38.14696	42.02097	5.15360	3.89537
245	49.12793	8989.11621	37.94553	41.90118	5.17325	3.91417
246	48.98047	9038.09668	37.98244	41.78144	5.19284	3.93296
247	49.22070	9087.31738	37.72591	41.66319	5.21248	3.95174
248	48.87598	9136.19336	37.82355	41.47164	5.23203	3.97051
249	49.20898	9185.40234	37.63025	41.50552	5.25167	3.98924
250	49.22168	9234.62402	37.63088	41.19804	5.27124	4.00803
251	49.12695	9283.75098	37.44904	41.14912	5.29086	4.02672
252	49.01953	9332.77051	37.34113	41.14503	5.31043	4.04543
253	49.15430	9381.92480	37.32267	40.89645	5.32997	4.06419
254	49.12598	9431.05078	37.18792	40.83174	5.34954	4.08287
255	49.10059	9480.15137	37.15241	40.77822	5.36900	4.10157
256	49.33887	9529.49023	37.04059	40.54934	5.38864	4.12029
257	49.04590	9578.53613	36.93482	40.49852	5.40819	4.13894
258	49.22461	9627.76074	36.79678	40.44360	5.42771	4.15762
259	49.13086	9676.89160	36.82978	40.13284	5.44721	4.17631
260	49.10059	9725.99219	36.56701	40.34573	5.46676	4.19490
261	49.31348	9775.30566	36.62588	39.97723	5.48620	4.21364
262	49.12891	9824.43457	36.50792	39.89574	5.50572	4.23234
263	49.17188	9873.60645	36.26750	40.01385	5.52522	4.25085
264	49.23145	9922.83789	36.44065	39.49833	5.54463	4.26956
265	49.04980	9971.88770	36.17482	39.76590	5.56417	4.28806
266	49.41113	10021.29883	36.09930	39.53331	5.58359	4.30674
267	49.12402	10070.42285	36.05172	39.35032	5.60303	4.32535
268	49.13477	10119.55762	35.93952	39.40032	5.62248	4.34391
269	49.35645	10168.91406	35.81976	39.11386	5.64190	4.36254
270	48.94824	10217.86230	35.81731	39.16689	5.66130	4.38108
271	49.47656	10267.33887	35.65370	39.02768	5.68073	4.39966
272	49.17871	10316.51758	35.58115	38.83564	5.70011	4.41826
273	49.09570	10365.61328	35.59325	38.82998	5.71950	4.43679
274	49.44238	10415.05566	35.22276	38.73525	5.73893	4.45536
275	48.88574	10463.94141	35.48940	38.54363	5.75819	4.47392
276	49.51367	10513.45508	35.23641	38.52499	5.77764	4.49243
277	49.23145	10562.68652	35.06890	38.42366	5.79699	4.51076
278	49.11328	10611.79980	35.27954	38.18066	5.81628	4.52951
279	49.42969	10661.22949	34.71568	38.41525	5.83573	4.54797
280	49.08984	10710.31934	35.02178	38.08594	5.85491	4.56656

ELECTRODE NUMBER	VOLTAGE INCREMENT (volts)	VOLTAGE TOTAL (volts)	CURRENT ANODE (amps)	CURRENT CATHODE (amps)	COORDINATE ANODE (m)	COORDINATE CATHODE (m)
281	49.45117	10759.77051	34.89827	37.94559	5.87429	4.58507
282	49.20313	10808.97363	34.53217	38.28441	5.89364	4.60353
283	49.54297	10858.51660	34.99118	37.56819	5.91283	4.62219
284	49.16016	10907.67676	34.23988	38.04746	5.93231	4.64053
285	49.22559	10956.90234	34.54935	37.72552	5.95141	4.65914
286	49.36621	11006.26855	34.48640	37.56239	5.97072	4.67753
287	49.42578	11055.69434	34.33636	37.50111	5.99003	4.69603
288	49.24609	11104.94043	34.14094	37.62481	6.00929	4.71453
289	49.44141	11154.38184	34.26905	37.23961	6.02849	4.73303
290	49.22559	11203.60742	33.93285	37.41138	6.04779	4.75147
291	49.28711	11252.89453	34.02160	37.31528	6.06694	4.76993
292	49.57324	11302.46777	33.96674	37.00300	6.08617	4.78847
293	49.19141	11351.65918	33.76895	37.11140	6.10542	4.80685
294	49.45117	11401.11035	33.80109	37.01541	6.12459	4.82531
295	49.37402	11450.48438	33.61338	36.72513	6.14381	4.84376
296	49.08105	11499.56543	33.57915	37.08484	6.16297	4.86210
297	49.84766	11549.41309	33.56523	36.62405	6.18213	4.88065
298	49.21680	11598.62988	33.40059	36.58659	6.20133	4.89900
299	49.22266	11647.85254	33.35893	36.72066	6.22048	4.91737
300	49.68848	11697.54102	33.28333	36.23637	6.23963	4.93584
301	48.91211	11746.45313	33.13668	36.61967	6.25878	4.95410
302	49.76953	11796.22266	33.17556	36.27851	6.27787	4.97259
303	49.38184	11845.60449	33.03924	36.12799	6.29703	4.99093
304	49.23633	11894.84082	32.95275	36.26140	6.31615	5.00924
305	49.58496	11944.42578	32.87852	36.00536	6.33525	5.02765
306	49.18945	11993.61523	32.79096	35.97847	6.35435	5.04596
307	49.43262	12043.04785	32.74285	35.96044	6.37342	5.06429
308	49.51172	12092.55957	32.67508	35.82001	6.39251	5.08265
309	49.44727	12142.00684	32.56466	35.65238	6.41159	5.10097
310	49.12207	12191.12891	32.48609	35.82821	6.43065	5.11924
311	49.84863	12240.97754	32.50275	35.42285	6.44969	5.13763
312	49.07813	12290.05566	32.25198	35.60054	6.46878	5.15584
313	49.49316	12339.54883	32.33226	35.41038	6.48776	5.17419
314	49.48438	12389.03320	32.27659	35.24425	6.50682	5.19247
315	49.32715	12438.36035	31.93510	35.41906	6.52588	5.21069
316	49.39648	12487.75684	32.30764	35.05338	6.54477	5.22904
317	49.62109	12537.37793	31.81578	35.16129	6.56391	5.24724
318	49.17969	12586.55762	31.90581	35.01473	6.58281	5.26552
319	49.50195	12636.05957	31.88513	34.89738	6.60179	5.28377
320	49.36426	12685.42383	31.84082	35.00987	6.62079	5.30196

ELECTRODE NUMBER	VOLTAGE INCREMENT (volts)	VOLTAGE TOTAL (volts)	CURRENT ANODE (amps)	CURRENT CATHODE (amps)	COORDINATE ANODE (m)	COORDINATE CATHODE (m)
321	49.79590	12735.21973	31.63488	34.59598	6.63980	5.32029
322	48.81934	12784.03906	31.69122	34.85850	6.65873	5.33841
323	49.94141	12833.98047	31.49686	34.61553	6.67770	5.35671
324	49.20215	12883.18262	31.53123	34.45631	6.69660	5.37491
325	49.43848	12932.62109	31.40436	34.50525	6.71557	5.39306
326	49.47559	12982.09668	31.29605	34.41540	6.73449	5.41128
327	49.34766	13031.44434	31.42160	34.17111	6.75337	5.42948
328	49.45996	13080.90430	31.05119	34.45450	6.77236	5.44759
329	49.56152	13130.46582	31.19236	34.04395	6.79117	5.46588
330	49.21289	13179.67871	31.14959	34.01706	6.81008	5.48398
331	49.50586	13229.18457	30.88435	34.18183	6.82901	5.50211
332	49.54102	13278.72559	31.17864	33.67503	6.84781	5.52035
333	49.23633	13327.96191	30.86397	34.05581	6.86682	5.53836
334	49.82813	13377.79004	30.67792	33.75275	6.88567	5.55661
335	49.08789	13426.87793	30.75569	33.61262	6.90444	5.57473
336	49.34766	13476.22559	30.75910	33.69916	6.92328	5.59280
337	49.53125	13525.75684	30.65058	33.50756	6.94217	5.61095
338	49.35645	13575.11328	30.63520	33.40359	6.96104	5.62905
339	49.47363	13624.58691	30.43220	33.57351	6.97991	5.64712
340	49.70801	13674.29492	30.58836	33.21434	6.99866	5.66531
341	49.30371	13723.59863	30.43394	33.20311	7.01749	5.68333
342	49.22168	13772.82031	30.39038	33.34430	7.03627	5.70139
343	49.69824	13822.51855	30.50076	32.81810	7.05504	5.71956
344	49.07129	13871.58984	30.57854	33.27253	7.07394	5.73747
345	47.78418	13919.37402	30.04113	32.92191	7.09290	5.75567
346	51.64453	13971.01855	30.03230	32.78749	7.11149	5.77370
347	49.09277	14020.11133	30.33662	32.87167	7.13011	5.79170
348	49.61426	14069.72559	30.07960	32.69326	7.14896	5.80978
349	49.33594	14119.06152	30.43721	32.64997	7.16769	5.82779
350	47.89355	14166.95508	29.76333	32.69728	7.18666	5.84581
351	51.45410	14218.40918	29.94693	32.43236	7.20520	5.86389
352	49.04590	14267.45508	29.99179	32.46895	7.22388	5.88185
353	49.57520	14317.03027	30.02833	32.32436	7.24261	5.89987
354	49.09180	14366.12207	29.99522	32.31897	7.26140	5.91785
355	48.58789	14414.70996	29.64326	32.27141	7.28018	5.93585
356	50.93848	14465.64844	29.78788	32.14235	7.29877	5.95386
357	49.35547	14515.00391	29.79073	32.03868	7.31745	5.97182
358	49.36133	14564.36523	29.55509	32.15944	7.33615	5.98976
359	49.48535	14613.85059	29.75693	31.84296	7.35472	6.00781
360	49.37207	14663.22266	29.55164	31.84465	7.37346	6.02571

ELECTRODE NUMBER	VOLTAGE INCREMENT (volts)	VOLTAGE TOTAL (volts)	CURRENT ANODE (amps)	CURRENT CATHODE (amps)	COORDINATE ANODE (m)	COORDINATE CATHODE (m)
361	49.38770	14712.61035	29.51388	31.97518	7.39211	6.04364
362	49.93164	14762.54199	29.54214	31.63511	7.41075	6.06168
363	49.24414	14811.78613	29.44641	31.65851	7.42941	6.07958
364	49.32715	14861.11328	29.54324	31.64490	7.44801	6.09748
365	49.63184	14910.74512	29.38555	31.47932	7.46669	6.11545
366	49.27441	14960.01953	29.65979	31.52159	7.48531	6.13331
367	49.60254	15009.62207	28.83149	31.42960	7.50414	6.15126
368	49.61426	15059.23633	29.46383	31.27991	7.52246	6.16918
369	49.39941	15108.63574	29.11512	31.27237	7.54117	6.13704
370	49.43164	15158.06738	29.28635	31.22769	7.55971	6.20494
371	49.54590	15207.61328	28.96727	31.15630	7.57834	6.22265
372	49.29785	15256.91113	29.08102	31.16908	7.59680	6.24074
373	49.91504	15306.82617	29.22413	30.82794	7.61535	6.25866
374	49.11426	15355.94043	29.00850	30.96022	7.63404	6.27644
375	49.47168	15405.41211	28.87599	31.02067	7.65260	6.29432
376	49.75488	15455.16699	28.94673	30.74135	7.67109	6.31226
377	49.33203	15504.49902	28.89526	30.74070	7.68963	6.33008
378	49.45313	15553.95215	28.90197	30.75448	7.70815	6.34792
379	49.75195	15603.70410	28.81391	30.56471	7.72670	6.36580
380	49.19141	15652.89551	28.81515	30.45143	7.74523	6.38366
381	49.38672	15702.28223	28.57259	30.65701	7.76379	6.40137
382	49.91211	15752.19434	28.39261	30.70964	7.78220	6.41930
383	49.41309	15801.60742	29.47635	29.62416	7.80050	6.43726
384	49.02832	15850.63574	28.31193	30.62306	7.81952	6.45466
385	49.73828	15900.37402	28.72567	30.12500	7.83779	6.47265
386	49.44336	15949.81738	28.35804	30.40846	7.85635	6.49036
387	50.94238	16000.75977	28.23913	30.38529	7.87466	6.50831
388	51.59766	16052.35742	29.23402	29.38742	7.89294	6.52626
389	51.12305	16103.48047	28.08254	30.24092	7.91187	6.54365
390	51.22656	16154.70703	28.27003	30.01018	7.93010	6.56156
391	51.30566	16206.01270	28.15409	29.99947	7.94852	6.57938
392	51.23730	16257.25000	27.80865	30.11342	7.96690	6.59722
393	51.34375	16308.59375	28.79633	28.96137	7.98509	6.61517
394	50.23145	16358.82520	27.74225	29.93954	8.00395	[illegible]
395	51.27441	16410.09961	27.87381	29.82371	8.02218	[illegible]
396	51.11133	16461.21094	27.68481	29.61800	8.04052	[illegible]
397	50.44531	16511.65625	27.88483	29.49043	8.05879	6.68594
398	50.63281	16562.28906	27.69342	29.46074	8.07723	6.70366
399	50.51953	16612.80859	27.61765	29.40440	8.09559	6.72136
400	50.60352	16663.41211	27.54058	29.35521	8.11393	6.73911

ELECTRODE NUMBER	VOLTAGE INCREMENT (volts)	VOLTAGE TOTAL (volts)	CURRENT ANODE (amps)	CURRENT CATHODE (amps)	COORDINATE ANODE (m)	COORDINATE CATHODE (m)
401	50.44141	16713.85352	27.43180	29.30881	8.13227	6.75763
402	50.26953	16764.12305	27.43229	29.22261	8.15057	6.77453
403	50.35156	16814.47461	27.39560	29.14970	8.16891	6.77225
404	50.18945	16864.66406	27.12059	29.21615	8.18727	6.80993
405	50.14063	16914.80469	26.92496	29.30670	8.20548	6.82768
406	50.34180	16965.14648	27.21609	28.95336	8.22360	6.84551
407	50.00781	17015.15430	27.44713	28.32519	8.24196	6.86316
408	49.16016	17064.31445	26.72773	29.29119	8.26051	6.88046
409	50.59766	17114.91211	26.98844	28.80602	8.27861	6.89606
410	49.76172	17164.67383	26.78363	28.79463	8.29694	6.91601
411	49.95508	17214.62891	26.83269	28.53855	8.31515	6.93068
412	49.70508	17264.33398	26.75730	28.60238	8.33345	6.95123
413	49.64453	17313.97852	26.52960	28.73502	8.35172	6.96664
414	49.60938	17363.58789	26.52014	28.65990	8.36989	6.98654
415	49.43555	17413.02344	26.51653	28.61452	8.38808	7.00420
416	49.41406	17462.43750	26.43151	28.61298	8.40631	7.02182
417	50.04492	17512.48242	26.43944	28.35677	8.42451	7.03946
418	49.18750	17561.66992	26.18660	28.52142	8.44276	7.05700
419	49.66797	17611.33789	26.26269	28.00747	8.46088	7.07468
420	54.40039	17665.73828	26.15433	28.64546	8.47908	7.09204
421	43.77344	17709.51172	26.14085	28.60957	8.49725	7.10977
422	49.71289	17759.22461	25.97363	26.24991	8.51544	7.12751
423	49.28906	17808.51367	25.98220	28.25332	8.53356	7.14506
424	49.33789	17857.85156	25.89281	27.80103	8.55171	7.16264
425	55.17383	17913.02539	25.82517	28.53782	8.56985	7.17997
426	43.56445	17956.58984	25.78834	28.29893	8.58797	7.19773
427	48.75586	18005.34570	25.68600	28.12934	8.60610	7.21536
428	49.00586	18054.35156	25.66214	28.09581	8.62420	7.23293
429	49.17188	18103.52344	25.60352	27.65900	8.64233	7.25049
430	53.94727	18157.47070	25.59157	28.18623	8.66044	7.26781
431	45.34766	18202.81836	25.33730	28.18329	8.67858	7.28546
432	47.82813	18250.64648	25.48006	27.90097	8.69658	7.30313
433	48.81641	18299.46289	25.37648	27.87984	8.71470	7.32063
434	48.86914	18348.33203	25.31412	27.87896	8.73280	7.33814
435	49.18164	18397.51367	25.20872	27.84842	8.75088	7.35566
436	49.09375	18446.60742	25.14592	27.77543	8.76893	7.37320
437	48.87891	18495.48633	25.21246	27.62608	8.78696	7.39072
438	48.61719	18544.10352	24.94079	27.77098	8.80508	7.40817
439	48.67578	18592.77930	25.07493	27.68145	8.82304	7.42572
440	49.10156	18641.88086	24.90364	27.63617	8.84113	7.44320

ELECTRODE NUMBER	VOLTAGE INCREMENT (volts)	VOLTAGE TOTAL (volts)	CURRENT ANODE (amps)	CURRENT CATHODE (amps)	COORDINATE ANODE (m)	COORDINATE CATHODE (m)
441	49. 63086	18691. 51172	24. 79355	27. 57868	8. 85914	7. 46067
442	49. 66797	18741. 17969	24. 70011	27. 30033	8. 87718	7. 47813
443	49. 80273	18790. 98242	24. 58300	27. 69388	8. 89520	7. 49545
444	49. 48047	18840. 46289	24. 50199	27. 59711	8. 91319	7. 51305
445	49. 16016	18889. 62305	24. 48395	27. 34123	8. 93116	7. 53058
446	49. 20508	18938. 82813	24. 37853	27. 47315	8. 94917	7. 54796
447	49. 51953	18988. 34766	24. 24194	27. 47315	8. 96715	7. 56544
448	49. 46875	19037. 81641	24. 32797	27. 28822	8. 98508	7. 58293
449	49. 13867	19086. 95508	24. 03784	27. 48331	9. 00312	7. 60033
450	49. 53320	19136. 48828	24. 12543	27. 10770	9. 02100	7. 61786
451	48. 95117	19185. 43945	23. 94987	27. 22957	9. 03898	7. 63520
452	49. 09180	19234. 53125	23. 89503	27. 17049	9. 05688	7. 65263
453	48. 77148	19283. 30273	23. 86619	27. 18670	9. 07479	7. 67002
454	49. 07813	19332. 38086	23. 77705	27. 23773	9. 09273	7. 68744
455	49. 57227	19381. 95313	23. 70029	27. 05586	9. 11065	7. 70489
456	48. 80078	19430. 75391	23. 52657	27. 08496	9. 12857	7. 72225
457	48. 98047	19479. 73438	23. 64172	26. 97836	9. 14639	7. 73967
458	49. 13867	19528. 87305	23. 43061	27. 05947	9. 16435	7. 75703
459	48. 61328	19577. 48633	23. 34215	26. 91776	9. 18221	7. 77447
460	49. 02344	19626. 50977	23. 33675	26. 95800	9. 20005	7. 79181
461	49. 27344	19675. 78320	23. 24281	26. 90631	9. 21792	7. 80920
462	48. 93945	19724. 72266	23. 16193	26. 87429	9. 23578	7. 82656
463	48. 74609	19773. 46875	23. 05445	26. 88965	9. 25364	7. 84392
464	48. 37695	19821. 84570	23. 01324	26. 84016	9. 27145	7. 86129
465	43. 07617	19864. 92188	22. 88201	26. 84946	9. 28929	7. 87862
466	41. 42578	19906. 34766	22. 93177	26. 77265	9. 30708	7. 89600
467	41. 10938	19947. 45703	22. 72406	26. 79435	9. 32496	7. 91334
468	41. 15625	19988. 61328	22. 70916	26. 58055	9. 34273	7. 93075
469	40. 68359	20029. 29688	22. 59242	26. 53304	9. 36054	7. 94806
470	40. 28711	20069. 58398	22. 49677	26. 54874	9. 37832	7. 96538
471	40. 09961	20109. 68359	22. 48619	26. 51259	9. 39607	7. 98275
472	40. 32031	20150. 00391	22. 36021	26. 43727	9. 41387	8. 00010
473	39. 75391	20189. 75781	22. 32731	26. 26431	9. 43163	8. 01747
474	39. 27734	20229. 03516	22. 16266	26. 36544	9. 44942	8. 03475
475	39. 67383	20268. 70898	22. 16098	26. 18465	9. 46713	8. 05214
476	39. 26172	20307. 97070	22. 04655	26. 16645	9. 48489	8. 06944
477	38. 93555	20346. 90625	21. 98043	26. 08890	9. 50262	8. 08676
478	38. 68750	20385. 59375	21. 88592	26. 07112	9. 52036	8. 10408
479	38. 58594	20424. 17969	21. 80407	25. 99076	9. 53808	8. 12141
480	38. 41016	20462. 58984	21. 70576	25. 98096	9. 55580	8. 13873

ELECTRODE NUMBER	VOLTAGE INCREMENT (volts)	VOLTAGE TOTAL (volts)	CURRENT ANODE (amps)	CURRENT CATHODE (amps)	COORDINATE ANODE (m)	COORDINATE CATHODE (m)
481	38.33203	20500.92188	21.62224	25.85207	9.57349	8.15627
482	37.89648	20538.81836	21.60060	25.77368	9.59118	8.17357
483	37.77539	20576.59375	21.43619	25.82557	9.60891	8.19085
484	37.80469	20614.39844	21.41570	25.66047	9.62657	8.20801
485	37.38281	20651.78125	21.26109	25.59084	9.64429	8.22527
486	37.07031	20688.85156	21.17712	25.64421	9.66195	8.24254
487	37.27734	20726.12891	21.16730	25.45825	9.67959	8.25982
488	37.13477	20763.26367	21.04762	25.53302	9.69729	8.27712
489	37.07422	20800.33789	20.88449	25.42919	9.71496	8.29445
490	36.81641	20837.15430	20.87494	25.30927	9.73257	8.31174
491	36.53125	20873.68555	20.77243	25.31607	9.75024	8.32899
492	36.43164	20910.11719	20.66622	25.22492	9.76790	8.34627
493	36.21484	20946.33203	20.54111	25.22386	9.78554	8.36353
494	36.08398	20982.41602	20.48106	25.07937	9.80314	8.38082
495	35.74414	21018.16016	20.43581	25.12157	9.82078	8.39804
496	35.68164	21053.84180	20.22745	25.05608	9.83844	8.41533
497	35.47266	21089.31445	20.16512	24.96201	9.85601	8.43261
498	35.22461	21124.53906	20.11305	24.85693	9.87362	8.44966
499	34.95898	21159.49805	19.92902	24.92764	9.89126	8.46707
500	34.94922	21194.44727	19.86493	24.86413	9.90882	8.48435
501	34.73438	21229.18164	19.79733	24.64523	9.92642	8.50164
502	34.30859	21263.49023	19.59768	24.76551	9.94405	8.51880
503	34.33398	21297.82422	19.53859	24.66279	9.96160	8.53608
504	34.07813	21331.90234	19.41352	24.60445	9.97918	8.55332
505	33.87891	21365.78125	19.30165	24.55165	9.99675	8.57055
506	33.68750	21399.46875	19.20310	24.46783	10.01432	8.58776
507	33.45703	21432.92578	19.06820	24.46878	10.03191	8.60496
508	33.33398	21466.25977	18.87607	24.43497	10.04947	8.62222
509	33.16992	21499.42969	18.80736	24.34296	10.06697	8.63947
510	32.89063	21532.32031	18.71454	24.28344	10.08451	8.65658
511	32.69336	21565.01367	18.57512	24.25745	10.10209	8.67369
512	32.53711	21597.55078	18.38800	24.18003	10.11965	8.69111
513	32.31250	21629.86328	18.28724	24.13236	10.13716	8.70830
514	32.12891	21661.99219	18.11597	24.16586	10.15470	8.72550
515	32.04688	21694.03906	17.99199	24.01339	10.17221	8.74275
516	31.73047	21725.76953	17.81547	24.03362	10.18974	8.75992
517	31.59570	21757.36523	17.71471	23.91182	10.20724	8.77714
518	31.31445	21788.67969	17.50772	23.94402	10.22478	8.79431
519	31.23047	21819.91016	17.33730	23.86472	10.24228	8.81153
520	30.80664	21850.71680	17.17750	23.79643	10.25976	8.82672

ELECTRODE NUMBER	VOLTAGE INCREMENT (volts)	VOLTAGE TOTAL (volts)	CURRENT ANODE (amps)	CURRENT CATHODE (amps)	COORDINATE ANODE (m)	COORDINATE CATHODE (m)
521	28.33008	21879.04688	17.04457	23.74955	10.27725	8.84570
522	23.98828	21903.03516	16.84014	23.58940	10.29477	8.86311
523	22.84180	21925.87695	16.66221	23.53510	10.31227	8.88026
524	22.39844	21948.27539	16.41816	23.52549	10.32977	8.89747
525	22.10156	21970.37695	16.27823	23.42355	10.34720	8.91468
526	21.69922	21992.07617	16.08718	23.38757	10.36469	8.93187
527	21.40430	22013.48047	15.84163	23.30695	10.38219	8.94907
528	21.04883	22034.52930	15.65279	23.18094	10.39964	8.96626
529	20.57617	22055.10547	15.42953	23.18991	10.41711	8.98341
530	20.16797	22075.27344	15.16175	23.17824	10.43458	9.00060
531	19.94727	22095.22070	14.96497	23.09270	10.45200	9.01783
532	19.42383	22114.64453	14.78733	22.95055	10.46947	9.03503
533	19.07422	22133.71875	14.55104	23.00098	10.48698	9.05213
534	18.87695	22152.59570	14.47855	22.91723	10.50438	9.06941
535	18.53125	22171.12695	14.39488	22.77498	10.52180	9.08662
536	18.08984	22189.21680	14.19528	22.70959	10.53930	9.10377
537	17.62500	22206.84180	13.99501	22.80441	10.55675	9.12091
538	17.42578	22224.26758	13.80548	22.69365	10.57416	9.13818
539	17.10547	22241.37305	13.71376	22.49439	10.59155	9.15539
540	16.50586	22257.87891	13.50454	22.53945	10.60904	9.17251
541	16.20508	22274.08398	13.30522	22.50178	10.62650	9.18971
542	15.99414	22290.07813	13.08879	22.44579	10.64392	9.20692
543	15.73047	22305.80859	12.93528	22.33051	10.66130	9.22413
544	15.15039	22320.95898	12.77757	22.24118	10.67874	9.24131
545	14.81445	22335.77344	12.51839	22.26710	10.69622	9.25847
546	14.52539	22350.29883	12.29461	22.20757	10.71364	9.27569
547	14.22852	22364.52734	12.11914	22.06040	10.73103	9.29291
548	13.78320	22378.31055	11.90228	22.02310	10.74847	9.31008
549	13.42969	22391.74023	11.66341	21.99629	10.76591	9.32726
550	13.12695	22404.86719	11.38564	21.91726	10.78333	9.34446
551	12.75586	22417.62305	11.21286	21.81118	10.80069	9.36166
552	12.29492	22429.91797	10.95469	21.83044	10.81816	9.37883
553	12.12891	22442.04688	10.60133	21.75483	10.83560	9.39606
554	11.72266	22453.76953	10.30862	21.64367	10.85295	9.41327
555	11.31250	22465.08203	10.01606	21.52655	10.87036	9.43046
556	10.98047	22476.06250	9.60686	21.57612	10.88785	9.44761
557	10.73633	22486.79883	9.24502	21.50030	10.90523	9.46484
558	10.32813	22497.12695	8.93433	21.34642	10.92259	9.48207
559	9.96875	22507.09570	8.55050	21.32890	10.94004	9.49923
560	9.56250	22516.65820	8.31001	21.28499	10.95748	9.51644

ELECTRODE NUMBER	VOLTAGE INCREMENT (volts)	VOLTAGE TOTAL (volts)	CURRENT ANODE (amps)	CURRENT CATHODE (amps)	COORDINATE ANODE (m)	COORDINATE CATHODE (m)
561	9.32227	22525.98047	0.00000	21.18401	10.97521	9.53365
562	8.92383	22534.90430	0.00000	21.10898	10.99277	9.55085
563	8.58398	22543.48828	0.00000	21.06532	11.01022	9.56804
564	8.29297	22551.78125	0.00000	21.02519	11.02763	9.58526
565	7.95508	22559.73633	0.00000	20.88284	11.04500	9.60249
566	7.61914	22567.35547	0.00000	20.81300	11.06246	9.61968
567	7.24414	22574.59961	0.00000	20.74872	11.07990	9.63687
568	6.85938	22581.45898	0.00000	20.73464	11.09728	9.65407
569	6.57227	22588.03125	0.00000	20.65001	11.11470	9.67131
570	6.28906	22594.32031	0.00000	20.49393	11.13212	9.68855
571	5.93750	22600.25781	0.00000	20.44877	11.14956	9.70572
572	5.57813	22605.83594	0.00000	20.41494	11.16697	9.72291
573	5.28906	22611.12500	0.00000	20.28989	11.18439	9.74016
574	4.96875	22616.09375	0.00000	20.23462	11.20186	9.75737
575	4.55859	22620.65234	0.00000	20.15168	11.21925	9.77460
576	4.26172	22624.91406	0.00000	20.05037	11.23666	9.79183
577	3.99414	22628.90820	0.00000	19.97641	11.25414	9.80904
578	3.69531	22632.60352	0.00000	19.89490	11.27160	9.82626
579	3.34375	22635.94727	0.00000	19.79274	11.28897	9.84346
580	2.98633	22638.93359	0.00000	19.72573	11.30641	9.86070
581	2.70117	22641.63477	0.00000	19.63677	11.32387	9.87794
582	2.37891	22644.01367	0.00000	19.52271	11.34133	9.89519
583	2.04883	22646.06250	0.00000	19.43214	11.35874	9.91241
584	1.71875	22647.78125	0.00000	19.33869	11.37616	9.92964
585	1.42773	22649.20898	0.00000	19.24575	11.39365	9.94686
586	1.16211	22650.37109	0.00000	19.12508	11.41111	9.96413
587	0.85156	22651.22266	0.00000	19.09126	11.42855	9.98136
588	0.50977	22651.73242	0.00000	18.90938	11.44596	9.99865
589	0.20313	22651.93555	0.00000	18.81213	11.46346	10.01587
590	-0.09180	22651.84375	0.00000	18.72914	11.48094	10.03311
591	-0.39063	22651.45313	0.00000	18.64681	11.49835	10.05037
592	-0.66992	22650.78320	0.00000	18.50722	11.51580	10.06766
593	-0.92969	22649.85352	0.00000	18.30130	11.53328	10.08493
594	-1.18750	22648.66602	0.00000	18.28241	11.55081	10.10211
595	-1.53906	22647.12695	0.00000	18.18652	11.56822	10.11940
596	-1.84375	22645.28320	0.00000	17.95650	11.58566	10.13672
597	-2.06055	22643.22266	0.00000	17.87429	11.60319	10.15394
598	-2.36133	22640.86133	0.00000	17.76912	11.62066	10.17121
599	-2.64648	22638.21484	0.00000	17.59848	11.63811	10.18851
600	-2.88477	22635.33008	0.00000	17.41624	11.65561	10.20578

ELECTRODE NUMBER	VOLTAGE INCREMENT (volts)	VOLTAGE TOTAL (volts)	CURRENT ANODE (amps)	CURRENT CATHODE (amps)	COORDINATE ANODE (m)	COORDINATE CATHODE (m)
601	-3.11914	22632.21094	0.00000	17.33260	11.67310	10.22302
602	-3.41211	22628.79883	0.00000	17.18703	11.69054	10.24033
603	-3.69922	22625.09961	0.00000	17.36521	11.70804	10.25764
604	-3.99805	22621.10156	0.00000	16.77004	11.72517	10.27530
605	-4.15039	22616.95117	0.00000	16.57514	11.74269	10.29252
606	-4.40234	22612.54883	0.00000	16.49506	11.76022	10.30972
607	-4.65234	22607.89648	0.00000	16.34511	11.77774	10.32701
608	-4.86328	22603.03320	0.00000	16.14199	11.79522	10.34434
609	-5.07422	22597.95898	0.00000	15.92227	11.81271	10.36165
610	-5.30078	22592.65820	0.00000	15.71979	11.83018	10.37893
611	-5.54297	22587.11523	0.00000	15.58185	11.84771	10.39620
612	-5.74414	22581.37109	0.00000	15.35743	11.86518	10.41355
613	-5.92383	22575.44727	0.00000	15.10947	11.88267	10.43089
614	-6.09180	22569.35547	0.00000	14.86464	11.90019	10.44820
615	-5.99414	22563.36133	0.00000	14.65834	11.91768	10.46549
616	-5.15039	22558.21094	0.00000	14.56032	11.93517	10.48279
617	-2.96484	22555.24609	0.00000	14.42769	11.95264	10.50019
618	-1.99414	22553.25195	0.00000	14.26508	11.97019	10.51750
619	-2.10938	22551.14258	0.00000	14.16053	11.98770	10.53479
620	-2.24805	22548.89453	0.00000	14.00117	12.00517	10.55215
621	-2.35352	22546.54102	0.00000	13.79094	12.02263	10.56952
622	-2.44336	22544.09766	0.00000	13.62442	12.04019	10.58685
623	-2.54883	22541.54883	0.00000	13.47521	12.05772	10.60415
624	-2.66016	22538.88867	0.00000	13.30657	12.07520	10.62150
625	-2.78516	22536.10352	0.00000	13.10824	12.09269	10.63886
626	-2.86133	22533.24219	0.00000	12.93028	12.11021	10.65619
627	-2.94727	22530.29492	0.00000	12.75137	12.12774	10.67354
628	-3.03711	22527.25781	0.00000	12.52446	12.14522	10.69091
629	-3.12109	22524.13672	0.00000	12.33017	12.16274	10.70825
630	-3.20313	22520.93359	0.00000	12.13885	12.18028	10.72560
631	-3.26563	22517.66797	0.00000	11.91613	12.19775	10.74297
632	-3.32813	22514.33984	0.00000	11.68239	12.21525	10.76033
633	-3.41016	22510.92969	0.00000	11.46837	12.23277	10.77767
634	-3.46289	22507.46680	0.00000	11.24488	12.25034	10.79504
635	-3.49805	22503.96875	0.00000	10.98119	12.26782	10.81243
636	-2.83789	22501.13086	0.00000	10.71693	12.28531	10.82979
637	-2.21094	22498.91992	0.00000	10.40581	12.30283	10.84717
638	-2.06836	22496.85156	0.00000	10.04604	12.32037	10.86455
639	-2.13281	22494.71875	0.00000	9.72161	12.33790	10.88189
640	-2.23047	22492.48828	0.00000	9.39582	12.35540	10.89926

ELECTRODE NUMBER	VOLTAGE INCREMENT (volts)	VOLTAGE TOTAL (volts)	CURRENT ANODE (amps)	CURRENT CATHODE (amps)	COORDINATE ANODE (m)	COORDINATE CATHODE (m)
641	-2.32227	22490.16602	0.00000	9.01796	12.37292	10.91606
642	-2.34961	22487.81641	0.00000	8.64472	12.39043	10.93406
643	-2.41797	22485.39844	0.00000	8.17133	12.40794	10.95142

Total anode current = 21077.78
Total cathode current = 21079.64

Total current in anodes 1 through 49 is 2446.17
Total current in cathodes 561 through 643 is 1358.30

D. WBS DETAILED WORK STATEMENTS

APPENDIX D
DETAILED WORK STATEMENTS

WBS 1100 POWER TRAIN INTEGRATION

A System Engineering Approach (SEA) methodology will be used in the execution of the MHD Advanced Power Train Development Program. The power train integration task includes the efforts (1) to scale down the requirements, established for the 200 MW(e) MHD/steam power plant, to those for the retrofit and the development programs; (2) to provide system engineering support for the management and direction of the design, development and test tasks; (3) to deal with the power train system as an entity; and (4) to reduce and analyze the development and test results and assemble the resulting information into an engineering data base for the power train.

The reference 200 MW(e) MHD/steam plant was designed in Task I and analyzed using a proprietary computer code package. Additional analyses of the design will be performed to insure that the plant (and especially the power train) can be operated in all of the necessary off-design conditions to meet the needs of the utility application. These analyses will be performed using modified versions of the code package.

The technical goals and objectives, for the Retrofit project, will be delineated and submitted for Customer approval. The 200 MW(e) plant design will be scaled down to the Retrofit rating and off-design operating conditions will be considered to insure that the test program can provide the requisite operational data and information.

The retrofit conceptual design will be documented in a Retrofit Power Train System Description and Specification, similar to that already prepared for the 200 MW(e) Power Train. The internal and external interfaces of the power train components will be delineated in this document.

Equipment Specifications, for each power train component will be prepared, consistent with the retrofit power train system descriptions and specifications.

This scale-down process will be continued for each power train to be built and tested in the program. The resulting specifications will be maintained as required by results obtained in the development activities.

The component design and development activities will be integrated to insure that each properly reflects the objectives and specification and correctly interface with all other power train and plant/facility activities. This will be accomplished by establishing liaison with other programs and participation in the project progress review and change control processes.

The Power Train Integration task will work closely with the Coordination of Testing Facilities task (WBS 1800). Power Train Integration also will support the Program Management task (WBS 1900) in project reviews, change control, technical documentation control and report preparation.

The power train integration is described herein in seven tasks: 1110, Plant Studies; 1120, Retrofit Power Train Conceptual Design; 1130, 50 MW(t) Power Train Conceptual Design; 1140, 50 MW(t) Power Train Integration; 1150, Retrofit Power Train Integration; 1160, Power Train Technology Development; and 1170, Engineering Data Bases.

1110 PLANT STUDIES

Objective

To refine and expand the 200 MW(e) plant studies, performed in Task I, to insure that the planned power train design and development efforts properly consider the total engineering and operational requirements of the early commercial plants.

Technical Approach

The proprietary Westinghouse SPA/SUMMARY code package will be utilized. This code was used in the Task I studies of the MHD/steam plants, the scaling studies, and in the Studies of MHD Program Options. As a result, the algorithms are generally sufficiently broad as to require only minor modifications only. However, it is anticipated that the details of the concept of the power train, and hence the plant, will be modified and refined as the results of the development program are realized. The algorithms will be maintained current and cataloged so as to be available in the pertinent form for studies as they are required. These algorithms will also constitute a useful program product. An example of the modification is the inclusion of a refined channel model. The basis for this refinement will be the results of the channel calculations that are being performed by STD Research Corporation. Further detailed analyses of the generator (channel, power management and magnet) will be required and these are discussed under WBS 1200. These may impact the system model and require model modification.

The SPA/SUMMARY code package, presently configured as a design code, will be reconfigured to permit analyses of off-design modes, including part power, dynamic and transient operations.

The range of applicability of the algorithms will be extended downward to insure adequacy in studies of the retrofit plant and in studies of test power trains.

The code package, along with other appropriate tools and methods, will be applied. The results will be used in the preparation and maintenance of power train descriptions and specifications. They will also be used in the integration activities, including consideration of change requests. The plant studies will be performed under two subtasks as described below.

1111 200 MW(e) PLANT ANALYSES

Objective

To provide current and detailed analyses of the anticipated early commercial plant as the basis for conceptual design of the retrofit plant and integration of the activities in the Engineering Development and Retrofit phases.

Technical Approach

The 200 MW(e) plant and system studies will be refined as required to provide the detailed technical direction for the development program and the design of test programs and facilities. The findings produced in this task will be factored into the Technical Direction document through revision and reissue.

The primary model is anticipated to be the SPA code package. Other models may be required and these will be obtained or utilized through subcontract (where they exist as proprietary property of other organizations or the organization has necessary calculational skills), or devised where necessary, when no suitable code can be identified. The SPA code package will be up-dated as necessary for the off-design analytical tasks identified in the course of the program.

The model will be exercised to explore the impacts on design that result from off-design operation of the power plant. The criteria to be considered in this analysis will be developed recognizing that a practical utility power plant must be capable of normal dispatch at part power without damage to the equipment, without excessive degradation of efficiency and without unreasonable operator difficulty.

The operation of the plant during non-steady state conditions may influence the steady-state design. The effects of non steady-state operation must be understood, in some detail, in order to design and develop the instrumentation and control system. It is an important part of the understanding of the start-up/shut-down procedures. These may impact the considerations related to the desired number of operating cycles to be included in the definition and achievement of the desired durability (lifetime) of components. These will influence the study of fault conditions and the failure effects and modes analyses (FEMA). The results of the studies envisaged under this task will be factored into the Technical Direction document through revision and reissue.

A version of the SPA code package will be modified to provide an efficient and cost effective tool for use in these dynamic and transient analyses. The package will be maintained current with the state of the development program so that it can be available for the design of facilities and plants in the future. That is, it will be a tool in the development program and the algorithms will also be a useful product of the program.

The above mentioned SPA code package will be exercised, as required, to support the I&C function in the definition of the requirements for the development of the I&C system. The selected control modes will be reviewed with utility engineers and operators to insure that they represent current utility requirements and practices and take into consideration any impact that might be expected from the connection to the power grid.

The above mentioned control mode analyses will be extended to include and consider the power train impacts from plant conditions during cold-to-hot and hot-to-power (and vice versa) modes. The impacts of emergency shut-down, whether power train or plant or utility system imposed, will be considered.

Conventional Fault Tree and Failure Effects and Modes Analysis (FEMA) methodology will be adapted to the MHD/steam plant (and power train) concept. The resulting modified packages and/or practices will be utilized to delineate the potential conditions and effects and to guide each function in their development efforts. These tools will also be utilized to assess proposed test designs to maximize the probability of successful testing programs. These tools will be maintained and provided as a product for use in future MHD programs.

Achieving low capital cost and low cost of energy (including the cost of the replacement of the MHD channel) represent major development requirements. The commercialization of MHD/steam plants depends directly on the success realized in developing rugged and reliable cost effective equipment. The cost impact on the final plant will be considered throughout the execution of the development program. The cost of the testing programs is an important consideration and must be kept to the necessary minimum. Economic studies of options and alternatives will be needed throughout the development program.

The Westinghouse proprietary SUMMARY code package utilized in the past MHD/APT effort, will be up-dated and maintained to contain the current algorithms of cost as these are impacted by progress (or problems) in the development program.

The SUMMARY code package, coupled with the SPA code package, will be utilized in studies of alternative modes of operation and/or the effects of design and development trades between component alternatives. The current SUMARY code package, coupled with the SPA code package, will be utilized in studies of alternative power train and component, design configurations. The results will be provided to the various functions to be utilized in the selection of approaches.

The desireability of implementing any proposed change in the design or in the program or its result will be defined conceptually, and the resulting cost will be estimated. The SUMMARY code package will be utilized to access the benefit that future plants might realize if the change is implemented.

1112 RETROFIT AND TEST POWER TRAIN ANALYSES

Objective

To provide detailed analyses of the Retrofit and Test Power Trains as the basis for conceptual design and integration activities.

Technical Approach

The SPA/SUMMARY code package, described in WBS 1111, will be extended to lower rating values to include the Retrofit plant rating and the anticipated test power train ratings.

The package will be used as required to provide the basis for conceptual design efforts and for trade-off studies needed in integrating the activities of the engineering development and retrofit programs. Further and more detailed analyses are anticipated at 20, 50 and 250 MW(t) ratings to guide the design of components for the tests, the planning and design of tests and analyses of the results.

1120 RETROFIT POWER TRAIN CONCEPTUAL DESIGN

Objectives

- To establish and agree upon the goals and objectives to be achieved in the retrofit program,
- To define and document the power train required for the Retrofit plant, and
- To define and document the specifications for the power train components to be developed in the Engineering Phase and provided in the retrofit phase.

Technical Approach

Specific performance, lifetime, cost-of-components and other goals will be recommended for the retrofit power train and its components. These will be reviewed and then submitted to the customer for approval.

The selection of these goals will reflect consideration of the risks involved in scale-up from the test power trains and the future scale-up to the early commercial plant power train rating.

The retrofit power train baseline design will be selected based on the results of the analyses performed in WBS 1110 and the agreed upon goals and objectives. This design will be documented in the Retrofit Power Train Description and Specification. Upon Customer approval, this will be expanded into Equipment Specifications that can serve as the controlling documents for the design and development of the components. This task will be performed under three subtasks as defined below.

1121 DEFINITION OF GOALS AND OBJECTIVES

Objective

To define the desired end-products of the retrofit program.

Technical Approach

The goals and objectives, both technical and operational, for the retrofit project will be recommended and submitted for customer approval.

These include such considerations as: a) trade-off of retrofit rating between assurance that results can be scaled to the early commercial plant with confidence and the cost of the retrofit plant, b) trade-off between assurance that component lifetime test results can be scaled up and the cost of the testing program, c) definition of test durability in terms of operating cycles as well as hours, allowable maintenance and energy production, d) capability to test components of more than one configuration, e) data acquisition requirements, including fine structure data requirements of equipment suppliers, f) operational data requirements of the utilities, g) operation and maintenance training requirements, h) capability to fire a range of coals, i) ability to access environmental impact, and j) capability to provide operational and maintenance training.

1122 SYSTEM DESCRIPTION AND SPECIFICATIONS

Objective

To provide the definitive and controlled documentation of the baseline retrofit power train.

Technical Approach

This document will be prepared in the format established in Task II. Specific data and information, obtained from the analyses performed under WBS 1112, will be incorporated. The conceptual design of the retrofit unit, initiated under Task II (Assessment of MHD Program Options), will be up-dated in conjunction with Montana Power Company personnel (and other organizations such as candidate component suppliers) to obtain the additional data and information needed to complete the retrofit power train system description and specification. This document will be maintained under change control throughout the program.

1123 COMPONENT SPECIFICATIONS

Objective

To provide the definitive and controlled documentation of the requirements to be realized by each power train component developer/supplier.

Technical Approach

An Equipment Specification will be prepared for each component of the power train. These will be used in the direction and integration of the design and development efforts. Like the System Description and Specification, these will be maintained under charge control throughout the program.

1130 50 MW(t) POWER TRAIN CONCEPTUAL DESIGN

Objectives

- To establish and agree upon the goals and objectives to be achieved in the development and testing of the 50 MW(t) power trains,
- To define and document the power train required for the test, and
- To define and document the specifications for the power train components to be designed and/or developed for the power train.

Technical Approach

Specific performance, lifetime and other goals will be recommended for the 50 MW(t) power train test programs. These will be reviewed with the Advisory Committee and then submitted to the customer for approval. The selection of these goals will reflect the state-of-technology and the impact on the program schedule that would result from goal definition requiring component development.

50 MW(t) Power Train System Description and Specification documents will be prepared. These will conform to the format of the existing Advanced Power Train System Description and Specification. They will contain data and information extracted from the power train analyses performed under WBS 1112, reflecting the agreed upon goals and objectives and data and information obtained in a conceptual design effort mounted under this task. The interfaces with the planned test facility will be identified in cooperation with the Coordination of Testing Facilities function.

This document will be expanded into Equipment Specifications that can serve as the controlling documents for the design and/or development of the components. Ths 50 MW(t) conceptual designs performed under this task will be prepared under the two subtasks defined below.

1131 50MW(t) ENDURANCE POWER TRAIN

Objectives

- To establish and agree upon the goals and objectives to be achieved in the development and testing of the 50 MW(t) Endurance power train,
- To define and document the power train required for the test, and
- To define and document the power train required for the specifications for the power train components to be designed and/or developed for the power train.

Technical Approach

The key goal for the endurance power train is the demonstration that the state-of-the-technology has been advanced sufficiently to allow the design and construction of the retrofit plant with confidence and reasonable risk. The time required for the production of the endurance power train components is 2.5 years. This will allow 1/2 year for installation and check-out and 1 year for the 500 hour test, all to be accomplished by the end of the fourth year of the program. These schedular considerations will be reflected in the definition of the goals and objectives for the endurance power train.

Effort to date indicates that the critical path is through the production, installation and check-out of the channel. The channel will be essentially the state-of-the-technology at the start of the program because a channel vendor estimates that 2.5 years will be required for its production.

The power conditioning system will incorporate power management. Recognizing the paucity of channel characterization data, the power management subsystem hardware will be designed with the maximum feasible flexibility. The planned tests at CDIF, where EPRI furnished instrumentation is to be installed, are expected to provide useful information. As noted in WBS 1410 and 1420, additional channel characterization and power management development efforts are planned to supplement the CDIF data and provide the basis for the design and calibration of the power management software.

The schedule permits further development of the combustor. It is anticipated that the 50 MW(t) Development combustor, and associated system, will be tested at CDIF and that the 50 MW(t) prototype combustor will be available for the endurance power train test. Other components also appear to require less than the available time for their design and production.

Engineering concepts exist for all components of the endurance power train. The conceptual design will utilize these concepts. State-of-the-technology aircraft type hoses will be utilized for the voltage stand-off feature in connecting lines. Existing electrical cable types, that have been demonstrated in the CDIF program, will be utilized. These examples of CDIF proven technology indicate the practicality of proceeding with the conceptual design without delay. It is recognized that these may not meet the requirements of the higher voltage power train that will be installed in the retrofit plant and that further development will be required before the retrofit plant design can be initiated.

Once the conceptual design is complete, the Endurance Power Train System Description and Specification will be prepared, following the format of the Advanced Power Train System Description and Specification. The analyses performed in WBS 1112, the interfaces with the selected test facility, and the results of the conceptual design effort will be utilized in establishing the data and information in the Description and Specification. This document, along with the accompanying Equipment Specifications, will be utilized in the subsequent integration function and to document the Endurance power train, as constructed. To the latter end, the documents will be placed under change control and maintained throughout the endurance power train program.

1132 POWER TRAIN WITH SUPERCONDUCTING MAGNET

Objectives

- To establish and agree upon the goals and objectives to be achieved in the development and testing of the 50 MW(t) power train to be tested in the existing superconducting magnet,
- To define and document the power train required for the test, and
- To define and document the specifications for the power train components to be designed and/or developed for the power train.

Technical Approach

The technical approach will be similar to that just described for the 50 MW(t) endurance power train, with the following exceptions:

The schedule for the initial operation of this power train is approximately 1.5 years later than that for the endurance power train. Therefore, the opportunity is presented to identify, develop and incorporate new technology into the channel. Therefore, the channel is envisaged as the first generation development channel. The establishment of goals and objectives and the conceptual design of the power train will take this into account.

It is expected that the power conditioning system used in the endurance power train test will also suffice for this power train. Hence, few if any changes are anticipated. The increased performance expected with the superconducting magnet will require consideration of power conditioning equipment adequacy and may result in modification. This possibility will be examined during the conceptual design of this power train. The operating experience gained in the test of the endurance power train will allow refined definition of the software.

The combustor and other components are also expected to be transferred from the endurance power train to this train and test.

The two 50 MW(t) power trains are assumed to be prepared for test in the same or similar test facilities, and hence the interfaces with the test facility are presumed to remain largely unchanged except for those associated with the superconducting magnet.

1140 50 MW(t) POWER TRAIN INTEGRATION

Objectives

- To provide system engineering services for the management and direction of the design, development and production of the components of the 50 MW(t) power trains,
- To support their installation, check-out and testing, and

- To analyze the test data and prepare the resulting data and information for use in the follow-on activities and in the engineering data base.

Technical Approach

The System Description and Specification, with accompanying Equipment Specifications, will be maintained throughout the program. Analyses and trade-off studies will be conducted to assist in the evaluation of proposed changes. The effects of any approved changes will be reflected into these documents through revisions or reissue.

Quality control resources, tools and methods will be provided to monitor and control the design and production of the components. Progress reviews will be conducted at regular intervals to ensure that each activity of the project is producing the planned technical results, on schedule and within resources. In each of these reviews, the rationale for any proposed change in the specifications or design will be thoroughly discussed. Change requests, so considered, will be examined for their effect on the overall power train and on interfaces with other components or the testing facility.

At the conclusion of each progress review, a Variance Report will be prepared to highlight any deviation from the project plan. This report will be provided to management so that their attention may be focused on the high priority problems and concerns of the project.

The test planning requirements will be produced and assistance will be provided to test facility personnel in the preparation of the test plan. Data acquisition equipment and efforts requirements will be considered in the integration effort.

Assistance will be provided, as required, during the test. The test data will be reviewed for completeness. It will be analyzed to produce the data and information needed for the Title I and Title II design, production and operation of the Retrofit power train. To the extent that the results apply, they will be prepared for inclusion in the engineering data base.

1141 ENDURANCE POWER TRAIN

Objectives

- To provide system engineering services for the management and direction of the design, development and production of the components of the 50 MW(t) Endurance power train,
- To support their installation, check-out and testing, and
- To analyze the test data and prepare the resulting data and information for use in the Retrofit program and in the Engineering Data Base.

Technical Approach

As previously noted, the key objective of the Endurance power train test is to demonstrate the readiness of the system for initiation of the Retrofit program. To this end, the integration effort will concentrate on the above noted tasks in a manner that will produce an endurance power train that is fully representative of the latest state-of-the-technology, is designed and produced of the best possible quality, and is installed and operated in accordance with the specifications.

A topical report, recording the endurance power train effort, will be prepared.

1142 POWER TRAIN IN THE SUPERCONDUCTING MAGNET

Objectives

- To provide system engineering services for the management and direction of the design, development and production of the components of the 50 MW(t) power train for operation in the superconducting magnet,
- To support their installation, check-out and testing, and
- To analyze the test data and prepare the resulting data and information for use in the follow-on activities and in the Engineering Data Base.

Technical Approach

The key objective of this power train test is to identify and quantify any effects of operation of a 50 MW(t) power train in a superconducting magnet that may impact the design and/or operation of the retrofit power train. A second objective is to explore the operation of the first development channel. To this end, the integration effort will concentrate on the above tasks in a manner that will produce a power train, in particular a channel, that is fully representative of the progress made in the channel development, is designed and produced of the best quality and is installed and operated in accordance with the specifications and the test plan.

The test operation and data, obtained during the design of the retrofit power train, will be analyzed and any pertinent results will be incorporated into the Title I and/or Title II design. Later test operation and data will be factored into the preparation of operating plans for the Retrofit power train. Operation and data will be factored into the continuing channel design and development effort on the second development channel.

Opportunities for modification of the channel, by adding modified sections that represent later progress in the channel development, will be sought and implemented. The channel operation and data will be examined for contributions to the Channel Engineering Data Base. A topical report, recording this power train effort, will be prepared.

1150 RETROFIT POWER TRAIN INTEGRATION

Objectives

- To provide system engineering services for the management and direction of the design, development and production of the components of the retrofit power train,
- To support their installation, check-out and testing, and
- To analyze the test data and prepare the resulting data and information for use in the follow-on activities and in the engineering data base.

Technical Approach

This task will be structured into three subtasks: WBS 1151, Title I Design; WBS 1152, Title II Design and WBS 1153, Title III Construction, Checkout and Test.

The Retrofit Power Train System Description and Specification, with accompanying Equipment Specifications, will be maintained throughout the program. Analyses and trade-off studies will be conducted to assist in the evaluation of proposed changes. The effects of any approved changes will be reflected into these documents through revisions or reissue. Quality control resources, tools and methods will be provided to monitor and control the design and production of the components.

Progress reviews will be conducted at regular intervals to ensure that each activity of the project is producing the planned technical results, on schedule and within resources. In each of these reviews, the rationale for any proposed change in the specifications or design will be thoroughly discussed. Change requests, so considered, will be examined for their effect on the overall power train and on interfaces with other components or the testing facility.

At the conclusion of each progress review, a variance report will be prepared to highlight any deviation from the project plan. This report will be provided to management so that their attention may be focused on the high priority problems and concerns of the project.

The test planning requirements will be produced and assistance will be provided retrofit facility personnel in the preparation of the test plan. Data acquisition equipment and efforts requirements will be considered in the integration effort.

Assistance will be provided, as required, during the test program. The test data will be reviewed for completeness. It will be analyzed to identify the data and information needed for the design, production and operation of the early commercial power train. The results will be prepared for inclusion in the engineering data base.

1160 POWER TRAIN TECHNOLOGY DEVELOPMENT

A significant portion of the technology, pertinent to the design and ultimate successful operation of MHD steam power plants, involves more than one component. This is illustrated by consideration of the interfaces discussed in the APT System Description and Specification. The overall power train technology, where it involves more than the technology of a single component, will be developed as required.

1161 ASSEMBLY/DISASSEMBLY

Objective

To provide the technology for assembly of the components into a working power train that can be readily and rapidly disassembled for maintenance and/or component replacement.

Technical Approach

The approach to this task was demonstrated during task 2.2.2, Design Approaches. A preliminary model of the power train, including an assumed superconducting magnet configuration, was installed on the computer aided design (CAD) facility of the Advanced Energy Systems Division of Westinghouse. This approach will be utilized in this task. As the design and development is carried out and the design is refined, the CAD model will be maintained current. It will be utilized to explore the practicality of options and alternatives as they are proposed.

1162 OPERATION AND MAINTENANCE STUDIES

Objective

To devise, select and develop power train concepts that will have the most favorable impact on operating and maintaining the ultimate plant, as well as on the success of the tests performed within this program.

Technical Approach

The CAD, SPA and SUMMARY code packages will be utilized, as they have in the past, to explore alternative approaches as to their impact on operation and maintenance. This technique will be utilized in the planning of test programs to explore the practicality of realizing the intended goals and objectives of the tests. The various versions of the SPA code package will be utilized to define the test instrumentation and control requirements and as the basis for the preparation of test manuals and plans.

1163 THERMAL/MECHANICAL FORCES ANALYSES

Objective

To provide the component development functions, particularly the Combustor Development (CD), with the data and information required for design of the components.

Technical Approach

The work to date suggests that the power train thermal expansion should be accommodated by fixing the location of the combustor and allowing thermal growth in the downstream direction. This is consistent with the desire to operate the train with essentially atmospheric pressure at the entrance to the HRSR. This physical interface appears to be the most logical location for the placement of the device for accommodation of the growth. The alternative would be to fix the train solidly at the HRSR and allow growth in the upstream direction. The impact of this approach would be to force the combustor to move. It would place increased stress on the intermediate components, including the channel, due to the weight of the combustor system. It would require accommodation of the resulting motion at the point where the voltage isolation must also be accommodated.

The choice of approach will be made in this task. Mechanical studies of the options will be carried out. Impacted functions will provide input, including conceptual designs and cost estimates for in analyses using SPA/SUMMARY.

1170 ENGINEERING DATA BASES

Objective

To identify and document the engineering data and information, on the power train and its components - especially the channel, needed for the design and operation of the 200 MW(e) MHD/steam power plant.

Technical Approach

To this end this task will establish and maintain the Engineering Data Bases as the data and information is produced in the program. The format for these data bases will be coordinated with the MHD Data Base being established by the Pittsburgh Energy Technology Center of the DOE. The state-of-the-technology was surveyed during the execution of Task I. These data will be up-dated and utilized as the base for the preparation of the plant and channel data bases herein.

Each development activity and each test will be examined for data and/or information that supplements or modifies the dat already collected.

1171 PLANT ENGINEERING DATA BASE

Objective

To identify and document the engineering data and information, on the power train and its components needed for the design and operation of the 200 MW(e) MHD/steam power plant.

Technical Approach

This data base is intended to concentrate on the plant and equipment other than the power train. The development activities on individual components, test power trains and the Retrofit power train will be examined for contributions to the data base. The related MHD development programs on the HRSR and Seed Regeneration will be followed to obtain and document up-dated power train interface data.

Interfaces with the remainder of the plant will be examined in the light of the design and operation of the Retrofit power train and plant. Particular attention will be paid to the documentation of engineering detail such as the specification of materials and processes. The Advanced Power Train System Description and Specification will be up-dated to include the technology represented in the final Engineering Data Base.

1172 POWER TRAIN ENGINEERING DATA BASE

Objective

To identify and document the engineering data and information, on the power train needed for the design and operation of the 200 MW(e) MHD/steam power plant.

Technical Approach

This data base is intended to concentrate on the channel. The development activities on the channel technology, the materials test and the channel aspects of the power train and Retrofit tests will be examined for contributions to the data base.

The related MHD development program on the magnet will be followed to obtain and document up-dated channel interface data. Interfaces with the remainder of the power train will be examined in the light of the design and operation of the channel. Particular attention will be paid to the documentation of engineering detail such as the specification of materials and processes. The Advanced Power Train System Description and Specification will be up-dated to include the technology represented in the final Engineering Data Base.

WBS 1200 MHD GENERATOR DEVELOPMENT

The combined assembly, consisting of the channel, the power conditioning subsystem, and the superconducting magnet, make up the electromagnetic generator. Most aspects of this assembly must be taken into consideration, essentially as a unit, in order to realize the optimum design.

It is recommended that the magnet be included in the scope of the Phase II Advanced Power Train (APT) contract. The magnet is excluded from the scope of the power train, as defined in the present contract. It has been necessary to assume characteristics, including the configuration, of the magnet in order to carry out the Phase I APT effort. The available information, along with calculations and conceptual design effort, has been sufficient for the work to date. However, the execution of the development program will require definitive data and information on the magnet.

The importance of the approach in which the power conditioning subsystem is included as a component of the generator, is apparent from the potential advantages that may be realized in the channel design by close integration of these components. One example, identified in the work under Task II, subtask 1, is the possibility that the channel may be shortened by 20 per cent if the anode-to-anode voltage can be properly controlled (through the power management subsystem).

There are two broad tasks included in WBS-1200, viz Analysis and Modeling (WBS-1210) and Design Integration (WBS-1220). The analyses and modeling that is centralized in this WBS element supports the channel and power conditioning development programs as well as the design integration function. The analytical effort requires consideration of most of the aspects of the generator assembly. The development plan is organized to reflect this requirement since it applies as well to the design and performance of power train test equipment as to the design and performance of MHD plants. The tasks in WBS-1220 provide direction, from an overview perspective, for MHD generator component design and development and integration of the generator components into the power train. Information that must flow from the combustor design to the generator subsystem design and from the generator design to the diffuser design for proper integration will be processed within this WBS element. There will also be direct interaction of the generator design integration with the Power Train Integration (WBS-1100) and Coordination of Test Facilities (WBS-1800), see Figure 1.

The Design, fabrication, installation, and testing of generator components have been placed in other WBS elements; Channels in WBS-1300, and Power Conditioning in WBS-1400.

1210 ANALYSIS AND MODELING

Objective

- To provide a detailed understanding of the generator phenomena
- To verify, by comparison with experiments, the capability of numerical codes to design and predict with reasonable certainty the performance and life of future prototype and commercial generators, and
- To provide detailed on-design, off-design, and transient interface specifications between the generator components and insure compliance with the interfaces between the generator and the other power train components and the plant.

Technical Approach

The approach to this task will be to identify and utilize the best existing computer codes, skilled personnel, and facilities, in the United States, for the performance of the required analysis and modeling, and to perform the analysis in a timely fashion. The numerical code capability to perform the required effort presently exists in the United States. This capability includes codes to perform one, two, and three dimensional steady state or transient analysis of the fluid mechanics of MHD generators. The capability for detailed investigation of finite electrodes with slag coatings is available. Codes also exist which can be used to evaluate the power management and magnet subsystems. Thermal, hydraulic and stress codes will be used primarily in the performance of tasks for the design of the generator components (WBS-1300 and 1400).

The results of these analyses will be utilized to provide broad support and guidance to the development of the MHD generator system and components, and to the establishment of the generator related portions of the Engineering Data Base.

1211 NUMERICAL SIMULATION OF GENERATOR EXPERIMENTS

Objective

- To improve the understanding and value of the experimental results of other tasks, and
- To provide improved verification of the numerical capability and an increased confidence in its reliability to predict performance of future larger generators.

Technical Approach

The efforts to calculate the performance of the AEDC and AVCO channels, by STD Research Corporation, will be the starting point for this task.

These same calculational methods will be utilized to predict the performance of generators that are to be tested in other tasks.

The results of the generator and channel tests will be analyzed and compared with the calculational results. After resolution of the differences, if any, the analytical methods and especially their input values will be up-dated.

1212 PLASMA DYNAMICS, PHYSICS, AND SCALING AND DELINEATION OF POTENTIAL CRITICAL EXPERIMENTS

Objectives

- To numerically evaluate in depth anticipated commercial scale generator concepts to determine if phenomena such as magnetoaerothermal instability, shorting, etc. might limit their performance or life,
- To define approaches to avoid or control the effects of such phenomena, and
- To define critical simulation experiments to provide experimental confirmation.

Technical Approach

Using existing calculational methods and codes, anticipated commercial scale generator concepts will be numerically evaluated in-depth. Particular emphasis will be placed on the assessment of the effects of phenomena, such as magnetoaerothermal instability and slag shorting, that may limit the performance and/or life of the generator concepts.

Where undesired effects are identified, numerical analyses of possible modifications of the concepts, that might avoid or control the undesired effects, will be performed to define their value.

Numerical analysis of possible simulation experiments, which might provide confirmation of the value of the modifications, will be performed. These results will be utilized in support of the channel and power conditioning development functions.

1213 NUMERICAL DESIGN SUPPORT

Objective

- To provide detailed analytical support to the system and plant studies,
- To provide detailed analytical support to the design of test and prototype generators.

Technical Approach

The analytical tools, confirmed in WBS 1211, will be utilized. As the plant and system studies are carried out, these tools will be applied to examine selected generators in depth to confirm that the system and plant performance analyses properly represent the generator. These studies will include the off-design, transient and fault mode studies.

Support will be provided to the Design Integration, Channel, and Power Management functions (1220, 1300 and 1400). The function of this effort is to optimize the plasmadynamic and electrical design of these generators consistent with the anticipated plant requirements and engineering. The optimum off-design operating strategy also will be defined. In addition, for all anticipated plant or generator faults or transient conditions the designs must be safe, reliable, and controllable (including interactions between the channel, power management, and magnet).

1220 DESIGN INTEGRATION

Objective

- To review and coordinate component designs, utilize the analytical results, and perform any design engineering necessary to assure proper integration and performance of the overall generators for the direction of the Channel and Power Conditioning functions, and

- To provide integration assistance in the design and planning of tests involving MHD generators, such that the test results will be of maximum usefulness in the ensuing development efforts and in the Engineering Data Base.

Technical Approach

Generator requirements will be derived from the MHD/steam plant requirements (1110). These will be reviewed and translated into requirements for the channel and power conditioning development efforts. Generator mechanical and electrical design studies, coordinated with the generator analysis and modeling efforts, will be carried out. Generator integration services will be provided to the channel and power conditioning efforts. These will include the detailed definition and maintenance of the interfaces between components within the generator. Assistance will be provided to the Coordination of Testing Facilities function (1800).

1221 ENDURANCE GENERATOR

12211 REQUIREMENTS

Objective

To ensure that the generator component requirements are defined consistent with the generator requirements and the System Description and Specification.

Technical Approach

The power train requirements and the up-dated System Description and Specification will be reviewed. Channel and Power Conditioning Requirements documents will be prepared. These will include the component interfaces, which will be maintained and up-dated as the results of the development program dictate.

12212 DESIGN

Objective

To provide the overall generator design efforts required in the power train development.

Technical Approach

Generator design and trade-off studies, to support the preparation of the component requirements definition will be coordinated with the Numerical Design Support function (1113). If the Phase II APT Development Program is implemented with the same work scope as in Phase I, i.e. without including the magnet, the design effort will include design studies of the superconducting magnet required for the adequate definition of the generator component interfaces with the magnet.

Generator design studies, of the proposed high power, high enthalpy extraction experiment, will be performed.

Generator design studies, as required to support the component development functions, will be conducted.

12213 COMPONENT INTEGRATION

Objective

To ensure that the development and design activities, within the component functions, are performed in conformity to the component requirements and interfaces.

Technical Approach

Component development progress will be reviewed at regular intervals, with emphasis on maintenance of the requirements and interfaces. Requests for revision of the component requirements or generator component interfaces will be reviewed and commented upon by this function. This review and comment will focus on the impact that the proposed change may have on the performance and/or life of the ultimate generator as a whole. These reviews will also consider the effect of the proposed change on the capability of the test generators to provide the desired test results. A further consideration in these reviews, will be the interfaces with the intended test facility.

12214 TEST PLANNING

Objective

To provide support to the preparation of plans for successful power train testing programs.

Technical Approach

All generator component, generator, and/or power train test plans will be reviewed to ensure that the overall generator requirements are considered and satisfied. Appropriate test plans, obtained from any source, will be reviewed to seek to identify opportunities to obtain the required generator data and information at least cost to the overall MHD development program.

12215 TEST SUPPORT

Objective

To provide all necessary generator related support to the Coordination of Testing Facilities function.

Technical Approach

Assistance will be provided, as required, to the Coordination of Testing Facilities function. Technical personnel will be provided to resolve questions that arise during the installation and operation of the test generators. Test results will be reviewed and analyzed to ensure the acquisition of the necessary data and information to confirm the generator requirements, designs, performance, and inputs to the Engineering Data Base.

1222 DEVELOPMENT GENERATORS

This task will serve the same role for the development generators that WBS 1221 serves for the endurance generators. It will be made up of the same set of five subtasks as those described under WBS 1221, namely requirements, design, component integration, test planning and test support.

1223 RETROFIT GENERATOR

This task will serve the same role for the retrofit generator that WBS 1221 and 1222 serve for the endurance and development generators respectively.

WBS 1300 CHANNEL DEVELOPMENT

The design and development of the channel is the most challenging task of the Advanced Power Train program. Thorough understanding and proper development of the channel is of critical importance to successful engineering development, plant integration, and establishment of the engineering data base for the commercial MHD/steam plant power trains and the ultimate commercialization of the MHD steam power plants.

The development effort, to date, has been carried forward in two parallel paths--demonstration of performance (rating) and demonstration of life (endurance). The program presented herein continues this approach and extends it to bring the two results together to demonstrate that the combined performance and life can be achieved.

This development program recognizes, and implements, the necessity for development of the rugged and reliable channels, economical of magnet warm bore, and low in cost, that will be necessary for power plants that must meet the requirements of the utility application.

The proof-of-concept channels for the system and later plant integration are based on use of essentially state-of-the-art technology. These channels do not require the economy of warm bore, ease of installation, or low cost of production that must be provided in the commercial channels. It is more important to complete the proof-of-concept (both system and plant) phases in the shortest time and at the lowest cost.

However, the program includes the fabrication and assembly development effort needed to provide the complete Engineering Data Base for the commercial channels. This additional effort is included because the achievement of the proof-of-concept phases without resolving the other requirements of the commercial channels would be for nought.

The channel development function will be closely coordinated with the Power Conditioning Development function. This will be provided by the integration effort described under the MHD generator development task (WBS-1200).

This program is based on recognition that the research and preliminary design phases of channel development have been successfully completed. It also recognizes the extensive and excellent capability for channel development that exists in the U.S. It is planned that all this capability will be utilized to reduce the cost of, and time for, the remaining development to the minimum.

The channel development is described herein in five tasks: 1310 Technology Development, 1320 Endurance Channel, 1330 Development Channels, 1340 Retrofit Channels, 1350 Fabrication & Assembly Development.

1310 TECHNOLOGY DEVELOPMENT

Objective

To perform experiments and development tests that do not require a full power train facility. This research and development is necessary to support the design and construction of the MHD channels required for the proof-of-concept or system integration, the plant integration, and the channel development activities that will establish the engineering data base for the design of channels for early commercial MHD/steam power plants.

Technical Approach

Both analytical and experimental studies will be performed to extend the data and information in the areas of basic plasmadynamics, interactions between the plasma and the power management subsystem, and the physics of cathode and general slag shorting phenomena.

The experiments currently underway to explore high interaction will be continued. Experiments to extend this understanding into the areas of high power and high enthalpy extraction will be designed and performed.

Channel concepts that offer the potential to control the undesirable effects of secondary flows and/or magneto-aero-thermal instabilities anticipated to be identified in the high power and high enthalpy extraction experiments will be devised, designed, constructed and tested.

The specific identification and detailed specification of channel element materials will be carried out using both out-of-power-train and in-channel experiments. Detailed process specifications will be produced for the control of consistent production, by competitive suppliers, of channel elements and channels.

The electrical and mechanical development required to design, produce and test advanced (development) channels will be carried out. Power train tests with partial channel sections will be utilized in this effort to provide the data and information for the channel Engineering Data Base.

The necessary facilities for these experiments already exist. These include the 20 to 50 MW(t) facilities at AVCO, CFFF and CDIF. The existing 6T superconducting magnet should be installed at one of these facilities. Some special test equipment, such as a short-duration, very high conductivity combustor and heat sink channels will be required.
This task is further broken down into four WBS tasks: 1311 Plasmadynamics, 1312 High Interaction and Power Experiments, 1313 Materials Engineering, and 1314 Electrical/Mechanical Development

1311 MHD CHANNEL PLASMADYNAMICS

Objectives

a) To provide an understanding based on test results of the physics of cathode shorting and general channel slag shorting phenomena.

b) To define the dynamic plasma interactions of the channel with the power management subsystem.

c) To continue the university basic studies in these areas.

Technical Approach

Both theoretical analysis and acquisition of data from power train tests, primarily performed for other reasons, will be utilized to improve the understanding of slagging channel phenomena and to determine their impact (as a function of coal chemistry) on channel operation, performance and life.

Twenty and fifty megawatt thermal simulated coal-fired and coal-fired facilities having iron core magnets exist to support this required effort. In addition, the new facilities that are involved in the developmental plan will provide additional data. The basic approach of this task will be to utilize, with minimum modification, the operating MHD channels and test facilities and to focus the U.S. industrial and university channel expertise on performing the primary functions in achieving the objectives of this task. The Stanford and Montana State University efforts would be included in this WBS element.

An additional benefit from this approach will be education of the future managers and engineers that will be needed to deploy MHD technology.

Tasks will include specification of diagnostics and measurements on the experimental channels, the accumulation of data, and the analyses and interpretation of the data when compared to predictions of the computational results obtained in WBS-1210.

Analytical studies and instrumentation of tests, primarily performed for other reasons, will be utilized to define the electrical interface between the channel and the power management subsystems. Studies will include evaluation of electrical fluctuations, potential control of location of cathode shorting, and prevention and/or extinguishing of inter-anode faults. These will be carried out in conjunction with the effort on the power management subsystem (see WBS 1420) and under the integrating direction discussed in WBS 1220.

1312 HIGH INTERACTION AND POWER EXPERIMENTS

Objective

To provide an experimental verification of the methodology for design prediction, control and optimization of the plasmadynamic phenomena anticipated in the large channels for the retrofit unit and for the 200 MW(e) and larger MHD/steam power plants.

Technical Approach

The currently on-going high interaction simulation experiments at AVCO and with concurrent analyses at STD will be continued to complete the understanding of the multidimensional phenomena exhibited by such channels. The numerical capability to predict these detailed processes will be confirmed. Determination of the types of computation and their analyses will be conducted within this WBS element; performance of the computer calculations will be conducted under WBS-1210.

The on-going AVCO Mk VI high interaction experiments are providing important and valuable data on the effects of secondary flows in MHD channels and the capability of existing numerical codes to predict such phenomena. However, the low power level of the Mk VI experiment limits its capability to exhibit the fully nonlinear effects expected in high power channels. The previous results obtained in the High Performance Demonstration Experiment (HPDE) performed at the Arnold Engineering Development Center (AEDC) indicated the potential of channels to extract enthalpy and power at the level required for the retrofit plant. However, the HPDE results show that this power level channel may also be exhibiting potentially disasterous magnetoaerothermal instabilities.

The experiments will be extended to higher power and higher enthalpy extraction levels. One option for these experiments is to repair the magnet at AEDC. Another option is to use the existing superconducting MHD magnet, heat sink channel, and available short-duration very high conductivity (greater than 100 mhos/m) combustor technology. The latter option is assumed herein, since it is synergistic with other Advanced Power Train and commercial channel development experiments that will also require the use of the superconducting magnet. Existing hybrid or solid rocket combustor technology would be used to power the experiments. The STD Corp. has recently demonstrated this approach successfully. Two generations of channels are to be tested: a conventional design and an advanced design. The advanced non-rectangular design would have the potential to better control secondary flows and to improve magnet warm bore utilization. Experimental power levels would be up to and including those anticipated for initial commercial plants, 70MW electric.

Limited numerical studies performed to date indicate that potential channel performance gains and magnet cost reductions (through better magnet warm bore utilization) should result from using non-rectangular cross section channels. Experimental verification of the most theoretically attractive case(s) should be possible in short duration heat sink channel experiments at high power, enthalpy extraction and interaction.

Efforts included in this WBS element are the design, construction, and installation of the test equipment. Test support, data analyses, and reporting will also be conducted.

1313 MATERIALS ENGINEERING

Objectives

a) To provide documented materials and process specifications for the design of channels.

b) To support the design and production of the test channels required in the development program.

c) To investigate new materials and processes that promise the potential to enhance channel performance and/or life or lower the cost of production.

Technical Approach

The state-of-technology investigation, carried out in Task I of the MHD/APT project, revealed that (in most cases) satisfactory materials were identified for channel production. However, it was determined that detailed characterization and specifications for their competitive procurement was not available. Samples of material used in such programs as the anode tests, in which AVCO demonstrated over 1000 hours of successful operation, will be secured and systematically analyzed and characterized. Literature search and contacts with experimenting organizations will be pursued.

Each channel built and tested in the program will be examined as a potential test bed for the generation, or confirmation, of materials data and information. Materials personnel will work closely with designers and experimenters to categorize and document the materials and processes used in channel and test piece production, to follow and record the results of tests, and to perform post-mortem analyses.

Materials engineering efforts will support the design and development leading to the Engineering Data Base for the commercial channels. The advanced MHD channel concept, identified in the Advanced Generator Study (Task II of the MHD/APT project) will require extensive materials and process development participation.

Candidate insulating materials will be explored. Boron nitride is the current insulation material of choice for the separation of electrodes and side-wall elements. Materials that are more amenable to manufacturing processes will be sought and tested.

Production processes that have promise for lowering the cost of channel fabrication, such as extrusion of electrical elements, must be developed to insure that the required configurations can be obtained, at the desired low cost without damaging the character of the materials.

A 2,000 hour test of a 20 MW(t) system is proposed by CFFF in the third year of the program. While this test is directed to the acquisition of downstream data and information, it offers the possibility of building long-term testing of materials oriented sections of the MHD channel at a very low incremental cost. These test sections will be designed, constructed, and installed. Support will be provided during testing and the test results will be evaluated.

Close coordination of the Materials and Electrical/Mechanical Development functions will be maintained to ensure that any beneficial trades between design and material selection will be exploited. The chemistry of materials and their environments, in the long exposure periods anticipated in the commercial channels, will require out-of-channel testing programs to confirm that the design selections are justified.

The results of the Materials Development program will be documented, utilized in the program and provided to the engineering data base.

1314 ELECTRICAL/MECHANICAL DEVELOPMENT

Objective

a) To provide the supporting engineering technology for the design of test, and ultimate commercial, channel design.

Technical Approach

The design of many of the channels to be tested in the program will be based on the current state-of-the-art because of the time element. An early be most demonstration that the MHD power train system can be designed, produced and operated at design conditions for long periods of time is needed. However, each succeeding channel will be designed and constructed factoring in the latest available technology whenever it can be applied at reasonable cost and without jeopardizing the probability of meeting the prime objectives of the channel test. This approach will minimize the program cost and schedule, and provide the most complete Engineering Data Base. To this end, the Electrical/Mechanical Development and the Channel Design functions (1321, 1331, and 1342) will work in close coordination.

Conversely, a major goal in the Electrical/Mechanical activity is the identification and development of concepts that will when implemented in future automated factories, produce the low cost channels that are absolutely necessary for the commercialization of MHD. Opportunities to simulate and prove out these concepts in the Development channels will be sought. To try to incorporate them into the Endurance or even the Retrofit channel, before they are adequately proven in out-of-channel tests and in small sections incorporated into other less crucial channel tests could be counterproductive.

Support will be provided to the design functions in the identification of suitable electrical and mechanical features for the various test channels that will enhance the chance for successful test operation.

The approach to the development of advanced electrical/mechanical concepts will be based on the channel concept derived in the Advanced Generator study (Task II, MHD/APT project). Iterative studies, cooperating with the Numerical Design Support function (WBS 1213), will be carried out to define the ideal configuration and performance level and to devise elements and methods that approach the ideal--always bearing in mind the limits imposed by practical production methods and the necessity for high reliability and low cost production of the commercial channels.

Extensive study of methods and concepts for adequate and reliable removal of heat from the channel will be required. The thermal and hydraulic features of the electrical elements will be examined in detail. Mechanical features, including the considerations of materials and chemistry, will be examined in analytical and experimental programs. Consideration will be given to requirements and concepts for the extensive instrumentation desired in the test channels as well as to the requirements and concepts for the operational instrumentation required for successful operation of the commercial channels.

Concepts for channel, including auxiliary features, that are economical of warm bore and simplify and expedite channel installation/removal will be studied. The basic concept identified in the above mentioned Advanced Generator study has produced the starting point for these studies.

Support will be provided to the Fabrication and Assembly function (WBS-1350). Engineering trades between element configurations, design features, and manufacturing methods will be supported.

1320 ENDURANCE CHANNEL

Objective

To provide the channel and support its installation and test for 500 hours that will demonstrate in an integrated power train system the practicality of a 20 MW(t)-50 MW(t)

Advanced Power Train and confirm the engineering base for designing the Retrofit MHD Power Train. The channel will be designed with the objective of operating life based on calculated wear rates in excess of 2,000 hours. The expected goal for the first retrofit channel.

Technical Approach

Consideration of the desired overall schedule for the early commercialization of MHD and the need for a large experiment in the 250 MW(t) rating range leads to the conclusion that the endurance test is required in the fourth year of the program. This, along the with examination of the actions required to produce and prepare the train for test, leads to the conclusion that the design of this channel must begin at the initiation of the program. Therefore, the technology of the Endurance channel will be the current state-of-the-art. Since this will be the most ambitious life test to date of a complete large channel, the design will be guided by the choice of conservative design limits and values. The most knowledgeable channel experts will be sought through subcontract and consulting agreements to participate in this design. This effort will integrate the best available (state-of-the-art) channel materials, construction, and plasmadynamics technology with the developing power management technology to design and construct an endurance demonstration channel. The channel will be designed for supersonic operation in an existing iron core magnet (CDIF or the nearly identical CFFF magnet). Channel wall construction, current densities, and electric fields will be similar to those anticipated in the initial retrofit channels. The channel will be conservatively designed for an operating life exceeding 2,000 hours.

The channel shall be tested with complete power management for a total of 500 hours of coal-fired operation. Facility capabilities may limit continuous test periods to 100 hours, but no channel repair or maintenance will be performed between test periods. Channel wear will be measured to provide a basis for predicting operating life.

If facility test capabilities permit, testing should be conducted at the facility in which the existing superconducting MHD magnet is installed. This will result in a cost saving for the subsequent development generator program using the superconducting magnet which could use the combustor and of the anticipated endurance generator power conditioning components.

Two channels will be produced. The importance of the test to the overall schedule is sufficient justification to provide a spare channel.

1321 DESIGN

Objective

To provide the detailed design of the Endurance channels for their fabrication and test.

Technical Approach

The channel requirements will be obtained from Generator Development, as derived from scaled-down plant requirements established by Power Train Development. Design will cooperate with Integration of Testing Facilities in the definition of the test facility interfaces.

This state-of-the-art supersonic channel shall include split conducting side wall bars. The channel system shall include a high purity closed loop cooling system.

The channel design will include all necessary auxiliary equipment for the successful operation of the test. Test instrumentation will be included.

The completed design will be presented to a design review panel prior to commitment to production. Support will be provided during the construction period, and final as-built drawings and specifications (including materials) will be prepared.

1322 CONSTRUCTION

Objective

To fabricate the Endurance channel.

Technical Approach

The channel will be fabricated to the approved drawings and specifications. Any necessary deviation will be documented in an engineering change request, a formal document that must be processed through the change control procedure before implementation, and must be reflected in the as-built drawings and specifications.

Channel construction shall use relatively easily repairable state-of-the-art electrode-in-a-box design. Fabrication shall include the required channel instrumentation and adequate spare parts to complete the required testing program.

Necessary packaging, crating, and handling equipment will be provided.

1323 INSTALLATION AND TEST SUPPORT

Objective

To provide technical support to Integration of Testing Facilities and the Test Facility Operator.

Technical Approach

Directives and instructions for handling will be provided. Technical support will be provided to resolve questions during installation and checkout of the channel.

The channel contractor shall approve channel test plans and shall, during test, maintain the responsibility to terminate testing if channel damage is anticipated.

Critical test operations will be observed. Preliminary on-site inspection of test results will be provided to ensure adequacy.

1324 DATA ANALYSIS

Objective

a) To understand the design implications of the test results, and b) To prepare the data and information in suitable format for use in the design of the Retrofit generator, further development activities and in the Engineering Data Base.

Technical Approach

The test results will be analyzed and converted into design data and information format. These will be compared to the design requirements and design assumptions for the purpose of revision of the design methodology. They will include estimated channel life based upon measured channel wear rates.

Performance results will be interpreted in terms of the scale-up to full size plant performance and lifetime predictions.

1330 DEVELOPMENT CHANNELS

Objective

To provide the channels and support their installation and test that will demonstrate the technology for the design of practical channels for the utility retrofit test facility and the early commercial MHD/steam power plants and provide the Engineering Data Base for their channel designs.

Technical Approach

The overall objective of the APT development program is to establish the Engineering Data Base for the design, construction and operation of the full scale early commercial power plants. The plant-related data and information for this Data Base will come from the power train and the Retrofit plant activities. However, most of these activities will utilize MHD channels that are based on the near-term state-of-the-art. Therefore, it is necessary to include in the overall program the development of the Engineering Data Base for the commercial channels. This task is included to carry out that activity. The most knowledgeable channel experts will be sought through subcontract and consulting agreements to participate in these designs.

Two generations of development channels are anticipated: 1) The first 50 MW(t) channel for power train proof-of-concept testing in the SCM, along with subsequent modifications to test development progress, and 2) The second 50 MW(t) channel for the final proof-of-concept test of the channel technology for the Engineering Data Base. These development channels will be complementary to the experimental channels defined in WBS 1310, viz, 1) a high power, high enthalpy extraction heat sink channel of rectangular configuration suitable for use with the existing SCM, 2) one or more nonrectangular channels for the same facility, and 3) one or more small material test channels or channel test sections.

The initial 50 MW(t) channel will utilize an internal construction similar to that which will be successfully demonstrated in the 2,000 hour life endurance channel. It will, in addition, develop the channel structure, cooling, electrical lead removal, and support approaches to be utilized in the initial retrofit channels. Its higher operating fields will also demonstrate improved performance over the prior endurance channel. The advanced channel(s) will exploit continuing developments in channel plasmadynamics, materials engineering, and fabrication and assembly. The advanced channel(s) will be designed to melt a goal of 4,000 hours of operation needed by the ultimate commercial plants.

1331 DESIGN

Objective

To provide the detailed design of development channels for their fabrication and test.

Technical Approach

The channel requirements will be obtained from Generator Development, as derived from scaled-down plant requirements established by Power Train Development and/or from the Technology Development function responsible for the testing in question. Design will cooperate with Integration of Testing Facilities to define the anticipated interfaces with the test facility. At the point where the design of any given development channel is to be committed to design, the latest state-of-the-technology development, as obtained under WBS-1310, will be identified and included in the design to the extent practical without impacting the prime objective of the test.

The initial channel shall have an internal design similar to the prior endurance channel. It shall primarily address the channel structural, cooling and electrical lead removal issues associated with good utilization of (and ease of removal from) the warm bore of a superconducting magnet. Advanced channel(s) design would include progress in channel technology and fabrication and assembly technology.

The channel design will include all necessary auxiliary equipment for the successful operation of the channel. Test diagnostics as well as operational instrumentation will be included.

The completed design will be presented to a design review panel prior to commitment to production. Support will be provided during the construction period, and final as-built drawings and specifications (including materials) will be prepared.

1332 CONSTRUCTION

Objective

To fabricate the Development channels.

Technical Approach

The channel will be fabricated to the approved drawings and specifications. Any necessary deviation will be documented in an Engineering Change Request, a formal document that must be processed through the change control procedure before implementation and must be reflected in the as-built drawings and specifications.

The initial channel would be based primarily on hand construction. Advanced designs would progressively exploit automated construction technology developments.

Necessary packaging, crating, and handling equipment will be provided.

1333 INSTALLATION AND TEST SUPPORT

Objective

To provide technical support to Integration of Testing Facilities and the Test Facility Operator.

Technical Approach

Directives and instructions for handling will be provided. Technical support will be provided to resolve questions during installation and check out of the channel. Critical test operations will be observed. Preliminary, on-site, inspection of test results will be provided to ensure adequacy.

1334 DATA ANALYSIS

<u>Objective</u>

a) To understand the design implications of the test results, and

b) To prepare the data and information in suitable format for use in the pertinent development activities, and in the Engineering Data Base.

<u>Technical Approach</u>

The test results will be analyzed and converted into design data and information format. These results will be compared to the design requirements and design assumptions for the purpose of revision of the design methodology. Performance results will be interpreted in terms of the intent of the test, as expressed in the design requirements. A design and test topical report will be prepared as a joint effort by Design and the requesting function.

1340 RETROFIT CHANNELS

<u>Objective</u>

a) To support the Baseline (conceptual) design of the integrated Proof-of-Concept plant facility, presumed to be a 250 MW(t) retrofit of an existing utility unit, and

b) To provide the channels for operation and test of this facility, and to demonstrate the required channel performance for 2000 hours of operation.

<u>Technical Approach</u>

The need for a large experiment in the 125 to 250 MW(t) rating range is evidenced by comparison of the performance and lifetime goals (identified as required for competitive commercial MHD steam power plants) with the demonstrated state-of-technology in performance and lifetime. The scale-up factors, without the large experiment, would be beyond the range of reasonable risk. The most knowledgeable channel experts will be sought, through subcontract and consulting agreements, to participate in these designs.

Initial retrofit channel internal design will be based primarily on the demonstrated endurance channel design.

Externally it will be similar to the initial development channel design. However, as appropriate, on-going developments in channel technology and fabrication and assembly will be included.

At least two channels will be provided, although one may be a spare and not significantly different in design, due to the necessity to commit to hardware at essentially the same time. The design of these channels will be required at roughly the mid-point of the overall schedule. Hence, the state-of-the-technology can be somewhat advanced, compared to that employed in the design of the Endurance channel.

1341 CONCEPTUAL DESIGN

Objective

a) To support the overall Baseline design effort, and

b) To provide the conceptual design of the Retrofit channel for use by various functions.

Technical Approach

The conceptual design will be performed during the first year of the overall program. Hence, it will consider the anticipated state-of-technology at the time of expected final design, but will perforce be solidly based only on the current state-of-the-art. The design will be prepared in coordination with WBS-1200.

The conceptual design will be recorded in a channel Equipment Description and Specification that will be the starting point for the development of the Retrofit channel. It will be maintained current during the intervening period up to the point of actual design of the channel and will be the starting point for that design.

1342 DESIGN

Objective

To provide the detailed design for the fabrication and test of the channels.

Technical Approach

The channel requirements will be established in cooperation with Generator and Power Train Development functions, in the course of the Baseline Design effort. The design shall be primarily a scaleup of the initial 50 MW(t) development channel design. Design will cooperate with Integration of Testing Facilities in the definition of the Retrofit plant interfaces.

The channel design will include all necessary auxiliary equipment for the successful operation of the test. Test instrumentation will be included. The completed design will be presented to a design review panel prior to commitment to production. Support will be provided during the construction period, and final as-built drawings and specifications (including materials) will be prepared.

1343 CONSTRUCTION

Objective

To produce the retrofit channel.

Technical Approach

The channel will be fabricated to the approved drawings and specifications. Any necessary deviation will be documented in an Engineering Change Request, a formal document that must be processed through the change control procedure before implementation, and must be reflected in the as-built drawings and specifications.

Necessary packaging, crating, and handling equipment will be provided.

1344 INSTALLATION AND TEST SUPPORT

Objective

To provide technical support to Integration of Testing Facilities and the test Facility Operator.

Technical Approach

Directives and instructions for handling will be provided. Technical support will be provided to resolve questions during installation and check-out of the channel.

Critical test operations will be observed. Preliminary, on-site, inspection of test results will be provided to ensure adequacy. The channel design contractor shall approve channel test plans and shall during testing maintain the responsibility to terminate testing if channel damage is anticipated.

1345 DATA ANALYSIS

Objective

a) To understand the design implications of the test results, and

b) To prepare the data and information in suitable format for use in the the engineering data base.

Technical Approach

The test results will be analyzed and converted into design data and information format. These will be compared to the design requirements and design assumptions for the purpose of revision of the design methodology.

Performance results will be interpreted in terms of the scale-up to full size plant performance and lifetime predictions.

A design and test topical report will be prepared.

1350 FABRICATION AND ASSEMBLY DEVELOPMENT

Objective

To perform the development required to: a) produce the channels and/or channel sections, of advanced technology, for test and demonstration, and b) Provide the Engineering Data Base for the production of the commercial channels.

Technical Approach

The advanced channel concept devised in Task II of the MHD/APT project will be the starting point for this development task. The development progress achieved in the overall development program will be factored into the effort in this task.

Out-of-channel development approaches will be utilized to the extent that it is practical. Where necessary, channel sections or channels will be devised for specific tests. The generator task and the Design and Construction functions will participate in the design and production of such test pieces.

In general, it is anticipated that channel sections will be produced and tested as part of other tests, taking care not to jeopardize the prime purpose of the test.

One key goal will be to define methods for the production of the electrodes by extrusion with the clad included in the extrusion process. This goal, if achieved, will contribute to the capability to produce the commercial electrodes with highly automated machinery and at low cost.

A second key goal will be to determine methods for the automated production of the insulator shape, and to eliminate the costly machining of the insulators.

A third goal will be to develop the methods for the production of the box structure. This (Patentable) structure will require extensive development and may not be available in time for inclusion in the Retrofit channel. It is expected that it will be demonstrated in the second Development channel, if not before.

Special cables and connectors are envisaged, to minimize the warm bore space, provide the electrical connection to the power management subsystem, and furnish the required cooling medium.

Particular instrumentation needs will be defined in the course of the overall development program and these will have to be accommodated in the fabrication and assembly development program.

Finally, the capability to rapidly and reliably replace the channel will be a key factor in the development of fabrication concepts, and it will be studied.

1351 ELECTRODES

Objective

To provide the technology for: a) The production of the test pieces to prove the electrode concepts, and b) The Engineering Data Base.

Technical Approach

The starting point for this task will be the copper electrode technology, where the anodes are capped with platinum or stainless steel and the cathodes have inserts of tungsten-copper. Since the generator concept includes conducting sidewall elements that are anodic or cathodic, these will be treated in the same manner. The electrode concept embodied in the advanced generator concept, derived in Task II of the MHD/APT project will be pursued.

Techniques and methods for their production by low cost automated methods will be developed. Both analytical and small scale experimental programs are planned. Electrodes that simulate the extruded product in configuration, but produced by more conventional methods, will be used in development channels.

1352 INSULATION

Objective

a) To explore alternatives to Boron Nitride as the insulation material, and

b) To devise methods for the low cost production of the insulating shapes needed for the MHD channels.

Technical Approach

Efforts to assess alternatives to Boron Nitride have been and are being pursued. These will be extended to include the particular requirements of the advanced generator concept. One approach to the gradual and continuous adjustment in side-wall angle along the length of the channel is to vary the dimensions of the insulators. This will be explored to identify and develop production methods that meet the total insulator requirements.

Alternative Boron Nitride production methods, such as the proprietary TRW plasma deposition process, will be evaluated. Tests of limited sections of developed concepts will be included in other channel tests as required to compliment and prove out the development progress.

1353 BOX STRUCTURE

Objective

To develop and demonstrate the novel channel box concept devised in the advanced generator study (Task II of the MHD/APT project).

Technical Approach

The unified structural approach employed in this channel concept requires the development of new manufacturing approaches which have not been employed to date in MHD channel development.

Small breadboard models will be made to investigate critical areas of the concept. These include fixturing of the elements and insulators, and molding and bonding of the composite structure. Details of the undercarriage springs, wall corner jointure, and leak-proof cooling water connections must be developed and proven in these models. The next step will be the production of full width channel sections and joining samples, to be evaluated. These will be followed by partial channel section production. These will be tested, both out-of and in channel.

The final proof-of-concept will be the production and test, in power train, of the second development channel.

1354 CABLE AND CONNECTORS

Objective

a) To develop and demonstrate the advanced cable and connector concepts, and

b) To provide the input to the Engineering Data Base.

Technical Approach

The cable concept devised in the advanced generator study (Task II of the MHD/APT project) will be the starting point for this task. A canvass of cable producers revealed that no such cable now exists, and a development program is necessary. The required cable characteristics will be refined as the channel development progresses. These will be translated into a development specification. Cable producers will be encouraged to participate in the development of the cables.

Assistance in the production of the resulting cable, to be used in cable qualification tests and in the MHD generator tests planned in the overall program, will be provided. Special quick-disconnect connectors, matched to the above cables will be required and will be developed. Assistance in the production of the resulting connectors, to be procured for used in qualification and testing programs, will be provided.

1355 INSTRUMENTATION

Objective

To develop fabrication and assembly methods that allow for the incorporation of the in-channel instrumentation that will be selected in the course of the development program, including test hardware as well as operational instrumentation.

Technical Approach

The instrumentation requirements, as defined by Generator and Channel designs, and as required to interface with the power train control system, will be translated into guidelines and directions to be realized in the development of fabrication and assembly techniques. As specific instruments are identified, means will be developed so that these can be incorporated into the test section and channel design and construction efforts.

1356 OVERALL ASSEMBLY

Objective

To support Power Train Development in the study and development of rapid channel replacement techniques.

Technical Approach

The key channel features, important to the rapid replacement study, include the flanges and disconnection features at the combustor and diffuser interfaces. These must be accessible and not interfere with the warm bore during insertion or removal.

The support structure for the channel must be developed to allow for thermal expansion of the power train, restraint of vibration, relative growth of the channel and the warm bore, and for ease of actual insertion and removal of the channel from the warm bore.

Both the cable and the cooling water connections will require disconnection for replacement. Techniques that expedite disconnection and reconnection must be considered. While the channel side of the disconnects will be replaced, it is reasonable to expect that the plant side of both will need to be reconnected to new channel connections. Hence, true interchangeability and long term reliability will be required.

WBS 1400-POWER CONDITIONING DEVELOPMENT

The power conditioning system provides the interface equipment to collect the electric output from the hundreds of MHD channel electrode pairs, and condition this DC output into the three phase AC power (at the voltage required) for introduction into the utility grid.

An approach to the system was devised by Westinghouse, and examined in the Task II effort, that performs these functions and offers additional advantages. It has the potential to control either the voltage or the current of each electrode, and has the flexibility to modify these controls in response to the mode in which the MHD generator is being operated or to the local condition of the channel. These advantages are expected to enhance the performance, and especially the lifetime, of the MHD channel. They are also expected to allow significant reductions in the cost of the channel and the superconducting magnet. The portion of the system that is designed to perform both the current collection and the control of the channel power is designated the "power management system" to distinguish it from the more conventional concept of current collection and control.

This task describes the effort required to define and develop the power management system. It also describes the efforts to provide the power conditioning equipment for power train tests envisaged in the program. In general, these tests will use the above described power management system. In one case, the high power/high enthalpy extraction experiment, the power conditioning system will be of the resistive dissipation network type since the tests will be of short duration.

WBS 1400 is structured into five subtasks: 1410 - Technology Development, 1420 - Power Management for 50 MW(t) power train, 1430 - Retrofit Power Management, 1440 - 50 MW(t) dc/ac Converter Design and Supply, and 1450 - Retrofit dc/ac Converter Design and Supply.

1410 TECHNOLOGY DEVELOPMENT

This task will provide the supporting technology development for the power conditioning and will be made up of the following subtasks: 1411 – Channel Interface Characterization, 1412 – High Power Experiment and 1413 – Support for Materials tests.

1411 CHANNEL CHARACTERIZATION

Objective

To experimentally determine the MHD channel conditions, especially large bandwidth, that must be controlled and thus to establish the interface conditions between the channel and the power management system.

Technical Approach

Instrumentation is planned to be supplied by EPRI and installed on the CDIF channel in 1985. Conventional, but solid state, current collection and control test systems, devised by AVCO, also will be installed. The results obtained from this program will be reviewed for any data and information that can contribute to the development of the power management system.

Additional testing will be performed to complete the data base to the degree necessary for the preparation of the specification for the power management system. A test program at another facility will be considered in order to provide a broader spectrum of data conditions.

The test plans for the available test facilities (CDIF, CFFF, and AVCO) will be reviewed to determine which sites can be made available for channel characterization. The data acquisition will be run in conjunction with other test programs, if possible without disruption of their experimental programs, to minimize cost. A determination will be made as to the needed data; to what bandwidth is needed for power management design.

The necessary data acquisition system (DAS) will be specified, procured and installed. The EPRI instrumentation will be reviewed to determine whether it, or a like set, will serve this purpose. Experts will be provided to work with Integration of Testing Facilities and Facility personnel during the installation and testing activities. The data will be reduced and analyzed to provide the basis for the specification and design of power management systems. The data considered will include that taken with the EPRI instrumentation at CDIF.

1412 HIGH POWER EXPERIMENTS

Power management equipment will provide the simulated load for use in the planned short term tests of special MHD generators. Very large power levels will be produced, but the energy produced will be limited due to the short term nature of the tests. Under these conditions, it is not cost effective to interface the facility with the electric utility grid. The energy produced would be of limited value and the transient nature of the test could possibly introduce problems on the grid. Hence, the power will be dissipated in resistive loads.

The purpose of the tests will be to confirm the calculational tools that are planned to be used in the scale-up to, and lifetime impacting performance effects of, the Retrofit and early commercial generators. This means that the specific generator conditions need not conform exactly to those anticipated in the full scale facilities, but they must be well characterized. Hence, the power dissipation system will be designed to remove the power at lowest cost, consistent with adequate measurement of the local performance of the channel.

The equipment will be procured and tested and support will be provided to the installation and test activities. Design requirements will be stablished in cooperation with the other functions involved in the High Power, High Extraction experiment. The system and equipment will be designed. A design review will be conducted to ensure that the purpose of the tests will be fulfilled. The equipment will be produced and factory tested to ensure functional integrity before shipment to the site of the test. Expert support will be provided to Integration of Testing Facilities and the facility organization in the installation, check-out and test activities.

1413 SUPPORT FOR MATERIALS TESTS

This subtask will provide power management support for the channel materials engineering to be performed under WBS 1313. A long duration test of channel electrode materials is planned under WBS 1313 and, as the coordination and test planning for that test proceeds under the cognizance of WBS 1812, the appropriate interfacing of power management equipment with the channel will be defined. This subtask, WBS 1413, will provide the power management hardware design, fab, installation and checkout to support the channel materials text.

1420-50 MW(t) POWER MANAGEMENT DEVELOPMENT

Objective

To design, develop and provide power management systems for the Advance Power Train testing programs at the 50 MW(t) level.

Technical Approach

Power management systems will be designed, developed and provided for the test programs in which channel lifetime, or plasma and current effects on materials, are important objectives.

Several test conditions are anticipated: a) The long duration materials test, b) The 50 MW(t), 500 hour PT duration test, c) The 50 WM(t) test in the super-conducting magnet, and d) The second Development channel. The possibility of designing a single power management set that will serve the needs of tests b), c) and d) will be explored.

Experimental programs will be coordinated with the testing of the MHD generators to provide the required data and information on the power management systems and equipment. The results will be reduced and analyzed and provided to the Engineering Data Base. Subtask elements for WBS1410 are defined below.

1421 DESIGN

The power management system design requirements will be defined. The data and information, obtained in the Channel Characterization task, will be augmented by design and analysis information provided by other tasks in the program so that design requirements will reflect the specific needs of the power train designs and operations plans.

Requirements will be provided for tests needed to develop the power management systems and for equipment to support tests needed for other programs. The possibility of designing a flexible test package that will serve both the needs of power management and some other test (to reduce cost) will be explored.

Prototype power management circuitry, suitable for verification experiments, will be designed. Studies to determine the required number of electrodes (12 to 48) to be controlled will be carried out. These will also consider the desirability of various possible channel connection schemes, such as end-to-end, mid-region, and end regions. Designs will be prepared for the full power management systems for the lifetime related tests.

1422 BUILD AND FACTORY TEST

Prototype equipment will be assembled and factory tested to assure functional integrity. Full scale systems will be assembled and factory tests will be performed.

1423 INSTALLATION

Experts will be provided to assist in the installation of the systems, including the DAS for the verification tests.

1424 SUBSYSTEM TEST

Tests will be performed without other components of the power train to insure that the equipment, as delivered and installed, is functioning in the proper manner.

1425 INTEGRATED TEST

Technical support will be provided for the tests with the generators. This will include both input to the test plans and personnel to be made available at the test site.

For the developmental system, verification tests will be performed. These test will include intentional off-design operating conditions and operation likely to produce the malignant channel behavior that the power management system has been designed to conteract/correct. For the generator lifetime tests, support will be provided (as required) for the proper and efficient performance of the tests.

1430 RETROFIT POWER MANAGEMENT

Objective

To design, develop and provide power management systems for the retrofit power train thus providing the Engineering Data Base for commercial power management systems.

Technical Approach

Power management systems will be designed, developed and provided for the test programs associated with the retrofit power train.

Experimental programs will be coordinated with the testing of the MHD generators to provide the required data and information on the power management systems and equipment. The results will be reduced and analyzed and provided to the Engineering Data Base.

1431 CONCEPTUAL DESIGN

The power management system design requirements will be defined from the specifications prepared in WBS 1123 and the data, obtained in the 50 WM power management task will be augmented by design and analysis information provided by other tasks. The conceptual design of the retrofit power management will be closely coordinated with WBS 1120, 1341, and 1451.

1432 DESIGN

Retrofit power management circuitry, suitable for verification experiments, will be designed. Studies to determine the required number of electrodes to be controlled will be carried out. These will also consider the desirability of various possible channel connection schemes, such as end-to-end, mid-region, and end regions.

1433 BUILD AND FACTORY TEST

Retrofit equipment will be assembled and factory tested to assure functional integrity. Full scale systems will be assembled and factory tests will be performed.

1434 INSTALLATION

Experts will be provided to assist in the installation of the systems, including the DAS for the verification tests.

1435 SUBSYSTEM TEST

Tests will be performed without other components of the retrofit power train to insure that the equipment, as delivered and installed, is functioning in the proper manner.

1436 INTEGRATED TEST

Expert support will be provided for the tests with the generators. This will include both input to the test plans and personnel to be made available at the test site. For the Retrofit tests, support will be provided during the early testing to ensure that the power management equipment is commissioned for long term, unattended operation.

1440 50 MW(t) DC-TO-AC CONVERTER DESIGN AND SUPPLY

Objective

To provide the inverter and utility interface equipment required to interface the power management output power with the electric utility grid, including the power factor correction and power quality functions.

Technical Approach

DC-to-AC converters (inverters) will be designed and provided for the test programs in which extended operation is planned and the electric output can make a significant contribution toward offsetting the cost of the test program. For those tests planned for the CDIF the existing converted will be reviewed to ascertain whether there is a need for modification. These activities will be initiated in conformity with the program schedule as the production of these equipments is not expected to lie on the critical path.

For all tests, coordination will be maintained with other functions to ensure the application of proper design requirements, such as the need for power factor correction within the converter system (as contrasted to the possibly lower cost option of providing the VAR generation by the rotating equipment. The converters will be designed, built, factory tested, installed and tested both as separate subsystems and as integrated parts of the installation.

1441 DESIGN REVIEW

A review of the existing design of dc/ac converter will be held predicated on the equipment presently installed at the CDIF.

1442 DESIGN MODIFICATION

Modifications, if required, will be designed for the existing CDIF inverter.

1443 UTILITY INTERFACE REVIEW

The utility interface, at the CDIF, was considered in the design and application of the existing inverter. These will involve the consideration of the conventional steam generation equipment since their presence offers different challenges and opportunities. Consideration will be given to the possible fault conditions and the protection system for handling these without incurring damage to converter or system equipment.

Interface equipment (such as transformers, reactors, switchgear and capacitors) will be specified.

1444 UTILITY INTERFACE EQUIPMENT

These equipment items will be obtained and arrangements made for delivery direct to the site, except for those that are required for the factory testing of the converters.

1445 BUILD AND FACTORY TEST CONVERTER

The inverters will be modified, if required, at the CDIF site, with components built and tested at Westinghouse.

1446 INSTALLATION

Expert support will be provided, in cooperation with the Integration of Testing Facilities, for the proper installation of the equipment.

1447 SUBSYSTEM TEST

Expert support will be provided, in cooperation with the Integration of Testing Facilities function for the testing of the equipment without other power train components.

1448 INTEGRATED SYSTEM TEST

Expert support will be provided, in cooperation with the Integration of Testing Facilities function, and as required. The activities will be to perform the test program and commission the equipment for long term unattended operation.

1450 RETROFIT DC-TO-AC CONVERTER DESIGN AND SUPPLY

Objective

To provide the inverter and utility interface equipment required to interface the power management output to the retrofit plant with the electric utility grid, including the power factor correction and power quality functions.

Technical Approach

DC-to-AC converters (inverters) will be designed and provided for the retrofit program.

For expected tests, coordination will be maintained with other functions to ensure the application of proper design requirements, such as the need for power factor correction within the converter system (as contrasted to the possibly lower cost option of providing the VAR generation by the rotating equipment).

The converters will be designed, built, factory tested, installed and tested both as separate subsystems and as integrated parts of the installation.

1451 CONCEPTUAL DESIGN

This converter conceptual design will be prepared in close coordination with WBS 1120, and 1431.

1452 DESIGN

DC/AC converters will be designed for the Retrofit facility in accordance with the conceptual design established under WBS 1451.

1453 UTILITY INTERFACE DEFINITION

The utility interface will be defined for the Retrofit facility and will involve the consideration of the conventional steam generation equipment since their presence offers different challenges and opportunities. Consideration will be given to the possible fault conditions and the protection system for handling these without incurring damage to converter or system equipment. Interface equipment (such as transformers, reactors, switchgear and capacitors) will be specified.

1454 UTILITY INTERFACE EQUIPMENT

These pieces of equipment will be obtained and arrangements made for delivery direct to the Retrofit construction site, except for those that are required for the factory testing of the converters.

1455 BUILD AND FACTORY TEST CONVERTER

The inverters for the Retrofit facility will be built and factory tested to ensure functional integrity before shipping to the site.

1456 INSTALLATION

Expert support will be provided, in cooperation with the Integration of Testing Facilities, for the proper installation of the equipment.

1457 SUBSYSTEM TEST

Expert support will be provided, in cooperation with the Integration of Testing Facilities function, for the testing of the equipment without other power train components.

1458 INTEGRATED TEST

Expert support will be provided, in cooperation with the Integration of Testing Facilities function, and as required. The activities will be to perform the test program and commission the equipment for long term, unattended, operation.

WBS 1500 COMBUSTOR DEVELOPMENT

The critical performance requirements of slagging MHD combustors are:

- Generation of a high plasma electrical conductivity through efficient combustion and low heat losses,
- Maintaining a high overall system efficiency through the minimization of pressure drops and,
- Controlling slag deposition and flow to achieve high slag rejection rates.

Engineering issues related to combustor development are:

- Design and construction to utilize high pressure - high temperature boiler feed water for shell cooling,
- Design of a continuous slag removal system and,
- Electrical isolation of the combustor system at the high voltages generated by the power channel.

Design and fabrication of a coal fired slagging combustor for an MHD/Steam Power Plant requires a development program, which should be cost effective and involves only acceptable or minimum risks. It is obvious that the existing hardware and the facilities should be utilized fully with minimum modifications. Information obtained from these tests would provide the data base for the design of larger combustors.

The MHD coal combustor development activities leading to acceptable risk hardware for integration in the 500 MW(t) commercial level plant needs testing at nominal levels of 20 MW, 50 MW, and 250 MW. Additional intermediate power level sizes are deleted from this development program because of the relatively large expense for the limited scaling data obtained. Scale sizes where significant power could be generated and the cost of the consumables could be offset by the sale of electricity is desirable. WBS 1500 has been structured into four major tasks which are presented below with further subtasks as appropriate.

1510 20 MW(t) DEVELOPMENT COMBUSTOR

Objective

- To design and fabricate a continuous operating slag removal and electrical isolation systems for the 20 MW(t) combustor,
- To evaluate combustor performance, slag removal and electrical isolation as part of an integrated power train (AVCO) and,
- To operate the combustor integrated with downstream components to characterize the gas carried over (CFFF).

Technical Approach

A continuous slag removal system with provision for electrical isolation will be designed and fabricated. An external voltage will be applied to simulate MHD operation, and different isolation techniques (dispersers) will be investigated to arrive at the appropriate system. The combustor will be tested with an integrated MHD channel at AVCO for an accumulated time of at least 100 hours. This system will consist of the same type hardware used in the original CFC/channel testing in 1982, with the addition of the continuous slag removal system.

The combustor will then be tested integrated with the downstream heat recovery system at CFFF. This testing will simulate full scale equipment regarding the parameters of slag carry over, seed entrainment in the slag, NO_X reduction, SO_X removal, convective tube deposition/corrosion and exhaust particulates and provide environmental data for future MHD plants.

1511 DESIGN AND FABRICATION

This task includes the fabrication of a (or two) 20 MW(t) combustor(s) based on the earlier design, and the design and fabrication of a continuous slag removal, electrical isolation system, and different dispersers to break the slag water mixture to droplets.

1512 COMPONENT TESTING

The combustor will undergo preliminary check-out as to its construction and general performance. The testing of the slag removal system will be done independently and will be focussed on:

1) Continuous slag removal operation,
2) Selection of the suitable disperser and,
3) Electrical isolation with full applied voltage.

1513 INTEGRATED POWER TRAIN TESTING

After coordination meetings with AVCO, the combustor will be shipped for power train integration tests at the AVCO facility. The electrical performance of the channel, and hence the combustor performance, the continuous slag removal system operation, and the effectiveness of the electrical isolation system will be studied.

1514 MATERIALS TESTING WITH DOWNSTREAM COMPONENTS

After coordination meetings with CFFF personnel, the combustor will be shipped to CFFF from AVCO. If another combustor system is fabricated for this purpose, this testing can be done simultaneously with AVCO testing and the combustor will be shipped to CFFF from TRW after preliminary check-out testing. The combustor will be tested as part of the CFFF flow train and studies of NO_X and SO_X control; seed entrainment in the slag; erosion, corrosion and deposition and; exhaust gas particulate characterization will be made to further verify the continuous slag removal system.

1515 DATA REDUCTION AND ANALYSIS

The data obtained from the two test series will be analyzed to determine the combustor performance and the combustor engineering (computer) model will be verified.

1520 50 MW(t) DEVELOPMENT COMBUSTOR

Objective

The main objectives of this task are:

- To verify the tubular-membrane wall design concept utilizing high pressure – high temperature boiler feed water for cooling,
- To select the proper design approach for second stage section under magnetic field and,
- To evaluate performance and to verify the computer model predictions.

Technical Approach

A spool section of tubular-membrane wall design, a second stage with appropriate design for the section under the magnetic field and an electrically isolated continuous slag removal system will be integrated with the slagging combustor first stage at CDIF. Power train testing will be performed to evaluate performance of combustor and slag removal system and flow diagnostics.

1521 DESIGN AND FABRICATION

The following components will be designed and fabricated under this subtask.

- A tubular-membrane spool section of the same diameter as the first stage to be tested at CDIF. This will be fabricated of the same material that will be used in the prototype and retrofit combustor and will utilize high pressure – high temperature water for shell cooling.
- A continuous slag removal – electrical isolation system based on test information obtained at the 20 MW(t) level and,
- A second stage, with a replaceable section under the area of magnetic interaction.

1522 CHECKOUT TESTING

The components fabricated under WBS 1521 will undergo checkout testing at TRW before shipping to CDIF.

1523 INTEGRATED TESTING

After coordination meetings between TRW and CDIF personnel, these components will be assembled with the combustor system for integrated power train testing. The combustor performance as evidenced by the electrical performance of the channel, slag rejection and off design operation of the combustor will be studied. Further diagnostic measurements such as gas and slag species and pressure, temperature and velocity profiles and fluctuations of the plasma at combustor exit, high frequency oscillations etc. will be made. Any special instrumentation required for safe combustor operation will be identified and limited information on component integrity will be collected. Various coals and seed materials and seed injection techniques and their impact on combustor performance and seed entrainment in slag will be investigated.

1524 DATA REDUCTION AND ANALYSIS

The experimental data obtained will be evaluated for combustor design and off design operation. The combustor/channel interface data will be prepared. The combustor model predictions will be compared and the scaling verified. Data base will be prepared for the design of the 50 MW(t) prototype combustor.

1530 50 MT(t) PROTOTYPE COMBUSTOR

<u>Objective</u>

To design and fabricate a 50 MW(t) prototype coal combustor and to perform endurance testing in the integrated power train including operation with a super conducting magnet. This will give the data base for the design and fabrication of the retrofit combustor.

Technical Approach

The continuous operating prototype combustor will be designed based on commercial practice satisfying the safety, life and operational and technical requirements. This combustor will consist of the coal feed hopper system, preheater, first stage, second stage and slag rejection system (with redundancy). It will undergo development testing at standard and off nominal operating conditions and for continuous operation.

The combustor system will be tested for over 500 hours and the integrity of the fabrication technique, the erosion effects due to current in the fringe field areas and the long term operation of the slag removal system will be thoroughly investigated.

1531 DESIGN AND FABRICATION

This sub task involves the design and fabrication of the continuous coal-feed system, coal-fired preheater, integrated first stage of tubular-membrane wall, second stage of tubular-membrane construction, continuous slag removal system.

1532 COMPONENT TESTING

The combustor will undergo preliminary testing at design and off-design conditions by the manufacturing contractor, after which the entire combustor system will be shipped to the endurance testing facility.

1533 ENDURANCE TESTING

After coordination meetings between the combustor manufacturer and integrator, the combustor system will be integrated with the MHD power train for endurance testing. Along with the lifetime study of the first and second stages and slag removal system, performance characteristics under low preheat operation, with different coal types and grind, and with different seed materials will be studied.

1534 TESTS WITH SUPER CONDUCTING MAGNET

The combustor will be relocated so that it can be tested with the super conducting magnet in a power train that also uses the first development channel. The overall objective of this task is to demonstrate a 50 MW(t) prototype of the type of equipment to be used later at the 250 MW(t) retrofit plant. The test program to be conducted with the power train will consist of the applicable engineering development including at least 100 hours operating time. Successful completion of this task will allow the fabrication of the 250 MW(t) equipment to begin. The effect of the increased fringe field on second stage section will be studied.

1535 DATA REDUCTION AND ANALYSIS

The performance analysis and analysis of erosion due to magnetic fringe field (currents) and the effect of combustion gas on erosion, corrosion and deposition characteristics will enable preparation of a data base to begin the design of the 250 MW(t) retrofit-combustor.

1540 250 MW(t) COMBUSTOR

Objective

To design and fabricate a 250 MW(t) retrofit combustor that could be operated in an MHD retrofit power plant facility in regular power generation mode. The data generated during this phase of the development program will provide the engineering data base to commercialize the MHD combustor technology.

Technical Approach

This power level is large enough to obtain specific details and to generate a thorough data base to manufacture commercial production MHD combustors. The 1:5 scale up from the 50 MW(t) combustor will verify scaling laws used and aid in refining the computer model. Integrated testing will provide information on performance and response of the combustor to load variations typical of a power plant.

The specific details and parametric variations of this testing will depend partly upon the site and facility where this unit is integrated.

1541 COMMERCIAL DESIGN

The conceptual design of the retrofit combustor will be prepared in concert with WBS 1120 and 1341.

1542 DESIGN AND FABRICATION

The following components will be designed and fabricated (based on information obtained from the testing of the 50 MW(t) prototype combustor system) coal-feed system, coal-fired preheater, first stage, second stages, slag removal system, electrical isolation, and support structure.

1543 INSTRUMENTATION

The instrumentation required for the safe operation of the combustor, any diagnostic instrumentation to verify performance on line, and the plant instrumentation typical to the combustor will be identified and installed.

1544 FACILITY MODIFICATIONS

The manufacturing contractor's test facility will be modified to allow preliminary testing of the retrofit MW(t) combustor system. This will involve modification of the coal feed system, oxygen/air feed system, cooling water system and support structure.

1545 COMPONENT TESTING

The combustor system will be tested at design and off-design conditions to evaluate performance on a stand-alone basis. Some limited endurance information can also be obtained.

1546 INTEGRATED POWER GENERATION TESTING

The retrofit MW(t) combustor system will be shipped to the test facility for operation in the power generation mode. Extensive testing on actual power generation mode will be made to study electrical isolation, slag rejection, low preheat operation, seed injection, influence of coal types, etc.

1547 DATA REDUCTION AND ANALYSIS

Detailed data analysis to study performance, scaling verification, identification of any problem arising in commercial operation mode, limited line time verification, and preparing the Engineering Data Base for the 500 MT(t) commercial power plant combustor design and fabrication will be performed under this sub task.

WBS 1600-DIFFUSER DEVELOPMENT

The MHD diffuser has to operate not only under unfavorable fluid mechanical conditions, but also under magnetic field and at elevated temperatures. The main fluid mechanics issues connected with MHD diffusers are inlet Mach numbers very close to transonic, very high inlet boundary layer blockages possibility of separated boundary layers at the electrode walls and velocity overshoots at the side walls.

These characteristics make the design of MHD diffusers more complicated than conventional diffusers. As a component of a power plant, the MHD diffuser should be able to operate at off design conditions without appreciable performance penalty. Further issues related to the diffuser design are:

- Use of high pressure, high temperature boiler feed water as the coolant.
- Operate under the fringe magnetic fields of the super conducting magnets, which are high enough to produce currents of sufficient magnitude to cause erosion of wall becoming a major concern.
- The diffuser should allow for the thermal expansion of the components downstream of the combustor, whereas interfacing with the radiant boiler which is also fixed. The diffuser should also allow for the removal of the MHD channel for replacement or refurbishment.

Thus, it is clear that the development of the diffuser has to proceed in two directions viz, fluid mechanical characterization and design development. The former involves not only component integrated testing, but also cold flow modeling to verify the fluid mechanical behavior of the diffuser under simulated MHD conditions. The diffuser cannot be tested as an independent component as it cannot operate as a stand alone unit. Whenever the MHD channel is tested, it is recommended that the diffuser is also tested in the power train. By instrumenting the diffuser for wall pressure measurements and pilot pressure pressure measurements in the core flow (preferably a pressure traverse), performance information can be obtained without requiring special testing. Total heat rejection to the diffuser wall can be obtained by calorimetry (cooling water flow rate and temperature rise) without interference to power train testing.

1610 TECHNOLOGY DEVELOPMENT

Objective

The main objectives of this task are to study the effects of thick and separated boundary layers and velocity overshoots on diffuser pressure recovery, to study the effects of high inlet Mach numbers on diffuser performance, and to provide a suitable diffuser to be used with the high power experiment.

Approach

Testing is to be conducted with a one-half scale model of the 20 MW(t) diffuser using water and hot air. The velocity overshoots can be simulated using shaped pressure drop plates having holes and/or cut-outs arranged to produce the desired profile. By matching the full scale, initial boundary layer blockage and overshoots, the effects of these on power train diffuser performance can be explored in cold-flow testing.

The effect of Mach number on diffuser performance can also be investigated (which would require a much higher pressure ratio facility than is needed for velocity profile studies alone). At higher entrance Mach numbers ($M > 1$), the shock recovery characteristics, can be studied. It is also possible by coldflow modelling to study the mixing of the thick boundary layer and velocity overshoot profiles and the resulting changes in profile with length. The computer model developed can be verified with the experimental results under these various conditions. Any modifications needed can be made and the computer model can be applied to design large size MHD diffusers, which would be tested during the development program.

1611 COLD FLOW TESTS

This subtask involves: 1) design, fabrication and assembly of a one-half scale model of the 20 MW(t) diffuser using plexiglass or similar transparent material with flexibility for changing length and wall angles; 2) design and fabrication of suitable pressure drop plates to simulate the required flow velocity profiles; 3) design and fabrication of necessary instrumentation, installation and checkout.

This subtask involves extensive testing by varying the boundary layer thickness and inlet velocity profiles, Mach number and the diffuser geometry (length and divergence). Both supersonic and subsonic inlet Mach number effect will be investigated.

The data obtained from cold flow tests will be analyzed in detail to study the velocity profile mixing behavior, reattachment lengths and the influence of the various operating parameters on diffuser performance. Further, the computer model predictions will be verified and any necessary changes and/or modifications in the code can be effected.

1612 HIGH POWER EXPERIMENT

Under this subtask an experimental diffuser will be designed, built and provided for integrated testing with the high power experiment under WBS 1312.

1620 50 MW(t) DEVELOPMENT DIFFUSER

<u>Objective</u>

The main objectives of these tasks are 1) to verify the performance and computer model predictions at the 50 MW(t) level, 2) to verify the tubular-membrane wall design concept using high pressure, high temperature boiler feed water for wall cooling, and 3) to select under the fringe magnetic field.

Technical Approach

Integrated testing at CDIF would offer verification of performance of the diffuser with its design and computer modelling. For commercial size MHD diffusers, boiler feed water (at approximately 185 atm pressure and 650°F) will be used as the coolant. Tubular-membrane wall has been recommended for fabricating the diffuser. A short section designed accordingly will be used so as to collect data and testing of this fabrication concept. Also the replaceable section under the magnetic field should be tested thoroughly for current flows, erosion (limited) rates, etc. Different design approaches for this section have been identified earlier. The best approach can be selected based on testing under this task. Preliminary feasibility studies of channel removal, provision of thermal expansion, etc., can also be studied at this power level. Any modifications needed in the fabrication technique can be determined and tried at this smaller power level.

1621 DESIGN AND FABRICATION

Three distinct sections will be designed and fabricated 1) the main section of the diffuser with jacketed wall design using low pressure, low temperature cooling water, 2) a short section with tubular-membrane wall design using high pressure, high temperature boiler feed water for cooling, and 3) a section designed to operate under the fringe magnetic field (different design approaches are being considered.

1622 INTEGRATED POWER TRAIN TESTING

After coordination meetings, the diffuser consisting of the above mentioned three different sections will be shipped to CDIF and installed in the power train. The testing will be conducted at design, and off design operating conditions. Preliminary reliability of the design concepts, the thermal growth and the channel removal effort etc. will be studied during this testing.

1623 DATA REDUCTION AND ANALYSIS

Pressure recovery, heat transfer and the exit velocity distributions will be analyzed from the data obtained. The computer model will be verified for performance predictions and any required changes and/or modifications made. Within the limited length of testing under this task, the integrity of the section under the magnetic field (based on erosion, current measurements etc.) will be investigated and the proper design approach selected.

1630 50 MW(t) PROTOTYPE DIFFUSER

Objective

The primary objective of this task is to perform life time testing in an integrated power train (at CDIF). The erosion and corrosion due to the magnetic field (current), and the integrity of fabrication will be investigated. Further, preliminary studies on quick disconnect to remove channel can be made.

Technical Approach

This diffuser will have all tubular-membrane wall construction and the selected design will be used for the replaceable section under the magnetic field. This represents a small scale version of the diffuser that will go in the retrofit plant. The emphasis on this task is long term endurance characteristics.

1631 DESIGN AND FABRICATION

This task constitutes the design and fabrication of the main body of the diffuser having all tubular-membrane wall design, and the section under the magnetic field using the selected approach.

1632 CHECKOUT TESTING

The diffuser section will flow be checked and the cooling water flow rates, pressure drops, heat transfer etc. will be verified at the facility of the contractor responsible for this prototype diffuser.

1633 INTEGRATED ENDURANCE TESTING

After coordination meetings between the manufacturing contractor and the Integrated Endurance testing facility, the diffuser will be shipped and integrated with the power train. Along with the endurance characteristics of the main sections and the section under the magnetic field, further quick disconnect of the diffuser and hoses, thermal growth and channel removal will be studied.

1634 DATA ANALYSIS

Further performance analysis will be made from the data obtained. Erosion and corrosion, and failure mechanisms (if any observed) will be carefully analyzed to predict the lifetime of the diffuser components.

1640 RETROFIT DIFFUSER

Objective

The main objective of this task is to design and fabricate a retrofit diffuser and test it in a retrofit plant generating electric power and feeding to the grid and to generate the Engineering Data Base required for the design of commercial MHD diffusers.

Technical Approach

This power level (250 MW(t) is large enough to obtain specific details to commercialize the MHD diffuser technology. Further the 1:5 scale up from the 50 MW(t) diffuser will be a good test for scaling verification and refining of computer predictions. The design of this diffuser will be based on the previous experience with the 50 MW(t) prototype diffuser. Integrated testing will provide information on performance and response to load variations typical of power plant operation.

The tubular-membrane wall diffuser will employ boiler feed water for cooling. The specific details of this testing will depend upon the site and facility location of this unit. A complete data matrix and design information can be prepared to design the 500 MW(t) and larger commercial diffusers.

1641 CONCEPTUAL DESIGN

The conceptual design of the retrofit diffuser will be prepared as part of the conceptual design guided by WBS 1120.

1642 DESIGN AND FABRICATION

This task involves the design and fabrication of the 250 MW(t) unit based on information obtained from the design, fabrication and operation of the 50 MW(t) unit.

1643 CHECK-OUT TESTING

The unit will be thoroughly checked for pressure, cooling water flow rates and pressure drops, at the manufacturer's facility and will be shipped to the retrofit facility after coordination meetings.

1644 INSTALLATION AND INTEGRATED TESTING

The diffuser will be integrated with the retrofit plant and operated on design load and part load conditions. The specific operational parameter variations depend on the retrofit site and facility demands.

1645 DATA REDUCTION AND ANALYSIS

Design and off design performance characteristics will be studied and the scaling verified. A complete data matrix using all the information obtained from this testing will be prepared for the design of future commercial MHD diffusers.

WBS 1700 INSTRUMENTATION AND CONTROL DEVELOPMENT

Each power train will require instrumentation to monitor performance and controls to be applied both internally and at the interfaces with the balance of the plant to assure proper operation. Data processing and the generation of control signals will take place in a number of microprocessors distributed through the plant. The microprocessors will be interconnected so that they can exchange information with each other and with the power plant's central control room and data logging facilities. Hardware that can perform these functions will be identified. Analytical studies will be performed to develop control strategies which will then be demonstrated during integrated power train tests to confirm the analytical work. Non-operational test instrumentation also will be required during both component and power train testing. The data base which will result will identify and characterize equipment and systems in sufficient detail to proceed with confidence with the design of the instrumentation and controls for a commercial MHD power train.

Test and operational instrumentation will be provided as necessary to demonstrate its operation at development facilities and a complete set of instrumentation and control equipment will be provided for the power train in a retrofit plant.

WBS 1700 has been structured into three major tasks described below with more detailed subtasks as appropriate.

1710 TEST INSTRUMENTATION DEVELOPMENT

Objective

The objective of this task is to assure that appropriate instrumentation is identified or developed for use during APT development testing. This instru- mentation will permit the performance of power train equipment and systems to be characterized so that an adequate engineering data base can be obtained for the design of commercial MHD power trains.

Technical Approach

A body of experience in making the anticipated kinds of measurements is available from work done by experimenters in MHD and related fields in the past. This experience will be utilized to the maximum extent possible, but much of the future experimental work will be at higher power levels and will involve the use of a superconducting magnet. This will aggravate the space, magnetic field, voltage and current problems previously encountered, particularly in the combustor and channel design areas.

Sensing and signal transmission techniques which have been used previously will be evaluated for use under the more severe conditions. Alternative methods of sensing parameters of interest and of transmitting and processing this information will be investigated. New hardware to meet program needs will be developed where neither industrial nor laboratory equipment to do so can be identified.

Integrated power train testing will involve the collection of data of interest to more than one group of designers, particularly where the data are being taken to define interfaces and interactions between major components or systems. Meeting this need could involve special measurements that may not be required for a power train in a commercial plant. To assure that such testing is accomplished in an expeditious and efficient manner, a test integration function will be included. Similarly, instrumentation hardware performance will be evaluated following each test and the results will be made available to all program participants for their guidance. In this manner, a data base of information relating to experimental instrument technology as applied to MHD will be built up.

This task will permit information relating to experimental instrument technology needs, capabilities and experience to be readily available. This task also will include data acquisition requirement reviews and new instrument technology development. All APT program participants will be involved in the task to some degree, and the task will be a valuable common resource.

1711 TEST INSTRUMENT DATA BASE

This task will consist of compiling and organizing available papers, reports, vendor literature and other pertinent information concerning instrumentation previously used in the acquisition of data during tests of components or systems relating to MHD power trains. Information will be sought from other scientific fields with similar instrumentation and data collection problems where their solutions might be applicable. Discussions will be held with designers and experimenters working in the areas where problems are anticipated in order to identify expected limits to available technology and to learn of new development work that is underway. Reports will be prepared to document such discussions and to make the information obtained in this way more widely available.

1712 TEST PLAN INSTRUMENT REVIEWS

As planning for component and power train testing gets underway, meetings will be held to review the data to be taken to assure that the data requirements of all program participants are considered and met. Potential measurement problems will be assessed, and potential measurement hardware and methods will be evaluated. Alternative methods will be specified, where appropriate, based on information available in the Test Instrument Data Base.

1713 INSTRUMENT DEVELOPMENT

Coal Processing Instrument Development

Experience to date indicates that improvements will be required in instrumentation to measure flow in pneumatically transported coal streams and to measure the moisture content of the coal in such streams continuously so that the drying process can be monitored and controlled. These instruments will be located in the plant coal preparation and delivery systems, but their importance in assuring that the combustor coal feed interface can be adequately monitored and controlled appears to justify their inclusion in the power train development program.

Plasma Stream Instrument Development

A layer of slag will be present inside the combustor, nozzle, channel and diffuser during integrated power train testing, and this slag layer will complicate any attempts to make measurements of the plasma directly. Plasma parameters which will be of interest include temperature, pressure, conductivity, velocity and possibly composition. All of these will require penetration of the slag layer which, in the past, has been accomplished by gas purges or mechanical penetration by probes. Development work will be required to extend these capabilities for use in the much higher electrical and magnetic fields of the new integrated power trains or to develop completely new techniques.

Fiberoptic Instrument Development

The extreme magnetic and electrical conditions combined with the space limitations in the area between the channel structure and the superconducting magnet bore liner are expected to make the use of existing instrument sensors and signal transmission techniques impractical for measuring channel performance parameters. Shielding of any appreciable number of individual conductors does not appear to be practical, so any wires exiting the magnet bore will have large noise components, and signals transmitted over such wires will probably be distorted. The use of fiberoptic cables and sensors which use light waves rather than electricity to sense and transmit information appear to be an ideal solution to this problem. Some work is already being done in this field, and the utility of such devices for channel instrumentation appears to justify their further development. A development program to develop practical temperature, pressure, strain and possibly voltage or current sensors in very small sizes using fiberoptic techniques will be initiated.

1714 TEST EXPERIENCE DOCUMENTATION

Throughout the course of the APT program, experience with various measuring techniques will be obtained. This experience will be documented and will be added to the instrument technology data base for use by other experimenters and, eventually, by the designers of the demonstration and commercial power plants. As tests are completed and the resulting data are evaluated, the success of the instrument systems in providing the data and their degree of precision and reliability will be evaluated and reported. This step is often neglected by experimenters, and it is believed that making this evaluation and documentation a specific program requirement will lead to better understanding and utilization of test instrument capabilities.

1720 OPERATIONAL INSTRUMENTATION DEVELOPMENT

Objective

The objectives of this task are to assure that (1) appropriate instrumentation is identified or developed to provide the sensory inputs to the operational control, protection and monitoring systems, (2) functional data displays are available for the integrated power trains, (3) to aid in obtaining an adequate engineering data base for the design of operational instrumentation systems for commercial MHD power trains, and (4) to provide operational instrument system equipment for a power train in a retrofit plant.

Technical Approach

Many measuring instruments available as standard catalog items are in use in industry and utility power plants today. Such proven devices will be applied in the operational instrument systems serving integrated power trains in the APT development program. These state of the art instruments will meet many conventional measurement needs and will require no further development other than the normal evolutionary improvements that occur in the competitive market place. Due to the strong magnetic field, high DC voltages and magnet bore space limitations associated with MHD power trains, some new operational instruments will have to be developed. The performance of these new instruments will be demonstrated to provide a sound technical basis for their application in commercial MHD power plants.

The first step in initiating the development of a new operational instrument will be to establish that there is a need which can not be met using standard industrial hardware. Requirements for measurements to be made will be developed as part of the control systems development work for each power train as described in WBS 1730 for control, protection or monitoring purposes.

It is not anticipated that any operational instrument measurements will be required that are not also required to provide test data, so the Test Instrument Data Base and development programs described in WBS 1710 will be used as a starting point in developing operational instruments. Test instruments will be used as operational instruments if there are doubts concerning the need for such measurements on commercial MHD power trains or until experience with the performance of a test instrument has been obtained in an integrated power train setting.

When the need has been established and the performance of an equivalent test instrument has been demonstrated, design work will be initiated to upgrade the instrument design to commercial standards. This work will include items such as extending and/or standardizing ranges, repackaging to meet manufacturing standards, converting hard wiring to printed circuits, adding calibration and self-checking features and increasing design margins. Prototypes will be constructed and qualification programs will be performed in order to demonstrate that the final design meets industrial standards such as shock and vibration, electromagnetic interference and ambient operating conditions and to develop detailed operating curves and application data. The end products will be operational instrument designs backed up by sufficient data so that the designs can be applied with confidence.

In addition to providing information for use in power train control and protection systems, measurements made by the operational instrumentation system will be used to generate displays for the use of operators in controlling and monitoring the performance of the power trains. Conventional practice would develop such displays using digital and analog meters, graphic panels, indicating lights and annunciator units. More advanced installations would use cathode ray tube screens on which tabulations of instrument readouts or schematic representations of plant systems (with system status and conditions indicated) could be made to appear. It is anticipated that even these advanced information display techniques will prove to be inadequate for a power train operator to monitor and make use of all of the information that will be available, particularly on the earlier power trains. To alleviate this potential problem, human engineering principles and computer color graphic capabilities will be applied together to simplify the power train operator's job by developing more meaningful simplified displays.

Finally, specifications will be prepared, vendors will be selected, and instrumentation equipment will be procured for installation and use in the operation of the power train to be retrofited into an existing power plant.

1721 MEASUREMENT REQUIREMENTS LISTS

This task will (1) review, evaluate and coordinate the requirements for measurements specified by control system designers, and (2) identify available commercial hardware that will satisfy the specified requirements. The result of these efforts will be a Measurement Requirements List for each power train design that identifies all needed instruments, specifies their performance characteristics (range, response times, output signal type, special application limitations, etc.) and identifies at least one supplier. Where suppliers can not be identified, the need to upgrade test instruments to commercial standards will be identified automatically.

1722 TEST INSTRUMENT DESIGN UPGRADING

Measurements derived from test instruments may be used as inputs to power train control systems during control system studies and demonstrations. When decisions are made to retain such inputs as permanent features of later power train control systems, the instrument designs will be upgraded to appropriate operational instrument standards. Test instrument designs will be considered prototypes, and this task will provide the required redesign support. The designs will be modified to meet any anticipated increases in range, magnet field strength or channel Hall voltage. Value engineering and failure analysis studies will be performed to evaluate changes which might simplify circuitry, reduce manufacturing costs or improve reliability. Maintenance features will be considered. Packaging and mechanical aspects of the design and thermal margins and limits also will be studied.

1723 NEW INSTRUMENT QUALIFICATION

Qualification tests will be conducted to demonstrate that samples of the upgraded instruments do, in fact, comply with applicable industrial standards for enclosures, shock and vibration, supply voltage and frequency variations, extremes of ambient temperature, pressure and humidity, electromagnetic interference etc. The tests performed and procedures used for the qualification testing will be taken from documents issued by standards issuing organizations such as IEEE, ISA, NEMA and ANSI whenever possible. The tests specified will depend on the particular device and intended service conditions.

1724 NEW INSTRUMENT APPLICATION DATA

Samples of redesigned instruments will be subjected to performance tests under controlled conditions. Data from such tests will be used to compile information on ranges, accuracy, response times and limitations which will characterize the performance of the instruments and assist in their future application. Installation and calibration information and procedures also will be developed.

1725 IMPROVED DATA DISPLAY DEVELOPMENT

Specialists in the human engineering and computer color graphics programming fields will meet with instrumentation and control system designers and MHD test facility operators to define the display requirements. This will include consideration of information that should be available to power train operators, operators' reactions to various changes in displayed information, related information to be displayed at the same time, potential diversions to operators' attention and how much time the operator will have to correct the abnormalities. With the issues thus defined, the human engineering specialists will develop more meaningful displays, and software to implement such displays will be developed by the computer programmers. The new display techniques will be verified on a computer simulation of an operating power train and evaluated by utility power plant operators.

1726 RETROFIT PLANT INSTRUMENTATION

Specification will be prepared for the instrumentation that will be required to monitor the performance of power train components and systems to be installed as a retrofit to an existing power plant. Vendors for the equipment will be selected, and the equipment will be procured and delivered for installation and use at the facility.

1730 RETROFIT CONTROL SYSTEM

Objective

The objectives of this task are (1) to develop control strategies and logic and to provide the required supporting analytical studies for the retrofit power trains, (2) to provide control system equipment for a power train in a retrofit plant, and (3) to demonstrate that a sound engineering basis exists for the integration of power train control systems into commercial MHD power plants.

Technical Approach

The preliminary design phase of the control system design task for each power train assembled as part of the APT Development Program will identify the controls required to operate the power train components and supporting systems. Operating scenarios or descriptions will be prepared outlining the functions and anticipated performance of major components and systems during manual and automatic control regimes. Mandatory equipment protection functions will be identified. Tabulations of status, warning and alarm signals, and data that will be monitored by power train operators will be prepared.

During the detailed design phase which follows, numerical values will be developed to define the design requirements identified during the preliminary design. Information will be obtained from other designers, and an interface control program will be initiated. Arrangements will be made for any special tests required to obtain missing design information.

A power train simulation and analysis task will be included in the design program. A mathematical model of the power train and control system will be developed and modeled on a computer. The model will be exercised to show how the power train and control system will respond under a full range of steady state, transient, and fault conditions. Different control system configurations and adjustments will be used until acceptable operation is achieved.

When the simulation work indicates that a satisfactory control system design has been achieved a final design description, drawings, and specifications will be prepared describing the design and detailing the requirements for the hardware with which it will be implemented.

Input will be provided relating to the control systems during the preparation of power train operating procedures, failure analyses, safety reports, test specifications and procedures, and equipment installation packages.

1731 CONCEPTUAL DESIGN

This task will develop a conceptual control system design for the retrofit power train. The conceptual design will identify power train components and supporting systems, open and closed loop control functions, automatic control and protection features and operational instrument measurement points. Operational monitoring provisions such as status indications, warning and alarm signals and data displays will also be specified. The design will be documented in a preliminary design report which will identify all required functions by means of diagrams, tabulations and descriptions of the control strategy and how it is intended that it be implemented during anticipated operating conditions.

1732 DESIGN

This task will develop specific numerical values to define requirements identified during the conceptual design work. Measurement requirements such as ranges, response times, and unusual operating conditions will be established by working with other system and component designers. An interface control plan will be implemented to coordinate any power train design changes that could impact the control system design details. Test plans will be developed or supplemented as necessary to obtain any missing information needed to completely define control system design and interface requirements.

Finally, specifications will be prepared, vendors will be selected, and control equipment will be procured for installation and use in the operation of a power train to be retrofitted into an existing power plant. Preliminary control system logic descriptions will be expanded and updated to assure that the control system description is complete.

Standard industrial control components suitable for use in a utility power plant environment will be specified to implement control system designs. This task will involve the preparation of system configuration diagrams and other descriptive material to identify each item of control hardware. Functional specifications will be prepared for each item to identify its required performance characteristics and capabilities and any mechanical and operating environment limitations and interface requirements that must be met.

1733 CONTROL SYSTEM PERFORMANCE STUDIES

Studies using computer modeling and simulation techniques will be conducted under this task to demonstrate system responses, stability, and interactions during steady state, transient, and fault conditions. Different control system configurations will be evaluated to identify the one with the most desirable characteristics. Acceptable ranges of controller adjustments will be developed. Particular attention will be paid to protection circuit responses to assure that protection requirements are met and to determine how much margin is available in the design. Special studies will be made which focus on the interaction of the power train with the utility transmission grid, steam turbine generator, and heat recovery systems.

1734 RETROFIT PLANT CONTROL EQUIPMENT PROCUREMENT

Specifications will be prepared for the control equipment that will be required for the power train to be installed as a retrofit to an existing power plant. Vendors for the equipment will be selected and the equipment will be procured and delivered for installation and use at the facility.

1735 INSTALLATION, OPERATION, AND TEST SUPPORT

Support will be provided under this task to prepare installation and/or facility modification packages, system checkout procedures, operating procedures and power train test plans. Detailed arrangement, installation and connection drawings and instructions will be prepared for use in installing new equipment or in the modification of old equipment at existing installations. Procedures will be prepared for the initial checkout and adjustment of components and systems and for subsequent power train operation. All test plans involving power train operation will be reviewed to assure that control requirements are compatible with control system capabilities.

WBS 1800 COORDINATION OF TESTING FACILITIES (GFE & OTHER)

Objective

The objective of this task is to coordinate the APT work with pertinent testing and other activities at component developers, national laboratories, and government owned MHD facilities. A good understanding of the results of the tests is essential to the performance of the Advanced Power Train Development and to the completion of the power train portion of the engineering data base for MHD/steam plants.

Technical Approach

The various tests and other activities, requiring programs in GFE and other facilities, will be identified by the cognizant engineers for all of the WBS elements. Test description packages, including justifications, desired schedules and anticipated results will be established in this cooperative effort. The manager of Task 1800 will provide these packages to Customer for approval and implementation through direction to the GFE facility. Support will be provided to Customer and the facility operator in planning for the test. Coordination between the facility operator and the appropriate cognizant engineer will be provided, including delineation of interfaces between test hardware and facility. Timely production and delivery of test hardware (the responsibility of the appropriate cognizant engineer) will be coordinated. Coordination will be provided to the facility operator in the modification of the facility and other test preparation, preparation of test plans and other test related activities. Readiness reviews will be conducted. Technical assistance will be provided during installation, check out, start up and operation of the test. Observers will be provided during the test and acquisition of test data and results. Cooperation will be provided to the appropriate cognizant engineers in the analysis and reporting of the results, including engineering data base input.

1810-20MW(t) TESTS

Tests are anticipated in MHD facilities at several performance levels. The studies carried out under the MHD/APT contract have confirmed that useful tests can indeed be performed st the nominal 20MW(t) level. These tests integrated, power train test and materials tests in downstream components. WBS 1811 and 1812 will coordinate these tests.

1820 50MW(t) TESTS

The studies carried out under the MHD/APT contract have confirmed that useful tests should be performed at the nominal 50MW(t) level. These include testing of the development and prototype combustors, test and advanced generators, and diffuser, power train, and interface data obtained as a by-product of other testing programs.

1821 DEVELOPMENT COMBUSTOR

Objective

To determine the operating characteristics of the development combustor, to obtain interface information pertinent to the design and operation of combustors, to obtain information pertinent to other program elements (in the course of the tests) so as to make maximum effective use of the operation of the test facility.

Technical Approach

A 50MW(t) two stage combustor has been developed and tested at TRW and, in conjunction with a channel, at CDIF. Modification of this combustor design, to include slag rejection, is planned. One or two combustors are to be produced and tested. Scale-up questions will be examined. Voltage isolation will be explored. Test section(s) of the design concept for the prototype combustor will be tested. Combustor exit conditions will be characterized. In establishing these tests, coordination with other program cognizant engineers will be carried out to identify and include other tests that can be conducted during the test and without interfering with the prime test.

1822 ENDURANCE POWER TRAIN

Objective

To operate all the components of the endurance power train to develop and demonstrate their satisfactory performance, including all of the interface impacts.

Technical Approach

The components discussed above will be utilized. The emphasis in these tests will be on the demonstration of technology related to lifetime. The 500 hour endurance test supporting the design of the 250MW(t) facility will be carried out. In the planning for this test, a specific definition of durability will be established, including selection of number and character of the cycles to which the generator is to be subjected during the 500 hour test.

1823 DEVELOPMENT POWER TRAINS

Objective

To determine the performance and lifetime potential of generators incorporating the features of the development channels.

Technical Approach

One or more generators, embodying essential state-of-art production technology, but incorporating simulation of the features desired in early commercial generators, will be tested in power train facilities. Scale-up in both performance and lifetime will be explored. The necessary supplier development testing will be integrated.

1824 INTERFACE LIAISON

Objective

The design and development of the power train components requires, and this task is to enhance, an understanding of the complex interactions with and impacts from other MHD/steam plant systems (these are lumped in the term interfaces).

Technical Approach

The interface data and information can be obtained from limited participation in MHD test programs that are primarily planned for other reasons. The plans of various test facilities will be obtained and examined for opportunities to either make minor modifications or simply to observe tests and test results to obtain the desired information.

1830 RETROFIT TESTS

Tests are anticipated in MHD facilities at several performance levels. The studies carried out under the MHD/APT contract have confirmed that useful tests can be performed in a total plant integrated facility.

1831 COMBUSTOR

Objective

To confirm the design of the combustor for use in the retrofit power train.

Technical Approach

A two stage combustor based on the data and information produced in the 50MW(t) combustor element will be tested in the supplier's facility.

1832 POWER CONDITIONING

Objective

To confirm the design adequacy of the power conditioning for the retrofit power train.

Technical Approach

The power conditioning for the retrofit power train, and incorporating the features of the production channel, will be checked at the supplier's facility than delivered to the retrofit facility for installation and checkout.

1833 INTEGRATED POWER TRAIN

Objective

To determine the performance and lifetime potential of the retrofit power train in a total integrated facility.

Technical Approach

The components discussed above will be utilized. The facility for use in this task must be identified. The facility design and power train requirements and specifications must be obtained and provided to the cognizant engineers in charge of WBS elements 1831 and 1832. In the planning for this test, a specific definition of durability will be established, including selection of number and character of the cycles to which the generator is to be subjected during the anticipated 2000 hour test goal.

1840 OTHER INTEGRATION AND LIASION

Data and information in a number of technologies and from a number of facilities will be required for the successful execution of the advanced power train development program. The manager of the WBS element 1800 will be responsible for establishing contacts and cooperation with these facility operators. The assistance of Customer is assumed. The list of subtasks will expand as the program unfolds, especially if international agreements are implemented.

WBS 1900 PROGRAM MANAGEMENT

The overall approach to program management of the APT program is presented in Section 4.0 of this Development Plan. To effectively manage the program, the WBS presented here is structured into four elements as follows:

1910 PROJECT PROGRESS REVIEWS:

Objective

To insure that the project is being carried out in full compliance with the contract, Work Plan and Technical Direction.

Technical Approach

These reviews are the basic responsibility of, and will be established and called by the Project Office. They will be conducted by the Manager of System Development (SD) or his designee. Any function may submit one or more Change Requests at these reviews. The change request if the tool for requesting permission to make a technical change in a component or system that is believed to deviate from the Technical Direction but has the potential to improve the affected component. It serves the purpose of alerting any other function that a change is being considered that may have impacts outside the directly affected component or system. The SD function will have at its disposal a Change Control Board composed of senior technical personnel. SD will prepare (or have prepared) an analysis of the impacts of the requested change. SD will convene the Change Control Board, following the review and analysis, to consider and recommend action or rejection of the Change Request(s). SD will report the decisions of the Board to the Project Office. The Project Office, with the assistance of SD, will review the recommended actions with the customer whenever they impact the Contract, Work Plan or Technical Direction. When the customer approves, SD will prepare and issue a revision of the Work Plan and Technical Direction to reflect the change.

Any deviation in the actual progress as compared to the plan, and as identified in the internal review, will be recorded by SD in a Variance Report, prepared immediately subsequent to the review. This Variance Report will be submitted to Project Office and to the Westinghouse Division Management. It provides a tool for the efficient focus of management attention on the crucial aspects of the program.

1920 ORAL REPORTING

Objective

To provide the overall Integration project with detailed progress reviews at which experts may question the project participants and comment on approaches and progress.

Technical Approach

The recommended frequency of oral reports is annually. These will take the form of one day presentations by the project participants including subcontractors, relating technical progress during the intervening period. They will close with a summary presentation, by the Project Office, comparing progress to Work Plan milestones and recommending the content of the project plan for the next ensuing period.

1930 TECHNICAL AND FINANCIAL REPORTS

Objective

To provide the Customer with written records of progress against milestones, schedule and budget. To provide a written record of the results obtained in the course of the project.

Technical Approach

Topical reports on specific subjects, regular reports on technical progress at intervals specified by the contract (brief resumes of monthly progress included with the monthly financial reports and a more comprehensive annual report summarizing the oral report are recommended), and a final report to provide the coordinated project results, are suggested.

1940 PROJECT MANAGEMENT

Objective

To provide the management function for the overall direction of the Advanced Power Train portion of the Engineering Development and Large Plant Experiment phases of the MHD program.

Technical Approach

The Project Office will accomplish the contract effort, using matrix management methodology and the System Engineering Approach, as part of the activities of the Advanced Energy Systems Division of the Westinghouse Electric Corporation. The detailed technical approach is discussed, above, in response to specific subjects delineated in the current contract work scope.

Services of activities, such as Purchasing and Project Schedule and Control, will be provided. Appropriate Divisional management oversight of the project will be provided. Standing and Ad Hoc committees of senior personnel will be established for Corporate review of progress and consistency with Westinghouse practice and procedure, and resolution of problem areas, respectively.