DOE/MC/28202-3535
(DE94000061)

# Environmental Report for the Gasification Product Improvement Facility (GPIF)

**Topical Report**

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**E.S. Norris**
**R.R. Duck**
**R.B. Hass**
**M.E. Morgan**
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January 1993

Work Performed Under Contract No.: DE-AC21-92MC28202

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By
CRS Sirrine Engineers, Inc.
Greenville, South Carolina

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Morgantown Energy Technology Center
P.O. Box 880
Morgantown, West Virginia 26507-0880

By
CRS Sirrine Engineers, Inc.
1041 East Butler Road
Greenville, South Carolina 29606-5456

January 1993

## TASK 1 - NEPA SUPPORT DOCUMENT TABLE OF CONTENTS

## LIST OF FIGURES



Missing Pages:
P.2, P.104 and P. 105

## LIST OF TABLES

NEPA DOCUMENTATION TABLE OF CONTENTS
PSIT SUPPORT

NEPA DOCUMENTATION TABLE OF CONTENTS
PSIT SUPPORT
LIST OF FIGURES

NEPA DOCUMENTATION TABLE OF CONTENTS
PSIT SUPPORT
LIST OF TABLES

## Task 1
## Gasification Product Improvement Facility (GPIF)
## Environmental, Safety, & Health (ES&H) Information
## National Environmental Policy Act (NEPA)

### 1. Introduction

The Department of Energy (DOE) Fossil Energy Program has a mission to develop energy systems that utilize national coal resources in power systems with increased efficiency and environmental compatibility. Coal gasification technology is a versatile candidate that meets this goal.

Optimized air-blown fixed-bed gasification power generation systems at a cost of about $1000 per kilowatt (KW) are possible if gasifier subsystem process components can be reduced or eliminated.

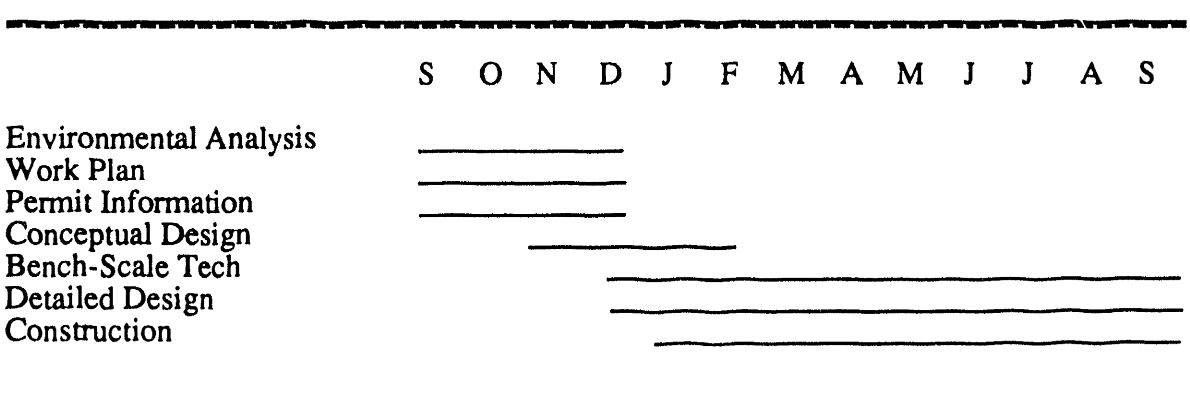
This two phased project consists primarily of the design, construction and operation of a 5-foot inside diameter (minimum) fixed-bed gasifier called PyGas™ and supporting infrastructure (Phase I), and an additional follow on phase consisting of the design, construction and operation of a hot fuel gas cleanup unit (Phase II).

### 2. Project Objectives

The main goal of the GPIF project is to develop systems and subsystems to resolve technological issues that surround the simplified IGCC concept. Issues expected to be successfully overcome by PyGas™ through its application in this test facility include the processing of high-swelling coals, which causes agglomeration in conventional fixed-bed gasifiers. Such coals comprise 87% of all eastern coals. Other issues expected to be eliminated or significantly reduced include: production of ash clinkers, production of ammonia, the presence of significant tars and fines, and the volatilization of alkalinity in the product fuel gas.

### 3. Schedule of Milestones

**Figure 1**
**Schedule of Milestones**
**FY93 Program Schedule**



## 6. Technical Approach

The gasifier test facility general arrangement drawing (Figure 2) utilizes the CRS Sirrine Engineers, Inc. proprietary gasification invention nominally rated (for materials handling purposes) at 6 tons per hour coal throughput. Its capacity is therefore anticipated to be approximately six times the capacity of the existing 42 inch diameter METC test gasifier. The operating pressure is 600 psi, and the gasifier is expected to be 5 feet (minimum) in diameter, and some 34 feet in height. It is designed to operate at a maximum coal firing rate of 150-MBtu/hr. Since it will be located at an existing utility site, it is anticipated that the products of combustion from the coal derived gas will be returned to the existing stack.

## 7. Existing Facility Description

Fort Martin Generating Station (Figure 3 & Table 1) is a 1000 MWe pulverized coal fired electric utility power plant located in Point Marion, West Virginia, some two miles down the Monongahela River from the Morgantown Energy Technology Center. It is operated by Monongahela Power Co., an Allegheny Power System company. High and low sulfur coals are currently blended to meet current sulfur emission limits. Coal is received by barge, conveyed to an enclosed breaker house, and loaded out to either long term or active open coal piles, and reclaimed in a manner that allows the utility to control feed quantities of the low and high sulfur coal feed stocks. Steam turbine condenser heat of condensation is rejected via conventional cooling towers to the atmosphere. Coal ash is pneumatically conveyed to ash silos and subsequently is trucked to a permitted coal ash landfill area on the premises. Care and due diligence is practiced to avoid excessive dusting using water sprays during ash loading onto the ash trucks, and wind screens are in place as a deterrent to wind blown ash from the landfill. Sulfur is currently the only criteria pollutant requiring controlled emission limits. Figure 4 shows a photograph of the existing site with alternate GPIF locations identified.

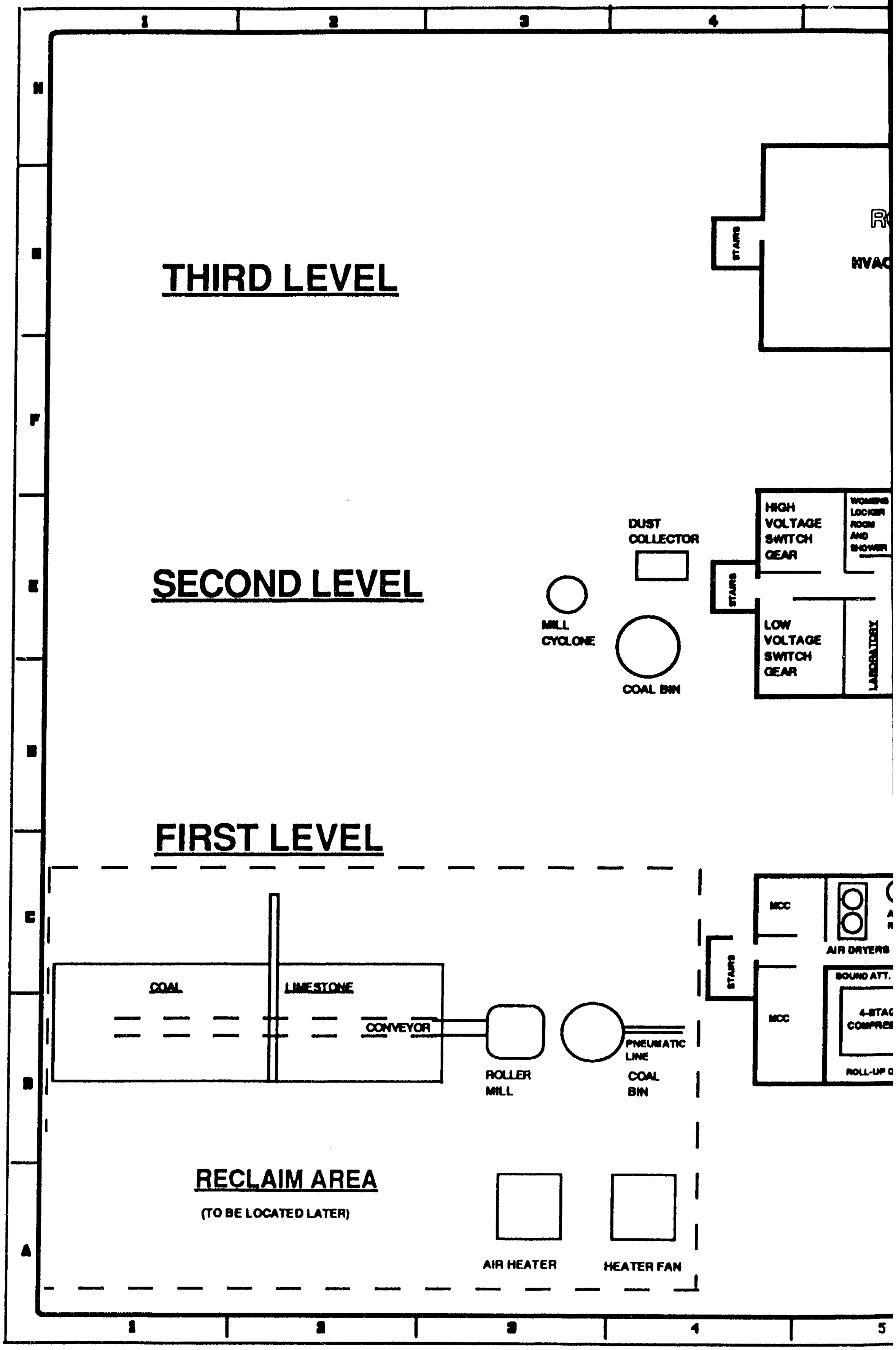
## 8. Test Facility Major Equipment Capacities and Ties to Ft. Martin

Included herewith are the process flow sheet (Figure 5) and typical mass balances (Table 2) for the existing Fort Martin Generating Station along with a mass balance predicted for the Gasification Product Improvement Facility (GPIF) under Phases I & II. The numbered columns match the circled numbers identified in the preliminary process flow diagram. Proposed ties to Ft. Martin are identified in Figure 6.

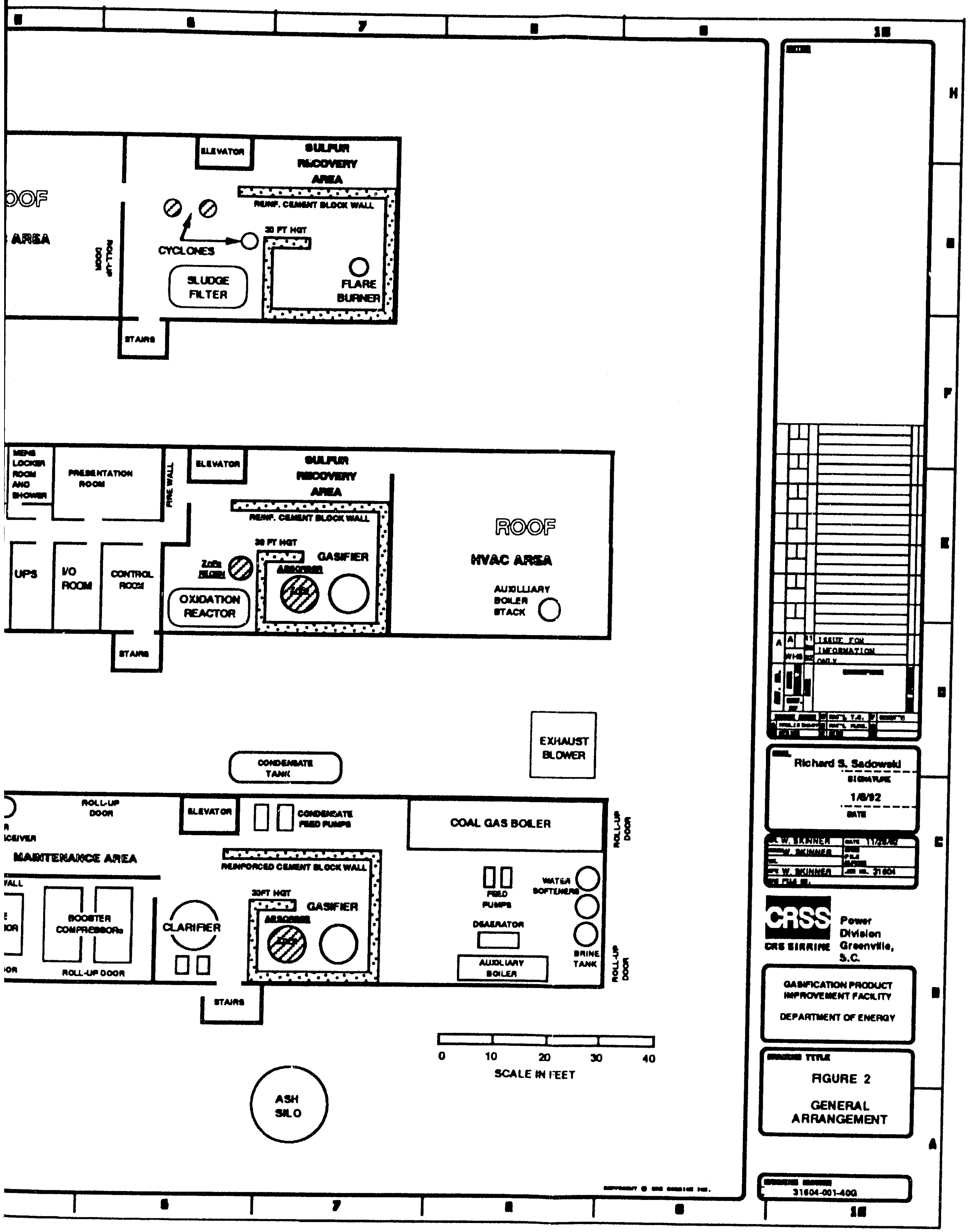
The concept is to fire coal gas in a closely coupled packaged auxiliary steam generator located within the GPIF. The products of combustion will then be ducted back to the existing flue gas duct of Fort Martin Unit #2 upstream of the existing stack. The heat released within the packaged fired auxiliary steam generator will be returned to the existing Fort Martin Unit #2 in the form of steam. As contemplated, the GPIF represents only approximately 1.5% of the full load rated station firing rate, an aliquot side stream of feedwater will be fed to and returned from the GPIF as auxiliary or high pressure steam for the utility company. The new boiler will have a capacity of approximately 90,000 lbs per hour of steam.

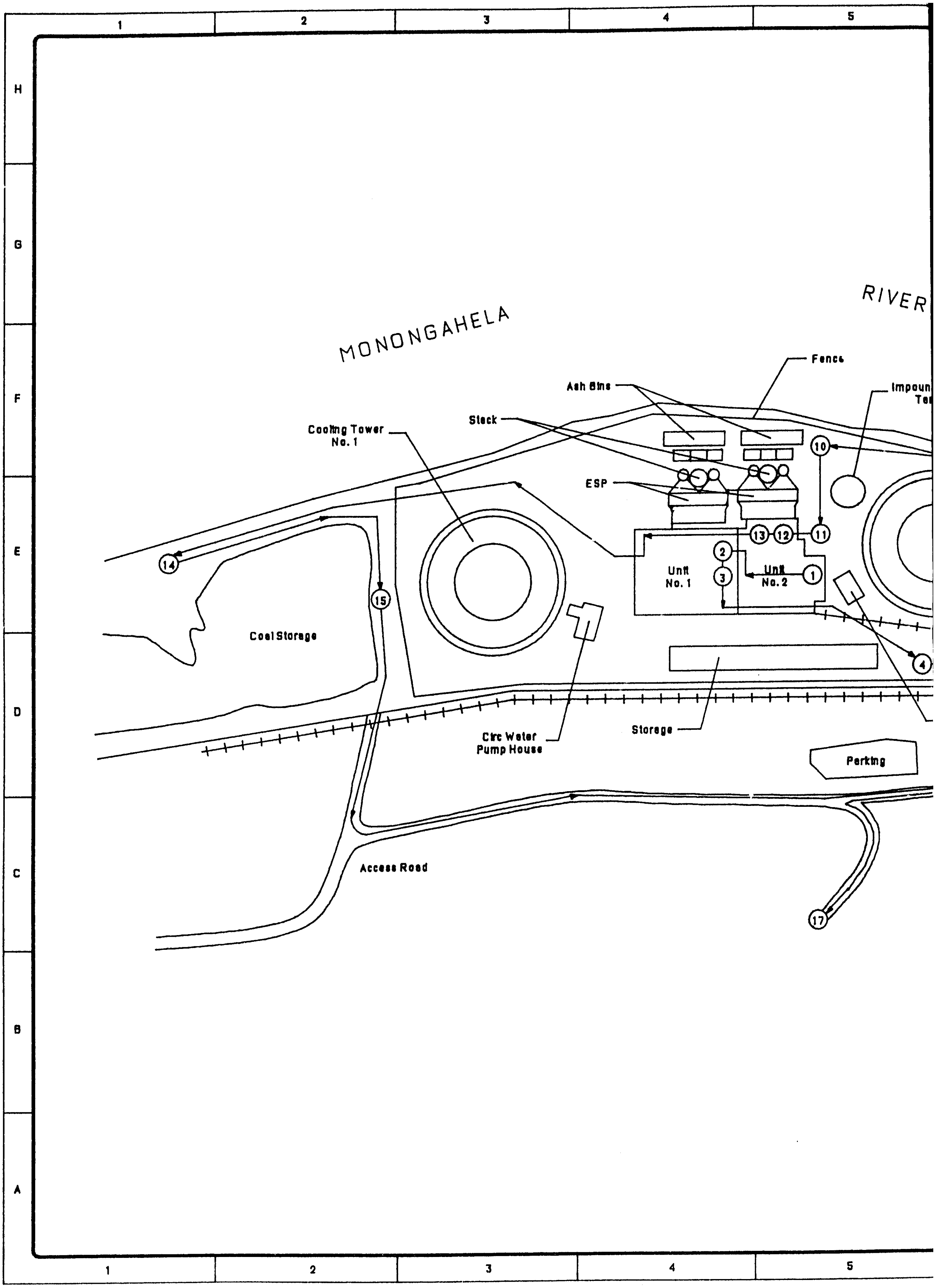
In addition to the light oil ignited coal gas fired heat recovery steam generator (HRSG), either a smaller 10,000 lbs per hour steam light oil fired packaged boiler, or equivalent steam from Ft Martin, vented to atmosphere is contemplated for space heating and gasification process steam.

The limestone feed capability to the PyGas™ coal gasifier may be sufficient in concert with coal gas combustion and steam generation to reduce Fort Martin sulfur emissions from currently



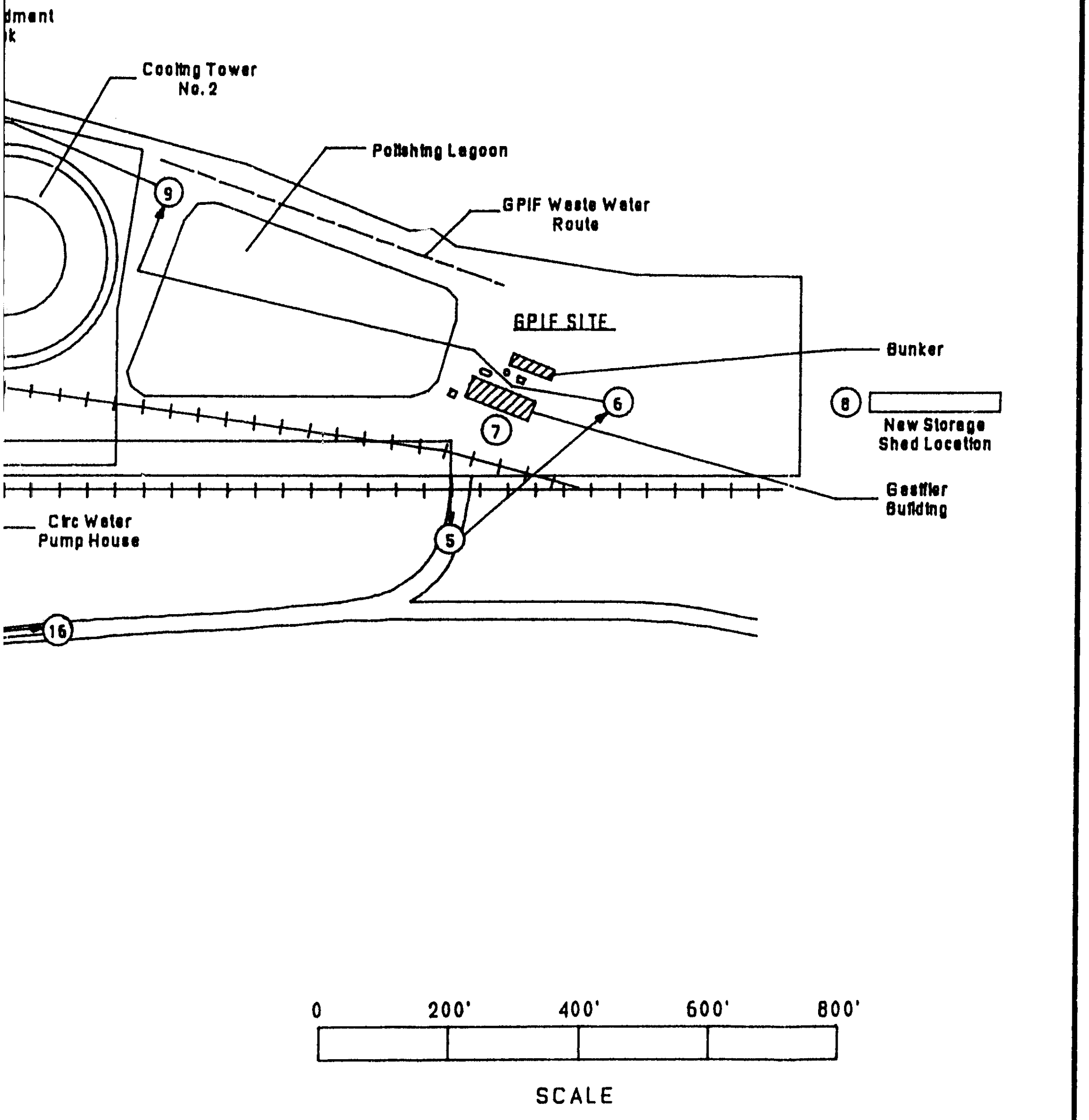
THIRD LEVEL
STAIRS
HVAC
SECOND LEVEL
DUST COLLECTOR
MILL CYCLONE
COAL BIN
HIGH VOLTAGE SWITCH GEAR
LOW VOLTAGE SWITCH GEAR
LABORATORY
FIRST LEVEL
COAL
LIMESTONE
CONVEYOR
ROLLER MILL
PNEUMATIC LINE
COAL BIN
MCC
AIR DRYERS
RECLAIM AREA
(TO BE LOCATED LATER)
AIR HEATER
HEATER FAN


ELEVATOR
SULFUR RECOVERY AREA
ROOF
AREA
ROLL-UP DOOR
REINF. CEMENT BLOCK WALL
30 FT HGT
CYCLONES
SLUDGE FILTER
FLARE BURNER
STAIRS
MENS LOCKER ROOM AND SHOWER
PRESENTATION ROOM
FIRE WALL
GASIFIER
HVAC AREA
AUXILLIARY BOILER STACK
UPS
I/O ROOM
CONTROL ROOM
OXIDATION REACTOR
EXHAUST BLOWER
CONDENSATE TANK
CONDENSATE FEED PUMPS
COAL GAS BOILER
MAINTENANCE AREA
REINFORCED CEMENT BLOCK WALL
33FT HGT
BOOSTER COMPRESSORS
CLARIFIER
ROLL-UP DOOR
FEED PUMPS
WATER SOFTENERS
DEAERATOR
AUXILIARY BOILER
BRINE TANK
0 10 20 30 40
SCALE IN FEET
ASH SILO
ISSUE FOR INFORMATION ONLY
Richard S. Sadowski
SIGNATURE
1/8/92
DATE
W. SKINNER
W. SKINNER
W. SKINNER
31604
CRSS
CRS SIRRINE
Power Division Greenville, S.C.
GASIFICATION PRODUCT IMPROVEMENT FACILITY
DEPARTMENT OF ENERGY
DRAWING TITLE
FIGURE 2
GENERAL ARRANGEMENT
31604-001-400


MONONGAHELA
RIVER
Fence
Impoun
Te
Ash Bins
Stack
Cooling Tower
No. 1
ESP
Unit
No. 1
Unit
No. 2
Coal Storage
Circ Water
Pump House
Storage
Parking
Access Road
1
2
3
4
10
11
12
13
14
15
17
H
G
F
E
D
C
B
A
5

6 7 8 9 10

NOTES




SEAL

SIGNATURE

1/8/93

DATE

CRSS

GPIF
PROJECT
Figure 3

DRAWING TITLE

SITE PLAN

DRAWING NUMBER



CRS SIRRINE

6 7 8 9 10

Table 1

## FORT MARTIN TOUR ROUTE

| | |
|---|---|
| Stop 1 | Training Room at the Fort Martin Power Station. Tour groups will be formed and introduced to the utility tour guides. |
| Stop 2 | Connection point for Filtered Water. Available at quantities up to 200 gpm for steam generation and general use. Anticipated pressure at connection point is 150 psig. |
| Stop 3 | Connection point for Service Water. Available for fire protection at quantities up to 1200 gpm. Anticipated pressure at the connection point is 85 psig. |
| Stop 4 | Connection point for Potable Water. Plant storage consists of a 20,000 gal tank. Conveyed (by gravity) to plant through a 3-inch PVC line at 15 gpm. Anticipated pressure at connection point is 120 psig. |
| Stop 5 | Approximate location of railroad crossing required for access to the GPIF. |
| Stop 6 | Approximate location of the GPIF, as shown by surveyors stakes. Access during construction and test operations will be via Stop 15 & 5. Approximately four acres. |
| Stop 7 | Existing storage shed to be relocated area near Stop 8. |
| Stop 8 | New location of storage shed presently located on the GPIF site. |
| Stop 9 | Anticipated route of buried GPIF process waste water pipes from the GPIF to the Plant ash settling basins. Plant will provide treatment and discharge. |
| Stop 10 | Plant ash settling basins. |
| Stop 11 | Approximate locale for GPIF fuel gas to enter the Plant for combustion in the coal-fired boiler |
| Stop 12 | Unit #2 coal-fired boiler |
| Stop 13 | Unit #2 Control Room. |
| Stop 14 | Coal storage pile for Plant operations. Low-sulfur coal will be made available for GPIF operations. |
| Stop 15 | Truck weigh station for ash trucks. |
| Stop 16 | Unimproved roadway leading to the railroad crossing and the GPIF site. |
| Stop 17 | Paved road leading to the ash disposal pit, contractors' entrance and exit. |

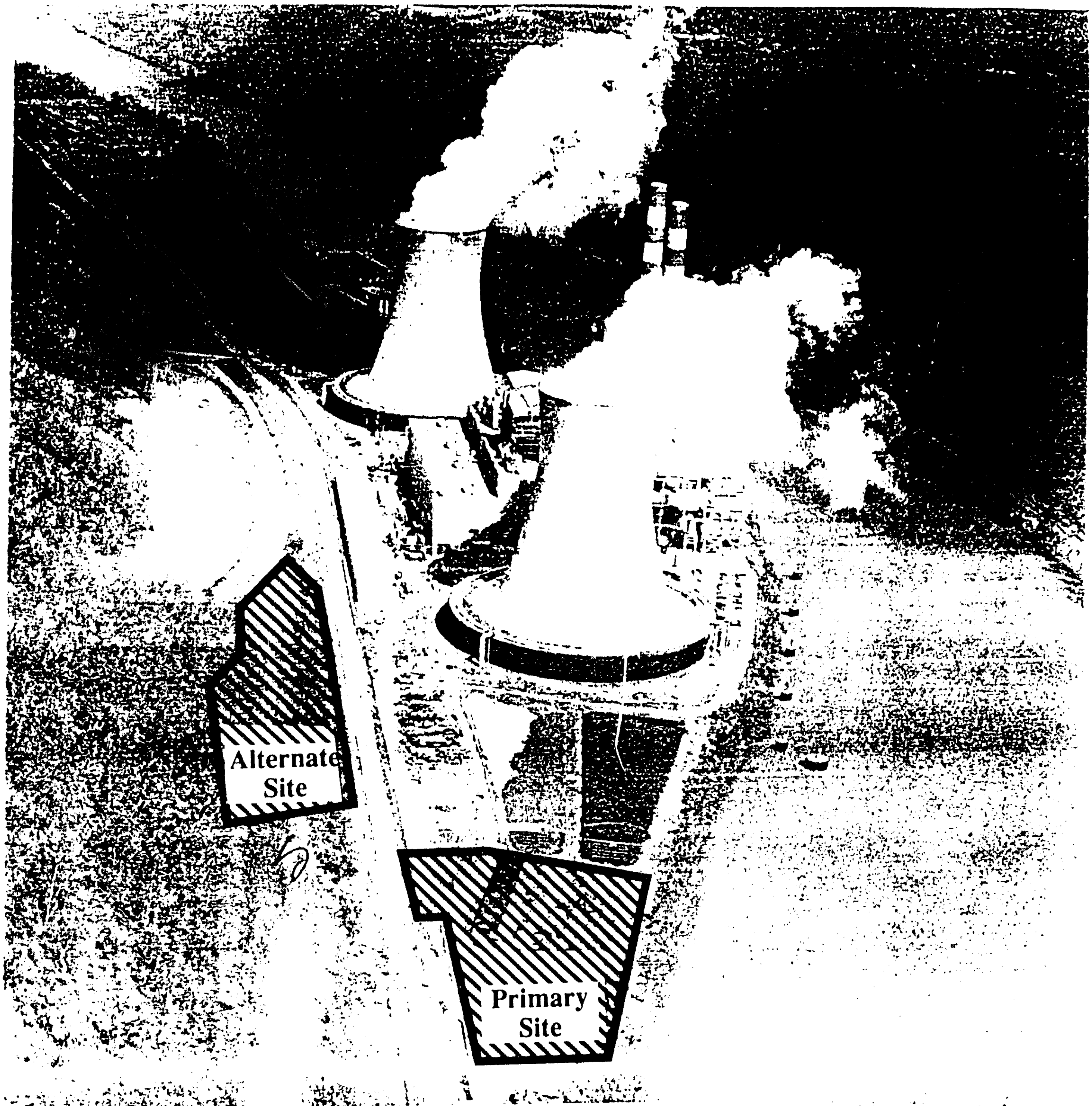
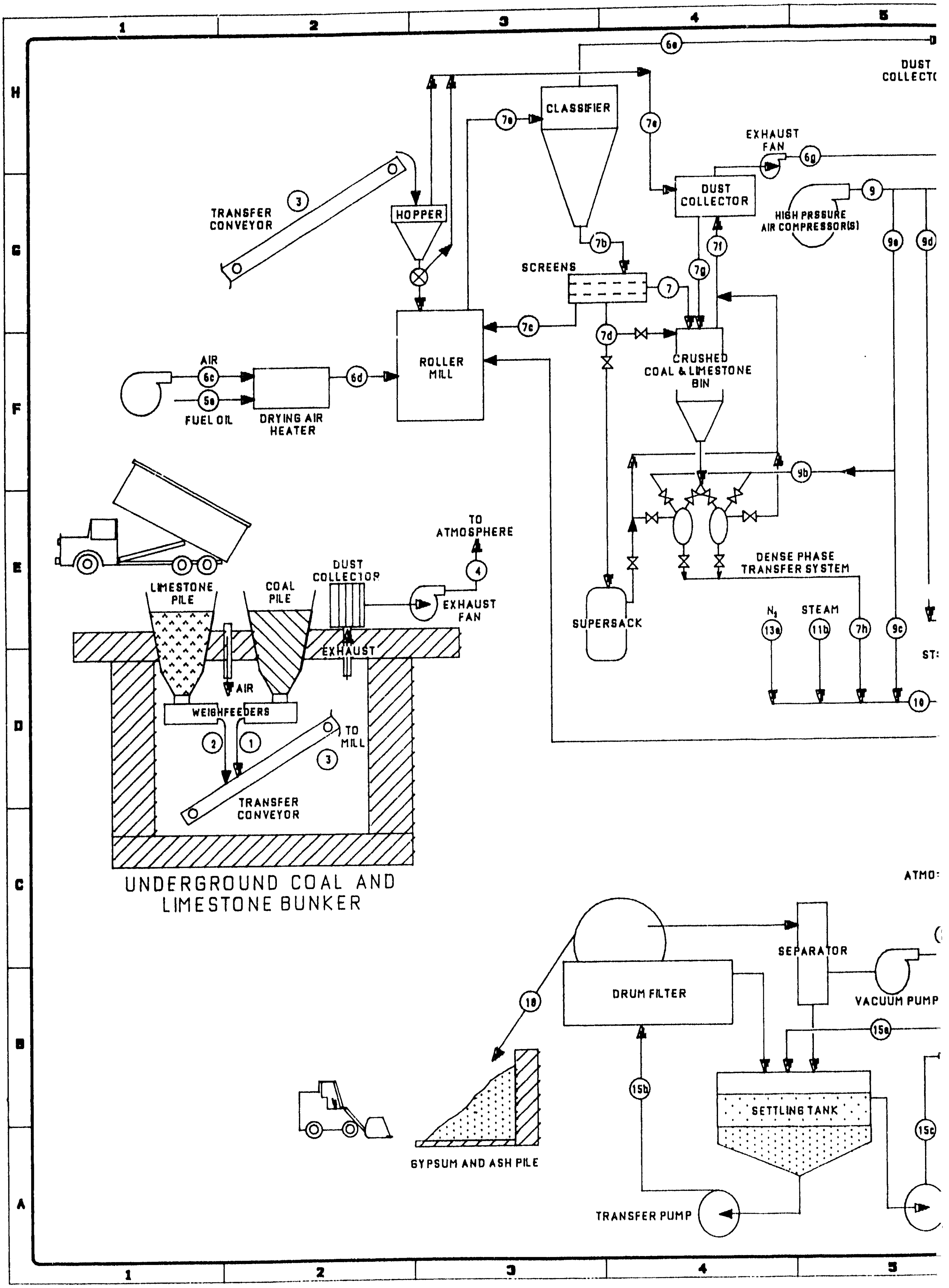
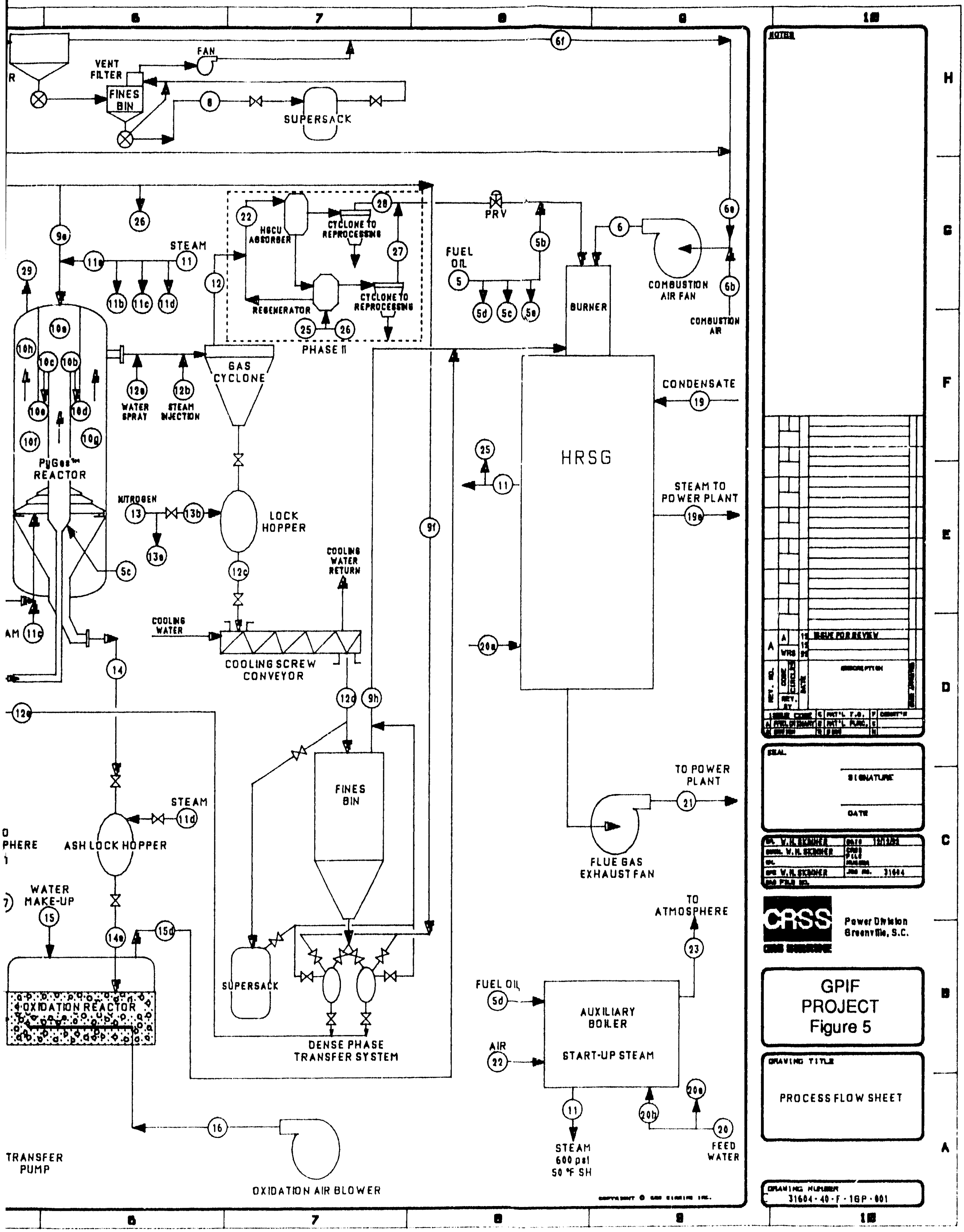



Figure 4
Alternate GPIF Sites
Ft Martin Generating Station
Monongahela Power



DUST COLLECTO
CLASSIFIER
EXHAUST FAN
TRANSFER CONVEYOR
HOPPER
DUST COLLECTOR
HIGH PRESSURE AIR COMPRESSOR(S)
SCREENS
ROLLER MILL
CRUSHED COAL & LIMESTONE BIN
AIR
FUEL OIL
DRYING AIR HEATER
DENSE PHASE TRANSFER SYSTEM
TO ATMOSPHERE
DUST COLLECTOR
LIMESTONE PILE
COAL PILE
EXHAUST FAN
EXHAUST
AIR
WEIGHFEEDERS
TO MILL
TRANSFER CONVEYOR
SUPERSACK
STEAM
UNDERGROUND COAL AND LIMESTONE BUNKER
SEPARATOR
DRUM FILTER
VACUUM PUMP
SETTLING TANK
GYPSUM AND ASH PILE
TRANSFER PUMP



FAN
VENT FILTER
FINES BIN
SUPERSACK
STEAM
HGCU ABSORBER
CYCLONE TO REPROCESSING
REGENERATOR
PHASE II
FUEL OIL
PRV
BURNER
COMBUSTION AIR FAN
COMBUSTION AIR
PyGas™ REACTOR
WATER SPRAY
STEAM INJECTION
GAS CYCLONE
CONDENSATE
HRSG
STEAM TO POWER PLANT
NITROGEN
LOCK HOPPER
COOLING WATER RETURN
COOLING WATER
COOLING SCREW CONVEYOR
FINES BIN
TO POWER PLANT
ASH LOCK HOPPER
FLUE GAS EXHAUST FAN
WATER MAKE-UP
TO ATMOSPHERE
SUPERSACK
OXIDATION REACTOR
DENSE PHASE TRANSFER SYSTEM
AUXILIARY BOILER
START-UP STEAM
AIR
STEAM 600 psi 50 °F SH
FEED WATER
TRANSFER PUMP
OXIDATION AIR BLOWER
NOTES
ISSUE FOR REVIEW
DESCRIPTION
SEAL
SIGNATURE
DATE
W. H. SKINNER
JOB NO. 31604
CRSS
Power Division
Greenville, S.C.
GPIF PROJECT Figure 5
DRAWING TITLE
PROCESS FLOW SHEET
DRAWING NUMBER
31604-40-F-1GP-001

## DOE - GPIF - CRSS Coal Gasification Process (Kinetically Balanced) — Table 2.2

NEPA Support Document, Mass Balance — *Using FW Data (High Steam - Low Btu) Case

| | | Mol Wt | 6 | 6a | 6b |
|---|---|---|---|---|---|
| 5 | Stream No. | | 6 | 6a | 6b |
| 6 | Identification | | Combustion Air | Combustion Air | Combustion Air |
| 7 | From | | Total | Exhaust Vents | Ambient |
| 8 | To | | HRSG Burner | HRSG Burner | HRSG Burner |
| 9 | Gas | Mol Wt | lb/hr | | |
| 11 | CO | 28.010 | 0 | 0 | |
| 12 | H2 | 2.016 | 0 | 0 | |
| 13 | CO2 | 44.010 | 49 | 922 | 4 |
| 14 | H2O | 18.015 | 652 | 426 | 65 |
| 15 | CH4 | 16.042 | 0 | 0 | |
| 16 | C2H6 | 30.068 | 0 | 0 | |
| 17 | H2S | 34.076 | 0 | 0 | |
| 18 | COS | 60.070 | 0 | 0 | |
| 19 | N2 | 28.013 | 76923 | 11,458 | 6546 |
| 20 | Ar | 39.948 | 1347 | 201 | 114 |
| 21 | HCl | 36.461 | 0 | 0 | |
| 22 | HCN | 27.026 | 0 | 0 | |
| 23 | NH3 | 17.030 | 0 | 0 | |
| 24 | CS2 | 76.131 | 0 | 0 | |
| 25 | SO2 | 64.059 | 0 | 3 | |
| 26 | NO | 30.006 | 0 | 0 | |
| 27 | O2 | 31.999 | 23559 | 3,270 | 2028 |
| 28 | NaCl | 58.497 | 0 | 0 | |
| 29 | KCl | 74.596 | 0 | 0 | |
| 30 | CaSO4 | 136.142 | 0 | 0 | |
| 31 | Ca(OH)2 | 74.095 | 0 | 0 | |
| 32 | Cl2 | 35.500 | 0 | 0 | |
| 33 | Total Gas (lb/hr) | | 102529 | 16,329 | 8620 |
| 34 | | | | | |
| 56 | | | | | |
| 57 | C | 12.011 | | | |
| 58 | H | 1.008 | | | |
| 59 | O | 16.000 | | | |
| 60 | N | 14.007 | | | |
| 61 | S | 32.060 | | | |
| 62 | CaO | 56.079 | | | |
| 63 | H2O | 18.016 | | | |
| 64 | NaCl | 58.497 | | | |
| 65 | KCl | 74.596 | | | |
| 66 | CaSO4 | 136.142 | | | |
| 67 | Ca | 40.080 | | | |
| 68 | CaS | 72.140 | | | |
| 69 | ASH, Inerts (pph) | | | | |
| 70 | Total Solids (pph) | | | | |
| 71 | Total Flow (pph) | | 156499 | 16329 | 862[illegible] |
| 72 | | | | | |
| 73 | Total Flow (pps) | | 43 | 5 | [illegible] |
| 74 | Pressure (psia) | | 15 | 15 | [illegible] |
| 75 | Temperature (F) | | 90 | 90 | [illegible] |

3/10/93 17:19 02

CONTRACT NO. DE-AC21-92MC28202 03

| | 6c Air Atmosphere Coal Dryer @ 1.25 lb/lb Coal | 6d Heated Drying Air Drying Air Heater Crusher Mill | 6e Classifier Air Classifier & Filter Coal Gas Burner @0 .01% Solids | 6f Dust Collector Exhaust Classifier Dust Collector Forced Draft Fan Intake @ 99% Removal Effic. | 6g Dust Collector Exhaust Hopper Dust Collector Forced Draft Fan Intake | |
|---|---|---|---|---|---|---|
| | 0 | 0 | 0 | 0 | 0 | 11 |
| | 0 | 0 | 0 | 0 | 0 | 12 |
| | 7 | 922 | 922 | 7 | 0 | 13 |
| | 96 | 425 | 425 | 96 | 1 | 14 |
| | 0 | 0 | 0 | 0 | 0 | 15 |
| | 0 | 0 | 0 | 0 | 0 | 16 |
| | 0 | 0 | 0 | 0 | 0 | 17 |
| | 0 | 0 | 0 | 0 | 0 | 18 |
| | 11,336 | 11,336 | 11,336 | 11,336 | 84 | 19 |
| | 198 | 198 | 198 | 198 | 1 | 20 |
| | 0 | 0 | 0 | 0 | 0 | 21 |
| | 0 | 0 | 0 | 0 | 0 | 22 |
| | 0 | 0 | 0 | 0 | 0 | 23 |
| | 0 | 0 | 0 | 0 | 0 | 24 |
| | 0 | 3 | 3 | 0 | 0 | 25 |
| | 0 | 0 | 0 | 0 | 0 | 26 |
| | 3,472 | 3,233 | 3,233 | 3,472 | 26 | 27 |
| | 0 | 0 | 0 | 0 | 0 | 28 |
| | 0 | 0 | 0 | 0 | 0 | 29 |
| | 0 | 0 | 0 | 0 | 0 | 30 |
| | 0 | 0 | 0 | 0 | 0 | 31 |
| | 0 | 0 | 0 | 0 | 0 | 32 |
| | 15,110 | 16,117 | 16,217 | 16,217 | 112 | 33 |
| | | | | | | 34 |
| | | | | | | 56 |
| | | | 1.69 | 0.017 | 6.43E-04 | 57 |
| | | | 0.11 | 0.001 | | 58 |
| | | | 0.28 | 0.003 | 1.08E-04 | 59 |
| | | | 0.03 | 0.0003 | 1.16E-05 | 60 |
| | | | 0.02 | 0.0002 | 9.01E-06 | 61 |
| | | | | | | 62 |
| | | | 0.05 | 0.0005 | 1.76E-05 | 63 |
| | | | | | | 64 |
| | | | | | | 65 |
| | | | | | | 66 |
| | | | 0.07 | 0.001 | 2.81E-05 | 67 |
| | | | | | | 68 |
| | | | 0.37 | 0.004 | 1.42E-04 | 69 |
| | | | 2.63 | 0.03 | 1.00E-03 | 70 |
| 0 | 15,110 | 16117 | 16220 | 16217 | 16117 | 71 |
| | | | | | | 72 |
| 4 | 4.20 | 4 | 5 | 5 | 4 | 73 |
| 5 | 14.7 | 14.7 | 14.7 | 14.7 | 14.7 | 74 |
| 0 | 80 | 500 | 150 | 367 | 367 | 75 |

02| DOE - GPIF - CRSS Coal Gasification Process (Kinetically Balanced) Reference Coal - Fort Mart

03| Mass & Energy Balance 5 ft Dia Test Size CRSS Predicted Output *Us

| | | | | |
|---|---|---|---|---|
| 04\| | | | | |
| 05\| | Stream No. | | 8 | 9 |
| 06\| | Identification | | Coal/Limestone Fines | Compressed Air |
| 07\| | From | | Classifier Dust Collector | High Pressure Compressor |
| 08\| | To | | Ft Martin Coal Pile | Total |
| 09\| | Gas | Mol Wt | lb/hr | lb/hr |
| 10\| | | | | |
| 11\| | CO | 28.010 | | 0 |
| 12\| | H2 | 2.016 | | 0 |
| 13\| | CO2 | 44.010 | | 24 |
| 14\| | H2O | 18.016 | | 321 |
| 15\| | CH4 | 16.042 | | 0 |
| 16\| | C2H6 | 30.068 | | 0 |
| 17\| | H2S | 34.076 | | 0 |
| 18\| | COS | 60.070 | | 0 |
| 19\| | N2 | 28.013 | | 37924 |
| 20\| | Ar | 39.948 | | 664 |
| 21\| | HCl | 36.461 | | 0 |
| 22\| | HCN | 27.026 | | 0 |
| 23\| | NH3 | 17.030 | | 0 |
| 24\| | CS2 | 76.131 | | 0 |
| 25\| | SO2 | 64.059 | | 0 |
| 26\| | NO | 30.006 | | 0 |
| 27\| | O2 | 3'.999 | | 11615 |
| 28\| | NaCl | 58.497 | | 0 |
| 29\| | KCl | 74.596 | | 0 |
| 30\| | CaSO4 | 136.142 | | 0 |
| 31\| | Ca(OH)2 | 74.095 | | 0 |
| 32\| | CaO | 56.079 | | 0 |
| 33\| | Total Gas (lb/hr) | | | 50548 |
| 34\| | | | | |
| 56\| | | | | |
| 57\| | C | 12.011 | 1.6741 | 7 |
| 58\| | H | 1.008 | 0.1072 | 36 |
| 59\| | O | 16.000 | 0.2799 | 11918 |
| 60\| | N | 14.007 | 0.0302 | 37924 |
| 61\| | S | 32.060 | 0.0235 | |
| 62\| | CL2 | 35.500 | 0.0000 | 49884 |
| 63\| | H2O | 18.016 | 0.0457 | |
| 64\| | NaCl | 58.497 | | |
| 65\| | KCl | 74.596 | | |
| 66\| | CaSO4 | 136.142 | | |
| 67\| | Ca | 40.080 | | |
| 68\| | CaO | 56.079 | | |
| 69\| | ASH, Inerts (pph) | | 0.3694 | |
| 70\| | Total Solids (pph) | | 2.5300 | 0 |
| 71\| | Total Flow (pph) | | 13 | 50548 |
| 72\| | | | | |
| 73\| | Total Flow (pps) | | 0.004 | 9 |
| 74\| | Pressure (psia) | | 15 | 600 |
| 75\| | Temperature (F) | | 80 | 200 |

n - Low Sulfur - 11/13/92 - MGAS Kinetics — Table 2.4 — 3/10/93 17:19 — 2

ng FW Data (High Steam - Low Btu) Case — CONTRACT NO. DE-AC21-92MC28202 — 3

| 9a | | | % Theo. Air | 9b | 9c | Row |
|---|---|---|---|---|---|---|
| Compressed Air@ | 2.27 A/C | | 26.57% | Coal/Lm'stn Convey Air | Compressed Air | 6 |
| gh Pressure Compressor | | | | High Pressure Compressor | High Pressure Compressor | 7 |
| Pyrolyzer | | | | Pyrolyzer | Pyrolyzer | 8 |
| lb/hr | mol wgt | wt % | mol% | lb/hr | | 9 |
| 0 | 0.00 | 0.00 | 0.00 | 0 | 0 | 11 |
| 0 | 0.00 | 0.00 | 0.00 | 0 | 0 | 12 |
| 15 | 0.01 | 0.05 | 0.03 | 3 | 12 | 13 |
| 196 | 0.18 | 0.64 | 1.02 | 37 | 159 | 14 |
| 0 | 0.00 | 0.00 | 0.00 | 0 | 0 | 15 |
| 0 | 0.00 | 0.00 | 0.00 | 0 | 0 | 16 |
| 0 | 0.00 | 0.00 | 0.00 | 0 | 0 | 17 |
| 0 | 0.00 | 0.00 | 0.00 | 0 | 0 | 18 |
| 23186 | 21.65 | 75.03 | 77.28 | 4397 | 18739 | 19 |
| 406 | 0.38 | 1.31 | 0.95 | 77 | 329 | 20 |
| 0 | 0.00 | 0.00 | 0.00 | 0 | 0 | 21 |
| 0 | 0.00 | 0.00 | 0.00 | 0 | 0 | 22 |
| 0 | 0.00 | 0.00 | 0.00 | 0 | 0 | 23 |
| 0 | 0.00 | 0.00 | 0.00 | 0 | 0 | 24 |
| 0 | 0.00 | 0.00 | 0.00 | 0 | 0 | 25 |
| 0 | 0.00 | 0.00 | 0.00 | 0 | 0 | 26 |
| 7101 | 6.63 | 22.98 | 20.72 | 1347 | 5754 | 27 |
| 0 | 0.00 | 0.00 | 0.00 | 0 | 0 | 28 |
| 0 | 0.00 | 0.00 | 0.00 | 0 | 0 | 29 |
| 0 | 0.00 | 0.00 | 0.00 | 0 | 0 | 30 |
| 0 | 0.00 | 0.00 | 0.00 | 0 | 0 | 31 |
| 0 | 0.00 | 0.00 | 0.00 | 0 | 0 | 32 |
| 30904 | 28.86 | 100.00 | 100.00 | 5860 | 25043 | 33 |
| | | | | | | 34 |
| | | | | | | 56 |
| 4 | | | | 7608 | | 57 |
| 22 | | | | 487 | | 58 |
| 7286 | | | | 1272 | | 59 |
| 23186 | | | | 137 | | 60 |
| | | | | 107 | | 61 |
| 30498 | Total | | | 0 | | 62 |
| | | | | 100 | | 63 |
| | | | | 0 | | 64 |
| | | | | 0 | | 65 |
| | | | | 0 | | 66 |
| | | | | 332 | | 67 |
| | | | | 0 | | 68 |
| | | | | 1679 | | 69 |
| 0 | | | | 11721 | | 70 |
| 30904 | 29693 | | | 17581 | 25043 | 71 |
| | | | | | | 72 |
| 8.58 | | | | 5 | 7 | 73 |
| 600 | | | | 600 | 600 | 74 |
| 150 | | | | 200 | 200 | 75 |

## DOE - GPIF - CRSS Coal Gasification Process (Kinetically Balanced)          Table 2

NEPA Support Document, Mass Balance          *Using FW Data (High Steam - Low Btu) Case

| | | | | |
|---|---|---|---|---|
| Stream No. | | 9d | | |
| Identification | Compressed Air@ | 0.83 A/C | | |
| From | High Pressure Compressor | | | |
| To | Gasifier Grate | | S/A | |
| Gas | lb/hr | lb-mol/hr | wt % | mol% |
| CO | 0 | 0.00 | 0.00 | |
| H2 | 0 | 0.00 | 0.00 | |
| CO2 | 5 | 0.01 | 0.05 | |
| H2O | 64 | 0.18 | 0.64 | |
| CH4 | 0 | 0.00 | 0.00 | |
| C2H6 | 0 | 0.00 | 0.00 | |
| H2S | 0 | 0.00 | 0.00 | |
| COS | 0 | 0.00 | 0.00 | |
| N2 | 7527 | 21.65 | 75.03 | |
| Ar | 132 | 0.38 | 1.31 | |
| HCl | 0 | 0.00 | 0.00 | |
| HCN | 0 | 0.00 | 0.00 | |
| NH3 | 0 | 0.00 | 0.00 | |
| CS2 | 0 | 0.00 | 0.00 | |
| SO2 | 0 | 0.00 | 0.00 | |
| NO | 0 | 0.00 | 0.00 | |
| O2 | 2305 | 6.63 | 22.98 | |
| NaCl | 0 | 0.00 | 0.00 | |
| KCl | 0 | 0.00 | 0.00 | |
| CaSO4 | 0 | 0.00 | 0.00 | |
| Ca(OH)2 | 0 | 0.00 | 0.00 | |
| Cl2 | 0 | 0.00 | 0.00 | |
| Total Gas (lb/hr) | 10033 | 28.86 | 100.00 | 1 |

| | | |
|---|---|---|
| C | 1 | |
| H | 7 | |
| O | 2365 | |
| N | 7527 | |
| S | | |
| CaO | 9901 | Total |
| H2O | | |
| NaCl | | |
| KCl | | |
| CaSO4 | | |
| Ca | | |
| CaS | | |
| ASH, Inerts (pph) | | |
| Total Solids (pph) | 9728 | |
| Total Flow (pph) | 9728 | |
| Total Flow (pps) | 2.70 | |
| Pressure (psia) | 600 | |
| Temperature (F) | 225 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| '.5 | | | | | 3/10/93 17:19 | 2 |
| | | | | | | 3 |
| | | | | | | 4 |
| | | 9e | | | 9 f | 5 |
| | Compressed Air@ | 0.82 A/C | | | Compressed Air | 6 |
| | | High Pressure Compressor | | | High Pressure Air Compressor | 7 |
| 0.560 | | Gasifier Top | | | Cyclone Fines Conveying | 8 |
| | lb/hr | lb-mol/hr | wt % | mol% | lb/hr | 9 |
| | | | | | | 10 |
| 0.00 | 0 | 0.00 | 0.00 | 0.00 | 0 | 11 |
| 0.00 | 0 | 0.00 | 0.00 | 0.00 | 0 | 12 |
| 0.03 | 5 | 0.01 | 0.05 | 0.03 | 0 | 13 |
| 1.02 | 61 | 0.18 | 0.64 | 1.02 | 0 | 14 |
| 0.00 | 0 | 0.00 | 0.00 | 0.00 | 0 | 15 |
| 0.00 | 0 | 0.00 | 0.00 | 0.00 | 0 | 16 |
| 0.00 | 0 | 0.00 | 0.00 | 0.00 | 0 | 17 |
| 0.00 | 0 | 0.00 | 0.00 | 0.00 | 0 | 18 |
| 77.28 | 7211 | 21.65 | 75.03 | 77.28 | 38 | 19 |
| 0.95 | 126 | 0.38 | 1.31 | 0.95 | 1 | 20 |
| 0.00 | 0 | 0.00 | 0.00 | 0.00 | 0 | 21 |
| 0.00 | 0 | 0.00 | 0.00 | 0.00 | 0 | 22 |
| 0.00 | 0 | 0.00 | 0.00 | 0.00 | 0 | 23 |
| 0.00 | 0 | 0.00 | 0.00 | 0.00 | 0 | 24 |
| 0.00 | 0 | 0.00 | 0.00 | 0.00 | 0 | 25 |
| 0.00 | 0 | 0.00 | 0.00 | 0.00 | 0 | 26 |
| 20.72 | 2208 | 6.63 | 22.98 | 20.72 | 11 | 27 |
| 0.00 | 0 | 0.00 | 0.00 | 0.00 | 0 | 28 |
| 0.00 | 0 | 0.00 | 0.00 | 0.00 | 0 | 29 |
| 0.00 | 0 | 0.00 | 0.00 | 0.00 | 0 | 30 |
| 0.00 | 0 | 0.00 | 0.00 | 0.00 | 0 | 31 |
| 0.00 | 0 | 0.00 | 0.00 | 0.00 | 0 | 32 |
| 00.00 | 9611 | 28.86 | 100.00 | 100.00 | 50 | 33 |
| | | | | | | 34 |
| | | | | | | 56 |
| | 1 | | | | | 57 |
| | 7 | | | | | 58 |
| | 2266 | | | | | 59 |
| | 7211 | | | | | 60 |
| | | | | | | 61 |
| | 9485 | Total | | | | 62 |
| | | | | | | 63 |
| | | | | | | 64 |
| | | | | | | 65 |
| | | | | | | 66 |
| | | | | | | 67 |
| | | | | | | 68 |
| | | | | | | 69 |
| | 9611 | | | | 0 | 70 |
| | 9611 | | | | 50 | 71 |
| | | | | | | 72 |
| | 2.67 | | | | 0.01 | 73 |
| | 600 | | | | 600 | 74 |
| | 225 | | | | 225 | 75 |

## DOE - GPIF - CRSS Coal Gasification Process (Kinetically Balanced)

NEPA Support Document, Mass Balance — *Using FW Data (High Steam - Low Btu) Case

| Stream No. | | 10 | 10a | | | |
|---|---|---|---|---|---|---|
| Identification | | Feed to Pyrolyzer | Products of Pyrolysis - Gases | | | |
| From | | Coal, Air, Steam | Pyrolyzer Section | | N in coal to NH3 in gas | |
| To | | Pyrolyzer Inlet | Upper Area of Gasifier | | 90.00% Conversion | |
| Gas | | lb/hr | lb/hr | lb-mol/hr | wt % | mol% |
| CO | 28.010 | 0 | 4859 | 173.48 | 13.29 | 12.52 |
| H2 | 2.016 | 0 | 264 | 130.74 | 0.72 | 9.43 |
| CO2 | 44.010 | 15 | 5741 | 130.45 | 15.70 | 9.41 |
| H2O | 18.015 | 197 | 1460 | 81.02 | 3.99 | 5.85 |
| CH4 | 16.042 | 0 | 256 | 15.96 | 0.70 | 1.15 |
| C2H6 | 30.068 | 0 | 0 | 0.00 | 0.00 | 0.00 |
| H2S | 34.076 | 0 | 113 | 3.33 | 0.31 | 0.24 |
| COS | 60.070 | 0 | | 0.00 | 0.00 | 0.00 |
| N2 | 28.013 | 23186 | 23274 | 830.84 | 63.66 | 59.96 |
| Ar | 39.948 | 406 | 442 | 11.06 | 1.21 | 0.80 |
| HCl | 36.461 | 0 | | 0.00 | 0.00 | 0.0C |
| HCN | 27.026 | 0 | | 0.00 | 0.00 | 0.0C |
| NH3 | 17.030 | 0 | 150 | 8.81 | 0.41 | 0.64 |
| CS2 | 76.131 | 0 | | 0.00 | 0.00 | 0.0C |
| SO2 | 64.059 | 0 | | 0.00 | 0.00 | 0.0C |
| NO | 30.006 | 0 | | 0.00 | 0.00 | 0.0C |
| O2 | 31.999 | 7101 | | 0.00 | 0.00 | 0.0C |
| NaCl | 58.497 | 0 | | 0.00 | 0.00 | 0.0C |
| KCl | 74.596 | 0 | | 0.00 | 0.00 | 0.0C |
| CaSO4 | 136.142 | 0 | | 0.00 | 0.00 | 0.0C |
| Ca(OH)2 | 74.095 | 0 | | 0.00 | 0.00 | 0.0C |
| Cl2 | 56.079 | 0 | | 0.00 | 0.00 | 0.0C |
| Total Gas (lb/hr) | | 30904 | 36715 | 1385.68 | 100.00 | 100.0C |
| C | 12.011 | 7612 | | 3846 | 3842 | -0.10% |
| H | 1.008 | 509 | | 520 | 525 | 0.79% |
| O | 16.000 | 8558 | | 8646 | 8711 | 0.75% |
| N | 14.007 | 23323 | | 23323 | 23398 | 0.32% |
| S | 32.060 | 107 | | 107 | 107 | 0.01% |
| CaO | 35.500 | 30498 | | | | |
| H2O | 18.016 | 100 | Carbon Utilized | | 50.55% | |
| NaCl | | | | | | |
| KCl | | | | | | |
| CaSO4 | | | | | | |
| Ca | | 332 | | | | |
| CaS | | | | | | |
| ASH, Inerts (pph) | | 1679 | | | | |
| Total Solids (pph) | | 11721 | 36715 | | | |
| Total Flow (pph) | | 42625 | 36715 | | | |
| Total Flow (pps) | | 11.84 | 10.20 | | | |
| Pressure (psia) | | 600 | 600 If No Heat Loss, Reduce Air Flow to Control Te | | | |
| Temperature (F) | | 150 | 1652 I.temp(F), calc. adiab. temp(F)= 3052 | | | |

Table 2.6 3/10/93 17:19

| 10b | | 10c | | | | 10d | | |
|---|---|---|---|---|---|---|---|---|
| Products of Pyrolysis - Solids | | Gases - Upper Portion of Gasifier | | | | Solids - Upper portion of Gasifier | | 6 |
| Pyrolyzer Section | | Pyrolyzer Section | | | | Pyrolyzer Section | Bed Voidage | 7 |
| Upper Area of Gasifier | | Fixed Bed | | | | Fixed Bed | 12.00% | 8 |
| lb/hr | wt % | lb/hr | lb-mol/hr | wt % | mol% | lb/hr | wt % | 9 |
| | | 4537 | 161.98 | 9.83 | 9.63 | | | 11 |
| | | 137 | 68.06 | 0.30 | 4.05 | | | 12 |
| | | 6955 | 158.02 | 15.06 | 9.40 | | | 13 |
| | | 3225 | 179.00 | 6.98 | 10.64 | | | 14 |
| | | 0 | 0.00 | 0.00 | 0.00 | | | 15 |
| | | | 0.00 | 0.00 | 0.00 | | | 16 |
| | | 113 | 3.33 | 0.25 | 0.20 | | | 17 |
| | | | 0.00 | 0.00 | 0.00 | | | 18 |
| | | 30485 | 1088.25 | 66.03 | 64.71 | | | 19 |
| | | 568 | 14.22 | 1.23 | 0.85 | | | 20 |
| | | | 0.00 | 0.00 | 0.00 | | | 21 |
| | | | 0.00 | 0.00 | 0.00 | | | 22 |
| | | 150 | 8.81 | 0.32 | 0.52 | | | 23 |
| | | | 0.00 | 0.00 | 0.00 | | | 24 |
| | | | 0.00 | 0.00 | 0.00 | | | 25 |
| | | | 0.00 | 0.00 | 0.00 | | | 26 |
| | | | 0.00 | 0.00 | 0.00 | | | 27 |
| | | | 0.00 | 0.00 | 0.00 | | | 28 |
| | | | 0.00 | 0.00 | 0.00 | | | 29 |
| | | | 0.00 | 0.00 | 0.00 | | | 30 |
| | | | 0.00 | 0.00 | 0.00 | | | 31 |
| | | | 0.00 | 0.00 | 0.00 | | | 32 |
| | | 46791 | 1681.66 | 100.00 | 100.00 | | | 33 |
| | | | | | | | | 34 |
| | | | | | | | | 56 |
| 3766 | 63.73 | | 3843 | 3843 | | 3766 | 69.17 | 57 |
| | CarbonRemaining | | 531 | 531 | | | | 58 |
| | 49.50% | | 10977 | 10512 | | | | 59 |
| | | | 30608 | 30608 | | | | 60 |
| | | | 107 | 107 | | | | 61 |
| 465 | | | | | | | | 62 |
| | | | | | | | | 63 |
| | | | | | | | | 64 |
| | | | | | | | | 65 |
| | | | | | | | | 66 |
| | | | | | | | | 67 |
| | | | | | | | | 68 |
| 1679 | 28.40 | | | | | 1679 | 30.83 | 69 |
| 5910 | 92.62 | 46791 | | | | 5445 | 100.00 | 70 |
| 5910 | | 46791 | | | | 5445 | | 71 |
| | | | | | | | | 72 |
| 1.64 | | 13.00 | | | | 1.51 | | 73 |
| 600 | | 600 | | | | 600 | | 74 |
| 1652 | | 2336 | | est. temp | 2336 | 2336 | | 75 |

## DOE - GPIF - CRSS Coal Gasification Process (Kinetically Balanced)

NEPA Support Document, Mass Balance *Using FW Data (High Steam - Low Btu) Case

| | | | | | |
|---|---|---|---|---|---|
| 4 | | | | | |
| 5 Stream No. | | | 10e | | |
| 6 Identification | | | Gases Evolved through Gasification | | |
| 7 From | | Down Through Fixed Char Bed | | | |
| 8 To | | | Slowed Endothermic Reaction Point | | |
| 9 Gas | Mol Wt | lb/hr | lb-mol/hr | wt % | mol% |
| 10 | | | | | |
| 11 CO | 28.010 | 9797 | 349.76 | 20.53 | 19. |
| 12 H2 | 2.016 | 280 | 138.95 | 0.59 | 7. |
| 13 CO2 | 44.010 | 4382 | 99.57 | 9.18 | 5. |
| 14 H2O | 18.015 | 1948 | 108.11 | 4.08 | 5. |
| 15 CH4 | 16.042 | 0 | 0.00 | 0.00 | 0. |
| 16 C2H6 | 30.068 | 0 | 0.00 | 0.00 | 0. |
| 17 H2S | 34.076 | 113 | 3.33 | 0.24 | 0. |
| 18 COS | 60.070 | 0 | 0.00 | 0.00 | 0. |
| 19 N2 | 28.013 | 30485 | 1088.25 | 63.88 | 60. |
| 20 Ar | 39.948 | 568 | 14.22 | 1.19 | 0. |
| 21 HCl | 36.461 | 0 | 0.00 | 0.00 | 0. |
| 22 HCN | 27.026 | 0 | 0.00 | 0.00 | 0. |
| 23 NH3 | 17.030 | 150 | 8.81 | 0.31 | 0. |
| 24 CS2 | 76.131 | 0 | 0.00 | 0.00 | 0 |
| 25 SO2 | 64.059 | 0 | 0.00 | 0.00 | 0 |
| 26 NO | 30.006 | 0 | 0.00 | 0.00 | 0 |
| 27 O2 | 31.999 | 0 | 0.00 | 0.00 | 0 |
| 28 NaCl | 58.497 | 0 | 0.00 | 0.00 | 0 |
| 29 KCl | 74.596 | 0 | 0.00 | 0.00 | 0 |
| 30 CaSO4 | 136.142 | 0 | 0.00 | 0.00 | 0. |
| 31 Ca(OH)2 | 74.095 | 0 | 0.00 | 0.00 | 0. |
| 32 CaO | 56.079 | 0 | 0.00 | 0.00 | 0. |
| 33 Total Gas (lb/hr) | | 47723 | 1810.99 | 100.00 | 100 |
| 34 | | | | | |
| 56 | | | | | |
| 57 C | 12.011 | | 5397 | 5397 | |
| 58 H | 1.008 | | 531 | 531 | |
| 59 O | 16.000 | | 10512 | 10512 | |
| 60 N | 14.007 | | 30608 | 30608 | |
| 61 S | 32.060 | | 107 | 107 | |
| 62 CL2 | 35.500 | | | | |
| 63 H2O | 18.016 | | | | |
| 64 ZnFe2O4 | | | | | |
| 65 ZnS | | | | | |
| 66 FeS | | | | | |
| 67 Fe2O3 | | | | | |
| 68 ZnO | | | | | |
| 69 ASH | | | | | |
| 70 Total Solids | | | | | |
| 71 Total Flow (pph) | | 48345 | | | |
| 72 | | | | | |
| 73 Total Flow (pps) | | 13.43 | | | |
| 74 Pressure (psia) | | 600 | | | |
| 75 Temperature (F) | | 1591 | | | |

Table 2.7 3/10/93 17:19

| | | | | | | | Row |
|---|---|---|---|---|---|---|---|
| | | | | | | | 3 |
| | | | | | | | 4 |
| | 101 | Uncomb | | 10g | Grate S/A 0.56 | | 5 |
| | Ash & Carbon | % of C | Hot Gas@ | | Overall A/C 3.92 | | 6 |
| | Gasifier | 29.06% | Lower Bed | | Overall S/C 0.46 | | 7 |
| | Above Grate | | Exit | | N2 in coal NH3 Conv. 0.0% | | 8 |
| | lb/hr | wt % | lb/hr | lb-mol/hr | wt % | mol % | 9 |
| | | | | | | | 10 |
| 31 | | | 3690 | 131.76 | 21.33 | 17.80 | 11 |
| 67 | | | 184 | 91.31 | 1.06 | 12.34 | 12 |
| 50 | | | 2284 | 51.89 | 13.20 | 7.01 | 13 |
| 97 | | | 3480 | 193.20 | 20.12 | 26.10 | 14 |
| 00 | | | 0 | 0.00 | 0.00 | 0.00 | 15 |
| 00 | | | 0 | 0.00 | 0.00 | 0.00 | 16 |
| 18 | | | 0 | 0.00 | 0.00 | 0.00 | 17 |
| 00 | | | 0 | 0.00 | 0.00 | 0.00 | 18 |
| 09 | | | 7527 | 268.71 | 43.52 | 36.30 | 19 |
| 79 | | | 132 | 3.30 | 0.76 | 0.45 | 20 |
| 00 | | | 0 | 0.00 | 0.00 | 0.00 | 21 |
| 00 | | | 0 | 0.00 | 0.00 | 0.00 | 22 |
| 19 | | | 0 | 0.00 | 0.00 | 0.00 | 23 |
| 00 | | | 0 | 0.00 | 0.00 | 0.00 | 24 |
| 00 | | | 0 | 0.00 | 0.00 | 0.00 | 25 |
| 00 | | | 0 | 0.00 | 0.00 | 0.00 | 26 |
| 00 | | | 0 | 0.00 | 0.00 | 0.00 | 27 |
| 00 | | | 0 | 0.00 | 0.00 | 0.00 | 28 |
| 0 | | | 0 | 0.00 | 0.00 | 0.00 | 29 |
| 0 | | | 0 | 0.00 | 0.00 | 0.00 | 30 |
| 0 | | | 0 | 0.00 | 0.00 | 0.00 | 31 |
| 0 | | | 0 | 0.00 | 0.00 | 0.00 | 32 |
| 0 | | | 16988 | 740.17 | 100.00 | 100.00 | 33 |
| | | | | | | | 34 |
| | | | | | | | 56 |
| | 2213 | 56.86 | | 2199 | 2206 | -0.30% | 57 |
| | | | | 574 | 574 | 0.00% | 58 |
| | | | | 6861 | 6860 | 0.02% | 59 |
| | 0 | 0.00 | | 7527 | 7527 | 0.00% | 60 |
| | 0 | 0.00 | | 0 | 0 | 0.00% | 61 |
| | | | | | | | 62 |
| | | | Sub-Totals | 17161 | 17166 | -0.03% | 63 |
| | | | | | | | 64 |
| | | | | Sum of | Sum of Gas | Mass | 65 |
| | | | | Streams | Const. | Unbalance | 66 |
| | | | | | balance check | | 67 |
| | | | | | | | 68 |
| | 1679 | 43.14 | 0 | | | 0.001 | 69 |
| | 3891 | 100.00 | | | | | 70 |
| | 3891 | | 16988 | | | | 71 |
| | | | | | | | 72 |
| | 1.08 | | 4.72 | | | | 73 |
| | 600 | | 600 | | | | 74 |
| | 1591 | | 1500 | | | | 75 |

# DOE - GPIF - CRSS Coal Gasification Process (Kinetically Balanced)

NEPA Support Document, Mass Balance — *Using FW Data (High Steam - Low Btu) Case

| Row | Stream No. | | 10h | | | |
|---|---|---|---|---|---|---|
| 6 | Identification | | Mixture of Gases from Upper Bed and Lower Bed | | | |
| 7 | From | | | Gasifier | | 86 scf/lb of c |
| 8 | To | | | Combustor | | |
| 9 | Gas | | lb/hr | lb-mol/hr | wt % | mo |
| 11 | CO | 28.010 | 13487 | 481.52 | 20.74 | |
| 12 | H2 | 2.016 | 464 | 230.26 | 0.71 | |
| 13 | CO2 | 44.010 | 6666 | 151.47 | 10.25 | |
| 14 | H2O | 18.016 | 5428 | 301.31 | 8.35 | |
| 15 | CH4 | 16.042 | 0 | 0.00 | 0.00 | |
| 16 | C2H6 | 30.068 | 0 | 0.00 | 0.00 | |
| 17 | H2S | 34.076 | 113 | 3.33 | 0.17 | |
| 18 | COS | 60.070 | 0 | 0.00 | 0.00 | |
| 19 | N2 | 28.013 | 38012 | 1356.96 | 58.46 | |
| 20 | Ar | 39.948 | 700 | 17.52 | 1.08 | |
| 21 | HCl | 36.461 | 0 | 0.00 | 0.00 | |
| 22 | HCN | 27.026 | 0 | 0.00 | 0.00 | |
| 23 | NH3 | 17.030 | 150 | 8.81 | 0.23 | |
| 24 | CS2 | 76.131 | 0 | 0.00 | 0.00 | |
| 25 | SO2 | 64.059 | 0 | 0.00 | 0.00 | |
| 26 | NO | 30.006 | 0 | 0.00 | 0.00 | |
| 27 | O2 | 31.999 | 0 | 0.00 | 0.00 | |
| 28 | NaCl | 58.497 | 0 | 0.00 | 0.00 | |
| 29 | KCl | 74.596 | 0 | 0.00 | 0.00 | |
| 30 | CaSO4 | 136.142 | 0 | 0.00 | 0.00 | |
| 31 | Ca(OH)2 | 74.095 | 0 | 0.00 | 0.00 | |
| 32 | Cl2 | 56.079 | 0 | 0.00 | 0.00 | |
| 33 | Total Gas (lb/hr) | | 65021 | 2551.16 | 100.00 | |
| 57 | C | 12.011 | | 7602 | 7602 | |
| 58 | H | 1.008 | | 1105 | 1105 | |
| 59 | O | 16.000 | | 17372 | 17372 | |
| 60 | N | 14.007 | | 38136 | 38136 | |
| 61 | S | 32.060 | | 107 | 107 | |
| 62 | CaO | 35.500 | | | | |
| 63 | H2O | 18.016 | Sub-Totals | 64321 | 64321 | |
| 64 | NaCl | | | | | |
| 65 | KCl | | | | | |
| 66 | CaSO4 | | | | | |
| 67 | Ca | | | | | |
| 68 | CaS | | | | | |
| 69 | ASH, Inerts (pph) | | 17 | | | |
| 70 | Total Solids (pph) | | 17 | | | |
| 71 | Total Flow (pph) | | 65333 | | | |
| 73 | Total Flow (pps) | | 18.15 | | | |
| 74 | Pressure (psia) | | 600 | | | |
| 75 | Temperature (F) | | 1568 | | | |

## Table 2.8

#########

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 2 |
| | | | | | | | | | 3 |
| | | | | | | | | | 4 |
| | 11a | | 11b | | 11c | | 11d | 11 | 5 |
| | Steam | @ H2O/coal | Steam @ H2O/coal | | Steam @ H2O/coal | | Steam | Total Steam | 6 |
| al | HRSG | 0.00000 | HRSG | 0.00 | HRSG | 0.46 | HRSG | HRSG | 7 |
| | Gasifier Top | S/C | Pyrolyzer | S/C | Grate | S/C | Ash Lock | GPIF | 8 |
| % | lb/hr | | lb/hr | | lb/hr | | lb/hr | lb/hr | 9 |
| | | | | | | | | | 10 |
| 18.87 | | | | | | | | | 11 |
| 9.03 | | | | | | | | | 12 |
| 5.94 | | | | | | | | | 13 |
| 11.81 | 0.00 | | 0 | | 5062 | | 169 | 5231 | 14 |
| 0.00 | | | | | | | | | 15 |
| 0.00 | | | | | | | | | 16 |
| 0.13 | | | | | | | | | 17 |
| 0.00 | | | | | | | | | 18 |
| 53.19 | | | | | | | | | 19 |
| 0.69 | | | | | | | | | 20 |
| 0.00 | | | | | | | | | 21 |
| 0.00 | | | | | | | | | 22 |
| 0.35 | | | | | | | | | 23 |
| 0.00 | | | | | | | | | 24 |
| 0.00 | | | | | | | | | 25 |
| 0.00 | | | | | | | | | 26 |
| 0.00 | | | | | | | | | 27 |
| 0.00 | | | | | | | | | 28 |
| 0.00 | | | | | | | | | 29 |
| 0.00 | | | | | | | | | 30 |
| 0.00 | | | | | | | | | 31 |
| 0.00 | | | | | | | | | 32 |
| 100.00 | 0.00 | | 0 | | 5062 | | 169 | 5231 | 33 |
| | | | | | | | | | 34 |
| | | | | | | | | | 56 |
| 0.00% | | | | | | | | | 57 |
| 0.00% | 0 | | 0 | | 566 | | | 566 | 58 |
| 0.00% | 0 | | 0 | | 4495 | | | 4495 | 59 |
| 0.00% | | | | | | | | | 60 |
| 0.00% | 0 | Total | 0 | Total | 5062 | Total | | 5062 | 61 |
| | | | | | | | | | 62 |
| 0.00% | | | | | | | | | 63 |
| | | | | | | | | | 64 |
| | | | | | | | | | 65 |
| | | | | | | | | | 66 |
| | | | | | | | | | 67 |
| | | | | | | | | | 68 |
| | | | | | | | | | 69 |
| | | | | | | | | 0 | 70 |
| | 0 | | 0 | | 5062 | | 169 | 5231 | 71 |
| | | | | | | | | | 72 |
| | 0.00 | | 0.00 | | 1.41 | | 0.05 | 1.45 | 73 |
| | 600 | | 600 | | 600 | | 600 | 600 | 74 |
| | 700 | | 486 | | 700 | | 700 | 700 | 75 |

# DOE - GPIF - CRSS Coal Gasification Process

| Row | | | | | | | |
|---|---|---|---|---|---|---|---|
| 3 | Mass & Energy Balance | | *Using FW Data (High Steam - Low Btu) Case | | | | |
| 4 | | | | | | | |
| 5 | Stream No. | | 12a | | 12b | | |
| 6 | Identification | | Water Spray | | Steam Injection | | |
| 7 | From | | Gasifier Outlet | | Gasifier Outlet | | |
| 8 | To | | Combustor/HGCU | | Combustor/HGCU | | |
| 9 | Gas | Mol Wt | lb/hr | wt % | lb/hr | wt % | lb/hr |
| 10 | | | | | | | |
| 11 | CO | 28.010 | | | | | 13487 |
| 12 | H2 | 2.016 | | | | | 464 |
| 13 | CO2 | 44.010 | | | | | 6666 |
| 14 | H2O | 18.015 | 2,900 | 100.00 | 0 | 100.00 | 8328 |
| 15 | CH4 | 16.042 | | | | | 0 |
| 16 | C2H6 | 30.068 | | | | | 0 |
| 17 | H2S | 34.076 | | | | | 113 |
| 18 | COS | 60.070 | | | | | 0 |
| 19 | N2 | 28.013 | | | | | 38012 |
| 20 | Ar | 39.948 | | | | | 700 |
| 21 | HCl | 36.461 | | | | | 0 |
| 22 | HCN | 27.026 | | | | | 0 |
| 23 | NH3 | 17.030 | | | | | 150 |
| 24 | CS2 | 76.131 | | | | | 0 |
| 25 | SO2 | 64.059 | | | | | 0 |
| 26 | NO | 30.006 | | | | | 0 |
| 27 | O2 | 31.999 | | | | | 0 |
| 28 | NaCl | 58.497 | | | | | 0 |
| 29 | KCl | 74.596 | | | | | 0 |
| 30 | CaSO4 | 136.142 | | | | | 0 |
| 31 | Ca(OH)2 | 74.095 | | | | | 0 |
| 32 | CaO | 56.079 | | | | | 0 |
| 33 | Total Gas (lb/hr) | | 2,900 | 100.00 | 0 | 100.00 | 67921 |
| 34 | | | | | | | |
| 56 | | | | | | | |
| 57 | C | 12.011 | | | | | |
| 58 | H | 1.008 | | | | | |
| 59 | O | 16.000 | | | | | |
| 60 | N | 14.007 | | | | | |
| 61 | S | 32.060 | | | | | |
| 62 | Cl2 | 35.500 | | | | | |
| 63 | H2O | 18.016 | | | | | |
| 64 | NaCl | 58.497 | | | | | |
| 65 | KCl | 74.596 | | | | | |
| 66 | CaSO4 | 136.142 | | | | | |
| 67 | Ca | 40.080 | | | | | |
| 68 | CaO | 56.079 | | | | | |
| 69 | ASH, Inerts (pph) | | | | | | |
| 70 | Total Solids (pph) | | | | | | |
| 71 | Total Flow (pph) | | 2,900 | | 0 | | 68233 |
| 72 | | | | | | | |
| 73 | Total Flow (pps) | | 0.81 | | 0.00 | | 18.95 |
| 74 | Pressure (psia) | | 600 | | 600 | | 600 |
| 75 | Temperature (F) | | 80 | | 700 | | 1350 |

## Table 2.9

3/10/93 17:19 | 2 |

| 12 Raw Gas Outlet Gasifier Outlet Combustor (Phase I)/HGCU (Phase II) b-mol/hr | wt % | mol% | 13 = 13a & 13b Nitrogen Inerting Nitrogen Tanks PyGas™ Gasifier & Locks lb/hr | 14 Ash & Carbon Gasifier Ash Removal lb/hr | Uncomb % of C 0.20% wt % | 14a Ash Lock Hopper Oxidation Reactor lb/hr | Row |
|---|---|---|---|---|---|---|---|
| | | | | | | | 3 |
| | | | | | | | 4 |
| | | | | | | | 5–9 |
| | | | | | | | 10 |
| 481.52 | 19.86 | 17.75 | | | | | 11 |
| 230.26 | 0.68 | 8.49 | | | | | 12 |
| 151.47 | 9.81 | 5.58 | | | | | 13 |
| 462.30 | 12.26 | 17.05 | | | | | 14 |
| 0.00 | 0.00 | 0.00 | | | | | 15 |
| 0.00 | 0.00 | 0.00 | | | | | 16 |
| 3.33 | 0.17 | 0.12 | | | | | 17 |
| 0.00 | 0.00 | 0.00 | | | | | 18 |
| 1356.96 | 55.97 | 50.03 | | | | | 19 |
| 17.52 | 1.03 | 0.65 | | | | | 20 |
| 0.00 | 0.00 | 0.00 | | | | | 21 |
| 0.00 | 0.00 | 0.00 | | | | | 22 |
| 8.81 | 0.22 | 0.32 | | | | | 23 |
| 0.00 | 0.00 | 0.00 | | | | | 24 |
| 0.00 | 0.00 | 0.00 | | | | | 25 |
| 0.00 | 0.00 | 0.00 | | | | | 26 |
| 0.00 | 0.00 | 0.00 | | | | | 27 |
| 0.00 | 0.00 | 0.00 | | | | | 28 |
| 0.00 | 0.00 | 0.00 | | | | | 29 |
| 0.00 | 0.00 | 0.00 | | | | | 30 |
| 0.00 | 0.00 | 0.00 | | | | | 31 |
| 0.00 | 0.00 | 0.00 | | | | | 32 |
| 2712 | 100 | 100 | | | | | 33 |
| | | | | | | | 34 |
| | | | | | | | 56 |
| | | | | 15 | 0.88 | 15 | 57 |
| | | | | | | | 58 |
| | | | | | | 89 | 59 |
| | | | | 0 | 0.00 | | 60 |
| | | | | 0 | 0.00 | 60 | 61 |
| | | | | | | | 62 |
| | | | | | | | 63 |
| | | | | | | | 64 |
| | | | | | | | 65 |
| | | | | | | 1218 | 66 |
| | | | | | | 222 | 67 |
| | | | | | | | 68 |
| | | | | 1679 | 99.12 | 460 | 69 |
| | | | | 1693 | 100.00 | 2064 | 70 |
| | | | | 1693 | | 2064 | 71 |
| | | | | | | | 72 |
| | | | | 0.47 | | 0.57 | 73 |
| | | | | 15 | | 14.7 | 74 |
| | | | | 700 | | 90 | 75 |

## DOE - GPIF - CRSS Coal Gasification Process

Mass & Energy Balance — *Using FW Data (High Steam - Low Btu) Case

| Row | | Mol Wt | | | |
|---|---|---|---|---|---|
| 5 | Stream No. | | 15 | 15a | 15b |
| 6 | Identification | | Make-up Water | Overflow | Thickened S |
| 7 | From | | Service Water | Oxidation Reactor | Settling Ta |
| 8 | To | | Oxidation Reactor | Settling Tank | Drum Filt |
| 9 | Gas | Mol Wt | lb/hr | lb/hr | lb/hr |
| 11 | CO | 28.01 | | | |
| 12 | H2 | 2.016 | | | |
| 13 | CO2 | 44.01 | | | |
| 14 | H2O | 18.015 | | | |
| 15 | CH4 | 16.042 | | | |
| 16 | C2H6 | 30.068 | | | |
| 17 | H2S | 34.076 | | | |
| 18 | COS | 60.07 | | | |
| 19 | N2 | 28.013 | | | |
| 20 | Ar | 39.948 | | | |
| 21 | HCl | 36.461 | | | |
| 22 | HCN | 27.026 | | | |
| 23 | NH3 | 17.03 | | | |
| 24 | CS2 | 76.131 | | | |
| 25 | SO2 | 64.059 | | | |
| 26 | NO | 30.006 | | | |
| 27 | O2 | 31.999 | | | |
| 28 | NaCl | 58.497 | | | |
| 29 | KCl | 74.596 | | | |
| 30 | CaSO4 | 136.1416 | | | |
| 31 | Ca(OH)2 | 74.09474 | | | |
| 32 | Cl2 | 35.5 | | | |
| 33 | Total Gas (lb/hr) | | | | |
| 57 | C | 12.0105 | | | |
| 58 | H | 1.008 | | | |
| 59 | O | 15.9995 | | | |
| 60 | N | 14.0065 | | | |
| 61 | S | 32.06 | | | |
| 62 | CaO | 56.0794 | | | |
| 63 | H2O | 18.0155 | 856 | 12835 | |
| 64 | NaCl | 58.497 | | | |
| 65 | KCl | 74.596 | | | |
| 66 | CaSO4 | 136.1416 | | 1827 | |
| 67 | Ca | 40.08 | | | |
| 68 | CaS | 72.14 | | | |
| 69 | ASH, Inerts (pph) | | | 690 | |
| 70 | Total Solids (pph) | | 856 | 15353 | |
| 71 | Total Flow (pph) | | 856 | 15353 | |
| 73 | Total Flow (pps) | | 0.24 | 4.26 | |
| 74 | Pressure (psia) | | 14.7 | 14.7 | |
| 75 | Temperature (F) | | 80 | 90 | |

Table 2.10 3/10/93 17:19

| ide k | 15c Overflow Settling Tank Oxidation Reactor lb/hr | 15d Vent Oxidation Reactor HRSG Burner lb/hr | 16 Air Oxidation Air Blower Oxidation Reactor lb/hr | 17 Drum Filter Vent Vacuum Pump Atmosphere lb/hr | 18 Gypsum & Ash Drum Filter Ft Martin Land Fill lb/hr | |
|---|---|---|---|---|---|---|
| | | 0.43 | 0.43 | 0.23 | | 13 |
| | | 446 | 5.84 | 9.41 | | 14 |
| | | 688.66 | 688.66 | 358.85 | | 19 |
| | | 12.06 | 12.06 | 6.28 | | 20 |
| | | 42.18 | 210.92 | 109.91 | | 27 |
| | | 1189 | 918 | 484.68 | | 33 |
| | | | | | 89 | 59 |
| 3851 | 8985 | | | | 406 | 63 |
| 1845 | 163 | | | | 1354 | 66 |
| | | | | | 222 | 67 |
| 621 | 69 | | | | 460 | 69 |
| 6117 | 9236 | 1189 | 918 | 485 | 2531 | 70 |
| 6117 | 9236 | 1189 | 918 | 485 | 2531 | 71 |
| 2 | 2.57 | 0.330 | 0.25 | 0.135 | 0.70 | 73 |
| 14.7 | 14.7 | 14.7 | 15 | 14.7 | 14.7 | 74 |
| 90 | 90 | 90 | 90 | 90 | 90 | 75 |

| 2 | DOE - GPIF - CRSS Coal Gasification Process (Kinetically Balanced) Table 2.11 | | | | | | |
|---|---|---|---|---|---|---|---|
| 3 | *Using FW Data (High Steam - Low Btu) Case | | | | | | |
| 4 | | | | | | | |
| 5 | Stream No. | | 19 | 19a | 20 | 20a | 20b |
| 6 | Identification | | Condensate | Steam | Feedwater | Feedwater | Feedwater |
| 7 | From | | R Martin | HRSG | Water Treatment | Water Treatment | Watcr Treatm |
| 8 | To | | GPIF | R Martin | GPIF | HRSG | Start-up Bol |
| 9 | Gas | Mol Wt | lb/hr | lb/hr | lb/hr | lb/hr | lb/hr |
| 10 | | | | | | | |
| 11 | CO | 28.010 | | | | | |
| 12 | H2 | 2.016 | | | | | |
| 13 | CO2 | 44.010 | | | | | |
| 14 | H2O | 18.015 | | 14507 | | | |
| 15 | CH4 | 16.042 | | | | | |
| 16 | C2H6 | 30.068 | | | | | |
| 17 | H2S | 34.076 | | | | | |
| 18 | COS | 60.070 | | | | | |
| 19 | N2 | 28.013 | | | | | |
| 20 | Ar | 39.948 | | | | | |
| 21 | HCl | 36.461 | | | | | |
| 22 | HCN | 27.026 | | | | | |
| 23 | NH3 | 17.030 | | | | | |
| 24 | CS2 | 76.131 | | | | | |
| 25 | SO2 | 64.059 | | | | | |
| 26 | NO | 30.006 | | | | | |
| 27 | O2 | 31.999 | | | | | |
| 28 | NaCl | 58.497 | | | | | |
| 29 | KCl | 74.596 | | | | | |
| 30 | CaSO4 | 136.142 | | | | | |
| 31 | Ca(OH)2 | 74.095 | | | | | |
| 32 | Cl2 | 35.500 | | | | | |
| 33 | Total Gas (lb/hr) | | | 14507 | | | |
| 34 | | | | | | | |
| 56 | | | | | | | |
| 57 | C | 12.011 | | | | | |
| 58 | H | 1.008 | | | | | |
| 59 | O | 16.000 | | | | | |
| 60 | N | 14.007 | | | | | |
| 61 | S | 32.060 | | | | | |
| 62 | CaO | 56.079 | | | | | |
| 63 | H2O | 18.016 | 84157 | | 10000 | 10000 | 10 |
| 64 | NaCl | 58.497 | | | | | |
| 65 | KCl | 74.596 | | | | | |
| 66 | CaSO4 | 136.142 | | | | | |
| 67 | Ca | 40.080 | | | | | |
| 68 | CaS | 72.140 | | | | | |
| 69 | ASH, Inerts (pph) | | | | | | |
| 70 | Total Solids (pph) | | | | | | |
| 71 | Total Flow (pph) | | 84157 | 14507 | 10000 | 10000 | 10 |
| 72 | | | | | | | |
| 73 | Total Flow (pps) | | 23 | 4 | 3 | 3 | |
| 74 | Pressure (psia) | | 200 | 600 | 600 | 600 | |
| 75 | Temperature (F) | | 382 | 700 | 80 | 80 | |

3/10/93 17:19

NEPA Support Document, Mass Balance

| ent er | 21 Flue Gas GPIF Ft Martin lb/hr | lb-mol/hr | wt % | mol% | Flue Gas GPIF spec vol scfm | 29 Emergency Flare Gasifier Atmosphere lb/hr |
|---|---|---|---|---|---|---|
| | 20.10 | 0.7 | 0.01 | 0.01 | 5 | 13487 |
| | 0.00 | 0.0 | 0.00 | 0.00 | 0 | 464 |
| | 31609 | 718.2 | 17.49 | 11.47 | 4503 | 6666 |
| | 14,953 | 830.0 | 8.27 | 13.26 | 6679 | 5428 |
| | | 0.0 | 0.00 | 0.00 | 0 | |
| | | 0.0 | 0.00 | 0.00 | 0 | |
| | 1 | 0.0 | 0.00 | 0.00 | 0 | 113 |
| | | 0.0 | 0.00 | 0.00 | 0 | |
| | 120489 | 4301.2 | 66.66 | 68.70 | 26996 | 36012 |
| | 2144 | 53.7 | 1.19 | 0.86 | 1369 | 700 |
| | | 0.0 | 0.00 | 0.00 | 0 | |
| | | 0.0 | 0.00 | 0.00 | 0 | |
| | | 0.0 | 0.00 | 0.00 | 0 | 150 |
| | | 0.0 | 0.00 | 0.00 | 0 | |
| | 227 | 3.6 | 0.13 | 0.06 | 22 | |
| | 23 | 0.8 | 0.01 | 0.01 | 5 | |
| | 11297 | 353.1 | 6.25 | 5.64 | 2225 | |
| | | 0.0 | 0.00 | 0.00 | 0 | |
| | | 0.0 | 0.00 | 0.00 | 0 | |
| | | 0.0 | 0.00 | 0.00 | 0 | |
| | | 0.0 | 0.00 | 0.00 | 0 | |
| | | 0.0 | 0.00 | 0.00 | 0 | |
| | 180744 | 6261 | 100 | 100 | 41804 | 65021 |

| | Criteria Pollutants Ft. Martin Station Stack (Normal) lb/hr | Criteria Pollutants Ft. Martin Station Stack (GPIF Operating) lb/hr | Criteria Pollutants Ft. Martin Station Change Due To GPIF % |
|---|---|---|---|
| SO2 | 24,880 | 24,640 | -0.96% |
| NOx | 5,443 | 5,442 | -0.0002% |
| Particulates | 453 | 624 | 37.89% |
| | | No.2 Oil Fired Startup Boiler | |
| SO2 | | 0.5 | |
| NOx | | 3 | |
| Particulates | | 1 | |

| | Criteria Pollutants Ft. Martin Station Stack (Normal) lb/hr | Criteria Pollutants Ft. Martin Station Stack (GPIF Operating) lb/hr | Criteria Pollutants Ft. Martin Station Change Due To GPIF % |
|---|---|---|---|
| SO2 | 24,976 | 24,735 | -0.96% |
| NOx | 9,366 | 9,366 | -0.0002% |
| Particulates | 454 | -685 | 37.89% |
| | | No.2 Oil Fired Startup Boiler | |
| SO2 | | 0.6 | |
| NOx | | 4 | |
| Particulates | | 1 | |

| | | |
|---|---|---|
| 00 | | |
| | | 17 |
| | | 17 |
| 00 | 180744 | 65333 |
| 3 | 50 | 18 |
| 00 | 14.7 | 600 |
| 80 | 275 | 1568 |

| Row | QN / QO / QP | QQ | QR | QS |
|---|---|---|---|---|
| 1 | | | | |
| 2 | Mass & Energy Balance | | DOE - GPIF - CRSS Co. Gasification | |
| 3 | Estimated Trace Metals Emissions for NEPA Report | | Typical Expected Case | |
| 4 | | | | 18 |
| 5 | Identification | Trace Elements | Trace Elements | Trace Elemen |
| 6 | From | Normal R. Martin Ash | Normal R. Martin Flue Gas | GPIF Ash |
| 7 | To | R. Martin Ash Landfill | R. Martin Stack | Ft. Martin Ash L |
| 8 | | lb/hr | lb/hr | lb/hr |
| 9 | | | | |
| 10 | NOTE : THE VALUES ON THIS PAGE HAVE BEEN CARRIED OUT TO SUFFICIENT SIGNIFICANT FIGURES | | | |
| 11 | THEY ARE NOT REFLECTIVE OF EXACTING MEASUREMENTS, BUT DO REPRESENT "TYPICAL" | | | |
| 12 | | | | |
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |
| 16 | Antimony | 0.7421 | 0.0042 | 0. |
| 17 | Arsenic | 14.6723 | 0.2557 | 0. |
| 18 | Barium | 105.3615 | 0.3785 | 2. |
| 19 | Beryllium | 1.362 | 0.0064 | 0. |
| 20 | Boron | 27.2296 | 3.0518 | 0. |
| 21 | Cadmium | 0.2905 | 0.0019 | 0. |
| 22 | Chromium | 9.2404 | 0.0896 | 0. |
| 23 | Cobalt | 3.7805 | 0.0136 | 0. |
| 24 | Copper | 9.894 | 0.0581 | 0. |
| 25 | Lead | 6.759 | 0.0830 | 0. |
| 26 | Manganese | 26.625 | 0.1210 | 0. |
| 27 | Mercury | 0.0125 | 0.1863 | 0. |
| 28 | Molybdenum | 2.0337 | 0.0190 | 0. |
| 29 | Nickel | 3.6515 | 0.0565 | 0. |
| 30 | Selenium | 1.5642 | 0.3472 | 0. |
| 31 | Vanadium | 13.5963 | 0.0877 | 0. |
| 32 | Uranium | 1.3015 | 0.0047 | 0. |
| 33 | Thorium | 1.9833 | 0.0071 | 0. |
| 34 | TOTAL TRACE METALS | 235.10 | 4.77 | |
| 35 | | | | |
| 36 | Normal Criteria Particulates | 92729 | 331 | [illegible] |
| 37 | (Ash, Limestone, Carbon Loss) | | | |
| 38 | | | | |
| 39 | TOTALS (Particulates & Trace Metals) | 92964 | 336 | [illegible] |

| | | | | |
|---|---|---|---|---|
| 40 | Estimated Trace Metals Emissions for NEPA Report | | | Worst Expected C |
| 41 | Stream No. | | | |
| 42 | Identification | Trace Elements | Trace Elements | Trace Element |
| 43 | From | Normal R. Martin Ash | Normal R. Martin Flue Gas | GPIF Ash |
| 44 | To | R. Martin Ash Landfill | R. Martin Stack | Ft. Martin Ash La |
| 45 | | lb/hr | lb/hr | lb/hr |
| 46 | | | | |
| 47 | | | | |
| 48 | | | | |
| 49 | | | | |
| 50 | | | | |
| 51 | | | | |
| 52 | | | | |
| 53 | Antimony | 0.7421 | 0.0042 | 0.0 |
| 54 | Arsenic | 14.6723 | 0.2557 | 0.2 |
| 55 | Barium | 105.3615 | 0.3785 | 2.0 |
| 56 | Beryllium | 1.3620 | 0.0064 | 0.0 |
| 57 | Boron | 27.2296 | 3.0518 | 0.6 |
| 58 | Cadmium | 0.2905 | 0.0019 | 0.0 |
| 59 | Chromium | 9.2404 | 0.0896 | 0.1 |
| 60 | Cobalt | 3.7805 | 0.0136 | 0.0 |
| 61 | Copper | 9.8940 | 0.0581 | 0.1 |
| 62 | Lead | 6.7590 | 0.0830 | 0.1 |
| 63 | Manganese | 26.6250 | 0.1210 | 0.5 |
| 64 | Mercury | 0.0125 | 0.1863 | 0.0 |
| 65 | Molybdenum | 2.0337 | 0.0190 | 0.0 |
| 66 | Nickel | 8.6515 | 0.0565 | 0.1 |
| 67 | Selenium | 1.5642 | 0.3472 | 0.0 |
| 68 | Vanadium | 13.5963 | 0.0877 | 0.2 |
| 69 | Uranium | 1.3015 | 0.0047 | 0.0 |
| 70 | Thorium | 1.9833 | 0.0071 | 0.0 |
| 71 | TOTAL TRACE METALS | 235.10 | 4.77 | 4 |
| 72 | | | | |
| 73 | Normal Criteria Particulates | 92729 | 331 | 25 |
| 74 | (Ash, Limestone, Carbon Loss) | | | |
| 75 | | | | |
| 76 | TOTALS (Particulates & Trace Metals) | 92964 | 336 | 25 |

| | GT | GU | GV | GW | GX | GY | GZ |
|---|---|---|---|---|---|---|---|
| Process | | Table 2.12 | | 3/10/93 16:43 | | | 2 |
| | | | | | | | 3 |
| | 21 | | | | | | 4 |
| ls | Trace Elements | Trace Elements | Trace Elements | Trace Elements | Trace Elements | | 5 |
| | GPIF Flue Gas | Combined Ash | Combined Flue Gas | Change Due To GPIF | Change Due To GPIF | | 6 |
| ındfill | R. Martin Stack | R. Martin Ash Landfill | R. Martin Stack | R. Martin Ash Landfill | R. Martin Stack | | 7 |
| | lb/hr | lb/hr | lb/hr | % | % | | 8 |
| | | | | | | | 9 |
| TO ARITHMETICALLY COMPUTE. | | | | | | | 10 |
| VALUES BASED ON RELEVENT PUBLICATIONS IN THE LITERATURE. | | | | | | | 11 |
| | | | | | | | 12 |
| | | | | | | | 13 |
| | | | | | | | 14 |
| | | | | | | | 15 |
| 0260 | 0.000043 | 0.75378 | 0.00416 | 1.574 | -0.905 | | 16 |
| 2900 | 0.001220 | 14.67923 | 0.25199 | 0.047 | -1.452 | | 17 |
| 0400 | 0.00051 | 105.36880 | 0.37171 | 0.007 | -1.795 | | 18 |
| 0270 | 0.000012 | 1.36272 | 0.00629 | 0.053 | -1.742 | | 19 |
| 3220 | 0.00815 | 27.32627 | 3.00107 | 0.355 | -1.662 | | 20 |
| 0062 | 0.0000080 | 0.29112 | 0.00187 | 0.212 | -1.508 | | 21 |
| 1810 | 0.000204 | 9.24313 | 0.08808 | 0.030 | -1.702 | | 22 |
| 0740 | 0.000020 | 3.78156 | 0.01336 | 0.028 | -1.782 | | 23 |
| 1930 | 0.000114 | 9.90412 | 0.05709 | 0.102 | -1.733 | | 24 |
| 1340 | 0.000237 | 6.76260 | 0.08164 | 0.053 | -1.644 | | 25 |
| 5530 | 0.000176 | 26.66433 | 0.11884 | 0.148 | -1.784 | | 26 |
| 0011 | 0.000901 | 0.01336 | 0.18361 | 6.871 | -1.446 | | 27 |
| 0450 | 0.000037 | 2.03946 | 0.01867 | 0.283 | -1.735 | | 28 |
| 680 | 0.000128 | 8.65259 | 0.05554 | 0.013 | -1.703 | | 29 |
| 0335 | 0.000779 | 1.56882 | 0.34128 | 0.296 | -1.705 | | 30 |
| 2730 | 0.000166 | 13.60699 | 0.08617 | 0.079 | -1.740 | | 31 |
| 0273 | 0.0000050 | 1.30369 | 0.00461 | 0.168 | -1.823 | | 32 |
| 0390 | 0.000010 | 1.98404 | 0.00697 | 0.037 | -1.788 | | 33 |
| 1.73 | 0.01 | 235.31 | 4.69 | 0.009 | -1.795 | | 34 |
| | | | | | | | 35 |
| 526 | 0.437 | 92557 | 325 | | | | 36 |
| | | | | | | | 37 |
| | | | | | | | 38 |
| 531 | 0.45 | 92792.48 | 329.97 | 0.58 | -1.795 | | 39 |

| | GT | GU | GV | GW | GX | GY | GZ |
|---|---|---|---|---|---|---|---|
| se | | | | | | | 40 |
| | | | | | | | 41 |
| | Trace Elements | Trace Elements | Trace Elements | Trace Elements | Trace Elements | | 42 |
| | GPIF Flue Gas | Combined Ash | Combined Flue Gas | Change Due To GPIF | Change Due To GPIF | | 43 |
| ıdfill | R. Martin Stack | R. Martin Ash Landfill | R. Martin Stack | R. Martin Ash Landfill | R. Martin Stack | | 44 |
| | lb/hr | lb/hr | lb/hr | % | % | | 45 |
| | | | | | | | 46 |
| | | | | | | | 47 |
| | | | | | | | 48 |
| | | | | | | | 49 |
| | | | | | | | 50 |
| | | | | | | | 51 |
| | | | | | | | 52 |
| 260 | 0.000043 | 0.75665 | 0.00418 | 1.96 | -0.52 | | 53 |
| 900 | 0.001220 | 14.73585 | 0.25297 | 0.43 | -1.07 | | 54 |
| 100 | 0.000510 | 105.77534 | 0.37317 | 0.39 | -1.41 | | 55 |
| 270 | 0.000012 | 1.36798 | 0.00631 | 0.44 | -1.36 | | 56 |
| 220 | 0.008150 | 27.43134 | 3.01285 | 0.74 | -1.28 | | 57 |
| 062 | 0.0000080 | 0.29224 | 0.00188 | 0.60 | -1.12 | | 58 |
| 110 | 0.000204 | 9.27878 | 0.08842 | 0.42 | -1.32 | | 59 |
| 740 | 0.000020 | 3.79615 | 0.01341 | 0.41 | -1.40 | | 60 |
| 930 | 0.000114 | 9.93430 | 0.05732 | 0.41 | -1.35 | | 61 |
| 140 | 0.000237 | 6.78868 | 0.08196 | 0.44 | -1.26 | | 62 |
| 130 | 0.000176 | 26.76707 | 0.11931 | 0.53 | -1.40 | | 63 |
| 11 | 0.000901 | 0.01341 | 0.18433 | 7.26 | -1.06 | | 64 |
| 50 | 0.000037 | 2.04731 | 0.01874 | 0.67 | -1.35 | | 65 |
| 80 | 0.000128 | 8.68597 | 0.05576 | 0.40 | -1.32 | | 66 |
| 35 | 0.000779 | 1.57356 | 0.34262 | 0.60 | -1.32 | | 67 |
| 30 | 0.000166 | 13.65945 | 0.08651 | 0.46 | -1.35 | | 68 |
| 73 | 0.0000050 | 1.30871 | 0.00463 | 0.55 | -1.44 | | 69 |
| 90 | 0.000010 | 1.99169 | 0.00700 | 0.42 | -1.40 | | 70 |
| 73 | 0.01 | 236.20 | 4.71 | 1.23 | -1.41 | | 71 |
| | | | | | | | 72 |
| 26 | 0.437 | 93867 | 327 | | | | 73 |
| | | | | | | | 74 |
| | | | | | | | 75 |
| 31 | 0.45 | 94103.19 | 331.26 | 0.95 | -1.41 | | 76 |

## DOE - GPIF - CRSS Coal Gasification Process, Phase II, Hot Gas Cleanup Unit (HGCU)

NEPA Support Document, Mass Balance *Using FW Data (High Steam - Low Btu) Case

| Stream No. | | 22 | | 23 | 24 |
|---|---|---|---|---|---|
| Identification | | Hot Raw Coal Gas | Hot Raw Coal Gas | Zinc Titanate (ZN4) | Solid Waste |
| From | | PyGas™ | PyGas™ | (or Zinc Ferrite) Makeup | HGCU Cyclon |
| To | | HGCU Absorber | spec vol | HGCU | Disposal |
| Gas | | lb/hr | scfm | lb/hr | lb/hr |
| CO | 28.010 | 13487 | 3036 | | |
| H2 | 2.016 | 464 | 1452 | | |
| CO2 | 44.010 | 6666 | 950 | | |
| H2O | 18.015 | 8328 | 3720 | | |
| CH4 | 16.042 | 0 | 0 | | |
| C2H6 | 30.068 | 0 | 0 | | |
| H2S | 34.076 | 113 | 21 | | |
| COS | 60.070 | | 0 | | |
| N2 | 28.013 | 38012 | 8517 | | |
| Ar | 39.948 | 700 | 447 | | |
| HCl | 36.461 | | 0 | | |
| HCN | 27.026 | | 0 | | |
| NH3 | 17.030 | 150 | 0 | | |
| CS2 | 76.131 | | 0 | | |
| SO2 | 64.059 | | 0 | | |
| NO | 30.006 | | 0 | | |
| O2 | 31.999 | | 0 | | |
| NaCl | 58.497 | | 0 | | |
| KCl | 74.596 | | 0 | | |
| CaSO4 | 136.142 | | 0 | | |
| Ca(OH)2 | 74.095 | | 0 | | |
| Cl2 | 35.500 | | 0 | | |
| Total Gas (lb/hr) | | 67921 | 18142 | | |
| C | 12.011 | 7602 | | | |
| H | 1.008 | 1430 | | | |
| O | 16.000 | 19947 | | | |
| N | 14.007 | 38836 | | | |
| S | 32.060 | 107 | | | |
| CaO | 56.079 | ----------------- | | | |
| H2O | 18.016 | 67922 | | | |
| Zinc Titanate or Zinc Ferrite | | ----------------- | | 68 | 6 |
| KCl | 74.596 | | | | |
| CaSO4 | 136.142 | | | | |
| Ca | 40.080 | | | | |
| CaS | 72.140 | | | | |
| ASH, Inerts (pph) | | 311 | | | |
| Total Solids (pph) | | 311 | | 68 | 6 |
| Total Flow (pph) | | 68233 | | 68 | 6 |
| Total Flow (pps) | | 19 | | 0.02 | 0.0 |
| Pressure (psia) | | 600 | | 14.7 | 14. |
| Temperature (F) | | 1350 | | 80 | 135 |

Table 2.13 3/10/93 17:19

| 25 | 26 | 27 @ SO2vol= 1% | | 28 | | | | Row |
|---|---|---|---|---|---|---|---|---|
| Steam | Air | Regeneration Gas | | Desulfurized Gas | | Desulfurized Gas | | 6 |
| HRSG | Compressor Dryers : | Regenerator | | HGCU Absorber | | HGCU Absorber | | 7 |
| HGCU | HGCU Regenerator : | HRSG | spec vol | HRSG | | spec vol | | 8 |
| lb/hr | lb/hr | lb/hr | scfm | lb/hr | lb-mol/hr | scfm | mol% | 9 |
| | | | 0 | 13494 | 481.76 | 3037 | 17.76 | 11 |
| | | | 0 | 464 | 230.26 | 1452 | 8.49 | 12 |
| | 3 | 3 | 0 | 6666 | 151.47 | 950 | 5.58 | 13 |
| 0 | 41 | 41 | 0.7 | 8328 | 462.30 | 3720 | 17.04 | 14 |
| | | | 0 | | 0.00 | 0 | 0.00 | 15 |
| | | | 0 | | 0.00 | 0 | 0.00 | 16 |
| | | | 0 | 1 | 0.03 | 0 | 0.00 | 17 |
| | | | 0 | | 0.00 | 0 | 0.00 | 18 |
| | 4865 | 4865 | 1090 | 38012 | 1356.96 | 8517 | 50.03 | 19 |
| | 85 | 85 | 64 | 700 | 17.52 | 447 | 0.65 | 20 |
| | | | 0 | | 0.00 | 0 | 0.00 | 21 |
| | | | 0 | | 0.00 | 0 | 0.00 | 22 |
| | | | 0 | 150 | 8.81 | 0 | 0.32 | 23 |
| | | | 0 | | 0.00 | 0 | 0.00 | 24 |
| | | 213 | 20 | | 0.00 | 0 | 0.00 | 25 |
| | | | 0 | | 0.00 | 0 | 0.00 | 26 |
| | 1490 | 1384 | 273 | 107 | 3.33 | 21 | 0.12 | 27 |
| | | | 0 | | 0.00 | 0 | 0.00 | 28 |
| | | | 0 | | 0.00 | 0 | 0.00 | 29 |
| | | | 0 | | 0.00 | 0 | 0.00 | 30 |
| | | | 0 | | 0.00 | 0 | 0.00 | 31 |
| | | | 0 | | 0.00 | 0 | 0.00 | 32 |
| 0 | 6485 | 6591 | 1438 | 67923 | 2712 | 18144 | 100 | 33 |
| 0 | 1 | 1 | | 7605 | | 7602 | -0.04% | 57 |
| 0 | 5 | 5 | | 1423 | | 1430 | 0.46% | 58 |
| 0 | 1614 | 1614 | | 20058 | | 19947 | -0.55% | 59 |
| 0 | 4865 | 4865 | | 38836 | | 38836 | 0.00% | 60 |
| 0 | | 107 | | 1 | | 0 | | 61 |
| 0 | 6485 | 6592 | | 67923 | | 67815 | -0.16% | 63 |
| 0 | 6485 | 6591 | | 67923 | | | | 71 |
| 0.00 | 1.80 | 1.83 | | 18.87 | | | | 73 |
| 600 | 600 | 600 | | 600 | | | | 74 |
| 700 | 200 | 1350 | | 1350 | | | | 75 |

2 DOE - GPIF - CRSS Coal Gasification Process (Kinetically Balanced) — Table 2.1

3 NEPA Support Document, Mass Balance — *Using FW Data (High Steam - Low Btu) Case

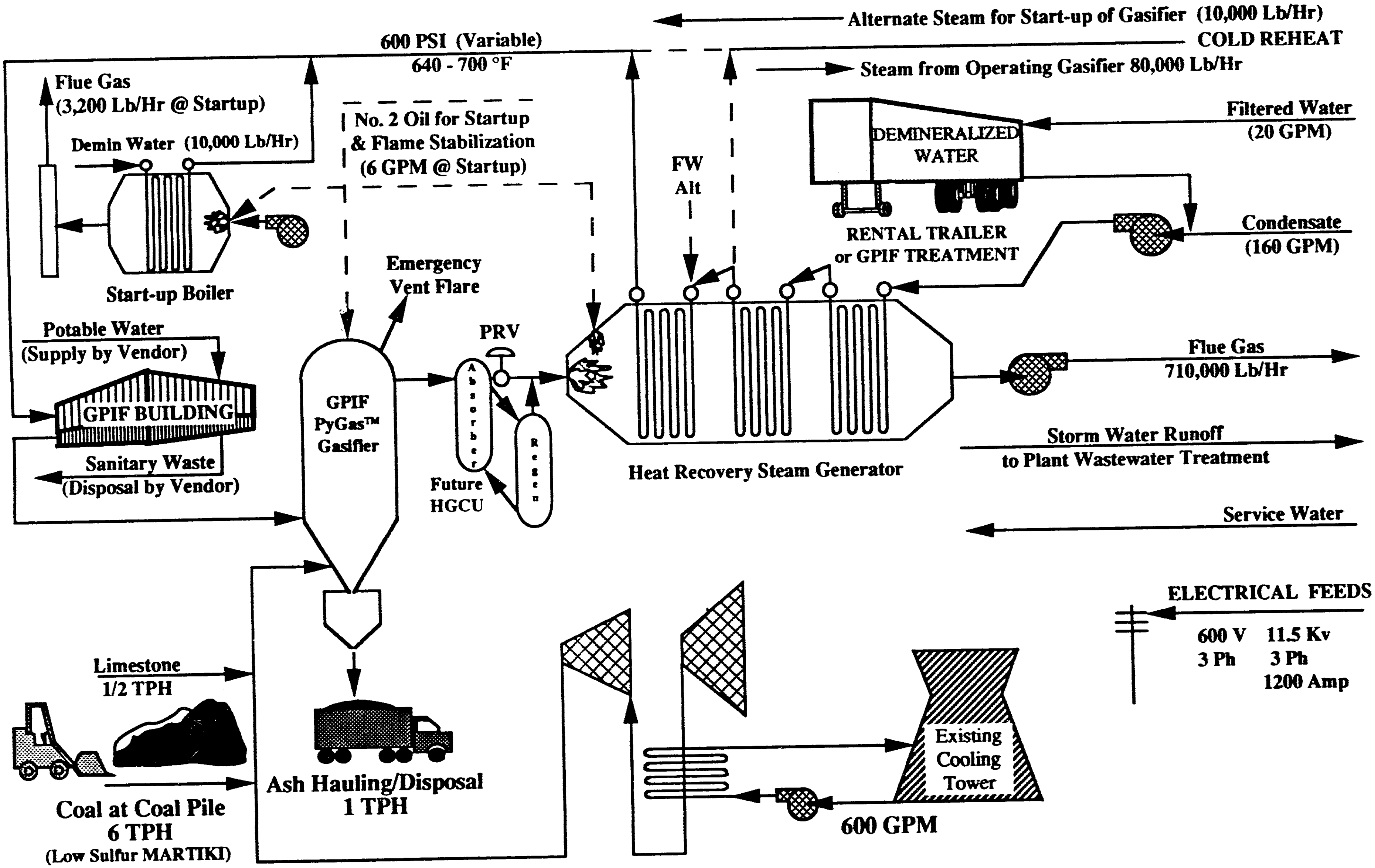
| | | Mol Wt | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 4 | | | | | | | | |
| 5 | Stream No. | | 1 | | Sorb/Coal | 2 | 3 | |
| 6 | Identification | | Raw Coal | | 0.088 | Limestone | Coal & Lm'stne | Du |
| 7 | From | | R. Martin Pile | | | GPIF Covered Pile | GPIF Rec'g Hopper | |
| 8 | To | | GPIF Receiving Hopper | wt % | | GPIF Receiving Hoppe | Crusher/Dryer | Al |
| 9 | Gas | Mol Wt | | | 2.50 *Ca/S Mole Ratio | | | |
| 10 | | | | | | | | |
| 11 | CO | 28.010 | | | | | | |
| 12 | H2 | 2.016 | | | | | | |
| 13 | CO2 | 44.010 | | | | | | |
| 14 | H2O | 18.015 | | | | | | |
| 15 | CH4 | 16.042 | | | | | | |
| 16 | C2H6 | 30.068 | Proximate Analysis | | | | | |
| 17 | H2S | 34.076 | | | | | | |
| 18 | COS | 60.070 | Vol Matter | 28.92% | | | | |
| 19 | N2 | 28.013 | Fixed Carbon | 54.86% | | | | |
| 20 | Ar | 39.948 | Moisture | 1.81% | | | | |
| 21 | HCl | 36.461 | Ash | 14.41% | | | | |
| 22 | HCN | 27.026 | | | | | | |
| 23 | NH3 | 17.030 | | | | | | |
| 24 | CS2 | 76.131 | | | | | | |
| 25 | SO2 | 64.059 | | | | | | |
| 26 | NO | 30.006 | | | | | | |
| 27 | O2 | 31.999 | | | | | | |
| 28 | NaCl | 58.497 | | | | | | |
| 29 | KCl | 74.596 | | | | | | |
| 30 | CaSO4 | 136.142 | | | | | | |
| 31 | Ca(OH)2 | 74.095 | | | | | | |
| 32 | Cl2 | 35.500 | | | | | | |
| 33 | Total Gas (lb/hr) | | | | | | | |
| 34 | | | | | | | | |
| 56 | | | Ultimate Analysis | | | | | |
| 57 | C | 12.011 | 69.03% | 8344 | 88% | 111 | 8455 | |
| 58 | H | 1.008 | 4.48% | 542 | Purity | | 542 | |
| 59 | O | 16.000 | 8.03% | 971 | | 443 | 1414 | |
| 60 | N | 14.007 | 1.26% | 152 | | | 152 | |
| 61 | S | 32.060 | 0.98% | 118 | | | 118 | |
| 62 | CaO | 56.079 | 0.00% | 0 | | | 0 | |
| 63 | H2O | 18.016 | 1.81% | 219 | 1% | 12 | 231 | |
| 64 | NaCl | 58.497 | | | Moisture | | | |
| 65 | KCl | 74.596 | | | | | | |
| 66 | CaSO4 | 136.142 | | | | | | |
| 67 | Ca | 40.080 | | | | 370 | 370 | |
| 68 | CaS | 72.140 | | | | | | |
| 69 | ASH, Inerts (pph) | | 14.41% | 1742 | | 124 | 1866 | |
| 70 | Total Solids (pph) | | | 12088 | | 1061 | 13148 | |
| 71 | Total Flow (pph) | | | 12088 | | 1061 | 13149 | |
| 72 | | | | | | | | |
| 73 | Total Flow (pps) | | | 3.36 | | 0.29 | 3.65 | |
| 74 | Pressure (psia) | | | 14.7 | | 14.7 | 14.7 | |
| 75 | Temperature (F) | | | 80 | | 80 | 80 | |

Reference Coal - Fort Martin - Low Sulfur - 11/13/92 - MGAS Kinetics 3/10/93 17:19 2

5 ft Dia Test Size CRSS Predicted Output 3

| 4 | | | 5a | 5b | 5c | 5d | 5 | 4 |
|---|---|---|---|---|---|---|---|---|
| l Collector Exhaust | | | Fuel Oil | Fuel Oil | Fuel Oil | Fuel Oil | Fuel Oil | 5 |
| Bunker | @0.01 lb/MBtu | | Storage Tank | Storage Tank | Storage Tank | Storage Tank | Storage Tank | 6 |
| nosphere | @100acfm | | Coal Dryer | Burner Support | PyGas™ Preheat | Start-up Boiler | Total Usage @ Startup | 7 |
| mol% | lb/hr | | lb/hr | lb/hr | lb/hr | lb/hr | lb/hr | 8 |
| | | | | | | | | 9 |
| | | | | | | | | 10 |
| 0.00 | 0.00 | | | | | | | 11 |
| 0.00 | 0.00 | | | | | | | 12 |
| 0.03 | 0.21 | | | | | | | 13 |
| 1.02 | 2.86 | | | | | | | 14 |
| 0.00 | 0.00 | | | | | | | 15 |
| 0.00 | 0.00 | | | | | | | 16 |
| 0.00 | 0.00 | | | | | | | 17 |
| 0.00 | 0.00 | | | | | | | 18 |
| 77.28 | 337.61 | | | | | | | 19 |
| 0.95 | 5.91 | | | | | | | 20 |
| 0.00 | 0.00 | | | | | | | 21 |
| 0.00 | 0.00 | | | | | | | 22 |
| 0.00 | 0.00 | | | | | | | 23 |
| 0.00 | 0.00 | | | | | | | 24 |
| 0.00 | 0.00 | | | | | | | 25 |
| 0.00 | 0.00 | | | | | | | 26 |
| 20.72 | 103.40 | | | | | | | 27 |
| 0.00 | 0.00 | | | | | | | 28 |
| 0.00 | 0.00 | | | | | | | 29 |
| 0.00 | 0.00 | | | | | | | 30 |
| 0.00 | 0.00 | | | | | | | 31 |
| 0.00 | 0.00 | | | | | | | 32 |
| 100.00 | 450.00 | | | | | | | 33 |
| | | | | | | | | 34 |
| | | | | | | | | 56 |
| | 0.11 | 86.65% | 250 | 1,015 | 1,015 | 444 | 2,724 | 57 |
| | 0.00 | 12.78% | 37 | 150 | 150 | 65 | 402 | 58 |
| | 0.44 | | | | | | | 59 |
| | 0.00 | 0.05% | 0 | 1 | 1 | 0 | 2 | 60 |
| | 0.00 | 0.53% | 2 | 6 | 6 | 3 | 17 | 61 |
| | 0.00 | | | | | | | 62 |
| | 0.01 | | | | | | | 63 |
| | | | | | | | | 64 |
| | | | | | | | | 65 |
| | | | | | | | | 66 |
| | 0.37 | | | | | | | 67 |
| | | | | | | | | 68 |
| | 0.12 | | | | | | | 69 |
| | 1.06 | | | | | | | 70 |
| | 1 | 100.00% | 288 | 1,172 | 1,172 | 512 | 3,144 | 71 |
| | | | | | | | | 72 |
| | 0.0003 | | 0.08 | 0.33 | 0.33 | 0.14 | 0.87 | 73 |
| | 14.7 | | 35 | 35 | 35 | 35 | 35 | 74 |
| | 80 | | 80 | 80 | 80 | 80 | 80 | 75 |

# Proposed Ties Between GPIF and Ft. Martin




CRS Sirrine Engineers, Inc.
Project 31604.00
Approved by: R.S. Sadowski
January 4, 1993

Figure 6

permitted levels. However, the need for the Phase II hot gas cleanup system is potentially of much greater significance to future emission limitations either legislated or required for future fuel cell combined cycle application. To insure that the GPIF does not add to the current sulfur emission levels of the Fort Martin Station. it is proposed that only low sulfur coal will be gasified until such time that the GPIF can be shown to be capable of achieving no net sulfur emissions increase on high sulfur coal. This can only be demonstrated after startup and demonstration on low sulfur coal.

One (1) by approximately 5 ft diameter PyGas™ test sized gasifier is expected to generate sufficient coal gas to test the gasification process while firing the fuel gas (approximately 150-million Btu/hr coal feed rate) in a fired Heat Recovery Steam Generator (HRSG) (Phase 1).

The PyGas™ test gasifier will be designed to utilize approximately 12,000 lb/hr of coal at 600 psi operating pressure.

A zinc ferrite type (or zinc titanate) hot gas cleanup process is contemplated for high efficiency sulfur removal and sorbent regeneration under Phase 2, and a conventional sulfur recovery process may be planned for the production of this valuable by-product of sulfur capture. The initial plan, however, is to return the captured sulfur oxides back to the HRSG as sulfur oxides and hence to the Fort Martin Unit #2 breeching to the electrostatic precipitator. Therefore, secondary firing with coal gas will be carried out in the HRSG, and the resulting products of combustion will be injected directly into the inlet side of the existing Fort Martin Unit #2 electrostatic precipitators. In the event of boiler shutdown or failure during gasifier operation, the coal gas must be directed to an emergency flare.

During normal operations, to the extent practical, all process vents and reliefs shall be directed to the auxiliary steam boiler for combustion. If the auxiliary boiler trips, then vents shall be bypassed to the emergency flare.

## 9. Functional Descriptions of Test Facility - Phase 1

Conceptual Design of the Gasification Product Improvement Facility

### Coal Receiving & Storage

Coal will be dumptruck delivered from the existing nearby Fort Martin low sulfur coal storage facility to a covered, live day bin. Provisions shall be made to collect all rainwater runoff, and pump it to the existing Fort Martin waste water treatment system. The required front end loader for loading from the utility coal pile as well as coal (also limestone and ash) trucks are expected to be subcontracted to a local trucking company familiar with current ash disposal requirements.

### Coal Reclaim

Live coal pile management is expected to be by front loader. Reclaim is accomplished via a weigh belt feeder capable of 0 to 12,000 lbs /Hr coal feed rate directly onto a continuous conveyor belt. The conveyor belt deposits coal continuously into a crusher/dryer (drying heat to come from a tubular type air heater located downstream of the fired auxiliary steam generator), thence to an inlet coal (and limestone) lock hopper of sufficient capacity for coal and limestone inventory discharge from the weigh belt feeder to the continuous conveyor belt discharge. Therefore all load change and accurate metering is accomplished by the weigh belt feeder. Provisions shall be made to collect all rainwater runoff, and pump it to the existing Fort Martin waste water treatment system. The feeding and conveying systems shall be properly ventilated, and the vented air shall be filtered before being released to the atmosphere.

Limestone Receiving & Storage

Limestone is received by dumptruck (by others) from an existing nearby rail unloading or quarry facility and dumped directly into a covered, live day bin. Provisions shall be made to collect all rainwater runoff, and pump it to the existing Fort Martin waste water treatment system. The feeding and conveying systems shall be properly ventilated, and the vented air shall be filtered before being released to the atmosphere.

The current plan is to operate the pyrolyzer tube in the slug-flow region at approximately 3.5 fps because Charlie Lowell (ref: DOE DE-AC21-78MC10484) was successfull at that point. This is effectively the same velocity as what Foster Wheeler calls "jetting". Therefore, the same 1/8 inch minus dolomite and 16 x 200 mesh limestone size gradation which Foster Wheeler (ref: DOE DE-AC21-86MC21023) was successfull with will initially be utilized at the GPIF.

Since milling is complicated by the differences in grindability or "work index" between limestone and coal (limestone is usually harder), we plan to receive pre-sized limestone or dolomite at 16 x 200 mesh and 1/8 inch minus respectively.

While this will lead to a smaller size fraction entering the gasifier, the tortuous path and co-current flow regime serve to assure calcination without unreacted limestone carryover. In turn, there will be less likelihood of "blinding" calcium sulfide crystals with an outside layer of larger gypsum crystals because of the greater surface to volume ratio of the smaller sized limestone. This is really something which we need to test to verify anyway, so these comments merely reflect our logic for a starting point. These comments have been added to the report.

Limestone Reclaim

Limestone pile management is expected to be by front loader. Reclaim is accomplished via a weigh belt feeder capable of 0 to 4,000 lbs /Hr limestone feed rate directly onto the coal conveyor belt thereby assuring homogeniety between coal and limestone with a minimum of solids attrition. The conveyor belt deposits the mixture of coal and limestone continuously into a crusher/dryer, thence to an inlet coal (and limestone) lock hopper of sufficient capacity for coal and limestone inventory discharge from the weigh belt feeder to the continuous conveyor belt discharge. Therefore all load change and accurate metering is accomplished by the weigh belt feeder.

Ash Handling & Storage

Ash sources include mainly the gasifier bottom ash along with a minor source from the gasifier outlet cyclone. Gasifier bottom ash will be pneumatically conveyed into a 100 ton ash silo. Gasifier outlet cyclone solids will also be pneumatically conveyed into the same ash silo. Since the PyGas™ process provides an oxidation zone immediately above the rotating grate, it is expected that retained sulfur in the ash will be predominently in the fully sulfated form.

In the event the ash contains unsulfated forms of sulfur, it will be first fed to a submerged combustion reactor to complete the sulfation reaction prior to disposal in the permitted Fort Martin existing coal ash landfill. While the quantity of GPIF ash to be added to the existing ash landfill is extremely small relative to current fill rates, it is likely to contain some unreacted alkali which should serve to provide some neutralization benefit in the ash pile.

## Ash Conditioning & Disposal

The ash is removed from the ash silo conical bottom via a water cooled ash conditioning screw into an ash disposal truck. During periods of limestone utilization, care must be exercised to minimize the use of any water spray for dust control to avoid heat increase by chemical reaction with unreacted but calcined lime. An ash removal truck fitted with bag filter vents is preferred followed by Water conditioning or the current method used at the permitted Fort Martin solid waste land fill site may be considered to minimize dusting. The PyGas™ coal gasification process is designed to produce sulfated ash product which is expected to be free of sulfides. However, provisions shall be made to oxidize all ash generated in the process in a submerged combustion reactor. The exhaust from this reactor shall be vented to the auxiliary steam boiler for additional combustion. The treated ash is then dewatered through mechanical filtration equipment, temporarily stored in the ash silo, and transported by truck to the existing ash pond area of the Fort Martin power plant. Fort Martin has an air permeable dust screen at their landfill site. While some air can pass through it, it does provide a good buffer on windy days resulting in less particulate becoming air-borne. We anticipate approximately 15% free moisture per Page 92 Figure 6. The anticipated properties are moist but dry handling granular solids, and conventional ash hauling trucks will be able to handle it.

The ash silo is sized for 100 tons. This is about four days of ash at full load and should accommodate weekends and holidays. We do plan to normally have daily ash hauls.

## Air Compressor

A four-stage centrifugal compressor will be used in conjunction with (2) reciprocating compressors to boost ambient air to 650 psia for injection into the gasifier. The centrifugal air compressor will incorporate two intercoolers and one aftercooler to control inlet air temperatures to stages 2 and 3 and the reciprocating compressor, respectively. The total air compressor package will consume 1.66 MWe. Cooling water needed for the intercoolers will be minimized by allowing larger temperature rises in the cooling water, if practical. Although this will increase power consumption and decrease compressor efficiency, it may allow the intercoolers to be used as economizers to preheat the necessary water for the cycle while at the same time decreasing water consumption from the host utility.

In addition to providing compressed air for the gasifier, the air compression system will be designed to allow instrument air bleed after the aftercooler which is placed in between the centrifugal and reciprocating air compressors. The instrument air will be extracted at 205 psia, 100°F and the pressure reduced to the instrument requirements.

Proprietary CRS Sirrine Engineers, Inc. PyGas™ Gasifier

The gasifier will be a shop fabricated water cooled vessel with three flanges, capable of operation at up to 600 psig. It will include a pressure lock upstream of its pneumatic crushed coal conveying pipe, and an ash pressure lock at the bottom of the gasifier vessel. A rotating grate similar to any conventional fixed-bed gasifier will be furnished complete with its motor drive assembly. Metered air, steam, and water spray nozzles will be furnished at three critical points within the gasifier vessel. The pressure locking valves will operate such that a continuous pressure seal is maintained constantly. A suitable purge and vent system and media will be incorporated into the design to avert reverse flow of hot coal gas into the coal feed system. An emergency (only) vent and flare stack will also be incorporated to automatically operate in the event of GPIF overpressure or a rare unrelated Ft Martin Unit 2 master fuel trip since the GPIF flue gas flow to it should be discontinued during such an upset condition.

Hot Coal Gas Piping

The test gasifier includes four (4) inch insulated and lagged stainless steel hot gas piping.

The hot low Btu gas produced by the gasifier shall be discharged to the primary gas cyclone via four (4) inch stainless steel piping insulated with calcium silicate insulation of seven (7) inch thickness and lagged.

Hot Cyclone

The gasifier outlet cyclone is an insulated stainless steel device intended to capture solids which carryover from the gasifier with the coal gas. It is anticipated that since it has performed well previously, the current GE cyclone will be scaled up to the size required for the gas throughput requirement (approximately a 12 to 1 scale up). The cyclone's captured fines stream discharge by gravity and requires a pressure locking chamber to partially depressurize the fines stream for pneumatic conveyance to the ash silo, separate sampling, or for reinjection back to the gasifier. The hot cyclone is approximately 13 ft tall by 2 ft diameter

The gasifier gas outlet cyclone may alternatively be a carbon steel device with 12" thick refractory liner, intended to separate solids carryover from the gasifier in the hot gas by centrifugal force. It is expected that the primary cyclone shall separate up to 600 lbs per hour of solids (char). As the gas stream and the cyclone shall operate at approximately 600 psig and 1120°F, the fines from the cyclone collection chamber shall be discharged via lock hopper and auto valves operated in sequence.

These locks shall initially be pressurized with inert gas up to the cyclone's operating pressure to prevent coal gas escape when the upper valve is opened to admit solids. Before the fines are discharged via the pneumatic conveying system to ash storage silo, the lock hopper may be depressurized to near atmospheric pressure, or the inert media at pressure may be used to convey fines.

### Vent Pipe, Rupture Disc, Detonation Arrester and Emergency Flare

A rupture disc, detonation flame arrester and vent stack with emergency flare are anticipated to be required in the gas line between the gasifier and primary gas cyclone for emergency pressure relief. These devises are specifically designed to relieve and arrest the high velocity and pressure flame fronts that may accidentally develop in the gas piping from gasifier, and to carry any deflagration front from the gasifier, away from personnel and out the top of the building for combustion prior to release to the atmosphere.

The Protectoseal model F25006, 6" bi-directional detonation flame arrester in 316 SS housing is included.

### Vortex Type Burner

A single vortex type coal gas burner (Coen or equal) shall be utilized to add sufficient air to the coal gas to completely combust the gaseous fuel product of the gasifier. The coal gas burner nozzle is rated at 154-million Btu/hr coal gas firing rate (including sensible heat in the coal gas).The coal gas firing rate is consistent with an excess air of approximately 10% at MCR which is normal for gas fired burners. While past experience has shown the ability to completely combust hot coal gas without support fuel requirements above 50% gasifier load, provisions shall be made to provide for flame stabilization support using light oil fuel using an NFPA Class I ignitor flame. Therefore, under any operating load, whenever the main flame scanner indicates the need for support flame, the ignitor shall be capable of being automatically placed in flame support service.
It is anticipated that the coal gas will be utilized to produce gasification process steam as well as for auxiliary steam generator duty for return to Fort Martin Station. This will allow the GPIF facility to operate at full capacity while the existing utility boiler operates at anywhere from half to full load. The intent is to render the effect of GPIF operation on the existing utility station to the insignificant level.

### Water Spray Injection

It is anticipated that water mist and steam will be sprayed into the hot raw gas from the GPIF such that the coal gas pipe temperature to the fired heat recovery steam generator (HRSG), and eventually in Phase II to the hot gas cleanup system does not exceed approximately 1100 -1400 degrees F. In this manner the coal gas piping is protected from excessive temperature at the 600 psig operating pressure. The heat of evaporation minimizes water requirements.

### Gasifier Water Jacket Steam Generator

The GPIF gasifier test unit includes steam generation heat recovery intended to provide a significant portion of the necessary steam for gasifier steam injection requirements. In this manner, the test facility may be steam self sufficient after startup. This then may allow the packaged boiler steam supply source to be required only during test startup. It has been determined that sufficient heat is available from the compressor intercooler, gasifier water jacket, and gasifier carbonizer tube cooling to generate the entire gasifier steam demand.

### Water/Steam Loop

A pump forced "once through" water cooled intercool loop is contemplated to control compressor temperatures up to 600 psia air compression. The same water cooling intercooler loop may then be circuited to the gasifier water jacket, possibly the gasifier carbonizer tube, and subsequently back into the gasifier grate air blast. The alternative is a circuit to the existing Ft Martin cooling tower.

### Feed Water Pump

The feed water pump must be sized to provide sufficient water for steam generation for gasifier grate air blast injection. Cooling water for air compressor intercooler will necessitate pump operating pressure significantly greater than the ultimate 600 psia needed for the gasifier. A 750 psia operating pressure is neither inconceivable nor particularly difficult to obtain from a number of suppliers. The cost estimate includes a 50 gpm feedwater pump for cooling and coal gas sprays, plus a 25 gpm feedwater pump booster for steam generation. If acceptable to the host utility, a feedwater bleed from the feedwater heater loop may be utilized in lieu of the above pumps.

An alternative under consideration is to receive feed water from Ft Martin using a booster pump, and make intermediate steam (600 psia/ 700°F) in the HRSG for use in the gasification system with all excess steam going back to the utility's cold reheat system. This alternative provides Ft Martin with more efficient use of steam generated in the GPIF system.

### Water/Steam Considerations

The proprietary PyGas™ test gasifier requires up to 10,080 lb/hr of steam for the gasification of caking coal. There are several heat sinks within the cycle that will be used to generate the needed saturated steam at gasifier pressure. The statement of work indicates that the 650 psia steam is required at 640 F. This is well above the saturation temperature of 495 F associated with the above pressure. It is contemplated that the heat sinks within the process provide enough heat to generate saturated steam at the gasifier pressure. The last heat sink would be the gasifier water jacket and carbonizer tube. Once the saturated steam leaves the gasifier water jacket, the steam is mixed with the compressed air. Since the air leaving the compressor is approximately 700 F, the steam mixed with the air will stay well above the saturation point and remain in a dry state.

To generate 10,080 lb/hr of 650 psia saturated steam, 11.85 million Btu/hr of heat must be absorbed by incoming water at 60 F. The heat sinks within the system are the intercoolers and aftercoolers in the air compression system, the gasifier water-cooled carbonizer tube, and the water/steam jacket on the gasifier. The water/steam jacket absorbs 8.47 million Btu/hr and the gasifier carbonizer tube absorbs 1.97 million Btu/hr for a total of 10.44 million Btu/hr of the needed 11.85 million Btu/hr. The remaining 1.41 million Btu/hr of heat can be absorbed from the air compressor intercoolers.

The information above indicates that the needed steam can be generated from the heat sinks within the process thus integrating the process as desired.

### Process Water Distribution System

The process water shall be distributed from the main process water line main near Monongahela Power's Unit No. 2 as shown on Exhibit 2 of the site tour of June 18, 1991.

The total process water consumption at the pressure 70 psig is estimated as:

Table 3
Process Water Consumption

| | | |
|---|---|---|
| 1. | GPIF feed water | 25 gpm |
| 2. | Coal gas cooling | 5 gpm |
| 3. | Ash conditioning | 1 gpm |
| 4. | Cooling Water Consumption | 500 gpm |
| | Total | 531 gpm |

A 2 inch main is included to supply this quantity of process water for the facility.

### Cooling Water Distribution

The cooling water distribution to the gasifier jacket, coal gas cooling and carbonizer tube cooling is estimated at 25 gpm. Cooling water from the GPIF will be returned to the existing Fort Martin Unit #2 cooling tower. There will not be a separate GPIF cooling tower.

### Packaged Boiler,Fired Heat Recovery Steam Generator (HRSG),& Induced Draft Fan

A small light oil fired packaged boiler is contemplated for space heating and gasification process steam raising during startup. In addition, a coal gas fired HRSG and tubular type coal dryer air heater followed by an induced draft fan shall provide the heat recovery system for returning the Btu's from the gasification of coal to the host utility. If necessary, the startup and space heating packaged boiler flue gas may be vented into the induced draft fan along with the coal gas fired auxiliary steam generator flue gas for removal back to the existing Fort Martin Unit #2 stack.

## Gasifier Integrated Steam Source

The test gasifier will require up to 0.84 lb of steam per lb of coal gasified. With the test gasifier consuming 12,000 lb of coal per hour, this equates to 10,080 lb/hr of steam. A small packaged boiler will be used for startup. Since, the air discharged from the compressor is at 700°F, saturated steam at gasifier pressure produced in the water/steam jacket can be mixed with the air to insure that the steam will remain dry. This prevents condensation in the pipes. Some 11.8 MMBtu/hr of heat must be absorbed to generate 10,080 lb/hr of saturated steam at 650 psia. Therefore, 8.5 MMBtu/hr is transmitted to the steam jacket of the gasifier. The remaining 3.4 MMBtu/hr of heat needed to make the saturated steam will be absorbed by the water through the heat sinks in the cycle. This heat will be absorbed by the water through the use of carbonizer tube cooling and intercoolers/aftercoolers of the compressor as economizers.

## Boiler Chemical Treatment

All water makeup to the auxiliary boiler and reactor cooling jacket shall be softened and injected with environmentally acceptable oxygen scavengers and corrosion inhibitor chemicals.

## Desulfurization

Provisions have been made for limestone feed to the proprietary PyGas™ coal gasifier. Based upon the results of other pyrolyzer tube testing, approximately 20% to 95% sulfur retention may be possible within the gasifier itself. This retained sulfur will be removed from the gasifier and disposed of in the Fort Martin Generating Station permitted coal ash landfill along with the gasifier bottom ash. It is expected that this solid waste product will contain some unsulfated alkali such that some beneficial neutralization of the currently slightly acidic coal ash contained within the landfill may occur. The expected range of calcium to sulfur mole ratios anticipated for testing is 1.0 to 3.0. Depending on sulfur content in the coal, this results in up to approximately a half ton of limestone per hour.

## Potable Water

A one inch potable water line and reservoir tank is included from the utility interface point to the GPIF for lavatory and shower consumption.

## Test Facility Horsepower Requirements

The following table serves to identify the anticipated motor horsepower requirements of the conceptualized test facility.

## Table 4
## Test Facility Motor Horsepower Consumption

The following is a list of motor and horsepowers associated with the test facility.

| ***Equipment Description*** | ***Horsepower*** | ***K W*** |
|---|---|---|
| Gasifier | | |
| Rotary Coal Metering Drives (2) | 10.0 | 7.45 |
| Grate Drive | 15.0 | 11.18 |
| Air Compressor | | |
| Centrifugal Compressor | 1750.0 | 1305.0 |
| Reciprocating Compressor (2) | 700.0 | 522.2 |
| Coal Receiving/Storage/Reclaim | | |
| Pile Runoff Collection Sump Pump | 1.0 | 0.74 |
| Gravimetric Feeder Drive | 3.0 | 2.24 |
| Transfer Conveyor Drive | 10.0 | 7.45 |
| Vent Fan Drive(Pit Ventilation) | 7.5 | 5.59 |
| Sample Cutter Drive | 1.0 | 0.74 |
| Coal Crusher/Dryer Drive | 20.0 | 14.90 |
| Limestone Receiving/Storage/Reclaim | | |
| Gravimetric Feeder Drive | 3.0 | 2.24 |
| Sample Cutter Drive | 1.0 | 0.74 |
| Coal Gas Combustion/Heat Recovery | | |
| Forced Draft Fan Motor | 125 | 93 |
| Feedwater Pumps | 10.0 | 7.5 |
| Induced Draft Fan Motor | 400 | 298 |
| Wet Oxidation System | | |
| Vacuum Filter Pump Motor | N/A | N/A |
| Transfer Pumps (2) | N/A | N/A |
| Oxidation Air Blower Motor | N/A | N/A |
| Ash Handling System | | |
| Ash Blower | 50.0 | 37.29 |
| **Totals:** | 2,857 | 2,131 |

Process Building

The building shell erected shall be : 30'W X 100'L X 50'H

The LRF envelope frame with 0.5:12 slope and BR-II roof panels has a clearspan double slope profile with tapered sidewall columns. It offers almost total flexibility in sizes within the limits of the LRF envelope. The wall panels shall have 2" insulation in each. Two (2) 3' X 7" personnel doors, one (1) 10'

X 10' overhead door, one (1) 25' X 17'-6" removable wall panel, gutters and downspouts over entrance area only, exhaust fan (75,000 CF/hr air exchange), intake louvers are included in the building design.

The building foundation and 6" concrete slab, with 4' X 4' X 6' sump and three (3) 4" floor drains to the storm runoff collection pit.

One sump pump, capacity 30 gpm, 52 HTDH, 2 HP

Steel stairs outside to 12' high elevation, with steel treads, landings and handrails per code.

For the heat protection in the winter to maintain 50°F ambient temperature at 0° exterior temperature, the steam-fired or electric unit heaters are included using existing 600 psi steam or electricity from Ft Martin Station.

Control room inside process building area 12' X 12', with 3' X 7' personnel door with half glass.

On the top of control room, second floor testing room 12' X 12' area, one 3' X 7' personnel door with half glass, entrance from the inter platforms. Heat and air conditioning are included, with 2-1/2" concrete floor over steel form deck.

A lavatory facility, to include separate male & female showers, two toilet stalls (each for handicapped persons), two wash basins (one for handicapped persons), complete with standard fixtures will be provided. A pumping and storage tank for waste disposal by portable tank truck will also be furnished.

A furnished combination meeting and break room complete with dry erase marker board, sink and microwave oven, and with coffeemaking, snack and soda machine provisions will be provided. Furniture will consist of two 4 ft x 8 ft folding type tables and twelve (12) straight back chairs.

All process runoff shall be collected in a sump and pumped to the existing Fort Martin Generating Station waste water treatment system.

Ash and Other Process Waste Particulate Handling Storage And Disposal

Ash handling from gasifier bottom and process fines from the outlet of the hot cyclone shall be pneumatically conveyed periodically on a timed basis into a 100 ton ash storage silo, dimensions 14' dia X 28'H.

It is expected that the total solids collection from all above mentioning source shall be in the range of 4007 lbs per hour. The ash shall be discharged periodically from the bottom of gasifier to bottom ash lock hopper by way of airlocks operating in sequence. This cycle proceeds automatically on a timed sequence before accumulated fines shall be discharged to the pneumatic system. The lock hoppers shall be depressurized to an atmospheric pressure. Similar discharge lock hoppers shall be employed after the gas cleaning cyclone.

The ash and other waste solids (spent sorbent) shall be unloaded in the disposal truck by telescopic spout when limestone is fed to the gasifier, or by water cooled ash conditioner. (No limestone utilization). The filter-separator bag shall be periodically cleaned by pressure air. The sequence shall be set by timer. Care must be exercised with ash conditioning water admixing whenever unreacted lime may be present, as heat of reaction and skin burns have been reported in industrial applications using lime. The ash silo shall be vented to the atmosphere by way of a bag filter or electrostatic precipitator.

## 10. Control and Instrumentation System Description

General

The test gasifier facility will be equipped with a state-of-the-art control and instrumentation system designed in accordance with the existing engineering practice for this type and size of equipment, with the scope sufficient to ensure a high level of facility's availability and reliability. Taking into account the experimental character of this facility, we have added a certain degree of redundancy, where exact process characteristics were unclear or required special attention to the process.

Process control and monitoring functions will be performed in a central control room (CCR) utilizing a microprocessor-based distributed control system (DCS) along with several dedicated control subsystems.

Conceptual design of the proposed system is illustrated in the system block diagram (Fig.1). From the control point of view, the overall plant equipment will be divided into several functional groups (FG), some of them will be equipped with their own, dedicated (possibly PLC-based) vendor supplied control systems, others will be controlled directly by DCS from CCR. Control systems of individual FG's will provide control interface and necessary inputs to DCS for centralized data acquisition, monitoring and reporting. These dedicated control systems may be based on PLC or DCS technology. Main requirements to their suppliers should be compatibility with the host DCS (i.e. the ability to communicate via a common data highway) and uniformity of their hardware basis (e.g. use of the same make of the PLCs).

The following FG's are expected to be controlled by their dedicated specialized control systems and/or PLC 's via remote I/O racks:

- Coal/Limestone Loading System;
- Steam Generation - Coal Gas Flare, Boiler, Water Treatment;
- Existing Boiler Burner Interlock System;
- Compressed Air and Instrument Air Systems;
- Continuous Emission Monitoring (CEM) System;
- Ash Handling System;
- Balance of Plant Systems;

The following FG's are expected to be controlled directly by the DCS:

- Coal Gasifier with Primary Cyclone;
- Hot Gas Clean-up with Secondary Cyclone and Sulfur Recovery System;

Standards

The C&I system shall conform to the applicable industry standards, such as:

- National Fire Protection Association (NFPA)
- National Electric Code (NEC)
- National Electrical Manufacturers Association (NEMA)
- Instrument Society of America (ISA)
- Institute of Electrical and Electronics Engineers (IEEE)
- American National Standards Institute (ANSI)

Controls Equipment Scope of Supply

Control Room Equipment

We anticipate that the following operator interface equipment will be located in the CCR:

Table 5
Control Room Equipment

| Equipment | Phase I | Phase II | Phase III |
|---|---|---|---|
| Operator Stations (CRT with keyboard) | 3 | 4 | 5 |
| Printers 2 | 3 | 3 | |
| Plant Paging & Telephone System | 1 | 1 | 1 |
| Fire Protection System 1 | 1 | 1 | |
| Main Control Room Panel | 1 | 1 | 1 |
| Sequence of Event Recorder | 1 | 1 | 1 |
| Emission Monitoring (CEM) and Reporting System | 1 | 1 | 1 |
| Logging Station w/printer | 1 | 1 | 1 |
| Video Copier | 1 | 1 | 1 |
| The following will be included with the DCS and located next to the CCR: | | | |
| Engineering Station w/keyboard | 1 | 1 | 1 |
| Historical Data Storage | 1 | 1 | 1 |
| Printers | 1 | 1 | 1 |

Control Systems and Equipment

The following FG control systems will be required and implemented for the two phases of the project outlined as follows:

Table 6
Control Systems & Equipment

| Functional Group | Phase I | Phase II |
|---|---|---|
| Coal/Limestone Loading | Yes | Yes |
| Coal Gasifier | Yes | Yes |
| HGCU/Sulfur Recovery | No | Yes |
| Steam Generation - Flare/Boiler | Yes | Yes |
| Existing Boiler Burner Interlock System | Yes | Yes |
| Cont. Emission Monitoring (CEM) | Yes | Yes |
| Ash Handling | Yes | Yes |
| Compressed Air | Yes | Yes |
| Instrument Air | Yes | Yes |

Control of Individual Functional Groups

Coal/Limestone Loading System

Coal and Limestone Loading System which includes coal and pebble limestone bunkers, gravimetric feeders, a common belt conveyor c/w the corresponding drives will be operated and controlled by a PLC-based local control system via remote I/O rack. A configured operator interface screen will be supplied for a window into the operation. The DCS will monitor and act as a data acquisition system via a data interface link between the DCS and PLC data highways.

Coal Gasifier System

The overall coal gasifier system, including the gasifier itself, coal feeding, air and steam supplies to the gasifier and coal gas system with the primary cyclone and (possibly) flare, will be controlled from the DCS via a dedicated redundant processor.

In order to monitor and control the position and intensity of the gasification zone in the coal gasifier, we are proposing to install 3 infrared (IR) monitors (scanners) on the sides of the gasifier. Each of these instruments will measure two parameters: intensity and frequency of the IR radiation, which, as we expect, will characterize the intensity and position of the zone of max heat generation. These parameter measurements will allow the operators, during the initial testing and commissioning period, to establish patterns of normal operation and to recognize patterns of abnormal situations. By applying methods of pattern recognition, IR monitors in combination with temperature measurements and gas analyzers will allow development of methods of positioning of the gasification zone and of optimizing the overall gasification process.

The gasifier system will also include a multipoint gas analyzer system to continuously monitor concentration of H2S and other gaseous components at the gasifier, primary cyclone outputs and within the process area. The gas analyzers will be located in the common chemical analysis room.

Our preliminary evaluation of the system control requirements indicates that the processor should be capable to support (approximately) the following number of I/O's:

| | |
|---|---|
| Analog Inputs (TC's, RTD's, 4-20mA): | 100 |
| Analog Outputs: | 25 |
| Digital (on/off) Inputs: | 75 |
| Digital (relay) Outputs: | 50 |

This system is based on the above I/O count and vendor quotations for control systems of a similar size and configuration.

## Hot Gas Clean-up and Sulphur Recovery Systems

Control requirements for these systems include a substantial number of control functions, mostly sequential logic operations. These systems will be controlled directly by DCS via a dedicated redundant processor.

The HGCU will be served by the multipoint gas analyzer system to continuously monitor concentration of $H_2S$ and other gaseous components in the hot coal gas upstream and downstream of the absorber and also will monitor oxygen in the regenerator system.

The latest GE RDC report of June 1980 and 50% contingency for the sulphur recovery system, we estimate that the system should be capable to support the following number of I/Os:

| | |
|---|---|
| Analog Inputs (T/Cs and RTDs) | 75 |
| Analog Inputs (4-20 mA) | 75 |
| Analog Outputs | 40 |
| Digital (on-off) Inputs | 120 |
| Digital (relay) Outputs | 100 |

Our estimate is based on this I/O count and a number of vendor quotations for similar size control systems.

This gas analyzer will be common for the gasifier and will be incorporated into one common gas monitoring system.

## Steam Generation System

The Gasifier Steam Generation System will be operated and controlled by a PLC-based local control system via remote I/O rack. The system will execute all necessary water treatment, feedwater, steam temperature and combustion control functions required to meet the load demand and to maintain boiler parameters.

## Coal Gas Combustion

The coal gas burners are expected to be equipped with a vendor supplied (possibly PLC-based ) burner management system (BMS) containing complete package of instruments, valves, flame scanners, etc., to comply with the NFPA recommendations for coal-fired burners. The BMS will be connected to the DCS via hardwired connections and will be controlled from the CRT operator stations. Interlocks and permissives consistent with the safety shutdown philosopy of the existing Fort Martin Station utility boiler's burner management system will be provided. A remote indication of coal gas combustion and steam generation status will be provided and located in the existing Fort Martin Station utility control room.

## Continuous Emission Monitoring System (CEM)

Emission monitoring equipment shall include stack analyzers to continuously monitor the flue gas exhaust for NOx, SO2, O2, CO, H2S and Opacity. The analyzers will be housed in a special environmentally controlled analyzer shelter adjacent to the exhaust duct of the auxiliary boiler. The analyzer housing will be shared with the bulk of the analyzer equipment which has to provide thorough monitoring of numerous gas components and solid particulates in the gasifier exhaust, primary and secondary cyclone outlets and HGCU outlet. The equipment will monitor facility compliance for all applicable Federal and State emission requirements. The system will be monitored by the DCS for alarms and critical measurements.

A stand alone personal computer located in the control room and software dedicated to the emission monitoring system will be included with the system. The equipment vendor will provide system certification, start-up assistance, installation supervision, personnel training and maintenance program.

## Ash Handling System

Bottom Ash Removal, Handling and Storage System will be controlled with a PLC-based local control system via remote I/O. System design, scope of supply, functions and interface with the DCS will be similar to the Coal/Limestone Loading System.

## Compressed Air and Instrument Air Systems
(From Process Air Compressors)

These systems which include centrifugal and displacement type compressors, filters, dryers, and pressure regulators will be controlled by a PLC-based local control system via remote I/O racks.

## DCS Capabilities and Controls

The DCS will include dynamic controllers, I/O racks, communication devices, and operator stations. The operator interface to the system will be through color

CRT's and operator keyboards which will be preprogrammed for easy access to color graphic displays and specialized operator functions.

The DCS will provide soft A/M stations for remote control of the various field devices and control loops. This control will be accomplished via the operator's CRT console.and keyboard. The logic control functions, such as motor control and discrete monitoring, will be accomplished in the DCS using key selection and dynamic displays on the operator console. The configuration of function codes and control strategies will reside in the non-volatile memory and will be maintained in the event of a power failure.

The control schemes will be hardware and software configured with consideration for redundancy as applicable. In the event of any single failure of power supply, processor / controller or highway / communication link / data multiplexers, it will alert the operator while continuing to keep the process under uninterrupted automatic control from the CRT.

If the primary control processor should fail, a secondary processor (operating in the "hot stand-by " mode) will assume control responsibility with bumpless transfer. In the event of a failure of both processors, the system will be configured such that analog and digital outputs will go to pre-determined fail safe positions.

Communication to the individual dedicated PLC-based control systems will be accomplished via one common data interface link between the DCS and PLC data highways. A Performance Assessment package will be configured in the DCS. This software application will gather information for each system and will provide real time displays to the operator.

Power supplies will be redundant, so that in case of a power supply failure, a back-up power supply will assume responsibility. The Operator interface will provide a user friendly environment for control and data acquisition functions. This interface will provide access to plant wide operations allowing the operator to monitor and take corrective action as required. The displays will provide dynamic information by updating information and status displayed to the operator.

An Engineering workstation will allow personnel to configure operator consoles and control hardware. The software package will enable the engineer to design, configure, monitor, trend, tune, modify and document process activities. Graphic symbols and function codes will be used to build the process logic control drawings on the CRT screen. The Engineering workstation will be used during start-up and de-bugging stage of commissioning. It will also be used as a tool to maintain, troubleshoot, operate and re-configure the system if required once the plant is operating.

The DCS will be field maintainable and configurable by the owners personnel after appropriate training.

## 11. Electrical System Assessment

General Requirements

Load Profile - New Gasification Plant

| | |
|---|---|
| 4160 V. Load | 2.85 MVA. |
| Total Load | 3.4 MVA. |

Project Concept

The Project concept is to supply existing Fort Martin Generating Station with steam from the proposed gasification plant. This plant is to be a stand alone satellite facility to be located in the vicinity of the generating station. All utilities are to be provided to the plant's battery limits. The 13.8 kV utilization voltage will require that the utility company furnish and install the required feeder to the plant's electrical system primary.

Codes and Standards

Except where noted, all electrical systems shall be designed, fabricated and installed in accordance with the latest edition of the National Electrical Code, and applicable ANSI, ICEA, NEMA, NESC, IEEE Standards as defined in the RFP ( exceptions taken will be defined). Components that are UL listed and labeled shall be provided if required by local authorities.

Electrical Equipment

Selection and design of all electrical components and systems shall be in accordance with the applicable codes and standards. Reliability of operation shall be the primary consideration in the facility design. The Preliminary single line diagram will serve as a typical basis of supply (CRSS Drawing SK-E-001).

The electrical equipment shall include the following, located in the facility building:

Table 7

MEDIUM VOLTAGE SWITCH GEAR HV-1
LOW VOLTAGE SWITCHGEAR LVSWG-1
175O HP STARTER WYE DELTA
2 (400HP) COMPESSOR WYE DELTA
1200A NON-SEGREGATED BUS
MCC-001-GPIF
STATION BATTERY AND CHARGERS
"UPS" UNINTERRUPTABLE POWER SUPPLY

15 kV Pole Line (by utility company)

A 15 kV ploe line feeder with parallel overhead ACSR conductors will interconnect the GPIF with the existing facility's 13.8 kV switchgear. This feeder line will be used to cold start the GPIF.

## Plant's Primary Transformer

The plant's primary transformer "T1" will be 5 MVA, outdoor, oil filled, 13.8 kV delta to 4.16 kV resistance-grounded wye, standard impedance, equipped with special winding and cooling fans to permit temporary overloading and allow for future growth.

## BUS DUCT.

The bus ducts sha!! be 5 kV, 1200 A, 3-phase, 3-wire plus ground, non-segregated phase type, rated to accommodate maximum design operating voltage. The rated momentary current will be based on the maximum three-phase fault current to which the bus can be subjected.

## Coal Gasification Electric Power System (parasitic loads)

The electrical power system will perform the following functions:

Provide a reliable source of electrical power for plant auxiliaries during all operating conditions.

Provide rapid isolation of any faulted equipment without unnecessary loss of supply to other equipment.

Provide satisfactory motor starting and bus voltage regulation.

Medium Voltage Distribution Switchgear HVSWG-1
(4.16 KV, Vacuum Type, 350 MVA).

The circuit breaker and metering portions of the medium voltage switchgear will be a non-drawout, metal-clad, dead front, with each breaker cubicle isolated from the adjacent cubicle by a metal barrier. The interrupting ratings will be selected in accordance with ANSI Standard C37.010 making full allowances for asymmetrical symmetrical current ratios. Incoming breaker and internal bus continuous current ratings will be chosen to be greater than the maximum expected loading.

## Medium Voltage Motor Controllers:

Motor controllers portion of the medium voltage switchgearwill be of the draw-out full-voltage across-the-line or reduced vacuum type (as indicated on the single line diagram), rated a minimum of 400 MVA, double-stacked wherever possible.

The controller and the bus will be adequately rated for the voltage class, the continuous current and the available short circuit level.

The protective fuses will be ANSI Class "R" for motor starting duty, and class "E" for transformer feeder duty. Single-phase protection will be provided to open contactors whenever any fuse blows.

Overload, under-voltage, single-phasing and ground fault protection will be provided.

Control voltage will be 120 V AC.

Each controller will have an ammeter and an ammeter switch.

All motors shall have motor circuit protection.

The switchgear lineup will include provisions for future bus extension on one end.

Switchgear rooms will be mechanically cooled and pressurized with filtered air to prevent the entrance of dust and dirt. Switchgear rooms will have at least two exits to assure safe personnel egress.

Secondary Unit Substations.

The 480 volt systems will be 4-wire, 3-phase, wye connected, and solidly grounded at the transformer neutral.

Transformer "T2" shall be an indoor dry-type, cast-coil, standard impedance, rated 1000 kVA.

For ease of maintenance, the 480 volt switchgear will be located indoors in pressurized switchgear rooms or other clean areas. Cast-coil, dry type transformers will be used indoors.

Transformer cooling fans will be provided to allow for future load growth and permit temporary overloading. The unit substations will be physically arranged to allow future switchgear additions, and to allow for transformer removal and replacement.

Main circuit breakers will be fully-rated, manually-operated withdrawable, air-break, stored energy spring operated, dead-front type, complete with solid-state overcurrent and ground fault trip devices.

Bus shall be fully rated to supply a continuous load of 1600 A.

Loads supplied directly from unit substations will include motor control centers, and other 480 volt loads larger than 100 amperes.

Motor Control Centers and AC Distribution Panels.

MCC's will have NEMA Type 1A enclosures with gaskets on doors and filler plates, or NEMA Type 12 in Water Treatment Area. Locations will be chosen with care to avoid damp, dirty, or hot areas and to allow adequate front and rear access.

Motor control centers will utilize standard modules factory assembled in suitable shipping lengths.

Motor control centers will be rated 65,000 A.S.C. and have NEMA Class I, Type B wiring rated 600 volts for 480 volt service. The upper limit of motor size supplied from MCC starters will be 200 hp where application is continuous duty with infrequent starting. Larger motors may be controlled by MCC starters where the application involves intermittent duty. Dual mounted molded case circuit breaker feeder units will also be provided in MCC's to supply 480 volt unit-related loads that do not require remote control.

Bus shall be fully rated to supply a continuous load as shown on the drawings and specifications.

Each fully rated combination starter unit will be complete with a molded case circuit breaker having adjustable magnetic trips only, magnetic contactor, three bimetallic overloads, auxiliary contacts, control power transformer, and control wiring terminal block. Control power transformers will be adequately sized to power the motor starter as well as the auxiliary control devices. Starter controls will be 120 volt AC with a coil seal-in contact.

The breakers will have 65,000 A interrupting capacity adequate for the available short circuit current.

All motor starters will be of the same manufacturer to ensure interchangeability of parts and to minimize stocking of spare parts. In addition, circuit breaker distribution panels will be provided at selected locations, as required, to serve small loads.

A minimum of 20% fully equipped space shall be provided in the motor control center for future additions.

DC Battery Powered Systems (breaker control).

125 VDC battery system with an energy storage capacity of four (4) hour minimum will include a lead-calcium, solid state rectifier-battery chargers, and main DC distribution panels.

The battery capacities will be adequate to supply all associated loads for the required sequence, duration, and combinations that occur when each breaker unit must be operated with no other power sources available.

The battery nominal voltage, float voltage and end of discharge voltage will allow operation over a voltage range acceptable to standard NEMA equipment with only occasional need for recharging.

The battery chargers will be sized to supply those DC loads that exist continuously during normal unit operation while simultaneously recharging a fully discharged battery. The maximum battery recharge period will be 12 hours. Chargers must be capable of operation without the battery.

A circuit breaker DC distribution panel will be provided adjacent to the batteries to minimize the length and maximize the security of the battery feeder cables. The circuit breakers will have thermal-magnetic overload trips, except for circuits feeding emergency auxiliary motors, which will have magnetic trips only.

DC battery powered emergency lighting system shall be furnished similar to the above in all respects.

## Grounding System.

In general, grounding system will be in accordance with the National Electrical Code and IEEE recommendations.

Instrument Grounding System.

A separate insulated grounding system will be provided for the computer and other noise sensitive electronic equipment. This will be a radial system, without loops and will be connected to the plant ground grid at one point only.

Instrument cable shields will be grounded at the load side only, leaving the sensor end ungrounded and insulated with the exception of thermocouples which are to be grounded at the instrument end.

## Lightning Protection.

The lightning protection system will be designed in accordance with the National Fire Protection Association Lightning Protection Code (NFPA 78) Class I or Class II systems, UL96A, the National Electrical Code, IEEE Standards and the Lightning Protection Institute - Installation Code (LPI-175).

## Electrical Heat Tracing.

Freeze protection and process heating systems will be provided for outdoor pipes, pumps, vessels and instrument sensing lines requiring process heating or freeze protection. The freeze protection system will automatically operate whenever the ambient falls below 40°F and will provide sufficient heat to prevent water freezing when the ambient temperature falls to 5°F less than the lowest ambient temperature recorded at the site. Control and monitoring systems for freeze protection will be centralized.

## Lighting Systems.

Plant lighting will consist of normal lighting and self contained DC operated emergency lights.

Normal lighting will provide illumination during normal operating conditions.

Facility indoor lighting distribution will be three-phase, four-wire. A 480/277 volt system will be used. Facility outdoor lighting distribution will be 480 volt, three-phase, three-wire with phase-to-phase connected loads.

Indoor lighting circuits will be distributed through three-phase. four-wire lighting panels, which will be located centered to and near their respective loads to minimize voltage drops.

Distribution will be designed so that failure of any single lighting panel will not totally black out any floor or single large area.

Lighting equipment selection will be based on the requirements of specific areas. Incandescent, fluorescent, and high pressure sodium sources with appropriate luminaries will be used depending on the application and the needs of each location. High pressure sodium lighting will be used for outdoor installations.

Generally, the illumination levels for facility areas will be those recommended by the Illuminating Engineering Society.

Lighting circuits will be switched at their distribution panels. Rooms and small buildings will have light switches at each doorway. Outdoor lighting will be photoelectrically controlled with provisions for manual override.

Loop road lighting will be in accordance with recommendations of the National Illuminating Engineers Society. These fixtures shall be suspended from building structural walls or members.

Emergency AC and lighting system will be provided for purposes of personnel egress and continuation of critical activities during emergency conditions.

Design illumination levels for egress lighting will be those required by applicable Federal, state, or local fire codes.

Communication Systems.

Telephones will be provided in the control room, in the offices and electrical switchgear room.

A facility paging and two-party communication system, complete with amplifying equipment, handset stations and speakers will be provided.

UPS System.

UPS System shall be 30 KVA with two 200 A, 3 ph., 4W outputs plus isolated ground for process controls and system architecture power supplies, with 15 minute ride-through and lead-acid battery racks as required.

Emergency Process Equipment.

The compressed air, auxiliary boiler and gasifier jacket cooling water feed systems shall be capable of automatic switchover to the auxiliary DC power source in the event of AC power source failure for equipment protection against overheating.

Life Safety System (fire alarms).

The zone panel shall be stand alone and report to a central command station located in the Engineer's Office. Total number of zones shall be at least 8 active with four spares.

Fire Protection System.

As separate electric source from Fort Martin Generating Station shall be utilized to power a dedicated fire pump serving the GPIF area in the event of fire.

## 12. Functional Descriptions - Phase 2

Conceptual Design for Coal Gasifier Test Facility

### Hot Gas Cleanup Unit & Sulfur Recovery

This area will be added under Phase II of the Coal Gasifier Test Facility.

Fluid Bed Absorber

The fluid bed absorber follows the ground rules suggested by METC to furnish a two stage bed. Given the reaction kinetics for the sulfidation of zinc ferrite, we feel that a single bed might be adequate to get the desired $H_2S$ removal. We assume a 2-stage bed is desirable for alternative research studies, and perhaps to produce ultra high sulfur capture, a landable goal.

Sorbent Regenerator

We have also used a riser tube sorbent regenerator as suggested by METC. If that arrangement is insufficient, we have allowed some space to install a moderately sized regenerator (fluid bed reactor) to obtain more residence time.

The revised arrangement could require the regenerator to be located above the absorber to permit gravity flow of regenerated sorbent into the absorber bed. That would raise the profile of the HGCU above the building roof thereby adding to the cost.

We have placed an airfin cooler to reduce the recycle gas to about 250-300°F as the recycle blower suction to allow standard materials (CS) in the blower.

Generally we are following the regenerator cooling cycle used by GE on their Schenectady pilot plant. It is believed that the system offers METC a flexible means to test various diluent circulating regimes to optimize the sulfur recovery feed gas.

Sulfur Recovery Unit

There are a variety of ways to convert the sulfur values in the off-gas to salable products.

The recovery of sulfur as sulfuric acid or liquid $SO_2$ are available as tested commercial processes so pilot plant study of such processes would be redundant.

The alternative of converting to elemental sulfur is supported by proven commercial processes such as the Allied/Davy Powergas SO2 Reduction Process.

Sodium/alumina catalysts (RTI bench scale work)

The tail gas from sulfur recovery should have the capability to be recycled to the process to eliminate final treatment to meet air emission standards.

Disposal of the recovered sulfur may present a problem. Because the sulfur is produced on an intermittent basis according to the pilot plant schedule, it may be difficult to find a user who would accept it. Also, at this point we are not certain of the quality of sulfur produced.

Those factors indicate that disposal to a solid waste dump appears to be a likely method of disposal. Solid sulfur is relatively insoluble, but it is combustible giving off hazardous products of combustion. Therefore, it may not be acceptable in landfills. The disposal of the sulfur will have to be investigated when a specific site is selected during the detailed design phase.

Liquid or solid sulfur produced from the test facility is expected to be either sold or properly disposed of in a disposal facility permitted for this type of material.

As an alternate, regenerated sulfur dioxide may be piped back to the gasifier or auxiliary packaged steam generator for ultimate ducting back into the breeching of Fort Martin Unit #2 upstream of the electrostatic precipitators.

## HGCU Description of Operation

### Coal Gas Cycle:

The purpose of the HGCU is to remove the $H_2S$ and sulfur compounds to a suitable level (<10 PPMV) from the coal gas stream. This unit also supplies the $SO_2$ rich feed gas to the direct sulfur recovery unit (DSRU).

The HGCU receives coal gas from the fines cyclone located in the gasifier area. The gas (which includes tars) is fed into the bottom of the HGCU absorber. The feed gas is at 600 psia and 1100°F.

The sorbent reagent is zinc ferrite with a binding agent to make a fluidizable grade catalyst. The zinc ferrite absorbs the sulfur bearing materials in the coal gas by converting the zinc and iron oxide components to zinc and iron sulfide. The sulfidation reaction is exothermic which raises the gas temperature to about 1200°F.

The coal gas passes through the perforated plate in the bottom of the absorber vessel. The gas fluidized sorbent bed allows intimate gas and sorbent contact.

The fluidizing coal gas then passes through a second perforated plate to a second fluidized sorbent bed. The final bed removes the last traces of sulfur bearing materials in the gas to a point less than 10 ppmv.

The cleaned coal gas passes out top of the absorber vessel through the internal cyclone which removes the larger particles from the gas and returns them to the upper bed through the cyclone dip leg.

The gas then passes through the sorbent fines cyclone to remove the sorbent fines from the coal gas before leaving the HGCU for delivery to the flare. The sorbent fines are removed to a tote bin through the cyclone lock hopper. The fines tote bin is either returned to the sorbent manufacturer or its contents are wasted to landfill depending upon sorbent economics.

### Sorbent Cycle

The sorbent treats the coal gas in two fluidizer beds in the HGCU Absorber. In this process, the zinc ferrite is converted to zinc and iron sulfide. This action is known as "sulfidation".

The sulfidation reactions are as follows:

$3\ Z_n\ Fe_20_4 + H_2 \text{-->} 3\ Z_n\ 0 + 2\ Fe_20_4 + H_20$
$Z_n\ 0 + H_2S\ \text{-->} Z_n\ S + H_20$
$Fe_3\ 0_4 + 3\ H_2S + H_2 \text{-->} 3\ Fe\ S + 4\ H_20$

It is necessary to continuously remove the sulfidated sorbent from the fluid beds and reactivate it to zinc and iron oxides. This process id known as "regeneration".

The sorbent is withdrawn from the lower bed by gravity into the spent sorbent receiver through a pipe. The inlet of the pipe is located near the top of the lower bed to catch the overflow of the bed. The rate of flow is controlled by a slide gate or other type of valve.

The sorbent in the spent sorbent receiver is in turn fluidized by the recycle gas stream entering the bottom of the spent sorbent receiver. Air is fed into the fluidized stream to provide oxygen to oxidize the sorbent according to the following reactions:

$ZnS + 2\ FeS + O_2 \rightarrow Zn\ Fe_2O_4 + 3\ SO_2$
$ZnS + 2O_2 \rightarrow ZnSO_4$
$ZnSO_4 \rightarrow Zn\ O + SO_3 + 1/2\ O_2$

The zinc sulfate reaction tends to occur at temperatures below 1200°F. Therefore, the regeneration temperature should be between 1250 and 1500°F.

The gas velocity in the riser tube is sufficient to transfer the sorbent up the tube to discharge into the regenerated sorbent cyclone. The cyclone drops out the sorbent into the body of the cyclone. The regeneration gas bearing the $SO_2$ gas leaves the top of the cyclone.

The regenerated sorbent is then fed by gravity into the upper fluid bed of the HGCU absorber. The flow rate of sorbent is controlled by a slide gate or other type of valve. The flow rate in the sorbent regeneration loop is controlled to prevent the break through of $H_2S$ in the coal gas discharge. Break through would be any level above 10 ppmv of $H_2S$ in the clean gas stream.

The sorbent passes from the upper bed to the lower bed through an internal standpipe to complete the sorbent cycle.

As the sorbent circulates, it wears and generates fines which are removed from the sorbent cycle. These losses are made up by feeding fresh sorbent through the fresh sorbent lock hopper. Fresh sorbent is received in tote bins from the sorbent manufacturer. Fresh sorbent batches are transferred through the fresh sorbent feeder and a dense phase pneumatic transfer system to the fresh sorbent lock hopper.

The fresh sorbent and fines lock hoppers must be vented and purged through the plant vent system to remove any coal gas in the vessels. This action is necessary from a safety and pollution control standpoint.

## Regeneration Gas Cycle

The carrier gas for the regeneration reaction in the riser tube is handled in the regeneration gas loop. The purpose of this system is to provide diluent gas for diluting the oxygen fed into the riser tube (regenerator). Dilution and distribution of the oxygen feed is necessary to prevent overheating of the sorbent. The sorbent breaks down when heated over 1500°F.

After the recirculation gas leaves the top of the regenerated sorbent cyclone, it passes through a fines removal cyclone to remove entrained sorbent fines. The fines are removed through a lock hopper to a fines tote bin for disposal.

The gas then passes through a porous metal or ceramic medium filter to remove any fine dust that passes through the fines cyclone. This piece of equipment was added to ensure a clean gas stream to avoid fouling the downstream shell and tube heat exchangers. This may be an optional piece of equipment for the pilot plant depending upon the dusting characteristics of the new fluid bed sorbents being developed.

Because the sorbent regeneration reaction was exothermic, it is necessary to remove the heat of reactions from the system. It is also necessary to cool the recirculating gas to ca. 300°F at the recirculation blower inlet to avoid overheating and the requirement of exotic materials. The recirculating gas heat exchanger accomplishes the cooling by reheating the cool recirculating gas before it is fed to the regenerator. Cold gas feed is likely to thermally shock the hot sorbent.

The $SO_2$ rich offgas is removed from the recirculating gas stream at either side of the recirc gas heat exchanger. This allows the offgas stream to be taken off at either 400°F or 1100°F as desired. The $SO_2$ rich offgas is bled off the system through a flow meter and flow control valve to feed the sulfur recovery system or to atmosphere through the dry lime quench system to suit pilot plant operating plans.

The still hot recirc gas then passes through the air preheater to heat up the regeneration system air supply. The regeneration air is supplied from the gasifier compressed air system.

It may also be desirable to dry the regeneration air supply to keep moisture out of the recirc gas system. Moisture in the air could combine with the $SO_2$ gas in the system to form $H_2SO_4$ which, in turn could cause corrosion in the equipment.

The recirc gas then passes through an airfin cooling coil to trim out any residual heat to reduce the gas temperature to 300°F. The cooled recirc gas enters the recirculation blower which increases the gas pressure back to 600 psia to pump it around the system. The blower serves to overcome the system pressure drops such as the riser tube, cyclones, filter, heat exchangers, etc., required by the system.

The blower discharges through the shell side of the recirculating gas heat exchanger into the bottom of the spent sorbent receiver to complete the cycle.

The regeneration air supply is distributed to the air inlets on the regenerator riser tube to burn off the sulfur. The air flow is controlled by a temperature control system to prevent overheating in the riser tube.

A electrically powered start-up heater is provided at the discharge of the blower to heat up the system by circulating hot nitrogen. This would be done for a cold system start-up.