TVA Coal Gasification Study
B&W Gasifiers

5.0 PLANT LAYOUT

INTRODUCTION

The development of the Key Plot Plan requires the optimization of all facilities from the standpoint of accomodating the process streams, minimizing piping sizes and lengths, consolidating common facilities, access to coal storage and ash deposit areas, minimizing changes in the topography of the site, minimizing visual intrusions into the environment, etc.

As the plant is now envisaged, the major, heavy, structural loads would be situated where some twenty feet of overburden occurs over occasional outcroppings of Chickamauga limestone. This would provide excellent subsoil conditions for accomodating foundations for gasifier reactor vessels and other, heavy, rotating equipment and tanks.

A prominent feature of the Key Plot Plan is the cluster of four gasification modules. Each module contains, in addition to the gasifier reactor, special coal preparation, raw gas cooling and compression (as may be required), extraction of by-products (when applicable) and treatment of the raw gas for removal of acidic compounds and sulfur.

Within the context of a conceptual design and level of detail expected in arriving at the cost estimate, the Key Plot Plan and elevation drawings, in two views of the entire plant, have been developed. The equipment and structures for the various process elements are representative of such units. The gasifier reactors and materials handling elevation views are fairly accurate representations of how the plant would actually appear.

The rationale and design philosophy for developing the Key Plot Plan and elevations is discussed below under the following headings.

KEY PLOT PLAN

Paragraph	Facility	Section No.
A.	Dock Facilities	2200
B.	Coal Storage, Handling & Preparation	100
C.	Coal Gasification	300
D.	Air Separation & Steam Generation	200, 1200
E.	Gas Treating & Removal of Sulfur	700, 600
F.	Waste Water Treatment	1500
G.	General Facilities	2000
H.	Flare & Incinerator	1400
I.	Ash Storage	2000
J.	Buildings	2100
K.	Cooling Water System	1300
L.	Elevation Views	---

KEY PLOT PLAN

A. Dock Facilities

A promontory on the N.W. shore of Murphy Hill has been selected for barge unloading as it incorporates the best features desired, considering:

1. Spillage of coal or water from coal into Guntersville Lake would be minimized.

2. There is minimal dredging required initially, and it is expected that future dredging of silt would be required on very infrequent intervals.

3. Docking and any movement of barges by tow boat, would be completely unhampered in this location. This is especially true in the event that 24 loaded and 24 unloaded barges had to be moored, as stipulated in the Design Criteria (1.2.3).

4. The conveyor, from the dock area inland, would pass along a land area at the S.W. corner of Murphy Hill which provides a convenient area for dead storage of coal to a height of approximately 50 ft.

A dock, auxiliary to the coal unloading facilities, is provided to accommodate the shipment of sulfur, either in a liquid state or as dry prills, by means of a barge. The auxiliary dock may also be utilized for the receipt of any bulk materials which would be necessary for the operation of the plant.

B. Coal Storage, Handling and Preparation

The acreage required for the 90 day dead storage, stipulated, is seen to occupy a peninsula at the S.W. corner of Murphy Hill. Maximal use is made of an area having an irregular boundary. The proportions of the area are such that the encircling roadway facilitates monitoring the coal pile to maintain compaction with a view to preventing fires and erosion of surface fines by the elements. One of the important benefits of the site selected for dead storage of coal is the latitude it provides for coal conveying and treatment. When coal is withdrawn from dead storage, there are several stations for transfer and processing of the coal before entering the final feed device for the gasifier or the ancillary combustion equipment. The lineal distance provided between reclaim from dead storage and the gasifiers is ample to accomodate limits on elevation feasible with the belt conveyors as coal is fed to various stations and, ultimately, to the gasifier feed.

C. Coal Gasification

The arrangement of the reactor for coal gasification is closely intertwined with the coal feed system and ash removal. As a consequence, the reactor vessels are aligned parallel to the raw coal feed and pulverizers and are in a linear arrangement so as to accomodate the system for removal of ash or slag as it occurs at the reactor itself. The process systems, ancillary to the coal gasifiers, are arranged in close proximity for each module.

D. Air Separation and Steam Generation

These plants are situated contiguous to each other and in close proximity to the gasifier to minimize the length of high pressure steam piping to the compressor turbine drives of the air separation plant. The economic necessity of minimizing the length of oxygen piping from the air separation plant to the gasifiers dictates having the air separation plant in close proximity to the gasifiers. Coal, flux and ash conveying design considerations have been a strong influence in determining the general location of the steam generation plant.

E. Gas Treating and Removal of Byproducts

The raw gas stream is processes to remove acidic compounds and to separate anc concentrate H_2S as well as other compounds containing sulfur in trace amounts. Ammonia is also separated from the raw gas for disposal by burning in the SRU reaction furnace. The separated gas stream containing the concentrations of sulfur compounds are then diverted to a Claus Sulfur Recovery Unit (SRU) to produce elemental sulfur. Inasmuch as each gasification module is provided with a separate gas treating and sulfur recovery system, all such units are contained in the plot area common to each module. A spare SRU is placed contiguous to the four modules.

F. Water Treatment

This area is for general service to the entire plant, exclusive of boiler feedwater treatment which is done in the utility area. The western area, adjacent to a cove S.W. of Murphy Hill, is a naturally low laying area at approximately 600 feet elevation. The principal reason for selecting this area is that it allows for adequate head to drain oily waters, and other liquid wastes for treatment. Considering the variety of ponds, tanks, clarifiers and separators, maximal utilization of the irregular terrain is possible with minimal requirements for grading. Inasmuch as the river flows from N.E. to S.W., overflow of treated wastewaters may be returned to the river, conveniently at a location downstream of the fresh water intake from the N.W. face of Murphy Hill, as shown on the Key Plot Plan.

G. General Facilities

This area is reserved for the storage of various chemicals such as limestone, chemicals for the treatment of wastewaters, catalysts, the storage of prilled sulfur ready for shipment, and the sewage treatment plant. The grade is at approximately 600 feet elevation to accommodate the gravity flow of sewage to the treatment plant, and is otherwise centrally located to serve various process units and the wastewater treatment area nearby.

H. Flare

A separate flare for each of the four modules is provided. The separate flare limits the maximum radiation from the flame of an emergency diversion of all process gas flows to the atmosphere. The flares are located S.E. of the process areas, to minimize the length of piping and yet, provide isolation of radiation from the flame. Moreover, the terrain where the flares are situated are areas which need only be cleared and grubbed, avoiding costly cutting and filling.

I. Ash Storage

Terrain laying generally N.E. of the process areas has been reserved for the storage of ash. The ash or slag storage commences from an area S.E. of Murphy Hill and occupies the terrain between the process areas and the shoreline surrounding the cove S.E. of Murphy Hill. This arrangement results in maximal utilization of an irregularly shaped terrain for the very considerable quantity of ash and slag which may require storage during the life of the plant. The entire perimeter of the ash and slag storage area is accessible by roadway which is built on an embankment constructed of rocky material from the plant site. At the foot of the embankment a drainage system is to be provided to collect surface water runoff.

J. Buildings

Administration, maintenance, visitor's center, laboratory, control, environmental data and dock buildings are some of the more important facilities which are identified on the Key Plot Plan. At the level of detail required for this phase of the study, additional buildings, stipulated in the Design Criteria, such as operator's shelters, weigh station instrument room, emergency first aid shacks, etc. are not shown but are otherwise included within the scope of the conceptual assessments.

Based on our preliminary estimate of ease of access to the site via either the connecting road running S.E. from the immediate exit of the plant thence to Five Points or S.W. of the main entrance, access to the plant is well selected, in our opinion.

K. Cooling Water System

The cooling towers and water circulating pumps are shown, at present, at the extremity of each of four gasification modules and adjacent to the air separation plant to minimize piping costs and pumping losses. As the cooling towers are situated, there is some, minimal, diffusion of cooling tower plumes over either the process areas or the buildings. As the reader may be aware, the prevailing wind in summer is to the south when the cooling towers would be operating at or near full capacity. In the winter months, the prevailing wind direction is to the north.

During summer operation, under windy conditions, cooling towers at the N.E. perimeter of the process areas would experience wind velocities which are flowing over the ash pile. The presence of the ash pile upstream of the cooling towers is not considered to have any measurable adverse impact on performance. This position appears to be confirmed by the results of tests on a tower-spoil hill configuration which duplicates, in almost every respect, the proposed design. Reference is made to the report: "Hydrothermal Modelling of Browns Ferry Nuclear Plant Cooling Towers" by S.C. Jain and J.F. Kennedy, Report No. 219, Iowa Institute of Hydraulic Research, April, 1979. The report, sponsored by TVA Water Systems Development Branch, makes the following statement in regard to the spoil hill upstream of the cooling towers.

> "The influence of the spoil hill on $\bar{R}$ (the recirculation ratio of effluent air stream into the intake louvers) is insignificant, amounting to no more than $\pm 1\%$"

(Foregoing appears on p. 25, VI. Summary of Results)

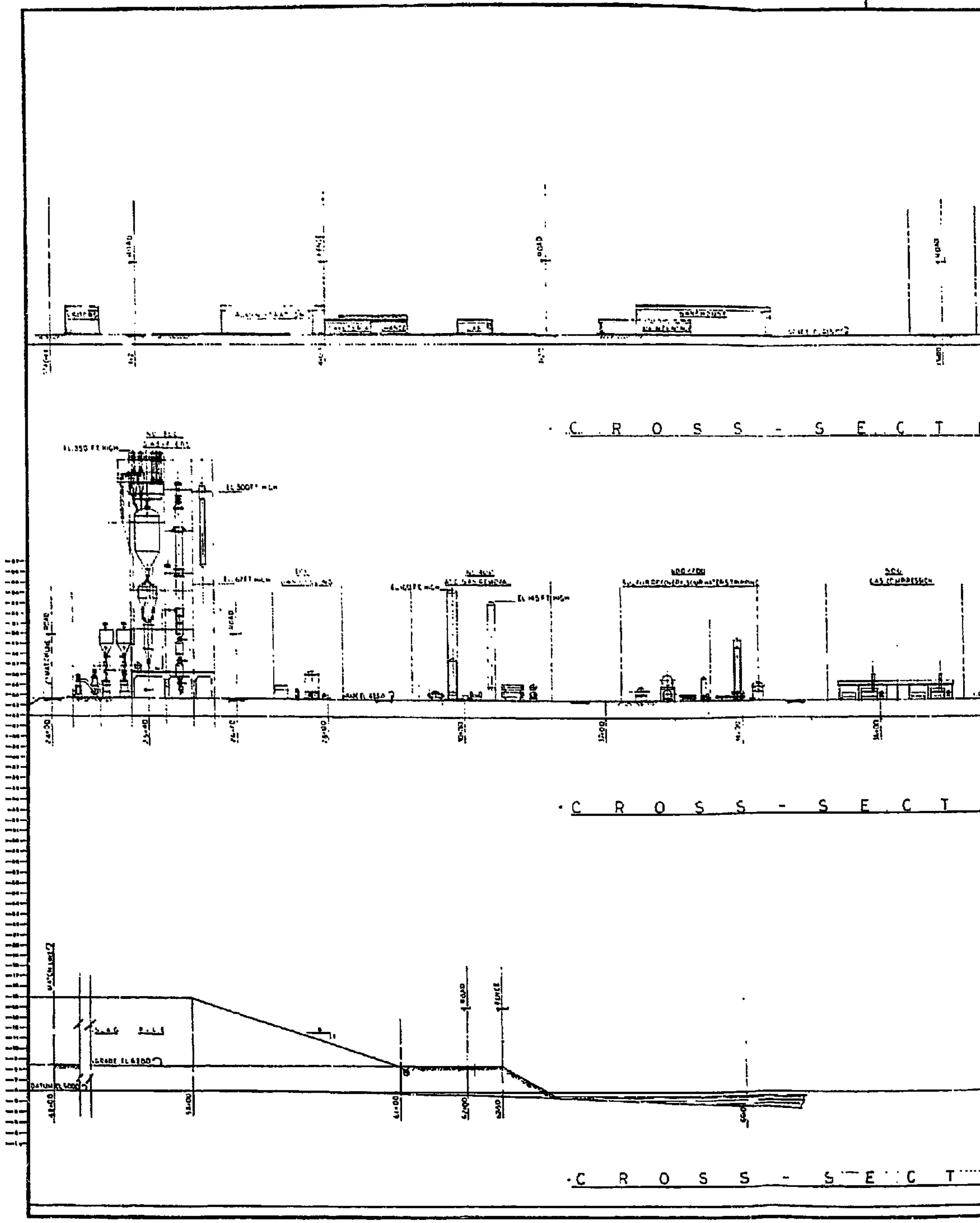
L. ELEVATION VIEWS

I. Terrain

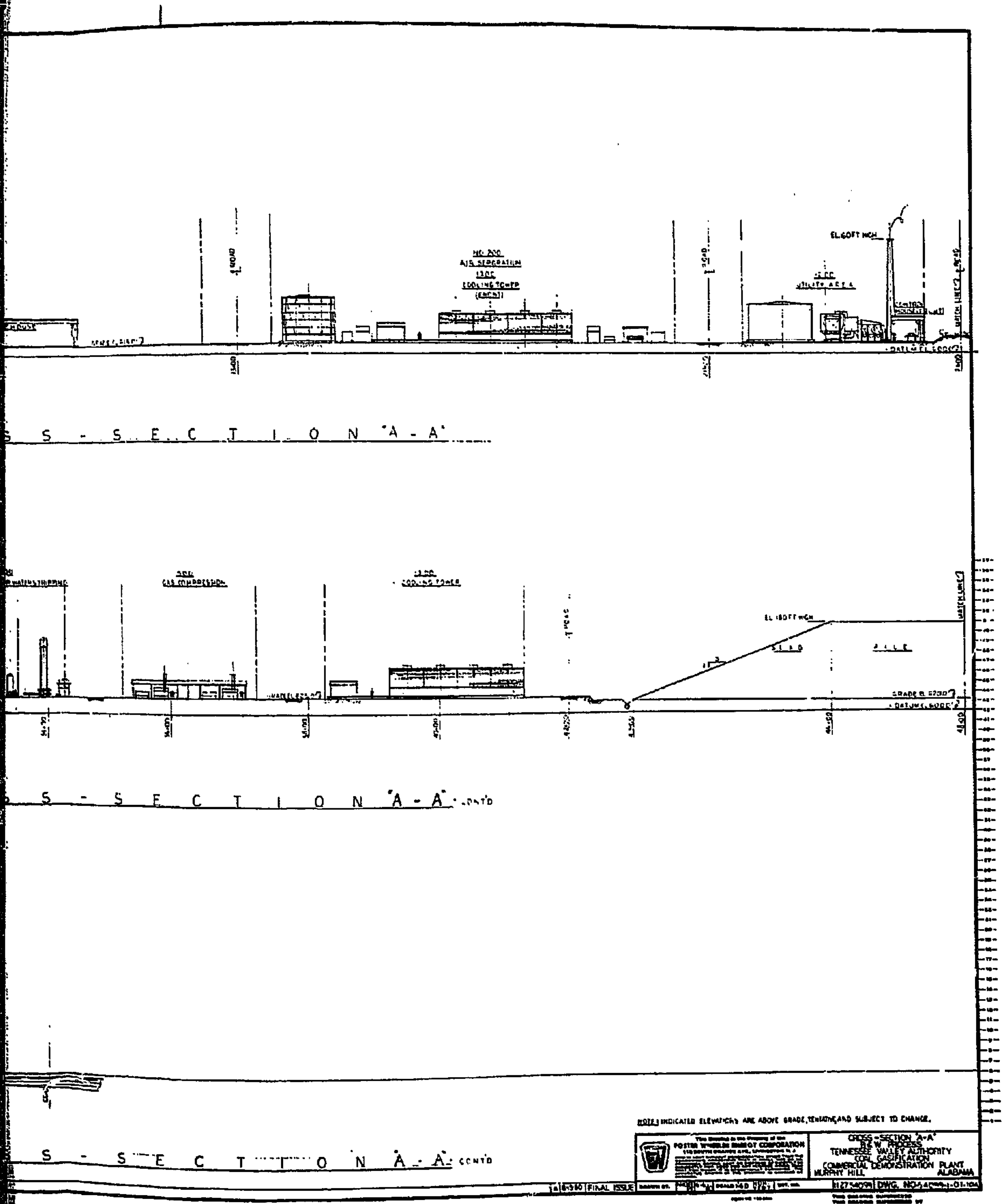
Considering the rocky nature of the subsoil, based on extensive boring and seismic depth of rock determination, the plant areas have been terraced in order to minimize costly cutting and filling of excavated materials. The terraces shown are substantially those which form the basis of the cost estimates. As will be evident from the drawings, every effort has been made to limit differences in elevation to 15 feet. Wherever a greater difference in elevation occurs, a roadway for access of fire fighting equipment has been provided at the higher elevation, paralleling the main service road below.

II. Process Units

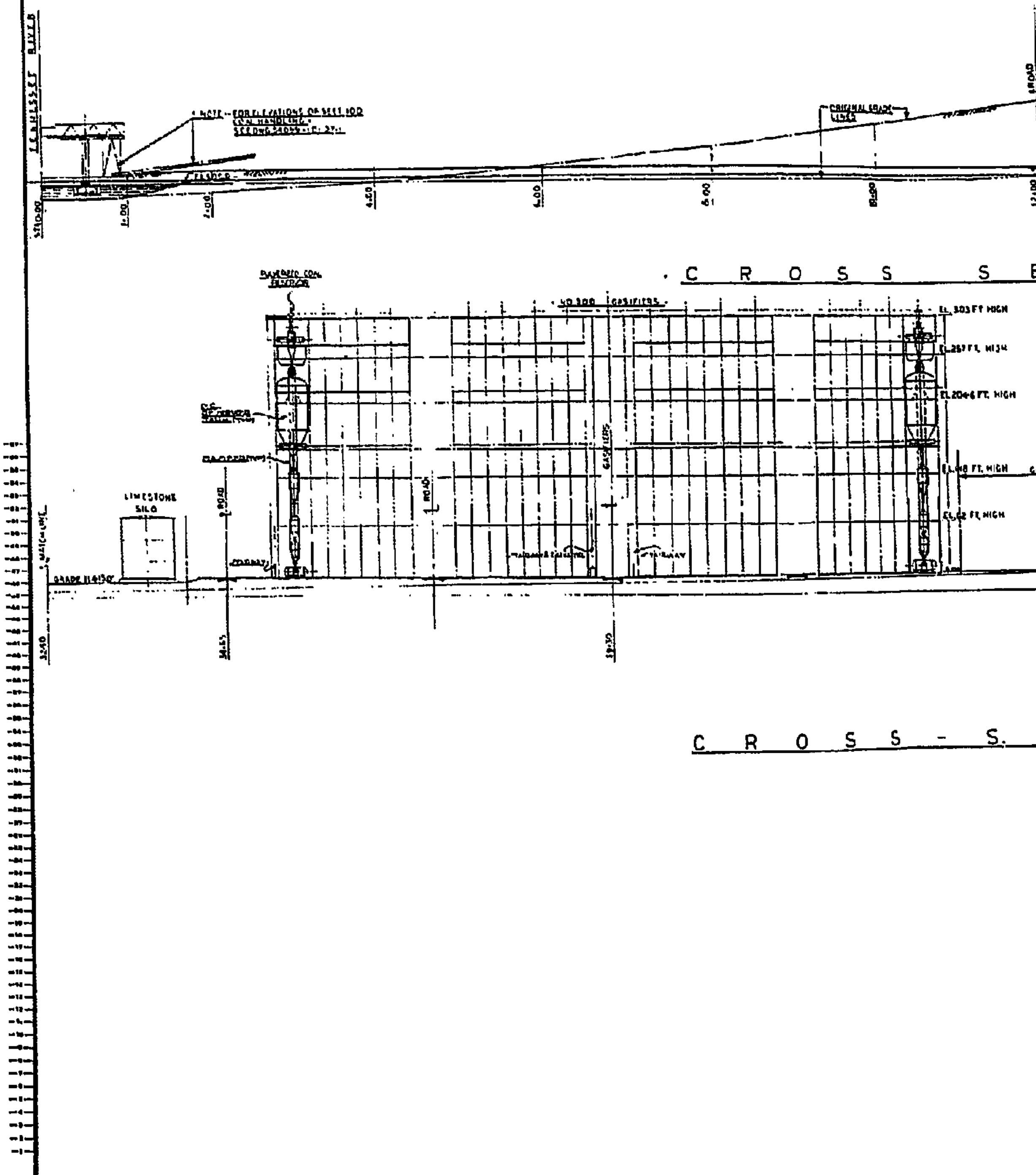
The structures, towers and other equipment shown are representative of the type of equipment for a particular process. Where fairly detailed information on both the size and quantity of equipment was available, as an example the gasifier reactors and ancillaries, the elevation views shown are substantially an accurate pictorial representation.

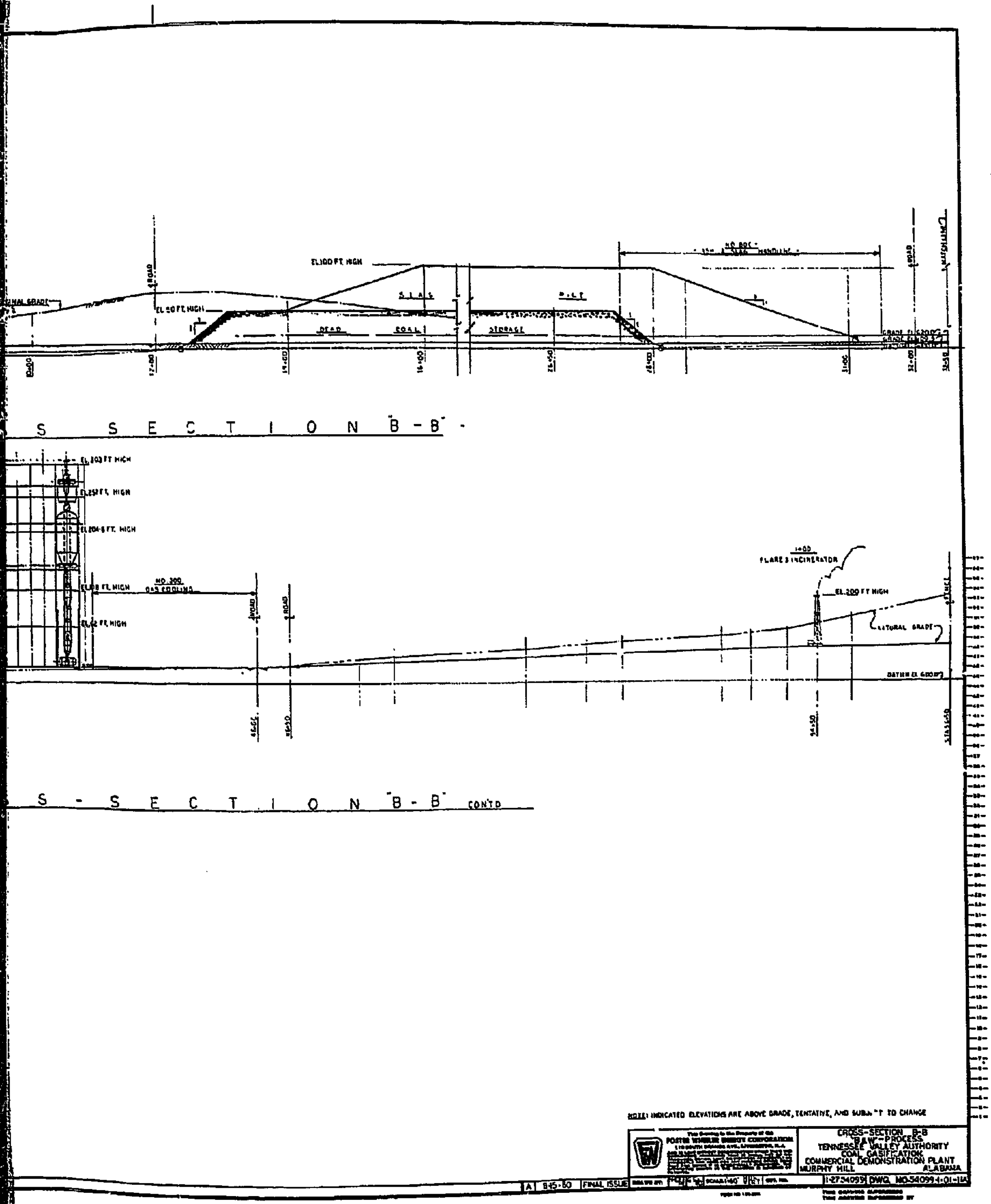


ROAD
C R O S S - S E C T
EL 350 FT HIGH
EL 145 FT HIGH
GAS COMPRESSOR
C R O S S - S E C T
SLAG PILE
ROAD
FENCE
C R O S S - S E C T



NO. 200
AJS SEPARATION
1300
COOLING TOWER
EL. 60FT HGH
UTILITY AREA
S - S E C T I O N "A - A"
500
GAS COMPRESSION
1300
COOLING TOWER
EL. 180FT HGH
PILE
GRADE EL 5700
DATUM EL 600
S - S E C T I O N "A - A" CONT'D
NOTE: INDICATED ELEVATIONS ARE ABOVE GRADE, TENTATIVE AND SUBJECT TO CHANGE.
FOSTER WHEELER ENERGY CORPORATION
CROSS - SECTION "A-A"
B&W PROCESS
TENNESSEE VALLEY AUTHORITY
COAL GASIFICATION
COMMERCIAL DEMONSTRATION PLANT
MURPHY HILL
ALABAMA
FINAL ISSUE
S - S E C T I O N "A - A" CONT'D


TENNESSEE RIVER
ORIGINAL GRADE LINES
GASIFIERS
EL. 303 FT HIGH
EL. 257 FT. HIGH
EL. 204-6 FT. HIGH
EL. 148 FT. HIGH
EL. 82 FT. HIGH
LIMESTONE SILO
GASE LEGS
ROAD
C R O S S S
C R O S S - S.


EL.100 FT. HIGH
S L A G
P I L E
DEAD
COAL
STORAGE
EL.50 FT. HIGH
ROAD
GRADE
S - S E C T I O N "B - B"
EL.303 FT. HIGH
EL.251 FT. HIGH
EL.204.6 FT. HIGH
NO. 300
GAS COOLING
EL.62 FT. HIGH
ROAD
FLARE & INCINERATOR
EL.200 FT. HIGH
NATURAL GRADE
S - S E C T I O N "B - B" CON'TD
NOTE: INDICATED ELEVATIONS ARE ABOVE GRADE, TENTATIVE, AND SUBJECT TO CHANGE
CROSS-SECTION B-B
"B&W"-PROCESS
TENNESSEE VALLEY AUTHORITY
COAL GASIFICATION
COMMERCIAL DEMONSTRATION PLANT
MURPHY HILL ALABAMA
A 8-15-80 FINAL ISSUE
SCALE 1"=40'
1-2734099 DWG. NO.540994-01-1A

SECTION 6.0

ENVIRONMENTAL ASSESSMENTS

TVA Coal Gasification Study
B&W Gasifiers

6.0 ENVIRONMENTAL ASSESSMENT

The emission usually associated with a coal gasification plant involves possible contaminants discharged as gases or particulates into the atmosphere, as dissolved and insoluble liquids and solids in the waste water from the plant including run-off and leachate from coal and ash piles as well as possible thermal pollution.

The gasifiers investigated for the TVA study all use cooling towers or air coolers so that thermal pollution of hot waste liquid to the rivers and streams is not a consideration. A process block flow diagram is attached which shows the major emissions and process effluent. Most of the sulfur in coal is gasified in the form of H_2S and COS. These compounds together with particulates are removed by aqueous scrubbing followed by Acid Gas Treating (Selexol). Sour water produced during gas cleanup is sent to the Sour Water Stripper, T-701, for removal of absorbed H_2S and NH_3, then clarified to remove solids before being pumped to wastewater treatment (Dirty Water Holding Basin, X-1501). Ammonia in the sour gas is destroyed and elemental sulfur recovered from H_2S in the Claus Unit. The Sulfur Plant has a tail gas cleanup unit for the unconverted sulfur gases from the Claus Unit called a Beavon Unit. All the gas remaining after sulfur removal is vented to the atmosphere with less than 200 ppm (v) of sulfur.

The Babcock and Wilcox process produces negligible amounts of ammonia and any nitrogen compound in the product gas is absorbed in the quench water and stripped in the sour water stripper, together with H_2S and sent to the Claus plant. In the Claus Unit the ammonia is converted to elemental nitrogen so that NOX is not formed in the product gas.

High pressure steam is generated in a coal fired fluidized bed of limestone removing some 90% of the sulfur dioxide formed with the combustion of coal. Hot flue gas together with additional flue gas from a flue gas generator is used to dry the wet coal in the coal pulverizer. The flue gas is then vented through a baghouse to minimize loss of particulate to the atmosphere.

Product gas is scrubbed with water in two stages of venturi scrubbers to remove particulates. The sour water from the scrubbers is stripped to remove dissolved acid gas and settled to remove char and then treated before discharge.

The principal gaseous emissions from this facility are the following:

a) Gas leaving the Beavon Sulfur Recovery Unit absorber, (Item No. 27-15-T-620)
b) Gas vented from the Beavon Unit Oxidizer Pit, (Item No. 27-15-X-620)
c) Gas from the Primary Pulverized Coal Baghouse, (Item No. 27-14-F-301)
d) Gas from the Secondary Pulverized Coal Baghouse, (Item No. 27-14-F-302)

The Claus Unit and Beavon Tail Gas Treating Unit together convert almost all the sulfur from sour gases to elemental sulfur. The clean gas stream containing less than 200 ppmv of total sulfur, emission "a" listed above, is discharged to atmosphere from the absorber in the Beavon Unit (part of Sec. 600).

Emission "b" results from air which flows through the Beavon Unit Oxidizer Pit and oxidizes the sulfides to elemental sulfur. The licensor has stated that this emission "b" is contaminant-free and is essentially nitrogen and oxygen (air). The quantity of oxygen which reacts is small.

The largest emission quantity, "c" leaves the Primary Pulverized Coal Baghouse in Sec. 300, Gasification. Hot flue gases from Steam Generation, Sec. 1200-4, are directed to the Coal Pulverizers, (Item No. 27-14-GR-301) in Sec. 300 and serve to dry the coal to about 2.0 wt. % water from 9.564 wt%. The flue gases are produced in the Flue Gas Generator and High Pressure Steam Generators in Sec. 1200-4 and also contain tempering air which serves to transport and also to cool the flue gas to the temperature required for drying.

The smaller emission "d" from the Secondary Pulverized Coal Baghouse is nitrogen released during venting of the lock hoppers and coal feed tank in order to permit continuous feeding of coal to the gasifiers.

The gaseous emissions described above are listed in Table I for a single module. The gasification plant will have a total of four gasification modules.

Emissions a) and b) were estimated from available data. Emission c) was calculated based on 20% excess air in the fluidized bed (H.P. steam) boilers and combustion of Kentucky #9 seam coal described in Table IV. The Pulverized Coal Cyclone, S-301, in series with the Primary Pulverized Coal Baghouse, F-301, together will achieve an overall efficiency for particulate removal of about 99.99%. The resulting emission level of particulates will meet the federal limit of 0.03 lbs/ million Btu fired. The Secondary Pulverized Coal Baghouse, F-302, which filters a small gas flow, will be approximately 99% efficient and will reduce particulates to less than 0.05 grains/ACF. Emission quantities are presented in Table I, items 3 and 4.

In addition to the above gaseous emissions, the cooling tower will emit large quantities of water vapor as evaporative and windage losses.

The principal normal effluent stream quantity is cooling tower blowdown. This stream will be treated to reduce zinc and chromium to undetectable levels before being discharged.

Clean water streams, rinse and neutralization water from demineralization, ash pile leachate and stormwater runoff will be surged in a common basin, then used in ash handling or perhaps fed to the cooling tower or discharged in part.

Coal pile runoff, service water and stripped sour water are combined and treated to precipitate chlorides and iron, then used as cooling tower makeup or alternatively they are discharged. BOD levels for coal pile runoff and service water are specified in Table III. The BOD level for stripped sour water is approximately equal to the suspended solids level or about 40 ppmw. The composite stream, after wastewater treating, will contain about 40 ppmw BOD.

Each of the above aqueous streams is described in Table III. Quantities indicated are per module and contaminants are our best estimates from engineering literature and past experience with similar or other gasification processes. Sanitary waste water, approximately 10,400 lbs/hr per module, is treated in a packaged biological system and is then discharged.

Modifications of the reported effluents may be expected based upon any additional information received from the process developer, from literature or from similar processes.

TABLE I

Emissions to Atmosphere

1. Vent Gas from Beavon Unit Absorber

Component	Molec Wt.	Mols/Hr	Lbs/Hr
Hydrogen (H_2)	2.016	2.402	4.84
Carbon Monoxide (CO)	28.011	—	—
Carbon Dioxide (CO_2)	44.011	336.759	14,821.1
Nitrogen (N_2)	28.014	1,075.025	30,115.75
Oxygen (O_2)	32.000	—	—
Hydrogen Sulfide (H_2S)	34.080	10ppmv max.	0.46
Carbonyl Sulfide (COS)	60.075	190ppmv	—
Total Dry Gas		1 414.187	44,942.15
Water		83.058	1,496.37
Total Wet Gas		1,497.245	46,439
Temperature, °F		95	

2. Vent Gas from Beavon Unit Oxidizer Pit T=100°F

Component	Mols/Hr	Lbs/Hr
N_2	177.75	4,979
O_2	47.30	1,514
Total Dry Gas	225.05	6,493
Water	15.54	280
Total Wet Gas	240.59	6,773

TABLE I

Emissions (Cont'd)

3. Flue Gas from Primary Pulverized Coal Baghouse (Sec 300)

To Atmosphere

Component	Molec Wt.	Mols/Hr	Lbs/Hr
CO_2	44.011	939.86	41,364
N_2	28.014	23,517.38	658,816
O_2	32.000	5,123.10	163,9[illegible]
SO_2	64.066	1.90	122
Cl_2	70.914	0.312	22
Particulates	—	—	6.1
NO_x		1.55	71.3
Total Dry Gas		29,584.11	864,340.4
Water		2,427.47	43,733.3
Total Wet Gas		32,011.58	908,074
Temperature, °F		150	

4. Gas from Secondary Pulverized Coal Baghouse (Sec 300)

Component	Moles	Lbs/Hr
Nitrogen	1,258	35,242
Particulates		3.7
Total Gas	1,258	35,246

TABLE II

EFFLUENT STREAMS and LOSSES

Source	Flow, lbs/hr		Net Aqueous Discharge, lbs/hr
Rinse and Neutralization	60,700 (50,000 to Ash Handling)		10,700 Or to Cooling Tower
Service Water	100,000	To Cooling Tower	0
Stripped Sour Water	303,000		
Cooling Tower Blowdown	275,000		275,000
Cooling Tower Evaporation	1,330,000		1,330,000
Cooling Tower Windage Loss	260,000		260,000
Air Separation Plant	(17,000)		(17,000)
Lime Sludge	16,000	Water	16,000
Aqueous Discharge			1,874,700 lbs/hr (3,750 gpm.)

Net Aqueous Makeup

After Raw Water Treating = 60,700 + 275,000 + 1,330,000 + 260,000 + 16,000 − 17,000

= 1,924,700 lbs/hr = 3,850 gpm

TABLE III

EFFLUENT STREAMS BREAKDOWN

	Streams	Discharge Flow Lbs/Hr	Estimated Quality
1.	Rinse and Neutralization Water	10,700	TDS 6,000 mg/liter PH neutral
2.	Ash Pile Leabhate	150,000 Intermittent Flow	TDS 500 mg/liter SS 200 mg/liter BOD 10 mg/liter
3.	ISBL Stormwater Runoff	28,000 Intermittent Flow	TDS 100-150 mg/liter SS 50-100 mg/liter BOD 20 mg/liter

Streams 1. + 2. + 3. are pumped to the cooling tower or discharged. If discharged, flow = 188,700 Lbs/hr, TDS = 64.2 + 75.0 + 3.5 = 142.7 #/hr.

SS = 30 + 2.1 = 32.1 #/hr, BOD = 1.5 + 0.56 = 2.06 #/hr, PH 6.5

	Streams	Discharge Flow Lbs/Hr	TO TRTG
4.	Coal Pile Runoff	24,000 Intermittent Flow	TDS 500 mg./liter (12#/hr) SS 200 mg./liter (4.8#/hr) BOD 8 mg./liter (0.19#/hr) COD 10-20 mg./liter (0.24-0.48#/hr) PH 2.5

TABLE III

EFFLUENT STREAMS BREAKDOWN (Cont'd)

	Stream	Discharge Flow Lbs/Hr	Estimated Quality
			TO TRTG
5.	Service Water	100,000	TDS 200 mg/liter (20#/hr)
			SS 200 mg/liter (20#hr)
			BOD 50-150 mg/liter (5-15#hr)
6.	Stripped Sour Water	303,000	TDS 7,000-8,000 (2,121-2,424#/hr)
			NH_3 20 mg/liter (6.1#hr)
			H_2S 5 mg/liter (1.6#hr)
			SS 40 mg/liter (12.1#hr)
			Cl 1,750 mg/liter (530#hr)

Streams 4 + 5 + 6 normally are pumped to the cooling tower. If discharged, flow = 24,000 + 100,000 + 303,000 - 16,000 = 411,000 Lbs/hr

water with lime sludge

		After TRTG
SS	30 mg/liter x 411,000	= 12.3 #/hr
COD	25 mg/liter x 411,000	= 10.3 #/hr
TDS	500 mg/liter x 411,000	=205.5 #/hr

	Stream	Discharge Flow	Estimated Quality
			TO TRTG
7.	Cooling Tower Blowdown	275,000 Lbs/hr	
			Cr 12 mg/liter (3.3#/hr)
			Zn 8 mg/liter (2.2#/hr)
			TDS 1,000 mg/liter (275#/hr)

TABLE III

EFFLUENT STREAMS BREAKDOWN (Cont'd)

7. Cooling Tower (Cont'd)

LVG. TRTG

Cr	0.05 mg/liter (0.0137#/hr) undetectable
Zn	0.1 mg/liter (0.0275 #/hr)
TDS	1,000 mg./liter (275 #/hr)

TABLE IV

Composition Given to FW for Kentucky #9 Seam Coal

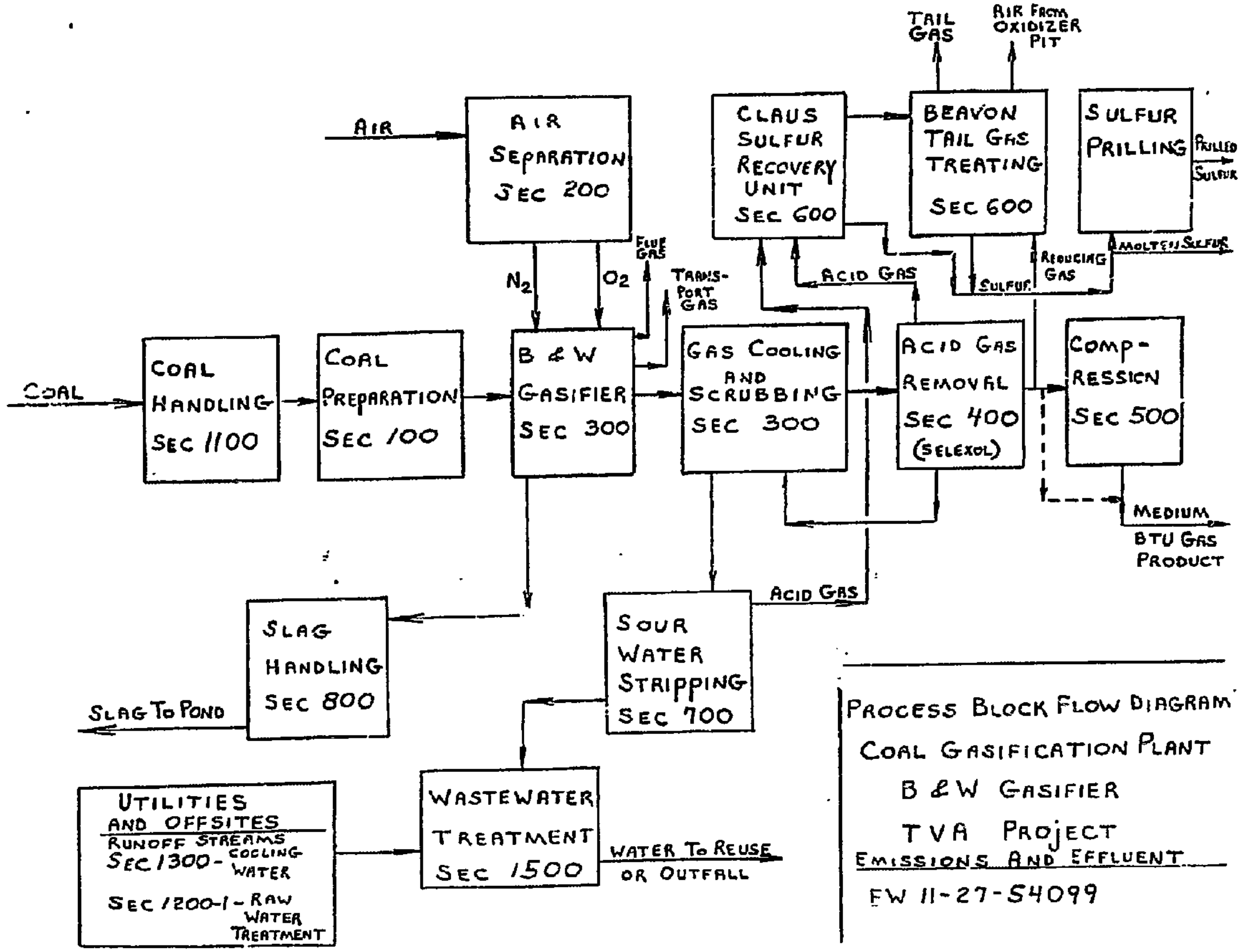
Component in Coal	Dry Wt%	As-Is Wt%
Carbon (C)	67.310	60.872
Hydrogen (H_2)	4.757	4.302
Nitrogen (N_2)	1.529	1.383
Oxygen (O_2)	6.343	5.736
Sulfur (S)	4.100	3.708
Ash	15.830	14.316
Chlorine (Cl_2)	0.131	0.119
H_2O	0	9.564
Total	100.000	100.000

TABLE V

SOLID WASTE STREAMS

(Dry Basis)

		One Module Tons/Day	Four Modules Tons/Day
1.	Slag From Gasifiers	645.2	2580.8
2.	Lime Sludge (solids)	48.0	192.0
3.	Ash and Spent Stone From Boilers and Flue Gas Heaters	100.6	402.4
	Total	793.8	3175.2



PROCESS BLOCK FLOW DIAGRAM
COAL GASIFICATION PLANT
B & W GASIFIER
TVA PROJECT
EMISSIONS AND EFFLUENT
FW 11-27-54099

SECTION 7.0

SUGGESTIONS FOR FOLLOW-ON WORK

SUGGESTIONS FOR FOLLOW-ON WORK

In the event that TVA selects the B & W Gasifier for further consideration relative to the proposed Coal Gasification Demonstration Plant, the follow-on work described below is suggested:

A. Carry out bench scale and pilot plant tests of TVA candidate coals. These tests would be extensive since no commercial or demonstration B & W gasifier is presently in operation.

B. Carry out further engineering studies of gasifier process and mechanical design.

C. Carry out further engineering studies and pilot tests of coal injection system at gasifier operating pressure.

D. Study properties of B & W gasifier slag and carry out engineering and tests on slag removal system.

E. Review and further optimize steam, cooling water and overall water usage in the plant.

SECTION 8.0

PROJECTIONS

PROJECTIONS

Future development of the B&W gasification system based upon economics would tend toward:

- Higher operating pressure
- Modified coal injection methods
- Better metallurgy for gasifier and waste heat boiler

Confidence will grow with the application of a demonstration plant for the B&W gasifier.

9.1 Investment Costs

The total capital investment required for the commercial coal gasification plant, based on the Babcock and Wilcox entrained flow gasifier, is estimated at $1.86 billion. Included in this total are the following capital related costs:

- Installed plant cost
- Initial catalyst and chemical inventory
- Cost of land at $3,000 per acre
- Plant start-up costs; taken as a percentage of the plant annual operating cost
- Required working capital; summarized in Table 9.7

The estimated installed plant cost, summarized in table 7.1, is $1.69 billion. This represents a conceptual cost estimate, based on first quarter 1980 costs for an Alabama site, having an expected accuracy of +30%,-15%. The accuracy range specifically means that the upper limit has a value of 30% higher than the estimated cost and the lower limit is 15% below the estimated value.

In addition to the battery limits processing units and support facilities, the installed plant cost includes site preparation, spare parts, and a project contingency factor. Process engineering and license fees are included in the costs for the individual process units. Additional breakdown of the costs associated with the plant support facilities is given in Table 9.2. It should be noted that only about 10% of the total required site preparation cost is included in the installed plant cost. The remaining site prepartion for ash disposal is treated as an operating expense over the life of the plant.

Items specifically excluded form the plant investment cost estimate are:

- Soil consultant expenses
- Environmental consultant expenses
- Craft training program
- Cost of all permits
- Import duties, if any
- Escalation from date of estimate
- Financing charges
- Construction camp facilities
- Sales and use tax

The estimated schedule of investment capital disbursements according to plant module is given in Tables 9.3 through 9.6. The disbursements corresponding to the erected plant cost were estimated according to Foster Wheeler's proposed overall project schedule shown in Figure 9.1. Cost of land acquisition was charged in the year 1981 while the cost for the initial charge of catalyst and chemicals was charged during the last year of construction. Working capital and start-up costs were accounted during the year of plant start-up.

TABLE 9.1

PLANT BASED ON BABCOCK & WILCOX GASIFIERS

Summary of Estimated Capital Investment
in Millions of Dollars (1980)

MODULE		1	2	3	4	TOTAL
ON-SITES						
SECTION	DESCRIPTION					
100	Coal Receipt and Preparation	39.8	0	0	0	39.8
200	Air Separation	78.3	72.3	72.3	72.3	295.2
300	Gasification	155.0	155.0	155.0	155.0	620.0
400	Acid Gas Removal	34.8	34.8	34.7	34.7	139.0
500	Product Gas Compression	4.5	4.4	4.4	4.4	17.7
600	Sulfur Recovery	24.7	12.4	11.3	11.3	59.7
700	Sour Water Stripper	5.0	4.9	4.9	4.9	19.7
800	Ash/Slag Handling	2.3	2.3	2.3	2.2	9.1
900	Phenol Recovery	-	-	-	-	-
1000	Ammonia Recovery	-	-	-	-	-
	SUB- TOTAL	344.4	286.1	284.9	284.8	1,200.2
	Offsites	113.8	55.1	39.7	25.6	234.2
	Spare Parts	8.0	5.4	5.3	5.3	24.0
	Site Preparation	10.6	0	0	0	10.6
	Contingency	73.3	48.9	48.9	48.9	220.0
	TOTAL INSTALLED PLANT COST	550.1	395.5	378.8	364.6	1,689.0
	Initial Catalyst & Chemicals	0.4	0.2	0.2	0.2	1.0
	Cost of Land	1.5	0	0	0	1.5
	Start-Up Cost	26.7	17.8	17.8	17.8	80.1
	Working Capital	23.6	21.7	21.5	21.2	88.0
	TOTAL CAPITAL INVESTMENT	602.3	435.2	418.3	403.8	1,859.6

Table 9.2

Summary of Support Facilities Cost

B&W Gasification

Section	Description	D&E Cost, MM$
1200	Utilities Area	
	Water Treatment	4.5
	Steam Generation	36.2
1300	Cooling Water System	27.5
1400	Flare System	3.2
1500	Waste Water Treating	20.0
2000	General Facilities	
	Storage	5.2
	Electric Power Distribution	45.7
	Lighting & Communications	2.5
	Roads & Fences	2.2
	Firewater System	5.0
	Inter-Connecting Piping	69.7
2100	Buildings	10.5
2200	Dock Facilities	2.0
		234.2

TABLE 9.3

PLANT BASED ON BABCOCK & WILCOX GASIFIERS

ESTIMATED INVESTMENT CAPITAL DISBURSEMENTS SCHEDULE

MILLIONS OF 1980 $

MODULE #1

Year	Installed Plant Cost	Other * Investment	Working Capital	Yearly Total
1980	9.35	-	-	9.35
1981	32.73	1.5	-	34.23
1982	151.29	-	-	151.29
1983	232.15	-	-	232.15
1984	124.58	9.4	11.78	145.76
1985	0	19.0	11.78	30.78
TOTAL	550.10	29.9	23.56	603.56

* Other Investment = Cost of Land, Start-Up (Costs) and Initial Catalyst & Chemicals.

TABLE 9.4

PLANT BASED ON BABCOCK & WILCOX GASIFIERS

ESTIMATED INVESTMENT CAPITAL DISBURSEMENTS SCHEDULE

MILLIONS OF 1980 $

MODULE #1 and 2

Year	Installed Plant Cost	Other * Investment	Working Capital	Yearly Total
1980	9.35	-	-	9.35
1981	32.73	1.5	-	34.23
1982	165.54	-	-	165.54
1983	293.70	-	-	293.70
1984	305.32	9.4	11.78	326.50
1985	138.96	19.2	11.78	169.94
1986	0	24.0	21.75	45.75
TOTAL	945.60	54.1	45.31	1,045.01

* Other Investment = Cost of Land, Start-Up (Costs) and Initial Catalyst & Chemicals.

TABLE 9.5

PLANT BASED ON BABCOCK & WILCOX GASIFIERS

ESTIMATED INVESTMENT CAPITAL DISBURSEMENTS SCHEDULE

MILLIONS OF 1980 $

MODULE #1, 2 and 3

Year	Installed Plant Cost	Other * Investment	Working Capital	Yearly Total
1980	9.35	-	-	9.35
1981	32.73	1.5	-	34.23
1982	165.54	-	-	165.54
1983	308.26	-	-	308.26
1984	375.75	9.4	11.78	396. 93
1985	330.65	19.2	11.78	361.63
1986	102.12	35.7	43.21	181.03
1987	0	8.5	0	8.5
TOTAL	1324.40	74.3	66.77	1,465.47

* Other Investment = Cost of Land, Start-Up (Costs) and Initial Catalyst & Chemicals.

TABLE 9.6

PLANT BASED ON BABCOCK & WILCOX GASIFIERS

ESTIMATED INVESTMENT CAPITAL DISBURSEMENTS SCHEDULE

MILLIONS OF 1980 $

MODULE #1 thru 4

Year	Installed Plant Cost	Other * Investment	Working Capital	Yearly Total
1980	9.35	-	-	9.35
1981	32.73	1.5	-	34.23
1982	165.54	-	-	165.54
1983	308.26	-	-	308.26
1984	394.10	9.4	11.78	415.28
1985	421.05	19.2	11.78	452.03
1986	292.51	35.7	43.21	371.42
1987	65.46	28.7	21.21	115.37
1988	0	0	-	-
TOTAL	1,689.00	94.5	87.98	1,871.48

* Other Investment = Cost of Land, Start-Up (Costs) and Initial Catalyst & Chemicals.

Table 9.7

Estimated Working Capital (1980 Dollars)

B&W Gasification

Plant Modules	1	2	3	4	Total
Coal inventory 90 days @ $1.25/MMBTU	13.93	13.93	13.93	13.93	55.72
Plant materials and supplies @ 0.9% installed cost	4.95	3.56	3.41	3.28	15.20
Plant payroll @ 90 days	1.13	0.71	0.57	0.45	2.86
Catalyst and chemicals @ 90 days	0.20	0.20	0.20	0.20	0.80
Electric power costs 90 days @ $0.024/KWH	3.35	3.35	3.35	3.35	13.40
Total, MM$	23.56	21.75	21.46	21.21	87.98

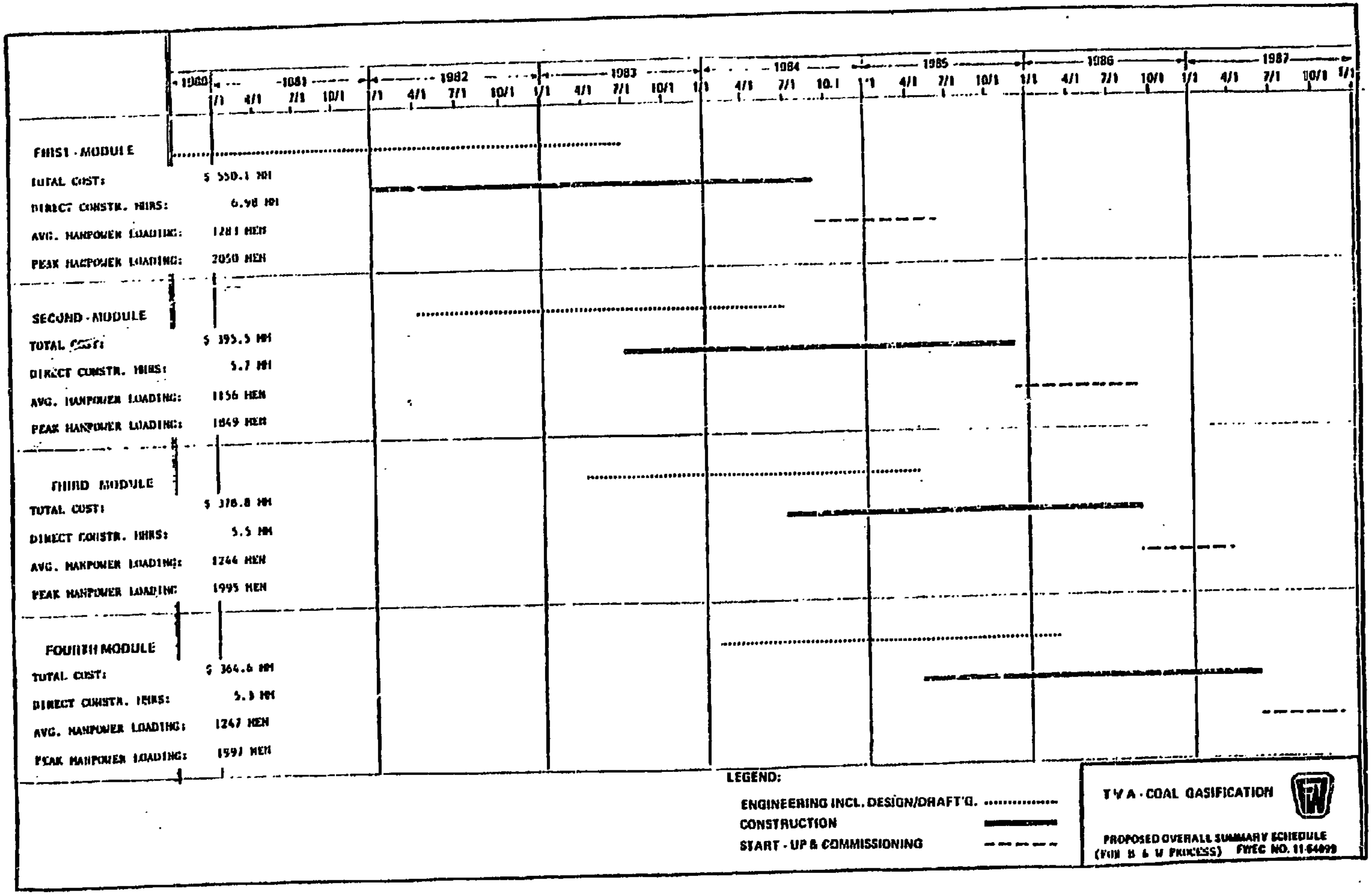

1980
1981
1982
1983
1984
1985
1986
1987
1/1 4/1 7/1 10/1
FIRST - MODULE
TOTAL COST: $ 550.1 MM
DIRECT CONSTR. MHRS: 6.98 MM
AVG. MANPOWER LOADING: 1281 MEN
PEAK MANPOWER LOADING: 2050 MEN
SECOND - MODULE
TOTAL COST: $ 395.5 MM
DIRECT CONSTR. MHRS: 5.7 MM
AVG. MANPOWER LOADING: 1156 MEN
PEAK MANPOWER LOADING: 1849 MEN
THIRD MODULE
TOTAL COST: $ 378.8 MM
DIRECT CONSTR. MHRS: 5.5 MM
AVG. MANPOWER LOADING: 1244 MEN
PEAK MANPOWER LOADING: 1995 MEN
FOURTH MODULE
TOTAL COST: $ 364.6 MM
DIRECT CONSTR. MHRS: 5.3 MM
AVG. MANPOWER LOADING: 1247 MEN
PEAK MANPOWER LOADING: 1597 MEN
LEGEND:
ENGINEERING INCL. DESIGN/DRAFT'G.
CONSTRUCTION
START - UP & COMMISSIONING
TVA - COAL GASIFICATION
PROPOSED OVERALL SUMMARY SCHEDULE
(FOR B & W PROCESS) FWEC NO. 11-64099

FIGURE 9.1

9.2 Operating Costs

The annual production and operating requirements corresponding to the 4-module gasification plant, based on the B&W gasifier, are summarized in Table 9.8. Values are given for 100% plant service factor. The service factor is the expected yearly production divided by the plant rated capacity for 365 days. A summary of the estimated plant service factors by module and year is given in Table 9.9.

Estimated annual operating costs, in 1980 dollars, for the 4-module plant are summarized in Table 9.10. The coal price used in this base calculation is 1.25 $/MMBTU as delivered, which corresponds to 27.45 $/Ton. No product credit is taken except for excess coal fines which are credited at 80% of the delivered coal price, i.e., 1.00 $/MMBTU.

The estimated plant staffing requirements are detailed in Tables 9.11 and 9.12. The salaries and wage rates employed follow the guidelines provided by TVA's design criteria (dated march, 1980).

Maintenance materials and subcontract labor were estimated as percentages of the erected plant cost. As requested by TVA, a corporate general and administrative expense of 1.0 percent of plant maintenance and operating cost, exclusive of coal, was included.

A separate operating expense designated as ash disposal costs is associated with the continuing site work required for stock piling the coal ash through the life of the project.

Table 9.8

Summary of Annual Operating Requirements

B&W Gasifier Case

Basis: 4-Module Plant @ 100 % Service Factor (365 Days/Year)

Item	Rate/Year	
Product Gas @ 360.1 MMMBTU/D	131.437×10^6	MMBTU
Coal Feed @ 22560 TPD	180.827×10^6	MMBTU
Limestone @ 160.8 TPD	58700	Tons
Catalyst & Chemicals	2.426	MM$
Electric Power @ 257 MW	2248.7×10^6	KWH
By-Product Coal Fines	-	
By-Product Sulfur @ 793 TPD	289430	Tons
By-Product Ammonia	-	
By-Product Naphtha	-	
By-Product Light Oil	-	
By-Product Tar	-	
By-Product Phenol	-	

Table 9.9

Summary of Plant Service Factors

Bases: Percent of 4-Module Plant Operating 365 Days/Year

Module	1	2	3	4	Total
1984	0	0	0	0	0
85	7.5	0	0	0	7.5
86	20.0	5.0	0	0	25.0
87	22.5	20.5	13.0	0	56.0
88		22.5	22.5	18.75	86.25
89				22.5	90.0
1990					
91					
92					
93					
94					
95					
96					
97					
98					
99					
2000					
01					
02					
03					
04	22.5				90.0
05	9.25	22.5			76.75
06	0	16.75	22.5		61.75
07	0	0	5.5	22.5	28.0
2008	0	0	0	0	0

TABLE 9.10

ESTIMATED PLANT ANNUAL OPERATING COSTS (1980 DOLLARS)

B&W GASIFIER CASE

Basis: 4 - Module Plant

NO.	ITEM	CALCULATION BASIS FOR 100% SERVICE FACTOR (S.F.)	ANNUAL COST, MM$ 100% SF	90% SF
1.	Coal Feed	$180.827 \times 10^6 \times 1.25$ $/MMBTU	226.03	203.43
2.	Limestone	58700 x 13 $/Ton	0.76	0.68
3.	Catalyst/Chemicals	(TABLE 9.8)	2.43	2.19
4.	Electric Power	$2248.7 \times 10^6 \times 0.025$ $/KWH	56.22	50.60
5.	Plant Labor & Supervision	(TABLE 9.11and 9.12)	14.42	14.42
6.	Operating Supplies	At 30% of Labor & Supervision	4.33	4.33
7.	Maintenance Materials	At 2.2% of Erected Plant Cost	37.15	37.15
8.	Maintenance S/C Labor	At 55% of Maintenance Material	20.43	20.43
9.	TVA G & A Overhead	At 1% of Items 2 through 8	1.36	1.36
10.	Ash Disposal		4.40	4.40
11.	Total Gross Operating Cost		367.53	338.99
12.	By-Product Credits	At Zero Credit	0.00	0.00
13.	Net Annual Operating Cost		367.53	338.99

TABLE 9.11

Estimated Plant Operating Staff

Basis: 4 - Module Plant

Position	Number	Annual * Salary/Wage, $	Annual Cost, $
Plant Superintendent	1	57936	57936
Plant Operating Supervisor	16	48990	783840
Shift Engineer	16	39192	627072
Ass't Shift Engineer	4	32092	128368
Unit Operator	80	28826	2306080
Ass't Unit Operator	48	24140	1158720
Auxiliary Operator	32	21726	695232
Yard Operations Supervisor	2	34080	68160
Plant Results Supervisor	1	48990	48990
Ass't Plant Results Supervisor	4	39760	159040
Instrument Unit Foreman	16	30672	490752
Instrument Mechanic	24	30160	723840
Instrument Mech. Apprentice	18	22880	411840
Mechanical Unit Foreman	16	30672	490752
Engineering Aide	16	23004	368064
Chemical Unit Foreman	4	30672	122688
Chemical Lab. Analyst	36	23004	828144
Materials Tester	12	23004	276048
Boilermaker Foreman	8	32234	257872
Boilermaker	16	27264	436224
Janitor (Senior)	16	20824	333184
Janitor	24	19170	460080
Coal Handling Foreman	2	29120	58240
Primary HEO	2	27040	54080
Apprentice HEO	2	22880	45760
Coal Tower Foreman	2	29120	58240
Coal Car Dump Operator	4	29120	116480
Track Foreman	2	29120	58240
Laborer	6	17680	106080
Total Operating Staff	430		11,730,046

* 1980 basis, includes fringe benefits

TABLE 9.12

Estimated Plant Maintenance Staff

Basis: 4 - Module Plant

Position		Number	Annual * Salary/Wage, $	Annual Cost, $
Mechanical Supervisor		1	48990	48990
Ass't Mechanical Supv.		4	39760	159040
Mechanical Engineers		28	22436	628208
Foreman:	Asbestos	2	34320	68640
	Electricians	7	32240	225680
	Ironworkers	4	31200	124800
	Machinists	5	28080	140400
	Steamfitters	10	33280	332800
	Painters	2	27040	54080
	Truck Drivers	6	21840	131040
Journeymen:	Electrician	7	30160	211120
	Ironworkers	4	29120	116480
	Machinists	5	26000	130000
	Steamfitters	7	31200	218400
	Painters	1	24960	24960
	Truck Drivers	4	19760	79040
Total Maintenance Staff		97		2,693,678

* 1980 Basis, Includes Fringe Benefits

Table 9.13

Sensitivity Analyses Summary

B&W Gasifier - 4 Module Plant

Case	Total Gas Production MMMM BTU	Relative Gas cost
Base Case	2341.2	1.00
Coal Cost @ +50%	2341.2	1.20
Plant Cost @ +25%	2341.2	1.07
Operating Cost @ +50%	2341.2	1.13
Plant Service Factor @ 80%	2081.1	1.06
70%	1820.9	1.14
60%	1560.8	1.25
By-Product Credit	2341.2	0.96
Design/Construction @ + 1 year	2341.2	1.08
- 1 year	2341.2	0.92
Plant Life @ + 5 years	2932.7	1.04
+ 10 years	3524.2	1.09
Sulfur @ 1.0 ppm	2341.2	1.02
Delivery Pressure @ 800 psig	2341.2	1.02
@ 200 psig	2341.2	0.97

9.3 Sensitivity Analysis

In accordance with TVA's requirements, sensitivity analyses were conducted to assess the effects of the following parameters on the MBG production rate and levelized gas product cost:

- Coal cost at +50%
- Plant capital cost at +25%
- Plant operating cost at +50%
- Plant service factors at 80%, 70%, and 60%
- Byproduct values, specified as:
  - sulfur @ 70 $/ton
  - ammonia @ 130 $/ton
  - naphtha @ 0.80 $/gal.
  - light oil @ 0.80 $/gal.
  - tar @ 0.60 $/gal.
  - phenols @ 0.75 $/gal.
- Design/construction period per module at ± one year
- Plant operating life at +5 years and +10 years
- Sulfur content in product gas at 1.0 ppm
- Product gas delivery pressure at 800 psi and 200 psi

All sensitivity analysis cases were conducted for the total 4-module plant concept only. The results of the sensitivity analyses for the plant based on the Babcock and Wilcox gasifiers are summarized in Table 9.13.