SECTION 4.0

PLANT REQUIREMENTS

4.1 Summary of Feed and Products

Discussion

Raw material requirements for the coal gasification plant based on K-T gasifiers, consist of coal, raw water and air. Coal is gasified to prodice the primary product, medium BTU fuel gas. In addition to coal, chemicals and raw water, the only other major purchased commodity is electric power, which is provided to supply a part of the power plant requirements.

Tabulation of Feed and Products

Major feed and product rates for the coal gasification plant are given in Table 32-1 . Total coal usage is 23,936 tons per day of as-received coal. Product gas having a heating value of 302 BTU/SCF is produced at a rate of 344.2 MMM BTU/Day. The only major by-product of the plant is elemental sulfur prills produced at a rate of 740 LTPD.

Heat Recovery Factor

One measure of the efficiency of conversion of coal to product fuel gas in this coal gasification plant is the heat recovery factor. This factor is defined as the heating value of the product gas divided by the heating value of the total coal consumed inthe plant. For this plant, based on K-T Gasifiers, this factor is:

$$HRF = \frac{344.2 \times 10^9}{(23{,}936)(21.96 \times 10^6)} \times 100 = 65.5\%$$

This factor does not include the heat equivalent of the electric power consumed in the plant. For this plant, based on K-T Gasifiers, the consumption of purchased electric power is large. The heat recovery factor should be adjusted for this power consumption in order to obtain a realistic measure of energy conversion efficiency. If this adjustment is made on the basis of 3415 BTU/KWH, the heat recovery factor becomes:

HRF (adjusted for power consumption)

$$= \frac{344.2 \times 10^9 \times 100}{(23{,}936)(21.96 \times 10^6) + 434{,}000 \times 24 \times 3415} = 61.3\%$$

TABLE 32-1

TVA COAL GASIFICATION DEMONSTRATION PLANT PROJECT

PLANT BASED ON KOPPERS TOTZEK GASIFIERS

SUMMARY OF MAJOR STREAM FLOWS - 4 MODULES

Coal Feed Rate TPD, as Rec'd.	
Gasification	22,116
Boiler Plt	1,820
Excess Fines	0
Total	23,936
Oxygen Feed, 98%, TPD	17,624
Product Gas	
MM SCFD	1,139.6
HHV BTU/SCF	302.0
MMM BTU/DAY	344.2
Compostion, MOL%	
H_2	29.02
CO	64.33
CH_4	0.10
N_2+Ar	2.05
CO_2	4.49
H_2O	0.01
C_2	-
Byproducts	
Sulfur LTPD	740.0
Ammonia. TPD	-
Phenols, TPD	-
Oil, BPD	-
Naphtha, BPD	-
Purchased	
Electric Power, MW	434.0
Raw Water, MGPM	16.9

4.2 Steam Balance

A. Reference Material

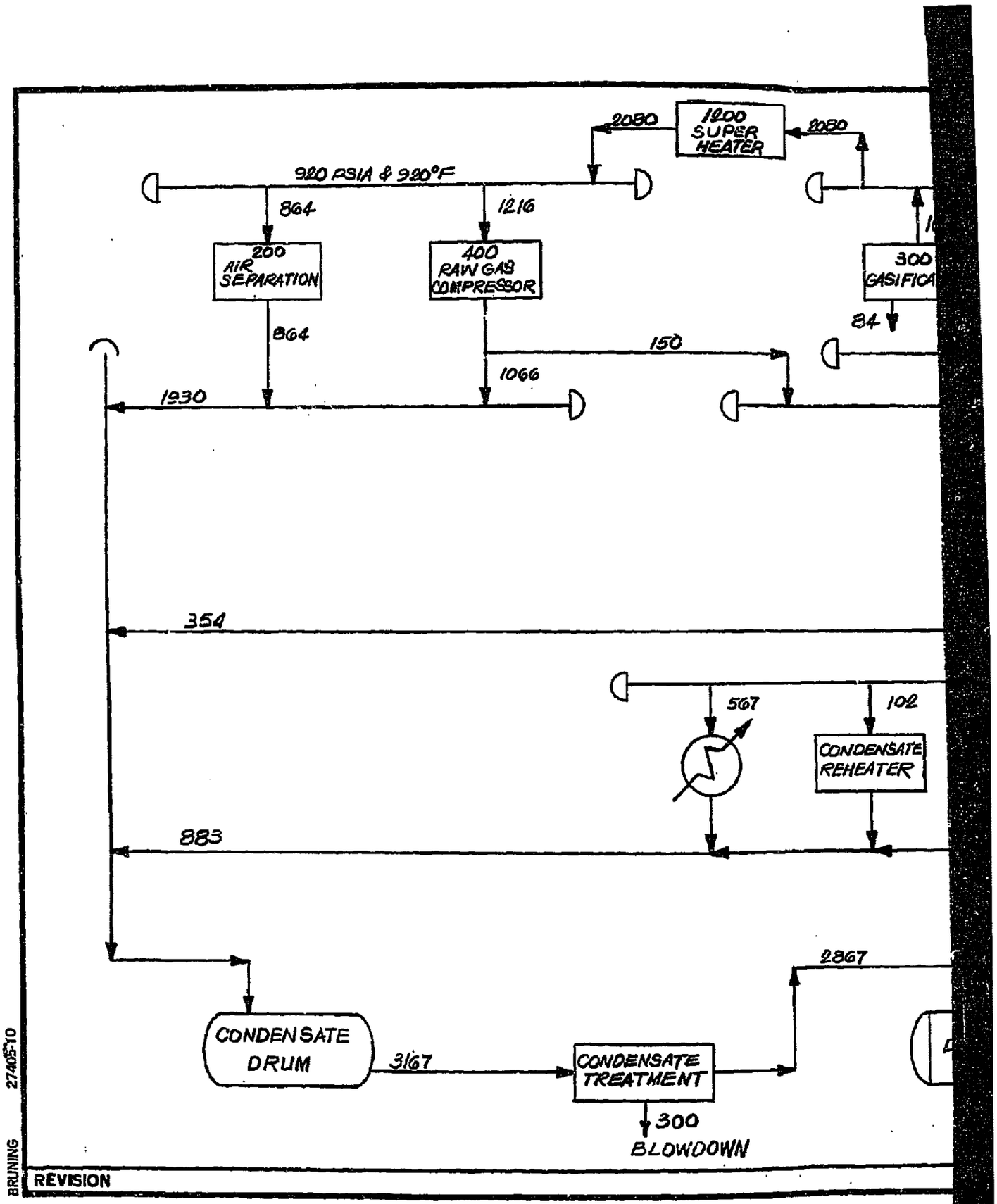
Drawing No. 54099-32-4-50-16

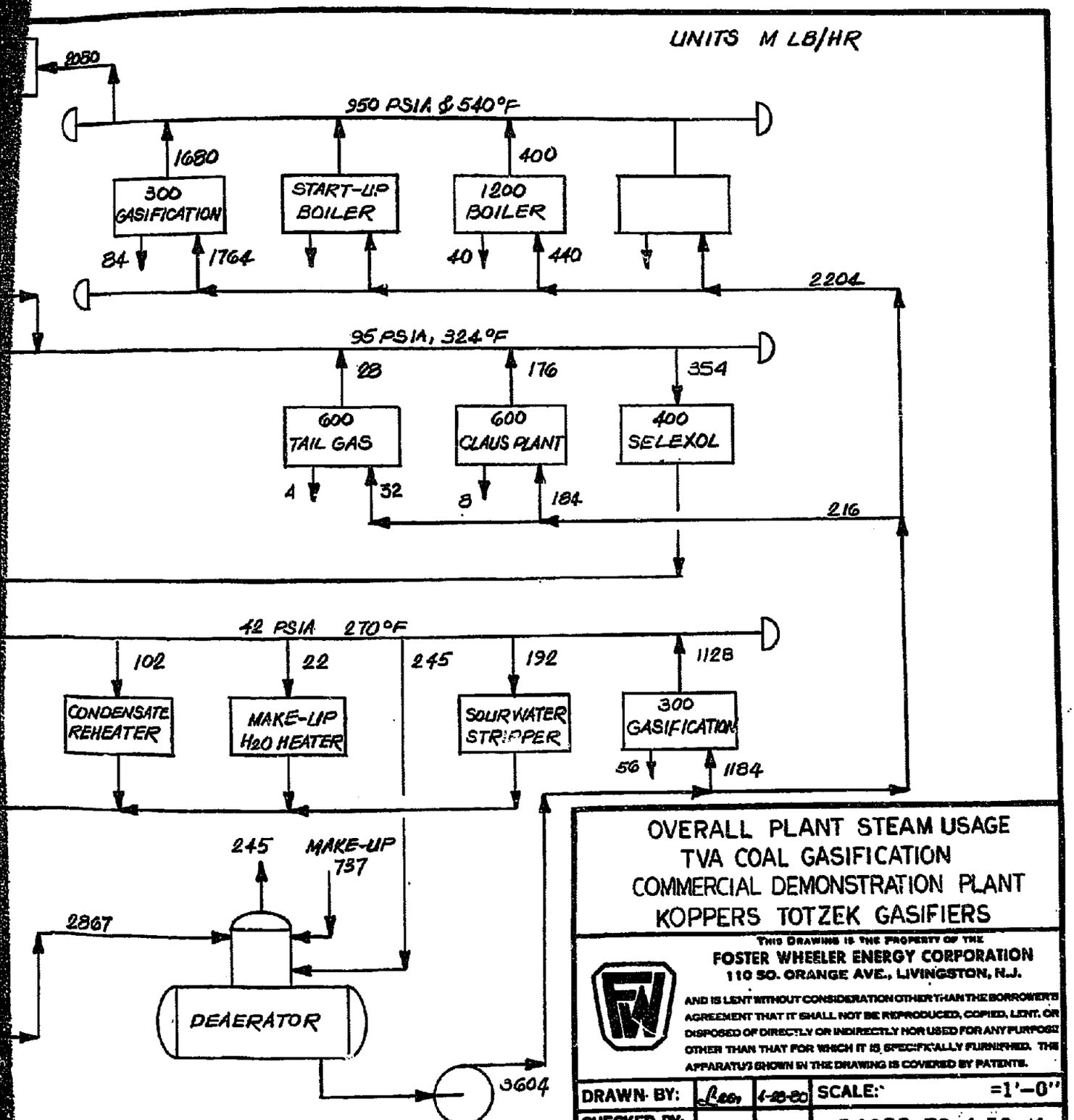
B. Description of Flow

K-T gasifiers produce a large quantity of high pressure saturated steam as a result of cooling hot gases produced in the high temperature gasification zone of this gasifier. A large amount of low pressure (42 psia) steam is produced in the jackets of the gasifier. Efficient utilization of this steam, particularly the high pressure steam, is required to achieve the best heat recovery factor possible.

A diagram showing overall plant steam generation and usage is shown in Drawing 54099-32-4-50-16. High pressure saturaged steam made in section 300 is supplemented by steam generation and then superheated in fluidized bed boilers. The superheated setam is used to drive half of the large compressors in section 200 (air separation) and section 400 (raw gas compression area). A part of the steam driving the raw gas compressors is withdrawn at a pressure of 95 psia to supplement similar pressure steam made in Claus and Beavon units. This steam is used in section 400 (Selexol unit reboiler).

Low pressure (42 psia) steam is used for condensate reheating, make-up BFW heating, and sour water stripping. Excess low pressure steam is condensed and the condensate mixed with other steam condensates for polishing and reuse.


2080
1200
SUPER
HEATER
2080
920 PSIA & 920°F
864
1216
200
AIR
SEPARATION
400
RAW GAS
COMPRESSOR
300
GASIFICA
84
864
150
1066
1930
354
567
102
CONDENSATE
REHEATER
883
2867
CONDENSATE
DRUM
3167
CONDENSATE
TREATMENT
300
BLOWDOWN
REVISION
BRUNING
27405-10


UNITS M LB/HR
2080
950 PSIA & 540°F
1680
400
300 GASIFICATION
START-UP BOILER
1200 BOILER
84
1764
40
440
2204
95 PSIA, 324°F
28
176
354
600 TAIL GAS
600 CLAUS PLANT
400 SELEXOL
4
32
8
184
216
42 PSIA 270°F
102
22
245
192
1128
CONDENSATE REHEATER
MAKE-UP H2O HEATER
SOUR WATER STRIPPER
300 GASIFICATION
56
1184
245
MAKE-UP 737
2867
DEAERATOR
3604
OVERALL PLANT STEAM USAGE
TVA COAL GASIFICATION
COMMERCIAL DEMONSTRATION PLANT
KOPPERS TOTZEK GASIFIERS
THIS DRAWING IS THE PROPERTY OF THE
FOSTER WHEELER ENERGY CORPORATION
110 SO. ORANGE AVE., LIVINGSTON, N.J.
AND IS LENT WITHOUT CONSIDERATION OTHER THAN THE BORROWER'S AGREEMENT THAT IT SHALL NOT BE REPRODUCED, COPIED, LENT, OR DISPOSED OF DIRECTLY OR INDIRECTLY NOR USED FOR ANY PURPOSE OTHER THAN THAT FOR WHICH IT IS SPECIFICALLY FURNISHED. THE APPARATUS SHOWN IN THE DRAWING IS COVERED BY PATENTS.
DRAWN BY:
CHECKED BY:
APPROVED BY:
SCALE: =1'-0"
54099-32-4-50-16
ORDER NO.
FORM NO. 285-63M

4.3 Water Balance

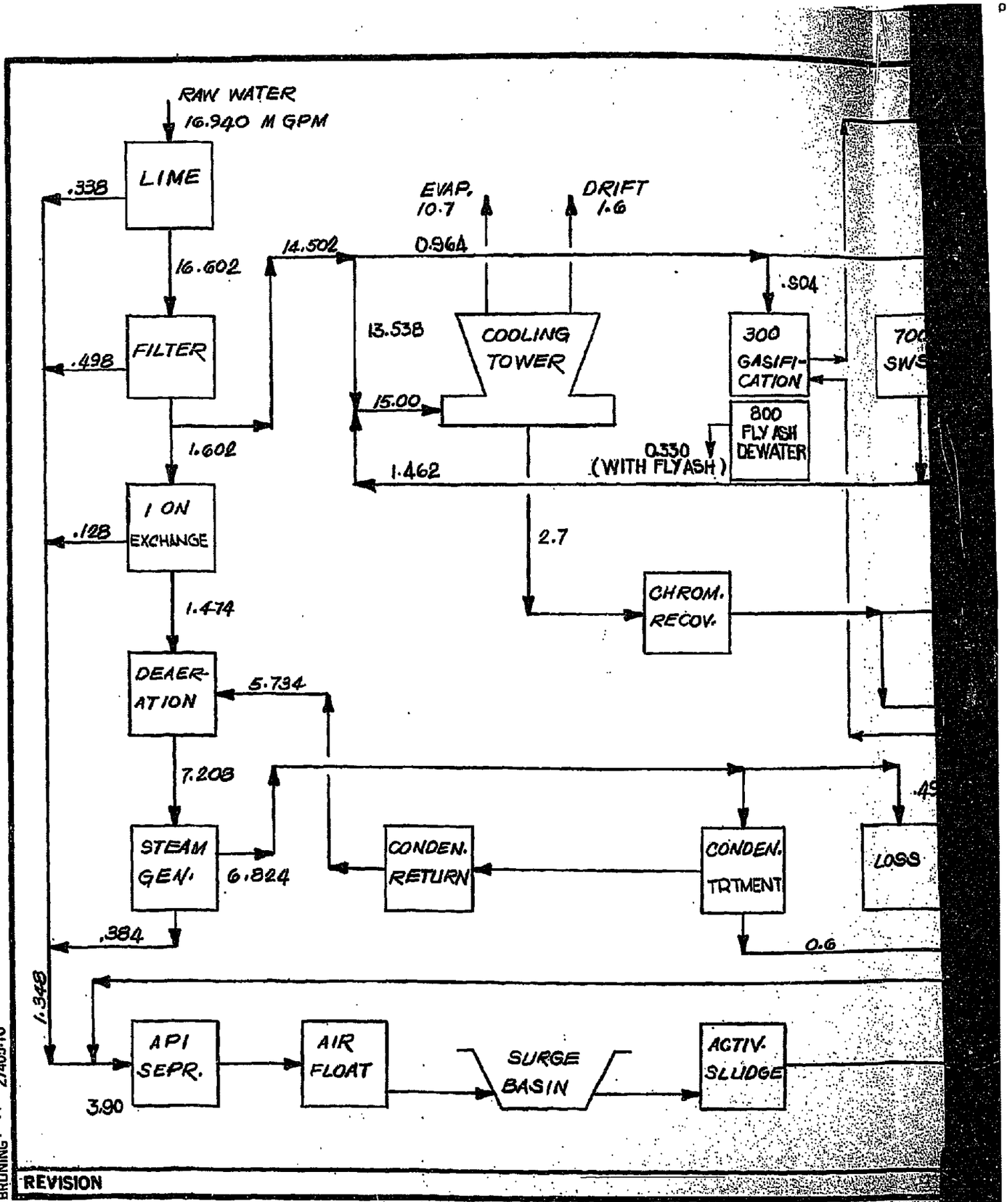
A. Reference Material

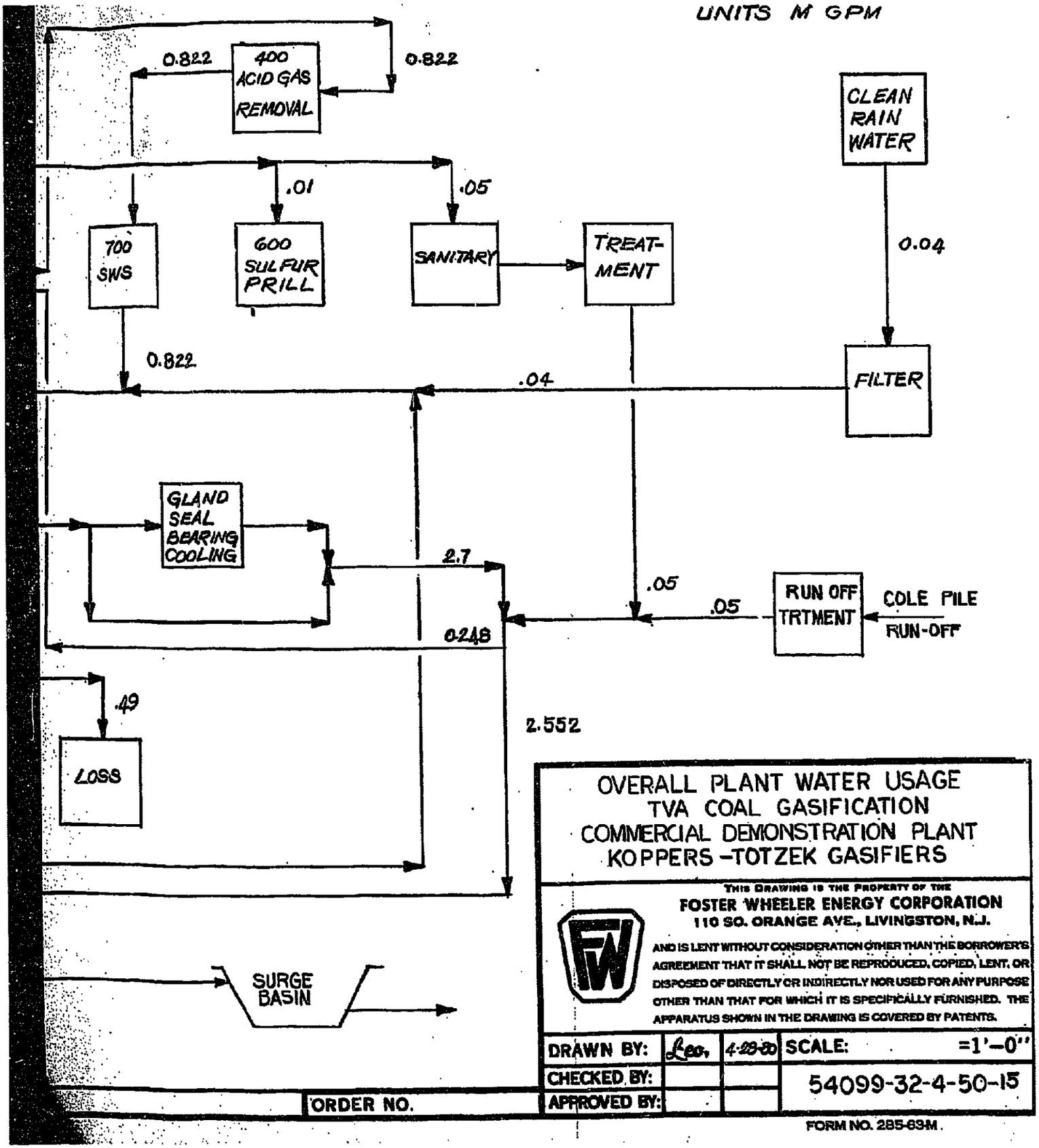
Drawing No. 54099-32-4-50-15

B. Description of Flow

Raw water is taken into the coal gasification plant to supply process and steam requirements as well as potable and sanitary water supply.

The water balance diagram is shown in Drawing No. 54099-32-4-50-15, which was discussed previously in connection with waste water treatment. Estimated raw water intake to the plant is 16,949 gpm.


RAW WATER
16.940 M GPM
LIME
.338
16.602
FILTER
.498
1.602
ION EXCHANGE
.128
1.474
DEAER-ATION
5.734
7.208
STEAM GEN.
6.824
.384
1.348
API SEPR.
3.90
AIR FLOAT
SURGE BASIN
ACTIV. SLUDGE
EVAP. 10.7
DRIFT 1.6
14.502
0.964
.504
13.538
COOLING TOWER
15.00
1.462
0.330 (WITH FLYASH)
300 GASIFI-CATION
800 FLY ASH DEWATER
2.7
CHROM. RECOV.
CONDEN. RETURN
CONDEN. TRTMENT
LOSS
0.6
REVISION
BRUNING
27405-10



OVERALL PLANT WATER USAGE
TVA COAL GASIFICATION
COMMERCIAL DEMONSTRATION PLANT
KOPPERS-TOTZEK GASIFIERS

DRAWN BY:	Leo.	4-29-80	SCALE: =1'-0"
CHECKED BY:			54099-32-4-50-15
APPROVED BY:			

ORDER NO.

FORM NO. 285-63-M.

4.4 Power Requirements

Discussion

This coal gasification plant, based on K-T Gasifiers, requires a large amount of power, primarily for compressor drivers in air separation and raw gas compression areas. As discussed previously, the waste heat steam produced by the gasifiers was superheated and used to supply approximately 50% of the large compressor requirements. The remaining power required for large compressors, as well as power required for other sections of the plant, was supplied by electric power purchased from the TVA grid.

This split between power supplied by onsite steam generation and power supplied by purchase was made to minimize environmental effects of onsite steam generation from coal and because an onsite steamor power generation facility to supply the total need would be more expensive than purchased TVA power.

Listing of Gross and Net Power Requirements

A listing of power requirements for each section of the plant is given in Table 32.2. The total gross power requirement is 659.7 MWH/HR. Power supplied by steam turbine drivers is 255.5 MWH/HR, leaving 434.2 MWH/HR as the net power demand.

TABLE 32-2

TVA COAL GASIFICATION DEMONSTRATION PLANT STUDY

PLANT BASED ON KOPPERS-TOTZEK GASIFIERS

ESTIMATED ELECTRIC POWER REQUIREMENTS

SECTION	ELECTRIC POWER REQ'D, MWH/H		
	Gross	From Steam	Net
100	2.3		2.3
200	217.1	104.5	112.6
300	54.5		54.5
400	295.1	121.0	174.1
500	44.8		44.8
600	3.7		3.7
700	0.1		0.1
800	3.1		3.1
	620.7		395.2
1200	3.2		3.2
1300	32.8		32.8
1400	0.2		0.2
1500	0.5		0.5
2000	2.1		2.1
2100	0.1		0.1
2200	0.1		0.1
	39.0		39.0
Total Gross	659.7	Net	434.2

4.5 Fuel Requirements

There are no continuous fuel requirements for the plant based on K-T Gasifiers other than the coal burned in the fluidized bed boilers as described previously and a small amount of product gas used as reductant in the Beavon Tail Gas Treatment process unit.

4.6 Catalyst and Chemicals Requirements

A listing of catalysts and chemicals used in the coal gasification plant is given in Table 32-3. together with estimates of the corresponding yearly costs.

TABLE 32-3

TVA COAL GASIFICATION COMMERCIAL DEMONSTRATION PLANT STUDY

PLANT BASED ON KOPPERS-TOTZEK GASIFIERS

CATALYST AND CHEMICALS COSTS

Chemicals	Estimated Yearly Cost, M$
Water Treatment Chemicals	
Raw Water and BFW Treatment	2500
Cooling Tower	2000
Waste Water Treatment Chemicals	6000
Solvents	
Selexol Solvent	100
Catalysts	
Sulfur Recovery Catalysts	300
DENOX Catalyst	600
Hydrolysis Catalyst	600
Limestone	1500
Total	$ 13,600

SECTION 5.0

PLANT LAYOUT

TVA Coal Gasification Study
Koppers-Totzek

5.0 PLANT LAYOUT

INTRODUCTION

The development of the Key Plot Plan requires the optimization of all facilities from the standpoint of accommodating 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 accommodating 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 & ELEVATIONS

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 unloadings 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 furutre 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 expecially 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 encirculing 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 preparation. 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 accommodate 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. As a consequence, the reactor vessels are aligned parallel to the conveyor for coal feed to the coal pulverizer and conveying system and 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 By-Products

The raw gas stream is processed to remove acidic compounds and to separate and concentrate H_2S as well as other compounds containing sulfur in trace amounts. Remaining trace amounts of ammonia are 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 waste waters, catalysts and the sewage treatment plant. The grade is 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 waste water treatment area nearby.

Prilled sulfur, anhydrous ammonia, phenol, naphtha and other distillate by-products are stored in various tanks and containers prior to shipment, periodically, from the plant.

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 & Slag Storage

Terrain laying generally N.E. of the process areas has been reserved for the storage of ash and slag. The ash and 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 $\overline{R}$ (the recirculation ratio of effluent air stream into the intake louvers) is insignificant, amounting to no more than $\pm 1\%$"

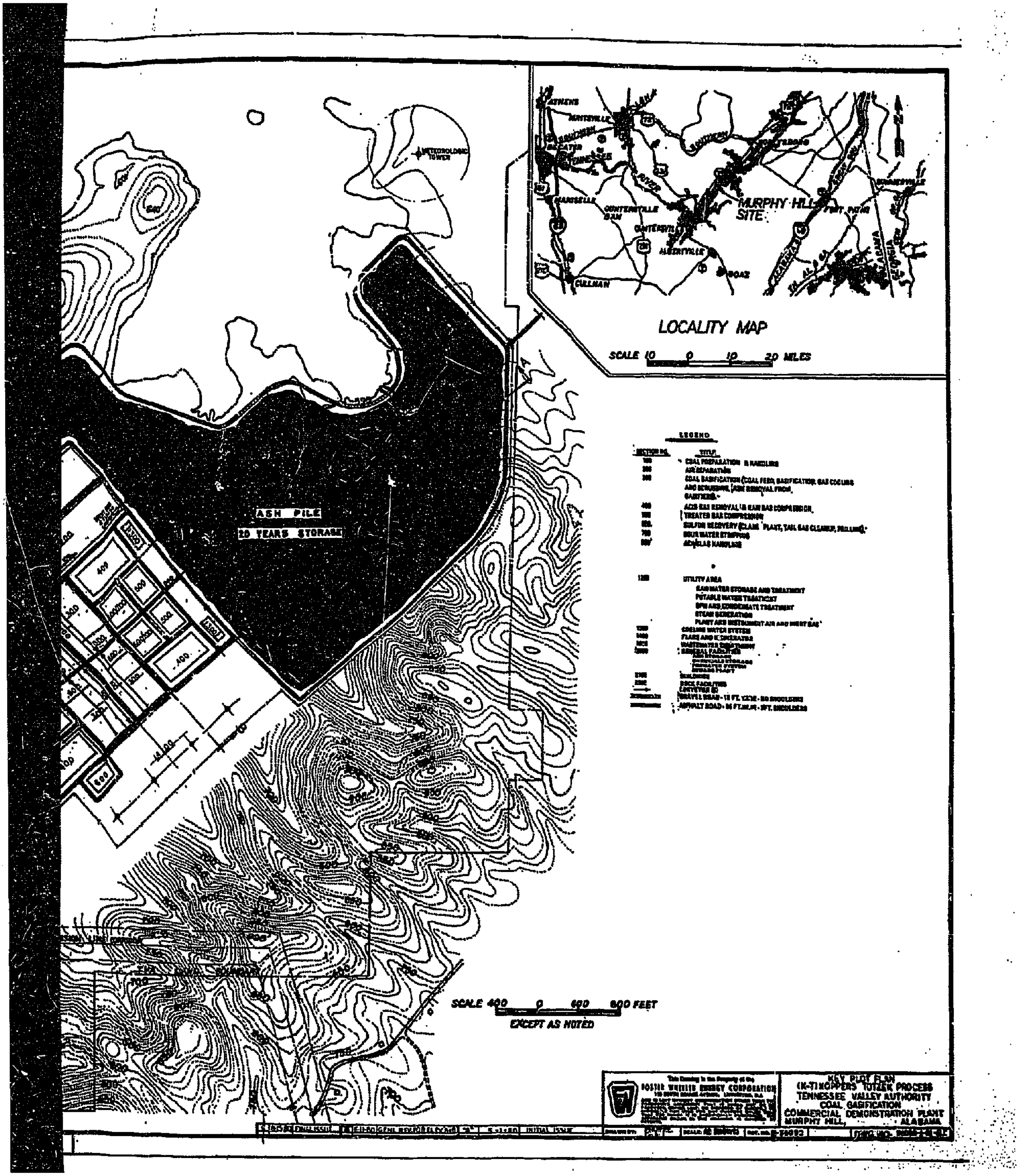
(Foregoing appears on p. 25, VI. Summary of Results)

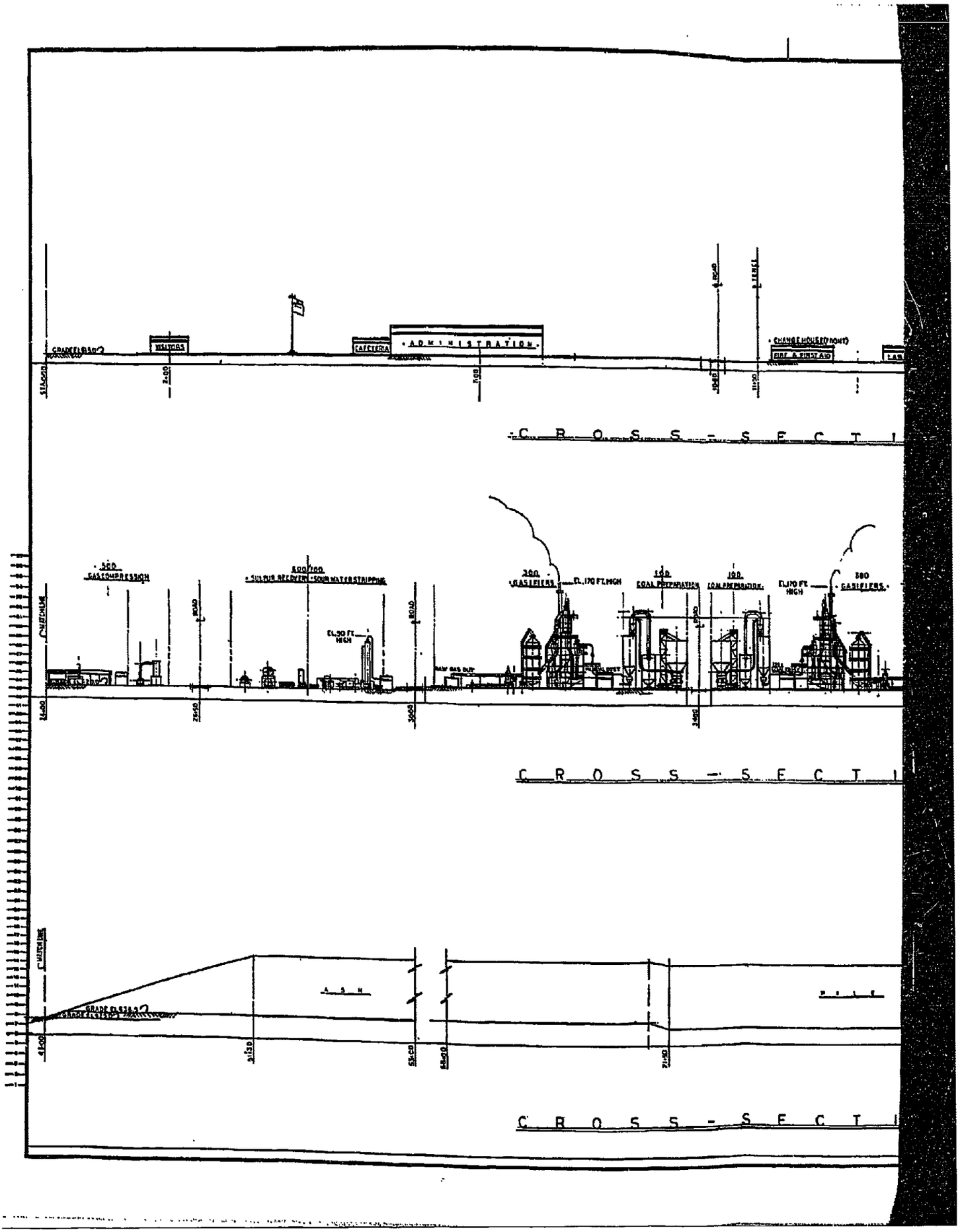
L. Elevation Views

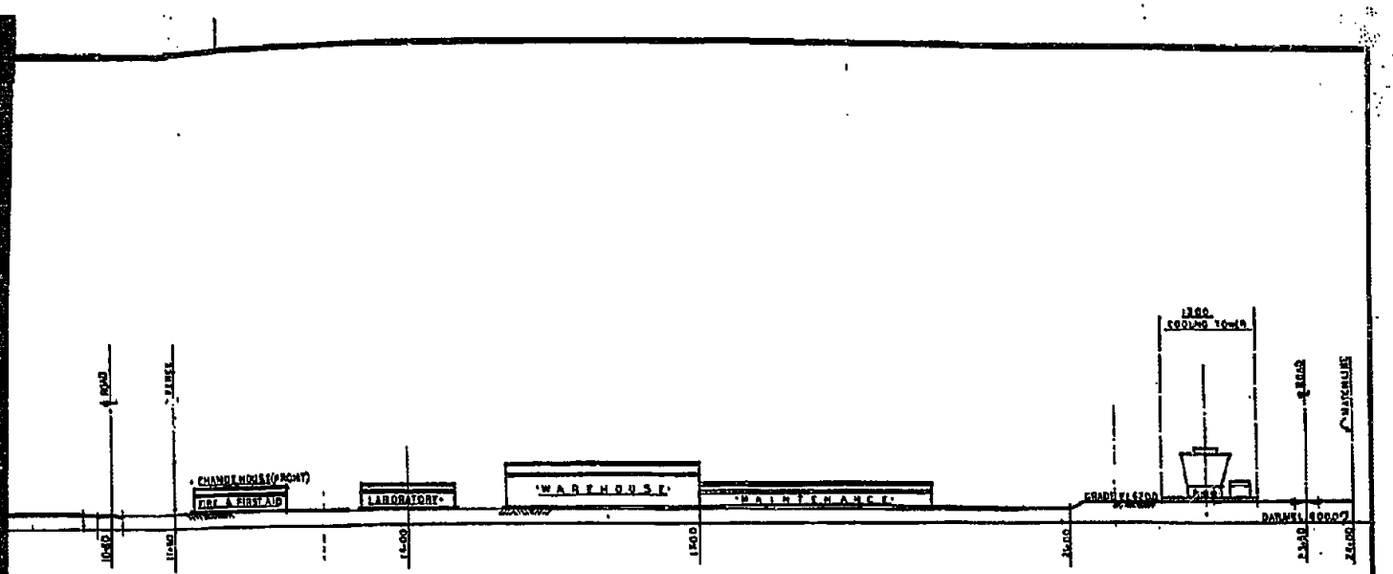
Terrain - considreing the rocky nature of the subsoil, based on extensive boring and seismic depth of rock determination, the plant areas have been terraced in order to minimize costly cutting and filling of excavated materials. The terraces shown are substantially those which form the basis of the cost 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.

Process Units - The structures, towers and other equipment shown are representative of the type of equipment for a particular process. Where fiarly 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 on accurate pictorial representation.

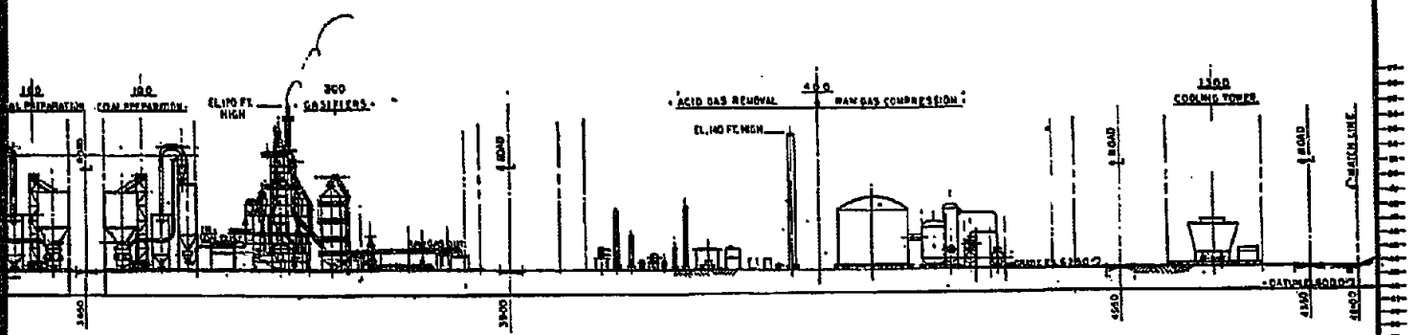

TENNESSEE RIVER GUNTERSVILLE RESERVOIR
MINIMUM NORMAL POOL EL. 595.0
MAXIMUM NORMAL POOL EL. 595.0
PROBABLE MAXIMUM FLOOD REGULATED EL. 595.5
TENNESSEE RIVER
FLOW
MILE 189
WATER INTAKE
DEAD STORAGE 60 DAYS
SUBSTATION
N


LOCALITY MAP
SCALE 10 0 10 20 MILES
MURPHY HILL SITE
ATHENS
HUNTSVILLE
DECATUR
CULLMAN
ALBERTVILLE
BOAZ
GUNTERSVILLE
ASH PILE
20 YEARS STORAGE
METEOROLOGIC TOWER
LEGEND
SCALE 400 0 400 800 FEET
EXCEPT AS NOTED
KEY PLOT PLAN
(K-T) KOPPERS TOTZEK PROCESS
TENNESSEE VALLEY AUTHORITY
COAL GASIFICATION
COMMERCIAL DEMONSTRATION PLANT
MURPHY HILL, ALABAMA

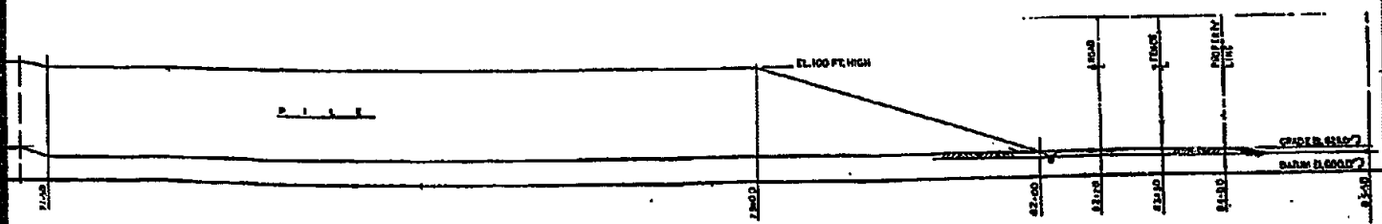

CRANE BRAD
WELDERS
CAFETERIA
• ADMINISTRATION •
• CHANGE HOUSE (FRONT)
FIRE & FIRST AID
LAB
STACKS
300
GAS COMPRESSION
400/700
• SULFUR RECOVERY • SOUR WATER STRIPPING
300
• GASIFIERS •
EL. 170 FT. HIGH
100
COAL PREPARATION
100
COAL PREPARATION
EL. 170 FT. HIGH
300
• GASIFIERS •
EL. 90 FT. HIGH
RAW GAS DUCT
ROAD
ASH
PILE
GRADE EL 636.2
C R O S S - S E C T I
C R O S S - S E C T I
C R O S S - S E C T I



S - S E C T I O N "A - A"



S - S E C T I O N "A - A" CONTD.



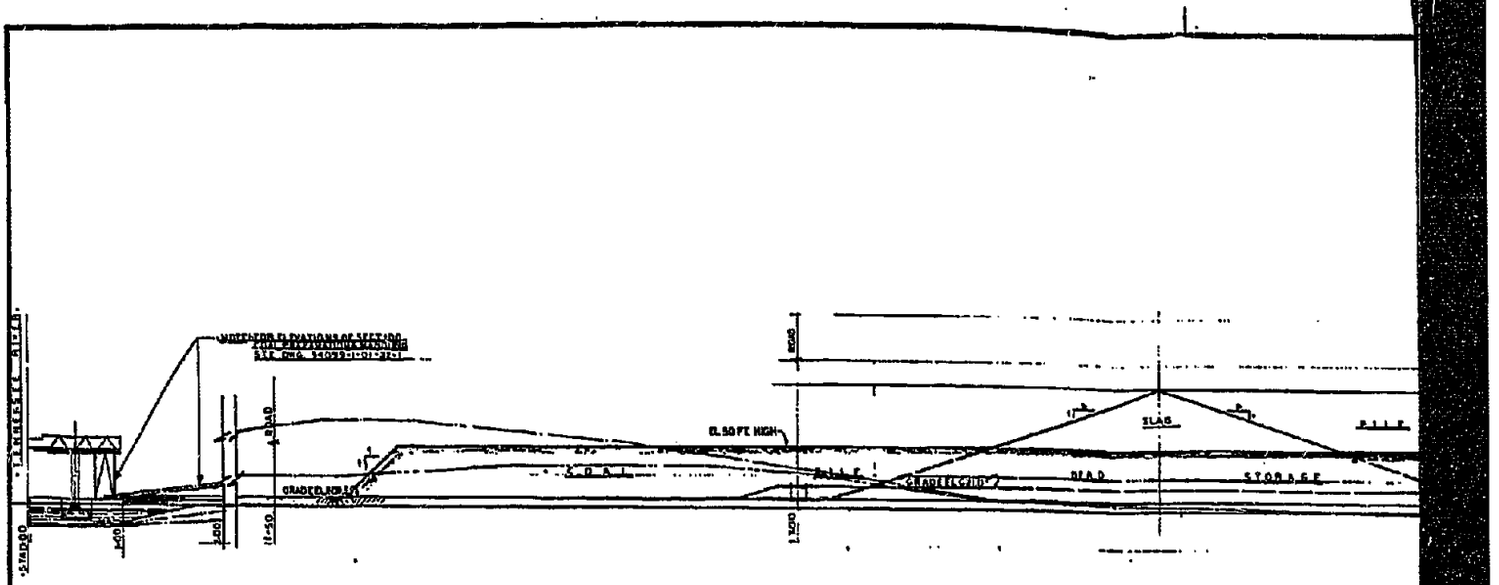
S - S E C T I O N "A - A" CONTD.

NOTES: INDICATED ELEVATIONS ARE ABOVE GRADE, TENTATIVE, AND SUBJECT TO CHANGE.

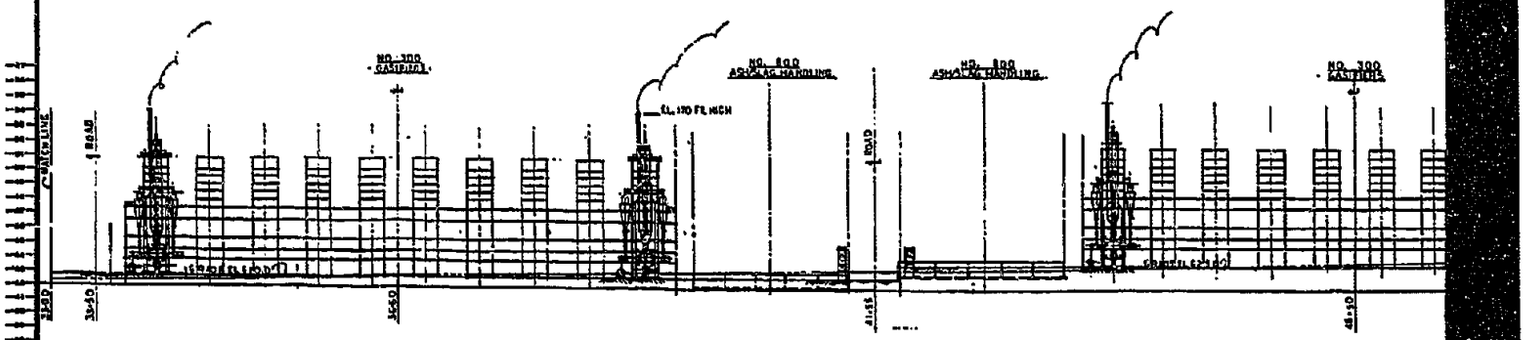
A	8-15-80	FINAL ISSUE	

POSTER WHEELER ENERGY CORPORATION

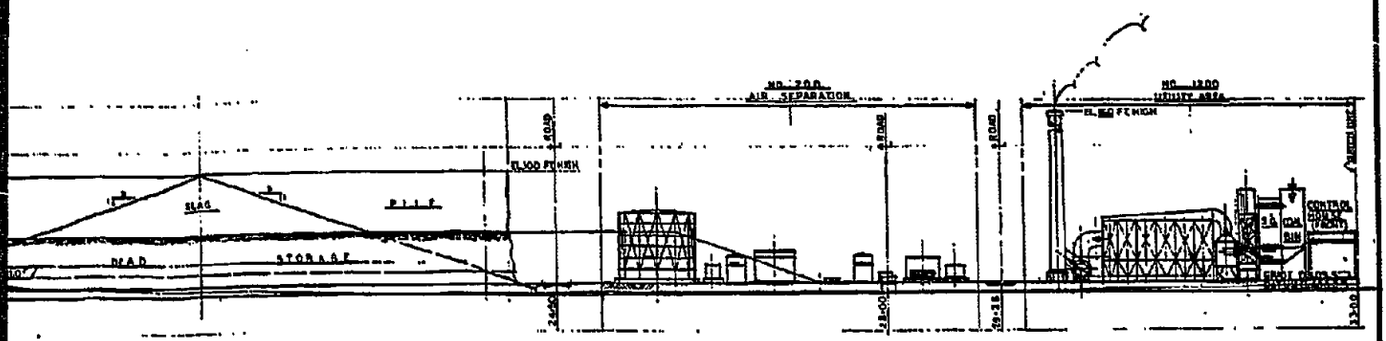
CROSS-SECTION "A-A"
(K-T) KOPPERS TOTZEK PROCESS
TENNESSEE VALLY AUTHORITY
COAL GASIFICATION
COMMERCIAL DEMONSTRATION PLANT
MURPHY HILL ALABAMA



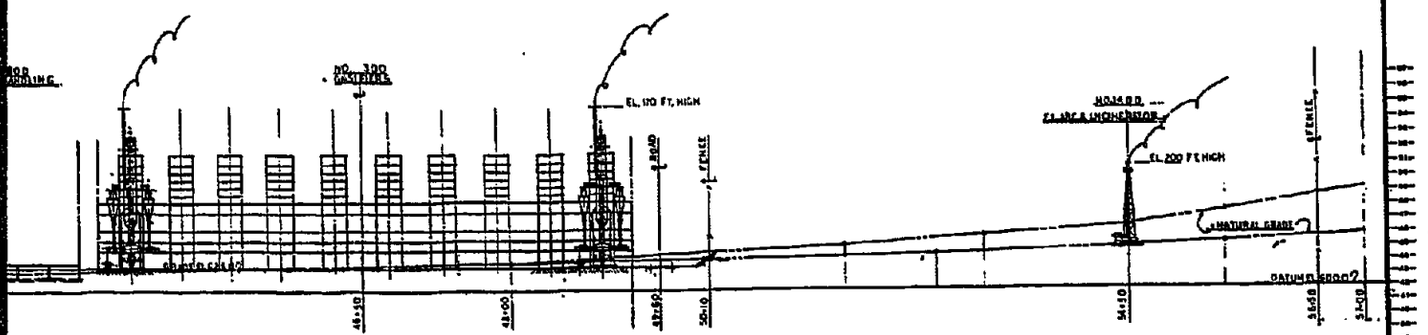
CROSS-SECTIO



CROSS-SECTIO



S - S E C T I O N 'B - B'



S - S E C T I O N 'B - B' CONTD.

NOTE: INDICATED ELEVATIONS ARE ABOVE GRADE, TENTATIVE, AND SUBJECT TO CHANGE

This drawing is the property of the FOSTER WHEELER ENERGY CORPORATION

CROSS-SECTION 'B-B'
(K-T) KOPPERS-TOTZEK PROCESS
TENNESSEE VALLEY AUTHORITY
COAL GASIFICATION
COMMERCIAL DEMONSTRATION PLANT
MUSCLE SHOALS, ALABAMA

C	9-13-80	FINAL ISSUE	B	1-27-80	B-M1 REVISIONS	A	6-13-80	INITIAL ISSUE	

SECTION 6.0

ENVIRONMENTAL ASSESSMENT

6.0 Environmental Assessment

Introduction

Summaries of gaseous, liquid, and solid emissions from the coal gasification plant are given in Tables 32-4 and 32-5.

TABLE 32-4

TVA Coal Gasification Demonstration Plant Study
Plant Based on Koppers-Totzek Gasifiers
Estimates of Emissions

Source	Flow Rate, TPD	Remarks
Gaseous Emissions		
Waste N_2 From Air Separation Plant	17,350	Primarily N_2
Excess N_2 From Air Separation Plant	43,750	Primarily N_2
Pulverized Coal Hopper Vent	8,295	Flue Gas & Conveying N_2, 87 lb/hr particulates
Sulfur Recovery Tail Gas	2,996	10 ppm H_2S; 200 ppm total S
Stretford Oxidizer Tank Vent	196	Air; Trace Sulfur Compounds
Steam Boilers	2,050	Flue Gas; 29 TPD SO_2
Coal Handling and Preparation	0.16	Coal Particulates
Cooling Water Vapor	7,710	Water Vapor
Cooling Tower Drift	1,152	Cooling Water Supply

TABLE 32-5

TVA Coal Gasification Demonstration Plant Study
Plant Based on Koppers-Totzek Gasifiers
Estimates of Emissions

Source	Flow Rate, TPD	Remarks
Liquid Emissions		
Treated Wastewater	2,880	Mostly cooling tower blowdown
Solid Emissions		
Gasifier Fly Ash and Slag	5,962	
Coal Ash & Spent Limestone from Boilers	774	

SECTION 7.0

SUGGESTIONS FOR FOLLOW-ON WORK

SUGGESTIONS FOR FOLLOW-ON WORK

In the event that TVA selects the K-T Gasifier process 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 candidate coals.

B. Identify and develop methods for raising gasifier jacket steam at higher pressure than the present 42 psia. This steam could provide a significant amount of power for use in the plant.

C. Identify and develop methods of raising superheated high pressure steam from the gasifier hot gas stream. This could also have a significant impact on plant heat recovery factors.

D. Evaluate systems for deaerating fly ash from K-T Gasifiers and test promising methods.

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

SECTION 8.0

PROJECTIONS

PROJECTIONS

The Koppers-Totzek coal gasification process is a mature technology, having been used for gasification of coal in commercial plants for many years. Improvements and developments in the process will probably be related to specific details such as the recent technique of removing NO_x from raw gas. Other possibilities are suggested in Section 5 of this report.

An exception to the above is the development currently underway by Shell and Koppers relating to a high pressure gasification process. This would be a major departure from the Koppers-Totzek gasifier and is likely to resemble the Texaco process rather than an evolution of the K-T gasifier.

SECTION 9.0

COST ESTIMATES

9.1 Investment Costs

The total capital investment required for the commercial coal gasification plant, based on Koppers-Totzek entrained flow gasifiers, is estimated at $1.99 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 9.1 is $1.77 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 preparation for ash disposal is treated as an operating expense over the life of the plant.

Items specifically excluded from 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 KOPPERS TOTZEK 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	38.1	0	0	0	38.1
200	Air Separation	97.8	71.7	71.7	71.7	312.9
300	Gasification	117.0	117.0	117.0	117.0	468.0
400	Acid Gas Removal	58.2	58.1	58.1	58.1	232.5
500	Product Gas Compression	2.4	2.4	2.4	2.3	9.5
600	Sulfur Recovery	25.1	12.6	11.5	11.5	60.7
700	Sour Water Stripper	2.5	2.4	2.4	2.4	9.7
800	Ash/Slag Handling	5.5	5.5	5.5	5.5	22.0
900	Phenol Recovery	-	-	-	-	-
1000	Ammonia Recovery	-	-	-	-	-
	SUB-TOTAL	346.6	269.7	268.6	268.5	1,153.4
	Offsites	151.7	77.3	59.6	59.5	348.1
	Spare Parts	7.7	5.2	5.1	5.1	23.1
	Site Preparation	10.0	0	0	0	10.0
	Contingency	76.8	51.2	51.2	51.2	230.4
	TOTAL INSTALLED PLANT COST	592.8	403.4	384.5	384.3	1,765.0
	Initial Catalyst & Chemicals	1.0	0.8	0.8	0.8	3.4
	Cost of Land	1.4	0	0	0	1.4
	Start-Up Cost	34.5	29.6	24.6	24.6	113.3
	Working Capital	27.8	25.6	25.3	25.2	103.9
	TOTAL CAPITAL INVESTMENT	657.5	459.4	435.2	434.9	1,987.0

TABLE 9.2

SUMMARY OF SUPPORT FACILITIES COST

K-T GASIFICATION

Section	Description	D & E Cost, MMs
1200	Utilities Area	
	Water Treatment	5.7
	Steam Generation	115.3
1300	Cooling Water System	31.9
1400	Flare System	3.2
1500	Waste Water Treating	20.0
2000	General Facilities	
	Storage	5.3
	Electric Power Distribution	77.5
	Lighting & Communications	2.5
	Roads & Fences	2.2
	Firewater System	5.0
	Inter-connecting Piping	67.0
2100	Buildings	10.5
2200	Dock Facilities	2.0
		348.1

TABLE 9.3

PLANT BASED ON KOPPERS TOTZEK GASIFIERS

ESTIMATED INVESTMENT CAPITAL DISBURSEMENTS SCHEDULE

MILLIONS OF 1980 $

MODULE #1

Year	Installed Plant Cost	Other * Investment	Working Capital	Yearly Total
1980	10.10	-	-	10.10
1981	35.30	1.40	-	36.70
1982	163.02	-	-	163.02
1983	250.15	-	-	250.15
1984	134.23	12.10	13.88	160.21
1985	0	23.40	13.88	37.28
TOTAL	592.80	36.90	27.76	657.46

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

TABLE 9.4

PLANT BASED ON KOPPERS TOTZEK GASIFIERS

ESTIMATED INVESTMENT CAPITAL DISBURSEMENTS SCHEDULE

MILLIONS OF 1980 $

MODULE #1 and 2

Year	Installed Plant Cost	Other * Investment	Working Capital	Yearly Total
1980	10.10	-	-	10.10
1981	35.30	1.40	-	36.70
1982	177.54	-	-	177.54
1983	312.92	-	-	312.92
1984	318.58	12.10	13.88	344.56
1985	141.76	24.20	13.88	179.84
1986	0	29.60	25.63	55.23
TOTAL	996.20	67.30	53.39	1,116.89

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

TABLE 9.5

PLANT BASED ON KOPPERS TOTZEK 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	10.10	-	-	10.10
1981	35.30	1.4	-	36.70
1982	177.54	-	-	177.54
1983	327.69	-	-	327.69
1984	390.06	12.1	13.88	416.04
1985	336.35	24.2	13.88	374.43
1986	103.66	44.5	50.95	199.11
1987	0	10.5	-	10.50
TOTAL	1,380.70	92.7	78.71	1,552.11

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

TABLE 9.6

PLANT BASED ON KOPPERS TOTZEK GASIFIERS

ESTIMATED INVESTMENT CAPITAL DISBURSEMENTS SCHEDULE

MILLIONS OF 1980 $

MODULE #1 thru 4

Year	Installed Plant Cost	Other * Investment	Working Capital	Yearly Total
1980	10.10	-	-	10.10
1981	35.30	1.40	-	36.70
1982	117.54	-	-	177.54
1983	327.69	-	-	327.69
1984	409.43	12.10	13.88	435.41
1985	431.65	24.20	13.88	469.73
1986	304.31	44.50	50.95	399.76
1987	68.98	35.90	25.20	130.08
TOTAL	1,765.00	118.10	103.91	1,987.01

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

TABLE 9.7

ESTIMATED WORKING CAPITAL (1980 DOLLARS)

K-T GASIFICATION

Plant Modules	1	2	3	4	TOTAL
Coal Inventory 90 days @ $1.25/MMBTU	14.78	14.78	14.78	14.78	59.12
Plant Materials and Supplies @ 0.9% installed cost	5.34	3.63	3.46	3.46	15.89
Plant Payroll @ 90 days	1.13	0.71	0.57	0.45	2.86
Catalyst and Chemicals @ 90 days	0.85	0.85	0.85	0.85	3.40
Electric Power Costs 90 days @ $0.024/KwH	5.66	5.66	5.66	5.66	22.64
TOTAL, MM$	27.76	25.63	25.32	25.20	103.91

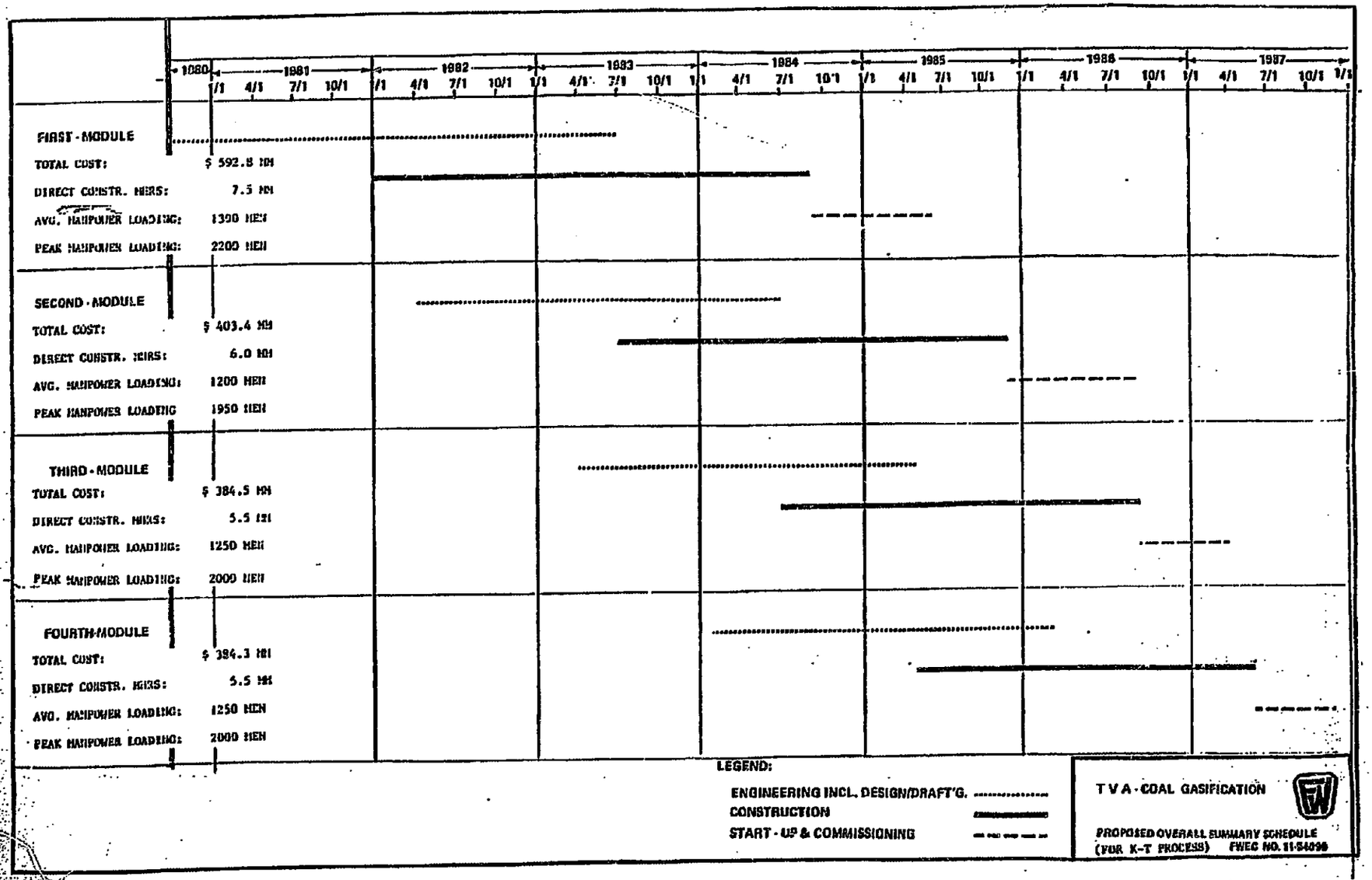

1980
1981
1982
1983
1984
1985
1986
1987
1/1 4/1 7/1 10/1
FIRST-MODULE
TOTAL COST: $ 592.8 MM
DIRECT CONSTR. MHRS: 7.5 MM
AVG. MANPOWER LOADING: 1390 MEN
PEAK MANPOWER LOADING: 2200 MEN
SECOND-MODULE
TOTAL COST: $ 403.4 MM
DIRECT CONSTR. MHRS: 6.0 MM
AVG. MANPOWER LOADING: 1200 MEN
PEAK MANPOWER LOADING 1950 MEN
THIRD-MODULE
TOTAL COST: $ 384.5 MM
DIRECT CONSTR. MHRS: 5.5 MM
AVG. MANPOWER LOADING: 1250 MEN
PEAK MANPOWER LOADING: 2000 MEN
FOURTH-MODULE
TOTAL COST: $ 384.3 MM
DIRECT CONSTR. MHRS: 5.5 MM
AVG. MANPOWER LOADING: 1250 MEN
PEAK MANPOWER LOADING: 2000 MEN
LEGEND:
ENGINEERING INCL. DESIGN/DRAFT'G.
CONSTRUCTION
START-UP & COMMISSIONING
TVA-COAL GASIFICATION
PROPOSED OVERALL SUMMARY SCHEDULE
(FOR K-T PROCESS) FWEC NO. 11-54096

FIGURE 9.1

9.2 Operating Costs

The annual production and operating requirements corresponding to the 4-module gasification plant, based on the Koppers-Totzek 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 TBA'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

K-T GASIFIER CASE

BASIS: 4-MODULE PLANT @ 100% SERVICE FACTOR (365 DAYS/YEAR)

Item	Rate/Year	
Product Gas @ 344.2 MMMBTU/D	125.633×10^6	MMBTU
Coal Feed @ 23936 TPD	191.857×10^6	MMBTU
Limestone @ 240 TPD	87600	Tons
Catalyst & Chemicals	12.42	MM$
Electric Power @ 434 MW	3801.84×10^6	KwH
By-Product Coal Fines	--	
By-Product Sulfur @ 829 TPD	302512	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)

K-T 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	191.857 x 10^6 x 1.25 $/MMBTU	239.82	215.84
2	Limestone	87600 x 13 $/Ton	1.14	1.02
3	Catalyst/Chemicals	(Table 9.8)	12.42	11.18
4	Electric Power	3801.84 x 10^6 x 0.025 $/KwH	95.05	85.54
5	Plant Labor & Supervision	(Table 9.11 and 9.12)	14.42	14.42
6	Operating Supplies	At 30% of Labor & Supervision	4.33	4.33
7	Maintenance Materials	At 2.1% of Erected Plant Cost	37.42	37.42
8	Maintenance S/C Labor	At 55% of Maintenance Material	20.58	20.58
9	TVA G & A Overhead	At 1% of Items 2 through 8	1.85	1.85
10	Ash Disposal		4.10	4.10
11	Total Gross Operating Cost		431.13	396.28
12	By-Product Credits	At Zero Credit	0.00	0.00
13	Net Annual Operating Cost		431.13	396.28

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

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 Koppers-Totzek gasifiers are summarized in Table 9.13.

TABLE 9.13

SENSITIVITY ANALYSIS SUMMARY

K-T GASIFIER - 4 MODULE PLANT

Case	Total Gas Production MMMM BTU	Relative Gas Cost
Base Case	2237.8	1.00
Coal Cost @ +50%	2237.8	1.19
Plant Cost @ +25%	2237.8	1.07
Operating Cost @ +50%	2237.8	1.15
Plant Service Factor @ 80%	1989.2	1.06
70%	1740.5	1.13
60%	1491.9	1.23
By-Product Credit	2237.8	0.97
Design/Construction @ +1 year	2237.8	1.08
-1 year	2237.8	0.92
Plant Life @ +5 years	2803.2	1.05
+10 years	3368.5	1.10
Sulfur @ 1.0 ppm	2237.8	1.02
Delivery Pressure @ 800 psig	2237.8	1.01
@ 300 psig	2237.8	0.98