# 2.0 INDIVIDUAL STUDIES

## PROCESS STUDY NO. 1

## HALF SIZE PLANT STUDY

### I. INTRODUCTION

This study determines the capital and operating costs for a plant that is one-half the size of the plant described in the feasibility study. Two variations for the half size plant were studied - a stand-alone plant and one expandable to a full size in the future. The estimate for the feasibility study provides the data for estimating the half size plants. Capital, operating, and maintenance costs were estimated based on the new plant configurations and material balances.

### II. SUMMARY

The estimated capital and operating and maintenance (O and M) costs for both half size plants are compared with the full size plant below:

Cost Estimates

| | Capital Investment (Jan., 1980 Dollars) | | O & M Cost (1980) | |
|---|---|---|---|---|
| | $MM | % of Case A | $MM/YR | % of Case A |
| Full Size Plant (Case A) | 3,304.3 | —— | 554.7 | —— |
| Half Size - Expandable (Case B) | 2,273.2 | 68.8 | 305.8 | 55.1 |
| Half Size - Not Expandable (Case C) | 1,975.2 | 59.8 | 300.5 | 54.2 |

PROCESS STUDY NO. 1 (Continued)

## III. COMPARATIVE PROCESS DESCRIPTION

### Plant Capacity

The full size plant (Case A) study was designed to process 28,567 tons of Illinois No. 6 coal per day to produce approximately 25,656 BPSD transport fuels, 156 MMSCFD SNG, a number of other types of fuels, and a spectrum of chemicals. Table I shows complete overall feed and product slate of the full capacity plant. The half size plants are based on coal feed to the plant of 15,334 TPSD (on-stream basis) and purchase of a maximum of 55 megawatts of electrical power.

One of the primary differences between the half size plant schemes is the amount of real estate that is required. The expandable plant (Case B) requires the same plot space as the full size plant. Case C, the nonexpandable plant, requires less plot space since no future unit additions are planned.

For the expandable half size plant (Case B), all single train units are identical to the full size plant. For multiple train units the following was used:

Even number trains - use one-half of feasibility study.

Odd number trains - use one-half of feasibility study rounded up to next whole number, i.e., 5 trains in feasibility reduces to 3 trains in half size study.

For the nonexpandable half size plant (Case C), all single train units

III. COMPARATIVE PROCESS DESCRIPTION (Continued)

are 50 percent of the full size plant. For multiple train units, the basis is the same as for the expandable plant.

During operation of the half size expandable plant (Case B), the oil work-up units would run at 50 percent of capacity. Expansion to 100 percent operation will most probably require some adjustments to equipment such as pump impeller replacements and also, some of the fractionating columns may require the addition of tray valves on sections that were blanked-off for the 50 percent operation.

Process Unit Descriptions/Sizes

Case A: Full Size Plant for Feasibility Study

Case B: Expandable Half Size Plant

Case C: Non-Expandable Half Size Plant

Coal Preparation Unit

As-mined coal delivered to the site is screened to 4-inch size and the overall coal is crushed to 4 inches in Bradford-type crushers which will reject stones and pieces of shale for dumping.

Case A: Full capacity

Case B: 1/2 capacity of Case A

Case C: 1/2 capacity of Case A

PROCESS STUDY NO. 1 (Continued)

III. COMPARATIVE PROCESS DESCRIPTION (Continued)

Coal Gasification Unit

The Lurgi process for coal gasification is used. The gasifier design is the latest model (Mark IV).

The Lurgi gasification process is a counter-current operation, which leads to high thermal efficiency. Coal, graded to the correct size distribution, is fed batchwise from coal locks at the top. As the coal moves down the reactor, it is successively heated and dried. The volatile matter in the coal is distilled off and the char formed is gasified.

Case A: Full capacity/36 Mark IV Gasifiers
2 gas holders
1 gas compressor train

Case B: 18 Mark IV Gasifiers, each same size as Case A
1 gas holder, same size as Case A
1 gas compressor train, same size as Case A

Case C: 18 Mark IV Gasifiers, each same size as Case A
1 gas holder, same size as Case A
1 gas compressor train, 1/2 size of Case A

Gas Cooling Unit

The gasification product gas leaving the waste heat boiler at approximately 365°F is cooled in the Gas Cooling Unit. The gas is cooled in a tempered water system from 365°F to 310°F, from 310°F to 130°F by air cooling and

III. COMPARATIVE PROCESS DESCRIPTION (Continued)

Gas Cooling Unit (Continued)

finally to 95°F by water cooling. The cooled gas then goes to Rectisol (Gas Purification Unit) for purification.

Case A: Full capacity/4 trains

Case B: 2 trains, such as the ones for Case A

Case C: 2 trains, such as the ones for Case A

Gas Purification Unit (Rectisol)

For gas purification the Lurgi standard (nonselective) Rectisol process is used.

Impurities in the crude gas are removed in three washing steps with cold methanol.

Case A: Full capacity/4 trains

Case B: 2 trains, each same size as Case A

Case C: 2 trains, each same size as Case A

Synthol Unit

The Synthol Unit uses the Fischer-Tropsch reaction to convert hydrogen and carbon monoxide to hydrocarbons and a small quantity of oxygenated hydrocarbons.

PROCESS STUDY NO. 1 (Continued)

III. COMPARATIVE PROCESS DESCRIPTION (Continued)

Synthol Unit (Continued)

Case A: Full capacity/5 reactor trains

2 nitrogen compressors

3 tail gas compressors

Case B: 3 reactor trains, each same size as Case A

1 nitrogen compressor, same size as Case A

3 tail gas compressors, 1/2 size of Case A

Case C: 3 reactor trains, each same size as Case A

1 nitrogen compressor, same size as Case A

3 tail gas compressors, 1/2 size of Case A

$CO_2$ Removal Unit

The purpose of the Benfield Carbon Dioxide Removal Unit is to remove carbon dioxide from the Synthol Unit tail gas prior to low temperature separation in the $C_2$ Recovery Unit.

Case A: 2 trains of unit

2 $CO_2$ recycle compressors

Case B: 1 train of unit, same size as Case A

1 $CO_2$ recycle compressor, same size as Case A

Case C: 1 train of unit, same size as Case A

1 $CO_2$ recycle compressor, same size as Case A

PROCESS STUDY NO. 1 (Continued)

III. COMPARATIVE PROCESS DESCRIPTION (Continued)

$C_2$ Recovery Unit

The purpose of this unit is to separate the Synthol tail gas into various fractions for further workup.

Case A: 2 trains of the unit

Case B: 1 train of the unit, same size as Case A

Case C: 1 train of the unit, same size as Case A

Ethylene Plant

The plant features a conventional ethylene recovery system based on the cracking of ethane except that more than half of the ethylene is already present in the feed stream.

Case A: Full capacity size as designed for the feasibility study

Case B: Number of Furnaces = 1/2 of number of furnaces in Case A
Other equipment is the same size/number as Case A

Case C: All equipment will have half the number or half the size (single train) of Case A

$H_2$ Purification Unit

The purpose of this unit is to purify a portion of the hydrogen-rich stream from the $C_2$ Recovery Unit for use in various units in the plant.

Case A: Full capacity (2 trains) as designed for the feasibility study

Case B: 1 train, same size as Case A train

Case C: 1 train, same size as Case A train

PROCESS STUDY NO. 1 (Continued)

III. COMPARATIVE PROCESS DESCRIPTION (Continued)

Oil Workup Unit

In the oil workup units, the feeds are processed to produce blending components for gasoline, jet fuel, diesel fuel, and medium fuel oil.

Case A: Full capacity size as designed for the feasibility study

Case B: All related units/equipment, same size as Case A

Case C: All related units/equipment, 1/2 size for Case A

Chemical Workup Unit

The function of the Chemical Workup Units is the recovery of useful products from the water-based effluent from the Synthol Units.

Case A: Full capacity size for all related units/equipment designed for the feasibility study

Case B: All related units/equipment, same size as Case A

Case C: 1/2 size of Case A for all units/equipment

Gas Liquor Separation Unit

This unit uses gravity separation to split the gas condensate produced in the gasification and gas cooling units into tar, oil and water phases.

Case A: 2 trains at full capacity size

Case B: 1 train, same size as Case A

Case C: 1 train, same size as Case A

PROCESS STUDY NO. 1 (Continued)

III. COMPARATIVE PROCESS DESCRIPTION (Continued)

Tar Distillation Unit

The Tar Distillation Unit is designed to fractionate the tar/oil mixture fed from the Gas Liquor Separation Unit. A small recycle stream of residue oil from the Naphtha Hydrogenation Unit is also fed to this unit.

Case A: 2 trains for feasibility study

Case B: 1 train, same size as Case A

Case C: 1 train, same size as Case A

Phenosolvan Unit

The function of this unit is to remove phenolic compounds dissolved in the gas liquor.

Case A: 2 full size Phenosolvan trains
Full size depitcher
Phenol upgrading unit

Case B: 1 Phenosolvan unit, same size as Case A
Full size depitcher
Phenol upgrading unit

Case C: 1 Phenosolvan unit, same size as Case A
Depitcher, 1/2 size of Case A
Phenol upgrading unit, 1/2 size of Case A

PROCESS STUDY NO. 1 (Continued)

III. COMPARATIVE PROCESS DESCRIPTION (Continued)

Stretford Unit

This sulfur recovery unit converts hydrogen sulfide in the Rectisol off-gas to elemental sulfur.

Case A: Full capacity size for the feasibility study

Case B: 1/2 size of Case A

Case C: 1/2 size of Case A

Ammonia Recovery Unit

The unit uses two distillation steps to obtain separation between ammonia and the other gases.

Case A: 2 full size recovery trains
Full size purification unit

Case B: 1 full size recovery train, same size as Case A
Full size purification unit, same size as Case A

Case C: 1 full size recovery train, same size as Case A
1/2 size of purification unit in Case A

Flue Gas Desulfurization Unit

The FGD process comprises two distinct sections, the sulfur dioxide absorption section and sodium regeneration section. Sodium is the alkali reagent

PROCES STUDY NO. 1 (Continued)

III. COMPARATIVE PROCESS DESCRIPTION (Continued)

Flue Gas Desulfurization Unit (Continued)

in the absorption section, and calcium is the reagent in the regeneration section.

Case A: 10 full size trains

Case B: 5 trains of the full size unit used for Case A

Case C: 5 trains of the full size unit used for Case A

Ash Handling Unit

Ash from the Lurgi gasifiers is discharged from the ash locks directly into a low velocity sluiceway. The ash is sluiced with water, which also serves to quench the hot ash and supporess dust. The sluiceway is totally enclosed and sealed.

Case A: Full capacity size

Case B: 1/2 size of the Case A

Case C: 1/2 size of the Case A

Utility Systems Description Sizes

Oxygen Plant

The purpose of the Oxygen Plant is to supply high pressure oxygen, nitrogen, instrument air, and plant air. Atmospheric air is cleaned, compressed, and cooled to below the condensation point. This liquid air is then separated into its various components by a process of fractional

PROCESS STUDY NO. 1 (Continued)

III. COMPARATIVE PROCESS DESCRIPTION (Continued)

Oxygen Plant (Continued)

distillation in an Air Separation Unit.

Case A: 4 trains sized as in the feasibility study

Case B: 2 trains, each same size as Case A

Case C: 2 trains, each same size as Case A

Steam Generation and Power Generation

The Process Steam Generation Unit produces high pressure superheated steam for use as process reaction steam and in-plant power requirements. Coal fired boilers are provided along with associated equipment including precipitators, coal bunkers, coal conveyor, deaerators, boiler feedwater pumps, ash handling collection and transport system, flue gas ducting, exhaust stack, blowdown systems and controls. Power generation facilities consist of five turbogenerators for the full size plant.

Case A: 6 boilers with superheaters sized as in the feasibility study
3 turbo generators with back-pressure turbines
2 turbo generators with condensing turbines

Case B: 3 boilers with superheaters, each same size as ones of Case A
2 turbo generators with back-pressure turbines, each same size as Case A
1 turbo generator with condensing turbine, each same size as Case A

III. COMPARATIVE PROCESS DESCRIPTION (Continued)

Steam Generation and Power Generation (Continued)

Case C: 3 boilers with superheaters, each same size as ones of Case A

2 turbo generators with back-pressure turbines, each same size as Case A

1 turbo generator with condensing turbine, each same size as Case A

Cooling Tower

Two separate cooling systems are used.

Utility Cooling Tower System

This system uses clarified river water as makeup. The system serves the Oxygen Plant which requires water free of organic material, and the Boiler Plant turbine condensers.

Process Cooling Water System

Purified effluent from the Effluent Treatment Unit is used as makeup water in the system. This water will still contain traces of organic compounds and ammonia. As at Sasol II, biogrowth will be kept under control by biocides.

For both cooling tower systems:

Case A: 2 towers at full capacity

Case B: 1 tower, same size as one of Case A

Case C: 1 tower, same size as one of Case A

PROCES STUDY NO. 1 (Continued)

III. COMPARATIVE PROCESS DESCRIPTION (Continued)

Offsites Descriptions

Tankage

Tankage for feed storage, product rundown, and final products is provided. Nearly all the required tanks are located in a segregated "tank farm" area.

Feed Storage

All unit feed tanks are operating tanks; i.e., a portion of the feed to the unit normally flows through the tank. Thus, material in the tank is continuously circulated and agitated. Levels in these tanks will normally be kept low to permit maximum utilization of the tanks in case of an emergency. Adequate storage capacity is provided in each tank for annual shutdown of an associated unit.

Intermediate Tankage

Intermediate tankage is provided for surge capacity and to allow operation of an individual unit when the downstream unit is offline.

Final Product Tankage

Final storage is specified on the basis of maintaining a specified total storage capacity for various blend components and blended products. Any product that does not require blending has only final storage, i.e., LPG, medium fuel oil, etc.

PROCESS STUDY NO. 1 (Continued)

III. COMPARATIVE PROCESS DESCRIPTION (Continued)

Final Product Tankage (Continued)

Case A: Full capacity for all types of tankage

Case B: 1/2 capacity of Case A

Case C: 1/2 capacity of Case A

IV. CAPITAL INVESTMENT AND OPERATING/MAINTENANCE COSTS

New material balances were used to calculate the capital investment for each version of the half size plant.

Capital costs for the half size plants were estimated in January 1980 dollars. This was also the basis for the feasibility study cost estimate. As shown in Section II, the capital investments of the expandable and nonexpandable half size plants are 68.8 percent and 59.8 percent, respectively, of the full size plant capital cost. Table II shows a summary of the comparative operating and maintenance costs of both half size plants; these costs are about 55 percent of the full size plant.

V. PROCESS FLOW DIAGRAM

Process block diagrams (001 and 002) with material balances for the half size plant were prepared. In addition, the water management (003) and sulfur balance (004) block flow diagrams were revised for the half size plant. A copy of each of these block flow diagrams is attached to this report.

PROCESS STUDY NO. 1 (Continued)

## VI. PLOT PLANS

Overall plot plans for the half size plants are included:

| Dwg. No. | Title |
|---|---|
| 835504-5-SK-5010 Rev. A | Half Size Expandable Plant |
| 835504-5-SK-5011 Rev. A | Half Size Plant |

TABLE 1

OVERALL FEED/PRODUCT SLATE

| | Units Per Calendar Day |
|---|---|
| **INPUT** | |
| COAL | 28,567 TPD* |
| LIMESTONE | 325 TPD |
| **OUTPUT** | |
| **FUELS** | |
| SNG | 145 MMSCFD |
| $C_3$LPG | 1,136 BPD |
| GASOLINE | 16,218 BPD |
| JET FUEL | 4,312 BPD |
| DIESEL GRADE 1-D | 3,120 BPD |
| DIESEL GRADE 2-D | 249 BPD |
| FUEL OIL | 471 BPD |
| **CHEMICALS** | |
| ETHYLENE | 448 TPD |
| MEK | 17.34 TPD |
| ACETONE | 53.09 TPD |
| HIGHER KETONES | 0.67 TPD |
| METHANOL | 3.94 TPD |
| ETHANOL | 119.65 TPD |
| PROPANOL | 34.51 TPD |
| BUTANOL | 17.94 TPD |
| PENTANOL PLUS | 17.10 TPD |
| PHENOLS | 41.46 TPD |
| CRESOLS | 50.68 TPD |
| CREOSOTES | 376.40 TPD |
| SULFUR | 526.76 TPD |
| AMMONIA | 202.61 TPD |

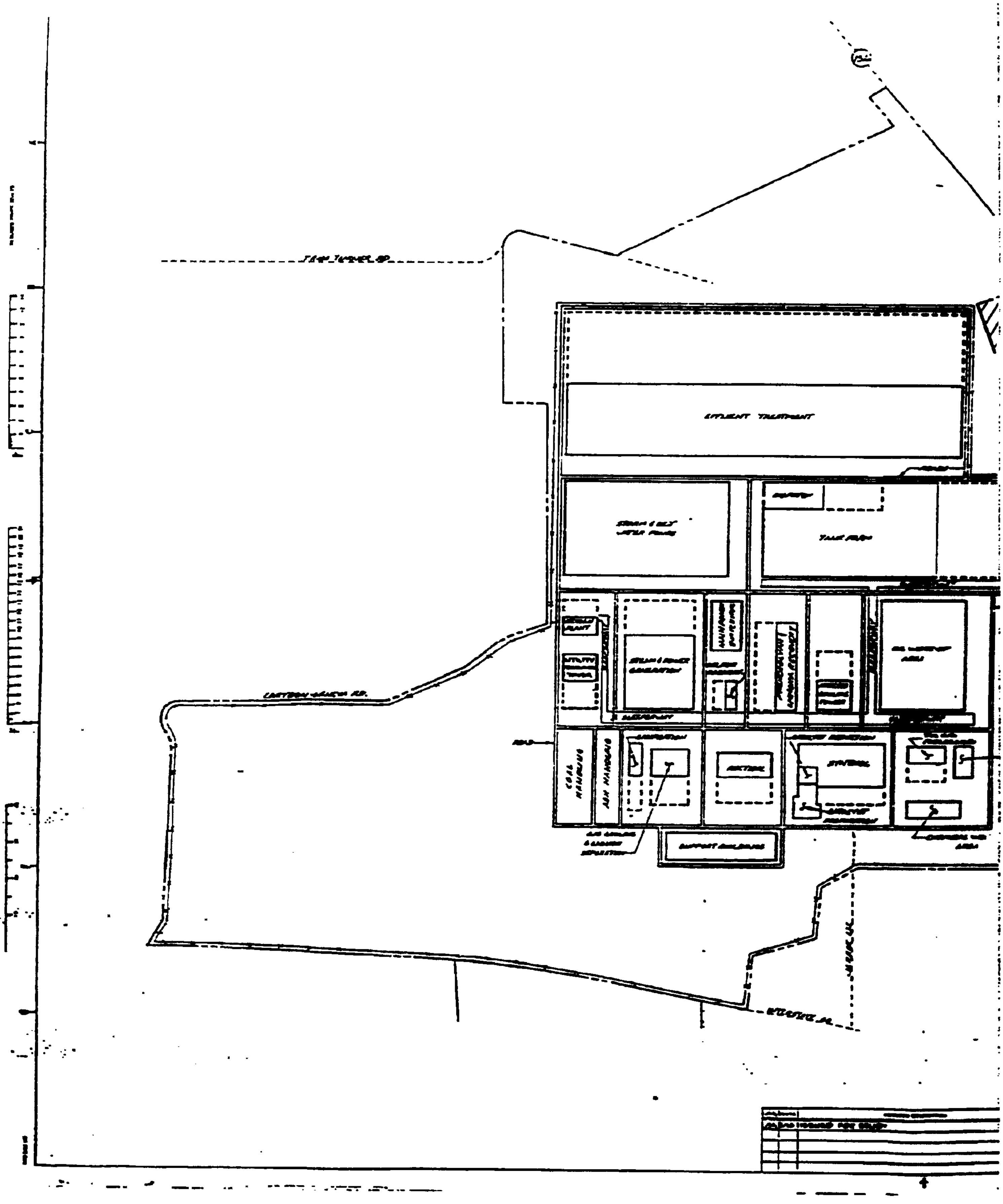
* 30,668 TPSD, based on on-stream day (340 Days/Yr.)

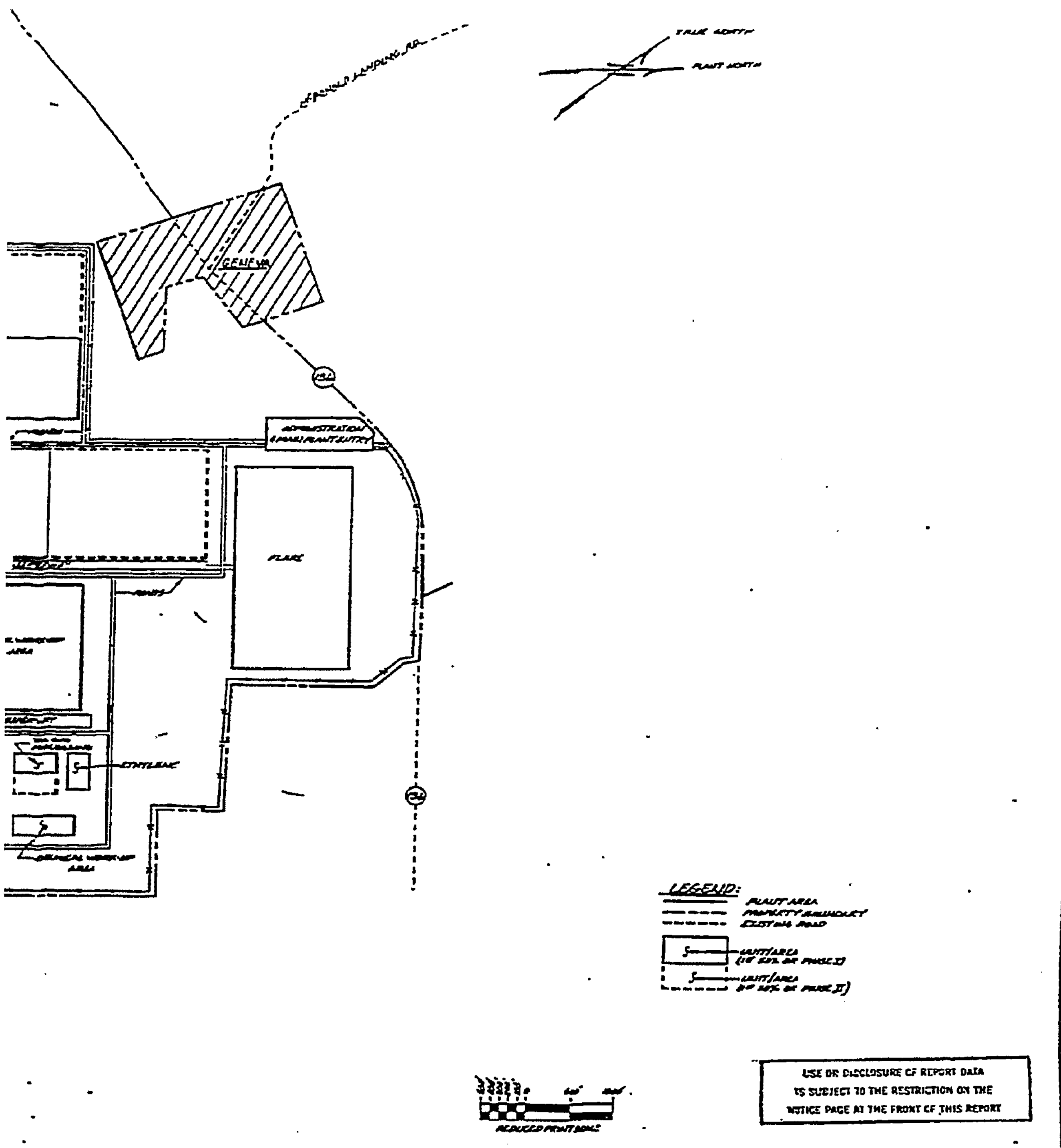
TABLE II

TRI-STATE SYNFUELS PROJECT

Summary of Operating and Maintenance Costs
($MM, 1980)

| | Case A | Case B | Case C |
|---|---|---|---|
| Coal Supply | 334.0 | 167.0 | 167.0 |
| Water Supply | 1.1 | 0.6 | 0.6 |
| Electrical Power (Purchased) | 37.3 | 18.5 | 18.5 |
| Labor | 69.6 | 52.2 | 52.2 |
| Materials and Supplies | 58.9 | 40.5 | 35.2 |
| Chemicals and Catalysts | 36.2 | 18.1 | 18.1 |
| Ash Disposal (To battery limits) | 6.3 | 3.2 | 3.2 |
| Insurance | 8.8 | 4.4 | 4.4 |
| Taxes Other Than Income | 2.5 | 1.3 | 1.3 |
| TOTAL | 554.7 | 305.8 | 300.5 |


EFFLUENT TREATMENT
COAL HANDLING
ASH HANDLING

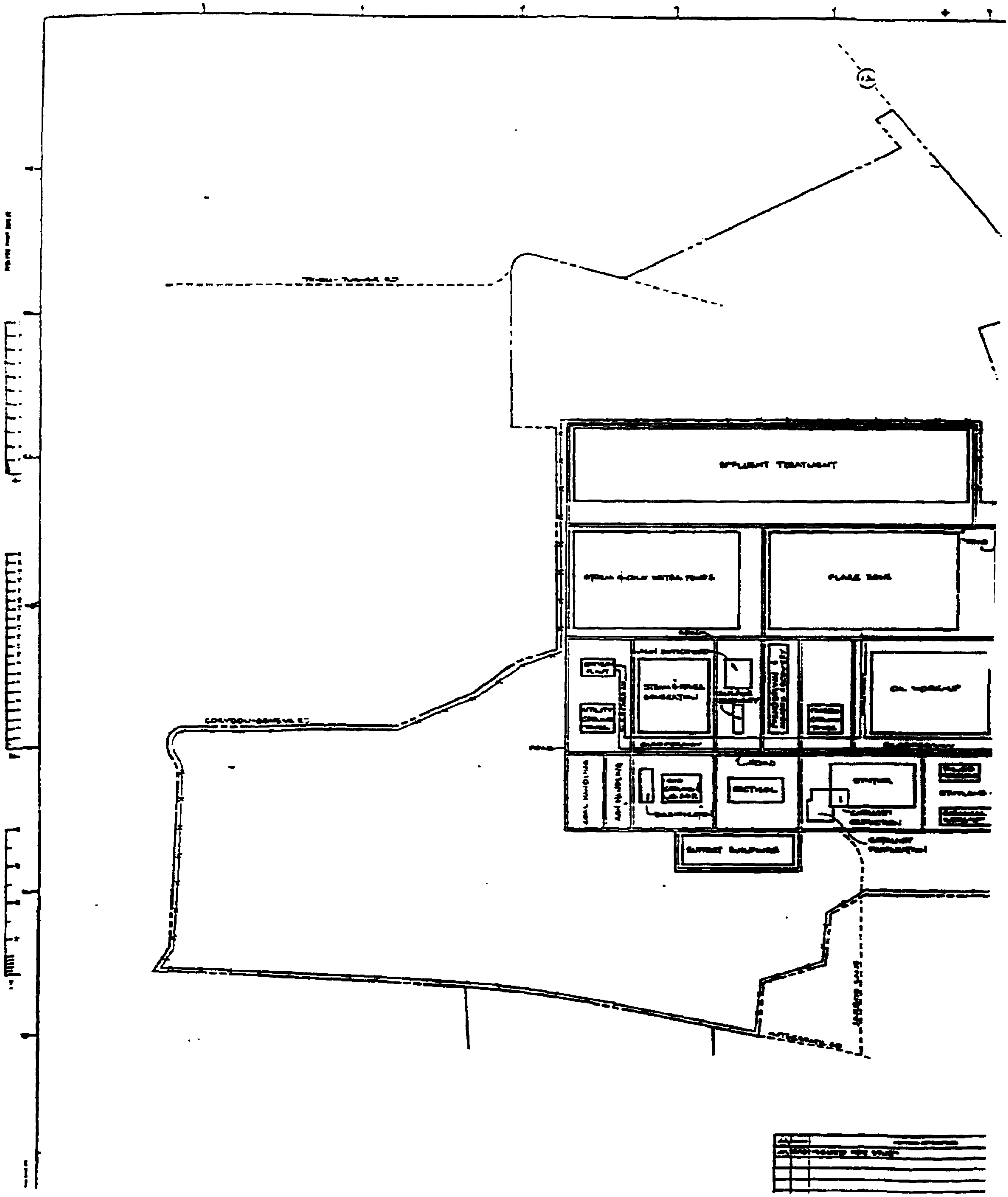


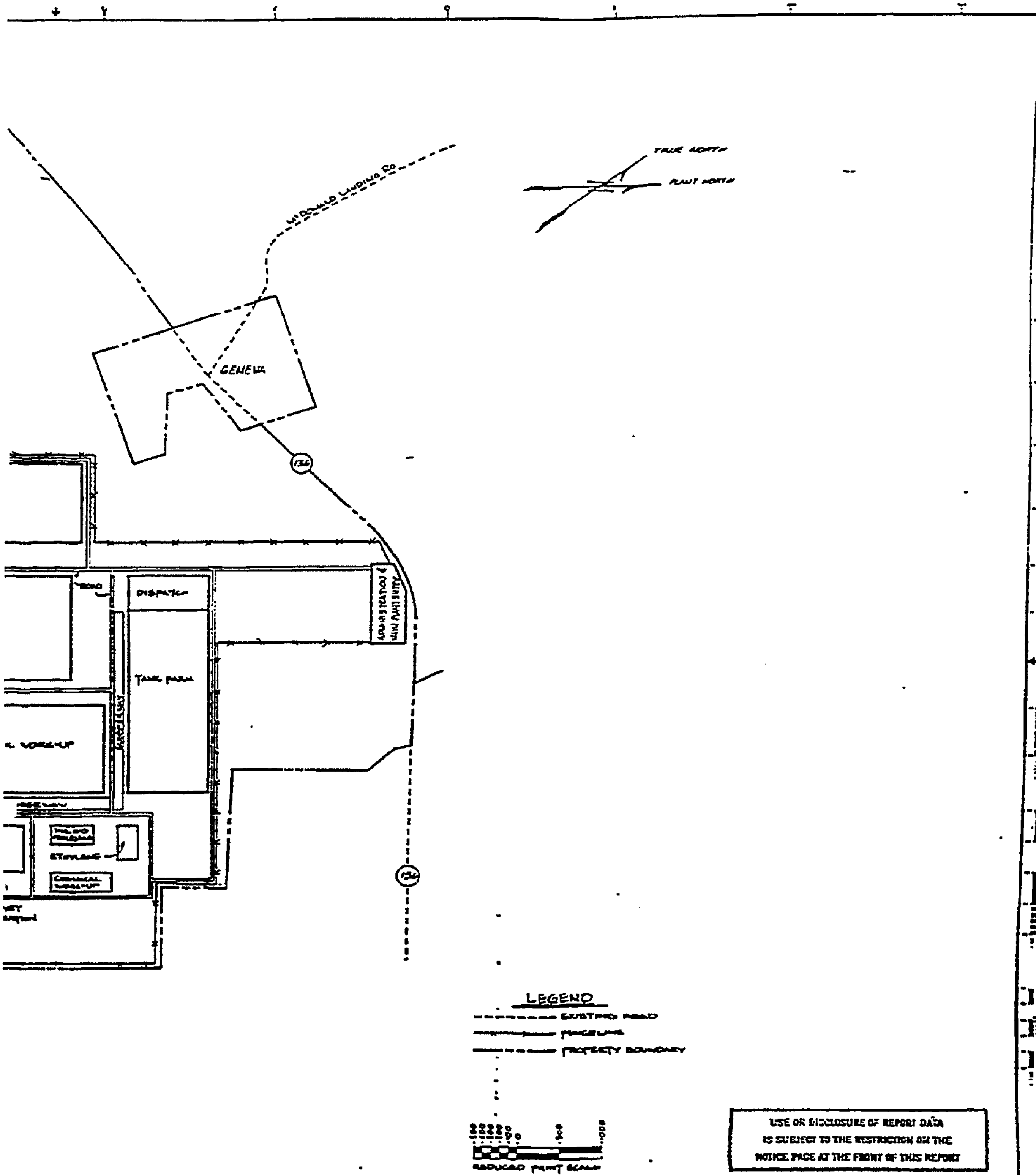

FLUOR

OVERALL PLOT PLAN
½ SIZE EXPANDABLE PLANT STUDY

T. COUTY

1"=500' | 835504-00-5-SK5010 | 01


EFFLUENT TREATMENT
FLARE ZONE
COAL HANDLING
ASH HANDLING
ROAD
SUPPORT BUILDINGS






FLUOR

OVERALL PLOT PLAN
½-SIZE PLANT STUDY
TRI-STATE SYNFUELS PROJECT WESTERN KENTUCKY

835304-00-S SK5011