

# OPTIMIZATION OF COAL GASIFICATION PROCESSES

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**OPTIMIZATION OF COAL GASIFICATION PROCESSES**

**By**

**Department of Chemical Engineering  
West Virginia University  
Morgantown, West Virginia  
C. Y. Wen, Project Director**

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## Introduction

In this chapter, the information developed in the previous chapters on subsystem optimizations of each of the phases; coal preparation and pretreatment, gasification, shift conversion, gas purification, and methanation are to be integrated to arrive at an overall plant optimization for the production of pipeline gas. Various alternate pipeline gas production processes selected will be examined, so that comparison can be made to determine the economic potential of each alternate.

In estimating the gas prices, based on the O.C.R. accounting procedures, from the cost of production of the gas by the various alternates, the fixed investment for the optimal design of each phase must be first computed. Information needed in the computer calculation of gas prices is described later. The effects of changes in the key parameters affecting the price of gas are described. The steps involved in various alternates having a technical uncertainty which may critically affect the success or failure of the selected alternate are identified.

### 1. Description of Gas Manufacturing Processes

Before the price of pipeline gas can be calculated, the alternate gasification processes must be clearly defined. In the study of thermodynamics and kinetics of gasifier performance, five major gasification schemes were formulated in Section 3.3 of Chapter IV. Studies made in that chapter were mainly concerned with the determination of operating conditions and the process design of gasification schemes. In this section, we discuss the interrelation of various phases which must be

individually arranged to construct an integrated pipeline gas manufacturing plant. Essentials of the five alternate processes formulated are as follows:

### 1.1 Alternate I

The flow sheet of this alternate is shown in Figure VIII-1. The partially cleaned coal received from the mine is sent to a coal preparation plant for grinding and screening. A portion of this crudely prepared coal is transferred to the coal storage field, and the remainder is pulverized to proper sizes. After the pulverized coal has been dried in a dryer, it is fed to a pretreater. The coal is made nonagglomerating by reacting with steam and a small amount of oxygen in the pretreater. The pretreated coal is introduced to a train of gasifiers through either lock hoppers or piston feeders.

In the gasifier, coal is fluidized and gasified by steam and oxygen. It is also possible to operate the gasifier under a slag condition at a higher temperature. Gas coming out of the gasifier contains mainly CO and H<sub>2</sub>. The effluent gas, after passing through a waste heat recovery system, is introduced to a shift converter. The gas mixture is catalytically shifted to a desired hydrogen to carbon monoxide ratio. After the temperature of the shifted gas is lowered in a product cooling system, it is introduced to the gas purification unit where CO<sub>2</sub>, H<sub>2</sub>S, C<sub>6</sub>H<sub>6</sub>, and other impurities are removed from the gas stream. Prior to entering the methanator, the purified gas is mixed with a portion of the hot product gas from the methanator. The CO in the mixed gas is catalytically reacted with hydrogen in the methanator. When the gas mixture in the methanator reaches a maximum allowable temperature

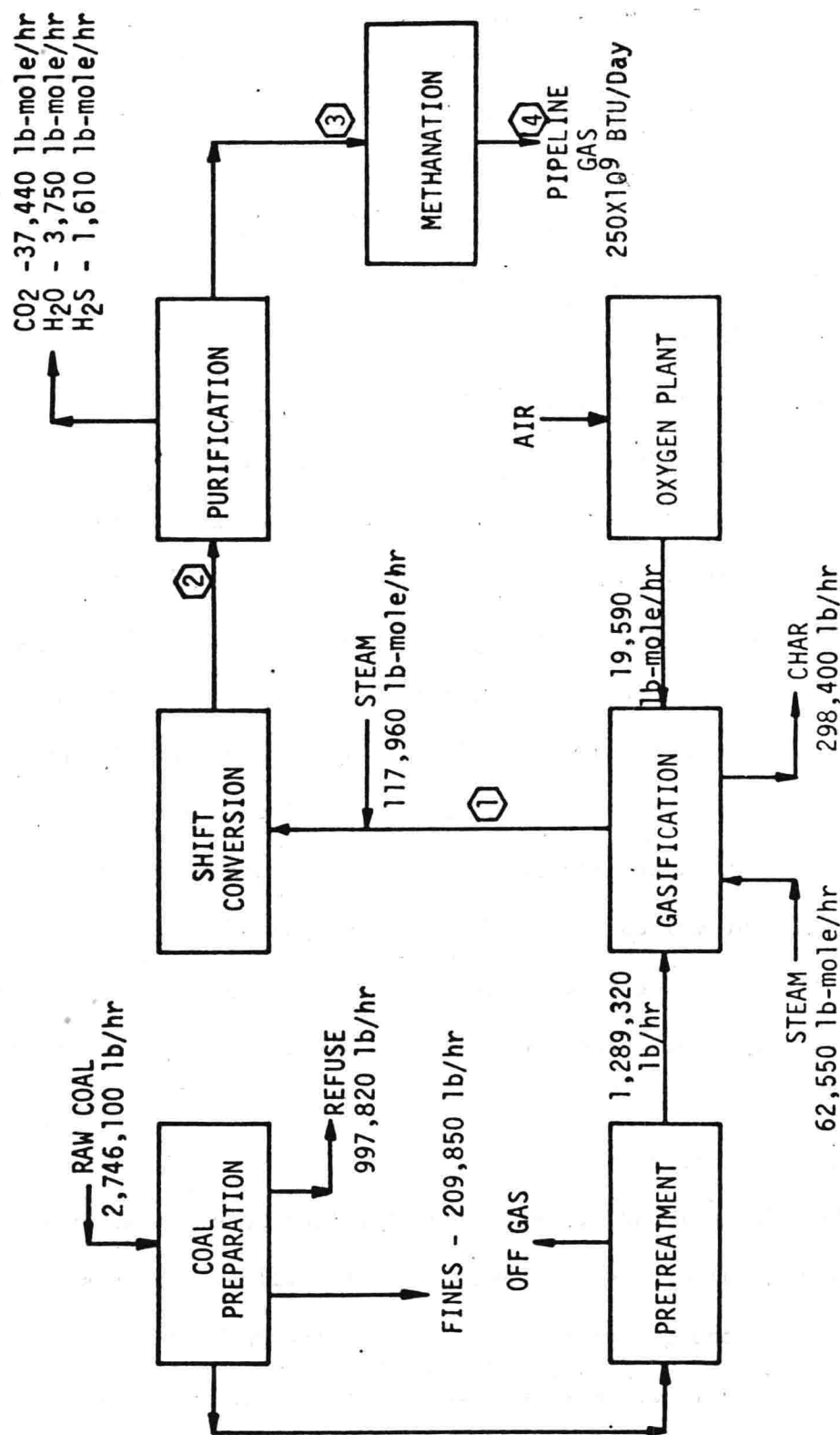


Figure VIII-1 Coal Gasification Process -- Alternate I

it is quenched with the cold feed gas. The procedure is repeated until the desired conversion is reached. The effluent gas from the methanator is passed through another waste heat recovery system where the excess water vapor is condensed before the gas enters the pipeline.

## 1.2 Alternate II

Depending on the type of gasifier selected, this alternate process can be divided into three processes.

### i. Alternate II-1

Stage I is a slag bed and Stage II is a fluidized bed. The schematic flow diagram of this alternate is shown in Figure VIII-2. The coal preparation and pretreatment section are the same as Alternate I. In the gasification phase, two reactors, Stage I and Stage II, are connected in series. The pretreated coal enters the gasification phase at the top of Stage II, where it is fluidized and reacted with the hot gas from Stage I. The partially reacted coal flows into Stage I through a standpipe. Stage I is a slag bed where the char from Stage II reacts nearly completely with oxygen and steam. The ash is discharged from Stage I in the form of molten slag. The effluent gas of Stage I enters the bottom of Stage II. The product gas from Stage II goes into a shift conversion unit. The gas, thereafter, follows the same route as described in Alternate I.

### ii. Alternate II-2

Both Stage I and Stage II are fluidized beds. A schematic flow diagram of this alternate is shown in Figure VIII-3. In this process, Stage II of the gasifier is the same as the one described in Alternate II-1. The only difference between the two processes is that

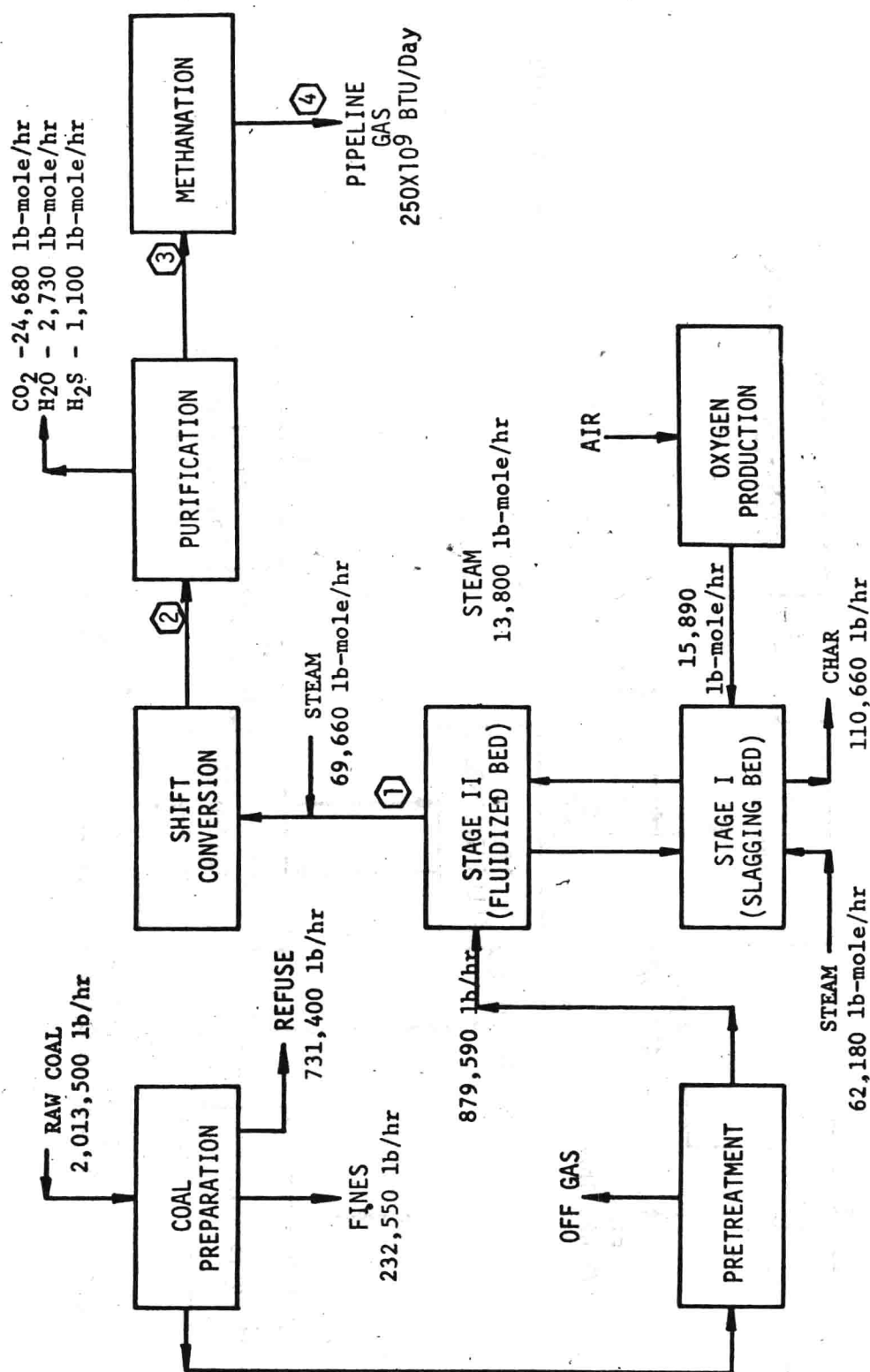


Figure VIII-2 Coal Gasification Process -- Alternate II-1



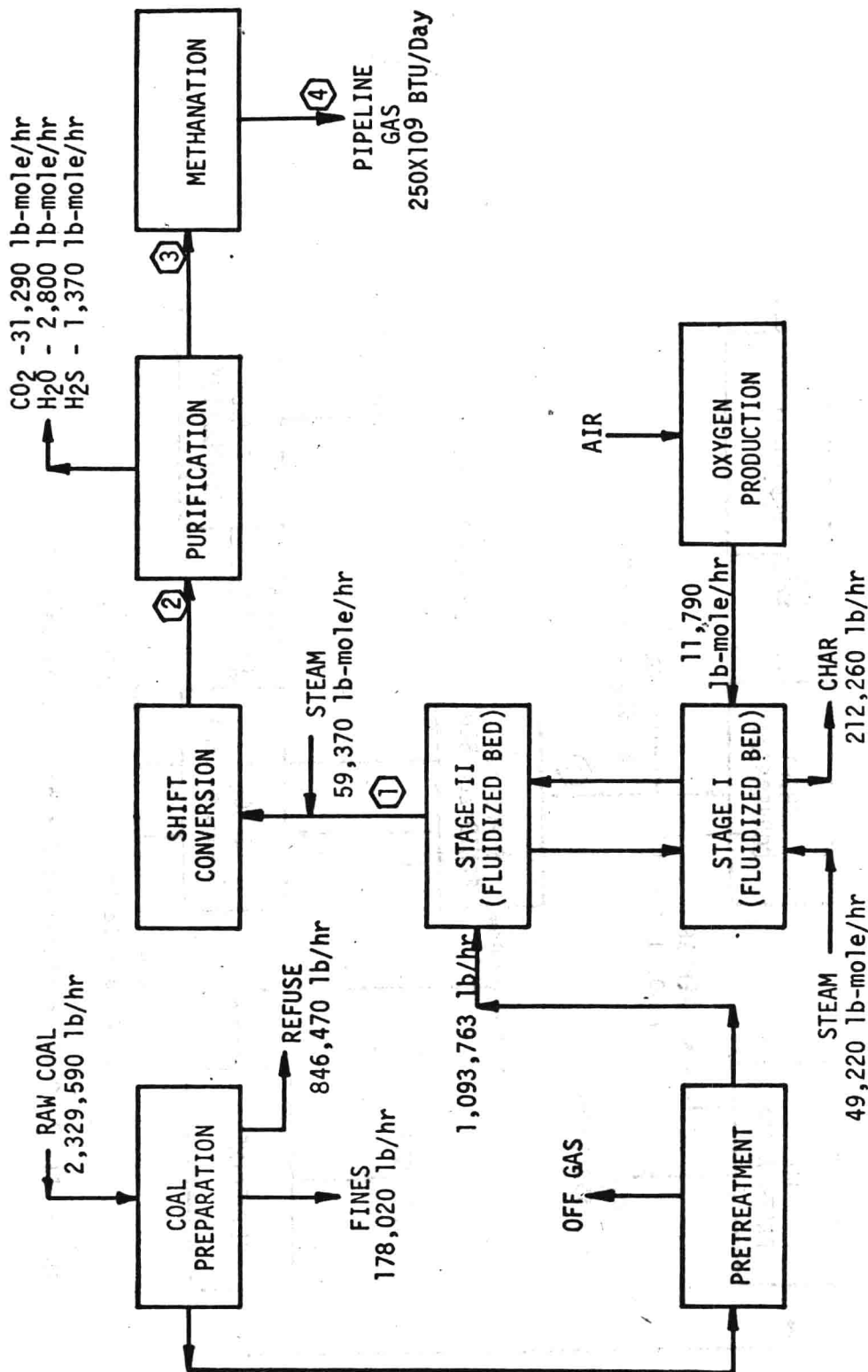


Figure VIII-3 Coal Gasification Process -- Alternate II-2

Stage I of this alternate is a fluidized bed. Since Stage I is a fluidized bed, the bed temperature is lower than that of the slag bed. From the shift conversion to the end of the process, the gas passes through the same steps as described in Alternate I.

### iii. Alternate II-3

Stage I is a slag bed and Stage II is an entrained bed. A schematic flow diagram of this alternate is shown in Figure VIII-4. In this process, untreated coal may be fed directly. The pulverized coal, through a feeding system, either by piston feeders or lock hoppers, is introduced into the bottom part of Stage II of the gasifier. The coal particles react with the gaseous medium while they are entrained through Stage II. The solid particles are separated from the gas stream by a cyclone separator. The partially reacted char, collected in the cyclone, is then introduced to Stage I where it reacts with oxygen and steam. The solid free gas from Stage II follows the same steps as the gas coming out of the gasifier in Alternate I for the production of pipeline gas.

### 1.3 Alternate III

A schematic flow diagram is shown in Figure VIII-5. Coal from the mine is prepared and pulverized. The coal is then pretreated by steam and oxygen in the pretreatment section before it can be gasified. Pretreated coal is fed to a train of fluidized bed hydrogasifiers, where the pretreated coal is brought into contact with a gas mixture rich in hydrogen. The partially reacted char is transferred into a train of gasifiers. Char particles are fluidized and reacted with steam and oxygen in the gasifiers. The effluent gas from the gasifiers is completely shifted, purified, and is then returned to the hydrogasifiers. The gas

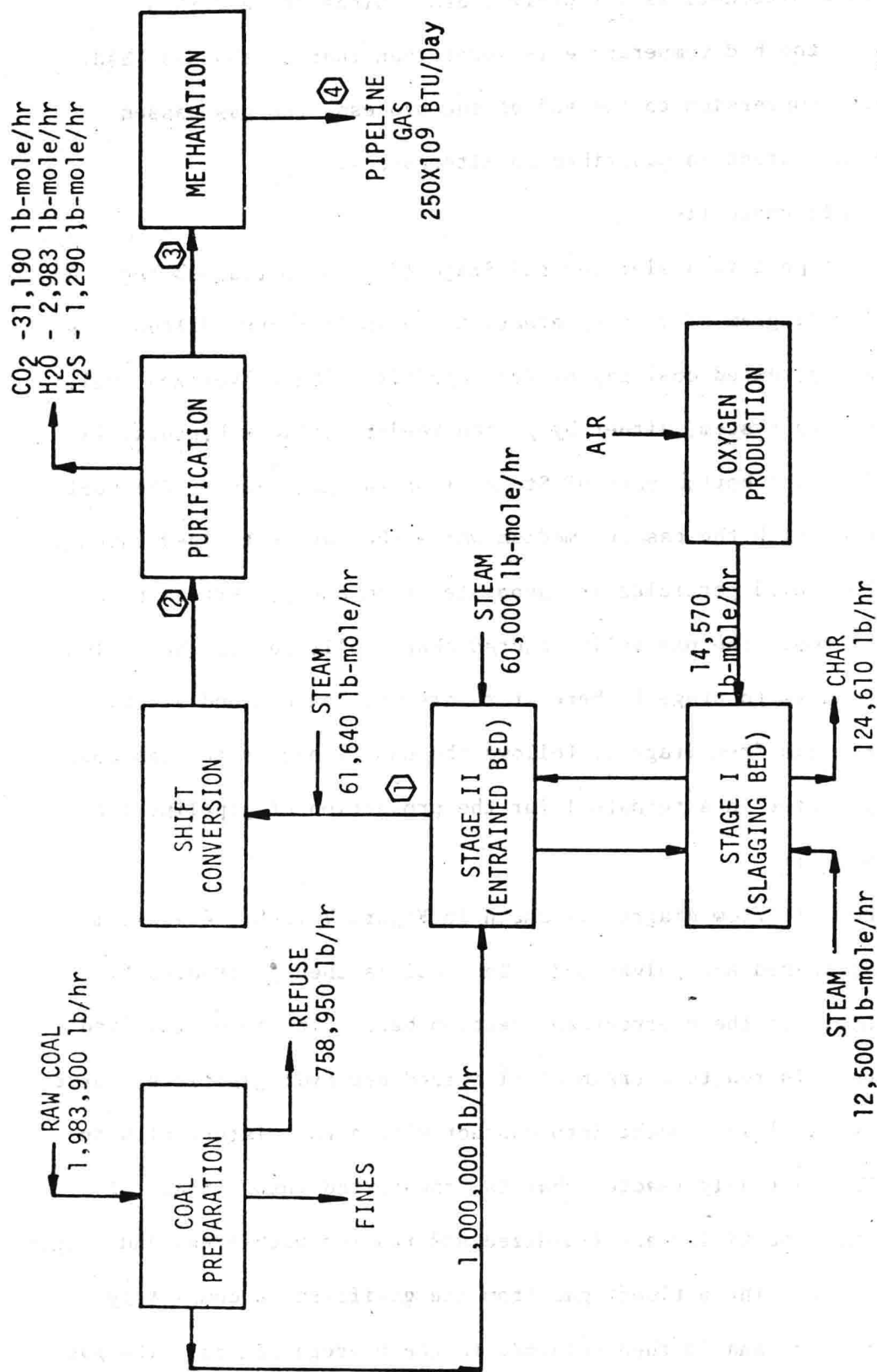


Figure VIII-4 Coal Gasification Process -- Alternate II-3

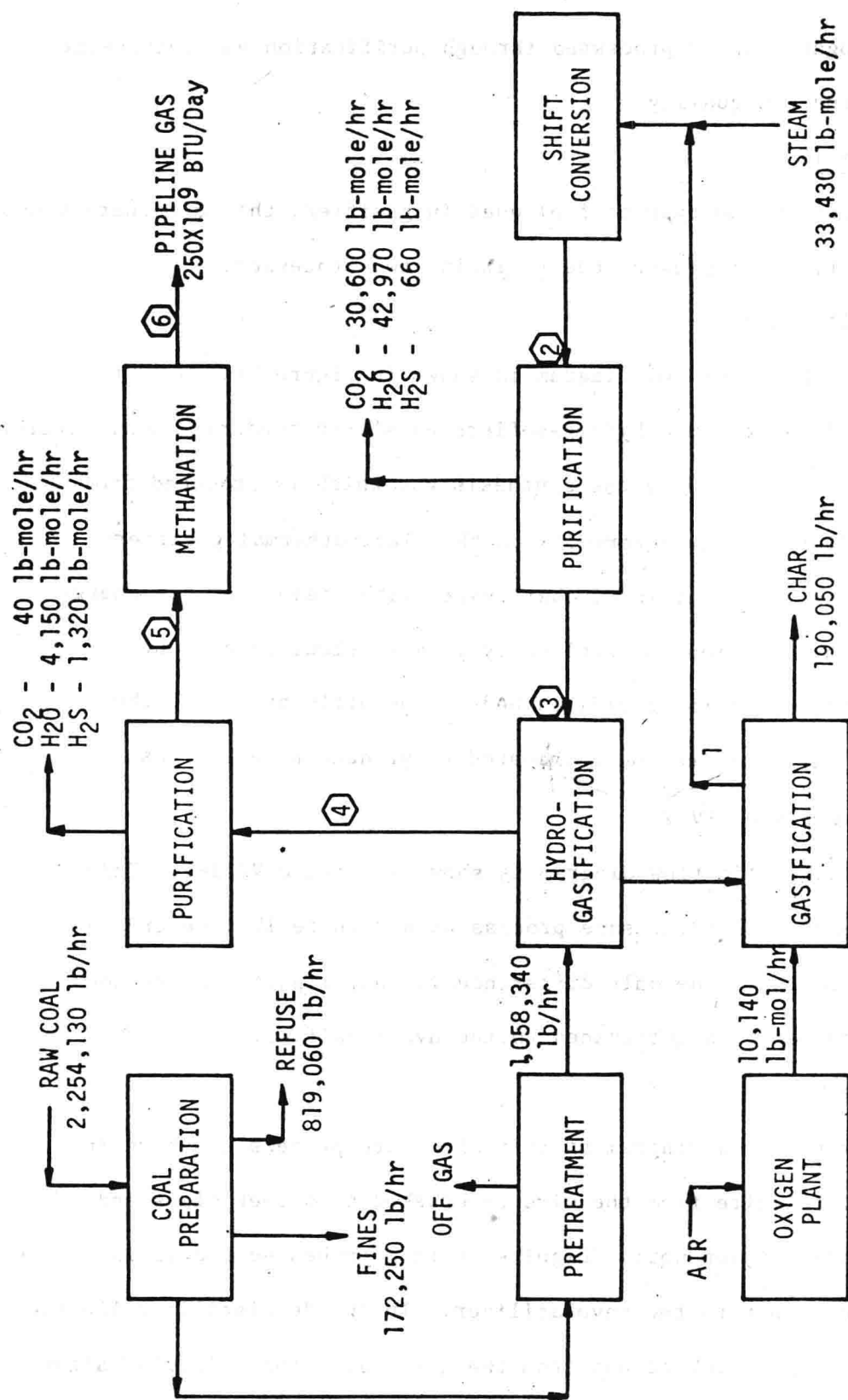


Figure VIII-5 Coal Gasification Process -- Alternate III

from the hydrogasifier is processed through purification and methanation to meet pipeline gas quality.

#### 1.4 Alternate IV

Depending on the type of fuel used in gasifier, this alternate scheme may be considered to represent the following two processes.

##### i. Alternate IV-1

A schematic flow diagram is shown in Figure VIII-6. The pretreated coal is fed into hydrogasifiers by slurry feeders. Coal particles are fluidized and reacted by the synthesis gas which is produced from the hydrogasifiers are transferred into the electrothermal gasifiers. In the electrothermal gasifiers, char reacts with steam, and the energy required for gasification is supplied by passing electric current through electrodes and the fluidized beds. The effluent gas of the hydrogasifiers is purified and methanated to produce pipeline gas.

##### ii. Alternate IV-2

A schematic flow diagram is shown in Figure VIII-7. This alternate is essentially the same process as Alternate IV-1 described in the previous section. The only difference is that lignite, which does not require pretreatment, is introduced to the hydrogasifier.

#### 1.5 Alternate V

A schematic flow diagram of this alternate process is shown in Figure VIII-8. Lignite from the mine is crushed to proper sizes and dried in the preparation unit. Lignite is then preheated and is introduced through a lock hopper to the devolatilizer. In the devolatilizer lignite reacts with hydrogen-rich stream from the gasifier. The volatile matter from the lignite leaves the top of the devolatilizer as methane, carbon monoxide, and hydrogen. The devolatilized lignite (char) is withdrawn

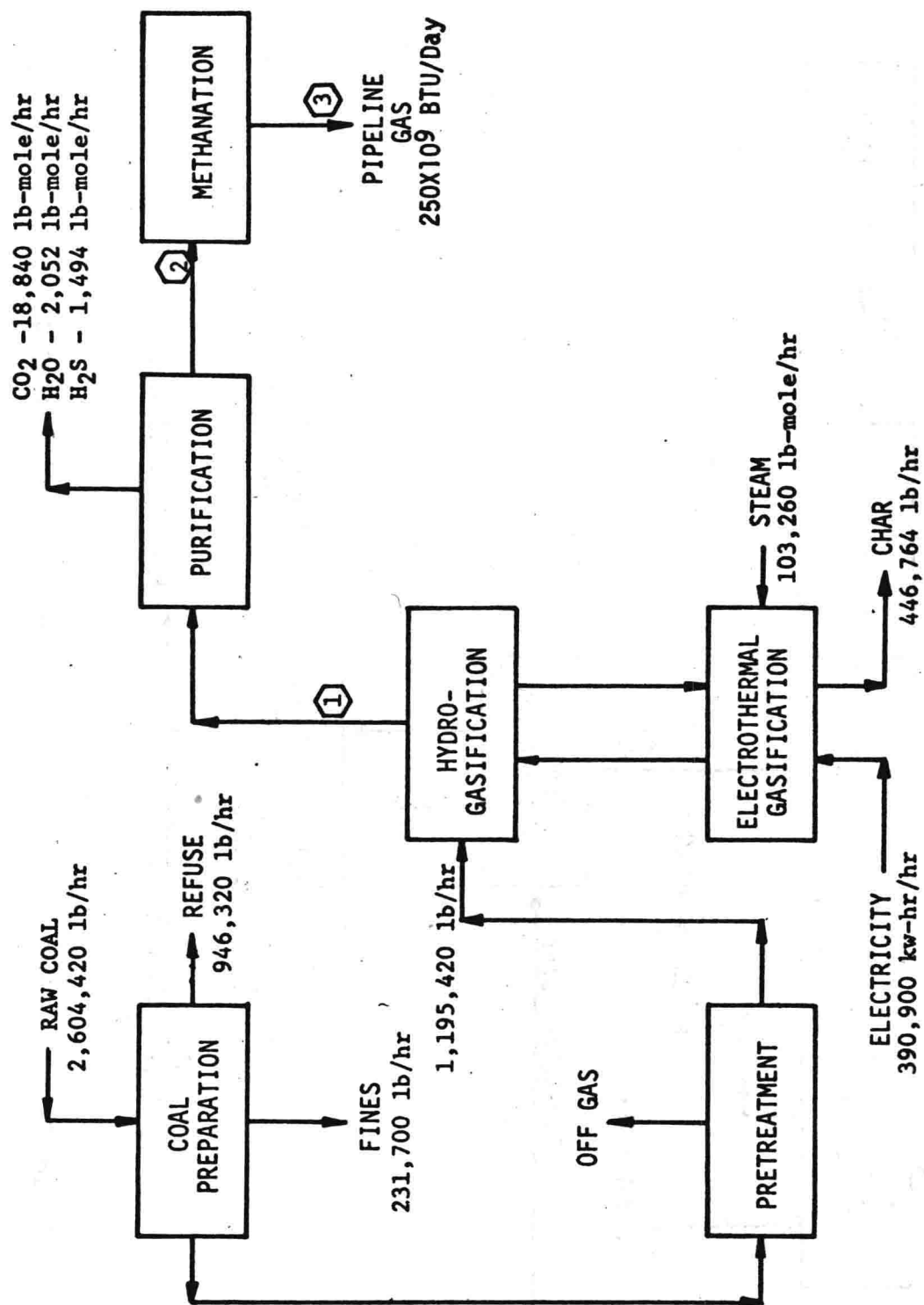


Figure VIII-6 Coal Gasification Process -- Alternate IV (Bituminous Coal)

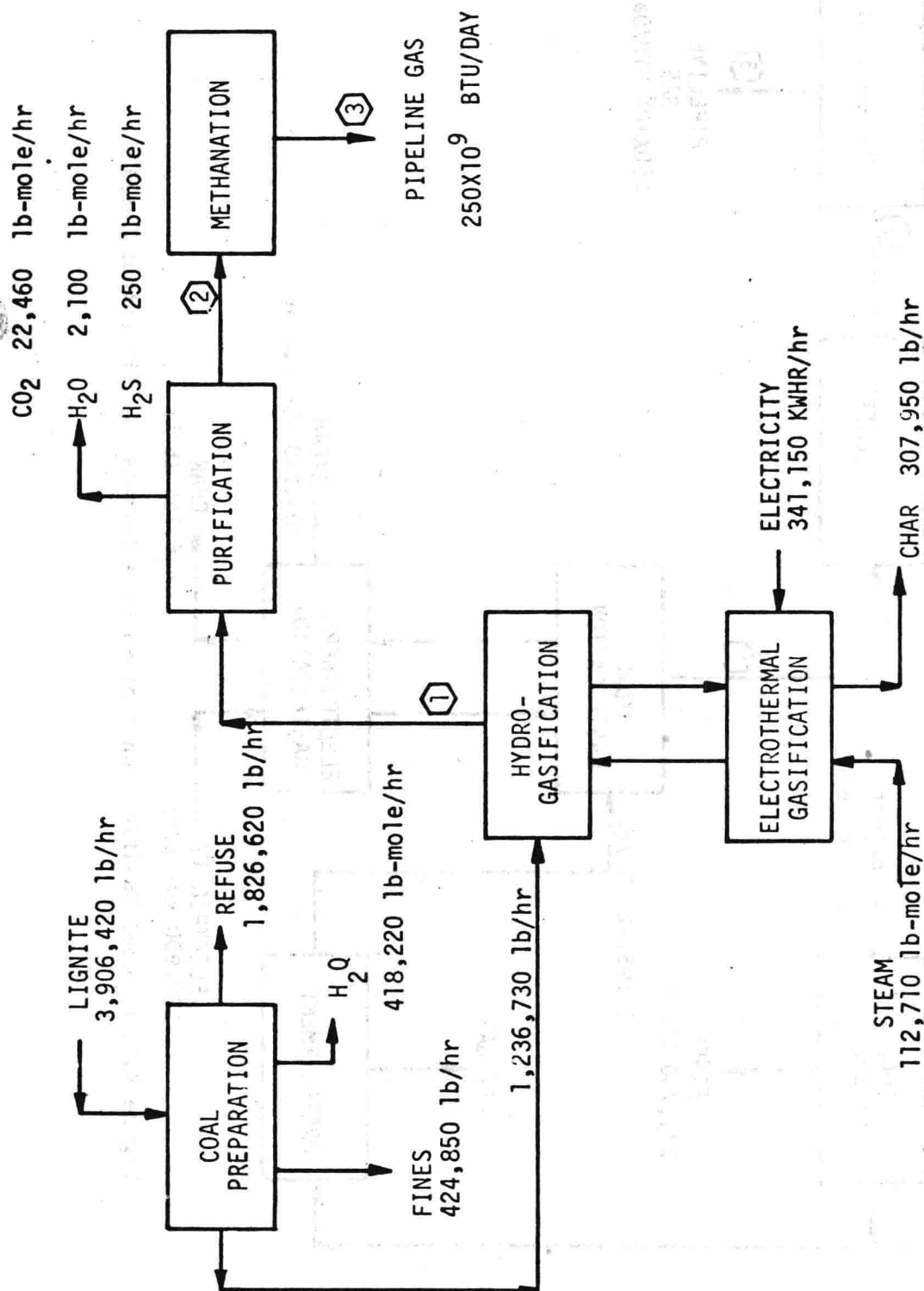


Figure VIII-7 Coal Gasification Process Alternate IV-2 (Lignite)

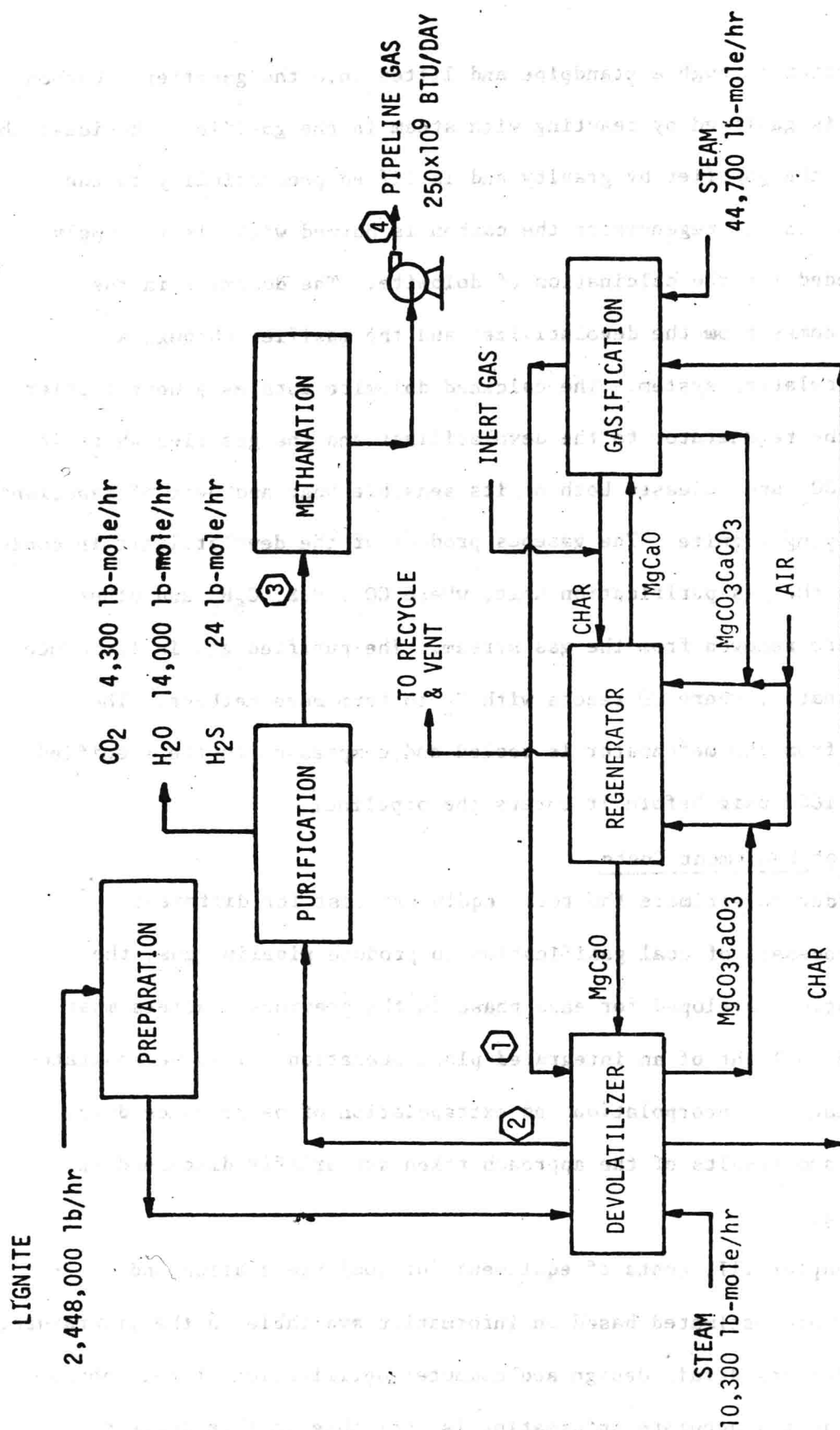


Figure VIII-8 Coal Gasification Process Alternate V



from the reactor through a standpipe and lifted into the gasifier. Carbon in the char is gasified by reacting with steam in the gasifier. Residual char flows out of the gasifier by gravity and is lifted pneumatically to the regenerator. In the regenerator the carbon is burned with air to supply the heat needed for the calcination of dolomite. The dolomite in the regenerator comes from the devolatilizer and the gasifier through a dolomite circulation system. The calcined dolomite acts as a heat carrier, flows from the regenerator to the devolatilizer and the gasifier where it reacts with  $\text{CO}_2$  and releases both of its sensible heat and heat of reaction to the gasifying lignite. The gaseous product of the devolatilizer is cooled, then sent to the gas purification unit, where  $\text{CO}_2$ ,  $\text{H}_2\text{S}$ ,  $\text{C}_6\text{H}_6$  and other impurities are removed from the gas stream. The purified gas is introduced to the methanator, where  $\text{CO}$  reacts with  $\text{H}_2$  to form more methane. The product gas from the methanator is cooled and compressed to the specified pressure of 1000 psig before it enters the pipeline.

## 2. Summary of Equipment Costs

In order to estimate the total equipment cost for different alternate processes of coal gasification to produce pipeline gas, the cost information developed for each phase in the previous chapters must be assembled in light of an integrated plant operation. This necessitates, in some instances, interpolation and extrapolation of performance data. The methods and results of the approach taken are briefly discussed in the following:

In Chapter III, costs of equipment for coal preparation and pretreatment are estimated based on information available in the literature, without performing detail design and computer optimization of this phase. Since sufficiently accurate information is available on this phase of operation, and the required cost of coal preparation and pretreatment