SECTION 18

ALTERNATE 1: SOUTHERN APPALACHIAN REGION OF THE EASTERN COAL PROVINCE

The objective of this portion of the conceptual design task assignment was to develop a second-order assessment of the technical and economic impacts of locating the POGO complex in alternate locations using local coal resources. This section presents the results of the assessment for the Southern Appalachian Region of the Eastern Coal Province (Southern Appalachia). Section 19 presents similar results for the Powder River Region of the Rocky Mountain Coal Province location (Alternate 2).

A major difference in a Southern Appalachia location as compared to the base case Eastern Region of the Interior Coal Province, is the method of coal mining. Alternate 1 is located at the southern tip of the Appalachian Region, where known coal resources, particularly strippable reserves, appear to be limited. Captive coal sources would consist of a combination of small strip and underground mines. Coal analysis differs from that for the base case mainly in being lower in volatile matter and higher in fixed carbon content. The coal from underground mining operations will be cleaner than strip mine coal, effecting a small cost reduction in coal preparation equipment compared to that of the base case. The process plant, power plant; and offsite units are, on the average, slightly smaller than those of the base case complex.

The net result is a higher fixed capital investment, largely because of high mine costs and an overall thermal efficiency of approximately 75%--possibly slightly higher than that of the base case.

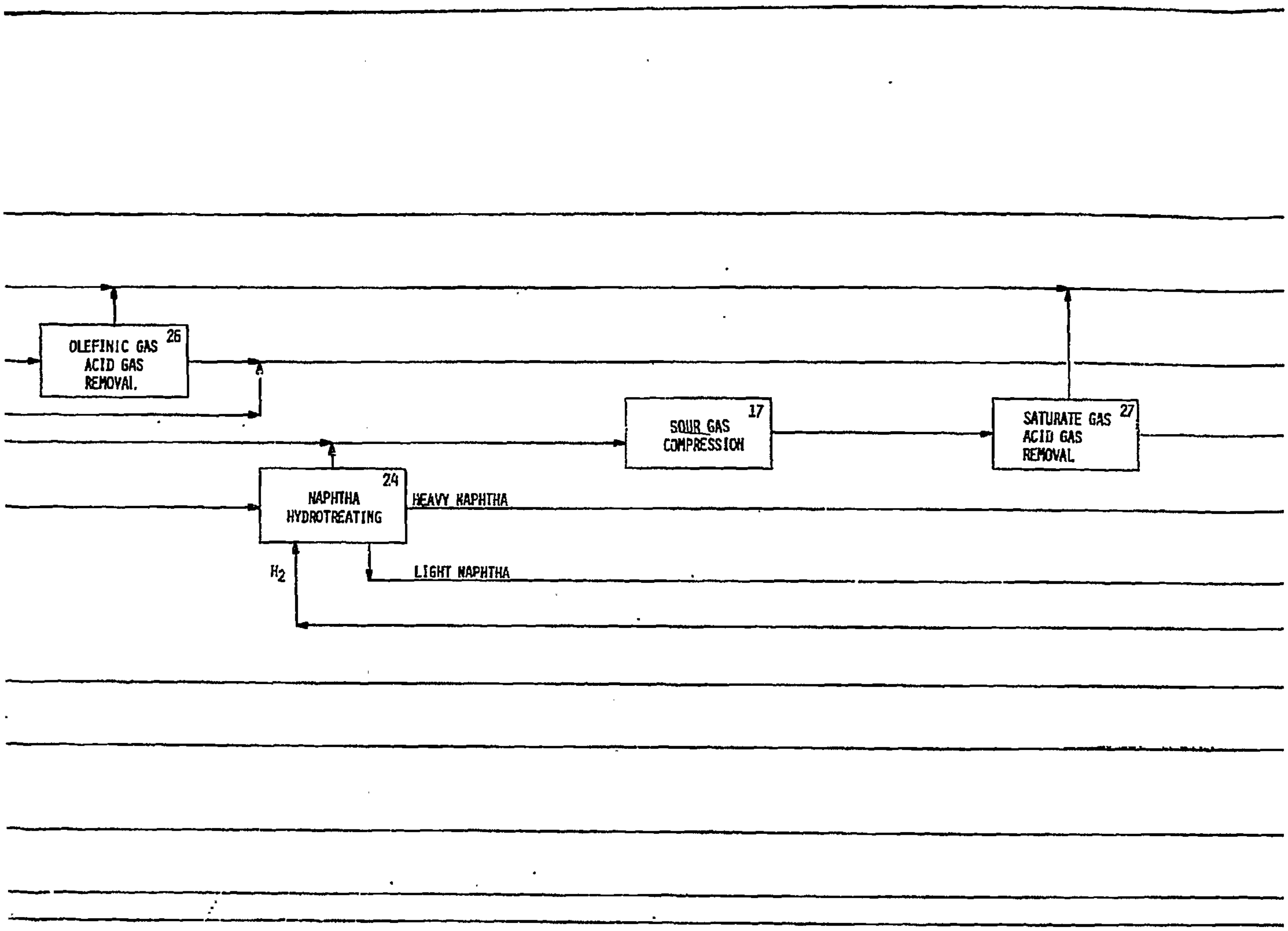
The block flow diagram with heat and material balance for the POGO process, Alternate 1, is shown in Figure 18-1. The overall material balance is presented in Figure 18-2.

18.1 COAL MINES

During the first 5 years of operation, run-of-mine (ROM) coal requirements of 54,000 TPD would be supplied by eight captive strip mines (1 MM TPY each) and five captive underground mines (2 MM TPY each).

At the end of the initial 5 years of operation, the strip mines would be mined out. Four additional underground mines, under development following the first year of operation, will then be placed into production at the beginning of the sixth year. Coal for the last 15 years of project operation will be supplied by nine underground mines.

Equipment and support facilities lists and operational details were prepared for both types of mines.



OLEFINIC GAS ACID GAS REMOVAL 26
SOUR GAS COMPRESSION 17
SATURATE GAS ACID GAS REMOVAL 27
NAPHTHA HYDROTREATING 24
HEAVY NAPHTHA
LIGHT NAPHTHA
H_2

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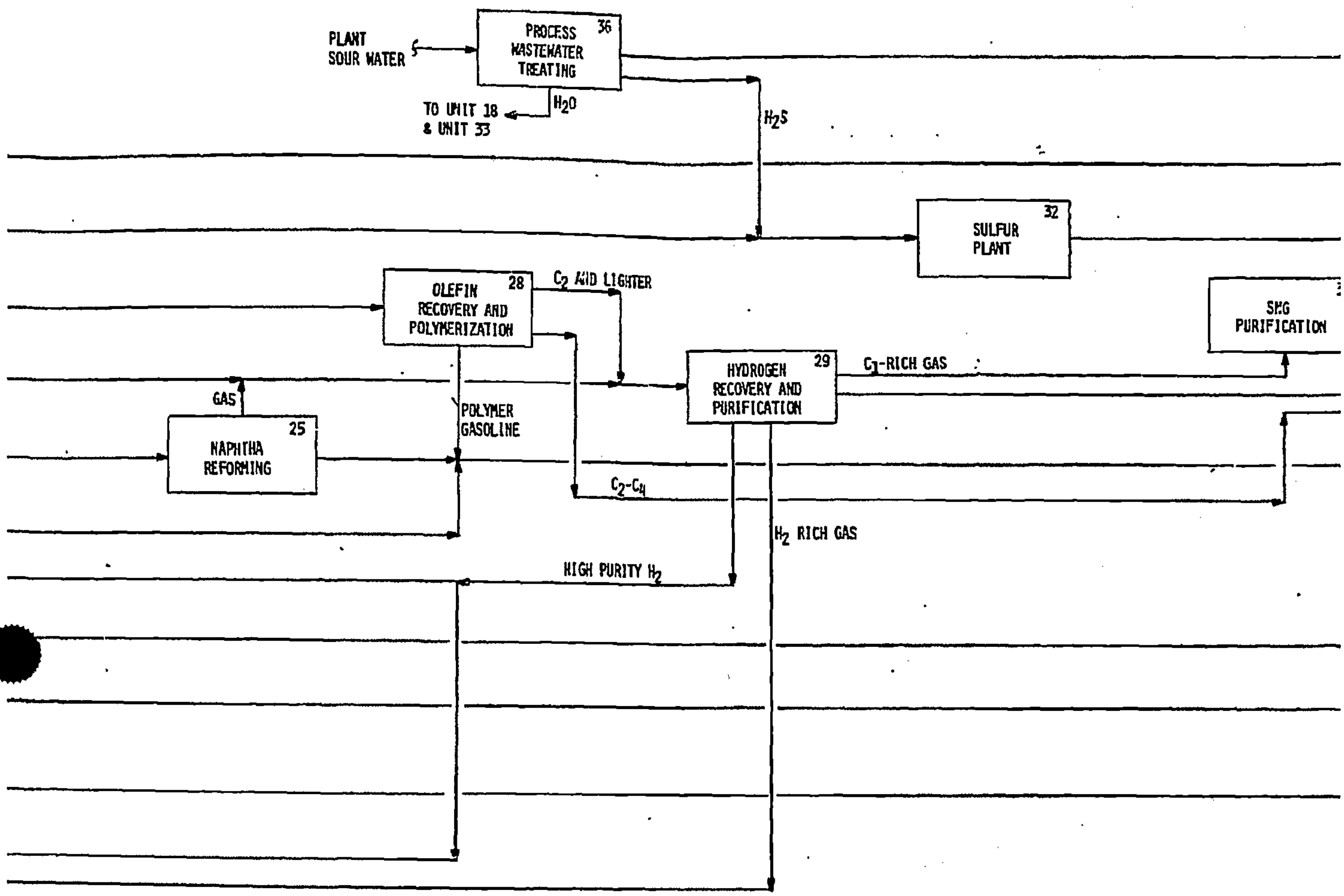
PLANT SOUR WATER
PROCESS WASTEWATER TREATING 36
TO UNIT 18 & UNIT 33
H_2O
H_2S
SULFUR PLANT 32
OLEFIN RECOVERY AND POLYMERIZATION 28
C_2 AND LIGHTER
SNG PURIFICATION
GAS
NAPHTHA REFORMING 25
POLYMER GASOLINE
HYDROGEN RECOVERY AND PURIFICATION 29
C_1-RICH GAS
C_2-C_4
H_2 RICH GAS
HIGH PURITY H_2

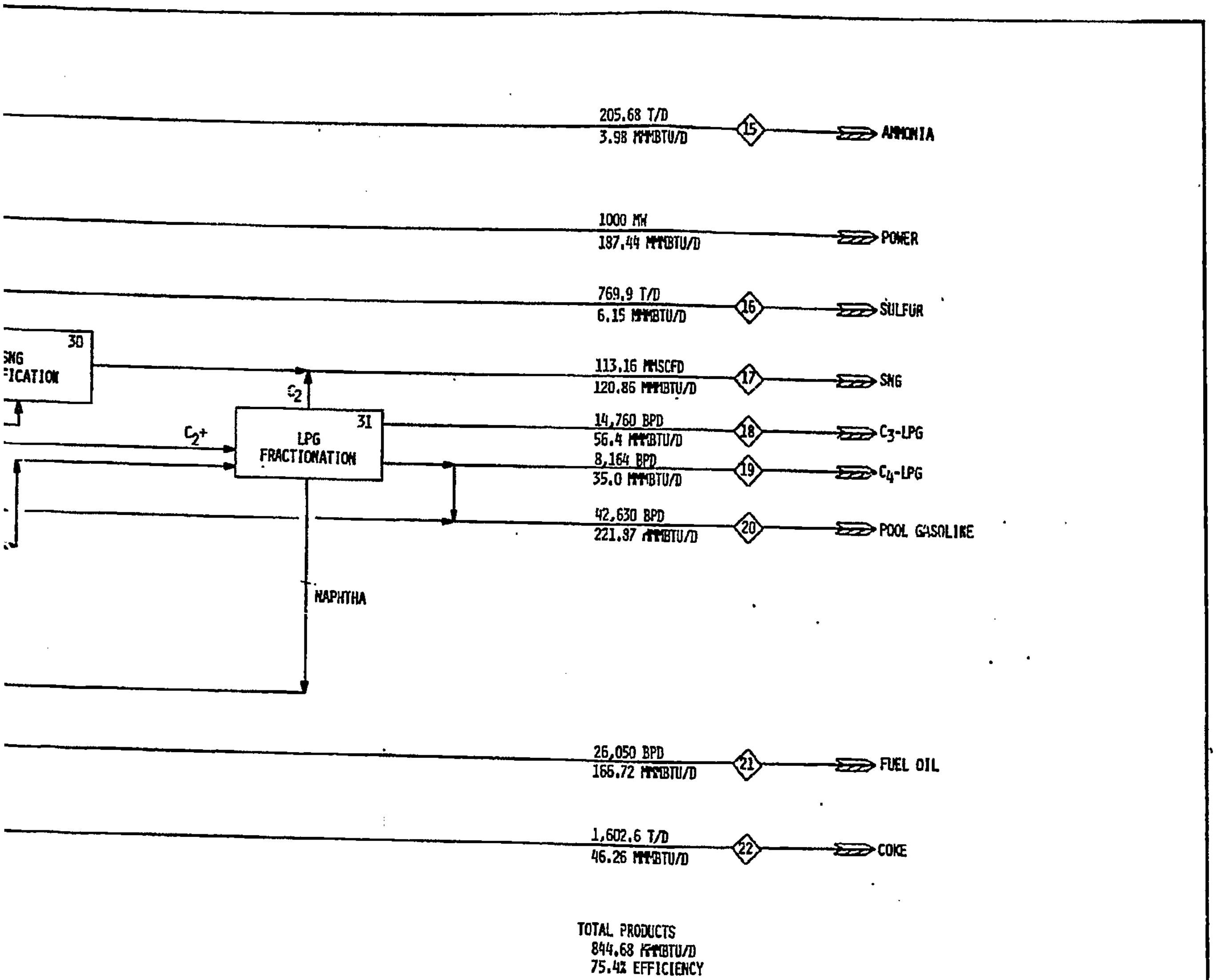

FIGURE 18-1

REV. NO.	DATE		REVISION	BY					
0			ISSUED FOR REPORT						

DEPARTMENT OF ENERGY - DIVISION OF COAL CONVERSION
POGO PLANT
BLOCK FLOW DIAGRAM
SOUTHERN APPALACHIAN REGION COAL

THE RALPH M. PARSONS COMPANY PASADENA, CALIFORNIA	JOB NO. 5435-4	DWG. NO. R-01-FS-2	REV. 0

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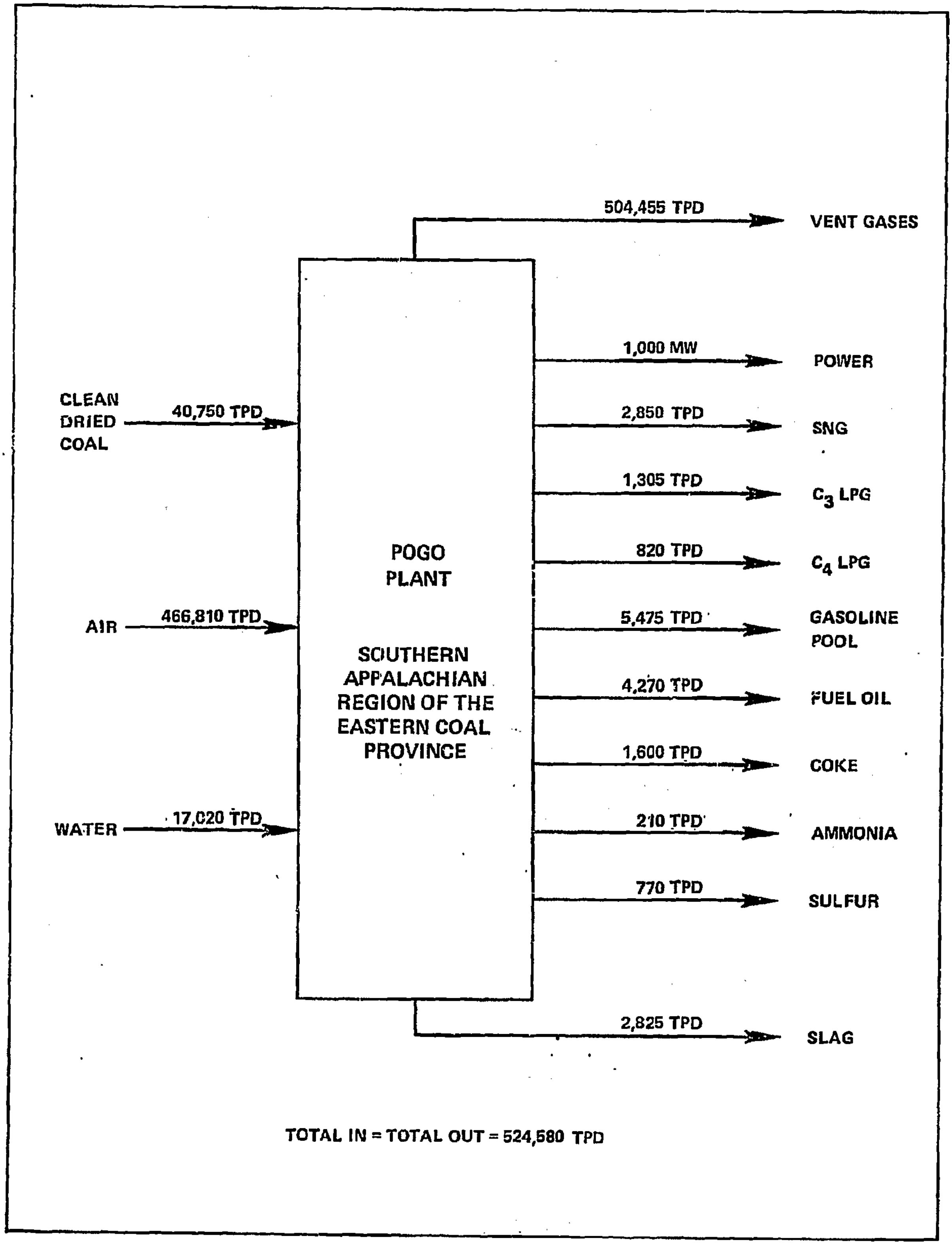

Figure 18-2 - Overall Material Balance — Process and Power Units

18.1.1 STRIP COAL MINE

A typical strip mine in this area requires the removal of 36 feet of waste or overburden to expose coal seams, which are typically 2 feet thick. Thirty-six million tons per year of overburden stripping produces one million tons per year of ROM coal. The overburden stripping operation, using 50-cubic yard electric shovels, is on a 20 shift per week basis. The mining of the actual coal is on a one shift per day, 5 days per week basis, using 6-cubic yard front-end loaders and transferring to the coal preparation conveyors with 85 ton bottom dump coal haulers.

In 5 years' time, an area of approximately 1400 acres would be stripped to produce 5 million tons of coal in the operation of each of the eight strip mines. The overburden and top soil are replaced and seeded as mining advances.

18.1.2 UNDERGROUND MINE

The underground mines incorporate current safety requirements, mining machinery, and methods. Mine depth will average close to 2000 feet with an approximate 4-foot coal seam thickness. It would have a shale roof and sandstone floor. Methane is a problem in underground mines in this area.

Each mine produces 2 million tons of ROM coal per year. One production shaft and one service shaft are provided for the 20-year life of the mine, plus four 4-inch diameter vent shafts during each year of operation. Seams will be partially degassed by drilling vent shafts ahead and drilling horizontal radial holes from the bottom of the shaft into the seam. Continuous miners, shuttle cars, and main haulage belt conveyors will be utilized.

There would be two 8-hour production shifts per day and 250 working days per year as is traditional in the eastern area. The mining rate, at a 45% coal recovery, would amount to nearly a square mile of mine area per year including pillars. Total ROM output is approximately 54,000 TPD for the last 15 years to supply the total requirement from nine underground mines.

18.2 COAL PREPARATION, STORAGE, GRINDING, AND DRYING

Coal preparation consists of a wet jigging, screening, wet cycloning, and centrifuge beneficiation system similar to that designed for the base case. Ash and rubble contents are reduced to produce a relatively uniform and clean coal at a high recovery rate.

The storage, grinding, and drying area uses the same cage mill grinding and fluidized bed/steam tube dryer system specified for the base case. Coal mesh size is also identical: 1/8-inch x 0 for the SRC process, 70% minus 200 mesh for pyrolyzer feed, and minus 20 mesh for the fuel gas gasification.

18.3 FLASH PYROLYSIS

The analyses of process feed coal to be used as the basis for the SRC unit and pyrolysis unit designs are shown in Table 18-1. The composition of the coal feed to fuel gas generation is also given in Table 18-1. The Southern Appalachia location feed analyses are based on the arithmetic average of analyses of Jefferson, Tuscaloosa, and Walker County coals.[25]

Flash pyrolysis yields for Southern Appalachia coal are based on the yield pattern developed for the base case. The design data base for flash pyrolysis yields from Illinois No. 6 coal was described in Section 15. This method was applied in lieu of experimental pyrolysis data for Southern Appalachia coal.

The details of the design procedure applied for this alternate case are:

(1) The yields and proportions of volatile products from flash pyrolysis of Southern Appalachia coal were derived from the base case. Flash pyrolysis of Illinois No. 6 coal yields total volatile product, including gas, water, and tar, which is 88 wt% of the volatile material (VM) of the coal. Likewise, total yield of volatile product from flash pyrolysis of Southern Appalachia coal is 88 wt% of the VM of the coal.

(2) Product compositions and properties from the base case were used as guidelines to compositions for pyrolysis products from Southern Appalachia coal. Adjustments of the product elemental compositions were made to account for differences in the elemental composition of the Alternate Case 1 coal. This resulted in a lower sulfur and oxygen content in all flash pyrolysis products from Southern Appalachia coal, compared to the base case pyrolysis products.

    The projected yields and elemental balances for pressurized flash pyrolysis for Southern Appalachia coal are given in Table 18-2.

(3) The yields from flash pyrolysis of slurry feeds from Southern Appalachia coal were estimated by applying coking correlations to the liquids and calcining the solid portions of the feed, as described previously. Table 18-3 summarizes the vacuum bottoms slurry conversion for the Southern Appalachia plant.

This procedure for estimating yields from pressurized flash pyrolysis of Southern Appalachia coal is considered logical and satisfactory. However, the effect of uncertainty on pyrolysis yields is greater for this alternative case than it is for the base case. The weight fraction of slurry feed in the total feed to the pyrolyzer is considerably greater for this alternative than for the base case. The validity of the projected yields, therefore, depends considerably on the procedure used for estimating pyrolysis yields from slurries, which, in turn, is based on limited information. Development of specific data from actual pyrolysis experiments using specific Southern Appalachia coal is recommended prior to final plant design.

Table 18-1 - POGO Plant Alternate Case 1
Southern Appalachia Coal Analyses
(Alabama-Warrior Field)

Analyses	Coal to Process	Coal to Fuel Gas Generation
Proximate Analysis (Wt%)		
Moisture	2.7	2.7
Ash	6.3	8.0
Volatile Matter	32.4	31.8
Fixed Carbon	58.6	57.5
Total	100.00	100.00
Higher Heating Value Btu/lb	13,841	13,590
Ultimate Analysis (Wt%)		
Carbon	77.2	75.7
Hydrogen	4.8	4.8
Nitrogen	1.6	1.6
Sulfur	1.6	1.6
Oxygen	5.8	5.6
Moisture	2.7	2.7
Ash	6.3	8.0
Total	100.0	100.0

Table 18-2 - POGO Plant Alternate Case 1 - Southern Appalachia Coal Pressurized Pyrolysis Yields - Coal Feed

Basis: 10,000 Tons Per Day Feed Coal (2.7% Moisture)
All Figures are Tons Per Day

Feed/Yield	Composition						
	C	H	N	S	O	Ash	Total
Stream							
Feed Coal	7,720.00	480.00	160.00	160.00	580.00	630.00	9,730.0
Water in Coal	-	30.21	-	-	239.79	-	270.0
Total	7,720.00	510.21	160.00	160.00	819.79	630.00	10,000.0
Products							
H_2	-	21.45	-	-	-	-	21.4
CH_4	241.88	81.20	-	-	-	-	323.1
C_2H_4	28.82	4.84	-	-	-	-	33.7
C_2H_6	45.45	11.44	-	-	-	-	56.9
C_3H_6	39.66	6.66	-	-	-	-	46.3
C_3H_8	36.50	8.17	-	-	-	-	44.7
C_4H_{10}	13.40	2.81	-	-	-	-	16.2
CO	23.64	-	-	-	31.49	-	55.1
CO_2	52.65	-	-	-	140.30	-	192.9
N_2	-	-	18.48	-	-	-	18.5
H_2S	-	1.94	-	30.84	-	-	32.8
H_2O	-	42.90	-	-	340.48	-	383.4
Tar	1,680.00	152.00	21.98	14.26	111.76	-	1,980.0
Char	5,558.00	176.80	119.54	114.90	195.76	630.00	6,795.0
Total	7,720.00	510.21	160.00	160.00	819.79	630.00	10,000.0

Table 18-3 - POGO Plant Alternate Case 1
Southern Appalachia Coal Pressurized Flash
Pyrolysis Yields from Vacuum Bottoms
Slurry Feed

Products	Yield Wt%
H_2	0.09
CH_4	2.87
C_2H_4	0.13
C_2H_6	0.83
C_3H_6	0.33
C_3H_8	0.72
C_4H_{10}	0.20
CO	0.22
CO_2	0.68
N_2	0.49
NH_3	0.23
H_2S	0.29
H_2O	0.40
Tar	4.52
Char	88.00
Total	100.00

18.4 SRC DISSOLVING

It is not possible to predict the SRC yield structure of a given coal based only on proximate and ultimate analyses; therefore, a literature search was made for laboratory or pilot plant data for this coal. The results of this search indicated that no information is available at this time on the dissolving characteristics for this Southern Appalachia coal. Therefore, SRC laboratory data for experiments using a Northern Appalachian Region coal, having similar proximate and ultimate analyses and characteristics, were chosen as the basis for determining the necessary yields.[26,27] In addition, the effect of inorganic constituents, such as iron on the yield structure of various coals was used to determine yields for the Southern Appalachia region coal.[28,29]

The details of the calculation procedure used for this alternative are:

(1) The Northern Appalachian region coal yields were converted to a moisture and ash free basis and the % removal of oxygen, nitrogen, and sulfur were determined.

(2) These yields were applied to the Southern Appalachia region coal with allowances made for the differences in ultimate analysis and for the effect of the inorganic constituents, such as iron.

(3) Finally, an elemental balance was determined with elemental distribution in the liquid cuts following similar trends to those given in the literature. The resulting balance, after all adjustments were made, is given in Table 18-4.

This procedure is considered a practical way to proceed for the conceptual design in the absence of specific laboratory or pilot plant data for the feed coal. However, because of the speculative nature of these yields and the sensitivity of the entire POGO plant to the SRC yields, the yields for this alternative are much more uncertain than those of the base case. Experimentation is needed for a more accurate assessment.

18.5 STEAM AND POWER GENERATION

This unit is identical in type and size to that of the base case. It comprises gas turbines, heat recovery steam generators, and steam turbines in the combined cycle mode. The major equipment items will be equivalent in number to those of the base case. Since a slightly lower amount of power generation is required, some minor capital cost saving results in the auxiliary equipment items.

18.6 PRODUCTS

Total quantity of products produced in this alternate design is slightly greater than for the base case, approximately 3% on a Btu basis. Less SNG and sulfur are produced, but increased quantities of LPGs and gasoline are obtained.

Table 18-4 - POGO Plant Alternate Case 1, Southern Appalachia Coal, SRC Yields

Feed/Yield	Composition						
	C	H	N	S	O	Ash	Total
Input, TPD							
MF Coal	15,440	960	320	320	1,160	1,260	19,460
H_2O w/Coal		60			480		540
H_2		803					803
Total	15,440	1,823	320	320	1,640	1,260	20,803
Output, TPD							
C_1	224	74	-				298
C_2	442	111	-				553
C_3	665	148	-				813
C_4	887	185	-				1,072
CO_2	102	-	-		273.0		375
CO	76	-	-		101.0		177
H_2O	-	145	-		1,157.0		1,302
NH_3	-	26	121.0		-		147
H_2S	-	14	-	256.0	-		270
Light Oil	2,007	303	11.6	2.3	4.6		2,328.5
Light Distillate	2,440	254	20.4	4.0	7.6		2,726.0
Heavy Distillate	4,900	362	78.3	14.0	24.3		5,378.6
Vacuum Bottoms	2,632	146	45.7	8.7	16.5		2,848.9
Mineral Residue	1,065	55	43.0	35.0	56.0	1,260	2,514.0
Total	15,440	1,823	320.0	320.0	1,640.0	1,260	20,803.0

Composition	Light Oil IBP-400	Light Distillate 400-650	Heavy Distillate 650-1200	Vacuum Bottoms 1200+	Mineral Residue
C	86.19	89.50	91.10	92.39	42.36
H	13.01	9.32	6.73	5.13	2.19
N	0.50	0.75	1.46	1.60	1.71
S	0.10	0.15	0.26	0.30	1.39
O	0.20	0.28	0.45	0.58	2.23
Ash	-	-	-	-	50.21
Total	100.00	100.00	100.00	100.00	100.00
HHV, Btu/lb	20,594	18,782	17,400	16,586	7,403

Heat of Reaction = -142 Btu/lb AR Coal

The approximate product slate for this alternative is:

Product	Quantity
Fuels	
SNG	113 MM SCFD
C_3-LPG	14,760 BPD
C_4-LPG	8,160 BPD
Gasoline	42,630 BPD
Fuel Oil	26,050 BPD
Power	1,000 MW
Byproducts	
Coke	1,600 TPD
Sulfur	770 TPD
Ammonia	210 TPD

Properties of these products would be similar to those of the base case as detailed in Section 7.

18.7 UTILITIES

Except for minor differences, utility requirements and facilities are similar to those for the base case. Table 18-5 summarizes utility sources and consumption.

18.8 ECONOMICS

The major economic factors covered in Section 14 were also determined for this alternate location. The fixed capital investment, except for the coal mines, was factored from the base case using unit by unit operating flows and conditions as a basis. The coal mines estimates were based on specific designs and equipment requirements.

18.8.1 FIXED CAPITAL INVESTMENT

The fixed capital investment, tabulated by cost centers, is:

Cost Center	$000
Coal Mine	555
Coal Preparation	70
Process Plant	1,370
Power Plant	447
Offsites	155
Total FCI	2,594

18.8.2 OPERATING COSTS

The annual operating costs estimated for this alternative are:

Cost Center	$000/yr
Coal Mine	240.0
Coal Preparation	5.5
Process Plant	114.9
Power Plant	31.2
Offsites	10.9
Total Operating Cost	402.5

The coal mine operating costs are based on equipment operating and labor costs for the specific mine designs. The operation of strip and underground mines during the first 5 years of the project and the operation of all underground mines during the last 15 years, are presented as average figures over the 20-year project life.

Table 18-6 presents the manpower summary for the initial 5 years of the project; total personnel requirement is 4,883. During the remaining 15 years of project duration, an additional 620 people would be required for underground mining operations. Table 18-7 summarizes coal mine manpower needs for years 1 to 5, and 6 to 20. The total personnel required for the complex would be 5,500.

18.8.3 REQUIRED ANNUAL REVENUE

The required annual revenue to obtain a 12% annual discounted cash flow, based on a 65/35 ratio of debt-to-equity financing, at an interest rate of 9%, is tabulated below, with corresponding product sales value and value-to-cost ratios:

Required Annual Revenue	$950.5 MM/yr
Possible Annual Sales Value	$974.2 MM/yr
Value/Cost Ratio	1.02

The Value/Cost Ratio is obtained by dividing the Required Annual Revenue by the possible Annual Sales Value.

The sales value is based on the same product sales values used in the base case economics, Table 14-23, Section 14.

The predicted required average fob product fuel and bus bar power selling prices, after taking credit for coke, sulfur, and ammonia byproducts, are shown in Figure 18-3. Typical price relationships are tabulated below:

Table 18-5 - POGO Plant Alternate Case 1
Southern Appalachia Coal
Utility Summary

Unit		Power (kW)	Steam (lb/hr)				Fuel Gas (MM Btu/hr)	Cooling Water (gpm)	Quench Water (gpm)	Sour Water (gpm)	Condensate Boiler Feedwater (gpm)
Number	Description		1,250 psig	600 psig	150 psig	50 psig					
08	Coal mine	(13,000)		-	-	-	-	-	-	-	-
09	Coal preparation	(10,000)	-	-	-	-	-	-	-	-	-
10	Coal storage, grinding, and drying	(14,100)	-	-	(378,500)	-	-	-	-	-	-
11	Oxygen plant	(91,434)	-	(1,024,884)	-	-	-	(120,589)	-	-	2,048
12	SRC dissolving	(51,900) 14,100	-	297,900	-	15,500	(730)	(3,370)	-	180	(650)
13	SRC atmospheric distillation	(1,296)	-	-	-	(60,605) 15,849	(718)	-	-	120	(30)
14	SRC vacuum distillation	(1,808)	-	-	(23,793) 417,606	(136,474) 135,808	(504)	(3,331)	-	609	(1,142)
15	Pyrolysis	(5,702)	163,104	-	24,103	25,485	-	(682)	-	} 43	(441)
16	Pyrolysis atmospheric distillation	(139)	-	-	(693)	-	-	-	-		-
17	Sour gas compression	(2,900)	-	-	-	-	-	-	-	-	-
18	Process gasification	(942)	267,944	-	-	-	-	-	(764)	-	(555)
19	Shift conversion	(901)	-	(311,176)	-	-	-	(4,917)	1,302	-	(1,542)
20	Selective acid gas removal	(10,459)	-	-	(97,763)	-	-	(12,640)	-	-	(69) 197
21	Heavy liquids hydrotreating	(22,875)	-	-	(4,538)	-	(292)	-	-	269	(185)
22	Thermal cracking	(2,595)	-	-	(8,649)	59,678	(389)	-	-	17	(121)
23	Coking	(1,307)	-	-	(48,782)	-	(209)	(418)	-	-	(87)
24	Naphtha hydrotreating	(6,799)	-	-	-	92,800	(45)	(1,873)	-	59	(191)
25	Naphtha reformer	(22,423)	-	-	-	-	(284)	(990)	-	-	-
26	Olefinic gas/acid gas removal	(440)	-	-	(1,750)	(36,800)	-	(140)	-	-	125
27	Saturate gas/acid gas removal	(2,600)	-	-	(8,700)	(211,100)	-	-	-	-	440
28	Olefin recovery and polymerization	(353)	(34,360)	(3,092)	(7,950)	(3,003)	(22)	(2,252)	-	-	88
29	Hydrogen recovery and purification	(98)	-	(14,703)	-	-	-	(784)	-	-	48
30	SNG purification	(31,680)	-	95,009	-	13,970	-	(5,144)	-	-	(234) 100
31	LPG fractionation	(4,260)	-	(416,500)	-	-	-	(53,830)	-	-	830
32	Sulfur plant	(3,735)	-	-	112,095	56,790	(43)	(1,193)	-	-	(360)
33	Fuel gas generation	(6,400)	811,800	72,700	-	-	15,000	(3,070)	(610)	706	(2,410)
34	Fuel gas/acid gas removal	(13,120)	-	-	(79,376)	-	-	(17,671)	-	-	(25) 156
35	Steam and power generation	(27,150) 1,370,796	(5,277,100) 4,068,612	(357,112) 1,838,888	106,690	250,422	(11,764)	(398,700)	-	-	(2,550)
36	Process waste water treating	(1,980)	-	(177,030)	-	(202,320)	-	(14,085)	-	(2,003)	756
37	Shops and buildings	(10,600)	-	-	-	-	-	-	-	-	-
38	Firewater system	-	-	-	-	-	-	-	-	-	-
39	Potable and sanitary water system	(50)	-	-	-	-	-	-	-	-	-
40	Raw water system	(19,300)	-	-	-	-	-	645,679	72	-	5,804
41	Effluent water treating	(200)	-	-	-	-	-	-	-	-	-
42	Product storage	(1,500)	-	-	-	(14,000)	-	-	-	-	-
43	Flare system	(50)	-	-	-	-	-	-	-	-	-
44	Site preparation, roads, and railroads	(500)	-	-	-	-	-	-	-	-	-
45	Instrument and plant air	(300)	-	-	-	-	-	-	-	-	-
	Total produced	1,384,896	5,311,460	2,304,497	660,494	666,302	15,000	645,679	1,374	2,003	10,592
	Total consumed	384,896	5,311,460	2,304,497	660,494	666,302	15,000	645,679	1,374	2,003	10,592
	Net for sale	1,000,000									

NOTE: Quantities in parentheses indicate consumption.
Quantities without parentheses indicate production.

Table 18-6 - POGO Plant Alternate Case 1,
Southern Appalachia Coal,
Manpower Summary, Years 1 through 5

Area	Personnel			
	Operating	Maintenance	Administrative	Total
Administration			365	365
Coal Mine	2,594	696		3,290
Coal Preparation	30	20		50
Process Plant	316	522		868
Power Plant	141	57		198
Offsites	85	27		112
Total	3,166	1,352	365	4,883

Table 18-7 - POGO Plant Alternate Case 1,
Southern Appalachia Coal,
Coal Mine Manpower Summary

Mine Type	Personnel Required			
	Single Mine Unit		Total	
	Operating	Maintenance	Operating	Maintenance
Years 1 through 5				
8 Strip Mines at 140 people each	113	27	904	216
5 Underground Mines at 434 people each	338	96	1,690	480
			2,594	696
Years 6 through 20				
9 Underground Mines at 434 people each			3,042	864
Total			3,906	

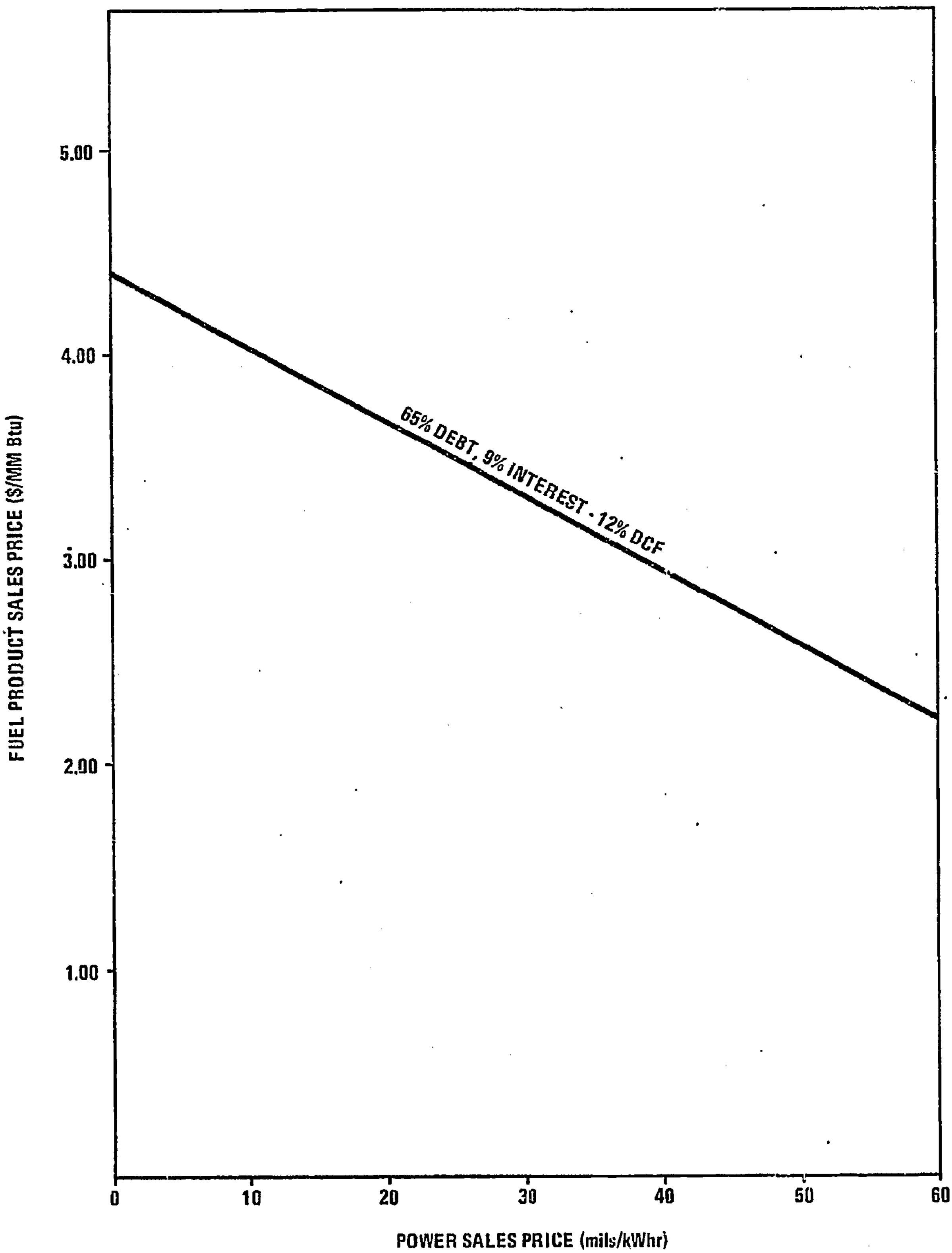

Figure 18-3 - Required Product Selling Price

Electricity Bus Bar Selling Price (in mils/kWh)	Average Fuel fob Selling Price	
	$MM/ Btu	$/Bbl (6 MM Btu/Bbl)
20	3.65	21.90
30	3.30	19.80
40	2.90	7.40

18.9 SUMMARY AND CONCLUSIONS

A POGO plant with captive mines in the southern extremity of the Appalachian region is indicated to have high overall fixed capital investment and production costs. The coal beneficiation, process, power, and offsite facilities capital and production costs are comparable to--and possibly slightly lower than--those for the base case. The coal field conditions and the mining methods required for this region--thin seams, high overburden-to-coal ratio, small strip-mine operations, and underground mines--result in higher coal costs than in areas having thicker coal seams, lower overburden-to-coal ratios, and more continuous areas amenable to mass production-type mining.

The process work on this alternate is for a conceptual plant. Directly applicable experimental work is not available. The extrapolations made to affect this alternate's design are deemed basically sound, but, at best, can result in only an approximation. Laboratory and pilot work, using the coal type to be processed, on pressurized flash pyrolysis, SRC hydroliquefaction, heavy liquids hydrotreating, thermal cracking, coking, and two-stage pressurized entrainment-type gasification, would furnish the basis for a more accurate design.