30-Ton-Per-Hour Coal-Hydrogenation Plant

Another study covered the economics of coal hydrogenation in a small plant producing both chemicals and fuels. With rising demands for the chemicals that can be produced by coal hydrogenation, it appears that operation of a small plant producing a maximum of those chemicals might be economically feasible. By holding the plant size to a single stall processing 30 tons per hour of moisture- and ash-free coal, incorporating all advancements in plant design, employing natural gas for hydrogen production, and utilizing purchased power for part of the electric power requirements, it was found that the capital requirements and return on investment are within current acceptable limits for utilities and other basic industries. The rate of return is, however, lower than that currently enjoyed by the petroleum and chemical industries.

The material balance for this study was based on coal from Western Kentucky (No. 11 seam), because complete data were available from Demonstration-Plant operations. Coal from Midwestern and Central States probably would give similar results.

Figure 22 is a flow sheet of the proposed plant, and table 13 summarizes the capital investment, including interest during construction, lump-sum royalty payments, and working capital.

Table 14 summarizes estimated operating costs on a calendar-day basis. Coal is included at $3.75 per ton delivered, natural gas at 30 cents per 1,000 cubic feet, and electric power at 6.3 mills per kw.-hr. Personnel requirements were estimated by extrapolating from the manpower requirements at the Demonstration Plant. Product distribution, throughputs, cost data, and proposed methods of operation were also based on Demonstration-Plant experience.

TABLE 13. - Breakdown of estimated capital requirements for 30-ton-per-hour coal-hydrogenation plant

Coking, pasting-oil unit	$ 1,306,000
Liquid-phase hydrogenation	7,251,000
Vapor-phase hydrogenation	2,768,000
Hydrocarbon-steam cracking	6,510,000
Liquid-phase distillation	520,000
Paste-preparation and injection	744,000
Vapor-phase distillation	435,000
Tank storage and pumping	1,305,000
Platforming and extraction	1,750,000
Gas recovery	1,200,000
Coal preparation	908,000
Phenol recovery	596,000
General plant facilities	2,800,000
General utilities	2,170,000
	30,263,000
Steam-power plant	2,600,000
Total construction cost	32,863,000
Interest during construction	1,035,000
Royalties	250,000
Total fixed investment	34,148,000
Working capital	4,033,000
Total	$38,181,000

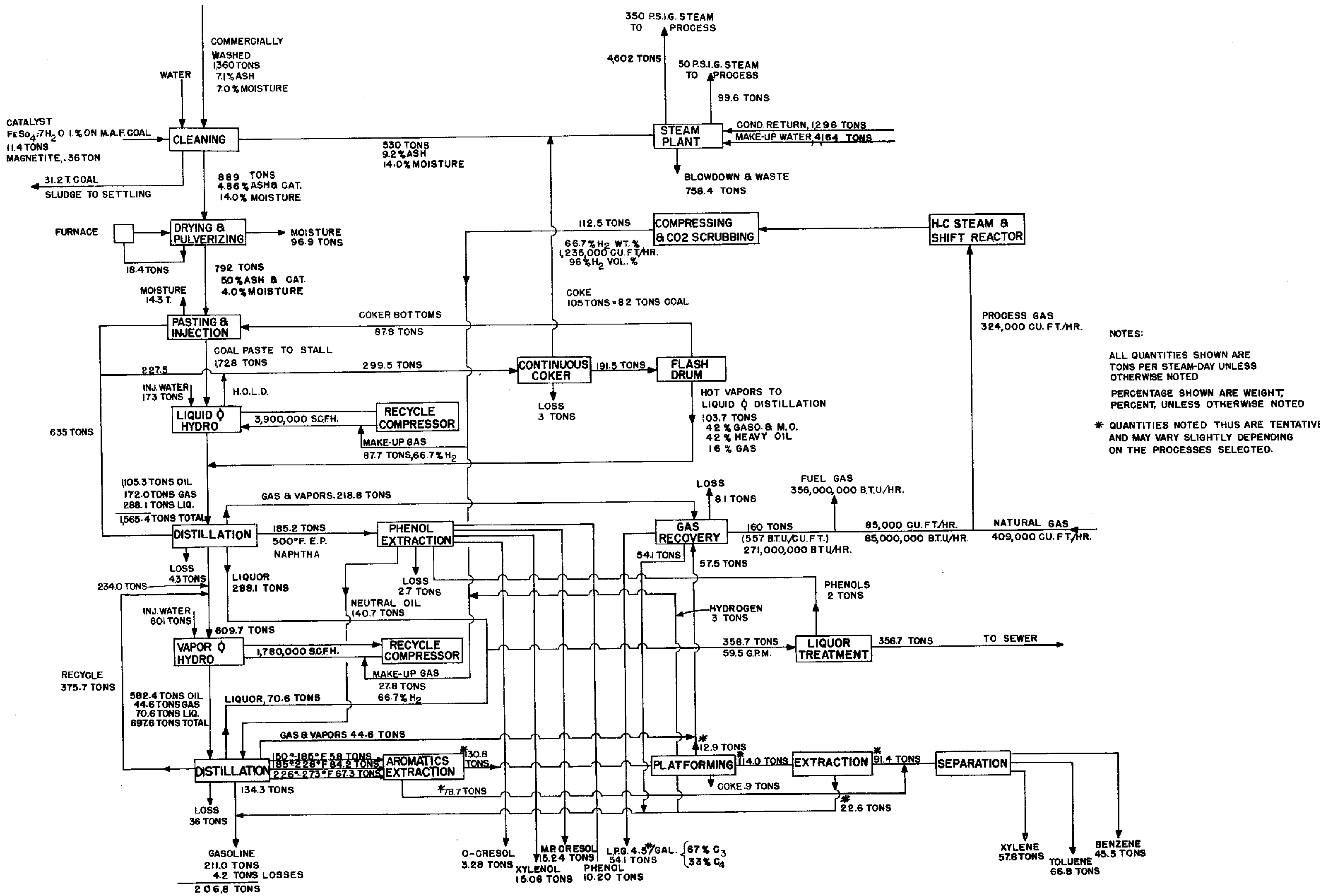

Figure 22. - Material balance - flow diagram, 30-ton-per-hour coal-hydrogenation plant.

TABLE 14. - Estimated operating-cost summary for 30-ton-per-hour coal-hydrogenation plant

	Dollars per calendar day
Raw material:	
Coal 1229.5 tons at $3.75/ton	$ 4,611
Catalyst $1,196/day	1,196
Utilities purchased:	
Natural gas 8.86 million std. cu. ft./day x $0.30/1,000 cu. ft.	2,658
Electric power, 8,137 kw. x 24 x $0.0063/kw.	1,230
Sanitary water	21
Total raw materials and utilities	9,716
Operating labor	2,235
Maintenance labor	1,499
Indirect labor	1,452
Payroll overheads at 18.5 percent	960
Total	6,146
Materials and other operating expenses:	
Process units	1,189
General plant	1,529
Total	2,718
Research and development - 1 percent of product value	373
Fixed costs:	
Taxes and insurance at 1 percent	900
Depreciation (25 year straight line)	3,742
Total fixed costs	4,642
Total operating cost	$23,595

Table 15 indicates the calendar-day production and value of products. The unit prices shown are f.o.b. plant.

A statement of estimated capital, income, pay-out time, and cash position of the plant is tabulated in table 16, both for first-year and for average-year operations. The choice of a 50-50 split of equity-debt capital was based on the recommendation of Ebasco Services, Inc., for coal-hydrogenation plants.

TABLE 15. - Product distribution and value for 30-ton-per-hour coal-hydrogenation plant

Production		Unit price	Calendar-day value
Phenol	18,411 lb./day at	$0.17/lb. =	$ 3,129
o-Cresol	5,918 lb./day at	.17/lb. =	1,006
m-p-Cresol	27,534 lb./day at	.17/lb. =	4,680
Xylenol	27,397 lb./day at	.17/lb. =	4,657
Benzene	11,233 gal./day at	.40/gal.=	4,493
Toluene	16,712 gal./day at	.35/gal.=	5,849
Xylene	14,446 gal./day at	.35/gal.=	5,056
Gasoline	60,548 gal./day at	.12/gal.=	7,265
LP-gas	21,698 gal./day at	.05/gal.=	1,084
Total			$37,219

TABLE 16. - Statement of estimated capital, income, pay-out and cash for 30-ton-per-hour coal-hydrogenation plant

Estimate of capital:		
Total capital required		$38,181,000
Assumed capitalization	50 percent debt	19,090,500
	50 percent equity	19,090,500

	First year of operation Dollars per calendar day	Average year of operation Dollars per calendar day
Estimate of income:		
Total sales	$37,219	$37,219
Total operating cost	23,595	23,595
Gross profit on sales	13,624	13,624
Interest on debt at 4 percent	2,092	1,088
Net income before income tax	11,532	12,536
Federal and State income tax at 55 percent	6,343	6,895
Net income	5,189	5,641
Net income, percent of equity	9.9	10.78
Estimate of cash position:		
Net income as above	5,189	5,641
Add: Depreciation	3,742	3,742
Total	8,931	9,383
Deduct: Debt retirement (25-year basis)	2,092	2,092
Balance available for replacements and dividends on equity capital	6,849	7,291
Pay-out (average year of operation):		
Gross profit on sales		13,624
Add: Depreciation		3,742
		$17,366
Pay-out before taxes		5.4 years
Pay-out after taxes		9.97 years

10,000-Barrel-Per-Day Gas-Synthesis Plant

Considerable work has been done on the cost estimate for a 10,000-barrel-per-day gas-synthesis plant. The process design has been completed and was based on use of 14,000,000 cu. ft. per hour of CO plus hydrogen to the synthesis reactors. This resulted in an output of 12,142 barrels per operating day or 11,000 barrels per calendar day. The Gas-Synthesis Process Subcommittee of the National Petroleum Council has reviewed the process design and, after certain corrections had been made, has approved the design as a satisfactory basis for completing the cost estimate that it has undertaken.

The cost estimate has not been completed; the discussion will, therefore, be limited to the features, material balances, and flow sheets of the process design.

General Description of Process

The gas-synthesis plant described herein will produce 12,141 barrels per operating day of product, which at 90-percent stream factor amounts to about 11,000 barrels per calendar day.

Products, barrels per operating day:

LP-gas	635
Gasoline	9,612
Fuel oil	1,894
Total	12,141

In addition, 211 tons of sulfur will be produced per operating day.

The LP-gas has the following composition:

	Mol percent
CO_2	0.3
Ethane	2.5
Propane	92.1
Propylene	4.6
Butane	.5
Total	100.0

The fuel oil is a distillate-cycle gas oil from the catalytic cracking unit, having a gravity of about 37° A.P.I., a carbon residue of less than 1.0 weight percent, and a viscosity of about 35 SUS at 100° F. It will be suitable as a cutter for Bunker "C" blending or may be sold directly as a good grade fuel. As it will be vanadium-free, it may be particularly attractive as a fuel for oil-fired gas turbines.

Gasoline composition, in barrels per operating day:

Butane	658
Polymer gasoline	1,836
Reformed gasoline	5,563
Catalytic cracked gasoline	1,555
Total	9,612

It is estimated that with 0.6 cc. of tetraethyl lead per gallon, 37.7 percent of this gasoline can be sold as 91.5 C.F.R.-R. Premium gasoline and the remainder as 85 C.F.R.-R Regular-Grade gasoline. These are the current ratio and octanes of gasoline being sold in the area where the plant is tentatively located.

The plant is designed to process a mixture of Nos. 9 and 11 Western Kentucky coal (Union County) having the following properties:

Raw coal (run-of-mine)			Ultimate analysis, dry basis weight percent	
Ash	weight percent	14.5	C	68.02
Moisture	do.	7.0	H	4.56
Combustible	do.	78.5	O_2	6.23
Heating-value gross (m.a.f.)	B.t.u./lb.	14,600	N_2	1.44
			S	4.13
			Ash	15.60
				100.00

The feed, products, and more important streams of the plant are as follows:

	Tons per operating day
Run-of-mine coal consumed in process	6,427
Run-of-mine coal used for fuel	1/ 1,342
Total coal required	7,769
Oxygen to coal gasifier (95 percent pure) (4,676,000 std. cu. ft./hr.)	4,702
Process steam to gasifier (172,900 lb./hr.)	2,085
Raw synthesis gas produced (dry) (16,400,000 std. cu. ft./hr.)	10,584
Sulfur recovered from H_2S in raw synthesis gas	211

1/ This figure is only tentative. It depends on final utility balance, which has not been completed in detail.

Purified synthesis gas to synthesis section:

	Std. cu. ft./hr.	Mol-percent	Lb. per hour	Tons per operating day
CO	8,210,320	56.8	606,567	7,279
H_2	5,741,890	39.7	30,300	364
CO_2	71,260	.5	8,272	99
N_2	287,030	2.0	21,204	254
CH_4	144,500	1.0	6,101	73
	14,455,000	100.0	672,444	8,069

Synthesis Products:

	Lb. per hour	Barrels per operating day
CO_2 vented to atmosphere	406,852	
Water and water sol. chemicals (recycled to gasifier)	42,930	
Fuel gas (used in processing)	89,219	
Burned coke, water and loss	5,323	
LP-gas (propane)	4,711	636
Gasoline (cat.-cracked)	17,185	1,555
Gasoline (reformed)	58,059	5,563
Polymer gasoline	19,517	1,836
Butane	5,473	658
Fuel oil (catalytic cycle gas oil)	23,175	1,894
	672,444	12,142

Yield of liquid products per ton of coal (about 20 wt. percent) = 1.56 barrels
Oxygen (95 percent pure) required per barrel of product = 0.38 ton

Description of Process by Sections

The gas-synthesis process involves three separate basic steps, as follows:

1. Coal gasification, where the coal is converted by reaction with oxygen and steam to a synthesis gas consisting of a mixture of hydrogen and carbon monoxide.

2. The Fischer-Tropsch-synthesis step, where the hydrogen and carbon monoxide are catalytically reacted under moderate conditions of temperature and pressure to produce a mixture of hydrocarbons and oxygen compounds.

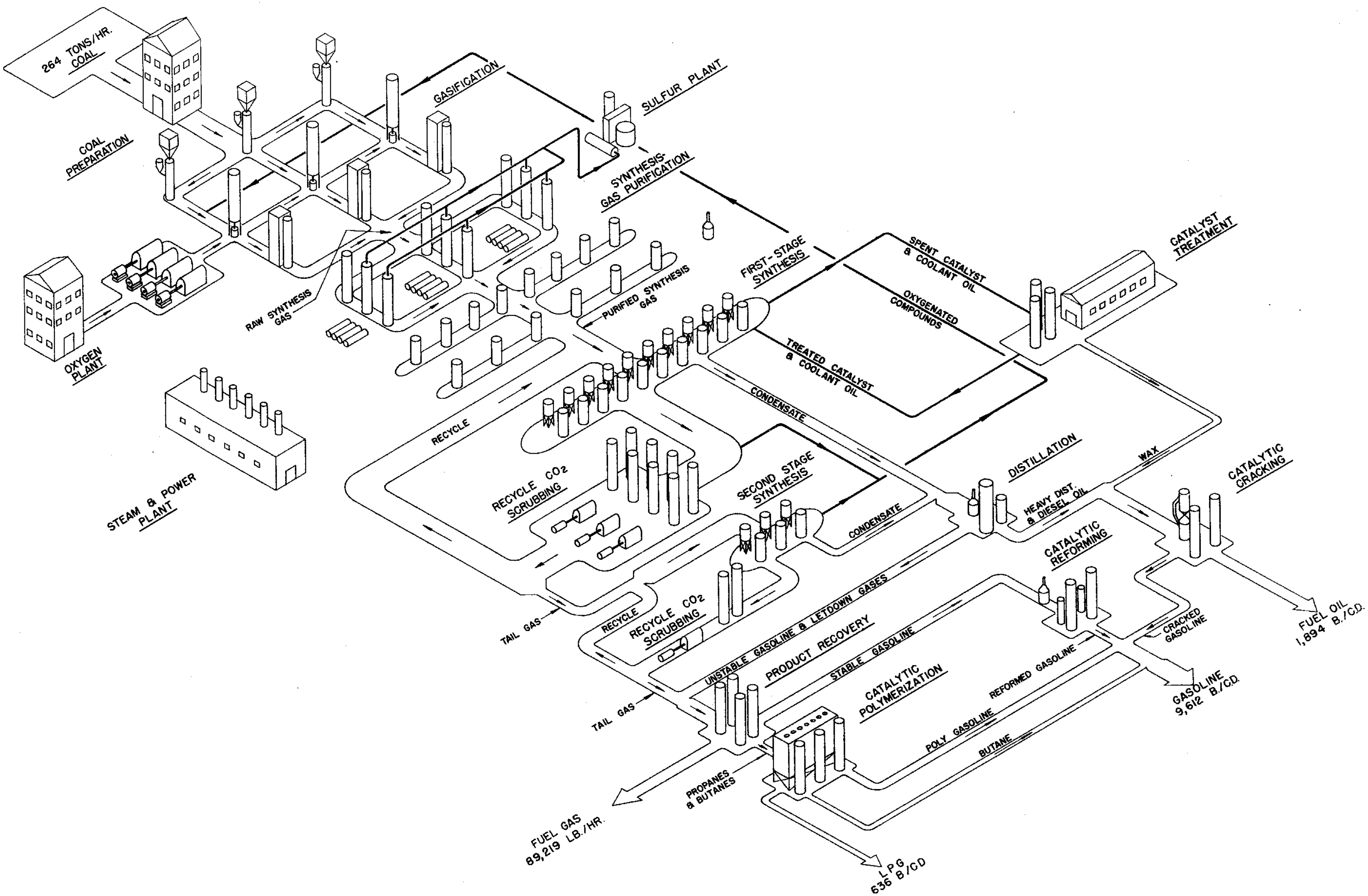

Figure 23. - Pictorial flow sheet, commercial gas-synthesis plant.

3. The finishing section, where the raw product is separated into various fractions, which are further processed and upgraded by conventional petroleum-refinery methods to produce finished merchantable products.

The processing sections required to accomplish these three basic steps are shown on the flow sheet (see fig. 23).

Coal Preparation, Feeding, and Gasification

In this design coal containing 7 percent moisture is fed to a hammer mill for reduction to 3/4-inch x 0 size and then to a drier where the moisture is reduced to 5 percent. A secondary hammer mill, combined with a screening operation, for separating oversized coal for recycle, reduces the coal to 100 percent -10-mesh.

The minus-10-mesh coal is fed by a lock-hopper system into a fluidized feeder. The fluidized coal is then transported with recycled synthesis gas into the top of the dispersed-phase gasifier. In the gasifier the coal reacts with superheated steam and the oxygen at 450 p.s.i.g.1/ The reaction temperature is such that the synthesis gas resulting from 95-percent conversion of the carbon in the coal leaves the gasifier at about 2,400° F. Fused ash flows from the bottom of the reactor into an accumulator, wherein it is disintegrated and cooled by a direct water quench.

The product gases leaving the reactor are cooled indirectly to within 50° F. of the gas dew point, the sensible heat of the gases being used to generate steam. The synthesis gas is further cooled and scrubbed to remove solids by direct contact with water, after which the gas flows to the purification section of the plant.

About 50 tons per hour of solid residue is removed from the slag accumulator and water scrubber as a hot-water slurry. These slurry streams are depressured into flash drums and fed to settling ponds, where the solids are removed and cooled.

The yields and operating conditions for the coal-gasification are as follows:

Operating conditions (predicted)

Gasifier outlet temperature	°F.	2,400
Gasifier pressure	p.s.i.g.	450
Moisture in coal to gasifier	percent	5.0
Ash in coal to gasifier (dry basis)	do.	15.6
Carbon conversion	do.	95
Steam preheat	°F.	1,000
Ratio, cu. ft. 100 percent oxygen/lb. dry coal		8.9
Ratio, pounds process steam/lb. dry coal		0.35
Ratio, hydrogen to CO in product gas		0.7
Ratio, std. cu. ft. of CO plus hydrogen/lb. dry coal		28.5

Feed to gasifier (estimated)

Coal	ton/hr.	262.4
Oxygen (95 percent pure)	std. cu. ft./hr.	4,676,000
Steam	lb./hr.	173,721
Water plus chemicals recycled from synthesis section (5,642 lb./hr. chemicals)	do.	42,930

1/ In addition to the coal, oxygenated compounds from the aqueous condensate produced in synthesis operation are burned in the gasifier.

Products from gasifier

Raw synthesis-gas product (dry)	std. cu. ft./hr.	16,400,000

Analysis of raw gas

	Volume, percent
H_2	34.9
CO	51.1
CO_2	9.5
N_2	2.0
H_2S	1.5
CH_4	1.0
	100.0

Oxygen Plant

No detailed oxygen-plant design was made. It was proposed that the capital and operating cost for this plant be estimated from vendor's data as a conventional utility.

Oxygen to gasifier

Oxygen purity	percent	95
Pure oxygen rate	std. cu. ft./hr.	4,442,000
Oxygen stream (95 percent purity)	ton/hr.	4,702
Oxygen pressure at coal gasifier	p.s.i.g.	500
Oxygen temperature at coal gasifier	$^{\circ}$F.	240
Gasifier pressure	p.s.i.g.	450

About 508,000 standard cubic feet of byproduct nitrogen from the oxygen plant is used to reactivate the charcoal in the gas-purification section, and about 50,000 standard cubic feet of nitrogen is required as coal-carrier gas in starting up the gasifiers before raw synthesis gas is produced.

Five 1,000-ton-per-day oxygen plants are proposed to satisfy the above oxygen requirement.

Purification of Synthesis Gas

In addition to removal of dust and fly ash from the raw synthesis gas after coal gasification it is necessary to remove sulfur compounds to avoid poisoning the synthesis catalyst. It is also necessary to remove carbon dioxide from the raw synthesis gas to prevent rapid deactivation of the catalyst. The raw synthesis gas contains 1.5 volume percent H_2S, and 9.5 volume percent CO_2. Purification is accomplished in three steps. In the first step CO_2 and most of the H_2S are removed from the gas by conventional diethanolamine absorption. This plant was designed by the Girdler Corp. Specifications were set up with 1.6 grains of H_2S per 100 cubic feet and 0.5 percent of CO_2 in the scrubbed gas. The specification on the carbon dioxide was arbitrarily set. Data on the Demonstration Plant indicate that 2 percent carbon dioxide in the scrubbed gas is tolerable and that the 0.5-percent limitation imposes an undue restriction on the design. The treated gas from the amine scrubbers passes through cold 100° F. iron oxide towers, where the remaining H_2S is removed. Final sulfur removal (mostly organic sulfur) is accomplished in activated-charcoal boxes.

The final purified gas contains less than 0.1 grain per 100 cubic feet of total sulfur and about 0.5 percent of carbon dioxide.

Recovery of Sulfur

The acid gas, which is stripped from the diethanolamine, consisting of about 83.5 volume percent CO_2 and 13 volume percent H_2S, is fed to a sulfur-recovery plant, where about 211 tons of elemental sulfur is produced by the modified Claus process. The design incorporated here is the Jelasco modification, estimated for the Bureau of Mines by the Chemical Construction Corp. As the H_2S in the feed gas is rather lean, part of the SO_2 is produced by burning a portion of the sulfur product with a controlled amount of air. The carbon dioxide passes through unreacted and is vented to the atmosphere.

Synthesis

The Synthesis Section is the heart of the plant. The chosen process, catalyst, and operating conditions used in this operation control the quantity and composition of the synthesis gas required to produce a certain amount of finished product of given quality.

Hydrogen and carbon monoxide are reacted over a catalyst to produce a mixture of hydrocarbons and oxygenated compounds of various molecular weights, with carbon dioxide and water as byproducts.

The reaction is highly exothermic and liberates about 6,200 B.t.u. per pound of C_3 + hydrocarbons and oxygenated compounds produced; as the reaction is very sensitive to temperature, it is necessary to remove the heat of reaction as rapidly as it is evolved. Excessive temperature results in high yields of methane and correspondingly low yields of the desired liquid products whereas, with too low reaction temperatures, the reactions become too slow and the product too heavy. The speed of the reactions and quality of product are also affected profoundly by the choice of catalyst, operating pressure, and composition, particularly the H_2-CO ratio of the synthesis-gas feed. The catalyst life is affected by its inherent physical and chemical properties, its manufacture, and pretreatment, as well as by the atmosphere surrounding it in the course of the reaction. The catalyst may be permanently poisoned by such impurities as sulfur.

The process incorporated in this design is known as the "expanded-bed" system, wherein the catalyst bed, consisting of 6- to 20-mesh particles, is kept continuously agitated by upflowing coolant oil, which has been mixed with the synthesis-gas feed.

The coolant oil, unreacted gas, and synthesis product are separated after disengagement from the catalyst bed. The liquid product goes to the recovery and refining section, and the unreacted gas after removal of CO_2 is charged to the second-stage reactors. Recycling gas is used in both stages. The coolant oil is cooled in external waste-heat boilers and returned to the reactor.

The basic data for design of the synthesis section are shown as follows:

Pressure	p.s.i.g.	400
Maximum temperature	°F.	494-504
Bottom temperature	do.	469-479
Recycle ratio		1.25
Oil velocity	ft./sec.	0.30
H_2:CO ratio, fresh feed		0.70
H_2:CO usage ratio		0.70
H_2 + CO conversion (fresh feed)		75
Space velocity (fresh feed), V/H/U		900
Number stages		2
CO_2 removed from fresh feed		To 5 percent CO_2
CO_2 removed from recycle		To 5 percent CO_2
CO_2 removed from interstage		To 5 percent CO_2

Yields, gm./m.^{3} (H_2 + CO) conversion:

Gas (C_1 and C_2)	25.0
Liquid (C_3 and heavier)	175.7
Chemicals	7.3
Total	208.0

Composition of liquid:

Gasoline and LP-gas	weight percent	58.5
Diesel	do.	13.5
Fuel oil	do.	17.0
Wax	do.	11.0
Total		100.0

The composition of the gas feed to the first stage and the over-all material balance for the synthesis section have been shown in the general description of the process.

The composition of the gas feed to the second-stage reactors is the same as that recycled to the first stage, as follows:

	Mol percent
CO	46.9
H_2	32.6
CO_2	.5
N_2	6.5
C_1	6.8
C_2	2.5
C_3+	4.2
	100.0

The fresh feed to the second-stage reactors amounts to 4,370,000 standard cubic feet per hour.

Ten 11-foot, inside-diameter by 32-foot reactors are provided for the first stage, and three 10-foot, inside-diameter by 37-foot reactors for the second stage. Each reactor holds about 120 tons of catalyst. The coolant-oil rate for each reactor is about 12,000 gallons per minute.

In the synthesis reaction is produced a substantial amount of oxygenated compounds (alcohols, acids, esters, and ketones) of varying molecular weights. Part of these are soluble in the byproduct water and the remainder in the hydrocarbon fractions, causing both streams to be corrosive and to have a highly objectionable odor. These oxygenated compounds, particularly those in the water stream, could be separated and sold as such, if market conditions warrant the expenditure for separation facilities. The first plant probably would be able to make a profit from extraction of these chemicals; however, as the output from subsequent plants would flood the market, chemical-recovery facilities were not considered. In this design all of the gasoline and heavier hydrocarbons are reformed or cracked catalytically, whereby the oxygenated compounds are converted to hydrocarbons. The water fraction, containing the water-soluble chemicals, is recycled to the coal gasifier.

The water-soluble chemicals produced in the synthesis step will amount to about 135,000 pounds per operating day. No estimate was made of the amount of oil-soluble chemicals formed.

Use of two reaction stages, with CO_2 separation from the feed and recycle to each stage, adds materially to the cost of the plant. It may be hoped that some day the same conversions and yields can be obtained in a single-stage operation without the expensive CO_2-removal steps.

Scrubbing Recycle CO_2

Pilot-plant data indicate that, with the reduced iron catalyst in the expanded-bed process, carbon dioxide must be removed from the gas recycled to the synthesis reactor to maintain catalyst life. A conventional amine-scrubbing system employing 30 weight percent, monoethanolamine solution is included in this design. The net tail gas and recycle gas from the first stage of synthesis (approximately 25 million std. cu. ft./hr.), containing 11.7 volume percent, carbon dioxide, is introduced into the monoethanolamine absorber operating at 360 p.s.i.g. The tail gas and recycle gas from the second stage of synthesis (approximately 7.6 million standard cubic feet per hour), containing 9.5 volume percent, carbon dioxide, is scrubbed in like manner. The tail gas from the second stage of synthesis, consisting of about 1.7 million standard cubic feet per hour of the purified gas, is sent to the light-ends recovery plant. The purified gas from both stages contains about 0.5 volume percent, carbon dioxide.

The CO_2 from the scurbbers, consisting of about 3 million standard cubic feet per hour from the first-stage and 0.7 million standard cubic feet per hour from the second-stage scrubber, is vented to the atmosphere.

The process design of this plant was checked by The Fluor Corp.

Synthesis Catalyst Plant

The 13 synthesis reactors will contain approximately 1,560 tons of catalyst (a fused reduced-iron catalyst of 6- to 20-mesh particle size), which has been promoted with both magnesium and potassium. It is made by electric-resistance fusion of a mixture of magnetite (Fe_3O_4), about 5 weight percent, magnesia (MgO), and less than 1 weight percent, potassium carbonate (K_2CO_3), in about the same manner as in the manufacture of synthetic ammonia catalyst. After fusion and crushing to the desired size, the catalyst must be reduced with hydrogen and "activated" with synthesis gas under controlled conditions.

The catalyst plant was designed to a capacity to revivify the charge every 30 days and completely rework the catalyst every 5 months.

Distillation and Recovery of Light Ends

The feed to the distillation is the condensed oil from synthesis reactors, which is fractionated into the following:

	Lb./hr.
Overhead gas and gasoline to light-ends recovery	58,624
Side-stream gas oil to catalytic cracking unit	19,010
Bottoms to catalytic cracking unit	23,106
Total	100,740

The light-ends recovery portion consists of a debutanizer and a refrigerated two-stage, fractionating-oil absorption system for recovering all butane and about 90 percent of the propane. A material balance on this unit follows:

Feed	Lb./hr.
Gas and gasoline from distillation	58,624
Tail gas from 2d-stage synthesis (after CO_2 removal)	108,320
Catalytic cracking unit off-gas	13,807
Reformer off-gas	452
Poly-plant off-gas	622
Total	181,825

Product	Lb./hr.
Debutanizer OH to poly-plant feed	30,764
Debutanized gasoline to reformer	56,950
Splitting still OH to catalytic reforming	2,863
Absorber tail gas to fuel	90,929
Loss	319
Total	181,825

Catalytic Reforming

The debutanized synthetic gasoline from the distillation and light-ends-recovery section is charged in a bauxite catalytic reforming unit operating at approximately 858° F. and 60 p.s.i.g. This is done primarily to isomerize and dehydrate the oxygenated compounds in the synthetic gasoline fraction to improve its corrosion and odor characteristics. At the same time, however, under these conditions, isomerization of the olefinic hydrocarbons occurs, as well as some polymerization and cracking, which further improve the quality of the gasoline. The material balance around the catalytic cracking unit follows:

Feed (from distillation section)	Lb./hr.	Approx. barrels per operating day
Debutanizer bottoms	56,950	
Splitting still OH	2,863	
Total	59,813	6,000

Product	Lb./hr.	
Tail gas to light-ends recovery	452	
Polymer to catalytic cracking	885	
Coke burned	417	
Stabilized reformed gasoline	58,059	5,563
Total	59,813	

Poly Plant

The C_3 and C_4 olefins, which are separated in the light-ends-recovery section, are polymerized at 1,000 p.s.i.g. in a conventional U.O.P. solid phosphoric-acid-catalyst poly plant, using tubular-type reactors. A material balance of this plant is as follows:

	Lb./hr.
Feed to poly plant, total	31,323
C_3 olefin in feed	9,787
C_4 olefin in feed	11,267

Product from Poly Plant

	Lb./hr.
Propane to storage	4,711
Gas to light-ends recovery	622
Butane to storage	5,473
Poly gasoline	19,517
Heavy ends to catalytic cracking unit	1,000
Total	31,323

Catalytic-Cracking Unit

All product fractions heavier than gasoline are blended and charged to a fluid catalytic-cracking unit of conventional design. The composite feed to this unit, amounting to about 4,850 barrels per stream-day (42.2° A.P.I. gravity), consists of the following streams:

	Lb./hr.
Gas oil from distillation	19,010
Heavy distillate from distillation	23,105
Wax from catalyst-preparation unit	13,602
Reformer bottoms	885
Poly-plant bottoms	1,000
Total	57,602

The operating conditions and yields proposed for this section are as follows:

Reactor conditions

Temperature	°F.	900
Pressure	p.s.i.g.	12
Space velocity	W/hr./W	2
Recycle ratio		0.5
Catalyst:oil ratio (fresh feed)		12.9
Conversion	percent	60.0
Coke let-down on catalyst	weight percent	6.0

Product

	Lb./hr.
Fractionator OH to light-ends recovery	12,097
Stabilized OH to poly plant	560
Catalytic-cracked gasoline (stabilized bottoms)	17,185
Catalytic-cycle gas oil to shells	23,175
Burned coke and water	4,585
Total	57,602

Final product is 1,894 barrels per stream day of 37° A.P.I. gas oil, and 1,555 barrels per stream day of catalytically cracked gasoline.

General

Power-Plant Operation

During 1952 the power plant was operated under the supervision of the Bureau of Mines by GESCO, Inc., through a contract, and will be returned to the Bureau of Mines on January 1, 1953. It continued to provide electric power for all purposes; steam for prime movers, process work and heating; and plant water and compressed air for the entire installation. Excess-power production increased during the year.

Average steam demand was 173,384 pounds per hour, with 300,000 pounds per hour peak load. Average electrical load was 9,187 kw.-hr., with 16,600 kw. peak. The power plant was operated on an average load factor of 61 percent. 52,362,800 kw.-hr. excess power was sold.

Major maintenance and improvement work included: Increasing the capacity of the water-softening and feed-water heating system; new fuel-oil storage tanks and piping; new 10,000 kv.-a. cubicle and feeder for excess power; and reblading of the three turbines is under way.

Safety

Accident-prevention efforts during the year were directed to revaluation and revision of safety procedures to effect more efficient and safer operations.

Safety record for the year (to date) is:

Frequency rate	5.1
Severity rate	.11
Man-hours of exposure	577,144
Number of disabling injuries.	3
Number of days lost	68