Synthesis and Distillation Units

Good weather and good labor relations, together with excellent supervision of the construction workers, enabled Koppers Co., Inc., to complete construction of the synthesis and distillation units (see figs. 19-23) early in the summer of 1950. Some savings were effected, and it was possible to include the erection, piping, and insulation of the synthesis carbon dioxide scrubber system and a large part of the piping and insulation of the catalyst reduction unit within the estimated cost of the plant.

Catalyst-Fusion Unit

A catalyst-fusion unit having a capacity of 1 ton per day of sized catalyst has been designed and built by Bureau of Mines personnel. A mixer for the raw materials, crushing and sizing equipment, and a small prefabricated building to house the crushing equipment, as well as a stock of the necessary raw materials, were procured.

Mill scale (magnetic iron oxide) is used as the base for the fused catalyst. It is a cheap material, readily obtainable from steel-rolling mills. After addition of the desired activators, the mixture is electrically fused. After cooling, the pig of fused catalyst is broken and crushed to the desired particle size. The fines resulting from sizing are returned to the fusion step.

Several trial fusions have been made, and active catalyst has been produced at a very reasonable cost.

Figure 24 is a flow diagram of the catalyst-fusion unit.

Catalyst-Reduction Unit

The continuous catalyst-reduction unit has been erected, tested, and is ready for operation. Initial tests to determine the operability of the star-wheel feeder and the functioning of controls were completed during early autumn. Initial operations are dependent en adequate supply of sized raw catalyst. Arrangements are made for storage of the reduced catalyst under oil to minimize deterioration in activity until needed for operations of the synthesis unit.

General

The preparation of operating directives for the various units of the Gas-Synthesis Demonstration Plant were completed. These directives present a detailed description of the equipment and a suggested method of operation.

Many special studies were made relating to design and operation of the catalyst fusion, catalyst reduction, synthesis, distillation, product storage, and other units of the Demonstration Plant. The most important of these are described below:

1. Coolant oil for the synthesis is essentially a specialty product. It must contain very little or no sulfur compounds and should boil within the range of 500° to 800° F. Such an oil has been very hard to find, as most petroleum oils contain more than the allowable sulfur content. A survey revealed that a few unusual low-sulfur crude petroleum oils are being produced. One of these, from the East White Lake Field in Vermillion Parish, La., was found to be a suitable material from which a satisfactory coolant oil can be produced by fractional distillation. Two tank cars

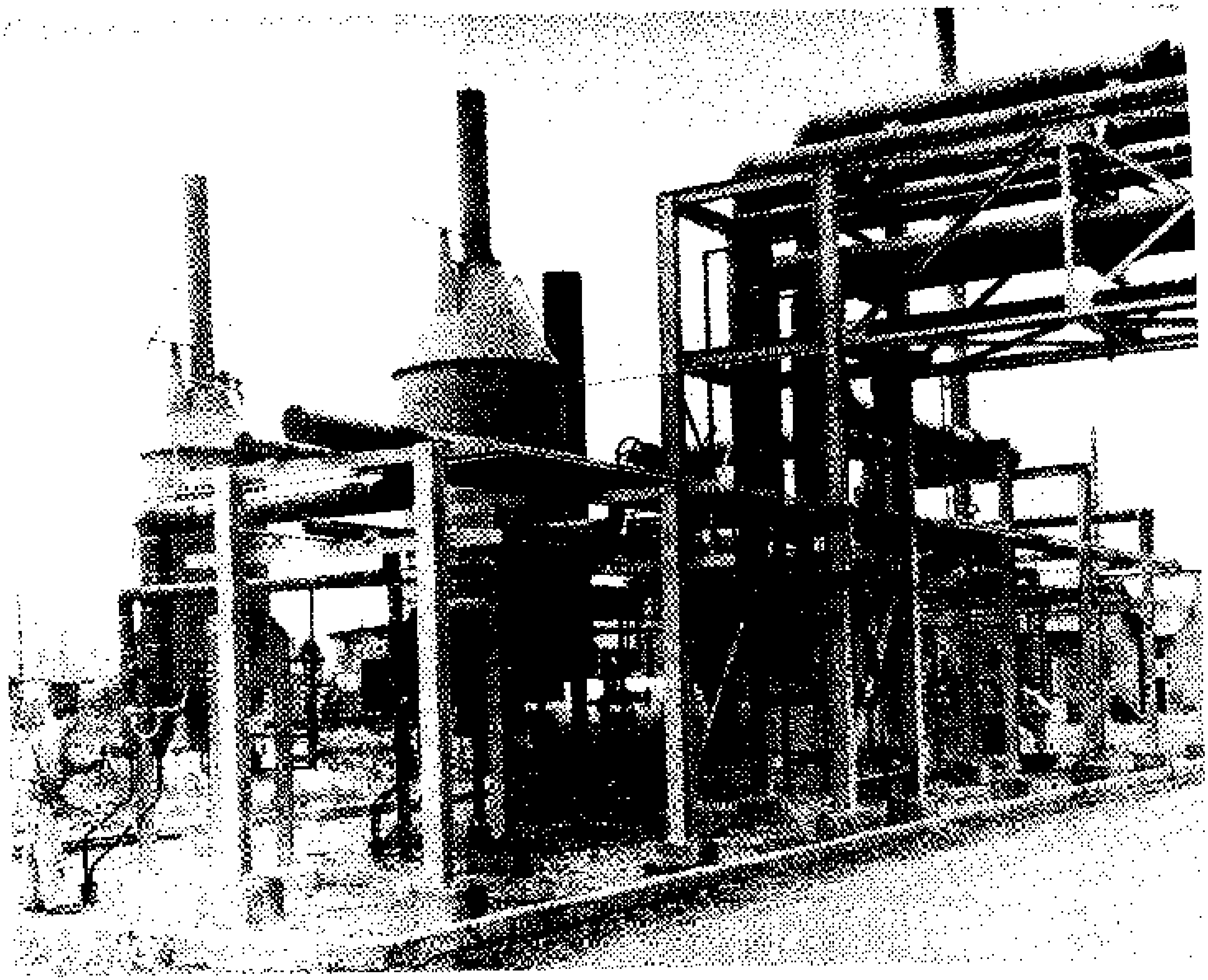

Figure 19. - Gas-fired heaters for preheating feed streams to synthesis and distillation units, Gas-Synthesis Demonstration Plant.

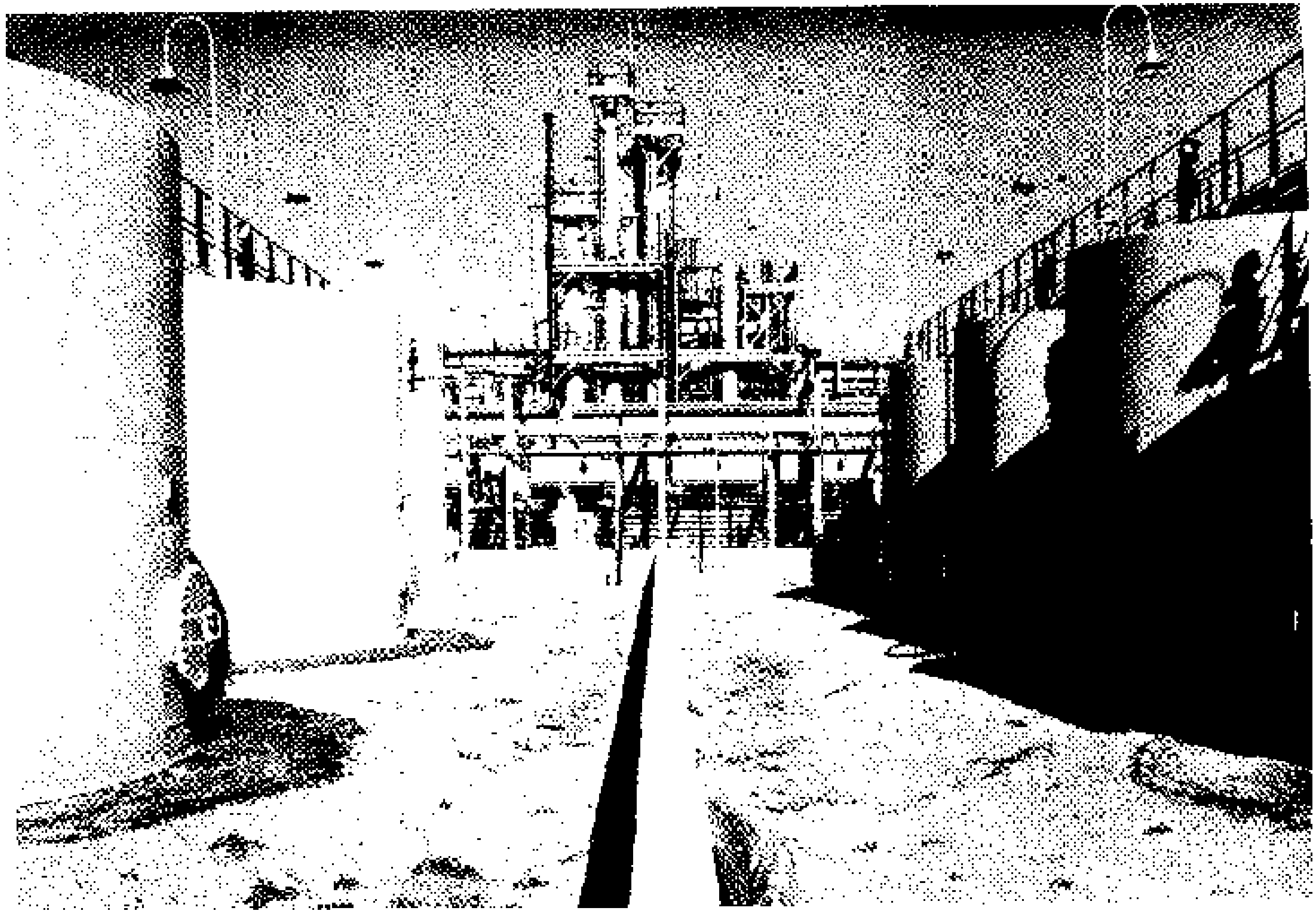

Figure 20. - View (looking north) of distillation unit, with tankage in foreground, Gas-Synthesis Demonstration Plant.

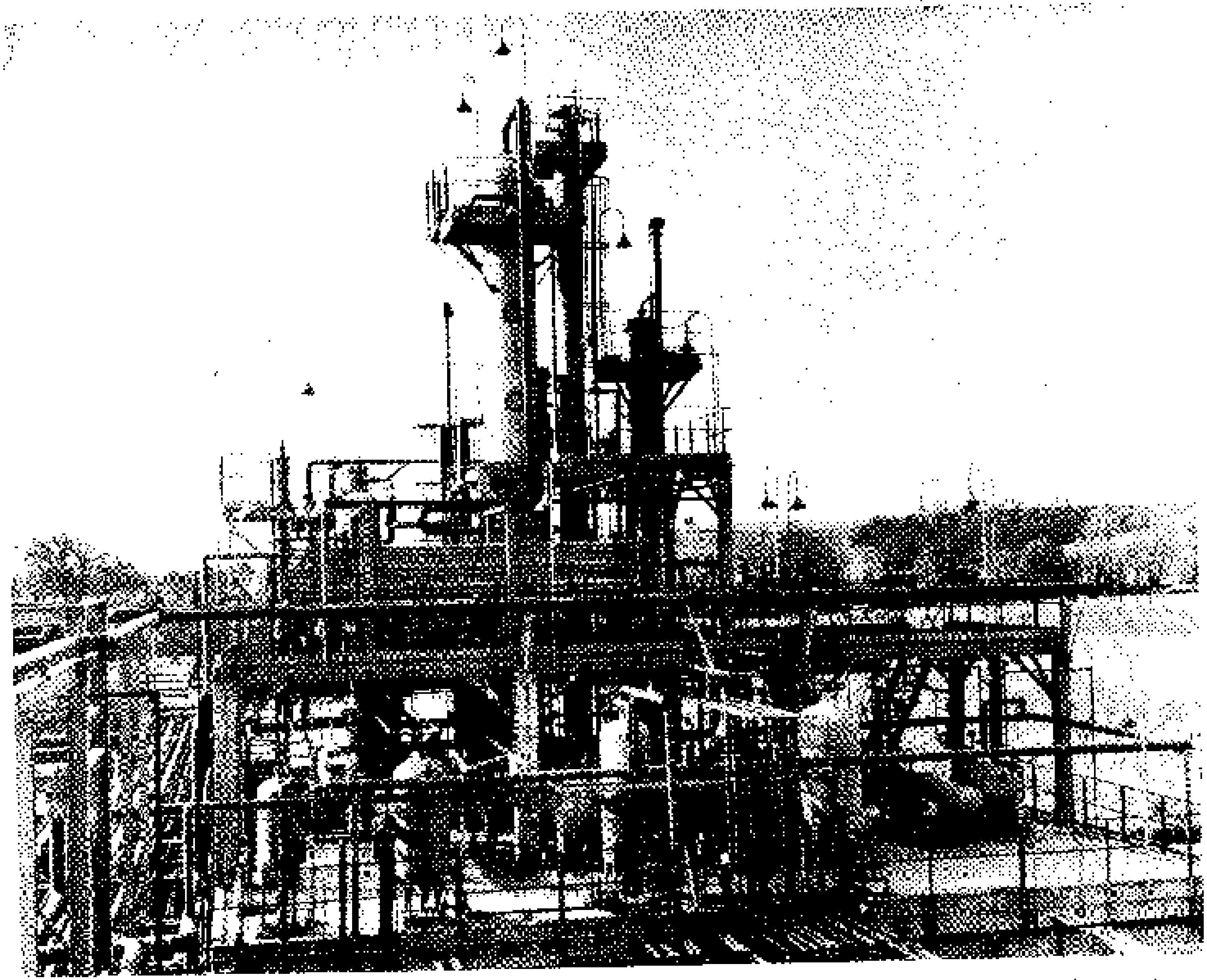

Figure 21. - View (looking south) of distillation columns for refining synthesis crude into finished products, Gas-Synthesis Demonstration Plant.

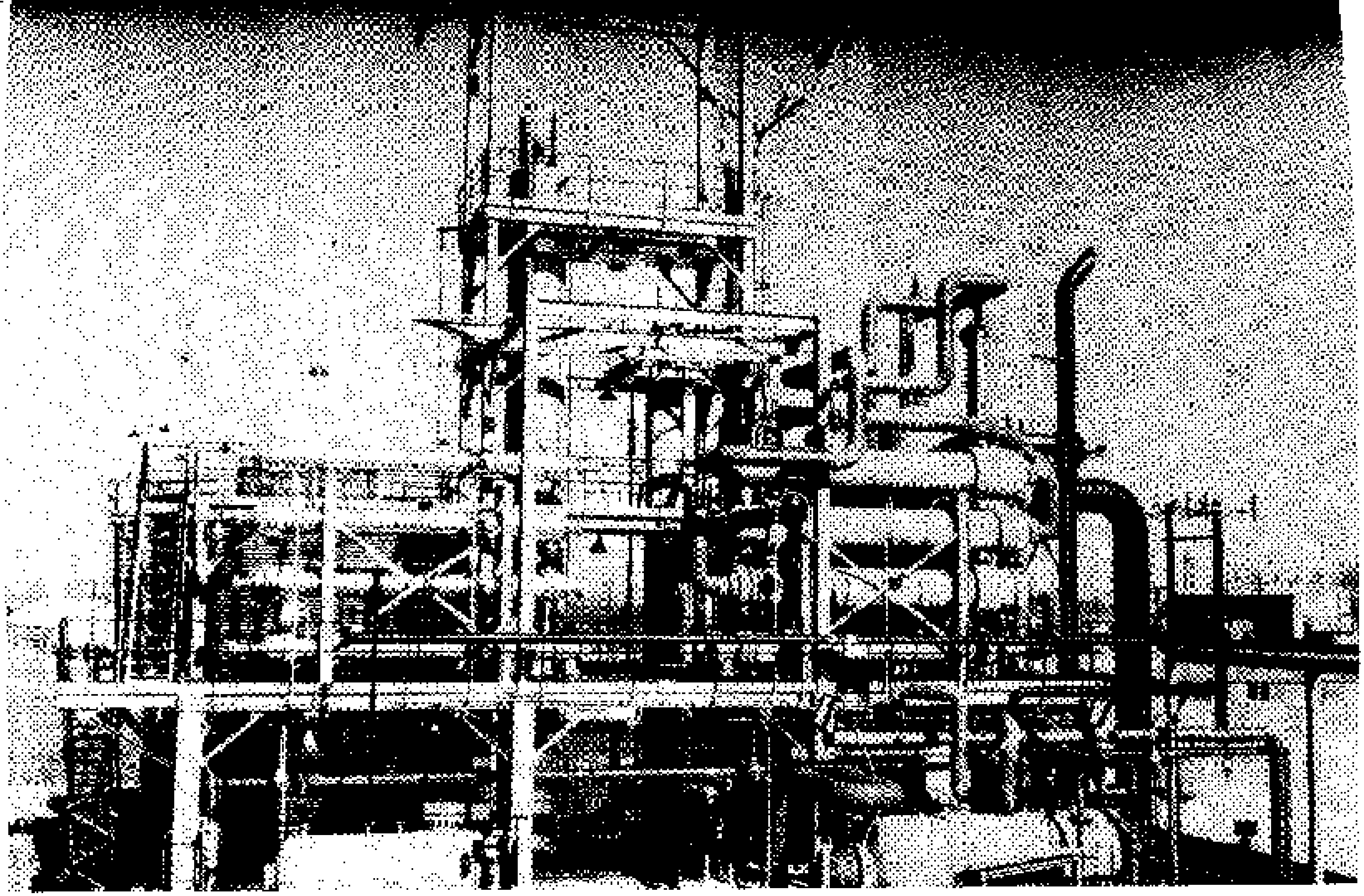

Figure 22. - View (looking north) of auxiliary equipment and piping of synthesis reactor, Gas-Synthesis Demonstration Plant.

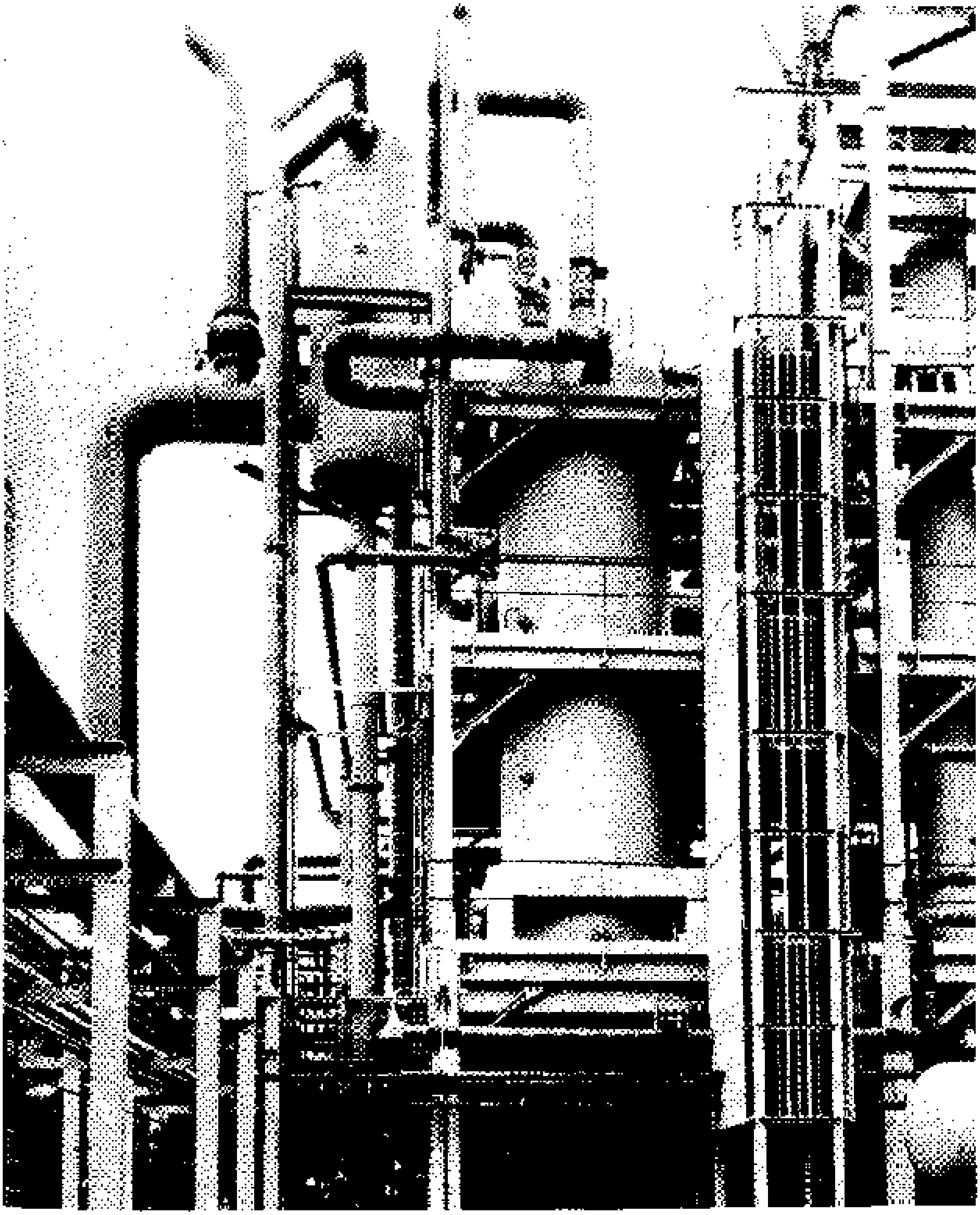

Figure 23. - Gas-synthesis reactor, Gas-Synthesis Demonstration Plant.

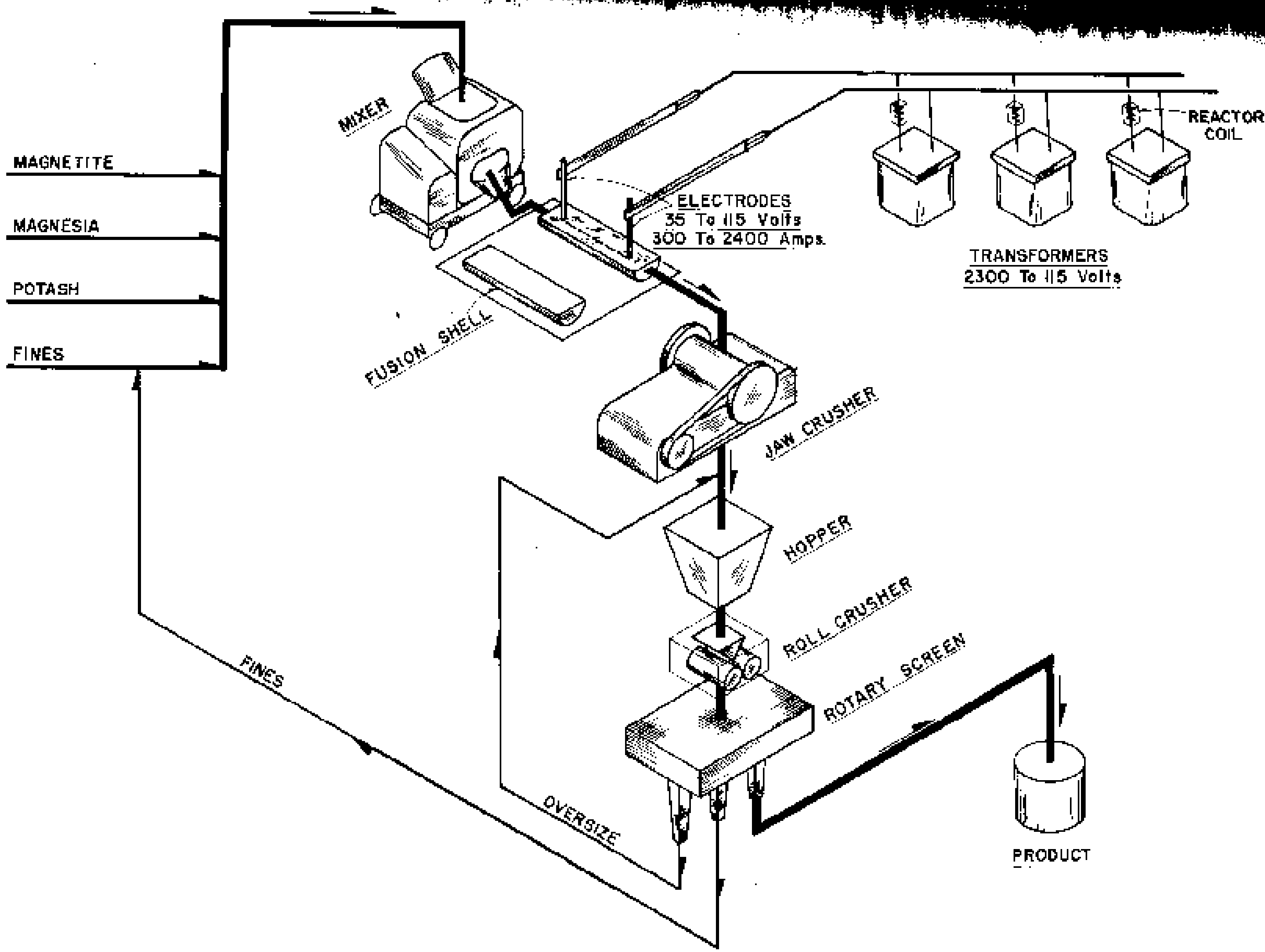

Figure 24. - Flow diagram of catalyst fusion unit.

(20,000 gallons) of this crude oil have been obtained and will be distilled to produce coolant oil for the synthesis unit and absorber oil for use in the distillation unit.

2. An economic study was made showing the effect of variations in synthesis operating conditions and process yields on the relative costs of producing a liquid product. The effects of such factors as (a) single- or multi-stage operation, (b) gas recycle, (c) carbon dioxide removal, (d) catalyst life, (e) space velocity, and (f) degree of conversion of the reacting gases have been evaluated for a basic case and fifteen variations thereof. Comparative cost figures developed in this study will be employed as a guide in planning demonstration operations and for further cost studies.

3. Special consideration was given to possible changes in operating variables that might affect the functioning of the interstage carbon dioxide removal unit. Gas flows, variations in carbon dioxide content of the feed gas under different operating conditions, rates of flooding under various pressure and flow conditions, and anticipated carbon dioxide absorption efficiencies were evaluated. These calculations indicate that it will be possible to remove the carbon dioxide contained in the reactor gases at expected flows and at pressures of 300 to 450 p.s.i.g.

4. Process studies have been made to explore the probable limitations of the demonstration plant in terms of flows, temperatures, pressures, and yields. Of these, the variation in the flows of reacting gas mixtures is most important. The flow of synthesis gas of variable H_2/CO ratio, the influence of variable recycle gas ratios, and the removal of carbon dioxide from the recycle gas change markedly the capacity of the synthesis unit.

Engineering and Economic Studies for Commercial-Size Operations

Various engineering and economic studies were made in connection with the design of commercial-scale plants to indicate the direction of research activities as well as to make preliminary determinations of the cost of various synthetic fuel products.

Shale-Oil Hydrogenation

In connection with shale-oil hydrogenation, the possibilities of making hydrogen from retort gas and coker tail gas produced in shale-oil refining were reviewed. It was determined that both of these gases will serve as feed to the hydrocarbon-steam cracking operation, whereupon 98 percent hydrogen could be produced by shifting and carbon-dioxide scrubbing of the effluent gases. From 21 million std.c.f. of retort gas, 34.2 million cu. ft. of hydrogen gas can be produced. Similarly, 3.25 million cu. ft. of coker tail gas will produce 8.7 million cu. ft. of hydrogen. Of the two gases, coker tail gas is preferred, owing to its lower total sulfur content and its lower content of inert materials, which make for smaller equipment sizes.

Effect of Octane Ratings on Production Costs

A study was made showing the effect of octane ratings on the production costs of coal hydrogenation plants producing various grades of gasoline. Results of this study are shown in graph form in figure 25.

PRODUCTS, BARRELS-PER-DAY					
MOTOR GASOLINE	23,000	23,000			
AVIATION GASOLINE, 91 O.N.			21,491	13,578	
AVIATION GASOLINE, 100 O.N.				11,920	
JET FUEL, J.P.-3					25,670
L.P.G.	7,130	7,130	8,639	2,582	4,465
TOTAL	30,130	30,130	30,130	28,080	30,135

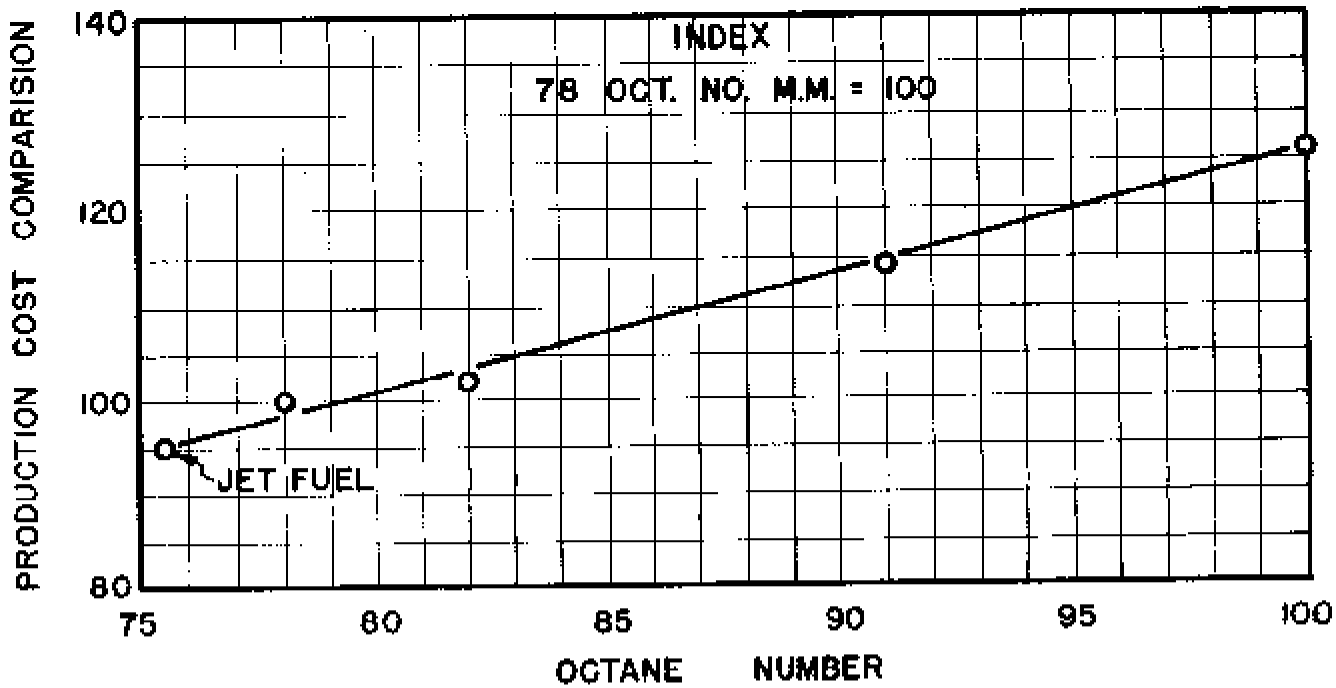

Figure 25. - Effect of octane ratings on production costs.

Anthracite Silt Gasification

A preliminary engineering and economic study was carried out to determine the cost of manufacturing a 900 B.t.u. per cu. ft. gas, using silt washings from anthracite coal-cleaning operations. The process selected was the gas-synthesis or Fischer-Tropsch process, using two fluidized bed reactors. Two alternates for the gasification of the silt were selected: (a) pressure dust gasification and (b) Lurgi gasification of pellets made from the silt. In each alternate, the basic process units consist of a coal-preparation plant, gasification and oxygen plants, a dust-removal system, a water-gas shift for adjustment of hydrogen and carbon monoxide ratio, a water-washing step for removal of carbon dioxide and hydrogen sulfide, a final sulfur-removal plant, and the synthesis step wherein hydrogen and carbon monoxide react over a suitable catalyst producing water, which condenses out, leaving the finished city gas.

The cost of production, including no profit but amortizing the total investment cost over a period of 15 years, is 54.5 cents per 1,000 cu. ft. of 900 B.t.u. per cu. ft. gas when using the pressure-dust gasification and 63.5 cents when using the Lurgi gasification.

Capital investment cost for the two alternates is $57,955,000 and $59,950,000, respectively, for 65,650,000 std.c.f. per calendar day of 900 B.t.u. city gas.

An engineering and cost comparison is shown in table 7.

TABLE 7. - Comparison of pressure-dust and Lurgi methods in gasifying anthracite silt.

	Pressure-dust gasification	Lurgi gasification
Process coal, tons/calendar day	5,760	4,194
Coal for power and steam, tons/calendar day	464	2,070
Coal for gasifier preheater, tons/calendar day	711	-
Coal for steam superheater, tons/calendar day	-	270
Total coal, tons/calendar day	6,935	6,534
Oxygen required, tons/calendar day	3,690	1,485
Operators per shift	45	59
Total plant investment including working capital and interest during construction	$60,155,000	$62,200,000
Operating costs, $/calendar day. Total direct costs (silt coal @ $1.25 and pellets @ $2.50/ton	$19,194	$24,424
Total indirect costs	3,900	4,285
Total fixed costs	12,590	12,930
Total daily costs	35,684	41,639
Gas production, cu.ft./calendar day (900 B.t.u./cu. ft.)	65,650,000	65,650,000
Cost, ¢/1,000 cu. ft.	54.5	63.5

Coal Gasification with Air

A rough cost estimate was made for a Fischer-Tropsch plant using air instead of oxygen. It was found that the capital cost of a 10,000-barrel-per-day plant using air is $23 million greater and that it would consume 1,388 tons per day more coal because of greater heating and power requirements.

Gasification and Synthesis Plant (10,000-Bbl./Day)

Considerable effort was expended on this project during the past year. Three complete estimates of the plant actually were made for the purpose of orientation and economic analyses. This work resulted in the change or elimination of certain process steps as follows:

1. The production of synthesis gas from tail gas was found to be uneconomical and, instead, it was decided to utilize this gas as fuel.

2. Low-temperature off-gas separation was found impractical and eliminated.

The latest estimate on this plant is now being reviewed by a committee appointed by the National Petroleum Council at the request of the Secretary of the Interior.

Coal-Hydrogenation Plant (30,000-Bbl./Day)

The cost estimate on this plant published in Report of Investigations 4564 also is being reviewed by the appropriate committee of the N.P.C. Several conferences have been held by Bureau engineers and members of this committee to familiarize the latter with the methods used, processes involved, and details of the high-pressure equipment required in this plant.

Data for Corps of Engineers

The Bureau of Mines prepares and maintains a current chart of commercial-scale synthetic-fuel plant requirements based on the most recent data available from industry and demonstration plant findings. This chart (see fig. 26) is a compilation of raw materials, water, power, personnel, products, and wastes typical of synthetic-fuel plant operations. The information shown is made available to the Corps of Engineers to assist them in their Nation-wide survey for the selection of general locations for plant sites.

Aromatic Hydrocarbons and Chemicals from Synthetic Liquid Fuels

A study was undertaken of the possibilities of producing benzene and other aromatic hydrocarbons, together with tar acids and other chemicals, from synthetic liquid fuels derived from coal and oil shale. The objectives of this study are manyfold and include determining the extent to which certain aromatic hydrocarbons can be obtained in the processing of synthetic liquid fuels, the processes employed for their recovery, the economics of such processes, and the effect the recovery of these substances will have upon the cost of synthetic liquid fuels.

This study is particularly timely, as the shortages of benzene and phenol have become more acute, and new sources for these materials must be found to satisfy the normal peacetime and defense needs of our country. In the past the major source of benzene has been coke ovens operated, for the most part, in conjunction with steel

		HYDROGENATION REQUIREMENTS FOR A 10,000 BBL./CD UNIT BASED ON A 30,000 BBL./DAY PLANT	SYNTHINE USING COAL REQUIREMENTS FOR A 10,000 BBL./CD UNIT BASED ON A 10,000 BBL./DAY PLANT	SYNTHINE USING NATURAL GAS [4] REQUIREMENTS FOR A 10,000 BBL./CD UNIT BASED ON A 7,000 BBL./DAY PLANT
A. DESCRIPTION OF PROCESS (Include: Brief description of flow sheet. Names of equipment or units proposed for use. Significant temperatures and pressures. Over-all efficiency [1] for average rank of coal and average quality of gas.)		Coal, which is made into paste by mixing with oil, is hydrogenated at 10,000 psi and 900° F. in two consecutive stages, liquid and vapor phase. Vapor phase products are distilled into finished gasoline and LP-gas. With slight modification alternate products, such as jet fuel, Diesel fuel, furnace oil, etc., can be produced if desired. Fuel gas needed is generated from coal. Hydrogen is produced at 350 psi pressure by gasification of coal with oxygen and conversion of hydrogenation off-gas with steam. Steam and power production facilities are provided with the plant. A coal cleaning plant is included showing the use of run-of-mine coal. The process data below are based on the following efficiency: Over-all 50.5% (1)	Raw coal is pulverized and gasified with oxygen and steam at 450 psi pressure. The resulting synthesis gas, composed of mainly CO and H_2, is purified by the removal of H_2S and organic sulfur compounds and then fed to a single stage synthesis reaction. The synthesis reaction takes place at 300 psi pressure and about 600° F. An internally cooled reactor, using liquid suspended iron catalyst, has been assumed in this estimate. Alternate types of reactors are solid bed catalyst internally cooled reactor, or iron catalyst slurry process. The liquid products are separated by distillation into motor gasoline, Diesel fuel and heavier fractions which are refined and upgraded by conventional petroleum and refinery processes to finished products. Steam and power facilities are provided within the plant. The data below are based on the following efficiency: Over-all .... 4 .2% (1)	Data presented below are based on Hydrocol process. Little information on this process is available at the present time. The process consists of burning a desulphurized natural gas with oxygen in a synthesis gas generator to form essentially carbon monoxide and hydrogen (2 parts hydrogen and 1 part carbon monoxide). Liquid and gaseous hydrocarbons are synthesized by passing this mixture into a fluidized bed of iron catalyst. Conventional oil refinery methods are used for separation, recovery, and upgrading the products. The data below are based on the following efficiency: Over-all efficiency ..... 47.2% (1)* Note: According to the licenser of this process, if there is a market for low pressure steam near the location of the plant, this efficiency can be raised to about 52.5%. *The natural gas having a field gas pressure of 500 psi, without compression and 1050 Btu./cu.ft. gross heating value. [3]

B. RAW MATERIALS — QUANTITY: FUEL REQUIREMENTS IN BTU X 10^8/CALENDAR DAY

	Line	Hydrogenation: Process	Hydrogenation: H_2 mfg. & fuel gas	Hydrogenation: Direct fired (Disk. etc.)	Hydrogenation: Power & steam	Hydrogenation: Total	Synthine using coal: Process	Synthine using coal: Total	Synthine using natural gas: Process	Synthine using natural gas: Total
Coal	2	60	31	[illegible]	19	[illegible]	124	126		
Natural gas	3								110	110

B. RAW MATERIALS — QUALITY

		Line	Hydrogenation	Synthine using coal	Synthine using natural gas
ASH	Maximum allowable ash content to equipment (dry basis)	4	Process 16%; H_2 mfg. & fuel gas 30%; Direct fired 30%; Power & steam 30%	Process 20%	
ASH	Other characteristics (Chemical analysis, etc.)	5	(1) Good washability is desirable. (2) Low calcium in process coal is preferable. (1) Chemical analysis & physical properties should be known.	(1) Good washability is desirable. (2) Chemical analysis & physical properties should be known.	
SULFUR	Cost of desulfurization	6, 7	Cost of desulfurization does not change materially with percent of sulfur in coal when credit of 1/5 of market price is taken for recovered sulfur.	Cost of desulfurization does not change materially with percent of sulfur in coal when credit of 1/5 of market price is taken for recovered sulfur.	Cost of desulfurization does not change materially with percent of sulfur in coal when credit of 1/5 of market price is taken for recovered sulfur.
SULFUR	Other characteristics	8	High organic sulfur content in raw coal is undesirable since it is not easily removed by cleaning (of only minor importance).	High organic sulfur content in raw coal is undesirable as it is not easily removed by cleaning.	
	Other characteristics (Effect of rank, opaque attritus, fusain, etc.)	9	Fusain and opaque attritus should be low in process coal. Fusain normally can be removed by cleaning. Volatile matter (maf) ...... 31% minimum. Fixed carbon (maf) .... Not to exceed 59%. Sulfur .... No limit. Moisture .... No limit. Rank of coal has little effect on total plant required. For coals of equal rank, higher net hydrogen is desirable. Information required for evaluation 1) Proximate analysis dry basis - include moisture as pound/pound of dry coal (face sample). 2) Fischer Assay (dry basis). 3) Ultimate analysis (maf basis) Btu content.	Fixed carbon.........................No limit. Volatile matter ....No limit. Sulfur ....No limit. Moisture ....No limit. Decrease in rank increases amount of plant required. (Range of plant cost 30% between extremes of rank). Information required for evaluation 1) Ultimate analysis (maf basis) Btu content. 2) Proximate analysis - dry basis - include moisture as pound/pound of dry coal (face sample).	1) Excess steam will be reduced by amount required to compress gas if available pressure is below 500 psi. 5) Impurities like N_2, CO_2, etc., increase the gas consumption and decrease the efficiency, and while details are not known, plant and operating costs will increase. 16% probable maximum increase due to addition of beneficiating plant.

Figure 26. - Data for Corps of Engineers.

			Hydrogenation: Requirements for a 10,000 bbl./cd unit based on a 30,000 bbl./day plant			Synthine using coal: Requirements for a 10,000 bbl./cd unit based on a 10,304 bbl./day plant			Synthine using natural gas (4): Requirements for a 10,000 bbl./cd unit based on a 7,900 bbl./day plant		
C. WATER			**Heat capacity of coolant required in Btu x 10⁹ calendar day (includes coolant for power requirements)**								
		1	35 Average for all Ranks of Coal			54 Average for all Ranks of Coal			31		
			Water requirements in thousand gallons per calendar day								
			Make-up	Consumed	Returned	Make-up	Consumed	Returned	Make-up	Consumed	Returned
QUANTITY	Evaporated (Cooling towers)	2	4,180	4,180		8,580	8,581		8,670	3,670	
	Blowdown from cooling towers	3	1,944	927	928	1,170	984	915	1,160	550	660
	Boiler makeup for hydrogen mfg.	4	483	338	146						
	Boiler make-up for synthesis gas mfg.	5				343	170	116	1,973	1,363	692
	Boiler make-up for boiler B. D.	6	345	46	498	731	747	580			
	H.P. injection water (process water)	7	80	60							
	Sanitary water for plant	8	72		72	58		58	47		47
	Sanitary water for mines	9	37		37	60		50			
	Water for coal preparation	10	253	83	170	162		162			
	Water for mines	11	Information not available. (Assumed to be self-sufficient)			Information not available. (Assumed to be self-sufficient)					
	Water for mine power	12	69	58	14	84	86	18			
	Miscellaneous 10%	13	682		682	1,002		1,002	683		815
	TOTAL	14	7,285	5,362	1,924	11,528	7,947	3,081	7,473	5,606	1,383
QUALITY			1. Boiler water suitable for treatment. 2. Sanitary water suitable for chlorination & potable. 3. Cooling water is based on soft water. Water of high solids content increases water requirements or necessitates a water treatment plant.			1. Boiler water suitable for treatment. 2. Sanitary water suitable for chlorination & potable. 3. Cooling water is based on soft water. Water of high solids content increases water requirements or necessitates a water treatment plant.			1. Boiler water suitable for treatment. 2. Sanitary water suitable for chlorination & potable.		
D. POWER	Total power required for mining (kw)	1	3,000 (based on 2 shifts/day - 5 day week - 6 kw-hr/ton)			3,500 (based on 2 shift/day - 5 day week - 8 kw-hr/ton)					
	Total power required for plant (kw)	2	58,000			118,600			58,000		
	Byproduct power (kw)	3	46,000 (Back pressure power)			118,600 (Produced from waste heat)			86,000		
	Prime power (kw)	4	(3) 12,000 May be produced from outside sources. Fuel requirements may be reduced in proportion)						0		

TOTAL OPERATING PERSONNEL REQUIRED FOR YEAR ROUND OPERATION

E. PERSONNEL				Hydrogenation				Synthine using coal				Synthine using natural gas
Plant (Complete) 365 days (year)	Operational	1	928				996				625
	Administrative	2	282				200				178
			Bituminous 602	Subbituminous 785	Lignite -		Anthracite -	Bituminous 800	Subbituminous 1000	Lignite -	
Underground mines (5) (2 shifts, 240 days per year operation)	Operational	3	97	39	-		-	40	55	-	
	Administrative	4									
Strip mine (5) (2 shifts, 240 days per year operation)	Operational	5	136	38	466		350	328	400	510	
	Administrative	6	12	14	31		16	14	50	36	
Gas Field (3 shifts, 365 days per year operation)	Operational	7									Requirements not available.
	Administrative	8									Requirements not available.

Figure 26. - Data for Corps of Engineers (continued).

F. PRODUCTS — ESTIMATED QUANTITY OF PRODUCTS PER CALENDAR DAY (RANGES ON SPECIFIC QUANTITIES)

HYDROGENATION: Requirements for a 10,000 bbl./cd unit based on a 30,000 bbl./day plant
SYNTHINE USING COAL: Requirements for a 10,000 bbl./cd unit based on a 10,000 bbl./day plant
SYNTHINE USING NATURAL GAS (3): Requirements for a 10,000 bbl./cd unit based on a 7,000 bbl./day plant

Product	No.	Hydrogenation	B/D	Btu./lb.		Btu./day	Synthine using coal	B/D	Btu./lb.		Btu./day	Synthine using natural gas	B/D	Btu./lb.		Btu./day
Nonliquefiable gases	1															
Liquefied petroleum gases	2	Propane –	1,708	21,700	=	6,520,000,000		470	21,700	=	1,483,000,000					
		Butane –	958	21,300	=	2,840,000,000										
Gasoline: Aviation base	3	Gasoline –	7,220	19,450	=	37,740,000,000	Gasoline –	7,280	20,440	=	37,264,400,000	Motor gasoline –	8,116	20,810	=	48,000,000,000
Gasoline: Motor	4															
Kerosine	5						Diesel oil –	1,403	19,905	=	10,720,000,000					
Distillate	6						Fuel oil –	460	19,775	–	2,181,000,000	Dist. fuel –	330	19,900	=	1,870,000,000
Residual	7											Residual –	505	19,776	=	3,400,000,000
												TOTAL	9,000			51,876,000,000
Other (Wax, lubricants, other oxygenated water soluble compounds, etc.)	8											Oxygenated (8) Compounds –	6,000 lb/hr	7,500	=	1,082,000,000 (To be credited only if recovered)
Byproducts	9	Phenols – (2)	418	12,730	=	2,300,000,000										
TOTAL	10		10,000			49,820,000,000		10,000			51,869,000,000					

G. WASTES — NATURE AND AMOUNT OF WASTES

Hydrogenation:

Plant	No.	Solid: Description	Tons/Day	Liquid: Description	Gal./Day	Gaseous: Description	Cu.ft./Day
Coal cleaning	1	Reject from cleaning plant					
	2						
Plant and/or mine	3						
	4						
	5	Spent catalyst:	40	Total	52,800	Total	6,100,000
	6	Ash (Total ash in coal)		(Composition of this waste is: H_2S = 0.5%, CO_2 = 7.0%, NH_3 = 2.0%, Phenols = 0.3%)		(Based on 1% sulfur in coal. Composition: H_2S = 1%, CO_2 = 10%, Air – 89%)	

Synthine using coal:

Plant	No.	Solid: Description	Tons/Day	Liquid: Description	Gal./Day	Gaseous: Description	Cu.ft./Day
Coal cleaning	1	Reject from cleaning plant					
	2						
Plant and/or mine	3						
	4						
	5	Spent catalyst				H_2S from stripped 240 c.f./1% sulfur/ton of coal (ok regulated). Can be converted to sulfur or served as SO_2	Varies with sulfur in coal
	6	Ash (Total ash in coal)					
		Dry per mass					

Synthine using natural gas:

Plant	No.	Solid: Description	Tons/Day	Liquid: Description	Gal./Day	Gaseous: Description	Cu.ft./Day
	5	Spent catalyst		After chemical recovery–total	450,000	Impurities in gas	
				Water containing approx. 1% oxygenated compounds. Composition unknown.			

H. AREA — AREA REQUIRED IN ACRES

	No.	Hydrogenation	Synthine using coal	Synthine using natural gas
Area	1	10	77	38

NOTES:

1. Over-all efficiency is defined as: $\frac{\text{Btu. in products}}{\text{Btu. in coal}} \times 100$
2. For hydro plant assumes normal cleaning plant losses and ratio of coal to gasification of 21×10^9 Btu./38×10^9 Btu.
3. Gas measured at 14.65 psig, 60° F.
4. Data for the synthine process are estimated from available literature and private correspondence.
5. Assuming 10 tons of coal per man and shift; administrative personnel 5% of operational.
6. Assuming 25 tons of coal per man and shift; administrative personnel 5% of operational.
7. Can be converted to gasoline with no loss in yield and with no additional equipment.
8. Present in dilute water solution. Facilities for their recovery have not been included in above data.
9. Water requirements would be 17.2% less total water for hydrogenation if prime power were purchased from some outside source.

Figure 26. - Data for Corps of Engineers (continued).

plants. In recent months benzene has been produced from petroleum, but the combined production still is insufficient, and shortages are predicted that may reach 50,000,000 gallons in 1950. Imports will ease but will not solve the problem.

A 30,000-barrel-per-day coal-hydrogenation plant could alleviate measurably the shortages of certain of these coal chemicals. Table 8 compares the total national production of benzene, toluene, xylenes, phenol, cresols, and xylenols that are obtained from coal hydrogenation and petroleum and the quantities of these chemicals available from a 30,000-barrel-per-day coal hydrogenation plant using a representative coal.

TABLE 8. - Comparison of U. S. production of aromatic chemicals and yield of a 30,000 bbl./day coal hydrogenation plant.

	1948	1949	Estimated annual yield coal hydrogenation plant
		Thousands of gallons	
Benzene....................	173,795	156,620	34,000
Toluene....................	83,463	81,752	49,500
Xylenes....................	61,071	57,557	50,300
		Thousands of pounds	
Phenol.....................	297,338	224,544	34,500
Cresols....................	21,419	13,477	57,000
Xylenols...................	-	-	75,000

Cooperative agreements are being negotiated to determine the costs and maximum practical yields of benzene, toluene, and xylene by applying conversion processes employed in the petroleum industry to coal-hydrogenation products, and to evaluate the tar acids and other chemicals available.

As the quantities of some of these chemicals produced by coal hydrogenation are appreciably higher than present consumption, market surveys are being conducted to appraise the potential market, and a research program directed towards conversion of excess materials into usable products has been formulated. Results from these studies should be available in 1951.

Safety

During the extended high-pressure operations, some emergency let-downs were necessary, and a fire occurred. The emergencies were handled effectively and without any personal injuries. Accident record for the year is as follows:

Man-hour exposure..............................	830,442
Disabling injuries (Lost-time accidents)...........	2
Frequency rate.................................	2.4
Severity rate..................................	.06