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REQUIREMENTS FOR THE COAL HYDROGENATION PROCESS AND THE FISCHER-TROPSCH PROCESSES FROM NATURAL GAS AND COAL

Prepared by W. I. Gwillim
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The following figures are based on estimated figures compiled by W. I. Gwillim and L. C. Skinner (unless otherwise noted), and are subject to revision as more accurate figures are obtained.

1. Coal Hydrogenation.

a. Processing Plant.

(1) Coal Hydrogenation process in two stages at 700 atm. pressure to produce 10,000 bbl/day, 30,000 bbl/day and 50,000 bbl/day of motor gasoline and by-products. This process can be efficiently operated to produce all types of petroleum products including LPG, motor gasoline, aviation gasoline, diesel fuel and heavy fuel oil. A coal hydrogenation plant can be designed to produce a minimum of 75% of any of the above products desired.

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(2) Cost of construction of plant (estimated).

10,000 bbl/day - $ 69,000,000
30,000 bbl/day - $244,000,000
50,000 bbl/day - $400,000,000

For a complete breakdown of construction cost see the 30,000 bbl/day plant estimate prepared by Bechtel Corp. and the Bureau of Mines at Louisiana, Missouri.

(3) Steel tonnage required.

10,000 bbl/day - 62,000 tons
30,000 bbl/day - 170,000 tons
50,000 bbl/day - 279,000 tons

For a complete breakdown of steel tonnage see the 30,000 bbl/day plant estimate prepared by Bechtel Corp. and the Bureau of Mines at Louisiana, Missouri.

(4) Molybdenum, copper and aluminum will be required, but in the quantities required, these materials are not considered critical.

b. Raw Materials.

(1) Bituminous, sub-bituminous coal or lignite and catalyst (Fe_2O_3).

(2) Coal Requirements.

The rank of the coal will determine the quantity required. The following figures are based on bituminous coal (11,900 Btu/lb as received or 14,000 Btu/lb MAF). Catalysts requirements have not been accurately determined, but the following figures are an approximation:

COAL REQUIREMENTS

Plant Size	10,000 bbl/day	30,000 bbl/day	50,000 bbl/day
Coal required per day	4,300 tons	12,500 tons	20,800 tons
Coal " " year	1,569,500 "	4,562,500 "	7,592,000 "
Catalyst " " day	40 "	120 "	200 "
Catalyst " " year	14,400 "	43,200 "	72,000 "

(3) Coal Requirements Breakdown - Bituminous Coal (11,900 Btu/lb as rec'd.)
(All figures in tons)

Plant Size	10,000 bbl/day			30,000 bbl/day			50,000 bbl/day		
	Daily	Annually	20 yrs. Life of Plant	Daily	Annually	20 yrs. Life of Plant	Daily	Annually	20 yrs. Life of Plant
Process Coal	3,100	1132×10^3	$22,600 \times 10^3$	9,250	3380×10^3	$67,600 \times 10^3$	15,400	5620×10^3	$112,400 \times 10^3$
Heat & Power Coal	1,190	434×10^3	$8,680 \times 10^3$	3,250	1187×10^3	$23,740 \times 10^3$	5,400	1970×10^3	$39,400 \times 10^3$
Total Coal	4,290	1566×10^3	$31,280 \times 10^3$	12,500	4567×10^3	$91,340 \times 10^3$	20,800	7590×10^3	$151,800 \times 10^3$
Sub-Bituminous Coal (9500 Btu/lb as rec'd.)									
Process Coal	3,850	1406×10^3	$28,100 \times 10^3$	11,600	4230×10^3	$84,600 \times 10^3$	19,300	7050×10^3	$141,000 \times 10^3$
Heat & Power Coal	1,850	492×10^3	$9,850 \times 10^3$	4,070	1488×10^3	$29,800 \times 10^3$	6,600	2400×10^3	$48,000 \times 10^3$
Total Coal	5,200	1898×10^3	$37,950 \times 10^3$	15,670	5718×10^3	$114,400 \times 10^3$	25,900	9450×10^3	$189,000 \times 10^3$
Lignite (7500 Btu/lb as rec'd.)									
Process Coal	4,900	1790×10^3	$35,800 \times 10^3$	14,700	5360×10^3	$107,400 \times 10^3$	24,500	8950×10^3	$179,000 \times 10^3$
Heat & Power Coal	1,700	620×10^3	$12,400 \times 10^3$	5,150	1880×10^3	$37,600 \times 10^3$	8,600	3140×10^3	$62,800 \times 10^3$
Total Coal	6,600	2410×10^3	$48,200 \times 10^3$	19,850	7240×10^3	$145,000 \times 10^3$	33,100	$122,300 \times 10^3$	$231,800 \times 10^3$

Anthracite Coal

According to available information at present, anthracite coal will not hydrogenate.

c. Power & Steam Requirements. (In addition to waste heat utilization)

Plant Size	10,000 bbl/day	30,000 bbl/day	50,000 bbl/day
Power Required	65,000 kw	190,000 kw	316,000 kw
Steam Required	225,000 #/hr.	640,000 #/hr.	1,065,000 #/hr.

d. (1) (a) Water Requirements (Minimum stream flow available)

Plant Size	10,000 bbl/day	30,000 bbl/day	50,000 bbl/day
Water evaporated (lost)	$6,624 \times 10^3$ gal/day	$19,872 \times 10^3$ gal/day	$33,120 \times 10^3$ gal/day
Water taken from and ret. to stream	$2,976 \times 10^3$ gal/day	$8,928 \times 10^3$ gal/day	$14,880 \times 10^3$ gal/day
Water - Total required for plant	$9,600 \times 10^3$ gal/day	$28,800 \times 10^3$ gal/day	$48,000 \times 10^3$ gal/day

(b) Breakdown of Water Requirements (All figures in gallons per day)

	10,000 bbl/day	30,000 bbl/day	50,000 bbl/day
Evaporated (Cooling Towers)	$5,832 \times 10^3$	$17,496 \times 10^3$	$29,160 \times 10^3$
Blow down from cooling towers	$1,740 \times 10^3$	$5,220 \times 10^3$	$8,700 \times 10^3$
Boiler Make Up for H_2 Mfg.	480×10^3	$1,440 \times 10^3$	$2,400 \times 10^3$
Boiler Make Up for Boiler Blow down	240×10^3	720×10^3	$1,200 \times 10^3$
H.P. Injection Water (Process Water)	72×10^3	216×10^3	360×10^3
Sanitary Water	276×10^3	828×10^3	$1,380 \times 10^3$
Miscellaneous	960×10^3	$2,880 \times 10^3$	$4,800 \times 10^3$
Total	$9,600 \times 10^3$	$28,800 \times 10^3$	$48,000 \times 10^3$

(2) Cooling Water Circulation Rate (With Cooling Towers)

Plant Size	10,000 bbl/day	30,000 bbl/day	50,000 bbl/day
Gallons per day	173×10^6	518×10^6	865×10^6
Gallons per month	$5,190 \times 10^6$	$15,540 \times 10^6$	$25,950 \times 10^6$
Gallons per year	$62,280 \times 10^6$	$186,480 \times 10^6$	$311,400 \times 10^6$

(a) Water Required for the Process Should be Fresh Water that can be Softened.

(3) Water Requirements with Unlimited Stream Flow Available. (No Water Evaporated)

Plant Size	10,000 bbl/day	30,000 bbl/day	50,000 bbl/day
Water make-up (lost)	792×10^3 gal/day	$2,376 \times 10^3$ gal/day	$3,960 \times 10^3$ gal/day
Water taken from and ret. to Stream	$166,000 \times 10^3$ gal/day	$500,000 \times 10^3$ gal/day	$830,000 \times 10^3$ gal/day
Total Water for Plant	$166,792 \times 10^3$ gal/day	$502,376 \times 10^3$ gal/day	$833,960 \times 10^3$ gal/day

3. Waste

(1) Solid Waste will consist of all of the ash in the coal, liquid phase catalyst, vapor phase catalyst, and any unconverted carbon.

Plant Size	10,000 bbl/day	30,000 bbl/day	50,000 bbl/day
Solid Waste	260 tons/day	780 tons/day	1,300 tons/day

(2) Liquid Waste. An approximate analysis of the liquid waste would be the following: 0.5% H_2S, 2% CO_2, 2% NH_3, and 0.3% phenols. With Chemical By-product recovery the effluent could be treated as follows: (1) phenol springing with CO_2. (2) Caustic or Girbotol treatment for removing the H_2S. (3) NH_3 removal by precipitating with H_2SO_4. (4) Aeration, dilution or trickling filters could be used for removing any remaining traces of phenols.

Plant Size	10,000 bbl/day	30,000 bbl/day	50,000 bbl/day
Liquid Waste	$2,310 \times 10^3$ gal/day	$6,930 \times 10^3$ gal/day	$12,550 \times 10^3$ gal/day

(3) Gaseous Waste would consist of combustion gases only. Most of the H_2S would be burned and produces SO_2 which is present in normal flue gases when burning coal containing sulphur. The H_2S from the aeration towers would go to the atmosphere. The NH_3 would in any case be present in the water from the plant, unless facilities for recovery were included. (See liquid waste)

(Based on coal with 1% sulphur)

Plant Size	10,000 bbl/day	30,000 bbl/day	50,000 bbl/day
H_2S	90,000 cu.ft./day	270,000 cu.ft./day	450,000 cu.ft./day

f. Personnel Requirements

(1) Personnel Requirements.

Plant Size	10,000 bbl/day	30,000 bbl/day	50,000 bbl/day
Technical Employees	600	2,200	3,500
Administrative & Clerical	75	200	300
Total Employees	675	2,400	3,800

(2) Personnel Requirements of Mine (underground)

Plant Size	10,000 bbl/day	30,000 bbl/day	50,000 bbl/day
Skilled Employees	380	1,140	1,915
Unskilled "	45	140	230
Technical "	25	70	115
*Total	450	1,350	2,260

*If the coal is strip mined, it will take approximately one-third of the total employees shown above, based on 10 tons/man day for underground mining.

g. (1) Pipeline Capacity - The pipeline should have the same capacity as the plant; that is, 10,000, 30,000, or 50,000 bbl/day. Also 30 day storage capacity should be provided at the plant.

(2) Transportation of By-products - Transportation of by-products depends on the location of the plant. L.P.G. could be transported in the gasoline pipeline. This is taking into consideration that all other by-products will be converted to gasoline.

h. Refinery is included in the cost of the plant so the products require no further treatment.

1. (1) Plant Production

Plant Size	10,000 bbl/day			30,000 bbl/day			50,000 bbl/day		
	B/D	B/yr	B/ton of coal	B/D	B/yr	B/ton of coal	B/D	B/yr	B/ton of coal
Gasoline	7,730	$2,783 \times 10^3$	1.73	23,200	$8,352 \times 10^3$	1.73	38,650	$13,914 \times 10^3$	1.73
L.P.G.	2,270	817×10^3	.50	6,800	$2,448 \times 10^3$	.50	11,350	$4,086 \times 10^3$	.50
Total Fuel	10,000	$3,600 \times 10^3$	2.23	30,000	$10,800 \times 10^3$	2.23	50,000	$18,000 \times 10^3$	2.23

2. Fischer-Tropsch from Natural Gas.

a. Processing Plant.

(1) Hydrocol process using fluidized bed of iron catalyst (little information on this process is available at this time). Alternate process using internally-cooled reactors operating under 20 atm. pressure over an iron catalyst as per experimental plant, Bureau of Mines experiment station.

(2) Cost of construction of plant (estimated figures based on $6,000 per barrel of products (quoted by Stanolind).

5,000 bbl/day = $ 36,000,000
10,000 bbl/day = 60,000,000
30,000 bbl/day = 180,000,000

(3) Steel tonnage required. (MPAC figure)

5,000 bbl/day = 30,000 tons
10,000 bbl/day = 58,300 tons
30,000 bbl/day = 175,000 tons

(4) No critical material known at present that might affect the size or capacity of the plant. Cobalt for a proven cobalt catalyst would be very critical. The amount of cobalt required has not been determined.

b. Raw Materials.

(1) (a) Natural Gas.
(b) Iron Catalyst - Chemical properties will be established.

(2) Natural Gas Requirements (figures in SCF 1000 Btu value)

Plant Size	5,000 bbl/day	10,000 bbl/day	30,000 bbl/day
Nat. Gas req'd per day	60×10^6	120×10^6	360×10^6
" " " " year	$21,600 \times 10^6$	$43,200 \times 10^6$	$129,600 \times 10^6$
Catalyst " " day)	Not known at present.		
Catalyst " " year)			

(3) Natural Gas Requirement Breakdown.

Natural Gas (1,000 Btu/SCF.)
(All figures in standard cubic feet)

Plant Size	5,000 bbl/day			10,000 bbl/day			30,000 bbl/day		
	Daily	Annually	20-yr-life of plant	Daily	Annually	20-yr-life of plant	Daily	Annually	20-yr-life of plant
Process Nat. Gas	60×10^6	$21,600 \times 10^6$	$432,000 \times 10^6$	120×10^6	$43,200 \times 10^6$	$864,000 \times 10^6$	360×10^6	$129,600 \times 10^6$	$2,592,000 \times 10^6$
Heat & Power Nat. Gas	0	0	0	0	0	0	0	0	0
Total Nat. Gas	60×10^6	$21,600 \times 10^6$	$432,000 \times 10^6$	120×10^6	$43,200 \times 10^6$	$864,000 \times 10^6$	360×10^6	$129,600 \times 10^6$	$2,592,000 \times 10^6$

c. Power & Steam Requirements.
All of the required power will be generated in waste heat boilers and all steam requirements will be generated by waste heat recovery.

d. (1) (a) Water Requirements (Minimum Stream Flow Available)

Plant Size	5,000 bbl/day	10,000 bbl/day	30,000 bbl/day
Water Evaporated (lost)	$4,500 \times 10^3$ gal/day	$9,000 \times 10^3$ gal/day	$27,000 \times 10^3$ gal/day
Water returned to the stream	$1,800 \times 10^3$ gal/day	$3,500 \times 10^3$ gal/day	$10,500 \times 10^3$ gal/day
Water - Total required for Plant	$6,300 \times 10^3$ gal/day	$12,500 \times 10^3$ gal/day	$37,500 \times 10^3$ gal/day

(b) Complete breakdown of water requirements not available at this time.

(c) Water required for the process should be fresh water that can be softened.

(2) Cooling water circulation rate with a 33° rise. (estimated, using cooling towers)

Plant Size	5,000 bbl/day	10,000 bbl/day	30,000 bbl/day
Gallons per day	140×10^6	270×10^6	810×10^6
Gallons per month	$4,200 \times 10^6$	$8,100 \times 10^6$	$24,300 \times 10^6$
Gallons per year	$50,000 \times 10^6$	$97,200 \times 10^6$	$291,600 \times 10^6$

(3) Water Requirements with unlimited stream flow available. (No water evaporated)

Plant Size	5,000 bbl/day	10,000 bbl/day	30,000 bbl/day
Water make-up (lost)	515×10^3 gal/day	$1,029 \times 10^3$ gal/day	$3,088 \times 10^3$ gal/day
Water taken from and returned to the stream	$83,000 \times 10^3$ gal/day	$166,000 \times 10^3$ gal/day	$500,000 \times 10^3$ gal/day
Total water for plant	$83,515 \times 10^3$ gal/day	$167,029 \times 10^3$ gal/day	$503,088 \times 10^3$ gal/day

e. Waste.

(1) Dry waste)
(2) Liquid waste) Not known at present
(3) Gas waste)

f. Personnel Requirements.

(1) Personnel Requirements of Plant.

Plant Size	5,000 bbl/day	10,000 bbl/day	30,000 bbl/day
Operating Personnel	300	450	1,350
Administrative & Clerical	35	50	150
Total	335	500	1,500

(2) Personnel Requirements for Gas Fields - Not known at present

g. (1) Pipeline Capacity - The pipeline should have the same capacity as the plant; that is, 5,000, 10,000 or 30,000 bbl/day. Also, a 30-day storage capacity should be provided at the plant.

(2) Transportation for by-products.

Transportation of By-Products

Plant Size	5,000 bbl/day	10,000 bbl/day	30,000 bbl/day
Gas Oil	3 tank cars/day	6 tank cars/day	18 tank cars/day

h. Refinery is included in the cost of the plant so the products require no further treatment.

i. Plant Production (Based on M.P.A.C. Report)

Plant Size	5,000 bbl/day			10,000 bbl/day			30,000 bbl/day		
	B/D	B/yr	B/MM cu. ft. gas	B/D	B/yr	B/MM cu. ft. gas	B/D	B/yr	B/MM cu. ft. gas
Gasoline	4,420	1591×10^3	73.66	8,840	3182×10^3	73.66	26,500	9547×10^3	73.66
Gas Oil	580	209×10^3	9.66	1,160	418×10^3	9.66	3,480	1253×10^3	9.66
Total Liquid Fuels	5,000	1800×10^3	83.32	10,000	3600×10^3	83.32	30,000	$10,800 \times 10^3$	83.32

3. Fischer-Tropsch using coal.

a. Processing Plant.

(1) Hydrocol process using fluidized bed of iron catalyst (little information on this process is available at the present time). Alternate process using internally cooled reactors operating under 20 atm. pressure over an iron catalyst as per experimental plant, Bureau of Mines experiment station.

(2) Cost of construction of plant. (U.S. Bureau of Mines figures based on preliminary estimates from Louisiana, Mo.)

10,000 bbl/day - $ 75,000,000
30,000 bbl/day - 225,000,000
50,000 bbl/day - 375,000,000

(3) Steel tonnage required.

10,000 bbl/day - 65,000 tons
30,000 bbl/day - 195,000 tons
50,000 bbl/day - 312,000 tons

(4) No critical material known at present that might affect the size or capacity of the plant. Cobalt for a proven cobalt catalyst would be very critical. The amount of cobalt required has not been determined.

b. Raw Materials.

(1) (a) Bituminous, sub-bituminous, and anthracite coal or lignite.
(b) Iron catalyst - Chemical properties will be established at a later date.
(2) Coal Requirements.

The rank of the coal will determine the quantity required. The following figures are based on bituminous coal (11,900 btu/lb. as received, or 14,000 Btu/lb. MAF). Catalyst requirements have not been accurately determined.

Coal Requirements

Plant Size	10,000 bbl/day	30,000 bbl/day	50,000 bbl/day
Coal req'd per day	5,100	15,400	25,700
Coal req'd per year	$1,836 \times 10^3$	$5,544 \times 10^3$	$9,252 \times 10^3$

(3) Coal Requirements Break-down
Bituminous Coal (11,900 Btu/lb. as Rec'd.)
(All figures in tons)

Plant Size	10,000 bbl/day			30,000 bbl/day			50,000 bbl/day		
	Daily	Annually	20 yrs. life of plant	Daily	Annually	20 yrs. life of plant	Daily	Annually	20 yrs. life of plant
Process Coal	4,500	$1,620 \times 10^3$	$32,400 \times 10^3$	13,500	$4,860 \times 10^3$	$97,200 \times 10^3$	22,500	$8,100 \times 10^3$	$162,000 \times 10^3$
Heat & Power Coal	600	216×10^3	$4,320 \times 10^3$	1,900	680×10^3	$13,600 \times 10^3$	3,100	$1,116 \times 10^3$	$22,320 \times 10^3$
Total Coal	5,100	$1,836 \times 10^3$	$36,720 \times 10^3$	15,400	$5,540 \times 10^3$	$110,800 \times 10^3$	25,600	$9,216 \times 10^3$	$184,320 \times 10^3$
Sub-Bituminous Coal (9500 Btu/lb. as recieved)									
Process Coal	5,600	$2,016 \times 10^3$	$40,320 \times 10^3$	16,900	$6,084 \times 10^3$	$121,680 \times 10^3$	28,000	$10,800 \times 10^3$	$216,000 \times 10^3$
Heat & Power Coal	800	288×10^3	$5,760 \times 10^3$	2,380	857×10^3	$17,140 \times 10^3$	4,000	$1,440 \times 10^3$	$28,800 \times 10^3$
Total Coal	6,400	$2,304 \times 10^3$	$46,080 \times 10^3$	19,280	$6,941 \times 10^3$	$138,820 \times 10^3$	32,000	$12,240 \times 10^3$	$244,800 \times 10^3$
Lignite (7500 Btu/lb. as recieved)									
Process Coal	7,100	$2,556 \times 10^3$	$51,120 \times 10^3$	21,400	$7,704 \times 10^3$	$154,080 \times 10^3$	35,500	$12,780 \times 10^3$	$255,600 \times 10^3$
Heat & Power Coal	1,000	360×10^3	$7,200 \times 10^3$	3,000	$1,080 \times 10^3$	$21,600 \times 10^3$	5,000	$1,800 \times 10^3$	$36,000 \times 10^3$
Total Coal	8,100	$2,916 \times 10^3$	$58,320 \times 10^3$	24,400	$8,784 \times 10^3$	$175,680 \times 10^3$	40,500	$14,580 \times 10^3$	$291,600 \times 10^3$
Anthracite (13,500 Btu/lb as recieved)									
Process Coal	3,970	$1,429 \times 10^3$	$28,580 \times 10^3$	11,890	$4,280 \times 10^3$	$85,600 \times 10^3$	19,820	$7,135 \times 10^3$	$142,700 \times 10^3$
Heat & Power Coal	530	190×10^3	$3,800 \times 10^3$	1,680	604×10^3	$12,080 \times 10^3$	2,730	983×10^3	$19,660 \times 10^3$
Total Coal	4,500	$1,619 \times 10^3$	$32,380 \times 10^3$	13,570	$4,884 \times 10^3$	$97,680 \times 10^3$	22,550	$8,118 \times 10^3$	$162,360 \times 10^3$

c. Power & Steam Requirments.

Plant Size	10,000 bbl/day	30,000 bbl/day	50,000 bbl/day
Power required in addition to waste heat utilization	25,000-41,700 KW	75,000-127,000 KW	127,500-212,000 KW
Steam Required	0	0	0

d. (1) (a) Water Requirments (Minimum Stream Flow Available)

Plant Size	10,000 bbl/day	30,000 bbl/day	50,000 bbl/day
Water (evaporated	$8,070 \times 10^3$ gal/day	$24,220 \times 10^3$ gal/day	$41,220 \times 10^3$ gal/day
Water returned to the stream	$4,040 \times 10^3$ gal/day	$12,110 \times 10^3$ gal/day	$20,400 \times 10^3$ gal/day
Total water required for plant	$12,110 \times 10^3$ gal/day	$36,330 \times 10^3$ gal/day	$61,600 \times 10^3$ gal/day

(b) Water Requirements Breakdown not available at present.
(c) Water required for the process should be fresh water that can be softened.

(2) Cooling Water Circulation Rate with a 33° Rise (estimated). (Using cooling towers)

Plant Size	10,000 bbl/day	30,000 bbl/day	50,000 bbl/day
Gallons per day	240×10^6	720×10^6	120×10^6
Gallons per month	$7,200 \times 10^6$	$21,600 \times 10^6$	$36,000 \times 10^6$
Gallons per year	$86,400 \times 10^6$	$259,200 \times 10^6$	$432,000 \times 10^6$

e. Waste

(1) Dry waste)
(2) Liquid waste) Not known at present
(3) Gas Waste

(3) Water Requirements with Unlimited Stream Flow Available. (No water evaporated)

Plant Size	10,000 bbl/day	30,000 bbl/day	50,000 bbl/day
Water make-up (lost	999×10^3 gal/day	$2,996 \times 10^3$ gal/day	$4,995 \times 10^3$ gal/day
Water taken from and returned to the stream	$166,000 \times 10^3$ gal/day	$500,000 \times 10^3$ gal/day	$830,000 \times 10^3$ gal/day
Total water for plant	$166,999 \times 10^3$ gal/day	$502,996 \times 10^3$ gal/day	$834,995 \times 10^3$ gal/day

f. Personnel Requirements.

(1) Personnel Requirements of Plant

Plant Size	10,000 bbl/day	30,000 bbl/day	50,000 bbl/day
Technical Employees	920	2,750	4,600
Administrative & Clerical	80	250	400
Total	1,000	3,000	5,000

(2) Personnel Requirements of Mines (underground)

Plant Size	10,000 bbl/day	30,000 bbl/day	50,000 bbl/day
Skilled Employees	400	1,225	2,000
Unskilled "	50	150	250
Technical "	25	75	125
*Total	475	1,450	2,375

* If the coal is strip mined, it will take approximately one-third of the total employees shown above, based on 10 tons/man day for underground mining.

g. (1) Pipeline Capacity - The pipeline should have the same capacity as the plant; that is, 10,000, 30,000, or 50,000 bbl/day. Also, 30-day storage capacity should be provided at the plant.

(2) Transportation of By-Products

Plant Size	10,000 bbl/day	30,000 bbl/day	50,000 bbl/day
Alcohols	5 tank cars/day	15 tank cars/day	25 tank cars/day
Gas Oil	6 " " "	18 " " "	30 " " "

h. Refinery is included in the cost of the plant so the products require no further treatment.

i. Plant Production (Based on M.P.A.C. Figures)

Plant Size	10,000 bbl/day			30,000 bbl/day			50,000 bbl/day		
	B/D	B/yr	B/ton of coal	B/D	B/yr	B/ton of coal	B/D	B/yr	B/ton of coal
Gasoline	8840	3182×10^3	1.72	26,520	9547×10^3	1.72	44,200	$15,912 \times 10^3$	1.72
Gas Oil	1160	418×10^3	.22	3,480	1253×10^3	.22	5,800	$2,088 \times 10^3$	.22
Total Liquid Fuels	10,000	3600×10^3	1.94	30,000	1080×10^3	1.94	50,000	$18,000 \times 10^3$	1.94

4. Coal Hydrogenation using Natural Gas for the manufacture of H_2.

The same figures would apply in this case as for coal hydrogenation with the exception of the following:

a. Coal Requirements for Process

Plant Size	10,000 bbl/day	30,000 bbl/day	50,000 bbl/day
Coal required per day	3,100 tons	9,300 tons	15,500 tons
Coal required per year	$1,131 \times 10^3$	$3,395 \times 10^3$	$5,657 \times 10^3$

b. Coal Requirements Break-down

Bituminous Coal, (11,900 Btu/lb as received)
(All figures in tons)

Plant Size	10,000 bbl/day			30,000 bbl/day			50,000 bbl/day		
	Daily	Annually	20-yr life of plant	Daily	Annually	20-yr life of plant	Daily	Annually	20-yr life of plant
rocess Coal	2,226	801×10^3	$16,027 \times 10^3$	6,668	$2,400 \times 10^3$	$48,000 \times 10^3$	11,130	$4,007 \times 10^3$	$80,140 \times 10^3$
eat & Power Coal	874	314×10^3	$6,293 \times 10^3$	2,632	948×10^3	$18,960 \times 10^3$	4,370	$1,573 \times 10^3$	$31,460 \times 10^3$
Total Coal	3,100	$1,116 \times 10^3$	$22,320 \times 10^3$	9,300	$3,348 \times 10^3$	$66,960 \times 10^3$	15,500	$5,580 \times 10^3$	$111,600 \times 10^3$
Sub-Bituminous Coal (9500 Btu/lb as received)									
rocess Coal	2,778	$1,000 \times 10^3$	$20,000 \times 10^3$	8,335	$3,000 \times 10^3$	$60,000 \times 10^3$	13,890	$5,000 \times 10^3$	$100,000 \times 10^3$
eat & Power Coal	1,097	395×10^3	$7,900 \times 10^3$	3,290	$1,184 \times 10^3$	$23,680 \times 10^3$	5,485	$1,974 \times 10^3$	$39,480 \times 10^3$
Total Coal	3,875	$1,395 \times 10^3$	$27,920 \times 10^3$	11,625	$4,184 \times 10^3$	$83,680 \times 10^3$	19,375	$6,974 \times 10^3$	$139,480 \times 10^3$
Lignite (7500 Btu/lb as received)									
rocess Coal	3,525	$1,269 \times 10^3$	$25,380 \times 10^3$	10,575	$3,807 \times 10^3$	$76,140 \times 10^3$	17,625	$6,345 \times 10^3$	$126,900 \times 10^3$
eat & Power Coal	1,739	626×10^3	$12,520 \times 10^3$	5,218	$1,878 \times 10^3$	$37,560 \times 10^3$	8,695	$3,130 \times 10^3$	$62,600 \times 10^3$
Total Coal	5,264	$1,895 \times 10^3$	$37,900 \times 10^3$	15,793	$5,685 \times 10^3$	$113,700 \times 10^3$	26,320	$9,475 \times 10^3$	$189,500 \times 10^3$

Anthracite Coal

Anthracite coal cannot by hydrogenated.

c. Waste

Plant Size	10,000 bbl/day	30,000 bbl/day	50,000 bbl/day
Solid Waste	177 tons/day	540 tons/day	885 tons/day

d. Natural Gas Requirements

Plant Size	10,000 bbl/day	30,000 bbl/day	50,000 bbl/day
Nat. Gas, cu.ft/day	25,700,000	77,000,000	128,500,000

e. Amount of Coal Replaced by Gas

Plant Size	10,000 bbl/day	30,000 bbl/day	50,000 bbl/day
Coal replaced	1,370 tons/day	4,100 tons/day	6,850 tons/day