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OIL SHALE AS A POTENTIAL SOURCE OF LIQUID FUELS

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ABSTRACT

Oil shale is a potential source of liquid fuels, and the vast known reserves in the West have served as an impetus for utilizing this reserve. The economics of a system using oil shale in the production of liquid products is examined in this paper. Included are mining, retorting, and refining to produce the salable product. Capital cost, operating cost, and a financial analysis are detailed.

INTRODUCTION

Oil shale deposits are available in many parts of the world and at one time were one of the major sources of petroleum-like products in several localities. The Scottish deposits were utilized on a commercial scale starting in the 1850's and were still being utilized until about 1964. In this country the Eastern shales associated with coal were used as a source of both oil and gas prior to the Drake well discovery. Between 1916 and 1920 there was a flurry of activity in the Western oil shale fields when there was some feeling that crude oil production was lagging behind an increase in consumption. Imports were available, chiefly from Mexico, but were not sufficient to make up the deficit. The discovery of the oilfields in Oklahoma, California, and Arkansas in the early 1920's, accompanied by the recession in that period, almost completely obviated the experimental effort in Colorado.

The oil shale resources of Colorado, Utah, and Wyoming occur in over 11 million acres and it has been estimated that 1.8 trillion barrels are available (having a grade of at least 10 gallons per ton) under the classification of "known reserves." Recently, interest in these reserves has been reactivated, largely because of the anticipated need to broaden the resource base to supplement conventional crude petroleum. This need to fill the gap between energy supply and demand is anticipated before 1980, by both government and industry.

PROCESS DESCRIPTION

Oil shale must be mined, crushed to a size suitable for retorting, and retorted to produce shale oil; next the shale oil is partially refined to produce a pumpable intermediate product which is then further refined to produce salable products. Figure 1 is a block diagram of a processing scheme developed by Bureau of Mines personnel to produce the products shown in table 1 using 60,300 tons per calendar day of oil shale having an average grade of 30 gallons of oil per ton of oil shale. The scheme consists of the following operations.

The oil shale mined by the room-and-pillar method is dumped into bins located above gyratory crushers which are used to crush the shale to a minus 10.5 inches. The crushed shale feeds by gravity into a 70,000-ton storage bin located underground at the mine site. From the bin the shale passes through the conveyor adit to the crushing units located at the retorts. The secondary gyratory crushers reduce the plus 4.5-inch material to minus 4.5 inches prior to feeding to a tertiary grinding step that further reduces the material to minus 3.5 inches. Screening removes the fines which are conveyed to a briquetting plant, leaving the minus 3.5-inch shale as the feed to the retorts.

Because of the Bureau's background in the development of the gas combustion retort, this type of unit was used in this study. The retorts are sized to process 9,483 tons per stream day of oil shale from which 6,395 barrels of crude shale oil, 56.9 million standard cubic feet of excess low-Btu gas, and 7,360 tons of spent shale and ash are produced per retort. Figure 2 is a schematic flow diagram of the retort operation.

The crude shale oil, which is viscous and will congeal at 80° F, must undergo partial refining before it can be pipelined to a refinery. It, therefore, is fed to a delayed coking unit which consists of a furnace to heat the oil to 940° F; the coking chambers where the oil decomposes into coke, liquids, and vapors having a wide boiling range; a fractionator which serves to separate the vapors and liquids into an overhead product consisting of all products boiling below 693° F; and a heavy liquid product which is recycled to the coke chamber. The overhead product is cooled and depropanized to yield a coker distillate product, 38,220 barrels per stream day, containing all of the C_4 and heavier materials with an end point of 693° F. The uncondensed gases, 17.8 million standard cubic feet per stream day, consisting of C_3 and lighter gases are utilized to produce the hydrogen required in a subsequent operation.

The distillate from the coker is hydrocracked at controlled conditions (835° F and 1,500 psig) to produce a product containing about 60 volume percent of material in the gasoline boiling range. Hydrogen requirements amount to 46.7 million standard cubic feet per stream day.

As shown in figure 3 a liquid-gas separation leads to the recovery of 36,860 barrels per stream day of distillate having an API gravity of 56.9° and a distillation end point of 680° F.

The initial refinery step provides for the recovery of sulfur, ammonia, and petroleum coke as byproducts of the operation.

The marketing area for the final end products was assumed to be in St. Louis, and therefore, the distillate is pumped via both private pipeline and commercial line to the area where standard refinery practices are employed to produce the salable products noted in figure 1.

COST ANALYSIS

The estimated capital investment for the operation as indicated in figure 1 is shown in table 1. It provides for the equipment required in mining, retorting, refining, and pipelining plus the initial catalyst and chemical requirement, interest during construction, and startup expense. Provisions are made for the working capital required for accounts receivable, accounts payable, and a cash reserve.

The approach used in determining the capital investment is one in which all major items of equipment are designed and specified. As an illustration, table 2 is a detailed listing of the equipment required in the retorting section of the plant. In table 3, the cost of this equipment, determined by weight (retort), horsepower (compressor), or length and width (conveyor), is delineated. The remaining cost items which are required to arrive at the total cost for the complete installation are not detailed and are based on factors obtained from definitive estimates for similar installations.

The estimated annual operating cost for this plant is shown in table 4. All items making up this cost are identified including taxes, insurance, and depreciation.

In table 5 financial analysis is made of the plant, taking into consideration both the depletion allowance and a Federal income tax of 50 percent. It indicates a net income of $11,543,350. Using the information contained in both tables 4 and 5, a discounted flow analysis indicates a potential discounted cash flow rate of 9.8 percent.

CONCLUSIONS

The vast reserves of the Western shales can be utilized to supply the needs of this country for many years to come. There are several processing schemes available today which can be utilized to convert the shale to marketable products. One such scheme has been reviewed in this study and from an economic standpoint shows a potential 9.8 percent D.C.F. value.

OIL SHALE PLANT
60,300 Tons Per Calendar Day

TABLE 1. - Capital investment summary

Unit	Capital investment, dollars
Mine	17,585,200
Retort plant:	
Retorting	29,641,700
Briquetting plant	797,000
Crushing and screening plant	2,249,700
Initial refining	39,141,600
Pipeline (includes pumps and terminal storage)	9,341,600
Product refining	14,584,300
Plant facilities	5,373,700
Plant utilities	22,323,300
Total construction	141,038,100
Initial catalyst and chemicals	5,433,100
Total plant cost (tax and insurance base)	146,471,200
Interest during construction	7,323,600
Startup expense	5,000,000
Subtotal (depreciation)	158,794,800
Working capital	26,687,400
Total capital investment	185,482,200

OIL SHALE PLANT
60,300 Tons Per Calendar Day

TABLE 2. - Detailed equipment list, retorting plant

Retort (7 required)

Size: 45' ID x 20' high retorting section.
Type: Bureau of Mines gas combustion retort and the Cameron and Jones[1] improved feeding and discharge mechanism.
Refractory: 9" firebrick, 9" K-30 insulating brick (retort section).
Drive for feeding and discharging: Motor-activated hydraulic.
Hp: 110 top (feed); 200 bottom (discharge).

Rotoclone[2] (42 required)

Capacity: 36,000 cfm.
Drive: Motor.
Hp: 100.
Head developed: 12" water.

Compressor (7 required)

(Recycle and product gas).
Type: Centrifugal.
Drive: Motor.
Hp: 1,730.

Air compressor (7 required)

Type: Centrifugal
Drive: Motor.
Hp: 225.

Electrostatic precipitator (14 required)

Size: 9' ID x 20' high.
Capacity: 75,000 cfm.
Power: 30 kwhr/hr.

Pump (7 required)

(Shale oil to storage).
Capacity: 200 gpm.
Δp: 20.
Drive: Motor.
Hp: 5.

Feed hopper (7 required)

Size: 21' ID x 21' high, 60° conical bottom.
Holdup: 1 hour.
Material of construction: Steel.

Retort feed conveyor (1 required)

Type: Belt.
Size: 54" wide x 325' long.
Drive: Motor.
Hp: 100.

Retort discharge conveyor (1 required)

Type: Belt.
Size: 54" wide x 625' long, no rise.
Drive: Motor.
Hp: 100.

Stacker conveyor (1 required)

Type: Belt.
Size: 2 - 54" belts x 50' long, 12' rise. (extend to each side of main conveyor).
Drive: Motor.
Hp: 25, each side.

1, 2 Reference to specific makes or models of equipment is made to facilitate understanding and does not imply endorsement by the Bureau of Mines.

OIL SHALE PLANT
60,300 Tons Per Calendar Day

TABLE 3. - Equipment cost summary, retorting plant

Item	Quantity	Cost: Material	Cost: Labor	Total cost
Retort	7	$1,886,500	$188,700	
Rotoclone	42	453,000	113,300	
Compressor	7	1,211,000	302,800	
Air compressor	7	157,500	39,400	
Electrostatic precipitator	14	1,400,000	280,000	
Oil pump	7	7,700	1,900	
Feed hopper	7	77,700	7,800	
Feed conveyor	1	62,900	6,300	
Discharge conveyor	1	90,400	9,000	
Stacker conveyor	1	33,800	3,400	
		5,380,500	952,600	$6,333,100
Foundations		538,100	715,700	
Structures		538,100	269,100	
Buildings		215,200	215,200	
Insulation		161,400	322,800	
Instrumentation		376,600	150,600	
Electrical		215,200	161,400	
Piping		2,152,200	1,076,100	
Painting		32,300	80,700	
Miscellaneous		538,100	430,500	
		4,767,200	3,422,100	8,189,300
Total direct		10,147,700	4,374,700	14,522,400
Field indirect				2,187,400
Total construction				16,709,800
Engineering				835,500
Overhead and administration				835,500
				18,380,800
Contingency				1,838,100
				20,218,900
Fee				1,016,800
				21,235,700
Pipelines to refinery				8,238,000
Heat recovery				168,000
				29,641,700

OIL SHALE PLANT
60,300 Tons Per Calendar Day

TABLE 4. - Operating cost

Item	Annual cost, dollars
Pump station power ...2,400 kwhr/hr x 8,760 hr/yr[1] x $0.01/kwhr...	$210,200
Charge for use of water (Colorado) ....150 M gph x 8,760 hr/yr[1] x $0.026/M gal...	34,200
Refinery raw water ....60 M gph x 7,920 hr/yr x $0.10/M gal...	47,500
Pipeline charge ....12,782,300 bbl/yr x $0.31/bbl...	3,962,500
Power ....7,000 kwhr/hr x 7,920 hr/yr x $0.01/kwhr...	554,400
Annual catalyst and chemicals	4,529,900
Direct labor	4,606,500
Direct labor supervision	585,000
Maintenance labor	1,845,800
Maintenance labor supervision	164,200
Maintenance material (100% of maintenance labor)	1,845,800
Operating supplies ....(includes $3,960,000 for mine)...	4,546,200
Payroll overhead ....25% of payroll...	1,800,400
Administration and general overhead	1,542,500
Taxes ....on land and plant....	374,000
Insurance	2,929,500
Depreciation	10,424,900
Total annual operating cost	40,003,500

[1] 24 hr/day, 365 day/yr

OIL SHALE PLANT
60,300 Tons Per Calendar Day

TABLE 5. - Financial analysis

Total Capital Investment	$185,482,200
Annual sales	64,939,000
Annual operating cost	40,003,500
Gross income	$ 24,935,500
Depletion allowance	1,848,800
Taxable income	$ 23,086,700
Federal income tax at 50%	11,543,350
Net income	$ 11,543,350

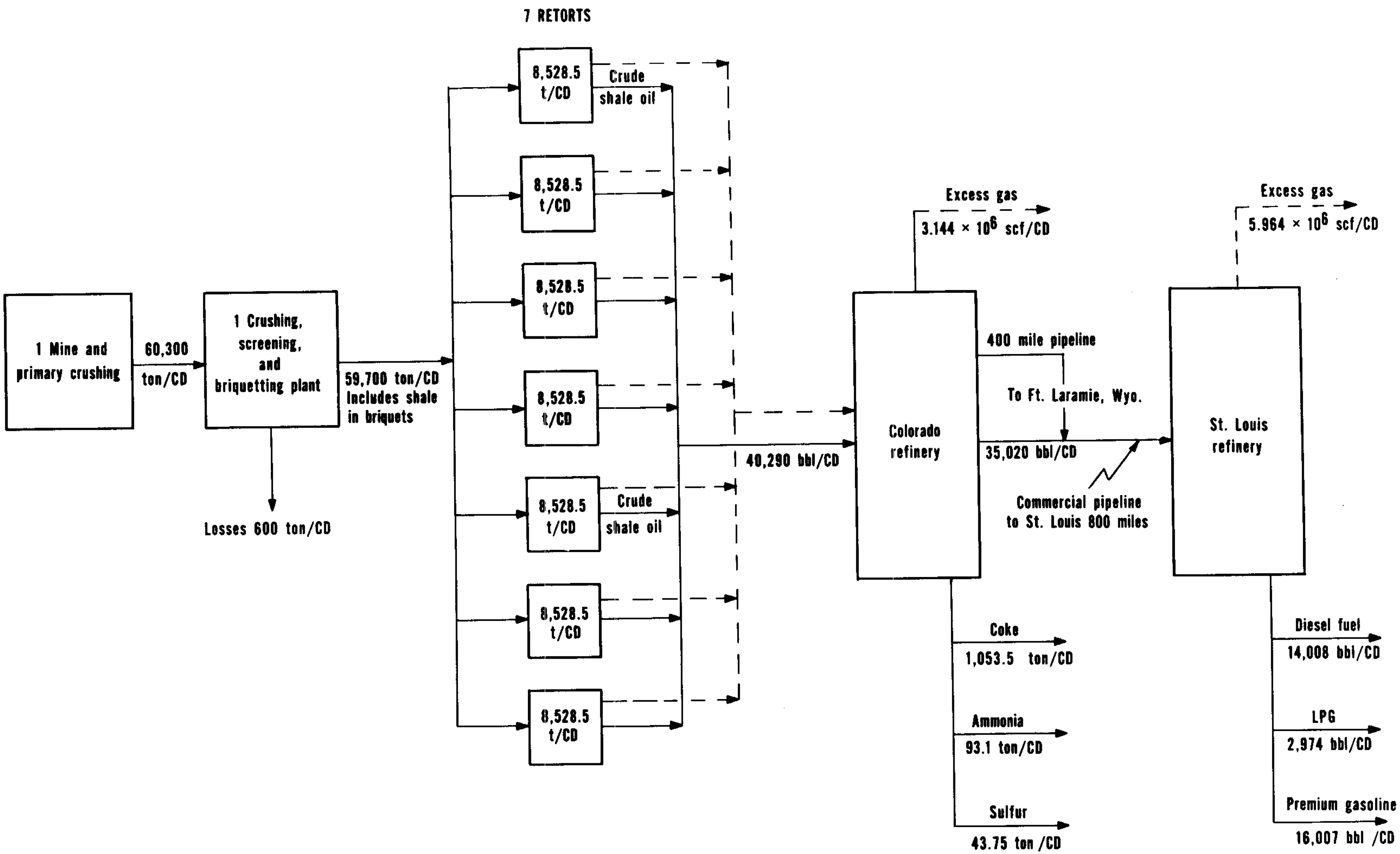

FIGURE 1. - General Block Diagram, Shale Oil Project (1966)

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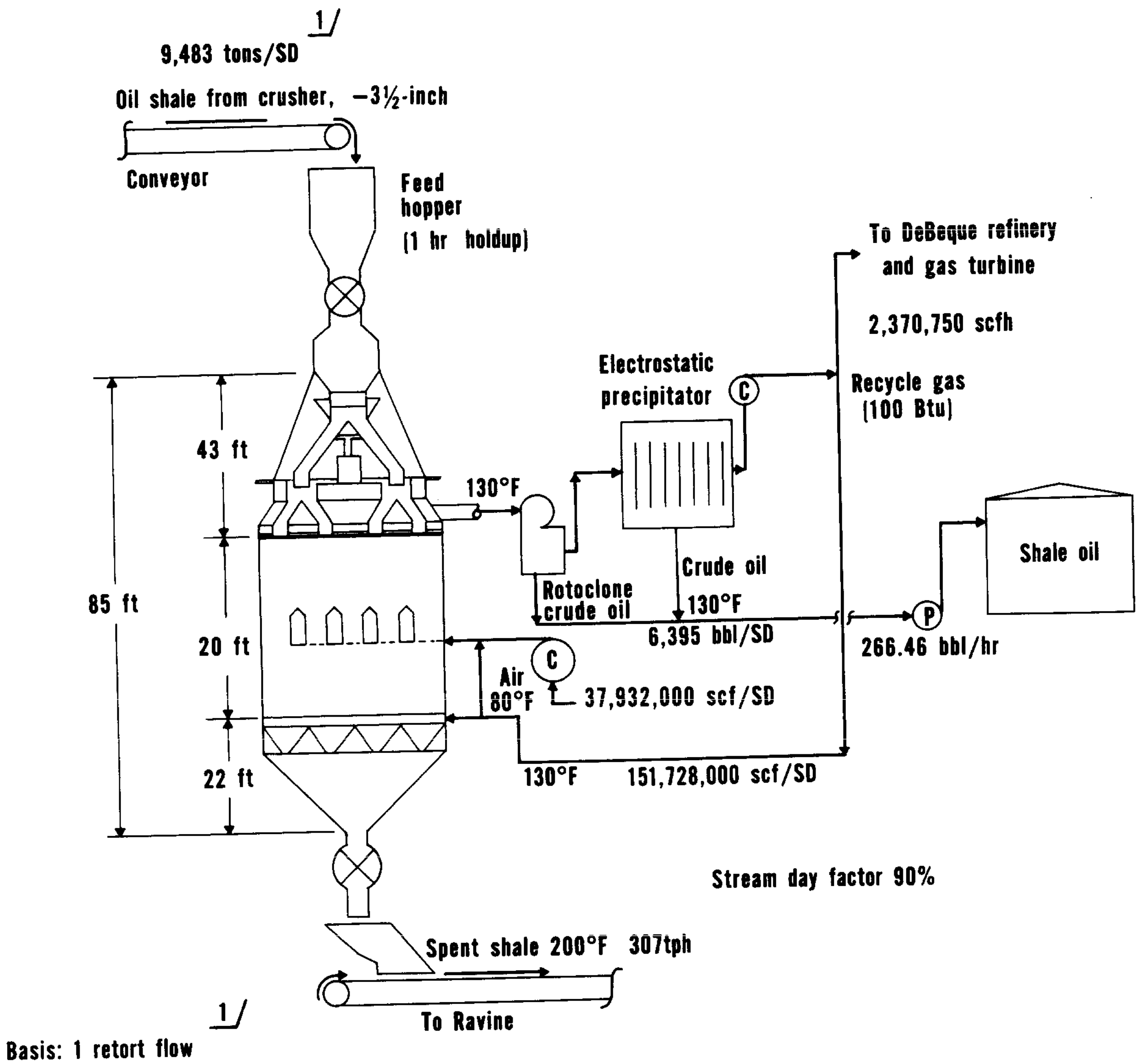

FIGURE 2. - Schematic Flow Diagram, Retorting

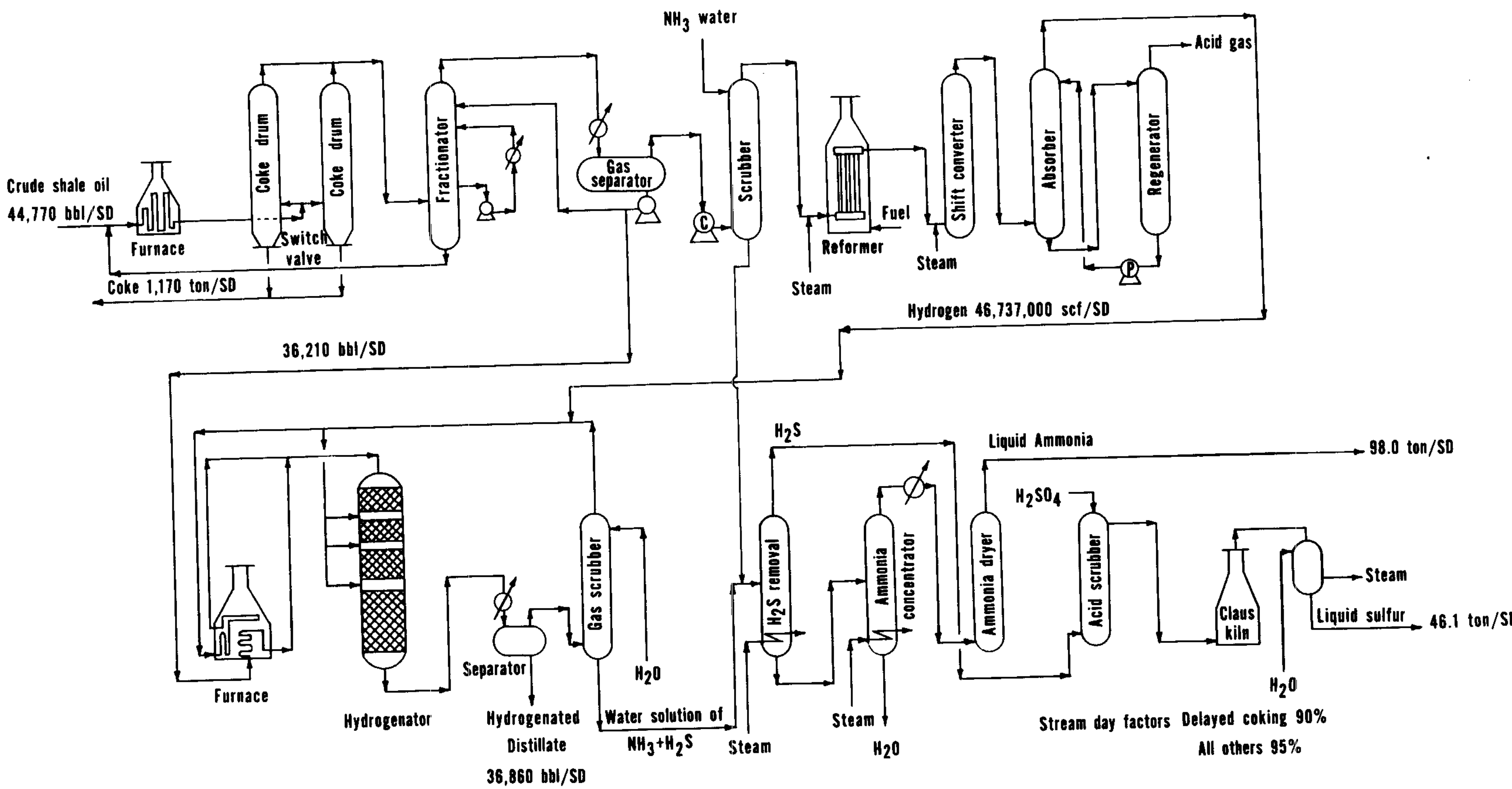

FIGURE 3. - Flow Diagram -- Shale Oil Partial Refining

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