ECONOMIC ASSESSMENT OF THE FUSHUN TYPE COMMERCIAL SHALE OIL PLANT

Li Chunnian (李春年) Yan Guanliang(阎观亮)
Luoyang Petro-chemical Eng. Co./SINOPEC
Luoyang, China

ABSTRACT

Based on the data of commercial operation of Fushun tpye retorting technology and pilot study of shale oil upgrading, the economic assessment of a 500,000 T./yr commercial shale oil plant is presented. This plant comprises oil shale retorting and product recovery, fluidized bed combustion of particulate shale, hydrotreating of shale oil and hydrogen manufaturing. Main product of the plant is synthetic crude, sulfur and ammonium sulfate are its by-products.

Syncrude may be further processed into liquid fuels by conventional refining processes.

The total investment of the shale oil plant of the above mentioned scale is estimated to be 222 MM U.S.D. The cost of syncrude is estimated to be 16.9-24.8 U.S.D/Bl, based on the cost of raw oil shale at 1-2 U.S.D/T. and the assumed DCF rate of return is 10% and 15% respectively.

INTRODUCTION

Oil shale is an alternative energy source for petroleum and shale oil industry is the integral part of energy industry. The people's Republic of China is rich in oil shale deposits, has accumulated extensive experiences in commercial operation of more than a half century in the oil shale industry and can make contribution to the development of oil shale industry for specific country.

Based on the commercial data of Chinese oil shale retorting and pilot study of shale oil upgrading, the economic assessment of a 500,000 T/yr. commercial shale oil plant is presented.

THE PLANT SIZE AND COMPOSITION

The size of the commercial shale oil plant in consideration is 500,000 T./yr. syncrude, 2350 T/yr. element sulfur and 151,000 T./yr. ammonium sulfate as by-products. Annual throughput of raw oil shale (6% Fischer Assay) is 13.30 MM. T.

The plant comprises two sections, i.e, retorting section and shale oil upgrading section.

(1) Oil shale crushing unit

The nominal capacity of the crushing unit is 14 MM. T/yr. The yield of 8-75 mm. process shale after crushing is 83%. <8 mm. particulate shale are used as fuel for FBB (fluidized bed boiler).

(2) Retorting unit

Retoting unit consists of 8 retorting groups. The nominal capacity of each group is 70,000 T shale oil (including light naphtha) per year. The capacity of each retort is 200 T. process shale per day. The oil yield (including light naphtha but excluding light ends) after retorting is 82%, Fischer Assay. On stream factor of the retort is 95%.

(3) Light naphtha stripping unit

Light naphtha is recovered from retorting gas by oil absorption process. The annual production rate of light naphtha is 66,000 T.

(4) Ammonium sulfate crystallization unit

Annual production rate of ammonium sulfate fertilizer is 151,000 T.

(5) Hydrotreating unit

The whole shale oil from the retorting unit is hydrotreated severely in the fixed bed reactor under <400°C and 200-300 Bar. to produce syncrude of low sulfur and low nitrogen content. Annual production rate of syncrude is 528,000 T.

(6) Hydrogen unit

Hydrogen is manufactured by steam reforming process. The capacity of the hydrogen unit is 20,000 NM^3/Hr.

(7) Sulfur recovery unit

Hydrogen sulfide (H_2S) in the tail gas is recovered by Claus process and 2350 T. of sulfur will be produced per year.

(8) Fluidized bed boiler and power generation

The quantity of <8 mm. particulate shale burned is 286 T/Hr., 40 Bar.

steam generated is 310 T/Hr. High pressure steam is used to generate electricity by bleed turbine for process units and general facilities. Medium and low pressrue steam networks are available for process use. Steam and power requirements of the plant is balanced with those internally produced from the combustion of particulate shale.

Fig. 1 is the block diagram of the plant.

ECONOMIC ASSESSMENT OF THE COMMERCIAL PLANT

The economics of the above mentioned shale oil plant will be assessed.

(1) Total capital investment

The basis of the total capital investment estimation are:

I. 1987 costs and the plant constructed in P.R.C.

II. Excluding the capital investment of the shale mining.

III. The working capital of the plant is accounted by 10% of the construction investments of the process units and offsite facilities.

The estimated total capital investment of 500,000 T/yr. shale oil plant (process units, utilites and general facilites) is as following:

	MM. USD.
Construction investment	201.4
Working capital	20.1
Total capital investment	221.5

(2) Production cost of syncrude

The production cost of syncrude includes investment cost, shale cost and operating cost. These costs are estimated respectively.

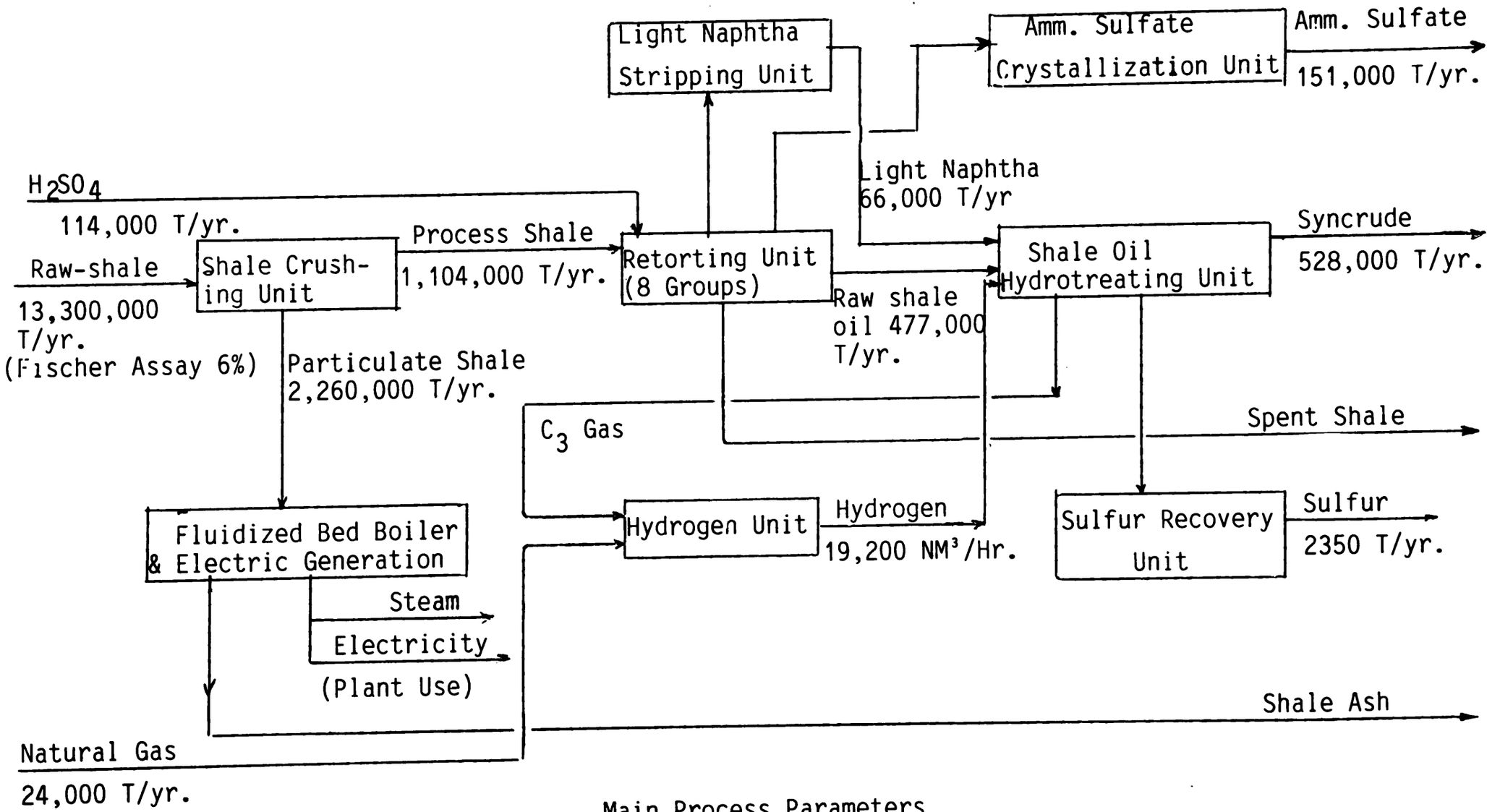
I. Investment cost

The investment cost is accounted on the basis 10%, 12% and 15% of return rate of investment. The results are shown in Table 1.

Table. 1. The investment cost of syncrude

Assumed rate of return, %	The investment cost of syncrude, USD/BL
10	8.6
12	10.2
15	12.9

Fig. 1. The flow diagram of the Fushun-type commercial shale oil plant
(Shale Retorting-Full Boiling Range Shale Oil Hydrotreating Process)



Main Process Parameters

1. Process shale yield after crushing: 83%
2. Oil yield (including light naphtha): 82%
3. Fischer assay of raw shale: 6%
4. Retorting unit on stream facter: 95%
5. Syncrude yield after hydrotreating: 97.3%
6. Hydrogen comsumption: 280 NM^3/T. shale oil
7. Oil yield of raw shale: 24.5 T. shale/T.shale oil
8. Syncrude yield of raw shale:25.2T.shale/T.syncrude

II. Cost of shale

Raw shale consumed is 25.2 T/T syncrude. The shale cost of the syncrude is shown in Table 2.

Table 2. Shale cost of syncrude

Raw shale cost, USD/T	Shale cost of syncrude, USD/BL
1.0	3.7
1.5	5.5
2.0	7.3

III. Operating cost of syncrude

The operating cost of syncrude is estimated on the following basis:

(1) Power and steam requirements are balanced by the power and steam generated by particulate shale burning.

(2) Cooling water system and water treatment facility is available in the plant. Process water is circulated for reuse. Make-up water and fresh water required is 1050 M^3/Hr. (4620 GPM).

(3) Maintenance cost is estimated at 1.5% of fixed assets of process units and general facilities per year.

(4) Chemicals, auxiliary materials costs and by-product price are estimated on Chinese price in USD.

(5) Taxes and insurance is estimated at 2% of fixed assets of process units and general facilities per year.

(6) Labor cost: wage for workers is estimated at 15 USD/man-day; salary for technical staff and managers estimated at 18,000 USD/yr.

The result is shown in Table 3.

Table 3. Operating costs of syncrude

Item	MM USD/yr	USD/BL
1. Feedstock for H_2 making	3.54	0.97
2. Chemicals & catalysts	7.48	2.05
3. Fresh water	1.05	0.29
4. Fuel	3.17	0.87
5. Wages & salaries	3.97	1.09
6. Maintenance	2.32	0.64
7. Taxes & insurance	3.10	0.85
Sub total	24.63	6.76
8. By-product credits		
a. Sulfur	0.25	0.07
b. Amm. Sulfate	7.54	2.07

Sub. total	7.79	2.14
9. Net operating cost	16.84	4.62

IV. The effect of investment cost and shale cost on that of syncrude is shown in Table 4.

Table 4. The cost of syncrude at different rate of return and shale cost.

	Total cost of syncrude, USD/BL		
Assumed rate of return	Raw shale cost at 1.0 USD/T	Raw shale cost at 1.5 USD/T	Raw shale cost at 2.0 USD/T
10%	16.9	18.7	20.5
12%	18.5	20.3	22.1
15%	21.2	23.0	24.8

Note: The operating cost=4.6 USD/BL.

(3) Economic Analysis of the Plant

Table 5. 500,000 T/yr Commercial Plant Economics Summary

	T/D	T/yr
I. Feed and product		
Feed		
Raw Shale (Fischer Assay 6%)	40,270	13,290,000
Product		
1.Syncrude	1602	528,000
2.Amm.Sulfate	460	151,000
3.Sulfur	7.1	2350
II. Economics		
1.Total investment, MM. USD.		221.5
2.Investement cost at 10% rate fo return, USD/BL		8.6
3.Shale cost at 1.0 USD/T, USD/BL		3.7
4.Operating cost, USD/BL		4.6
5.Total cost of syncrude, USD/BL		16.9

The characteristies of syncrude from oil shale are superior to those of most petroleum crude, and a variety of petroleum products may be yielded by conventional refining process. Therefore the syncrude should commend a premium price and the selling price should be over that of conventional crude.

The DCF rate of return of the 500,000 T/yr. commercial shale oil plant is calaulated at different selling prices of syncrude. The results are shown in Table 6. The basis of this economic assessment are as

follows:

I. The construction period of the plant is 3 years. The investment payment during the construction is equal to 25%, 50% and 25% respectively.

II. During the first year of operation, the throughput is 50% of design capacity, 100% in the second year and thereafter.

III. The projected life of the plant is 20 years. The salvage value of the fixed assets is equal to 5% of construction investment.

IV. Sales tax is accounted by 10% of selling income.

Table 6. The DCF rate of return of 500,000 T/yr. shale oil plant

selling price of syncrude USD/BL	DCF rate of return, %
20	12.4
22	14.8
25	18.0

EXPLANATIONS

(1) The mining cost of shale has significant effects on the cost of syncrude and the economics of the shale oil plant. Shale cost make up 20-30% of the total cost of syncrude.

(2) Shale ash utilization is relative to the mineral composition of the shale. Shale ash from Chinese shale may be used for mine filling and raw material for constructional material (cement, haydite and brick) production.

Shale ash utilization can improve economics in oil shale processing industry.

(3) The economic assessment is performed according to the operating data of Chinese oil shale industry. For the grass root plant, the increase in oil yeild and the reduction in energy consumption of the plant can be realized by improving the retorting technology and the automization level, therefore the economic benefits of the plant may be improved accordingly.