SHALE OIL INDUSTRY IN MAOMING

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ABSTRACT

In Maoming, oil shale is open pit mined with annual capacity of five million tons oil shale and is retorted with annual production of 100,000 tons shale oil. Two sets of medium pressure boilers of 35 tons steam per hour have been built. A cement works of 80,000 tons annual capacity using shale ash as raw material are in operation. High quality kaolinite overlying oil shale deposits can be used as coating material for paper making. In Maoming, the production cost of shale oil is lower than the cost of crude oil in international market.

INTRODUCTION

Maoming Petroleum Industrial Corporation, an enterprise under SINOPEC, is a petroleum processing center in South China. Its construction began in 1955. Now a refinery of annual throughput of six million tons of petroleum has been built up, with comprehensive facilities of machinery and equipment manufacturing, pipeline transport, construction and installation, design and research etc. Mining and retorting of oil shale is one of the operations in Maoming. An open-pit mine of annual capacity of five million tons oil shale and a retorting plant of annual production of 100,000 tons shale oil as well as production of cement and other building materials are in operation. Comprehensive utilization of oil shale is also being studied. Fluidized bed and suspension combustion boilers have been developed to utilize particulate oil shale for steam generation in power plants. Shale ash from fluidized bed boiler and retorting plant is used to make cement and building blocks. The topsoil overlying oil shale is

a raw material for quality kaolinite to be used in paper making. The underlying soil, which contains some combustibles, can be used to make bricks. More and more usage of oil shale is being deveolped.

OPEN-PIT MINE

There are rich deposits of oil shale in Maoming, which extends more than 50 km, with a maximum width of 10 km, thickness of 20-25 m. The total shale reserves amount to 5 billion tons. The mining area is located in the southwestern border of Maoming Basin, the deposits being lower Tertiary sediments of monoclinal, gently dipping occurrence. The low burial permits open pit mining. The currently producing Jintang Mine has a reserve of 860 million tons, extending 7 km. The Fischer assay of oil shale is 4-12%, averaging 6.5%. The shale quality does not change much in the horizontal direction.

Table 1. Physical Properties of Oil Shale

Appearance	Yellowish brown	Fusibility	
Bulk weight	1.85	Deformation temp.	1260°C
Specific weight	2.2	Softening temp.	1290°C
Hardness (Shore scale)	14-20	Fusing temp.	1340°C
Compressive strength	250 kg/cm²		

Table 2. Proximate Analysis

Volatile matter	Ash	Carbon dioxide	Moisture	Heating value
V^G %	A^G %	CO_2^G %	W^a %	kcal/kg (dry)
20.12	72.1	1.95	4.84	1745

Table 3. Elemental Analysis (analytical basis)

Carbon	Hydrogen	Oxygen	Nitrogen	Sulfur
C^a %	H^a %	O^a %	N^a %	S^a %
14.04	2.28	5.5	0.47	1.17

Table 4. Fischer Assay (analytical basis)

Shale oil %	Moisture %	Semi-coke %	Gas + loss %
8.28	10.78	76.48	4.46

Table 5. Composition of Ash

SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	CaO %	Na_2O, K_2O, SO_3, etc.%
64.37	22.37	8.17	1.51	0.85	2.73

Power-driven shovels with dipper capacity of $4m^3$ are used for excavation, first the overburden, then the oil shale. Electric locomotive and dump-cars are used for transport to the dump yard and retorting. The annual excavation of oil shale is about 3.5 million tons.

OIL SHALE RETORTING

Two types of retort, gas combustion rectangular retort and cylindrical retort with gasification section are used.

The operation conditions of Maoming retorting plant with an annual throughput of 100,000 tons are as follows:

Table 6. Operating Conditions of Retorting

		Cylindrical retort	Rectangular retort
Shale Fischer assay	%	6.24	6.7
Shale moisture	%	16.53	17
Shale size	mm	12-125	12-125
Throughput per retort	t/day	146	185
Air per ton shale	Nm^3/t	133.5	325
Recycle gas	Nm^3/t	975	
Off-gas	Nm^3/t	1169	1395
Recycle gas temperature	°C	574	
Oil yield (against Fischer assay)	%	60.2	60
Surplus gas	Nm^3/t	15	385
Heating value	$Kcal/Nm^3$	1500	614

SHALE OIL PROCESSING

Table 7. Properties of shale oil

Specific gravity d_4^{20}	0.9122	Asphaltene %	1.54
Engler distillation °C		Gum %	43
IBP	214	Conradson carbon %	2.2
10% distil off	259	Elemental annalysis	
30% distil off	306	C %	84.82
50% distil off	350	H %	11.40
		S %	0.48

Viscosity, Centistokes, 50°C	9.6	N %	1.10
Solidification point °C	30	O %	2.20
Paraffin %	13.2	C/H	7.40

Shale oil from retorting used to be processed by thermal cracking, giving 10.5 % cracking gas and LPG, 28% gasoline, 16% diesel fuel, 45% fuel oil, 0.5% loss. Gasoline was marketed after acid-alkali treatment.

Since processing of crude oil has taken up the full capacity of refinery plants, shale oil is now marketed directly as fuel oil. Testing of catalytical cracking of crude shale oil to produce more light fractions is under way.

LIQUID AND SOLID WASTE DISPOSAL

Retorting waste water after interception of oil, aeration and biochemical treatment can be used partly for cooling shale ash in ash trough, and the remaining is sent to drainage.

Most of shale ash along with overburden in open-pit mining is transported to dump yard, where land reclamation by tree-planting is carried out.

Phenols, pyridines, corrosion inhibitors etc. are recovered from acid and alkali sludges.

COMPREHENSIVE UTILIZATION OF OIL SHALE

Comprehensive utilization of oil shale is important in making full use of natural resources, reducing environmental pollution, achieving economic results,to the advantage of developing oil shale industry. Our programs include utilization of particulate oil shale and shale ash, utilization of topsoil overlying shale, utilization of underlying coal and other deposits.

1. Fluidized Bed Boiler

Testing on fluidized bed boiler burning oil shale fines below 8mm which can not be utilized in Maoming retorts, was carried out from 1964 to 1966 to generate steam in power plant. Trial operation on a 14 tons boiler showed that stable combustion could be achieved with particulate oil shale below 8mm (heating value 1158 kcal/kg, moisture 16.3%). 1.3 tons of 12 kg/cm^2 steam were generated for each ton shale,

the thermal efficiency of boiler being 77%.

Oil shale was charged by belt feeder continuously in fluidized bed. Air entered the bottom through a tuyere. Shale ash was discharged from overflow outlet for preheating air. Flue gas passed through convection section and economizer upward the stack.

Table 8. Operation parameters of boiler

Shale charge	t/hr	9.8
Shale size	mm	8
Shale moisture	%	16.3
Shale heating value	kcal/kg	1158.6
Air consumption	Nm^3/t	1460
Bed temperature	°C	744-755
Flue gas temperature	°C	180
Steam generation	t/hr	13
Steam pressure	kg/cm^2	12
Steam temperature	°C	258
Boiler thermal efficiency	%	77

The successful trial operation of fluidized bed boiler opened a new way of utilizing low grade fuel. Two sets of medium pressure boiler of 35 tons steam per hour are now in trial operation, and a 12000 kw generator is being built. A power plant of 50000 kw burning oil shale with 3 sets of fluid bed boilers and 2 sets of generators is scheduled.

2. Shale ash cement

The hydrous kaolinite in shale when decomposed is chemically active, especially for fluidized bed with a lower burning temperature the shale ash has higher activity and can be used as cement blend.

Table 9. The composition and activity of shale ash

SiO_2 %	Al_2O_3 %	Fe_2O_3 %	CaO %	MgO %	SO_3 %	Soluble SiO_2 %	Soluble Al_2O_3 %	Lime absorption
58.92	26.75	11.2	0.43	0.98	0.08	2.45	17.91	35.58

Cement clinker can be blended with different amounts of shale ash, with its properties changed as shown in the following table.

Table 10. Properties of Cement

Blending ratio	cement clinker	100	90	80	70
	shale ash	0	10	20	30
	gypsum	3	4	4	4
Stability		pass	pass	pass	pass
Tensile strength,	kg/cm² 7 days	28.61	27.34	29.8	28.63
	28 days	26.36	33	37.73	33.18
Comperessive strength,	kg/cm² 7 days	490	568	502	441
	28 days	583	691	737	642
Set time, hr	initial set	2:07	1:54	1:38	2:40
	final set	3:08	3:25	3:2	3:40

It can be seen that the cement blended with shale ash has satisfactory strength. Shale ash is now commonly used as blending material in cement works in Maoming and other places near the railway. Addition of 15-25% of shale ash can produce siliceous cement and pozzolanic siliceous cement.

In addition, shale ash can also be used to replace clay as cement raw material to an amount of 20%. The total amount of shale ash used in cement production accounts for 40-50% of raw material.

Pozzolanic cement of grade 500 is produced in a cement works of 80000 tons annual capacity in Maoming Petroleum Industrial Corporation. Its capacity will be expanded to 300000 tons and more shale ash will be used.

3. Shale ash in making building blocks

Silicate building blocks of grade 150 can be made from shale ash mixed with a little lime and gypsum by pressurized forming and steam curing.

Table 11. Properties of Building Blocks

Mixing ratio	Shale ash %		92.8	90.4	88
	Lime %		6	8	10
	Gypsum %		1.2	1.6	2.0
	Water %		38.3	39.2	38.1
Strength:	Natural state	Compressive kg/cm²	156	156	204
		Tensile kg/cm²	42.4	33.7	30.8
	Saturated state	Compressive kg/cm²	136	148	188
		Tensile kg/cm²	43.2	42.8	52.5

4. Quality kaolinite

Quality kaolinite exists in the topsoil overlying oil shale deposits. The kaolinite belongs to Miocene of Tertiary Period, being a

secondary deposit formed by flushing, transport and deposition of weathered feldspar and quartz sandstone. Samples were collected by channelling on mining surface and analyzed. Testing by research institution of paper-making industry showed that Maoming kaolinite is a high quality coating material for paper-making.

Table 12. Kaolinite as Coating Material

Chemical composition of kaolinite								
Al_2O_3 %		SiO_2 %		Fe_2O_3 %		Ignition loss %		
38-38.5		45.5-46		0.3-0.5		13.7-13.9		
Particle size								
<0.2	μ	<2	μ	<5	μ	>10	μ	
5-6	%	85	%	9.9	%	0	%	
Brightness	87-88							
Yellowness	1.4-1.8							
Concentration yielding viscosity 500 mPa s, %						71-72		
Maximum solids content in coating composition, %						60		
Attrition rate mg		4-6						
Luster 75°C, %		63-69						

The kaolinite from Jintang Mine shows a pseudohexagonal electron diffraction pattern or a scale structure with good crystallinity.

The iron content in kaolinite is no greater than 0.5%, titanium content no greater than 0.2%. The iron content is reduced by 30-40% after bleaching.

No special stripping technique is required for this fine kaolinite. There is very little quartz and no montmorillonite, pyrophyllite nor allokite, which is conducive to low viscosity and attrition.

Table 13. Properties of Coated Paper

	1	2
Solids content in coating composition, %	60	49
pH	8.5	8.5
Viscosity 60rpm mPa.s, 27°C	1230	812
Amount of coating, g/m²	20	20
Brightness, %	86.1	92.9
Smoothness, %	705	1020
Luster 75°C %	69	66
Speed giving broken filament cm/s	77	71

Testing has shown that kaolinite from Jintang can be made into a good coating composition for paper making. A pilot plant is being built.

5. Underlying Mud

The underlying mud, which contains a little combustibles can be used for making bricks without external fuel. This mud is now used in neighboring counties.

At the bottom of oil shale deposit there are thin-layered carbonaceous shales, which are mined and used by local industry or for domestic.

Retort sludge mixed with powdered coke and pulverized oil shale can be shaped into honeycomb briquet for rural households.

PROSPECTS

The deveolpment of shale oil industry depends on its production cost. Comprehensive utilization of oil shale will be conducive to effective use of natural resource, reduction of production cost, and abatement of pollution.

In the immediate future we will try to achieve more from the present production capacity (Fig. 1). The annual production of 5 million tons oil shale should be better utilized. Oil shale of bigger size accounts for 2.5 million tons, which are sent to retorting to produce shale oil. The shale charge should be first properly dried to enhance retorting and reduce waste water discharge. Further processing of shale oil into quality products should also be done. The under-size oil shale will be used as boiler fuel. More shale ash will be used as cement blend and raw material for making building blocks. We will try to produce more kaolinite to achieve better economic results. This will contribute to develop a technically feasible, economically profitable industry with full potential of progress.

The production cost of shale oil in China is lower than the cost of crude oil in international market, about $16 per barrel. The production cost can be reduced by 10%, if discarded under-size shale can be utilized for boiler fuel. Electric energy obtained from combustion and shale ash utilization up to 10% of total amount can reduce the cost of shale oil by 10% and 8% respectively. If by-roduct coal, mud and kaolinite are taken into account, the reduction in shale oil cost may be as high as by 30-40%.

The present low oil price discourages the effort for finding

alternate fuel. Nevertheless, the production cost of crude oil will inevitably increase with diminishing oil reserves. The rich resources of easily exploitable oil shale, comparable properties and similar processing techniques of shale oil, will make shale oil a promising alternate fuel, if its production cost can be further reduced.

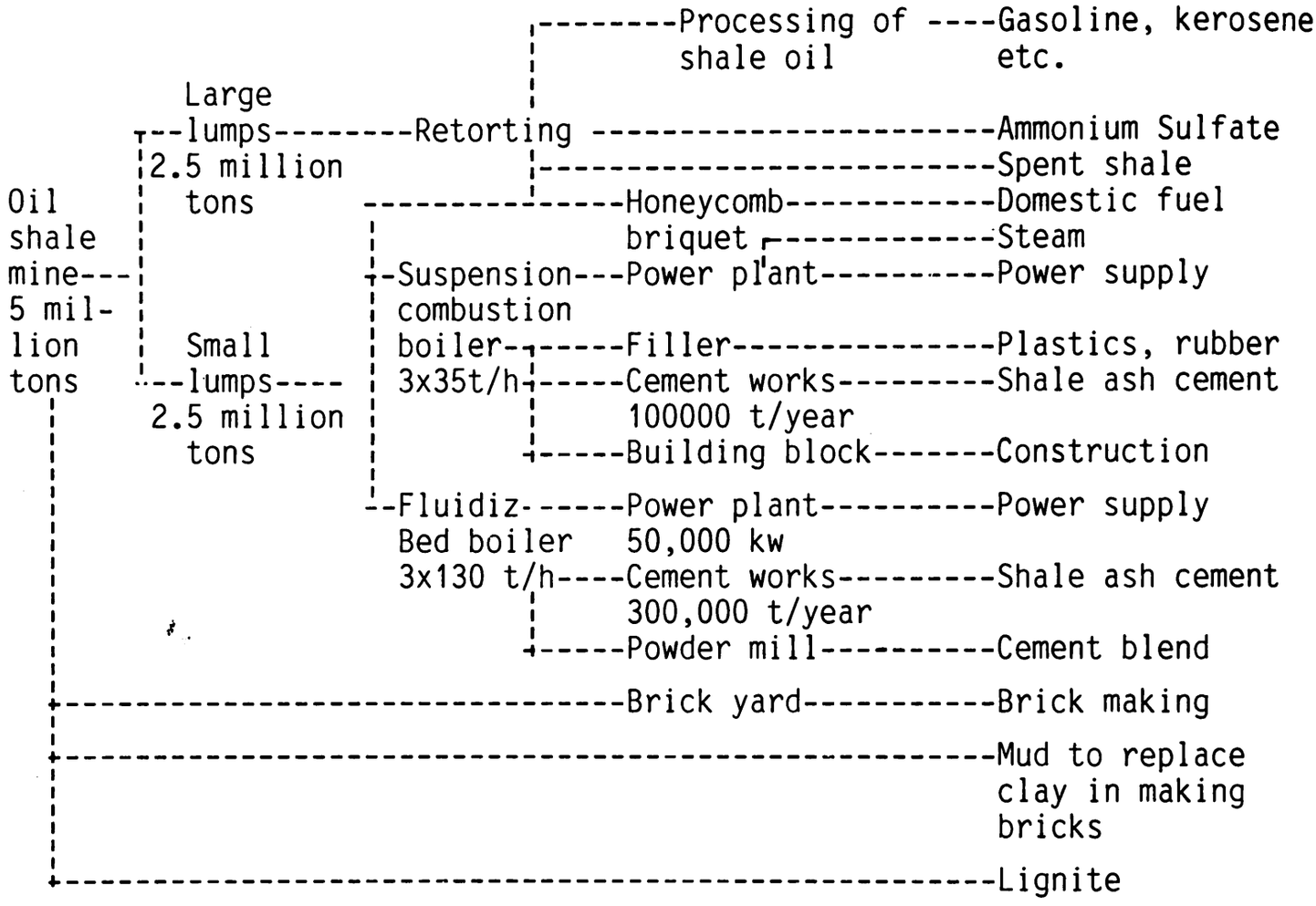

Fig. 1.