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April 1, 1979.

Mr. Tammachart Siriradhanakul,
Director of Regulatory Division,
National Energy Administration.

Dear Mr. Tammachart,

Re: OIL SHALE

(TRANSLATED INTO ENGLISH FROM "PETROTECH"
OF THE JAPAN PETROLEUM INSTITUTE)
AUTHOR: MR. MINORU ENOMOTO
NATIONAL RESEARCH INSTITUTE
FOR POLLUTION AND RESOURCES

I present you Mr. Minoru Enomoto's paper subjected "OIL SHALE" which I translated into English during the holiday. Some engineers in NEA and Ministry of Industry have interested in oil shale, so I want to deliver this translated paper to the above gentlemen. I request your permission.

(1) Oil shale reserves in Thailand

800,000 Bbl (Equivalent crude oil)

When Thai refinery capacity is 1,000,000 BPSD, and 20% of crude oil is replaced by shale oil, Thailand can be used 11 years.

800,000,000 Bbl ÷ (1,000,000 BPSD x 20%) = 4,000 days
= 11 years

1,000,000 BPSD crude thruput will be in 2000.

(2) Quality of Thai oil shale is very high.
(see ATTACHED information)

	Colorado	Thailand
Oil Recovery	10.7	20.1

I appreciate if it would be useful for you.

Sincerely yours,

Y. Kawase

OIL SHALE

TRANSLATED INTO ENGLISH FROM "PETROTECH"
OF THE JAPAN PETROLEUM INSTITUTE
(PUBLISHED ON SEPTEMBER 1978)

AUTHOR: MR. MINORU ENOMOTO
NATIONAL RESEARCH INSTITUTE
FOR POLLUTION AND RESOURCES

CONTENTS

OIL SHALE

TRANSLATED FROM "PETROTECH"
OF THE JAPAN PETROLEUM
INSTITUTE

AUTHOR: MINORU ENOMOTO
National Research Institute
for Pollution and Resource

I HISTORY OF OIL SHALE

History of oil shale is very old and for the first, the patent which shale oil is recovered by heating was submitted in England in 1964. Shale oil was recovered by improved process of English patent in France in 1938, then in Scotland in 1850. They had been operated before the crude oil discovery in USA in 1859. Then small scale of shale oil production is commenced in Australia in 1865, Brazil in 1881, New Zealand in 1900, Switzerland in 1915, Sweden in 1921 and Estonia in 1921.

But these countries suspended shale oil production, because oil fields were discovered in all over the world and cheap oil was produced according to the promotion technics of exploitation and production especially in USA. But shale oil production has been continued in Estonia (USSR) and Fushun (Red China).

As well-known fact, in 1973, crude oil price was increased for 3 eimes in advance, so promoted countries faced the crisis. For the reason, development of substituted resources for crude oil has been accelerated. It is possible to compete with utilization of coal and oil shale which are placed at a disadvantage in cost compared with crude oil. Especially, USA abounded of crude oil resource, but in present state of affairs crude oil reserves are going down, a stand point of self-supply energy, SNG production from coal and synthetic oil from oil shale are highlighted again.

Japan has not a lot of energy source himself, so a view point of having various energy source, Japan is studying about coal, solar energy, subterranean heat, tar sand and oil shale (but Japan has no tar sand and oil shale).

II OIL SHALE RESOURCE

According to Duncan's definition[2] of the oil shale, the oil shale is shale which has minute structure and contains of organic matter which is much different by region, and oil is produced from shale by pyrolysis. The origin is various according to produced areas, but mostly remains of fresh-water weed and seaweed would be pile up in the mud, and formed oil shale.

Color of oil shale is black, brown, grey, yellow or orange according to production area, in many cases thin layers are heaped up and constructed accumulated layer. Photograph of Fig.1 shows Thailand oil shale in the right hand side and American oil shale in the left hand side.

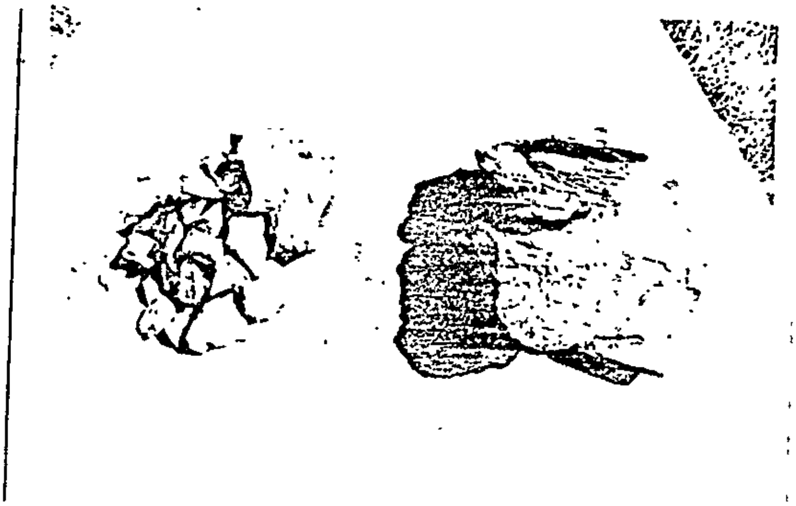

Fig.1 Oil Shale Ore

As shown on TABLE 1, kerogen (organic matter) content is big different[3] in accordance with production area. A stand point of the industry, shale which 10~15 gal/ton oil can be produced by pyrolysis is regard as oil shale. C/H ratio of kerogen is 7~8 and bituminous coal is 13~15, so kerogen has double hydrogen compared with bituminous coal. It means that oil production from oil shale is easier than from coal by pyrolysis.

Reserves of oil shale are not perfectly investigated, and its reserves is big changed with oil content range which would be considered as oil shale. TABLE 2 shows Bureau of Mines data which was presented in 1965[4].

TABLE 1 COMPOSITION OF OIL SHALE ORE

	Oil Shale Raw Ore (wt%)					Kerogen (wt%)				
	Organic Carbon	Total Nitrogen	Total Sulfur	Ash	Inorganic CO_2	Oil gal/t	Organic Carbon	Organic Hydrogen	Ash	C/H
Alaska	53.86	0.30	1.50	34.1	0.1	139.0	83.28	11.48	1.5	7.3
Argentina	8.88	0.26	0.48	82.6	4.5	14.2	51.66	6.60	34.9	7.8
Australia	81.44	0.83	0.49	4.4	0.1	200.0	83.58	10.69	1.7	7.8
Brazil	12.79	0.41	0.84	75.0	0.6	17.8	64.88	8.52	12.5	7.6
Canada	7.92	0.54	0.70	84.0	2.4	9.4	54.78	5.57	33.4	9.8
Colorado (USA)	12.43	0.41	0.63	65.7	18.9	27.7	66.38	8.76	12.9	7.6
France	22.25	0.54	2.32	66.3	8.4	25.0	70.47	6.45	17.7	10.9
New Zealand	45.69	0.78	4.79	32.7	0.1	66.2	63.89	7.48	9.9	8.5
Oregon (USA)	25.83	0.51	2.20	48.3	0.2	48.0	47.32	6.00	36.2	7.9
Scotland	12.33	0.46	0.73	77.8	3.2	22.2	67.61	7.62	18.6	8.9
South Africa	52.24	0.84	0.74	33.6	0.9	99.8	81.14	9.12	1.3	8.9
Spain	26.01	0.55	1.68	62.8	2.3	46.9	61.08	7.04	26.0	8.7

TABLE 2 RESERVES OF MAJOR PRODUCTION COUNTRIES

Countries or Region	Equivalent Crude Oil (MM Bbl)
Argentina	400
Australia (inc. Tasmania)	270
Brazil	800,000
Balkan and Middle Europe	340
Burma	2,000
Canada	50,000
Chile	20
China	28,100
England	1,000
France	425
West Germany	2,000
Israel	20
Jordan	45
Sicily	35,000
Luxembourg	700
New Zealand	560
Congo	100,000
Republic South Africa	130
Scotland	580
Spain	280
Sweden	2,500
Thailand	800
USA	2,200,000
USSR	
Estonia and Leningrad	22,000
Other European Russia	13,000
Siberia	80,000
Total	3,340,000 (658,193)*

Note:* Crude oil reserves as Jan. 1, 1976.

In TABLE 2, total shale oil which would be produced from more than 10 gal/t contained oil shale. Oil shale reserves are existed all over the world, but crude oil and oil sand reserves are omnipresent. USA has the biggest reserves of oil shale, the next is Brazil and the third is USSR. Total oil shale reserves is 530,000 MM KL equivalent crude oil, as compared with 90,000 MM KL crude oil reserves, it is almost 6 times. The literature[5] said that oil shale reserves which is including undiscovery but anticipatory resource of oil shale is 54,000,000 MM KL equivalent crude oil all over the worl. In any event, enormous resource of oil shale is distributed certainly all over the world.

III THE SITUATION OF DEVELOPMENT

III.1 Mining

According to oil shale deposit, there are the surface and the underground mining and moreover an in situ retorting has been studied mainly in USA.

Green River formation which stretches over Colorado, Utah and Wyoming is 44,000 Km^2, and has oil shale deposit which can be produced 600,000 MM bbl equivalent crude oil.[6), 7)] Mahogany zone which is along the famous Colorado Valley has deposit of 30 gal/t, and the deposit being in existence above 500 m depth from the ground surface, so experimental digging which is the room and pillar method has been operated from 1946.[8)]

It was reported that 2,730 t oil shale was produced in Estonia region of USSR in 1967, and a half of them was produced by the surface mining, and another half by the room and pillar method.[9)]

At Irati formation which is located in Parana Province, Brazil, is covered by 30 m thickness soil, so after covered soil is taken off, the surface mining is carried out and 2,200 t/day shale is retorted by Petrosix process.

In fusion (China) of former Manchuri, the surface mining of coal was carried out, but 5,400 MM t oil shale is accumulated above the coal layer. For the coal surface mining, oil shale must be taken off. The oil content of oil shale is only 6%, so it is poor ore, but the cost of oil shale mining must be included in the cost of coal mining, consequently the cost of oil shale mining is for nothing, furthermore spent oil shale can be used as filler for hole of coal mining.[11] Just after the 2nd world war, Manchuri was taken over by China, and China continues the oil shale mining.

In USA, oil shale deposit is comparatively deep from the surface of the earth, hence the cost of mining is high and the restoration of minining hole by the spent oil shale is required much money. And a stand point of environment destruction the in situ retorting would be advantage if efficiency of oil recovery was going on effective. In USA, Bureau of Mines, Sinclair oil and other companies have been developed the in situ retorting about 20 years ago.

III.2 In Situ Retorting

The oil shale deposit is artificially fractured by high pressure air,[12] hydrolic power,[13] electric current,[14] detonator,[15] and nuclear explosion,[13] and fractures is successful in opening passages for gas flow, then dry distillation is carried within fractures by combustion of fuel gas or heated hot gas. Sinclair[39] process which was developed in 1953 was fractured by high pressure air, but gradually passages of gas flow was becoming difficult.[12] Bureau of Mines study many processes[38] how to make good passages for gas flow, the study carried out by using oil shale deposit model from nearly 1960. As the result of the study, the best way is that at first the deposit was drilled, then cracks along the oil shale formation were made by electric current, then cracks are expanded by high pressure air, after that explosive compound was filled up in cracks and passages for gas were made by explosion.[16] Study of nuclear explosion is the cheapest way for huge scale fracture but radio-active contamination of the earth and water is indispensable and kerogen may be decomposed into hydrogen and carbon according to very high temperature.[17]

Recently, the most powerful process is RISE PROCESS. At first, a conventional horizontal tunnel is made and volume of the tunnel is about 20% of the ore deposit, then the ore bed of above tunnel is crushed by explosion, according to explosion 20% of passages for gas are made.[18] In this case, oil shale which is come out by digging the tunnel is dry distillated on the ground. Nevertheless 6 - 9 $/Bbl oil is expected to produce from oil yield 20 gal/t ore which is in 400 ft thickness ore deposit. Occidental Petroleum Company has conducted similar RISE PROCESS[19] since 1972. Other process, Equity Oil[37] has made field test of the in situ retorting by using steam through natural passages of gas since 1968, and Bureau of Mines has made the field test[20] of same way since 1970, but there are still experimental stage. Till the in situ distillation is commercial operation, technics of making uniform size of oil shale and uniform passages of gas should be developed, and improvement of product yield by the in situ distillation and effective rate of mining of reserves resource and other technics should be desolved.

III.3 Distillation on The Ground

Until a recent date, reliable oil recovery process from oil shale is pyrolysis of ore on the ground. Experiments of kerogen extraction by solvent was tested. For instance, Thomas used 14 Kg/cm^2.G CO_2 for elimination of Ca, Mg, Fe, Al and other matals from Colorado oil shale, and kerogen was concentrated, ash was de creased to 3%.[21] Same purpose, acetic acid, HCI, HF and etc. were used.[22] Vitorovic and others tested an extraction of kerogen by using several organic solvents from Yugoslavian oil shale, and they reported that the most effective solvents were cyclohexanol (extraction rate 38.6%), aniline (52.6%), tetraline (32.1%).[23] But, the solvent which can extract 98% yield has not been discovered at present, so the best way for recovery of organic matter from ore is pyrolysis for the time being.

Guthrie[24] enumerated that retort fulfils as following conditions: (1) continuous operation (2) bigger retorting capacity (3) Process energy should be self-supplied by perfectly recovery of waste heat and chemical energy (4) initial cost should be lower (5) operation should be more simple and easier (6) consumption water should be smaller (7) wide range of ore grain diameter could be used efficiently (8) no pollution. Among these conditions, (7) is expecially important, the most suitable size to be retorted is selected from crushed oil shale for the purpose of stable operation, hence the smaller size grain must be retorted by another way. When process of powdered oil shale retorting is applied, cost of energy for

TABLE 3 FEATURE OF TYPICAL RETORT

		Country	Retort Type	Heat Carrier	Diameter of Grain	Pyrolysis Temp. °C	Operation	t/day/unit	Reference
1	NTU retort	USA	Vertical Cylinder	Flue Gas	-	-	-	-	16)
2	U.S.B.M gas combustion retort	"	"	"	1/4 in.	ca 800	1940 ~ 1950	150	16), 35)
3	Union Oil retort								16)
	a) "A"	"	"	"	1/8 in.	-	1957 ~ 1958	1,200	16)
	b) "B"	"	"	Circulation Gas	"	"	"	-	16)
	c) SGR retorting system	"	"	"	"	"	1975 ~	1,500 (schedule)	16)
4	Paraho retorting process	"	"	Fuel Gas (and Circulation Gas)	1/2~3in.	-	1973 ~ 1975	400	6), 26)
5	TOSCO II retorting system	"	Rotary	Ceramic Ball	~1/2 in.	510 - 640	1972	1,000	25), 6)
6	Lurgi-Ruhrgas process	Germany	Screw	Waste Shale	1/4~1/3in.	ca 550	1963	20	16)
7	Petro SIX process	Brazil	Vertical Cylinder	Circulation Gas	-	< 400	1970 ~	2,200	28), 29)
8	GGS retort	USSR	"	(Flue Gas Producer Gas)	-	ca 800	New Operating	20 ~ 185	30), 9)
9	Chamber oven	"	Vertical Chamber	Flue Gas (Shell heating)	-	ca 800	"	500~1,000	30), 9)
10	UTT retort	"	Rotary	Waste Shale	Powder-Grain	Oil 470-520	1960 ~	500	9)
11	Fushun dry distillation Furnace	China	Vertical Cylinder	(Flue Gas Producer Gas)	20 ~ 50 (mm)	ca 550	1939 ~	200	11)

crusher would be higher, and when spent oil shale is thrown away, it is the problem that spent oil shale is scattered.

Types of retort are (1) vertical cylindrical vessel type (2) rotary kiln type (3) screw furnace type (4) chamber oven type. And heating methods are (a) internal combustion method (b) external combustion method (c) combination of (a) and (b). And heat carriers for heating are classified into: (A) flue gas (B) circulation gas (C) solid heat carrier. At present, more than 10 kinds of retort which are combination of the above mentioned retort type, heating method and heating carrier are used as commercial size plant or test plant. These retorts are listed up in TABLE 3. Four kinds of typical retort which have actual result are explained as follows:

III.3.1 TOSCO II retort system[6), 16), 25)]

After Oil Shale Corp. tested for 24 t/day pilot plant, Standard Oil and other one company organized Colony Development, and he installed 1,000 t/day plant at Parachute Creek of Piceance Basin, and operated till 1967. Then Atlantic Richfield joined with him and 1,000 t/day field test had been carried out till 1972. Fig.2 shows flowsheet of field test.

A rotary kiln utilizing ceramic balls heated in external equipment accomplished the retorting. Conventionally mined oil shale is crushed to ½ in or less, and is preheated and pneumatically conveyed through vertical pipes by hot flue gases from the ball heater. The preheated shale enters the retort (rotary kiln) simultaneously with the heated balls, retorting the oil shale at a temperature of about 900°F (482°C). The mixture is then passed over a trommel screen to separate the balls for recycling through the ball heater, and the processed oil shale is cooled and compacted as a land fill with subsequent revegetation. Compared to the other above surface processes, the TOSCO II process is highly developed and offeres advantages of high oil yield and a product gas undiluted by products of combustion.

Oxygen does not come in the retort, so oxydized products are very small, and liquified hydrocarbon yield is 99%. Whole oil shale which is less than ½ in size can be retorted, but

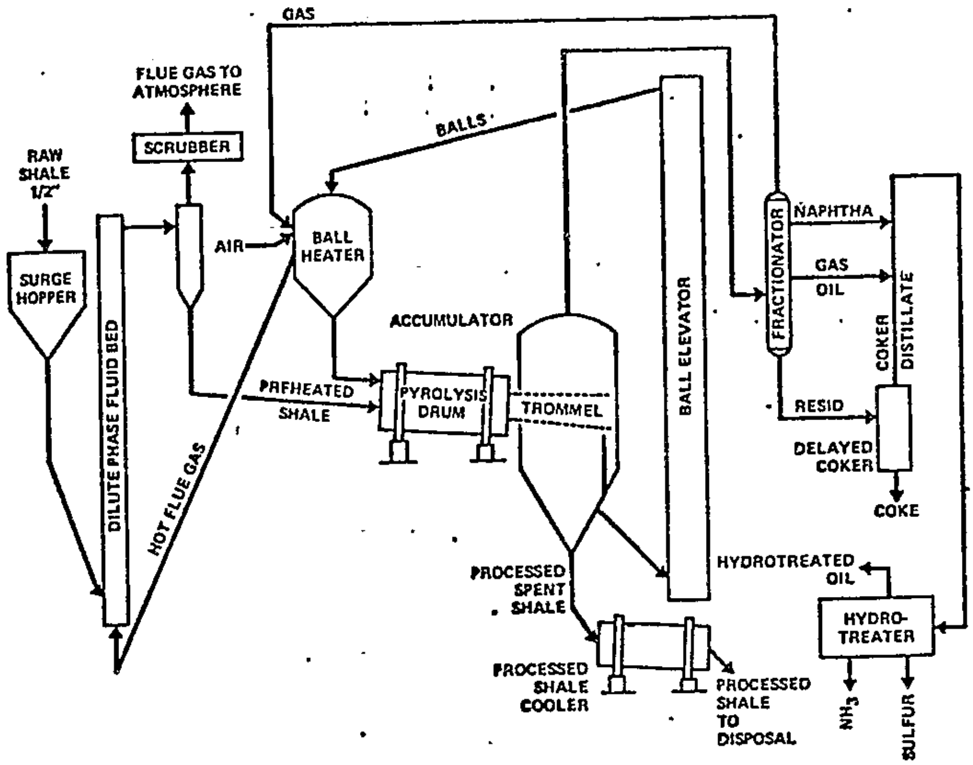

Fig. 2—Tosco II process.

it has a defect of very high cost of crushing, and the plant is very complicated and movable parts are too much so many troubles are come out and ceramic balls are worn out.

III.3.2 Paraho retort[6), 26)]

In USA, oil shale retortings on the ground were developed by individual organization for several years ago. Afterward, the Paraho project, a joint venture with 17 industry sponsors of energy and engineering companies, has been formed to test a modified vertical kiln retorting technics at the government Anvil Points experimental facilities in 1974 and the test plant capacity is 400 t/day.

The novel feature of the Paraho patented technology is the injection of combustion air at more than one level within the bed of shale in a counter-flow vertical kiln (Fig.3). This feature is said to permit control of the time-temperature relationship during retorting and also permits lower maximum bed temperatures than would otherwise be necessary. Except for the multiple zones for combustion, the process closely resembles the gas combustion process developed by the US Bureau of Mines.

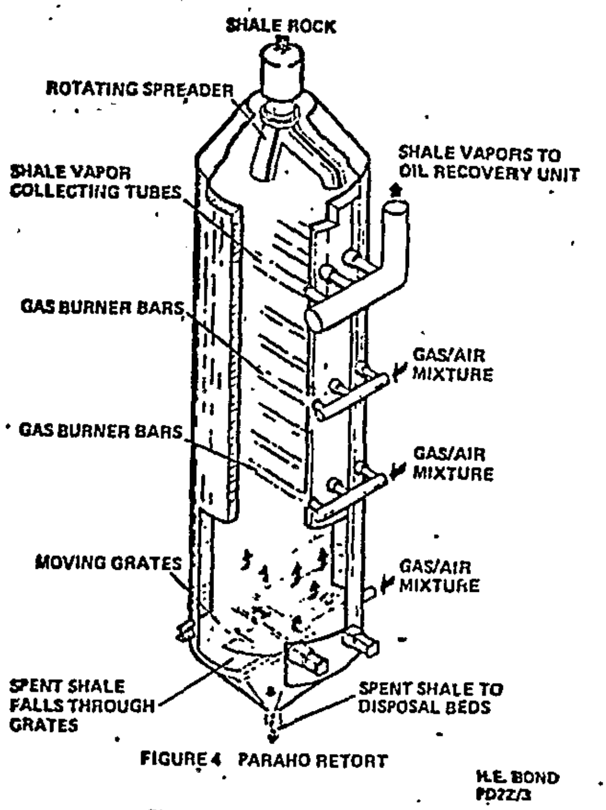

Fig. 3—Paraho retort.

Fig.3 shows that gas and air mixture is sent to the retort from separated three spots which are located below the middle of kiln and flue gas is contacted with shale counter current as the above mentioned. The upper gas burner produce high temperature combustion gas for pyrolysis, the middle gas burner is for recovery chemical energy of burning carbon which is produced in pyrolysis zone, gas and air mixutre which is injected to lower is recovered latent heat of spent shale. Grates of bottom for discharge of spent shale and separated into 3 gas burners system are patents of Paraho, but detail mechanisms are unknown. Shale size is wide range of ⅛ ~ 3 in, but powder which is less than ⅛ in can not be retorted, so it must be retorted by another process. The process is the internal combustion, thus heat value of by-product gas is very low. The gas is only used as own (processing) fuel. Therefore, the external combustion process is studying at the same time. It is said that 11,500 t/day test plant which is based on the result of 400 t/day plant is planning.

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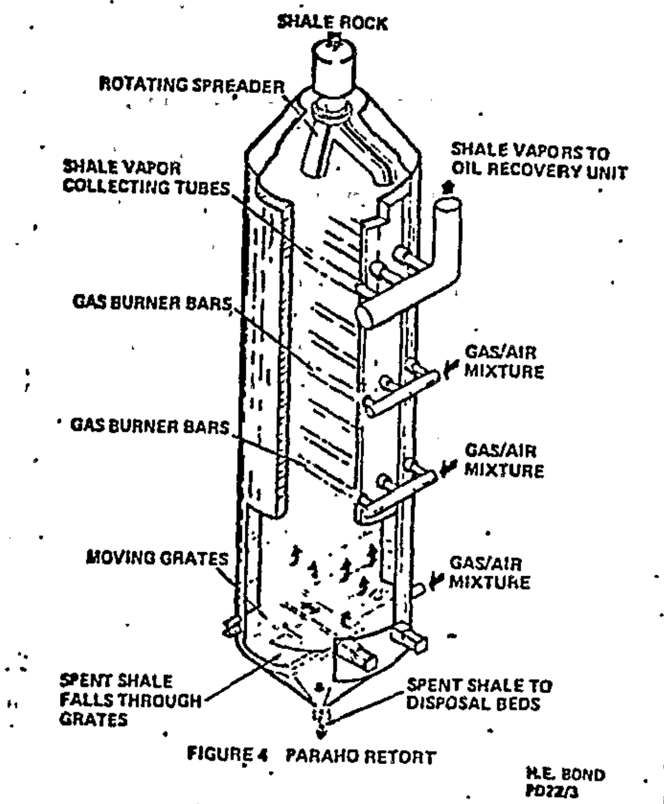

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III.3.3 Petrosix process[28), 29)]

Petrobras, Brazil, installed and is operating the semicommercial plant of 2,200 t/day. The charge stock of oil shale is produced from Irati formation near state of Parana, Brazil. From the semicommercial plant 1,000 bbl/day oil, 36,500 m^3/day of fuel gas, 17 t/day of sulfur and ammonia are produced. Fig.4 is shown the process flow diagrams. The process is very similar to Paraho retort construction but it is different that circulating gas is heated outside. The feature of external combustion process is that pyrolysis is carried out in reducing atmosphere so good quality of oil which is not contained oxydized products is available, and by-product gas has high alorie, but carbon on the spent shale is not recovered and powdered oil shale is difficult to retorting.

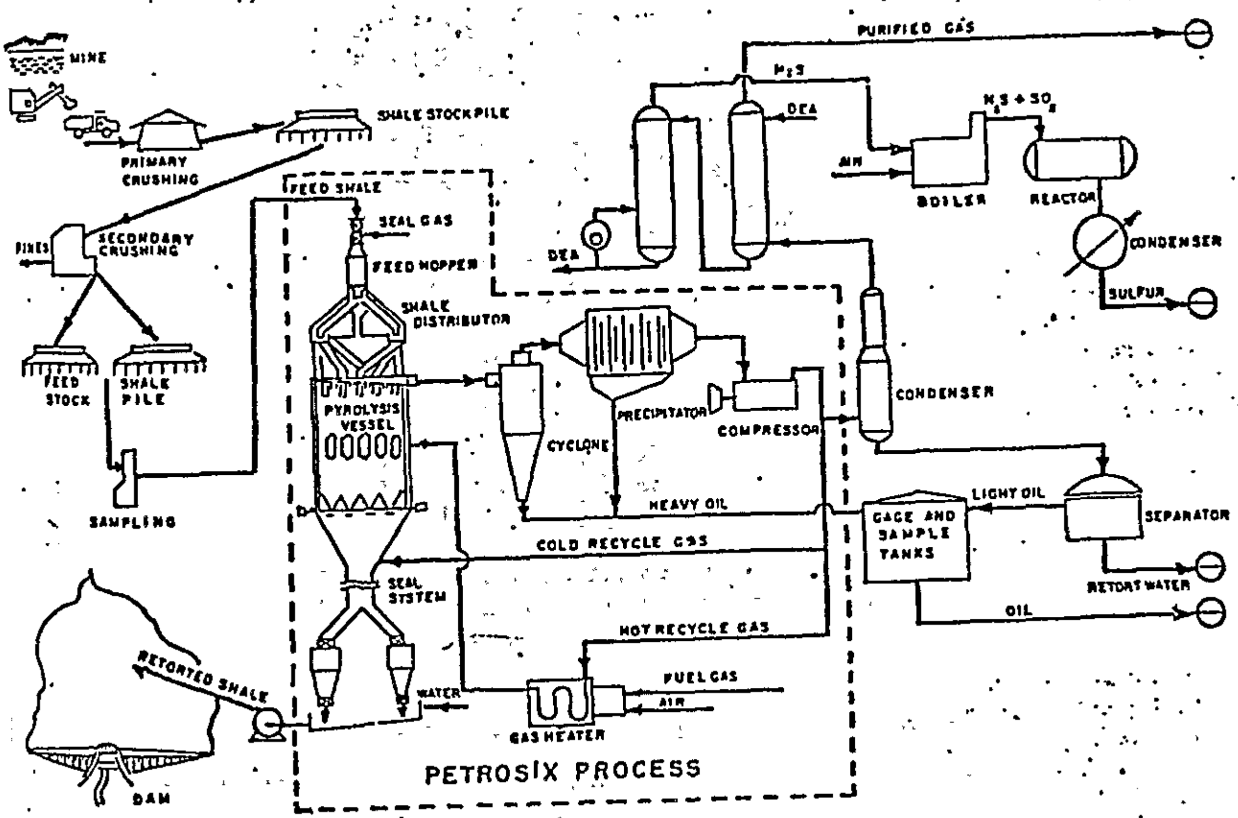

Fig.4—Petrosix and process flow diagrams.

III.3.4 GGS (Gas Generator Shaft)[9), 30)]

In Estonia, USSR, there have been industries which are utilized oil shale for long years ago. Oil shale is still used for town gas manufacturing and electric power generation. Oil shale utilization in Estonia side was 18,000,000 t and in Soviet side was 5,500,000 t in 1970.[9)] As the retort is mainly GGS chamber oven type and 60% of total oil shale is retorting by GGS. Contents of organic matter in Estonia oil shale is 31-36%, therefore powdered oil shale is directly fired for boiler of electric power station, and fly ash is utilized for cement and building materials.

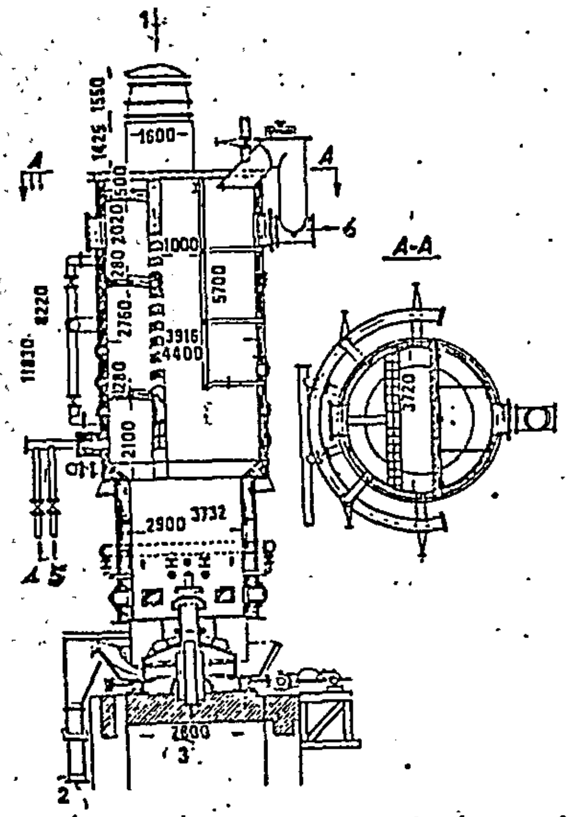

Fig.5 -Gas generator with the cross-flow heat carrier. 1, Oil shale; 2, ash; 3, steam-air mixture; 4, gas; 5, air; 6, air-gas mixture.

GGS process is shown in Fig.5. Oil shale is continously charged from the top, and spent oil shale is discharged from the bottom. Air and fuel gas mixture burns in combustion chamber which is located in the middle, and the flue gas is sent to 2 parts of retort, and the flue gas and oil shale are cross-flow, and the pyrolysis is carried out at about 800°C. Carbon on high temperature spent ash is recovered as water gas by air and steam. The process is very similar with Fushun retort (in red China) which was installed by Japan. This process is internal combustion process, so heating value of gas is low about 1,000 Kcal/m^3 and oil yield is 15 ~ 16% on charged oil shale and 26 ~ 31% of oil is phenols.

IV CHARACTERIZATION OF SHALE OIL

Characterizations of produced oil and by-product gas from 2 kinds of retort are shown in TABLE 4.

TABLE 4 CHARACTERIZATION OF PRODUCED OIL AND BY-PRODUCT GAS

	B.M. Gas Combustion Process[36]	TOSCO II[34]
Oil		
Specific Gravity (60°F/60°F)	0.927	0.927
Pour Point (°C)	29.4	27
Viscosity (cSt)(38°C)	18.5 (54°C)	22
Elementary Analysis wt%		
C	—	85.1
H	—	11.6
N	2.11	1.9
O	-	0.8
S	0.68	0.9
Oil Recovery %	86.2	100
ASTM Distillation		
IBP °C	184	<93
10 %	258	135
30 %	352	260
50 %	431	
Gas		
Composition vol%		
O_2	0.2	—
N_2	62.2	—
CO	2.6	2.88
CO_2	25.2	14.33
H_2	4.3	33.65
H_2S	-	2.50
Hydrocarbon	5.5	46.63
Heating value (Kcal/Nm^3)	1,089	7,275

Characterization of produced oil and gas are changed according to dry distillation temperature, atmosphere of heat carrier and different kinds of oil shale. In case of internal combustion process, oxygen comes in the system so phenols and oxidized organic matters are much, and polymerization is carried out accordingly produced oil is heavier (Bureau of Mine Gas Combustion Process). In case of external heating of circulation gas, it is in reducing atmosphere so oxygen and nitrogen is small in the produced oil but carbon on the spent ash and latent heat of it are difficult to recover (TOSCO II).

Characteristics of Khafji crude are as follows: specific gravity is 0.886, pour point is -12.5°C, viscosity is 12.4 cSt (50°C), ASTM distillation test is Initial Boiling Point (IBP) 26°C, 10% 114°C, 30% 239°C and sulfur content 2.9%. Comparison with Khafji crude and produced oil from oil shale is as follows: Produced oil from oil shale is (1) high pour point (-4 ~ 34°C), (2) high nitrogen content (1 ~ 2%), (3) high oxygen content (about 1%), (4) high IBP (100°C), (5) low metal content (example of USA[9]): Ni 6.4%, V 6.0%, Fe 108.0 ppm).

V REFINING OF SHALE OIL

Produced shale oil is distillated by atmospheric distillation unit (topping unit), but sulfur content of each distillate is very high, because sulfur content of shale oil is very high, for instant USSR shale oil is contained of 2-3% sulfur and about 1% nitrogen,[32] so sulfur and nitrogen must be eliminated. The retorting of oil shale must be carried out near the oil shale deposit, but it is benefit that produced shale oil is sent to refinery which is closed to consumption region, therefore pour point and viscosity of shale oil must be reduced.

Recently, shale oil refining process which is considering by USA, USSR and Brazil is the separation of light fraction by the atmospheric distillation unit (topping unit) at first, then residue of topping unit is cracked into light fractions and coke by coker. 50,000 BPD synthetic crude and by-products of 850 t/day ammonia and 43 t/day sulfur are produced by Bureau of Mines'process from 52,000 BPD shale oil. Characterization of synthetic crude which is produced by topping unit and coking unit is shown in TABLE 5,[9] but example only. Metal contents of coke are very low, but more effective production process of synthetic crude manufacture such as hydrocracking (as well as denitrogenation, desulfurization) must be developed.

TABLE 5 EXAMPLE OF SYNTHETIC CRUDE

	Crude Shale Oil	Synthetic Crude
°API	28.0	46.2
Pour Point °C	24	10
S Content wt %	0.8	0.005
N_2 Content wt %	1.7	0.035
Viscosity (SUS 38°C)	120	40

VI THE POINT AND PROSPECT OF DEVELOPMENT

It should be pointed out that the manufacture of shale oil, processing of mining, crushing, dry distillation, refining and spent ash disposal are necessary. Ratio of energy for processing and energy content in products on TOSCO II process was estimated.[33] Necessity energy fro processing is consisted of research and development, plant election, capital cost of wear and tear (consumption) relacted production. Output energy divided by input energy is 8.8 when 35 gal/ton shale is mining by the room and pillar process, capacity is 100,000 BPCD and 20 years operation. The ratio is compared with other energy production processes as TABLE 6, the developing of oil shale has a good possibility.

TABLE 6 ENERGY PRODUCTIVITY OF REFINING PROCESSES

Process	Out-put/In-put
Oil Production from Off-shore	14.9
Oil Shale Dry-distillation	
above ground	8.8
under ground	15.0
Tar Sand	15.9
Coal (USA Eastern Coal)	55
Coal Gasification	1.4
Secondary Recover in Oil Field	1.9

As the above mentioned, oil shale development is worth and progressed technology is practicable, inspite of USSR and China have commercial plants, West European country has not yet commercial plants, the reason is because of the high production cost and environment assessment.

Production cost of pipeline grade of synthetic crude and initial investment are as follows: (Paraho is based on data of 200 BPD test plant).

TABLE 7 PRODUCTION COST AND INITIAL INVESTMENT

Process	Capacity BPD	Production Cost $/bbl	Initial Investment $10^9$$	Remark
Paraho[27)]	100,000*	11.5	1.2	in 1976
TOSCO	48,000	9.26**	1.0	in 1975
ERDA	300,000	-	***	planning completion in 1985

* pipeline grade

** excluding profit

*** Estimated initial investment of 50,000 BPD plant was $0.4 \times 10^9$$, but 3 years later it was going up $1.2 \times 10^9$$.

Production cost of shale oil would compete with 13 - 15 $/bbl crude oil, but initial investment is very high, thus there are big risk concerning with crude oil price. In USA, high quality oil shale is deposited in national property. US government is negative for release the land because of environmental destruction. Thus enterpriser can not industrialize according to the big risk and US government negative. At present, 8 enterpriser groups have plan of the project, and they endeavor to get indemnity for risk from US government.[27)]

In USA, spent oil shale back to shaft is not considered at present, spent oil shale will be disposed to open space, so water spray and afforestation must be necessary to prevent ash flying. In Estonia, USSR, powdered oil shale is burnt directly at electric power station, and air pollution of dust and SO_x is big problem.[9)] Environment assessment regulation is becoming severe year by year, so when oil shale project is realized, countermeasure of environmental assessment should be unavoidable, thus production cost of shale oil should be going up according to construction of environmental assessment unit.

Required process water for dry distillation on the ground is 3~4 bbl/bbl synthetic crude and for dry distillation underground is 1~2 bbl/bbl synthetic crude. Above mantioned water must be secured. And another big problem is that pollution of drainage when water is sprayed on disposed spend shale oil.

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ATTACHMENT: Mr. M. Enomoto's information

In the present time, petroleum is one of the most important raw materials in producing fuels and petro-chemical products. The world petroleum reserves are, however, reported to expire in the near future. Then, the next available fossil resources will be coal, oil sand and oil shale. Although we do not have a large reserve of oil shale in Japan, there is a large amount of oil shale throughout the world, As Japan is obligated to assist the technical developments in utilizing fossil resources owned by developing countries, we, Petroleum Processing Division, are carrying out the study on oil shales from overseas.

An experimental retorting unit was constructed, in which oil shales from fifferent sources can be pyrolized varying retorting conditions such as temperature and the atmosphere of carrier gas. The product, crude oil, is analysed to clearify the relationships between the oil properties and retorting conditions. Based on the data, we aim at developing a new efficient retort.

The main themes in upgrading shale oil are denitrogenation, desulfurization and lightening of shale oils without the deposition of carbon.

Presently, we are carrying out experiments using oil shale from Thailand and Colorado, USA.

Oil shale retorting system

The batch retorting system (capacity 10 kg/one charge) was constructed to obtain such amount of oil shale that various kinds of analyses are possible for the evaluation of the shale oil. The retorting chamber, 60 cm (width) x 60 (depth) x 5 (height), heated with electric furnace to the max. of 800°C, can rotate within the degrees of 180° to facilitate the charging and discharging of oil shale.

Various kinds of gases, such as mitrogen, air and hydrogen, are introduced into the chamber to study the effect of a carrier gas on the oil properties.

Some of the data concerning the properties of shale oil obtained, using the above-mentioned retort in the presence of nitrogen as a carries gas, are given in the following:

Sources of oil shale	Colorado	Thailand
Shale oil properties		
Oil recovery (wt%)	10.7	20.1
Sp. gr. (50.0°C)	0.867	0.832
Pour point (°C)	25	37.5
Viscosity (cSt)	5.3	4.7
Sulfur content (wt%)	0.79	0.76
Nitrogen content (wt%)	1.66	0.97
Distillation (wt%)		
lower than 200°C	10.8	11.0
200° - 300°	21.2	16.7
300° - 400°	26.9	28.9
400° - 500°	33.4	34.5
residual oil	5.7	7.9
loss	2.0	1.0
Spent shale residual carbon wt%	12.4	12.1
By-product gas composition vol%		
H_2	22.6	30.8
CO	7.9	8.5
CO_2	32.8	15.9
H_2S	1.3	1.0
CH_4	18.3	26.3
C_2 - C_5	17.1	17.5

J K G H I

(G)

June 16, 1979

Request Technical Assistance for New Project

Project Title Additional Refinery Capacity for Thailand

Requesting agency National Energy Administration (NEA)
Ministry of Sciences Technology and Energy.

Proposed Sources of Assistance:

JAPAN;

1. Background

Petroleum products constituted 82 percent of the entire energy consumption in 1978 in Thailand. Total national consumption for petroleum products in 1978 was approximately 11,526 x 10^3Kl. The structure of petroleum consumption can be classified in percent of volume on total petroleum products consumption in 1978, is as follows :

diesel oil	34.02
fuel oil	34.43
motor gasoline	20.03
kerosene	2.30
JP-1, JP-4	6.83
LPG	2.39

At present, there are three local petroleum refineries with the combined nominal capacity of 165,000 barrels per stream day or 8,643 x 10^3Kl per year, actual crude oil thruput is 182,000 barrels per stream day or 9,750 x 10^3Kl per year in 1978. These refineries are private enterprises and produced about 78 percent of the country's need in petroleum products in 1978. In 1978, Thailand spent 795 million US dollars for crude oil and 245 million US dollars for the imported petroleum products. The entire amount accounted for 20 percent of the total import value. About 58 percent in value of the imported petroleum products was diesel oil. Before the energy crisis in 1974, the annual growth rate for petroleum products in Thailand was 16 percent. The demand for petroleum products is increasing at the growth rate of approximately 12 percent and would reach 16,863 x 10^3Kl per year or 322,000 barrels per stream day in 1980.

Due to the fact that the existing refineries are deficit to meet demand. Thailand is in urgent need of additional refinery capacity. If construction of expansion of existing refinery and/or new refinery is commenced soon, the construction might be completed in 1983 at the earliest. If so, additional capacity needed might be about 200,000 barrels per stream day in 1983. Therefore, installation work of expansion and/or new refinery should be commenced in urgent.

2. Details of the Project

2.1 Program goal

- To set up the optimum plan for increasing the refinery capacity in Thailand over a period of 5-15 years ahead

- To provide the computer program (s) used in the study

- Training the counterparts (NEA's staff) to have the capabilities to revise or updating the plan and computer programs.

2.2 Project objective

The project objective is to give recommendation to NEA and provide training facilities to its staff concerning the optimum plan and schedule to increase the refinery capacity in Thailand. The Study will identify locations, processes, crudes, products pattern and the comparative cash flow of each alternative in order to achieve the most benefit to Thailand within a period of 5-15 years.

2.3 Conditions expected at completion of project

If the study is completed, the Government will use the result of this study as guide line or setting up oil refinery policy in the future.

2.4 Recommended sources of information and data

2.4.1 Basic data and information supplied by NEA.

2.4.1.1 Statistical data of consumption, production, import and export of petroleum in Thailand and others.

2.4.1.2 Historical demand, origin and type of crude oil.

2.4.1.3 The capacity of existing petroleum refinery industries and yield pattern.

2.4.1.4 The past pattern of demand and supply of petroleum products, listing individual products.

2.4.1.5 The past pattern of import and export of petroleum products, listing individual products.

2.4.1.6 The consumption pattern of petroleum by economic sectors for the previous 5 years.

2.4.1.7 Specification of petroleum products required by the laws and analysis of petroleum products in the market..

2.4.1.8 Studies of petroleum product demand forecast made by NEA up to A.D. 2000.

2.4.1.9 Natural gas sales schedule and heating value, LPG production schedule from natural gas and C_{5+} production schedule from natural gas treament unit, not including condensate from gas well platform.

2.4.1.10 Thailand energy consumption.

2.4.1.11 Country economic development plan.

2.4.1.12 Other information and data.

a. import CIF price of each crude oil.

b. demurrage of crude oil tanker.

c. crude oil import business.

d. exrefinery price of each petroleum product.

e. import CIF price of each petroleum product.

f. export FOB price of each petroleum product.

g. petroleum product import and export business.

h. royalty or rental fee of refinery.

i. existing crude oil unloading facilities.

j. crude tanker size and unloading time at present

k. tanker and barge size of water shipping of each petroleum product at present.

l. petroleum products terminal location and capacity at present.

m. distribution business.

n. industrial water, drinking water, electricity and labor cost.

o. financial condition in Thailand.

p. depreciation.

q. import duty for petroleum products, construction materials and equipments in Thailand.

r. refund for export petroleum products in Thailand.

s. tax, fee and reserve for company.

  registration fee.
  municipal immovable property tax.
  corporate income tax.
  legal reserve.
  medical compensation fund.
  reserve for retirement allowance.
  personal income tax.

t. insurance.

  construction all risk insurance
  election all risk insurance.
  fire insurance (all risk cover).
  public reliability insurance.

2.4.2 Basic data and information supplied by the consultant.

2.4.2.1 Statistical data of consumption, production, import and export of petroleum in the Southeast Asia region, especially, the present and future refinery capacity in this region should be supplied by the consultant.

2.4.2.2 Market survey of petroleum product in Southeast Asia region should be carried and report should be supplied by the consultant.

2.5 <u>Duration of the project</u> : Starting as

from : as soon as possible

to : 18 months later

2.6 <u>Project site</u> : Thailand

2.7 Project work plan

The following scope of work must be included in the feasibility study, but not limited to what herein described.

2.7.1 Scope and format of the feasibility report.

The feasibility report would be comprehensive in scope, giving due regards to all aspects of the most up-to-date concepts for determining the feasibility of this project.

2.7.2 Technical studies for 1st stage.

2.7.2.1 Review the petroleum product demand forecast and Thailand energy consumption made by NEA.

2.7.2.2 Determine the best means of expanding refining capacity from the current level.

2.7.2.2.1 By increasing the capacity of the existing oil refineries where possible.

2.7.2.2.2 By building a completely new refinery related with existing refineries.

2.7.2.3 Determine the maximum profit refining capacity.

2.7.2.3.1 Recommend the suitable types of crude oil charged.

2.7.2.3.2 Recommend the maximum profit refining scheme including the size of process units and auxiliaries.

2.7.2.3.3 Recommend the import and export petroleum products.

2.7.2.3.4 Recommend the most economical crude oil tanker size.

2.7.2.3.5 Recommend the most reasonable crude oil reserve.

2.7.2.3.6 Recommend the plant site.

2.7.3 Economic studies for 1st stage.

2.7.3.1 Initial investment including unloading and loading facility of grass roots refinery on breakdown.

2.7.3.2 Utilities consumption including chemicals, catalysts and own fuel on breakdown.

2.7.3.3 Organization and duty for planning, construction and operation stage.

2.7.3.4 Maintenance including preventing and turnaround, communication, guard and firefighting system.

2.7.3.5 Economic justification at various interest rates.

2.7.3.5.1 B/C

2.7.3.5.2 Rates of return.

2.7.3.5.3 Cash flow.

2.7.3.5.4 Refining operation cost per barrel per stream day of crude oil charge and exrefinery cost of each refining product.

2.7.4 Technical studies for next 20 years.

2.7.4.1 Determine the best capacity expansion schedule for oil refining industries for the next 20 years showing additional installation as required to meet the needs into stages of development.

2.7.4.1.1 Recommend the suitable types of crude oil charged.

2.7.4.1.2 Recommend the size of process units and auxiliaries.

2.7.4.2 Considerations concerning the conservation of energy.

2.7.4.2.1 Better control of operation with the aid of special equipments.

2.7.4.2.2 Better recovery of waste heat such as integrated or semi integrated and waste heat boiler.

2.7.4.3 Considerations of refining capacity.

2.7.4.3.1 Recommend the optimum configuration of the facility, i.e. single train, multiple trains, several small refineries, with cracking units.

2.7.4.3.2 Recommend the economic optimum combination of refining procession steps for the new facilities taking into account.

a. the fuel oil processing.

b. the handling of multiple crude oil.

c. the utilization of special process units such as coker, catalytic crackers and so on to produce more diesel oil.

d. the commutor program for maximizing profit.

e. the refinery yield patterns that are suitable for the demand.

f. the reliability of refining and safty.

g. pollution and environmental requirements for products specification and effluents.

2.7.4.3.3 Increase efficiency and flexibility.

2.7.4.3.4 The combination use of steam and power.

2.7.5 Economic justification for General.

Based upon the information obtained from (2.7.2) and (2.7.4), determine the cost estimates and comparison for the additional refining capacity of 100,000, 150,000 and 200,000 bpsd. The report shall justify.

2.7.5.1 B/C at various interest rates.

2.7.5.2 Rates of return.

2.7.5.3 Refining operation cost per barrel of crude oil charged and exrefinery cost of each refined product.

3. <u>Operating agency</u>

National Energy Administration

4. <u>Assistance requested</u>

4.1 <u>Expert</u>

Field of operation/activity	Total		1979		1980	
	No.	m-m	No.	m-m	No.	m-m
(1) Petroleum Management	1	18	1	6	1	12
(2) Petroleum Economic	2	18	1	6	2	12
(3) Petroleum Engineering	1	12	1	6	1	6
(4) Petroleum Environment	1	5	1	2	1	3
(5) Petroleum Refining and Processing	1	6	1	3	1	3
(6) Petroleum Marketing	1	9	1	3	1	6

4.1.1 Justification for requesting experts :

The method of setting up oil refinery policies and the guide for justifying on additional refinery capacities are the tasks involving highly technical and economics knowledge and experience in which the government does not have people of this qualifying available at the present time.

4.1.2 Job description of experts

The work of experts should consist principally as follows :.

4.1.2.1 Refinery process units which are capable of refining 100,000 - 200,000 barrels of crude oil per stream day with 50% possible expansion capacity. Final capacity of new refinery is not exceed 300,000 barrels of crude oil per stream day.

4.1.2.2 Refinery offsites which include utility facilities and pollution abatement of suitable size.

4.1.2.3 Crude oil storage which is including running stock and reserve.

4.1.2.4 Storage tanks for suitable size and number of unfinished and finished products.

4.1.2.5 Storage of spare parts and other equipments.

4.1.2.6 Marine facilities for the unloading of crude oil and petroleum products to the refinery, and water and land shipping facilities for petroleum products from the refinery.

4.1.2.7 Appurtenant facilities which include machine shops, laboratories, administration building, etc.

4.1.2.8 Necessity of petroleum product terminals and gasoline service stations.

4.1.2.9 Infrastructure such as road and railroad.

4.2 Fellowship

Field of study/training	Total		1979		1980	
	No.	m-m	No.	m-m	No.	m-m
(1) Petroleum Management	4	24*	2	12	2	12
(2) Petroleum Economic	3	18	2	12	1	6
(3) Petroleum Engineering	3	18	2	12	1	6
(4) Computer Sciences (optimization Model)	2	12	1	6	1	6

Note: * We should train our staff before the project begin.

4.2.1 Justification for requesting fellowships

The decision on additional refinery capacities and setting up petroleum policies should be reviewed or revised frequently; at present, we are really in need of well qualified personnels to run this project.

4.3 Equipment

4.4 Other

5. Thai Government counterpart contribution to the project

Description of Government counterpart contribution	Total contribution already available	Total contribution To be requested	1979 (Baht)	1980 (Baht)	1981
I. Project Personnel					
(1) Project manager (level 6 or higher)	1	-	30,000	60,000	-
(2) Engineers (level 4-5)	2	-	40,000	96,000	-
(3) Engineers (level 3)	1	4	6,000	120,000	-
(4) Economist (level 4-5)	2	-	40,000	96,000	-
(5) Economist (level 3)	2	6	16,000	192,000	-
(6) Computer (level 4-5)	2	1	16,000	144,000	-
(7) Others (below level 3)	15	10	67,500	450,000	-
II. Equipment					
(1) Premises and building	100 sq.m.	100 sq.m.	60,000	240,000	-
(2) Expendable equipment	as required	-	30,000	50,000	-
(3) Non-expendable equipment	"	-	5,000	20,000	-
III. Other					
(1) Internal travelling expense			50,000	50,000	-

Note: Government officers'salaries : level 6 = 5,000 Baht
level 4-5 = 4,000 Baht
level 3 = 2,000 Baht
level 3 below = 1,500 Baht

6. Related projects/activities

Energy Master Plan Project

7. Future Work Plan

NEA will use the result of this Study and its developed expertises to propose the suitable additional oil refinery-capacity to our Government and will revise its proposal continuously according to the changes in related situation such as price of crude oil and finish products. inflation, investment cost etc. in cooperate with NEA-Thailand Energy Master Plan Project.

8. Reports

(1) The reports with a separate volume of summary shall be transmitted to the Government of Thailand not later than 60 calendar days after the completion of the studies and the written acceptance thereof by the Thai Government.

(2) The submission of reports shall be in steps as shortly described as follows :-

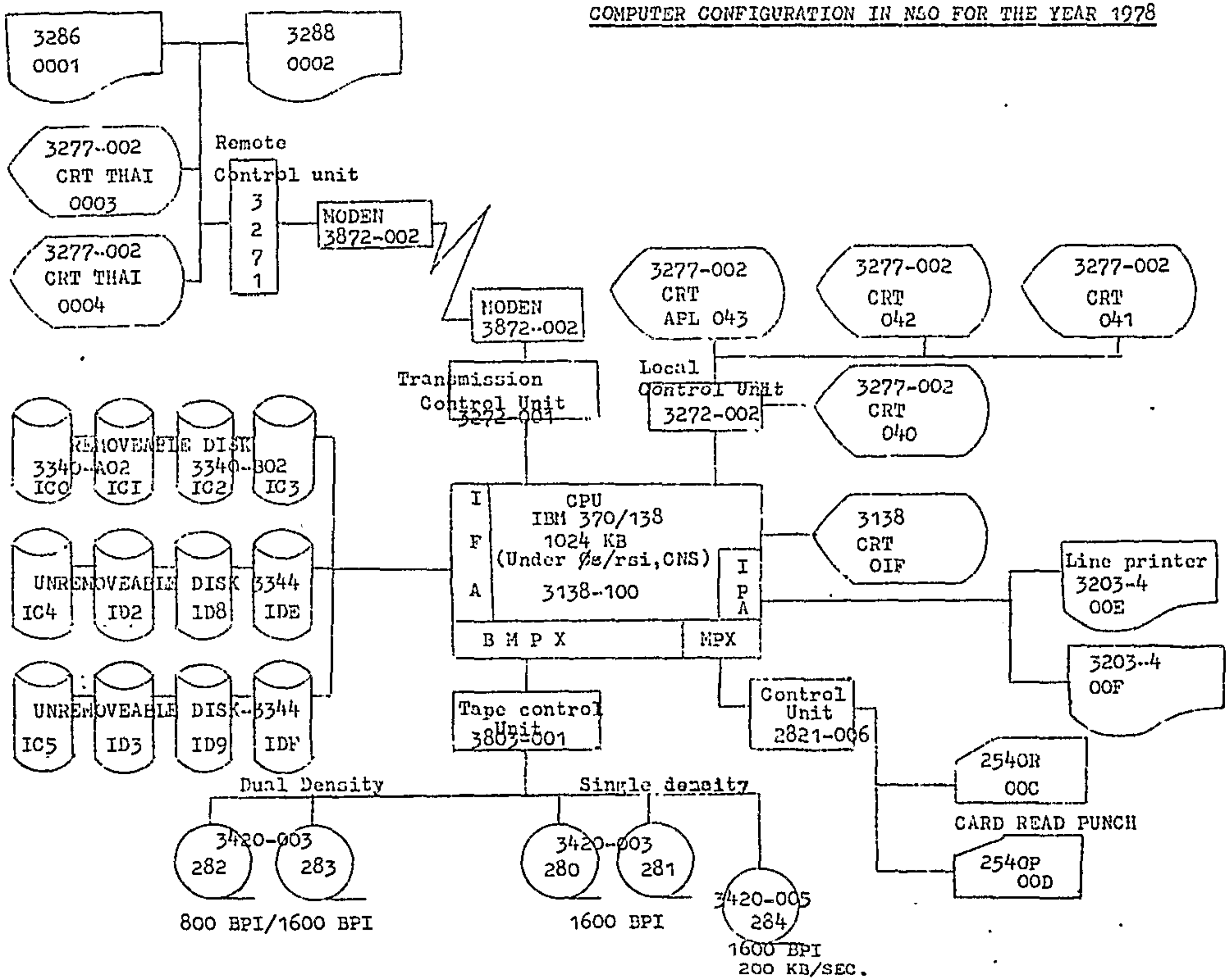
- expert team submits to NEA 10 draft copies
- one month period for NEA's reviews, checking, evaluates and comments .
- one month for expert team correction and final prints
- expert team submits to NEA 50 copies
- expert team submits to Embassy and DTEC 10 copies

(3) The expert team leader shall submit to the appropriate agency of the Government of Thailand 10 copies of progress report for every month from date of the beginning of this study.

(4) All calculations, design, drawing, specification, estimates, statement, charts, schedules, reports, notice and all other documents and written communication should be carried out in English.

(5) All data, computations, notes studies, reports, designs, drawings, specifications, and other materials and documents relating to this project shall be the property of NEA and the said documents shall be delivered to NEA upon completion or termination of the Plan of Operation provided however, that the expert team may retain copies for his own use.

COMPUTER CONFIGURATION IN NSO FOR THE YEAR 1978



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MEMORANDUM

September 17, 1979

To:

From: Y. Kawase

I. REFINERY

SUMMIT Industrial Corp. (Panama)

(1) SUMMIT —— belong to Ministry of Defence

(SUMMIT + CALTEX) ↓ Organization of Fuel Oil (OFO)

Products → Military

Products → EGAT (South Bangkok Power Station)

Products → SUMMIT (Derivery Company)

SUMMIT rents Bangchark Refinery and Fang Refinery from Ministry of Defence, so SUMMIT pays rental fee.

(2) Thai Oil Refinery Co. Ltd. (TORC)
(Shell)

TORC is under the supervision of Ministry of Industry.
TORC pays royalty to Ministry of Industry.
In near future, Thai Government will invest a half of share (Thai Government will buy TORC Refinery then he will invest).

(3) ESSO Standard Thailand Ltd.

ESSO is under the supervision of Ministry of Industry.
ESSO pays royalty to Ministry of Industry.

II. EXPANSION

Bangkok Post and Nation News said expansion of three refineries is as follows.

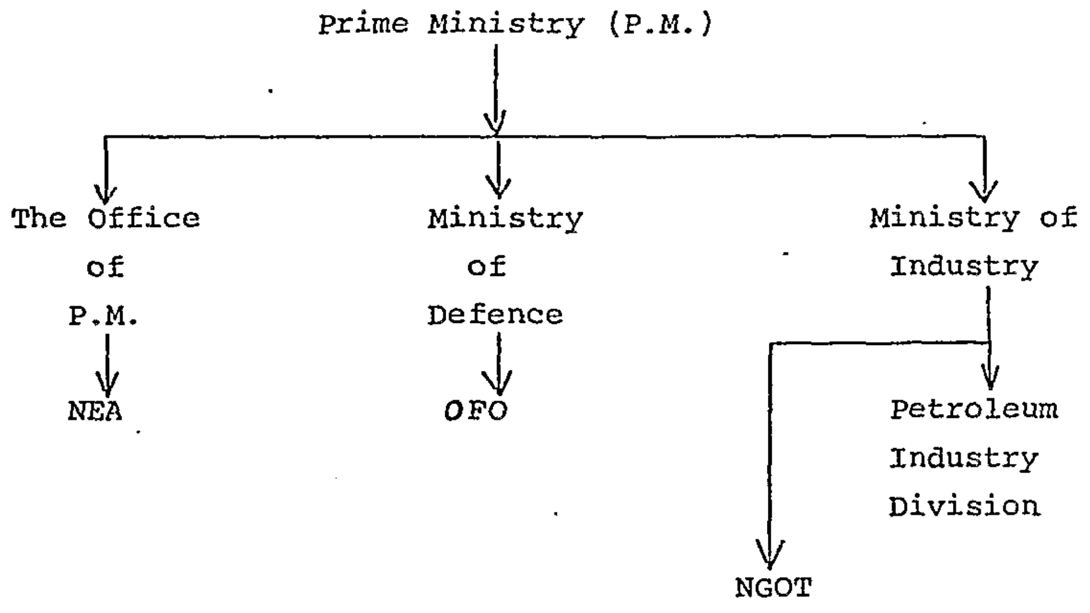
	Existing	Expansion
SUMMIT	65,000 BPSD	45,000 BPSD
TORC	65,000 "	65,000 "
ESSO	35,000 "	35,000 "
Fang	1,000 "	

NEA said to me that expansion of three refineries is not decided, still flexible.

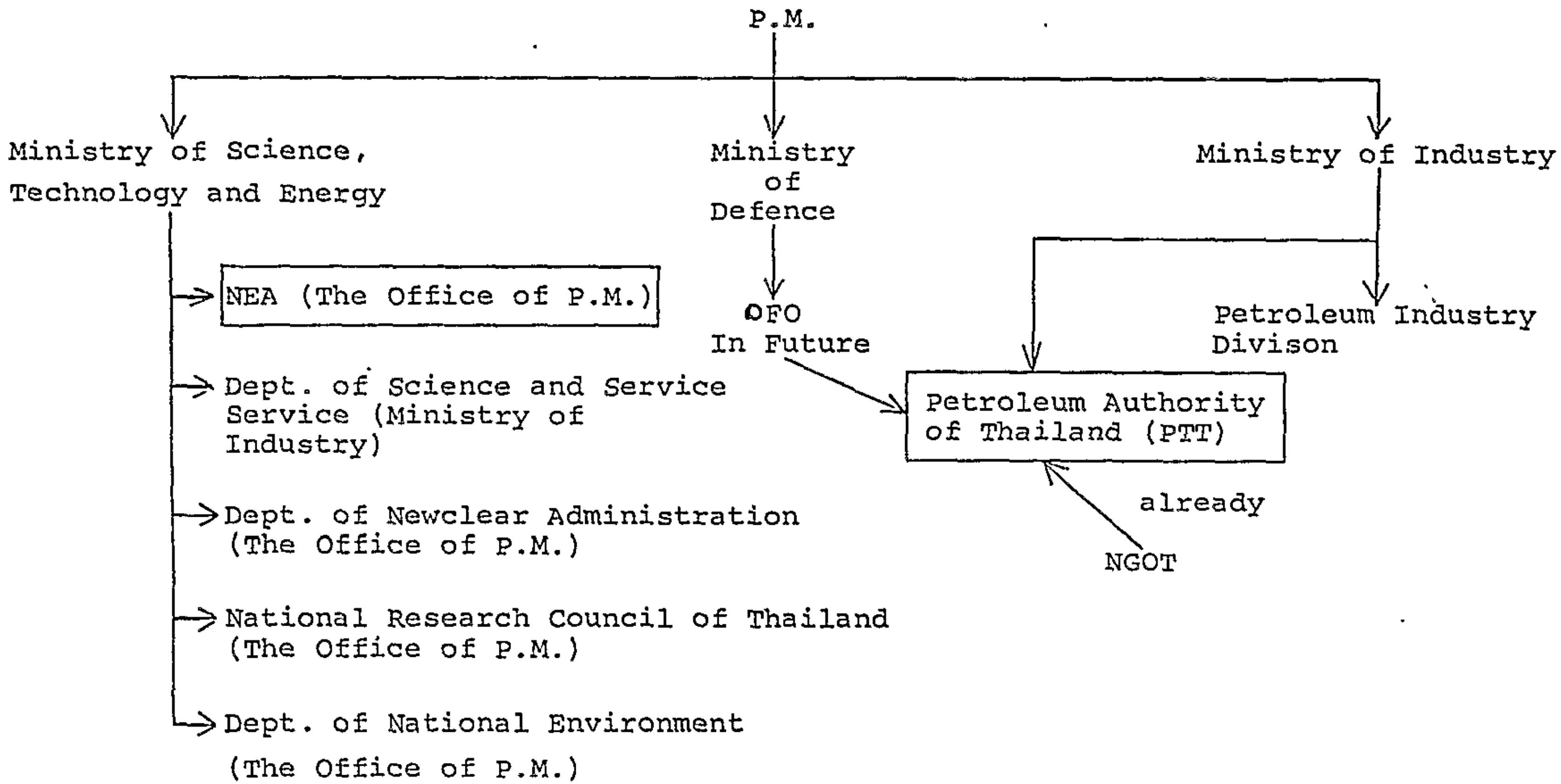
According my estimation, another 90,000 BPSD grass-roots refinery should be needed in 1981.

III. ORGANIZATION

(1) Former



(2) Present + Future



( ) : Former belong to office or ministry

END