THERMAL ENHANCED OIL RECOVERY IN INDONESIA. PROSPECT OF HTGR APPLICATION

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Abstract

In the next future, Indonesia will face oil scarcity. The present reserves are estimated to be depleted in 20 years. However, after primary and secondary recovery processes, there are still more than 50 % of original oil in place remaining in the reservoir, and this could be recovered by using tertiary recovery method or which is known as enhanced oil recovery (EOR) processes.

Among the three major methods of EOR, steam flooding is a thermal recovery method into which High Temperature Reactor (HTR) module can be integrated for producing steam. However, the feasibility of application of HTR as an alternative to conventional oil-fired steam generator will depend strongly on the price of oil.

This paper discusses EOR screening for Indonesian oil fields to identify the appropriate oil reservoirs for steam flooding application as well as the possibility of steam supply by HTR module. Also reviewed is the previous study on HTR application for Duri Steam Flood Project.

1. INTRODUCTION

As considerable quantity of oil still remains in reservoirs after primary and secondary recovery, application of EOR is a very promising proposition. It also becomes more and more important due to limited new oil discovery in Indonesia.

Thermal enhanced oil recovery process, especially steam flooding, is a proven technology which can be applied for increasing oil recovery, particularly for reservoirs and crude oils having appropriate characteristics for this method.

HTR is a small high temperature reactor with low enriched uranium fuel. It is especially suited as a universal energy source for the cogeneration of steam and electricity, and process heat steam applications. The application of HTR in steam flooding project can substantially save crude oil burned for steam generation.

This paper discusses EOR screening for Indonesia's oil fields to identify the possible oil reservoirs for steam flood application, the technical possibility of steam supply by HTR module and briefly reviews the previous study on HTR application for Duri Steam Flood Project.

2. OIL RESOURCES IN INDONESIA[1,2]

Indonesia's oil fields are mainly found in the western and central parts of the country. Among the 60 tertiary basins in Indonesia, 38 basins have been explored and 14 basins are on production. The total oil reserves in Indonesia is about 9.5 billion barrels, consisting of 5.2 billion barrels of proven and 4.3 billion barrels of potential reserves (Table 1).

PERTAMINA and its operating contractors are currently exploiting oil and gas in Indonesia with total production capacity 1,5 million barrels crude oil/day including condensate.

Table 1

Oil and Condensate Reserves In Indonesia, Status 1-1-1994 (MMSTB)

No.	Operating area	Proven	Potential	Total
1	North Sumatera	278.4	302.1	580.5
2	Central Sumatera	2,657.5	2,807.4	5,464.9
3	South Sumatera	359.4	185.9	545.3
4	Java	771.2	341.9	1,113.1
5	Kalimantan	801.1	492.0	1,293.1
6	South China Sea	194.2	171.2	365.4
7	South Sulawesi	10.2	0.0	10.2
8	Irian Jaya	95.0	6.4	101.4
Total		5,167.0	4,306.9	9,473.9

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The scarcity of oil resources makes it necessary to apply an appropriate enhanced oil recovery technique because there are still more than 50% oil left in the reservoir after primary and secondary recovery.

3. EOR[3,7]

The term EOR is used in a broad sense. It covers a wide range of technology for improving oil recovery, from water flooding to the more sophisticated techniques such as chemical flooding. EOR is a technology which continues to develop, expanding its potential to increase oil recovery from old and newly discovered fields.

In general terms, the processes in EOR are based on introducing several means such as energy source and other means to modify favorably the characteristics of the reservoir rocks and fluids. These include injection of gas, flooding with water, introducing surfactant, injection of water including polymer to increase viscosity, introducing steam, in situ combustion, miscible gas floods and stimulating with microbes.

3.1. Screening of Indonesian Oil fields For EOR[1,3]

Suitable EOR method for a given reservoir is determined through screening. Many of the screening criteria are related to the reservoir properties. The screening criteria of EOR processes are summarised in Table 2. The initial evaluation based on suggested screening criteria generally is followed by laboratory and field test.

The results of a study on EOR screening of Indonesian oil reservoir which has been conducted are presented in Tables 3 and 4. It was estimated that 24 billion barrels of oil could be produced through the application of EOR. The increase of recovery through steam flooding is estimated to be about 4.2 billion barrels and through in situ combustion about 6.5 billion barrels. These figures could be higher as recent technology development indicated that even lighter oil reservoirs can be treated with steam flooding.

The oil fields appropriate for steam flooding of heavy oil in Indonesia are mainly located in Riau, namely in PT. CPI area.

3.2. EOR by Steam Flooding[5,6,7,8]

Thermal processes aim to recover more oil by reducing viscosities by injecting or generating heat in a reservoir.

Table 2
Guide for Technical Screening Criteria

No.	Reservoir Parameter	Units	Thermal		Chemicals			Miscible			Microbial
			Steam flood	Insitu comb.	Poly-mer	Surfac-tant	Alka-line	HC gas	N2 gas	CO2 gas	
1	Rock type	-	sst	sst	sst/lm	sst*	sst*	sst/lm	sst/lm	sst/lm	sst/lm
2	Net thickness	ft	>20	>10	NC	>10	NC	thin	thin	thin	NC
3	Depth	ft	<5000	>500	<9000	<8000	<9000	>2000	>5000	>2000	<5500
4	Temperature	F	NC	>150	<200	<175	<200	NC	NC	NC	<200
5	Ave. permeability	md	>200	>100	>40	>60	>20	NC	NC	NC	>50 mD
6	Ave. porosity	%	20	20	20	20	20	NC	NC	NC	-
7	Ave. oil saturation	%	40-50	40-50	>40	40-50	Sor	>30	>30	>30	>25
8	Pressure	psi	1500	2000	NC	NC	NC	-	-	MMP	<20000
9	Oil gravity	Api	10-25	<25	>25	>25	13-35	>35	25-35	>25	>15
10	Oil viscosity	cp	>20	>1000	<200	<40	<90	<10	<10	15	-
11	Oil composition		NC	asphal	NC	Light	NC	Light	heavy	heavy	-
12	Salinity (TDS)	ppm	NC	NC	<50,000	<30,000	100,00	NC	NC	NC	-
13	Wettability		OW	WW/OW	WW	WW	OW	WW/OW	WW/OW	WW/OW	WW/OW
14	Transmissibility, Kh/u		5	5	NC	-	-	-	-	-	-
15	Minimum oil content at Start of Process ϕ. So	Fraction	>0.1	>0.08	NC	-	-	-	-	-	-
16	Inject. water salinity	ppm	-	-	<50,000	20,000	-	-	-	-	<190,000
17	Clay content	%	-	-	<10	<8	-	-	-	-	-
18	pH	-	-	-	-	-	-	-	-	-	4-9

Note : NC - Not Critical
WW - Water Wet
OW - Oil Wet

sst - sandstone
lm - limestone (carbonate rock)
sst* - sandstone is preferable

Ref. 3

Table 3
EOR Screening of Indonesian Oil Fields

No.	Flooding Method	Number of Reservoirs	Estimation of Recovery Increase MMSTB
1	Water	929	1,640
2	Polymer	886	2,797
3	Surfactant	796	2,533
4	Alkaline	215	3,438
5	Miscible CO_2	270	2,910
6	Steam	106	4,203
7	In Situ Combustion	274	6,458
Total		3,476	23,979

Table 4
Reservoirs Potentials
To Perform Steam Flooding
(Criteria : heavy-medium heavy oil)

No.	AREA	NUMBER OF RESERVOIR ASSESSED	NUMBER OF RESERVOIR PASSED THE SCREENING	NUMBER OF POTENTIAL RESERVOIRS FOR STEAM FLOODING	ESTIMATION OF PRODUCTION INCREASE, MMSTB
1	WEST JAVA	550	218	13	268.4
2	RIAU	1,394	502	52	3,893.9
3	EAST KALIMANTAN	1,284	659	38	36.7
4	SOUTH SUMATERA	100	34	3	4.4

The recovery potential through thermal treatments such as steam flooding and in situ combustion are most suited to heavy, low API gravity crudes which will tend of not flow at all in the reservoir under natural conditions.

In steam drive process, because of its relatively low density and viscosity, steam tends to bypass oil along the reservoir (Figure 1). The steam may also cause the oil to vaporise by increasing its temperature. In suitable reservoirs, recoveries of up to 60 per

Table 5
Economic Evaluation (1987)
Application of HTR To Duri Steam Flood Project

No.	Net Cash Flow	HTR	Conventional
1	Pay out time (years)	7	4
2	Total Government take from the year 2001-2010, billion US $	23.7	16.2
3	PT. CPI profit share, billion US $	3,3	2,2
4	Oil substituted by nuclear fuel, million bbl/y	17	-

Data/assumptions :

- Oil price in 1987, $ 18/barrel
- Prediction of oil price escalation, 6% p.a. ($ 26/bbl in 1994, $ 40/bbl in 2000).
- Project life time : 40 years

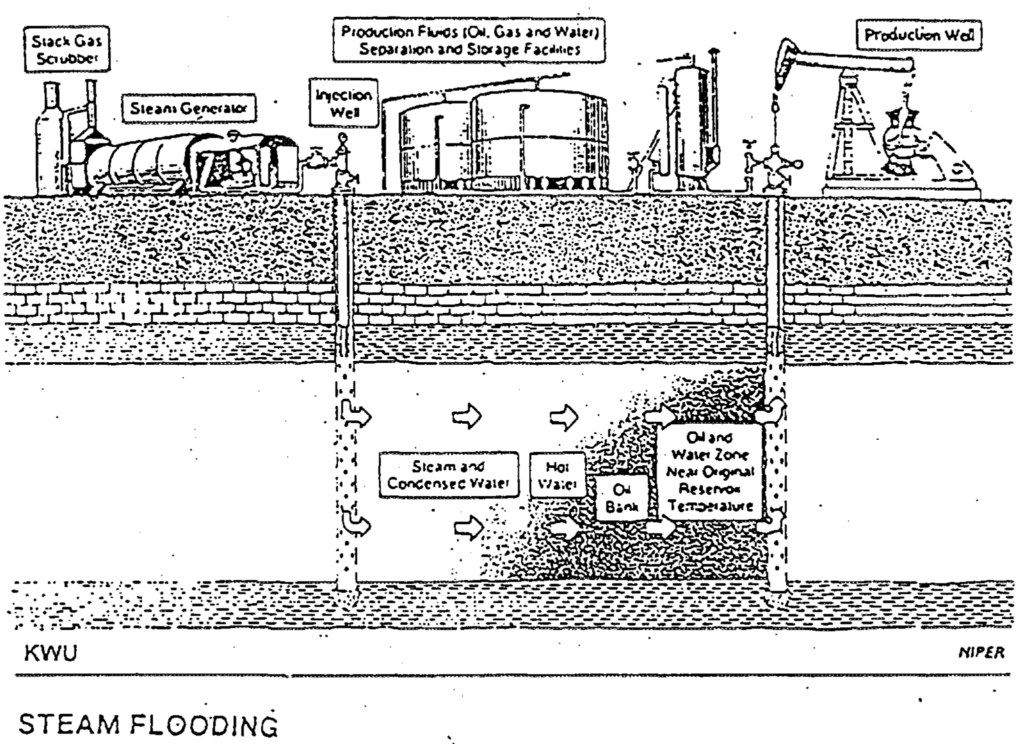

FIG. 1. Steam flooding.

cent of oil in place may be expected, with oil to steam ratio of 1.2 to 4.0 barrels per ton of steam. This compares very favorably with primary recoveries from shallow heavy oil reservoirs of 1 to 10 per cent of oil originally in place.

There is potential application of steam drive in the enhanced recovery of residual light oil. The oil evaporates when exposed to steam, and the resulting vapor of light components is transported (along with the steam) to cooler parts of the reservoir. The trapped oil is stripped by steam until a non-volatile residue is left. An oil bank forms ahead of the steam condensation front and is driven to the producing wells. The energy balance of this method is critical and it is suitable when a cheap energy source is available.

4. HTR MODULE APPLICATION[5, 6]

Because the temperature of HTR is higher than that of the current nuclear power plants, this plant could be used to produce steam and electricity (cogeneration). The flow scheme of this plant is presented in Figure 2. The high pressure steam will flow first into the high pressure turbine, and then flows into the medium and low pressure turbine. A part of the steam is sent to the steam injector.

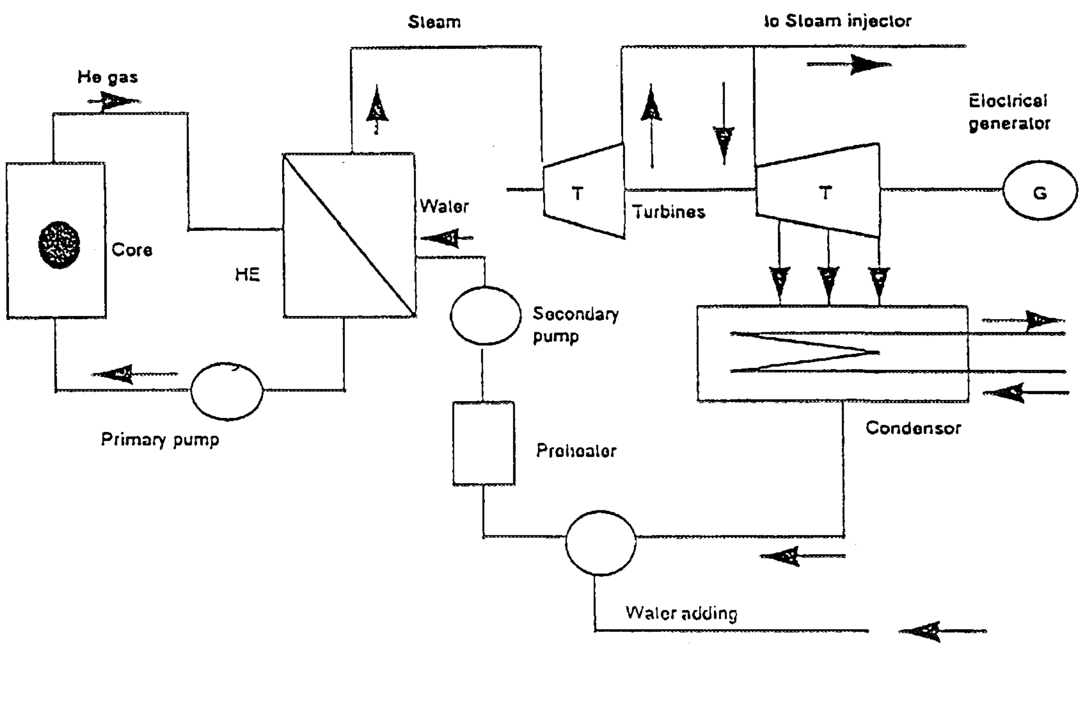

FIG. 2. Flow scheme of HTR cogeneration plant.

The steam pressure and temperature of 200 MW_{th} HTR as output of the heat exhanger (HE) are about 150 bar and 530°C. If 75% of steam (75 bar, 300°C) is sent to the steam injector, the electrical generator could produce about 25-30 MW electric power. This electric power is required to fulfill the electrical demand, i.e. for injector pumps, production pumps, water treatment, office, etc.

5. REVIEW ON STUDY OF HTR APPLICATION FOR DURI STEAM FLOOD PROJECT[5]

A study was conducted in 1987 to investigate the feasibility of the application of HTR-Module plants for injection steam and electricity in Duri steam flood project.

5.1. Project Description[5]

Duri field was discovered in 1941 and was commercially put on production in 1958. Duri crude is of medium heavy type (21°API), high wax content and rather viscous. The original oil in place is estimated at 7.1 billion STB.

Field trial of steam flood was performed for 10 years beginning 1975 and showed promising results. The steam injection in the project development area was subsequently started in March 1985.

The Duri Steam Flood (DSF) project was subdivided into 19 development areas covering 9000 ha of productive area (Figure 3). This project is recognized as the biggest steam flood project in the world. The typical area plot plant of the production facilities is presented in Figure 4. Surface facilities plan is based on decentralized system, so each quadrant of a development area has its independent system.

Peak production capacity of 300.000 bbl/d was achieved in Octobre 1994. It was predicted that the project could be operated up to year 2039 and could be on high production rate until 2033 (Figure 5). Figure 5 also presents the fuel requirement for generating steam. The total steam requirements averages between 4,000 and 5,000 tons/h in the peak time which means that about 20% of oil produced is needed for generating steam.

The steam is generated by oil fired steam generators. The steam pressure and quality at surface lines system from steam generator injection wells is presented in Figure 6.

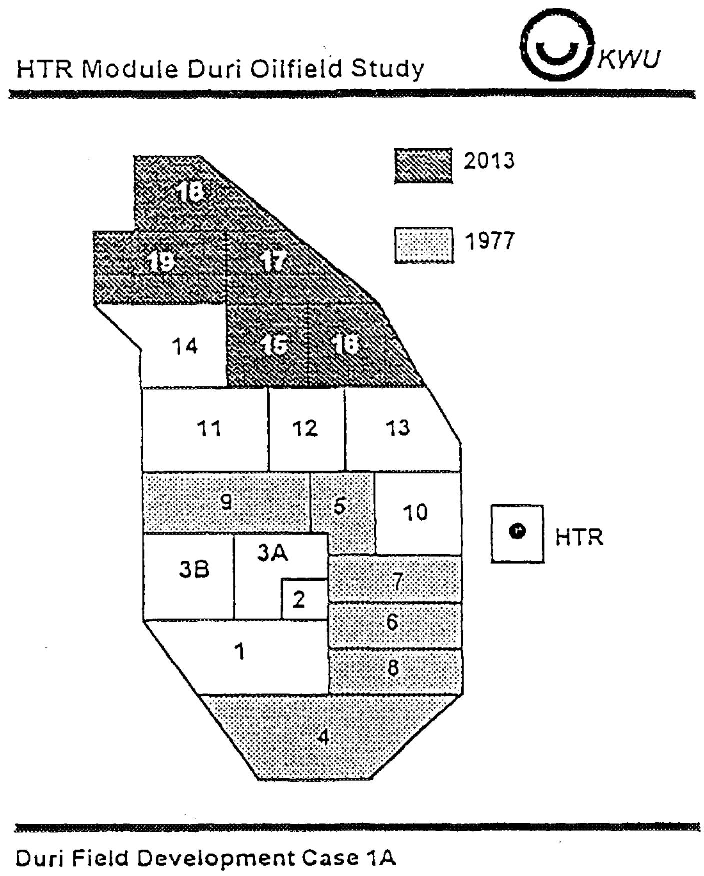

FIG. 3. Duri field development Case 1A.

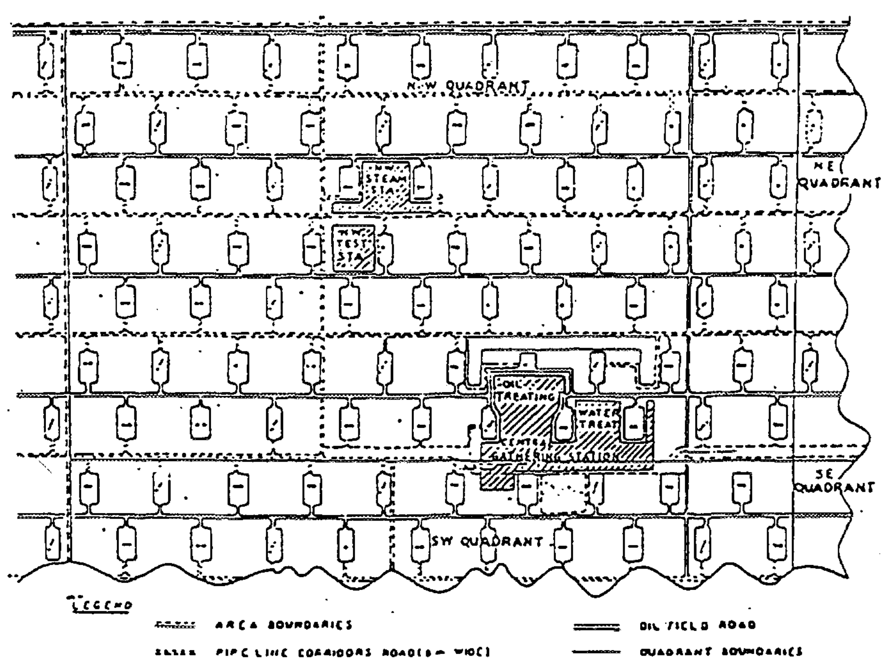

FIG. 4. Duri field typical area plot plant.

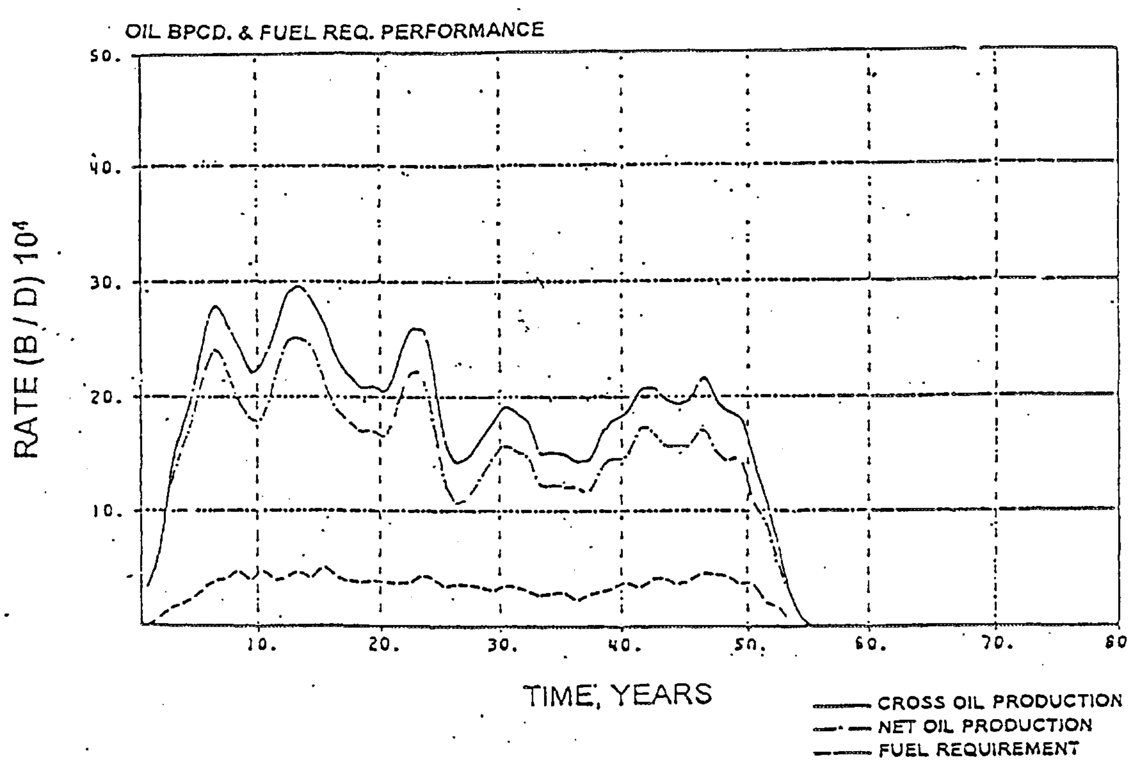

Fig. 5. Duri field predicted steamflood performance Case 1A.

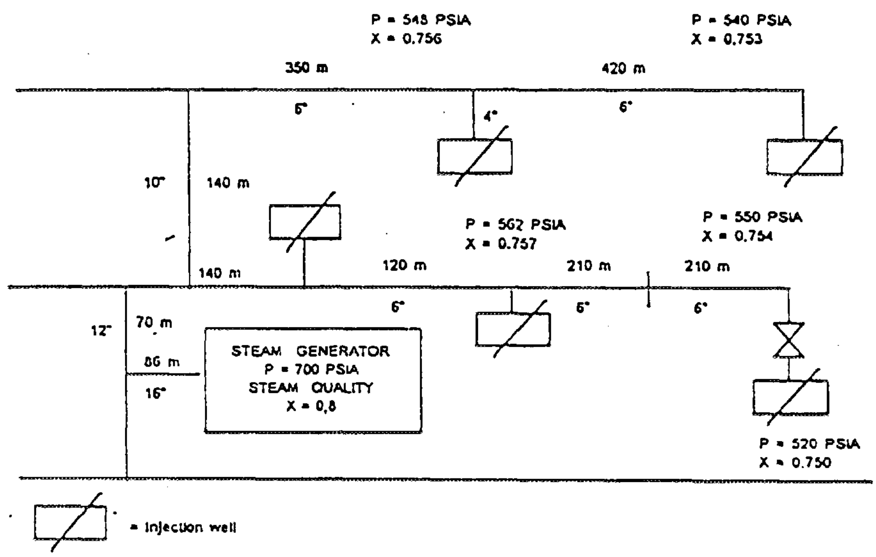

FIG. 6. Duri field steam pressure and quality at surface lines system from steam generator injection wells (typical calculation results).

5.2. Steam Supply by HTR

The total steam requirement (averages between 4,000 and 5,000 ton/h in the peak) gives a potential for installing at least 4 units HTR-4 Module Plants, each with 1,000 ton/h injection steam production capacity and 76 MW net electricity generating capacity (Figure 5).

In contrary to the development plan with oil fired steam generators, the development plan with HTR-Modules is based on centralized system supplying each Development Area with steam and electricity from the HTR-Module location to the delivery point in the supplied Development Areas.

5.3. Economic Evaluation

The feasibility and the profitability study of this project was performed based on the forecast of the oil price development.

The calculation were carried out on the basis of crude oil price of US $ 18/bbl in 1987, with the assumption of 4% inflation rate (investment price escalation) and 1,2, and 3% p.a above inflation escalation rates for oil price, giving 5,6, and 7% oil price increase rate.

The study showed promising results for HTR compared to conventional alternative from net cash flow, discounted net cash flow, pay out time, total Government take, Caltex profit share points of view (Table 4). However, the fact that transpired from 1987-now (1995) showed that the forecasted of oil price development did not match the real one because actually the oil price is still at the level of $ 18/barrel. The uncertainty of oil price development has made the economic study very difficult.

6. CONCLUSION AND RECOMMENDATIONS

1. Indonesia oil reserve is limited, enhanced oil recovery is therefore a very important method to increase oil recovery.

2. According to the available screening study (1991), only oil fields located in Central Sumatra are appropriate for the application of steam flooding. However, there would be a strong possibility to widen the application of this method to light oil.

3. Application of HTR is possible for steam flooding method, however the economic feasibility of using HTR as fuel alternative will strongly depend on oil price escalation, which is very difficult to predict.

4. Considering the development of steam flood method and criteria it will be worthwhile to update the screening study of Indonesian oil fields in order to reidentify the potential reservoir for steamflooding.

5. Beside the oil price, other alternatives of application scheme of HTR could improve the economic feasibility such as integration of crude oil refining processing plant. Further study on this could also be useful.

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