KAMOJANG GEOTHERMAL FIELD 10 YEAR OPERATION EXPERIENCE''

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ABSTRACT

The vapor dominated Kamojang geothermal field is located about 35 km south of Bandung, the capital city of west Jawa province. This first Indonesian geothermal field has been operated since 1983 and currently producing 140 MWe.

The geothermal system is associated with Quaternary volcanic centres of about 400,000 years old and appears to occupy the graben like structure. The reservoir has low gas content of less than 1% by weight and porosity of order 4-7% which is found at an average depth of 1200 m below the ground level. The field size is estimated to be about 21 km² with a potential of about 300 MWe.

Up to the end of 1993, 46 wells have been drilled within an area of 14 km² providing a total proven potential of 200 MWe. A total steam output of 1125 tonnes/hour produced from 24 production wells with three makeup wells and three reinjection wells placed in the centre part of the reservoir is currently used to generate 140 MWe capacity. Well output performance monitored during a ten year production period indicate an annual decline rate of approximately 3% which is considered low suggesting that the reinjection strategy is likely to be well decided.

Three Mitsubishi turbine units used indicate high efficiency with an average capacity and load factors of 85% and 97.5% respectively during 10 year production period, eventhough the field faces a silica deposition problem.

The total field installed capacity will be raised from 140 MWe to 220 MWe with the Kamojang extension area which is expected to be on line in 1997. This additional capacity will be supplied from wells with standard and big hole well completion of 10 3/4 inch liner. Well bore simulation studies shows that wells with this size are capable of producing steam of approximately twice greater that of standard size wells.

INTRODUCTION

The Kamojang geothermal field is located in west Jawa, Indonesia, about thirty five kilometers south of Bandung (Figure 5 index map). This field was discovered in 1920 by the Dutch during the colonialism period. Initial exploration was initiated in 1973 by the cooperative work between the Government of Indonesia and the Government of New Zealand.

The field is the first operational Indonesian geothermal field and has been commercially operating and producing reliable electricity for 10 years since 1983. The Kamojang field currently produces 140 MWe. A commercial operation of an additional 80 MWe is expected to begin in 1997.

The Kamojang geothermal field is located within protected forest, productive forest and nature reserve forest. Environmental studies show that the geothermal activities do not affect or give significant damage on the natural ecosystem. This is also applied to other fields in Indonesia.

FIELD CHARACTERIZATION

Geological setting

The Kamojang geothermal field is situated in east-west trending Rakutak-Guntur volcanic chain lying at an altitude of about 1500 m above sea level. The system is associated with 400,000 year quaternary volcanic products of Pangkalan and Gandapura volcanic centres and it appears to occupy a volcanic depression created by the Pangkalan caldera rim inside the northeast-southwest graben formed by the Kendeng fault in the west and Citepus fault in the east (Figure 1). The Pangkalan caldera rim, Citepus fault and west-east trending faulting system on the northern part of the field provides attractive drilling targets because of their association with high steam productivity.

The system of the field is manifested by active surface thermal features encompassing fumaroles, steaming ground, turbid hot lakes, mud pools and hydrothermally altered ground with temperatures mostly close to boiling point. The lower temperature hotspring of Citepus located in the southeast of the field margin represents distal outflow fluids from the main system.

The top of the Kamojang reservoir is found at an average depth of about 1200 m below the surface (Figure 2). The basaltic andesite productive reservoir is overlain by a thick, low permeability cap rocks of volcanics with pervasive argillic alteration.

Resource characterization

The Kamojang geothermal field has a proven productive area of approximately 14 km² giving a total proven resource of 200 MWe. The total resource potential of this field could be as high as 300 MWe occupying an area of about 21 km².

The Kamojang reservoir has water saturation of the order of 25-35% with temperature ranging from 235 to 245°C and pressures are aabout 32-40 bars (GENZL 1992). Wells were completed in the vapor dominated reservoir and mostly produce 100% steam. Values of permeability-thickness products are in the range of 500 to 140,000 millidarcy meter where the productive wells display values of greater than 4,900 millidarcy meter (GENZL, 1992). The non condensable gas content in the discharging fluid is less than 1% by weight, mostly CO2, and very low to nil chloride content. The porosities within the basaltic andesite reservoir are mostly of the order 4-7%. Table 1 shows the summary of well production characteristics and principal facts of Kamojang.

Analysis of the reservoir permeability shows that the Kamojang geothermal field has at least three areas of high transmissivity (Figure 1) separated by zones of poor transmissivity suggesting that the three areas are not connected.

PRE-OPERATION EXPERIENCE

Exploration stage

Initial exploration survey was conducted over the Kamojang area by cooperative work between the government of Indonesia and the government of New Zealand in early 1964 to assess its potential for geothermal development. Geological survey revealed that the Kamojang geothermal system was controlled by Pangkalan collapse and graben-like structure bordered by Kendeng fault in the west and Citepus fault in the east. Geochemical analyses of the surface thermal fluids and gas indicated that the system was vapor dominated with temperature the about 235°C. Further survey of DC-schlumberger electrical method and 8 shallow temperature gradient holes with a depth of 50 m resulted in a 14 km² potential geothermal area (Hochstein, 1975) where the reservoir could be as deep as 500-600 m in the field margins and 1300 m in the center of the field (Sudarman et al, 1983).

Five exploration wells were drilled down to 700 m throughout the area in 1974-1975. Two of which are productive producing dry steam from shallow feed zone of 232°C at about 600 m depth.

Development stage

In the period of 1975 to 1979, nine standard development wells of 7" liner were drilled within the center of the field with the deepest well attaining 1800 m. Six of which were producing 350 tonnes/hour *dry* steam produced from both the shallow feed zone of approximately 700-900 m depth and a deep feed zone of about 1100-1250 m.

The construction of the first 30 MWe turbine unit, under Government to Government cooperative works, was initiated in 1979 and the turbine was started to commercially operate in the late 1982.

After the termination of the cooperative work between the two Governments in early 1983, PERTAMINA was responsible for further development. Further assessment done by PERTAMINA showed that the field was actually capable of supporting a generation of an additional of 110 We. Therefore another 16 standard development wells were drilled and they produced a total output of nearly 1000 tonnes/hour *dry* steam which was adequate for the generation of 2x55 MWe of Units II and III. Steam *required* to generate a total current capacity of 140 MWe was delivered from 24 of 31 production wells with a total steam output of 1125 tonnes/hour. Up to present, three makeup wells have been drilled and three deep unproductive wells have been used as reinjection wells to cope with the total field production. The three reinjection wells are situated in the center of the field.

Further geophysical exploration survey using the CSAMT method in 1989 delineated that the field actually extended further out from the proven reserve providing a total area of 21 km² (Sudarman et al, 1990) giving a total potential of about 300 MWe, therefore Pertamina plans to increase the current field capacity from 140 MWe to 220 *We*.

OPERATION EXPERIENCE

Reservoir performance

Up to 1993, the Kamojang geothermal field has been in operation for 10 years. The field has been generating 140 MWe since 1987 supplied by steam from 26 wells at the average optimum well head pressure of about 15 bars to feed 6.5 bar inlet pressure of the Mitsubishi turbines. The steam production is predominantly from two areas within the proven field (GENZL, 1992). These areas are in the north around well KMJ-18 and in the northwest around well KMJ-30 occupying an area of cummulative mass withdrawl of about 2.5 km² (Figure 1) coincide with the north and west high trasmissivity areas. The southeast area of high transmissivity has not been exploited. The wells in this area are prepared for additional 50 MWe development.

At the start of 140 MWe production in 1987, the total of 26 wells produced 1315 tonnes/hour steam and it gradually decreased to about 1086 tonnes/hour in 1993 giving an average annual well productivity decline of 2-3% (Figure 3). Estimates of reservoir pressure and temperature decline are consistent with each other and with mass output decline of the wells. It appears that the pressure decline of 1 to 2 bars has been experienced in the exploited reservoir, with a corresponding temperature decline of 2 to 4°C. Wells in the localised areas of rather poor permeability exhibit higher pressure drawdown and more rapid well output decline.

Wells in the western and eastern sector of the field give high permeability-thickness products. Therefore a wellbore simulation study is required to know the possibility of increasing well productivity by using big hole well completion. The study revealed that big hole completion wells with 10 3/4" liner in the east & south sectors are capable of producing more steam of 2 (av.) times greater than that of using standard size well of 7" liner (Table 2, Kris Pudyasuti, 1994). This is achieved if the wells display values of permeablity-thickness products of at least 40 Darcy meter.

Power plant performance

Three Mitsubishi condensing turbine units of 1x30 MWe and 2x55 MWe have been used. The 1x30 MWe turbine has been producing reliable electricity since 1983 and the 2x55 MWe turbines since 1987. The generated electricity is connected to 150 KV transmission delivered to the Bandung grid system. The turbines show high efficiency with an average capacity, availability and load factors of 85%, 90% and 97.5% respectively (Figure 4), eventhough each turbine requires an overhaul job every year to remove silica deposit within turbine blades and in the steam pipe which shows a tendency to increase after the production of 140 MWe.

FUTURE DEVELOPMENT

Reservoir simulation study indicates that the present proven resource is capable of supplying 140 MWe until the year 2021 corresponding to a 38-year life for Unit I (30 MWe), and a 34-year life for Unit II and III (55 MWe each). The addition of extra production units of 55 MWe drawn from the present proven resource will result in reservoir exhaustion before year 2021 (GENZL, 1992).

Scientific evidence indicates that the Kamojang reservoir is larger than that already proven by drilling. Therefore, the increase of generation capacity in Kamojang is still possible. Pertamina plans to develop additional capacity of 80 MW by installing 1x20 MWe and 2x30 MWe turbine units supplied by steam from east and west areas of the Kamojang extension (Figure 5) using well with standard and big hole completion of 10 3/4" liner. Makeup wells are also planned to be drilled by using big hole well completion. The additional capacity is expected to begin commercial operation in 1997. Complete works which have been done from 1971 to 1994 are presented in Table 3.

CONCLUSIONS

The development of the first 30 MWe unit required 9 years since early 1974 when exploration surveys were completed. The second and third units of 2x55 MWe developments by PERTAMINA were completed within 5 years.

Kamojang, the first geothermal field in Indonesia, is a friendly vapor dominated field which has been operating for ten years and does not experience significant changes in resource characteristics or significant problems during exploitation.

The additional capacity of 80 megawatts, which is expected to operate comercially in 1997, will be easily developed supplied by steam from eastern and western sector of the Kamojang extension.

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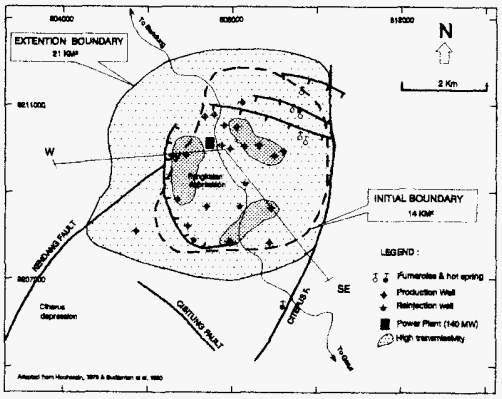


FIGURE - 1 : MAP OF THE KAMOJANG FIELD SHOWING SIZE, WELLBORES, GEOLOGICAL STRUCTURE, THERMAL FEATURES AND TRANSMISSIVITY ZONE

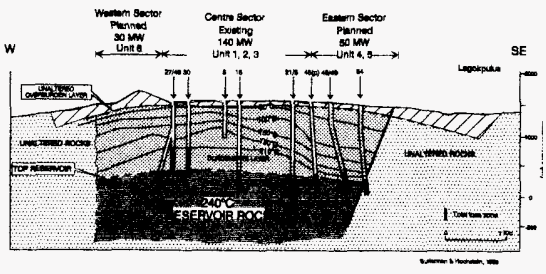


FIGURE - 2 : SECTION OF THE KAMOJANG FIELD SHOWING WELL AND TEMPERATURE PROFILE

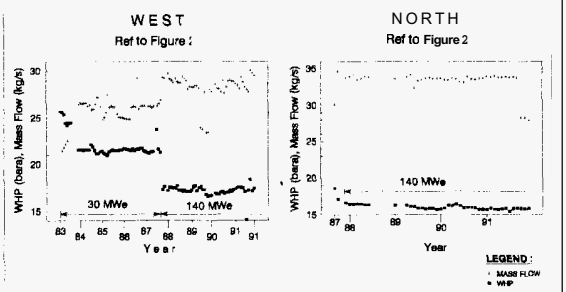


FIGURE - 3 : WELL PERFORMANCE : PRESSURE AND MASS FLOW PATTERN

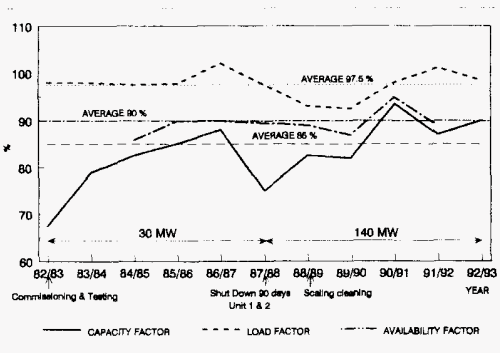


FIGURE - 4 : POWER PLANT PERFORMANCE

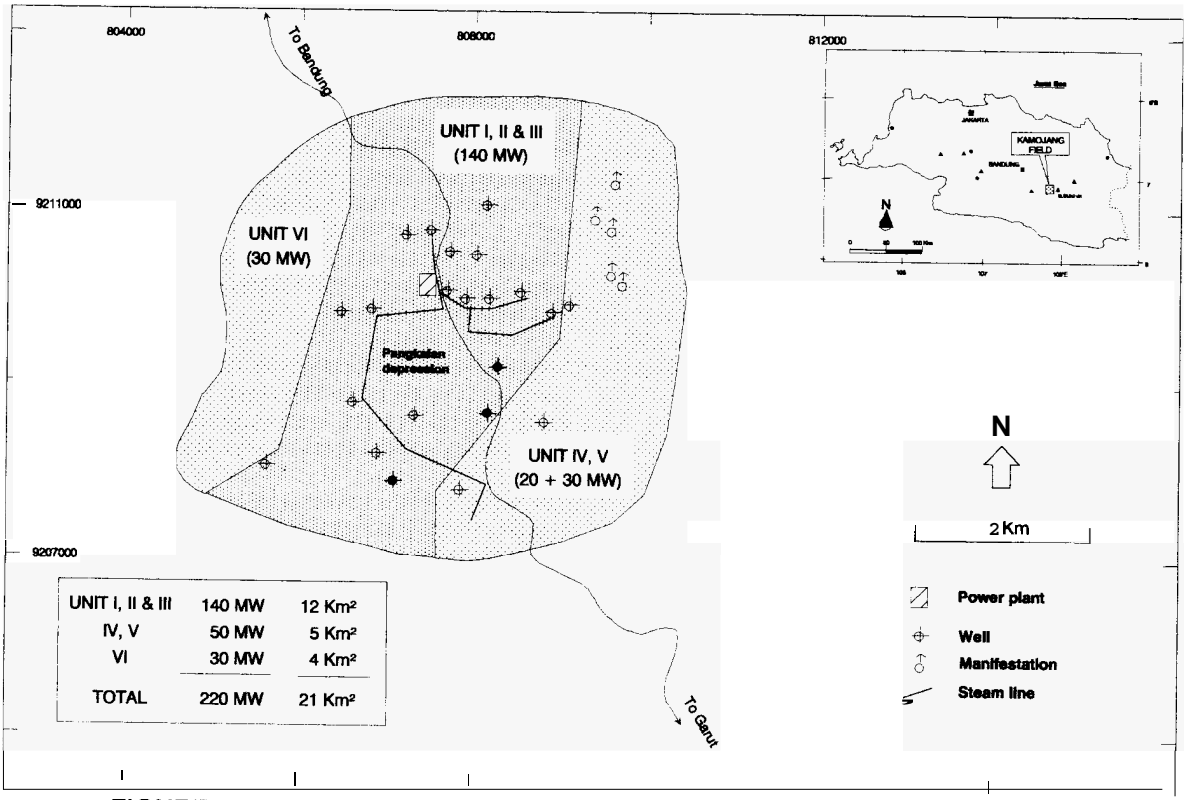


FIGURE - 5 :DEVELOPMENT SCENARIO OF KAMOJANG ADDITIONAL CAPACITY

TABLE - 1 : PRINCIPAL FACTS OF THE KAMOJANG FIELD

SIZE	
Field potential (MW)	300
Proven Productive Area (km²)	14
Total Proven Resource (MW)	200
Installed Capacity (MW)	140
RESOURCE	
Phase	*Steam*
Temperature (°C)	235 - 245
Steam Flash (%)	100
Permeability (MDM)	To 140,000
Porosity (%)	4 - 7
CHEMISTRY	
Liquid	
NCG in steam, % by weight	< 1
DRILLING	
Number of wells	53
Depth of wells (m)	500 - 2200
Average Production	

TABLE - 2 : ESTIMATES OF CAPACITY INCREASE USING BIGHOLE WELL

AREA	WELL	Ich DM	BIGHOLE CAPACITY INCREASE	TD/FEED ZONE (m)	PRODUCTION LINER (inch)
NORTH	16	120.0	1.12	935/750	10 3/4
	11	28.5	1.56	1029/900	10 3/4
	17	30.0	1.39	1058/875	10 3/4
	14	6.5	1.12	1000/750	7
	24	45.0	1.11	2200/1100	10 3/4
SOUTH	31	24.0	1.11	2200/1100	10 3/4
WEST	36	40.0	2.21	1250/875	10 3/4
	41	48.0	1.73	1275/1100	10 3/4
	42	6.0	1.29	1427/1300	10 3/4
EAST	48	70.0	2.57	1375/1200	10 3/4
	49	-	1.17	1500/1050	9 5/8
	53	-	1.18	1250/750	10 3/4

TABLE - 3 : KAMOJANG THE FIRST GEOTHERMAL FIELD IN INDONESIA

INSTALLED CAPACITY 140 MW, STATUS AUGUST 1994

