Proceedings World Geothermal Congress 2015
Melbourne, Australia, 19-25 April 2015

Steam Ratio Obtained From the Mass Amount of Condensate Reinjection by Means of Monitoring the Performance of a Groups of Production Wells 140 MWe Geothermal Field Kamojang - Indonesia

Ahmad Yani
PT. Pertamina Geothermal Energy Lahendong, Jl. Raya Tomohon no. 420, North Sulawesi – 95431
ahmadyani@pertamina.com

Keywords: Reinjection Strategy, Production Decline, Steam Recovery

ABSTRACT

To date, Kamojang has been operating for over 30 years in commercial operation. The first commercial operation was in 1982 of Unit-1 power plant 30 MWe (power plant belong to PT. Indonesia Power), subsequently an additional 110 MW of Unit-2 and Unit-3 (power plant belong to PT. Indonesia Power) was opened for operation in 1987 and to date the Kamojang exists with a total capacity of generation 200 MWe. The last power plant, Unit-4 generates 60 MWe in 2008 (where the steam field and power plants belongs to PERTAMINA). PERTAMINA intended to develop with the capacity of generating from 200 MWe to 230 MWe and next step development by evaluation the response of the reservoir during the previous step development is used to estimate the size of next development step.

The Kamojang geothermal field is one of the world's few developed dry steam reservoir. Unbalance mass extraction where less than 30% of steam can be recovered to be a condensate, it's a serious concern in reservoir management special on apply of reinjection strategy to maintain reservoir performance. A good reinjection strategy is the key for a sustainable steam supply to power plan. Some of injection does not give any impact to maintain the productivity yet, some of injection give good response to minimize decline but other hand also cause the loss productivity. To anticipate it, reinjection strategy changed by repositioning the reinjection well in. Within evaluation of reinjection management trough production data monitoring of active production well in qualitatif will give description percentage of condensate mass recover to be steam. On this paper will show simple evaluation of production performace monitoring data from group of group production well PL-401, 402, 403 and 404 where support total capacity 140 MW in Kamojang geothermal fields.

1. INTRODUCTION

Kamojang field has been in operation for about 30 years as Indonesia's first geothermal field is located in the province of West Java, with a total production capacity of 200 MW of electricity currently consists of generation supply PLTP Unit - 1 from 1983 (30 MW), Geothermal Power Plant Unit - 2 & 3 respectively commencing in 1987 (2 x 55 MW) and PLTP Unit - 4 began in 2008 (60 MW).

Gathering system PLTP Unit - 1 , 2 and 3 are integrated from the wellhead steam is passed through the 4 (four) main pipeline (PL) joined with the turbine inlet header of each 6.5 bar (7.7 tons steam consumption / MW) with a total capacity of 140 MW , the PL hereinafter referred to as PL - 401 , 402 , 403 and 404. The PLTP Unit - 4 with a capacity of 60 MW steam flowed separately through PL - 405 with turbine inlet pressure 10.5 bar (steam consumption of 6.7 tons / MW) . Each PL in support by the group of production wells and re –injection wells.

Character fluid reservoir Kamojang is the dominance of steam with the conditions of superheated at the wellhead , as well as mapping of the subsurface reservoir is currently visible distribution of superheated reservoir within the average range 2-5 º C more widespread , especially in the block section of West reservoir depicting mass reduction, Yani (2012). A continues monitoring using absolute gravimeter in 2009, 2010 and 2011 revealed a highe negative gravity changes in some area more than 40 µGal and the decline mass trend also supported by declined pressure and steam flow rate of production wells, Yayan, et. al (2012).

Re - injection is right one of the keys to be able to continue to sustain optimally manage field. The main purpose of the re - injection is to prevent environmental impacts, reservoir pressure support, to maximize the extraction of energy from hot rocks and prevent subsidence. However, management re - injection resulted in improper cooling effect to result in a loss of productivity of the reservoir production wells even blockage by scaling the wellbore so that the necessary number of charges for stimulation, Sanyal et al. (1995). The re–injections wells are located in the low permeability region (Figure 2) with an average depth of about 1500-2000 MKU (400-200masl). While the production wells have an average depth of between 800-1300md (800-400masl). The Kamojang field permeability distribution can be grouped into three (3) groups: Low (2-10mD), moderate (10-30mD) and high (30-80mD) as shown in Fig.2, Sudarman et al (2000) and Suryadarma, et al (2010).

With the injection wells are located in areas with low permeability that is a little more in depth than the expected production well water injection flow that will not degrade the quality of the steam. Condensate is injected is expected to move slowly and gradually infiltrated the production zone. Thus the water can move in any direction and experienced the heat exchange of the rock so that water eventually turns into a vapor phase before re-produced.

200 MW of electricity production in support of the 45 production wells scattered in each groups of PL with available re-injection wells are KMJ-13, 15, 21, 20, 30, 32, 35, 46 and 55 to inject 300-400 tons / hour condensate (20 -30% vapor mass produced). Activation of the nine wells based recommendations include the provision of time and the rate of injection system of monitoring the results of the evaluation of the impact of re-injection. Distribution of wells in the PL group distribution shown in Fig. 3.

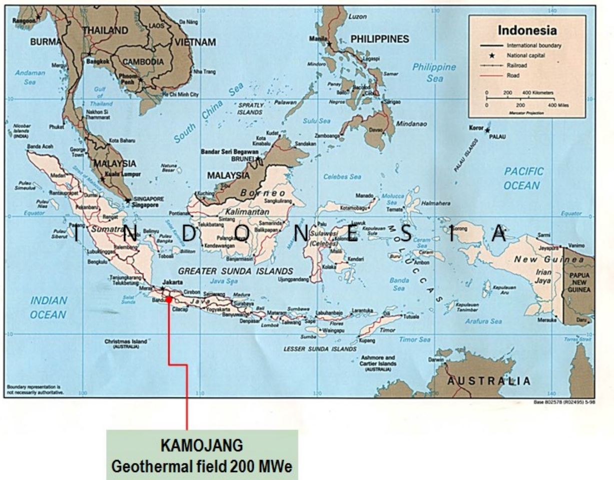

Figure 1. Location of Kamojang Geothermal Field, Indonesia

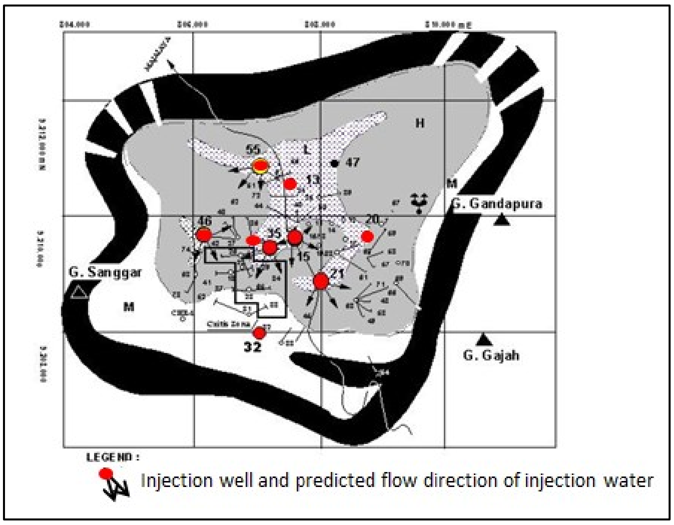

Figure 2. Position re-injection wells to the distribution area Lahendong permeability and estimated water injection flow direction.

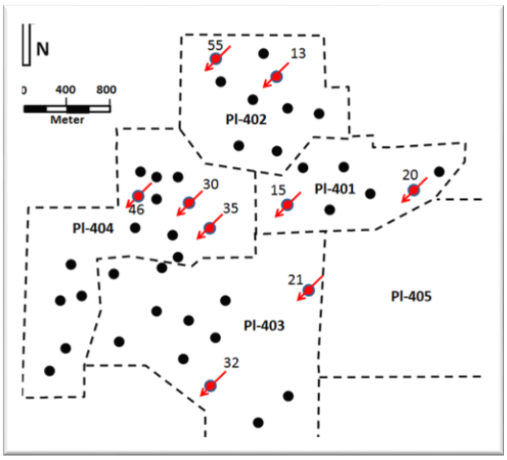

Figure. 3. Grouping of wells based on the main pipeline to supply steam geothermal power plants.

In addition to the results of a study of data dissemination structure geology, evaluation of the relationship between the production wells and reinjection wells have been several studies in the field tracer tests using radioactive tracer Kamojang generally tritium ($_3H$), so the prediction of the direction of movement of the fluid is known as shown in Figure-2, and quantitative evaluation of the data was performed to predict the thermal tracer breakthrough with various injection rates, Dwikorianto et al. (2005). It was early in 2013 conducted HFC R341a tracer injection, the program implemented as a comparison and correction of previous tracer study results. Data were collected over a meeting of the previous study that is expected to acquire the data and a more accurate modeling as well as other possible applications such as multi-fracture models in data processing.

The relationship between the injection wells surrounding production wells can also be monitored directly from routine sampling data changes in chemical vapor production wells, Yani (2012), some wells respond HBO_2 and % change in the concentration of NCG during the period of re-injection. Of course, the above data can be corrected with some other data parameters such as the rate of production, reservoir pressure and temperature, changes in the degree of superheated, CO_2/H_2S ratio and others.

2. PERCENT RECOVERY FAKTOR (RF)

The method used was simple monitoring changes in the productivity of the wells during the period of re - injection , RF is defined as the percentage of the addition of steam to the boiling process condensate mass injected , reflected a change in rate of decline or an increase in the flow of the injection period, Goyal (1995). There are several factors that influence the trend of decline which is re - injection cooling factor, deposition of scale in the wellbore, fluctuating flow of production and the addition of new wells in the system or the existence of well stimulation activities. This method will be applicable only if the changes are caused by the production decline factor of re - injection wells around.

Production data in the calculation of normalized flow rate of decline is at minimum well head pressure each of the wells and wells generally experience a natural decline Kamojang very closely related to the amount of PI (productivity index) of the wells. There are several wells that indicated experiencing especially severe scaling wells bordering the western marginal areas (reservoir boundary).

Here is a tabulation of data cummulatif mass reinjection and RF calculation results of each group of wells, where the observation year for the 1st, 2nd and 3rd based on the marked in Figures 3 to 6.

Table. 1. Annual injection data and RF in various Area of Kamojang Geothermal field.

PL GROUPS	PL-401			PL-402			PL-403		
YEARS	I	II	III	I	II	III	I	II	III
CUMM. TOTAL OF INJECTION (TON/HR)	496,696	831,244	631,121	1,021,936	936,468	975,069	972,682	1,186,867	1,503,095
CUMM. STEAM PRODUCTION RECOVERY (TON/HR)	17,905	24,079	27,421	16,917	21,699	29,439	20,857	19,865	20,161
% RECOVERY	4%	3%	4%	2%	2%	3%	2%	2%	1%
CUMM. RECOVERY (mWh)	2,238	3,010	3,428	2,115	2,712	3,680	2,607	2,483	2,520
RECOVERY (AVG. MW)	6	8	9	6	7	10	7	7	7
INJECTION WELL	INJECTION FROM LHD-15			INJECTION FROM LHD-15			INJECTION FROM LHD-35		
CUMM. TOTAL OF INJECTION (TON/HR)	307,792	186,401	246,351	248033.18	197,609	286,245	0	-	622,082
CUMM. STEAM PRODUCTION RECOVERY (TON/HR)	17,905	24,079	27,421	16,917	21,699	29,439	20,857	19,865	20,161
% RECOVERY	6%	13%	11%	7%	11%	10%	0%	0%	3%
INJECTION WELL	INJECTION FROM LHD-20			INJECTION FROM LHD-55			INJECTION FROM LHD-21		
CUMM. TOTAL OF INJECTION (TON/HR)	188,904	644,843	384,770	773,903	738,859	688,824	639,533	751,835	836,428
CUMM. STEAM PRODUCTION RECOVERY (TON/HR)	17,905	24,079	27,421	16,917	21,699	29,439	20,857	19,865	20,161
% RECOVERY	9%	4%	7%	2%	3%	4%	3%	3%	2%
INJECTION WELL							INJECTION FROM LHD-32		
CUMM. TOTAL OF INJECTION (TON/HR)							333,150	435,032	44,586
CUMM. STEAM PRODUCTION RECOVERY (TON/HR)							20,857	19,865	20,161
% RECOVERY							6%	5%	45%

2.1. Groups of Wells PL-401

Groups of wells PL-401 (Fig. 3) consists of 5 (five) production wells and injection wells nearby that is surrounded by KMJ-13, KMJ-15 and KMJ-20. Tracer injection wells through the 3rd detected tracer mass recovery in production wells PL-401. In the observation period as shown in Fig. 3, from the years 2002 to 2006 injections of KMJ-15 (50-60 tons / hour) at 2.27% production decline, the trend of decline turned into a 15.25% since switched injection KMJ-13 (80 tons / hour). It is seen that KMJ-13 negative impacts (cooling) and reinforced with chemical data indicate the increase in % NCG wells during the injection period.

Termination injection KMJ-13 visible change in trend decline from 15.25% to 9.08%. Beginning in 2009 enabled the injection wells KMJ-20 with the initial rate at 80 tons / hour visible impact increasing production and decreasing decline rate of 9.08% to 2.28%. Further back production decline with rising trend of decline of 2.28% to 10.49%, immediately after the cessation of injection of KMJ-20. From a series of re-injection program in PL401 seen that the activation KMJ-20 provide a positive impact on the recovery of steam condensate boiling injected. Chemical data support the presence of HBO_2 and decrease % increase in NCG, which describes the additional boiling steam from the condensate injection.

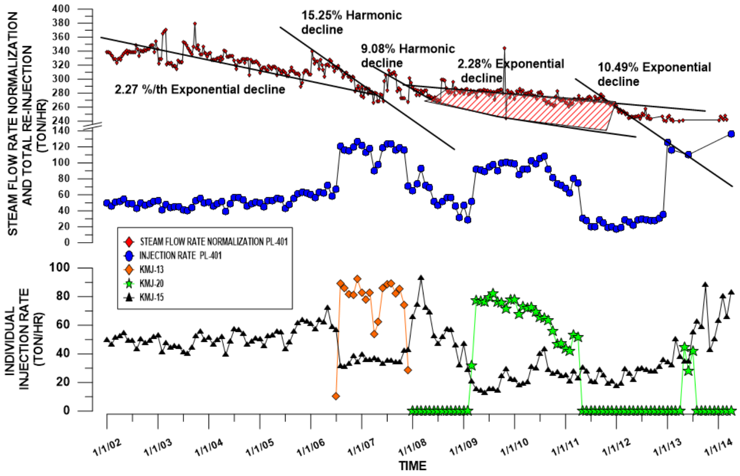

Figure. 4. Performance decline rate to the rate of injection wells PL-401 group

Average RF boiling condensate of the total injection in PL-401 from July 2008 – June 2011 was 4%, and if only the cumulative injection of condensate through the KMJ-20 RF 7% (area marked Fig.4). RF annual basis by 4% in the first, second year of 3% and 3rd 4%. If converted to MW then re-injection program is able to recover run average of 8 MW. Suggested immediately re-activate KMJ 20 reinjection wells as the minimum rate at the rate of 60-80 tones / hour, allowing for a try improved gradually becoming 120-150 tons / hour and do routinely monitor changes in the chemical properties of production.

2.2. Groups of Wells PL – 402

Group of wells PL - 402 as shown in Fig.4, that 7 (seven) active production wells in this group supported by two (2) injection wells in the north , and three (3) wells in the south . Through fig. 5 seen a decrease in injection KMJ - 15 and KMJ - 30 injection cessation causes of 4.29 % decline rate increased to 21.31 %. Termination KMJ - 30 with the intention that these wells have a negative effect on the wells PL - 403 and 404. Raising KMJ - 55 injection rate of 40 tons / hour to 100 tons / hour and improvement cause decline of 20.31 % to 7.32 %. RF of the total boiling condensate entering into PL-402 in the interval 3 (tree) years (area marked Fig.5) began in June 2010 was 2% (first year 2%, 2% in the second, and 3% in the third). This condition is equivalent to an average of 8 MW of power generation recovery. While the rate of injection RF KMJ - 55 by 3 % and if from KMJ-15 by 9%. It is advisable to maintain KMJ - 55 injection at least 100 tons / hour and can be increased gradually from 120 tons / hour - 150 tons / hour, monitored regularly. Also simultaneously injection of KMJ-15 maintained a minimum of 50 tons / hour and gradually increased to 120 tons / hour.

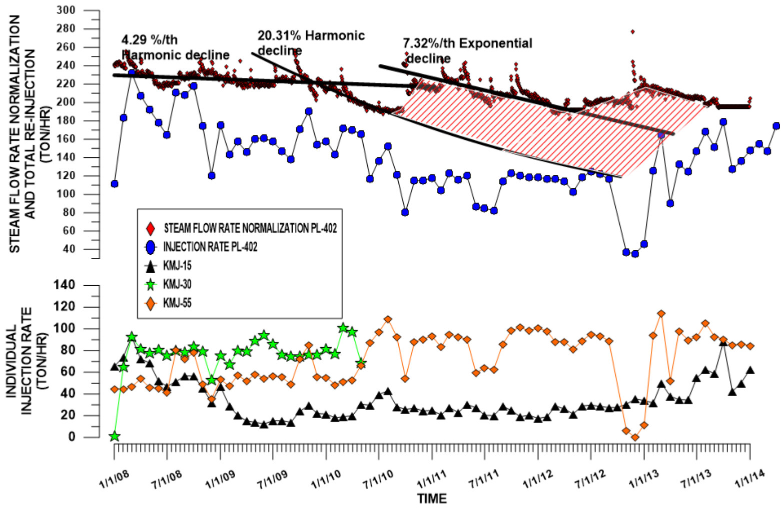

Figure. 5. Performance decline rate to the rate of injection wells PL-402 group

2.3. Groups of Wells PL-403

Group of wells located in the southern part consists of 10 (ten) production wells, supported the re-injection wells closest east that KMJ-21, KMJ-32 and KMJ-35 from the north. Currently being carried out monitoring of HFC R134a tracer test wells KMJ-21 for model evaluation and comparison of tracer corrections before using Tritium. From the results of monitoring changes in the chemical properties of the production wells in PL-403 is seen that KMJ-32 existence respond firmly, that the increase in injection KMJ-32 gives rise HBO_2 concentration and a decrease in% NCG which indicate boiling of condensate re-injection (Yani, 2012). Fig.6 shows the injection wells KMJ-21 at the beginning of 2008 until mid-2010 was injected stable in the range of 60 tons / hour and KMJ-32 injected fluctuate. Seen by increasing the rate of injection KMJ-32 during the period there was an increase in total production response. The increase can be seen clearly in the period mid-2010 to mid-2011, production increased with the value of 2.28% improvement where during this period KMJ-21 and KMJ-32 were injected continue. Furthermore, after a period of mid-

2011 back production decline with increasing production decline of 16.44%. The next period mid-2011 to the end of 2012 looks back occurs when the production wells improvement of production operation of injection wells KMJ-35.

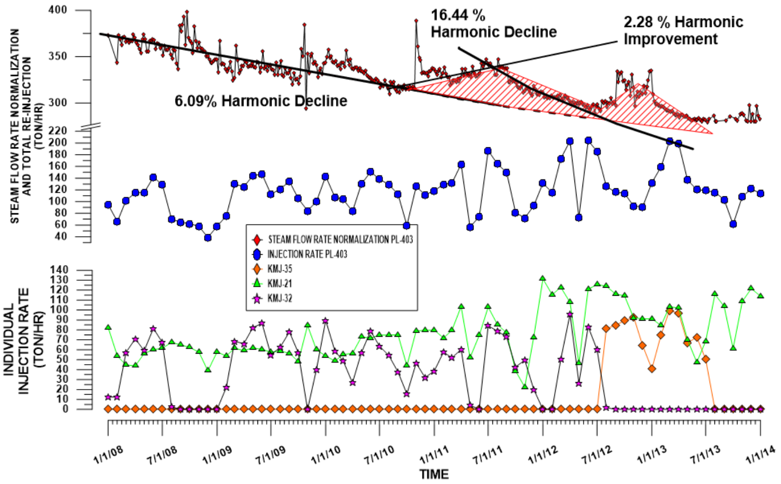

Figure. 6. Performance decline rate to the rate of injection wells PL-403 group

RF production trend marked improvement in Figure 6 at 2% of the total condensate is injected into the PL-403. This improvement is equivalent to an average conversion of 7 MW of electricity. Seeing the performance of the above it is advisable to increase the injection of KMJ-32 at a flow rate of 80 tons / hour can even be increased to 120 tons / hour, also maintaining maximum injection KMJ-35 at 80 tons / hour. Perform routine monitoring of chemical properties change in response to production.

2.4. Groups of Wells PL-404

There are 12 (twelve) production wells belonging to the PL-404 and there are three (3) North section of injection wells, while in the West there are injection wells. The western part of the reservoir is a border area with marginal zone (outside the reservoir boundary), where the pressure drop in the reservoir causes the recharge of the area outside the entrance to the reservoir. Mixing between recharge the reservoir fluid can cause scaling in the reservoir wells. It is seen several wells have no indication of scaling well even silica scale tests carried out at the time of production.

Observation of the effect of re - injection wells on PL - 404 group is as shown in Fig. 7, that the influence of injection causes an increase in rate of decline. Injection KMJ - 46 and KMJ - 30 with a rate of 60 tons / hour - 80 tons / hour impacts decline is quite high, whereas at the end of the observation that a single injection of KMJ - 35 in PL gives low decline rate of 4.01 % . For now maintained KMJ - 35 injection gradualy 40 ton/hour and monitor the impact of the re-injction. Study the possibility of placing the re-injection wells in the south-West to maintain the production of PL-404.

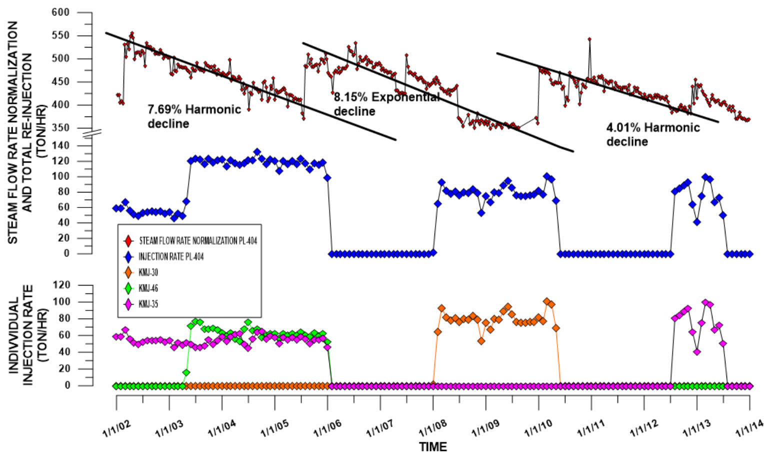

Figure. 7. Performance decline rate to the rate of injection wells PL-404 group

3. CONCLUSION

Supporting factor gains RF of the program running on the PL group Kamojang is: superheated reservoir conditions, injection wells are not located in the reservoir area due to injection wells added relatively little deeper and is located in the low permeability zone so there is no flow directly and quickly into the reservoir. Distance re-injection wells to production wells already optimum prevent immediate breakthrough.

Thus the benefit to increase the re-injection of increasing RF it is advisable to run the program re-injection as suggested in the discussion above in each PL. Obtaining optimal RF can reduce the amount of make-up wells and extend the field life time management. Especially for PL-404 needs to be re-injection wells placement in the western part and western regions - the South to support the wells in this group in order to obtain optimal RF.

REFERENCES

Dwikorianto, T., Z. Abidin, Y. Kamah, D. Sunaryo, A. Hasibuan, Prayoto, 2005, Tracer simulation in Kamojang Geothermal field , west Java Indonesia, Proceeding geothermal congress 2005 Antalya, Turkey, 24 – 29 April 2005.

Goyal, K., P,. Jr, Box, W., T., 1992. Injection recovery based on production data in Unit 13 and unit 16 area of the geyser filed. WGC Stanforrd, California 1992, SGP-TR-141

Goyal, K., 1995. Injection influence on production wells in the unit 13, unit 16, SMUDGEO#1, and Bear Canyon areas of Southeast Geysers. WGC -1995.

Sanyal, S, K,. Granados, E., E., Menzies, j., A., 1995. Injection – related problem encountered in geothermal project and their mitigation: the united states experience. WGC 1995

Sudarman, S., Guntur, B., Satyajit, D., Sumantri, Y., 2000. Mapping reservoir permeability with geoelctrical, FMS, and Spiner data Kamojang field Indonesia. In: Proceedings WGC, Kyushu-Tohoku, Japan, May 28 june 10, 2000, pp.2911-2017.

Suryadarma, Dwikorianto, T, Zuhro, A. A., Yani, A., 2010. Sustainable development of Kamojang geothermal filed. Geothermics 39 (2010), pp 391-399

Yani, A., 2012. Optimization of monitoring the impact of the exploitation of the field Kamojang through equilibrium models Natural Gas and Isotope 2H and 18O. Internal report Kamojang 2012, 80p

Sofyan, Y,. Daud, Y., Suprianto., Yani, A., Tommy Herdiansyah., Nishima, J., Fujimitsu, Y., Fukuda, Y,. 2012. Decline mass trend of unbalanced production to recharge activity in Kamojang geothermal field, Indonesia : Continuous monitoring with hybrid gravimetry, Proceeding Thirty-seventh workshop on geothermal reservoir engineering stanford University, stanford, California, Januari 30 – Febuary 1, 2012.