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Life Time Prediction of Steam Supply of Well Groups PL-405 Based on the Maximum Discharge Pressure Decline Monitoring Kamojang Geothermal Area

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ABSTRACT

Maximum discharge pressure is a technique in decline curve analysis that was used for prediction of life-time supply of steam to the power plant in the Kamojang geothermal field. The straight line correlation obtained over the first 15 years of production was plotted for a productive groups of well in Kamojang.

By using the trend analysis of each well, it was possible to get an indication of the sustainable pressure from in-flow to the reservoir and the wells were grouped based on the trend of the curve.

1. INTRODUCTION

Kamojang geothermal field was the first geothermal field in Indonesia when it started to be produced over 25 years ago. Starting in 2008, the Komojang production capacity was increased through the successful development of the 60 MW Power plan unit-4. Now the total production capacity of Kamojang is 200 MW. The Unit-4 power plant is PT. Pertamina Geothermal Energy's first power plant.

The Kamojang reservoir is steam dominated with 230 - 240ºC reservoir temperature and around 25 bar reservoir pressure as of 2008. After 25 years of operation all of the wells had declining production capacity and there was also declining maximum discharge pressure at the well head of each the wells. There are the different turbine inlet pressure designs of the power plants between the last 60 MW power plant Unit-4 (60 MW) and the 140 MW power plant Unit-1 (30 MW), Unit-2 (55 MW) and Unit-3 (55MW). The existing unit power plant operates at 6.5 bar inlet turbine pressure and the last unit-4 operates at 10.15 bar. Considering to this situation, there is a need for serious attention to keep sustainable steam supply from the wells.

Kamojang wells are grouped into five pipe line systems, which are PL-401, PL-402, PL-403, PL-404 and PL-405. The wells connected to PL-401, PL-402, PL-403 and PL-404 are grouped together and supply steam to the existing 140 MW power plant unit. They are integrated with each other at header gathering system. Wells which are grouped in the PL-405 supply steam to the 60 MW power plant unit-4 and are separated with another pipe line system.

Through continuous monitoring of the decline in maximum discharge pressure of the wells we can predict and take action to solve the problem of power plant sustainability from steam supply. Such monitoring studies have been applied in other fields in the world like Wairakei, New Zealand. Kamojang is dry steam like the Geysers and Larderello geothermal fields.

2. THEORETICAL APPROACH

Much of theory has been developed to solve decline rate calculations. One of the theories used in this paper is decline monitoring of maximum discharge pressure (MDP) in the well head (James, 1980). The reduction of condensate layer (water level) in the reservoir causes a reduction of the pressure of the reservoir and that causes a reduction of MDP in the well head.

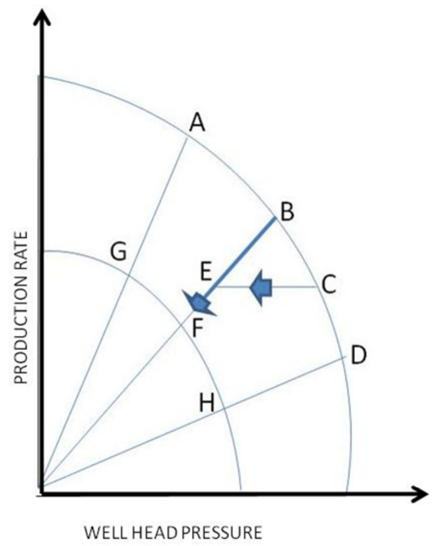

Figure 1: Sketch showing relation between rate and well head pressure, and how output curve shrinks towards the origin with time during production (Russell James, 1995)

The measurable part of the curve is AD, where point A is the highest flow with wide-open vertical discharge. Point B is wide-open horizontal discharge suitable for maximum electric power. Point D is the condition of maximum discharge pressure (MDP) and gives the greatest wellhead pressure under flowing condition (not bleeding). With years of production, curve ABCD shrinks towards the origin so that when the flow and pressure have halved, the output curve has reduce to GFH. It is important to note that geothermal systems usually follow the radial path BO, with both discharge and power directly proportional to MDP. Experience with powerful wells indicates point B will decline along BO over the years to half its origin value at point F. Point C is for the throttled condition where discharge is held constant until point E is intersected. The locus CE cannot be extended horizontally because the radial BO is for all valve wide-open, hence the locus has now to continue along the radial EO for the remainder of its productive life, with flow, wellhead pressure, MDP and power decreasing together (R. James, 1996).

In the case of dry steam fields such as the Geysers, Larderello and Kamojang which is discussed in this paper, the instantaneous closed-in wellhead pressure is the analogue of the MDP of hot water fields and occurs at zero flow rate (Russell James, 1995).

MDP theory was developed by R. James (1995) where the plot of $\left(\frac{P_O}{P}\right)^2$ versus time should give a straight line.

$$\left(\frac{P_O}{P}\right) = 1 + Ct \qquad (1)$$

P = MDP at time = t

P_o = Original MDP at time t = 0

C = Constant

MDP data for this paper is taken from Kamojang wells production history database, row data interval 2 – 5 years. An exception is wells grouped in the PL-405 interval because there is less than one year of data available because they were only operated in 2008. Due to the limited data test for instantaneous closed-in wellhead pressure from the wells in Kamojang case, MDP was taken from the maximum of production wellhead pressure where the master valve was full open during production .

Each of the well has a different slope and profile "Half-Life" (Russell James, 1995). Half-life is the time where MDP value decrease to be a half of original value. The plotting result of $\left(\frac{P_O}{P}\right)^2$ versus time from all of the wells can be re-plotting together in one graph by changing the value of (t) to be the non-dimensionless "Relative-Time."

$$RELATIVETIME = \frac{t}{Half - life} \qquad (2)$$

2.1. Production Decline

Experience dictates that no matter how big the reservoir, how large the discharge and how small the number of wells, there will be decrease in output over time from the beginning of production (James Russell, 1996).

That happened in Kamojang where the production of all of the wells was decreasing during production, and it will be shown that there can be a big decline in production at the beginning of starting production. After a long time of producing the reservoir, there is a more stable condition and the decline rate goes down. Wells supporting the power plant Unit 140 MW have a 3%/year decline rate and wells supporting Unit 60 MW have a 25%/year (after one year).

Production decline was correlated with decreasing of MDP, so that from MDP monitoring decline we can make a prediction of the life time of steam supply to the power plan. If MDP reaches the limited inlet turbine pressure or minimum line pipe pressure in gathering system, the wells will no longer be able to supply steam to the power plan.

2.2. Reinjection Strategy

Good reinjection strategy is the key to success for providing a sustainable steam supply to a power plan. Each of the well groups in Kamojang include injection wells. Tracer tests were evaluated for good understanding of connectivity studies between production and injection wells.

3. KAMOJANG MDP ANNALYSIS

3.1. Well Group PL-401

Almost all of the most productive wells of Kamojang were in the PL-401 pipe line group, from which production started in 1982. Data from one of the wells, KMJ-11, and the value of $\left(\frac{P_O}{P}\right)^2$ are given in Table.1. A plot of dimensionless time squared against time is shown in Figure 1.

Table.1. Decline in maximum Discharging-Pressure (MDP) for well KMJ-11 during years of production at Kamojang, Indonesia.

Moth /year	t years	P(MDP) Ksc	(Po/p)2
Mar-83	0	23	1
Mar-86	3	22.5	1.04
May-88	5.08	18.7	1.51
Dec-90	7.58	17.6	1.71
Jul-93	10.25	16.3	1.99
Mar-98	14.91	14.2	2.62
Sep-00	17.41	15.2	2.29
Jun-03	20.16	15.1	2.32
Sep-05	22.41	13.9	2.74
Dec-07	24.49	12.2	3.55

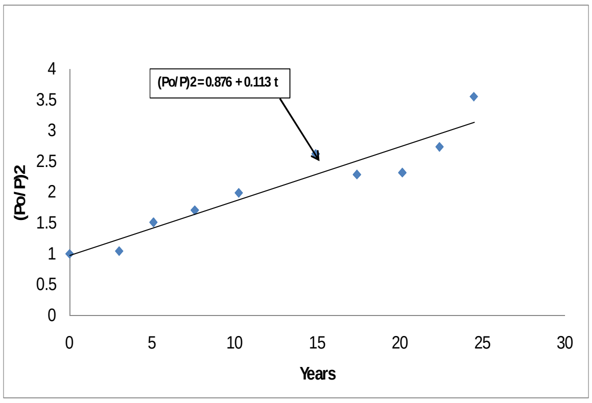

Figure 2: Plot of $(Po/P)^2$ with time KMJ-11

The data can be fit with a straight line with the formula of:

$$\left(\frac{P_O}{P}\right)^2 = 0.876 + 0.113t \qquad (3)$$

It is seen that after 15 years the straight line fits well, but after 15 years the plot diverges from the straight line. For example, at t = 17.41 years, from equation (3), we will get P = 16.04 Ksc whereas actual value is 15.2 Ksc as given in Table. 1. This condition can be use for crosscheck the reinjection strategy and this indicates water inflow to the reservoir to help stabilize pressure in the reservoir.

From Figure (1) we can get Half-life of $(Po/P)^2$ = 1.75 at the straight line of 7.73 using equations (3). The same technique was used to calculate the Half-life of the other wells in this group, which are given on Table (2).

Table 2. Half-Life MDP of Wells PL-401.

Wells PL-401	HALF-LIFE (years)
KMJ-11	7.73
KMJ-14	6.28
KMJ-17	4.77
KMJ-18	5.64

Data from of all the wells PL-401 were re-plotted, $(Po/P)^2$ against Relative-Time, as shown in Figure (2). From Figure (2) we see the end of straight line at Relative-Time = 2.25.

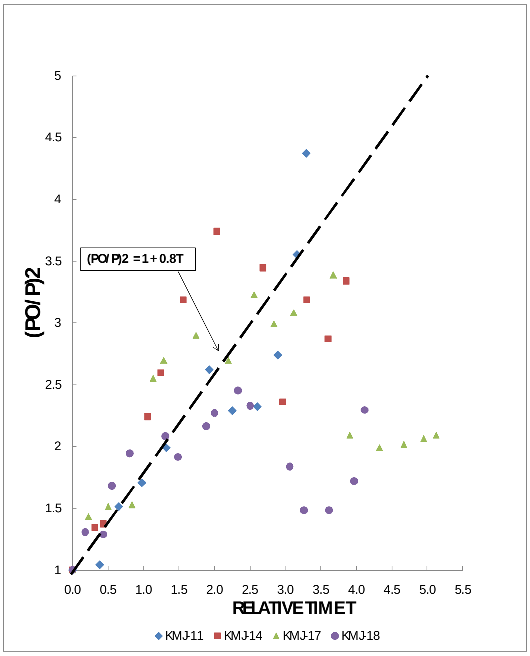

Figure 2: Plotting variation of value (Po/P)2 against Relative-Time of wells PL-401, Kamojang, Indonesia

3.2. Well Groups PL-405

As previously stated, the wells in group PL-405 started production at the beginning of 2008, less than 1 year total. Using the same method with the limited data from wells in group PL-405, we get a straight line equation on the plot of $(Po/P)^2$ against Relative-time as in Figure (3) $(Po/P)^2 = 1 + 0.8T$, and the real value of t (time) can be used to calculate the Half life Value as given in Table (3).

Table 3. Half-life MDP of Wells PL-405.

Wells PL-405	HALF-LIFE (years)
KMJ-53	0.43
KMJ-58	0.63
KMJ-59	0.45
KMJ-61	0.93
KMJ-71	0.7
KMJ-75	0.54
KMJ-76	0.62

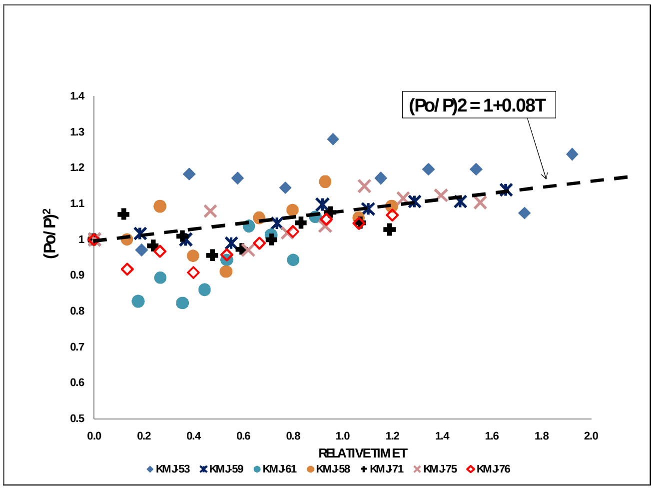

Figure 3: Plotting variation of value $(Po/P)^2$ against Relative-Time of wells PL-405, Kamojang, Indonesia

4. DISCUSSION

Using MDP decline trend analysis we can predict life time of a power plan based on sustainable steam supply from the wells. Plotting results together, as shown in Figure (2) and (3), gives the equations (Po/P)2=1+0.8T and (Po/P)2=1+0.08T, which can be used to predict values of Pressure (P) at time (t). The results of the calculations are shown in Table (4) and (5).

Half-life time values are shown inn Table (2) and Table (3). There is some variation, but in the same group, values stay relatively close to each other. This means the wells are in the same reservoir.

Wells in group PL-401 supply steam to Power plan Unit-1 with minimum turbine inlet pressure 6.5 bar (6.62 Ksc) and wells on groups PL-405 supply steams to power plan Unit-4 with minimum turbine inlet pressure 10.15 bar (10.35 Ksc). Assuming a pressure drop from wellhead to power plant Unit-1 of about 0.5-1 Ksc and 2 Ksc for power plan unit-4, it can be estimated that PL-401 have discharge pressure limit at 7 bar and 12.5 for PL-405.

As shown in Figure (3), the plot of $(Po/P)^2$ against relative-time tends to straight line for the entire plot. But for PL-401, as shown in Figure (2), the plot diverges from a straight line after T = 2.5. This indicates that flow in the reservoir has become more sustainable.

Considering that PL-405 has just started to be produced, there is a need for good data collection through continuous monitoring. To get high confidence in a prediction can take several years of monitoring. Decisions need to be as quick as possible in development of a geothermal area. The life time of power plan can be predicted using the MDP decline analysis method. The results of calculations using this method in the Kamojang wells are shown in Table (4) and (5). The results are a warning to immediately do the best reservoir management possible in order to produce the reservoir sustainably.

Table 4. Comparison of Maximum Discharge Pressure (P) base on calculation using equation to actual data monitoring.

Wells PL-401	Relative Time T @ 25 years	$(PO/P)^2$	P Calculation (ksc)	P actual November 2008 (ksc)
KMJ-11	3.23	3.59	12.1	11
KMJ-14	3.98	4.19	11.3	12.6
KMJ-17	5.24	5.19	10.1	15.5
KMJ-18	4.43	4.55	11.3	15
Wells PL-405	**Relative Time T @ 25 years**	**$(PO/P)^2$**	**P Calculation (ksc)**	**P actual November 2008 (Ksc)**
KMJ-53	1.85	1.15	18.4	17.1
KMJ-58	1.28	1.11	19.8	19.2
KMJ-59	1.77	1.15	20.5	20.1
KMJ-61	0.86	1.07	16	15.8
KMJ-71	1.14	1.09	21.2	21.1
KMJ-75	1.49	1.12	19.7	19.6
KMJ-76	1.28	1.11	17.5	17.1

Table 5. Time Calculation at Pressure Condition.

Sumur PL401	Po	Relatif Time T @ P = 7 Ksc (6.86 bar)	t @ value P= 7 Ksc (year)
KMJ-11	23	12.24	95
KMJ-14	23.2	12.48	78
KMJ-17	23	12.24	58
KMJ-18	24.1	13.57	77
Sumur PL405	**Po**	**Relatif Time T @ P = 12.5 Ksc (12.25 bar)**	**t @ value P= 12.5 Ksc (year)**
KMJ-53	19.8	18.86	8
KMJ-58	20.8	22.11	14
KMJ-59	22	26.22	12
KMJ-61	16.6	9.54	9
KMJ-71	22.2	26.93	19
KMJ-75	20.9	22.44	12
KMJ-76	18.4	14.58	9

CONCLUSION

Through Maximum discharge pressure we can predict life time of power plan by know the time of the well where supply steam no more. But the shortage of steam will handle with make-up wells.

The best continues monitoring need to do to the wells for to get the accurate data for get best result. Minimum data test need to do is every 1 to 2 years.

Wells in the one group are lean to have close value of half-time, its means wells in the same reservoir. We can choice the one of the wells for continues monitoring of MDP.

Need to apply the injection scenario to the wells in group Pl-405 to help sustainability steam supply as compare with reservoir condition at wells group Pl-401.

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