Proceedings World Geothermal Congress 2005
Antalya, Turkey, 24-29 April 2005

The Productive Feed Zones Identified Based on Spinner Data and Application in the Reservoir Potential Review of Kamojang Geothermal Area, Indonesia

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Keywords: Spinner, Productive Feed zones, Geothermal reservoir, Pertamina-Kamojang

ABSTRACT

Spinner Logging is a tool that directly identifies flow rate at points in a borehole. It's closely correlated with the formation permeability. Spinner data are useful for prediction of reservoir productivity zones. Depletion curve of spinner informs the steam entry or steam loss in the reservoir zones.

Spinner data of sixteen wells identify two major productive feed zones in the Kamojang geothermal Reservoir. Upper Feed zone (FZA) is at 700-800 masl elevation and lower feed zone (FZB) is at 100-500 masl elevation. At FZA, production wells are 60 – 65 tons/hour; at FZB, they are 75 – 80 tons/hour with the wellhead pressure of 15 Ksc. In the Kamojang Reservoir, the productive feed zones are distributed in the Western and Eastern blocks.

The evaluation spinner data can be used for supporting make-up well prognosis and predicting the well output early, before the well completion.

1. INTRODUCTION

Kamojang geothermal field is located 42 km East of Bandung, the capital city of West Java, Indonesia. See map on Figure 1.

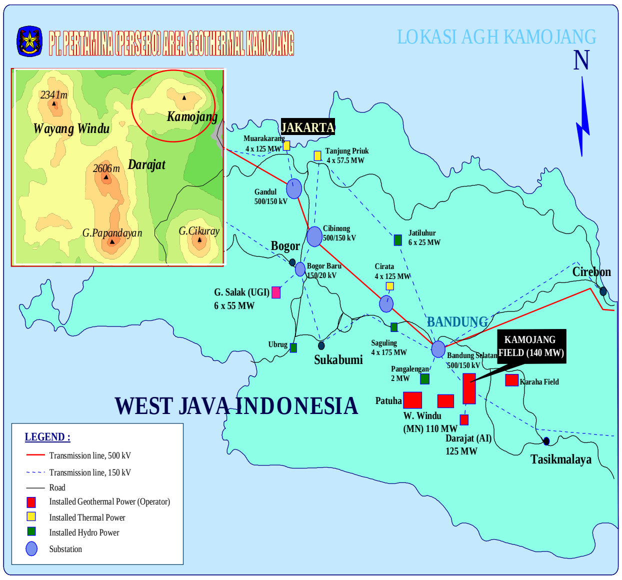

Figure 1: Location of Kamojang geothermal area, Indonesia

A field size of 14 km^2 was determined by DC-Schlumberger. Further filed delineation of 21 km^2 was determined from the CSAMT resistivity, Sudarman (1988).

Seventy-seven wells have been drilled in this area since 1974. Fifty-three of these wells are located in the main production area. The other wells are drilled for both stand by wells as maintenance's supplying 140 MWe and for future extension of another 60 MWe at the Eastern Kamojang Block, Sasradipoera et al. (2000). See Figure 2.

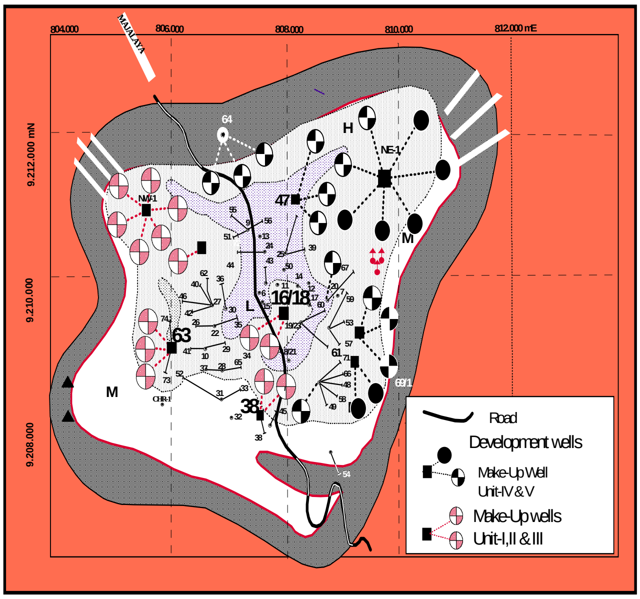

Figure 2: Kamojang boundary. Area that includes 77 wells

This field is the first geothermal development in Indonesia with the capacity of 2.5 MWe. Supplying 30 production wells to the electricity turbine, the geothermal system of Kamojang reservoir is vapor dominated with to date developing capacities of around 140 MWe, Sudarman, et al (1995).

The alteration study at the Kamojang geothermal field is still limited in determining the hydrothermal mineral presence. Sometimes, in these situations, subsurface geoscience problems are not answered, e.g. real top to bottom reservoir, reservoir thickness, and the well output.

The PTS (Pressure Temperature and Spinner) survey is an excellent method for solving the problems mentioned above. The PTS data and analysis results inform the pressure and temperature distribution, top of fluid level in hole, physical condition of casing, liner in the hole and wells productivity, which contribute to one or both feed and thief zones.

2. KAMOJANG GEOTHERMAL FIELD

2.1. Background

The Kamojang field is associated with a Quaternary andesitic stratovolcano. Geological structures, which have been identified through the field studies, include volcanic collapse structure forming crater walls on manifest horsts and grabens associated with normal faults (Figure 3).

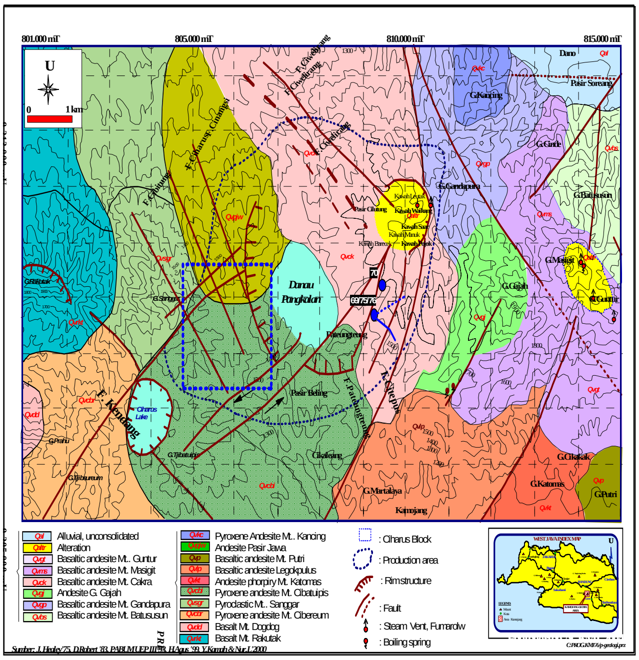

Figure 3:Geological map of Kamojang

The geothermal system is manifested by fumarole, solfataras, boiling springs, mud pools and intensive hydrothermal clay alteration which occurs at an intersections between the N-S Citepus fault and a series of NW-SE faults within the Gandapura formation (0.4 my). Clay alteration within the Gandapura formation forms a cap rock in the system. The underlying Rakutak basaltic andesite (two of which are mine) is the primary reservoir rock. Loss of circulation while drilling is frequently found along the contact between the Rakutak and Gandapura formation. Reservoir entries are also believed to be associated with fractures permeability, which is related to the faults Sudarman et al (2000) and Pokja (2000).

Some faulting and rim caldera control the permeability in the drilling target reservoir. The best permeability of The Rim caldera of Pangkalan supports the western block. It is mainly productive feed zones. Lithological contacts also present target permeability but it has been just a little more productive than the permeability from the structure.

Sudarman et al (1990) interpreted that the field has an areal extent of about 21 km^2, based upon the CSAMT (Controlled Sources Audio Magneto Telluric) resistivity anomaly. Exploration wells in the north and southeast have confirmed the size of the system. Only about 40 % of the area have been intensively drilled. It mostly covers the central part of the filed. About nine of the production wells have low output due to inadequate permeability in the Rakutak formation.

The Kamojang reservoir is steam dominated and includes an area of 21 km^2 (commercially proven with the help of the productive wells). The additional drilling is needed in order to complete the steam requirements for units IV and V which will be placed within these zones.

Based on Magneto telluric resistivity data and with the combination of the drilling data, it is likely that an additional area of 7 km^2, lying largely in the western part of the block, is needed. Based on these areas and on a typical reservoir range of 15 to 20 MW per km^2 for such volcanic system, the estimate for the Kamojang geothermal field ranges from 210 to 280 MW for the period of 30 years, Sanyal et al. (2000).

Production is obtained from fractured andesite with the top of reservoir at elevation of about 900m (msl) in the northern part of the area, sloping from there to the west and south, and dropping sharply in the extreme south to about 200m (msl), Sanyal et al. (2000).

Chemical data from the representative wells are typical for the steam wells with total non-condensable gas content generally below 1% of the weight and with H_2S gas content less than 300 parts per million of the weight.

2.2 Permeability Distribution

Sudarman et al (2000) presented the Kamojang reservoir permeability distribution on the permeability distribution map shown on Figure 4:

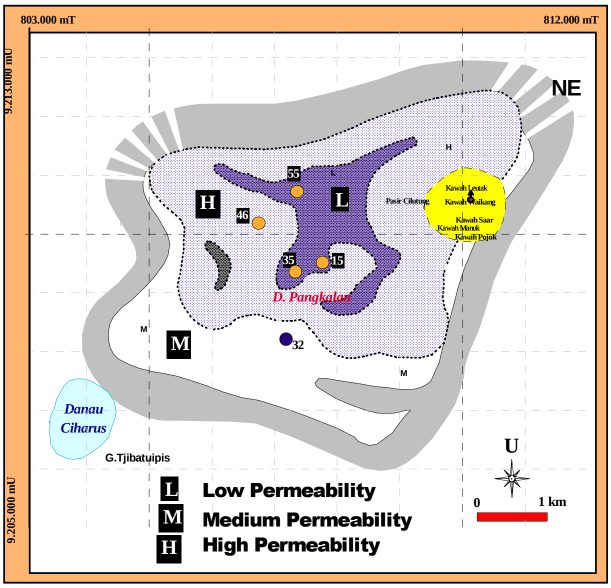

Figure 4. Permeability distribution on Kamojang reservoir area

The permeability can be incorporated into a permeability map characterizing the reservoir features. Reservoir permeability is controlled by both steeply dipping faults and bedding planes along the contact of the Rakutak and Gandapura formations. The bedding planes influence widespread lateral high permeability zones that are expected from the distribution of the faults. The permeability map shows that the lateral high permeability zones extend to the northeast and northwest of the production area, which provides a new target for drilling.

3. SPINNER SURVEY AND PROCESSING DATA

3.1. Methodology

Spinner Logging is a tool to directly identify flow rate at points in borehole. It is closely correlated with the formation of permeability in the reservoir. Spinner logging is running in the hole joints, which are parallel to the pressure and temperature surveys (as we sometimes call PTS survey). PTS survey has capability of detecting trouble early. Fluid loss in thief zone, fractures plugged, channelling around cement bound, casing or tubing break are the problems that PTS can detect.

In the Kamojang geothermal area, both PT.Welltekindo and Trident Well Service (USA) have been running the PTS logging survey in 13 wells. Operational system that uses Surface Read Out (SRO) directly records data along the depth, which is computer memory efficient. Within this system approach, we decrease the time, while the result of survey is more accurate than that of the mechanical system. The spinner equipment was developed by the Trident,USA, in 1986, and is widely used for handling geothermal wells, Weltekindo Nusantara (1998).

The Surface Read Out System (SOR) operating system has high performance. It records data per two seconds. Recording resolution is 0.01 psi and the accuracy is around 0.2 % of full-scale pressure. The accuracy of the temperature is up to 0.01 F degrees on the 1.50 F of full scale. The other advantage of this system is its ability to quickly detect any error during the run in the hole.

The equipment tool is set at a very high temperature. Thus, both electrical and non electric tools support extreme pass-out, which according to the military standard of up to 600 degree F. Especially for the spinner tool, the equipment must be resistant to a very high temperatures because of the possibility of the mineral composition breakage. The impeller is free rotated. This equipment is supported by special bearing with the joint support of 14-cylinder magnet for the optimal rotation. The impeller is made from alloy cupric beryllium in order to preserve the ion to anode change. This protects the depositing of any minerals where the tool rotating point is optimal.

By rotating the impeller in the magnetic field, we get the continuous electric signal, which is transmitted to the computer software at the surface.

Minimum speed of the impeller is 0.06 cycles per second or 0.084 counts/hertz/pulse per second, while the maximum impeller rotating speed is 417-cycle per second or 5.833 counts/hertz/pulse per second. The impeller's speed range allows the fluid flow in the hole. See Table 1.

Table 1: PTS tool specification

PTS TOOL SPESIFICATION

Mechanical :		**Pressure System :**	
Tool Temperature Rating	600 Deg F	Pressure Range	0-10000 PSI
Tool Pressure Rating	10000 PSI	Resolution	0.010 PSI
Tool OD	1 11/16"/3"	Accuracy	0.2 %
Length	110-120 inc		
Weight	50-75 lb		
Flow Measurement :		**Temperature System :**	
Temp Rating	600 Deg F	Temp. Range	75 - 600 Deg F
Minimum flow	10 Ft/min	Resolution	0.010 Deg F
		Accuracy	1.50 %

3.2 PTS Procedure Survey in Wells

Supporting materials for the spinner job in the hole include a wire line tools and winch unit complete with the monoconductor 5/16" and bride line 3/16", which are resistant to the high temperature (600 degree F) and wire line with length equal to the depth of the reservoir. Also, it includes power pack with machine capacity of 80-90 HP, surface pressure control equipment BOP (blow out preventer), lubricator act, telescopic rig and computer record.

The first step before starting the PTS survey is to run sinker bar in order to detect the conditions in the hole (the optimal depth of the well). The results are used as a guide to plan PTS component equipment and setting the point of interest in the hole.

The PTS operational procedure starts by installing PTS equipment into the rope socket at the monoconductor cable. The equipment slowly logs down from surface to the total depth with the speed frequency of 100 FPM (feed per minutes). The WHP (wellhead pressure) is used for recording. During log down the recording activity continuously sends the signal to the computer. Table 2 shows the results of the continuos ordinate of depth versus speed in cycles per second:

Table 2. Data recording sample from CHR-1

Depth (m)	Press (PSI)	P. Grad (PSI/ft)	Temp (deg F)	T. Grad (deg F/ft)	Spinner (cps)
Started Log Down					
0	260.43		401.74		136.47
0.56	261.03	0.3243	401.75	0.0056	136.47
0.99	261.09	0.0432	401.83	0.0067	136.47
1.37	261.08	0.0080	401.82	0.0067	136.47
act	act	act	act	act	act
Started log up to the top of liner					
1783.34	333.98		424.20		0
1782.39	333.61	-0.0602	424.35	0.1278	0

Twenty minutes past tandem, in its deepest, the PTS equipment log up to the depth of top of liner is 7". For log down, WHP and speed frequency are constant as well. For some log down, the PTS equipment continuously recorded data from the bottom to the top of liner as 7". The meaning of the PTS equipment stop for log up at the top of liner as 7" is the accuracy target data for both depth and speed in cycles per second, because the potential target running PTS is in the reservoir feed zones.

During log down and log up, the data produced results instantly, informing some of the major feed zones as a target. Thus, the next activity is to log down again but stop at the main feed zones and a stationary stop. Recording is still continuous with changes of the WHP per 10 - 20 minutes. In the Kamojang geothermal wells, the WHP schedule runs are 17.5 Ksc, 15 Ksc, 12.5 Ksc and 10 Ksc. The last step is to perform the continuous log down to the bottom parallel to the recording and to run up or log up to the surface.

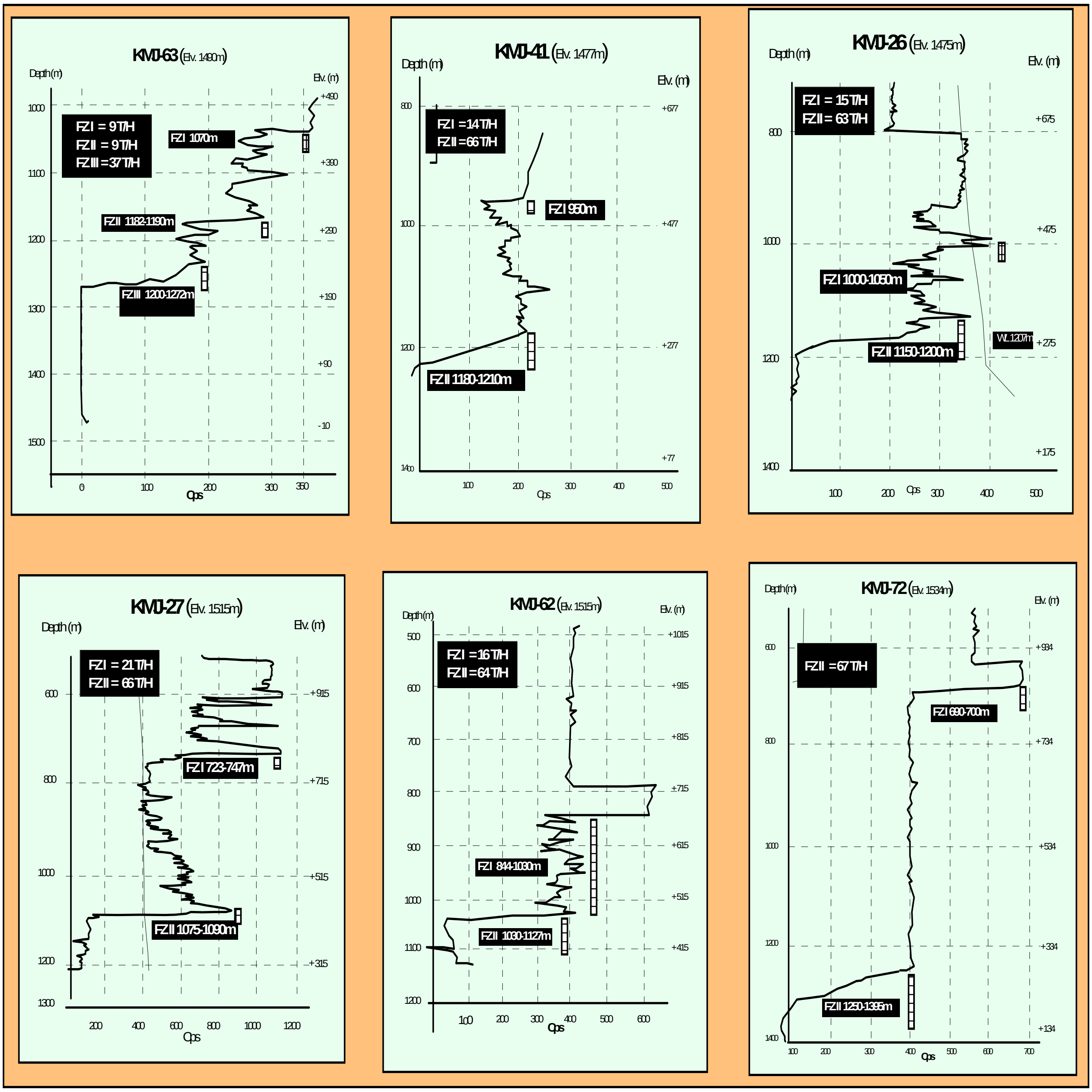

Figure 5: Spinner data graphics joint the pressure and temperature in view wells

3.3 Processing and Analyses Data

During the monitoring of log down or log up PTS in the holes, the well still produced fluid while flowing to the pipe line production. These situations effectively influence the spinner equipment which rotates freely at the point of feed zone where the fluid flows throughout to the surface and/or reverse to the thief zones.

The results of running PTS are shown in Figure 5 as graphic charts of function of depth (meters or feet) versus temperature (C or F), pressure (Ksc) and speed (cycle per second).

These charts are produced by processing data that inform the point of interest. Furthermore, this result can be used as a guide for minimizing the cost and time, which in turn will lead to the decision of whether to develop the area or not.

4. RESULTS AND DISCUSSION

4.1 Interesting Zones and Reservoir Productivity

Figure 6 shows the main feed zones of CHR-1 well at three points of depth: FZ I (feed zone I) at 1506-1600 m depth, FZ II at 1450-1456 m depth and FZ III at the depth of 1399-1402 m. These figures show one of the best performance samples of spinner data. The results are closely correlated with the point of true depth of potential feed zone, which is a main target for producing a fluid.

The spinner curve depletion indicates the fluid capacity throughout the hole from the feed point. As was mentioned before, Kamojang geothermal reservoir is steam dominated. Thus, in order to calculate the capacity of steam flow the assumption of mass balance rule (capacity produce is constant with unit of ton/hour) should be made. Enthalpy is kept constant and capacity to each point of zone in reservoir should be calculated as a reflection of the spinner depletion curve in cps (cycles per second).

After completing the production of the well test using several wellhead pressures, we can show the initial production per well (in unit ton/hour and/or MWe@ WHP). For example, for the well CHR-1 initial well production is 21 tons/hour at 15 ksc WHP.

Total spinner depletion is 189 cps. Thus, each FZ is delta speed per total depletion times of the initial well productivity, which is equal to the productivity of each FZ. The productivity of FZ I, FZ II and FZ III is 49, 22 and 29 percent respectively of the total well productivity.

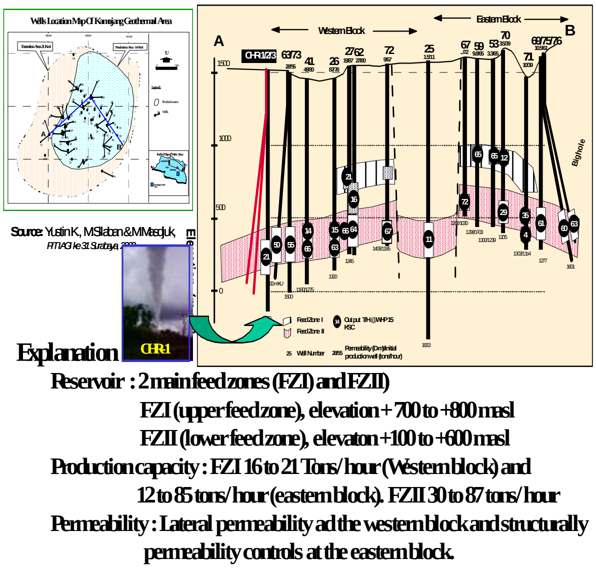

Figure 6: Result of the Spinner running in well CHR-1 Kamojang

These results clearly show the drilling target. Thus, the production of the well can be predicted early, before the completion. The other benefits include the depth target that is realistic and the casing design that is reduced.

4.2 Correlation of Main Feed Zones and Distribution of Production Wells

Figure 7 shows the section of the Kamojang geothermal reservoir trending SW – NE with respective correlation between 16 wells. The main objective is to represent the distribution of major feed zones and well productivity.

Kamojang reservoir consists of two major feed zones. The upper FZ (FZ I) elevation ranges between 700 and 800 m asl (meters above sea level) and the lower FZ (FZ II) elevation is between 100 and 600 masl. The production capacities (FZ I) range between 16 and 21 tons/hour for the western block and between 12 and 65 tons/hour for the eastern block, while in the FZ II productivity range between 30 and 87 tons/hour.

According to the distribution of production, capacities in the reservoir show that FZ II is the major feed zone that mostly represents the optimal developments that extend to more than 200 MWe. The trending of major feed zones still opens to the SW and NE. At the SW trending, the production casing is deeper than the NE point. However, in all cases, the extensive approach is needed.

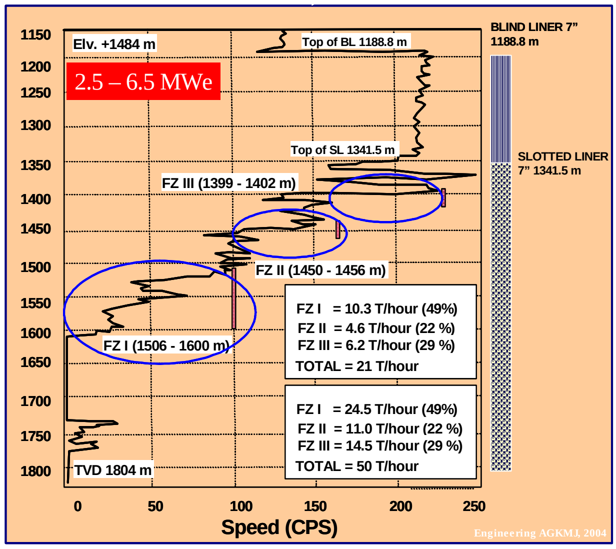

Figure 7. Reservoirs feed zone distribution at the SW to NE trending, Kamojang

4.3. Permeability control in reservoir zones

Referred to as a back view of geological structure map, spinner result of distribution, production capacity of the wells and reservoir major feed zones indicate that the reservoir permeability control should be separated at minimum by two major controls.

The western block has dominantly lateral permeability where a bedding plane through formation contacts between Rakutak formation and Gandapura formation. One of the indicators of this is a relatively similar well capacity of steam produce. At the eastern block, the permeability is in the dominant structure control because the capacity produce per well is not the same and is separated by the permeability barrier.

5. CONCLUSIONS

These results clearly show the drilling target. Thus, the production of the well can be predicted early, before the completion. The other benefits include the depth target that is realistic and the casing design time that is reduced.

According to the distribution of production, capacities in the reservoir show that FZ II is the major feed zone that mostly represents the optimal developments that extend to more than 200 MWe. The planning drilling strategy that uses the extensive approach is needed in all cases.

Back view of geological structure map, spinner results, production capacity and reservoir major feed zones indicate that the reservoir permeability control can be separated at minimum by two main controls. The western block has dominantly lateral permeability. The eastern block has the permeability of the dominant structure control.

ACKNOWLEDGEMENTS

The author thanks the Management of Pertamina Ltd for permission to publish this paper. We also acknowledge the Management of the Kamojang Geothermal Area for supporting the final decision on this paper.

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