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Ulubelu, First Year Reservoir Monitoring

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ABSTRACT

Production of Ulubelu geothermal field in Lampung, Indonesia, has been commenced by Pertamina Geothermal Energy since mid-2012. 11 production wells has been supplying steam to two PLN turbines of 55 MWe capacities each. Produced brine is re-injected into the reservoir through 4 wells while the condensate is re-injected through one well. Results of reservoir monitoring during first year of production are presented here.

Changes have occurred in observed wellhead pressures which may indicate an early decrease in reservoir pressure, or may also be a transient response of reservoir due to early production. Production rate and enthalpy are monitored from daily data and changes are observed from tracer dilution test data. Injection tracer test was also conducted as a part of reservoir monitoring to determine the effects of reinjection wells.

1. INTRODUCTION

Ulubelu Geothermal Field is located about 100 km west of Bandar Lampung, Lampung, Indonesia. The area is situated within a row of volcanoes (M. Rendingan and Tanggamus). Altitude is 700 m to 900 m above sea level. Geothermal explorations in Ulubelu first started in 2007 by PT Pertamina Geothermal Energy. Geological, geophysical and geochemical data obtained indicated high temperature geothermal energy resource in the region. As a follow-up, three shallow wells UBL-SH1, UBL-SH2, and UBL-SH3 were drilled to depths of less than 500 meters in the southern block.

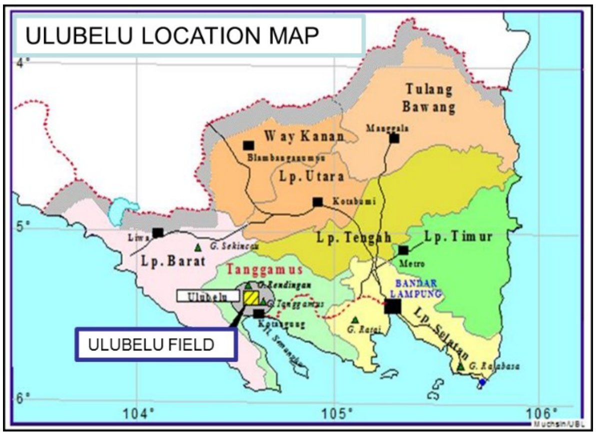

Figure 1: Ulubelu Location Map

Further exploration led to a development plan of 220 MWe electricity generation consisted of 4 power plant units. In 2012, the first and second units were commissioned and have been producing 110MWe electricity up till now, while the next two units should be operational by 2016 or 2017. In agreement with PLN (state electricity company), unit 1 and 2 are operated under Steam Sales Contract scheme while unit 3 and 4 will be under Energy Sales Contract.

Initially, 11 production wells from 3 clusters produced ± 800 t/hr. steam and ± 3000 t/hr. brine which was sufficient for supplying the two units. Brine and condensate were re-injected back through 4+1 injection wells. Additional wells have been drilled in order to support the production of unit 3 and 4. Changes in reservoir were observed through reservoir monitoring activities which mainly includes flow, pressure, and enthalpy monitoring.

2. FIELD OVERVIEW

Ulubelu reservoir is inferred to be situated in a graben. Due to the existence of numerous structures inside the graben, relatively homogeneous reservoir properties are established although geological structures dictates the permeability distribution. Permeability were generally moderate to good and uniformly distributed.

Boundary of the reservoir to the sides (West and East) would be the graben walls that have also been proved by drilling. To the North, upflow zone exists near Mount Rendingan and outflow should be to the South/SW without evident physical boundary.

As shown in the pressure and temperature profile (figure 2), which is typical for Ulubelu, reservoir fluid is single phase brine with average temperature value of 250 °C in the prospect area. Boiling zone may appear in some wells, but is not believed to occur in reservoir condition. This condition results in production fluid with moderate enthalpy.

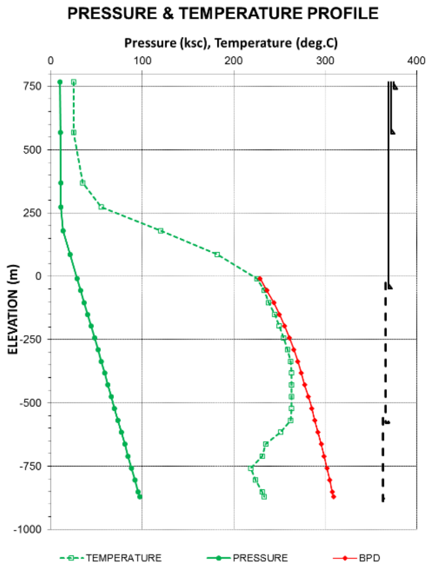

Figure 2: Typical Ulubelu Pressure and Temperature Profile

Production wells for unit 1 and 2 are located in 3 clusters named B, C, and D. Separators were built for each production cluster. Cluster B and C each holds 4 operating production wells while cluster D holds 3. Other clusters exist to enclose production wells for the upcoming unit 3 and 4. Production fluid has average enthalpy of around 1100 kJ/kg which at current separation pressure turns to about 20% of dryness. With turbine inlet pressure value of approximately 6.5 bar, around 800 t/hr. steam is required to generate 110MWe of electricity, during which process 3000 t/hr. brine is produced.

Problems occurred during early production in 2 production wells that limits current generation to below 110MWe. Several idle production wells dedicated for unit 3 and 4 are now being piped into the gathering system of unit 1 and 2 to temporarily add steam to maintain production.

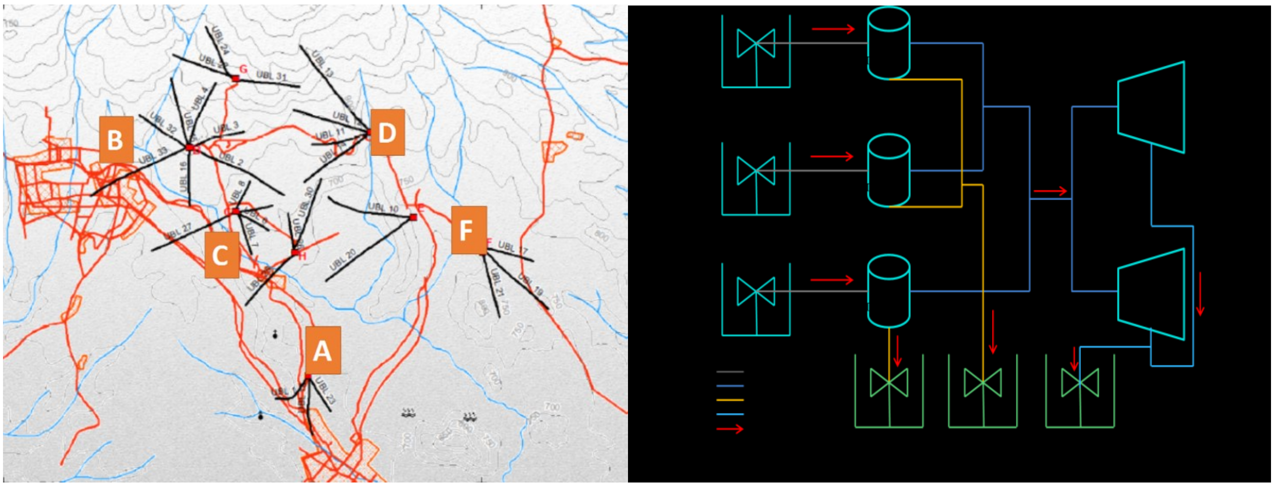

Figure 3: Ulubelu Production and Injection Well Map (left) and Simplified Schematic (right)

Reinjection in the field were programmed for pressure maintenance aside from keeping zero surface disposal to avoid environmental issues. To accommodate injection of brine and condensate from units 1 and 2, currently 5 reinjection wells are operational. For Ulubelu, basically the injection strategy was to inject as far as possible from the production zone while still inside the reservoir. This is to avoid rapid thermal breakthrough that would lower the enthalpy of the reservoir. However, current injection clusters are located relatively near the production zone. New injection clusters are planned to accommodate brine from both current production and the production of the upcoming unit 3 and 4.

Hot brine is injected to 4 wells, two of which are located in cluster A while the other two are in cluster F. Condensate is injected through a well in cluster A. Brine and condensate injections are gravitational with additional pressure from the separator.

3. FIRST YEAR RESERVOIR MONITORING, RESULTS AND DISCUSSION

Reservoir monitoring are conducted mainly by observations of surface data, physical and chemical (not presented here) data are analyzed respectively by reservoir engineer and geochemical engineer. Reservoir engineer analysis and monitoring are mainly based on wellhead pressure and separator flow rate data. Daily well and surface facilities data (pressure, temperature, and valve opening) from the field are recorded and stored into an internally developed online database for later analysis by reservoir engineer at head office.

Subsurface monitoring in production wells such as downhole pressure and temperature monitoring are yet to be conducted due to operational limitations. Several activities such as installation of capillary pressure tube (for reservoir pressure monitoring) and downhole PT measurement of production wells are programmed for the near future. Tracer dilution tests are established as an essential part of the monitoring activities with which individual well production (contribution) could be determined thus allowing enthalpy calculation.

Meetings discussing production and reservoir (subsurface) issues are held quarterly, allowing production team to discuss issues with subsurface team. Current organization's lack of onsite subsurface engineers renders the meetings vital. Efforts are made to enable smooth data sharing between the field and Jakarta head office and have so far contributed to the mentioned database (PURe). Reservoir performance monitoring is highly crucial in Ulubelu as development of Unit 3 and 4 are underway. It can also secure steam supply for existing contract of Unit 1 and 2 power plants.

Reservoir monitoring along the first year of production provides surface data as shown in figure 4. Production wells from the 3 clusters appeared to experience decline in well head pressure. During analysis, well opening (throttle and main valve opening for each well) data was analyzed and showed that only one well per cluster had opening variation during the period. This means that the majority of production wells operated at constant openings and that the apparent decline was accurate. Even though pressure decline during early production is considered common because it represents transient condition of the reservoir due to the new disturbance of the production to the (initially) equilibrium system, further analysis were conducted in order to ensure that the decline was indeed not an indication of severe damage in the reservoir such as overproduction or temperature decline.

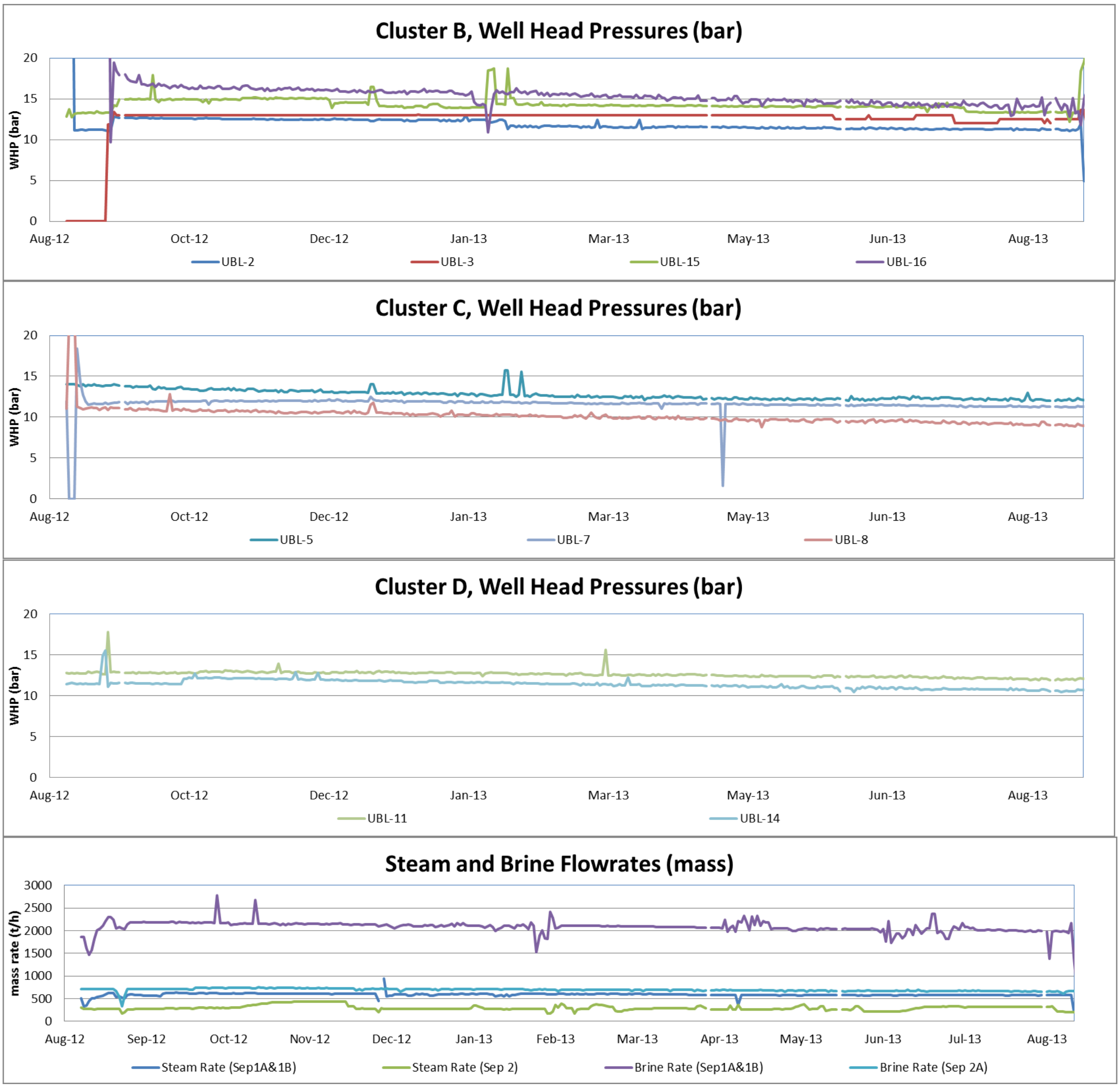

Figure 4: Wellhead Pressure and Flow Rate

The declining pressure caused well flow rates to also decline. However, production decline of each well could not be accurately observed due to the absence of flow recorders on each well. Well production decline could be approximated after calculating daily well flow (incorporating well contribution approximation obtained from tracer dilution test) from the total flow which was recorded in real time. Even so, low frequency of the tracer dilution test would result in low accuracy of the well flow calculation that could cause the decline approximation to be potentially inaccurate.

Under these circumstances, well head pressure and total fluid production data would be the primary tool to monitor the performance of the reservoir.

Wellbore simulations were conducted to calculate downhole flowing pressure of each well and to approximate pressure change in the reservoir. Furthermore, several scenario related to changes of reservoir properties (pressure and temperature) were incorporated into the simulations. Simulation results indicated that simple reservoir pressure decline scenario could not provide satisfying model to simulate present condition for all wells, thus other factors might have contributed to the decline. In the future, downhole measurement for production wells will be done to validate the simulation results.

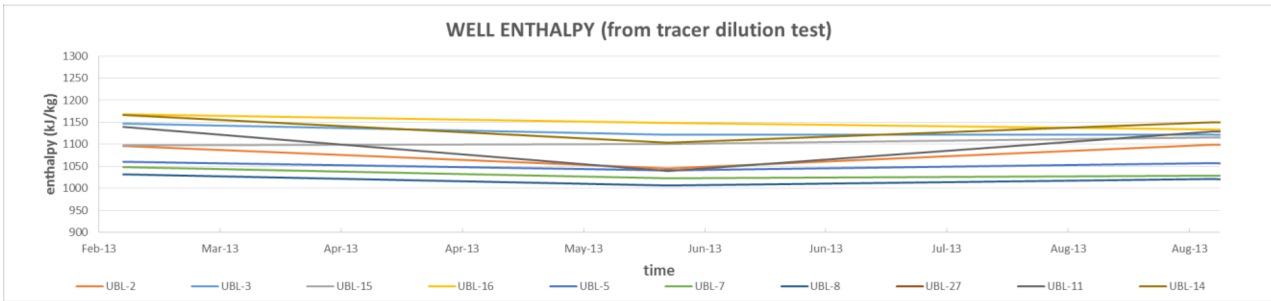

Figure 5: Well Enthalpy (Tracer Dilution method)

Tracer dilution test results allow calculation of production well fluid enthalpies. Until mid 2013, 3 tests were conducted and gave calculated enthalpies for each well as shown in figure 5. Slight enthalpy decline was present at all production wells. Chemistry monitoring indicated that chemical breakthrough from reinjected fluids might have caused the decline.

During early production, 2 wells experienced severe problem that prevented the wells from discharging. Downhole investigations (PT measurement (figure 6), chemical sampling and analyses) were conducted, data analysis showed that both wells experienced temperature decline that was caused by intrusion of lower temperature fluid into the well from shallow zone due to casing problem. Well repair is planned to be conducted in 2014.

The intrusion has then also been considered as potential problem for the reservoir. The low temperature fluid could spread through the two wells feedzones to other parts of the reservoir which in the long term could affect larger part of the reservoir. However, chemical monitoring has not seen occurrence of surface/peripheral water contained in production fluid so far.

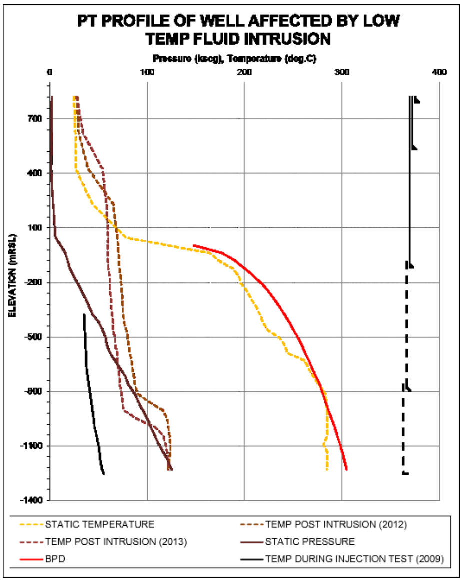

Figure 6: Pressure and Temperature Profile of Well Affected by Low Temperature Fluid Intrusion

Given all the information, the most likely factor causing the production and wellhead presure decline, aside from transient reservoir pressure change, should be temperature decline (represented by enthalpy decline) in the reservoir caused by temperature breakthrough from the reinjected brine.

To verify this, injection tracer test has been commenced by the end of 2013. Monitoring and analyzing activities are still ongoing by the time this report is written. The test involved injection of 5 different tracers to 5 injection wells and detection of the tracers in 10 production wells. Early analysis already pointed to rapid injection return time. Further and more comprehensive analysis would be conducted after complete data is collected.

In addition to unit 3 and 4 production wells, several more wells are planned to be drilled in the near future. 3 make up wells are planned to be drilled in 2015 and 6 injection wells are prepared to accommodate relocation of injection clusters with additional fluid from unit 3 and 4 production.

4. CONCLUSIONS

Ulubelu, a newly produced geothermal field, produces medium enthalpy fluid to generate 110 MWe of electricity. 11 production wells were initially operated to supply the fluid required with 5 injection wells used to reinject the brine and condensate. Reservoir performance are monitored through series of activities involving surface and subsurface data. Production parameters shows decline in wellhead pressure and thus production rate, which has limit production to below 110MWe. Analyses and enthalpy monitoring data show that the decline might not only be due to pressure drawdown. It is suggested that the additional decline might be due to the effects of reinjected fluids breakthrough. Further monitoring and downhole data acquisition are to be conducted to verify the theory. Short term efforts to top off production are made and long term solutions are prepared.

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