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INJECTION TEST EVALUATION FOR NEW INJECTOR CANDIDATES IN DARAJAT FIELD AS PART OF DARAJAT INJECTION MANAGEMENT

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ABSTRACT

Injecting condensate back into the reservoir plays an important role in maintaining sustainability of the geothermal resource. The injection process provides pressure support and recharge to the reservoir. However, injecting condensate back into the reservoir requires optimization of the amount of condensate injected to minimize interference between the injection and production wells. Excessive injection would cause reservoir cooling that results to condensation of the steam reservoir. Strong interference between the injection and production well would also cause rapid condensate breakthrough that may reduce steam production or even kill the production well.

This paper describes the evaluation of back-up injector candidates DRJ-05A, DRJ-12 and DRJ-24 by conducting injection tests in 2011. Although (less than a month each), nevertheless these injection tests have provided important data regarding injection impact using a multi-disciplinary set of data. For future injection tests, it is highly recommended that the tests be performed for a minimum of three (3) months. This test duration is currently perceived to be sufficient to observe the movement and impact of the condensate to surrounding wells.

INTRODUCTION

Darajat is the largest producing vapor dominated geothermal field in Indonesia. It is located near Garut City, West Java Province, Indonesia about 150 km southeast of Jakarta (Figure 1). Darajat currently has 3 power plants (Units I/II/III) that generate a total of 260 MW of electricity to Java Island. Unit-I generates 55 MW and is operated by PT. Indonesia Power. Unit-II/III generates 95 MW and 110 MW, respectively, are operated by Chevron Geothermal Indonesia.

The field lies within the Kendang volcanic complex, one of many volcanoes in the volcanic arc that extends from the northern tip of Sumatra, through Java, and eastward through the Banda Arc. The Kendang volcanic complex is part of a Quaternary volcanic range, extending from Papandayan volcano in the southwest to the Guntur volcano in the northeast. The exploration of this field started on 1984 and the generation of the electricity began in 1994. Currently, the Darajat field has 28 active production wells that supply steam to the power plants, 1 active injection well, and 6 monitoring wells.

Figure 1: Location of the Darajat geothermal field in relation to other cities in Java island.

Properly managed reinjection generates "new steam" as the injectate boils in the reservoir, hence maintaining reservoir pressure and increase energy extraction efficiency over the life on the reservoir. Reinjection of plant condensate should reduce the potential early reservoir dry out and field wide rapid production decline. However, inappropriate placement of injection wells, injection rate and duration of injection, can lead to premature breakthrough, reservoir cooling or waste the injected water. These phenomenon provide setbacks to the goal of enhancing energy extraction. In addition, injection breakthrough could result in operational problems, such as derating of plant output, scale development, additional costs for makeup wells and modification to surface facilities.

Historically, there are seven wells (DRJ-01B, DRJ-03, DRJ-05A, DRJ-07, DRJ-12, DRJ-15, and DRJ-37) have been used as injectors within different purpose. However, only three wells (DRJ-1B, DRJ-03, and DRJ-15) have been used for daily injection operation which both of them (DRJ-03 and DRJ-15) are the longest injection utilization. There are several findings relates with operational issue and negative impact to other production wells during injecting DRJ-03 and DRJ-15 at the same period. Centralized injection at both DRJ-03 and DRJ-15 has created some negative impacts such as superheat development, high decline rate and near wellbore scaling in DRJ-04, DRJ-10, DRJ-13, and DRJ-24. Inadequate standby injection wells also create limitation of utilizing other injection wells if either DRJ-03 or DRJ-15 fails. Therefore, injection program is the most critical issue that requires proper management.

DARAJAT INJECTION MANAGEMENT

Injection Management Team (IMT) was established in 2010 consists of Reservoir Engineering, Production Engineering, Geosciences, Drilling Engineering, Facility Engineering, and Operation. This team developed injection strategy for managing injection properly so that long term reservoir sustainability is able to be achieved. Several objectives of optimizing injection management are ensure sufficient capacity and flexibility to inject all condensate, minimize thermal impact by injecting in deep wells on reservoir margin, and drill new injection wells when appropriate.

Several strategies of implementing injection scenario were then prepared in order to obtain all of objectives above. Those injection strategies were implemented from 2010-2012 where each year has different program. Phase 1 implementation in 2010 focused on evaluating some injection wells candidate (DRJ-05A, DRJ-12, DRJ-24) then eliminating shallow injection at DRJ-03 by removing Unit-1 condensate injection to DRJ-05A. Phase 2 implementations in 2011 focused on completing permanent injection line to DRJ-05A and DRJ-19, removing Unit-1 condensate injection to DRJ-19 and Unit-2/3 condensate injection to DRJ-05A and DRJ-19 then perform tracer test at DRJ-19 to evaluate reservoir response after DRJ-19 injection. Phase 3 implementation in 2012 focused on evaluating the need for a new injection well.

INJECTOR CANDIDATE EVALUATION

New injector candidate needs to be evaluated prior to utilize it as a long term injector. This evaluation will give preliminary information about the impact of injecting condensate in a certain well to surrounding producers. The well evaluation includes Pressure Temperature Spinner (PTS) logging at two different injection rates (low and high rate) in order to obtain additional information of liquid level data for each injection rate and finally expected injection rate is able to be determined from this correlation. Comprehensive monitoring of daily production data, geochemistry sampling, and geophysics MEQ are also performed during a certain period of continuous injection of each well in order to evaluate the impact of injection to surrounding wells.

DRJ-05 Injection Test

DRJ-05A injection test was conducted on August 2010 during drilling standby for inspection in Darajat. The Pressure Temperature Spinner (PTS) logging was conducted within 2 different injection rates of 12.2 BPM and 18.2 BPM. Four production wells consist of DRJ-08, DRJ-13, DRJ-23, and DRJ-27 were selected primarily to be closely monitored during DRJ-05A injection because of their relative location with DRJ-05A. DRJ-05A injection monitoring program at those wells above was conducted for 3 weeks on 31 August 2010 – 21 September 2010.

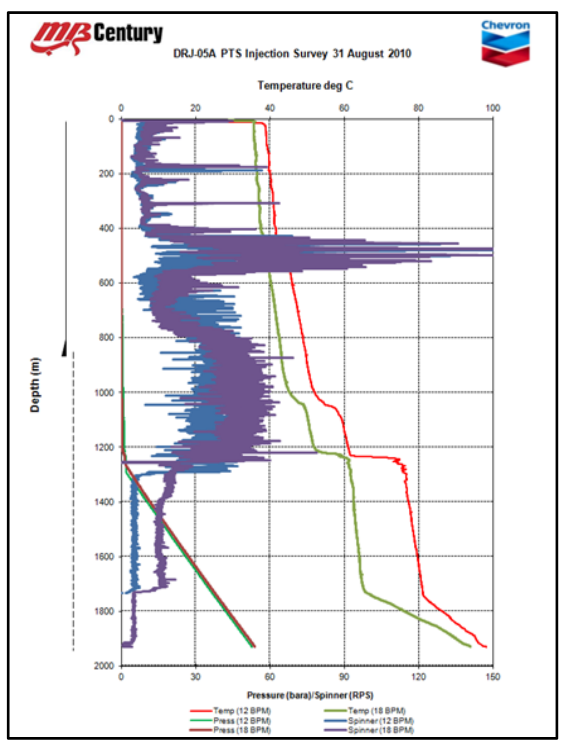

Figure 2: DRJ-05A Pressure Temperature Spinner (PTS) injection profile.

Figure 2 shows pressure, temperature, and spinner profile of DRJ-05A at both injection rates 12 BPM and 18.2 BPM. This profile was then analyzed to determine feed zones depth including their contribution. According to the PTS analysis, there are four active feed zones in DRJ-05A which top of two feed zones still produce heat to wellbore while the two bottom feed zones received liquid injected. Detail mass balance calculation including contribution percentage of each feed zone is provided from Table 1.

Table 1: DRJ-05A injection test mass balance calculation result.

No	Rate (BPM)	Depth (m MD)	Pwf (bara)	Pres (bara)	Flowrate (kg/s)	Flow Frac (%)	Direction
1	12	1036	0.9	29.3	0.4	1.2	IN
		1219	1.3	30.1	0.9	2.6	IN
		1765	39.2	32.4	28.3	81.1	OUT
		1920	50.9	33.1	5.3	15.2	OUT
2	18.2	1036	0.2	29.3	0.4	0.8	IN
		1219	0.7	30.1	0.9	1.8	IN
		1765	40.3	32.4	43.6	87.0	OUT
		1920	53	33.1	5.2	10.4	OUT

Table 1 shows that DRJ-05A has four feed zones at 1036m, 1219m, 1765m, and 1920m. Heat flows into wellbore through depth 1036.3m and 1219m, while condensate enter reservoir through depth 1765m and 1920m. Most of the condensate injected enter reservoir through depth 1765m which is indicated by the highest flow fraction at both 12 BPM and 18.2 BPM injection rate. Based on this injection test result, it was decided to continue injecting DRJ-05A within 9.5 BPM.

Production monitoring at several production wells during DRJ-05A continues injection is shown by Figure 3. Generally, the injection impact of three weeks DRJ-05A continues injection to the surrounding wells has not been identified. It is indicated by stable production of DRJ-23, DRJ-08, and DRJ-27. Zero production of DRJ-13 on 9 September 2010 was caused by DRJ-13 shut in. DRJ-13 was decided to be shut because this well showed significant decline prior DRJ-05A injection as indication of wellbore scaling. Production drop of DRJ-23 and DRJ-27 on 14 September 2011 was caused by Unit-3 turbine trip so that it created back pressure to all Unit-2/3 wells including DRJ-23 and DRJ-27. Meanwhile, low production of DRJ-27 in early monitoring program was caused by well throttling at DRJ-27 for PT Spinner Discharge program.

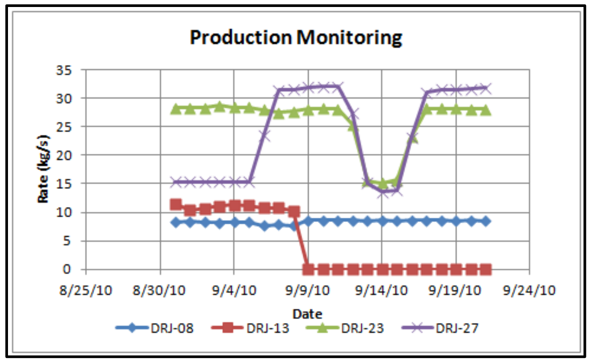

Figure 3: Production profile of monitored wells during DRJ-05A continuous injection.

Since DRJ-13 was shut-in a week after DRJ-5A injection was started due to an abnormal decline therefore there were only 3 remaining monitoring wells which will be evaluated. Figure 4 shows the NCG trend of monitored wells during DRJ-05 continuous injection. Although the results from the month-long injection test of DRJ-05A were inconclusive with a lot of data quality issues, it was still observed that there were no significant changes in the production of nearby wells hence a month-long injection of DRJ-5A at 9.5 BPM is probably safe. There was observed superheat increase and corresponding NCG drop which were thought to be a result of the DRJ-13 shut-in. It was believed that the number of nearby production wells affected the amount of condensate being boiled and the rebound of the superheat. The September 19, 2010 data (while DRJ-13 was shut in) showed that the monitoring wells exhibited a decrease in NCG and increase in superheat estimates.

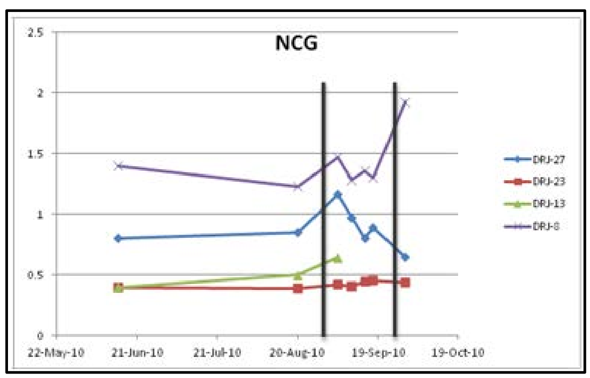

Figure 4: NCG trend of monitored wells during DRJ-05A continuous injection.

Figure 5 shows Microseismic (MS) events during DRJ-05A injection within certain injection period. This data shows that only four events could be related to DRJ-05A injection located along Cibereum Fault. Those events which located along the Cibereum Fault indicate that condensate injectate moving relatively slow through a fracture system near to Cibereum

Fault during this injection test. No seismicity in a new injector in Darajat is unusual. Typically we even see seismicity induced during the short time we use condensate while drilling make up wells in the reservoir. This result indicates that so far the injectate is moving a seismically (at least first week) indicating moving through a part of the fracture system that is not critically stressed and/or cooler. This is an indication that the condensate injectate is not migrating deep below the TD of the well and may be moving in relatively good permeability. This means nearby wells could see a fairly rapid impact.

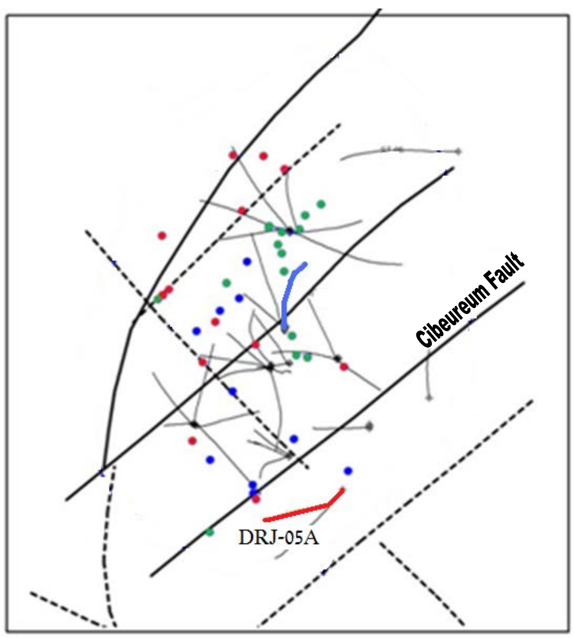

Figure 5: MS events occur during period of DRJ-05 continuous injection. Different color dots show different week of monitoring. The blue line shows injector well.

DRJ-12 and DRJ-24 Injection Test

DRJ-12 and DRJ-24 injection test were conducted on July 2011 after 2009-2010 Darajat Drilling Campaign. This injection test was conducted after drilling campaign because the available condensate was prioritized for drilling activities. Injection test was conducted at DRJ-12 first then continued at DRJ-24, while the comprehensive monitoring was conducted simultaneously for both injections. The Pressure Temperature Spinner (PTS) logging for DRJ-12 was conducted within 2 different injection rates of 8 BPM and 19 BPM while PTS logging for DRJ-24 was conducted only at higher injection of 14.5 BPM due to loss tension at lower injection rate (9 BPM) which is suspected due to insufficient rate to fully flooded at the upper feed zones. Eight production wells consist of DRJ-07, DRJ-08, DRJ-09, DRJ-11, DRJ-17, DRJ-18, DRJ-22, and DRJ-23 were selected to be closely monitored during DRJ-12 and DRJ-24 continuous injection. DRJ-12 injection monitoring program at those wells above was conducted for 3 weeks on 7 July 2011 – 1 August 2011.

Figure 6 shows pressure, temperature, and spinner profile of DRJ-12 at both injection rate 8 BPM and 19 BPM. According to the PTS analysis, there are eight active feed zones in DRJ-12 which top two feed zones still produce heat to wellbore while bottom six feed zones received liquid injected. Detail mass balance calculation including contribution percentage of each feed zone is provided from Table 2.

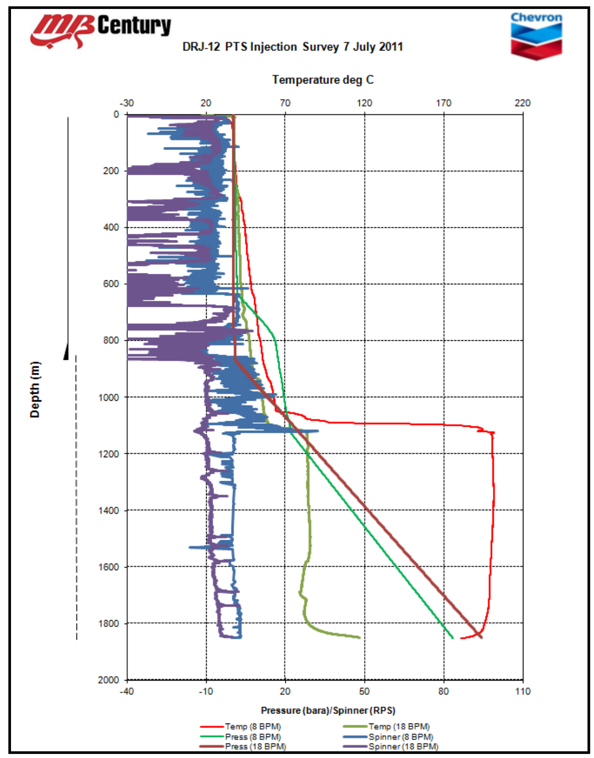

Figure 6: DRJ-12 Pressure Temperature Spinner (PTS) injection profile.

Table 2 shows that DRJ-12 has eight feed zones at 930m, 1119m, 1230m, 1310m, 1524m, 1610m, 1710m, and 1800m. Heat flows into wellbore through depth 930m and 1119m, while condensate enter reservoir through remaining six feed zones. Feed zone depth 1230m gives the highest contribution among other feed zones in receiving condensate at both 8 BPM and 19 BPM. Based on this injection test result, it was decided to continue injecting DRJ-12 within 9 BPM.

Table 2: DRJ-12 injection test mass balance calculation result.

No	Rate (BPM)	Depth (m MD)	Pwf (bara)	Pres (bara)	Flowrate (kg/s)	Flow Frac (%)	Direction
1	8	930	19.34	27.1	0.1	1.38	IN
		1119	23.08	27.35	7.15	98.62	IN
		1230	31.81	27.51	6.86	24.03	OUT
		1310	38.5	27.67	4.92	17.23	OUT
		1524	56.57	31.52	3.63	12.71	OUT
		1610	63.84	38.78	5.24	18.35	OUT
		1710	72.3	47.44	4.86	17.02	OUT
		1800	79.94	55.31	3.04	10.65	OUT
2	19	930	6.89	27.1	0.21	6.14	IN
		1119	25.43	27.35	3.21	93.86	IN
		1230	36.03	27.51	13.72	25.4	OUT
		1310	43.69	27.67	7.08	13.11	OUT
		1524	64.16	31.52	8.92	16.51	OUT
		1610	72.38	38.78	12.59	23.31	OUT
		1710	81.97	47.44	5.24	9.7	OUT
		1800	90.56	55.31	6.47	11.98	OUT

Figure 7 shows pressure, temperature, and spinner profile of DRJ-24 at injection rate 14.3 BPM. According to the PTS analysis result, there are seven active feed zones in DRJ-24 which top two feed zones still produce heat to wellbore while bottom five feed zones received liquid injected. Detail mass balance calculation including contribution percentage of each feed zone is provided from Table 3.

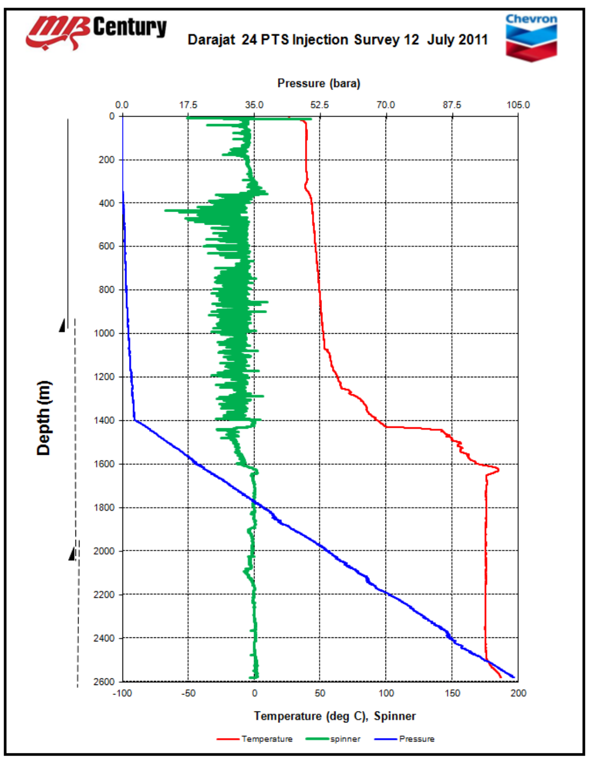

Figure 7: DRJ-24 Pressure Temperature Spinner (PTS) injection profile.

Table 3 shows that DRJ-24 has seven feed zones at 1396m, 1600m, 1917m, 2134m, 2322m, 2438m, and 2560m. Heat flows into wellbore through depth 1396 m and 1600m, while condensate enter reservoir through remaining five feed zones. Depth 2134m is the feed zone that gives highest contribution in receiving condensate at 14.3 BPM. Based on this injection test result, it was also decided to continue injecting DRJ-24 within 9 BPM.

Table 3: DRJ-24 injection test mass balance calculation result.

No	Rate (BPM)	Depth (m MD)	Pwf (bara)	Pres (bara)	Flowrate (kg/s)	Flow Frac (%)	Direction
1	14.3	1396	3.8	25.8	5.3	69.74	IN
		1600.2	17.6	26.1	2.3	30.26	IN
		1917.2	45.2	26.5	8.6	18.94	OUT
		2133.6	63.7	26.8	17.6	38.77	OUT
		2322.6	80.2	27	2.8	6.17	OUT
		2438.4	89.6	27.2	8.2	18.06	OUT
		2560.3	100.6	27.3	8.2	18.06	OUT

Production monitoring at several production wells during DRJ-12 and DRJ-24 continuous injection is shown by Figure 8. Generally, the injection impact of three weeks DRJ-12 and DRJ-24 continuous injection to the surrounding wells has not been identified yet due to small injection rate or insufficient time to inject those wells. It is indicated by stable production of most monitored wells. Declining rate of DRJ-17, DRJ-18, DRJ-22, and DRJ-23 on early of August 2011 is caused by DRJ-21 on line to power plant so that create back pressure to all Unit-2/3 wells. Meanwhile, declining rate of DRJ-11 in early monitoring is due to its characteristic after long time shut in. DRJ-11 requires weeks to obtain stable production rate after long time shut in. In early monitoring, DRJ-11 was just opened three days after one month shut in during Unit-1 SDTA

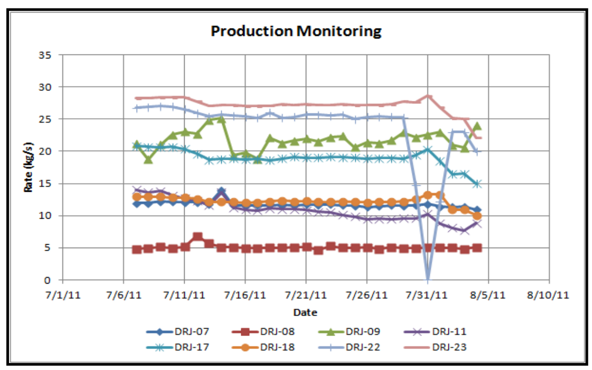

Figure 8: Production profile of monitored wells during DRJ-12 continuous injection.

Three combined geochemistry data of superheat, boron and NCG were monitored continuously in 3 weeks during DRJ-12 and DRJ-24 continuous injection. Figure 9, figure 10, and figure 11 show the profile of each geochemistry data mentioned above. A comparison with baseline data trend should be done to be able to see any effect from DRJ-12 and DRJ-24 injection test. The baseline data were taken from regular monthly sampling activity.

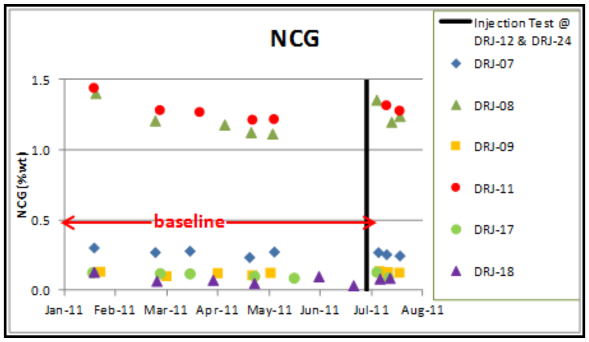

Figure 9: NCG data trend of monitored wells during DRJ-12 & DRJ-24 continuous injection.

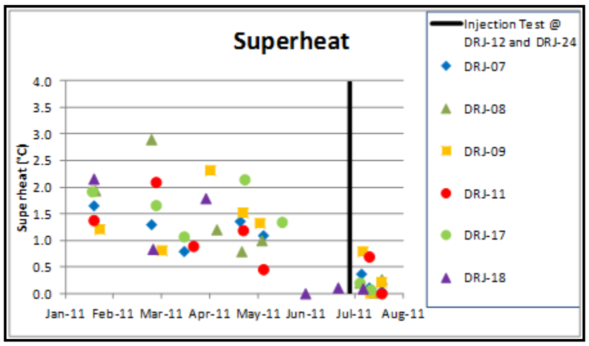

Figure 10: Superheat data trend of monitored wells during DRJ-12 & DRJ-24 continuous injection.

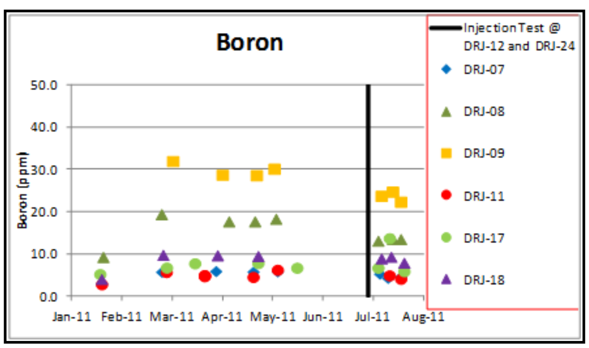

Figure 11: Boron data trend of monitored wells during DRJ-12 & DRJ-24 continuous injection.

Some of the wells such as DRJ-7, 8, 9, 11, 17 and 18 showed slightly drop superheat and Boron while NCG remained stable. The slightly drop of those two parameters may indicate less boiling in the reservoir due to the condensate injectate from DRJ-12 and DRJ-24. Unit-1 shutdown in May – June may oppose the hypothetical theory of less boiling due to DRJ-12 and DRJ-24 injection test. Because of these two possibilities, therefore a month injection test result from geochemistry monitoring may not be able to give a robust conclusion.

Similar with DRJ-05A injection test, MEQ monitoring was also conducted simultaneously with Geochemistry and Production monitoring in order to obtain comprehensive analysis of DRJ-12 & DRJ-24 injection impact. Figure 12 shows MEQ events during DRJ-12 and DRJ-24 continuous injection. There were only about 22 events recorded during period 1-31 July 2011 and very similar number with Micro Seismic (MS) during June 2011 which is about 23 events. None of MS occurs during July 2011 clearly clustered around DRJ-12 and DRJ-24 which could be concluded as a seismic behavior related to DRJ-12 & DRJ-24 injection activities. These MEQ responses could be occurred due to low injection rates for both wells (9 BPM). This epicenter maps shows that some MS near to DRJ-15 is related to DRJ-15 injection as primary injector well. Some of MS occurs on relatively SW alignment from DRJ-12 along Cibereum fault which unusual on the previous period prior the injection DRJ-12. This indicates MS occurs due to DRJ-12 condensate injectate could also move through fracture along this fault.

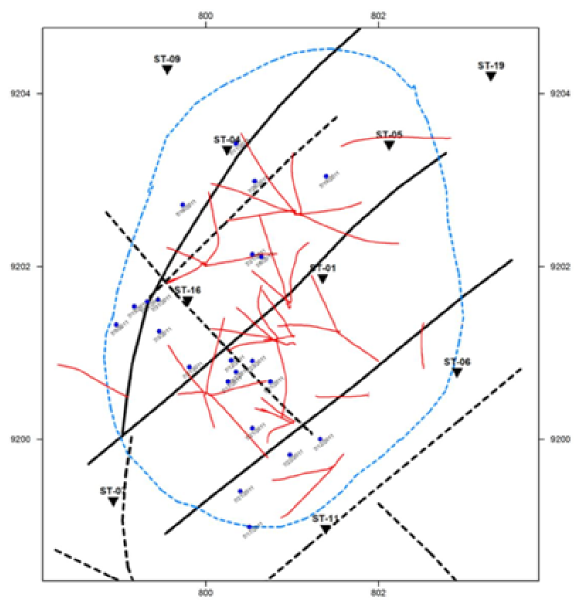

Figure 12: MEQ events during DRJ-12 & DRJ-24 continuous injection.

CONCLUSION

All of injection tests in Darajat have been conducted safely and successfully in period of 2010 – 2011. These injection tests have provided important data and several indications of injection impact although it is not conclusive yet (indicated by production rate, geochemistry, and geophysics responses) due to short injection period (less than a month). Therefore it is highly required to perform longer injection period to obtain clear injection impact to surrounding wells. Geochemist suggests 3 months of injection as a minimum period to conduct a comprehensive injection test. The shallowest feed zone that significantly received condensate injectate belongs to DRJ-12, while the deepest feed zone that significantly received condensate injectate belongs to DRJ-24. Therefore, DRJ-24 is highly recommended to be selected as the first priority of alternative injection well if either DRJ-03 or DRJ-15 fails. However, it will be high cost operation to inject condensate into DRJ-24 due to no injection facilities available and its higher elevation compared to all Units power plant. DRJ-12 is the best current alternative injector if only DRJ-15 fails because DRJ-12 has already had injection facility and its lower elevation compared to Unit-2/3 power plant. According to the current DRJ-12 injection test, this well is safely injected at low injection rate (9 BPM)

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