Proceedings World Geothermal Congress 2020+1
Reykjavik, Iceland, April - October 2021

The Phenomenon of Cooling Geothermal Wells in PT.Pertamina Geothermal Energy Fields; Investigation And Handling

Muhamad Bayu Saputra, Gamal Hastriansyah, JB Rully Putradi, Fernando Pasaribu, and Marihot SP Silaban

PT. Pertamina Geothermal Energy, Skyline Building MH Thamrin Street 9 Central Jakarta Indonesia

Mb.saputra@pertamina.com, Gamal.h@pertamina.com, Rully.Putradi@Pertamina.com, Fernando.pasaribu@pertamina.com, Marihot@pertamina.com

Keywords: Geothermal wells, temperature decline, well integrity

ABSTRACT

PT.Pertamina Geothermal Energy operates 9 geothermal areas, including Ulubelu, Karaha and Hululais project. Ulubelu Geothermal Area is located in Lampung Province, Pulau Panggung District area, Tanggamus Regency – Lampung provice, The location of Karaha Geothermal Area is in the area around Malangbong Subdistrict, West Java Province and Hululais Project is administratively located in Lebong Regency, Bengkulu Province.

Monitoring well conditions such as pressure and temperature are carried out since the well has been drilled until the well has been producing regularly. Based on the results of condition monitoring of the wells there were significant decreases in temperature between 100 – 160 ^{o}C in several wells in different time. Investigations were conducted to determine the root cause of temperature decline by doing PTS logging and downhole sampling. Solution for this problem has been done by using remedial casing and squeeze cementing. Evaluation after handling the problem is carried out either by conducting a production test and or by a wellbore simulation analysis then compared its condition with previous condition before this problem occurred.

1. INTRODUCTION

PT.Pertamina Geothermal Energy operates 9 geothermal areas, including Ulubelu and Hululais project. Ulubelu Geothermal Field is located around 100 km west of Bandar Lampung, Lampung, Indonesia. This area is in a row of volcanoes (M. Rendingan and Tanggamus). The altitude is ranging from 700 m to 900 m above sea level. Ulubelu geothermal area is currently operated by PT. Pertamina Geothermal Energy (PGE) to supply South Sumatera region electricity. Geothermal power plant of 4 x 55 MWe has been installed at Ulubelu Field, Tanggamus region since 2013 by the commercial generation of units 1 & 2. The following units 3 & 4 were on line on 2016 & 2017 respectively. Geothermal exploration in Ulubelu was first started in 2007 by PT Pertamina Geothermal Energy. At the beginning of production, 11 production wells from 3 clusters (Cluster B, Cluster C and Cluster D) produced ± 800 t / hour steam and ± 3000 t / hour brine which is enough to supply two units. Brine and condensate are reinjected through 4 + 1 injection wells located in cluster A and cluster F. At current condition there are 25 production wells and 13 injection wells to support for 4 installed power plants. Generally, there are 5 (five) sectors based on the reservoir characteristic (PT profile & geochemistry). In the upper North (UN) sector characterized by its highest enthalpy (2600 kJ/kg), vapor dominated reservoir & high NCG content (1,7-3 wt%). It consists of wells in J cluster. Several sectors namely North, Central East, Central West sector are characterized as high enthalpy (1250 - 1300 kJ/kg) with NCG content that varies in each sector.

The location of the prospect of the Karaha Geothermal Field is administratively located in the Ciawi District, Tasikmalaya Regency, West Java Province. PLTP Karaha Unit 1 has been declared commercially operated or COD on April 6, 2018 with a capacity of 30 MW. During the development of this PLTP project, PGE drilled as many as 10 wells, including injection wells and monitor wells. Karaha geothermal system is a type of "hot neutral chloride water" with temperatures of 230 °C - 240 °C covering an area of 14 km² with a reservoir depth of around 1000 m.

Hululais Project is administratively located in Lebong Regency, Bengkulu Province. It is ± 180 km from the city of Bengkulu on the axis of the Bengkulu-Curup-Muara Aman road. The Hululais field reservoir fluid is liquid r dominated system with an average temperature value of 240 – 300 ^{o}C. The generation of 2 x 55 mw is planned to be installed. Currently, , 21 wells that have been drilled on projects spread over several clusters. Ten (10) production wells are scattered in clusters A, C, E, G, 8 injection wells in the P, Q and H clusters, and monitoring wells in cluster B, D. Monitoring well condition including pressure and temperature of the wellbore is carried out during the well heating up period and well production period regularly. Based on the results of condition monitoring of the wells there were significant decreases in temperature between 100 – 160 ^{o}C observed in 2 wells in Ulubelu field & 1 well in Hulu lais field in different time. The paper describe briefly the investigation and handling of this phenomenon for each well.

2. WELL DATA AND INVESTIGATION

2.1 Casing Data Configuration

Geothermal wells generally use consecutive casing configurations from surfaces that have a diameter of 20 ", 13 3/8", 9 5/8 "and liner 7" or better known as standard holes. But now the wells in the PGE fields use a larger casing configuration or big hole where the casing sizes used in succession from the surface are casing 30 ", 20", 13 / 3/8 "and liner 10 3/4" , liner 8 5/8 " as shown in table 1 below.

PT. PGE has used several cementing systems that are commonly carried out in the world of drilling for production casing, namely single stage systems (long string system), Multi stage systems (Dual Stage Cementing collar and Tie back system). The wells discussed in this paper are wells that use a multi stage system cementing system, namely system tie back. The system was used in drilled wells after 2012 replacing the dual stage cementing collar system used in previous years

Table 1. Casing Configuration & Cementing System

CASING SIZE	DEPTH (mMD From Cellar)					
	WELL#1 UBL-12	CEMENTING	WELL#2 HLS-C1	CEMENTING	WELL#3	CEMENTING
CASING 30”	0 - 30	Single stage	0 – 15	Single stage	0 - 35	Single stage
CASING 20”	0 - 290	Single stage	0 – 388	Single stage	0 – 388	Single stage
CASING 13 3/8”	0 - 992	Multi stage (tie back string)	0 – 1025	Multi stage (tie back string)	0 – 1344	Multi stage (tie back string)
LINER 10 ¾”	956 - 1789		991 – 1988		1314 - 1945	
LINER 8 5/8”	1747 - 2279		1954 – 2875		1904 - 2401	
LINER 7”	-		2844 - 2992			

2.2 Well Monitoring

Reservoir monitoring are conducted by observations of surface data, physical and chemical (not presented here) data are analyzed respectively by reservoir engineer and geochemical engineer since the wells begun to be produced. During early production, Well#1 & Well#3 experienced severe problem that prevents the wells from discharging. PT measurement shows declining temperature for each well during early production. However, it did not occur in Well#3 which showed a decrease in temperature before the well was tested . It was known after the well was used as a temporary injection well.

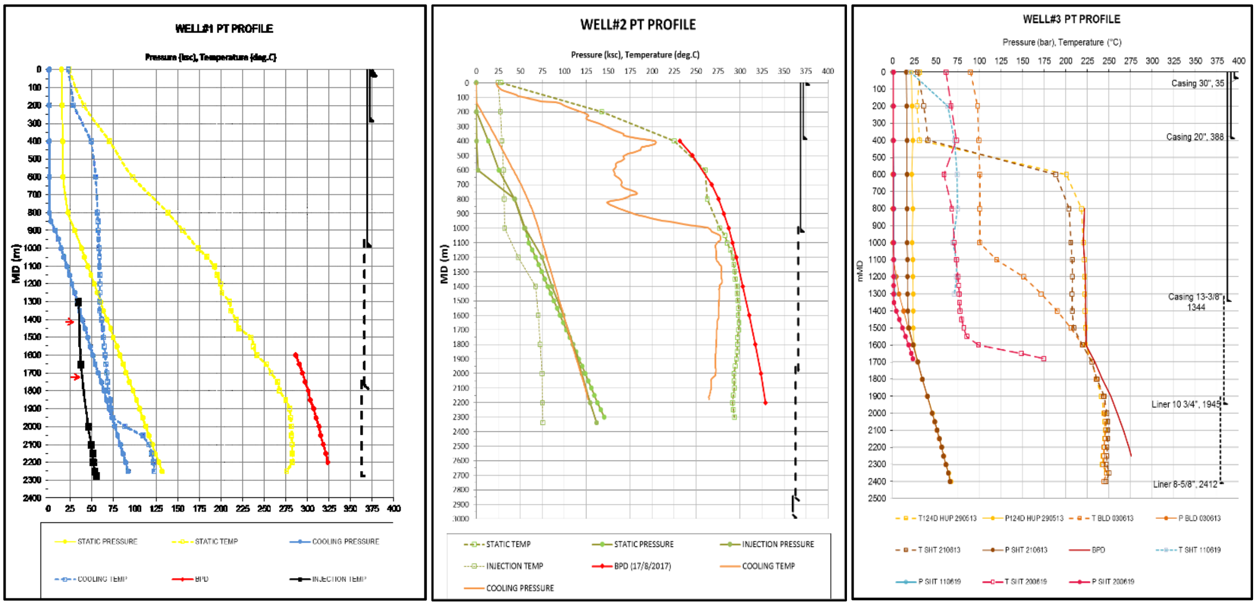

Figure 1: Pressure and Temperature of Cooling Wells

Figure 1 shows the decrease in well temperature which varies in each well. In 2009, Well#1 has a temperature of around 279 °C in its static condition before degradate down to 157 °C, production test implemented in 2011 shows this well has a potential of 7 MW at 11 barg well head pressure with steam supply consumption 8 ton per hour / megawatt. However in the next production test held on 2012 its well can not flow anymore. Well#2 is one of the big wells , had a production test in 2012 with the potential genaration 20 MW at 15 barg well head pressure with steam supply consumption 8 ton per hour / megawatt. The well has a static temperature of around 300 °C before it was used as temporary injection well. After injected, the well temperature did not increase to the previous static condition and being stagnant of around 260 °C on maximum temperature measured. Well#3 is one of the backbone of generation in the field which began in production a year earlier. After a year has passed the production of this well decreases which is marked by a decrease in wellhead pressure. Bottom hole temperature and pressure data retrieval were carried out only reaching a depth of 1680 mMD because logging tools could not enter deeper. From the data it could be seen that there was a decrease in temperature where the previous temperature was 220 deg.C to changed to 71 deg.C.

2.3 Pressure Temperature Spinner Logging

Spinner logging was used to investigate the condition of cooling wells. It was carried out during shut in condition by entering the PTS tool into the well which with variations in cable speed. PTS logging was run in Well#1 on sept, 2013 during shut in condition. The Logging Spinner of the well#1 was run with two speeds, 0.5 mps and 0.75 mps. On the fourth running, log down 0.5 mps, log up 0.5 mps, log down 0.75 mps and log up 0.75 mps showed sufficient precision and consistency so that it could be used to analyze the flow in the wellbore. Based on the results of spinner data processing at this well shows that at a depth of 258 mMD there is a slight flow of water entering / leaking into the well from behind the casing 13 3/8 "& 20". This is indicated by decreasing in mass flow (t / j) from base line 0 t / j to an average of around -6 t / j. Then at a depth of 767 mMD there is also a significant increase in inflow into the wellbore to be -83 t / j. At a depth of 1250 mMD there is flow into the well then total mass becomes -88 t / j. At a depth of 1829 mMD the fluid comes from the formation to the wellbore with the total mass of -106 t / j. Then at the next depth in 1926 mMD fluid also enters the well with the total mass of -110 t / j. Then at a depth of 2109 mMD the fluid enters the formation making the total mass become -41 t / j. At 2227 mMD the total remaining fluid flow into the formation causes the total mass to return to 0 t / j. Based on the results of the analysis above, this well shows the flow into the wellbore from behind the casing 13 3/8 "and 20".

In well # 2 the Spinner survey was carried out in a shut-in (static) condition with 3 different speed. The results of data processing shows a flow in the well at a depth of ± 270 mMD to ± 900mMD. The velocity of the fluid is equivalent to a rate of 5-6 kg / s. Noting the location of the start and loss of fluid flow, interpreted that the fluid enters the receptacle tie back and exits the slotted liner. If this interpretation is correct, then this well might have a problem with the cement behind the case 20 "and also in the area around the receptacle. However, there is no indication of casing damage.

Spinner survey has been run in well #3 on June 2019 in shut in condition with 3 speed variations. Changes in deflection spinner began to appear at a depth of 224 mMD. Spinner rotation changes are not so big compared to the 2 previous wells that have been delivered. Water flow of about 1 kg / s is likely to enter through the body of the casing and flow down through the casing walls so that the flow is not readable clearly in the spinner rotation. Subsequent deflection is observed at a depth of 933 mMD where the incoming flow is around 0.5 kg / s and going down into the bottom hole. Based on these data where spinner spin is not clear enough to conclude so further steps are needed to confirm the leak in this well

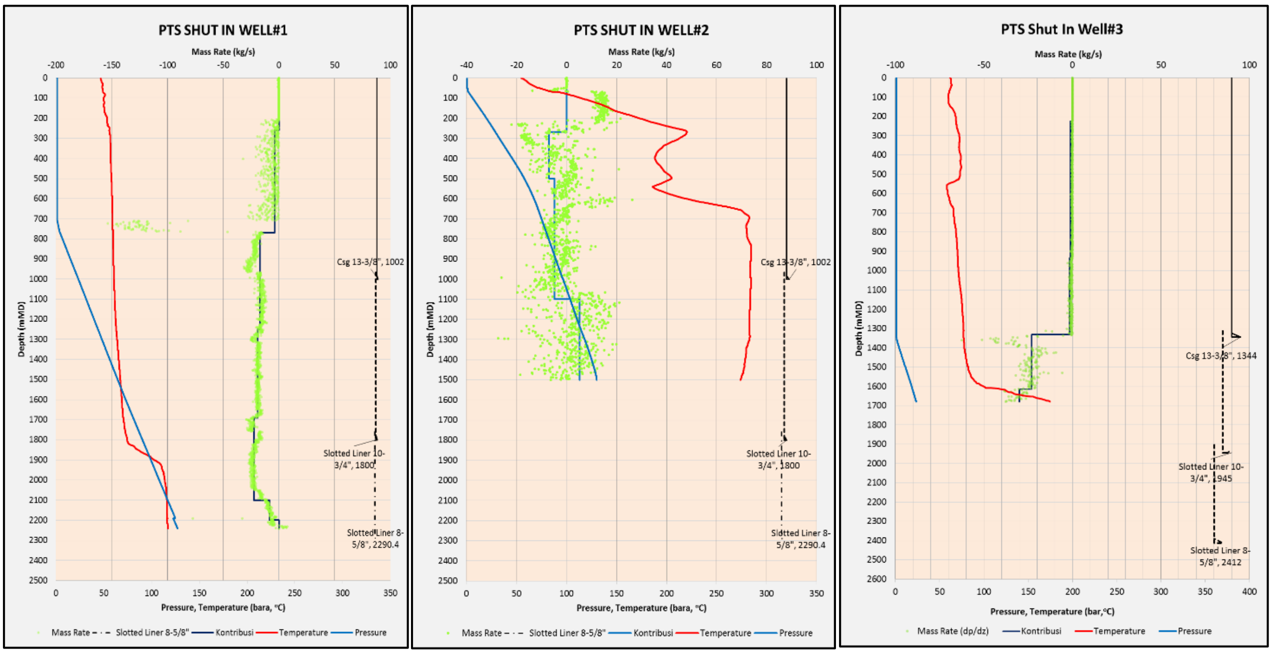

Figure 2: Pressure temperature spinner interpretation

2.3 Down hole sampling and advance logging

Downhole sampling activities at well#1 were carried out on February 27-28, 2013. Samplingg was carried out at 4 different depth points, namely: 900, 1200, 1700, and 2150 mMD. Downhole Sampling results in 2012 can be compared with chemical composition data during the production test in 2011. Based on the graph in Figure 3 which is the result of a plot of data during production and downhole sampling, it is seen that there has been a significant decrease in Cl, SiO2, Na, and other elements in the downhole sampling data are compared with production test data. This indicates the presence of large volumes of cold water intrusion originating from the condensate layer or near surface water which has a lower chemical composition compared to the geothermal (dilute) fluid. In addition, there was an increase in the concentration of SO4, Mg, and Ca, and the most significant increase in concentration was found in HCO3 (Figure 3). So based on these data, the indication of cold water intrusion that has occurred in well #1 is getting stronger. Where many elements of HCO3, SO4, Mg, and Ca are contained in water which is in the condensate layer or water zone near the surface. Based on the ternary diagram Cl, SO4 and HCO3 (Figure 4), it can be seen that the 2011 data shows that geothermal fluid in the well #1 is mature chloride water. Meanwhile, downhole sampling data shows that the geothermal fluid in the well #1 is bicarbonate water. There has been a change in the type of geothermal fluid in the well #1 from water chloride to bicarbonate. This change in water type is influenced by changes in the chemical composition that has occurred and indicates the process of mixing the geothermal fluid in the well with cold water

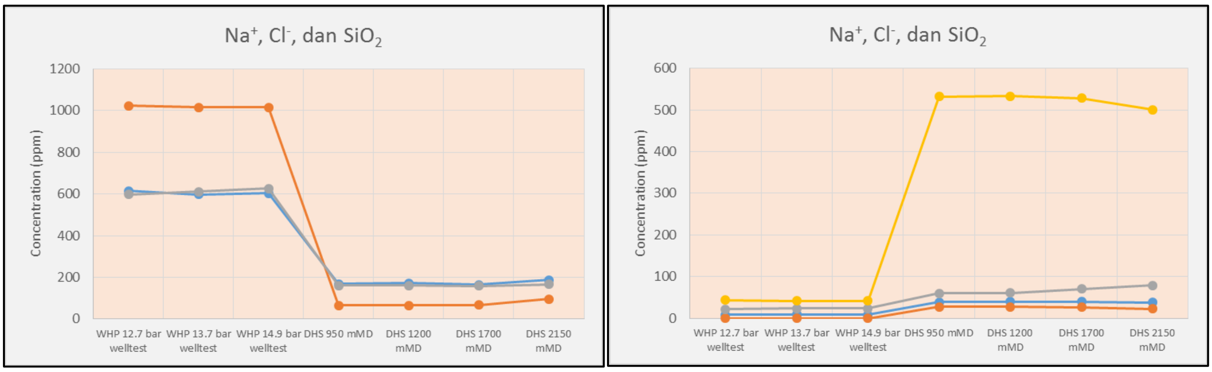

Figure 3: Graph of changes in water chemical concentration in production test and downhole sampling

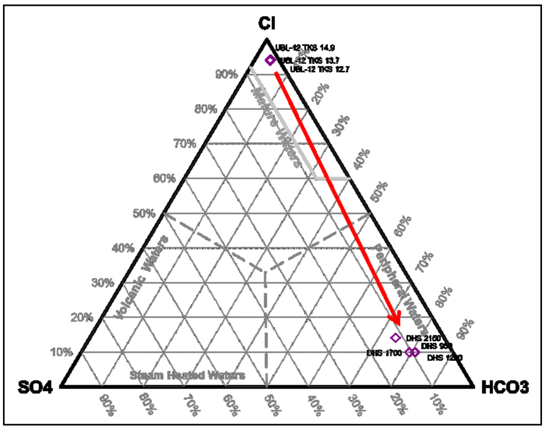

Figure 4: Trilinier diagram Cl, SO4, and HCO3

downhole sampling is not conducted from inside well # 3 and its function is replaced by other logging such as caliper, acoustic and electromagnetic logs. Multi finger caliper with 56 independent caliper logging curves is used to identify the condition of the borehole diameter on the 13-13/8" casing. This shows that there is an abnormality of the condition of the borehole where the penetration conditions reach 100% at a depth of 223.8 mMD. This is confirmed from the results of logging electromagnetic (MTD-Magnectic Thickness Detection) readings which have been carried out where at a depth of 223.9 mMD it is read that there is an intensive indication of corrosion which shows a maximum wall loss of up to 40.9% and behind the casing is a 20 "casing which also shows corrosive indications where the maximum wall loss is around 11%. ALFA, acoustic logging was carried out to determine the condition behind the casing and indicated that there was a water flow from reservoir at 145 m, flowing behind 20 "casing channeling down to 223.8 m and exit from 13-3 / 8 "to wellbore at same depth and shows water flow from reservoir at 544 – 678 m, flowing behind 13-3/8”casing channeling down then exit to wellbore thru 13-3/8” casing damage at 933 m

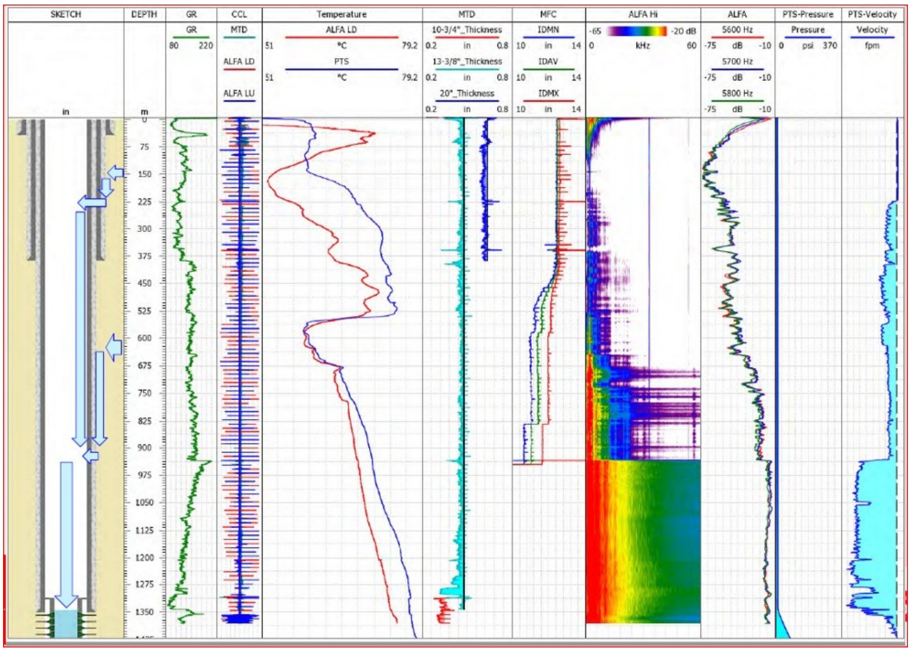

Figure 5: Caliper, Electromagnetic and Acoustic logging well #3

3. WELL HANDLING

Based on the result of spinner that well#1 had 2 leakages at depth 258 mMD and 767 mMD, so wooden plug was dropped and pushed to the top of the liner casing 10 3/4" at depth 956 mMD then dropped the coarse material and conducted cement plug and squeeze job as a barrier. Several times of cement plug and squeeze job were conducted to make sure that leakages were cured before running casing 9 5/8" L-80, 43.5 ppf for remedial cementing job. It was conducted using bottom plug and top plug, which cement slurry keep returned during job and was observed no level cement drop in annulus during wait on cement. Cement and wooden plug then drilled and pushed to the bottom before well#1 can be produced.

Well#2 had a problem of leakage at the tieback & receptacle which caused by bad cement condition behind the casing 13 3/8”, it was confirmed by spinner. Handling problems in well#2 using different methods than well#1. Inflatable packer assembly was used to replace wooden plug. It was run to depth 437 mMD (leak was at 352 mMD) than set and activated using cementing unit. Squeeze cementing job for curing the leakage was conduceted after the coarse material dropped as a barrier above the inflatable packer to prevent cemented during squeeze cementing job. It was designed to be retrieved at the end of job. Inflatable packer assembly has the advantage of saving cost and time, Which inflatable packer assembly placement as close as the leakage so reduce volume cement slurry, eliminate dropped-drilled-pushed the wooden plug job sequence, and also eliminate potential debris from drilled-wooden plug. Cement and coarse material were drilled and circulated out after combating leakage using squeeze cementing job, then run overshot 5 7/8” for retrieving the inflatable packer.

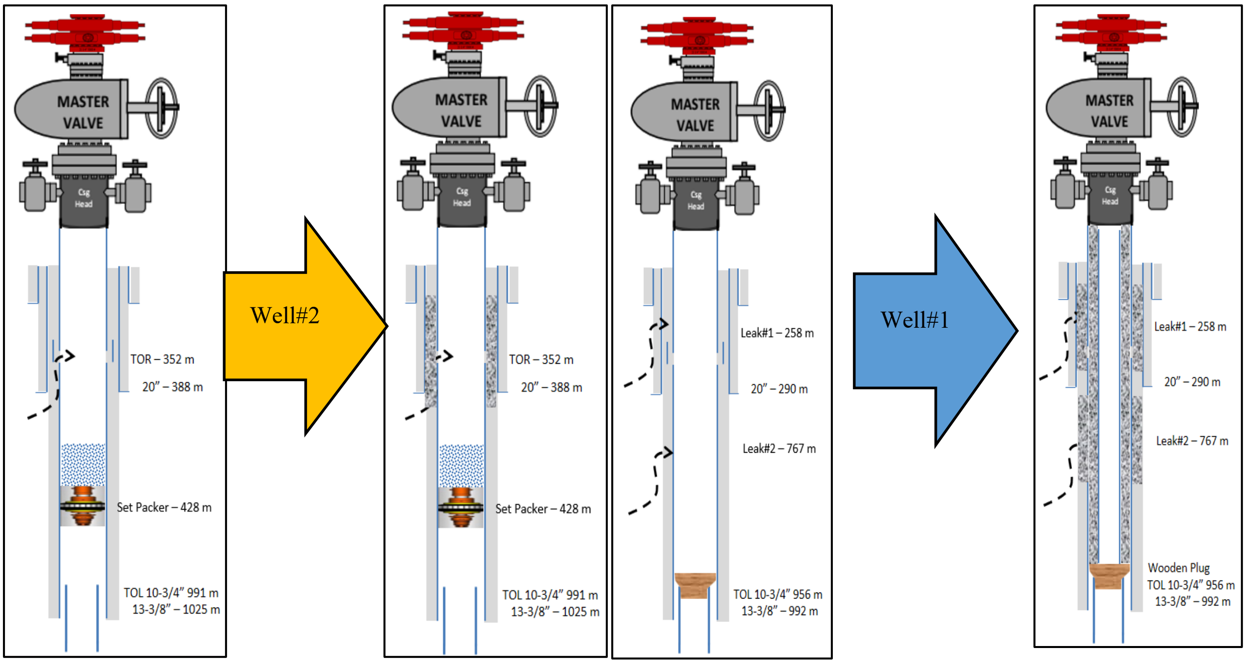

Figure 6: illustration of well handling in well #1 & well #2

4. WELL EVALUATION

Evaluation in well # 1 has begun since the workover work was completed. The injection test is performed to check the reservoir parameters unchanged after repairing the casing. PTS felling is not done at the well and its function is replaced by PT monitoring after the workover work is complete. The downhole temperature 1 day after the workover work is not clear enough to ensure the downflow problem is resolved properly. but if you see the results of measurements of temperature during the heating period where the well temperature gradually rises to 273 deg.C which means it can be concluded that the flow of cold water that previously cooled well # 1 no longer exists or in other words the casing remedial work has been carried out properly

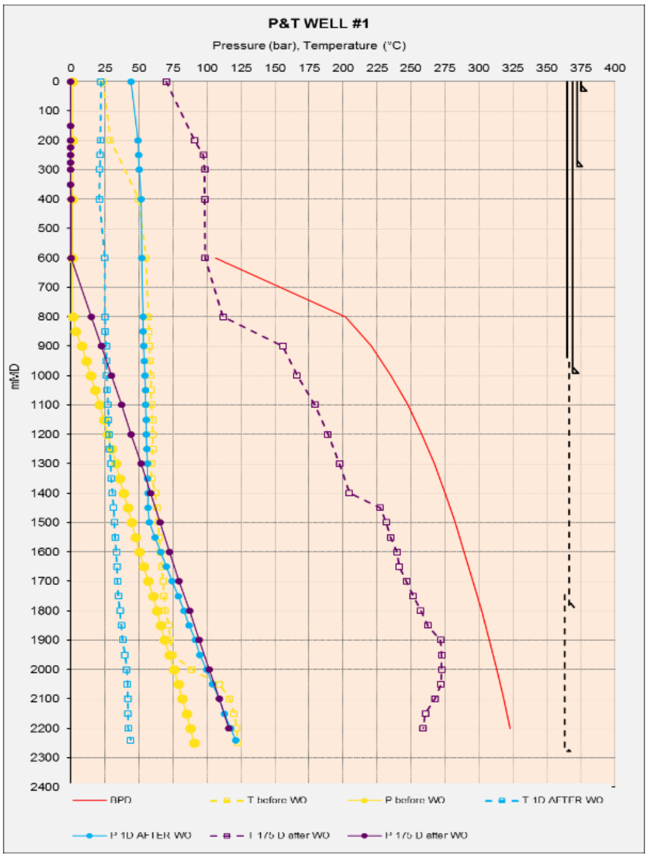

Figure 7: PT monitoring well #1 before and after Workover

After remedial casing has been carried out in well #1, it can start flowing to the system with a steam flow rate of 6.4 kg / s. the production rate is jump down around 43% from the initial production test data where the data can be seen in figure 7 below

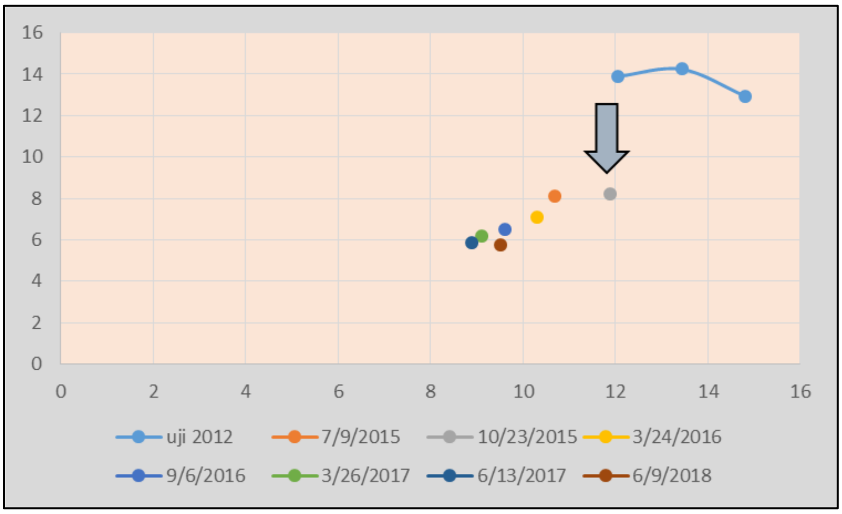

Figure 7: Result of production test well#1

The well #2 which was spud in on July 15, 2018 at 14.00 WIB and was declared completed on July 25, 2018. After squeeze processing finished, The logging PTS is conducted to determine the condition of the wellbore after a squeeze cementing, this is done by using 2 cable speed 30 & 45 meters / minute and from the results it can be seen that the RPM profile is relatively stable and does not show any deflection. Then, from the stationary point no spinner spin was detected. It shows of no flow in or out of this well (figure 8). After well # 2 finished workover, the wells were re-tested and the result is similar with the previous test. the initial production test in 2012 the total steam rate at 100% openings at the wellhead and the 15 barg wellhead pressure was 44.8 kg / s. while the well test in 2018 was obtained at 100% openings at the wellhead and the wellhead pressure was 16.8 barg was 46.26 kg / s

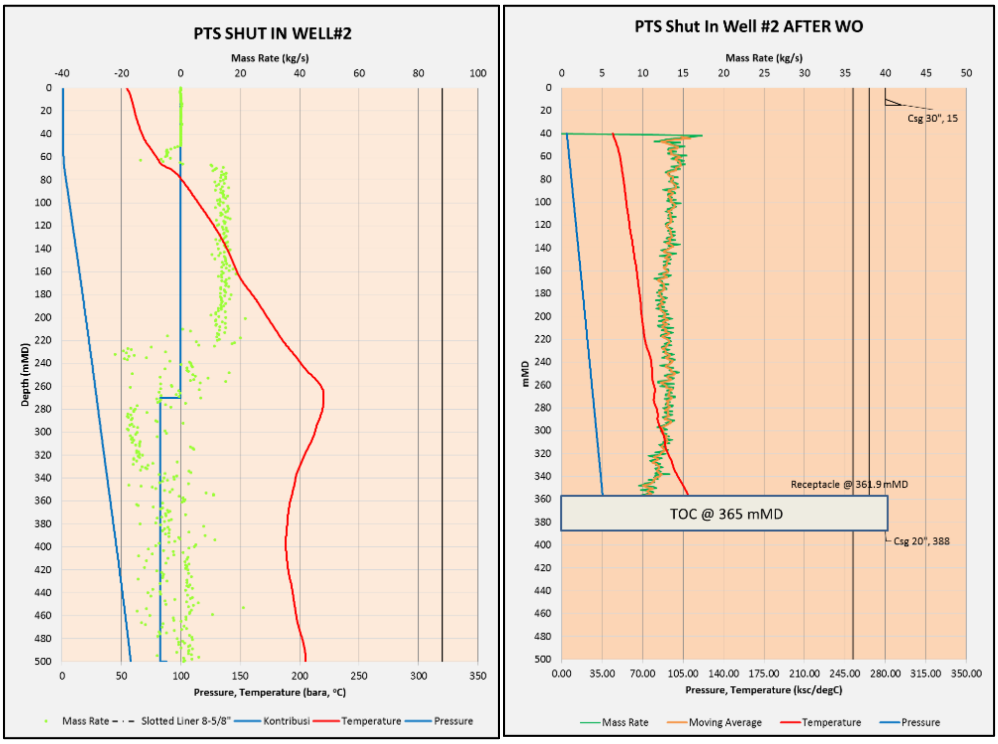

Figure 8: Comparing PTS Logging Before and After Workover

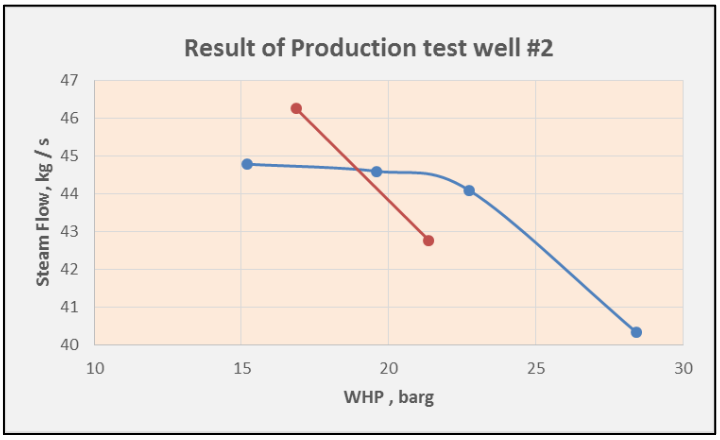

Figure 9: Result of production test well#2

5. CONCLUSION

The decrease in the temperature of geothermal wells in the PGE field is caused by cold water intrusion, this has been proven by the presence of deflections from spinner at shallow depths. This is also confirmed by the results of analysis of fluid samples taken from wells at certain depths. Running other logging to strengthen the indication of the flow of cold water in wells that have a decrease in temperature can be done to obtain data qualitatively, in this case the logging work done is by logging caliper, acoustic logging and electromagnetic logging. in well 3 it was clear that the analysis of the three logging tools explained that the flow of cold water came from the aquifer behind the casing wall and entered into the well from behind the 20 "casing which was damaged and entered through the 13 3/8 casing" which had been degraded metal loss is quite high. However, it should also be considered that carrying out logging jobs is quite expensive.

Well handling was carried out with 2 different methods for well 1 and well 2. Well 1 was carried out with a remedial casing using the 9 5/8 casing "where the operation was carried out using a wooden plug to isolate the reservoir zone from cement contamination during the casing remedial work. The second well was done with squeeze cementing only in the zone of suspected leakage that was previously insulated to maintain the reservoir zone from cement contamination. The results obtained in well 1 shows that the generation obtained is lower by 43% compared to the results of the initial well test, not so for well 2 where by using a squeeze cementing at the well, the steam flow rate obtained is not much different from the previous test results, but the squeeze method in well 2 has not been proven from its resistance because the well has not been operated as a production well yet.

6. ACKOWLEDGMENT

The authors wish to sincerely thank the PT. Pertamina Geothermal Energy for permission to publish this paper. Thank you to the Reservoir Management Team at the Exploitation Division for their support.

REFERENCES

Yuniar, Dhanie M., Hastuti, Pudyo., Silaban, Marihot,, Ulubelu, First Year Monitoring, (2015)

Pertamina Geothermal Energy, Laporan Akhir Pemboran Sumur UBL-12 (Unpublish Report), (2009)

Pertamina Geothermal Energy, Laporan Akhir Pemboran Sumur HLS-C1 (Unpublish Report), (2012)

Pertamina Geothermal Energy, Laporan Akhir Pemboran Sumur KRH 5-2 (Unpublish Report), (2012)

Pertamina Geothermal Energy, Laporan Well Completion Test Sumur UBL 12 (Unpublish Report), (2009)

Pertamina Geothermal Energy, Laporan Kegiatan Uji Produksi Sumur UBL 12 (Unpublish Report), (2011)

Pertamina Geothermal Energy, Laporan Kajian Subsurface Terkait Pendinginan Sumur UBL-6 dan UBL-12 (Unpublish Report), (2013)

Muhadjir, Alan., andono, widyanto., and laksono, agung.,: KRH-5.2 Well Integrity Surveillance MTD-MFC-ALFA (Unpublish Report), *National Petroleum Services* (2019)

Muhadjir, Alan : Well Leak Problem – A Case Study : Precise diagnosis and cure technology delivers fast and effective well remediation, avoiding costly recompletion , (2013)