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PRODUCTION PERFORMANCE ANALYSIS OF MAKE-UP WELL X AND INTERFERENCE EFFECT IN GEOTHERMAL FIELD Y

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ABSTRACT

The problem currently occurring in the Y geothermal field is a decrease in production, especially at the geothermal power plant unit 4. The solution is to drill a make-up X well, the production test using orifice meter method is one way that can be used to determine the performance of a geothermal well, which will then produce a deliverability curve. When drilling a make-up X well, of course there is a water injection process into the well, this will cause an interferenceeffect on the surrounding wells. The results obtained from the production test using orifice meter method on make-up X well, has an electrical potential of 9.49 Mw with a steam flow rate of 70.920 kg/kWh, and the type of production fluid issuperheated steam. Whereas, the wells that were interfered with by make-up X well are production wells Well-B and Well-G, for production wells that are completely uninterrupted by make-up well are Well-E, Well-K, Well-H, Well-N, and Well-O. However, there are wells that experience instrument and data manipulation problems, so that the temporaryconclusion is that they are not interfered with by make-up X well, including the production wells Well-C, Well-A, Well-F, Well-D, Well-J, Well-L, Well-M, and Well-I.

Keywords: make-up well; interference effects; production test using orifice meter method; electric potential

I. INTRODUCTION

As a country located along the Ring of Fire, Indonesia has abundant geothermal resources. This is evident from the existence of 117 active volcanoes spread throughout Indonesia, including on the islands of Sumatra, Java, NusaTenggara, Maluku, and Sulawesi (Nasruddin et al, 2016). One of the geothermal fields developed in Indonesia is the Y geothermal field with a reservoir area of 14 km². From geological, geophysical and geochemical investigations and observations, it is estimated that there are geothermal resources that can produce 100-200 MW of electrical energy for25 years (Melysa, 2017). The current problem at the unit 4 geothermal power plant in the Y geothermal field is experiencing a decrease in production caused by problems such as scale, casing damage and so on. One of the solutions taken by the company to meet the steam supply target to the unit 4 geothermal power plant is to use make-up wells. These make-up wells are mostly dominated by dry steam, so the flow rate measurement using an orifice meter is suitable for single-phase wells (Saptadji, 2001). Measurement and testing of geothermal wells can be done during the drilling process or after drilling is completed. One of the tests conducted after drilling is a production test. This production test produces a deliverability curve, which is a graph that shows the well's ability to produce mass in relation to well head pressure (WHP) (Saptadji, 2001). A make-up well is a type of well specifically designed to provide the steam supply required by a geothermal power plant with a certain capacity. To calculate the number of make-up wells required, several parameters must be determined, such as power plant capacity, project life, average flow rate of geothermal wells, and steam consumption to generate electricity (Purwaningsih, 2017).

During the drilling process of make-up well X, drilling mud in the form of cold water is injected into the well. Interference tests are conducted after drilling in geothermal fields, to evaluate whether there is communication between wells that have been drilled and the effect of one well on another (Sutopo, 2012). In this research, we will analyze the production performance of the X make-up well based on the deliverability curve obtained from the production test results using an orifice meter, during the production test using throttle valve openings of 15%, 23%, 25%, 35% and 100%. The final result of the deliverability curve analysis will be the potential make-up X well and the type of fluid tobe produced. Meanwhile, related to the interference effect, an analysis is carried out based on production data at the geothermal power plant unit 4 combined with data on the drilling timeline of the make-up X well and the productiontest time of the make-up X well. Later, if the steam flow rate and well head pressure (WHP) parameters decrease or increaseat both times, it can indicate the interference effect of the make-up X well on the surrounding wells.

II. METHODS

This research was conducted using the literature study method to analyze the production performance of make-up well X based on production test data using the orifice meter method and the relationship of make-up well X with surrounding wells to determine the interference effect that occurs. The procedure of this research can be seen in **Figure 1** as follows:

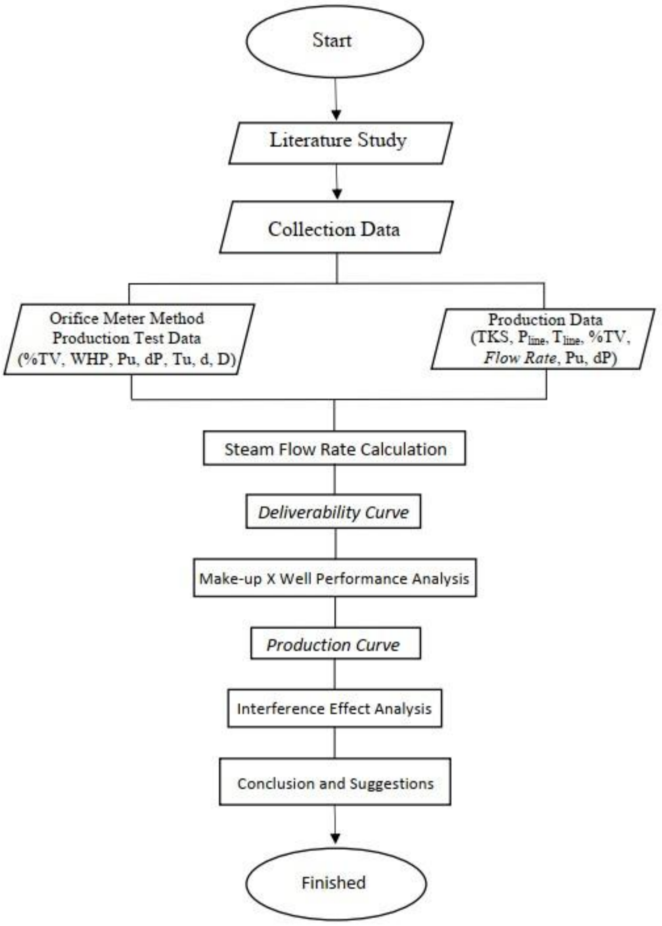

Figure 1. Research Flowchart

III. RESULTS AND DISCUSSION

3.1 Performance Analysis of Make-up Well X

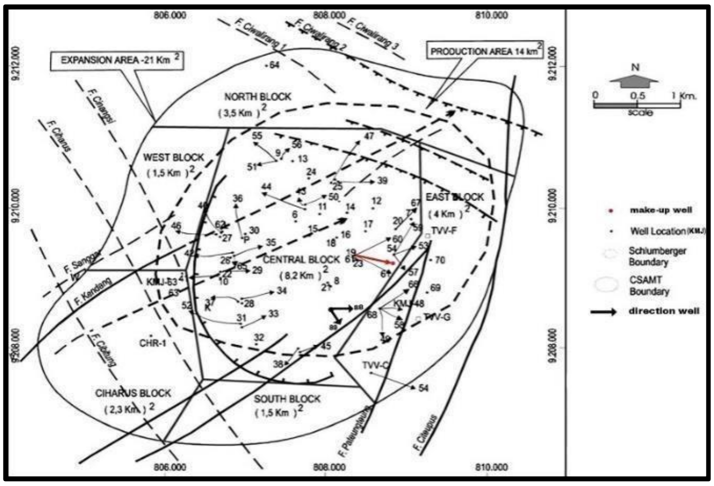

Figure 2. Location Map of Make-up Well X
(Sumintadireja, 2000)

Make-up well X is a well dominated by dry steam, and is produced to supply the geothermal power plant (PLTP) unit 4 area Y by flowing through pipe line 405. The make- up X well is located in cluster 19 and around production wells 61, 54 and 57. The Y geothermal field is a single-phase geothermal field dominated by dry steam, the Y reservoir has a temperature ranging from 230°C to 250°C with a pressure of 30-34 bar. A geothermal make-up well needs to know its performance, one way that can be done is with the orifice meter method production test. Production tests have been carried out at the X make-up well from December 14, 2023 to January 28, 2024, with variations in throttle valve openings of 15%, 23%, 25%, 35% and 100%. The variation of throttle valve opening is intended to achieve the desired well head pressure target, for example with a target of 12 barg requiring a throttle valve opening of 35% and so on. The achievement of the well head pressure target has been determined at the beginning before conducting production tests on a geothermal well by considering the pressure line and turbine inlet pressure. This X make-up well has an elevationof 1482.75 masl with an initial pressure of 27 barg, meaning that the reservoir pressure in this X make-up well is 27 barg. Reservoir pressure can be determined before conducting the orifice meter method production test, based on the results of the pressure build up (PBU) test. From the PBU curve, the initial reservoir pressure or static reservoir pressurecan be estimated. This helps in evaluating reservoir conditions and available production potential.

3.2 Production Test Results Using the Orifice Meter Method

The steam flow rate calculation uses the British standard 1042 method because the P2/P1 value ≥ 0.75 Pa, meaning that the deferencial pressure divided by the upstream pressure is still greater than 0.75 Pa. Make-up well X is a single-phase well dominated by dry steam, so the flow rate calculation is only the steam flow rate without taking into account the water flow rate. Based on the calculations that have been carried out, the following results are obtained:

Table 1. Orifice Meter Method Production Test Results

Bukaan Throttle Valve	Average Well Head Pressure (barg)	Average Steam Flow (ton/hours)
15%	21,63	51,28
23%	18,49	64,04
25%	15,45	66,48
35%	12,06	69,72
100%	8,49	73,48

The orifice meter method production test will produce well head pressure (WHP) values and steam flow rates at each throttle valve opening, the results of these measurements are obtained from the observation of the tranding curve. The tranding curve refers to a pattern or trend in the data that shows the direction of movement or development over time, so that the data used as a result is based on a curve with a stable movement without any dynamic increase or decrease. This is because using a curve that shows a stable movement will reduce the effect of data noise and focus more on the patterns or trends that arise.

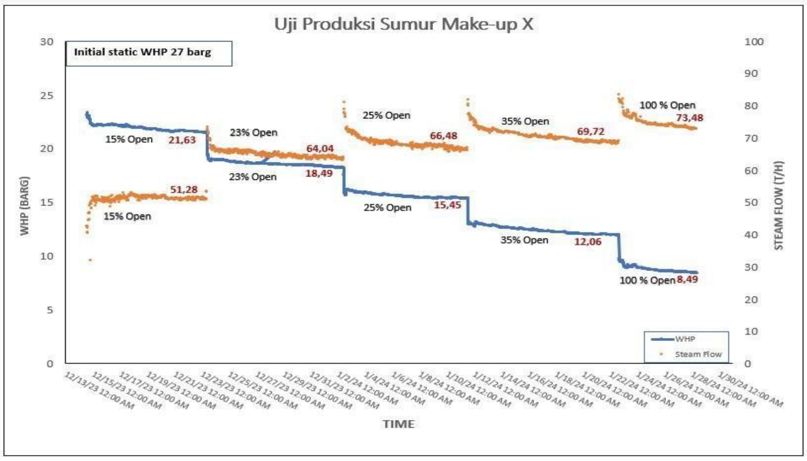

Figure 3. Tranding Curve of Production Test Results of Make-up Well X

3.3 Determination of Deliverability Curve

From the production test data that has been obtained, the next step is to calculate Log Q (steam flow rate) and Log dP^2 (initial pressure - well head pressure). This is because the deliverability curve is a logarithmic curve type, so the determination of the steam flow rate cannot be done linearly.

Table 2. Deliverability Curve Equation

WHP (barg)	Q (ton/hours)	dP^2	Log Q	Log dP^2	C
21,63	51,28	261,14	1,709	2,416	6,57
18,49	64,04	387,12	1,806	2,587	7,10
15,45	66,48	490,30	1,822	2,690	6,75
12,06	69,72	583,56	1,843	2,766	6,64
8,49	73,48	656,92	1,866	2,817	6,70

Steam flow rate equation:

$$Q = C^{*}(Pr^2 - WHP^2)^n \tag{1}$$

To be able to use the above equation, it is necessary to first find the value of C and the value of n, by making a logarithmic plot graph between Log Q (steam flow rate) and Log dP2 (initial pressure - well head pressure). Where, Q isthe steam flow rate of a geothermal well, Pr is the average reservoir pressure, WHP is the well head pressure, and C is a constant. This constant reflects the position of t h e stable deliverability curve on the log-log plot, while the constant n represents the slope of the stable deliverability curve and usually has a value between 0.5 and 1.0. To be able to use the above equation, it is necessary to first find the value of C and the value of n, by making a logarithmic plot graphbetween Log Q (steam flow rate) and Log dP2 (initial pressure - well head pressure). The value of n is obtained fromthe constant representing X on the trendline, with an x value of 0.369, indicating that the slope of the curve is sloping towards the X axis. While the value of C can be known by entering the steam flow rate equation based on the Q value during the previous orifice meter method production test. Based on the calculation of the average C value at various variations of the throttle valve opening of 6.75.

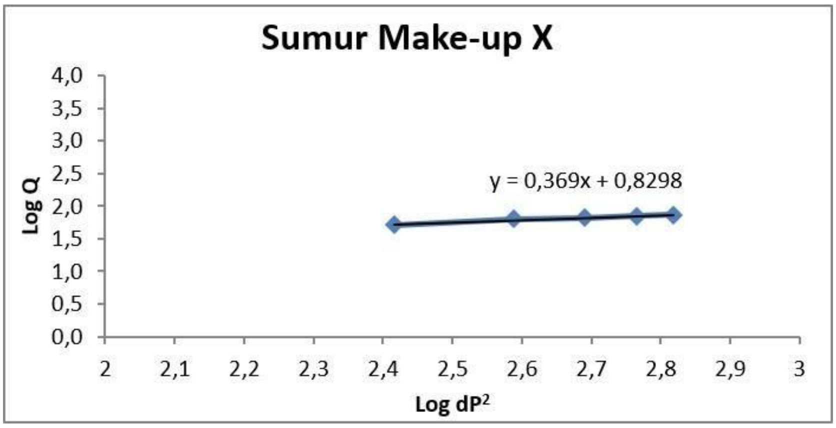

Figure 4. Log Plot Curve

The Q (steam flow rate) equation is a modification of the gas deliverability curve equation, the significant differencelies in the WHP value used. Gas wells use the value of flowing bottom-hole pressure (Pwf) as the wellhead pressure value, while in geothermal wells the pwf value is assumed to be the well head pressure value. This is because the reservoir pressure and temperature are very high in geothermal wells, making it impossible to take measurements at the bottom hole. Then the next step is to find the Q value at each WHP based on the steam flow rate equation, starting from 0 barg (blonk pressure) to 27 barg (reservoir pressure). One way that can be done to find out whether the calculation is wrong / correct, by matching the results of the simulated Q value with the Q production test. If the results obtained from the two values are the same or slightly different then the calculation can be said to be in accordance with the actual situation. Furthermore, if the Q value at each WHP is known, the last step is to create a deliverability curve by plotting between the steam flow rate and well head pressure.

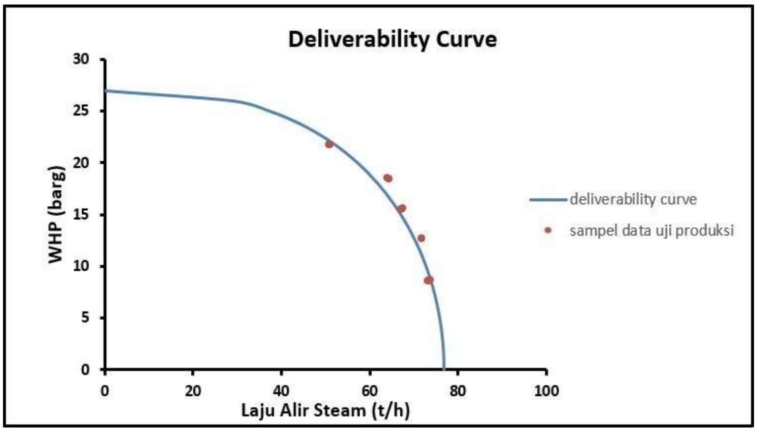

Figure 5. Deliverability Curve of Make-up Well X

Deliverability curve can be analyzed for optimal WHP operation by also considering the value of pipe-line pressure and turbine inlet pressure. The make-up well X is a well located in cluster 19 which is a cluster to fulfill the steam supply to the geothermal power plant unit 4 with pipe-line-405 as a steam flow pipe. According to Mawardi (2010) explains that pipeline-405 maximum working 15 bar or 14.2 barg and specific steam consumption (SSC) unit 4 is 7.47 kg/kWh. Specific steam consumption (SSC) is a measure of the efficiency of steam use in certain industrial processes, which refers to the amount of steam required to produce one unit of output or electrical output if in the geothermal power generation industry. Meanwhile, the value of the turbine inlet pressure of unit 4 is 11 bar (10.2 barg), therefore it can be concluded that the optimum WHP operation is 12.8 bar (12 barg). The calculation of the electrical potential of make-up well X can directly divide it by the SSC value of the unit 4 geothermal power plant, the equation used is as follows:

$$\text{Potensi} = \frac{Q}{SSC} \quad (2)$$

Table 3. Optimal Well Head Pressure

%TV	WHP (barg)	Q (ton/hours)	Q (kg/kWh)	W gen gross (kW)	W (Mw)
15%	21,63	51,28	51280	6864,79	6,86
23%	18,49	64,04	64040	8572,96	8,57
25%	15,45	66,48	66480	8899,60	8,90
35%	12,06	69,72	69720	9333,33	9,33
100%	8,49	73,48	73480	9836,68	9,84
35%	12	70,92	70920	9493,97	9,49

3.4 Determination of Production Fluid Type

The orifice meter method production test is carried out to identify the type of fluid in the reservoir and the production capability of a well, after the production test is carried out one of the outputs obtained is to know the type of reservoir fluid. The type of fluid is determined by calculating the data that has been obtained such as well head pressure (WHP), upstream pressure, differential 3.5pressure, flow rate and so on. Furthermore, the calculation results are combined with the steam table, which aims to facilitate the determination of the type of reservoir fluid.

Table 4. Make-up Well Production Fluid Type X

	Subcooled steam	Saturated Steam	Superheated steam
WHP	>19,5 barg	19 barg	<19 barg
Temperature	< 211,5 ºC	211 ºC	> 212 ºC

So with a well head pressure (WHP) operation of 12 barg with a throttle valve opening of 35%, the type of steam produced will be superheated steam.

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3.5 Interference Effect Analysis

Analysis of the interference effect of make-up well X with surrounding wells aims to evaluate fluid flow behavior in geothermal reservoirs. This interference test helps in understanding the interaction between adjacent geothermal wells, determining reservoir characteristics such as permeability and pressure, so that it will be able to plan efficient and sustainable production. The parameters used in the interference effect analysis are steam flow rate and well head pressure (WHP), because these two parameters can represent the performance of a geothermal well. Steam flow rate indicates the amount of steam produced by a geothermal well, an increase or decrease in steam flow rate can illustrate the effect of interference from other wells in the reservoir. If the steam flow rate decreases without a clear explanation, this could indicate negative interference that reduces production from the well. Meanwhile, well head pressure (WHP) reflects the pressure of the reservoir translated to the surface. Interference from other wells can affect this pressure, either positively or negatively. If the well head pressure experiences an unexpected increase or decrease, this could indicate the effect of interference between wells in the geothermal reservoir.

3.5.1 Wells Interfered by Make-up Well X

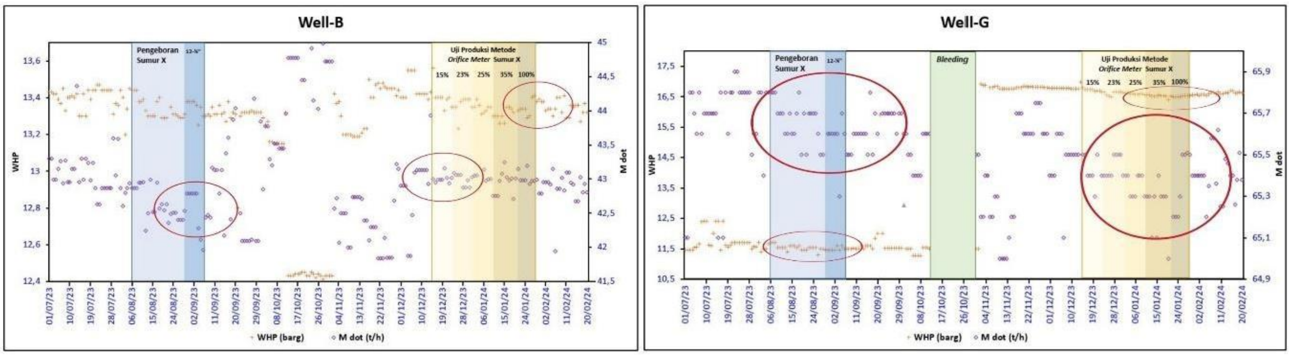

Figure 6. Well-B and Well-G

Well-B is interfered with by the make-up well X based on the figure above in the section marked in red, the value of steam flow rate and well head pressure (WHP) decreased during the production test. After the X make-up well production test is carried out, it can also be seen that the rebond has risen again. At the time of drilling the make-up wellX route 12 ¼″, it was seen that the steam flow rate had increased, this was probably due to the injection of water thathad penetrated the reservoir. With the water supply entering the geothermal reservoir, the steam resources increase and the superheated level of the steam decreases. Based on **Figure 6,** it can be seen in the section marked by the red circle that the steam flow rate and well head pressure (WHP) decreased during the drilling of the X make-up well and also during the orifice meter method production test. This can indicate a connection between the Well-G well and the X make-up well, reinforced also at the time after drilling and production tests both observation parameters, namely steam flow rate and well head pressure (WHP) rebounded to the actual value.

The impact of interference between geothermal wells can be addressed by determining the optimal distance between wells, which can be done based on accurate reservoir modeling that takes into account the geological characteristics and fluid flow conditions in the reservoir. By spacing wells sufficiently apart, the risk of interference can be significantly reduced. The use of advanced monitoring technology**,** to monitor the production conditions of each well in real-time. This includes the use of sensors to monitor pressure, temperature, flow rate and fluid composition. With accurate and immediate information, operators can take the necessary actions to avoid or reduce interference. Coordinated productioncontrol**,** this includes the use of automated control systems capable of adjusting production flow based on actual reservoir conditions and valve settings to deliver optimal well head pressure (WHP). With good control, pressure or temperature drops that could affect other wells in the vicinity can be avoided. Appropriate use of injection techniques**,** if necessary using injection techniques (such as water or gas injection) in a prudent and coordinated manner. Re-injection of fluid into the reservoir can help maintain reservoir pressure and reduce the negative effects of inter-well interference. Long-term evaluation and planning**,** by conducting regular evaluations of well performance and planning for long-term development with interference impacts in mind. This includes accounting for the potential to adjust production or well development strategies based on actual reservoir conditions.

3.5.2 Wells Not Interfered by Make-up Wells X

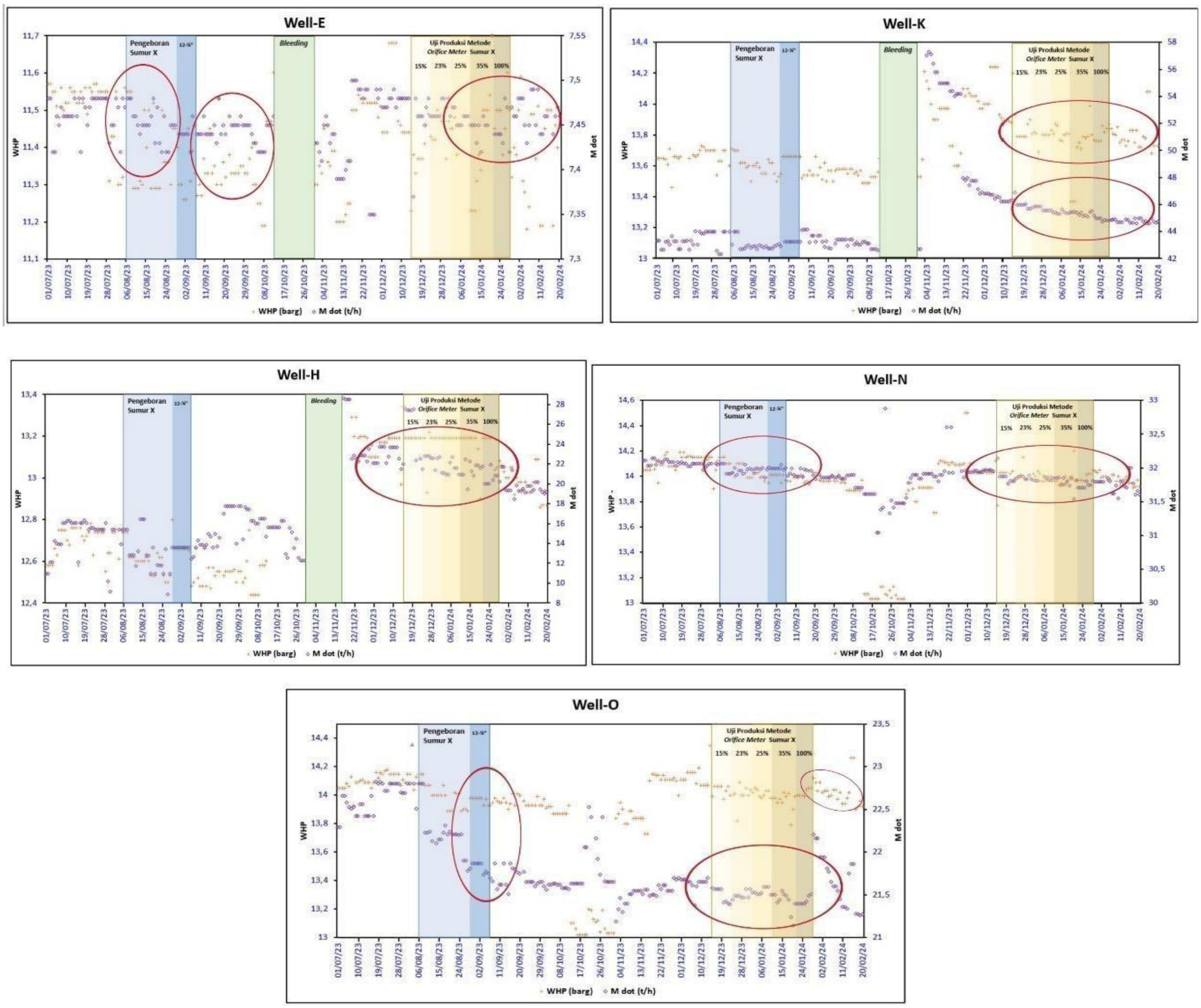

Figure 7. Well-E, Well-K, Well-H, Well-N, and Well O

Well-E, Well-K, and Well-H can be concluded that these wells are not interfered by the presence of make-up well X. In the red circle, it can be seen that the steam flow rate value decreased during the orifice meter method production test, but this is due to the bleeding process before the orifice meter method production test was carried out. Judging from the value of the steam flow rate which is not inversely proportional to the well head pressure. The well head pressure (WHP) parameter also decreased during the X make-up well production test, but the value will return to its original position after the effect of bleeding is gone. Before the bleeding process, the steam flow rate and well head pressure experienced dynamic movements, but this could not be analyzed because the data experienced instrument constraints. The bleeding process is a process where steam is flowed into the atmosphere with a small flow rate. This aims to release H2S gas in thegeothermal well so that later after the bleeding process is completed, steam will accumulate in the well and eventually cause a temporary increase in steam flow rate and over time the steam flow rate will return to its actual condition.

Geologically and on the well location map of the Y Geothermal field, Well-N and Well-O are far away from the make-up well X, so there is no possibility of interference. Supported by the interference test data in the red marked section, the steam flow rate and well head pressure values in these two wells are not affected by the drilling of make-up well X and the orifice meter method production test. When viewed in Figure 7 Well-N both parameters used, the movement tends to be stable without any dynamic movement fluctuations. While the decrease and increase of steam flow rate in Well-O during the drilling of make-up well X, is caused by the increasing value of well head pressure (WHP) and not due to the effect of water injection in make-up well X. After the production test, the steam flow rate and WHP showed a downward trend again. This can be caused by several other factors, namely, changes in reservoir pressure and production management.

3.5.3 Wells with Instrument Constraints

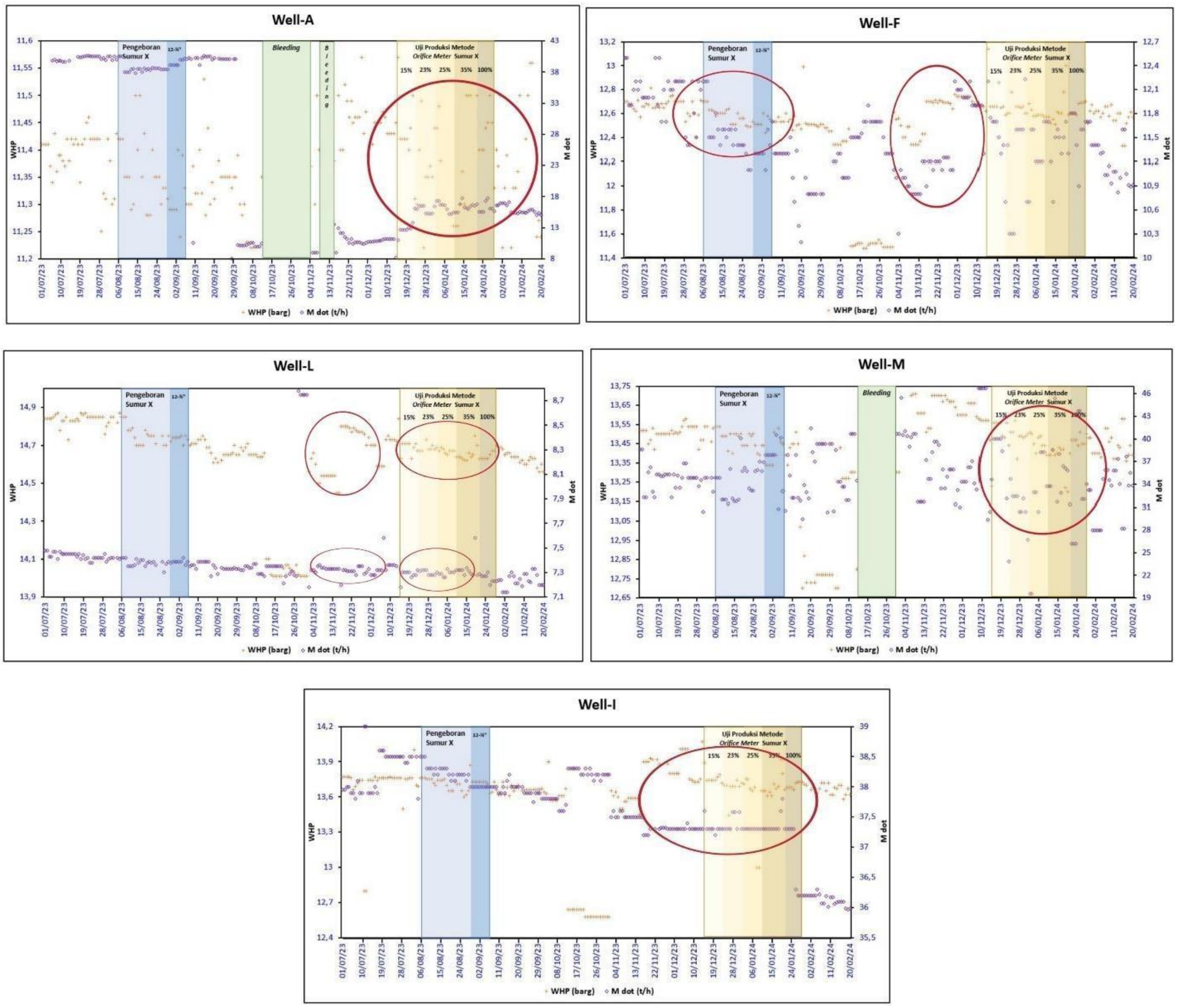

Figure 8. Well-A, Well-F, Well-L, Well-M, and Well I

In the figure above, it can be seen that in the section marked by the red circle, the value between the steam flow rate and well head pressure (WHP) is not accurate, because the relationship between these two parameters should be inversely proportional. It can be seen that the values of steam flow rate and WHP are not bound to each other, so for the time being the resulting data cannot be analyzed for its interference effect. However, geothermal wells that experience instrument constraints are not necessarily not interfered by make-up well X, so they will temporarily be classified as wells that are not interfered by make-up well X. Instrument constraints in geothermal wells can be a serious problem because accurate monitoring is needed to optimize the exploration of geothermal resources. Here are some examples of instrument constraints that may occur: Temperature or pressure sensor failure**,** fluid flow monitoring instrument failure**,** connection or communication problems, structural damage and instrument corrosion. The impact of instrument constraints in geothermal wells can disrupt stable and efficient energy production, and hinder the ability to respond quickly to technical problems or changes in conditions in the well. Regular maintenance is an appropriate preventive measure and the use of instruments that can withstand extreme environments is essential to maintain optimal performance of geothermal wells.

3.5.4 Wells that Experience Data Maneuvering

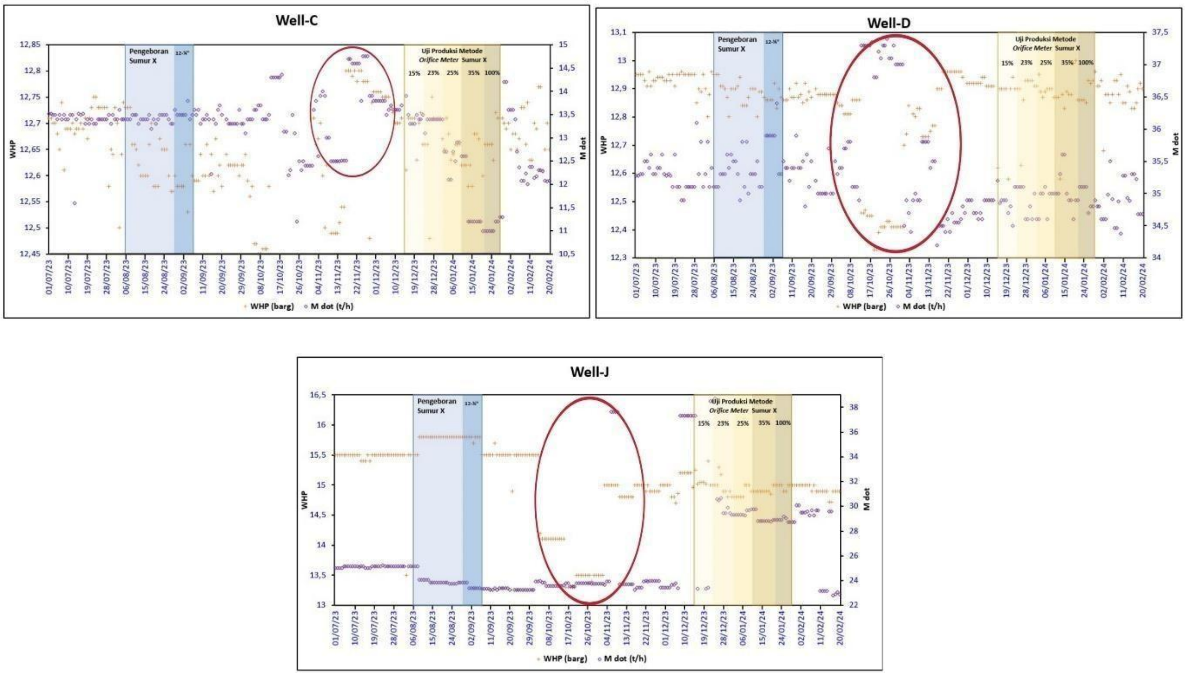

Figure 9. Well-C, Well-D, and Well J

In **Figure 9** above, it can be seen in the red mark that there is a significant change in both the steam flow rate and well head pressure (WHP) values. This significant change in value is without any bleeding process or other well workover, so the resulting data is not accurate for analyzing the interference effect. When a geothermal well experiences data maneuvering, it refers to a situation where the data generated by instruments or well monitoring systems are not reliable or accurate. This can be caused by various factors, such as technical glitches, measurement errors, or problems with the instruments used. As with wells experiencing instrument problems, wells experiencing data maneuvers are also temporarily classified as wells that are not interfered with by make-up X wells. However, this does not rule out the possibility that if the data obtained is valid and accurate, the three production wells could have a connection with the X make-up well.

To overcome the problem of data maneuvering in geothermal wells, it can be done in several ways including conducting regular maintenance on instruments and monitoring systems to ensure they are in optimal condition, ensuring instruments are properly calibrated to reduce measurement errors, and having a real-time monitoring system that can provide early warning of problems that may arise. By keeping the instruments and monitoring systems of geothermal wells in optimal condition, it can improve the accuracy of the data obtained and support efficient and accountable management.

IV. CONCLUSION

The conclusions that can be drawn in this research are as follows:

1. Based on the results of the production test using the orifice meter method, the performance of the make-up well X, in terms of electrical potential is 9.49 Mw with a steam flow rate of 70,920 kg/kWh. As for the optimum well head pressure (WHP) at the X make-up well is at 12 barg by producing the type of production fluid is superheated steam.

2. The interference effect caused by make-up well X has an impact on Well-B and Well-G and for wells that are not interfered with, namely Well-E, Well-K, Well-H, Well-N and Well-O. However, there are some wells that experience instrument and data maneuvering constraints so that for the temporary conclusion these wells are considered not interfered by the X make-up well, including Well-C, Well-A, Well-F, Well-D, Well-J, Well-L, Well- M, and Well-I.

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