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Evaluation of Geothermal Reservoir Characteristics Based on Pressure, Temperature, Spinner (PTS) Analysis and Gross Permeability Test

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Abstract

Geothermal energy is an alternative energy source that is increasingly important in meeting global energy needs. Well Completion is carried out to obtain well characteristic data through a series of tests. This study analyzes well X in field Y qualitatively and quantitatively using the Pressure, Temperature, Spinner (PTS) and Pressure Fall Test methods. Based on the quicklook analysis of the PTS graph, a liquid level injection of 1200 GPM was identified at a depth of 628 m from the pressure data. The correlation of temperature and spinner data shows four feed zones, namely at depths of 1074–1095 m, 1170–1195 m, 1232–1234 m, and 2604–2611 m. The slope value of the spinner analysis results against the cable speed is 7.2. The average fluid flow rate in each feed zone is -1.27 m/s, -1.42 m/s, -1.35 m/s, and -2.27 m/s, respectively. The largest mass flow rate contribution comes from the first feed zone at 11.06 kg/s (42%), followed by the second feed zone at 8.08 kg/s (30%), the fourth feed zone at 5.78 kg/s (22%), and the third feed zone at 1.38 kg/s (6%). The estimated production capacity reaches 13.15 MWe. The average Injectivity Index value is 532.81 tons/hr/coal. The results of the Pressure Fall Test show a reservoir permeability of 763.43 mD and a skin factor of -24.69, indicating improvements in reservoir characteristics.
Keywords : *Feedzone , Injectivity Index, Permeability, PTS, Fall of Test*

INTRODUCTION

Geothermal energy is a renewable energy source that is increasingly important in meeting global energy needs. Its use for power generation has been implemented in various countries, including the United States, the Philippines, Indonesia, Mexico, and New Zealand (Bertani, 2015). Geothermal energy originates from the natural heat within the earth and offers the advantage of being a clean, renewable, and reliable energy source, capable of providing a sustainable energy supply at a competitive cost (Barbier, 2002; Gupta and Roy, 2007; Chandrasekharam and Bundschuh, 2008).

Indonesia has enormous geothermal potential due to its location at the junction of active tectonic plates. National geothermal energy reserves are estimated to exceed 27,000 MWe, making it one of the largest in the world (Hutabarat and Alfian, 2008). With Indonesia's electricity demand continuing to increase, projected to reach 272.34 TWh or approximately 31,089 MW in 2020 (Muchlis and Permana, n.d.), geothermal energy has the potential to make a significant contribution to national energy security. However, its utilization remains relatively low, with generating capacity only reaching approximately 1,189 MW.

Geothermal systems generally originate from hydrothermal systems formed by volcanic magma intrusion, although there are also non-volcanic hydrothermal systems associated with sedimentary environments, metamorphic rocks, plutonic rocks, and tectonic activity. Geothermal reservoir characteristics are a crucial aspect in field evaluations because they influence the technical and economic feasibility of geothermal development. Common parameters analyzed include feedzone depth, fluid flow contribution, and reservoir pressure and temperature response. To determine well and reservoir conditions, a Pressure, Temperature, Spinner (PTS) survey is used, which measures pressure, temperature, and fluid flow rate within the well. Spinner data is recorded in revolutions per second, which is then processed into mass flow rate. The use of PTS surveys has become a standard method in the geothermal industry to characterize subsurface conditions in production and injection wells (Spielman, 1994). By combining pressure, temperature, and spinner data at various logging speeds, these surveys can provide the information necessary to more accurately determine fluid flow characteristics

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and reservoir conditions.

METHODOLOGY

This research involved evaluating the PTS data analysis conducted during the completion test of a geothermal well. The data was then processed to obtain several parameters related to the well and reservoir characteristics in the field.

The data collection method in this study was systematic to obtain the parameters necessary for analyzing the characteristics of geothermal wells and reservoirs (Sidiq, 2018). The research began with a literature review to understand the concepts of geothermal reservoirs, PTS tools, and PTS logging through books, journals, modules, and previous research. Data collection and preparation included reservoir data, completion tests in the form of PTS injection, multi-rate injectivity tests, pressure falloff tests, PT shut-in tests, and PTS flow tests.

This data was then analyzed to determine the location and thickness of the feed zone, the injectivity index value, well pressure and temperature, permeability thickness, permeability, initial pressure, and skin factor. The results of the analysis were used to evaluate the characteristics and quality of the reservoir in the studied well.

Once the required data has been collected, the author can conduct an evaluation and analysis, which will be explained in more detail in the next chapter. These include:

Data Preparation: Data obtained through a PTS survey, including depth, pressure, spinner, temperature, and cable velocity per second. Therefore, data sorting is necessary to facilitate data processing.

Slope Determination: The slope is the incline value obtained by plotting the spinner frequency against the cable speed, then plotting it against depth. This slope value will be used as a parameter to determine the fluid flow rate.

Fluid Flow Rate Calculation: In the data processing process, only one slope value is used, from the average value. The fluid flow rate calculation can be obtained using the fluid flow rate equation plotted against depth.

Mass Flow Rate Calculation: The mass flow rate can be determined after obtaining the fluid flow rate value and calculating it using the mass flow rate equation with supporting data such as density (steam table) and the cross-sectional area of the well/casing. Then, the depth is plotted to analyze the location of the inflow and outflow. This can then be used as a parameter to calculate the contribution of each feed zone.

The first method used in the GPT is the Injectivity Test, where the well is injected at different rates over a specific time period and depth. After the Injectivity Test survey is conducted, the well is shut in by stopping the injection into the well. The following series of tests is the Fall Off Test (FOT), which analyzes the pressure drop over time. From the results of these two series of surveys, the injectivity index, gross permeability, skin factor, and transmissivity, which reflect the ease with which fluids pass through a rock formation, can be calculated.

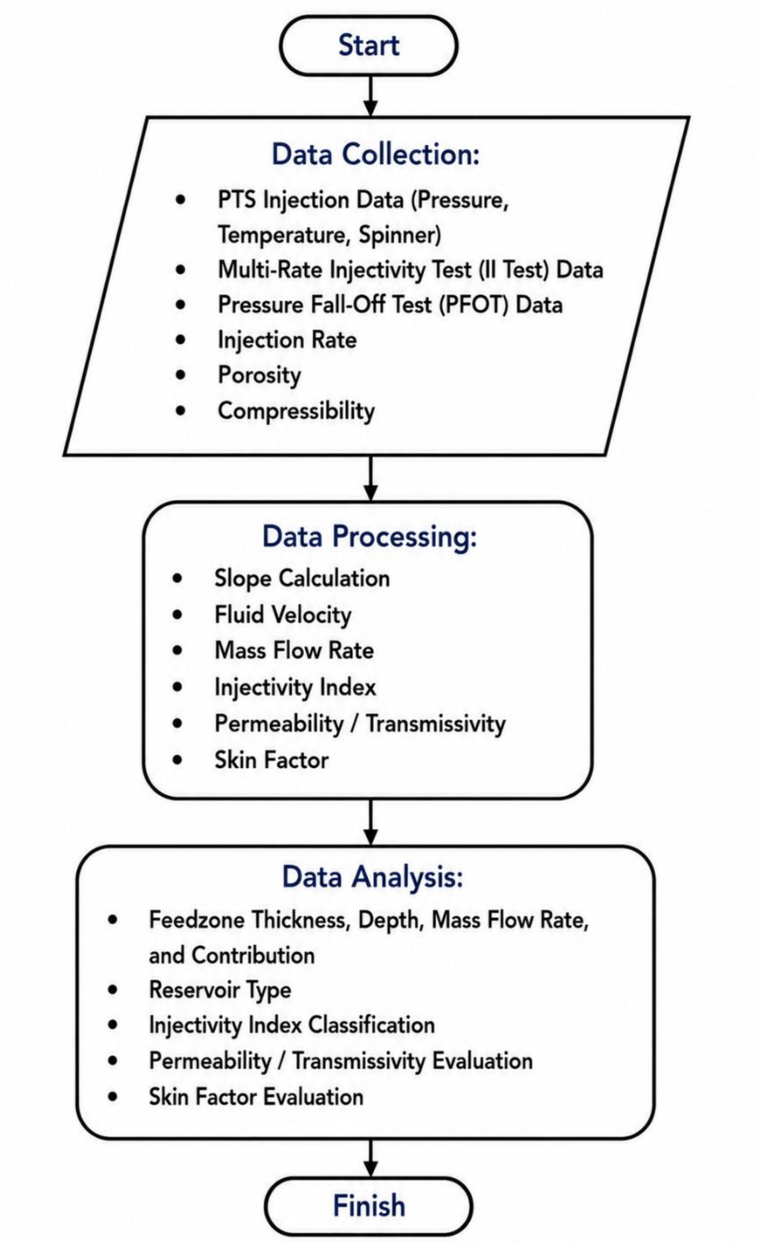

Figure 1 *Research Flowchart*

RESULTS AND DISCUSSION

The geothermal system in Field Y is characterized by a water-dominated system (Indonesian Geothermal Potential Book, ESDM, 2017) and a steam zone, a neutral pH, a salinity level of 2,500 mg/kg, and a NCG content of less than 0.3 wt%. This system has an estimated reservoir temperature of 250-300°C. Field Y is also categorized as high relief with fumaroles. The estimated reservoir depth is 1,140-1,350 m above sea level (1,000-500 m), and reservoir water is distributed northward for approximately 3 km, with high temperatures at high elevations and hot springs at lower elevations.

Geologically, the geothermal system model in Field Y is dominated by a main structure running northeast-southwest, as well as structures running northwest-southeast, and north-south. The combination of these structures is thought to determine the distribution of manifestations and alteration.

Below is another well graph as supporting data in determining the reservoir dominance system in well X. It can be seen that the liquid level depth at shut-in conditions is in the top of the 10-3/4" perforated liner area at around 952 m depth, indicating that the reservoir system is dominated by a water

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dominated system and has a large liquid column along the well depth with a high probability of being produced to the surface after the well is flowed:

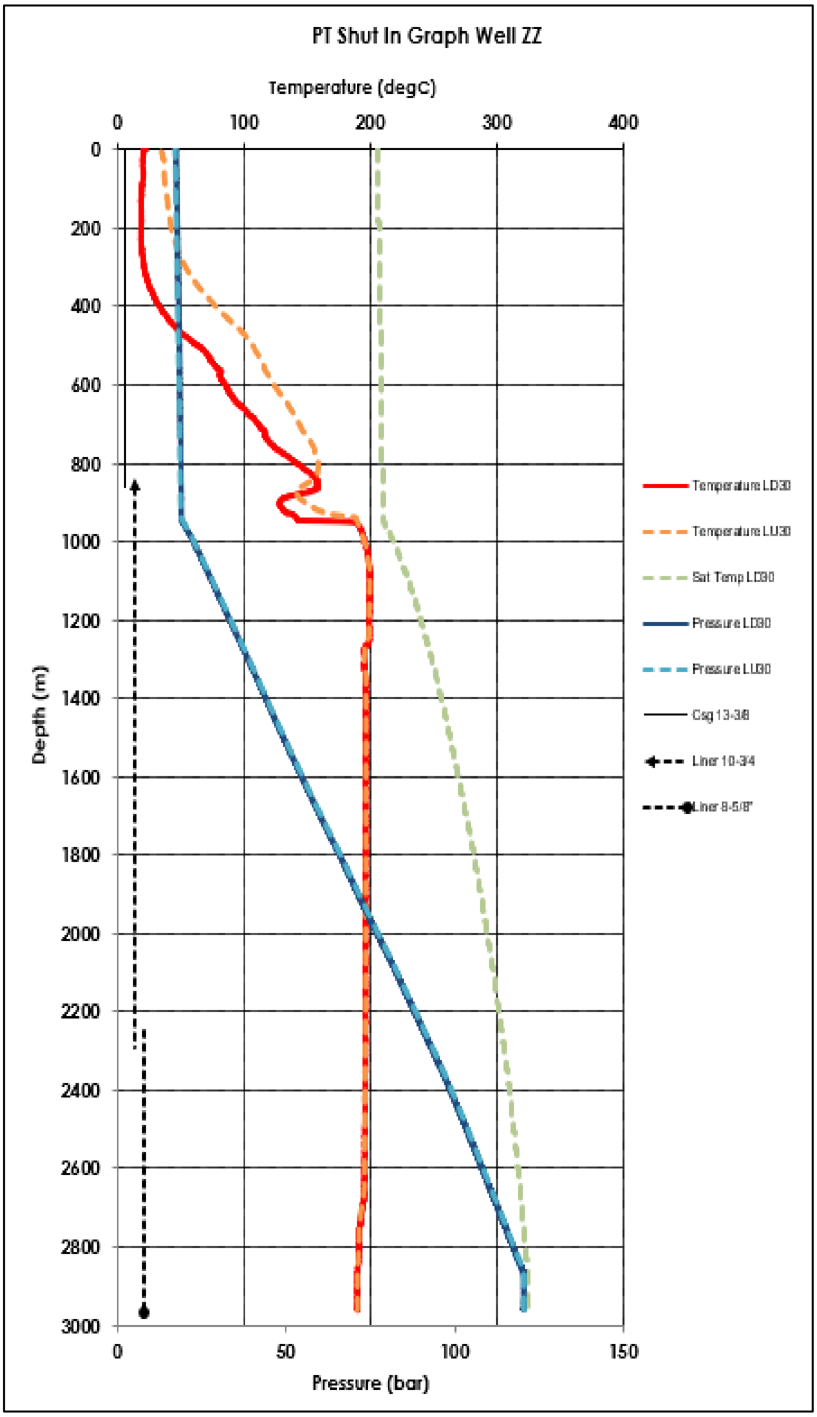

Figure 2 *PT Shut-In Graph of Well ZZ*

(Research Results, 2023)

It should be noted that the calculations in the current analysis need to be correlated and confirmed through other test surveys such as PT Heating-Up, PT Shut-In and PTS Flowing (flow test after the drilling process is completed) in determining further well characteristics in order to determine the actual potential of the well so that the next decision can be made whether the well will be a production well or an injection well.

The PT Shut-In Well ZZ graph shows the relationship between pressure and temperature versus well depth down to approximately 3,000 m. The pressure curve (blue) shows a nearly linear increase with depth, from approximately 18 bar at 900 m to over 120 bar at the bottom of the well. The agreement between the pressure curves during the down-logging (LD30) and up-logging (LU30) indicates relatively stable well conditions and good data quality.

The temperature profile (red and orange) shows the temperature increase from the surface to a depth of approximately 800–900 m. During this interval, changes in the curve shape, or temperature anomalies, are visible, indicating the possible presence of a permeable zone or feed zone, the area where fluids from the reservoir enter the well. After approximately 1,000 m, the temperature tends to remain constant at around 85–90°C until near the bottom of the well, indicating relatively stable thermal conditions during the shut-in period.

The actual temperature curve is to the left of the saturation temperature curve (dotted green) throughout the well depth. This indicates that the fluid temperature is still lower than its boiling point at local pressure, so the fluid in the well is predominantly subcooled liquid and has not undergone significant boiling. Overall, the graph indicates that the well is in stable hydrostatic conditions, with indications of a permeable zone at a depth of approximately 850–950 m, which has the potential to become the main reservoir fluid flow pathway.

Quicklook PTS Graph/PTS Data Analysis

After sorting the data using a PivotTable and plotting a graph of depth versus pressure, temperature, and spinner (PTS) injection data at a depth of 1200 m, a quicklook analysis was performed to identify the location of the zone of interest (feed zone). In Figure 3, PTS All Section and PTS Perforated Section are used to evaluate the distribution of injection fluid within the well. The left graph shows the entire well, while the right graph zooms in on the perforated zone (around 1000–2700 m) for easier analysis.

Focusing on a depth of around 1200 m, several important points are visible:

1. The Spinner Curve exhibits significant changes
- The spinner curve (purple and green) is used to measure fluid flow velocity within the well.
- In the interval around 1100–1250 m, the spinner value shows a decrease compared to the section above it.
- This decrease indicates that some of the injection fluid is escaping from the wellbore into the formation through the perforations located in that interval.
2. The presence of perforations in the interval of approximately 1180–1230 m
- The right graph shows a horizontal red line labeled PERF2.
- PERF2 is located right around the 1200 m depth.
- When combined with the spinner response, this indicates that this zone is an injection-receiving zone.
3. Pressure and temperature support the indication of injection
- The pressure curve shows a normal increase with depth without any major anomalies.
- The temperature curve shows a gradient change around the perforation zone, which typically occurs due to the entry of injection fluid at a temperature different from the formation temperature.
- This strengthens the interpretation that fluid transfer occurs from the well to the reservoir at a depth of approximately 1200 m.

If measurements were taken at an injection rate of approximately 1200 GPM (gallons per minute), then the zone around 1200 m can be interpreted as one of the main zones receiving injection fluid. However, based on the shape of the spinner curve, this zone does not appear to be the only receiving zone. Spinner changes are still visible at deeper perforations (around 2600 m/PERF4), suggesting that the injection rate is likely split across multiple perforation intervals.

At a depth of around 1200 m, particularly in the PERF2 interval, there are strong indications that injection fluid is entering the formation. This is indicated by changes in the spinner response, indicating a loss of flow rate within the well, supported by changes in the temperature profile and the presence of perforation intervals. With an injection rate of 1200 GPM, this zone serves as one of the primary feed

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zones receiving injection, although the injection distribution is likely still split across deeper perforation zones.

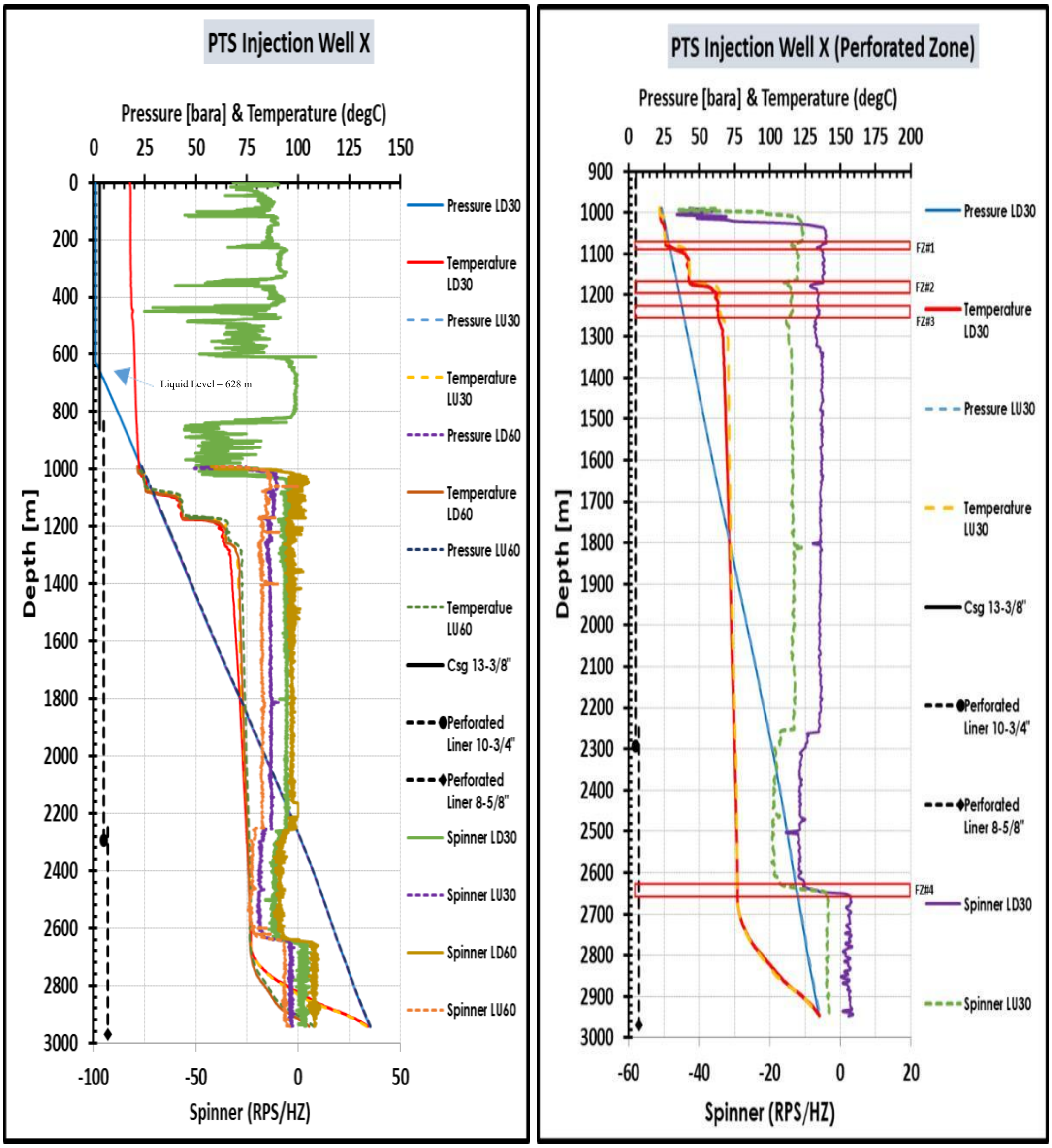

Figure 3 *PTS All Section & PTS Perforated Section*
(Research Results, 2023)

The presence of a feed zone can be identified through a spike in the temperature graph and correlated with changes in the spinner graph. Changes in impeller rotation on the spinner indicate the presence of reservoir fluid inflow or outflow zones, while pressure data is used to determine wellbore pressure and liquid level. Well schematic information is also needed to locate the casing and perforated liner, facilitating survey data interpretation.

Spinner surveys are generally conducted at two different logging speeds to obtain more accurate and comprehensive data. This method aims to improve the accuracy of fluid flow rate measurements, identify flow contributions from each reservoir zone, detect potential crossflow between zones, and evaluate reservoir and formation characteristics. Furthermore, the use of two logging speeds also serves to verify the performance and calibration of the spinner tool and understand fluid flow dynamics, which can change over time. Therefore, spinner surveys with multiple speeds are an important method for reservoir characterization and geothermal well performance optimization.

The accuracy of log-up and log-down data depends on well conditions, the type of logging tool, and the survey objectives. Log-up generally produces more stable measurements due to the smaller influence of gravity and fluid flow disturbances, making it often used to evaluate formation conditions around the well. Meanwhile, log-down can provide a better picture of dynamic well conditions, but is more susceptible to the effects of tool eccentricity and the risk of tool jamming due to fluid or material in the well. Therefore, both methods have their respective advantages and limitations.

In practice, log-up and log-down data are often used in conjunction to verify measurement results and gain a more comprehensive understanding of subsurface conditions. The choice of data depends on the analysis objectives, well conditions, and logging equipment characteristics. Furthermore, advances in logging tool technology and data correction methods have increased the reliability of measurement results in both logging directions.

In wells X and ZZ, it was found that the reservoir type has a two-phase system. Based on other reference wells, the reservoir behavior in the field is water-dominated. Several other data are shown in the table below:

Table 1 *PTS Graph Quicklook Results*

Description	**Value**	**Remarks**
Feedzone#1	1074-1095 m	Inflow
Feedzone#2	1170-1195 m	Inflow
Feedzone#3	1232-1234 m	Inflow
Feedzone#4	2604-2611 m	Inflow
Liquid Level	628 m	1200 gpm
TOL 10-3/4"	835 m	Perforated
TOL 8-5/8"	2250 m	Perforated

(Research Results, 2023)

Geothermal reservoir behavior in the research field indicates a relatively stable system still dominated by the liquid phase (water-dominated system). Reservoir stability is maintained through a recharge process involving reinjection of condensate and brine produced into the reservoir using active injection wells. Although the number of production wells exceeds the number of injection wells, the reservoir is currently in equilibrium and has not shown any indication of depletion or significant pressure decline.

Reservoir pressure remains generally stable, but there are indications of a decline in production, suspected to be caused by scale formation in the reservoir rock, production casing, and perforated liner. Furthermore, monitoring results indicate that the reservoir remains dominated by the liquid phase and has not transitioned to vapor dominance. Changes in reservoir fluid chemistry are also continuously monitored through periodic brine sample analysis to assess reservoir condition developments. Therefore, continuous monitoring of pressure, fluid composition, and scale formation is crucial for maintaining the sustainability and efficiency of geothermal energy production.

PTS Survey Data Processing

After obtaining a brief overview of the quicklook analysis results from the PTS Injection data, the next step is processing the previously simplified PTS data. Slope values can be calculated by analyzing the spinner versus cable speed data, then plotting it against depth.

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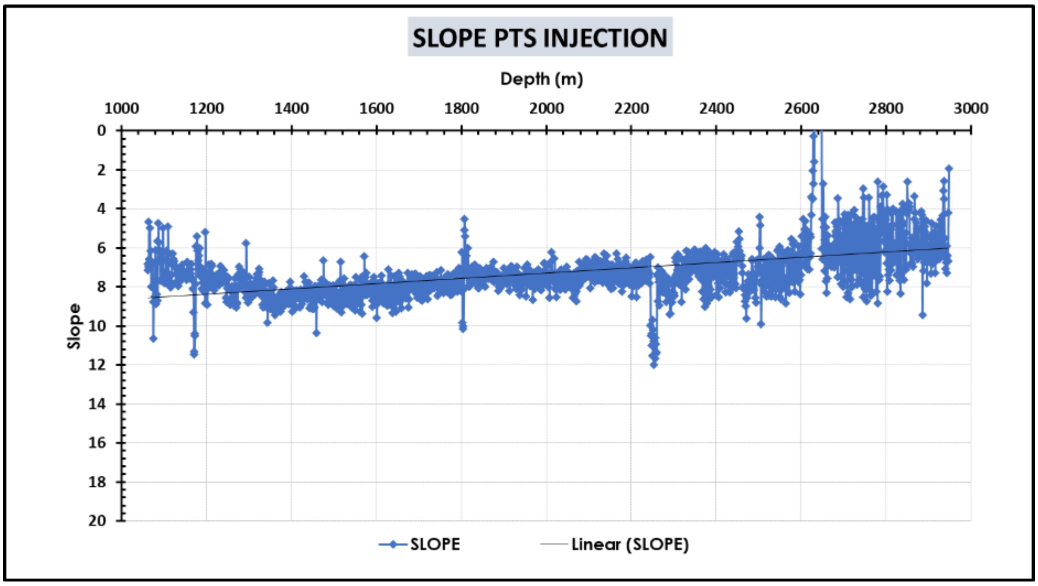

Figure 4 *Slope vs. Depth (Perforated Zone)*
(Research Results, 2023)

Based on the average trend generated, the slope value obtained based on PTS data is 7.2. The slope value is then used as a parameter to determine the fluid flow rate (fluid velocity). The slope value is the average value of each feed zone where the fluid velocity or fluid flow rate can then be calculated in Microsoft Excel. Several parameters are needed as data to calculate fluid velocity such as slope value, spinner frequency and cable speed per depth. In this calculation, the slope value will be calculated as the average per interval into the feed zone, while for fluid velocity, 2 calculations are carried out, namely fluid velocity log down and fluid velocity log up, then the average fluid velocity is calculated based on the log-down and log-up results.

From the fluid velocity calculations for each feed zone, the fluid flow rate in feed zone #1 is -1.27 m/s, feed zone #2 is -1.42 m/s, feed zone #3 is -1.35 m/s, and feed zone #4 is -2.27 m/s. After obtaining the fluid flow rate values, the mass flow rate at each depth can be calculated. However, parameters such as fluid density are required, which can be obtained from the steam table using the temperature function, which determines the change in fluid density due to temperature changes in the well and the casing cross-sectional area data.

From the mass rate calculations for each feed zone, the mass flow rate in feed zone #1 is -11.06 kg/s, feed zone #2 is -8.08 kg/s, feed zone #3 is -1.38 kg/s, and feed zone #4 is -5.78 kg/s. Using the mass and heat balance concept, assuming the amount of fluid entering the feedzone equals the amount leaving the feedzone, we can estimate the mass rate of each feedzone and the total well capacity. The 1074-1095 m depth is considered the main feedzone because it contributes the most compared to the other feedzones. The well schematic shows that feedzone #4 is located on an 8-5/8" perforated liner, while feedzones 1, 2, and 3 are located on a 10-3/4" perforated liner. The casing cross-sectional area affects the fluid flow rate and mass flow throughout the well.

However, the analysis values based on the PTS Injection survey must be correlated and corrected with post-well production data, namely the PTS Flowing survey to obtain the Productivity Index and the PT Shut-In survey to confirm the actual mass rate (well capacity) and feedzone location.

The following is a table of the results of the calculation of fluid velocity, mass rate from well X based on the depth of the feedzone to determine the percentage contribution of each feedzone, then the estimated production potential can also be calculated with the assumption of a flow rate of 2 kg/s steam (specific stream consumption) which can produce an output of 1 Mwe, namely:

Table 2 *Feedzone Interval, Mass Rate & Contribution*

Feed Zone	Depth (m)	Fluid Vel (m/s)	Mass Rate (kg.s)	Contribution
1	1074-1095 m	1.27	11.06	42%
2	1170-1195 m	1.43	8.08	30%

3	1232-1234 m	1.35	1.38	6%
4	2604-2611 m	2.27	5.78	22%
Estimate Total Mass Rate (kg/s)			**26.3**	
Estimate Production (Mwe)			**13.15**	

Injectivity Test & Pressure Fall Test Data Processing

Geothermal reservoirs are classified as dual porosity reservoirs because they possess two types of porosity: fracture porosity and matrix porosity, which are interconnected by the rock matrix and fractures. Therefore, the assumed porosity value for dual porosity is 0.1. Therefore, to obtain the reservoir's gross permeability, an injectivity test was used to determine the injectivity index and a pressure fall test to determine the reservoir's skin factor.

The MRI (multi-rate injectivity test) results obtained pressure values at different injection rates: 1200 GPM, 900 GPM, 700 GPM, and 500 GPM at a depth of 1400 m. The obtained pressure values were then plotted against each injection rate, resulting in an injectivity index (II) value of 532.81 tons/hr/coal. This injectivity index result is considered very high, indicating that the reservoir is capable of accepting or absorbing large amounts of injected water.

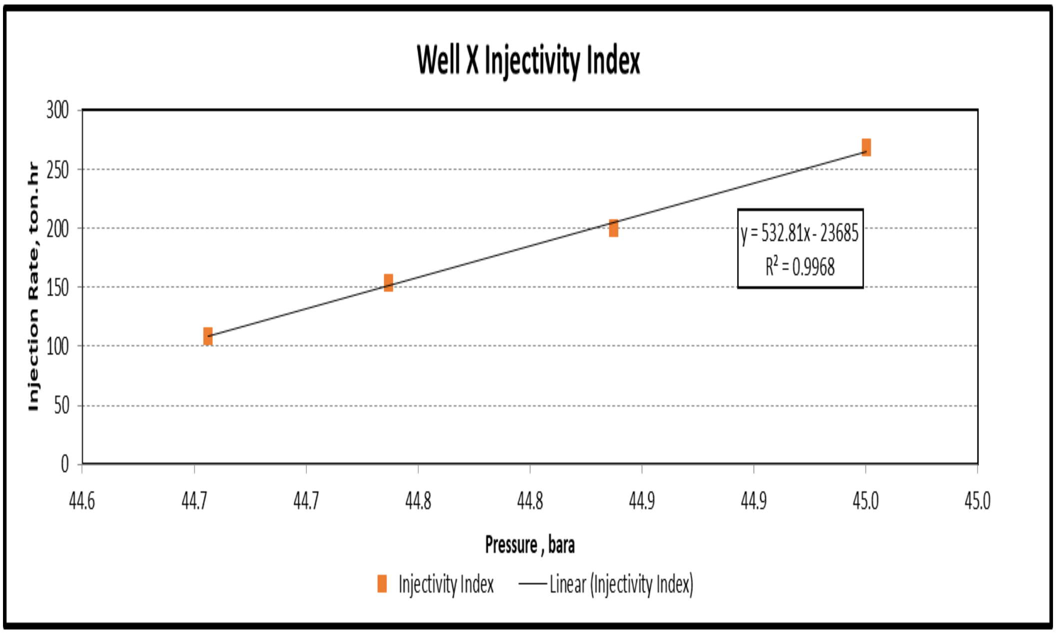

Figure 5 *Injectivity Index*
(Research Results, 2023)

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After the injectivity test, a pressure fall of test (PFOT) program is performed by shutting down the pump. The goal is to observe the transient pressure drop as data to obtain transitivity, permeability, and skin values. To determine these values, other parameters are needed. The pressure data is plotted against time using the Horner method to obtain the slope and initial pressure values to calculate permeability and skin factor.

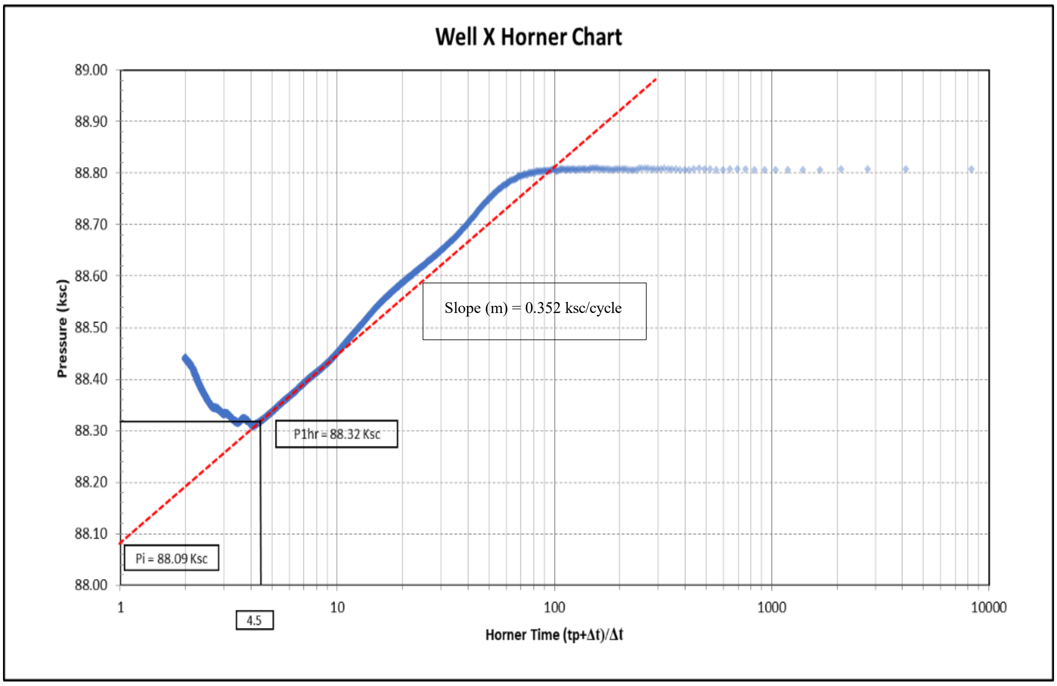

Figure 6 *Horner Chart*
(Research Results, 2023)

Based on the results of the analysis using the Horner Chart, by using the equation to obtain the slope by determining 2 points on the graph, the slope value is obtained at 0.352 ksc/cycle, the initial pressure (Pi) is 88.09 ksc and the 1-hour pressure (P1hr) is 88.32 ksc. After obtaining the slope value, the permeability, transmissivity and skin values can be calculated using equations (2.10 & 2.11). There are several data as calculation parameters such as viscosity, injection rate, feedzone thickness. The following data is used to determine the permeability value:

Table 3 *Permeability Calculation Data*

Parameter	**Value**
Fluid Viscosity, kg/m-s	0.000103067
Injection Rate, m3/s	0.075708
Slope, N/m2/cycle	34529.79624
Feedzone Thickness (h), m	55

From the calculation results using equation (2.10), the average permeability value is 763,430 mD. The permeability value of the rock matrix in the geothermal reservoir is classified as high permeability, namely more than 100 mD. After obtaining the permeability value, the skin factor in the reservoir can be calculated to determine the initial formation damage due to drilling and injection activities during the survey. Several other parameters needed to calculate the skin factor such as porosity data, compressibility, viscosity, permeability, and wellbore radius are presented in the table below:

Table 4 *Skin Factor Calculation Data*

Parameter	**Value**
Fluid Viscosity, kg/m-s	0.000103067
Injection Rate (Q), m^3/s	0.075708
Slope (m), N/m2/cycle	34529.79624
Feedzone Thickness (h), m	55
Compressibility (Ct), Pa^{-1}	0.00000000300
Initial Pressure (Pi), ksc	88.09
Pressure @ 1 hr (P1hr), ksc	88.32
Permeability (k), mD	763.430
Porosity (Ø), fraction	0.1
Wellbore Radius, m	0.125095

The skin value obtained for the reservoir was -24,692, which in the skin value classification is negative, indicating an improvement in the reservoir condition (no formation damage). Further testing is still required as a step to confirm and correlate the actual conditions when the well is produced (PTS Flowing) so that the Productivity Index (PI) value can be determined even under shut-in conditions.

CONCLUSION

Based on the results of Pressure, Temperature, Spinner (PTS) analysis, the reservoir in well X in Field Y has excellent characteristics with high production potential. The reservoir is categorized as a two-phase reservoir dominated by water (water dominated system), indicated by the presence of a liquid level at a depth of 628 m during injection conditions and the geological conditions of the well that penetrate the aquifer zone to a depth of approximately 2600 m. The PTS Injection analysis identified four feed zones, namely FZ#1 at a depth of 1074–1095 m, FZ#2 at 1170–1195 m, FZ#3 at 1232–1234 m, and FZ#4 at 2604–2611 m. The main feed zone (FZ#1) contributed the largest mass flow rate of 11.06 kg/s (42%), followed by FZ#2 at 8.08 kg/s (30%), FZ#4 at 5.78 kg/s (22%), and FZ#3 at 1.38 kg/s (6%). Based on the contributions of these four feed zones, the well's production potential is estimated at 13.15 MWe.

Reservoir testing results showed an Injectivity Index (II) of 532.81 tons/hr/coal, indicating excellent well injectivity. Furthermore, the Pressure Fall Test analysis yielded a reservoir permeability of 763.43 mD, indicating a high level of formation connectivity. A skin factor of -24.69 indicates improved reservoir conditions, with no formation damage observed during drilling or injection. Overall, the reservoir parameters obtained indicate that well X has good reservoir quality, high productivity, and promising development prospects.

REFERENCES

Axelsson, G, et all.(2018*). Logging, Testing And Monitoring Geothermal Wells.* Geothermal Training Programme, United Nations University. Burlington, United States.

Buscato, Normann M.(2012*). Quantifying Feed Zone Contributions from Pressure-Temperature-Spinner Data and Pressure Transient Analysis Using Welltester*. Geothermal Training Programme, Iceland.

ESDM, Kementerian.(2017*). Buku Potensi Panas Bumi Indonesia.* Jilid 1.
Kementerian Energi dan Sumber Daya Mineral.

Fekadu, M.(2020*). Well Testing and Power Plant Scenario Analysis for Hverahlid Geothermal Field.* Mechanical Engineering and Computer Science, University of Iceland.

Submitted: **09/06/2026**; Revised: **12/06/2026**; Accepted: **20/06/2026**; Published: **30/06/2026**

Grant, Malcolm A. Dan Paul F. Bixley.(2011). *Geothermal Reservoir Engineering,* Humaedi, M.T., dkk. (2016*). A Comprehensive Well Testing Implementation during Exploration Phase in Rantau Dedap.* Indonesia, 5th ITB

International Geothermal Workshop, Indonesia.

Mahajan, M.(2006*). Successes Achieved in Acidizing of Geothermal Wells in Indonesia.* SPE 100996 Asia Pacific Oil & Gas Conference and Exibition, Adelaide, Australia.

Marisa, D. P, et all.(2016). *Karakterisasi Feed Zone dan Potensi Produksi Sumur Panas Bumi ML-XX Muara Laboh, Solok Selatan*. Jurnal Fisika Unand Vol. 5. Andalas University, Padang.

Martasari, D.(2023*). Analysis of Gross Permeability Test Based on Well Completion Test At RL-25 Well Geothermal Field Area CLX.* Jurusan Teknik Geofisika, Universitas Pembangunan Nasional Veteran Yogyakarta, Indonesia.

Rachmarifqi, A, et all.(2019). *Identifikasi Kondisi Dan Potensi Sumur Berdasarkan Data Pts Sumur X.* Journal of Mechanical Engineering and Mechatronics. Trisakti University, Jakarta.

Rakha, M, et all.(2019). *Analisis Keberadaan Feedzone Sumur Y Berdasarkan Hasil Analisis Pts Injection Di Lapangan Panas Bumi MRD.* Seminar Nasional Cendekiawan ke 5 Tahun 2019. Trisakti University, Jakarta.

Sadiq, J.(2019*). Geothermal Well Test Analysis.* Elsevier Akademic Press. United Kingdom.