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Utilization Potential of Marginal Well to Maintain Steam Supply to Geothermal Power Plants: Case Study of Lahendong Field, Indonesia

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ABSTRACT

Problems in Lahendong geothermal fields are related to the decline in steam supply from existing production wells. This can be caused by various factors, including reservoir pressure decline or damage to production wells. On the other hand, there are several marginal wells in the Lahendong prospect and Tompaso prospect. This research focuses on the Tompaso prospect, although steam availability is still sufficient to meet the commitment of 40 MW generation, we must prepare a steam buffer to avoid steam shortages which cause a loss of revenue. The LHD-B well, a marginal well in the Tompaso prospect, has a temperature of 284°C and exhibits potential permeability, as indicated by total loss circulation during drilling. The stimulation equipment available was limited at that time so the discharge effort was not continued. Optimizing LHD-B wells lies in addressing the challenge of declining production without the need for costly and time-consuming new drilling. The method used in this study includes a comprehensive evaluation of the inactive well conditions, reservoir performance analysis, and the application of stimulation techniques. After well repairs were carried out to restore well integrity, wellbore simulations were conducted to determine the potential steam production capacity. The results of this study indicate that the LHD-B well has the potential to increase steam supply and maintain the stability of the operation of PLTP Units 5 & 6, thus potentially delaying the need for new well drilling

1. INTRODUCTION

Geothermal exploration in Lahendong started back in 1973. The first commercial operation (COD) began in 2001 with an initial capacity of 20 MW. Since then, the field has expanded significantly and now produces 120 MW. The Lahendong Working Area (WKP) has two main prospects: Lahendong, which supplies Units 1-4, and Tompaso, which supplies Units 5 & 6. The electricity generated from this geothermal field is integrated into the SulutGo transmission system, contributing around 20% (Fanani, 2021). The contribution of the Lahendong working area to the SulutGo transmission system can continue to increase in line with the planned development of additional power plant units.

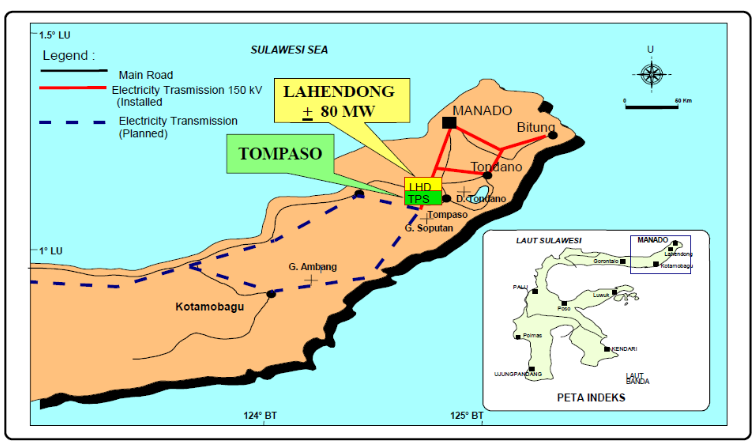

Figure 1: Lahendong Location map (Prabowo, 2015)

Maintaining a consistent steam supply is one of the most critical challenges in geothermal power plant operations. Over time, steam production can decline due to several factors, including reservoir pressure depletion, scaling within the wells, and integrity issues. These issues can significantly affect the efficiency and output of geothermal plants, leading to reduced power generation capacity and increased operational costs.

To address these challenges, one promising strategy in this field is the assessment and optimization of marginal wells within the geothermal field. Marginal wells, which may have been abandoned due to operational inefficiencies or reduced productivity, can often be rehabilitated and utilized to support steam supply. By conducting a thorough assessment of the marginal wells—analyzing their structural integrity, permeability, and reservoir connectivity—operators can identify wells with the potential for reactivation. By leveraging marginal wells, geothermal operators not only improve steam availability but also maximize the value of existing resources, reducing the need for costly new drilling operations. This dual approach—identifying marginal well potential and implementing targeted rehabilitation—can play a vital role in sustaining steam supply while ensuring the long-term viability of geothermal projects.

2. ASSESSMENT OF WELL POTENTIAL AND CHALLENGES

LHD-B well is the second well in the LHD-A cluster of the Tompaso Prospect, in the Lahendong geothermal area, North Sulawesi, and is a directional well: N 91º E, with Kick-Off Point (KOP) is at 450 mRKB and the planned total depth is 2304 mRKB or 1952 mTVD.

2.1 Reservoir Characteristics LHD-B

Upon entering the reservoir zone, partial loss circulation was observed starting at a depth of 1450 meters, with varying rates ranging from 0.3 to 5 bpm (barrels per minute) until reaching 2197 meters, before ultimately experiencing total loss circulation at a depth of 2198 meters (approximately 100 meters to total depth.

Initially, after drilling was completed, the discharge attempt at well LHD-B was carried out by air compression until the wellhead pressure reached 70 barg, limited by the capacity of the air compressor. However, the discharge attempt at that time was unsuccessful. The stimulation equipment available was limited at that time so the discharge effort was not continued. This well has been idle for approximately 12 years.

Subsequently, periodic monitoring measurements were conducted for well LHD-B. The results measurement was conducted on August 18, 2021 showed a maximum pressure of 149 barg and a maximum temperature of 284°C at a depth of 2200 mMD. The water level was recorded at 200 mMD, and the reservoir fluid condition was identified as undersaturated.

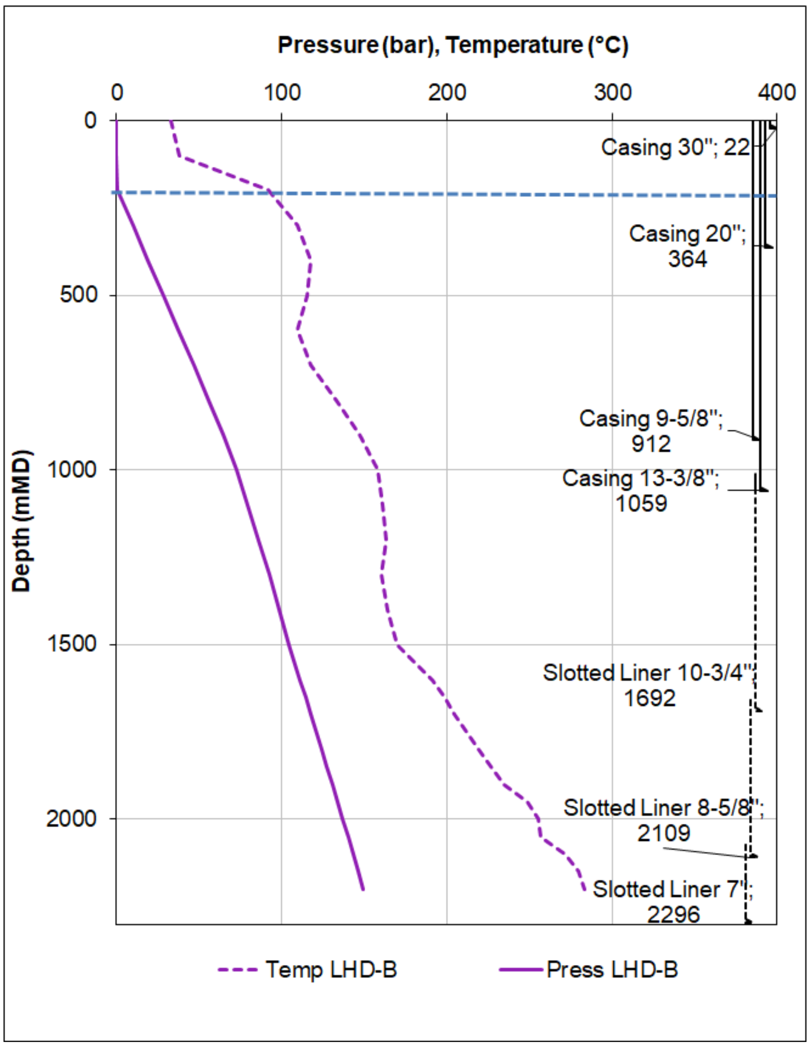

Figure 2: Pressure-Temperature Profile.

2.2 Challenge Discharge LHD-B

The distance between the feed zone and the water level is also a key factor in estimating the well's discharge capacity. According to Mubarok and Zarrouk (2017), wells with a feed zone more than 600 meters below the water level are unlikely to self-discharge. This observation aligns with the empirically derived Af/Ac ratio equation proposed by StaAna (1985), which helps determine whether a well can self-discharge or require stimulation. Based on the pressure-temperature stability, the calculated Af/Ac ratio is 8.6e-5, which is significantly lower than the threshold value of 0.85, indicating the well's inability to self-discharge. The pressure-temperature stability is illustrated in Figure 2.

Even though best practice indictats that a well is not flowing, there is no downside to try a discharge this well again. In 2021, larger capacity compressors are available than in the past, making this possible. The series of well-stimulation activities from July to August 2021 is as follows. Between July 19 and 22, 2021, with a wellhead pressure (WHP) of 83 barg and a 3-day compression period, air compression stimulation was performed but failed to induce discharge. A similar attempt was made from July 22 to 27, 2021, with a WHP of 91 barg over 5 days, and from July 30 to August 16, 2021, with a WHP of 95 barg over 17 days, both using air injection. However, neither attempt succeeded in achieving discharge. Finally, on August 19 and 20, 2021, a combination of air compression and soap stick stimulation was applied with a WHP of 93 barg over one day, resulting in a successful discharge. Furthermore, a combination of air compression and soap stick stimulation was applied to non-self-discharged wells, especially in the Tompaso prospect

During the discharge of the well on August 20, 2021, for 30 minutes the well successfully built up from WHP 0 barg to 7 barg. The brine observed in the weirbox was quite high, and there was the presence of back pressure from the Lip Pipe. The well flowed successfully for 30 minutes but then suddenly experienced a ground jolt, causing the well to immediately shut down (WHP dropped from 7 barg directly to 0 barg) as if it had been abruptly shut in.

2.3 Investigation Casing Condition LHD-B

Well integrity campagin was conducted on LHD-B to assess the condition of the wellbore. The 10" impression block was placed at a depth of 46.35 m. It appears to have encountered an obstruction, resulting in the outer edges bending inward. Another tool was seated at a similar depth: the go-devil 8.5" at 47.9 m and the sinker bar 2" at 48.4 m.

Figure 3: Impression Block Result.

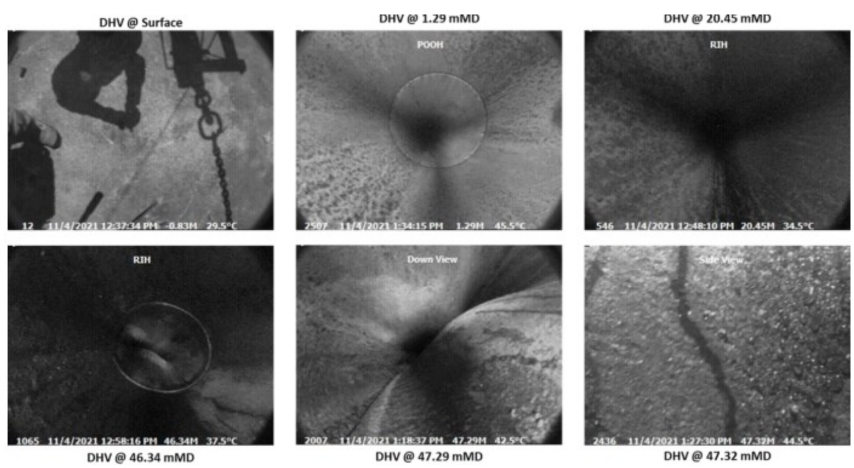

Figure 4: Downhole Video Results

In November 2021, a downhole video was conducted to better understand the wellbore's obstacles. In the "Down View" and "Side View," indications of cracks or structural disturbances on the wellbore wall are observed. This data provides crucial information for further evaluation of the well's condition, particularly in determining the necessary remedial actions to maintain the well's operational integrity

3. RECOVERY STRATEGIES

The remedial casing work for the well was completed in approximately 23.25 days. There was a casing collapse on the 13-3/8” production casing. Following that, milling/redressing was successfully carried out on the collapsed casing. Apart from this depth, there was no further damage to the 13-3/8” production casing, and thus the 9-5/8” remedial casing was installed.

3.1 Post Remedial Well Completion Test

This well completion test aims to determine the well's characteristics after the workover operations. The stages of the well completion test include PTS injection, gross permeability testing, and PT heating up.

A dummy tool with an outer diameter of 2 inches and a length of 4.06 meters was used. The dummy was successfully run to a depth of 2250 mMD, 5 meters shallower than the depth achieved using a 6” bit, without any signs of obstruction in the well. PTS under injection conditions was performed with a pumping rate of 700 gpm. Logging was conducted at speeds of 25 m/min and 35 m/min using a 5P pitch spinner to a depth of 2245 mMD, 5 meters off-bottom from the last probing depth of 2250 mMD. Based on the PTS results, a gradual feed zone interval was identified at depths of 1875–2100 mMD. The feed zone results from either formation permeability or a network of diffuse interconnected fractures (Glynn-Morris et al., 2011).

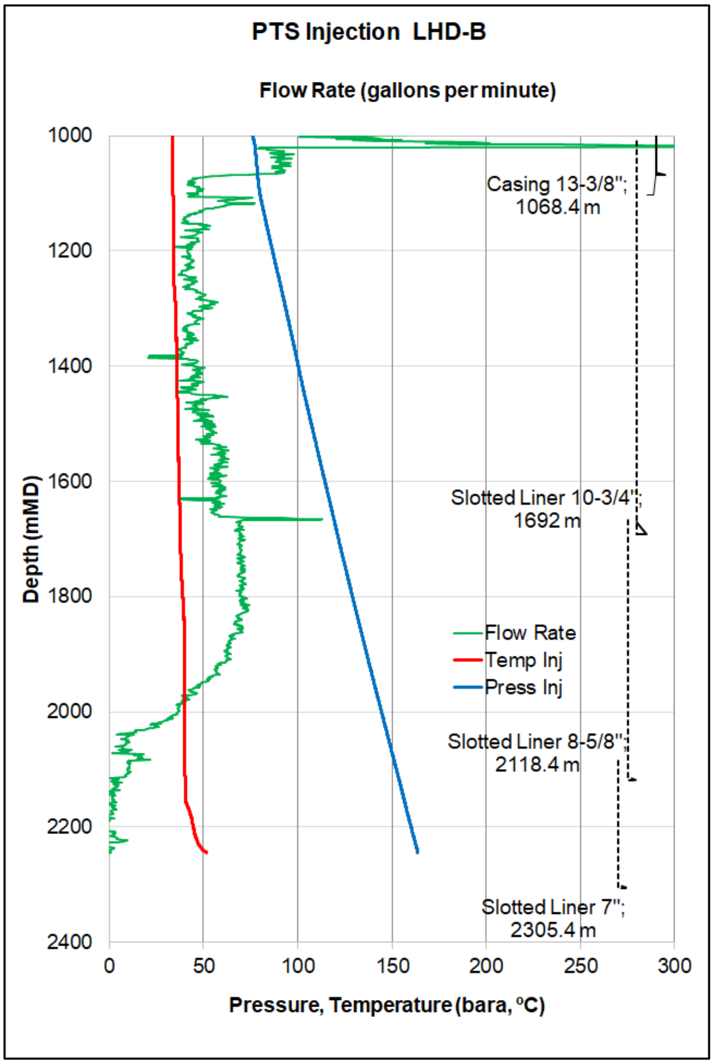

Figure 5: PTS injection during well completion test.

The Gross Permeability Test included an Injectivity Test and a Fall-Off Test (FOT), with the PTS tool placed at a depth of 2000 mMD (based on RKB). The GPT program used a step-up pumping scheme, considering that the well had experienced total loss circulation, requiring the formation of a water column to stabilize pressure data recording. Pumping began at rates of 700, 800, 900, and 1000 gpm, followed by stopping the pump to perform the Fall-Off Test (FOT). The FOT process lasted approximately 12 hours. Below is the pressure profile at the tool hanging depth overtime during the Gross Permeability Test.

Based on the Injectivity Test results, the Injectivity Index (II) for well LHD-B was identified as 17 kg/s.bar. Additionally, the analysis revealed transmissivity (kh) and skin values of 46.75 Dm and -4.819, respectively.

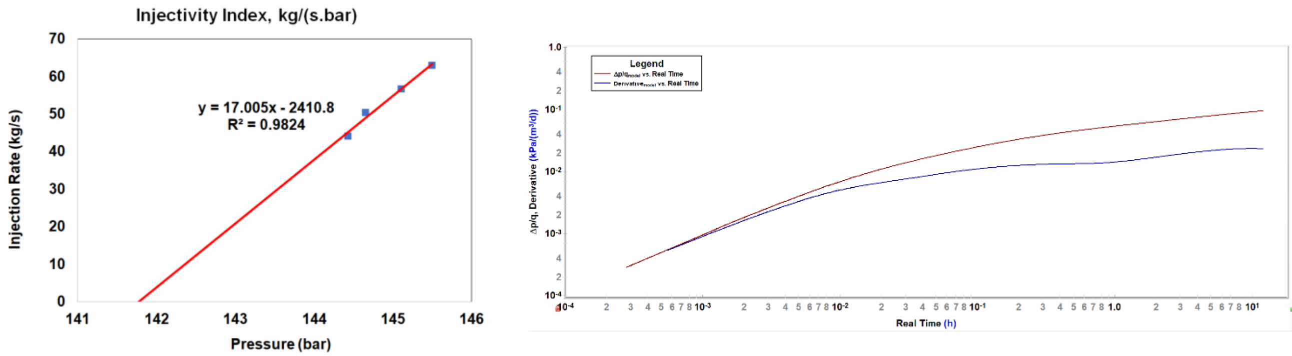

Figure 6: Gross permeability test result included injectivity index and fall off test

The initial data recording involved running in hole (RIH) from the Gross Permeability Test (GPT) depth of 2000 mMD to 2245 mMD, followed by retrieving the PTS tool to the surface. The heating PT measurement results, taken 12 hours after completing the FOT, indicated that the wellhead pressure (WHP) was 0 barg, with the water level at 200 mMD. The maximum pressure recorded was 157 bara at a depth of 2245 mMD, and the maximum temperature reached 167°C at a depth of 1800 mMD.

3.2 Well Output Prediction

The well productivity was carried out using wellbore simulation based on an injectivity index, assuming a feed zone at a depth of 2000 mMD (based on PTS Injection results). Then, the reservoir pressure and temperature, approximately 138 bar and 255°C respectively (based on PT values from 2023), were used.

The relationship between the productivity index and the injectivity index in each field might vary. This variation arises from differences in enthalpy and the viscosity of the steam-air mixture. Certain wells in New Zealand exhibit a PI and II correlation ranging between 0.2 and 0.3 (Grant and Bixley, 2011). For the case LHD-B, output curve simulation with sensitivity correlation PI = 0.1II, 0.15II, and 0.3II.

At a correlation of 0.1, the mass flow rate is 62.6 kg/s, while at a correlation of 0.15, the mass flow rate increases to 78.7 kg/s. Further exercised to 0.3, the mass flow rate achieves the highest value in the table, which is 102.7 kg/s. All of the mass rate at WHP of 15 bar. The distance between LHD-B and the production line is approximately 4 km. Considering the production parameters in Unit-5 & 6, where the production line pressure is 9.4 bara, and assuming a pressure drop of 2 bar/km, then with a WHP of 15 bara, the LHD-B well has the potential to discharge and contribute to the steam supply.

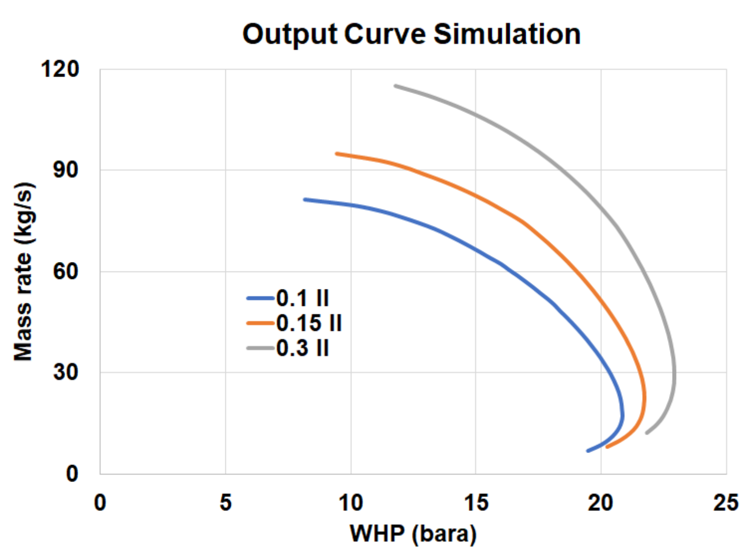

Figure 7: Output Curve Simulation

4. CONCLUSION AND RECOMMENDATION

4.1 Conclusion

The LHD-B well is a marginal well in the Tompaso Prospect, North Sulawesi, and faced initial discharge challenges. Despite multiple unsuccessful stimulations, combining air injection and soap stick finally induced discharge. However, the well suddenly stopped discharge. The well integrity results indicated that the casing was damaged and required remedial casing work. Subsequently, milling/redressing was successfully carried out on the collapsed casing and thus the 9-5/8" remedial casing was installed. Well-completion tests are conducted to assess the well's properties after the workover operations. Well output predictions based on simulations show a promising flow potential, affirming the well's commercial production potential.

4.2 Recommendation

It is necessary to re-confirm the production potential of the LHD-B well by conducting a production test. Additionally, by performing a PTS analysis under production, we can correlate the productivity index and injectivity index for the well.

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