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# Challenges in Well Testing Initiatives in Dieng-2 Geothermal Expansion Project, Central Java, Indonesia

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**ABSTRACT**

PT Geo Dipa Energi GDE (Persero) has embarked on the expansion of Dieng Geothermal Field in Central Java, Indonesia in November 2021 based on the updated resource assessment and reservoir modelling of greater Dieng resource, follow on geoscientific studies and feasibility update of Dieng project. The expansion program called for drilling of five (5) production wells and five (5) injection wells to support the 55 MWe Dieng-2 power plant. The drilling campaign was successfully completed in July 2023, but the programmed production well testing activities encountered a good number of challenges that presented difficulties in proving the capacity of the wells to confirm the power plant infrastructure development.

This paper details the challenges involved in confirming the production capacities of Dieng-2 wells namely a) meeting the prescribed environmental, safety and social standards related to $H_2S$ gas emissions, brine carryover, noise levels and vibration that could potentially affect the nearby households, b) discharge fluids highly supersaturated with common minerals (e.g., silica), and c) production casing damage from unprogrammed mechanical workover. GDE has designed several work initiatives to mitigate and address the above challenges and considered some novel solutions which are elucidated in this paper.

## 1. INTRODUCTION

Dieng Geothermal Field is one of the large liquid dominated geothermal field located in Central Java, Indonesia with relatively deep and high temperature reservoir. The geothermal reservoir is controlled by fractures caused by the volcanic activities around. The expansion of Dieng Geothermal Field started in 2019 through the updated Dieng resources assessment and feasibility study for the next 55 MWe Dieng-2 power plant. The expansion program was formalized in November 2021, with the drilling five (5) production wells and five (5) injection wells. The corresponding well testing program was designed to be undertaken in parallel after the wells have been drilled.

Well testing for production and injection wells aims to obtain wellbore and reservoir characteristics (e.g., pressure, temperature, fluid chemistry, gas content), productive zone location, production/injection capacity estimate, and wellbore condition. There are three types of well testing that is commonly applied during development stage: Completion testing, Heating-up survey and Discharger test. Well completion testing is conducted immediately after well drilling is completed. The standard test consists of the familiar Water loss test, Step rate Injection test and Pressure Fall-Off test to determine the feed zone location, Injectivity Index, and permeability characteristics respectively. Due to the injection of cold fluid (water/air) during drilling, the formation around the wellbore is relatively cool. Therefore, the well requires a heating up process to prevent casing failure when discharge test is performed. Heating-up survey provides information related to conductive/convective gradients, temperature peaks and inversion, boiling condition, liquid level, reservoir pressure, and wellbore condition (Grant, 2011).

Horizontal discharge testing is conducted to measure the discharge fluid characteristic and fluid chemistry with the aim of establishing the production characteristics of the well. The atmospheric silencer testing method is generally the acceptable and preferable technique of testing production wells because of its low cost and simple installation. Separating the water and steam phases in a cyclone separator (pressurized) and measuring the two phases (while contained within pipelines) separately is generally considered more accurate method of testing the output of a production well. More recently, the Low Emission Compact Muffler (LECM) is being used to replace the cyclone separator and address brine carryover during discharge test. The application of tracer flow testing (TFT) method can also be an option in establishing well flows during horizontal discharge test. The TFT method was initially developed for the on-line measurement of brine and steam flows and total enthalpy within a pipeline carrying two-phase geothermal fluid. The selection for the discharge test method usually depends on the expected fluid type, production rate, and delivery pressure. Besides these fluid characteristic parameters, external aspects need to be considered too, such as the availability of equipment, duration of testing, environmental condition, location of the well and permission from local community.

## 2. CHALLENGES AND SOLUTIONS

Discharge testing of Dieng production wells is expected to produce two-phase fluid at the wellhead that requires measurement of enthalpy of the steam-water mixture as well as the total mass flow. Here, the James Lip pressure method is applied in calculating the flows using the Low-Emission Compact Muffler (LECM) unit. Unfortunately, the programmed well testing activities encountered several challenges that presented difficulties in proving the capacity of the wells.

The well pad location in Dieng geothermal field is shown in Figure 1. The production and injection wells drilled in Dieng are located near residential areas and mostly surrounded by plantation. GDE has prescribed the environmental, safety and social standards provision during the discharge test to meet the parameters related to $H_2S$ gas emission, brine carry over, noise levels and vibration. These standards are enumerated in Table 1 below.

**Table 1: Standard Allowable during Well Testing**

| Parameters/Issues | Standard Allowable Value |
|---|---|
| Gas emission | $H_2S$ Content:<br>Field Work & Outside Pad Area : 0 ppm<br>Source of H2S (LECM, Wellhead, NCG Tank) : < 5 ppm<br><br>$CO_2$ Content:<br>All areas : < 5000 ppm |
| Brine Carry Over | No Brine Carry Over outside Pad Area |
| Noise Level | Daylight: : < 55 dB<br>Night Shift : < 45 dB |
| Vibration | < 6.3 Hz (depends on vibration velocity) |

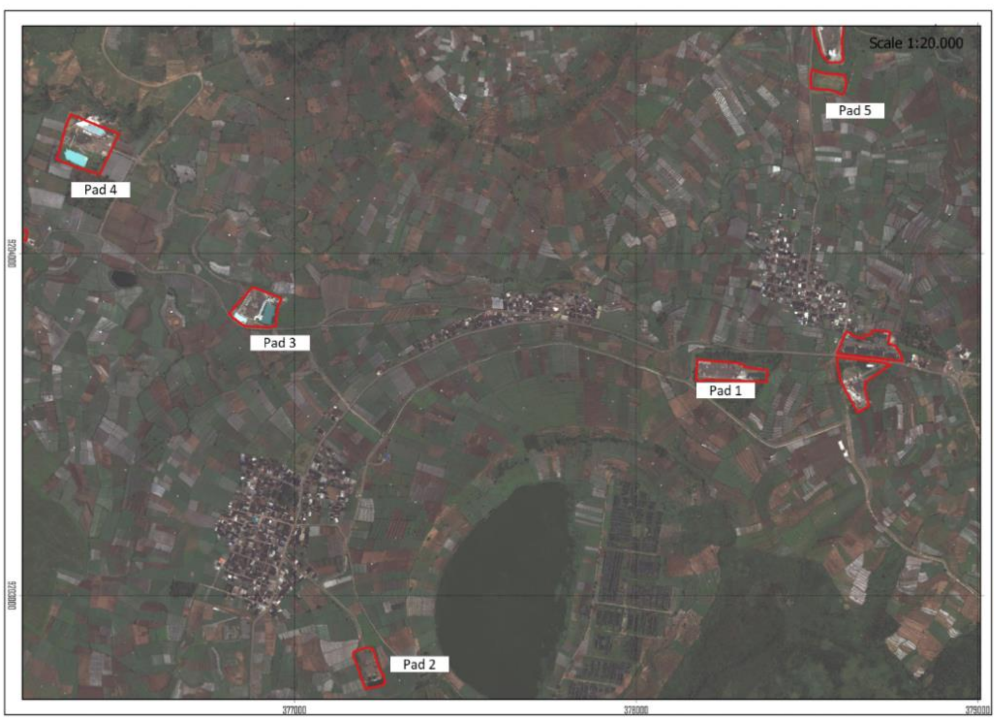


**Figure 1: Well Pad Location in Dieng production field**

### 2.1 Well Testing at Pad 1

The first well that tested in Dieng located at Pad 1, where the nearest residential area is 300 meters from the well-pad. To meet the environmental, safety and social standards provision, GDE has made mitigation plan as describe in details below:

a) Air Dispersion and Noise Level Modelling

GDE has conducted air dispersion and noise level modelling to understand the characteristic and magnitude of the impact of emission & noise during discharge test. The modelling results can also be used to define action plans and procedures regarding social mitigation plan. The modelling tools and approach are based on best practices and developed and recommended by international organizations. The software used for this modelling option are Screen View (Screening Air Dispersion Model) and SoundPLAN.

Several factors were considered in the air dispersion and noise level modelling. They are: a). factors influencing are emission sources, b). noise level source, c). atmospheric and climate conditions, and d). the environment surrounding the receptors. The modelling for air emission considered the H2S and CO2 gases since these are the dominant gas contained in the NCG. Three different scenarios are examined and presented in Table 2 below.

**Table 2 Scenarios for Air Emission Modelling**

| Scenario | Description |
|---|---|
| Scenario 1 | Failure in bleed facilities |
| Scenario 2 | Bleed NCG with operation condition without NCG Tank |
| Scenario 3 | Bleed NCG with operation condition with NCG Tank |

The result of model simulations are shown in Figure 2. In Scenario 1 (failure in bleed facilities), for 100 meters radius from the source, the model produced gas concentrations of 10.30 to 10.91 ppm which is above the allowable standard of gas release to environment. Scenario 2 (bleed NCG without NCG Tank/Abatement System), for 100 meters radius from the source, the model gave gas concentrations of 2.17 to 4.66 ppm which meet the standard limit of 5 ppm. The third Scenario (bleed the NCG with NCG Tank), produced gas exposure of 0.44 to 1.02 ppm which is way below the standard limit. The third scenario favorably supported the proposed set-up for well testing that was installed in Dieng.

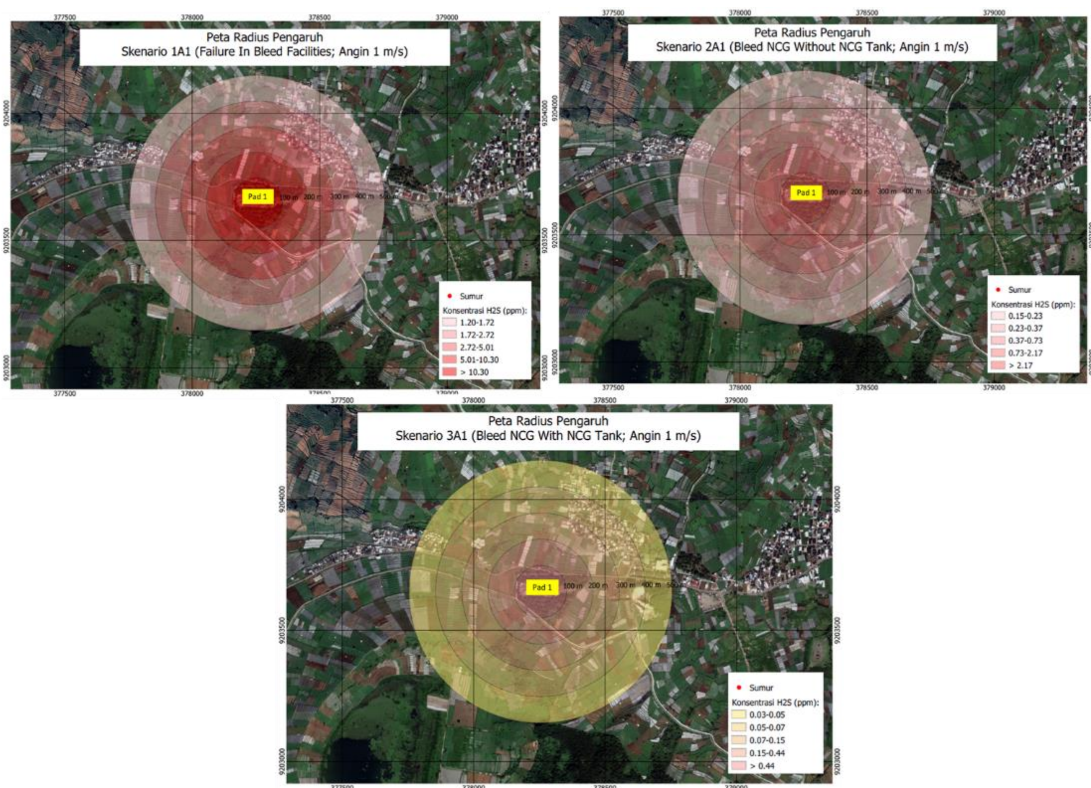


**Figure 2: Model Results of Screen View for each Scenario**

Two scenarios were considered for the noise level modelling, namely: without sound barrier and with sound barrier. For a given point source of 100 dB, the model results for the two scenarios are presented in Figure 3 below. The red line coverage area produced noise levels > 55 dB during daylight and the green line coverage area for noise levels > 45 dB during nighttime. The maximum noise contribution at receptor for the model without sound barrier is 52.8 dB and 51.2 dB for the model with sound barrier. The conclusion from the noise level modelling is that excess in noise level was found to be small near surrounding Pad area and there was no excess noise level in the residential area.

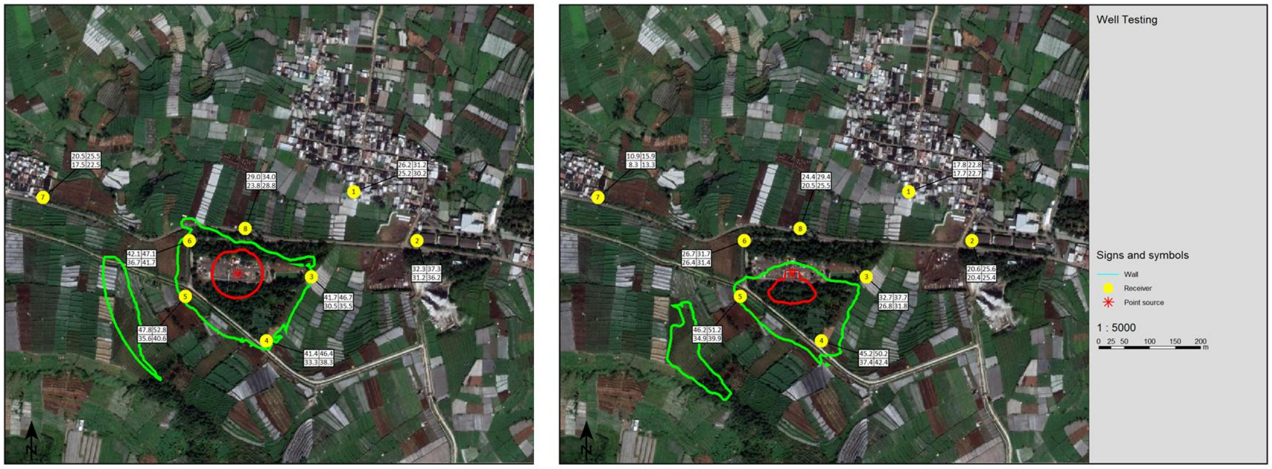


**Figure 3: Noise Level Simulation Result without barrier (left); with barrier (right)**

b) Preparation of detailed and safe well test procedures

As the result of modelling simulations, a detailed and robust well test protocols and procedures need to be implemented in Dieng. The well test procedures cover the preparation activities before the discharge test, bleeding activity and the actual discharge test. Several important activities must be captured in the preparation activities such as well test facility inspection, preparation of safety equipment and signage, determination of environmental baseline data and socialization and information drive activities in the community. Pre-job safety meeting and follow through inspection is conducted during the actual discharge test operation.

Air dispersion modelling shows that best scenario that suggested for mitigate the NCG ($H_2S$, CO, $CO_2$) release to environment is by bleeding the gas with NCG Tank/abatement system. A gas abatement system is installed to neutralize the $H_2S$ gas during the gas bleeding operation. Other than that, an orifice plate is also installed in the bleed line to maintain and control the safe flow of gas release to the abatement system. The gas bleeding process is conducted only in daylight for safety purposes. Routine gas and fluid pH monitoring is undertaken in strategic locations during the gas bleeding operation. The formal discharge test to the main flow line and LECM follows, after completing the gas bleeding activity. The FCV valve manipulation is controlled by the prescribed environmental parameters as shown in Table 1. The GDE Safeguard monitoring team conducts the monitoring of the parameters during well testing.

The usage of James Lip method and LECM have potential noise and vibration problem that affecting nearby residential. The elevated sound level is created mainly from the throttling process in the flow control valve (FCV) and the reduction of the James pipe to diffuser section. To mitigate this problem the James pipe was made to be similar diameter with the 12" main flow line.

c) Preparation and installation of suitable well test facility

The other challenge observed during well testing in Dieng is the noise and vibration levels that affected the nearby households. In addition, a sound barrier made of soundproof foam material was also installed to cover the FCV unit and diffuser section. The sound barrier installation in Dieng is shown on Figure 6.

The well testing conducted after completing all the mitigation plan mentioned above. During the execution at 15% of well opening, the noise level recorded in nearest residential is approximately 100 dB and reported some vibration in building. This situation insists well testing process need to stop. As the result of noise modelling, the application of sound barrier is decided to use. While preparing sound barrier facility, the well is experienced leaked between 13-3/8" to 20" annulus, remarked by steam out in surface. The well diagnostic surveys conducted to observe the causes of leakage, using PT logging, Impression block and downhole video. The result of observation shows in Figure 4. It indicated the location of leakage is at around the tie-back section where temperature spike is observed along that depth from PT data and impression block is showed some stamp. However, downhole video has poor result due to steam presence in wellbore.

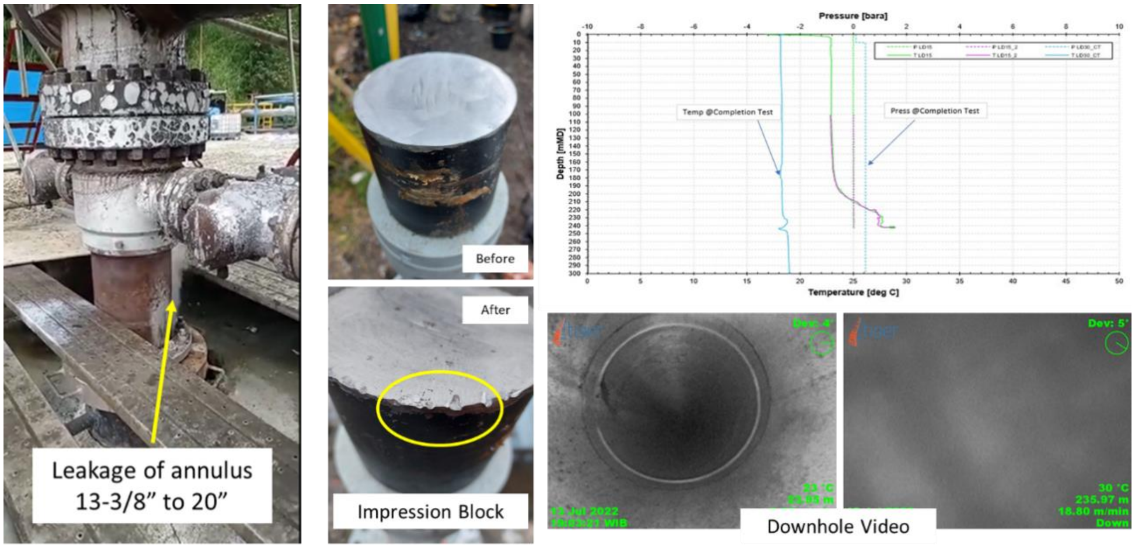


**Figure 4: Observation Result of Leakage in Production Well at Pad 1**

To mitigate any problem that can be occurred during operation in the future. The proposed solution to address the leakage was to squeeze cement and reline the section with small production casing. Therefore, the workover was programmed for this well and the well testing moved to Pad 2. The comparison of well configuration before and after remedial is shown on Figure 5. As consequences of this production casing damage, it reduced the production capacity of the well.

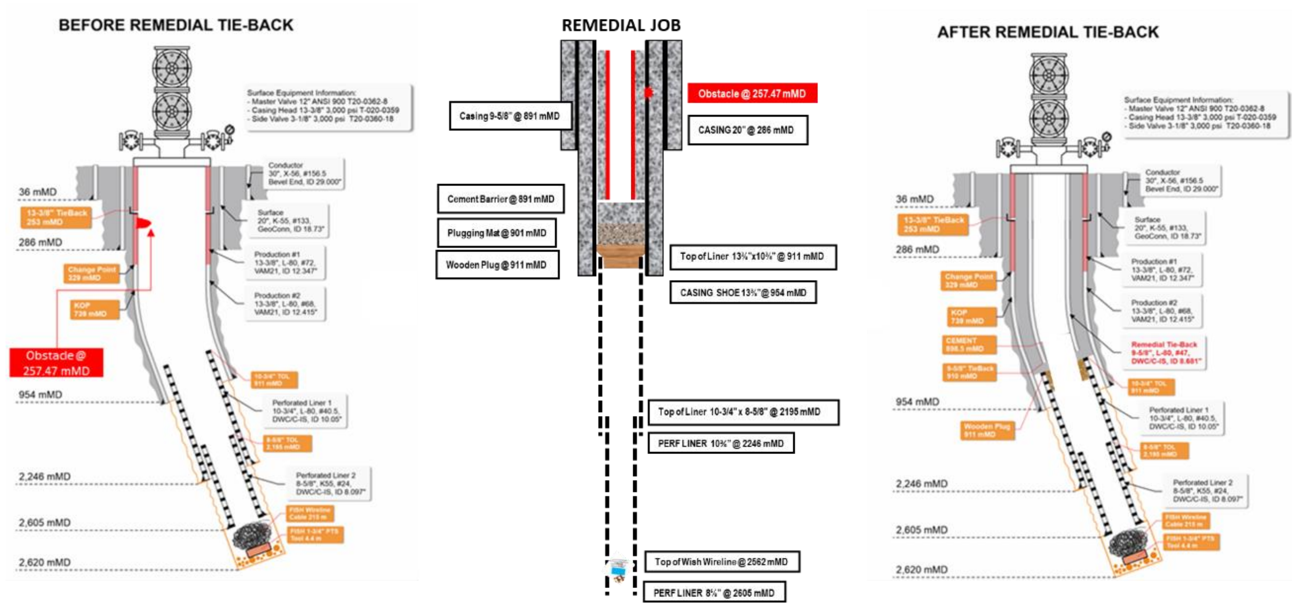


**Figure 5: Well Configuration before and after remedial Tie-back**

### 2.2 Well Testing at Pad 2

Well Testing continued at Pad 2 prior to workover operation at Pad 1. In addition to mitigate the same problem occurred during well testing in this pad, a sound barrier was installed. It made of soundproof foam material and installed to cover the FCV unit and diffuser section. The sound barrier installation in Dieng is shown on Figure 6. The usage of sound barrier facilities has reduced the noise level in the source place by about 10dB. Figure 7 shows the noise level comparison inside and outside diffuser section that indicate the effectiveness of sound barrier in reducing noise level.

**Figure 6: Sound Barrier Implementation in Dieng**


**Figure 7: Comparison Noise Level Inside and Outside Diffuser**

After 7 days of flow test, brine carry over was initially observed around the LECM area. The weather condition at that time, also contributed to distribute the brine carry over. It became worse and affected the surrounding plantation. Figure 8 shows the observed brine carry over near the LECM. The problem of brine carry over was investigated and visual check of the LECM showed the mist pads were already plugged by silica scale. This condition made the separation process of two-phase fluid to be inefficient. Figure 9 (left) shows the condition of mist pads that were plugged by silica scale. The mist pads were found to be in bad condition after testing that prompted GDE to find alternative solution to remedy the situation. Moreover, significant silica scaling also found in brine manifold pipe to pond. Figure 9 (right) show the silica deposition at the brine manifold.

**Figure 8: Brine Carry Over Observation**

**Figure 9: Mist Pad Condition after plugged by Silica (left); Silica deposition at brine manifold (right)**

It is decided to reinforce the damaged mist pads by installing additional layer of perforated plate containing palm fibers and mist pads. The proposed installation of inexpensive palm fibers would also help improve the efficiency of separation process of the discharge fluid. The configuration of mist pad placement inside LECM is shown on Figure 10 (above). The short-term solution for the problem of silica deposition at brine manifold is by using four (4) brine disposal pipelines from the LECM to the disposal pond during well testing. Two (2) pipelines are used for the brine disposal and the other two (2) contingency lines used as backup if the other lines are in the cleaning process from silica deposition. The configuration of brine line is also shown in Figure 10, (below).

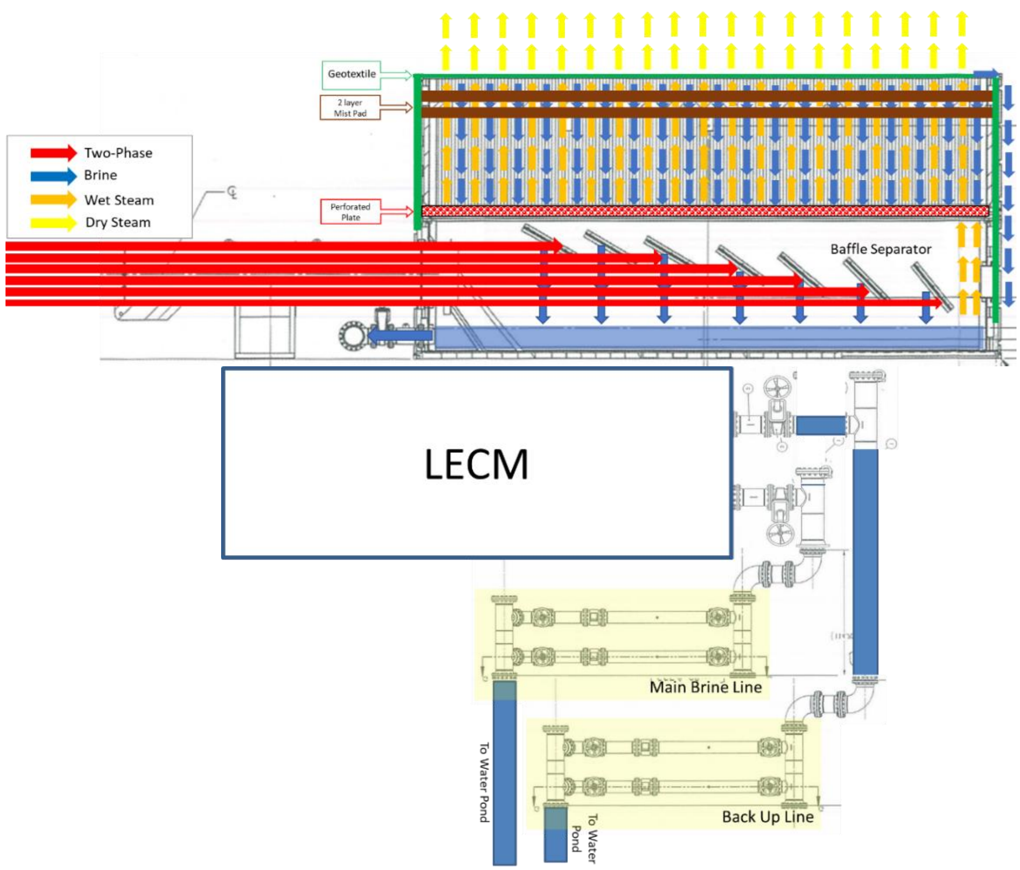


**Figure 10: Configuration of Modification inside and outside LECM (above); Configuration of brine manifold (below)**

In addition, the LECM was covered with additional Geotextile membrane to serve as barrier to prevent any brine carry over escaping the LECM. The Geotextile membrane also functions as extra-separation due to the nature of materials that are fine and tight fibers. Figure 11 shows the well test facility condition after the modification.

**Figure 11: Facility Condition after Modification**

The short time well testing conducted by gradually increasing the FCV opening until maximum level acceptance of allowable safety and environment standard. It aims to observe the efficiency and effectiveness of modification facility. The modification inside LECM gave an indication that the installation of second layer of perforated plate with combination of palm fibers and mist pads would address the brine carry over issue due to the increment of brine production. However, brine carry over was still observed at larger well opening during extended testing duration.

The result of short test well testing testing also found the vibration level can be addressed at larger FCV well opening. A high vibration level was recorded during the flow test at 12% FCV well opening where higher steam flow is observed. A significant reduction in noise and vibration level monitored in nearby neighborhood was obtained during the flow test at higher 18% FCV well opening. The results obtained during noise and vibration level monitoring is shown on Table 3.

**Table 3: Result of Measurement Noise and Vibration during Well Testing**

| FCV Opening | Measurement Noise and Vibration Level Outside Pad |
|---|---|
| 10% | • Noise: 47.7 dB<br>• Vibration : 0.1 Hz |
| 12% | • Noise: 53.3dB<br>• Vibration : 1 Hz |
| 15% | • Noise: 52 dB<br>• Vibration : 0 Hz |
| 18% | • Noise: 47.4 dB<br>• Vibration : 0.01 Hz |

During short well testing, PT survey conducted to observe wellbore condition and it is found the PT tool failed to reach the last clearance depth. The location of obstruction is estimated near the flashing area The investigation was conducted by running sampling catcher and impression block. The result of investigation shown in Figure 12. The obstruction is likely due to mineral scaling that occurred around the flash depth. GDE will continue to investigate the mineral scaling process that will reinforce the appropriate well intervention in the well.

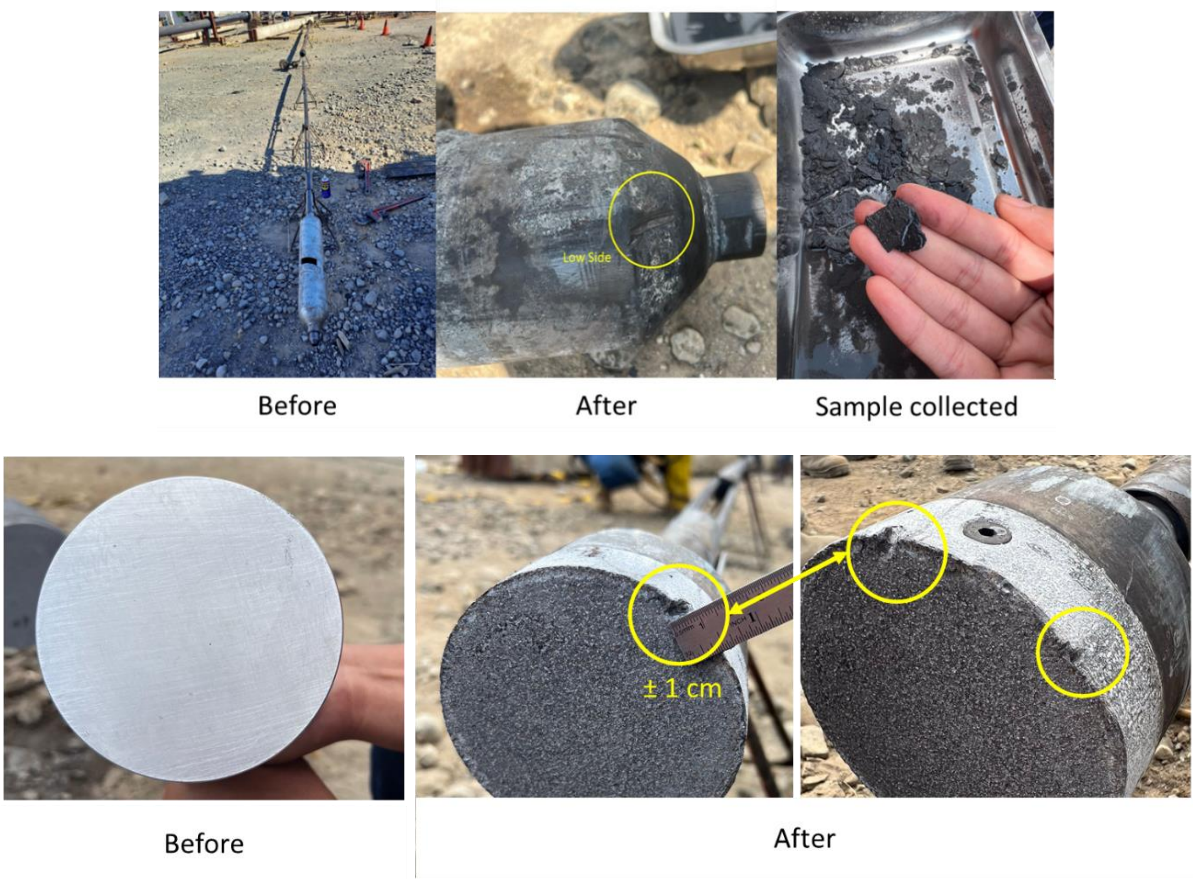


**Figure 12: Observation Result of Obstacle in Production Well at Pad 2**

## 3. SUMMARY

During the well testing in Dieng, PT Geo Dipa Energi encountered three main challenges. These challenges are a) meeting the prescribed environmental, safety and social standards related to $H_2S$ gas emissions, brine carryover, noise levels and vibration that could potentially affect the nearby households, b) discharge fluids highly supersaturated with common minerals (e.g., silica), and c) production casing damage from unprogrammed mechanical workover.

As explained in this paper, PT Geo Dipa Energi has designed and successfully implemented several work initiatives to address the challenges encountered in confirming the production capacities of Dieng-2 wells. The solutions summarized as:

- Simulation of air dispersion and noise modelling
- Preparation of detailed and safe well test procedures
- Preparation and installation of suitable well test facility
- Observation of wellbore condition after well testing

The proposed solutions to the challenges were satisfactorily obtained although the outstanding issue of brine carry over still needs further consideration. GDE has also examined the application of pressurized test separators to fully address the issue. This could be the final option for testing the wells in Dieng.

Besides being a problem of well testing, silica deposition has potentially caused operational problem in the future. The problem will occur mainly in surface pipelines that lead to power plant production shortfall and decline in well injection capacities. The very high reservoir temperatures in Dieng have produced fluids with high silica content and brine salinity. Rapid silica precipitation occurs when these reservoir fluids are flashed to atmosphere during testing, causing scale formation in wells, surface equipment and injection systems (Hauksson et al, 2023).

GDE understands the main challenges brought about by mineral scaling as experienced in Dieng-1 power plant operation. Silica scaling has been prevalent in surface production equipment, brine disposal pipelines and injection wells. More recently, other forms of mineral scaling (sulphide) in Dieng-1 production wells have been detected. GDE has implemented the "cold brine injection" option for Dieng-1 where the highly supersaturated brine was diverted to settling ponds to address the high silica content but with very limited success. The brine from the settling ponds is still supersaturated with silica that eventually affected the capacity of the injection wells. GDE has conducted mechanical workovers and acid treatment as stop-gap solution to address the affected injection wells. GDE has also implemented the brine pH modification using inorganic acid (HCl) to lower the pH and delay polymerization of silica but encountered operational challenges that also did not presented good success.

The current Dieng-2 expansion program has provided GDE the desire to further investigate and obtain workable solutions to address the expected silica deposition. GDE has initially considered the following proposed solutions and presently under detailed evaluation:

- High Pressure Separation and Hot Brine Injection

- Operating the Dieng-2 production wells at high separation pressure to limit silica supersaturation can be a feasible option. The drawback for this option is not maximizing the full production potential of the wells at lower separation pressure similar to Dieng-1 plant operation. The reject brine after separation would also give manageable silica levels for hot brine injection. Brine pH modification

- The brine pH modification has been shown to be effective and inexpensive compared to others inhibitors (E. Guerra et al, 2012). The brine pH modification process is being evaluated by GDE with the option of using organic acid (acetic acid). The application of acetic acid to modify the brine pH could be favorable in terms of attaining good control in dosing levels that would maintain constant silica levels. Silica Inhibition using Commercial Inhibitors.

  GDE is also examining the application of commercial inhibitors to inhibit silica deposition. GDE plans to conduct field trials to establish performance of these inhibitors, to support cost-effectiveness to address the scaling problem.

**REFERENCES**

E. Guerra et al.: pH Modification for Silica Control in Geothermal Fluids. Short Course on Geothermal Development and Geothermal Wells, Santa Tecla, El Salvador. (2012)

Grant, M. A. and Bixley, P.F.: Geothermal Reservoir Engineering - Second Edition. Elsevier.Inc (2011)

Hauksson, T., et al.: Dieng Geothermal Field: Testing of effectiveness of pH modification for the mitigation of silica and arsenic-sulfide scaling in heat extraction process using a pilot plant. Proceedings World Geothermal Congress, Reykjavik, Iceland. (2023).

PT. Geo Dipa Energy (Persero) Internal Report (Unpublised Report), Air Emission & Noise Dispersion Modeling Summary Report for Well Testing (2022).