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# Utilizing Nitrogen Lifting as an Alternative to Electrical Submersible Pumps in the Alaşehir Field, Turkey

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## ABSTRACT

Geothermal wells that have experienced a decline in reservoir parameters, such as pressure, temperature, and non-condensable gases, are considered candidates for artificial lifting to compensate for the reduced production. Nitrogen lifting is a reliable gas injection method for production wells, serving as an alternative to Electrical Submersible Pumps (ESPs). This study presents the first successful application of nitrogen lifting in the Alaşehir geothermal field. Technical details of the nitrogen lifting are provided to offer valuable insights for geothermal operators. The advantages and risks associated with the demonstration are also discussed. It was found that nitrogen lifting offers certain advantages over downhole pumps in ensuring reliable production.

## 1. INTRODUCTION

Gas lifting is an artificial lift method that uses compressed gas in the production well to reduce the dynamic head in the wellbore by lowering the density of the liquid column (Takacs, 2005; Aydin and Merey, 2024). Continuous gas lift is the most widely applied technique, though intermittent gas lift is also an option. Unlike other methods, gas lifting does not require rotating or electrical equipment to operate in the harsh downhole conditions. This makes gas lift particularly suitable for geothermal wells with high temperatures and corrosive gases.

The typical gas lift scheme is illustrated in figure 1. In this standard application, compressed gas is injected into the annulus and enters the tubing through valves. This process decreases the density of the liquid column in the production tubing, allowing more fluid to be extracted from the reservoir by reducing the bottom-hole flowing pressure. The valves enable injection at different depths with fixed pressure and different gas rates depending on the nozzle's size. Guo (2007) emphasized the importance of considering the productivity index (PI) and bottom-hole pressure values when selecting candidate oil wells for gas lift applications. We adopt this approach for identifying geothermal wells suitable for gas lift applications, as shown in Table 1.

**Table 1: Geothermal wells favorable for gas lift application**

| Characteristic Properties | Case-1 | Case-2 | Case-3 |
|---|---|---|---|
| Productivity Index (PI) | high | high | high |
| Reservoir Pressure | high | high | low |
| Reservoir Temperature | high | low | low |
| Non-condensable Gas Content | low | low | low |

There are two types of gas lift methods: continuous and intermittent. A continuous gas lift operation provides a steady-state flow of fluid to the surface. However, in intermittent gas lift operation, the flow is in an unsteady state, meaning it depends on the start-and-stop cycles of the gas lifting system. Intermittent gas lifting is generally applied in low PI wells with low reservoir pressure (Guo, 2007).

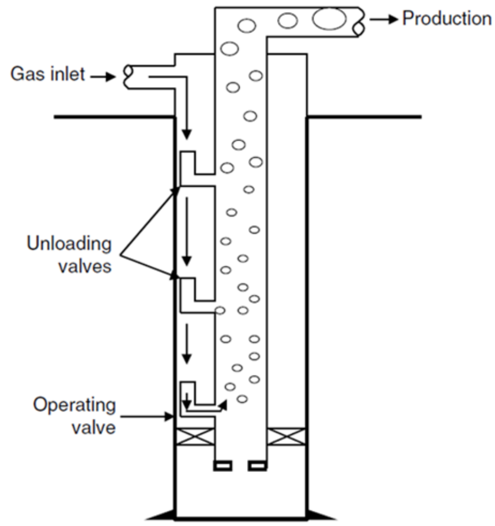


**Figure 1: A typical gas lift scheme (Guo, 2007)**

Carbon dioxide ($CO_2$) and nitrogen ($N_2$) gases can be used for gas lifting. $N_2$ has several advantages over $CO_2$, such as being non-corrosive (inert gas), having low solubility in geothermal brine, a lower density, and non-toxic properties. $N_2$ is typically used in coiled tubing acidizing operations after well completion to clean geothermal wells (Akin et al. 2015). Buiiing et al. (1998) reported successful $N_2$ lifting in 28 out of 38 geothermal wells in the Philippines. Aydin and Merey (2024) presented a case study of gas lifting application in West Anatolia. They performed sensitivity analyses on gas lifting using $N_2$ and $CO_2$ at differing depths, rates, and tubing sizes. $N_2$ provided a better production performance compared to $CO_2$ because of its lower density.

Turkiye has experienced a remarkable increase in installed geothermal power capacity over the past two decades, growing from 15 MW to more than 1,700 MW (Aydin et al., 2024). All the developed fields are located in western Anatolia, Turkiye. The Alaşehir field is one of the most active areas for geothermal exploration and production activities. More than 6 operators are exploiting this field on a strictly competitive, and largely confidential, basis without significant exchange of resource information among them (Aydin et al. 2018). Aggressive production has led to significant pressure and temperature declines due to high interference between wells. Electrical Submersible Pumps (ESPs) have been effectively used in geothermal wells to compensate for the loss of production in power plants. However, ESPs have been reported to experience premature failures due to harsh downhole working conditions (Aydin et al., 2021). This study presents a successful $N_2$ lifting application in the Alaşehir geothermal field as an alternative to ESPs. The applied $N_2$ lift system offers several advantages over ESPs, including lower capital investment and maintenance costs, reduced power consumption, and greater reliability, as it lacks electrical and critical mechanical components in the downhole environment

## 2. DESIGN OF NITROGEN LIFTING SYSTEM

The candidate well is located in the Alaşehir field. It produces from intersecting faults: an east-west trending, north-dipping normal fault, and a south-north trending, west-dipping strike-slip fault. These intersecting faults contribute to the well's high permeability. The productivity index (PI) of the well is 61.2 tons/hour/bar, and the reservoir pressure is effectively maintained through re-injection support. The reservoir pressure decline is approximately 1.5 bars per year.

Good connectivity with injection wells, however, has drawbacks, such as temperature and non-condensable gas (NCG) content decline. The NCG content in the Alaşehir field has been reported to range between 2% and 3% (Haizlip et al., 2016; Aydin et al., 2018; Aydin and Akin, 2019). As the field put on operation, Aydin et al. (2021) reported an NCG content of 0.3% by weight for certain wells, equivalent to 190 g/kWh. This decline in NCG is possibly due to the dilution effect of gas-free re-injection fluids, which results from the strong hydraulic connectivity between injectors and producers in the field.

The combination of high PI, stable reservoir pressure, and low NCG content makes the candidate well suitable for gas lifting. The production performance of the well has been assessed through flow tests using Silencer-weirbox. It was producing 270 ton per hour at 8.2 bar of wellhead flowing pressure. Our aim was to increase the flow rate to 320 ton per hour at the same flowing pressure.

A deeper gas injection depth is desired for effective lifting performance; however, this will require higher compression power. First, we determined the flashing depth of the flow profile at the designed flow rate. The gas injection depth (550 meter) was selected to be deeper than the flashing depth (350 meter), where inhibitor chemicals are injected to prevent scaling issues. Gas injection is carried out through 2 7/8-inch tubing, which is slotted at the end section and equipped with a nozzle set that diverts the gas into the annulus, where it mixes with the geothermal brine. The inhibitor injection line (1/4-inch) is installed inside the 2 7/8-inch tubing, allowing the inhibitor to travel with the injected $N_2$ before mixing with the geothermal brine in the annulus (Figure 2).

$CO_2$ and $N_2$ are the most suitable gases for gas lifting in geothermal wells due to their technical and economic advantages. $N_2$ is readily available and can be easily generated from air using an $N_2$ generator, given its abundance in the atmosphere. On the other hand, $CO_2$ is the dominant gas produced in Turkiye's geothermal reservoirs, accounting for over 99% of the total gas output in most geothermal fields in the western region of the country. $N_2$ has been using for the continuous gas lifting application because it is non-corrosive, and easy to process comparing to $CO_2$.

The surface facility used for the $N_2$ lifting is illustrated in figure 3. Air is first captured from the atmosphere using air compressors, then dried through a filter and stored in the feed tank. The dry air then flows to the $N_2$ generator, which produces nitrogen with high purity levels. In the current operation, the purity exceeds 99% (Figure 4). The purified $N_2$ is then stored in a tank that feeds booster compressors at 7 bar. The booster compressors increase the gas pressure to 200 bar, which is then stored in 24 high-pressure vessels connected to a gas regulator that adjusts the $N_2$ flow to the gas injection line, which delivers it through the well.

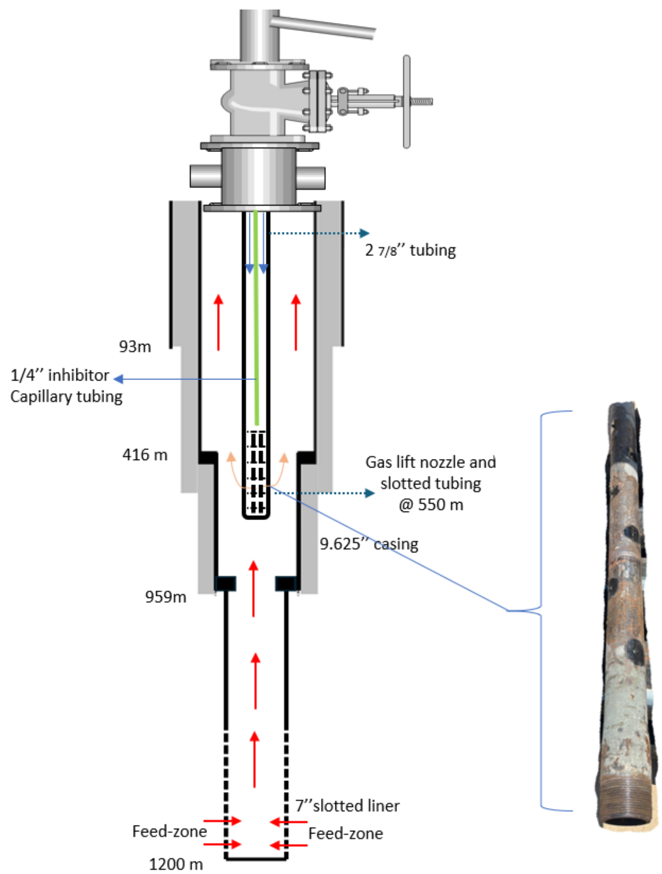


**Figure 2: Scheme and setup of the gas lifting system in the geothermal wellbore**

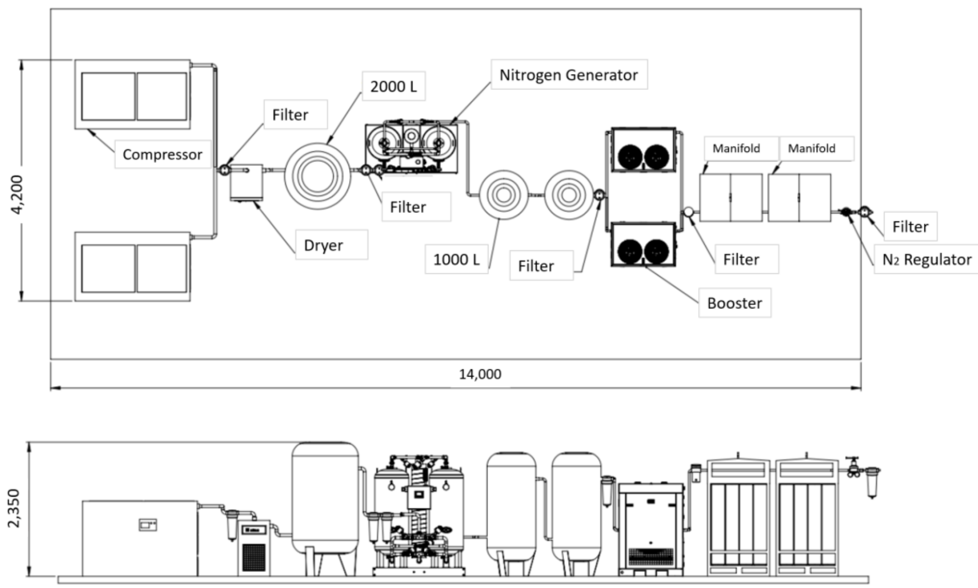


**Figure 3: Scheme of the Surface Facility for the $N_2$ lifting**

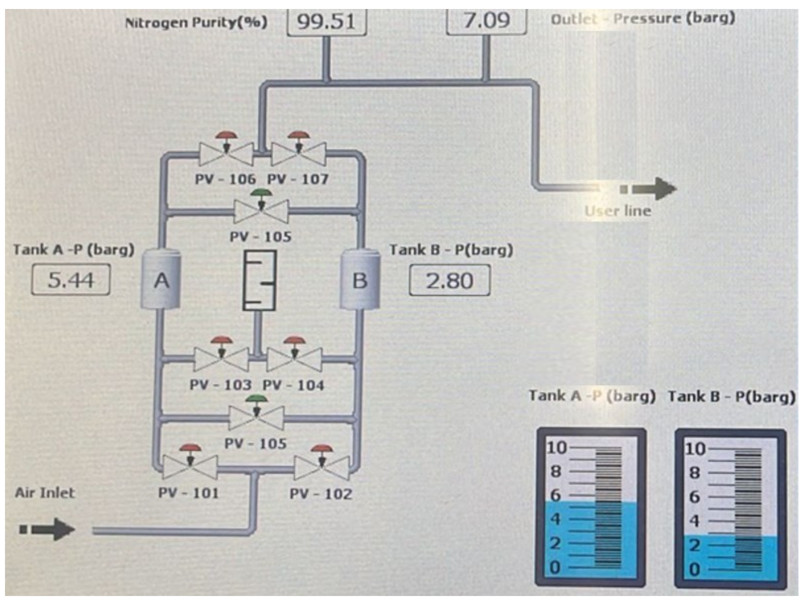


**Figure 4: Screen of the nitrogen generator displaying $N_2$ purity and tank pressures.**

## 3. RESULTS AND DISCUSSION

To evaluate the effect of $N_2$ injection on flow performance, we conducted a wellbore simulation using the academic version of Pipesim to analyze the impact of gas on the flow profile and overall performance of the well. The production performance of the well at an injection rate of 200 Sm³/hr of $N_2$ was simulated using the wellbore simulator, and the results were validated through Silencer-Weirbox measurements (Figure 5). With a power consumption of 120 kW, the production rate of the well increased by 50 ton/hr. The net power output of the $N_2$ lifting for the studied well is 715 kW per hour.

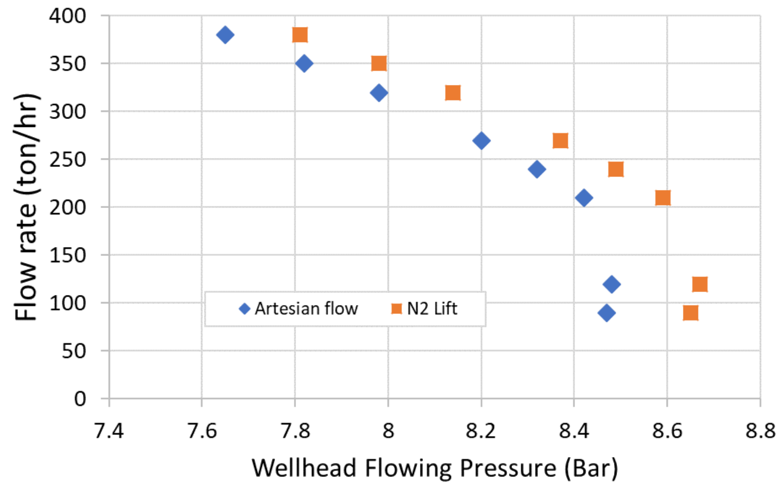


**Figure 5: Production performance of the well with artesian and $N_2$ lifting**

The wellbore flowing profile is shown in Figure 6. $N_2$ injection at 550 m did not significantly change the flow profile due to the low $N_2$ injection rate. The NCG content of the well increased from 0.3% to 0.36% by weight. The flashing depth of the well was at 330 m, and $N_2$ was injected below this depth to ensure the effectiveness of the inhibitor application for precipitation mitigation. There were no indications of precipitation on the coupons inserted at the wellhead.

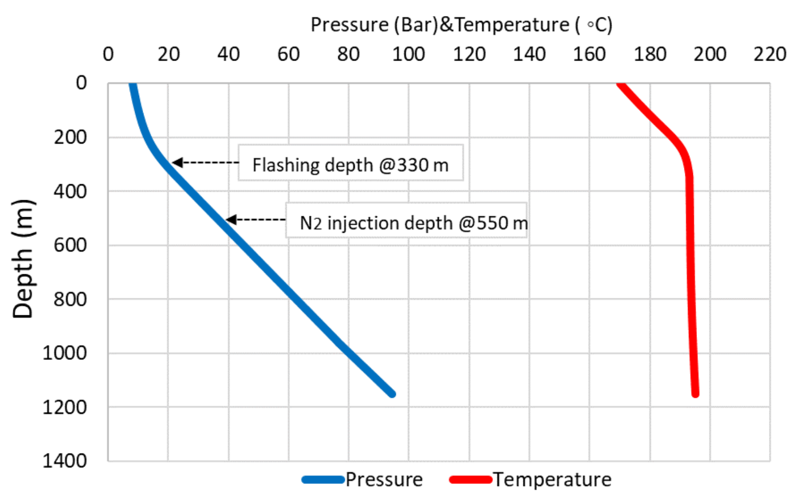


**Figure 6: Wellbore flow profile with $N_2$ lift at 200 $sm^3$**

The $N_2$ system used for the lifting application has a 200 $sm^3/hr$ rate limitation. This capacity can be increased by adding an additional unit alongside the existing one. The high PI value and reservoir pressure enabled us to extract an additional 50 ton/hr of geothermal brine from the reservoir. A higher gas injection rate would be required for the same production flow rate if the PI or reservoir pressure were moderate or low.

The $N_2$ lifting system used in this study does not include any electrical or rotating equipment, such as pumps, in the wellbore. Therefore, the system requires lower operating expenditures compared to ESPs, which typically have a run life of 6 to 18 months in most geothermal wells with moderate to high temperatures (Aydin and Camci, 2024). The surface equipment, such as compressors, requires periodic maintenance, costing less than one-third of the expenses for ESP spare parts (motor, protector, cable) in a year.

Although the $N_2$ generator can achieve a purity of more than 99.0%, continuous monitoring of corrosion caused by oxygen in the injected gas would be necessary at high gas injection rates. In the studied case of 200 Sm³/hr, no evidence of corrosion was observed. It is planned to pull the 2 7/8-inch tubing after one year of operation to check for any corrosion-related issues.

## 4. CONCLUSION

In this study, we presented a continuous $N_2$ lifting application in the Alaşehir geothermal field, Türkiye. The $N_2$ lifting system has been successfully operating and demonstrated that it can be considered an alternative to ESP applications, particularly in high-temperature wells with a short ESP run life. The following important remarks can be drawn from this study:

- The $N_2$ lifting system operating at 200 Sm³/hr increased the production rate of the well by 50 ton/hr, demonstrating its efficiency in boosting geothermal brine extraction.

- Compared to ESPs, the $N_2$ lifting system incurs significantly lower operating costs due to the absence of electrical and rotating components, as well as lower maintenance expenses for surface equipment.

- The system's capacity can be increased by adding additional units, making it adaptable for wells with higher productivity requirements or changing reservoir conditions.

- Although the $N_2$ generator achieves a purity level of over 99.0%, oxygen in the injected gas necessitates continuous corrosion monitoring, especially at high gas injection rates.

- The $N_2$ lifting system is particularly well-suited for high-temperature geothermal wells with short ESP run life, offering a reliable alternative in challenging downhole environments.

- During the study, no evidence of scaling or corrosion was observed, supported by inhibitor injection and effective system design. Future inspections, such as pulling the tubing after one year, are planned to confirm the system's long-term reliability.

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