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The Design of the Geothermal Laboratory (GEOLAB) at Hellisheiði Geothermal Park

Nursanty Elisabeth Banjarnahor*[1,2], Guðrún Sævarsdóttir[1], María Sigríður Guðjónsdóttir[1]
Reykjavik University[1]*, GRÓ-Geothermal Training Program[2]
nursanty24@ru.is

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INTRODUCTION

Pressure and mass flow rate at the wellhead are essential parameters for the design and operation of geothermal fields. In some cases, wellhead pressures are below the level required by the utilization system, either after drilling (Sveinbjornsson, 2014) or later due to pressure decline, causing them to become unusable. This presents a significant operational and economic challenge because of the high cost of drilling since the primary cost drivers, accounting for between 30-57% of the installation cost of a plant (Akindipe and Witter, 2025). One promising solution is the use of an ejector, a device that allows a high-pressure well to induce flow from a low-pressure well. By combining these wells, the total mass flow and exergy contribution to the system can be increased, potentially restoring low-pressure wells to productive operation (Guðjónsdóttir, et al., 2023).

A patent for an ejector for use in geothermal wells has been published in 1999, however, does not provide details of operation (United States Patent No. 5899273, 1999). A project at the Hellisheiði Power Plant utilized an ejector to mix fluid streams to mitigate scaling (Guðjónsdóttir, et al., 2023). Preliminary tests at the Theistareykir power plant with a rudimentary subsonic ejector successfully used well ThG-15 as a low-pressure source and well ThG-11 as a high-pressure source. However, that particular setup was insufficient for the normal operational for the plant condition (Guardia, et al., 2023). As a continuation, a supersonic ejector with a converging-diverging nozzle was proposed using analytical model to design the sizing and performance of the ejector in Theistareykir (Guardia, et al., 2023).

Another persistent challenge in geothermal operations is the reliable measurement of two-phase mass flow and enthalpy. Traditional separator-based testing requires wells to be disconnected temporarily, yielding only periodic snapshots of well performance. Differential-pressure-based methods offer an alternative capable of delivering real-time flow and enthalpy estimates without interrupting production. Recent advances combining DP measurements with modern data processing and machine-learning approaches have demonstrated high accuracy under geothermal operating conditions (Largaespada, 2023).

This research bridges these two challenges by validating both ejector performance and differential-pressure two-phase measurement in a controlled environment using geothermal fluids. To achieve this, a dedicated experiment will be conducted at the geothermal laboratory (GEOLAB) located in the Hellisheiði geothermal field. The research facilities also collaborate with the University of Iceland and ON Power. As part of developing this facility, several laboratories across Europe were visited to study best practices in high-temperature fluid handling, instrumentation, and experimental safety.

By combining controlled ejector experiments with differential-pressure-based measurement techniques, this study aims to validate analytical sizing methods, identify geometry sensitivity, quantify the influence of key design parameters such as nozzle exit position (NXP) and constant-area mixing section (CAMS), and assess the feasibility of real-time flow monitoring for geothermal wells.

1 METHODS & RESULTS

To design the proper laboratories, the objective of the experiment and the expected results need to be clearly stated. Using the process flow diagram (PFD) and heat and mass balance calculations, the major components will be identified. The present study will conduct controlled experiments at the GEOLAB geothermal laboratory in Hellisheiði. Hellisheiði is a geothermal field with a two-phase dominated reservoir, and several power plant units have been commissioned, one of the largest geothermal plants in the world, with installed capacity of 303 MWe and 200 MWth. The plant is owned and operated by ON Power, a subsidiary of Orkuveita Reykjavíkur (OR), which is owned principally by the City of Reykjavik (Ragnarsdottir et al., 2023). From the tapping point, anticipated ~3 kg/s saturated brine at 170 °C, adjustable steam quality (0.2–1.0) and pressure (3–7 bar(a)) will

be available for the GEOLAB laboratory. The proposed design required pressure vessels, separators, flash tanks, heat exchangers, vortex meters, and differential pressure instrumentation, as shown in the schematic of

Figure 1.

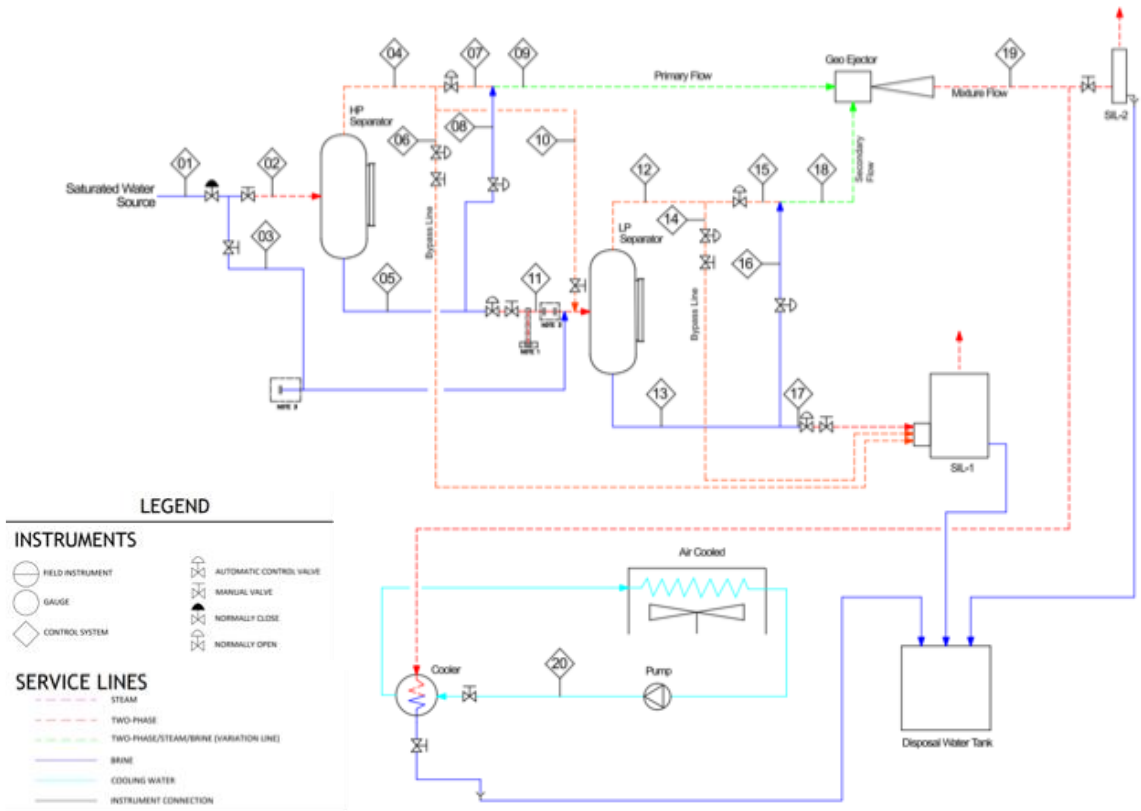


Figure 1. Process and flow diagram for experimental setup in GEOLAB

The system begins with a saturated water source extracted from the tapping point and routed through isolation valves (Nodes 01, 02, and 03). The saturated brine is delivered to the high-pressure separator, where the geothermal fluid undergoes partial flashing. This separator produces a primary steam stream directed toward the ejector through instrumentation at Nodes 04, 07, and 09 (see Figure 1). The separated brine is controlled by valve (Node 05) and can either be routed to the low-pressure separator or reintroduced into the primary line to regulate steam quality.

In the low-pressure separation stage, flashed fluid or controlled bypass flow enters the Low-Pressure (LP) Separator (Node 11), regulated by valves. This unit generates the secondary steam supply for the ejector. The secondary steam line passes through flow-control and measurement instrumentation (Nodes 15 and 18) before entering the ejector. Both the primary and secondary fluids then mix within the ejector. Instrumentation surrounding the ejector includes pressure gauges, differential-pressure transmitters, flow meters, and temperature sensors positioned both upstream and downstream.

The ejector discharge is routed through a dedicated line to silencers (SIL 1 and SIL 2), which ensure safe atmospheric venting of high-velocity steam. The silencers will be equipped with rupture disks and additional pressure-relief devices to provide emergency over-pressure protection. Brine and waste streams are conveyed to the disposal system. A secondary cooling loop, which includes an air-cooled heat exchanger and a circulation pump, reduces the temperature of the brine from both separators to safe levels prior to disposal or reinjection.

The GEOLAB system is housed within two adjacent 20-foot container modules installed side-by-side. Container 1, designated as the process and ejector module, accommodates all high-temperature and high-pressure equipment, including the high- and low-pressure separators, ejector test section, steam and two-phase piping, brine drainage system, and emergency discharge lines. The container is equipped with a blast-resistant wall, removable access panels for maintenance of ejector components, thermal insulation and heat shielding for hot lines, and pressure-rated penetrations for instrumentation cabling. Container 2 serves as the workstation and manifold area and provides space for storage. All instrumentation cables are routed through a protected conduit connecting the two modules, ensuring that the operator environment remains fully isolated from the high-pressure zones. The modular configuration facilitates mobility, operational safety, and straightforward installation within the Hellisheiði geothermal park while enabling controlled testing of an ejector system using real geothermal brine and steam.

As part of the preparatory work for this study, several high-temperature research laboratories across Europe were visited to benchmark best practices for designing safe and reliable geothermal experimental facilities. In total, six laboratories were visited across Iceland, Denmark, Germany, Belgium, and the Netherlands. Key findings from these visits emphasized the need for modular experimental areas with allowance for future expansion, full visibility of all experimental units from the control room for safe and effective monitoring, and a structured workflow encompassing preparation, testing, data acquisition, analysis, and archiving to ensure traceability and operational efficiency.

The laboratory will incorporate essential utilities such as fresh water, electricity, and compressed air. Appropriate thermal and acoustic insulation will be installed to ensure stable and safe operation. Safety measures include plexiglass or acrylic protection panels, mandatory personal protective equipment (lab coats, safety glasses, gloves, and protective footwear), and routine leakage and pressure testing with certification when required. The facility will include signage marking high-pressure and high-temperature areas and indicating flow directions. Adequate ventilation, together with comprehensive risk assessment and mitigation procedures, will be implemented to support safe long-term operation.

2 CONCLUSION & FURTHER WORK

The development of the geothermal laboratory (GEOLAB), in conjunction with ejector testing and real-time two-phase measurement, represents a significant advancement in the utilization of geothermal wells. By integrating analytical modelling, engineering design, and insights gained from laboratory visits across Europe, the GEOLAB facility provides a safe, flexible, and fully instrumented environment for evaluating ejector performance under real geothermal conditions. The dual 20-foot container configuration, consisting of a high-pressure process module and a cooling/control module, offers a modular platform for assessing ejector geometries, flow behaviour, and two-phase measurement techniques. The results are expected to produce validated performance for ejector configurations, improve understanding of sizing influences, and demonstrate the feasibility of real-time flow monitoring for geothermal wells. These possibilities to be available for various geothermal projects in the future, making the project one of a kind.

The finalization of the GEOLAB design, particularly the safety framework and engineering approach, must be completed in detail before procurement can proceed. Comprehensive risk assessment and mitigation planning are also required. Overall, GEOLAB provides a unique platform for advancing geothermal ejector technology and enhancing the utilization and long-term sustainability of geothermal wells by testing in a controlled environment using geothermal fluids.

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REFERENCES

Akindipe, D., and Witter, E.: 2025 Geothermal Drilling Cost Curves Update, *Proceedings*, 50th Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, United States (2025).

Andal, J.: Master's thesis. Geoejector: Extracting geothermal fluid from a low-pressure geothermal well, Reykjavik University, Reykjavik, Iceland (2023).

Andal, J., Lárusson, R., Guardia, X., Sævarsdóttir, G., Tesfahunegn, Y., Júlíusson, E., Guðjónsdóttir, M: Improvement of a Geoejector Design Using an Analytical Model and Data from Theistareykir Geothermal Field, Iceland, *Proceedings*, World Geothermal Congress 2023, Beijing, China (2023).

Guardia, X., Andal, J., Lárusson, R., Sævarsdóttir, G., Tesfahunegn, Y., Júlíusson, E., Guðjónsdóttir, M.: Connecting high- and low-pressure geothermal wells using an ejector: Analysis of first field tests at the Theistareykir Geothermal Power Plant, *Proceedings*, World Geothermal Congress 2023, Beijing, China, (2023).

Guðjónsdóttir, M., Andal, J., Guardia, X., Lárusson, R., Júlíusson, E., Einarsson, H., Sævarsdóttir, G.: GeoEjector: Extracting geothermal fluid from a low-pressure geothermal well, *Proceedings*, 45th New Zealand Geothermal Workshop, Auckland, New Zealand, (2023).

Jung, D.: United States Patent No. 5899273 (1999).

Largaespada, A.R.: Predicting Real-Time Geothermal Well Flow Rate and Enthalpy with Machine Learning Techniques, *Master's thesis*. Reykjavik University, Reykjavik, Iceland (2024).

Ragnarsdóttir, K.R., et al.: Project Silverstone: Reduction of CO_2 Emissions by 95% at the Hellisheiði Geothermal Power Plant, SW-Iceland*, Proceedings*, World Geothermal Congress 2023, Beijing, China, (2023).

Sveinbjornsson, B.: Success of High Temperature Geothermal Wells in Iceland, Iceland Geosurvey, Reykjavik, Iceland (2014).