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Repurposing A Geothermal Well With A Closed Loop Vacuumized Pipe-In-Pipe Solution

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ABSTRACT

The Groß Schönebeck site is located approximately 50 km north of Berlin, Germany, and is used to investigate, understand, and optimize all steps related to the sustainable provision of geothermal energy from a deep sedimentary basin from two deep wells completed as a geothermal doublet system for producing and injecting thermal water. The reservoir, located at a depth of 4,100 to 4,400 m in the Lower Permian of the North German Basin, reaches a temperature of 145°C in the production well. Both wells were hydraulically stimulated to enhance productivity. However, it was not possible to achieve sustainable commercial flow rates and the wells are currently suspended.

To both repurpose one of the wells and to test a new geothermal closed loop solution, a continuous vacuumized pipe-in-pipe will be installed in one of the wells after the lowest perforated section is isolated to create a closed space. The goal of this well test is to investigate and demonstrate the insulation capability of the vacuum pipe ensuring only a few percent heat loss of the heated water returning to the surface. Furthermore, the performance of the well will also be tested to evaluate the effects of varying flow rates and the impact of highly thermally conductive salt. Finally, the potential for repurposing suspended oil, gas and geothermal wells in general is reviewed.

1 INTRODUCTION

The Groß Schönebeck site is located approximately 50 km north of Berlin, Germany. It is used to investigate the sustainable provision of geothermal energy from two deep wells completed as a matrix-dominated Enhanced Geothermal System (EGS) for producing and injecting thermal water from the Rotliegend formation. The permeability of the Rotliegend formation is insufficient for commercial hydrothermal energy development. Therefore, EGS technologies have been used to increase well productivity and injectivity. While the hydraulic stimulation treatments performed at the site significantly improved well productivity and injectivity in the short-term, long-term productivity declined due to a variety of processes (Blöcher et al., 2016). In the framework of the regional development project TRANSGEO (Transforming abandoned wells for geothermal energy production), multiple repurpose options have been investigated for the Groß Schönebeck wells (Christi et al., submitted) and repurposing the wells into Deep Borehole Heat Exchangers (DBHEs) has been identified as a technically feasible and energetically interesting reuse option. Such closed loop systems offer an alternative technological approach for extracting heat from hot, but low-permeability formations.

To achieve the highest possible thermal capacity and temperature from such a closed-loop system in an existing well the key is to maximize the thermal isolation of the pipe that separates the cold fluid flowing down the annulus and the hot fluid flowing up the tubing. Therefore, it is planned to demonstrate the deployment and operation of a vacuumized pipe-in-pipe solution at Groß Schönebeck. This technology is part of a new co-axial geothermal well solution for an efficient geothermal heat extraction as the heat loss is minimized due to the vacuum (Maver, 2025).

In late 2024, the vacuumized pipe-in-pipe solution was installed at the Ullrigg test site in Stavanger, Norway and 525m of pipe was tested as part of reaching Technology Readiness Level (TRL) 5. The pipe-in-pipe solution was run to the planned depth for testing the equipment design, measurements and procedures. The insulation effect

and the pipe in pipe design were successfully tested for further TRL development. In 2026, a new geothermal well with a slanted section will be drilled in the Northern part of Denmark, where the pipe-in-pipe solution will be installed bringing the solution to TRL8. A heat offtake agreement for 30 years with the utility company, Aalborg Forsyning, has been signed and the Danish Energy Agency supports the project with 11.5 million Euro. The suspended geothermal well GrSk4/05 in Groß Schönebeck is used as a test of the vacuumized pipe-in-pipe solution, it's ability to extract heat from the subsurface and investigate its response to varying operational conditions with at least 1 year of heat production to bring the solution to TRL-7.

2 THE GROß SCHÖNEBECK RESEARCH AND DEMONSTRATION SITE

The Groß Schönebeck site serves to investigate the sustainable provision of geothermal energy from two deep wells completed as Enhanced Geothermal System (Huenges et al., 2007; Regenspurg et al., 2024; Zimmermann et al., 2011). The first well, GrSk 3/90, was originally completed in 1990 as a gas exploration well but was abandoned due to non-productivity. It was reopened in 2000 and underwent hydraulic stimulation. The second well, GrSk 4/05, was drilled in 2006 with the aim of extracting thermal waters and forming a doublet system of hydraulically connected boreholes. In this well, the Lower Permian sandstones and volcanics are located at a depth of 4,100 to 4,400 m, with a measured temperature of 145°C. Both wells were hydraulically stimulated to enhance productivity (Figure 1). However, sustainable high flow rates could not be achieved, and the wells are currently suspended.

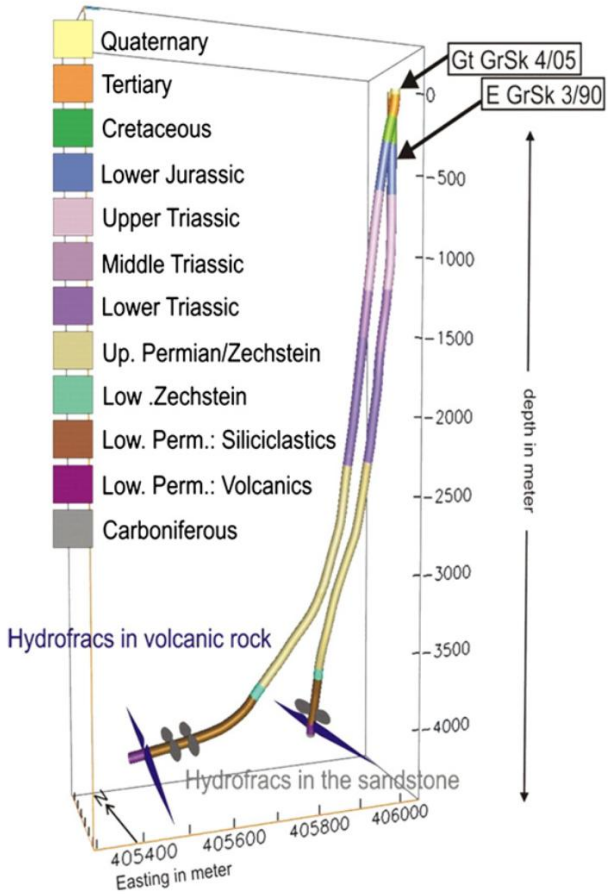


Figure 1. The well doublet at the Groß Schönebeck geothermal test site where the GrSK 4/05 is to be repurposed with the vacuumized pipe-in-pipe solution (Moeck et al., 2009).

3 VACUUMIZED PIPE-IN-PIPE SOLUTION

3.1 Co-axial design

The patented co-axial closed-loop system to be installed in the GrSK 4/05 well circulates a working fluid that is heated by the surrounding geological formations. The fluid flows downward between the well casing and an outer pipe, absorbing heat from the geological formations along the way (Figure 2). Once heated, the working fluid returns to the surface through a vacuumized pipe-in-pipe assembly, which consists of an inner and an outer pipe working similarly a thermos flask. The continuous and controlled vacuum in the pipe-in-pipe provides thermal

insulation, minimizing heat loss. As a result, the temperature of the water returning to the surface is reduced by only a few percent. Without a vacuum to insulate the circulating working fluid, a significant heat loss can be experienced. Managing this loss of heat is key to making the vacuumized pipe-in-pipe solution unique and the projects economically viable (Maver, 2025).

The co-axial solution is flexible in its heat provision. This is a benefit in cases where the heat demand is a subject to seasonality. The flexibility is realized by either changing the flow rate or completely stopping the working fluid flow for a period of time. This allows the subsurface to reheat for over-extracting heat during other periods or even reversing the working fluid flow to use excess energy and heat the subsurface for heat storage.

In some cases, the flow of the circulating working fluid in the well can sustain itself by the thermosiphon effect due to the heated fluid in the inner pipe being less dense than the cold water in the outer pipe. However, the circulation of working fluid at various flow rates requires a small circulation pump.

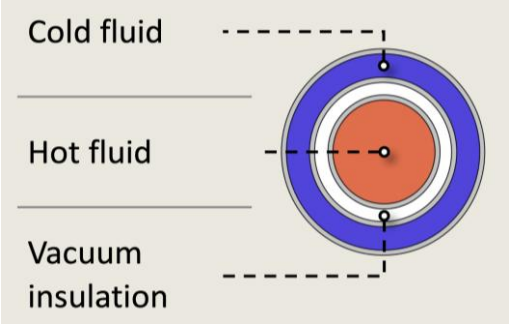


Figure 2. The co-axial well design with the vacuumized pipe-in-pipe solution.

3.2 Installation and maintenance

The individual pipe-in-pipe sections are pre-assembled and are then the sections are assembled on the rig floor and lowered into the well (Figure 3). The vacuum pump is located on the surface for easy maintenance. The process of vacuumization can be initiated as soon as the completion string is hung off the wellhead. The vacuum will be regularly tested during the installation process to ensure the vacuum integrity of proven technology used in the oil & gas industry and that have been enhanced for geothermal heat production. The tubulars used for the pipe-in-pipe solution is qualified by design in the oil & gas industry for drilling and completing deep wells.

With no downhole operational equipment, only limited maintenance is required for the surface equipment which is a circulation pump, vacuum pump, heat exchanger, expansion tank and control panel that easily fits into a 20-foot container. This closed-loop solution eliminates corrosion and offers an expected service life of 50+ years.



Figure 3. Pipe-in-pipe solution (left), connections of the pipe-in-pipe solution (centre) and the rig floor assembly of the pipe-in-pipe solution (right).

3.3 Installation in new geothermal wells

For full scale commercial geothermal projects with new wells, each well is drilled to a vertical depth of 3-5 km, depending on the temperature requirement, with a 2-5 km horizontal (or slanted) section either as a single well or a group of wells, depending on the required thermal energy that is in the range of 1-3 MW per well. By adding a horizontal section, the thermal output of the well increases substantially and by drilling a cluster of 5-10 individual wells industrial scale heat production of 10 - 30 MW thermal is possible.

4 REPURPOSING WELL GRSK 4/05

In summer 2025, the GrSK 4/05 well was investigated for dimensional accuracy and over-all well integrity (Figure 4).



Figure 4. Groß Schönebeck test site: GrSK 4/05 well head (left), caliper tool (centre) and temporary packer (right).

A caliper log confirmed that the well dimensions and structural integrity are suitable for recompletion. The perforated section of the well will be isolated to create a closed-loop space prior to installing the closed-loop well completion. A vacuumized pipe-in-pipe system, consisting of a 3.5” inner pipe and a 4.5” outer pipe, will be installed, maintaining a continuous vacuum from the surface to 3,200 m (Figure 5). The geothermal performance of the well, specifically the transfer of heat from the geological formations, will be tested to assess the effects of varying flow rates and the impact of highly thermally conductive salt.

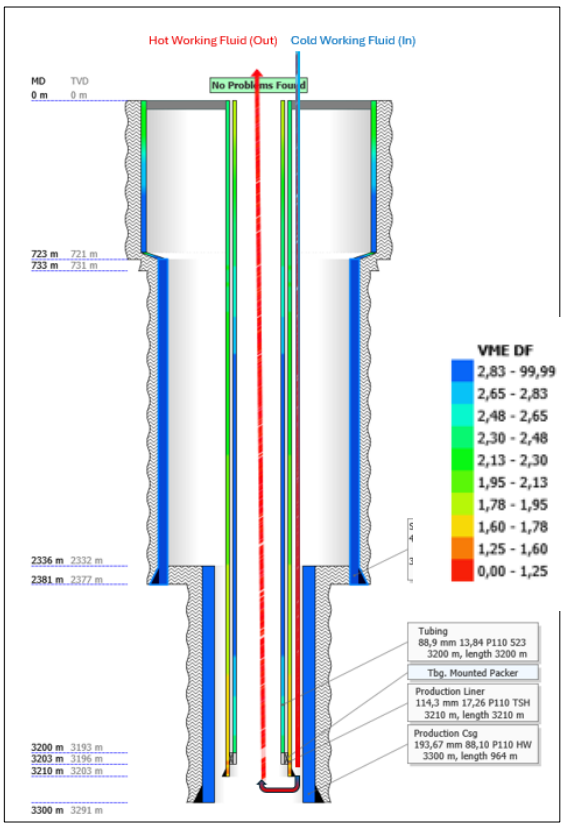


Figure 5. Vacuum pipe-in-pipe structural design and with safety factors (Von Mises stress design factor (VHE DF)).

An initial geothermal model has been developed for the well with the proposed well design. The flow rate remains constant at 2.6 kg/s throughout the full 10-year simulation and because the flow rate does not adapt to preserve outlet temperature, the extraction temperature gradually decreases over time. The initial extraction temperature is 115 °C and after 10 years the predicted extraction temperature reaches approximately 74.5 °C with a constant return temperature of 40 °C. The average thermal output over 10 years is 0.4 MW (Figure 6).

The overall performance of the formation's heat transfer and the vacuum dual-pipe completion will be evaluated over a one-year period. The geothermal performance test of the vacuum pipe-in-pipe solution will also further qualify the completion tubing design and structural modelling for the circulation of varying fluid temperatures in the well.

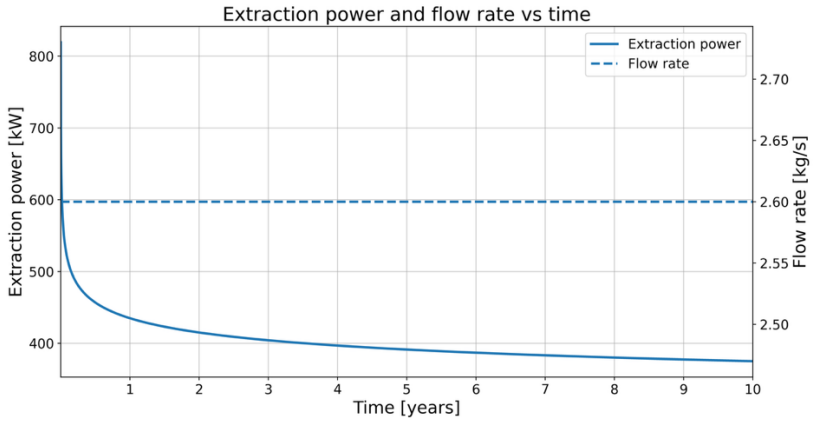


Figure 6: Modelled output temperature over 10 years with a constant fluid flow rate of 2.6 kg/s.

5 DISCUSSION AND CONCLUSION

The GrSk 4/05 well is fit for geothermal repurposing with a closed-loop solution using a vacuumized pipe-in-pipe solution.

The test deployment and operation will evaluate the efficiency of the solution in extracting heat from the closed-loop well, ensuring that the temperature of the water returning to the surface is reduced by only a few percent.

The solution would have a significant application in disused oil and gas wells as being reviewed in the TRANSGEO project. It is a regional development project that aims to explore the potential for producing sustainable geothermal energy from abandoned oil and gas wells in central Europe in the study areas North German Basin, South German Molasse Basin, Vienna Basin, and Pannonian Basin. Hungary, as an example, has from past oil and gas development activities more than 8,000 deep wells. The reuse of some of these wells in geothermal projects could result in significant cost reductions as they do not need to be abandoned and new wells do not need to be drilled for geothermal purposes (Hofmann et al., 2024; Fedor et al., 2024). Studies have confirmed that repurposing of idle oil and gas wells as geothermal wells can be economic and would be a valuable heat source for district heating networks (Koltzer, 2024).

An additional outcome of the test deployment and operation is a much wider application of the solution as it will be possible to produce geothermal heat nearly anywhere, as the geological requirements are limited, and by adding a horizontal section to increase the area for extracting heating making the solution commercially attractive (Maver. 2025)

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Experience gained from the recompletion of the suspended hydrothermal well will be reviewed and may be applied to other geothermal wells, as well as to suspended oil and gas wells.

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Andromachi Kalogirou has performed the geothermal modelling for the GrSK 4/05 well.

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