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An Evaluation on Closed-Loop Geothermal Energy Recovery from Canadian Deep High Enthalpy Systems

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Summary

Geothermal energy resources are widely distributed in Canada, with the highest potential areas occurring in the western and northwestern parts of the country (Grasby et al., 2011; Majorowicz and Grasby, 2010, 2014, 2019). Recently many geothermal energy projects have been initiated in Canada (e.g., Hickson et al., 2020; DEEP, 2021; Eavor Technologies, 2021) to demonstrate either the resource development technology or geothermal resource concepts. Closed-loop geothermal energy recovery technology (Fig. 1) has advantages of being independent of reservoir fluid and permeability, experiencing less parasitic load from pumps, and being technologically ready and widely used for heat exchange in shallow geothermal systems. Commercial application of closed-loop geothermal technology to deep high-enthalpy systems is now feasible given advances in drilling technology. However, the technology it uses has been questioned due to contrasting heat transport capacities of convective flow within the wellbores and conductive flux in the surrounding rock. Here we demonstrate that closed-loop geothermal systems can provide reasonable temperature and heat duty for over 30 years using multiple laterals when installed in a suitable geological setting. Our results indicate that the closed-loop geothermal system is sensitive to reservoir thermal conductivity that controls the level of outlet temperature and interference between wells over time. The residence time of the fluid in the horizontal section, a ratio of the lateral length to flow rate, dictates heat transport efficiency. A long vertical production section could cause large drops in fluid temperature in a single lateral production system, but such heat loss can be reduced significantly with multiple laterals in a closed-loop system.

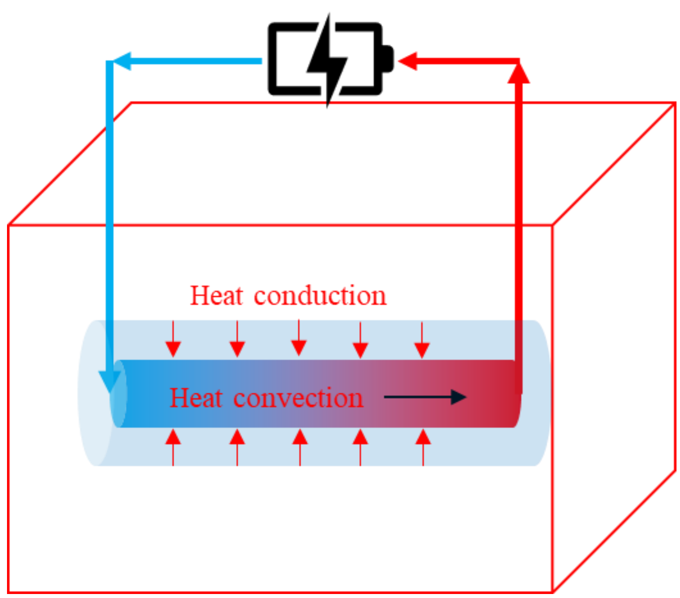

Figure 1. Schematic diagram of a closed-loop geothermal energy recovery system and its heat transfer mechanism. Colours represent working fluid temperatures ranging from cold (blue) to hot (red). The battery symbol reflects end heat usage (direct heat use and/or power generation).

Theory / Method / Workflow

Two analytical methods were applied in modeling and the evaluating the closed-loop geothermal energy production system. Duhamel's convolution method used in oil and gas industry was applied in modelling of a single lateral closed-loop geothermal energy recovery system. For more complicated cases, such as multilateral wells, and heterogeneous and bounded reservoirs, the natural coupling analytical method was applied to help better characterize heat transfer behaviour and interaction between the working fluid and reservoir in a closed-loop system. The two methods were applied to the closed loop system in a case study with typical geothermal reservoir properties to demonstrate the workflow and effectiveness of the proposed methods. The outlet temperature profiles over 30 years from two different approaches are comparable with high accuracy. The heat balance check between energy production and heat loss from the reservoir helps validate the proposed methods for the closed-loop geothermal recovery technology.

Results, Observations, Conclusions

A sensitivity study suggests reservoir thermal conductivity, determining the efficiency of heat transfer from reservoir to the working fluid in tubing, is the most important parameter to evaluate whether a reservoir is suitable for a closed-loop geothermal energy recovery project. Well interference in a multilateral configuration could be eliminated or reduced by increasing well spacing. Higher reservoir thermal conductivity will also lead to earlier well interference and larger temperature drops through time. However, the lateral length and flow rate compensate for each other on overall heat extraction performance. For a given thermal reservoir, optimizing the operational parameters, such as length, spacing, flow rate and number of laterals in the project design phase can greatly increase efficiency. The heat loss in vertical part of production well is minimal in a 10-multilateral closed-loop configuration. With the application example case, the closed-loop geothermal energy recovery technology could provide 9 to 11 MW stable heat production over 30-years of operation. Our results show that a deep closed loop system can effectively produce energy over long time periods under suitable geological settings regarding thermal gradient and thermal conductivity. Overall, this technology is independent of reservoir fluid and permeability, and applicable to sedimentary basin as well as volcanic belts, providing an alternative solution for many high enthalpy geothermal projects. As well, a closed-loop system eliminates challenges associated with production of geothermal fluids, greatly reducing environmental risks. Further research can greatly expand the deployment of geothermal development to support the transition to clean energy resources.

Novel/Additive Information

In this study, two novel analytical methods were proposed to evaluate heat energy production in the closed-loop system. The two methods coupled the transient heat transfer process in reservoir formation and simplified isothermal pipe flow in a closed-loop system. The mesh-free analytical solution of heat transfer in the reservoir improves the computational efficiency while providing accurate heat production output calculations.

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References

DEEP Earth Energy Production, 2020. About DEEP. Available on the Internet: https://deepcorp.ca/.

Eavor Technologies Inc., 2020. Available on the Internet: https://eavor.com/about/technology.

Grasby, S.E., Allen, D.M., Bell, S., Chen, Z., Ferguson, G., Jessop, A., Kelman, M., Ko, M., Majorowicz, J., Moore, M., Raymond, J., and Therrien, R., 2011. Geothermal Energy Resource Potential of Canada, Geological Survey of Canada, Open File 6914, 322 p. doi:10.495/288745.

Hickson, C., Kumataka, M., Akto, P., Cotterill, D., Benoit, D., Eccles, R., Huang, K., Colombina, M., Collins, S., 2020. Alberta #1: The Province's First Electrical Geothermal Project. 1–13.

Majorowicz, J. and Grasby, S.E., 2010 High potential regions for enhanced geothermal systems in Canada. Natural Resources Research, 19, 177-188.

Majorowicz, J. and Grasby, S.E., 2014. Geothermal energy for northern Canada – Is it economic? Natural Resources Research, 23, 159-173.

Majorowicz, J., Grasby, S.E., 2019. Deep geothermal energy in Canadian sedimentary basins vs. fossil based energy we try to replace – Exergy [KJ/Kg] compared. Renewable Energy, 141, 259-277.