Experimental and numerical performance assessment of standing column well operating strategies

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Standing column wells (SCWs) are efficient ground heat exchangers that use local groundwater as a heat source/sink for heating and cooling buildings. In a SCW, high heat exchange rates are achieved by recirculating groundwater in a single deep (75 m to 450 m) and uncased borehole. Discharging (“bleeding”) a small amount of the pumped water outside the SCW also allows maintaining the groundwater temperature within the heat pump's operational range during peak demand periods. This strategy has been identified as the most significant parameter of SCW operation and is associated with reductions in total length, surface and cost of the borehole heat exchanger compared with the more common closed-loop systems.

This work aims at improving knowledge of the dynamic mass and heat transfer processes involved in SCW operation, in order to promote adoption of this energy-efficient technology and encourage good practice. To this end, data is collected using an experimental SCW system located near the city of Montreal, Canada, and made of a 215-m-deep SCW and a 150-m-deep injection well available for discharge of bleed water. The wells are also connected to a large-scale geothermal laboratory designed and equipped to mimic the heating and cooling operation of a small commercial building. First, an advanced finite-element model coupling advection-diffusion of heat and groundwater flow within a SCW and the surrounding ground is developed in the Comsol Multiphysics environment and is validated using experimental datasets collected through downhole temperature measurements, a pumping test, a thermal response test as well as 25 days of winter operation. The numerical model is then used to evaluate the impact of the pumping arrangement and bedrock fracturation on the well's outlet temperature. Secondly, the operational parameters logged during the dynamic heat extraction test are analysed to provide insight about various operating strategies and their effect on the system's performance.

The work conducted so far demonstrates that the proposed finite-element model reproduces the hydraulic and thermal behaviours of a SCW with satisfying accuracy. Numerical results suggest that placing the submersible pump near the top of the well avoids installation and maintenance difficulties without compromising heat pump operation compared with the usual reverse configuration. It is also shown that deep fractured zones are beneficial to heat pump operation in
heating mode, whereas near-surface fracturing tends to impair the performance of the system throughout winter as it eventually favours recharge of the well with colder water. At last, analysis of the winter test data indicates the effectiveness of a three-level bleed control and on-off sequence for maintaining the groundwater temperature above the freezing point, while minimizing the volume of discharged water and allowing to reach a 160 W/m heat extraction rate.