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MODELING ON THE CYCLIC OPERATION OF STANDING COLUMN WELLS UNDER REGIONAL GROUNDWATER FLOW*

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Abstract: Coupled hydrogeological-thermal simulation of the Standing Column Well (SCW) system is essential to provide an optimized configuration and operation schedule for boreholes on the site. This paper presents numerical investigations and thermo-hydraulic evaluation of standing column well system operating under cyclic flow regime. A three-dimensional numerical model for groundwater flow and heat transport is used to analyze the heat exchange in the ground. The model includes the effects of convective and conductive heat transfer, heat loss to the adjacent confining strata, and hydraulic anisotropy. The operation scenario consists of cyclic injection and recovery and four periods per year to simulate the seasonal temperature conditions. For different parameters of the system, performances have been evaluated in terms of variations in recovery temperature. The calculated temperatures at the producing pipe are relatively constant within a certain range through the year and fluctuating quarterly a year. Pipe-to-pipe distance, injection/production rate, ground thickness, and permeability considered in the model are shown to impact the predicted temperature profiles at each stage and the recovery water temperature. The influence of pressure gradient, which determines the velocity of regional groundwater flow, is most substantial.

Key words: standing column well, thermo-hydraulic evaluation, cyclic regime, numerical simulation

Introduction

In recent years, Ground-Source Heat Pump (GSHP) systems have become increasingly popular for use in residential and commercial buildings[1]. The systems are designed to reject and/or extract heat from ground. There are several different variations of GSHP systems including Ground-Coupled Heat Pump (GCHP) systems, Surface Water Heat Pump (SWHP) systems, and Ground-Water Heat Pump (GWHP) systems. Being included in GWHP systems, Standing Column Well (SCW) systems use groundwater drawn from wells as a heat source/sink.

In SCW systems, water is circulated between the well and the heat pump. Deep boreholes are drilled in rock, creating a standing column of water. Water is recirculated from one end of the column to the heat pump, and back to the other end of the column. The concept of standing column well systems is about as old as the GWHP systems, but is recently receiving much more attention because of their economic advantages from lower installation cost, lower operating cost, and improved overall performance in the regions with suitable geological conditions. The system also provides environmental benefits because of its lower CO_2 emission than any other conventional alternatives. Considerable research effort has been made on ground heat source heat pump systems, especially on the single U-tube ground heat exchanger. However, relatively few design tools and simulation models are available for the SCW systems.

Estimation of heat recovery rate and temperature distribution in the aquifer is required in SCW projects before the system is installed. At present, the use of computer modeling constitutes an integral part in the prediction and evaluation of geothermal performance[2,3]. In carrying out SCW development projects, a numerical modeling based on coupled mass and energy transport theory has to be conducted on the behavior of local subsurface geothermal system to evaluate and optimize a project design.

A number of researchers have highlighted the important role of numerical modeling in the analysis

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