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Development of geo-thermal heat pump systems using groundwater

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1. Introduction

Air-conditioning systems of efficient heat pumps using geo-thermal energy are getting popular because of their low environmental impacts. There are two types of geo-thermal heat pumps. One is an closed type which gets heat through the heat exchanger installed underground, and the other is an open type which pumps up groundwater directly for the source of heat pumps. Nowadays, the closed type is widely used with few restrictions of location. On the other hand, the open type which can simplify well equipments is considered to have several advantages in respect of cost, and it has a potential to be spread in the area where groundwater resources are abundant. The authors report the feasibility of open type heat pump air-conditioning systems which combine groundwater circulation heat pumps and a secondary side air-conditioning systems.

2. Heat pumps and secondary side air-conditioning systems

As the secondary side air conditioners, dedicated outside air system that combines outside air handling with a fan coil unit using dry coils was adopted. By the systems, comparatively high temperature groundwater can be used with for sensible heat source, and high coefficient of performance (COP) of a heat pump will be expected. Furthermore, there is a possibility of free cooling which uses groundwater for air-conditioning directly without heat pump in summer, which means proposed system will be suitable for the open type heat pumps. In this study, the hybrid systems of heat pumps and free cooling systems were newly proposed, and their efficiency was examined.

3. Groundwater Water Quality Control

When the heat pumps use groundwater circulation, it is necessary to prevent the bad influence of groundwater quality like water pressure fall and land subsidence caused by recharging well clogging. Common clogging materials are iron, manganese, or fine clay particles. Especially, ferrous iron ions in groundwater are easily oxidized by air and will become suspended solids. Moreover, calcium ions in heat exchangers or wells may precipitate onto pipe surface as a solid material. In this examination, Na type ion-exchange resin was adopted as the water softening and removal method of these ingredients. As a result of laboratory experiments, it was shown that about 1m3 of water can be softened by 1L of ion-exchange resin. This means that it can miniaturize equipment compared with standard coagulation/filtration method, when the iron concentration is comparatively low .

4. Parametric study of pumping wells/ recharge wells layout planning

In this system, recharge wells after using groundwater heat must be installed in the ground as well as pumping wells as a heat source. For preventing short circuits, which means used groundwater may be pumped again from pumping wells; there must be a sufficient distance between pumping wells and recharge wells. Moreover, the trans-seasonal thermal storage effect by ground heat storage capacity may be expected by switching recharge well in summer season to pumping wells in winter season. Groundwater and heat flow coupled analysis using TOUGH2 was simulated to examine the effective wells arrangement. It was shown that a short circuit does not happen when there are more than at least 30-m distance between pumping wells and recharge wells. The trans-seasonal thermal storage effect showed about 2 to 4 C heat advantage.

5. Comprehensive Evaluation of System Performance

The comprehensive quality assessment by a simulation model was performed for 3 cities (Sapporo, Nagano, and Fukuoka) using a model office building of 1,000 m2. This system showed 55 to 60% energy saving effects compared with conventional air conditioners.

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Keywords: groundwater, heat pump, geo-thermal, water quality control, flow analysis