EXPERIMENTAL ANALYSIS OF A CONTINUOUS OPERATING GROUND SOURCE HEAT PUMP SYSTEM IN WUHAN, CHINA

by

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Coefficient of performance of air conditioning system is the ratio of cooling capacity and power consumption, and also is an important parameter to characterize the performance of the system. Based on an actual ground source heat pump system in Wuhan, China, this paper calculated the coefficient of performance of the system under long-term continuous cooling operation and then evaluated the performance of the system through experiment. The continuous testing time ranged from June 1, 2017, to June 15, 2017, and the outside air temperature ranged from 21 °C to 32 °C during the testing progress. The experimental results show that the coefficient of performance of the system changes non-linearly with time, and varies greatly with the atmospheric temperature. The results also show that the coefficient of performances average value of the system is about 3.3, and the system has good performance under refrigeration conditions. This paper helps to understand the changes in the distribution characteristics of the coefficient of performance of the ground source heat pump system and promote the wide application of the ground source heat pump system.

Key words: *ground source heat pump, coefficient of performance, experimental test*

Introduction

Saving energy and protecting the environment are the key projects because of the increasing fossil fuel pollution in the past decades [1, 2]. Air pollution and water pollution strongly affect our life at every moment. It is well known that renewable energy is the wave of the future, *i. e*., solar energy, wind energy, and geothermal energy [3, 4]. Ground source heat pump (GSHP), as a renewable and sustainable power, is extensively used for space heating and cooling buildings. The *COP* is a most important parameter representing to the systems performance. Therefore, *COP* is always more than one based on the energy balance law. It is well known that the GSHP system characteristics including: The heat transfer fluid is the mixture of water and antifreeze. Closed loop relative to open loop is usually used in the real projects due to it safety and cleanness. A heat exchanger is main set-up that heat transfer from the ground to the fluid. The soil temperature distribution can stay at a relative constant status, so the heat pump can be used throughout the year. The benefits of using a GSHP system are

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the following [5]: enjoying lower fuel bills, eliminating the need for fuel deliveries, reducing annual maintenance costs, reducing carbon emissions dramatically, earning significant income from the renewable heat incentive, and installing a safe, silent, invisible heating system with no planning restrictions.

The *COP* value of the GSHP system depends on the system design, configuration, operating parameters and temperature of the outside air, and so on. In the recent researches, most studies have concentrated on improving the performance of the GSHP system by experimental and numerical method. Some papers concentrate on the experiment and simulation on the thermal performance of ground heat exchanger（GHE）for the GSHP system [6-8]. Cao *et al*. [6] used the experiment and CFD simulation to make research on the thermal performance for a new type of ground heat exchanger, and also analyzed the entire thermal resistance of the GHE and the soil temperature distribution. Yuan *et al*. [7] reviewed the analytical solution, numerical solution and experimental investigation of the heat transfer of GHE, and the paper also analyzed the simulation model and long-term operation performance of the GSHP system. Other papers focus on the thermodynamic, economic and energy analysis of GSHP system [9-11]. For instance, Menberg *et al*. [10] studied a detailed thermodynamic analysis of individual components of a hybrid GSHP system. And this paper highlights importance of a low temperature spread in the comparison of heating and cooling mode. Lu *et al*. [11] used the recorded cost data and average *COP* value of 3.8 and 3.6 for heating and cooling operation to analyze the economic performance of the GSHP system in Melbourne, Australia. A few researches just focus on the application of system, in different application environments, control strategies or climate areas. Zeng *et al*. [12] introduced a novel multi-objective optimization method for CCHP-GSHP coupling systems. Zhang *et al*. [13] studied the influence of GSHP system design parameters on the geothermal application capacity and electricity consumption at city-scale for Westminster, London. Li *et al*. [14] analyzed the application of a GSHP system which was installed in a nearly zero energy building in China. Hepbasli [15, 16] summarized the cooling performance of a GSHP system which was installed in a 65 m^2 room in the Solar Energy Institute, Izmir, Turkey.

In the previous literatures, it can be seen that the studying focuses on the systems performance and configuration parameters effect. The most researches are based on the numerical approach or intermittent operating condition. However, the experimental analysis of a real and continuous operating is limited. This is may be that the experimental investment of a GSHP system is very huge and the building load is also intermittent in most instances. In this paper, a real and continuous operating GSHP system is established and the *COP* value has been calculated based on the testing parameters. The testing time in this work ranges from June 1, 2017 to June 15, 2017 and temperature of the outside air changes from 21°C to 32°C during the testing progress. The aim of this paper is to the knowledge the changing distribution characteristics of the *COP* value with a continuous operating condition and evaluate the performance of the system.

Experimental process

In order to test the *COP* value of the system, GSHP system has been established and located at Wuhan University of Science and Technology, Wuhan, China, and then a photo of this system has been shown in fig. 1. It can be seen from this figure that there are two heat pump units with each power of 8.3 kW in the system. A well designed GSHP system can provide the lowest running cost of any heating system, because it uses a small amount of electricity to transfer a large amount of naturally occurring heat from the ground into the buil-

Figure 1. Photo of the GSHP located at Wuhan University of Science and Technology

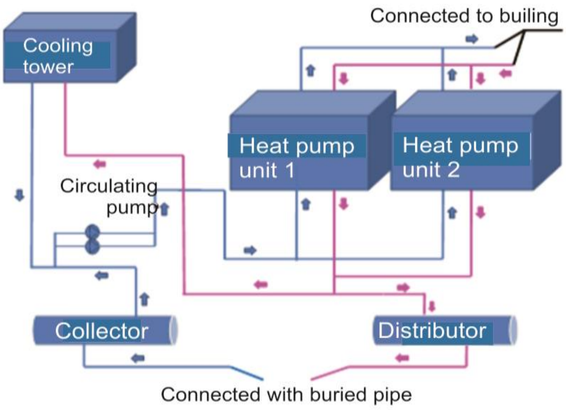

Figure 2. The system diagram of GSHP

ding. The detailed parameters of this system and operation are: the system works by absorbing heat from the ground and transferring the heat to buildings. This GSHP system has two kinds of heat exchangers, which are two horizontally spiral and five vertical U-tubes exchangers, however, the five vertical exchangers are open during the testing process. The depth of the buried pipe is 100 m with a diameter of 100 mm. The flow mass of the fluid in the building is 8.0 m^3 per hour for the standard condition. Continuous operation of about 360 hours in this system has been performed, and the aim is to analyze the *COP* value of this system. In this experiment, all set-ups, *i. e.*, thermocouple, flow meter, have been checked before the experiment begins, so the testing error within 5% meets the requirement.

The whole systems workflow has been shown in fig. 2. It can be seen that the different flow of this system is obviously shown in this figure based on different colors. For cooling conditions, the GSHP unit extracts heat from the terminal, and then transmits the heat to ground source by circulating heat transfer fluid through buried pipes in horizontal trenches or vertical boreholes.

Experimental results

By testing the water temperature of input and output from the heat pump unit, the water mass of the heat pump unit in the load side, then *COP* value of the system can be calculated easily based on the energy balance law. Figures 3-7 shows that testing results of *COP* value of this system from June 1, 2017, to June 15, 2017, respectively. For every day, testing time ranges from 00:00 to 24:00, so it is a continuous testing period. Because the highest temperature of outdoor air is about 33°C, it belongs to cooling operating condition.

Figure 3 shows the calculating results of the *COP* value on June 1, June 2, and June 3, 2017. It can be seen from this figure that there is a similar trend of *COP* value for three days. The *COP* value ranges from 1.33 to 4.59. The average *COP* values of this system are 3.34, 3.14, and 3.21 for June 1, June 2, and June 3, respectively.

Figure 4 shows the calculating results of the *COP* value on June 4, June 5, and June 6, 2017. It can be seen from this figure that the *COP* value ranges from 1.53 to 4.53. The average *COP* values of this system are 3.04, 2.85, and 3.33 for June 4, June 5, and June 6, respectively.

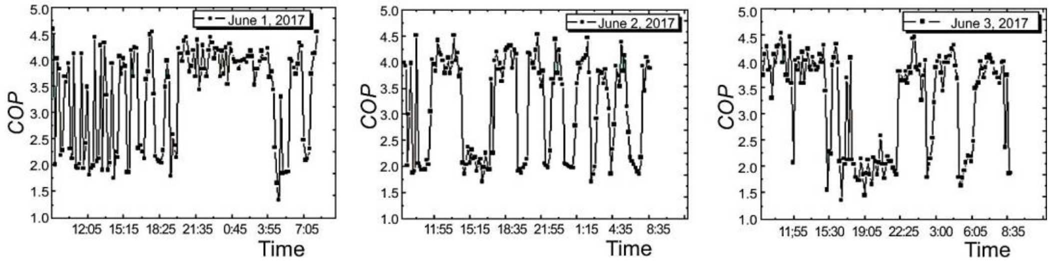

Figure 3. The *COP* values on June 1-3, 2017

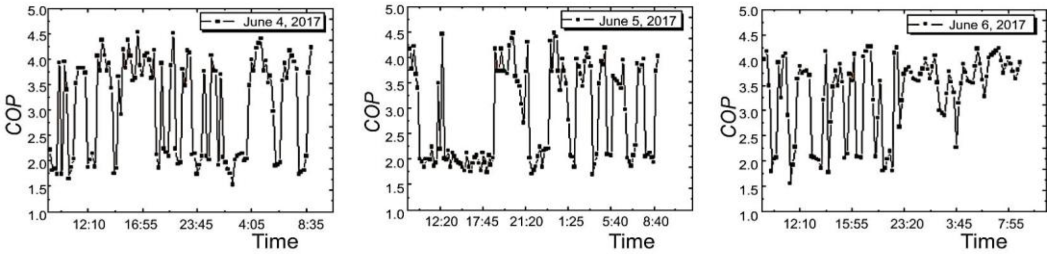

Figure 4. The *COP* values on June 4-6, 2017

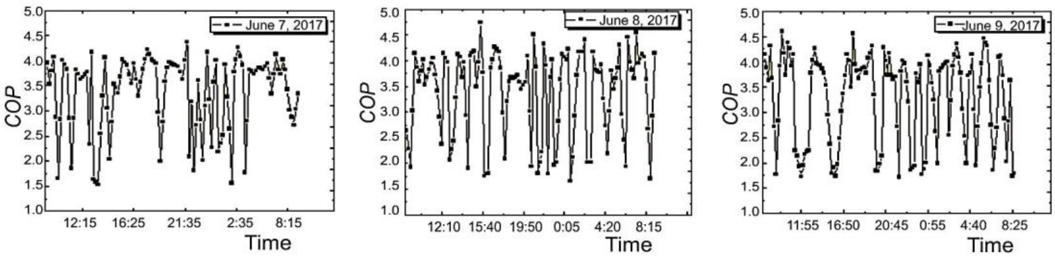

Figure 5. The *COP* values on June 7-9, 2017

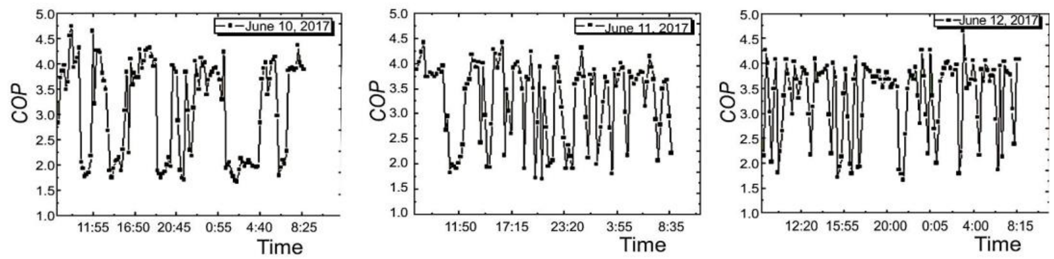

Figure 6. The *COP* values on June 10-12, 2017

Figure 5 shows the calculating results of the *COP* value on June 7, June 8, and June 9, 2017. It can be seen from this figure that the *COP* value ranges from 1.53 to 4.74. The average *COP* values of this system are 3.37, 3.39, and 3.28 for June 7, June 8, and June 9, respectively.

Figure 6 shows the calculating results of the *COP* value on June 10, June 11, and June 12, 2017. It can be seen from this figure that the *COP* value ranges from 1.66 to 4.74. The average *COP* values of this system are 3.09, 3.25, and 3.34 for June 10, June 11, and June 12, respectively.

Figure 7 shows the calculating results of the *COP* value on June 13, June 14, and June 15, 2017. It can be seen from this figure that the *COP* value ranges from 1.55 to 4.79. The average *COP* values of this system are 3.47, 3.46, and 3.37 for June 13, June 14, and June 15, respectively.

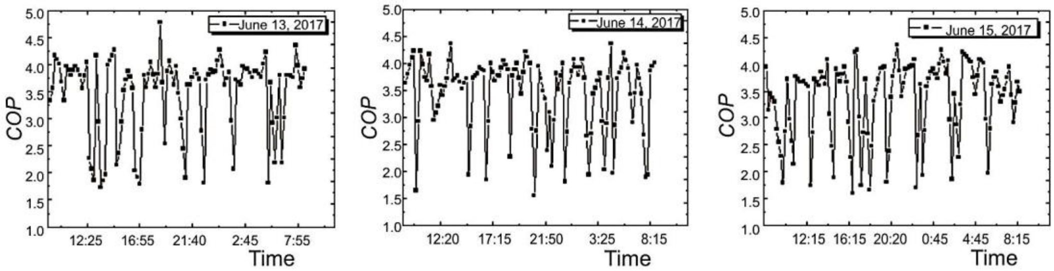

Figure 7. The *COP* values on June 13-15, 2017

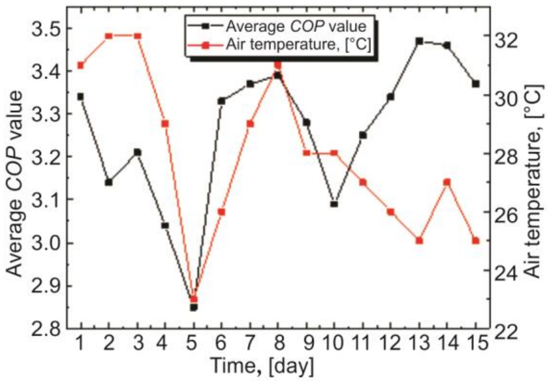

Figure 8. The average value of COP and air temperature on June 1-15, 2017

In summary, it can be seen from figs. 3-7 that the *COP* value has changed non-linearly with testing time, and has a minimum of 1.33 and a maximum of 4.79, respectively. Due to the atmospheric temperature changes strongly during the testing period, there is a similar trend of *COP* value for these days and the most of timely *COP* value change around 2 or 4. Also, *COP* value depends on the systems' design, configuration parameters, and building load, as well as the operation period.

Figure 8 shows the recorded air temperature and the calculating results of the average *COP* value on June 1-15, 2017. In this figure, it can be seen that the *COP* value varies greatly with the changes of air temperature and the variation trend of the *COP* of the system basically consistent with the change of air temperature. By comparing the *COP* values of the first and last days, it can be found that the *COP* value of the system has not changed much after 15 days for continuous operation mode. This may be due to the not long enough experimental time or those factors previously mentioned.

Conclusions

The GSHP system is electrically powered systems that tap the stored energy of the greatest solar collector in existence: the Earth. It uses the earths' relatively constant temperature to provide heating, cooling, and hot water for indoor building and commercial buildings. It is a useful approach to save energy and protect environment. In this paper, a real and continuous operating GSHP system is established and the *COP* value has been calculated based on the testing parameters. The testing time in this work ranges from June 1, 2017, to June 15, 2017. The results show that *COP* value strongly changes with the atmospheric temperature or the testing time, and a distribution characteristic for different testing times, non-linear, has been obtained. Also, the relationship curves of the average *COP* values, atmospheric temperature and testing date has been obtained. The results also show that the average *COP* value of 15 days continuous operating experiment is about 3.3, which prove its good performance in cooling condition for this system. The aim of this experiment is to provide a reference for improving high-efficiency utilization of GSHP system.

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