May, 2017, Vol.8

AHPNW NEWSLETTER

CONTENTS

~Related News~

1. New government - New energy policy
2. China Refrigeration Expo Opening
3. - 2016 Energy Conservation Prize Ceremony at ENEX 2017
   - The current situation of full Liberalization of the Power Retailing Business
   - Full Liberalization of the City Gas Retailing Business
   -'Energy management by using Thermal Storage Air-conditioning System' has published. - From a plan and a design to an operation –

~Research Papers~

4. Application Analyse of a Ground Source Heat Pump System in a Nearly Zero Energy Building in China
5. Load Variations with Seasonal Conditions Affected to Coefficient of Performance of Air to Water Heat Pump

From Korea

■ New government - New energy policy

It is noteworthy how President Moon's realization of the energy policy promise presented during the presidential election will be realized. The key to President Moon's energy policy pledge is to increase the LNG and renewable power generation instead of lowering the nuclear power plant and coal-fired power considered main cause of fine dust occurred.

Firstly the government proposed to suspend the construction of Shin Gori 5 and 6, extend the life of Wolseong 1, and reexamine the entire plan for construction of new nuclear power plants. For old-age nuclear power plants, they should be strengthened with seismic capacity of 6.5 or higher and nuclear power plant is not able to enhance with seismic performance should be shut down in sequence, and the extension of the life span of Wolseong Nuclear Power Plant 2, 3 and 4 is strictly restricted. It also decided to curb the construction of a new coal-fired power plant. It is time to reexamine the construction of nine coal-fired power plants. It aims to raise the utilization rate of LNG power generation from 20% to 60%, and to achieve 20% of renewable energy generation by 2030 mainly with solar and wind power.

President Moon is expected to curb nuclear power plants and coal-fired power plants, but it is unlikely that it will be easy to cancel plans for construction of nuclear power plants and coal-fired power plants that have already been decided. If the proportion of LNG and renewable energy is relatively high instead of reducing nuclear power plants and coal-fired power generation costs that are low in power generation costs, it is inevitable to raise electricity costs due to rising costs. The national consensus is a big challenge. Mr. Moon thinks that he will reduce the burden on consumers by improving efficiency and strengthening demand management. Although the LNG industry is expected to see a positive impact on the sales of private LNG producers, it is welcomed, but it is a difficult task for the government. The Ministry of Industry and Energy has pointed out that it is necessary to enlarge the proportion of LNG power generation to reduce greenhouse gas emissions. In addition to environmental protection, it is necessary to balance various aspects such as economic efficiency and energy security. LNG power generation contributes to greenhouse gas reduction compared to coal, but it is disadvantageous compared to nuclear power plants. In North America and Europe, it is possible to use relatively cheap power generation costs by using shale gas or PNG as a fuel. However, we believe that it is desirable to operate with the peak demand because the cost of introducing LNG is high.

President Moon is planning to reorganize the energy price system for energy supply considering safety and environment. And it is to improve the taxation system for power generation fuels. Also, it is expected that the new and renewable energy industry will be revitalized, but there are many obstacles to be overcome such as deregulation of the downtown area. It is noteworthy that policy changes such as the improvement of the RPS system and the re-introduction of the FIT system will take place by expanding the proportion of renewable energy, mainly solar and wind power. It is suggested that technological progress is necessary to utilize the electricity generated by solar power and wind power as well as to utilize remaining electricity to charge electric vehicles.

President Moon also expressed his intention to broaden the distributed power supply and encourage the integrated energy supply. An expert in the industry said, "The promise to expand the integrated energy supply as a core business of the distributed power supply is not only one-off, but it must be fostered in the long run." In the light of the reduction of nuclear power plants and coal-fired power, I look forward to it. "

President Moon said that the current government organization is limiting the change of energy policy and that he is considering the creation of the Energy Independent Ministry (Climate Energy Department).

(Source : 12 May 2017, Today Energy Magazine)

From China

■China Refrigeration Expo Opening

April 12, 2017, China Refrigeration Expo opened in Shanghai.

Exhibitors were from 33 countries and regions, more than 1,200 enterprises and institutions. The total exhibition area was about 103,500 square meters, net area was close to 50,000 square meters.
The exhibition attracted the attention of the world's refrigeration HVAC industry, the vast majority of well-known brands. More than 100 countries and regions, more than 60,000 professional visitors and users came to visit and negotiate cooperation.

The theme of the exhibition was ingenuity, intellectual creation, tolerance, sharing. Around these theme, the organizers organized a wide range of exchange activities during the exhibition, including the comprehensive analysis of national policies, the industry hot spots, technological innovation and future development of the general direction to promote the development of green exhibition concept, to fulfill the sponsor's social responsibility during the exhibition.

(Source:http://www.cr-expo.com)

From Japan

■2016 Energy Conservation Prize Ceremony at ENEX 2017

On February 15, on the occasion of ENEX2017, the Energy Conservation Prize Commendation
Ceremony was performed. This commendation program is intended to commend excellent attempts at
energy saving, products and business models having high energy performance made or developed by
manufacturers or organizations that can serve as a model for others. The prize is organized by the
Energy Conservation Center, Japan (ECCJ) and aims to contribute to the expansion of nationwide
awareness of the need for energy conservation and to create an energy conservation-oriented society
by dispatching the necessary information and accelerating PR through publicly announcing the results
of screening and prize winners, while showing all application examples and outlines of prize-winning products.
JARN introduces the prize-winning companies in the Product/ Business Model Category.
Panasonic received the Minister Prize of Economic, Trade and Industry in the Product (Home) Segment for its
WX series room air conditioners (RACs) incorporating a double temperature and simultaneously/ selectively
discharging airstream system.
Daikin won the Minister Prize of Economic, Trade and Industry in the Product (Commercial) Segment for its
Retrofit System for existing variable refrigerant volume (VRV) systems.
Moreover, Mitsubishi Heavy Industries Thermal Systems (MTH) was awarded the Director General Prize of Agency
of Natural Resources and Energy in the Product (Commercial) Segment for its GART/GARTI series energy saving,
large capacity, and compact centrifugal chillers.
The following companies are the Chairman Prize of ECCJ winners. Daikin for its residential multi-split air conditioner
that can be connected to a floor heating system; Mitsubishi Electric for its Mr. Slim ZR series type P280 packaged
air conditioners (PACs) for store/office use; Panasonic Ecology Systems for its residential heat exchanging system
incorporating an IAQ Control function; Johnson Controls-Hitachi Air conditioning (JCH) for its Flexmulti high efficiency
heat pump type variable refrigerant flow (VRF) systems for building air conditioning; JCH for its Stainless Clean
Shirokumakun X series RACs; Toshiba Carrier and Chubu Electric Power for their Super Power Eco Gold P224 and
P280 air conditioners for store/office use; Toshiba Lifestyle Products and Services for its Magic large capacity series
energy saving freezer-refrigerators; Corona and Denso for their Corona Premium Eco Cute heat pump water heater
adopting CO2 refrigerant;and Rinnai for its Eco One residential hybrid water heating apace heating system.

(source : 2017/3/25,JARN)

■ The current situation of full Liberalization of the Power Retailing Business

On April 1, 2016, the power retailing business was fully liberalized, and all consumers including ordinary households and stores are now able to freely select power suppliers and electric rate systems.The size of the newly liberalized electricity market is worth approximately 8 trillion yen annually. Competition caused by new entries from other business sectors is bringing about benefits to consumers such as a restraining effect on price increases and provision of new services.

As of 6th April 2017, about 390 retailers were registered and approximately 181,000 customers has switched their power suppliers. So newly established power company's share is now 3% in low voltage customers market and also 8% in total electrical power market.Innovation based on diverse consumer needs will create dynamic power-related markets and general energy companies targeting overseas markets may emerge in the future.

(Source; Japan, METI homepage etc.)

■ Full Liberalization of the City Gas Retailing Business

On April 1, 2017, the gas retailing business was fully liberalized. To the commercial big users, the market was liberalized from 1955.So the two third of the total Gas retailing market has liberalized and about 30 companies are entered this business.
However, ‘Security Obligation’ is one of the big entry barrier, so the new entry companies are very limited, compared with the Power Retailing liberalization.

*Security Obligation : New company needs to prepare personels who can check the security matters

(Source; Japan, METI homepage etc.)

■ ’Energy management by using Thermal Storage Air-conditioning System’ has published.
- From a plan and a design to an operation –

Contents
1.What the thermal storage air-conditioning system is
2.Energy management by TES
3.The main point on the plan of a thermal storage type air-conditioning system
4.The design of a thermal storage type air-conditioning system
5.The design of a heat storage tank, and construction of a thermal storage type air-conditioning system

Related News

6.Operation and the maintenance/control of a thermal storage type air-conditioning system
7.The case study of the energy management by a thermal storage type air-conditioning system
8.The real application of a thermalstorage type air-conditioning system

*Edit and issue: 2017 March 31 The society of Heating, Air-Conditioning and Sanitary Engineers of Japan(SHASE)
(source : http://www.shasej.org/)

Application Analyse of a Ground Source Heat Pump System in a Nearly Zero Energy Building in China

Huai Li, Wei Xu, Zhen Yu, Jianlin Wu, Zhifeng Sun

Abstract

Ground source heat pump system has been widely utilized in office buildings in China. Its application in nearly zero energy office building pioneers an innovation in China. This paper focuses on real operation introduction and performance analysis of a Ground Source Heat Pump (GSHP) system in a nearly zero energy building (NZEB) with different HVAC terminal for the first time. The paper introduces the nearly zero energy building with a general presentation of its energy system, then analyzes GSHP system operation and soil temperature variation from November 2014 to September 2015 based on real operation data. The analyses manifests that the HP2# worked under an average COP of about 5.4 and 5.0 in summer and winter, respectively and HP1# worked under an average COP of 3.9 and 3.0 in winter and summer respectively. In the winter season floor and ceiling radiation system has a relatively higher performance than radiator system due to low supply water temperature going into the room. Room temperature keeps above 20℃ in the winter season and fluctuated around 26℃ in the summer season. Good room temperature and COP proves the GSHP system functions excellently. Soil temperature could recover in one year operation.

Keywords: Nearly Zero Energy Building, GSHP system operation, soil temperature variation, indoor environment comfortable

1. Introduction

Reducing energy consumption in the building sector is one of the most important measures for global energy reduction and climate adaptation. Nearly/net zero energy building is one promising path leading to further building energy conservation. Research regarding design methodologies, technologies, monitoring method or evaluation process et al of nearly zero energy building has been carried out either by researchers or constructors.

Zhihua Zhou et al. [1] published articles regarding operation performance of a “net zero energy building” in China, in which they manifested challenges of nearly zero energy building development, and gave suggestions for nearly zero energy building to realize design target in China. Muhammad Waseem Ahmad, et al. [2] focused on available technologies for building energy metering and environment monitoring in nearly zero energy building by analyzing their advantages and disadvantages. Limei Shen, Xiwang Pu et al [3] presented the first study on thermoelectric technology applications in NZEB, which shows the system could satisfy cooling and heating requirement outstandingly, and improves annual solar generation 767kWh (34%). It provides a progress way to apply thermoelectric technology in NZEB. ShengZhang [4] proposed a multi-criterion renewable energy system design optimization method for NZEB under un-certainties, Shicong Zhang[5] introduced the operation performance of ground source heat pump in CABRNZEB, and analyzed its good performance in summer season.

China has the biggest GSHP market, and the fastest GSHP yearly application in the world. Due to high performance and environmental friendly properties, GSHP system has been recognized as the best choice of energy system of buildings. Researches on ground source heat pump(GSHP) system goes to two directions, one is numerical simulation work[6-10], for purposes of proper GSHP design guidance, optimizing system operation especially for a combined system, longer term system operation observation, evaluation of special types of heat exchanger simulation. The others focus on system application effects, in different application environments, control strategies or climate zones [11-20].

A large borehole ground source heat pump system was adopted in a Nearly Zero Energy Building (NZEB) in Beijing, China. It is a 4-floor office building, with a floor area of about 4000 m2 and occupancy of approximately 180 full-time employees. Adhering to the design principle of "passive building, proactive optimization, economic and pragmatic", the project integrated cutting-edge building technologies and set up the ambitious annual energy consumption cap of 25 kWh / (m2.a) (including heating, cooling and lighting energy) with an acceptable indoor environment.

This article focuses on performance analysis of a GSHP system in a nearly zero energy building with different HVAC terminal through a whole year (2014.11-2015.9) based on real operational data, including a heating period and a cooling period. Important parameters such as inlet and outlet water temperatures in the primary and secondary side, coefficients of performance in summer and winter season, as well as typical days that are presented to help understanding system performance with different terminal in a low heating and cooling load building. Suggestions are provided to help optimize GSHP system operation after real operation data analysis.

2. Building Introduction

The NZEB integrated cutting-edge building technologies and strived to lay a foundation for China's NZEB standard. The building adopted prominent thermal insulation to reduce the cooling and heating energy demands. It uses vacuum insulation board with a thermal conductivity of 0.006W/ (m2 K) as insulation. The window has a K value of 1.0 W/ (m2 K) which uses vacuum glass and internal electrical shading design. EPS with a thermal conductivity of 0.03W/ (m2 K) is used in the ceiling. Careful attention has been paid to the detailed design to avoid the thermal bridge and to maintain good air tightness.

There are different function rooms distributed on each floor. Four floors have almost the same structures, including office room and meeting rooms, whereas the difference is the scale of the meeting rooms. The meeting room on the first floor could maintain almost 50 people, and the one on the fourth floor is capable of 150 people.

Figure 1 Front view of the nearly zero energy building

3. Energy System Description

3.1 Energy System

The building serves as an experimental building in several sections, such as renewable energy application, building envelop, indoor environmental comfort, HAVC terminals and others.

Solar thermal combined with ground source heat Pump system works as the main energy system of this building. As described previously, each floor has office room and meeting rooms respectively, and considering the demonstration purpose, different heating and cooling terminal are adopted. Water source variable refrigerant volume (WS-VRV) system and radiator system are utilized for the first and fourth floor in summer and winter respectively, whereas the second and third floor employs floor and ceiling radiation systems respectively.

3.2 Operation strategy

One absorption chiller and two GSHP units are involved in this energy system that are shown in Figure 2. In summer season when the solar radiation is sufficient, the absorption

chiller, driven by hot water (≥70℃) which was produced by two types of solar collection systems, processes the ventilation load of the 1st and 4th floor, otherwise (hot water temperature < 70℃), a 50kW HP (GSHP1#) will serve the function of absorption chiller instead, when the switching operation of the two machine unit is controlled by BAS (building automation system). On the other side, room cooling load of the first floor is provided by (WS-VRV) system, the fourth floor is served by (WS-VRV) and water loop heat pump (WLHP) system respectively. On the other side, GSHP with 100kW provides ventilation and cooling load of the 2nd and the3rd floor. In the winter season, GSHP1# provides heating and ventilation load of the 1st and 4th floor except for the meeting room which was supported by WLHP if meeting room is in use. The other 100kW GSHP (GSHP 2#) unit is in place to meet heating and ventilation demands from the radiant terminals for the 2nd and the3rd floor. Performance parameter of the two heat pump is shown in Table 1.

Table 1 Performance parameter of heat pumps

HP	Cooling Capacity（kW）	Power Input（kW）	EER	Heating Capacity (kW)	Power Input (kW)	COP
GSHP1	50	9.3	5.4	51.7	13.1	3.9
GSHP2	99.5	18.6	5.3	103.7	25.2	4.10

4. Borehole System

Borehole tube is adopted as heat source or heat sink for the system in winter and summer, and cooling tower is set as an auxiliary cooling system of borehole in summer. Borehole distribution is illustrated in Fig. 3. Seventy boreholes are placed in open space of the demo building boundary, with 20 for double U-tube and 100 meter-depth to the south, and 50 for single U-tube with depth of 60 meters to the north and west. These boreholes are grouped in 7 sub-loops, where ground water join in a header before entering the building, and water inside the boreholes exchanges heat with the ground. Since very high temperature and humidity weather and relatively good U-tube water temperature in summer, cooling tower is out of use in this system now.

Water in the U-tube has few ways entering the building due to different season and operation modes, in the summer season, water goes to absorption chiller (if hot water is available), HP 1# (if required), HP 2#, VRV system and WLHP units; and in the winter seasons, water goes to GSHP 1#, GSHP 2#, VRV systems and WSHP units if necessary.

Soil temperatures around both single and double borehole tube in different depths is monitored by PT1000 sensor and operation data are recorded in building energy monitoring system. PT1000 was calibrated by standard equipment.

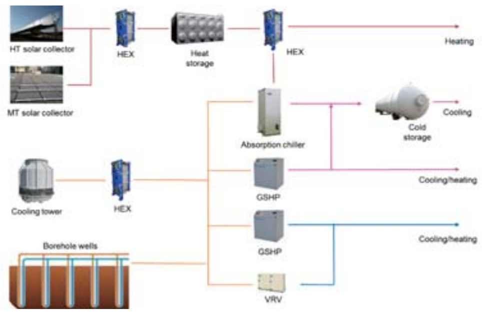


Figure 2. Heating and cooling system of the NZEB building

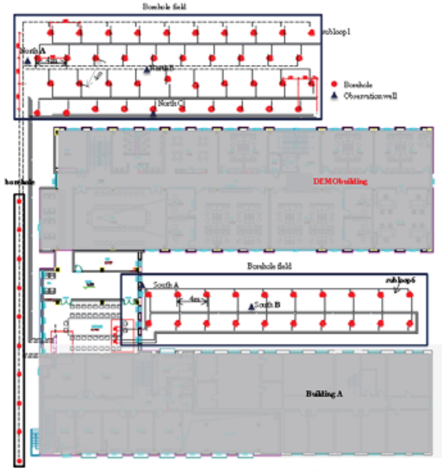


Figure 3. Borehole System Distribution

5. *Operation Analyze*

5.1 Winter Season Operation

The construction of CABR demo building was finished in May 2014.The test operation of the energy system started from July 1st 2014, when the energy monitoring system was on operation and progressing elaboration during the first half years. Now the system is under the second winter operation mode. For complete data analysis, this paper focuses on system operation from November 2014 to the end of September.2015.

The first winter season operation of the energy system started from 15th November to end of March, Fig. 4 shows outside air temperature variation during this period, which varies from -7 to 5℃. It was a relatively warm winter.

GSHP system operation in a typical day is analyzed first and the system operation of the whole winter is presented then. The system operated only on weekdays from around 7:00 am to 17:00pm, 10 hours a day.

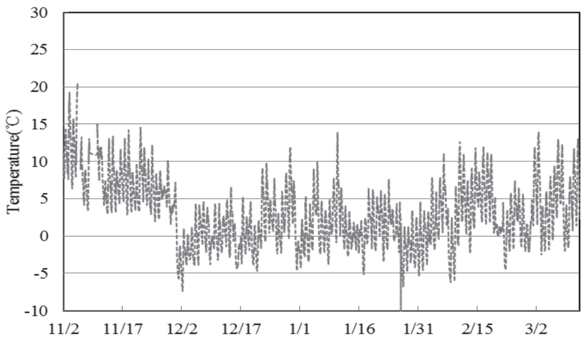


Figure 4. Outside air temperature variation in winter season

Research Paper From China

5.1.1 System Operation in Typical Day

GSHP 1#

In the winter season, GSHP 1# provides heating and ventilation loads of the 1st and 4th floor. Supposedly, if the system operation in the coldest day could satisfy level of the room temperature comfort, it could meet the heating requirement of the building in the whole winter season as well.

The system operation in January 27th is analyzed when outside air temperature is about -7℃. The system works from around 7:00 am to 17:00 pm as shown in figure 5. Supply (T2out) and return (T2in) water temperatures of the secondary side was approximately 42 and 38℃ respectively, with about 4 degrees difference. Inlet (T1in) and outlet (T1out) water temperatures on the primary side are about 13 and 9℃, and the temperature difference is approximately 4℃. T1out is found about 0.7℃ temperature decrease after the one-day operation, which shows the system operated in an interval mode. About 320 kWh heat is supplied to the building. The hourly average coefficient of performance (COP) is about 3.9 on average that can be seen from figure 6.

The COP is a measurement of the performance of the system, and it is calculated from Eq.(1)

$$\mathrm{COP} = \frac{Q}{E} \qquad (1)$$

In which Q is the obtained heat or released heat rate, E is the electrical rate; and Q is calculated from Eq.(2)

$$Q = c\rho G(T_{i,out} - T_{i,in}) \qquad (2)$$

Where i represents 1 or 2 in the paper, which means primary or secondary side of the heat pump unit. c is the specific heat of the water, ρ is the density of water and G is the flow rate of water.

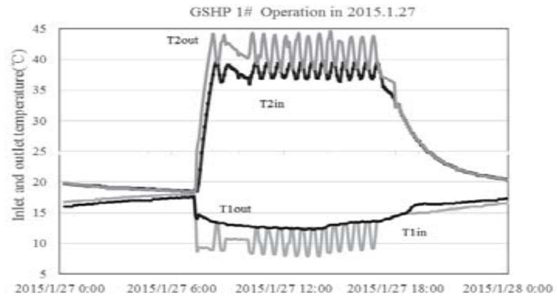


Figure 5 Inlet and outlet water temperature of GSHP 1# in 2015.1.27

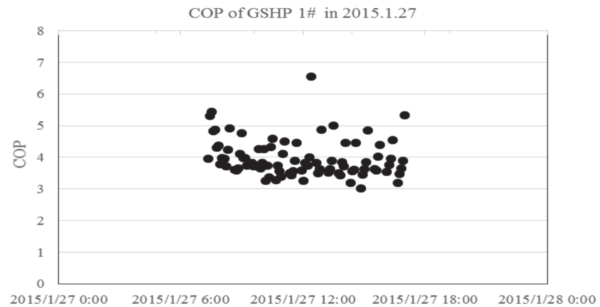


Figure 6 COP of GSHP1# in 2015.1.27

GSHP Unit2

GSHP 2# provides heating for radiation system of the second and third floor. Figure 7 presents inlet and outlet water temperature variation of the primary (T1in, T1out) and secondary side (T2in, T2out) of GSHP 2#. It is known from Figure 7 that HP 2# works from around 7:00 am to 14:00 pm in this day. Since outside temperature decreases quickly, T2in and T2out increase from 29℃ to 35℃ and 35℃ to 43℃ respectively about 5℃ temperature difference, and T1in and T1out is about 13 and 7℃, respectively. Totally 680 kWh heat is supplied to the building. The average hourly coefficient of performance (COP) in this day is about 4.6 as shown in Figure 8.

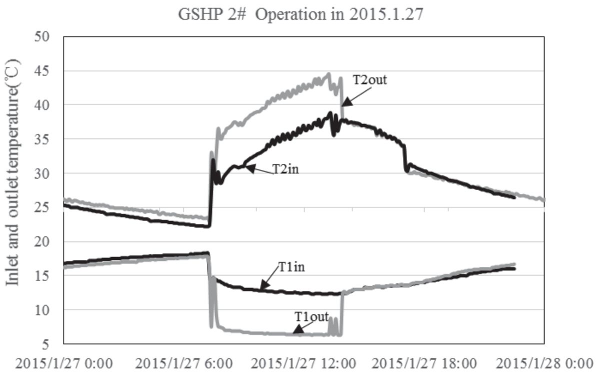


Figure 7 Inlet and outlet water temperature of GSHP 2# in 2015.1.27

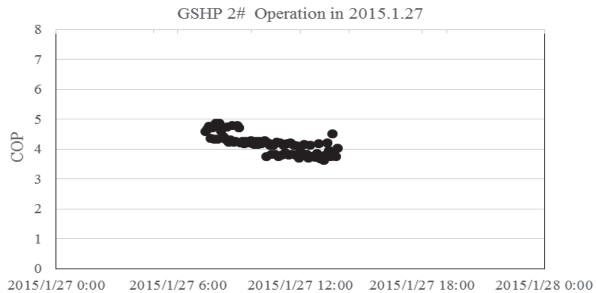


Figure8 COP of GSHP2# in 2015.1.27

Room temperature in working hours and outside air temperature variations are plotted in figure 9. The outside temperature goes down to -7.3 at around 7:00 and the room temperature is about 19.5 at the point. During the rest of the time room temperature keeps above 20℃,and at around 14:00, room temperature raise to about 25℃, even without GSHP system operation, room temperature keeps above 20℃ all the time.

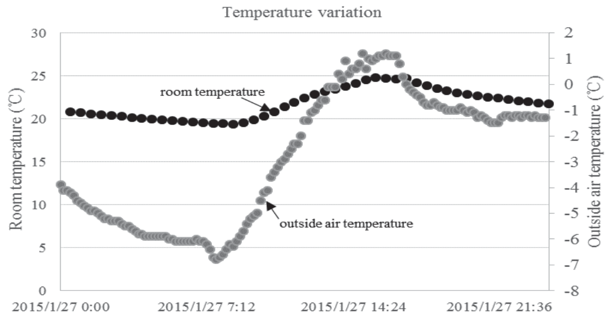


Figure 9 Room temperature and outside air temperature variation in January 27th (GSHP2#)

5.1.2 System Operation in Winter Season

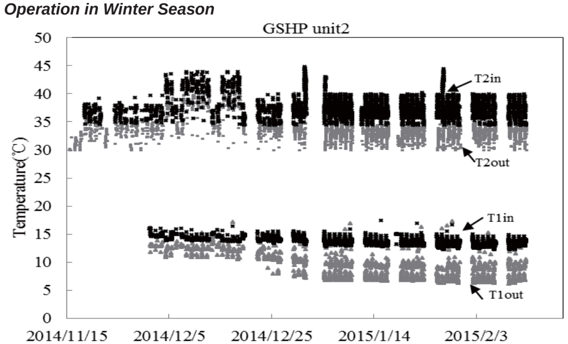


Figure 10 Water temperature variation of primary and secondary side of GSHP2# during winter season

The winter operation started from 15th November to end of March (Figure 10). GSHP 2# provides hot water for radiation system, When T2out and T2in is about 37 and 32℃ at the beginning. They increase to 43℃and 37℃ at mid of December, and downs to around 37 and 32℃ at the end of Dec. T1in and T1out water temperatures remains at 15 and 10℃ respectively at the beginning of the winter season, and decrease slightly as operation continues, that T1in keeps around 15, and T1out downs to around 8.5℃.

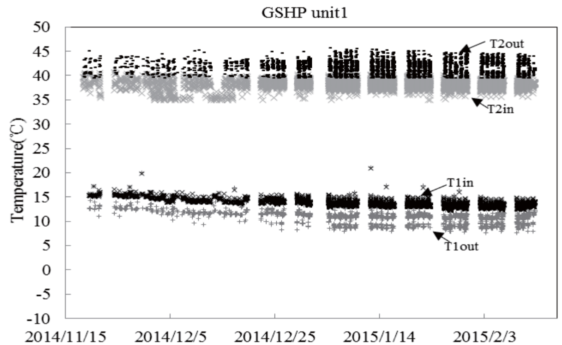


Figure 11 Water temperature variation of primary and secondary side of GSHP 1# during winter season

GSHP 1# provides hot water for fresh air system and room radiator (Figure 11), T2out and T1in are about 45 and 40℃ respectively which are 3℃ higher than those of the radiation system. T1in and T1out are about 15℃ and 10℃ respectively.

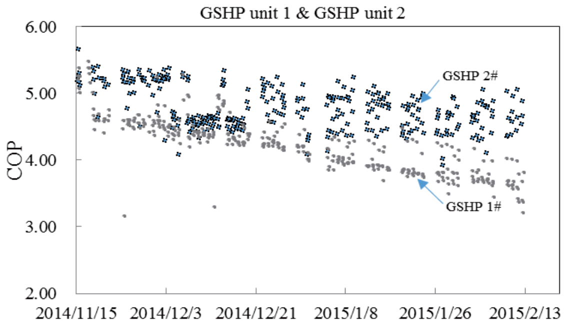


Figure 12 COP of GSHP1# and GSHP 2# in winter season

COP of GSHP 1# and 2# in the winter season are shown in figure 12. Black points represent COP of GSHP 2#, which decreases gradually as system operation continues from about 5.5 to 4.8 and the average COP was about 5.0. Grey points are COP of GSHP1#, which decreases faster than that of GSHP 2#, with an average about3.9.

5.1.3 Discussion

Since GSHP 2 serves radiation system for the radiation terminal that requires a lower supply water temperature (T2out)to the room in the winter season, and in this building, the supply hot water temperature is set at approximately 37℃ at the beginning, about 5 lower than GSHP1 unit which provides hot water for Fresh Air Unit (43℃) and room radiators (43℃) at the beginning of the winter season (this temperature will increase with outside air temperature decrease). It is known that a relative low supply hot water temperature is better for heat pump performance, as the two GSHP units have almost the same primary side inlet and outlet water temperatures, COP of GSHP2# is much higher than that of GSHP 1# unit. Figure 13 is the relationship between COP and secondary side outlet (supply to room, secondary T2out) water temperature. Data of T2out is get from heat Meter. About 3000

Research Paper From China

original data are used to plot this relation. Since COP is influenced by several factors such as soil temperature, room heating load, T1in, T2out, Heat pump et al, A simple relation could not be found by either one factor. By the measurement data, a rough and simple trend is found from the figure that COP increases with a decrease of T2out. Thus, a linear relation is shown in figure 13 and R2 is about 0.0177.

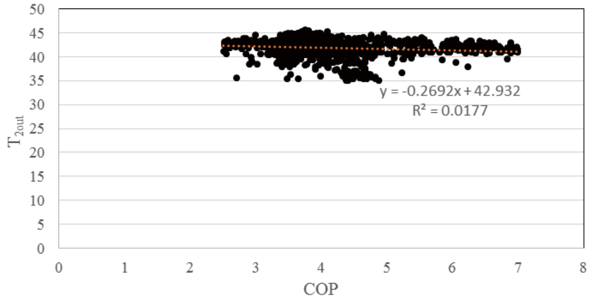


Figure 13 relationship between T2out and COP of GSHP1#

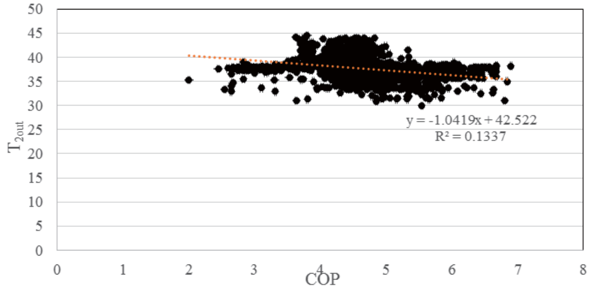


Figure 14 Relationship between T_{2out} and COP (GSHP2#)

Figure 14 is the relation between COP and T2out. Data of T2out gets from heat meter, about 3000 original data are used to plot this figure. A rough trend demonstrates that COP increase with a decrease of T2out, Thus a linear relation is shown in the figure and R2 is about 0.1337.

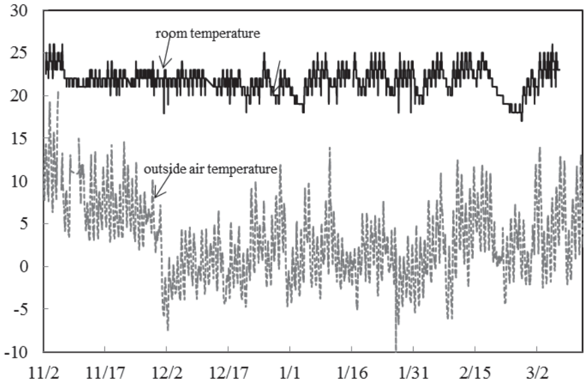


Fig 15 Outside and indoor air temperature variation in winter season

Outside and indoor air temperature variations in winter season are shown in Fig.15. The air temperature is above 20℃ during these periods no matter how low the outside air temperature is. In January, indoor air temperature raises gradually and is above 23℃ for the most of the time. Therefore, GSHP system operation, especially daily interval operation, could keep air temperature above the limitation.

5.2 Summer Season Operation

5.2.1 System Operation in Typical Day

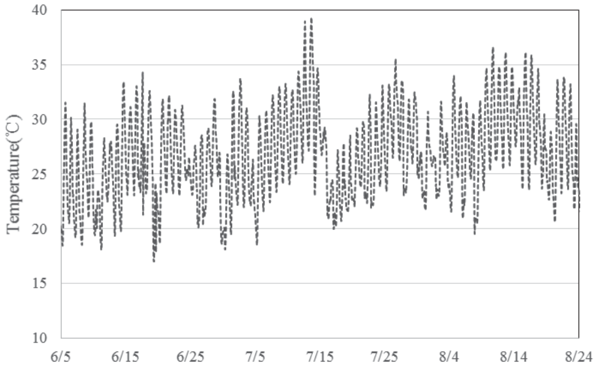


Figure 16 Outside air temperature variation in summer season

Outside daily air temperature in the summer season of 2015 is plotted in figure 16. The highest air temperature is around 40℃ and the lowest is around 22℃.

Solar thermal and absorption chiller is priority-of-use, and GSHP 1# serves as a backup. Since solar radiation is relatively sufficient in this summer, GSHP1# works only when absorption chiller rests. Additionally, GSHP2# works the same as its operation in winter. Under this operation principle,

System operation on July 15th is analyzed, in which GSHP 1# works half day (absorption chiller works the half day), and system operation in whole summer seasonal is analyzed later.

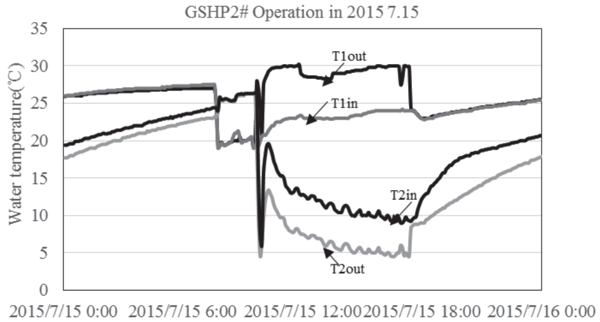


Figure 17 Primary and secondary side water temperature variation of GSHP 2# on July 15th

Figure 17 presents operation of GSHP2# on July 15th when outside air temperature is about 31℃, T1in and T1out are around 28℃and 23℃ respectively, with 5℃ temperature difference and about 1℃temperature increase after the one day operation. Moreover, after one day operation, T2out decreases from about 15℃ to about 10℃, about 5℃ decreases, and T2in varies in a similar pattern.

COP of GSHP 2# varies between 4 and 6 and about 4.8 as an average as shown in Figure 15. COP of GSHP 2# is marked as 4.6 at under the standard condition, which is inferred that operation of the system in the day is better than the standard condition.

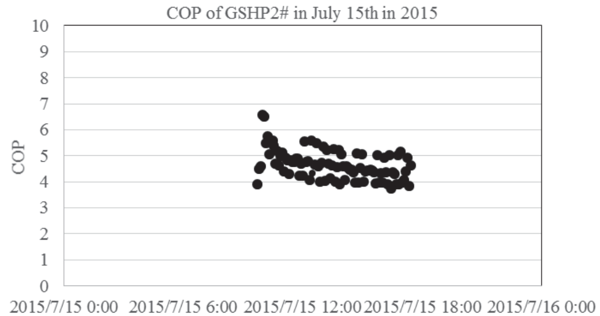


Figure 18 COP of GSHP 2#

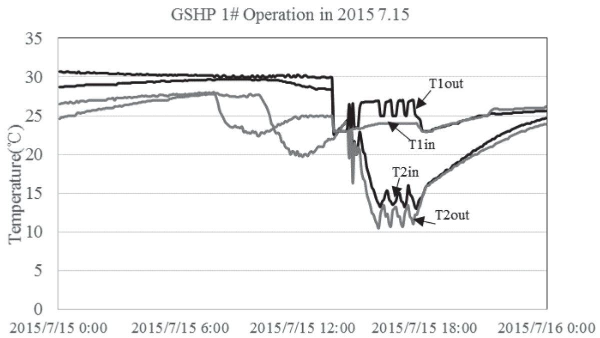


Figure 19 Primary and secondary side water temperature variation of GSHP 1# in July 15th

Figure 19 presents operation of GSHP 1# in the same day. Since absorption chiller operated in priority before 13:00, T1in and T1out of GSHP1# are around 28℃and 23℃ respectively, with 5℃ temperature difference. Inlet and outlet water temperatures increase 1℃ in the one day operation. T2in and T2out are around 12℃ and 15℃. COP of GSHP 1# is around 3.0 as shown in Figure 20.

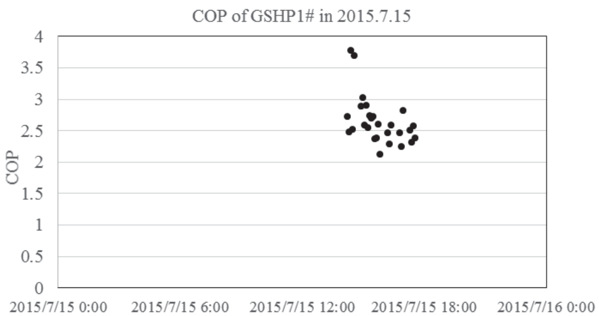


Figure 20 COP of GSHP 1# in July 15th

5.2.2 System Operation in Summer Season

Summer operation starts from June 1st to end of August. Figure 21 records water temperature variations of the primary and secondary side of GSHP 2# in this period, except data record missing from July 23rd to August 5th. GSHP2# provides chilled water for radiation system, with supply and return water temperatures of about 10 and 15℃ respectively, which is much higher than normal chiller equipment. While chilled water from the Heat Pump (HP) unit to the ground is about 27℃, after heat exchange, water enters into HP unit is at about 22℃.

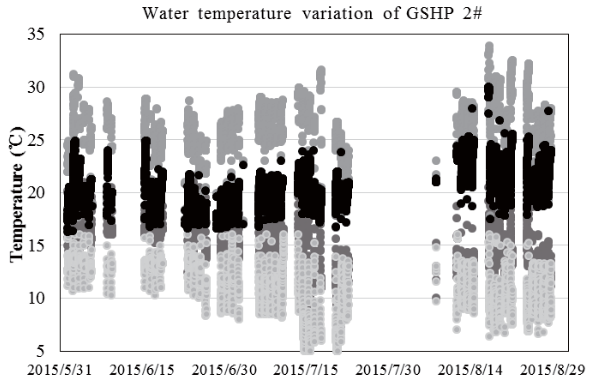


Figure 21 Operation of GSHP 2# in summer season

COP of the GSHP 2# in this summer is plotted in Figure 22, It is around 6.5 at the beginning, and decrease slightly into 5.0, with an average of about 5.4 in the whole season. GSHP 1# works for a few days, while seasonal operation of GSHP 1# are not introduced here.

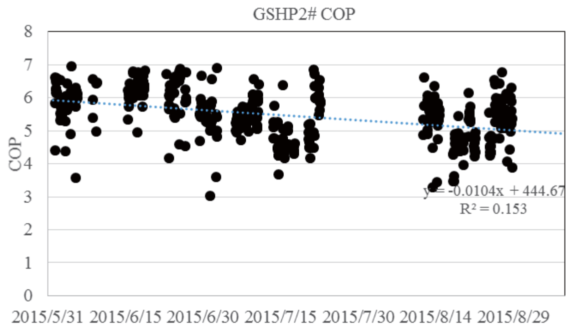


Figure 22 COP of GSHP 2# in summer season

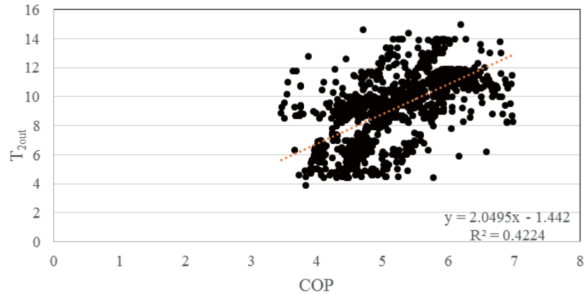


Figure 23 Relationship between water temperature and COP

Figure 23 shows the relationship between COP and T2out.The Y axis is T2out and the X axis is COP. About 3 months of data are arranged and about 1500 points are used to analyze this relation. A rough linear relation is found between the two parameters, that COP increased gradually with the increase of the secondary side outlet water temperature T2out.

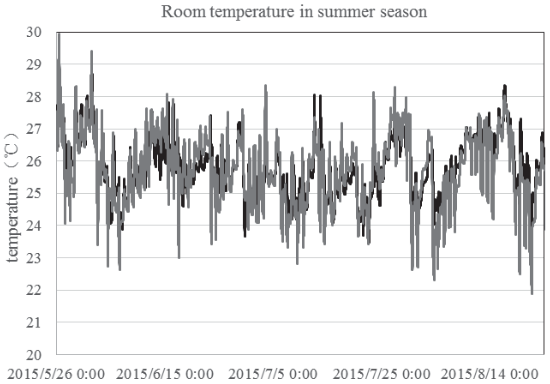


Fig 24 outside and indoor air temperature variation in summer season

Indoor air temperature in summer period is plotted in Fig 24. The temperature varies from 24℃ to 27℃ for most of the time. Since GSHP units stops working after 17:00 on weekdays, indoor room temperature shows a little fluctuation, but varies within 3 degrees. Therefore, good building envelops greatly benefit the maintaining of indoor temperature, and operation of GSHP unit also contributes to it.

5.3 Error Analysis of the Measurement Data

The uncertainties of the direct measured quantities can be obtained by the general principles for the determination of Type A and Type B uncertainties[21]. Since all the data used in this paper were measured only once, Type B uncertainty is utilized to analysis the data error. Table 2 and 3 gives the stated accuracies of the direct measured quantities in the project and the standard uncertainties of the direct measured quantities, respectively.

Table 2 Accuracy levels of the measuring instruments

Direct Measured Quantities	Measuring Instruments or Sensors	Measuring Range	Accuracy
inlet water temperature	PT1000	0.0-99.9	±0.1
outlet water temperature	PT1000	0.0-99.9	±0.1
water flow rate	magnetic flow meter	0-9999.99m3	±0.01
electricity consumption	three-phase electric energy meter Acrel DTSD1352	\	≤0.5s/d
soil temperature	PT1000	0.0-99.9	±0.1

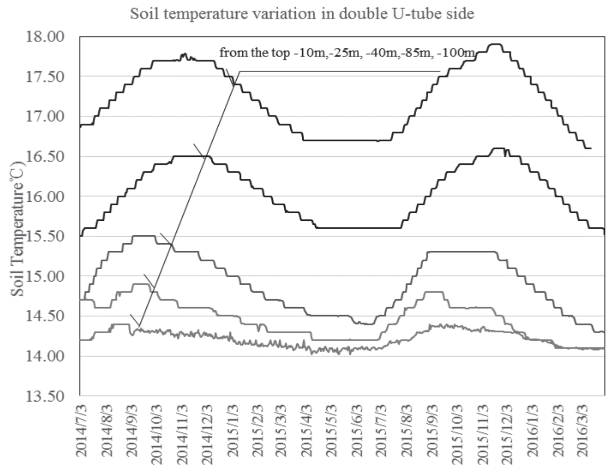
The Combined uncertainty of heat transfer rate and COP is calculated by method RSS[21]

Table 3 Standard uncertainties of the direct measured quantities in the project

number	measured quantities	symbols of uncertainties	units	distribution	types-B Standard uncertainties	value
1	$T_{1in}/T_{1out}/T_{2in}/T_{2out}/T_{soil}$	U(T)	℃	Uniform	±0.1/√3	0.058
2	G_f	$U(G_f)$	m3/h	Uniform	±0.01/√3	0.006
3	E	U(E)	kW	Uniform	±0.5/√3	0.289
					combine uncertainties	value
4	Q	U(Q)	kW		$\sqrt{U^2(T)+U^2(Gf)}$	0.058
5	COP	U(COP)	/		$\sqrt{U^2(T)+U^2(Gf)+U^2(E)}$	0.294

6. Soil Temperature Variation

Ground is the heat source and sink of the energy system. The heat is extracted or released to the ground through the borehole tube. There are 70 boreholes with a total length of 5000m distributed in the open space around the building. Double and single borehole tubes are arranged for experiments. Water temperature variation at the inlet and outlet side is analyzed previously. The soil temperature variation around the tube is monitored as well to check the impact of system operation to the ground.



.Figure 25 Soil temperature variation in double U-tube side

Soil temperature at -10, -20, -40, -80 and -100m in double U-tube side are monitored and plotted in Fig 25. During almost 2 years of the energy system operation, soil temperature appears a fluctuation variation with season switch. Soil temperature increases in the summer season, but remains constant in the following months and decreases in the winter season.

During the first year from 2014/7/3 to 2015/7/3, soil temperature in depth of -10, -20, -40,-85 and -100m increases about 0.8,1,0.8,0.3 and 0.2℃, respectively, and decreases to its original or even lower level after the winter season operation. Compared with the second summer period, soil temperature at the some depths has an even higher increase than in the first summer period. For instance, as depths of -10m, the soil temperature increases about 0.8 and 1.3℃ in the summer of 2014 and 2015 respectively, but the soil temperature at depth of -40m and -85m in 2015 changed almost to the same extent as it in 2014, which verified that soil temperature at lower depth is more sensitive to the solar radiation. It is also found from the figure that at depth of -40m soil temperature are more easily increase to the peak in summer and downs to the valley in winter than the temperature variation at other depth which inferred that heat change happens mainly in the middle part of the U-tube.

Due to a good soil temperature variation, we could conclude that the released and extracted heat amount kept in a good balance which promise a good environment of good GSHP operation condition, it also infers that the operation of the system is relatively good so far.

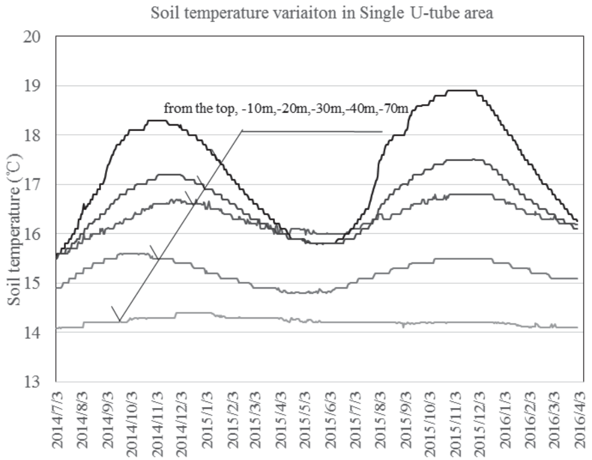


Figure 26 Soil temperature variation in southern side

Two observation wells are placed in single U-tube field, marked as North A and B in figure 2. Since single U-tube is 60m deep, soil temperature of well A at depth of -10m, -20m, -30m, -40m and -70m are measured, and their variation with seasons are shown in figure. 27. The soil temperature shows a higher fluctuation along with seasons in different depth. For instance, at depth of -10m, it increases about 2.2 and 2.8℃ respectively in two summer seasons compared to original temperature; and in the depth of -20m, it varies about 1.6℃ and 1.7℃, respectively. While, it varies about 1.0℃ and 0.8℃respectively at depth of -30m, and it varies 0.6℃ at depth of -40m at and 0.2℃respectively compare to its original soil temperature in two summer seasons. Nevertheless, they could return to their original levels after the winter season operation.

7. Contribution of the GSHP to the Nearly Zero Energy Building

About 30000 kWh heat is provided to the building by heat pump2 in the winter season. The floor area of 2nd and 3rd is roughly 2000m2, daily operation hour is roughly 10 hours, system operation about 100 days in this winter, so the heat load of the heat pump 2 is about 14.6W/m2.

There are solar thermal, WLHP, WS-VRV and GSHP system worked together to provide heating and cooling of the building, and it is calculated that there are about 64400kWh heat is supplied totally in winter season from Nov. 2014 to Mar. 2015, and 48500kWh heat is directly supported by GSHP system, if contribution ratio is calculated by ration of suppled heat and required heat, then contribution ratio of GSHP is about 75.3. While in summer season, there are totally 3000kWh cold is provided by GSHP units, and 51000kWh cold is provided by the energy system, so the contribution ratio is about 57.8%.

Research Paper From China

GSHP worked as main energy system of the building, and it performed very well during the operation.

8. Conclusion

The paper mainly introduces a GSHP system operation and its performance in a nearly zero energy building. The system operation during Nov. 1st 2014 to Sep. 30th 2015 is analyzed based on measurement data.

GSHP system works splendidly in this building, that average COP in the winter season is about5.0 and 3.9, and is about 5.4 in the summer season. GSHP units works for two different terminal systems, which is found from monitoring data that GSHP unit for radiation system has a better performance than that works for fan coil unit and radiator in the winter season, since radiation system needs a lower supply of water temperature in winter and higher supply of water temperature in the summer which is just good for heat pump performance in both winter and summer.

The room temperature maintains above 20℃,and variates between 20 and 23℃ in the whole winter season, and it fluctuates from 25 to 27℃ during summer season（including non-working hour）by the operation of the energy system. The steady room temperature variation and good indoor environment. infer a relatively good operation of the energy system.

The soil temperature in different depths are monitored and they goes to the peak in the summer, and could recover prominently in the winter season. After two years' operation, the soil temperature in different depths recover to their original level, which provide a good operation environment for GSHP system operation.

The application of GSHP system in nearly zero energy building is a promising roadmap. Good envelop and airtightness provide a relatively low indoor heating and cooling load, which provides advantages for combination of GSHP and radiation system. The performance of the GSHP is relatively good, that even 10 hours' operation during weekday and non-operation at weekends could satisfy the requirement of the room environment.

ACKNOWLEDGEMENT

This research is supported by financial support from the National Key Technology R&D program in the 12th Five Year Plan of China Key Renewable energy utilization to achieve higher energy efficiency target(No. 2014BAJ01B03)

Reference

[1] Zhihua Zhou, LeiFeng, Shuzhen et al, The operational performance of "net zero energy building": A study in China, Applied Energy 177(2016) 716-728

[2]Muhammad Waseem Ahmad, et al, Building energy metering and environmental monitoring –A state –of –the art review and directions for future research, Energy and Buildings 120 (2016) 85-102

[3] Limei Shen, Xiwang Pu, Yongjun Sun et al, A study on thermoelectric technology application in net zero energy buildings, Energy, 113(2016) 9-24

[4] Sheng Zhang, Pei Huang, Yongjun Sun, A multi-criterion renewable energy system design optimization for net zero energy buildings under uncertainties, Energy, January 2016, pages 654-665

[5] Shicong Zhang, et al, Operation performance in cooling mode of a ground source heat pump of a nearly –zero energy building in the cold region of China, Renewable Energy 87(2016) 1045-1052

[6] Huai Li, Katsunori Nagano, Yuanxiang Lai, Kazuo Shibata, Hikari Fujiimoto. Evaluating the performance of a large borehole ground source heat pump for greenhouses in northern Japan, Energy 2013. Volume 63, pages 387-399.

[7] Weijuan Sun, Pingfang Hu, Fei Lei, Na Zhu, Zhangning Jiang, Case study of performance evaluation of ground source heat pump system based on ANN and ANFIS models, Applied Thermal Engineering, Volume 87,5 August 2015,Pages 586-594

[8] Neng Zhu, Jingmei Wang, Performance evaluation before and after solar seasonal storage coupled with ground source heat pump, Energy Conversion and Management, Volume 103, October 2015, Pages 924–933
[9] Yujin Nam, Ho-Byung Chae, Numerical simulation for the optimum design of ground source heat pump system using building foundation as horizontal heat exchanger, Energy 73 (2014)933-942
[10] Molina Giraldo N, Bayer P, Blum P. Evaluating the influence of thermal dispersion on temperature plums from geothermal system using analytical solutions. Int J,Therm Sci 2011;50;1223-31
[11] X.Q, Zhai, X.W.Cheng, R.Z.Wang, Heating and cooling performance of a minitype ground source heat pump system. Applied Thermal Engineering, xxx (2016) xxx-xxx, article in press
[12] B.Hu,Y.Li et.al Extremum seeking control for efficient operation of hybrid ground souce heat pump system, Renewable Energy 86 (2016) 332-334
[13] N.Zhu,J,Wang, Li,liu, Performance evaluation before and after solar seasonal storage coupled with ground source heat pump, energy Convers.Manage.103(2015) 924-933
[14] P.Shen,J.R.Lukes, Impact of global warming on performance of ground source heat pumps in US climate zones, Energy Convers. Manage. 101(2015) 632-643.
[15] Huai Li , Katsunori Nagano, Yuanxinag Lai, A new model and solutions for a spiral heat exchanger and its experimental validation. International Journal of Heat and Mass transfer, Volume 55 Issues 15-16,July 2012, Pages 4404-4414
[16] Giuseppe Emmi, Angelo Zarrella, Michele De Carli, Antonio Galagaro, An analysis of solar assisted ground source heat pump in cold climates, Energy Conversion and Management, Volume 106, December 2015, Pages 660-675
[17] Shicong Zhang, YiQiang Jiang, et.al. Operation performance in cooling mode of a ground source heat pump of a nearly-zero energy building in the cold region of China, Renewable Energy 87(2016) 1045-1052
[18] Rui Fan,Yiqiang Jiang, Yang Yao et.al. A study on the performance of a geothermal heat exchanger under coupled heat conduction and groundwater advection, Energy 2008. Volume 32, Pages 2199-2209.
[19]Aymeric Girard, Eulalia Jadraque Gago, Tariq Muneer, Gustavo Caceres, Higher ground source heat pump COP in a residential building through the use of solar thermal collectors, Renewable Energy, Volume 80, August 2015, Pages 26-39
[20] Mohamad Kharseh, Mohammed Al-Khawaja et al, Potential of ground source heat pump systems in cooling-dominated environments: Residential buildings, Geothermics, Volume 57, September 2015, Pages 104–110
[21] Measurement Uncertainty Analysis Principles and Method, NASA Measurement Quality Assurance Handbook-ANNEX3. 2010-07-13

Load Variations with Seasonal Conditions Affected to Coefficient of Performance of Air to Water Heat Pump

Amornrat Kaewpradap, Piyatida Trinuruk and Surachai Sanitjai

Department of Mechanical Engineering, Faculty of Engineering, King Mongkut's University of Technology Thonburi, Thailand

Introduction

Air to water heat pump is a device that transfers heat energy from air source to water sink. Heat pump consists of four main components such as compressor, evaporator, condenser and expansion devices. Moreover, air to water heat pump is denoted as technology for producing hot water with higher energy efficiency. Nowadays, heat pumps are supported by Ministry of Energy in Thailand to apply widely because of high efficiency, decrease of emission and energy conservation. Regarding heat pump efficiency, the ratio between thermal energy and electrical energy as coefficient of performance (COP) was defined by heating process. Following European standard EN255-3 [2] which consists of heating-up period, hot water tapping period, determination of reference hot water temperature, standby and determination of the maximum quantity of usable hot water in single tapping. During hot water tapping period, there is tapped equivalent to 15.0 L/min of outlet water flow rate. Coefficient of performance for tapping process (COPt) was defined the performance of heat pump [3]. Study of the seasonal performance rating of heat pump water heater was discovered that the range of ambient air temperature hot water temperature and humidity affected to COP [4]-[6]. However, COP obtained from previous study was analyzed by heating process which was not reflected to actual application. To investigate the performance of heat pump with actual utilization load, COPt based on EN255-3 standard is analyzed for this study. As the variation of temperature among different seasons were effected to COP, it is necessary to investigate load variations such an outlet hot water temperature with ambient temperature and air humidity and from air to water heat pump.

Methodology

The experiment was operated based on EN255-3 standard which the load variations as outlet hot water temperature and the variation of temperature among different seasons as ambient temperature and air humidity from air to water heat pump were studied. The experimental conditions are adjusted at the range of ambient temperature between 18-34oC and %RH=50-80.

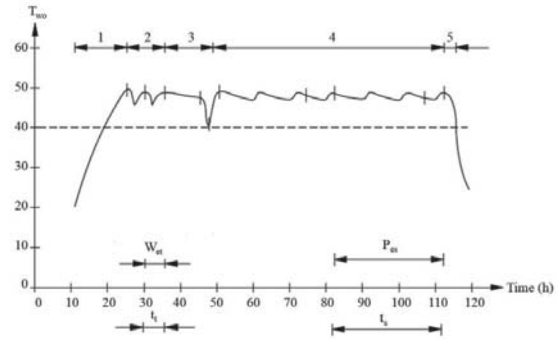


Fig.1 Operating cycle of heat pump based on European standard (EN255-3).

The heat pump is set as inlet water temperature at 25oC and outlet water temperature interval between 40-55oC. The operating cycle of heat pump based on European standard EN255-3 is shown in Fig. 1. The first stage is heating-up period, which is started from turned on heat pump until turned on thermostat. The second stage is tapping process for determination of COPt, which volume of hot water is tapped equivalent to half of nominal volume of hot water storage tank, reheated until the water temperature reach the setting point. The third stage is called a determination of reference hot water temperature which volume of hot water is tapped until the hot water temperature below 40ºC. The fourth stage is standby period, which is a determination of standby power input. To obtain standby power input, Outlet water temperature in storage tank is dropped to 5oC, heat pump is turned on to setting point and it is called 1 cycle. The operating for number of cycles should not be operated less than 24 hours and at least 3 cycles. Final stage is a determination of the maximum quantity of usable hot water in single tapping, the volume of hot water is tapped until the outlet water temperature below 40ºC after standby period. Corresponding to European standard EN255-3 [2], the determination of COPt is calculated from measured of outlet water energy (Qt), electrical energy input for tapping process (Wet), standby power input (Pes) and tapping time (tt).

Results

Experimental results based on EN255-3 standard

The results show five stages of heat pump testing based on EN255-3 as heating-up period, hot water tapping period, determination of reference hot water temperature, standby and determination of the maximum quantity of usable hot water in single tapping. Figure 2 shows the time series of experimental results at Ta=18 oC with %RH = 60%. Following EN255-3 standard, outlet water temperature flow rate of tapping hot water and power input (P) were analyzed as shown in Fig.3. The results show 5 stages of operating cycle of heat pump experimented by EN255-3 standard. Firstly outlet water temperature was increased from 25oC -55oC which affected to higher power while almost constant water tapping flow rate was obtained for heating-up stage. Secondary, followed by EN255-3 standard, two times of water tapping and less 10% difference of obtained outlet water energy were experimented. As the results, heat pump was operated when water was tapped and outlet water temperature decreases to 50oC (setting point temperature). Following tapping process corresponding to the actual load, thus COPt was calculated to evaluate performance of heat pump.

Effects of ambient temperature (Ta) related with air humidity (%RH)

As the results based on EN255-3 as shown in Fig.2, tapping time, outlet water energy, electrical energy input for tapping process and COPt were analyzed. To study the effects of load variations, ambient temperature were increased from 18 to 34oC and air humidity was raised from 50% to 60%, 70% and 80%. The result shows increasing of ambient temperature brought about lower tapping time and electrical energy input data , however outlet water energy were almost constant with ambient temperature variations. It was because of higher thermal energy caused by increase of ambient temperature which was absorbed by refrigerant in evaporator and affected to decrease of tapping time. Moreover, higher COPt was slightly affected by higher air humidity due to the droplet deposition rate on evaporator increased with air humidity, which released latent heat was greater than sensible heat [7]. As the results, the increase of ambient temperature enhances COPt due to increase of heat source induced higher COPt followed by thermodynamics laws as shown in Fig.3.

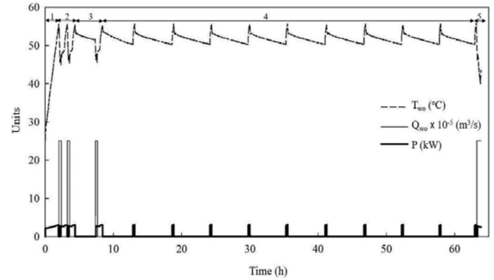


Fig.2 Time series at Ta=18oC with %RH=60% based on EN255-3.

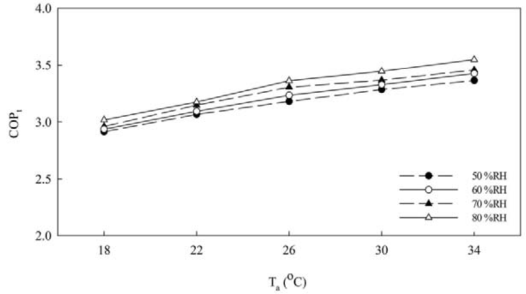


Fig.3 Relations between Ta and COPt for %RH=50%, 60%, 70% and 80%.

Effects of ambient temperature (Ta) related with outlet hot water temperature (Two)

This result shows relations between Ta and tt for Two = 40 oC, 43 oC, 43 oC, 49 oC, 52 oC and 55 oC. As the above results, lower tapping time was induced by higher ambient temperature, moreover it was affected by lower outlet water temperature owing to decrease of required outlet water energy outlet water energy. Figure 4 shows relations between Ta and Wet for Two =40 oC, 43 oC, 43 oC, 49 oC, 52 oC and 55 oC. When ambient temperature was higher with lower outlet water temperature, Electrical energy input for tapping process is lower due to lower load of compressor. The overshot electrical energy input was observed at specified ambient temperature for each outlet water temperatures and resulted to diminish COPt significantly as illustrated in Fig.5.

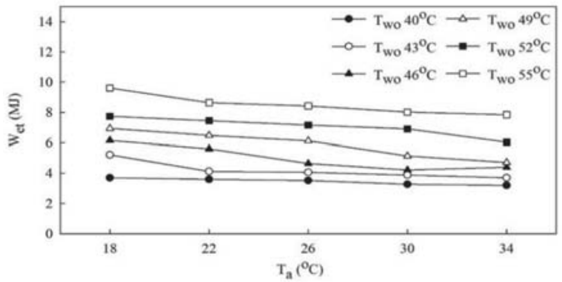


Fig.4 Relations between Ta and Wet for Two = 40□C - 55□C.

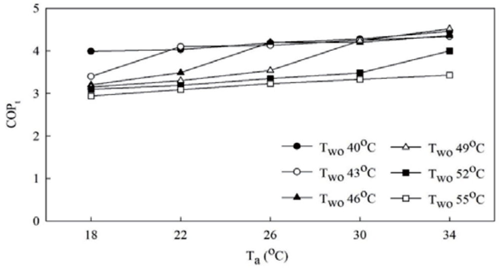


Fig.5 Relations between Ta and COPt for Two =40, 43, 43, 49, 52 and 55□C.

Conclusion

Based on EN255-3 standard, coefficient of performance for tapping process (COPt) was defined from performance of heat pump during tapping process. As the variation of temperature among different seasons, the load variations of ambient temperature, air humidity and outlet hot water temperature from air to water heat pump (11kW) were studied to obtain COPt. This study focused on the effects of load variations from air to water heat pump by variation of Ta = 18oC, 22oC, 26oC, 30oC and 34oC. Moreover, the variation of ambient temperature was experimented with increase of Two = 40oC, 43oC, 46oC, 49oC, 52oC and 55oC and %RH = 50%, 60%, 70% and 80%. The results showed increase of ambient temperature enhanced COPt because lower electrical energy input was induced by higher ambient temperature. Moreover, higher COPt was affected by higher air humidity owing to the droplet deposition rate on evaporator increased with air humidity, which released latent heat was greater than sensible heat [6]. The results were shown that decrease of outlet water temperature affected to higher electrical energy input and enhanced higher COPt. This study could be concluded that higher ambient temperature, air humidity and lower outlet water temperature enhanced to higher COPt. Especially, two significant parameters such as ambient temperature with specified outlet water temperature, the boundary of maximum COPt = 3.99, 4.10, 4.20, 4.24 and 4.52 for Ta = 18 oC, 22 oC, 26 oC, 30 oC and 34 oC for air to water heat pump was obtained.

References

[1] Heap, R.D., 1983, Hear pump, 2nd ed., E. & F.N. Spon. London, p.3.

[2] BS EN255-3, 1997. Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors – Heating mode, Part 3: Testing and requirements for marking for sanitary hot water units.

[3] Amornrat Kaewpradap, Piyatida Trinuruk and Surachai Sanitjai, 2015, Study of Energy Performance of Heat Pump used in Thailand, Proceedings of The 6th TSME International Conference on Mechanical Engineering, Regent Beach Cha-am Hotel, Petchburi, Thailand, pp.92.

[4] G.L. Morrison, et al., Seasonal performance rating of heat pump water heaters, University of New South Wales, Solar Energy. Vol.76, 2004, pp.147-152.

[5] J.J. Guo, et al., Experimental research and operation optimization of air-source heat pump water heater, Shanghai Jiao Tong University, Applied Energy. Vol. 88, 2011, pp.4128-4138.

[6] Hae Won Jung, et al., Performance comparison between a single-stage and a cascade multi-functional heat pump for both air heating and hot water supply, Korea University, International Journal of Refrigeration. Vol. 36, 2013, pp.1431-1441.

[7] Bu Xu, et al., Experimental investigation of the performance of micro channel heat exchangers with a new type of fin under wet and frosting conditions, Shanghai Jiao Tong University, Applied Thermal Engineering. Vol. 89, 2015, pp.444-458.

Asian Heat Pump Thermal Storage Technologies Network

To promote energy savings and combat global warming, there is an urgent need to spread efficient heat pump and thermal storage technologies on the demand side. Countries in Asia, which are enjoying rapid economic growth, should coordinate with one another to spread this technology. Five to ten years from now, Asia will become a global economic powerhouse and heat pump technologies will play a considerable role in all sectors. Asian countries will therefore need to address common issues and problems that have already been faced in Europe and North America. Concerning the building of connections and networks among countries, it is essential to share information on diffusion policies, technology trends, applications, etc., and then to make incremental improvements. Further, situations which can or should be handled through collaboration should be handled flexibly, on a case-by-case basis, with the collaboration of all countries. In order to encourage the use and development of heat pump and thermal storage technologies in Asian countries we have established AHPNW in 2011.

Participating Countries and Entities

CHINA: China Academy of Building Research (CABR)

INDIA: The Energy and Resources Institute (TERI)

JAPAN: Heat Pump and Thermal Storage Technology Center of Japan (HPTCJ)

KOREA: Korea Testing Laboratory (KTL)

VIETAM: Hanoi University of Science and Technology (HUST)

THAILAND: King Mongkut's University of Technology Thonburi (KMUTT)

INDONESIA: Heating, Cooling & Thermo Fluids Technology Indonesia (HCTFTI)

Please visit our website for more information.

⇒http://www.hptcj.or.jp/e/ahpnw/tabid/571/language/en-US/Default.aspx