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AHPNW NEWSLETTER

SPRING HAS COME!!

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ABSTRACTS OF EACH PAPER

OUTLINE OF THE BUILDING ENERGY STANDARD IN JAPAN AND EVALUATION OF HEAT PUMPS IN THE STANDARD

Primary energy consumption in the commercial and residential building sectors in Japan represents approximately 34 % of the country's total energy consumption, and has been increasing steadily. With the aim of decreasing energy consumption, a new building energy standard was implemented in 2013: the Government has announced that it will become mandatory by 2020. This article presents an outline of the standard and how energy performance of heat pumps is evaluated in it.

DEVELOPMENT OF ENERGY EFFICIENCY STANDARDS FOR HEAT PUMP IN THAILAND

This study is to review the development of suitable energy efficiency criteria for heat pumps and update the status of draft MEPS and HEPS for heat pump in Thailand. The minimum energy efficiency criteria for heat pumps and to promote high efficiency heat pump usage are enforced following 20-year energy efficiency development plan (A.D 2011-2030) from Ministry of Energy. The draft MEPS and HEPS had finished and currently it has been submitted to Energy Efficiency Standards Sub-Committee and under the approval process. Appropriate MEPS and HEPS are reported in the draft that the criteria MEPS of heat pump which is either manufactured or sold in Thailand could be not less than COP_t = 2.4 and HEPS could be determined as $3.0 \leq COP_t \geq 4.0$.

A STUDY ON THE PERFORMANCE PREDICTION OF AIR TO WATER HEAT PUMP

An air source heat pump system for hot water supply was developed and tested in the calorimeter chamber. The cycle simulation to predict the performance of the heat pump system was conducted in standard and cold climate region conditions. Vapor injection was applied to the heat pump operated in the standard ambient air conditions and its effects on the performance of the heat pump were investigated precisely. Cascade cycle operated in cold climate region conditions was analyzed through simulation, and then the simulation results were verified with the experimental results.

ABSTRACTS OF EACH PAPER

Application of Ground Source Heat Pump System in a Nearly Zero Office Building

A GSHP system was installed as one of the energy system at China Academy of Building Research in Beijing, China. This paper describes and analyzed its operation on cooling season from July 15th to 30th August with aid of energy management system, including ground-side water temperature and flow rate, chilled water temperature and flow rate, heat release amount of both ground side and the GSH

GENERAL

■Korea Heat Pump Industry Forum has been established

In this year a new non-profit organization, which is called as “Heat Pump Industry Forum” has been established in Korea in order to support heat pump industry and encourage heat pump technology nationally. Last 13 May an inaugural general meeting was held with more than 40 private and corporate members in L-Tower, Seoul.

Source; KLT, AHPNW

■ Kobe Symposium 2014 Provides Valuable Information on Low-GWP Refrigerants

Organized by the Japan Refrigeration and Air Conditioning Association (JRAIA), the International Symposium on New Refrigerants and Environmental Technology 2014 (Kobe Symposium 2014) was held at the Kobe International Conference Center on November 20 and 21. About 490 people, the second highest ever, attended this 11th edition of the Symposium. The two-day program included keynote addresses, technical sessions, and poster sessions.

In his opening address, Ichiro Hongo, chairman of the JRAIA, touched on the laws relating to the rationalization of use and control of fluorocarbons as well as planning to convert refrigerant use in various countries. In addition to the legal regulations and technical standards, he also covered many of the pressing issues faced by the refrigeration and air conditioning industry.

Masafumi Ohki, director of the Fluoride Gases Management Office, Ministry of Economy, Trade and Industry (METI), who was invited to be a keynote speaker, gave an address on ‘New Policy Measures and Financial Support in Japan that Manage HFCs and Promote Alternatives’

Another keynote address was given by Dr.-Ing. Rainer Jakobs of the Information Centre on Heat Pumps and Refrigeration, IZW e.V. in Germany, on the theme of ‘Recent Technologies and Developments in European Heat Pumps.’

Source; JARN, January 25, 2015

■Establishment and first workshop of compiling group of China national standard technical specification for cool storage air conditioning system

According to *the notice of printing ‘the plan of drawing up and revise engineering construction standard’ by Ministry of Housing and Urban-Rural Development*, the industry standard *technical specification for cool storage air conditioning system JGJ158-2008* , compiled by China Academy of Building Research, was involved in the plan. The establishment and first workshop of compiling group was held in Beijing in April the 13th, 2015. Forty specialists attended the meeting, including leadership from Standard and Quota Institute of Ministry of Housing and Urban-Rural Development, executive from CABR and Building Environment and Energy Standardization Technical Committee of Ministry of Housing and Urban-Rural Development, and staff of compiling group.

Source; CABR, AHPNW

POLICY

■ Direct subsidy project for investment and improvement and improvement by the machinery, material and equipment to energy conservation.

Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy, has launched a direct subsidy project to promote energy conservation for the fiscal year 2015 (B.E 2558). The objective of the project is to encourage the entrepreneur reduce costs by implementing energy measures while maintaining the quality of the product offer. The reduction of the cost will enhance the competition with the other. However, some measure need to be invested for improvement and modification low energy efficiency machinery, material, and equipment to high energy efficiency. The entrepreneur which needs the support on the investment grant even on multiple measures can send the application on the amount not exceeding Baht 3,000,000 (three million baht) under the condition of the term of payback period less than 7 years. In this fiscal year, DEDE will be implementing with a grant of 500 million baht.

Source; KMUTT, AHPNW

MARKET

■ Air Conditioner Market Takes Hit from Falling Yen

On December 5, the value of the Japanese yen fell sharply in trading on the New York foreign exchange market, closing at 121.50 yen to the dollar, the lowest the Japanese currency has fallen in about seven years and four months, since the last low recorded on July 20, 2007. The yen has dropped sharply to the 120-yen range after trading for about two years at the 80-yen range since 2012.

While many analysts view the weaker yen as a positive for the Japanese economy as a whole, the sharp depreciation is putting a question mark on the 'golden rule' of success for Japanese air conditioner manufacturers, namely producing air conditioners at overseas factories and shipping them to Japan for sale.

The currency depreciation has now made products produced in Japan more cost competitive, while air conditioners made overseas have lost some of their cost competitiveness compared to a few years ago. Will this trend cause Japanese air conditioner manufacturers to gear up shifting production back to Japan?

Source; JARN, January 25, 2015

■ JRAIA Announces Japanese Domestic Shipment of AC&R Equipment

The Japan Refrigeration and Air Conditioning Industry Association (JRAIA) announced the domestic demand forecast (shipment quantities) of 14 main models in 2014-2016 period based on the voluntary statistics of air conditioning and refrigeration (AC&R) appliances by the members of the association.

This survey is conducted for the purpose of preparing the reference data in surveying the demand trend of the AC&R industry. This demand forecast is carried out annually as the activity to collect and provide information of the statistical survey committee, but this time, the review of the time of questionnaire to the member companies and re-examination of the related economic indicators per model were made to enhance the forecast accuracy by statistical method adopting rational explanatory variables.

Source; JARN, March 25, 2015

■LG Electronics has furnished with full GHP lineup - To launch the world's highest efficiency GHP(Gas Driven Heat Pump) of the 30HP class

LG Electronics (www.lge.co.kr) has launched a new 30HP GHP of the world's highest efficiency, and thereby strengthens the domestic heat pump market. LG Electronics has launched the 30HP 'GHP Super 2' which is new GHP. The 30HP class has 85kW of cooling capacity and 95kW of heating capacity, which is the world's largest level of capacity. LG Electronics is the unique company among domestic manufacturers to produce and develop products with its own technology.

Source; KTL, AHPNW

ACTIVITES

■The 4th Meeting of AHPNW was held in Beijing, China

The wider promotion of the high efficient heat pump and thermal storage technologies on the demand side is an urgent task in promoting energy conservation and prevention of global warming. Especially in Asian countries where the energy consumption is continuously increasing due to the rapid economy growth, to cooperate with each other countries is highly essential.5 countries such as China, India, Japan, Korea, and Vietnam gathered together on October 2011 and established Asian Heat Pump Thermal Storage Technologies Network (AHPNW). Up to now we have held 3 international meeting and published 3 newsletters. And this year, Thailand has joined as a new member.

Recently, 4th meeting was held in Beijing, China on 26th-27th Nov. 2014.
On the 1st day, open workshop was held under the theme “Shaping the better future through Heat Pump Utilization “and over 20 people attended.

Source; HPTCJ News press

■Primary energy saving effect by increasing diffusion of Heat Pumps in Japanese market

Heat Pump & Thermal Storage Technology Center of Japan (member of AHPNW), a general incorporated foundation that endeavours to promote heat pump and thermal storage systems that contribute greatly to measures for saving energy and mitigating global warming and are recognized as the equipment to use renewable energy in Europe, has unveiled its forecast for diffusion of heat pump equipment till FY2040 and estimated primary energy saving effects in conjunction with widespread use of such equipment and systems.

Source; HPTCJ News press

■Heat Pumps Workshop in India

Heat Pump & Thermal Storage Technology Center of Japan (member of AHPNW) has participated the workshop on “Japanese Experience on Promoting Heat Pump Systems for Energy Efficiency” and made public relations for diffusion of heat pump equipment in India.

Source; HPTCJ News press

OHTERS

■Japan Promoting AC Standardization in Southeast Asia

In collaboration with the Japan Air Conditioning and Refrigeration Testing Laboratory (JATL), the Institute of Energy Economics, Japan (IEE) is actively moving forward with the Innovation Technology Research Association (INOTEK) project. The International Standard Innovation Technology Research Association (IS-INOTEK) is a technology research association established in January 2012 to perform R&D, extend support, and give technological instruction concerning international standardization and certification projects. It consists of 18 companies, one university, one independent corporation, and six groups. In cooperation with Southeast Asian countries, ISINOTEK is currently proceeding with international standardization projects for air conditioners and refrigerators.

Source; JARN, December 25, 2014

■ Samyang Eco-Energy, receives ‘Green Technology’ Certification by ‘Tandem Heat Pump design technology using turbo heat pump’

Seawater air conditioning technology was recognized by Green-technology to improve installing existing heat pump, and utilizing the high efficiency large turbo pump.

Samyang Eco-energy (CEO, Yunho Kim), new energy specialist company, noticed that they received Certification of 'Green Technology' by tandem heat pump design technology using turbo heat pump.

Source; KTL, AHPNW

OUTLINE OF THE BUILDING ENERGY STANDARD IN JAPAN AND EVALUATION OF HEAT PUMPS IN THE STANDARD

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ABSTRUCT

Primary energy consumption in the commercial and residential building sectors in Japan represents approximately 34 % of the country's total energy consumption, and has been increasing steadily. With the aim of decreasing energy consumption, a new building energy standard was implemented in 2013: the Government has announced that it will become mandatory by 2020. This article presents an outline of the standard and how energy performance of heat pumps is evaluated in it.

KEY WORDS: Heat pump, Building Energy Standard

Outline of the Building Energy Standard

In Japan, the Energy Conservation Act was implemented in 1979 and, based on it, the first Building Energy Standard was enforced in 1980. The standard consisted of two parts: one for commercial buildings, and the other for residential buildings. The commercial buildings standard evaluated the energy performance of the building envelope and five types of energy demand, for air conditioning, lighting, ventilation, hot water and elevators, separately. The residential standard evaluated only the performance of the building envelope. These standards were substantially revised in 2013, and introduced a new common index "Designed Primary Energy Consumption" (GJ / year) (Fig. 1), to represent the energy performances of both commercial buildings and residential buildings. When constructing or renovating large buildings, with floor areas of 300 m^2 and more, reporting the energy performance based on the standard is mandatory. On the other hand, reporting is voluntary for small buildings. However, buildings which apply the standard can receive various benefits such as tax benefits and subsidies. Although these energy standards are at present voluntary for some buildings, compliance with them will be mandatory by 2020.

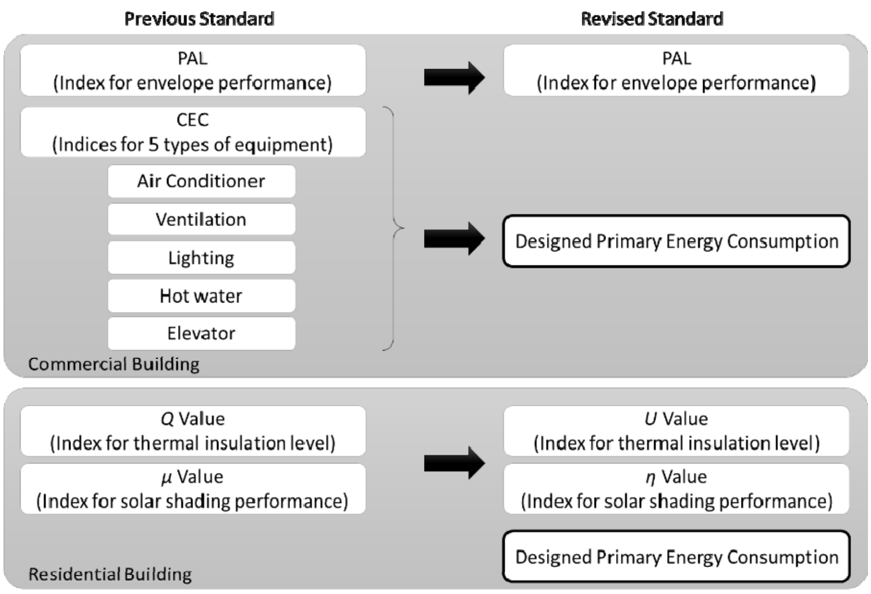

Figure 1 Indices for energy performance in the standards

Design primary energy consumption

In order to comply with the standard, the design primary energy consumption calculated for a applied building should not exceed the reference primary energy consumption. Both the design and the reference primary energy consumptions are based on the same method of calculation. The design primary energy consumption must be calculated based on the building envelope and equipment specification of the building, while the reference primary energy consumption must be calculated based on the building envelope and equipment specification defined in the standard, which are of equivalent performance to the corresponding features of the building as normally used in Japan (Fig. 2).

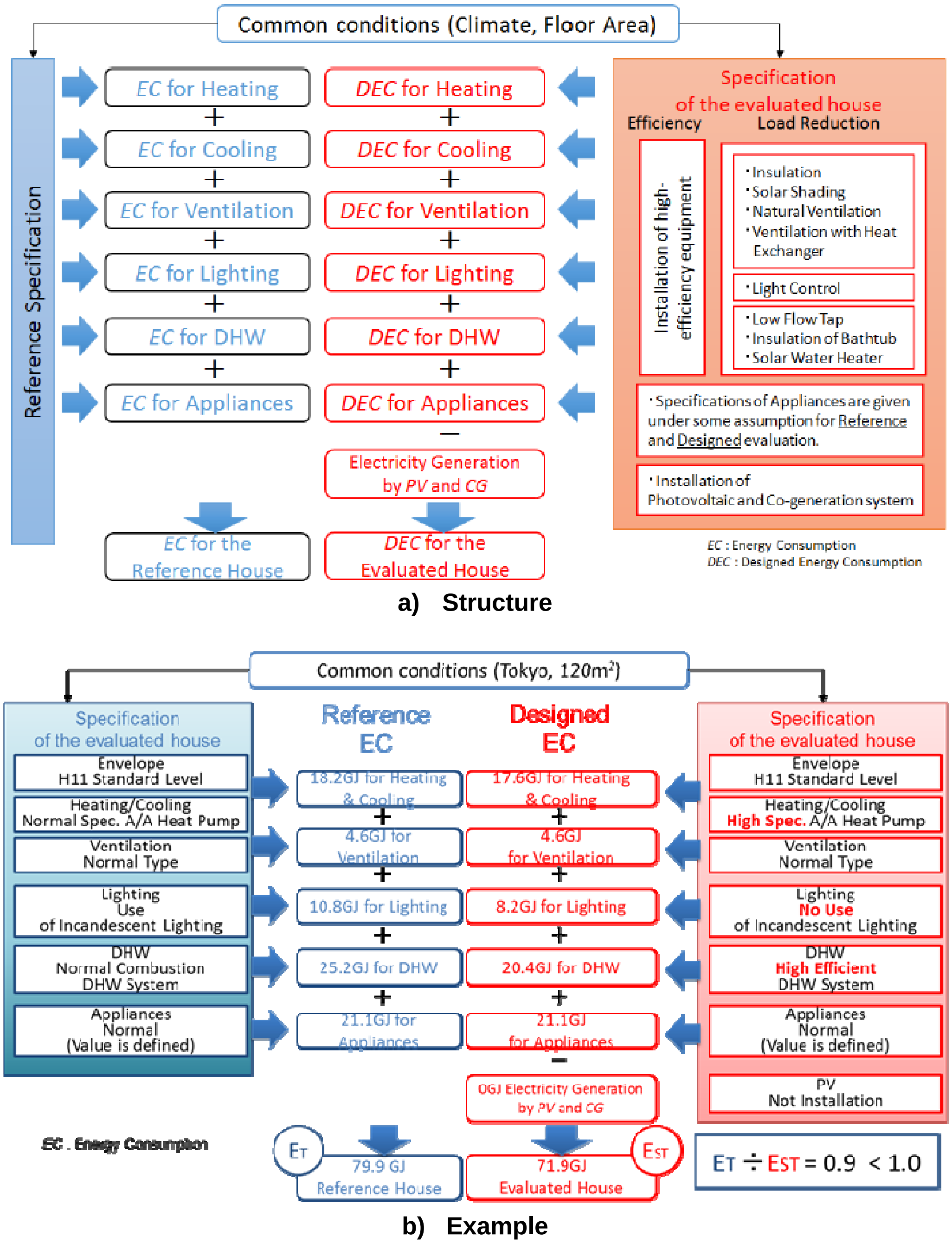

Figure 2 Reference and design primary energy consumption*

** For residential buildings. For commercial buildings, the energy consumption for elevators is added.*

Occupants' behaviour, such as how length of occupation per day, and duration and frequency of use of the building services, is previously defined for each building/space usage in the standard, and it can be therefore said that the design primary energy consumption is a kind of benchmark test value for energy conservation at the design stage. Methods for calculating the design primary energy consumption are published in textbooks and on the web page of the Building Research Institute (BRI) (Fig. 3).

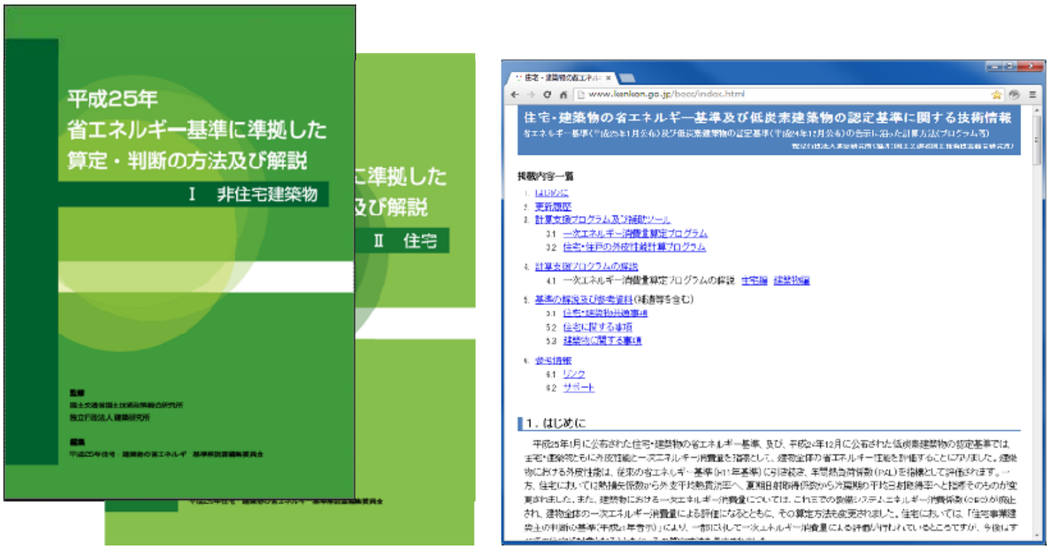

Figure 3 Textbooks and BRI web page* for the standard

* *http://www.kenken.go.jp/becc/*

Since these methods are very complex, web-based calculation programmes have also been developed and are available on the BRI home page (Fig. 4). The programmes are hosted on web servers: local computers simply send the input data to the servers and receive the results from them, which means that designs can be calculated by any computer, including tablet-type devices. Applicants normally calculate and prepare application forms by utilizing these programmes.

Figure 4 Calculation program, application form and labelling

Estimation of energy performance of heat pumps

Energy consumption for space heating and cooling is calculated on an hourly basis, with design primary energy consumption being the sum of these hourly energy consumptions over a period of one year (Fig. 5). Since the efficiency of heat pumps depends strongly on the outdoor temperature and the heating or cooling load, efficiency curves for various systems are defined in the standard. These efficiency curves were developed based on various experiments and simulations (Fig. 6) in a research project by BRI and the National Institute for Land and Infrastructure Management (NILIM). Outdoor temperatures are also defined in the standard. Building areas in Japan are divided into eight climate zones, based on the number of heating degree-days: the tables of standardised hourly outdoor temperatures are updated for each revision. The hourly heating and cooling loads are calculated based on the data given in the standard for the building envelope performance and the intended use of the building or space.
Based on this calculation, the differences in the efficiency of heat pumps between the different climate zones can be considered. The reduction in average efficiency resulting from mismatching of the heat pump capacity with the heat load, such as overcapacity of the equipment, can also be evaluated. Additionally, operating conditions such as climate and building usage are identical for various types of the equipment (e.g. gas boilers, heat pumps, electric heaters), thus enabling users and designers to compare the energy performance of any types of equipment's by using this calculation program.

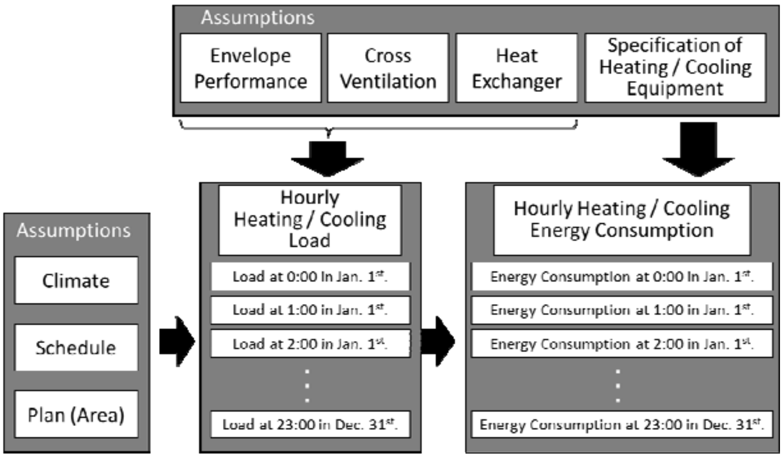

Figure 5 Method of calculating space heating / cooling energy consumption

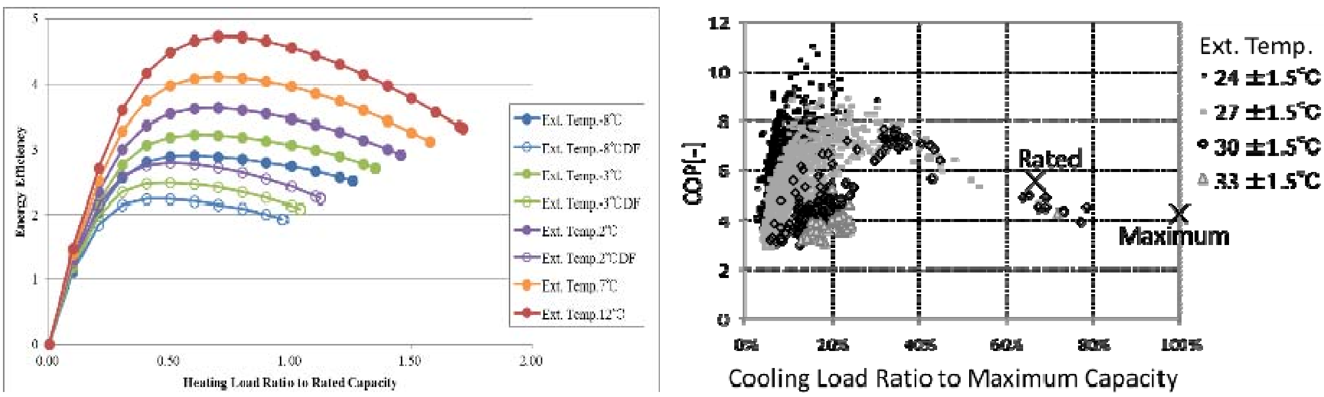

Figure 6 Examples of heat pump efficiency curves
(Left: Curves for calculation / Right: Experimental results)

CONCLUSION

This report described the outline of the recently revised building energy standard and its energy calculation tools, and also described how to estimate the energy performance of heat pumps. There are many indices to represent the energy efficiency of heat pump such as APF, COP and EER. These indices can be measured values under rated test conditions, or calculated values assuming the given operating conditions. Alternatively, designers can investigate the effects of changing various building characteristics such as envelope performance, climate, utilisation of cross ventilation and heat exchangers, and can also compare the performance of various types of heating systems such as combination boilers or electric heating. We can say that indices based on a specific and defined set of conditions, such as APF, COP and EER can be used for comparing the performances of heat pumps of the same type, and so promoting competition in terms of technological development. "Designed Primary Energy Consumption" can also be used by designers and users for designing and selecting the equipment for a given building.

DEVELOPMENT OF ENERGY EFFICIENCY STANDARDS FOR HEAT PUMP IN THAILAND

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Abstract

This study is to review the development of suitable energy efficiency criteria for heat pumps and update the status of draft MEPS and HEPS for heat pump in Thailand. The minimum energy efficiency criteria for heat pumps and to promote high efficiency heat pump usage are enforced following 20-year energy efficiency development plan (A.D 2011-2030) from Ministry of Energy. The draft MEPS and HEPS had finished and currently it has been submitted to Energy Efficiency Standards Sub-Committee and under the approval process. Appropriate MEPS and HEPS are reported in the draft that the criteria MEPS of heat pump which is either manufactured or sold in Thailand could be not less than $COP_t = 2.4$ and HEPS could be determined as $3.0 \leq COP_t \geq 4.0$.

Keyword: MEPS, HEPS, Energy efficiency standard, Draft

1. Introduction

The framework of Thailand's energy policy is scoped on five issues: enhancing energy security, promoting alternative energy as national agenda, promoting energy efficiency, fair and stable energy pricing, and environmental protection. Therefore, the Energy Conservation Promotion (ECP) Fund in Thailand has been established. The ECP Act has been used since 1992, and issue NO. 2 was effective in 2007. The ECP Act, under the Section 23, empowers the Thai Government with the regulatory authority to improve energy efficiency of appliances, machinery and equipment. The Act under the Section 40 also mentions that a producer or distributor of high efficiency machinery or equipment, or materials to be used in the energy conservation programs, shall have the right to request for promotion and assistance. Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy has planned to establish Minimum Energy Performance Standards (MEPS) to be both voluntary and mandatory standards by collaboration with Thai Industrial Standards Institute (TISI) to eliminate low energy efficient appliances and equipment from the market, while High Energy Performance Standards (HEPS) is required in the Ministerial Regulations to be a voluntary program.

Heat pump is also one of targeted appliance to enforce MEPS criteria and promote to high efficiency heat pump usage following 20-year energy efficiency development plan (A.D. 2011 - 2030) from Ministry of Energy. To determine an appropriated MEPS and HEPS for heat pumps in Thailand, the project "A study of heat pump for setting up Ministerial Regulation draft in energy efficiency following the Energy Conversion Promotion Act (No.2) B.E 2550" was launched to acquire the supporting information for the Ministerial Regulation draft as following the requirement of drafting process. Therefore, the paper is to review the process for developing energy efficiency standard of heat pump in Thailand.

2. The Process for Setting Draft MEPS and HEPS

To understand clearly on the process for setting draft MEPS and HEPS in Thailand, the different of MEPS and HEPS could be provided in detail. For both draft MEPS and HEPS, DEDE is empowered to set energy efficiency standards under ECP Act, Section 23. After setting the draft, only HEPS is enforced by DEDE, while MEPS is enforced by TISI. MEPS can be voluntary program only in the early stage, but finally, it is authorized by TISI to establish as the mandatory program.
The products which are achievable MEPS, will receive an endorsement label, called a TIS mark [1]. There are two different types of the certification marks, voluntary and mandatory certification marks, which are represented with the different color as illustrated in **Fig.1**.

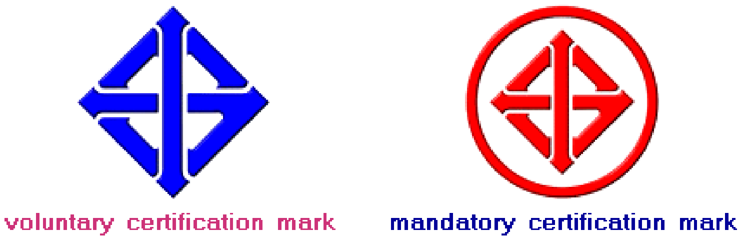

Fig. 1 Two different Certification marks in Thailand

For Voluntary Energy Efficiency Standards, HEPS program can be implemented for both electrical and non-electrical equipment on a voluntary basis and use labelling program to be a representative for high energy efficiency products. There are two types of labelling programs. The first label is for household appliances which are responsible by EGAT, as shown in **Fig.2 (a)**, such as air-conditioners, refrigerators, etc. including energy efficient lighting equipment under Demand-Side Management program (DSM). Another label, as shown in **Fig.2 (b)**, is for industrial and non-electric products which are responsible by DEDE.

(a) Household appliances (b) Non-electric and industrial products

Fig. 2 Energy Label in Thailand

Fig. 3 shows the process of setting draft HEPS and MEPS. This process takes around one year, by starting with hiring a consultant by DEDE to conduct technical research. Then, DEDE has the authority to monitor the project; hence, technical committee is set. The technical research study is an importance process to get the support information. Therefore, the framework of technical report must include with: the study in market sharing, standards, testing method, and etc. After collecting enough data, technical committee will start the meeting and has the authority to approve the testing method, numbers and models of sampling products, and draft MEPS and HEPS. Simultaneously, all stakeholders are invited to participate in public hearing of draft MEPS and HEPS. Finally, draft MEPS and HEPS will be edited as following the stakeholders' recommendation and the comment from technical committee.

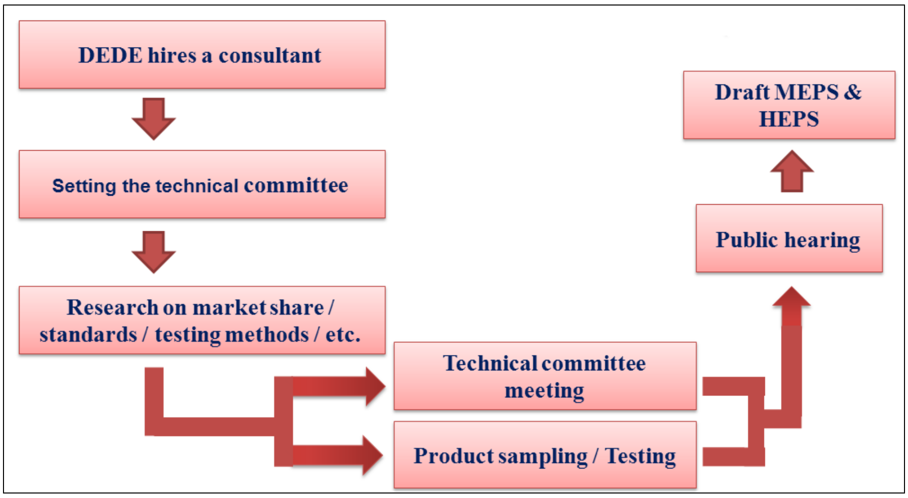

Fig. 3 Process of setting draft MEPS and HEPS

3. The Criteria of MEPS and HEPS

The testing results from sampling products and secondary data are statistically analyzed and plotted normal distribution curve. The criterion of MEPS is set that 3% of low energy efficient products should be failed from the market, while 20% of high energy efficient products should be promoted as HEPS, as illustrated in **Fig. 4**. However, the standard of MEPS and HEPS can be adjusted according to the approval of technical committee or the recommendations from public hearing.

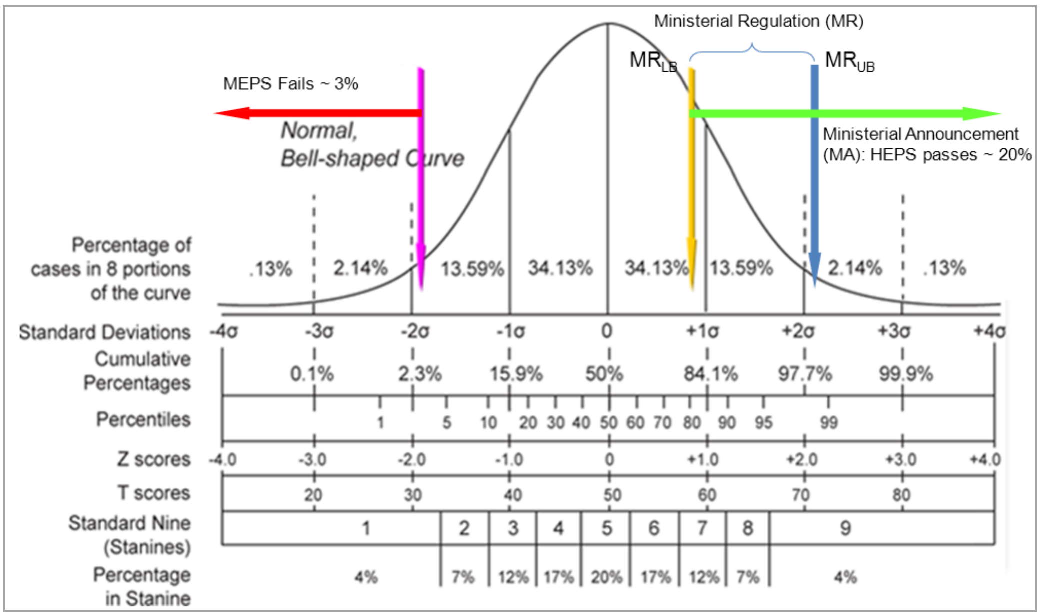

Fig. 4 Criteria of MEPS and HEPS

4. Law Procedure

When draft MEPS and HEPS have been completed, it will be preceded to the law process which will take time around 2 - 3 years. Draft MEPS and HEPS will be submitted to Energy Efficiency Standards Sub-Committee, which permanent secretary of Ministry of Energy is a chairman of this committee. When the drafts are approved in this step, only draft MEPS is sent to TISI while draft HEPS is preceded by DEDE. Then, drafts HEPS will pass to Ministry of Energy Law Committee, and proceed to National Energy Policy Committee (NEPC), Cabinet, Office of the Council of State of Thailand (OCST), and signed by Energy Minister. Finally, draft MEPS and HEPS are announced in Royal Gazette. Those are all process for drafting MEPS and HEPS.

5. Study of Heat Pump in Thailand [2]

King Mongkut's University of Technology Thonburi (KMUTT) had been hired by DEDE as a consultant to proceed the setting draft procedure to determine the suitable energy efficiency criteria for heat pumps in Thailand which will be reported in draft MEPS and HEPS. The methodology of the study included with as follows:

5.1 Reviewing

The market information of heat pump in Thailand and other countries, as well as the market trend, were reviewed. By market information from year 2008 – 2012, 1,603 of heat pumps were sold with the size range of 0.5 - 100 kW_{th} and the most popular size was 25 kW_{th}. Global standards related to the heat pump were examined and studied in the detail of testing procedure.

Fig. 5 Test room for heat pump at KMUTT

5.2 Determining

Proper testing standard for heat pump in Thailand was selected. The requirements in a selected standard were accompanied to construct a test room and set the testing conditions. EN255-3 was chose as the most suitable standard. Test conditions for heat pump in Thailand were specified and followed the testing procedure of EN255-3. The test room for heat pump energy efficiency test was built for supporting energy efficiency criteria test method. **Table 1** shows the comparison of test conditions between EN255-3 and adopted test conditions for Thailand.

Table 1 the comparison of test conditions between EN255-3 and for Thailand

Test Conditions	EN 255-3 standard	Test condition for Thailand
Dry bulb temperature in test room ($T_{drybulb}$)	15 °C	35 °C
Wet bulb temperature in test room ($T_{wetbulb}$)	12 °C	24 °C
Dry bulb of outlet air temperature	N/A	> 30 °C
Feed water temperature	15°C	25 °C
Set point of water temperature at Cut-off condition	Following spec.	55 °C
Set point of water temperature at working condition	Following spec.	50 °C
Flow rate of water utilization	15.6 l/min	15.6 l/min

5.3 Sampling

Available heat pumps in Thailand's market in year 2013 with the size of 4.5–36 kW_{th} were selected with a limit number to be used as the representative of this research. 13 models of heat pump were chose with the variety of types and sizes for high efficiency test. In this testing, test range of heat pump was specified at 0.5 - 36 kW_{th} which overcomes the most population of heat pumps application in Thailand.

5.4 Defining the results

Energy efficiency test of 13 heat pumps were conducted at test laboratory at King Mongkut's University of Technology Thonburi. It was found that COP_t value was in the range of 2.4 – 3.7 with COPt in average at 3.0. The analytical results of all 13 heat pumps in energy efficiency indicted that the different sizes of heat pumps did not affect to the magnitude of energy efficiency. Therefore, the energy efficiency criteria are the same for all heat pump sizes.

5.5 Identifying MEPS and HEPS

Fig. 6 presents the results of COP_t of 13 heat pump models. COP_t of 13 heat pumps is analyzed with the statistical method to get a normal distribution curve of COP_t as shown in **Fig. 7**. Then, the criteria of MEPS and HEPS which was mentioned in section 3 are implemented as followed the policy of energy efficiency standard. 3% of the available heat pumps are failed the MEPS criteria, while 20% of available heat pumps are passed the HEPS criteria. In this study, it was found that 3% of the curve is addressed at COP_t of 2.4 and 20% of the distribution curve is at COP_t of 3.2. From this research, it concluded that the criteria MEPS of heat pump which is either manufactured or sold in Thailand could be not less than COP_t = 2.4 and HEPS could be determined as 3.0 ≤ COP_t ≥ 4.0. Those values, as summarized in **Table 2**, are proposed to Ministry of Energy for Thai Industrial Standard and Ministerial Regulation of high efficiency heat pump.

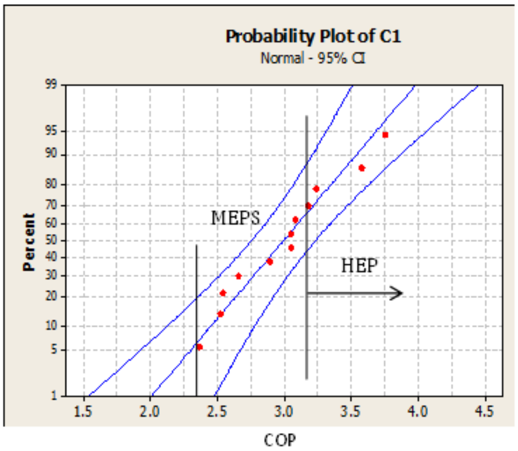

Fig. 6 The results of COP_t of 13 heat pump models

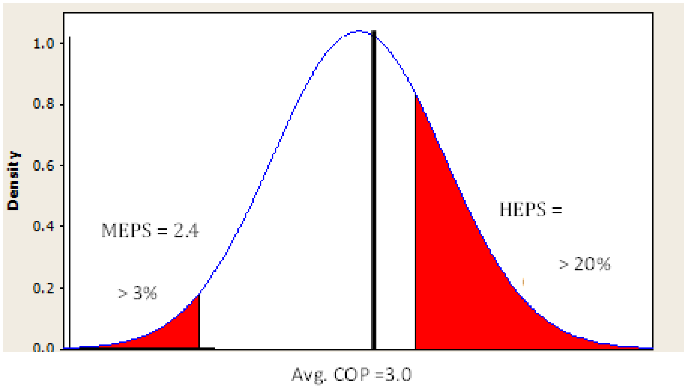

Fig. 7 The criteria of MEPS and HEPS

Table 2 COP_t for Draft MEPS and HEPS for heat pump in Thailand

Standard	COP_t
MEPS	$\geq$ 2.4
HEPS	$3.0 \leq COP_t \leq 4.0$

5.6 Public hearing

An opening seminar for distributing information obtained in this project for heat pumps to stakeholders about suitable heat pump energy efficiency criteria in Thailand was conducted under the requirement of setting draft process. The recommendation from that open seminar by all stakeholders is included in the final report of this project.

6. Conclusions

Now, draft MEPS and HEPS of heat pumps for Thailand has been submitted to Energy Efficiency Standards Sub-Committee and under the consideration.

7. References

1. Thailand Greenhouse Gas Management Organization (TGO), Thailand Environment Institute Foundation (TEI), 2013, *"ES&L implementation status and MEPS information for BRESL products in Thailand and Other Countries*", January 2013.
2. DEDE, 2013*, "A study of heat pump for setting up Ministerial Regulation draft in energy efficiency following the Energy Conversion Promotion Act (No.2) B.E 2550*".

A Study on the Perforamce Prediction of Air to Water Heat Pump

Ook Joong Kim, Korea Institute of Machinery & Materials, Republic of KOREA

Abstract

An air source heat pump system for hot water supply was developed and tested in the calorimeter chamber. The cycle simulation to predict the performance of the heat pump system was conducted in standard and cold climate region conditions. Vapour injection was applied to the heat pump operated in the standard ambient air conditions and its effects on the performance of the heat pump were investigated precisely. Cascade cycle operated in cold climate region conditions was analysed through simulation, and then the simulation results were verified with the experimental results.

Introduction

Since a heat pump has a high carbon dioxide reduction effect compared to a direct-fired system such as boiler, it has been given the limelight as a heating system. According to such a trend, a heat pump is included in the efficiency improvement field of the green energy road map[1], which aims at practical plans for green growth in the Republic of Korea; therefore, much research and development has been conducted regarding it. Also, KEPCO (Korea Electric Power Company) has conducted a feasibility study to substitute a late-night electrical hot water boiler for an air-to-water heat pump for producing hot water, and is attempting to supply the heat pump on a trial basis. Also, KEPCO has suggested the performance standards for the commercialized model of the heat pump[2].

This study is related to the development project of the hot water heat pump for substituting a late-night electrical hot water boiler by KEPCO. The study was aimed to treat the cascade cycle designed to produce a hot water above 80°C. For the air heat source type of hot water heat pump used for substituting a late-night electrical hot water boiler (that is now under development in KEPCO), the hot water discharge temperature varies from 50°C to 80°C, for which KSCOP (Korea Seasonal Coefficient of Performance) is suggested. The KSCOP is utilized in the calculation by applying weighting factors, and the performance is measured in a state in which ambient air is changed from the standard conditions (dry bulb at 7℃ and wet bulb at 6℃) to -15℃. In each of the operating conditions, a more than certain level of heating capacity compared to the rated amount must be secured. Therefore, in order to develop a heat pump system equipped with such conditions, it is required to apply the cascade cycle as described in the foregoing, and it is important for securing the performances in the ambient air and water outlet conditions including the standard conditions, the cold climate region conditions, and the frosting & defrosting conditions. In this study, the performance test was conducted for the system manufactured for the hot water heat pump for substituting a late-night electrical hot water boiler, a cycle simulation that could simulate test results was conducted, and the simulation results were verified. The heat pump operating state in cold climate region conditions at -15℃ was predicted by utilizing the verified cycle simulation results. Also, the effects of vapor injection[3, 4] are expected to increase performance together with an increase in capacity.

Experimental apparatus and methods

The schematic diagram of the air-to-water heat pump for substituting a late-night electrical hot water boiler, which was developed in this study, is shown in **Figure 1** below. The heat pump was configured with the cascade cycle in which R410a and R134a refrigerants were applied to the low and high stage, respectively, and a fine-tube heat exchanger applied with louver was installed as the heat exchanger to the air side. A refrigerant flow was adjusted by the electronic expansion valve (EEV) and a plate heat exchanger was used as the condenser that exchanges heat with water. The KSCOP test conditions and the weighting factors of KSCOP according to regions for the hot water heat pump for substituting a late-night electrical hot water boiler, which are suggested by KEPCO, are listed in **Table 1**. Above SCOP_C 2.5 from Table is required for a commercialized model.

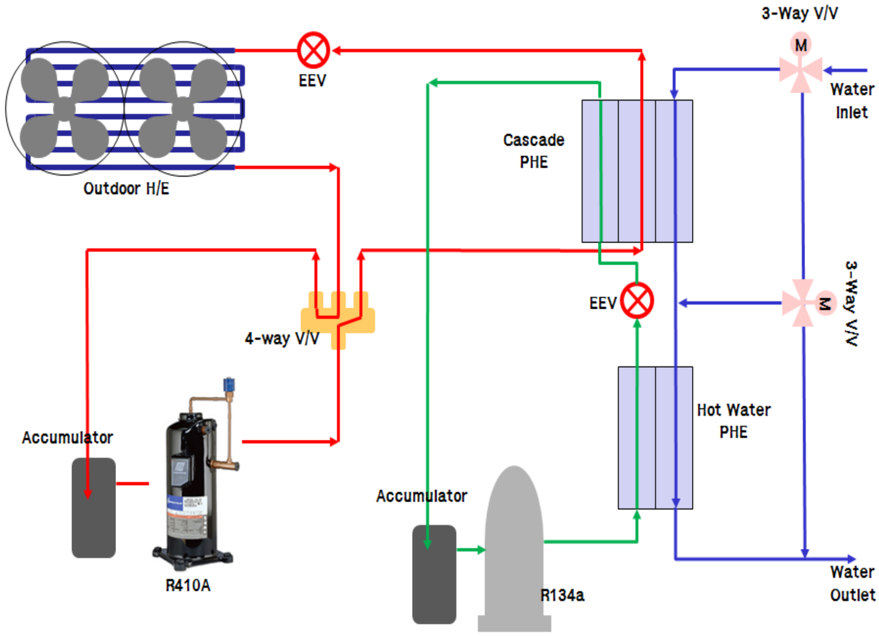

Figure 1. Schematic diagram of the air to water heat pump

In the study, the cascade heat exchanger was configured with two passes of refrigerant and hot water, as shown in **Figure 1**, to make application possible in single cycle and cascade cycle, in order to match diversified hot water and ambient conditions and heating capacities that are listed in **Table 1**.

Performance test for the manufactured heat pump was conducted in the calorimeter of 20 HP class. Optimal refrigerant filling volumes in the single and cascade cycles were obtained from an experiment. Temperature and pressure sensors were installed on the suction and discharge sides of the compressor terminals in order to survey temperature and pressure characteristics in the cycles. Also, optimal injection amounts in each of the operating conditions were found by adjusting the open rate of the electronic expansion valve manually, which was installed in the vapor injection circuit. The performance test results of the heat pump are summarized in Table 2. As shown in the table, the heating capabilities according to hot water inlet temperatures in a state that the temperature difference with ambient air temperature of 10℃ were maintained to satisfy the standards, but SCOP_C, the final averaged performance, does not meet the standards of 2.5. The measured values of temperatures and pressures in the system in the standard and cold climate region (-15℃) conditions are shown in Table 3. It shows that even in a state in which 80℃ hot water was discharged, the system was being operated stably in the level that the maximum pressure was about 2500 kPa and the maximum discharge temperature was about 100℃, respectively.

Table 1. Weighting factors for KSCOP

Temperature	COP	Cold climate region	Average	Warm climate region
-15□/-	COP@-15	7%	2%	0%
-7□/-	COP@-7	39%	22%	5%
2□/1□	COP@2	39%	48%	48%
7□/6□	COP@7	15%	28%	47%
KSCOP		SCOP_C	SCOP_M	SCOP_W

-$SCOP\_C = 0.07COP_{@-15} + 0.39COP_{@-7} + 0.39COP_{@2} + 0.15COP_{@7}$

-$SCOP\_M = 0.02COP_{@-15} + 0.22COP_{@-7} + 0.48COP_{@2} + 0.28COP_{@7}$

- $SCOP\_W = 0.05COP_{@-7} + 0.48COP_{@2} + 0.47COP_{@7}$

Table 2. Test results of the heat pump (performance)

Heating capacity(kW), Power consumption(kW) and COP according to hot water inlet temperature (□)		Standards	Ambient air temperature (□)			
			-15	-7	2/1	7/6
40	Heating capacity	18/14/10/8	18.9	17.4	20.5	24.2
	Power consumption	15↓	8.7	7.2	7.5	7.6
	COP	-	2.17	2.40	2.74	3.18
50	Heating capacity	18/14/10	19.6	23.2	23.0	
	Power consumption	15↓	9.7	10.0	10.1	
	COP	-	2.01	2.17	2.30	
60	Heating capacity	18/14	20.0	21.9		
	Power consumption	15↓	10.9	11.4		
	COP	-	1.84	1.92		
70	Heating capacity	18	19.5			
	Power consumption	15↓	12.1			
	COP	-	1.61			
AVERAGE COP		-	1.91	2.16	2.52	3.18
SCOP_C		2.44				

Table 3. Test results of the heat pump (cycle characteristics)

Hot water inlet temperature (□)	Measures values of refrigerant pressure (kPa) and temperature (□) and hot water flow(LPM) in the system	Ambient air temperature (□)	
		-15	7/6
40	High pressure / low pressure in the low stage	1325.0/384.5	2956.0/771.0
	High pressure / low pressure in the high stage	1329.0/357.2	-
	Discharge temperature in the high / low stages	67.1/50.0	82.4/-
	Hot water flow	27.2	35.5
50	High pressure / low pressure in the low stage	1383.0/376.3	
	High pressure / low pressure in the high stage	1680.0/390.0	
	Discharge temperature in the high / low stages	76.7/53.8	
	Hot water flow	28.8	
60	High pressure / low pressure in the low stage	1443.0/359.0	
	High pressure / low pressure in the high stage	2066.0/420.0	
	Discharge temperature in the high / low stages	88.0/57.6	
	Hot water flow	29.7	
70	High pressure / low pressure in the low stage	1519.0/345.0	
	High pressure / low pressure in the high stage	2527.0/460.0	
	Discharge temperature in the high / low stages	100.0/53.5	
	Hot water flow	29.5	

Cycle simulation and verification

Cycle simulation was simplified to given basic operating conditions for the cycles in each of the terminals, so that it was analyzed thermodynamically when the REFPROP Program was utilized as thermodynamic material properties. In the state that basic input values were given incorporating heating capacities, evaporation temperature of the low stage, condensing temperature of the high stage, temperatures and temperature differences of the medium heat exchanger, and efficiencies of each of the terminal compressors, we have obtained electrical consumptions and performance coefficients of the system, and have excluded volumes and refrigerant flows of the compressors.

In addition, in order to survey the effects of vapor injection in the standard ambient air conditions, we have applied the compressor and flash tank model in which the economizer was installed in FrigoSim ver 2.5[5], a commercial program, like in the previous study[6].

Results of the cycle simulation for the single cycle (R410a) that is being operated at hot water inlet temperature 40℃ in the standard ambient air conditions of **Table 2** are shown in **Figure 2**. Also, the results were applied with the compressor displacement (13.97 m^3/h) and the isentropic efficiency (68.2%) equal to the previous study[5], and the refrigerant flows in the system coincided with the basic cycle analysis results utilized by the refrigerant diagram by changing the compressor volume efficiency. In the state that hot water and ambient temperature conditions were given, on the cycles of **Figure 2** where heating capacities, required powers, and performance coefficients coincide with the experimental values, it is shown that UA values of the condenser and the evaporator are approximately 13,500 W/K and 3,400 W/K, respectively. Additionally, it is shown that it needs approximate 1.3 kW of power, due to the power loss of the compressor driving motor, and a fan because of the controller.

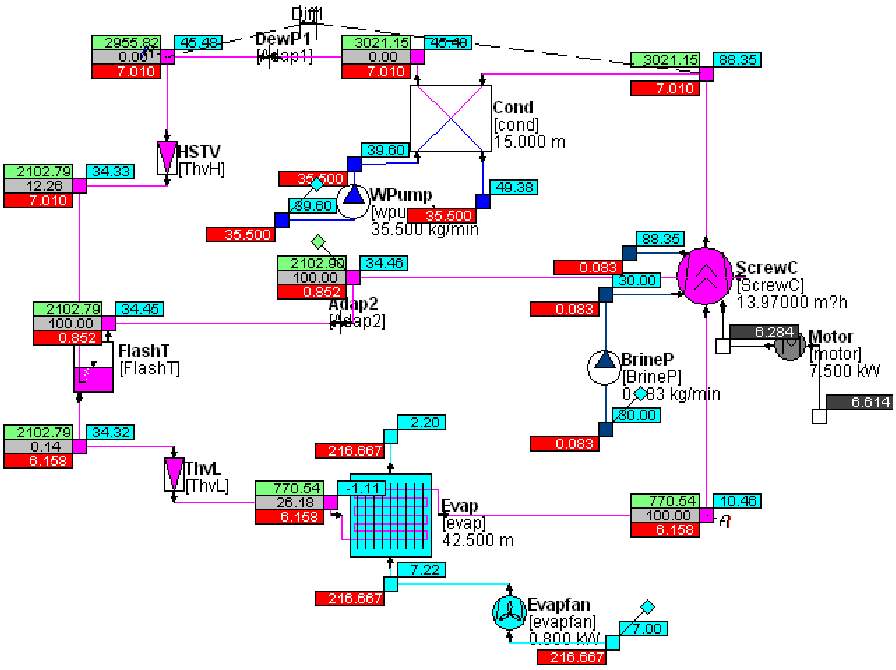

Figure 2. Results from the low stage cycle simulation

Changes in heating capacities, electrical consumptions, and performance coefficients of the heat pump according to vapor injection (that is VR), are shown in **Figure 3**. It is shown that the heating capacity and the electrical consumption are decreased as the volume ratio is increased, and it exists a vapor injection amount that a performance coefficient is maximized when a decreased rate is differentiated. Consequently, as shown in Figure 3, the heating capacities, the electrical consumptions, and the performance coefficients that coincided with the experimental values are fully represented in VR=2.0, and at that time, the ratio of vapor injection for the whole refrigerant flow is about 12%.

From the results, it is our judgment that it is available to properly predict performances of the heat pump system by using thermodynamic material properties and by utilizing the commercial program.

The heat pump performances with cascade cycle that were operated in the cold climate region conditions of -15℃ were predicted similarly to the single cycle, and the results are shown in Figure 4. Even though it is not shown in the figure, it is our opinion that a volume adjustable compressor needs to be applied, because the excluded volume of the compressor varied slightly as the temperature of the hot water inlet increased; when the required power increased as isentropic efficiency decreased, however, the performance coefficient decreased because near-equal heating capacity was maintained. In order to obtain performance coefficients that coincide with the experimental values, it is our judgment that a power of 1.6 kW, (which increase to about 0.3 kW compared with single operation), power loss of the two compressor driving motors, and a fan to the controller are needed.

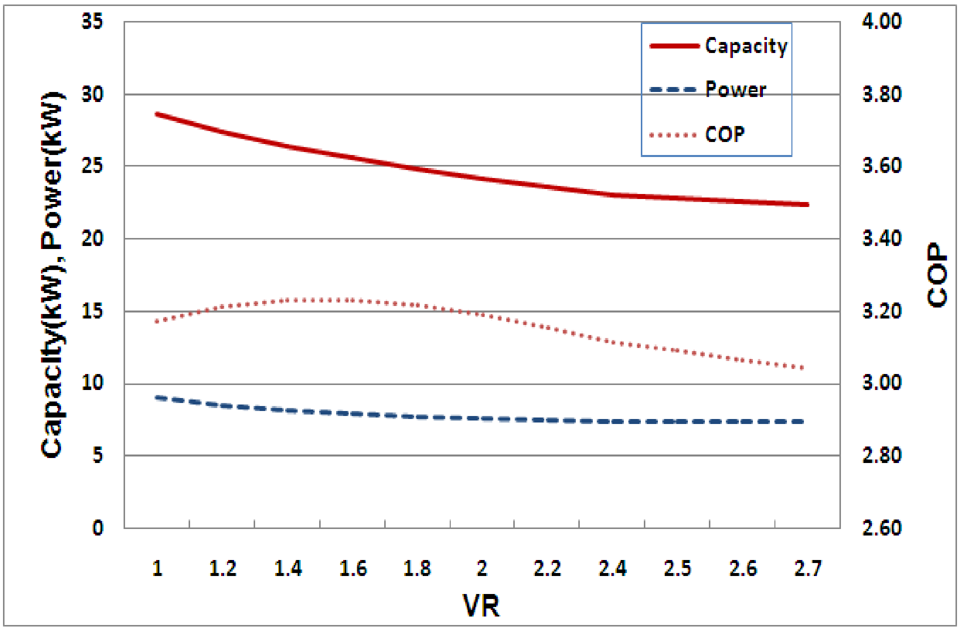

Figure 3. Changes in heat pump performance according to VRs

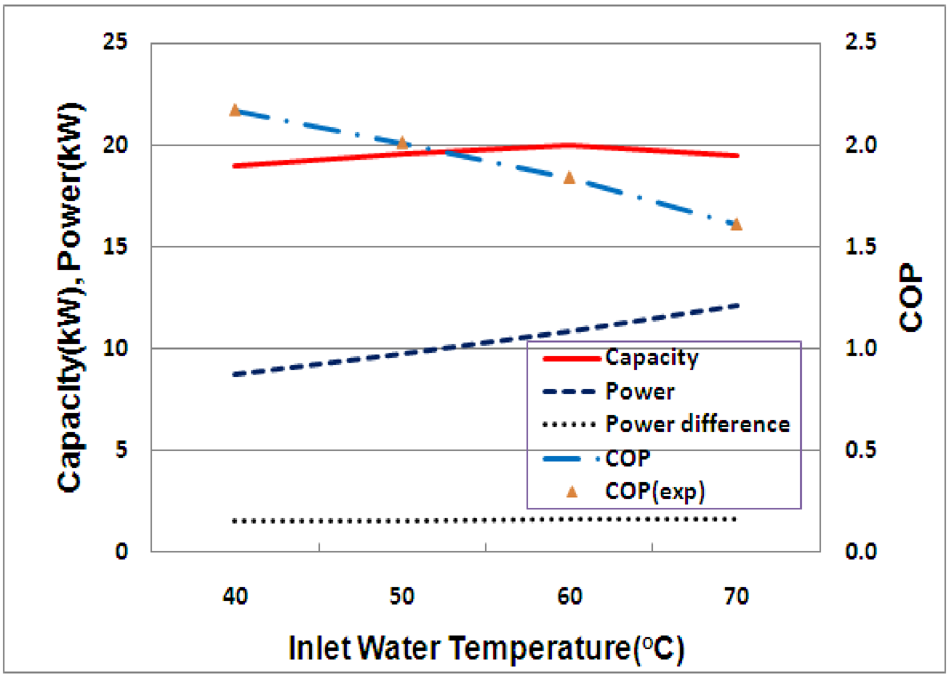

Figure 4. Performance of the heat pump operated with cascade cycle according to hot water inlet temperatures

Conclusions

Performance tests for the system developed for the hot water heat pump used for substituting a late-night electrical hot water boiler were conducted, the cycle simulation that can simulate test results was conducted, and then the results were verified.

This study predicted UA values of the condenser and the evaporator of the heat pump operated in standard ambient air conditions, ratios of vapor injections to the whole flow, and additionally needed powers caused by losses from the compressor driving motor and a fan in the controller.

Performances of the heat pump, as well as operational characteristics of the compressor and heat exchanger that were operated with cascade cycle in the cold climate region conditions at -15℃ were surveyed. Predictions were made for excluded volumes of the compressor according to hot water inlet temperatures, additionally needed powers due to operation with high stage, and operational characteristics of the cascade heat exchanger.

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Application of Ground Source Heat Pump System in a Nearly Zero Office Building

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Keywords: Nearly Zero Energy Building, GSHP, Ground Tube, Contribution rate

SUMMARY

A GSHP system was installed as one of the energy system at China Academy of Building Research in Beijing, China. This paper describes and analyzed its operation on cooling season from July 15th to 30th August with aid of energy management system, including ground-side water temperature and flow rate, chilled water temperature and flow rate, heat release amount of both ground side and the GSHP units, and system contribution to the Nearly Zero Energy Building was discussed.

INTRODUCTION

Global energy demand from buildings is projected to grow by an additional 838 Mtoe till 2035 compared to 2010 (IEA, 2012a). 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 for future direction of building development. Proactive measures with renewable energy sources, is recognized to help realize building energy saving, jointly with “passive design”.

A large borehole ground source heat pump system was introduced to the Nearly Zero Energy Building (NZEB) for China Academy of Building Research (CABR). This is a 4-floor office building, as shown in Fig.1, with floor area of 4025 m2 and occupancy of approximately 180 full-time employees. Adhering to the design principle of "passive building, proactive optimization, economic and pragmatic", the demonstration 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 acceptable indoor environment. It strives to lay foundation for China’s NZEB standard.

Figure 1. North Façade of CABR Nearly Zero Energy Building

Energy System Description

Since the demo building services also as an experimental building, HAVC terminal of each floor is quite different. Water source variable refrigerant volume (WS-VRV) system is utilized for the first and fourth floor, and the second and third floor employs floor and ceiling radiation systems respectively. Other terminal devices, such as fan coils, radiators, GSHP, etc. are adopted for different zone and space.

One absorption chiller and two GSHP units are involved in this energy system as shown in Figure 2. In summer, the absorption chiller, driven by two types of solar collection systems, processes the ventilation load, supplemented by a 50kW GSHP unit. The other 100kW GSHP unit is in place to meet both heating and cooling demand from the radiant terminals for the second and third floor. Coupled with ground source heat pump, solar collection systems provides direct heating in winter with thermal storage.

Through integrated energy system design and smart use of renewable energy, it is expected that building heating demand in winter could be met with zero use of fossil fuel and cooling energy consumption in summer could be reduced by 50%. Since solar radiation is very strong in summer in the locale, this energy system is designed to under operation of primary solar energy, when available, and GSHP as the supplementation, to maximum utilization of natural resource and realization of energy conservation.

Borehole System Description

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 with 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 and ground water join in a header before entering the building. Water flow was balanced by balancing valves and monitored before being distributed to different units.

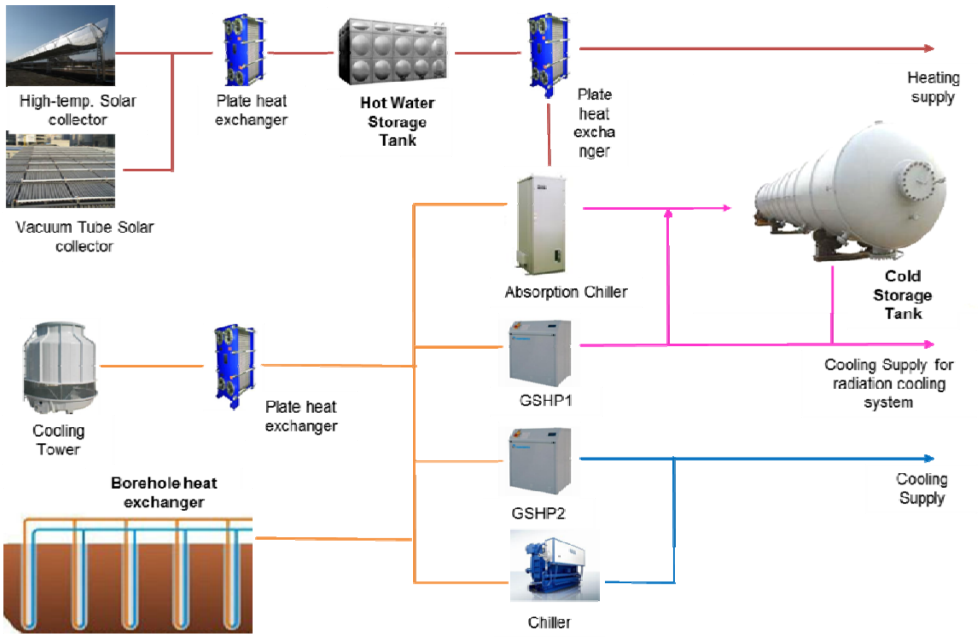

Figure 2. The heating and cooling system of the CABR NEZB

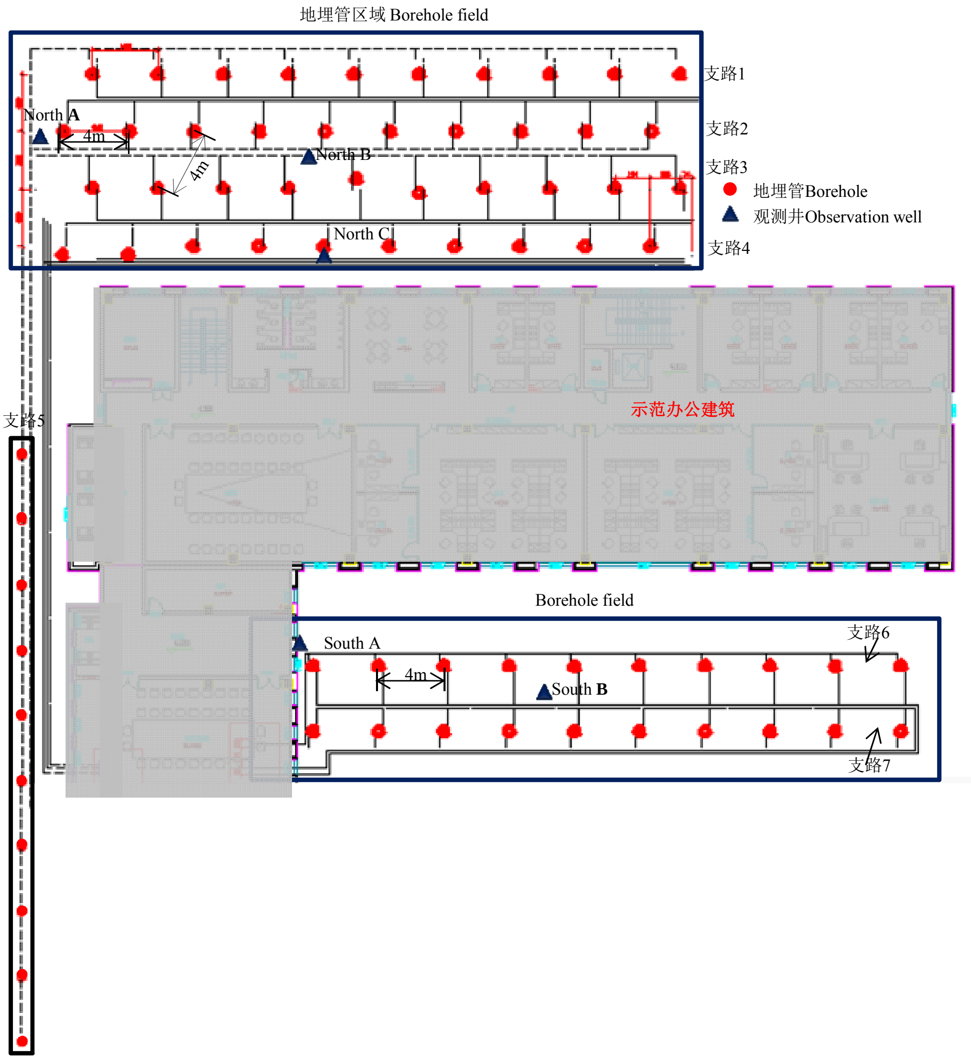

Figure 3. Borehole System distribution

Summer Operation Mode

As shown in Figure 2, an absorption chiller, 2 GSHP units combined with 70 boreholes and solar collectors provides cooling and heating requirement of the whole building.
During summer period, when the solar radiation is available for the absorption chiller, it will be operated with priority to supply chilled water for HVAC system which require a water temperature of 7℃, e.g. PAUs, Otherwise, it is standby with GSHP1(50kW). The GSHP2 is acts for the cooling supply for the radiation cooling system.

Measurement Data Description

1. Borehole system

Steady data collection and system operation was available from July 15th after the system was in operation and under commissioning. Operation data of borehole and GSHP units during summer was monitored and analysed. Ground circulation water temperature during operation period is illustrated in Fig. 3.
Figure 3 shows inlet and outlet water temperature of ground tube from July 15th to August 30th, where the main axis (left) represents water temperature and the secondary axes (right) represents temperature difference. System works almost every weekday except for a short break period from August 6th to 12th. And it is seen that inlet and outlet water temperature ranges from 23-28℃and 20-26℃ respectively during system operation, and temperature difference ranges betwen3 to 4℃ on average. Since the system works under intermittent mode, water temperature raise about 4 ℃ during working hours and decrease at night.

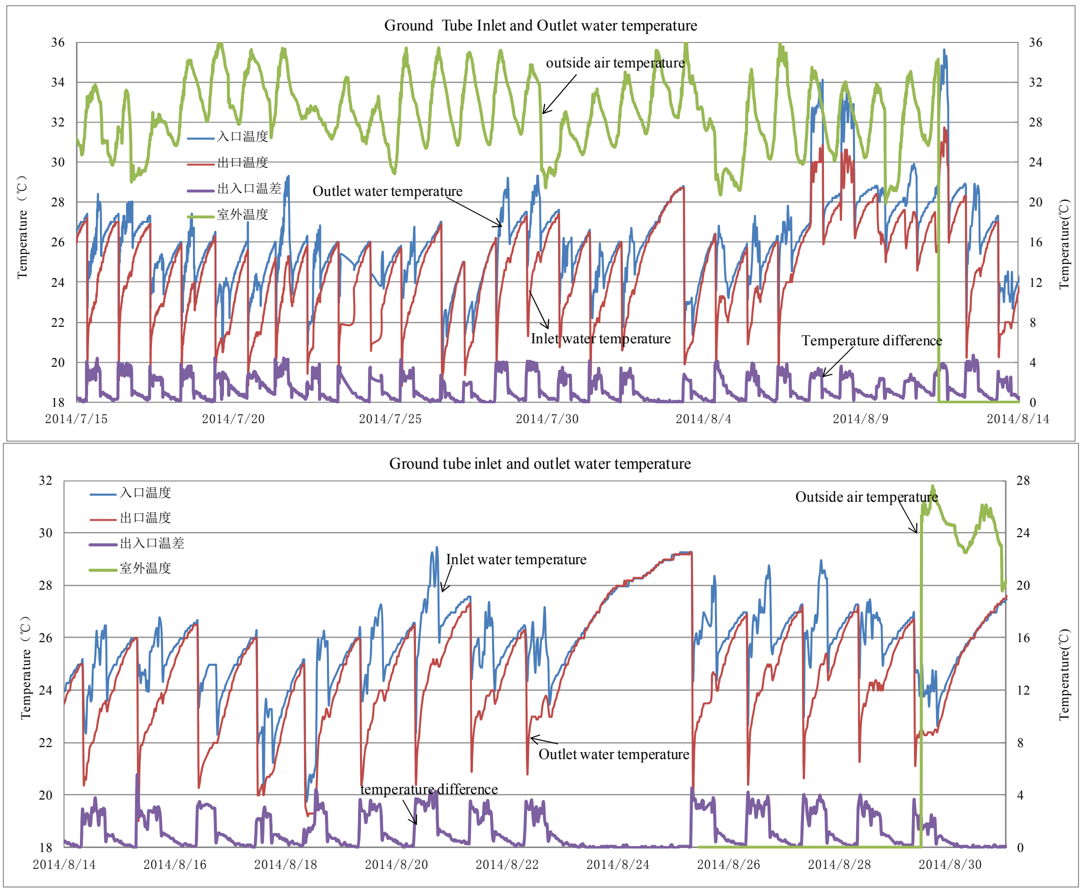

Figure 4 Ground water inlet and outlet temperature variation from July 15th to 30th August

2. GSHP units

Figure 5 illustrates primary and secondary water temperature variation of GSHP unit 1 at working time during summer period, yellow and blue points on the upper side of the figure shows primary side inlet and outlet water temperature ,while green and purple color points on the bottom of the figure represents secondary side water temperature. It is seen from the figure that supply water temperature of secondary side was about 8℃, return water temperature was about 12.5℃ , temperature difference was about 4.5℃.

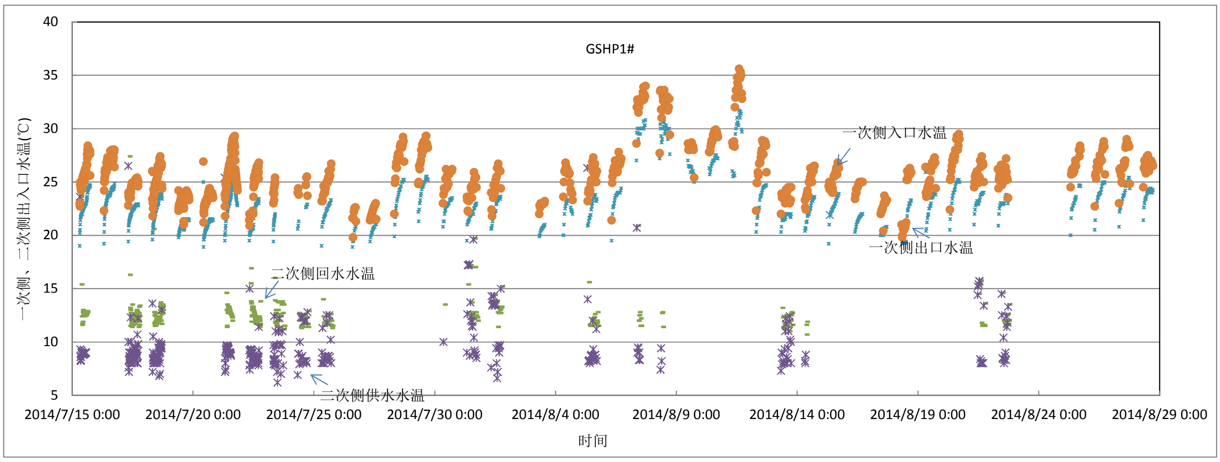

Figure 5 Primary and secondary water temperature of GSHP1

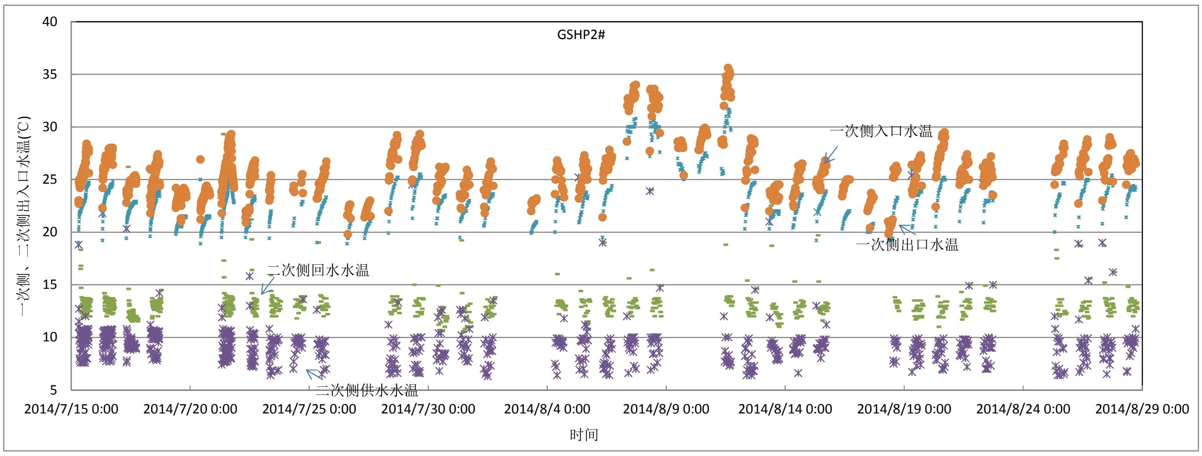

Figure 6 Primary and secondary water temperature of GSHP2

Secondary and third floor of the building adopted ceiling and floor radiation system, since supply water temperature of radiation system is higher than air conditioning system, as shown in figure 6. Supply water temperature of radiation system is about 9℃, and return water is around 13℃, temperature difference is about 4℃.

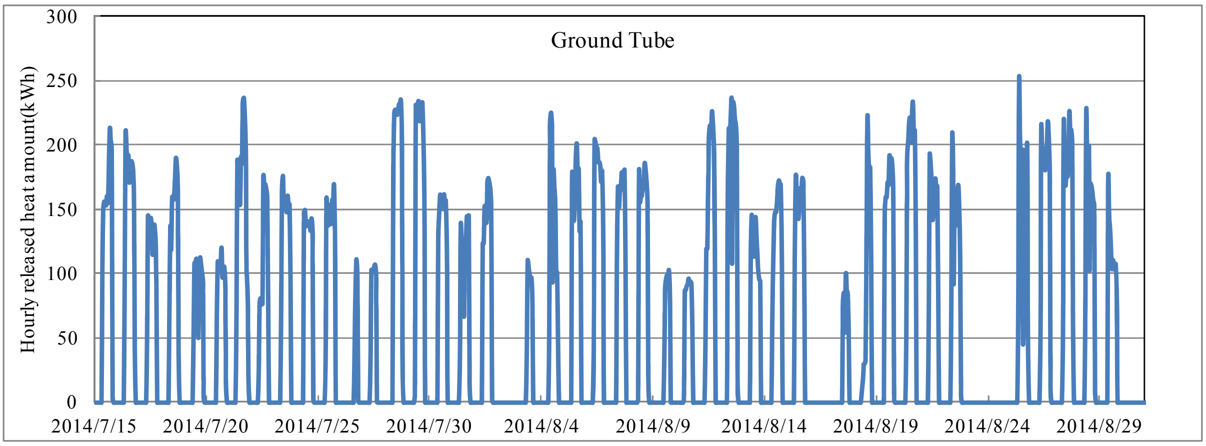

Figure 7 Heat released amount of borehole system in summer

Figure 7 shows hourly heat release amount of borehole ground-tube, a maximum hourly release heat amount of about 220kWh with an average is about 120 kWh was found in the figure, accumulated released heat amount is about 54000kWh. COP is assumed as 4.0 on average, cooling load of the building is about 4320kWh.

Figure 8 is the heat amount which was produced by GSHP1(50kWh), as shown, hourly heat release amount is about 60kWh, totally released heat amount by this unit is about 3900kWh.

Figure 9 plots heat released amount by GSHP2 (radiation system), a maximum hourly heat release amount 90kWh was found in the figure, with an average is about 60kWh. Heat release amount of this unit is about 19000kWh.

Total released heat amount by GSHP1 and GSHP2 unit is about 22900kWh. Contribution rate of GSHP unit is about 54.5%.

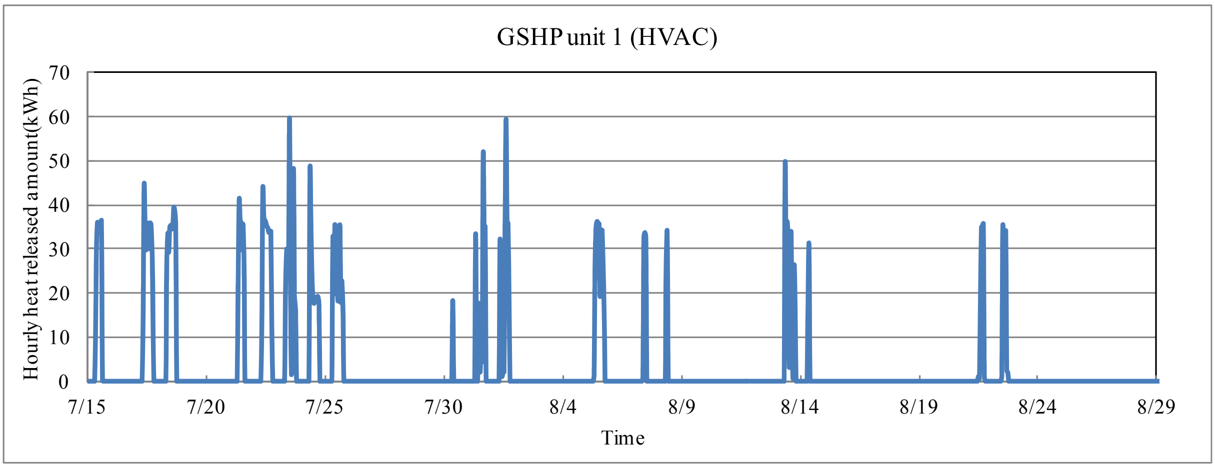

Figure 8 Heat released amount of GSHP1(HVAC) in summer

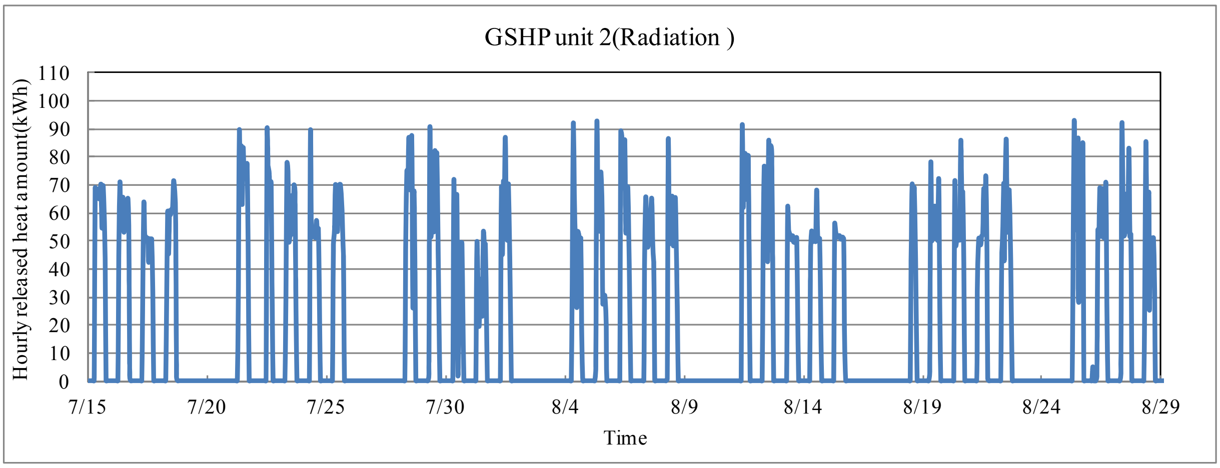

Figure 9 Heat released amount of GSHP unit 2(Radiation) in summer

Conclusion

A GSHP system application in CABR Nearly Zero Energy Building was introduced in this paper mainly. System operation during July 15th to 30th August was analyzed based on measurement data, and GSHP units contribution to the energy system of the building is discussed in addition. It is found that water temperature of ground tube works at about 23-28℃and 20-26℃ respectively, as inlet and outlet. Heat released amount through the tube to the ground is about kWh.GSHP unit for the radiation system works almost every day, and supply and return temperature is about 9℃ and 13℃, respectively, with a temperature difference of about 4℃.A heat amount of 19000kWh was supplied to the building by this unit. GSHP 1（50kW）works as a standby of absorption chiller in summer season, and system provide 4300kWh heat for the building, and the GSHP unit contributes 54.5% of heat of the building load.

Renewable energy is expect to provide cooling of the whole building under the design principle of passive design and proactive optimization, since this article discussed GSHP system only, it is hard to evaluate the performance of the renewable energy system, studies will be continuous regarding to the whole energy system.

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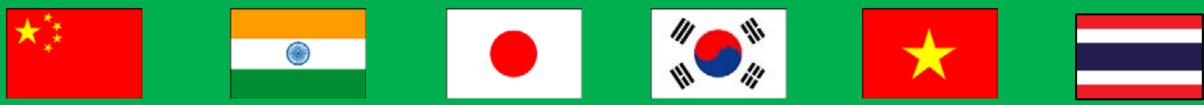

Asian Heat Pump Thermal Storage Technologies Network

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)

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