A RETROFIT PROJECT WITH THE GROUNDWATER HEAT PUMP IN PLACE OF AN EXISTING HVAC SYSTEM

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Abstract: Application of groundwater heat pumps (GWHPs) in HVAC systems has gained popularity in China in recent years. A retrofit project is reported in this paper with the GWHP in place of an existing system with a boiler and a cooling tower. The characteristics of the screw water-to-water heat pump used in the project are recommended. High quality performance has recorded in the past operations of the GWHP system.

1. INTRODUCTION

Ground-source heat pumps (GSHPs) make use of the more moderate and more constant temperatures of the earth for heating and cooling buildings more efficiently. The ground-source heat pump contains various types of systems, including ground-coupled heat pumps (GCHPs), groundwater heat pumps (GWHPs), and surface water heat pumps (SWHPs) (Kavanaugh and Rafferty 1997). GWHPs have been the most widely used type of GSHPs in North America and Europe (Lund and Freeston 2001). In recent years application of the groundwater heat pump in heating, ventilating and air-conditioning (HVAC) systems has also become more and more popular in China. In GWHP systems large quantities of water can be delivered from a relatively inexpensive well that requires very little ground area. The capital cost of a well water system is much lower for a larger system than that of a GCHP system (Rafferty 1995). The water well is very compact. A single high-volume well can often serve an entire building. Properly designed groundwater loops with well-developed water wells require no more maintenance than conventional air-and-water central HVAC systems. Another advantage of the GWHPs is that water well contractors are widely available.

The important incentive to popularization of GWHP systems in China is the increasing concerns about the air pollution caused by coal-burning boilers for heating. Small and medium-sized coal-burning boilers have been banned in most Chinese cities for environmental concerns. At present the applications are focused on institutional and commercial buildings, where the internal water loop with fan-coil units is usually employed. So, a lot of the existing HVAC systems need to be revamped, and water-to-water heat pumps are especially in demand for such applications. On this background Yantai Ebara Air-conditioning Equipment Co. Ltd. has become a major supplier of water-to-water heat pumps in the Chinese market.

Yantai Ebara Air-conditioning Equipment Co., Ltd. is a joint venture enterprise invested by Ebara Corporation, Japan, and Yantai Moon Co., Ltd., China, in 1996. Ebara Corporation produced its first centrifugal refrigerating machine in Japan in 1929. Up to now, Ebara has a history of more than 70 years to develop and produce refrigerating equipment. Yantai Moon Co., Ltd. is a state-owned backbone enterprise in China's machinery industry. It started to produce refrigeration and air-conditioning equipment in 1956, and has been a main production base for large-size refrigeration and air-conditioning equipment in China. The joint venture, Yantai Ebara, is the first refrigeration machinery manufacturer for Ebara outside Japan. As a production base facing to international market, Yantai Ebara manufactures mainly steam-type, directly-fired and warm-water-type absorption chillers and modular screw water chillers (heat pumps) with state-of-the-art technology, and supplies them to China, Japan and other countries and regions.

This paper reports a GWHP project, which was completed in May 2001 in Yantai with an Ebara screw heat pump in place of a conventional HVAC system with a boiler and a cooling tower. More first-hand data on GWHP system operation have been obtained from the project, which will certainly help in further optimizing design and operation of the system.

2. THE PROJECT BACKGROUND

The retrofit project is on Yantai Ebara's office building, which was constructed in 1996. It is a three-story 3000m^2 structure, where the ground floor serves as a dining hall and locker rooms while the other two floors are offices. The building has a concrete frame structure and windows with aluminum alloy frames.

Fig. 1 The Outlook of Yantai Ebara Air Conditioning Equipment Co. Ltd.

A conventional air-conditioning system was installed in the building equipped with a boiler for heating and a reciprocating compressor water chiller with a cooling tower for cooling. The old system was unable to fulfill the increasing loads of the building while bringing about a substantial power demand. Besides, the boiler had to be abolished as required by government regulations. In order to demonstrate the Ebara heat pump and analyze the performance of GWHP system an Ebara RHSCW060YM heat pump has been installed for the project together with a water well group in place of the old water chiller and boiler. At the same time the original indoor air-conditioning system has also been renovated.

3. SYSTEM DESCRIPTION

3.1 The GWHP System

The groundwater comes from an aquifer of about 50 meters under the ground, and its undisturbed temperature here in Yantai is around 15℃. Two supply wells and one return well have been drilled. The return well is located 60 meters away from the supply wells to minimize interference between the supply and return wells. A 6mm-thick steel pipe was placed in each well. The groundwater flow rates are listed in Table 1.

Table1 Water well parameters

Well number	Well Diameter	Well Depth	Groundwater flow
1# supply water well	300mm	51m	$10m^3/h$
2# supply water well	300mm	50m	$15m^3/h$
3# return water well	300mm	48m	$40m^3/h$

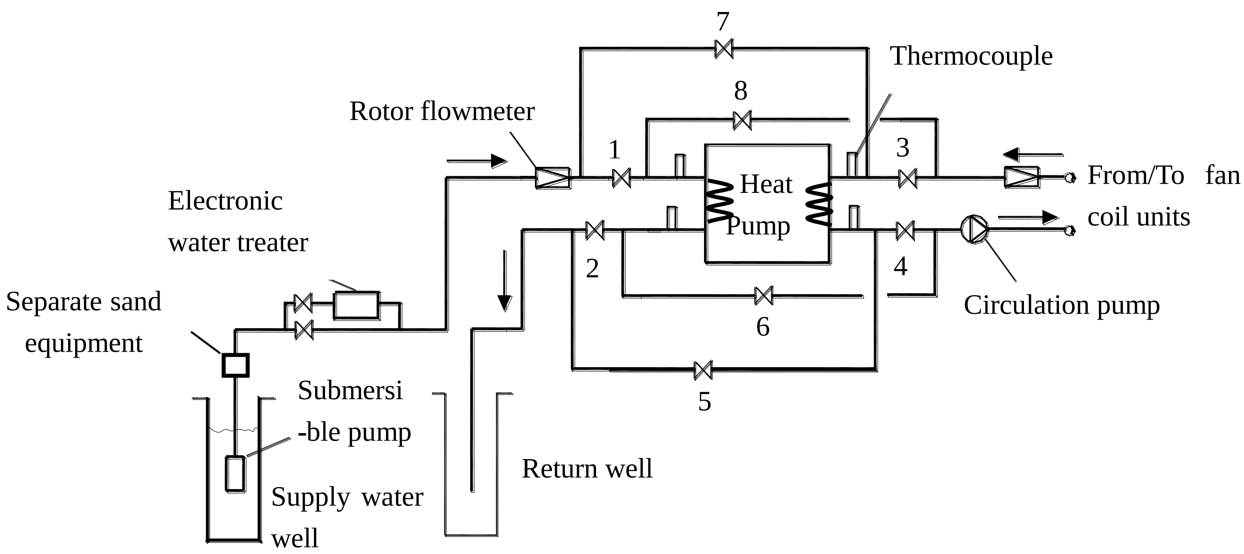

Fig. 2 The GWHP System

The GWHP system layout is illustrated in Figure 2. It is noticed that the valves 1, 2, 3 and 4 are open while valves 5, 6, 7, 8 are closed in the cooling mode, and their settings reverse in heating. The interior distribution loop employs fan coil units.

3.2 The heat pump

Heat pumps use high capability semi-hermetic screw compressor. Evaporator and condenser are stainless plate heat exchanger. Control panel employs micro-computer of Japan. The innovative refrigerant HFC134a is used in the units to protect the ozone layer in atmosphere. Principle drawing of heat pump system is Fig.4.The modularized water chiller (heat hump) can be a multiple chiller system composed of one to five individual units with a total refrigerating capacity ranging from 216 to 1080 kW. Fig.3 is the outline of heat hump being experimented.

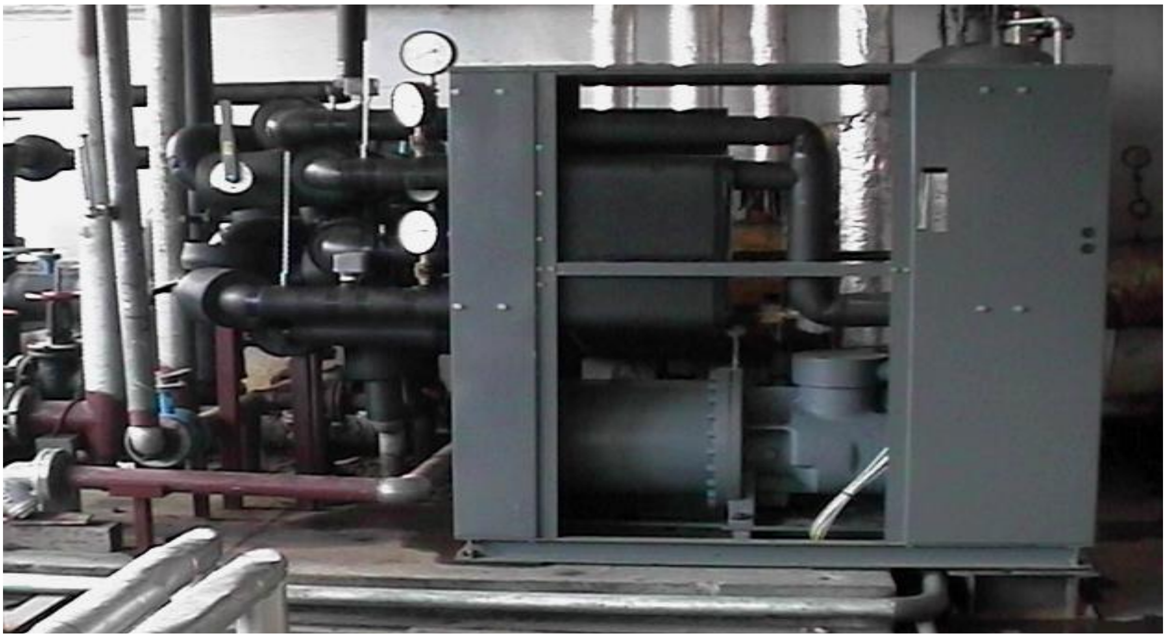

Fig.3 the outline of heat hump being experimented

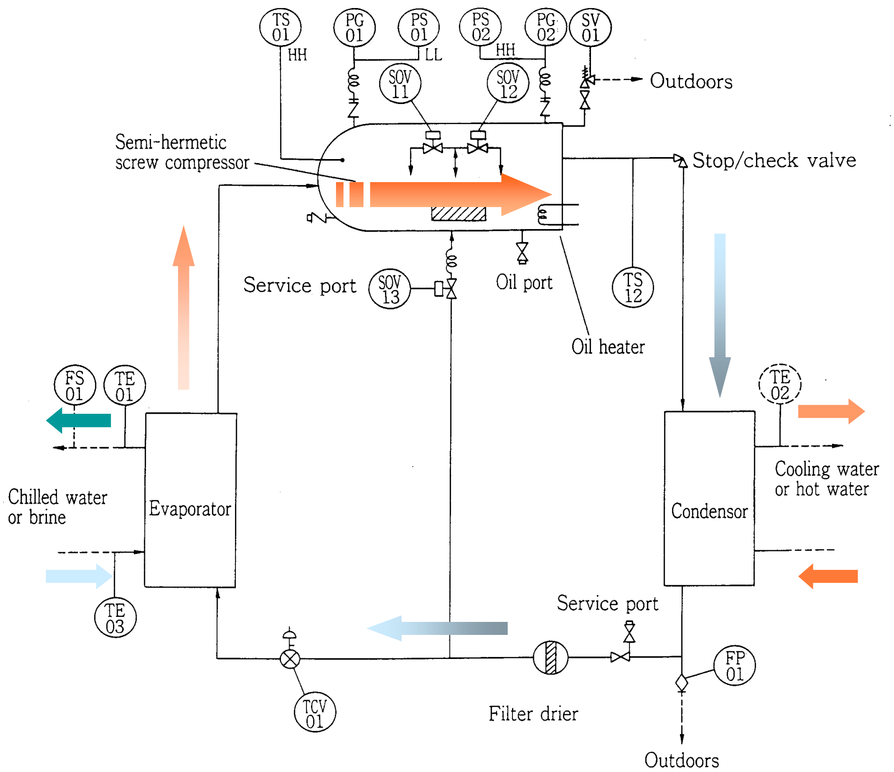

Fig. 4 Diagram of the Screw Heat Pump

4. SYSTEM PERFORMANCES AND EFFICIENCY

The system has operated since later May 2001. In summer 1# supply water well and the disposal water well are used. The supply/return service water temperatures are set as 7/12℃, and the supply/return groundwater temperatures are about 15/25℃, which can maintain the indoor temperature at 22-25℃ as designed. In heating mode the supply/return service water are of 55/50℃, and the supply/return groundwater temperatures are about 15/10℃, which can maintain the indoor temperature at 20-23℃. In winter both supply water wells are ready for use to satisfy the larger load and keep the leaving water from freezing. It operates from 7:00 to 17:00 every day both in heating and cooling modes, and has performed satisfactorily since being put into operation.

In order to gain information on the GWHP performance and the heat pump efficiency in working conditions, sensors and monitoring devices have been installed to measure the groundwater flow rate, its temperatures and the compressor power consumption in the system. The data acquisition system can also be seen in Figure5.

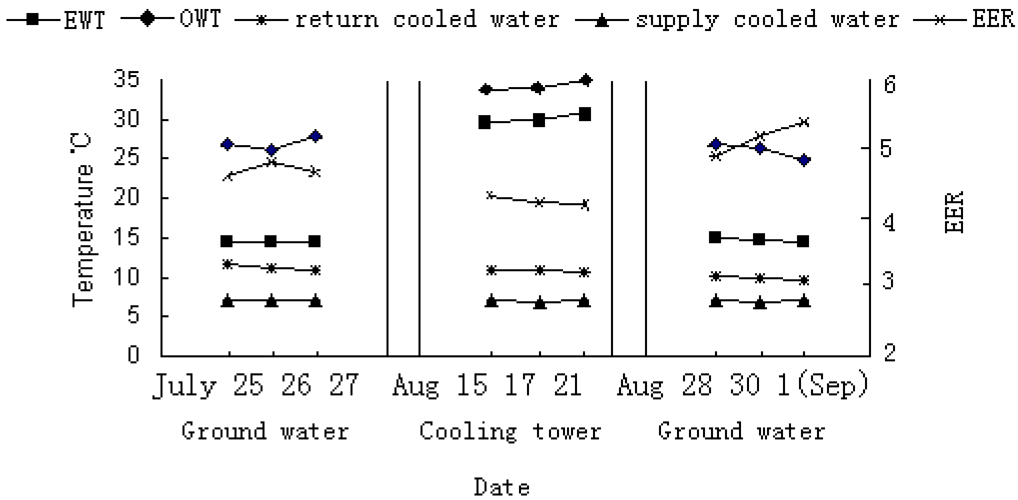

Fig. 5 (a) Heat Pump Cooling Performance

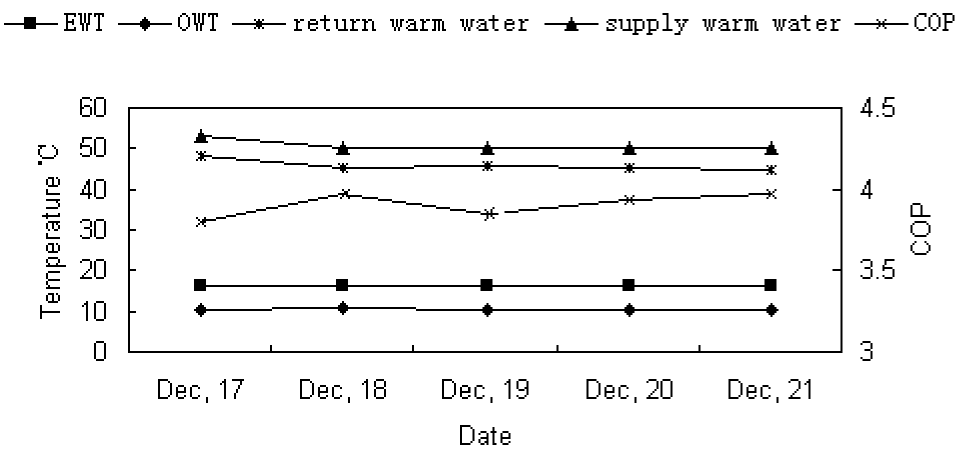

Fig.5 (b) Heat Pump Heating Performance

A few typical data of the operating days are shown in Figure 3. The recorded data in cooling and heating mode are presented in Figure 3(a) and 3(b), respectively. Here,

EWT: entering groundwater temperature, ℃

OWT: outlet groundwater temperature, ℃

EER: Energy efficiency ratio in cooling mode, kW/kW

COP: Coefficient of performance in heating mode, kW/kW

As shown in Fig.5, The flux of groundwater and working condition of the heat pump were non-stable in last mid August because of insufficiency of the groundwater and machine's partial blocking in July. The machine can run normally at the end of August.

Comparing to cooling tower, it can also make EER increase move 10 per cent though the least flux of underground water is only 60 per cent of rated flux.

More running time of the system and improvement in measurement accuracy are still required to better analyze the system performance both in heating and cooling modes.

5. DISCUSSIONS

The retrofit project has been operating satisfactorily since its completion. It provides much larger cooling capacity, and it has been proved economically advantageous due to its higher efficiency than that of the original boiler and cooling tower system.

Some problems were experienced with the GWHP system. It has been found that the groundwater flow decreases in continuous operation, which may vary from 16 m^3/h to 10 m^3/h. A steady supply of groundwater is vital to successful operation of GWHP systems. Therefore, more studies on the aquifer have to be done, and additional supply well may be needed.

From this experiment, notice must be taken if making use of underground water:

1. Water must be treated in order to prevent from scaling .
2. Separate sand equipment must be installed to protect heat exchanger damage.
3. Choose different material according as local condition.

More data are necessary to fully analyze the GWHP system economy, which are expected to be accumulated in future operations.

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