

The System Producing Hot Water by Recovering Condenser Heat from Central Air Conditioning System: A Case Study

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Abstract: Central air conditioning systems emit lots of waste heat during operation, which is dissipated to the atmosphere through cooling towers. However, domestic hot water is necessary in many buildings. The hot water is usually produced by fossil fuel-fired boilers, which is not an energy-efficient way, as well as pollutes environment. The waste heat can not usually be used directly because of its lower temperature. Hence, heat pumps are employed to raise the temperature of waste heat, which makes up of heat pump type air conditioning waste heat recovery system. This paper illustrates this type of heat recovery system detailedly by a practical project producing hot water for a certain conference center. Economic feasibility analysis indicates the proposed system is attractive in hot water production compared with municipal heating network and gas boiler. Besides, the system benefits to environmental and social considerations. This heat recovery system evidently sets a good example to express the concept of sustainable development. This type of hot water production is worth popularization.

Keywords: waste heat recovery, scheme design, heat pump, hot water production

1. INTRODUCTION

Nowadays, people widely employ air conditioning systems to create comfortable occupant spaces. This not only consumes a lot of energy, but also leads to many environmental issues, of which the heat pollution is more and more paid attention to. As effective methods to lower the energy consumption of air conditioning systems, heat recovery technologies are developed actively and utilized gradually. Various air to air energy recovery exchangers are developed to precool or preheat the fresh outdoor air by the exhaust indoor air in ventilation, which prove energy-saving in most cases [1-3]. Furthermore, a special emphasis is focused on chillers, the hearts of central air conditioning systems because those units reject 1.15~1.3 times as massive waste heat as their cooling capacity. Currently, nearly all technical projects recovering waste heat from chillers are to produce hot water by existing condensers or added heat recovery heat exchangers [4-7]. The principle of this technology is to utilize high-temperature refrigerant discharge from compressor to heat water, which can take full advantage of both the sensible and the latent heat of refrigerant. In fact, this technology gives birth to a new type of units, namely so-called heat recovery air conditioning units.

Many practical applications indicate heat recovery units are cost-effective and energy-saving equipment. However, we should determine the ratio of heat reclaim capacity to cooling capacity carefully when

using this type of units. That is to say, heat reclaim should not undermine the normal operation of the whole air conditioning system. Moreover, the demand variation of supply water and hot water, as well as the interlocking effects of preheating, heating and heat rejected by cooling tower make it considerably complicated to control those units, which restricts the availability of this technology. Here, this paper presents an alternative technology, i.e. employing heat pump systems (they are independent systems compared with the above-mentioned heat recovery heat exchangers) to recover sensible heat from cooling water. Details are illustrated in the following sections by a practical blueprint.

2. PROJECT DESCRIPTION

2.1 Overview

A certain conference center, the total structure area of which is $27 \times 10^4 \text{ m}^2$, needs cooling, heating and domestic hot water. At present, six 2000RT liquid chillers are adopted to provide space cooling in warm summer months, and municipal heating network is selected to produce hot water. Due to the turnaround of municipal heating network in summer, a heat pump heat recovery system is presented as a standby heat source for hot water production when the municipal heating network is idle.

2.2 Heat Recovery System

The proposed heat pump heat recovery system is shown in Fig.1 and associated components are listed in table 1.

unfavourable working conditions, such as the cooling water inlet and outlet temperature of cooling tower are 30°C and 25°C, respectively, the COP is still high with

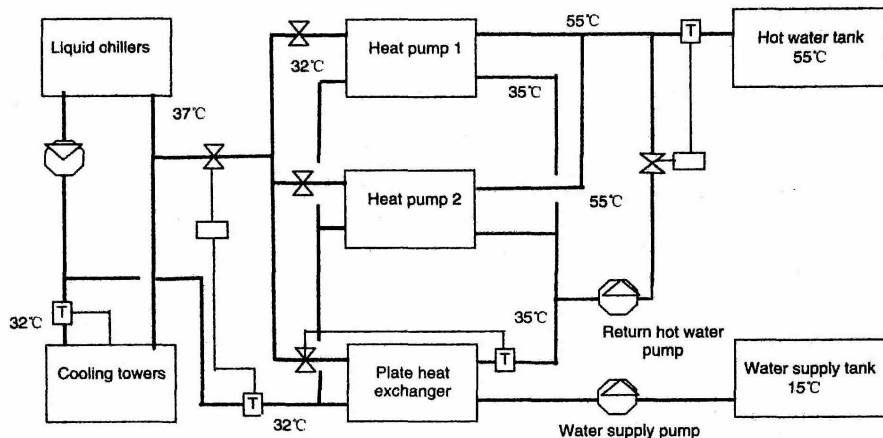


Figure 1: Heat pump heat recovery system

Table 1: Components of the heat pump heat recovery system*

Item	component	type	number
1	Moderately high temperature heat pump	QYHP-2150M	2
2	Plate heat exchanger	-	1
3	Internal circulating pump	-	3
4	By-pass valve	-	2
5	Piping	-	Based on practical demands
6	Electric control	-	Based on practical demands

*The installation floor area is about 80~100m² and the added electricity capacity is 1000kVA. Furthermore, table 1 does not include water supply tank, hot water tank, water supply pump, circulating pump, and hot water piping and its control system of municipal heating network.

The design hot water flow rate is 161m³/h and the total cooling water flow rate is 8,713t/h. The heat exchange area of plate heat exchanger is 119m². The water outlet temperature of the plate heat exchanger is set as 35°C. The heating capacity of 3,744kW is required when the water is heated from 35°C to 55°C with a flow rate of 161t/h. Thus, two QYHP-2150M (temperature rise type heat pump) moderately high temperature heat pumps are employed as the core of this heat recovery system owing to their reliability in technology and extremely high coefficient of performance (COP=7.2 in the working condition shown in Fig.1). Even if the system operates in

the value of 6.43. In detail, each heat pump can provide 1,862kW heating capacity while the input power is 289.5kW.

The water flow rate of the heat recovery system can be adjusted according to the water outlet temperatures of heat pumps and plate heat exchanger, hence, the cooling water temperature of chillers can be maintained in a desired value. The cooling tower fans are manipulated according to the water outlet temperature of cooling towers. If the both heat pumps run simultaneously, the temperature set value of cooling water leaving cooling tower can be decreased in order to raise the efficiencies of chillers. The water flow rate of plate heat exchanger in high-temperature side is controlled by an electric regulator valve, which can keep the hot water outlet temperature of plate heat exchanger at 35°C. The hot water temperature in user side can be lowered by allowing less water to enter the heat pumps. Whereas, the user side hot water temperature can be maintained in a relatively high level by allowing more water to enter the heat pumps even if only one heat pump is working.

Let the heating capacity is 4,000kW and the temperature difference is 5°C, the ratio of heat transfer quantity in condenser side to that in evaporator side is 1.16 for the heat recovery system; the required heat transfer capacity of the plate heat exchanger is 3,744kW with the water flow rate of 644t/h; the total water flow rate of heat recovery system in evaporator side is 1,236t/h, accounting for 14.2% of the total cooling water flow rate. Besides, for the sake of supplying hot water steadily and reliably, a water supply pump and a hot water tank is needed. The head of this pump is about 20m and the added power is 13.5kW. The tank is 209m³, which can be omitted if there is no appropriate room for installation.

3. ECONOMIC FEASIBILITY ANALYSIS

3.1 Primary Data

The useful data for economic feasibility analysis on the above-mentioned system is summarized in table 2.

Table 2: Associated data for analysis

Item	Value
Average electricity price	0.678yuan/kWh (11:00-18:00 & 7:00-8:00)
Valley electricity price	0.313yuan/kWh (23:00-7:00)
Peak electricity price	1.064yuan/kWh (8:00-11:00 & 18:00-23:00)
Natural gas price	1.8yuan/m ³
Natural gas heat value	32,500kJ/Nm ³ =9.02kWh
Gas boiler efficiency	85%
Coal boiler efficiency	70%
Coal heat value	7000kcal/kg
Price of hot water produced by municipal heat network	5yuan/t (only for heating price and water heated to 50°C)
Estimated hot water consumption per day	850t
Hot water usage time in summer	From May 1 to october 1 (150 days in all)
Heat used for heating water	21,352GJ
Recycled water price	1.0yuan/t
Lending rate	7%

3.2 Compared with Municipal Heating Network

The comparison preconditions are the following: the estimated average COPs of the heat pumps are 6.7; cooling period lasts 150 days per year and the heat recovery system operates 10 hours per day in full load condition; the electricity consumption for heating water is 4.17kWh/t. The calculated results are listed in table 3.

Table 3: Economic comparison between the proposed system and the municipal heating network

Item	Value
Heat pumps electricity consumption per year	531,161kWh
Electricity consumption for added water pump per year	20,250kWh
Total electricity consumption for heat recovery system per year	551,411kWh
Total operating cost for heat recovery system per year	374 thousand yuan
Cost for heating water by municipal heating network per year	638 thousand yuan
Saved cost per year	264 thousand yuan

Referring to table 3, we can find the heat pump heat recovery system is superior to the municipal heating network economically in summer and suggest the system should be used first.

3.3 Compared with Gas Boiler

The calculating assumptions are the same as those in section 3.2. Besides, the lifetimes of heat pump and gas boiler are set as 15 years. Accordingly, the calculated results are shown in table 4.

Table 4: Economic comparison between the proposed system and the gas boiler

Item	Value
Total operating cost for heat recovery system per year	374 thousand yuan
Gas consumed to produce as much heat as provided by the heat recovery system per year	770 thousand Nm ³
Total operating cost for gas boiler per year	1,386 thousand yuan
Saved cost per year	1,012 thousand yuan
Investment cost for the 6t/h gas boiler and associated devices	1,800 thousand yuan
Static payback period of the heat pump system based on gas boiler	1.3 years
Annual depreciation cost of the heat pump system based on gas boiler	83.6 thousand yuan
Annual net saved cost	928.4 thousand yuan

In addition, the dynamic payback period is less than 2 years. And the net present value of the heat recovery system is up to 6,670 thousand yuan, which can effectively compensate the total investment cost for the system. In a word, the heat pump heat recovery system is preferred rather than gas boiler from the viewpoint of economy.

4. ENVIRONMENTAL AND SOCIAL BENEFITS

Using the primary data listed in table 1, we can evaluate the environmental performance of this heat recovery system. In China, the emissions of CO₂, NO_x and SO_x for burning 1 tonne of coal are 2.72tonne, 3.2kg and 6.4kg, respectively. As a result, the emissions reduction of CO₂, NO_x and SO_x are about 2834tonne, 3.3tonne and 6.6tonne annually, respectively, if the coal boiler is replaced with this heat recovery system. Since the burning of natural gas will also emit lots of CO₂ and NO_x, accounting for 60% and 20%~40% of those from coal combustion, respectively, the heat recovery system is environmentally friendly even compared with gas boiler.

Water resource is very important, however short in China. Conventional cooling tower dissipate waste

heat to the surroundings by exchanging heat and moisture between cooling water and air. Generally, the cooling water loss is 3,000tonne per 10,000m² cooling area annually. As the cooling tower load can considerably decreased thanks to the use of the heat pump heat recovery system, this project is desired to save about 20,000tonne water per year.

It is a new type of clean heat source usage to use moderately high temperature water source heat pumps for recovering rejected heat from air conditioning system in summer, which overcomes the actuality that low-temperature waste heat resource cannot be employed by conventional heat pumps. Moreover, the proposed heat recovery system can make use of the existing heat exchange devices and hot water delivery devices of the municipal heating network. Obviously, the heat recovery system takes on the features of energy saving, environmental protection, convenience and practicality. Thus, the heat recovery system tallies with the requirements of sustainable development of society.

5. CONCLUSION

This paper presents a novel air conditioning waste heat recovery system, which is different from most conventional heat reclaim units (they are special heat recovery type air conditioning units), i.e. the proposed system is an independent system and only recovers sensible heat from cooling water by heat pumps. So this heat recovery system is right suitable for retrofitting the existing air conditioning systems.

The proposed system is illustrated in detail through a pilot project applying the heat pump heat recovery system to provide hot water for a certain conference center. The novel heat recovery system is attractive in the aspects of economic feasibility, environmental and social benefits. Without question,

the project can be regarded as a good example embodying the connotation of sustainable development, as well as is worthwhile to spread to the similar situation that lots of low temperature waste heat needs recovering.

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