# APPLICATION OF COLD HOT ELECTRIC COMBINED HEATING PUMP SYSTEM IN ECOLOGICAL ENVIRONMENT BUILDING DESIGN

by

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*Aiming at energy saving and consumption reduction, this project applies the technology of combined heating and cooling heat pump to ecological building design. The combined hot and cold system is an integrated control system, which utilizes the solar system and heat pump technology (air source heat pump, water source heat pump) to complement each other based on changes in the outdoor environment, thus providing users with hot water heating and cold water cooling in winter. After installing a new heating and cooling system, coupled with well-equipped automatic control equipment, the heating coal consumption has been significantly reduced, and the emissions of $CO_2$, $SO_2$ dust, and other pollutants have also been correspondingly reduced. Compared with the cold and hot split supply system using electric refrigeration and thermal heating, the winter and summer sharing of the cold and hot combined supply device not only improves energy utilization efficiency, but also saves investment in heat source construction, thereby reducing costs and environmental pollution.*

Key words: *cold hot electric heating pump system, ecological environment, architectural design, application*

## Introduction

The absorption heat pump technology is introduced into the conventional heat cogeneration, the utility model cannot only improve the energy saving efficiency of conventional thermal combined heat and heat, but also improve the operation performance of the system, and make use of the waste heat efficiently. This paper analyzes the application of absorption heat pump technology in this project through a specific case. In the process of urban construction in China, this problem is directly related to the expansion of the scale of urban heating and the effective energy supply of the existing heat source. In order to ensure the supply of heat sources, especially for the huge energy consumption in heating in northern areas in winter, cogeneration hydronics is used to save energy and reduce emissions, in cogeneration hydronics, it is the way of centralized heating, not only does it have high economic and environmental benefits, but it is also the main form of application in current urban centralized heating [1]. Apply cogeneration hydronics in urban heating to save heat energy and improve energy utilization [2, 3].

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The advantages of applying absorption heat pump technology in cogeneration hydronics are to reduce the contradiction in urban heating, increase the heat supply capacity of heat sources and improve the transmission capacity of heat network. Absorption heat pump heating technology can be applied to cogeneration hydronics. The back pressure heating and extraction heating of steam turbine are combined with cogeneration system. According to the back pressure, the exhaust pressure of steam turbine for heating needs to be greater than atmospheric pressure, therefore, in practice, it is not necessary to consider the heat loss of power devices and pipe-lines, and it can also meet the theoretical heat energy utilization rate. According to the application of air extraction heating and cogeneration hydronics, the steam turbine is mainly used for air extraction by means of adjustable air extraction volume. With this technical form, it is not only unnecessary to add the absorption heat pump unit of the original cogeneration hydronics, but also can directly recycle the low temperature waste heat of a large amount of cooling water, and can keep the scale of the thermal power plant unchanged, realize the demand for heating capacity of winter heat sources. The absorption heat pump heating based on cogeneration, the adjusted system needs to transform the traditional heat exchange station, and also replace the ordinary water heat exchange unit with the absorption heat exchange unit with large temperature difference. Using such hot spot cogeneration heating cannot only optimize the actual engineering conditions of the thermal power plant, but also greatly improve the heat supply capacity of the system. In the cogeneration hydronics, the absorption heat pump technology is used to improve the temperature difference of water supply in the heating network and improve the transmission capacity of the heating network, which has significant environmental benefits, energy utilization has also been improved, and can also significantly reduce the system operating costs. Energy and environment are two important issues nowadays. At present, China's energy consumption (such as heat, refrigeration, and water temperature) accounts for 30% of the total energy consumption in society, and this proportion will increase with the development. Home energy consumption directly or indirectly consumes a lot of First Energy, so the development and utilization of new energy and energy conservation reduce the use of home energy have attracted more and more attention.

As clean energy, solar energy and energy-efficient heat pump technology have received great attention and application. At present, domestic scholars have carried out active research on solar heat pump technology. In northern China, coal is still the main source of energy for heating, and winter haze weather is frequent. There is a long way to go for air pollution control [4]. On one hand, it is the people's livelihood demand for heating in winter, and on the other hand, it is the green water and blue sky that the people constantly pursue. Therefore, promoting clean energy heating is of great significance for the warm winter and reducing haze in northern regions. As a clean and RES, geothermal energy provides a new idea for air quality control. In December 2017, the National Development and Reform Commission published the Report on the Development and Use of Nuclear Power Plants to Promote the Reduction and Transfer of Heat in the North, which proposed to base on the regional geology, water resources and characteristics of shallow geothermal energy, residents' energy demand, combined with urban, park, suburban and rural economic development, resource endowment, meteorological conditions, building distribution, power distribution conditions, *etc.*, reasonably develop and utilize shallow geothermal energy contained in surface water (including rivers, lakes, seas, *etc.*), sewage (reclaimed water), rock and soil mass, groundwater, *etc.*, and constantly expand the application of shallow geothermal energy in urban heating.

In April 2020, the National Energy Administration organized a seminar on the *14th Five Year Plan for Renewable Energy Development (Geothermal Part)*, at which experts clearly emphasized the necessity of promoting clean heating in winter in the north. At present, ground source heat pump using private electric heater, especially ground source heat pump using private electric heater as cold and heat source, has been widely used. However, there exist problems such as blindness or construction failure of ground source heat pump in China. The fundamental reason for this phenomenon is that people have insufficient understanding of the importance and rationality of ground source heat pump system design, and the technical difficulties in engineering design have not been paid enough attention and solved. Ground source heat pump (WHPS) is a cooling and heating system that uses ground-water as a cool and heat source, including water source heat pump, ground source heat exchanger, and power plant. Building energy saving is an important means and development trend to realize the efficient use of energy. Heat pump technology can realize the efficient use of low grade energy, and has the advantages of low energy consumption and no pollution. The combination of solar energy and heat pump has formed a comprehensive system which can increase the utilization rate of solar energy, decrease energy efficiency, save energy cost, and protect environment [5, 6].

In order to reduce energy consumption, the application of air conditioning and heat pump in ecological environment building design is proposed. The cold and hot water hydronics in this paper are the technical management system of solar energy and heat pump (heat pump, water source heat pump). According to the change of outdoor environment, the heat supply system integrates, providing users with hot water for winter heating and cold water for summer. After the adoption of the new system of combined cold and heat supply, coupled with the perfect supporting automatic control equipment, the heating coal consumption is greatly reduced, and the emissions of $CO_2$ and $SO_2$ dust are also reduced accordingly.

Through the practical research of solar heat pump technology in the cold and hot combined heating system, we have found that the combination of solar energy and heat pump, as well as the co-ordinated operation of various heat sources, enables RES (solar energy, air source, water source) fully utilized and reduce energy costs. At the same time, the equipment of the system can also be shared, saving money. By using technologies such as solar energy and air source heat pump to ensure the temperature of the heat storage tank, the heat pump can effectively control the heat capacity under low temperature, thereby reducing energy consumption, reducing operating costs, improving energy efficiency, and increasing COP value. The waste heat reuse of industrial water tanks provides low grade energy for water source heat pumps, further utilizing energy. When heating, the boiler room system such as coal and gas can be omitted, and there is no combustion process, avoiding smoke exhaust pollution.

Aiming at energy saving and consumption reduction, this project applies the technology of combined heating and cooling heat pump to ecological building design. The combined hot and cold system is an integrated control system, which utilizes the solar system and heat pump technology (air source heat pump, water source heat pump) to complement each other based on changes in the outdoor environment, thus providing users with hot water heating and cold water cooling in winter. After installing a new heating and cooling system, coupled with well-equipped automatic control equipment, the heating coal consumption has been significantly reduced, and the emissions of $CO_2$, $SO_2$ dust, and other pollutants have also been correspondingly reduced. Compared with the cold and hot split supply system using electric refrigeration and thermal heating, the winter and summer sharing of the cold and hot combined supply device not only improves energy utilization efficiency, but also saves investment in heat source construction, thereby reducing costs and environmental pollution.

## Methods

### *Principle of combined cooling and heating system*

The combined cold and hot supply system refers to a system that shares cold and heat sources and other related equipment, making the cold and hot parts interconnected and integrated, fig. 1 [7]. The combined hot and cold system is an integrated control system, which utilizes the solar system and heat pump technology to complement each other based on changes in the outdoor environment, thus providing users with hot water heating and cold water cooling in winter. Compared with the cold and hot split supply system using electric refrigeration and thermal heating, the winter and summer sharing of the cold and hot combined supply device not only improves energy utilization efficiency, but also saves investment in heat source construction, thereby reducing costs and environmental pollution.

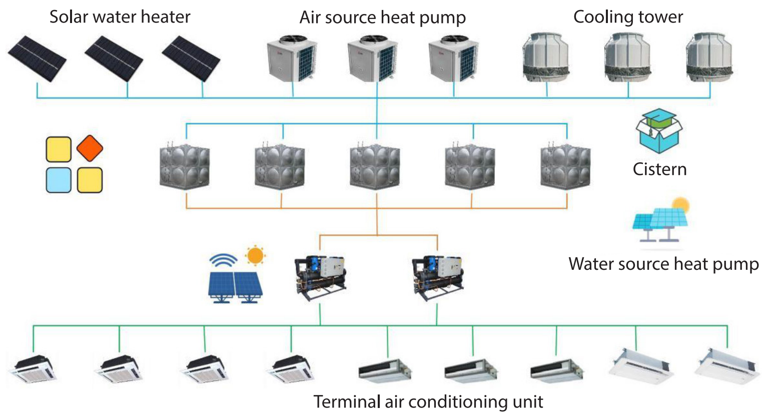


**Figure 1. Schematic diagram of the combined cooling and heating system**

### *Composition of the combined cooling and heating system*

The combination of air conditioning and heating system mainly consists of heat pump, heat pump, solar collector, circulating water pump, heat plate, and other equipment. The resource assessment tools are shown in tab. 1.

**Table 1. Equipment list of cold and hot integrated system**

| Device name | Equipment model | Heating/cooling capacity [kW] | Other parameters | Number |
|---|---|---|---|---|
| Water source heat pump unit | SGHP-260AII | Cooling capacity 223 | Cooling power 42 kW | 2 |
| | | Heating capacity 258 | Heating power 57 kW | |
| Air source heat pump | THP-200D | Heating capacity 41 | Power 17.5 kW | 3 |
| | THP-100D | Heating capacity 33 | Power 8.25 kW | 4 |
| Solar collectors | SLU4715-12 | | Heat collection area 340 m$^2$ | 1 |

## System operation mode

There are three operation modes for the combination of refrigeration and heating: solar heat pump type (Type I), solar/air source heat pump type water source heat pump type (Type II), and industrial waste heat pump type/air conditioning type (Type III).

### *Solar + air source heat pump heating mode (Mode I)*

Early and late of summer heat, the outdoor temperature is high. When the outdoor solar is enough, the solar system increases the temperature of the heat storage tank to 40-459 °C by heat transfer. When there is insufficient sunlight during the day or at night, turn on the air source heat pump for heating. Similarly, increase the water temperature of the heat storage tank to 40-45 °C, and set the water supply temperature to 45 ° C. Supply indoor heating through the air conditioning system heat exchanger.

### *Solar/air source heat pump+water source heat pump heating mode (Mode II)*

In the middle stage of heating, when the outdoor temperature is low, because of the insufficient heat capacity of the heating system, the heating system combines solar for daytime heating, air source heat pump and water source heat pump, and night heating. The internal temperature of the heat pump is 15-25 °C, and the setting water temperature for the heat pump is 45 °C.

### *Industrial waste heat + water source heat pump heating/cooling mode (Mode III)*

*Starting condition*: When the temperature of the industrial waste heat exchanger is more than 159 °C, the system changes to the industrial waste-water and the waste-water for the combined heat exchanger. When this system operates in three different modes, the corresponding opening and closing status of each device and accessory in the system is shown in tab. 2. The temperature requirements of the corresponding equipment in the three modes of the system are shown in tab. 3.

**Table 2. The system operates in three modes for each device**

| | Water pump | | | | | Valve | | | | | | Solar energy | Air source heat pump | Water source heat pump | Industrial waste heat |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mode | P1/2 | P3/4 | P5/6 | P9/10 | P11/12 | V10 | V11 | V12 | V15 | V16 | V18 | | | | |
| I | – | + | + | + | + | – | + | – | – | – | + | + | + | – | – |
| II | – | + | + | + | + | + | – | + | – | – | + | + | + | + | – |
| III | + | – | + | – | – | + | – | – | + | + | – | – | – | + | + |

**Table 3. Temperature requirements for each equipment of the system in three operating modes**

| | Temperature | | | Notes |
|---|---|---|---|---|
| Mode | Heat storage water tank | Air source heat pump | Water source heat pump | |
| I | >35-45 °C | 35-45 °C | – | The solar system automatically realizes cycle control based on the difference between its outlet temperature and the temperature of the water tank |
| II | <10-35 °C | 10-25 °C | – | Both solar and air source systems automatically cycle and control based on the temperature of the water tank |
| III | – | – | >15 °C | The water source heat pump determines whether to operate this mode based on the temperature of the industrial water tank |

*System operation status*

This system is used for winter heating in a comprehensive office building in the northern suburbs of A. The building has three floors and a heating area of 4500 m. The heating design temperature in A is –9% °C, and the design heat index is set at 50 W/m$^2$. Therefore, the design heat load of the complex building is 225 kW. The system operated for a total of 75 days from December 2014 to March 2015, with room temperature maintained at 18~20 °C, meeting the heating requirements of City A. When the system is put into operation, it is in the middle stage of heating, and the outdoor temperature is relatively low. At present, only relying on air source heat pump heating cannot meet the needs of heating. It is heated by solar energy during the day and ground source heat pump at night. The temperature in the heat storage tank is between 15-25 °C, while the heat storage tank accounts for an average of 459 °C. When the water temperature of boiler is more than 15 °C, it can be changed to use industrial waste heat and underground heat sources for heating together. At the end of heating stage, the external temperature is high. If there is enough sunshine outside, the system works the first way, from 10 a. m. to 10 p. m., using the sun's rays to heat it up. The temperature of the sink is between 40-45 °C. During the day or night, when there is less sunshine, the system operates in Mode II, heating the air source heat pump with a total heating capacity of 44.13 kW/h (turn on $3\times20$ units or $2\times20$ + $2\times10$ units for a total of 60 units, and set the water supply temperature at 45% °C.

## Economic analysis of energy conservation and environmental protection

During 75 working days in winter heating period, the total energy consumption of the system is 75608.43 kWh, with an average daily energy consumption of 1008.11 kWh. At the maximum time of 8 hours of daily energy consumption, the electricity price is 1.1 Yuan per kWh. During the minimum electricity period of 16 hours, the electricity price was 0.37 Yuan per kWh.

*Calculation of heating costs for complex buildings*

Daily heating cost:

= Y1.1 × 8 + 0.37 × 16Y × 1008.11/24 = 618.3 Yuan per day

The heating period in A is calculated as 123 days. According to A's meteorological statistics, the working days under three modes are shown in tab. 4.

Taking into account the maintenance structure, orientation, and height of the comprehensive building, the average thermal index of the building is taken as 38.8 W/m$^2$ [8, 9].

**Table 4. Working days in three modes**

| | Mode I | Mode II | Mode III |
|---|---|---|---|
| Working days | 20-30 | 70-90 | 15-30 |

Calculation of annual heating heat consumption:

Annual heating consumption = building area × average thermal index × the heating time of = 4500 × 38 × 123 × 24 × 3600 = 185.46 × 104 MJ standard coal has a calorific value of 29326 kJ/kg, which is equivalent to 63.24 tons of standard coal. The comprehensive office building operates according to this design system, and the annual heating power consumption is calculated annual heating power consumption = annual heating days × Daily average power consumption = 123 × 1008.11 = 124000 kWh, equivalent to 15.24 tons of standard coal, can save 48 tons of standard coal annually for heating.

*Environmental indicators*

According to $CO_2$ emissions: $QCO_2$ = 2.47QStandardcoal. The $SO_2$ emissions: standard coal ‘$QSO_2$ = 0.02QStandardcoal. Dust emission: Qdust = 0.01QStandardcoal, which can calculate the energy consumption indicators of the original system, the combined cooling and heating system, and the energy saving system, as shown in tab. 5 [10]. From tab. 5, it can be seen that the adoption of a new combined cooling and heating system, coupled with a complete set of automatic control equipment, significantly reduces heating coal consumption, and correspondingly reduces emissions of $CO_2$, $SO_2$ dust, and other pollutants.

**Table 5. Comparison of energy consumption between the original system and the combined cooling and heating system**

| | Coal [tonne] | $CO_2$ [tonne] | $SO_2$ [tonne] | Dust [tonne] |
|---|---|---|---|---|
| Original operating system | 63.25 | 156.20 | 1.261 | 0.631 |
| Combined heat supply system | 15.25 | 37.65 | 0.31 | 0.151 |
| Saving/reducing emissions | 48 | 118.57 | 0.96 | 0.481 |
| Savings rate of each indicator | 75.9% | | | |

## Conclusion

Through the practical research of solar heat pump technology in the cold and hot combined heating system, we have found that the combination of solar energy and heat pump systems, as well as the joint operation of various heat sources, make full use of RES (solar energy, air, water source) heating and reduce energy costs. At the same time, the system resources can also share, save money. By using technologies such as solar energy and air source heat pump to ensure the temperature of the heat storage tank, the heat pump can control the heat capacity under low temperature, thus reducing energy consumption, reducing operating costs, improving energy efficiency, and increasing COP value. The waste heat reuse of industrial water tanks provides low grade energy for water source heat pumps, further utilizing energy. When heating, the boiler room system such as coal and gas can be omitted, and there is no combustion process, avoiding smoke exhaust pollution.

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