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# *Performance Study of Coupling Municipal Wastewater with a Second Lithium Bromide Absorption Heat Pump for Heating*

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***Abstract:*** Nowadays, promoting the development of new energy sources is an important way to achieve the goal of "double carbon", both in the building sector and in industry, the large amount of sewage and waste water discharged is rich in thermal energy, and the rational use of this thermal energy will bring changes to our living standards. With more and more types of heat pumps and improvements in heat pump technology, the utilisation of the thermal energy from municipal wastewater is gradually increasing. This paper investigates the performance of coupling municipal wastewater with a second lithium bromide absorption heat pump for heating, analyses the indirect use of municipal wastewater sources for heat extraction, and develops a dynamic simulation model for the second lithium bromide absorption heat pump, resulting in a 34% energy saving compared to other heating methods by coupling municipal wastewater sources with this heat pump system.

## 1. Introduction

Industry and construction are the most important areas of heat consumption in China, with industry consuming more energy. In addition the industrial waste heat excluded from processes such as chemical, pharmaceutical, paper and non-ferrous metal smelting accounts for 40% of the total energy consumption. In these waste heat there is a large amount of low-grade waste heat of 30-80°C. And the city, the main waste heat waste heat from life, effective recovery and use of urban sewage heat, has a significant energy-saving effect, economic effect and environmental protection effect, is to make the city sewage resource an advanced technology, it is to improve people's living standards, promote the rapid development of the economy and promote the progress of society has great strategic significance[1].

In recent years, with the national energy-saving policy, China's heat pump technology research has been innovative, for example, the main heat source of air-source heat pumps from the air, the working medium is easy to obtain, the system is safe and environmentally friendly and energy-saving, and through the adjustment of the four-way valve can make the system both heating and cooling, but for the winter in northern areas, the outdoor temperature is too low may cause frost on

the unit, the maintenance costs are higher[2]. The water source thermal pump is mainly based on the surface water as the heat source to cool down or heated as an integrated heat pump unit. Cooling and heating methods, theoretical calculations can reach 7, and the actual operation is 4-6. However, the nature of the water source in different regions to the application of water source heat pump is difficult to overcome[3].The operating medium of solar heat pump is solar energy, the system is stable, the structure is simple, the cost is low, and the effect of collecting solar energy is better, but the system is affected by the weather, causing the solar heat pump system to heated the unstable and intermittent problems[4].It can be seen that the lithium bromide absorption heat pump with thermal energy as the power is both energy -saving and environmentally friendly and safe and reliable, and it is more convenient to maintain management.

The energy saving of lithium bromide absorption heat pumps in the field of heating has been highly valued. After entering the 21st century, lithium bromide products and technology have developed greatly. After 2005, the lithium bromide market began to flourish. In 2021, my country entered the "double carbon". In the first year, the energy use of energy comprehensive energy has been valued in various places, and lithium bromide crews can make full use of the advantages of waste heat waste heat. In 2021, the lithium bromide absorption heat pump increased by 28.66%year -on -year to reduce emission reduction for national energy conservation, especially in terms of waste heat heating. A large number of research reports on theoretical and applications of lithium bromide absorption heat pump at home and abroad have been reported.Qiu Zhongju [5] analyzed that the lithium bromide absorption heat pump system can use the power plant at 30℃-45℃ as a low temperature balance heat source, and the heating coefficient is above 2.2.Li Jianfeng[6]and others artificially reduced the energy consumption of thermal power joint crew in the concentrated heating process, proposed a heating method for circulating water and thermal pump coupling of power plants, established the energy efficiency computing model of the heating mode, and used a certain 350 MW supercritical supply As an example, the heat machine group is calculated to calculate the energy efficiency indicator of this mode.Han Tingao[2]and others analyzed the research status of biomass boilers and air source heat pump suitable for biomass boilers and air source heat pumps suitable for use in rural areas, and briefly summarized the benefits of combining the two heating methods.

The research on the heat pump abroad is relatively earlier. In the 1930s, the heat pump entered the commercial stage for the first time. Some countries in the world began to develop heat pumps to promote heat pump heating.And S. Manu[7]simulated and detailed thermodynamic analysis of single -grade lithium bromide steam absorption heat pumps, and verified the model by considering the literature value, and inspected the effects of cooling water on lithium bromide absorption heat pump flow, COP, and conductivity.

On the basis of consulting a large number of literature, this article selects a relatively scarce urban sewage source and lithium bromide absorption heat pump coupling heating system. In this context, this article will make up for the blank in this area and promote the recycling of urban sewage. It will have certain innovation innovation. Sexuality and practicality.By studying the working principle and performance of lithium bromide absorption heat pump, and the method of urban sewage heat removal, the overall operating framework is constructed, and the influencing factors of the second type of lithium bromide absorption heat pump and urban sewage source coupling heating operating conditions are creatively analyzed. This establishs further research on dynamic models. And summarize the actual operation of the second type of lithium bromide absorption heat pump and urban sewage source coupling, reasonably set the heat net water supply temperature, and the low temperature waste temperature of the evaporator inlet can effectively improve the performance of heat pumps to improve energy saving.

## 2. System introduction

The research objects of this article are mainly divided into two parts, the first part is the urban sewage heat removal system, and the second part is the second type of lithium bromide absorption heat pump operation system.

### 2.1. Urban sewage source heat extraction technology

Urban sewage thermal energy has its own unique characteristics and has been recognized as clean energy sources that have not been effectively developed and utilized. Therefore, under the current severe situation of the global energy crisis and serious environmental pollution, from the perspective of protecting the environment, human beings will also enter a diverse era in terms of energy utilization. Effective recycling and using urban sewage thermal energy, which has major energy -saving effects, economic effects and environmental protection effects. It is a advanced technology that makes urban sewage resources. It has improved people's living standards, promoting the rapid development of the economy, and promoting social progress in society. It has great strategic significance.

Although the heat removal technology of urban sewage sources has started very late for most cities, it has developed rapidly. For example, the Beijing Gaobian Store sewage treatment plant has developed a set of construction heating of 900 $m^2$ in the sewage source heat pump. Then install a set of sewage source heat pumps for building heating and refrigeration for 6000 $m^2$ at the Beidou sewage treatment plant. There are relatively few studies that unite the urban sewage heat extraction technology and heat pump system. Related studies have shown that urban sewage source heat extraction technology is mainly divided into two methods: direct and indirect use. The direct use of the thermal energy of urban sewage refers to the recovery of the heat in the sewage through the heat pump, and directly transport it to the heat supply building; the sewage is sewage; the sewage; The indirect use of thermal energy means that after the sewage is exchanged through the heat exchanger, the heat in the sewage will be recycled through the heat pump to the heat supply building through the thermal pump. The indirect system is generally adopted by engineering because of its mature technology. In the indirect system, the heat transfer route is: sewage, intermediary water, refrigerant. The indirect system has been promoted in fact, and the direct system development is less sufficient because:(1) The sewage of indirect systems does not directly enter the unit, so the requirements for the unit are not high. It only requires ordinary water ring heat pump units. In addition, the sewage heat exchanger required by the indirect system has been successfully developed and put into production in China; (2) Although the direct system saves the investment cost of the sewage heat exchanger than the indirect system, the unit uses special treatment, and it will increase the operation of the system. It is not recommended to use the direct system[8].

Urban sewage is a more complicated sewage composed of domestic sewage and industrial wastewater. This brings challenges to the sewage heat recovery system with urban sewage as a water source. Therefore, this article needs to solve the problems existing in the following sewage source heat extraction technology:

When the sewage flows through the pipeline and equipment, the surface layer of the heat exchanger is prone to stagnation. To relieve the problem of hindrance to the pipeline, in addition, the filter needs to be replaced regularly;

A substances with strong oxidation that cause the equipment to be shortened in the sewage can take a certain technical means to restore before the sewage takes through the thermal removal system;

Regularly check the sewage treatment equipment and sewage heat removal equipment to ensure the efficient operation of the system.

Finally, after solving the above problems, we found that urban sewage is a huge low -temperature residual heat heat source. The use of sewage source heat extraction technology combined with heat pump coupling to correctly develop and apply this heat source, which can create a new type of clean energy for urban humans to save savings to save conservation The use of coal and petroleum and other first -level energy sources to truly realize energy conservation and emission reduction[9].

## 2.2. The second type of lithium bromide absorption heat pump operation system

The second absorbing heat pump is the power to enter medium temperature heat energy (industrial waste heat, urban sewage and other waste heat), so as to convert a part of the low -temperature level of the low temperature to a higher temperature at a higher temperature, supply industries or other users, and another part Energy is discharged into the environment. The second absorbing heat pump does not require a lot of high -quality energy and electricity, nor consumes useful high temperature heat. It only needs to consume recovered low -temperature waste heat or a small amount of recycling. Essence In the green age of vigorously advocating carbon neutrality, the use of the second absorbing heat pump will cause the remaining heat to increase, which is more widely used in the use of compressed heat pumps and the first absorbing heat pump. Attention. Figure 1 shows a diagram of the cycle principle of the second absorption heat pump[10].

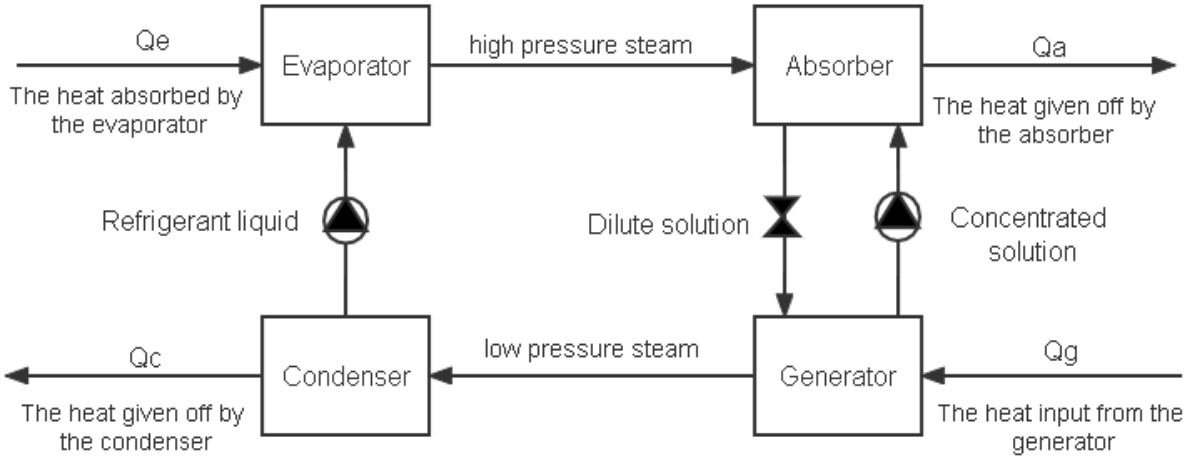


Figure 1: Simple second absorption heat pump cycle

Specific operation process of heat pump: The second absorption of lithium bromide operating medium is flowing into the generator first, which is heated by the urban sewage provided by the outside and outside of the generator. The pump is hit into the absorber via the heat exchanger. The produced refrigerant steam was cooled into the refrigerant liquid in the condenser, and the refrigerant pump was pumped into the evaporator. The refrigerant liquid in the evaporator absorbed the waste heat steam (or hot water provided by the inside and outside of the heat transfer tube through the spray device.) The heat evaporates into a high -pressure refrigerant steam into the absorber. The refrigerant steam is absorbed by lithium bromide thick solution, becoming a lithium bromide dilute solution. At the same time, it produces absorption heat and heated the application water. Figure 2 shows the heating flowchart for urban sewage and the second absorption heat pump.

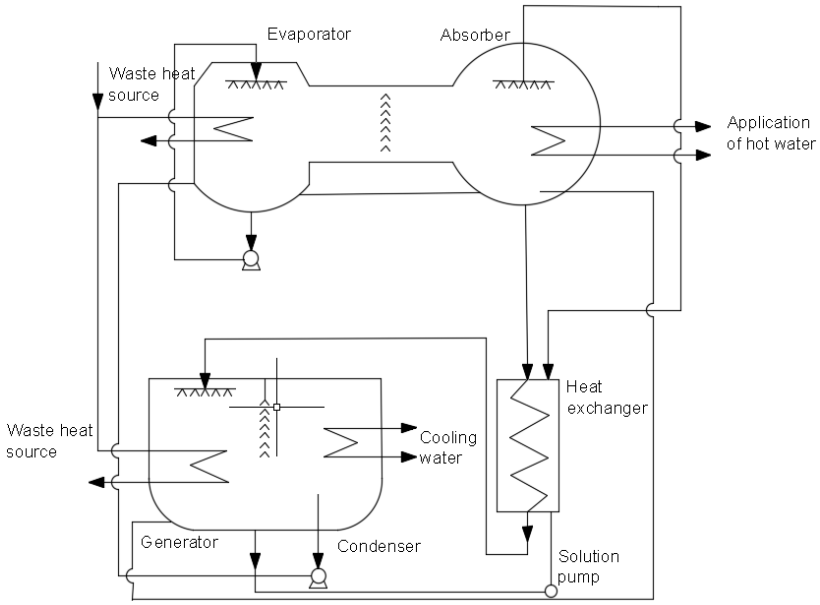


Figure 2: Urban sewage and second absorption heat pump coupling heating flowchart

## 3. System model simulation

### 3.1. Corporation of Lithium Bromide absorption heat pump model

The research objects in this article are mainly divided into two parts. The first part is the urban sewage heat selection system, and the second part is the second type of lithium bromide absorption heat pump operation system. The system running design diagram is shown in Figure 3.

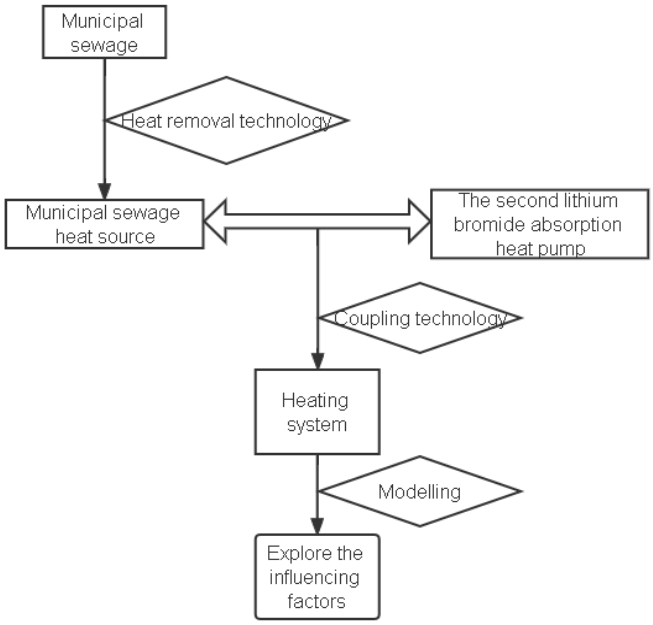


Figure 3: System running design drawing

The operation process of the heat pump unit is shown in Figure 4. The system is mainly composed of 1 evaporator, 2 absorbers, 3 low -temperature solution heat exchangers, 4 high -temperature solution heat exchangers, 5 high -pressure generators, 6 low -pressure generators, and 7

condenser. Cold agent water process: The refrigerant steam generated in the high -pressure generator is transformed into a refrigerant steam through 6 through 6, and the cold agent steam 15 generated in the low -pressure generator enters the condenser to be condensed. After the heat water 3 absorbs the heat of the remaining heat water, the refrigerant steam 16 is output.

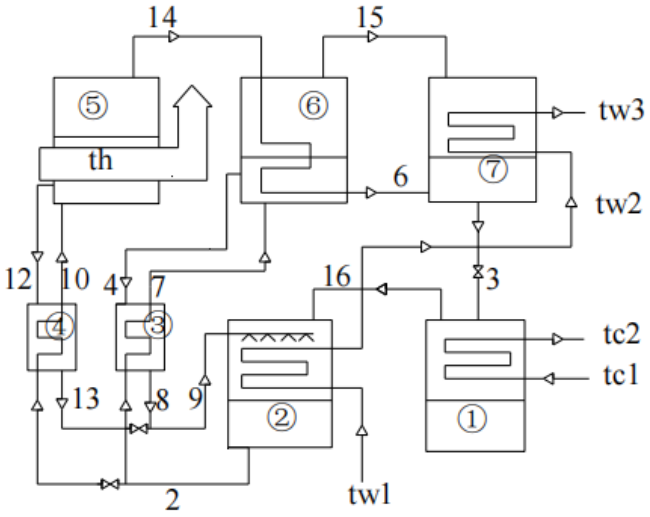


Figure 4: The operation process of the second type of lithium bromide absorption heat pump

### 3.2. Numerical model establishment

The numerical method involves establishing mathematical correlations based on the thermal properties of water, water vapour and aqueous lithium bromide solutions, and forming mathematical equations with the numerical models of the components in a Type II lithium bromide absorption heat pump to calculate the thermal coefficients. In order to model the system with a certain degree of accuracy, it is necessary to make the following assumptions: the system is assumed to be in steady state operation; the heat transfer losses between the components and the external environment are ignored; the components of the system in which the gas and liquid phases exist are in equilibrium; the lithium bromide aqueous solution at the outlet of both the absorber and the generator is saturated; the coolant vapour exiting the generator is superheated vapour at the corresponding generator pressure and the temperature is the The temperature is the average of the inlet and outlet temperatures of the generator.

According to the above assumptions, the components of the second type of lithium bromide absorption heat pump unit are considered to satisfy the conservation of mass and energy in operation. According to the numerical model of the double-effect lithium bromide absorption heat pump, it is known that it is mainly a coupled process of heat and heat transfer of seven components, so this paper adopts Newton's method for iterative solution, and the model solution process is shown in Figure 5. The known parameters of the input heat pump unit are defined as follows: heat absorbed from the low temperature waste heat source 50kW; low temperature waste heat source water inlet temperature tc1 is 30℃; low temperature waste heat source water outlet temperature tc2 is 20℃, heat network return water temperature tw1 is 35℃; heat network water supply temperature tw2 is 55℃; heating steam pressure 0.7MPa; heating steam temperature 165℃; dilute solution concentration 54%.

After ensuring the above conditions, the numerical modelling of its components is carried out as follows.

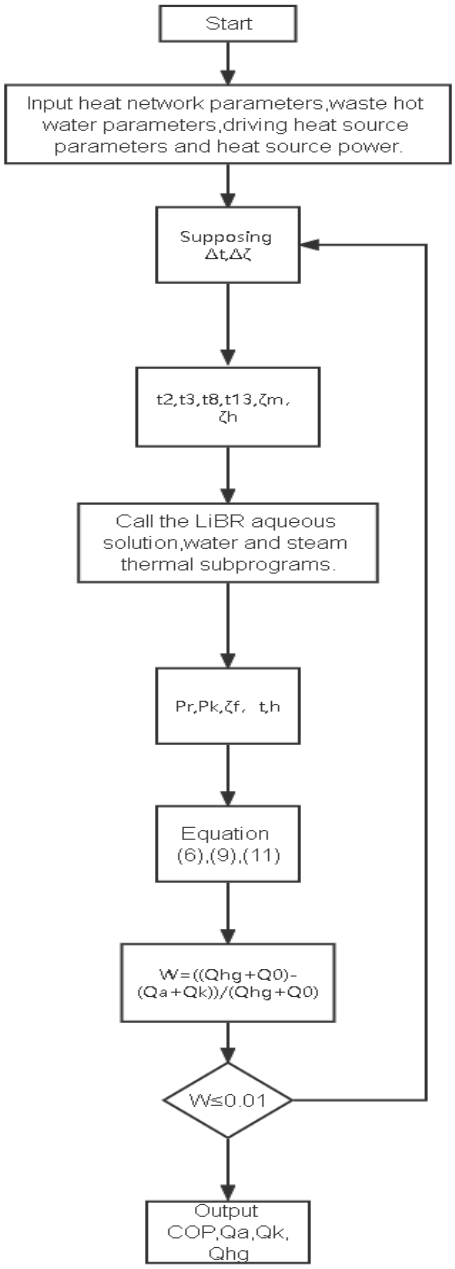


Figure 5: Numerical model solving process for heat pump units

### 3.3. Analysis of the simulation conclusions

The numerical model of the heat pump unit is used to analyse the performance coefficient of the unit in relation to the heat network water supply temperature and the temperature of the low temperature residual hot water inlet to the evaporator. With the increase of the heat network water supply temperature, the heat pump performance COP reaches its optimum at around 49℃, which is about 2.67. As the temperature of the low temperature residual hot water at the evaporator inlet rises, the heat pump performance COP reaches approximately 2.67 at around 47℃. The simulation results are compared with the measured system COP values from the literature and are found to be more accurate.In addition, the system COP increases as the temperature of the driving heat source

rises. In the actual operation of the second lithium bromide absorption heat pump, reasonable settings of the heat network water supply temperature and the evaporator inlet low temperature residual hot water temperature can effectively improve the heat pump performance. The calculation results show that the average error rate of the equipment load of the heat pump unit of the numerical model in this paper is 0.001 and the error rate of the performance coefficient is 0.004, indicating the reasonableness and correctness of the numerical model of the heat pump unit in this project.

The use of urban sewage heat recovery and utilization system can replace part of the use of high energy sources (such as coal, oil, energy, etc.), thus enabling the suppression, decentralization and rational allocation of urban energy consumption, improving the efficiency of the effective use of urban energy and showing obvious energy-saving effects (according to the measured results of the urban sewage heat recovery and utilization system actually operating in Japan, compared with other previous heat supply (According to the measurement results of the urban wastewater heat recovery and utilisation system in actual operation in Japan, the energy saving can be approximately 34% compared to other previous heat supply systems.)

The second lithium bromide absorption heat pump differs from other heat pumps in that it consumes thermal energy to complete a non-spontaneous process, rather than using mechanical energy, and is simply the recycling of waste heat, and in some large cities or enterprises generally emit a larger amount of low temperature and low pressure steam or hot water, so the use of the second absorption heat pump can fully exploit the potential to improve energy utilisation.

## 4. Conclusions

In practice, there is a wide variety of heating load variations, both in the form of constant flow/variable temperature difference in the central heating sector and in the form of constant temperature difference/variable flow in the process heat sector, and even in the form of a mixture of two heat supplies. In order to fully exploit the dynamic operating characteristics of the absorption heat pump, a dynamic simulation model of the lithium bromide absorption heat pump considering the mass transfer and distribution parameters is established, taking into account the heat storage characteristics of each component stock.

For the first 2 forms of heating load variation, the change in performance coefficients is studied experimentally and the main causes are analysed using state parameters. A coupled heating system between a municipal wastewater source and a second type of lithium bromide absorption heat pump that can simultaneously reflect energy efficiency, environmental protection and economy. The numerical model of the second lithium bromide absorption heat pump is established by means of mass and energy conservation equations, and the influence of the variation of three external factors, namely the heating temperature of the municipal wastewater source, the temperature of the low temperature residual hot water at the evaporator inlet and the temperature of the driving heat source, on the system performance is analysed to find the operating conditions when the heat pump is coupled with the municipal wastewater source for optimum performance. It provides guidance for the second type of lithium bromide absorption heat pump to improve the performance of the heat pump with reasonable equipment parameters in the actual operation process.

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